Towards a new century of Light

Paris, 12-19th of April 2013

CIE Centenary Conference

Final Programme & Abstract Booklet

CNAM, Paris - 15-16th of April 2013

http://www.CIEcentenary.insight-outside.fr

Photo JC. WETZELImage&son—Cnam

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Invitation Letter

Dear Colleagues,

CIE is celebrating its one hundredth anniversary! A century during which our knowledge of lighting fundamentals has taken enormous leaps forward, bringing new applications of light supported by both technological advances and economic success. A century that began with the revolution of the electric light and efforts to bring both the electric light bulb and the power it required into common use ends with the need to reduce energy distribution and use, and brings a technology that promises to achieve this for lighting.
CIE's mission "to promote worldwide cooperation and exchange of information on matters associated with light and lighting" is as relevant today as it was one hundred years ago.
As we move into a new century, knowledge, technology and the economy bring new challenges, among them:

- Light is important for vision, and is also crucial for health and mood
- Light is in need of measurement, appropriate to application and effect
- Light is a commodity, but it is also art and design, interactive and personalised
- Light is a commodity, but it can also be disruptive, a pollutant, an irritant, a waste

Our understanding of new technologies and the impacts of light must be used to enhance the positive and reduce the negative effects of light. Light, like life, should show versatility, intelligence and sustainability, realising that "the more the better" is not always necessary or best.
In celebration of a centenary of knowledge, and in recognition of our new challenges, we present a conference centred around three themes:

Rhythm of life, rhythm of light
Intelligent lighting
City at night

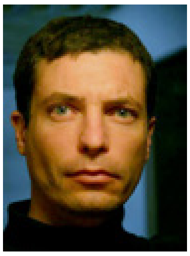
We would like to celebrate our centenary in the company of our valued CIE members, with their vast technological expertise, and with those who use and appreciate light as art and healing or inspiration, providing a special forum for discussion and interaction.

Invitation Letter

It is our honour to invite you to discuss these subjects during a two-day conference, as participants or as contributors. We have chosen the venue in Paris for its very obvious long history in lighting. This is also where the CIE was officially created and hosted.

We are looking forward to meeting you in Paris.

Ann Webb
President of the CIE



Cyril Chain
President of CIE-France

International Scientific Committee

(in alphabetical order):

Jean Bastie (DIV2, FR)	PhD, (retired from INM/CNAM as Head of the Optical Radiation Measurement Department)
Peter Blattner (DIV2, CH)	PhD, Head of Optics, Federal Institute of Metrology (METAS), CH, Director CIE Division 2
Cyril Chain (DIV4, FR)	PhD, international expert in Light and Lighting for the French Government (Ministry of Territory Equality, Transport, Housing METL + Ministry of Ecology, Sustainable Development and Energy MEDDE)
Jean-Michel Deleuil (DIV4,FR)	PhD, Prof. at the Environment and Urban Planning Department, INSA engineer school, FR
Dominique Dumortier (DIV3, FR)	PhD, Vice-Director of LASH laboratory, ENTPE engineering school, FR
Christine Fernandez-Maloigne (DIV8, FR)	PhD, Prof, Director of SIC laboratory, University of Poitiers, FR
Marc Fontoynont (DIV3, FR)	PhD, Prof at Aalborg University in Copenhagen, DK
Ron Gibbons (DIV4, US)	PhD, FIES, Director, Center Infrastructure Based Safety Systems, Virginia Tech Transportation Institute, US, Asscociate Director CIE Division 4
Teresa Goodman (VPP, GB)	Principal Research Scientist in the Optical Radiati on Measurement Group at the National Physical Laboratory (NPL), GB, CIE Vice President Publications
Jacques Lecocq (DIV5, FR)	Application Support Manager, Thorn Lighting, FR
Ronnier Luo (DIV1, GB)	PhD, Professor of Zhejiang University (CN), Leeds University (GB), Colour and Imaging Science, National Taiwan University of Science and Technology (Chair), Director CIE Division 1
Jan Morovic (DIV8, GB)	PhD, Senior Color Scientist, Hewlett-Packard Company, GB, Director CIE Division 8
John O'Hagan (DIV6, GB)	PhD, UK Health Protection Agency;Visiting Fellow, Loughborough University, GB, Director CIE Division 6

International Scientific Committee

Yoshi Ohno (Chair, US)	PhD, NIST Fellow and the Group Leader for Lighting and Color Group at Sensor Science Division, National Institute of Standards and Technology, US, CIE Vice President Technical
Peter Schwarcz (DIV5, HU)	Director CIE Division 5
Jennifer Veitch (DIV3, CA)	PhD, Senior Research Officer in the National Research Council of Canada, Institute for Research in Construction, CA
Françoise Viénot (DIV1, FR)	PhD, Prof. Emeritus at the National Museum of Natural History (MNHN), FR
Peter Zwick (CB)	PhD, Technical Manager CIE Central Bureau

International Organizing Committee

Conference Presidency:
Ann Webb
Cyril Chain

Members (in alphabetical order):
Marie-Pierre Alexandre
Marc Fontoynont
Teresa Goodman
Yoshi Ohno
Martina Paul
Lorne Whitehead

Local Organizing Committee

(in alphabetical order):

Marie-Pierre Alexandre
Jean Bastie
Cyril Chain (Chair)
Éric Dumont
Dominique Dumortier
Alain Azaïs
Jean-Jacques Ezrati
Christine Fernandez-Maloigne
Alain Floris †
Marc Fontoynont
Jacques Lecocq
Eric Loisy (Insight Outside, Event Organizer)
Gaël Obein
Leo Trausnith (CB Office Manager)
Françoise Viénot

Conference Information

Conference Information

CONGRESS LANGUAGE

The congress language is English. No simultaneous translation will be provided.

CERTIFICATE OF ATTENDANCE:

Upon arrival all registered delegates will receive a certificate of attendance together with their delegates' bag or sent after the conference (registration kit).

ABSTRACT SUBMISSION/REGISTRATION/ACCOMMODATION:

All registration procedures for the CIE 2013 conference will be conducted online.
In case you have no access to the internet please contact the conference organizers as indicated below. It will gladly forward the necessary registration forms to you.

CONFERENCE ORGANIZER & Sponsoring

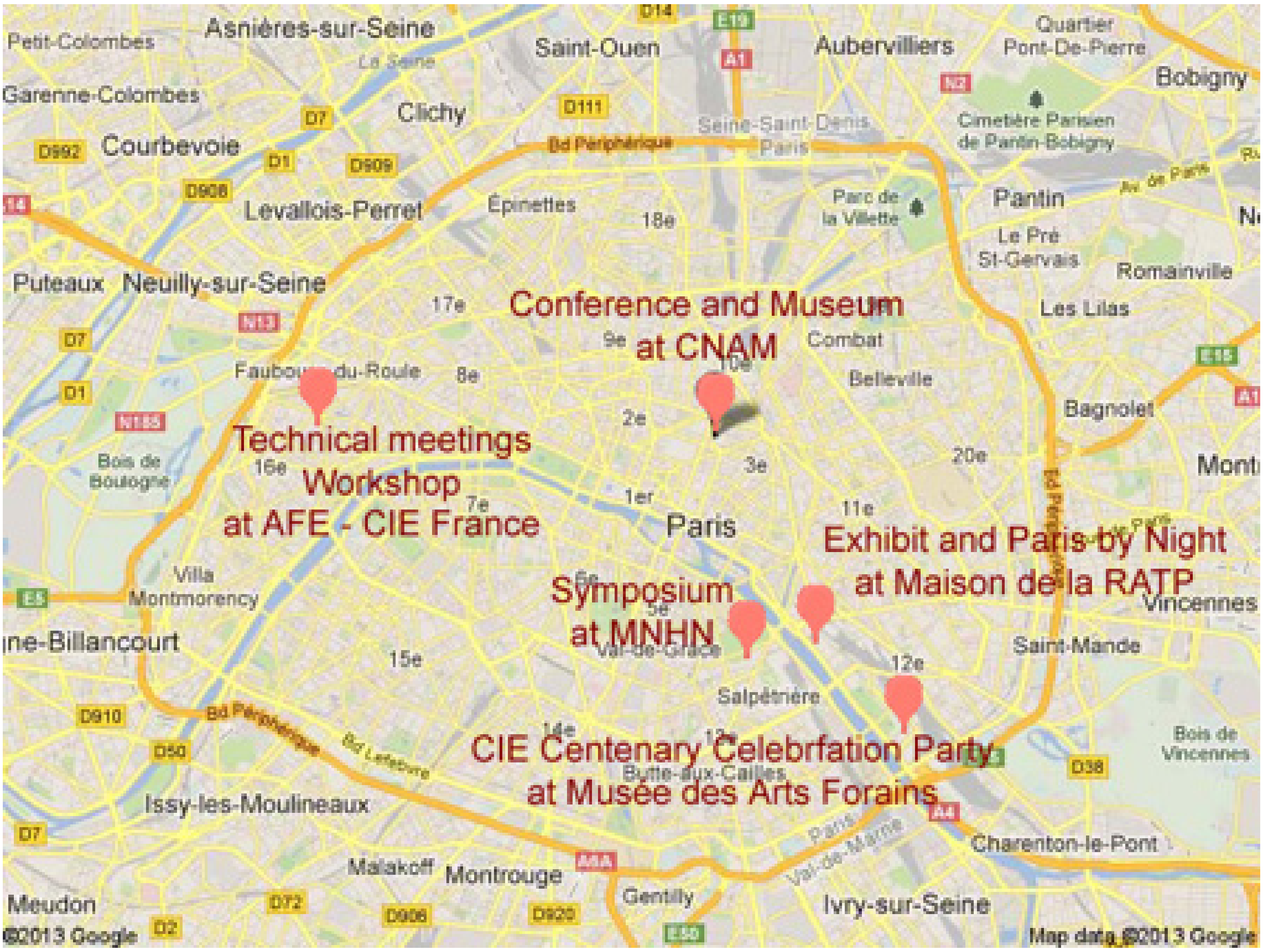
CIE France
17, rue de l'Amiral Hamelin
75016 PARIS
France
contact: CIEcentenary@afe-eclairage.com.fr

CONFERENCE VENUE

CNAM
293, rue Saint-Martin
75003 Paris
France

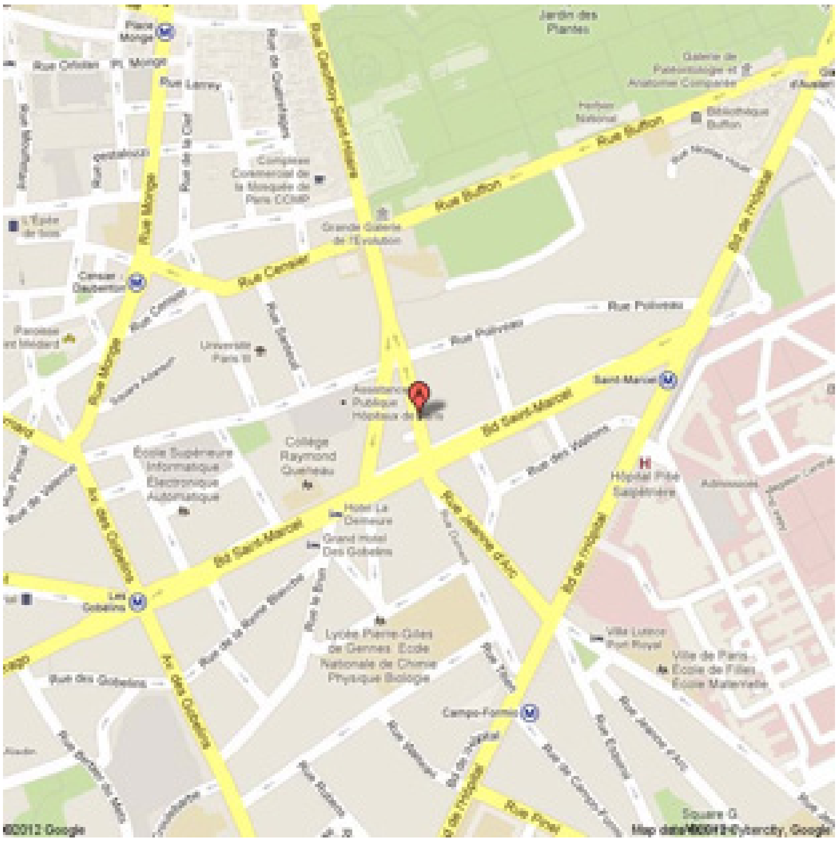
Rooms: Amphithéâtres Painlevé, Say & Faure

GENERAL MAP

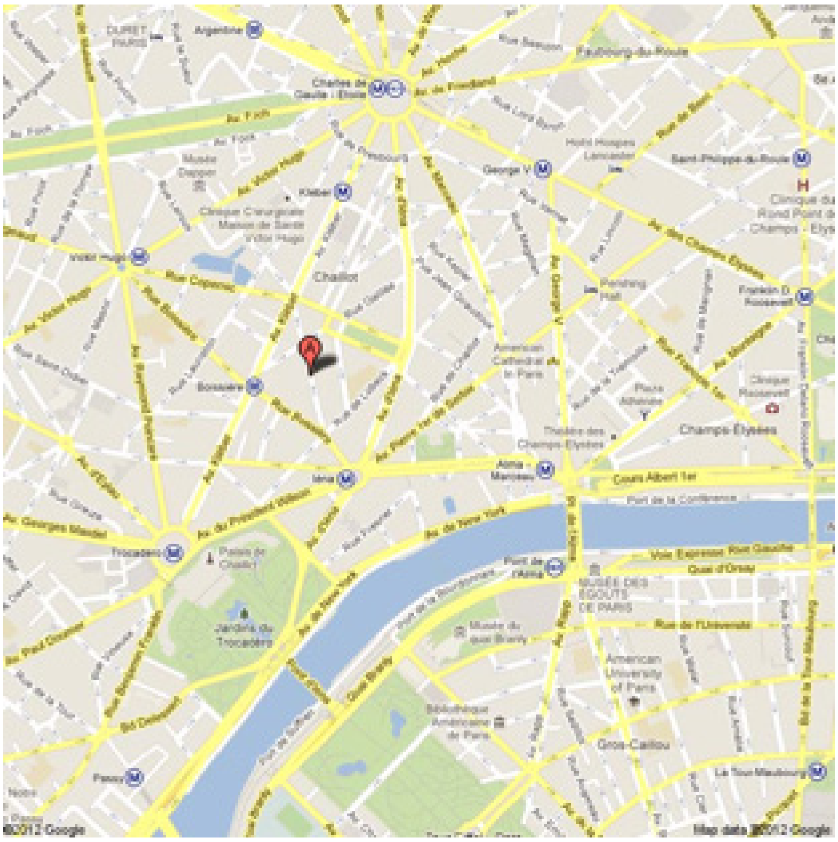


CONFERENCE AND MONDAY EVENING SITE – MONDAY AND TUESDAY

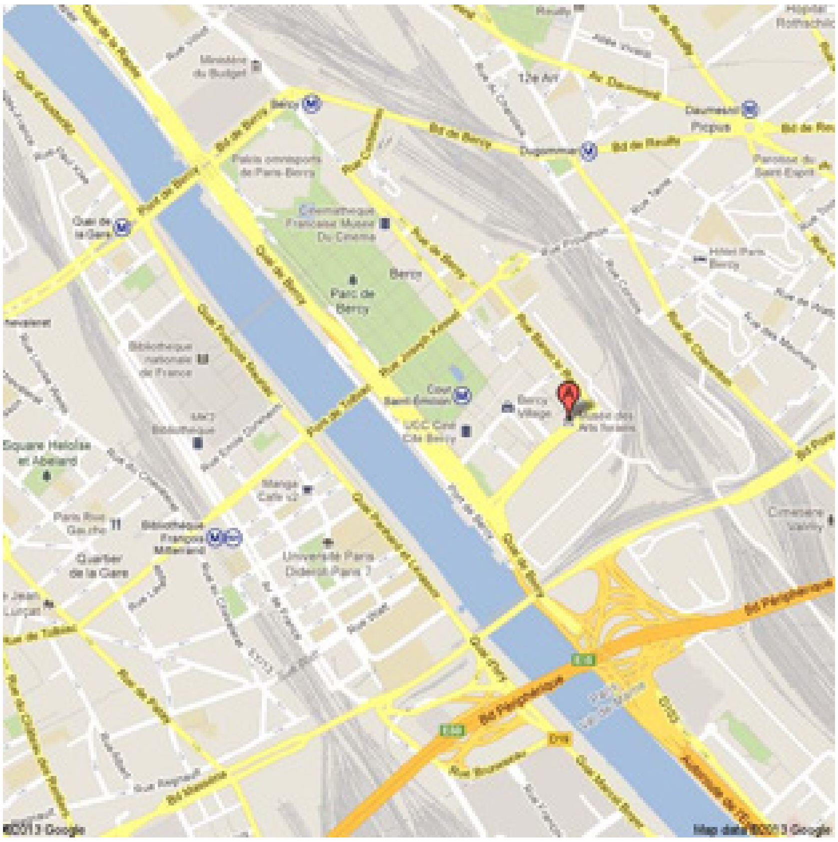
SYMPOSIUM SITE – THURSDAY & FRIDAY



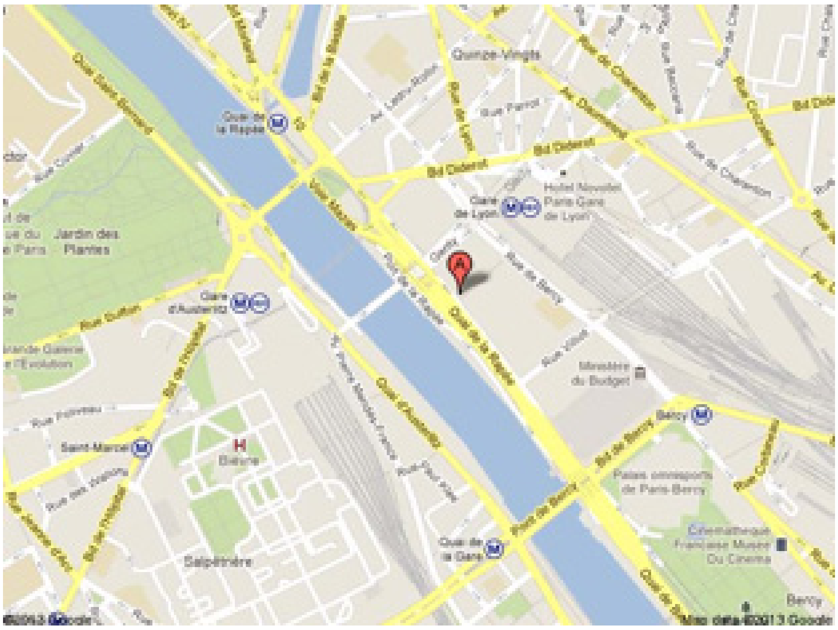
TECHNICAL MEETING AND WORKSHOP SITE – WEDNESDAY TILL FRIDAY



CENTENARY CELEBRATION PARTY – TUESDAY NIGHT



RATP – THURSDAY NIGHT



A Word from the Partners

CIE-FRANCE

CIE-France is a national mirror committee of the CIE that brings together top level researchers and scientists – it is the French representative for the International Commission on Illumination. Its main missions are:

• to represent France in the CIE, in particular in terms of its participation in the development of standards, recommendations and technical reports;

• to vote on documents proposed by this institution;

• to disseminate in France of international works, both through its involvement in the AFE recommendations and the organisation of conferences for the general public.

Finally, CIE-France also constitutes the AFE's scientific committee, making it possible to identify a network of expertise on the subjects covered by its activity.

THE FRENCH LIGHTING ASSOCIATION (ASSOCIATION FRANÇAISE DE L'ÉCLAIRAGE - AFE)

The AFE brings together a group of actors from the fields of light, lighting and vision - architects, urban planners, designers, decorators, doctors, researchers, ophthalmologists, civil engineers, highways agencies, electricians and electricity companies, wholesalers, distributors as well as those who manufacture lamps, lighting and the systems and component parts for managing lighting.

The AFE's mission is:

• to formulate scientifically based opinions on the practical matter of lighting;

• to contribute to independent scientific projects aimed at quantifying the effects of light on vision and on health;

• to communicate with the international scientific and technical community, in particular through the monitoring of works undertaken by the International Commission on Illumination (CIE) via its scientific committee CIE-France;

• to provide a platform for all the stakeholders, therefore contributing to the dissemination of good practices in the field of lighting;

• to inform consumers about the benefits of good quality lighting - in terms of safety, health and the management of electric energy for the comfort and well-being of all.

The AFE publishes recommendations and technical guides concerning lighting, a leading review on light and lighting, organises information days and training sessions on lighting – its techniques and applications, aimed at lighting professionals. Every two years, the AFE organises National Light Days (JNL), at regional level, which are attended by over 500 participants.
http://www.afe-eclairage.com.fr/

THE NATIONAL CONSERVATORY OF ARTS AND TRADES (LE CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS - CNAM)

The National Conservatory of Arts and Trades (CNAM) is a major higher education institution, dedicated to lifelong education. Several of its courses in the fields of industrial sciences and information technologies are linked to the sub-domain of ‚Metrology' and provide a scientific basis to the business of lighting.

A word from the Partners

The CNAM houses a section of the LNE-CNAM, a laboratory shared between the LNE (national testing laboratory) and the CNAM (National Conservatory of Arts and Trades).The LNE-CNAM acts as a national reference for all fields, except for time metrology and ionising radiation.Its research is aimed at improving current standardisations or fundamental constants as well as developing new ones.It is, in particular, in charge of maintaining the Candela; the international base unit for the measurement of luminous intensity.
http://inm.cnam.fr/presentation/institut-national-de-metrologie/

CERTU, THE MINISTRY OF ECOLOGY, SUSTAINABLE DEVELOPMENT AND ENERGY (MEDDE) AND THE MINISTRY OF EQUALITY OF TERRITORIES AND HOUSING (METL)

The MEDDE and the METL are French government ministries in charge of aspects linked to the environment and energy, but also sustainable development, urban planning, mobility, infrastructures and transport, public buildings and housing. Their respective missions mean that these ministries are those which are the most closely involved in the matters relating to lighting, its impact on the environment and energy policies, its efficiency in the safety of transport and its ability to offer sustainable solutions.
The Grenelle (French forum for sustainable development) law notably addresses the issues of energy saving and light pollution (biodiversity, night skies etc.) linked to artificial lighting.
Several of the experts working for the MEDDE and the METL are responsible for monitoring projects being carried out by the International Commission on Illumination. The president of CIE-France has also been recognised as an ‚international expert' by these ministries.
CERTU – Centre d'Études sur les réseaux, les transports, l'urbanisme et les contructions publiques – constitutes the Study Centre heading the Scientific and Technical network for these two Ministries especially in the lighting field. Its aims are to capitalize, develop and disseminate knowledge and methodologies on a wide range of urban issues, for local authorities, institutes and companies which are involved in public service activities.
http://www.certu.fr/certu/english

THE FRENCH NATURAL HISTORY MUSEUM (MNHN)

The MNHN is both a scientific institution and a public service, responsible for carrying out research and the dissemination of knowledge; it has five main, founding missions: fundamental and applied research, management and conservation of collections, teaching and pedagogy, dissemination of knowledge and expertise. Apart from their concentrated activities on the theme of biodiversity and the environment, the Museum has traditionally carried out research into light radiation and colour and continues to this day with its work on the effects of light on the living environment and on materials.
In association with, and immediately following the conference entitled 'CIE-Centenary, Paris 2013: Towards a new century of light', the Museum is organising a "CIE Symposium on colour vision in memory of Yves Le Grand".
http://www.mnhn.fr/museum/foffice/transverse/transverse/accueil.xsp

Programme Overview

Programme Overview

Monday, April 15				
09:00	OPENING CEREMONY			09:00
09:10	Keynote & Plenary Session 1: History of Lighting and Art			09:10
10:35	COFFEE BREAK			10:35
11:00	Plenary Session 2: Hot Topics in Outdoor Lighting			11:00
12:20	LUNCH			12:20
14:20	Colour Quality Assessment	Health and Wellbeing	Workplace Lighting Concepts	14:20
16:20	COFFEE BREAK (during Poster Viewing)			16:20
16:20	POSTER VIEWING			16:20
Tuesday, April 16				
08:30	Plenary Session 3: Hot Topics in Interior Lighting			08:30
10:10	COFFEE BREAK			10:10
10:40	Advanced Correction Methods for Spectroradiometry and Goniophotometry	Lighting the City - Applications and Economics	Integrating Daylight and Electric Lighting	10:40
12:00	LUNCH			12:00
14:00	LED Photometry and Performance of Photometers	Lighting the City - Luminaires and Design	Concepts in Lighting Quality	14:00
15:20	COFFEE BREAK			15:20
15:50	Brightness and Colour, Individual or Shared Percepts	Lighting the City - Spaces	Well-being, Glare and Comfort	15:50
16:55	Keynote: Towards a New Century of Light			16:55
17:30	CLOSING CEREMONY			17:30

Colour Key

DAY	PARALLEL SESSION / TOPIC
KEYNOTES / PLENARY SESSION	POSTER
BREAK	OPENING/CLOSING CEREMONY

Programme per Day

Monday, April 15

Monday, April 15
Morning

09:00 - 09:10	**OPENING CEREMONY**	09:00 - 09:10
	Keynote & Plenary Session 1: History of Lighting and Art (Chair: Ann Webb, GB)	
09:10 - 09:40	**Keynote:** **Jean Bastie, FR** **ONE HUNDRED YEARS OF CIE AND EVOLUTION OF LIGHTING**	09:10 - 09:40
09:40 - 10:00	**OP01** **Gertrud Olsson, SE** **ONE AND A HALF MILLENNIUM OF COLOURED LIGHT**	09:40 - 10:00
10:00 - 10:20	**OP02 (Invited Talk)** **Jean-Jacques Ezrati, FR** **BACK ON A HUNDRED YEARS OF TECHNOLOGICAL DEVELOPMENT IN THE SERVICE OF THE MUSEUM LIGHTING**	10:00 - 10:20
10:20 - 10:35	**Discussion**	10:20 - 10:35
10:35 - 11:00	**COFFEE BREAK**	10:35 - 11:00
	Plenary Session 2: Hot Topics in Outdoor Lighting (Chair: Ron Gibbons, US)	
11:00 - 11:20	**OP03** **Steve Fotios, GB** **RELATIVE WEIGHTING OF LIGHTING ALONGSIDE OTHER ENVIRONMENTAL FEATURES IN AFFECTING PEDESTRIAN REASSURANCE**	11:00 - 11:20
11:20 - 11:40	**OP04** **Ambroise Romnée, BE** **A NEW REAL TIME INTELLIGENT MANAGEMENT MODEL FOR STREET LIGHTING**	11:20 - 11:40
11:40 - 12:00	**OP05** **Ingrid Heynderickx, NL** **ESTIMATING EYE ADAPTATION FOR TYPICAL LUMINANCE VALUES IN THE FIELD OF VIEW WHILE DRIVING IN URBAN STREETS**	11:40 - 12:00
12:00 - 12:20	**Discussion**	12:00 - 12:20
12:20 - 14:20	**LUNCH**	12:20 - 14:20

Colour Key

DAY	TOPIC
KEYNOTE SPEECH / PLENARY TALK	POSTER
BREAK	OPENING/CLOSING CEREMONY

Monday, April 15
Afternoon

	Colour Quality Assessment (Chair: Ronnier Luo, GB)	Health and Wellbeing (Chair: John O'Hagan, GB)	Workplace Lighting Concepts (Chair: Yasuko Koga, JP)	
14:20 - 14:35	OP06 Peter Bodrogi, DE SEMANTIC INTERPRETATION OF COLOUR RENDERING INDICES AND COLOUR FIDELITY INDICES: A COMPARISON OF CRI AND CRI2012	OP12 Andreea Biro, RO LIGHT AS A MOTOR FOR INNOVATION AND WELLBEING	OP18 Miyoshi Ayama, JP DISCOMFORT GLARE OF WHITE LED SOURCES OF DIFFERENT SPATIAL ARRANGEMENTS	14:20 - 14:35
14:35 - 14:50	OP07 Sophie Jost, FR COLOUR RENDERING OF FACE COMPLEXION AND HAIR UNDER LED SOURCES	OP13 Ann Webb, GB THE RHYTHM OF THE SUN VS MODERN LIFE AND CULTURE IN SUN EXPOSURE FOR VITAMIN D SYNTHESIS	OP19 Celine Villa, FR SUITABLE LUMINOUS ENVIRONMENT FOR VARIOUS ACTIVITIES IN SHARED OFFICE	14:35 - 14:50
14:50 - 15:05	OP08 Yoshie Imai, JP A STUDY OF COLOR RENDERING PROPERTIES BASED ON COLOR PREFERENCE OF OBJECTS IN ADAPTATION TO LED LIGHTING	OP14 Andreas Wojtysiak, DE APPLICATION STUDIES ON NON-VISUAL EFFECTS OF LIGHT WITH TRADITIONAL AND SOLID STATE LIGHT SOURCES	OP20 Youko Inoue, JP STUDY ON ILLUMINANCE BALANCE BETWEEN WORKING AREA AND AMBIENT EFFECTS OF DISTRIBUTION OF LUMINOUS INTENSITY OF AMBIENT LIGHATING AND THE ORDER AND SPEED OF ADJUSTMENT	14:50 - 15:05
15:05 - 15:20	OP09 Ayako Tsukitani, JP OPTIMIZATION OF COLOR QUALITY FOR LANDSCAPE LIGHTING BASED ON FEELING OF CONTRAST INDEX	OP15 Tommy Goven, SE VISUAL AND NON-VISUAL EFFECTS OF DIFFERENT SPECTRAL POWER DISTRIBUTIONS FROM LIGHT SOURCES - LIGHT EMITTING DIODES (LED) VS. 3-PHOSPHORUS FLUORESCENT TUBES	OP21 Naoyuki Suzuki, JP A STUDY ON THE PERMISSIBLE RANGE OF UNUNIFORMITY BY AMBIENT LIGHTING IN A WORKPLACE	15:05 - 15:20
15:20 - 15:35	OP10 Balázs Nagy, BR THE EFFECT OF AMBIENT ILLUMINATION SPECTRUM ON VISUAL PERFORMANCE	OP16 Maria Ámundadóttir, CH MODELING NON-VISUAL RESPONSES TO LIGHT: UNIFYING SPECTRAL SENSITIVITY AND TEMPORAL CHARACTERISTICS IN A SINGLE MODEL STRUCTURE	OP22 Annika Kronqvist, SE REVIEW OF OFFICE LIGHTING RESEARCH	15:20 - 15:35
15:35 - 15:50	OP11 Justine Decuypere, BE SIMULATION OF THE RETINA RESPONSE TO MESOPIC VISUAL SCENES	OP17 Pierre Boulanguez, FR BLUE-LIGHT HAZARD OF LEDS - COMPARISON OF THE PHOTOBIOLOGICAL RISK GROUPS OF FIFTEEN LEDS ASSESSED USING THE STANDARD PROTOCOL AND A NEW SPECTRAL IMAGING APPROACH	OP23 Ásta Logadóttir, DK COMPARISON OF USER SATISFACTION WITH FOUR DIFFERENT LIGHTING CONCEPTS	15:35 - 15:50
15:50 - 16:20	Discussion	Discussion	Discussion	15:50 - 16:20
16:20	COFFEE BREAK (during Poster Viewing)			16:20
16:20 - 18:00	Poster Viewing			16:20 - 18:00

Tuesday, April 16

Tuesday, April 16
Morning

	Plenary Session 3: Hot Topics in Interior Lighting (Chair: Marc Fontoynont, FR)			
08:30 - 08:50	**OP24** Jennifer Veitch, CA WHAT WE KNOW ABOUT WINDOWS AND WELL-BEING AND WHAT WE NEED TO KNOW			08:30 - 08:50
08:50 - 09:10	**OP25** John Mardaljevic, GB A ROADMAP FOR UPGRADING NATIONAL/EU STANDARDS FOR DAYLIGHT IN BUILDINGS			08:50 - 09:10
09:10 - 09:30	**OP26** Naomi Miller, US FLICKER IN SOLID-STATE LIGHTING: MEASUREMENT TECHNIQUES AND PROPOSED REPORTING AND APPLICATION CRITERIA			09:10 - 09:30
09:30 - 09:50	**OP27** Jonathon Porritt, GB THE REBOUND EFFECT - AN OVERIEW OF THE IMPLICATIONS FOR LIGHTING ENERGY			09:30 - 09:50
09:50 - 10:10	Discussion			09:50 - 10:10
10:10 - 10:40	**COFFEE BREAK**			10:10 - 10:40
	Advanced Correction Methods for Spectroradiometry and Goniophotometry (Chair: Peter Blattner, CH)	Lighting the City - Applications and Economics (Chair: Yandan Lin, CN)	Integrating Daylight and Electric Lighting (Chair: Dominique Dumortier, FR)	
10:40 - 10:55	**OP28** Yuqin Zong, US DETECTOR-BASED METHOD FOR CALIBRATION OF SPECTRORADIOMETERS USING AN AUTOMATED KHZ TUNEABLE OPO LASER SYSTEM	**OP32** Jean-Michel Deswert, BE INTELLIGENT STREET LIGHTING AND LEDS: BUSINESS CASE AND RETURN ON EXPERIENCE	**OP36** Mandana Sarey Khanie, CH INVESTIGATION OF GAZE PATTERNS IN DAYLIT WORKPLACES: USING EYE-TRACKING METHODS TO OBJECTIFY VIEW DIRECTION AS A FUNCTION OF LIGHTING CONDITIONS	10:40 - 10:55
10:55 - 11:10	**OP29** Günther Heidel, DE PRACTICAL EXPERIENCES WITH STRAY LIGHT CORRECTION ON ARRAY SPECTROMETERS FOR LED-PRODUCTION	**OP33** Steve Fotios, GB CRITICAL PEDESTRIAN TASKS: USING EYE-TRACKING WITHIN A DUAL TASK PARADIGM	**OP37** Birgit Painter, GB CAPTURING THE USER EXPERIENCE OF ELECTROCHROMIC GLAZING IN AN OPEN PLAN OFFICE	10:55 - 11:10
11:10 - 11:25	**OP30** Jianping Wang, CN STRAY LIGHT CORRECTION IN GONIOPHOTOMETRY MEASUREMENT	**OP34** Ronald Gibbons, US A FIELD TEST OF THE SPECTRAL IMPACTS OF ROADWAY LIGHT SOURCES	**OP38** Cláudia Amorim, BR LIGHTING AND DAYLIGHTING QUALITY: CRITICAL REVIEW OF CRITERIA AND RECOMMENDATIONS AND ITS INSERTION IN BRAZILIAN CONTEXT	11:10 - 11:25
11:25 - 11:40	**OP31** Cong Chen, CN DETERMINATION OF SCANNING RESOLUTION BASED ON NYQUIST SAMPLING THEOREM IN GONIOSPECTRORADIOMETRY	**OP35** Riad Saraiji, AE PEDESTRIAN CONTRAST PROFILE	**OP39** Yoshiki Nakamura, JP JUST SUFFICIENT LIGHTING CONDITION UNDER HYBRID-LIGHTING OF REAL DAYLIGHT AND ARTIFICIAL LIGHT	11:25 - 11:40
11:40 - 12:00	Discussion	Discussion	Discussion	11:40 - 12:00
12:00 - 14:00	**LUNCH**			12:00 - 14:00

Tuesday, April 16 Afternoon				
	LED Photometry and Performance of Photometers (Chair: Armin Sperling, DE)	Lighting the City - Luminaires and Design (Chair: Peter Schwarcz, HU)	Concepts in Lighting Quality (Chair: Anna Pellegrino, IT)	
14:00 - 14:15	OP40 Roman Dubnicka, SK ANALYSIS OF PERFORMANCE PARAMETERS OF ILLUMINANCE METERS PER CIE DS 023 QUALITY INDICES FOR SPECIFIC FIELD MEASUREMENTS	OP44 Dionyz Gasparovsky, SK LIGHTING PROPERTIES AND EFFICIENCY OF LUMINAIRES EXCEEDING THEIR LIFETIME	OP48 Raphael Labayrade, FR VISUAL QUALITY ASSESSMENT OF LED SPOTS IN COMPARISON TO LOW-VOLTAGE HALOGEN SPOTS	14:00 - 14:15
14:15 - 14:30	OP41 Christophe Martinsons, FR INFLUENCE OF CURRENT AND VOLTAGE HARMONIC DISTORTION ON THE POWER MEASUREMENT OF LED LAMPS AND LUMINAIRES	OP45 Yukio Akashi, JP VISUAL MECHANISMS OF DISCOMFROT GLARE SENSATION CAUSED BY LEDS	OP49 Ronnier Luo, TW ASSESSING COLOR HARMONY IN A ROOM USING LED LIGHTINGS	14:15 - 14:30
14:30 - 14:45	OP42 Udo Krüger, DE SPECTRAL MISMATCH CORRECTION FACTOR ESTIMATION FOR WHITE LED SPECTRA BASED ON THE PHOTOMETER'S F1' VALUE	OP46 Xiaoyan Zhu, CN THE LUMINAIRE BEAM-SHAPE INFLUENCE ON DISCOMFORT GLARE FROM LED ROAD LIGHTING	OP50 Chloé Pagot, FR EVALUATION OF INDOOR LIGHTING SITUATIONS IN PUBLIC ACCESS BUILDINGS AND OUTDOOR SITUATIONS AT NIGHT BY VISUALLY IMPAIRED PEOPLE	14:30 - 14:45
14:45 - 15:00	OP43 Petri Kärhä, FI RADIOMETRIC DETERMINATION OF THE JUNCTION TEMPERATURE OF AN LED	OP47 Mathias Niedling, DE INFLUENCE OF A GLARE SOURCES SPECTRUM ON DISCOMFORT AND DISABILITY GLARE UNDER MESOPIC CONDITIONS	OP51 Nozomu Yoshizawa, JP A STUDY ON THE APPEARANCE OF PAINTINGS IN THE MUSEUM UNDER VIOLET AND BLUE LED	14:45 - 15:00
15:00 - 15:20	Discussion	Discussion	Discussion	15:00 - 15:20
15:20 - 15:50	COFFEE BREAK			15:20 - 15:50
	Brightness and Colour, Individual or Shared Percepts (Chair: Miyoshi Ayama, JP)	Lighting the City - Spaces (Chair: Dionyz Gasparovsky, SK)	Well-being, Glare and Comfort (Chair: Alessandro Rizzi, IT)	
15:50 - 16:05	OP52 Laurent Blondé, FR COLORIMETRIC OBSERVER CATEGORIES AND THEIR APPLICATIONS IN COLOR AND VISION SCIENCES	OP55 Katja Bülow, DK INTEGRATION OF RHYTHMIC URBAN LIGHTING INTO ARCHITECTURAL CONCEPTS	OP58 Shau-Wei Hsu, TW RELATIONS BETWEEN FLICKER GLARE AND PERCEPTUAL RATINGS OF LED BILLBOARDS UNDER VARIOUS CONDITIONS	15:50 - 16:05
16:05 - 16:20	OP53 Janos Schanda, HU INDIVIDUAL CHANGES OF BRIGHTNESS PERCEPTION	OP56 Roselane Bezerra, PT REINVENTING URBAN SPACES THROUGH LIGHT AND COLOUR: CACILHAS PROJECT	OP59 Yi-Chun Chen, TW FLICKER AND VISUAL COMFORT EVALUATIONS OF LED PANEL DISPLAY	16:05 - 16:20
16:20 - 16:35	OP54 Miki Kozaki, JP A PROPOSAL OF PREDICTIVE EQUATION FOR "SPATIAL BRIGHTNESS" CONSIDERING THE EFFECT OF LOOKING AROUND AND ITS APPLICATION TO REAL PROJECT	OP57 Thomas Conniasselle, BE IMPRESSION OF LIGHT AND FEELING OF SECURITY IN THE CITY - EXPERIMENTING MESOPIC VISION	OP60 Ronnier Luo, TW INVESTIGATION OF DISCOMFORT GLARE OF RGB LED BILLBOARD AT NIGHT	16:20 - 16:35
16:35 - 16:50	Discussion	Discussion	Discussion	16:35 - 16:50
	Keynote: Towards a New Century of Light (Chair: Yoshi Ohno, US)			
16:55 - 17:30	Cyril Chain, FR TOWARDS A NEW CENTURY OF LIGHT			16:55 - 17:30
17:30 - 17:40	CLOSING CEREMONY			17:30 - 17:40

Colour Key

DAY	TOPIC
KEYNOTE SPEECH / PLENARY TALK	POSTER
BREAK	OPENING/CLOSING CEREMONY

Posters

Posters

PP001
Price, L.L.
INFORMATION ENTROPY AND THE COLORIMETRY OF SPECTRA

PP002
Polster, S., Schierz, C.
TOWARDS A FIELD SIZE INDEPENDENT METAMERISM

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Abstracts

Oral Presentations

Keynote & Plenary Session 1: History of Lighting and Art

(Chair: Ann Webb, United Kingdom)

KS01

ONE HUNDRED YEARS OF CIE AND EVOLUTION OF LIGHTING

Bastie, J.
France

Celebrating the centenary of the CIE is a good opportunity to look back at its history in order to point out the major achievements which were realised during these hundred years. Although, it is usually admitted that CIE was founded in Berlin in 1913, its birth is a little more complicated and, in fact, it spreads between 1900 and 1921 and Paris took a special place in this birth.
Starting in 1900 with a working program limited to the definition of the rules for photometric measurements of incandescent gas mantles and to the unification of screw-threads used in gas engineering, the "Commission Internationale de Photométrie", CIP, the ancestor of the CIE, progressively increases its activities to all the fields of lighting and becomes, very quickly the "Commission Internationale de L'Eclairage".
At its first meeting in Zurich, in 1903, the CIP recommended the organisation of an international comparison of the various photometric standards used at that time by the national metrological laboratories. Although, this comparison activity of the CIE is not well known it continues in various fields until the end of the 70's or the beginning of the 80's. In this field the CIE was a forerunner since now international comparisons of standards are organised on a regular basis by the Bureau International des Poids et Mesures and the regional metrological organisations.
Another activity which has started very early at the CIE, and which is still active, is the definition, the compiling and the publication of the International Lighting Vocabulary. At the CIE meeting of Paris in 1921, the definitions of the luminous flux, illumination and luminous intensity, and their units were adopted. There was the three first terms of the vocabulary. The last edition of the vocabulary published in 2011, has 1448 terms.
The contribution of the CIE was also very important for encouraging and coordinating fundamental researches in the field of light. The most known achievements of the CIE were in the fields of photometry and colorimetry.
The standard photopic observer was defined in 1924 by the function V(λ) followed by the standard scotopic observer in 1951 defined by the function V'(λ). These two photometric observers have been endorsed by the Comité International des Poids et Mesures, respectively in 1933 and 1971. Recently, in 2010 and 2011, the CIE published technical reports on photometry in the mesopic region opening the way for photometric measurements on the whole light intensity range.
For colorimetry, the 2° standard observer, in connection with the CIE 1931 XYZ colour space and the standard illuminants A, B and C were defined in 1931. In 1964, the 10° CIE standard observer and the new standard daylight illuminant D6500 were added. The CIELAB and the CIELUV colour spaces were developed in 1976 and are now widely used. More recently, in 1994 and 2000, colour difference formulas were recommended
At the end of the 80's the CIE has been recognised by ISO and IEC as an international standardization body for the field of light and lighting. The CIE has also signed a Memorandum of Understanding with the Bureau International des Poids et Mesures and has representatives in two consultative committees.
Now the CIE is turned towards a new century of light.

OP01

ONE AND A HALF MILLENNIUM OF COLOURED LIGHT

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What is coloured light? It can be colour applied with a coloured light source. It can be a material that reflects light-colour to such a degree that the room is perceived to be coloured by light. In addition, a transparent or translucent material (like Plexiglas) can be perceived as immaterial, and thereby it can be interpreted as luminous light.
In the Ravenna basilicas, the Byzantine technique with walls done with mosaics was new in the 5th and 6th centuries. The mosaic masters acquired understanding of the changes colours underwent with distance, and also of the interaction of light and material. The new material that the Byzantine mosaic masters introduced, was coloured glass – and gold. These materials interact in a special way with vision and light. The surface is shiny, hard, and reflective. The gold picks up light and reflects gold light back into the room.

In medieval times, the Venetian's introduced coloured plane glass. The material was used for stained glass windows (rose windows) in churches. For example, the abbot Suger re-designed in 1140 the monastery church Saint Denis to the very first Gothic cathedral. In the sanctuary, polycrome windows with glass pictures, created illuminated walls. According to the abbot, the cathedral with coloured light became a tribute to the Real Light.
The spectacular illumination of architecture has a long prehistory. Since the Renaissance, public and private festivals in Europe often included architectural illumination and fireworks at night. One example is the fireworks on Castel Sant'Angelo in Rome, the festivity remembered thanks to an oil painting from 1775.
In an open space near the Eiffel Tower, the whole World Exhibition in 1889 closed with the so-called Chateau d'Eau. Out of the Palais de l'Électricité flowed a cascade of water, coloured with red, blue, and yellow light. During the day, the buildings of the Paris Expo, were themselves already alive with polychrome. Many of the building surfaces, were faced with coloured ceramic tiles, a reflecting material with strong expression.

The German poet Paul Scheerbart describes in 1913 a translucent architecture in coloured glass. His book Glasarchitektur reflects his ideological and technical interest in coloured glass. Scheerbart's utopian view is that via the illumination, the coloured glass in the house would generate coloured light through the windows and out to the surroundings.
In the 1920s the Bauhaus artist Laszlo Moholy-Nagy examines transparency and coloured light. He tries to create a stage design only with light and shadows, generating an architecture that seemed completely immaterial. In the ballet production Tales of Hoffman (the State Opera in Berlin 1928), everything on stage was transparent. The transparent material collected, scattered, and reflected the light. The manifold reflection by mirrors created an illusion of swaying. The colours were perceived as immaterial. A colour didn't simply belong to an object or material but was mixed with shadows and reflected out into the room.

Finally, in contemporary architecture, we find coloured light created by the artist James Turrell. He has designed a number of permanent colour light installations in architecture, for example in Bahnhof Zug (2003) in Switzerland and in Administration Building for AG (1997) in Leibzig. In Expomedia Light Cube (2000) in Saarbrücken, the architects Kramm & Stigl have designed a facade in constant change. The light colours transfer via a computer, and the facade transforms in a progressive pulsation. The Galleria West Fashion Mall (2005) in Seul, South Korea has been transformed by UN Studio and Arup Lighting into a glowing light box. Messages and patterns of colour are moving around the facade. The lighting artist Olafur Eliasson's Your rainbow panorama (2011) is a circular panoramic walkway, in the rainbow's colours. It is constructed on the roof of the cubic museum building in Aarhus, Denmark.

This paper is a survey of 1 600 years with coloured light from Byzantine time to contemporary architecture. Viewed retrospectively, how do we inherit the tradition with coloured light in contemporary architecture? Do we recollect the illuminated parks 110 years ago; the gold shimmering mosaic light in the Ravenna basilicas from the 500s; the

transparency in the Gothic cathedrals that allowed reflection and dispersal of light? Do we recall the idea of coloured light as a utopia in modernism?

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OP02

BACK ON A HUNDRED YEARS OF TECHNOLOGICAL DEVELOPMENT IN THE SERVICE OF THE MUSEUM LIGHTING

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It may be suggested that lighting design (of exhibition, stage, architecture, etc.) is self-defined as art (technical) in a way it may be controlled and used expressively, like any other medium. Since it must be produced and canalised by technology, light is also the fruit of science and knowledge. At the beginning of the last century the art of artificial lighting was at its premises. Gas was widely used in department stores and theatres. Museums, because of the risk of fire, preferred to wait for the advent of electric lighting. Natural light remained the only source of lighting in exhibition rooms in most museums. It was not until around 1930 that museums were equipped, opening the era of artificial lighting which, by its flexibility, established the foundations of lighting design. Light sources and equipments are only the support of the art, and not the reverse. From filament lamp to light emitting diodes, from rheostats to digital technology, technology is evolving in the service of art, whose bases have always been the same: general lighting and localized lighting, choice of colour temperature, intensity, etc.

Plenary Session 2: Hot Topics in Outdoor Lighting
(Chair: Ron Gibbons, United States)

OP03

RELATIVE WEIGHTING OF LIGHTING ALONGSIDE OTHER ENVIRONMENTAL FEATURES IN AFFECTING PEDESTRIAN REASSURANCE

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The decision to walk follows five hierarchical factors: feasibility, accessibility, safety, comfort and pleasureability [1]. If the needs of feasibility and accessibility are met, then the potential pedestrian can begin to consider the needs of safety, and this is driven by characteristics such as the presence of vandalism, graffiti, litter and threatening/loitering individuals. A reason why road lighting may be installed in residential areas is to increase pedestrian reassurance after dark, which in past studies has been addressed under the label of perceived safety or fear of crime. While several studies have suggested that lighting affects reassurance it is possible that fear of crime is inflated by the procedure with which it is measured [2]. For example, responses to a survey carried out before and after changes to the installed road lighting may be a reaction to an obvious change, exaggerating the impact of lighting. Improved lighting does not always aid reassurance [3]. Lighting allows pedestrians to see their environment more clearly, however if this makes graffiti, litter and loitering individuals more visible, then better lighting will not improve reassurance.
This paper presents an alternative method for determining whether lighting affects reassurance developed in conjunction with an environmental psychologist and a criminal sociologist. The aim is to placing lighting in the overall context of reassurance at night time, by the consideration of other attributes such as spatial features, familiarity and the presence of other people, thus giving a holistic picture of the pedestrian experience.

Test participants (53) were asked to take photographs of two roads where they would feel confident walking alone at night-time, and two roads where they would not feel confident. The sample included approx. equal numbers of younger (mean 22y) and older (mean 68y) people and genders. Their photographs were subsequently used as prompts during a three-stage interview. Stage 1: participants were asked to give general reasons regarding the issues that affect their confidence when walking alone at night and this discussion was carried out without the aid of any visual prompts. Stage 2: participants were asked to give reasons for the presence or absence of feelings of reassurance in locations of their own choosing, using their photographs of these locations as prompts. Thus, these discussions of reassurance focused on real locations familiar to the test participant, rather than being judgements based on photographs of unfamiliar locations. Stage 3: evaluations of safety in the scenes presented in five photographs of outdoor locations at night-time, these images having been pre-selected by the experimenter.

Reasons given for feelings of reassurance were collated into seven categories (presence of road lighting, access to help, spatial features, familiarity, mobility, presence of threatening others and presence of CCTV) chosen to include established theory (e.g. spatial features includes factors related to prospect and refuge [4]) and issues raised by the participants. Positive and negative reasons were included, e.g. “it was really dark with just one street light” indicated that poor road lighting contributed to low reassurance, while “pretty well lit on both sides of the road” indicated

that road lighting contributed to satisfactory reassurance. The frequency by which these reasons were used to explain feelings of reassurance were used to interpret their relative importance.
Fig. 1 shows the frequency by which these categories were used to explain feelings of reassurance without the aid of visual prompts. 39 of the 53 participants mentioned adequate road lighting as a reason for feeling reassured; 37 people mentioned darkness or a lack of adequate lighting as a reason for not feeling reassured. Overall 49 people (92%) expressed the presence/absence of lighting as a factor contributing to reassurance. The presence or absence of access to help was the only factor mentioned with equal frequency as road lighting: spatial features and familiarity were mentioned less frequently.

Fig. 2 shows the frequency by which the categories were used to explain feelings of reassurance in stage 2 of the interview which used photographs provided by test participants as prompts for particular locations, for each of the 210 locations. For 130 locations, road lighting was mentioned as a reason for the presence or absence of reassurance. This is a similar frequency to spatial features, less frequent than access to help, but more frequent than familiarity or the presence of threatening other people. Overall 46 (87%) of the 53 test participants mentioned street lighting as a reason for feeling reassured on two streets of their choice and 45 (85%) mentioned lack of adequate street lighting or darkness as a reason for not feeling reassured on two streets of their choice.

These results suggest that road lighting can play an important role in improving reassurance and provides more confidence that the effect of lighting was not enhanced by obvious changes of lighting in test images. What is not yet known is how this effect varies with light level; further research is on-going to address this.

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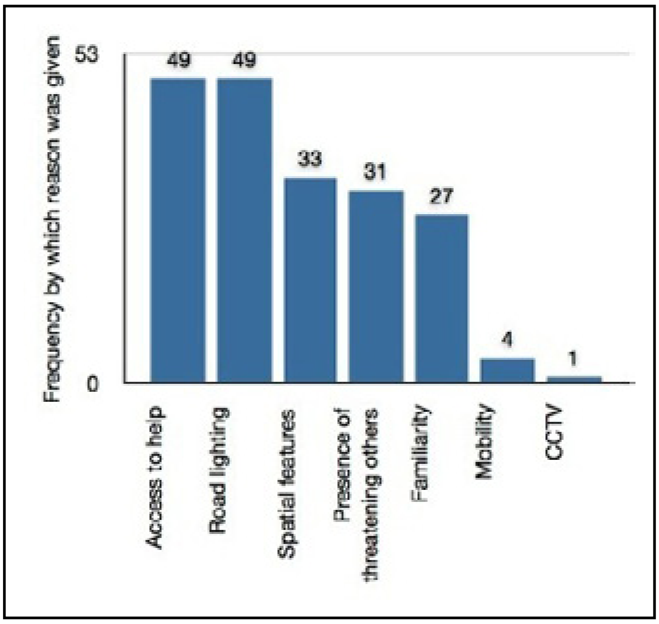

Figure 1 – Reasons given for feelings of reassurance: response without visual prompt

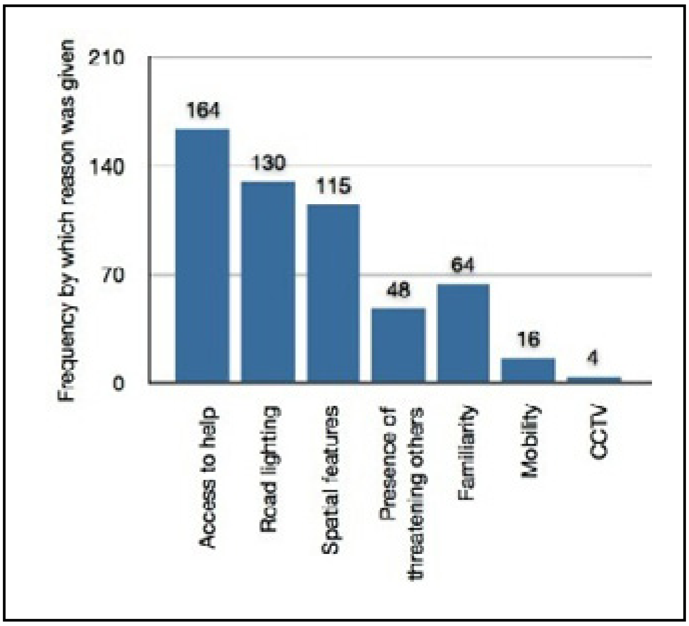

Figure 2 – Reasons given for feelings of reassurance: discussion using photographs provided by participant

OP04

A NEW REAL TIME INTELLIGENT MANAGEMENT MODEL FOR STREET LIGHTING

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The energy consumption of public lighting is a major item in the cost that have to be borne by the public authorities in Belgium. The last developments of the LED technology combined with intelligent control systems of lighting can help saving energy.
Concerning the intelligent control of lighting, the European standards give only few recommendations and no guidelines on the method that should be set up.
The management systems currently used do not consider any lamp flux variation according to real time traffic. At best, these management systems decrease the lamp flux (and thus their absorbed power) during certain fixed periods of time, according to an average of the traffic, measured during a specific previous time. This type of management solution is interesting for roads having continuous traffic during the whole night (i.e. highway) but, in case of activity parks, where the night circulation is significantly reduced during the night, a more advanced management system could bring higher energy savings.

For this reason, we have developed a model of intelligent lighting that combines the mesopic CIE model with two original principles of dimming : the spreading out of the maximum power and the power transfer curve. (The spreading out will be developed later in the article because it is currently the subject of a patent deposit.)
The integration of the mesopic vision's model allow to reduce the maximum power of the lamps, while maintaining a similar perceived photometry to the one required in photopic visual conditions.
The power transfer curve is the second original principle of dimming; the lamp power is modified according to the speed and the position of the vehicle (or the pedestrian).
More precisely, the lamps are dimmed from a maximum power determined by the class of lighting to a minimal safety power following a continuous dimming curve developed using a mathematical model of normal distribution.

The objective of the transfer curve implementation is to switch on to their full power only the lamps which are located in the user area of interest. This area of interest is defined according to the visibility distance of the driver, this distance being defined by the user speed.
Beyond the visibility distance, the lamps are dimmed, according to the user's position. The gradation of the lamp power is continuous and follows a sigmoidal curve.
Behind the user, lamps are gradually turned off using a symmetrical curve, whose coefficient of symmetry is itself adjustable according to the user's speed.
The integration of the LED technology, the mesopic vision model and the implementation of intelligent management system can bring substantial energy savings. A simple simulation model applied on the site that will be soon renovated according to this principles predicts a saving of 14327 kWh/year (= 78 %).
The developed intelligent management model makes it possible to illuminate economically in the right place at the right time in the right direction and with the right intensity.

The values of the parameters used in the power transfer curve will be soon validated on site. The power transfer curve modifies the lamp power according to the speed and the position of the user.

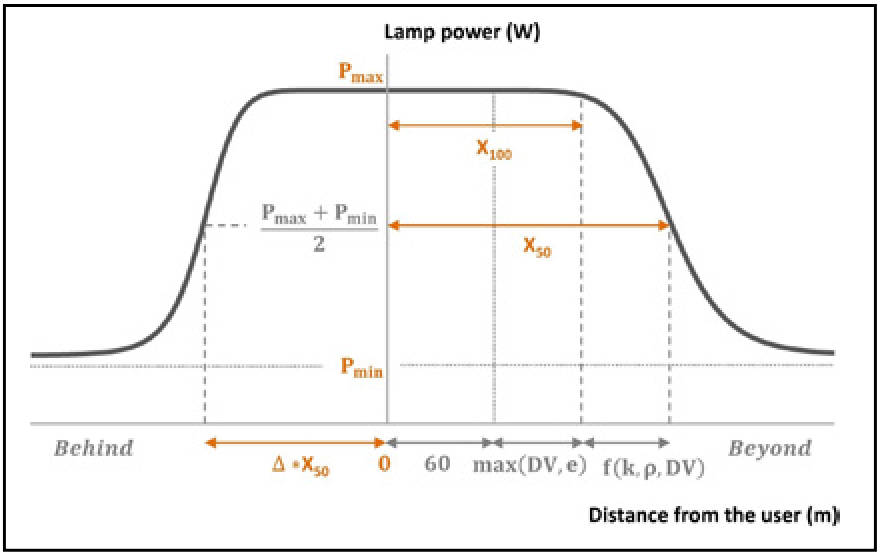

Figure 1 – The power transfer curve modifies the lamp power according to the speed and the position of the user

OP05

ESTIMATING EYE ADAPTATION FOR TYPICAL LUMINANCE VALUES IN THE FIELD OF VIEW WHILE DRIVING IN URBAN STREETS

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Introduction

Glare typically occurs when a luminance considerably higher than the one we are adapted to falls into our field of view. Especially when driving a car, our eyes are adapted to relatively low luminance levels, and as a consequence, road lights, streets lights or headlights of cars may be perceived as glary, hampering visibility of objects on the road, or at least generating visual discomfort.

Models to predict glare for road lighting exist [1-3]. They model perceived glare as a function of the luminance of the light source, its eccentricity with respect to the line of sight, and the background luminance. These models assume that the human eye is adapted to the background luminance, which under experimental conditions in a laboratory set- up is a good approximation. On real roads, however, our eyes continuously scan the environment, and hence, the luminance distribution falling into our field of view is spatially complex and continuously changes over time.

Visibility and light adaptation are very well studied for spatially complex patterns that are stable over time [4] or for single patches of light that change over time [5], but not for real situations existing of complex light patterns that also change over time. As a first step to determine the type of experiments needed to establish human eye adaptation under these complex circumstances, we measured typical luminance distributions in the field of view while driving a car in urban streets (in our case, more specifically in the Netherlands).

Experimental set-up

Since our head-mounted eye-tracker was insufficiently safe to use and insufficiently accurate to record eye movements while driving, we used a laboratory set-up in which the participants were requested to look at a recorded video of driving in urban streets as if they were driving themselves. While watching the video on a display screen, the participant's eye movements were recorded with a remote eye-tracker (SMI RED). While the driving scenes were recorded local luminance values in these scenes were simultaneously captured with a luminance camera (Prometric 1423E-1) calibrated with a luminance spot meter (Konica Minolta CS-100). By relating the participants' eye fixations to the luminance values, we could establish the luminance distribution in the field of view of a driver as a function of time.

Data analysis

To analyse the experimental data we first calculated a series of saliency maps over time from the eye fixations per participant and over all participants (see e.g., [6]). Each resulting saliency map (of the series over time) was then weighted with the luminance map of the urban scene (at the same time slot). From the series of resulting luminance weighted saliency maps, we extracted the time course of the luminance falling on the fovea. We then applied the temporal adaptation model for foveal light stimulation [5,7] to this time course, to determine the extent to which the actual "perceived" luminance on the retina is damped as a consequence of temporal adaptation.

Temporal adaption

To perform the data analysis, described above, we had to make some assumptions. One unknown was the visual angle over which to integrate the luminance weighted saliency in order to estimate the luminance falling on the fovea. Making the visual angle too small implies that the actual luminance value becomes very sensitive to the particular fixation of each participant, and therefore, becomes less representative. Making the visual angle too big implies that the luminance weighted saliency is integrated over a region, also including a large part of the background. Using various values of this angle we determined that for an angle of 8o the luminance value of the retina was stable. Secondly, we neglected the time needed for light adaptation, and used the model for early dark adaptation [7] to estimate the actually perceived luminance for the actual luminance steps at the fovea, analysed on a seconds time frame. Figure 1 illustrates the time course of the luminance on the fovea (on a log-scale, blue curve) and the perceived luminance as a consequence of adaptation (red curve, hardly visible).

Conclusion

The main conclusion from this graph is that for typical light fluctuations during driving also dark adaptation is so fast in the first tenths of a second that the perceived luminance practically follows the actual luminance on the fovea.

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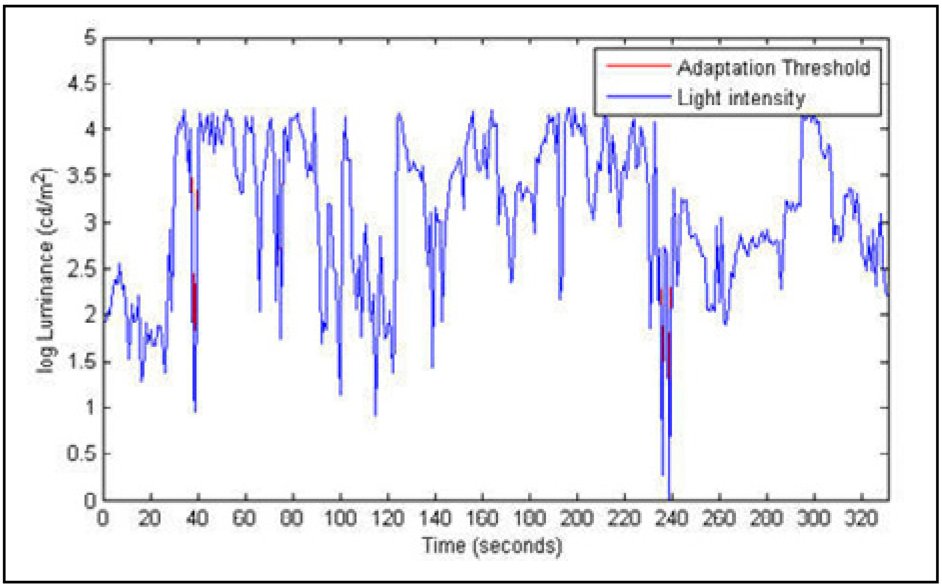
Adaptation Threshold
Light intensity
log Luminance (cd/m^2)
Time (seconds)

Figure 1

Colour Quality Assessment

(Chair: Ronnier Luo, United Kingdom)

OP06

SEMANTIC INTERPRETATION OF COLOUR RENDERING INDICES AND COLOUR FIDELITY INDICES: A COMPARISON OF CRI AND CRI2012

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1. Introduction:

CIE TC 1-69 recommended a method to improve the performance of the current CIE colour rendering index, the CRI2012 colour fidelity index. It has several advantages including an improved set of reflecting samples, modern colour difference evaluation by CAM02-UCS instead of the obsolete U*V*W* method of the current CRI and a new scaling by a new function which better reflects human perceptual responses. This function is partially based on an experiment of the present authors (see “Experimental Method”). Its continuous colour similarity scale (between 1.0 and 6.0) was labelled at its integer values by a set of categories to alleviate its semantic interpretation for non-experts using the terms of natural language: very good (1), good (2), moderate (3), low (4), bad (5), very bad (6). Two further visual experiments applying a similar method were carried out with different light sources and different reflecting colour samples including homogeneous colour patches and real objects. Their aim was the same i.e. to scale colour similarity. These two experiments have been described elsewhere in detail.

2. Experimental Method:

Eleven light sources were used at 2800K, an incandescent reference and ten test light sources of different colour rendering properties with Ra values ranging between 18 and 93 (mixtures of white and RGB LEDs). They illuminated a still life of coloured test objects, see Figure 1. 15 subjects assessed the change of colour appearance of the individual objects when the light source was changed from the reference to one of the test light sources using the above mentioned colour similarity scale. Observers had to move a slider by the aid of the mouse as long as the position of the slider agreed with their colour similarity rating, see Fig. 1. Colour differences between the test and reference appearance of the same object were measured instrumentally at the same time.

3. Semantic interpretation of CAM02-UCS colour differences:

The above mentioned three experiments (the one described in Section 2 and the two similar experiments described elsewhere) resulted in a unified dataset of semantic colour similarity values (R) between two colour appearances of a reflecting colour sample, under a test light source and a reference light source. Based on this dataset, these values (R) were predicted by a prediction curve using the physically measured and calculated CAM02-UCS colour differences (ΔE’) between the two stimuli, i.e. the reflecting colour sample under the test light source and the reference light source.

4. Aims of the present paper:

As the new colour fidelity index CRI2012 is based on CAM02-UCS (ΔE’), the above mentioned semantic interpretation function R(ΔE’) can be applied to interpret the new general colour fidelity index (Ra,2012) directly. One aim is the validation of the last step i.e. the re-scaling in the CRI2012 method. Another aim is to specify the semantic categories corresponding to the values of the new general colour fidelity index (Ra,2012), e.g. does Ra,2012=89 represent a good, good-very good, or a very good similarity between the colour appearance of the test light source and the reference illuminant? The answer to this question is important for non-expert light source users. An aim is to derive a mean semantic interpretation function R(Ra) for the current general colour rendering index and to compare it with R(Ra,2012). Another aim is to quantify the error caused by this non-uniformity for the current special colour rendering indices, in terms of semantic interpretation. In this abstract, only one example (blue trousers) is shown. The aim is to point out the advantage of using the new specific colour fidelity indices (Ri,2012).

5. Semantic interpretation of the indices:

In Fig. 2, the semantic interpretation of the following four indices is shown: Ra (the current CIE general CRI); Ra,2012 (general colour fidelity index according to the new CRI2012 method); an object specific colour rendering index (Ri) for

the example of the measured spectral reflectance function of a pair of blue trousers and the object specific new colour fidelity index (Ri,2012) for the same object. As can be seen from Fig. 2, the function R(Ra,2012) reveals a linear tendency. This verifies the last step (re-scaling) of the CRI2012 method. The mean function R(Ra) - obtained in a calculation - is non-linear implying that the CRI scale does not represent the human perceptual response. For a given category (e.g. “moderate” colour similarity), the values of the current Ri for “blue trousers” (computed for different test light sources) are higher than the values of the current general colour rendering index (Ra) implying that the scale of this special colour rendering index is visually incompatible with the Ra scale and with the scale of other special colour rendering indices. One reason is the perceptual non-uniformity of U*V*W*. This can also be seen from Table 1 summarizing the semantic interpretation of the four indices.

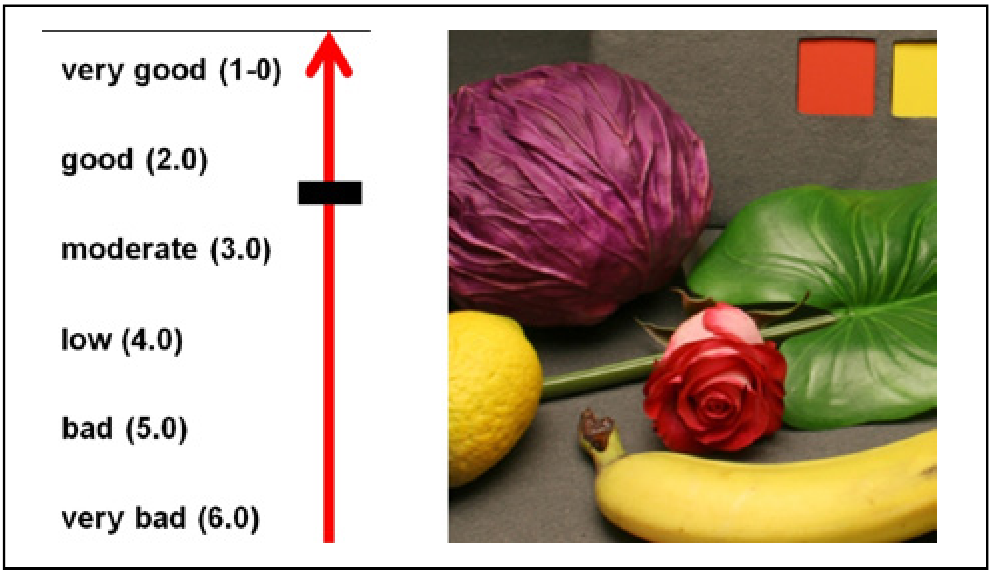

Figure 1 – Left - Colour similarity scale labelled with categories for easy semantic interpretation with a slider (black bar on the red arrow); Right – still life with coloured test objects: the observer could switch back and forth between the test and the reference light sources illuminating the objects to assess colour similarity by moving the slider on the left scale

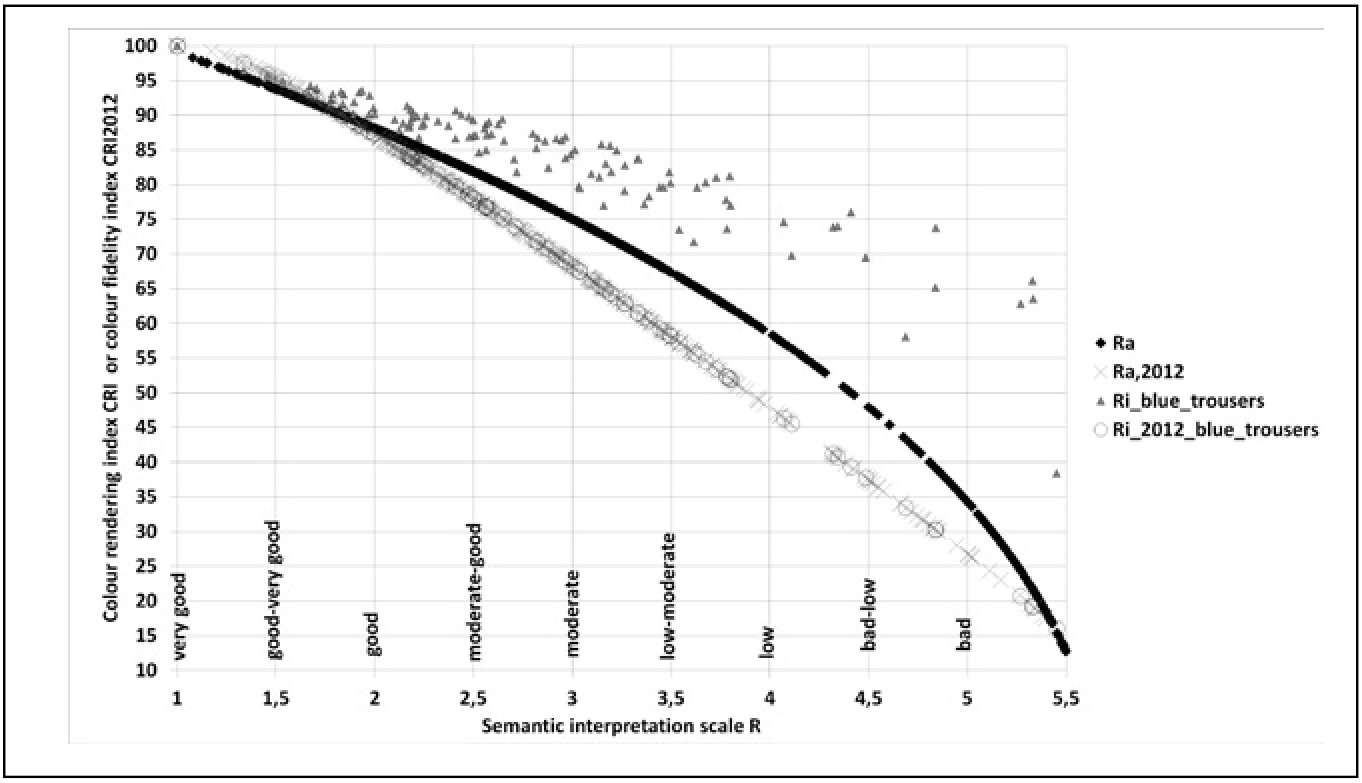

Figure 2 – Semantic interpretation of four indices: Ra (CIE CRI), Ra,2012 (CRI2012), object specific colour rendering index (Ri) for "blue trousers" and object specific colour fidelity index (Ri,2012) for the same object

Category	Very good	Good-very good	Good	Moderate-good	Moderate	Low
R	1.0	1.5	2.0	2.5	3.0	4.0
Ra	100	94	88	82	75	58
Ra,2012	100	95	87	78	67	47
Ri	100	95	91	87	85	72
Ri,2012	100	95	87	78	67	47

Table 1

OP07

COLOUR RENDERING OF FACE COMPLEXION AND HAIR UNDER LED SOURCES

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Introduction

Skin colour, is arguably one of the most important factors affecting the acceptability of a lighting installation and is, consciously or unconsciously, often a criterion to evaluate the colour rendering of sources. Lighting system that render skin poorly will be unacceptable and rejected by occupants and a lighting that flatters people may be preferred.

This study investigates these questions and tests the perceived colour rendering of light sources on face complexion and hair by comparing participants' preferences for their own skin colour viewed under several different light sources. The aim is to identify the mixing of LEDs which various observers will judge as the most appropriate for complexion and hair and to determine which metric describe best subjects advice.

Experiment

In order to study these questions, a viewing box was specially designed (figure 1). The device is equipped with a mirror surrounded by sources hidden under diffusers (figure 2). The luminous plates are lit with fluorescence tubes or LEDs sources (cool white, red, amber, blue and green).

During the experiment the box is totally closed (no other light penetration), the reference light source is supplied by two fluorescent tubes Master TL5HO 830 24 W and we selected 16 clusters of LEDs. The illuminance level on the face of the observer was 220 lux ± 5 lux and the colour temperature is 2700K ± 12K.

63 observers took part in the experiment. Three skin types and different colour of hair were tested. We also used a copy of the 24-sample edition of the GretagMacbeth ColorChecker Chart (MCC) to see the influence of a multicoloured chart on the answers of participants.

A categorical rating was proposed to the subjects. The observers were asked to determine the acceptability of the colour appearance for the different targets (skin, hair and MCC) on a 7 points scale. In a session, the observers have to express on 20 light sources presented sequentially (the fluorescence is presented four times. The experiment was assisted by a computer which randomly change the order of the presentation of the stimuli for each participant and recorded the answers. Each session lasted approximately 30 minutes.

Results

We obtain inter-observer variability which is inherent to perceptive test but the none statistical significance difference and the low intra-observer variability permit to conclude that the test is well understood and that it was not too difficult to achieve.

Analyses of variance on skin show that the effect of lamp and the interaction between lamps and colour of skin were significant. ANOVAs on hair and MCC show that the effect of light sources was significant. To interpret these findings, post-hoc analysis, were applied and permit to classify sources in different preferred categories.

In the highest rated category we find fluorescence and 3 LED clusters. Which permit to conclude

that some LEDs mixing are as good as fluorescence for the colour rendering of skin.
Cluster of LEDs with RGA or RGB are not appreciated and should be avoided.
The cluster of LEDs preferred are those with a greatest amount of red, this underlines the importance of the quality and the quantity of red LED in a cluster.
The investigation of interaction between lamp and skin colour shows that Asian people tend to prefer highly saturated sources more than the other population and dislike the none saturated ones more.

Additional ANOVAs were performed to examine whether age, sex, glasses, job, expertise and locus of lamp lin the
chromaticity diagram have influence on the relative preference. None effect were statistically significant except the locus. The sources with chromaticity coordinates close to the Planckian locus are significantly preferred over the others, while the sources with locus near the green region are significantly disliked. Light sources relatively richer in red than green were preferred
The study of averages and standard deviations seems to show that skin colours provides a more sensitive indicator of colour rendering than do the other targets. These results were also found by Rea (1).

Some studies have found that the Test-Color method recommended by the CIE (2) does not accurately predict the outcome of visual experiments (3, 4). Our experiment permit to examine this question by comparing metrics with visual perception.
We calculated different colour rendering metrics:

- Special (Ri) and general colour rendering index (Ra) recommended by the CIE
- The NIST Colour Quality Scale (CQS) and the provisional index Qf, Qp and Qg
- The full spectrum colour index (FSCI)
- The gamut area index (GAI) adapted to the colour of MCC and CRI.
- The Memory Colour Rendering Index

The comparisons between visual ranking vs metrics underline that neither CRI nor R13 which represents the special colour rendering index on the human complexion give an accurate estimation of the visual rendering of skin complexion.
Corelations show that skin colour rendering seems to be better determined by MCRI and Qp.

Acknowledgement
The authors gratefully acknowledge Philips for their contribution in the development of the experimental setup and their financial support.

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Figure 1 – Viewing box

Figure 2 – Subject evaluating is appearance

OP08

A STUDY OF COLOR RENDERING PROPERTIES BASED ON COLOR PREFERENCE OF OBJECTS IN ADAPTATION TO LED LIGHTING

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1 Introduction

White LED light sources are efficient, long-life, and compact. LED lighting sources have more flexible in spectral design than conventional light resources.
The calculation method of the CIE color rendering specification is based on colorimetric fidelity to the reference illuminant. Therefore, the CIE color rendering indices of white LED light sources is not suitable for measuring emotional feeling as preference or naturalness of illumination. It is expected that the inherent spectral power distributions of white LED light sources interact with the spectral reflectance of test color samples. It is assumed that the order of magnitude of color differences when color samples are illuminated by a white LED light source is different from that by other light sources. However, the interrelated effects of chromaticity, color rendering, and other aspects of spectra on lighting are still not well understood. It needs to investigate the effect of distinctive sensibility with LED lighting.
We developed the lighting system with various spectral distributions of LED lights [1]. In addition, subjective experiments were carried out under LED illumination with various spectral power distributions. It was suggested that the relationship between the preference evaluation and the saturation of object colors has a higher correlation than the relationship between the preference evaluation and the Ra of various LED lighting.
In this paper, we carry out detail investigation including memory colors in order to make it clear that the relationship between the preference evaluation and the saturation of object colors.

2 Methods

Subjective experiments were carried out also in this study using the spectrally adjustable lighting system (SALS). Then, they were analyzed by focusing in particular on the relationship between the preference evaluation and the saturation of object colors.
There were the following three points differing from our previous experiment: (1) the subjects observed one object at a time, (2) the sample objects were selected in consideration of memory color objects, and (3) the evaluation criteria were limited to preference, naturalness, vivid, and near to memory.
SALS had the advantage that evaluation in a real-life setting could be performed, because the subjects were able to be completely adapted in lighting environment at 700 lux or higher. SALS consisted of 1,500 high-power LEDs of eight color channels (red, orange red, amber, yellow, green, blue green, blue and white) covering the 440 nm to 640 nm region. The LEDs were controlled by computer programs directly and it could illuminate with various CCT and with the color rendering properties.
Color appearance under the LED lighting with CCT 3000K, 5000K and Ra60 to Ra96 were evaluated subjectively. Apple, orange, lemon, cauliflower, egg apple, plants and human skins were selected respectively for memory color samples. In addition, wool yarns with orange, cyan and

yellowish green color also were selected. About 30 subjects observed one of the sample objects at a time.

3 Experimental Results

The experimental results were analyzed mainly in terms of preference and saturation. Figure 1 shows the relationship between the preference evaluation data and the C* values of the orange sample in the LED lightings. These scores were 30 persons‘ average value. Figure 2 shows the relationship between the preference scores and C* of a wool yarn with orange color. The results in Fig.1 and Fig.2 show that the range in preference for color saturation of the object existed as the previous experiments for the several samples. When the object’s color was not only somber but also too vivid, the experimental preference score was low.

In addition, the preference score in Fig.1 is different from that in Fig.2 at the same C* value. In general, the color of clothes and wool yarns was not supposed to be correspond to memory colors. It was confirmed that the optimal range in preference evaluation changed with the objects and the memory colors.

Furthermore, in order to analyze in detail, the regression analysis was applied. The preference score was high correlation by the secondary regression. That is, it was suggested that the score of the preference to objects can be approximated with sufficient accuracy. The investigation about the color of memory color is useful and may be able to be applied for evaluation of preference. However, color investigations for each object are difficult from a perspective of huge number of objects, variability of subjects and complexity of models. It is necessary to examine a simple evaluation method for preference.

4 Conclusion

From the experimental results in various LED lighting, it turned out that the range in the preference for color saturation of an object exists as previous experiments for several samples. In addition, it was suggested that the memory color relates to the preference evaluation. However, investigations for memory color of each object are difficult from the aspect of huge number of objects and complexity of models. It is necessary to examine a simple evaluation method for preference, also taking memory color into consideration.

This research project has been supported by NEDO, New Energy Industrial Technology Development Organization of Japanese Government.

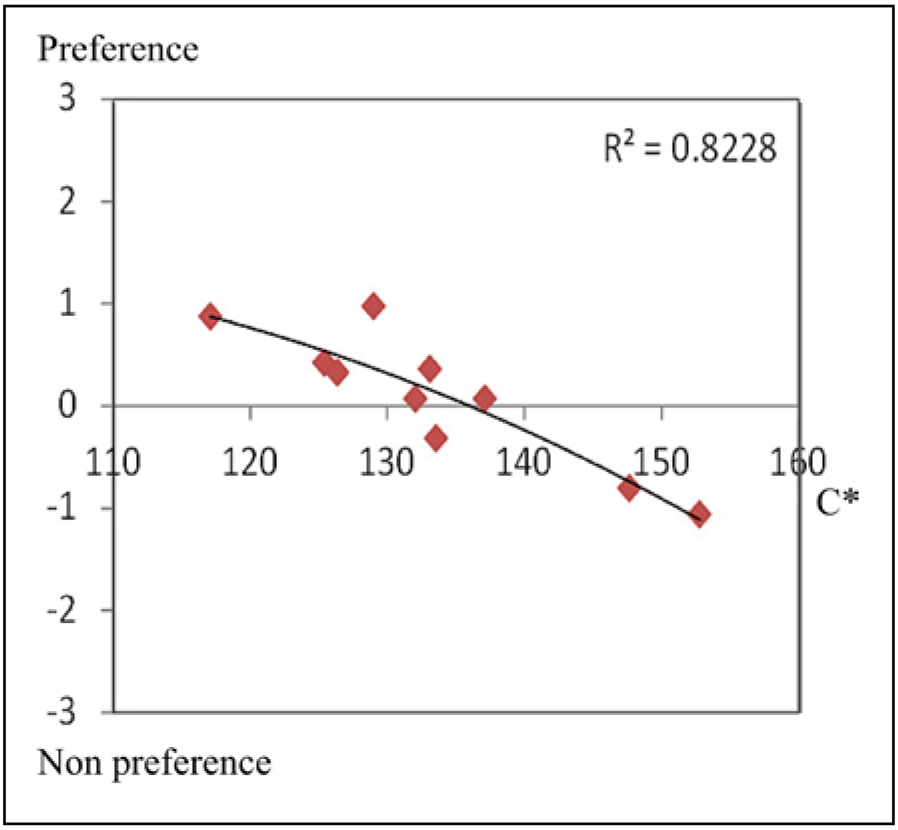

Figure 1 – C* versus experimental preference score for orange

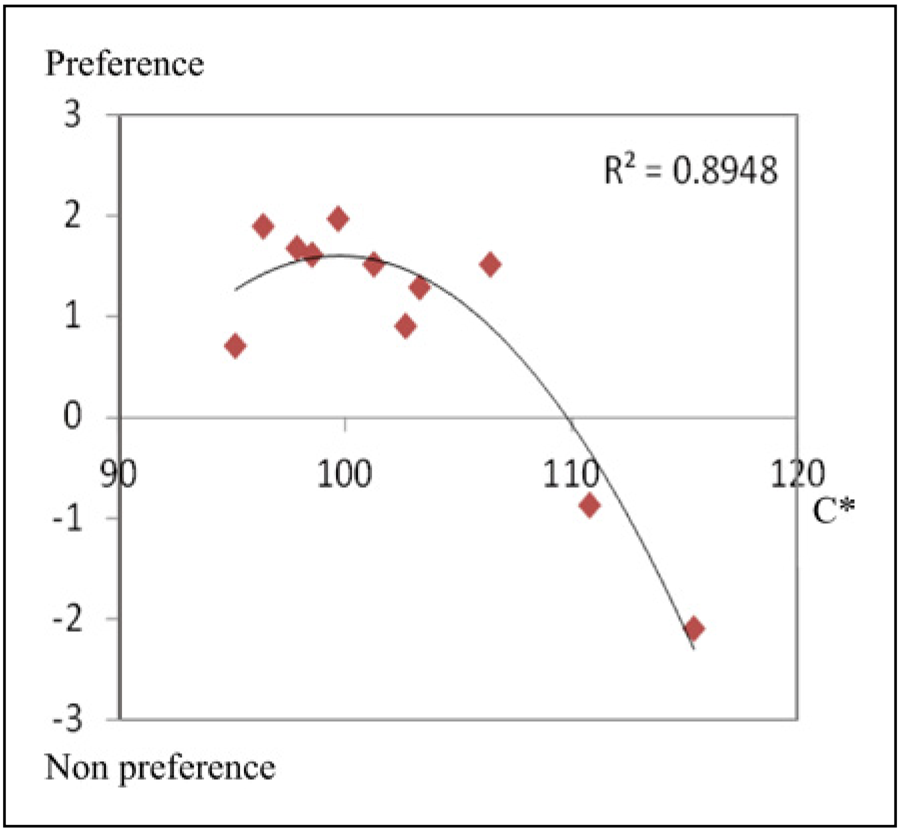

Figure 2 – C* versus experimental preference score for wool yarns with orange

OP09

OPTIMIZATION OF COLOR QUALITY FOR LANDSCAPE LIGHTING BASED ON FEELING OF CONTRAST INDEX

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Background

Recently, Light-Emitting-Diode (LED) lamps have been installed in various places for energy saving. In outdoor lighting, high-efficiency LED lamps have been replacing conventional light sources. Not only illuminance level for visibility but also color rendering property is important, especially when lighting up trees, flowers and buildings for attractive appearances.
On the other hand, the problems of color rendering index (CRI) have been discussed. Now, various color rendering methods are proposed as alternatives or supplements. Feeling of contrast index (FCI) is one of them. FCI is designed to measure the visual clarity and feeling of contrast that a light source provides when illuminating colored objects. FCI is derived using a simple transformation of the gamut area consisting of highly saturated red, green, yellow and blue in CIE LAB color space. In calculation, CIE chromatic adaptation transform (CIE 109-1994) are used. For all type illuminants, the reference illuminant is D65. The FCI of illuminants which have larger gamut area than D65 are greater than 100.
In case of landscape lighting, it might be considered good appearance when the color of leaves or flowers rendered to high saturation. So, there is possibility that high FCI light sources show the objects attractively.

Objective

This study aims to reveal the characteristics of light sources which show the color of plants attractively. The usefulness of FCI is also considered in this study.

Methods

29 spectrums were designed as test illuminants of psychophysical experiment. Design parameters were FCI and correlated color temperature (CCT). FCI was set at 7 levels (90 to150). CCT was set at 2 levels (2800K, 3000K). We modified a spectrum of B-Y type LED to reach target values. The FCI value can be changed by controlling the intensity sharply in a narrow range of wavelength which affects FCI value or broadly in a wide range. So we designed spectrums by these two ways for each FCI level. The relationship between FCI and Ra in the experimental illuminants is shown in Fig.1. Very high FCI (>140) illuminants do not have very high Ra values because they cause saturation enhancement. Some high FCI illuminants and low FCI illuminants have almost same Ra values, but their color shift direction is opposite. The relationship between FCI and Ra is shown in Fig.1. Duv is set within -5 to +5. Two spectrums of commercially available LED lamps were used as reference illuminants (CCT=2800K, FCI=113, CIE Ra=80, Duv=4 / CCT=3000K, FCI=108, CIE Ra=85, Duv=0).
These spectrums were generated by ELS-VIS (Nikon), which has a xenon lamp, grating system and liquid crystal filters.
We prepared 3 kinds of plants for observation objects. They were potted marguerites as green

objects, leaves of red tip photinia as red objects and leaves of ginkgo as yellow objects. Two sets of plants were placed in two boxes. The boxes were placed side by side, and illuminated with the reference illuminant and the test illuminant respectively. The illuminance at the object plane was 150lx. Test illuminants were compared with the reference illuminant which has same CCT.
In the experiment, 22 observers (15 male / 7 female) were asked to rate the color quality by two methods. Firstly, observers assessed the color of plants by magnitude estimation method. For example, if they think that the color quality of one test illuminant is 1.2 times as much as that of the reference illuminant, they give 120 to the test illuminant. Observers were instructed that color quality means overall impression of the color appearance of planting from the view point of attractiveness and adequateness. The colors of three plants were assessed collectively and individually. Next, they assessed the impression of set of plants using 5 word pairs on absolute evaluation. The word pairs were vivid / faded, fresh / not fresh, natural / unnatural, bright / dark, beautiful / not beautiful. All terms were presented in Japanese. They assessed the impression on a 7-point scale about each word pairs.

Results
The result of magnitude estimation revealed that illuminants which have higher FCI values were more preferable especially in collective estimation and individual estimation of green and red. Most preferred illuminant was FCI=150, CIE Ra=75 in 2800K condition. Changes in the evaluation of yellow were smaller than that of other colors. It was also shown that higher FCI illuminants show the plants more vividly, freshly, brightly and beautifully. Under the illuminants of which FCI values were over 140, 7 of 22observers evaluated that higher FCI illuminants makes poorer appearances in naturalness. The appearance of plants under test illuminants which have high CIE Ra values (90 to 95) were not evaluated as most natural. There was no difference between the results of 2800K condition and that of 3000K condition.
Conclusion
High FCI illuminants show the color of plants attractively even if they don’t have good CIE Ra values. So, for landscape lighting, light sources which render the color of objects to high saturation are suitable rather than light sources which render the color of objects faithfully. However, for landscape lighting, it is important that everyone feel comfortable, so light sources which show the color unnaturally for some people are not appropriate. As a result of this experiment, it is not appropriate to use light sources whose FCI values are too high (150 or higher).
We can evaluate color rendering property based on preference by clarifying the optimal values of FCI for landscape lighting. And we can design optimal spectrum for it by using FCI. For other field where objects colors are preferred when they are rendered to high saturation, there is possibility that we can optimize color quality by using FCI.

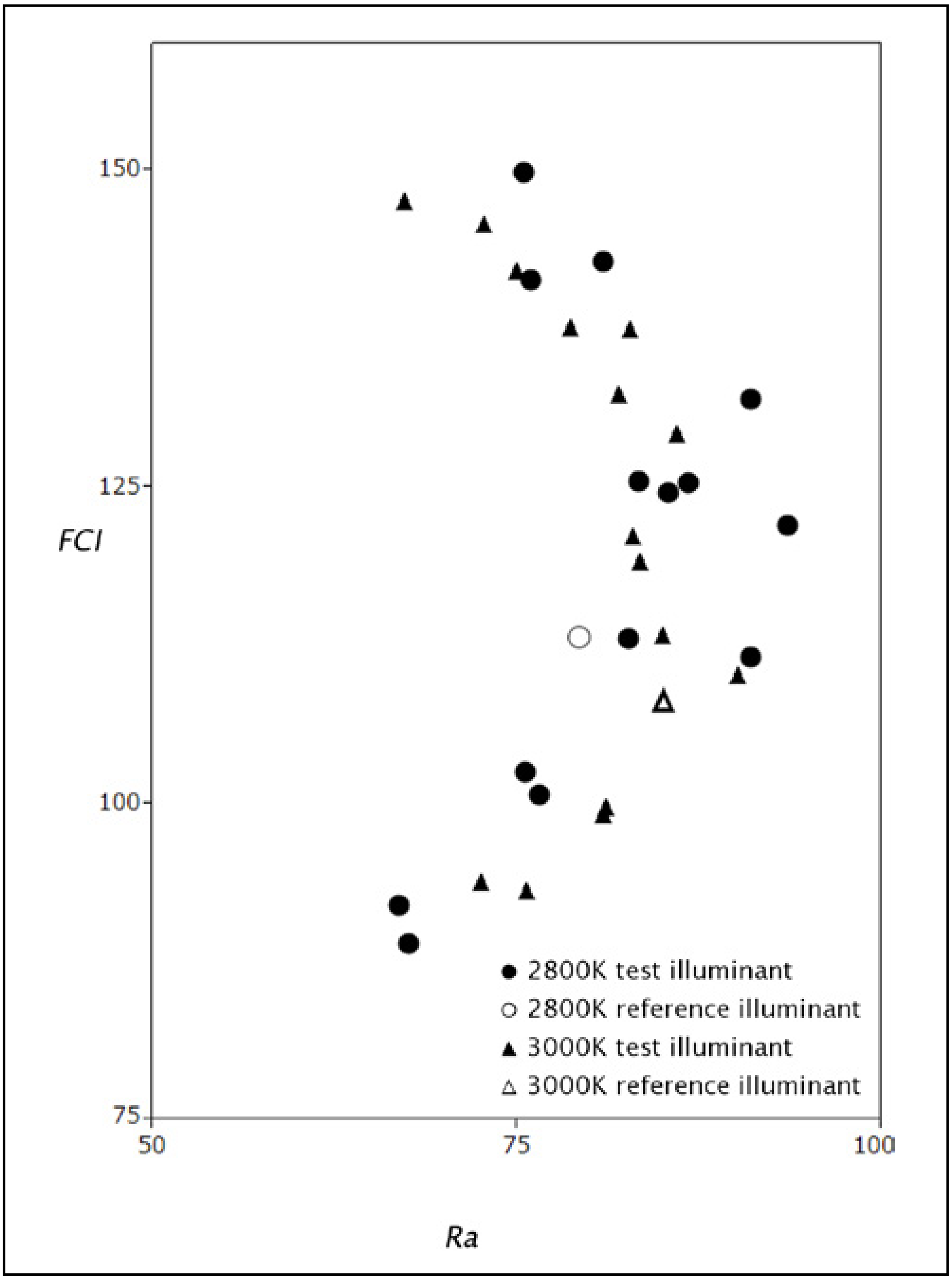
150
125
100
75
FCI
50
75
100
Ra
2800K test illuminant
2800K reference illuminant
3000K test illuminant
3000K reference illuminant

Figure 1

OP10

THE EFFECT OF AMBIENT ILLUMINATION SPECTRUM ON VISUAL PERFORMANCE

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Introduction:

In lighting practice ambient illumination is generally characterized by photometric parameters related to measured or simulated illuminance values. In some cases, especially when the observer's position can be determined luminance values are also considered. The colorimetric parameters of the illumination are usually defined by the correlated colour temperature of the light sources, in rare cases of the luminaires. In carefully designed projects the CIE 1931 colour coordinates might also be taken in account. However we can state that the spectral characteristics of the lamps are almost never applied in practical lighting calculations.

In our current research study our intention is to show how the spectral characteristics of the ambient illumination affect human visual performance supporting the importance of considering illumination spectrum in specific visual tasks.

Methods:

To have the illumination spectrum as the single varied parameter a special lighting booth was designed and constructed incorporating four different light source types creating indirect illumination. The mean ambient luminance and correlated colour temperature along with the CIE 1931 x, y colour coordinates were adjusted to be equal within 5% for three of the four ambient illuminations ($L = 361 \pm 15$ cd/m^2; CCT = 2645 ± 53 K; $x = 0.2637 \pm 0.0032$; $y = 0.3565 \pm 0.0016$), while the fourth light source type served as a chromatic reference with its CCT of approx. 6500K. The similarity of luminance distribution of the ambient in the case of each light source type was realized accurately positioning the light sources.

Two age groups of human test subjects were involved in the research (20 subjects in the age group of 20 to 35 years and 10 subjects above the age of 55). Individuals with colour vision defects or visual acuity less than 20/40 were excluded from the test group. The subjects were fully submerged in the illuminated ambient for at least five minutes prior to testing to ensure adequate adaptation. Several standard clinical and laboratory visual tests were applied in each ambient to test the visual parameters of the subjects. Basic colour vision tests such as the Ishihara plates along with the Lanthony D15d colour ordering test were used as light reflecting colour vision tests while the Cambridge Color Test (CCT) was presented on a computer monitor along with the Contrast Sensitivity Function (CSF) test. For these latter two the VSG 2/5 video card of the Cambridge Research Systems was used with the computer display placed outside the illuminated ambient in a 5.5° visual angle avoiding all possible reflections or glare from the inside illumination. The relatively small visual angle and the fact that the display was turned off during adaptation phases were to minimize possible interference of visual adaptation to the display's photometric and colourimetric parameters. All monitor tests were also applied in dark ambient to serve as absolute reference. To test reading performance a modified paper version of the reading test from the ISO 9241-304 standard was applied.

Results:

The Ishihara test was completed with no errors in all illumination conditions. This result shows that the test is not sensitive for the illumination spectrum in the case of colour normals.

In the D15d test the lowest error values were found for the incandescent (1.059 ± 0.059) and the 6500K (1.038 ± 0.040) illuminations while the LED and the 2700K fluorescent lamps gave higher (1.110 ± 0.123 and 1.094 ± 0.069) error rates.

The CSF tests did not give statistically significant differences regarding the comparison of contrast sensitivity at the used spatial frequencies and chromatic and achromatic stimuli. However applying a ranking analysis the results indicate the most effective performance under the 6500K (ranked best in all test conditions) illumination and the least effective with the incandescent lamps (ranked worst in 66% of the test conditions).

The reading test results have demonstrated better performances under 6500K FL and LED illumination for the age group of 20-35 and under 6500K FL for the age group above 55 years. However the differences were not statistically significant due to the large interpersonal variations.

The largest statistically significant differences ($p < 0.05$) were found in the CCT tests where the 6500K FL illumination

clearly affected the tritan discrimination (122.8 ± 68.8 vs < 100.0) while the protan and deutan discriminations were more affected by the 2700K lamps with the incandescent having the largest effect supposed to be related to its continuous spectral power distribution.

The tendencies of the differences were generally the same for the two age groups. However the group of 55-70 had smaller differences in all tests generally without statistical significance. This latter fact might also be related to the relatively smaller number of participants from this group.

Conclusions:

In general subjects have shown better results under the 6500K illumination in several tests even though the this light source was a fluorescent type. In the comparison among the three 2700K illuminations the LED ambient resulted best in monitor tests and provided the highest score in the reading test. As expected from its colour rendering characteristics the incandescent lamp induced better results in the colour ordering test. Based on the visual tests performed we can state that indeed the spectral characteristics of the ambient illumination affect visual parameters however the chromatic characteristics of the light source has seemingly significant effect as well.

OP11

SIMULATION OF THE RETINA RESPONSE TO MESOPIC VISUAL SCENES

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[2.] Université Catholique de Louvain - UCL, Louvain-la-Neuve, Belgium.

This paper presents an image-based approach to lighting design in mesopic lighting conditions. Firstly, we generate a multispectral image of a visual scene from the considered view point (a pedestrian walking along an urban street for example). Secondly, we transform this multispectral image into perception maps using a computational model of the retina. Finally, we analyse those perception maps and compare them by varying parameters in the multispectral image (spectrum of the light source, photometric distribution, geometry of the street, type of building, materials...). The aim is to determine which light spectrum gives the best results in a given situation.

1. Multispectral image

We have implemented a generator of multispectral images. The characteristics of the scene are defined as well as the spectral accuracy (number and widths of spectral ranges, 16 ranges from 400 nm to 700 nm by steps of 20 nm for example). The spectrum of each light source and the spectral reflectance of each material need to be defined with the same accuracy. Then, the generator calls the Radiance ray-tracing software system several times (16 in this example) in order to calculate the spectrum of each pixel.

2. Retina model

We have been developing a non-chromatic computational model of the retina that mimics the various steps of processing within the retina in front of a mesopic visual scene. This model consists of several spatio-temporal filters and functions that simulate the functioning of the layers of the retina. We have evaluated its ability to predict many visual phenomena occurring in mesopic vision by virtually reproducing psychophysical tests [1].
The model can be divided into two main steps. The first step is the transduction of the luminous signal by rods and cones [2]. This transduction depends on the intensity and spectrum of the signal as well as on the adaptation state of the cells. We use a spatio-temporal model of adaptation. Temporally, low-pass filters simulate the time course of the various mechanisms of adaptation. Spatially, a Gaussian filter simulates the adaptation of a cell due to its neighbouring cells. The size of the Gaussians grows up with eccentricity, according to the size of physiological receptive fields of retinal cells. The second step models the retinal processing (horizontal, bipolar, ganglion cells) using classical filters used in computational vision models [3]. The main function is the convolution of a difference-of- Gaussians filters with the transduction result, each Gaussian being convolved with an exponential decay function to simulate the latency of the different types of cells. As a result, we produce perception maps of the parvocellular and the magnocellular pathways of the retina. The model considers the variable density of rods and cones and the increase of receptive fields sizes with eccentricity.

3. Results

Figure 1 shows the results of the computational model on the same scene with two different light source spectra. All other elements were similar in both situations during the generation of the multispectral image. The photopic luminance maps are thence very similar while the scotopic luminance maps vary. This allows us to compare the effect of the two light spectra on the retina. The first one is an High Pressure Sodium (HPS) spectrum (S/P=0.6) while the second one is a Metal Halide (MH) spectrum (S/P=1.39). We can notice on the response maps that the MH gives a better detection of edges in the periphery of the visual field. For example, the borders of the windows and the shape of the pedestrian walking on the opposite side of the street are sharper. The detection is also quicker with MH than with HPS.

4. Discussion

In the mesopic range, rods and cones of the retina are simultaneously activated. This leads to a shift of the spectral sensitivity of the eye to shorter wavelengths [4]. As a result, a mesopic scene illuminated by sources with a higher S/P ratio (that stimulates stronger the rods) produces higher responses within the retina, especially in its periphery. If the materials and geometry of an environment are known, our model could be used during the lighting design of this environment in order to choose between different light sources. Point of views of pedestrians and drivers may be then taken into account.

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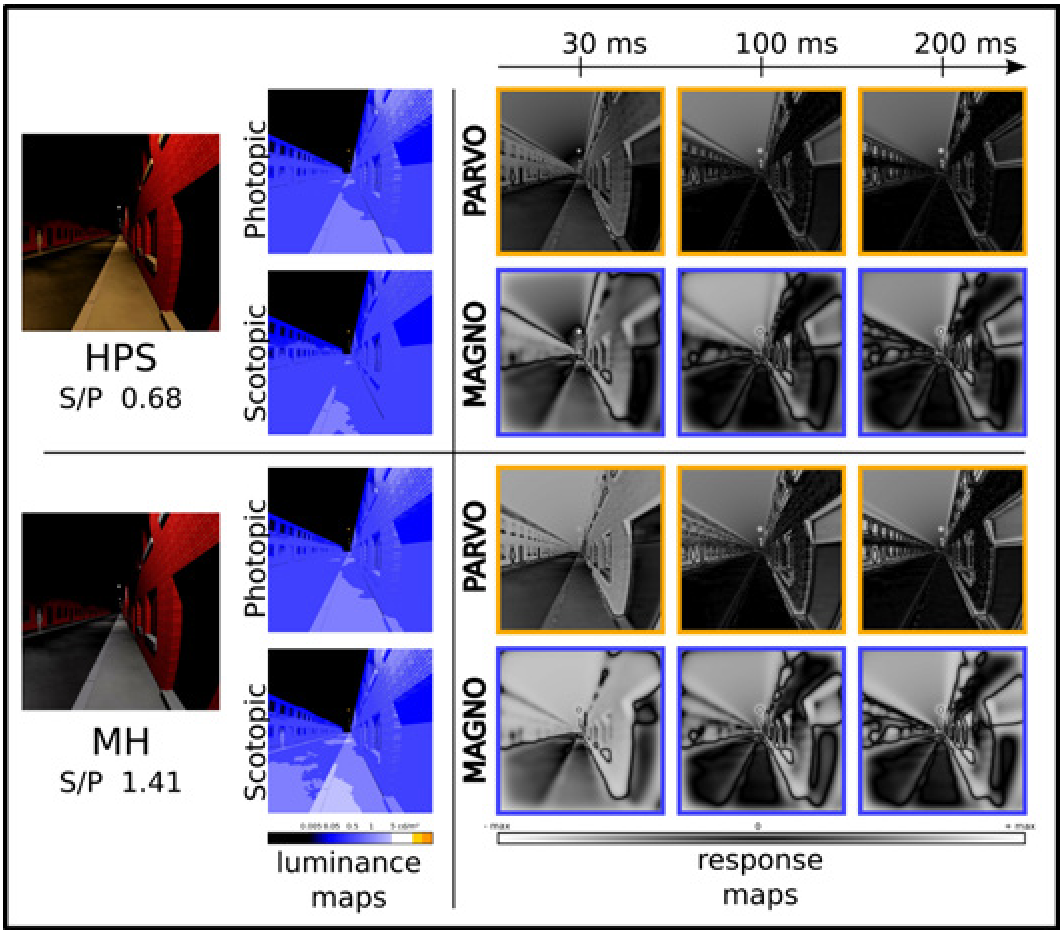

Figure 1 – Comparison of luminance maps and response maps for a scene illuminated with HPS and the same scene illuminated with MH

Health and Wellbeing

(Chair: John O'Hagan, United Kingdom)

OP12

LIGHT AS A MOTOR FOR INNOVATION AND WELLBEING

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The fascination of light is present everywhere in art and architecture. The playful game of shadow and light, color and contrast, creates and shapes the atmosphere of space. Light, from the perspective of its functional and aesthetic role in the interior space, is a factor that generated constant innovation in architecture and technology in the past, present and it will continue to do so in the future.
The need of light has a strong impact on human life. We can say that light has a physiological role, as it helps us see, understand our environment, orientate in space and perceive three dimensional objects. It has a psychological effect, as it can determine our sense of wellbeing, it can make us feel safe/unsafe, good or bad, comfortable or not, it stimulates attention and banishes monotony. Also light has a chronobiological effect on the human body, as the circadian rhythm regulates active and passive phases of biological activity, according to the time of day and year.
In the past, interior spaces were determined by the physiological role of light. At the beginnings of architecture, introducing daylight into buildings had a strong influence on the configuration of space. When the first buildings were created, the dimensions of interior spaces were shaped by the distance to which natural light was able to penetrate through the openings left in the outer walls.
In different parts of the world, architecture adapted to the specific climatic conditions and original building typologies were developed in order to ensure the proper use of daylight in the interior space. The position and dimension of the openings was strongly influenced by the geographic location of the buildings and the need to protect these openings generated a series of findings, from oiled parchment to thin slabs of marble, until transparent glass was finally produced in larger sheets.
The development of artificial light sources was a cradle for innovation. In the last century, we arrived from the use of candles and gas lamps to the general use of electric light; we built power plants and vast networks, which transport electricity to large distances. We illuminated interior spaces and flooded in light entire cities.
We developed regulations for interior lighting, new light sources competed in efficiency and lifespan and luminaires were created to house these new sources, protect them from direct view and distribute luminous flux in well determined directions. During the last decades, the explosive development of lamps and luminaires was boosted by the implementation of new technologies, the use of new materials and optical systems and was driven by the urge to maximize economic efficiency and minimize environmental impact. The design of luminaires is a field where innovation is only limited by creativity.
In our days the emphasis is put on the psychological role of light and on energy efficiency. Interior lighting received an innovative approach. We seek to create comfortable visual environments, we think about atmosphere, mood, health, we search ways to combat monotony and stimulate attention. We think in terms of lighting systems and not individual luminaires. We have lighting designers who develop lighting concepts.

Abstracts

The economic and energy crisis together with the need for better lighting conditions have generated a whole range of innovations in the fields of architecture, building materials, technology, design and concept development.
We try to reduce the energy consumption for interior lighting by harmoniously integrating natural light into interior lighting concepts. As we push for the use of natural light, the need to control the access of direct sunlight generates a series of innovations in the field of building materials and solar control fixtures. Thus, we have developed spectrally selective low-emissivity glass, which transmits visible light, but reduces the transfer of ultraviolet and infrared radiations from the sun and reduces glare.
On the other hand, in the case of large glazed structures, a wide variety of solar shading systems optimize the use of daylight while reducing the heat accumulation and glare.
We developed intelligent buildings, where interior lighting and solar control systems are integrated into the buildings energetic structure and are automatically controlled by building management systems, which ensure comfortable interior environments and reduce energy consumption.
But, innovations related to lighting are still open to endless possibilities. The future, as we see it today, is focused on the chronobiological effect of light, while energy efficiency is still imperative.
We are developing electric lighting systems that mimic the changes of natural light throughout the day in order to enhance the wellbeing of the users of interior spaces.
Also, the future is about using active solar technologies, such as photovoltaic panels to capture, convert and distribute solar energy, even from the opaque parts of buildings that are exposed to sunlight.
It is about hybrid solar lighting systems, which collect and channel sunlight through optical fibers into hybrid luminaires, in order to supplement electric lighting.
The future belongs to solar architecture and to the active and passive techniques of using solar energy. Architects have to orient buildings according to the sun, choose materials with favorable thermal mass and light dispersing properties, carefully select window types, size and orientation, incorporate clerestory windows, light shelves, skylights and solar tubes, provide exterior shading devices and use photovoltaic panels in order to exploit solar energy in every possible way.
Looking into the future, we rest connected to the past. We turn back to the sun and apply all the knowledge and technologies that we have accumulated during centuries of innovations, in order to harness its benefits and minimize the use of electric energy.

OP13

THE RHYTHM OF THE SUN VS MODERN LIFE AND CULTURE IN SUN EXPOSURE FOR VITAMIN D SYNTHESIS

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The sun provides us with more than just light (visible radiation) for vision, its spectrum also includes radiation of ultraviolet and infra-red wavelengths. The short wavelength cut-on of the solar spectrum begins in the UVB (280- 315nm), mirroring the spectral decline in absorption by ozone. This short wavelength radiation, specifically in the UVB waveband, initiates the synthesis of vitamin D in human skin. For the vast majority of people this sunlight-driven source accounts for about 90% of the body's vitamin D supply, the remainder being accounted for by diet. Polewards of sub-tropical regions the availability of solar UVB radiation, and thus the ability to produce vitamin D, becomes increasingly seasonally dependent. In an agriculture-based society with extensive outdoor exposure one would expect to observe a corresponding seasonal cycle in vitamin D status. In our modern, high-tech society there is no need to follow the rhythm of the sun and exposure to any available UV radiation cannot be assumed. In addition, people travel, moving, briefly or permanently, to regions where the solar environment is not matched to their skin type and often take cultural norms associated with their original environment with them. These changes, in lifestyle and the match between location and skin type, become superimposed on the annual cycles of the sun in determining the major source of vitamin D. We explore patterns of (UV) sun exposure of different sub-groups of the Manchester population, both school children and adults, fair skinned and pigmented, and associate their exposure with vitamin D status.

OP14

APPLICATION STUDIES ON NON-VISUAL EFFECTS OF LIGHT WITH TRADITIONAL AND SOLID STATE LIGHT SOURCES

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Beyond vision, light affects humans physiologically and psychologically with considerable impact on health and wellbeing. With increasing knowledge and understanding of non-visual effects of light is has become feasible to address effects known for decades and attributed to natural daylight with modern artificial lighting systems. There is general consensus among lighting experts that natural daylight can't be fully replaced by artificial light, as complex dynamic changes and their impact on wellbeing are not likely to be understood in conceivable time. But despite these limitations, there is also a growing consensus to include recently developed knowledge on non-visual effects of light into interior lighting solutions. The idea is to provide the lighting stimuli required for the human biology even in the indoor environment.

Lighting for human biology

Non-visual photoreception via melanopsin expressing photoreceptors (intrinsic photosensitive Retinal Ganglion Cells- ipRGCs, third photoreceptor) requires blue spectral proportions in the light around the maximum sensitivity of the photopigment at 460 – 480 nm. Laboratory research results as well as the arrangement and dendritic shape of receptor cells indicate that the "sensor system" is tuned to the sky as natural stimulus. To effectively address this system in indoor environments, a comparable broad light distribution in the upper part of the room and with considerable blue fraction in the spectrum should be used. Our internal timing system, the so called biological clock, needs the rhythmic lighting change as it appears in nature to synchronize internal processes and to be in line with the outer world. Light acts via non-visual pathways as the main timer, adjusts the internal clock setting and stabilizes the circadian rhythm. The right light and the right darkness at the right times support daytime performance and simultaneously nocturnal recovery of humans.

Application studies

In different application fields, we have transferred the scientific findings into chronobio¬logically adapted lighting solutions. Together with partners from industry and independent scientific research, we studied the outcome in terms of beneficial effects for health and wellbeing. Cognitive performance and circadian effects in two office-like laboratory settings and in a real office field have been studied with the Institute for Cognition and Perception of the University of Tuebingen, the AG Sleep Research of the University Clinics Charité, Berlin, and the Institute for Medical Psychology at Ludwig-Maximilian-University in Munich. Social Jetlag in older school pupils and cognitive performance was addressed in cooperation with the Centre for Neuroscience and Learning at the University of Ulm, Germany. Daytime activity and communication as well as sleep/wake rhythms in the elderly are being investigated in long-term studies by the K-Licht consortium (Dornbirn, Austria) in three nursing homes in Vienna, Austria. Reduction of jetlag and improvement of wellbeing for air travel passengers were tested in collaboration with the napcabs GmbH and the

Generation Research Program of the LMU Munich. In addition this was studied with partners from aircraft industry (Airbus, Diehl Aerospace) and scientific research (Bergische Universität Wuppertal, Fraunhofer Institute for Building Physics) in realistic, long-term night flight simulations. Other studies are ongoing and expected to deliver new results soon. Taken together, we see from application studies and basic research that aligning of body's rhythms with natural ones is a key factor for mood, performance, and health. In the presentation, we will highlight on our experiences in finalized and ongoing studies to eliciting non-visual lighting effects in application fields as raised above.

OP15

VISUAL AND NON-VISUAL EFFECTS OF DIFFERENT SPECTRAL POWER DISTRIBUTIONS FROM LIGHT SOURCES – LIGHT EMITTING DIODES (LED) VS. 3-PHOSPHORUS FLUORESCENT TUBES.

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Abstract

This abstract shows a comparison of the subjective experience between indirect light from LED and T5-fluorescent tubes at different ambient light levels in an indoor working environment. The test was conducted as a laboratory study containing 50 subjects, ranging from 18 to 68 years of age. The experience of the environment was measured by using semantic scales. Furthermore the experience of the lighting situation was conducted by means of semantic scales.

Experimental design and methods

The experimental sites where arranged as two equally equipped office rooms without windows and with the following dimensions; width=4900 mm, length=2700 mm and room height=2700 mm. Each room was equipped with a desk and a chair and the desk was provided with flat display screen equipment (LCD) and some magazines for reading. A clock was positioned in the corner at the upper the side of the front wall. There were no other decorations in the room. The ceiling consisted of diffuse white panels with a reflectance of 82% and the walls were painted diffuse white with a reflectance of 84%.

The aim of the present study was to investigate whether ambient light in the normal field of view was experienced as brighter at luminance levels of 100 and 300cd/m^2 on the walls comparing LED Fortimo vs. T5 fluorescent tubes at 4000K .

The spectral irradiance from the different light sources as well as from the indirect perceived light was measured and evaluated using a spectroradiometer Avaspec 2048, Avantes.

Measurements were repeatedly carried out of the horizontal illuminance / luminance at the workplace as well as the vertical illuminance/luminance of the ambient light of the front wall. The average values were then calculated out of these measurements.

Two hypotheses were stated:

- Ambient light from the LED may be experienced more bright than from T5
- Ambient luminance levels up to 300cd/m^2 may not be experienced as glaring.

Results were investigated in terms of:

- Room appearance
- Experienced brightness
- Experienced lighting quality
- Biological aspects – hormone analyses

Subjects
50 subjects were selected to participate in the study based on the screening criteria and partly in order to obtain a suitable distribution of age and gender. However eight subjects had to be discarded due to different reasons, such as illness or severe headache. The remaining group consisted of 19 women and 23 men between 18 and 68 years of age (m=43, SD=18). The group represented a variety of occupations both blue-collar workers and white-collar workers. 31subjects wore glasses and 5 used contact lenses.

Statistics
The statistical treatment of data was mainly conducted by means of analysis of variance SPSS: MANOVA, either with
a simple factorial design or with a design including repeated measures and both within-group and between-group variance. Both these designs allow for analysis of covariance. Tests were carried out for all main effects and interactions.
Statistical level of significance were set to p<.05, and with a tendency at p<.10. In a few cases missing values were replaced with individual means. This will not influence group differences but, for the repeated measures may tend to reduce the variations.

Results
Results show that the experienced brightness from LED was significant higher in both ambient light levels and there was also a tendency to experience light quality as better from LED as better than from the T5 tubes at 100cd/m^2.

Room appearance
The two test rooms in the two different ambient lighting conditions were perceived quite neutral. The rooms were perceived neither pleasant nor unpleasant, neither complex nor much unified and no significant differences where found between perceptions of the light sources at same CRI and CCT.

Experienced brightness
In general the results show that the experienced brightness from LED was significant higher in both ambient light levels than from T5 tubes. Differences in experienced light intensity between T5 4000K vs. LED 4000K, CRI=80 at different ambient light levels, p=.034. Furthermore, the difference in brightness increased at the highest ambient light level of 300cd/m^2.

Experienced lighting quality
There was a tendency to experience the light from LED as better than from the T5 tubes (p=.07) at 100cd/m^2. However, the lighting quality was reduced for LED at the higher ambient light level of 300cd/m^2, although not significant.

Biological aspects - Hormone analyses
The cortisol levels showed a significant increase when the ambient light from the different room surfaces was increased from 100 cd/m^2 to 300 cd/m^2 at all three times measured over the whole

day. Differences in cortisol levels during the day and between the two ambient light levels (p=.000, p=.044 N=42). No significant differences were found between T5 4000 K and LED 4000 K.
The results indicate that there are differences in the experience of brightness and lighting quality from reflected light from bright interior surfaces between LED used in this study and T5 fluorescent tubes at the same CCT of 4000K. This is due to the differences in the spectral distribution in the shorter wavelengths. This must be considered while evaluating measured photometric data.
The study is a cooperative work between Lund University, Fagerhult and the study was sponsored the Swedish Energy Agency.

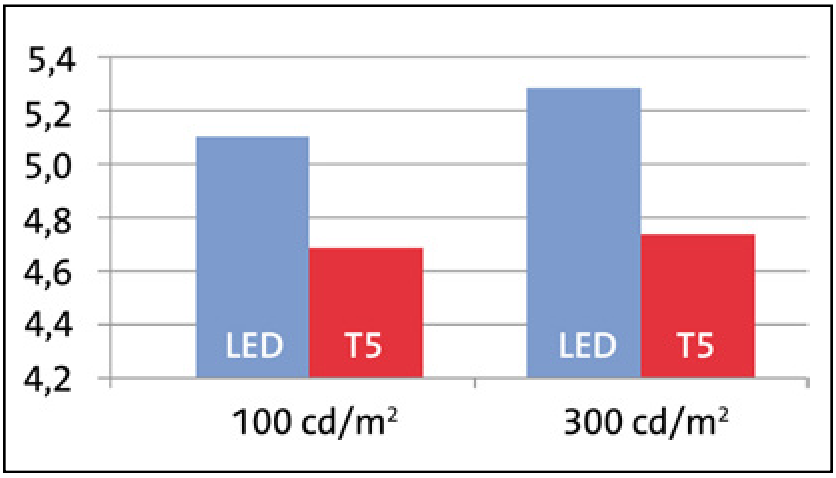

Figure 1 – Experienced brightness on front wall at different light levels

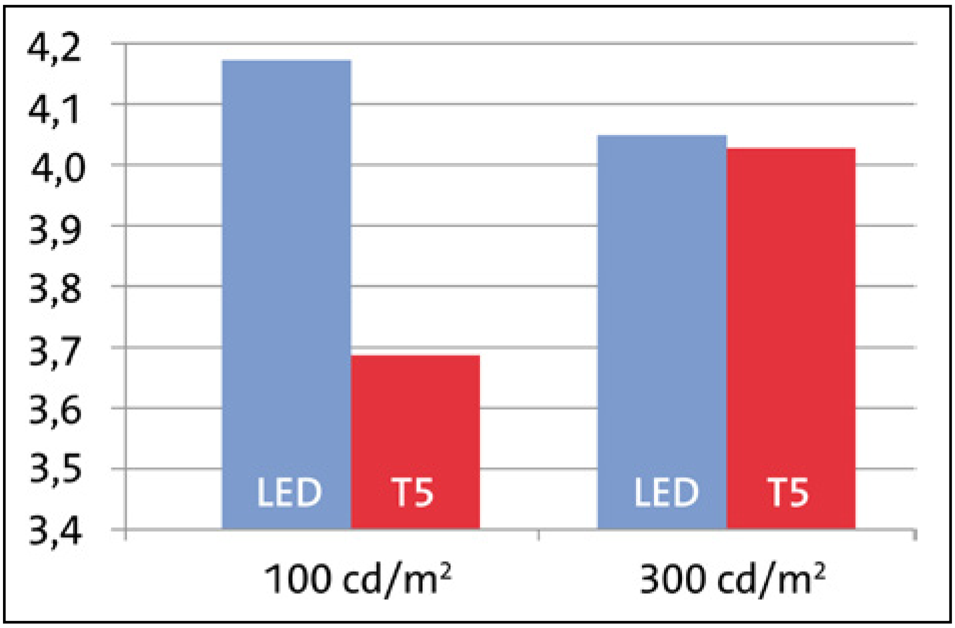

Figure 2 – Experienced lighting quality

OP16

MODELING NON-VISUAL RESPONSES TO LIGHT: UNIFYING SPECTRAL SENSITIVITY AND TEMPORAL CHARACTERISTICS IN A SINGLE MODEL STRUCTURE

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The discovery of a novel type of photoreceptor that mediates non-visual light responses in humans has sparked a growing interest in the role of lighting design on health. These intrinsically photosensitive retinal ganglion cells (ipRGCs) contain the photopigment melanopsin. Melanopsin is more sensitive to short-wavelength light with peak sensitivity blue-shifted (~480 nm) relative to the scotopic rod-based vision (~505 nm) and photopic cone-mediated vision (~555 nm).
There are at least five main characteristics of light exposure that contribute to the non-visual light response: intensity, spectrum, duration/pattern, history and timing. These characteristics should all be considered when developing a model of non-visual light responses. Currently, there is no mathematical model that incorporates all five characteristics to predict the non-visual effects of light on humans. In this paper, a modular model structure is proposed that consists of elements with a clear physiological interpretation and aims to bring together experimental and theoretical perspectives.

It is known that the non–visual system has a non-linear response to both the intensity and duration of light exposure. Further complexities arise because ipRGCs also receive input from rod and cone photoreceptors. The relative contribution of the three different types of photoreceptors to non-visual responses in humans remains unclear. Unless the light is under the threshold of activation for melanopsin, at low light levels and at the start of a light exposure, cone and melanopsin-containing photoreceptors contribute similarly to non-visual responses. The relative contribution of cone inputs seems to decrease across the duration of a continuous light exposure, however, and therefore, to model these effects, the non-visual system should be represented with a time-varying spectral sensitivity function.

A block-structured model is proposed to model the non-linear response of the non-visual system. The model is represented by inter-connections of different blocks or elements. The preliminary model structure comprises three blocks: two blocks containing causal filters separated by a block containing a static non-linear intensity-response curve. The two filters reflect the temporal processing between the light stimulus and the output response. The first filter is associated with the temporal integration of the retina. The second filter reflects the adaptation of the non-visual system to continuous light exposure. Experimental findings have shown that the highest rate of activation of the non- visual system occurs at the onset of the light exposure with a reduced but sustained response that saturates after a few hours of continuous light exposure.
The spectrum of the light stimulus that is given as an input to our model must be weighted ac-

cording to the spectral sensitivity of the system. Due to the differences in temporal properties between cone and melanopsin-containing photoreceptors, the magnitude of non-visual responses will strongly depend on the spectral distribution and temporal characteristics of the light stimuli. Thus, light exposures of different durations may produce sensitivity functions with different weights for the relative contribution of cone and melanopsin-containing photoreceptors. A transition from a predominantly cone response to a predominantly melanopsin response causes a shift in the peak wavelength sensitivity from 555 to 480 nm.

The sensitivity of the non–visual system also depends on the history of light exposure. The previous light history affects the intensity threshold of the non–visual response. A fourth block in the model is a feedback loop that can extend the dynamic range of the system and produce a dynamic intensity-response curve. The fifth block contains the effect of light exposure on the non–visual system, which is known to depend on the timing of circadian rhythms such that the magnitude of response can be described by a phase response curve. Due to the modular nature of the model structure, other existing models of circadian rhythms can be linked to our model to make a complete system.

It is important to advance research in this field to ensure that lighting design is based on a more complete understanding of the underlying mechanism of the non-visual system. The proposed model structure is modular and can be adapted as more knowledge accumulates. The long-term goal of the present model is to establish a computational scheme that can be used to study and model human non-visual processing of light. Such a model holds promise because it aims to understand and functionally describe the underlying mechanism of the non-visual system. Further research is needed to refine and validate model predictions, and to assess the model's reliability and adequacy to effectively inform design decisions. Ultimately, the proposed model may lead to a new approach to support healthy lighting design.

OP17

BLUE-LIGHT HAZARD OF LEDS – COMPARISON OF THE PHOTOBIOLOGICAL RISK GROUPS OF FIFTEEN LEDS ASSESSED USING THE STANDARD PROTOCOL AND A NEW SPECTRAL IMAGING APPROACH

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In this paper, we present a comparative study of two assessment methods for the [EN62471] photobiological risk group of lamps. The measurement method in [EN62471] is compared to an original imaging spectrophotometry approach, more adapted to sources whose spectra vary with the emission position and the direction (e.g. LEDs, dichroic lamps...).
The standard [EN62471] classifies lamps and lamp systems into four photobiological risk groups, labeled from ‚no risk' to ‚high risk'. A lamp's group is determined according to threshold's values in the received hazard-radiance dose (J m^{-2} sr^{-1}) at specified distances (0.2m, 0.5m, 1m, and 2m) and for a set of specified actinic action spectra. Let us remind that the hazard-radiance dose is the time integrated hazard-radiance, which in turn, is declined into blue-light hazard radiance L_B, for instance, defined as $L_B = \int S_\lambda B_\lambda d_\lambda$ where S_λ is the source's spectrum and B_λ the blue-light hazard actinic action spectrum.
The measurement protocol for the blue-light hazard recommended in [EN62471] can be described as a three staged procedure: (1) the source's luminous fluxes propagating within specified solid angles are measured with a luxmeter and a diaphragm, or an imaging luminancemeter; (2) the source's spectrum is measured in an integrating sphere; and (3), the photopic sensitivity associated with the measurements in (1) is converted into the blue-light hazard actinic action spectrum using the spectral distribution measured in (2). This approach therefore assume that the spectrum of the source does not varies with the position on its surface or with the propagation direction (i.e. uniform spectrum).
While practical and safe for most sources, it is inadequate for LEDs, as spectra of these sources vary over minute distances upon their surfaces and emission directions [LED11]. Off-the-shelf ‚white' LEDs are indeed often composed of a blue-emitting diode exciting a yellow-emitting phosphor embedded in an epoxy dome. The emitted spectra of a given LED thus depend on the diode itself, on whether rays originate from the diode or casing material in its vicinity, and on the thickness of traversed phosphorescent material. The minimum integration surface in [EN62471] is a disk of 0.35 millimeter diameter (at 20 centimeters and for 0.25 second integration time), which is much smaller than the total surface of most LEDs. The uniform spectrum assumption can thus lead to inaccuracies in the assessment of their groups of risk.
Results of a comparative study, conducted in a collaboration between the centre scientifique et technique du bâtiment (CSTB) and the agence national de sécurité sanitaire (ANSES), are presented in this paper, assessing the impact of the uniform spectrum assumption on the measurement of the group of risk. To that end, fifteen off-the-shelf lamps were measured using the [EN62471] protocol, and a second method that does not relies on this assumption.
This second method is presented in detail in the final version of the paper, and makes use of spectral imaging. Summarizing, it relies on an original imaging spectrophotometer [Boulenguez2010],

assembly of a liquid crystal tunable filter (LCTF), a high-dynamic range camera, and a narrow-FOV objective (see Figure 1). Dedicated software acquires hyperspectral image cubes (i.e. a spectrum for each pixel), then computes blue-hazard radiance doses by a direct weighting of these spectra with the blue-hazard actinic action spectrum.
The comparative study showed that for some lamps characterized by a directional emissivity, the uniform spectrum assumption can lead to an underrating of the photobiological group of risk.

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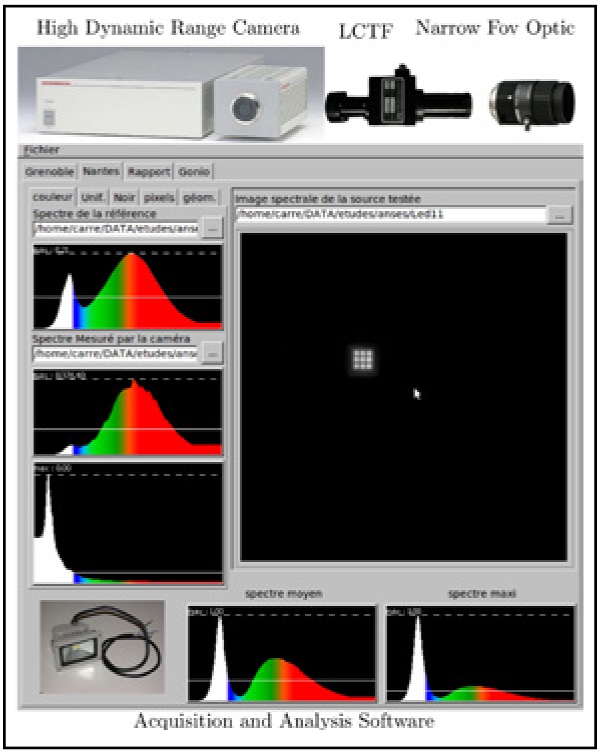

Figure 1 – Overview of the spectral imaging apparatus used to assess the photobiological group of risk. A hyperspectral image cube of the lamp is acquired using a composite imaging spectrophotometer, custom assembly of a high-dynamic range camera, a liquid crystal tunable filter (LCTF), and a narrow-fov objective. Spectra, one for each pixel, are next converted into blue-hazard action weighted values. The black and white image in the center corresponds to the blue-light hazard radiance of the LED in the lower-left corner.

Workplace Lighting Concepts

(Chair: Yasuko Koga, Japan)

OP18

DISCOMFORT GLARE OF WHITE LED SOURCES OF DIFFERENT SPATIAL ARRANGEMENTS

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1. Introduction

In recent few years, usage of white LED in general lighting, such as indoor lighting for stores, street lighting, or forward lighting of automobiles, is rapidly increasing. Maximum size of LED chip commercially available is a few mm square, and LED light has both advantage and disadvantage due to such small size of luminous area. Compactness and freedom of design are distinguished advantages, whereas inhomogeneity in a luminaire and glaring due to the array of small devices with high luminous intensity are disadvantages. Especially on discomfort glare, LED light is sometimes very dazzling, and manufacturers receive complaints from clients and consumers. However, the present regulation for discomfort glare, UGR for example, is applicable for light sources assuming that each light source in the visual field of observer has a homogeneous luminous surface. Whether the present regulation for discomfort glare is applicable for inhomogeneous light such as LED has not yet reached consensus in the field of illumination engineering.

In this study, in order to investigate the relationship between discomfort glare evaluation and some photometric quantity for LED light source, we carried out 3 experiments using different spatial arrangements.

2. Experiments

In Experiment 1, effect of homogeneuity of LED source was investigated. Three kinds of LED sources were employed as stimuli. Each of the sources is composed of nine LED elements whose color temperature was about 5000 K, arranged in a three-by-three matrix within an area of 13 cm x 18 cm, i.e., 2.5 deg x 3.4 deg in visual angle. The first one was made of raw LED elements, the second one was made of the LED elements covered by a lens cap, and the third one was the LED matrix covered by translucent glass to obtain a roughly homogeneous surface. They were called Type I, II, and II, respectively. Detail of this part was presented in the CIE20101).

In Experiment 2, effect of the pitch length of 3x3 LED matrix was tested. The pitch lengths of 0.2, 0.4, 0.6, 0.8, 1.0, 1.3, 1.6, 1.9, and 2.5 deg in visual angle were employed. Detail of this part was presented in the CIE20112).

In Experiment 3, effect of the density of LED within a fixed area of 3.8 deg x 3.8 deg was examined. Matrices of 2 x 2, 3 x 3, and 5 x 5 were used as the stimuli.

The background luminance was changed between four levels, 0.1, 1 and 10 cd/m^2,for Experiment 2 and 3. In addition to these conditions, dark background condition was employed in Experiment 1. For each of the conditions, seven intensity levels that cover from unnoticeable level to unbearable level were determined in preliminary experiments, and they were controlled by inserting different neutral density filters in front of the LED source. Scaling procedure is common to all ex-

periments. We used Matsuda's response scale3), where 1, 5, and 9 corresponds to unnoticeable, beginning to feel discomfort glare, and unbearable, respectively.
The experimenter presented the observer the light source at a certain intensity for three seconds. The observer subjectively evaluated the degree of discomfort glare using Matsuda's scale. Stimulus of different intensity was presented in a random order.

2. Results and Summary

In the previous presentation, we proposed "effective glare luminance" as that the sum of luminance in the source area divided by the total size of area where some luminance value exists2). The area is called "effective area" and derived by the sum of pixels within the luminaire area that have luminance value in the HDR image of LED source. Unfortunately, we found serious miscalculation In the analysis of Experiment 1, and good agreement between the source types with different homogeneity has not obtained using the raw value of effective glare luminance. In this study we modified it by using different weighting coefficients for different level of luminance. The higher the luminance, the larger the weighting factor, and then, sum up the luminance value of each pixel in the effective area.
We found that neither the illuminance at the observer's eye nor equivalent veiling luminance, could explain the scaling results of discomfort glare using light sources of different spatial arrangements1,2). Scaling results for Experiment 1,
2, and 3 were plotted against the effective glare luminance using different weighting coefficients. Curves in the same background condition but having different spatial arrangement agree with each other. Weighting factor function which provides the best fit for all experimental results become an exponential function. Correlation between experimental and theoretical values is strong giving the value of r2 =0.93 as shown in Figure 1. It is thus suggested that effective glare luminance is a strong candidate for a proper index of discomfort glare for light sources having different spatial luminance distribution.

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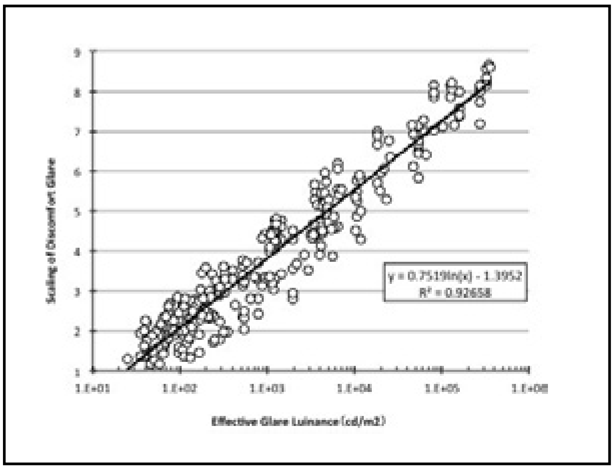
y = 0.7519ln(x) - 1.3952
R² = 0.92658
Scaling of Discomfort Glare
Effective Glare Luinance (cd/m2)
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1
2
3
4
5
6
7
8
9

Figure 1

OP19

SUITABLE LUMINOUS ENVIRONMENT FOR VARIOUS ACTIVITIES IN SHARED OFFICE

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The article presents a psychovisual experiment about luminous environment in office shared by two users conducted on the internet with 1860 subjects. The office is lit by daylight, controlled by an exterior shading system, and by artificial light, composed by ceiling sources and a task lamp on each desk. The goal was to study if luminous environments (defined with the orientation of the shading device, the percentage of ceiling luminous flux, the state of each task lamp (switched on/off)) suitable for both users conducting various activities (paper-based work, computer- based work, meeting with a visitor) can be identify. Twelve psychovisual tests have been conducted depending on: 1) the point of view (user close to the window, user far from the window); 2)the conducted activity (paper-based work, computer-based work, meeting with a visitor); 3) the type of sky (overcast, sunny (for one position of the sun)).

For each psychovisual test, 48 stimuli were assessed. By employing incomplete block experimental design, each test required a panel of 282 subjects which judged 16 among 48 stimuli. Each stimulus was judged 94 times (48*94=16*282). In total, 576*94=54144 judgments of luminous environments were collected. From the collected database, the following issues were investigated:

- Are results related to considered sky type?
- Do preferred luminous environments vary according to the conducted activity?
- Are luminous environments related to the position of the user in the office?
- Does individual control with task lamp make it possible to identify luminous environments that satisfy both users?
- Does individual control with task lamp on one desk have an effect on the lighting quality for the user on the other desk?

To sum up results, for a desk far from the window, suitable luminous environment do not differ according to the activity. On the other hand, suitable luminous environments for user close to the window are different according to the realised activity, in particular under sunny conditions. In addition, individual control of task lamp does not have negative effects on the satisfaction of the other users. On the contrary, they help to balance luminances in the room and were judged especially suitable for computer-based work.

OP20

STUDY ON ILLUMINANCE BALANCE BETWEEN WORKING AREA AND AMBIENT, EFFECTS OF DISTRIBUTION OF LUMINOUS INTENSITY OF AMBIENT LIGHTING AND THE ORDER AND SPEED OF ADJUSTMENT

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This research aims at offer of comfortable TAL (Task and ambient lighting). TAL is the method of securing illuminance for the working area with task lighting, and holding down the circumference to the minimum illuminance. Today improvement in the practicality of TAL goes pressing need due to reduce energy consumption.
In the previous paper (2010 CIE Lighting Quality), the allowance balance T/A between working area and ambient is proposed with consideration by the initial lighting condition. Next, in 27th session of the CIE 2011, the effects of the distribution of luminous intensity of task lighting and the front wall illuminance on the allowance balance T/A, visual performance and impression is discussed.
In this paper, the purpose is to examine the influence of the illuminance distribution by ambient lighting and the order and speed of adjustment on following elements such as the task and ambient ratio, visual performance and impression.
In order to propose comfortable and low consumption energy TAL, in addition to the luminous intensity distribution of each instrument, the order of lighting and adjustment speed are examined and consumption energy comparison is performed. Furthermore, a comfortable adjustment speed without the darkness feeling in the case of shifting to TAL from uniform lighting, and the glare feeling in that case of being reverse is examined.

Keywords: TAL, Allowance ratio of T/A, Luminance distribution, Adjustment order, Adjustment speed, Darkness, Glare, Visual performance, Consumption energy

1. Laboratory and Evaluation

The laboratory has the luminous ceiling (FL 4500K), the wall washer (LED 4400K), the spotlight (LED 4800K), the desk stand (LED 5000K) and white walls.
Controling ambient lighting means being adjusted to the critical condition that is possible to work comfortably with constant task illuminance by subjects. Task illuminance is kept constant with the automatic control of task lighting. Before and after controling ambient lighting, subjects evaluate the following.
Visual performance : analyzed with the correct and wrong percentage of marked Landolt rings, and speed (only examination on the illuminance distribution of task lighting)
Impression : examined with evaluation on space and a desk surface

2. Definition of illuminance, and Evaluation

The condition of T/A=∞ is un-uniform by only task lighting, and that of T/A=1 is uniform by only ambient lighting. It is defined that each illuminance is as follows.

(1) Task illuminance T = the work area illuminance = the total illuminance of the center of the working area

(2) Ambient illuminance A = the work area illuminance by only ambient lighting

(3) Periphery illuminance P= he average illuminance of four corners of the desk

(4) Environment illuminance E = the average illuminance of seven spots that are front wall, side walls and four corners of the desk

(5) Wall illuminance W = the vertical illuminance of the center of front wall

3. Influence of the distribution of luminous intensity of ambient lighting

Subjucts are 30 young females. Task illuminance is set to 75, 300, and 600 lx. The initial lighting condition is that of only task lighting. Subjects control ambient lighting, this time, one of ambient lighting is turned on.

Allowed ambient illuminance are high in order of the luminous ceiling, the wall washer, and the spotlight. By the spotlight, wall illuminance is higher than environment illuminance, that is, irradiating front wall locally can hold down
environment illuminance. In the case of the same task illuminance, although impression on TAL which controled each ambient lighting is better than the condition of only task lighting, it is worse than condition of only the luminous ceiling. When each required ambient illuminance is secured, to energy consumption by the luminous ceiling, the wall washer is 75.6% and the spotlight is 60.1%.

4. Influence of the order of adjustment

Subjucts are 5 young females. Task illuminance is set to 75 lx. The initial lighting condition is only task lighting or allowed TAL. After adjusting to the initial lighting condition, wall illuminance is changed by the spotlight. Wall illuminance-increase is set to 4 stages. Subjects control the luminous ceiling again. Allowed TAL is the combination of task lighting and the luminous ceiling. It is average condition of each subject when controling ambient lighting from the condition of only task lighting three times.

In each initial lighting condition, allowed environment illuminance is so high that wall illuminance-increase is large. For any wall illuminance-increase, allowed environment illuminance is low when the initial lighting condition is only task lighting. This is the same result that allowed T/A is smaller when adjusting high environment illuminance. Since environment illuminance is high, impression is slightly better when the initial condition is only task lighting than allowed ambient illuminance. After controling ambient lighting, the lower the wall illuminance is, the larger the difference of impression on the initial condition is. In which the initial condition, impression on the condition of allowed ambient illuminance approximate almost the same when wall illuminance is high enough.

5. Influence of the speed of adjustment

Subjucts are 20 young females. Task illuminance is set to 75 lx, 300, and 600 lx. The initial lighting condition is allowance T/A or only uniform ambient lighting.

The adjustment speed which the ambient illumination of the permission minimum at the time of work is made to decrease from uniform lighting and which raises the ambient illumination from TAL to uniform lighting is clarified. The adjustment method of the ambient lighting for avoiding the feeling of darkness and glare at the time of using TAL is considered.

OP21

A STUDY ON THE PERMISSIBLE RANGE OF UNUNIFORMITY BY AMBIENT LIGHTING IN A WORKPLACE

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1. Introduction

The accident of the Fukushima nuclear power plant caused by the Great East Japan Earthquake (in March 2011) and sequential shutdowns of other nuclear power plants lead to a serious shortage of electric energy in Japan. The Working Group in Architectural Institute of Japan [WG on investigation into luminous environment in offices with urgent electricity saving caused by 2011 earthquake] has investigated the actual situations of office buildings in Japan last year to identify effective ways to save electrical power consumption for lighting. The results of the field measurements, conducted in 14 different office spaces, mainly located in Tokyo, showed that the number of illuminated lamps was reduced (partial lighting) and the desktop illuminance was reduced by almost half compared with that before the earthquake in more than half of the measured offices.
In Japanese office buildings, it is quite common for the occupants to work together with the others in a deep-plan office space, and the space is highly illuminated to make the lighting environment uniform in general. However, turning off some lamps deteriorates luminous uniformity, and that may cause discomfort glare, low brightness levels in spaces and so forth. Therefore, the permissible range of luminous ununiformity in office spaces should be identified to balance the energy saving and the quality of lighting environment.
This study investigated how ununiformity with ambient light affects the occupants‘ evaluation of the workplace. The experiments were conducted in an actual office space for 4 months under various lighting conditions.

2 Experimental method

The size of the experimental room was 7.8m in wide and 14.4m in depth, where 32 LED luminaires with 4,000 K of CCT were mounted on the ceiling. Electrical power consumption for each LED luminaire was 66.1 Watt. Eight different experimental conditions combining with the average illuminance on the desk and luminous uniformity, as shown in Table1 and Figure1, were prepared. Some conditions were presented repeatedly to test the influence of the occupants‘ adjustment to the new lighting environments. Luminous uniformity was set by covering some of the luminaires and the average illuminance was set by dimming. Each condition was set on Friday night and the occupants were exposed to each condition for one week, from next Monday to Friday. Uniformity ratio of illuminance in Table1 was calculated by dividing minimum illuminance by average illuminance in the space.
About twenty occupants aged 20 to 50 evaluated the luminous environments, such as brightness on the desk, brightness sensation of the whole office space, discomfort glare and satisfaction levels in the workplaces and so forth, on the latter half of the week.
In the experiments, illuminance on the desk and vertical illuminance at the occupant’ eyes were

recorded at intervals of one minute, and luminance distributions from the viewpoints of the occupants' eyes were also measured at intervals of one hour.

3 Results and Discussion

Figure 2 shows the results of satisfaction levels with the luminous environment of each condition in the office space. It can be seen that the occupants evaluated differently although the lighting conditions were the same (see No.2 & No.6, or No.11 & No.14). One of the possible reasons for this was that the occupants were exposed to brighter environment in the previous week and they might sense the office space much darker than before and the satisfaction level was lowered. However, under the conditions of No.6 & No.10 [500lx and High-Uniformity] the percentages of the occupants who were satisfied/ dissatisfied with the space were almost the same, so it can be implied that the evaluations under the conditions of 500 lx could be reproduced in the second circle. In the second circle, the percentage of the occupants who were „dissatisfied“ had a negative correlation with uniformity ratio of illuminance regardless of the same average illuminance.

4 Conclusion and future works

In the present work, to address the effects of non-uniformity of illuminance in workspaces, the experiments in an actual office with about 20 occupants has been conducted. It is predictable from the results that the percentage of the occupants who were „dissatisfied“ with the luminous environment in the office space had a negative correlation with uniformity ratio of illuminance regardless of the same average illuminance in the office space. Detailed analysis of luminance distribution and glare is under way, and we are going to start the same experiments in the laboratory from November 2012.

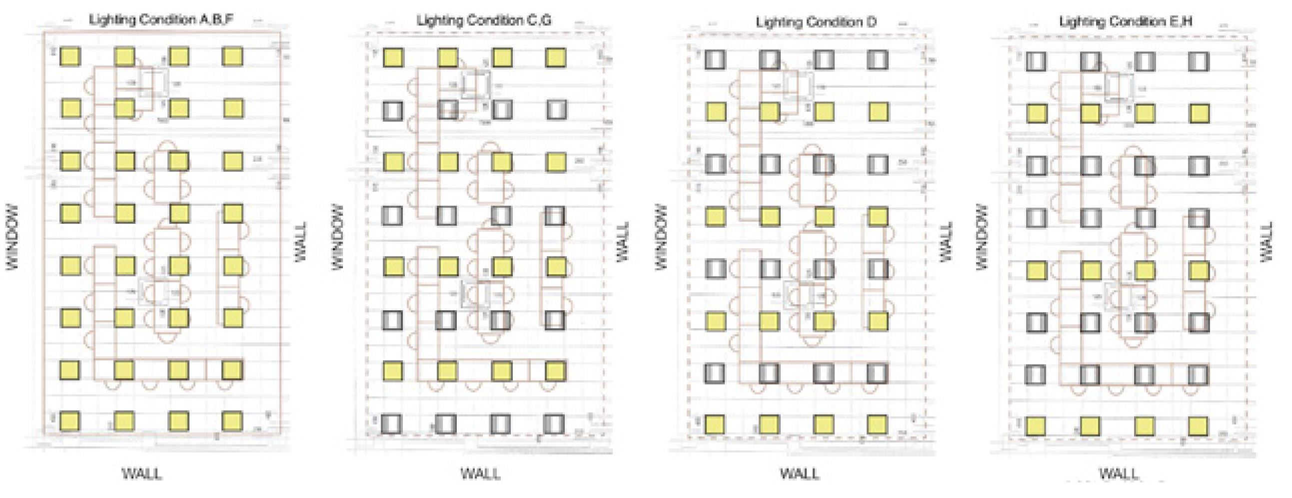

Figure 1

Figure 2 - Satisfied of the Workspace

No	Lighting condition	Average Illuminance(lx)	Uniformity Ratio	Electrical Power Consumption(W)	Notes
1	A	726	0.66	944.9	
2	B	517	0.68	672.8	
3	C	520	0.37	676.6	wall is bright
4	D	522	0.52	679.5	wall is dark
5	F	523	0.38	681.1	
6	B	520	0.69	676.8	
7	C	516	0.46	671.7	wall is bright
8	D	510	0.50	663.3	wall is dark
9	E	522	0.34	679.0	
10	B	522	0.66	679.6	
11	F	306	0.65	398.6	
12	G	306	0.50	398.9	wall is bright
13	H	309	0.29	401.9	
14	F	300	0.63	390.0	

Table 1 – Circle of Lighting conditions

OP22

REVIEW OF OFFICE LIGHTING RESEARCH

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Background

As office tasks are transformed they are resulting in the computer screen (VDT) occupying the visual field and demanding a contrast relationship that differs from traditional paper work (Piccoli, Soci, Zambelli & Pisaniello, 2004). Studies have shown that illuminance preferences in computerised offices differ from preferences in traditional offices (Veitch & Newsham, 2000a; Escuyer & Fontoynont, 2001), and that the office lighting recommendations and standards need to be adjusted to suit VDT based tasks.

Humans are affected by light (Fig. 1), and studies have found an arousal effect of light (Cajochen et al., 2005; Lockley et al., 2006; Revell, Arendt, Fogg & Skene, 2006; Vandewalle et al., 2006), as well as a support of social and biological processes. Light also provides a trigger for circadian rhythms (Czeisler et al., 1995), hormonal balances (Cajochen et al., 2005) and processes important to our general well-being (Figueiro, Bierman, Plitnick & Rea, 2009). Depending on available natural daylight the need for artificial light to support human physiological and psychological processes varies (Begemann, van den Beld & Tenner, 1997; Partonen & Lönnqvist, 2000; Fleischer, Krueger & Schierz, 2001; Nicol, Wilson & Chiancarella, 2006; Rüger, Gordijn, Beersmaa, de Vries & Daan, 2006; Revell, Arendt, Fogg & Skene, 2006; Küller, Ballal, Laike, Mikellides &Tonello, 2006; Aan het Rot, Moskowitz & Young, 2008; Hoffman et al, 2008; Hubalek, Brink & Schierz, 2010) Lighting furthermore has an influence on visual acuity, as well as on performance, social interaction, safety and orientation. It indirectly supports other visual needs by creating a stimulating environment (Loe, Mansfield & Rowlands 1994; Loe & Rowlands, 1996; Loe, Mansfield & Rowlands, 2000). Study participants see and appreciate differences in lighting conditions and visual appraisal is influenced by appearance as a whole (Boyce, 2003).

The quality of ambient light needs to be defined both to support tasks associated with VDTs and to promote health and performance. This review is intended to suggest areas of interest for further research as well as to identify weaknesses in contemporary research related to office lighting.

Method

The review is based on searches in databases available at the University of Jönköping, Sweden, from November 2010 to January 2011. Research performed prior to 2000 was viewed with caution since the modern VDT displays a technology different from the older type, and office layout, work tasks and tools have undergone significant changes in the last decade.

Selected keywords were combined in a 12*12*11 search of the chosen databases.

Eighty-six published studies were chosen and sorted into three different categories (Fig. 2). Not only articles published in peer-reviewed journals and conference proceedings were included, but also scientific reports of interest published elsewhere.

Results

The number of participants in the reviewed studies ranges from 5-1017, and can differ between periods in the same study (De Kort et al., 2010). Demographic information is often excluded, side-stepping considerations derived from ageing, gender and culture. The gender distribution in the reviewed studies is sometimes heavily skewed. (Boyce et al., 1997; Rüger et al., 2006; Partonen et al., 2000; Aan het Rot et al., 2008; Hubalek et al., 2010).

The interior design in many of the reviewed studies is subdued and in some cases even non-existent in order to avoid influencing the results.

Experimental settings using a baseline setting for comparison do not always include information about the type of luminaires nor overall lighting design for the baseline condition. Several of the studies additionally did not account for neither spectral power distribution nor CCT. The CCT of light is so intimately connected with other parameters, such as colour rendering and illuminance, that contradictory results are found in studies of similar character.

Discussion

This review study includes different types of studies but the experimental settings and tested variables vary, impeding comparison. Even if they aim to describe the same phenomenon, the studies are uniquely designed and include and

exclude variables seemingly at random. It is worrying that the scarcity of information on lighting layout, glare incidences and light source properties obstructs evaluations. Additionally, technical advancements have shortened the lifespan of many studies. The research community needs to clarify threats to internal validity such as selection bias or instrumentation, and sample characteristics threatening external validity should be discussed. Existing recommended models for assessing lighting conditions in VDT applications show no agreement with the results of subjects with a group age of 60+ (Moghbel & Wienold, 2009) emphasising the need to consider age. Research further claims that women are generally more sensitive to changes in light settings than men (Knez, 2001), stressing the need for an equal gender distribution.

Moreover a possible effect of the experimental lighting environments discussed in this review is a distortion of the results and suppression or failure to invite the hypothesised responses. Experimental settings that are uncomfortable to the participants create situations causing stress and increased arousal, making the application of observations difficult.

Conclusion

Although there is much relevant research, knowledge is fragmented and lacks coordination. Lighting planning research suffers from the fact that a normal office setting is too unobtrusive to stimulate a response. To define the concept of good lighting quality a complete and stringent set of test parameters should be applied to secure results that are comparable.

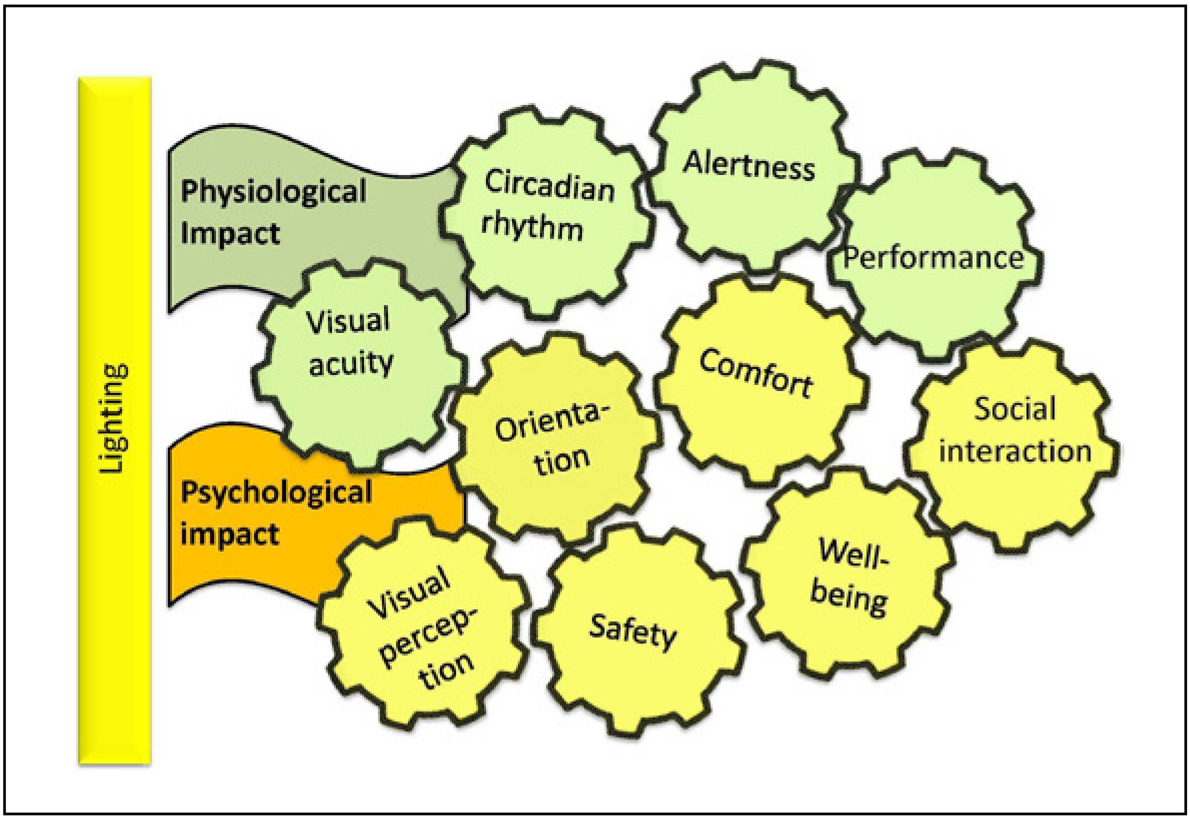

Figure 1 – Lighting impact

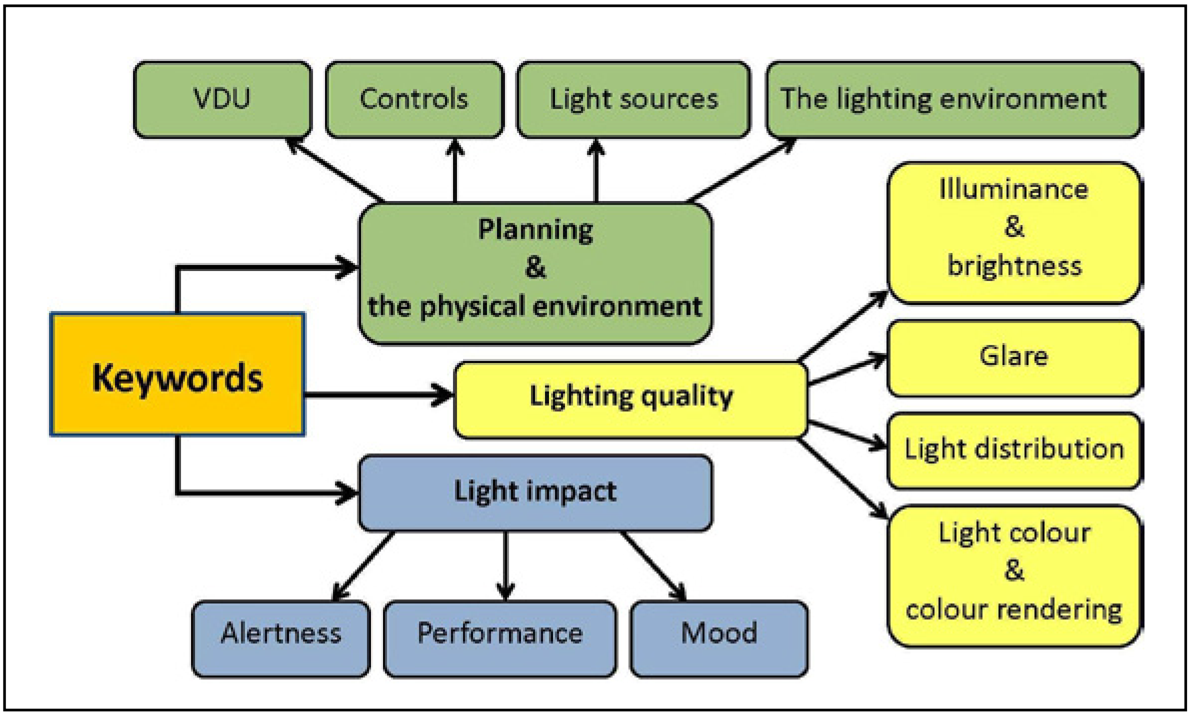

Figure 2 – Map of research included in the review article

OP23

COMPARISON OF USER SATISFACTION WITH FOUR DIFFERENT LIGHTING CONCEPTS

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This study aims at comparing user satisfaction for different lighting concepts in an office environment using an LED lighting system. The lighting concepts being compared are:
a) A conventional, ceiling mounted, static lighting concept providing evenly distributed 400 lux at desktop height (0,85m) with correlated colour temperature (CCT) of 3500 K.

Concepts b) to d) have ceiling mounted luminaries providing evenly distributed 3500K, 200 lux measured at desktop height (0,85m) in the rooms, as well as:

b) Task light with adjustable illuminance from 0 to 300 lux on the task area and CCT of 2700 K.
c) Task light with adjustable CCT from 2700 to 7000K and illuminance of 300 lux on the task area.
d) Task light with automatically controlled CCT following the measured CCT of daylight measured in the window and illuminance of 300 lux on the task area.

The aim is to identify which of the four chosen lighting concepts is rated as most preferred by the test subjects.

The lighting system used in this study is a custom made LED system including ceiling mounted luminaries and a task light on each desk. The system includes a miniature spectrometer that is placed in the window. The different lighting concepts a) – d) are pre-programmed and can be chosen by the researchers.

The study is a laboratory study with restricted daylight contribution. The different concepts were tested in two parallel rooms set up as an office with two subjects in each room performing office tasks. A total of 70 subjects participated in the study. Subjects were exposed to four lighting concepts (duration of 1.5 hours) and the concept was rated using an online questionnaire at the end of each session. An equal amount of subjects started out with each of the lighting concepts. The order of the concepts during the day was randomized. At the end of the day, the subjects were asked to compare the different lighting scenarios according to their preference.

The questionnaires answered at the end of each session included rating the colour of the light (on a scale from warm to cold), light level (on a scale from too low to too high), satisfaction with the colour and light level, if they considered the lighting to suit their work task, if they considered the lighting normal and if they were bothered by noise or flicker. Additional questions, regarding changes in light level and light colour, appeared in the questionnaire when testing concept d) automatic control of task light. The questionnaires answered at the end of the day contained rating of satisfaction with each lighting concept, preference for concept, preference for adjustment possibilities and concept preferences according to their task.

The results show that lighting concept c) with the adjustable CCT of the task light was the most preferred lighting concept followed by concept b) adjustable illuminance of the task light. Concept d) the automatically controlled task light came in third and concept a) without task light was the least preferred. When asked if the subjects preferred different lighting according to their task, 81% agreed. The preference results showed that concept b) rated highest for computer work, while concept c) rated highest for reading and writing on paper.

Plenary Session 3: Hot Topics in Interior Lighting

(Chair: Marc Fontoynont, France)

OP24

WHAT WE KNOW ABOUT WINDOWS AND WELL-BEING, AND WHAT WE NEED TO KNOW

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Interest in using light to the benefit of building occupants through daylighting and lighting design has never been higher. Scientific advances such as the discovery that intrinsically photoreceptive retinal ganglion cells (ipRGCs) are responsible for entraining circadian rhythms to patterns of light and dark, and furthermore that those cells are most sensitive to short-wavelength optical radiation, led the CIE in 2004 to promulgate five "principles of healthy lighting" (CIE 158:2004/2009). The same report also suggested that these principles should lead to a renewed emphasis on architectural daylighting. Daylight is rich in that area of the spectrum, and bright at the times of day that seem most important to these processes.

The science has moved rapidly in the ten years since the last substantive reviews of the state of the art on the health and well-being effects of daylight and windows, making it time for a renewed examination of the literature. We recently reviewed this literature with a focus on residential buildings, but in the process identified much that applies to any building type. This conference paper will focus on what is known generally about the effects of windows on human well-being and will conclude with a set of research questions that are as yet unanswered.

Research Summary:

Windows admit light that we use to see tasks using visual processing. Visual performance is very well understood to be determined by task contrast, task size, and retinal illuminance, but moderated by ocular health and age. Vision science uses strong research methods that have led to predictive models for achromatic tasks performed at photopic luminance levels. Chromatic tasks, however, are less well understood by visual performance models.

Windows contribute to spatial appearance. Spaces with windows are generally preferred over those without, and provide a combination of prospect and refuge that is pleasing. Although the research designs used to study these effects are strong, there is too little specificity from which to derive design guidance concerning window sizes or shapes. Furthermore, there is some evidence that desires for privacy in different room types influence window preferences and that these might also vary across cultures.

Sunlight provision provides light and warmth; in homes and in some non-domestic buildings this is sometimes seen as therapeutic. Sunlight nonetheless needs to be linked to appropriate controls to minimize possible thermal and/or visual discomfort to the occupant. The degree of visual discomfort can be predicted in part by vertical eye illuminance, glare source luminance, solid angle and position; however there is some evidence that task focus, the glare source being sunlight, and the quality of the exterior view, might moderate the experience. Data concerning how individuals use shading devices to prevent discomfort is inconclusive.

Windows also promote restoration following stressful experiences by providing a view of out-

doors. Most of this research has focused on a nature view, but there is limited evidence that the quality of the view also plays a role. An attractive view, whether of a built or natural scene, might promote cognitive, affective, and physiological restoration. Of these three forms of restoration, the cognitive effects are best understood.

Turning to the non-visual processes that are mediated by retinal photoreception, we see that since the 2004 CIE report 158, it has become clearer that there are at least two channels: one for circadian regulation, and one regulating mood and alertness. The path from the ipRGCs to the suprachiasmatic nucleus of the hypothalamus takes information about irradiance to the brain centres that govern circadian rhythms. There is not yet consensus concerning the action spectrum of the ipRGCs, nor concerning the effects of polychromatic light exposures. The original observation of CIE 158:2004/2009, that daylight – through windows or outdoors – could be a good source of short-wavelength and bright daytime light exposure to regulate circadian rhythms, stands.
The realization that mood and alertness might operate according to a separate pathway is comparatively new. Limited evidence, but consistent across methodologies, suggests that acute bright light exposure by day can influence serotonin metabolism, leading to improved mood and more cooperative social behaviours. The spectral sensitivity function of these effects is not known. Windows, of course, remain an excellent source of this bright light exposure. Windows also expose skin to radiation at both the ultraviolet and infrared ends of the spectrum. Although heat transfer can predict the thermal effects of windows based on the window properties and the environmental conditions on both sides, the thermal comfort effects of windows are very difficult to predict. Conditions that one person will find acceptable, another will not. On the ultraviolet (UV) end of the spectrum, questions remain about the necessary UV dose to promote vitamin D metabolism, but there are no questions concerning whether windows should be designed to deliver this dose: The risks to materials and individuals are too great to use windows in this way.

Conclusions:
Daylight through windows allows us to see, regulates important physiological functions in daily cycles, and promotes positive feelings and alertness. Views through windows and of spaces with windows make spaces look pleasant and provide the means to explore and overlook the environment, contributing to safety and restfulness. Further exploration of these research directions will provide the necessary details to integrate these effects with the building sciences, leading to practical guidance for the architectural community concerning the right balance between the considerations for daylight, view, ventilation, temperature control, and energy use.

OP25

A ROADMAP FOR UPGRADING NATIONAL/EU STANDARDS FOR DAYLIGHT IN BUILDINGS

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It is now widely accepted in the research community, and increasingly so amongst practitioners, that the standards/guidelines for daylight in buildings are in need of updating. The basis for the majority of EU guidelines is the half-century-old daylight factor. The daylight factor (DF) considers relative illumination under a single overcast sky. Thus the DF is insensitive to prevailing climate and orientation of the building or site. The expert daylight designer does of course appreciate these intrinsic deficiencies in the DF approach. If sufficiently experienced, the designer can roughly guesstimate the likely daylighting performance of the space and so recommend suitable facade treatments to temper the luminous environment. The expert designer may recommend different treatments for the north, south and east/west elevations. And the advice would most likely change if the building were relocated from, say, Stockholm to Madrid. After all, 'climate-adapted design' is a notion that relates closely to vernacular architecture. If however the client demands that the daylight credit from a particular guideline document (e.g. BREEAM, LEED, etc.) must be achieved, then the success of the design will hinge to a large degree on the nature of the 'target' sought - invariably some measure based on the daylight factor. In which case, the best the expert designer can do is try to make good the failings that might, and often do, result from compliance chasing. The client may even decide that the expert is not required since the facade treatment will be 'optimised' by someone using a software tool: tweaking here and there until the compliance target is reached. Thus a desire to achieve the compliance target for daylight can have a profound effect on the facade design.

Attempts to advance standards beyond the daylight factor have, so far, met with limited success. There are a number of reasons for this - which will be discussed more fully in the presentation. A key reason to note here is that, with one largely overlooked exception, it appears to be impossible to advance the DF methodology by incremental means. The incremental 'advances' that have been suggested include the various 'clear sky options' described in LEED and ASHRAE. The rationale for the 'clear sky options' has never been properly explained. Furthermore, as will be shown, the basis for these approaches appears to be flawed if not actually unsound. For example, notwithstanding the lack of clarity in the guidelines, the general understanding is that some of the options recommend that the user predict absolute values of illuminance under clear sky conditions without a sun - a physically impossible illumination scenario in nature. In contrast, climate-based daylight modelling (CBDM) delivers predictions of luminous quantities under conditions that are realistic: time-varying sun and sky conditions derived from standardised climate files. Metrics founded on CBDM have been proposed, e.g. daylight autonomy (DA) and useful daylight illuminance (UDI). Climate- based metrics been used effectively on a number of projects large and small, e.g. from the New York Times Building to residential dwellings. However, CBDM tools are either the preserve of research or freely-available but largely unsupported. For CBDM to become mainstream it needs to be taken up by one or more major software houses. Here lies a classic 'chicken and egg' conundrum. On one hand, those who draft guidelines are reluctant to recommend metrics founded on CBDM because tools to predict the metrics are generally not available, at least not as 'supported' software. On the other hand, the software vendors are understandably loathe to dedicate the resources to develop and maintain CBDM tools because - inasmuch as climate-based metrics are not in the guidelines - there will be no real market for these new tools. This presents something of an impasse to all those who strive to advance daylighting standards beyond the current guidelines.

A way around this impasse is presented here. In order to obtain 'buy-in' from all stakeholders (e.g. standards bodies, designers, end-users, tool developers, etc.) it is important that they all recognise the benefit of the changes proposed. These benefits should include: a more robust approach to evaluating daylight in buildings using existing tools with modest enhancements; a methodology that allows for later progression to more reality-based evaluations; a transition 'roadmap' with clear market horizons to ensure that software vendors invest the necessary resources to develop advanced tools (i.e. for CBDM). To initiate this process, it is proposed to move the basis of daylight evaluation from relative values based on a single sky (i.e. the DF), to the annual occurrence of an absolute value for illuminance (e.g. 300 lux) estimated from the cumulative availability of diffuse illuminance as determined from standardised climate files. This is an application of an established but largely neglected approach. This proposal offers several advantages. Firstly, since the estimate is derived from daylight factors, it requires only a modest enhancement to existing software tools that predict DFs. Next, it provides some 'connectivity' to the prevailing climate. A target that has been proposed for the new metric is that a side-lit design should achieve 300 lux across half of the work plane for half of the year when the sun is above the horizon. To achieve this for say, Stockholm, half of the sensor points must have a DF of 2.6% or greater, whereas for the Madrid the 'target' DF would be 1.8%. There are other advantages - the median approach informs on the spatial distribution of daylight whereas an average daylight factor value does not. The presentation describes how this approach allows for 'smooth' transition to full-blown CBDM evaluations.

OP26

FLICKER IN SOLID-STATE LIGHTING: MEASUREMENT TECHNIQUES, AND PROPOSED REPORTING AND APPLICATION CRITERIA

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Solid-state lighting is already bringing energy-efficiency, excellent color, long life, controllability, and unique optics and form factors to architectural lighting. However, the flicker found in some SSL sources or systems can be a significant barrier to adoption. Furthermore, the pairing of dimming controls with SSL sources can increase flicker, or even induce it in sources which do not exhibit flicker when operated on a standard switch.

Flicker has been shown to induce photosensitive epilepsy, migraines and headaches, and increased autistic behaviors in certain people. Reduced task performance, stroboscopic motion effects, distraction, and annoyance can also result from exposure to a flickering light source. Various light source characteristics, including modulation depth, frequency, and waveform shape have been shown to affect flicker sensitivity. Similarly, the effects of flicker are also known to be dependent upon exposure time, adaptation luminance, contrast, the size of the retinal area being stimulated, the distance to a flickering source and its location in the visual field. An IEEE Committee has been diligently applying existing research to a risk assessment of known health effects resulting from flickering light sources with various characteristics. Despite what is known, flicker is rarely reported in product literature, and there is little to no guidance for practitioners applying LED products that may flicker in architectural lighting applications.

The authors have developed a means for measuring and reporting lighting flicker. The data collection and analysis techniques will be presented, along with measurements from a wide variety of conventional and SSL products operated using both simple switches and various dimming controls. The qualitative evaluation of commercially available SSL products for flicker and other lighting quality characteristics will also be presented, based on surveys of professionals with various lighting industry roles who were exposed to multiple samples of a specific product type installed in a common lighting application. Finally, current estimations of risk will be discussed in the context of real- world lighting demands to propose flicker reporting requirements and design criteria for outdoor, healthcare, education, retail, and office applications. The authors hope these straw-man criteria can help guide practitioners in their evaluation of lighting products and conversations with product manufacturers, and clients regarding their potential sensitivity to flicker.

OP27

THE REBOUND EFFECT - AN OVERIEW OF THE IMPLICATIONS FOR LIGHTING ENERGY

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Energy efficiency has long been considered an essential tool to tackle rising global energy consumption and the associated climate change impacts. However, estimates of possible energy savings through energy efficiency frequently fail to acknowledge the impact of possible ‘rebound effects’ that accompany the introduction of energy efficient technologies. The term ‘rebound effect’ is an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency, with significant implications for current climate change mitigation policies.

In 1865, William Stanley Jevons [1] put forward the idea that economically justified energy efficiency improvements will increase rather than reduce energy consumption, based on observations related to coal use and steam engines. This notion is now known as the ‚Jevons Paradox.‘ As engines became more efficient at pumping flood water out of mines, greater production of lower cost coal was enabled thus making it more affordable for steam engines to consume coal for many other uses. One such important use was in pumping air into blast furnaces, increasing temperatures and lowering the amount of coal required to make iron, thus lowering the cost of iron. This created a positive feedback cycle which led to the development of railways which subsequently lowered the cost of transporting both coal and iron.

Three types of price-induced rebound effects are recognized:

1. Direct rebound effect - where increased efficiency, and the associated cost reduction, of a product or service results in its increased consumption because it is cheaper.
2. Indirect rebound effect - where savings from efficiency cost reductions enable more income to be spent on other products and services.
3. Economy wide rebound effect - where more efficiency drives economic productivity overall resulting in more economic growth and consumption at a macroeconomic level.

Although there is, in general, no dispute that the rebound effect exists, there is much disagreement about the magnitude and impact. Where rebound effects are greater than 100% of the expected technical energy savings, ‚backfire‘ is said to occur.
The rebound effect associated with energy efficiency in lighting is estimated at 5 to 12 % in developed countries for private households and 0 to 2 % for industry and commerce [2]. The ever-growing demand for artificial light in the home (e.g. outdoors lighting, security lighting) and also in offices and factories to increase productivity at night, has been well documented [3]. This has led to a spectacular increase in total light consumption, which, for example, by 2000 in the UK was 25,000 times higher than in 1800 [4]. However, since then many incandescent light sources have been phased out to be replaced initially by CFLs, with the prospect that CFLs will themselves soon be displaced by LED sources.

The ‚Addressing the Rebound Effect' project initiated by the European Commission set out to:

- Review the current, state of the art, knowledge and practice on the rebound effect occurring in the EU from EU policies on resource efficiency, waste prevention and Sustainable Consumption and Production (SCP) (direct, indirect and economy-wide) as well as wider international experiences;
- Analyse ways to prevent, reduce or counteract the rebound effect and their effectiveness;
- Develop guideline recommendations for addressing rebound in policy in order to achieve the maximum environmental benefit through these policies.

The final report from the project [5] concludes that the existence of the rebound effect does not mean efficiency-based policies and technologies are not valuable instruments for environmental improvement. It means that understanding the magnitude of the take back in anticipated environmental savings from the rebound effect is important when developing interventions. It also clarifies that where rebound effects are significant, efficiency policies need to be more ambitious, and that policies alone will not be sufficient. Other measures will be required, in particular interventions focused on sustainable consumption

An important factor in mitigating rebound effects is through behaviour change initiatives. Predicting responses to energy efficiency measures, however, is not straightforward. The use of energy and other resources is inevitably deeply embedded in cultural norms and established infrastructures. It is suggested that new measures may be needed to support individuals, institutions and businesses to better manage their energy usage such that rebound effects are minimised.

An alternative approach is simply to view the potentially adverse consequences of the rebound effect as the principal reason for improving the quality of life without increasing the demand for electrical energy generation. Thus, the pursuit of energy efficient lighting systems, while ensuring a high quality visual experience for the end user, will continue to make major contributions to sustainable economic growth in the coming decades.

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Advanced Correction Methods for Spectroradiometry and Goniophotometry

(Chair: Peter Blattner, Switzerland)

OP28

DETECTOR-BASED METHOD FOR CALIBRATION OF SPECTRORADIOMETERS USING AN AUTOMATED KHZ TUNEABLE OPO LASER SYSTEM

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We describe a detector-based method for calibration of spectroradiometers using a fully automated optical parametric oscillator (OPO). The new method is based on measurements of the total energy of a pulsed OPO train using a test spectroradiometer and a standard detector with a current integrator (also called charge amplifier) for obtaining total integrated electric charges. The expanded uncertainty of this method is expected to be 0.1 % (with a coverage factor of k = 2), which is almost an order of magnitude improvement compared to that using conventional source based calibration method.

1. INTRODUCTION

Spectroradiometers are typically calibrated against broadband spectral standard sources (e.g., deuterium lamps for the ultraviolet (UV) spectral region and quartz tungsten halogen lamps for the UV, visible, and infrared (IR) regions). Using the conventional source-based calibration method, however, the calibration uncertainty for spectral irradiance/radiance responsivity is limited to on the order of 1 %. In the deep UV and UV regions the calibration uncertainties are much larger due to relatively low spectral radiant power of the calibration source and spectral stray light inside the spectroradiometer [1].

We have previously developed a method for detector spectral irradiance/radiance responsivity calibrations with an expanded uncertainty of 0.05 % (k = 2) using a ns pulsed optical parametric oscillator (OPO) laser system with kilohertz (kHz) repetition rate [2]. The OPO laser system is relatively low cost and is fully automated over a wide tuneable range approximately from 200 nm to 2500 nm. In this paper we describe a new, detector-based method for calibration of spectroradiometers using the OPO laser system in order to reduce calibration uncertainties significantly. The new method is based on measurements of the total energy of a pulsed OPO train using the test spectroradiometer and the standard detector with a current integrator (also called charge amplifier) for obtaining total electric charges.

2. THE DETECTOR-BASED METHOD

A schematic diagram of the detector-based method for calibration of spectroradiometers is shown in Figure 1 as an example. The calibration system is composed of a 1 kHz pulsed OPO, a laser shutter and its controller, a multimode fibre optic, an ultrasound bath, an integrating sphere, a test spectroradiometer with an irradiance probe, a standard detector, a monitor detector, two electrometers. The laser shutter is used to control the length of OPO pulse train. The OPO is coupled into the integrating sphere through the multimode fiber optic to form a uniform irradiance source. The ultrasonic water bath is used to remove speckle from the coherent OPO radiation on the detectors. The two electrometers are set to 'Coulomb' mode to measure the total electric charges from the standard detector and the monitor detector, respectively.

The spectroradiometer measures total electric charges of its detectors over the integration time.

Charge measurements between the test spectoradiometer (or the standard detector) and the monitor detector are synchronized. Calibration of the test spectroradiometer is performed using a substitution method. The test spectroradiometer and the standard detector are aligned, in turn, to measure a pulsed OPO train over a period of time. The monitor detector is used to correct fluctuation of the pulsed OPO between the test spectroradiometer measurement and the standard detector measurement. The entire measurement sequence is controlled by a computer.

3. SUMMARY

A detector-based method, using a kHz OPO laser system, for calibration of spectroradiometers is described. The OPO laser system is relatively low cost and is fully automated over a wide tuneable range approximately from 200 nm to 2500 nm. The estimated expanded uncertainty is expected to be 0.1 % (with a coverage factor k = 2), which is almost
an order of magnitude improvement in calibration uncertainty compared to that using the conventional source based method.

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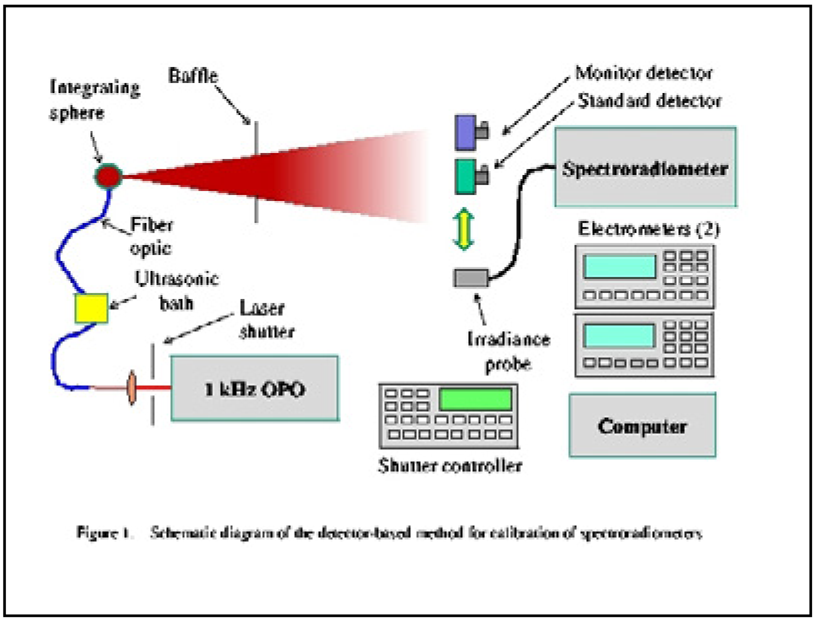

Figure 1 – Schematic diagram of the detector-based method for calibration of spectroradiometers

OP29

PRACTICAL EXPERIENCES WITH STRAY LIGHT CORRECTION ON ARRAY SPECTROMETERS FOR LED-PRODUCTION

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Array spectrometers are the instruments of choice for LED-measurement in laboratory as well as in production. Unfortunately their measurement accuracy can be affected by stray light effects. Stray light means a light, consisting of wavelengths which hit the detector array at a location which is actually not detecting these special wavelengths. The stray light behaviour of a spectroradiometer can be derived by illuminating the spectrometer's optical entrance with a tuneable laser system, which can be adjusted to every wavelength of the spectrometers scan range, and for each illumination measure the spectral answer of the spectrometer. The idea is to use the knowledge of the tuneable laser measurement to build a matrix to correct this negative effect.
This presentation shows our experiences with 2 array spectrometers with different monochromator designs in terms of accuracy improvement for LED measurement by using stray light correction.

The evaluation has been performed as follows:
Step 1: We let measure the two spectrometers with the tuneable laser system 'Tulip' at PTB in Braunschweig (Germany).
Step 2: We calibrated the two systems with a tungsten standard lamp and corrected the measured spectrum with the stray light matrix before the spectral correction curve was calculated.
Step 3: We measured 12 LEDs (2 pieces of 6 different colours) running at steady state condition. A first set of data was taken under 'normal' calibration (i.e.: without stray light correction) of the array spectrometer and a second set of data was taken with the stray light corrected calibration.
Step 4: We measured the 12 LEDs with a double monochromator, which is supposed to have nearly no stray light. We used a bandwidth of 1nm to get results which are really close to reality.
Step 5: We interpreted the results when comparing the two data sets (corrected and uncorrected) with the double monochromator references for each of the two array spectrometers.

The results revealed that the readings of the stray light corrected array match closer to the reference readings of the double monochromator readings, especially for the system with the worse stray light behaviour. But we also found some 'over-correction' for the superior array spectrometer.

OP30

STRAY LIGHT CORRECTION IN GONIOPHOTOMETRY MEASUREMENT

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1 General

The uncertainties of photometric measurement in goniophotometers are mostly involved by the photometric detector, spatial angle, stray light, temperature effects, mirror flatness and polarization etc. However, the stray light is currently become a key issue in advanced goniophotometers. In the far-field goniophotometry measurement, luminous intensity of a tested lighting source in a certain direction is obtained by multiplying illuminance at a given detecting distance with the square of the distance from the tested source. It is very important that the photometric detector should be set to receive the beam of the source only in a given detecting direction, not response to the beam outside the detecting direction. However, in a actual photometric laboratory, although floors, walls, ceilings and equipment surfaces in the laboratory are made with matt black paint, there is at least 4% of the reflected light from the black surface [1], and the reflection light will be very high when the incident beam angle is larger, such as grazing incidence of the beam (Figure 1). Therefore, the detected light of the goniophotometer shall include true beam of the source emitting in the detecting direction and stray light reflected from surfaces in the laboratory, and it is generally unable to distinguish (Figure 2). In the case of near-field goniophotometry measurement, the situation is very similar.

2 Methods

Stray light is annoying generally in optical systems because of difficult elimination. A stray light correction matrix has been developed in array spectrometers[2]. By using the correction matrix, measurement errors arising from stray light are corrected by a simple, fast matrix multiplication. But in goniophotometry measurement, the method to correct the stray light effectively is very expectant in order to improve the uncertainty of goniophotometry.

In a type of goniophotometer installed in free space of laboratories because of limitation of beam path as in the figure 2, a diaphragm can be integrated in front of the photometric head to reduce the stray light. However, a preferable method in most far-field goniophotometers to eliminate stray light is to set several diaphragms with relative apertures of detecting beam size between the tested source and photometric detector [3]. Nonetheless, large part of stray light reflected by back surface in reverse measurement direction of the source, and scattered by the edges of the diaphragms will still exist.

There are two types of goniophotometer structure, fixed detectors with rotating tested light sources and rotation detectors in the space at given distance which include the type of equivalent rotation of mirrors in mirror goniophotometers. In first one, the receiving geometry of the detector related to laboratory room is consistence in the measurement, and in another type the detector direction varies with the measurement direction of the sources. Whatever the structures of the goniophotometry laboratories, we can measure spatial coefficient of stray light in the laboratory, and then obtain the corrected intensity by detracting stray light related to tested source.

the measurement of stray light by synchronous rotation of the light sources, combined with the

rotation of the detector A unidirectional output collimated light source which can spatially be rotated is prepared to instead of the tested light source for measurement of spatial coefficient of stray light. In a given detector direction, we can obtained an m × n array of spatial light distribution matrix. Meanwhile, considering the detector direction variation in the goniophotometer(as mirror goniophotometer), or position variation of the mechanism of the goniophotometer, the spatial light distribution matrix should be considered at each angular direction of the goniophotometer, and finally an j ×m × n matrix shall be constituted, thereby to obtain the distribution spatial stray light coefficient of the goniophotometer system.
Then, in the measurement of of light sources, the true luminous intensity distribution can be obtained by detected intensity I'(m, n) and the spatial light distribution matrix function of a unidirectional beam h(j, m, n), through FFT convolution as following,

$$I(m, n)= F\text{-}1(F(h(j, m, n))/ F(I'(m, n))) \qquad (1)$$

Angle j is the detector direction of the goniophotometer.

3 Results

In our experiments, significantly improved the goniophotometer uncertainty after use of the correction of stray light, particularly for luminaires with narrow beam, the effect is more obvious. The flux error in measurement of a narrow beam source is reduced from 12% to about 1%.

4 Conclusions

The effect of stray light is the main uncertainty in the goniophotometry measurement. So we designed a directional beam to measure the stray light coefficient of the goniophotometry system. And uncertainty of measurement in the goniophotometer by applying spatial correction of stray light coefficient can be improved greatly.

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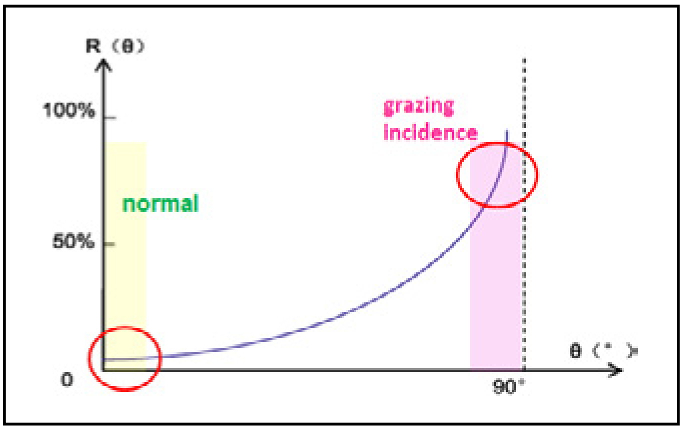

Figure 1 – Reflected light in the black surface

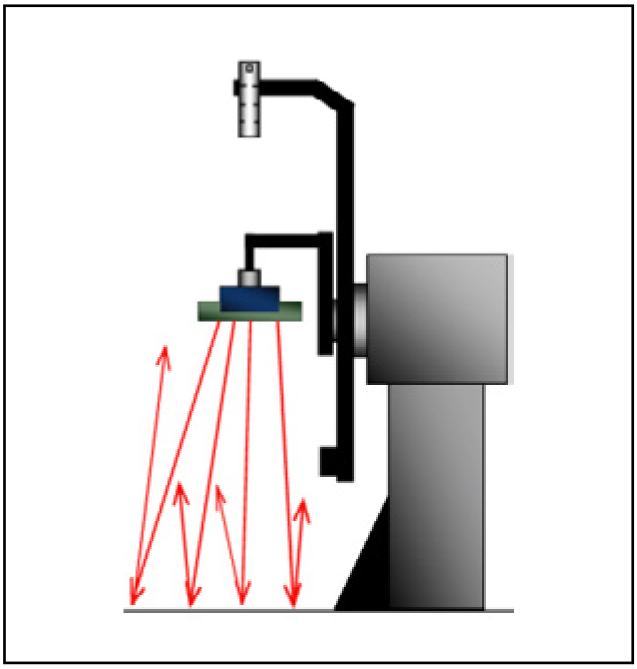

Figure 2 – Stray light in the darkroom

OP31

DETERMINATION OF SCANNING RESOLUTION BASED ON NYQUIST SAMPLING THEOREM IN GONIOSPECTRORADIOMETRY

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1. Objective

In goniospectroradiometry, it is important to determine appropriate scanning resolution for the measurements of radiometric, photometric and colorimetric quantities. As we know, an inadequate resolution will increase the error of the measurement results, e.g. the measurement of total radiant/luminous flux by integrating irradiance/illuminance. However, a higher scanning resolution requires more measurement time. So, how to determine the scanning interval appropriately? Here, we proposed a determination method for scanning resolution based on Nyquist Sampling Theorem (NST).

2. Methods

According to Nyquist Sampling Theorem, the real signal can be recovered completely as long as the scanning resolution satisfy the following terms

$\Delta C \leq 1/(2fC\_max), \Delta\gamma \leq 1/(2f\gamma\_max)$ (1)

where ΔC and Δγ are scanning intervals, fC_max and $f\gamma\_max$ are the maximum frequency in C, γ directions, respectively. So, it seems that everything will be solved according to this term. Unfortunately, it is not that simple, because there is no way to obtain the maximum frequency before the measurement.

In order to apply the NST in the measurement, we shall establish the determination procedure based on sampling and recovery of the tested quantity. The tested quantity can be expressed by a comb function, as show as Equation (2).

$gs(C,\gamma)=comb(C/\Theta)comb(\gamma/\Gamma)g(C,\gamma)$ (2)

Then, the signal can be recovered by Fourier Transform and filtering in frequency spectrum, which can be expressed as Equation (3).

$g(C,\gamma)=F\{Gs(fC, f\gamma)H(fC, f\gamma)\}$ (3)

where $Gs(fC, f\gamma)$ is frequency spectrum of $g(C,\gamma)$, $H(fC, f\gamma)$ is the filtering function. It is reasonable to ignore the slight components of frequency spectrum, because these components contribute little to the total signal. So, it can be judged whether the term of $F(fs)/Fmax<\delta$ is satisfied, where fs is sampling frequency. If not, decrease the scanning interval, and repeat the procedures again until the judgment term is satisfied. So, the scanning resolution can be determined, and the recovered signal will match with the real one as good as possible.

Of course, the matching result between recovered and real signal is dependent on the value of δ. The details about the influence of δ and related mathematical analysis will be introduced in the full paper.

3. Results

According to the method introduced above, some simulations are made to verify the determination procedure. A spatial distribution of CCT is constructed as the real signal. Then, it is measured by above method under the different set value of δ. The measurement results are shown in Fig 1 (a), (b) and (c). It can be seen the matching between the real and recovered signal will be better and better when the value of δ decreases. So, it seems the determination procedure works well, and the determined scanning resolution is also acceptable in practical measurement. Of course, the determination method may need to be improved for other kinds of signals, which will be studied in full paper.

4. Conclusion

In this paper, a determination method for scanning resolution based on NST is proposed. According to the simulation results, it can be seen the method works well, and the determined scanning resolution may be also acceptable in practical measurement. So, it will be very meaningful for the improvement of measurement error.

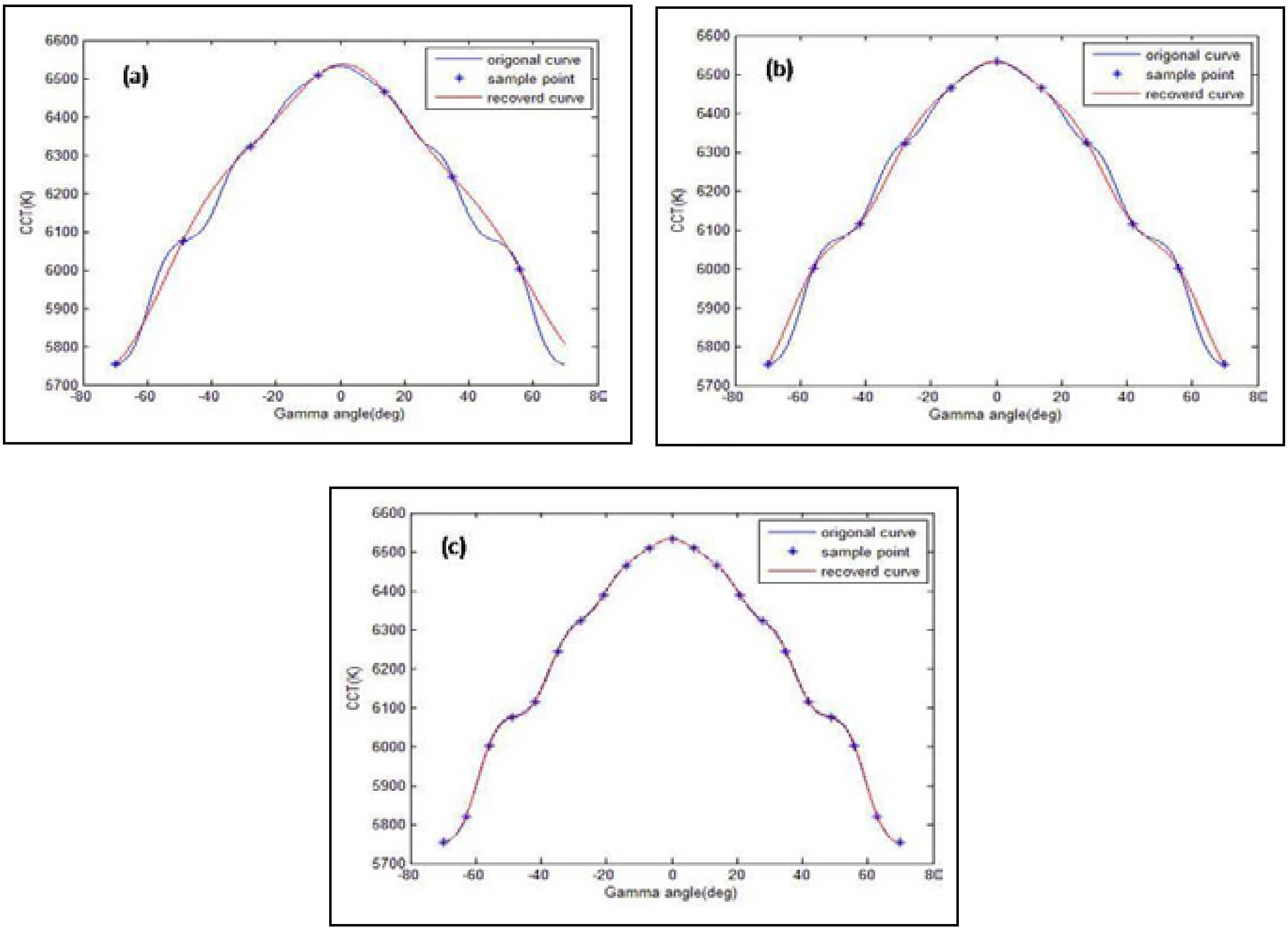

Figure 1 – (a) Recovered and real signal when δ=0.04, the determined value of scanning interval is 21 degree;
(b) Recovered and real signal when δ=0.028, the determined value of scanning interval is 14 degree;
(c)Recovered and real signal when δ=0.028, the determined value of scanning interval is 7 degree.

Lighting the City - Applications and Economics
(Chair: Yandan Lin, China)

OP32

INTELLIGENT STREET LIGHTING AND LEDS: BUSINESS CASE AND RETURN ON EXPERIENCE

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The innovations in street lighting are driven by the energy savings, the increase of security and the reduction of the maintenance costs. In order to answer these challenges, the Belgian grid operators, among which EANDIS, started in 2009 studies on two technologies: the intelligent street lighting and the LED. The goal of these studies is to verify the technical feasibility and reliability but also to calculate the economical interest. This paper shows the main results and conclusions about these two technologies.

LED luminaires in street lighting

For LED luminaires, the first results (2010) showed very big differences in quality between the luminaires available on the market, no systematic energy profit and higher Total Cost of Ownership compared to High Intensity Discharge lamps. Nevertheless, some very promising LED luminaires and the increasing demand of the municipalities pushed the grid operators to continue the studies. Based on laboratory measurements and several field tests, the Belgian grid operators write a national technical specification for LED luminaires including requirements regarding the performance, endurance and lifetime. For some applications like bycle paths and residential areas, LED lighting is now one of the accepted technologies.

Some questions still remain about LED luminaires like the maintenance factors. Future work will focus on the maintenance factor of LED luminaires. Is maintenance (for example cleaning) needed to guaranty the lighting requirements?

Intelligent Street Lighting

Regarding Intelligent Street Lighting, market studies and business cases show the interest of some features like the dimming of the light sources, the use of sensors to control the lighting of cycle paths or the compensation of the maintenance factor.

Next to the theoretical interest, the grid operators start laboratory and field tests. These tests show some unexpected issues regarding the ease of installation and the reliability of the components (like sensors). The endurance of these components has also to be proven.

Simple Intelligent Street Lighting systems are already in use, but more complex systems (including light point control and sensors) have to be tested more in detail. This new technology and features will highly increase the complexity of the street lighting installation (increase the default risk), but also drastically change the way of managing the street lighting.

The LED technology is particularly well adapted to Intelligent street lighting. Indeed, LEDs have as advantages to start immediately, to be easily dimmable and to be efficient (if the luminaire is correctly designed). The combination of LED and ISL is thus a part of the future in street lighting

Figure 1 – Based on laboratory measurements and several field tests, the Belgian grid operators write a national technical specification for LED luminaires

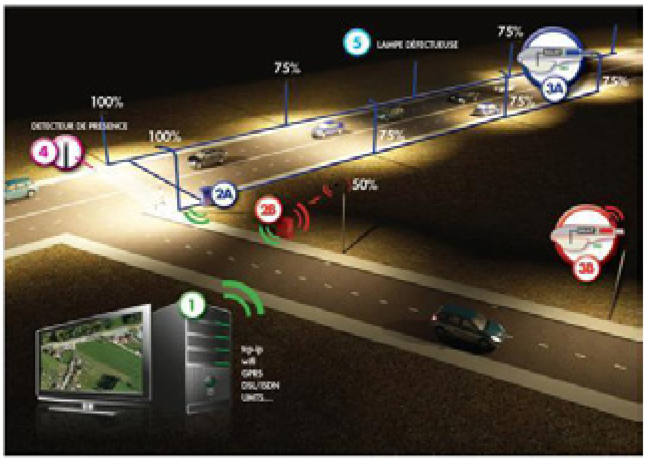

Figure 2 – More complex Intelligent Street Lighting systems (including light point control and sensors) have to be tested more in detail

OP33

CRITICAL PEDESTRIAN TASKS: USING EYE-TRACKING WITHIN A DUAL TASK PARADIGM

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Existing design criteria for road lighting provide recommended horizontal illuminances for different types of highway. Recommended illuminances for residential streets range between 2 lux and 15 lux. However, there appears to be little empirical basis for these illuminances [1]. One requirement for establishing an empirical basis for recommended illuminances on residential roads is understanding what visual tasks are important to pedestrians after dark. There is little previous research investigating critical pedestrian tasks. In one recent study it was found that pedestrians spent 40%-50% of their time looking at the pavement [2]; however, the authors acknowledged that it was difficult to confirm whether a person was actually attending to the object their gaze was fixated on or that it was important for the task of walking.

This issue raises questions over how to reliably determine what visual tasks are important to pedestrians in residential roads. The current study used eye-tracking within a dual-task paradigm. Attention is a finite resource: the visual tasks required when walking down a street use some attentional capacity but it is unlikely they use all or even most of the capacity available under normal circumstances as it is not a cognitively taxing task. Therefore the eye movements we make that are relevant to the task of walking on a street will be intermingled with eye movements that are not relevant to that task, and periods in which our vision may not be connected to our mental processes, e.g. if we are daydreaming. Research has shown that introducing additional tasks that use up attentional capacity can reduce task-unrelated thoughts and the effects of visual 'distractors' that focus our visual attention away from the task in hand [3]. This finding applies equally well to internal distracters (e.g. when we experience "mind wandering") as external distracters. Using up attentional capacity in task-relevant processing can reduce instances of task-unrelated thoughts [4]. These findings show that the allocation of attention to task-unrelated stimuli and thoughts can be reduced by increasing the load on the attention mechanism, e.g. through increased cognitive processing produced by a concurrent dual-task.

The current research used a dual-task approach to determine the important visual tasks of pedestrians. Eye tracking equipment was used to monitor eye movements and fixations whilst participants walked down a road in two sessions: once during daytime and once after dark. The route walk was divided into two sections: low obstacle density and high obstacle density street. Whilst walking along the test route, participants were also given a concurrent cognitive task. It was proposed that noting the instances when performance on the secondary task was interrupted (e.g. a delayed or incorrect response) would identify the instances when the pedestrian was distracted by something critical to their walking task. Participants were questioned about their experience during the experiment immediately after their final test session, and again shortly afterwards whilst reviewing the fixation-point video captured by the eye tracking equipment.
The results will be used to identify critical visual tasks for pedestrians, through analysis of fre-

quency/duration of observation, distance of observation and eye-related metrics including pupil dilation, mean number of saccades and mean number of fixations (overall and at categorised regions of interest). The questions targeted are:

- The low obstacle density street will produce results indicative of easier visual tasks involved in walking, relative to the high obstacle density.
- The high obstacle density street will produce more fixations and a greater proportion of looking time regions of interest that are thought to be important in walking safely on a street
- Regions of interest for walking down a street are likely to include the immediate pavement area, pavement edges, areas further ahead of the participant to provide visual information for strategic planning of travel, and other pedestrians
- The after-dark sessions are expected to produce results indicative of more difficult visual tasks involved in walking, relative to the daylight sessions.

The methods used in this study will allow more confident conclusions about the visual tasks that are important to pedestrians at night, compared with previous research.

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OP34

A FIELD TEST OF THE SPECTRAL IMPACTS OF ROADWAY LIGHT SOURCES

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The purpose of this project was to provide an initial investigation into the effects of different light source spectral distributions on detection and color recognition of roadway objects and pedestrians. This project included an investigation of both the light source spectrum from the overhead lighting as well as that from the vehicle headlamps. In order to investigate this, high-pressure sodium (HPS) and solid state (LED) overhead lighting systems were considered, as well as headlamps filtered to resemble LED and the amber HPS sources. The experiment was conducted on the Virginia Smart Road, which is a closed test course outfitted with a variable lighting system.

Methodology

Participants, driving a test vehicle under controlled combinations of overhead and headlamp lighting, evaluated the detection and color recognition of pedestrians and wooden targets. The roadway was illuminated with both 6000K LED sources and HPS sources. A dimming system was installed and the systems were controlled to have the same average horizontal illuminance under the each of the sources. Two different dim levels of overhead lighting were tested. Small red, green, blue and gray targets as well as pedestrians clothed in red, blue, gray and black clothing were located at various points along the roadway, both in the line of travel (on-axis) and off to the side of the line of travel (off-axis). Participants, from 2 different age groups (younger < 35 years old and older > 65 years old), were driving an instrumented test vehicle at two different speeds (35 mph and 55mph). Participant vision was not constrained to a specific line of sight rather they were driving as they normally would on a roadway. The vehicle recorded both the detection distance and the color recognition distance. This test vehicle was equipped with a headlight filter system that could be changed to vary the spectral output and the intensity. Two different spectral output (blue and amber) along with two different intensity levels for the headlamp were used in the investigation.

Results

The detection and recognition distances were evaluated using an Analysis of CoVariance (ANCOVA) methodology. The analysis was conducted separately for objects that appeared in the roadway as well as those appearing to the side of the roadway (off-axis). The results indicate that for detection distance the age of the participant, the color of the target or the clothing color of the pedestrian and the interaction of object color, overhead lighting type and overhead lighting intensity were significant. It is interesting to note that the headlamp color and intensity did not impact the detection and recognition distance.
As expected, older participants were out-performed by the younger participants with the average detection distance being approximately 100ft shorter for the older participant than the younger.
The interaction of the overhead lighting type and the lighting intensity for on-axis pedestrian object provides and interesting comparison. At high levels of overhead lighting intensity, the LED systems outperformed the HPS with the HPS outperforming the LED at low levels of intensity.

This is shown in Figure 1. This result is counter to the expectation that would result from a Mesopic lighting analysis where the LED would be expected to perform at a higher level. However, it is important to remember that these objects were placed in the roadway and could be considered to be foveal to the driver where a Mesopic impact would not be expected. Another consideration is that the LED systems are much more uniform than the HPS. This may also have contributed to this result as the object contrast may be impacted by the roadway luminance.
When the Off-Axis pedestrian objects were considered a much more predictable result was found. The LED systems outperformed the HPS systems. This is shown in Figure 2. Here, although the overall detection distance was less than that of the on-axis objects, the LED system showed a marked improvement to that of the HPS.
In terms of the target color and the pedestrian clothing color, the red and green targets showed a slight improvement in detection distance under the LED source as compared to the HPS source and the gray clothed pedestrian
performed better under the HPS systems. This indicates that the reflected spectral luminance from the light sources and the target can impact the contrast and therefore impact the detection distance.

Conclusions

The conclusions from this investigation indicate that:

1. Overhead lighting is a significant factor in the detection and color recognition of pedestrian clothing and that the object location, the type of overhead lighting and the intensity all play a role in determining the visibility distance.
2. Pedestrian clothing color and Target color plays a significant role in pedestrians being detected and their clothing color recognized.
3. Headlamp color appears to have a minimal impact on detection and color recognition of pedestrians and targets.
4. Spectral components of overhead lighting may play a much more significant role in pedestrians located peripherally, than those along the roadway.
5. The improvement of color recognition of pedestrians and targets off-axis to the roadway under the bluer LED overhead lighting is consistent with the expectations of the behavior of the human eye regarding night driving and mesopic vision.

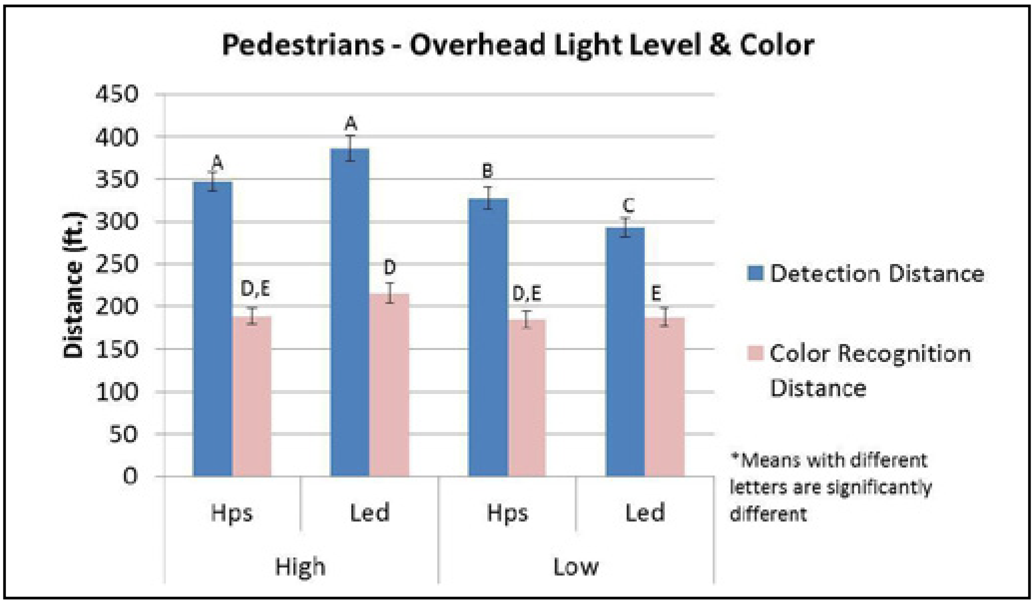

Figure 1 – Impact of Overhead Lighting Type and Intensity for On-Axis Pedestrians

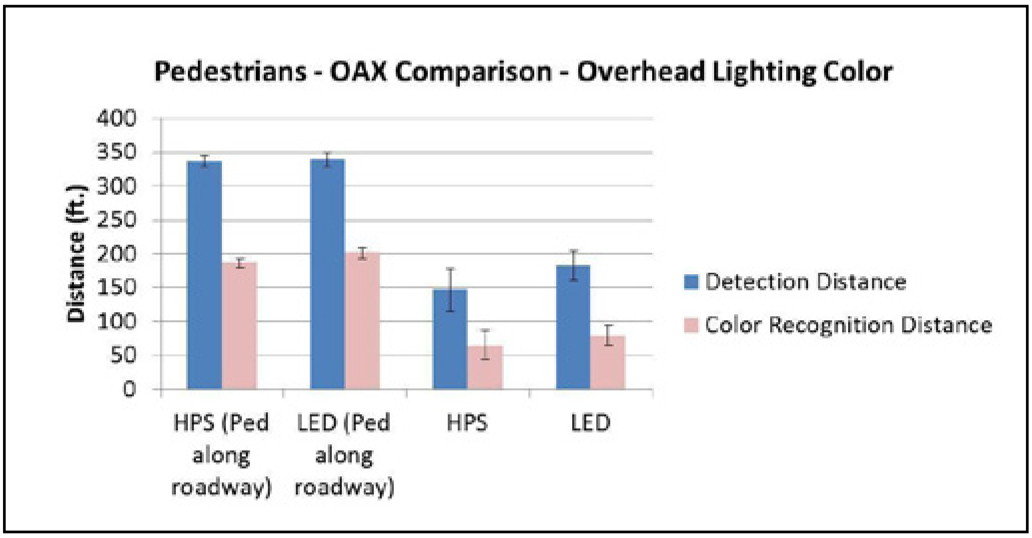

Figure 2 – Impact of Overhead Lighting Type for both On and Off Axis Pedesrtains

OP35

PEDESTRIAN CONTRAST PROFILE

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The night time visibility of pedestrians is a complex phenomenon. Whereas, visibility indices found in the literature rely on the target contrast, street lighting design standards such as CIE (115) and IESNA RP 8 use vertical Illuminance as a design targets. Semi cylindrical Illuminance is another metric that can be used while designing the visual environments for pedestrians. The question is whether drivers need to see the face of a pedestrian to recognize its presence or can they realize the presence of pedestrian by recognizing any part of a pedestrian.

Since pedestrians are three dimensional by nature and their Illuminance profile changes from top to bottom or from their left to their right, pedestrian contrast is not constant along the height. The contrast might also be different from one side (right side) of the pedestrian to the other side (left side). This is coupled with the fact that the background luminance might be different from top to bottom.

The objective of this work is to explore the various pedestrian contrast profiles that could exist to understand pedestrian night time visibility.

Methodology to characterize Pedestrian Contrast

A pedestrian and its background was divided into zones shown in Figure 1. Each zone has a constant luminance. The background is divided into three zones, upper, middle and lower background. Whereas, the pedestrian is divided into six zones; top left and top right, middle left and middle right, bottom left and bottom right. The result is six contrast zones: 1) contrast of the upper left zone (CLU), 2) contrast of the upper right zone (CRU), 3) contrast of the middle left zone (CLM), 4) contrast of the middle right zone (CRM), 5) contrast of the lower left zone (CLL) and 6) contrast of the lower right zone (CRL). Thus, two contrast profiles could be developed, one for the right side of the pedestrian and one for the left side as shown in Figure 1. When one starts to experiment with all the possibilities of how those contrast zones could vary, we quickly realize that the contrast profile can be very diverse and complex. Further elaboration on the various possibilities with varying background luminance would result into (640 profiles). One can classify those profiles as:

Dominant profile
Non- dominant profile
Vertically opposite profile
Vertically symmetric profile

Furthermore, using this theoretical approach to the contrast profile, one can infer that the pedestrian contrast could be:
Bi-polar (i.e. contrast polarity is different from left side as opposed to the right side) Dynamic (i.e changes as the driver gets closer to the pedestrian)
To further understand the dynamic of pedestrian contrast, Dialux computer simulations were made. A street 7-meter wide and 300 m long with 2 m sidewalks was modelled. Six 10-meter high poles were used with 50-meter spacing. The type of street light used was a 101 W, 7404 lm Led luminaire with spill control optic. Five 3-D pedestrians were placed 2.25 m apart across the street. Simulations were performed by placing the five pedestrians on 12 pedestrian grids along the length of the street.

Results
The luminance values of 12 points along the right side of the pedestrians were obtained with 12 points on the right background. Similarly the luminance values of 12 points along the left side of the pedestrians with 12 points of the background on the left side were found. The contrast C of each point i was then obtained by using two equations:

$$C_i=(L_{Ti}-L_{Bi})/L_{Bi}$$
Or
$$C_i^{'}=(L_{Ti}-L_{Bi})/L_{Gi}$$

Whereby, LTi is the pedestrian luminance at point i, LBi is the background luminance at point i and LGi is the greater value of the luminances at point i. C' was used to limit the values of the contrast to below 1.0. An example of the outcome of the simulation is shown in Figure 2.

The Concept of Dominant Contrast
The aforementioned findings lead us to believe that pedestrian contrast is very complex by nature. This complexity adds more difficulty to a rather complex task of night time visibility. In an effort to simplify this complexity, the concept of dominant contrast is proposed. The dominant contrast (DC) is defined as the contrast of any part of the pedestrian that would provide the highest recognition of the presence of pedestrian. The Dominant contrast ignores all the points that have low contrast and averages the points that are considered to have a dominant contrast.

Conclusion
Pedestrian contrast changes along the height as well as the width of the pedestrian. The contrast could be bipolar and dynamic. The Bipolarity results from the change in pedestrian contrast from negative to positive along the height or the width of the pedestrian. The dynamic contrast is a result of the change of the luminance of the background and the luminance of the pedestrian as the driver's eyes get closer to the pedestrian and see the pedestrian and its background from different perspectives. Furthermore, the position of the pedestrian along the lateral as well as the longitudinal direction of the street has a direct impact on its contrast. The concept of Dominant contrast is proposed. The dominant contrast is defined as the contrast of any part of the pedestrian that would provide the highest recognition of the presence of pedestrian.

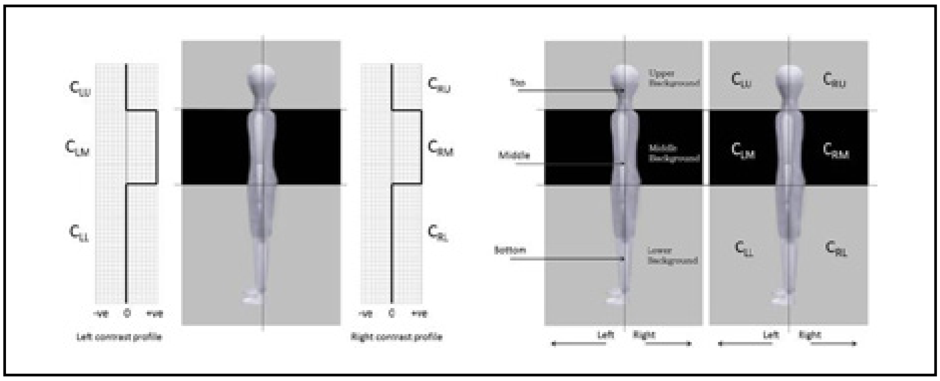

Figure 1 – Pedestrian Contrast zone and Contrast profiles.

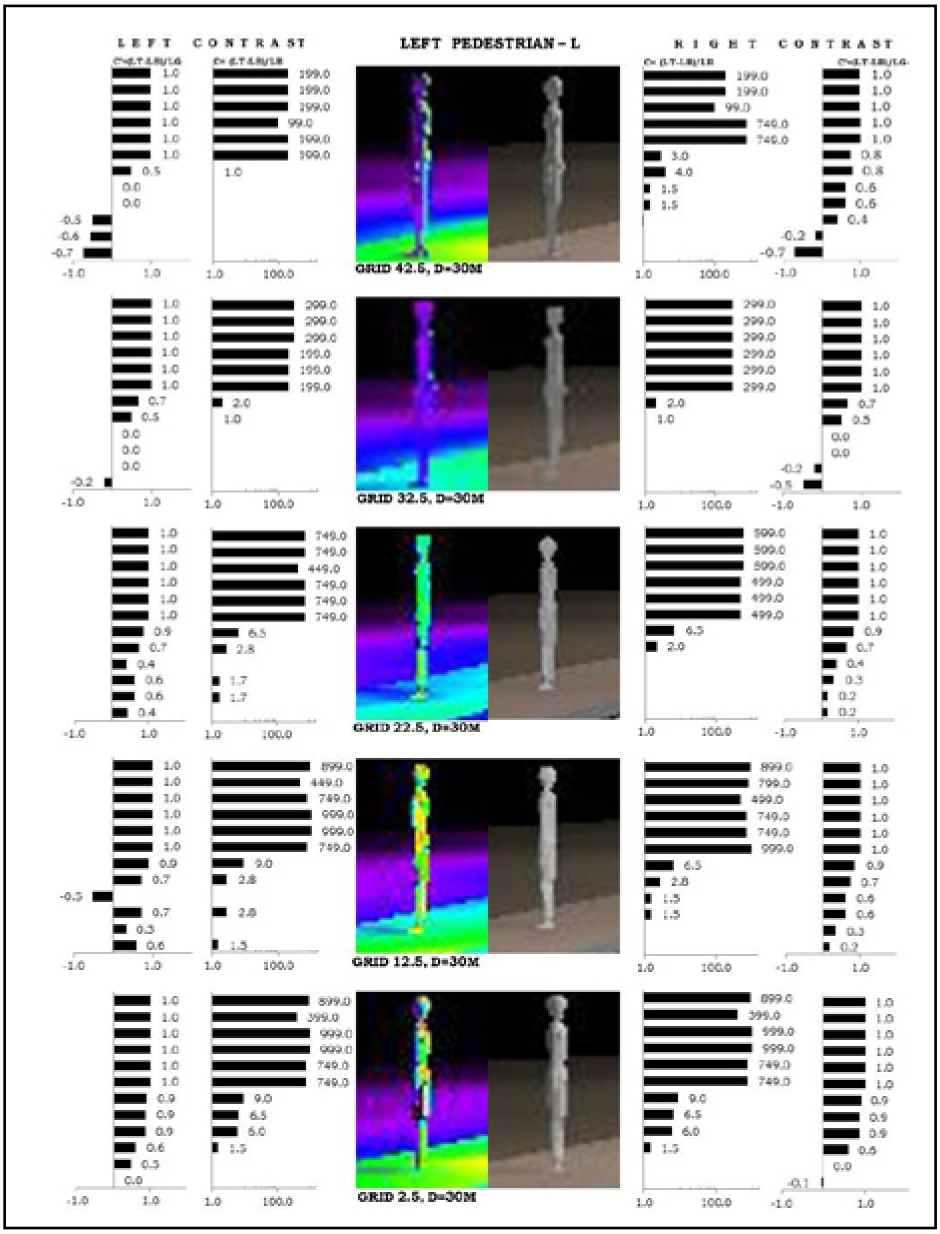

Figure 2 – Variation in Contrast values when the distance between the pedestrian and the driver is constant at D = 30 m while the location of the left pedestrian changes along the longitudinal direction of the street from G2.5 to G42.5

Integrating Daylight and Electric Lighting
(Chair: Dominique Dumortier, France)

OP36

INVESTIGATION OF GAZE PATTERNS IN DAYLIT WORKPLACES: USING EYE-TRACKING METHODS TO OBJECTIFY VIEW DIRECTION AS A FUNCTION OF LIGHTING CONDITIONS

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There is a general consensus that glare is the main cause of occupant interactions with shading and thus a major source of potential dissatisfaction from occupants. The more common type of glare for interior spaces, referred to as discomfort glare, induces negative reactions that are critical to be solved with proper design and lighting controls, though no observable disability. Despite numerous efforts in coming up with glare indices through surveys conducted either with luminaires or, more recently, with daylight, predicting occupant discomfort with a glare index still poses important challenges in design. A major limitation shared by all known glare indices is to ignore where we actually look and what causes a view pattern. Actual changes in view direction will have a strong impact on the assumed position of the glare source and indirect implications on glare adaptation or angular size, thus ultimately a significant influence on glare evaluation outcomes: if lighting and perceived comfort in turn influence the preferred line of sight, this influence should also be reflected in the glare index.

While early studies already pointed out that visual context, task and expertise all play a key role in driving eye movements, we now know that they can override each other depending on the specific conditions. Yet surprisingly few studies can be found on the relationship between eye movements and building-induced visual context, such as a window, and none of these linked eye movements to comfort perception.

Eye movements as a variable for visual comfort studies can actually not be addressed with psychophysical procedures typically used for glare evaluation: the latter rely on subjective occupant perception whereas people are oblivious to their specific head and eye movements. From previous work demonstrating the profound influence that cognitive factors have on eye movements, one can hypothesize that there are clear relations between gaze patterns, glare and luminous environment, which could be revealed using wearable eye-tracking technology. Recent advances in eye-tracking methods indeed open up opportunities to uncover relationships between gaze and glare in realistic scenarios and hold promise for getting a better grip on the dynamics of visual comfort.

We hypothesize that lighting parameters within a workspace's visual context – especially seating relative to window and daylight luminance contrasts – have a profound influence on gaze and thus on glare and ocular light exposure; thereby, ultimately, also a direct influence on performance and well-being. Extensive glare discomfort should bias the view away from glary areas whereas, for some tasks, discomfort will increase blink rate and demand a higher cognitive load, reflected in less spread eye positions and increased average pupil size.

To start uncovering these relationships, this paper aims to identify which eye-tracking parameters could serve as the most robust predictors of glare discomfort through a series of user experiments in an office-like laboratory setting with fully controllable lighting parameters at Fraunhofer ISE. During a user study, a sequence of different well-controlled daylighting conditions is be generated, ranging from dim and low contrast to bright and high contrast, while environmental parameters (illuminance, luminance distribution from HDR images) are monitored. For each daylighting scenario, the participants were asked to perform a sequence of standard office tasks, during which we measured subjective (self-evaluated) comfort and performance, as well as gaze behavior. Eye-tracking parameters were recorded (saccade frequencies, dwell times, etc) using a wearable eyetracker (EyeSeeCam). For each task, eye- tracking parameters and subjective comfort ratings were assessed as dependent variables, while contrast and brightness conditions were the independent variables.

OP37

CAPTURING THE USER EXPERIENCE OF ELECTROCHROMIC GLAZING IN AN OPEN PLAN OFFICE

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Introduction

Electrochromic (EC) glazing shows promise as a viable alternative to fixed transmittance glazing with traditional shading devices. In an EC window, users can control glare from direct sun or bright patches of sky by adjusting the transmittance (or 'tint') of the glazing. If the minimum transmittance is low enough, it should be possible to control visual and thermal comfort without the use of window blinds. This could significantly improve the level of access to daylight and views to outside. Furthermore, EC glazing could reduce energy usage through a reduction of electric lighting use and a reduction of solar heat gain.
This paper outlines a case study into the application of EC glazing in a typical office environment, and will focus on the challenge of capturing the experience of the users.

Background

The potential of EC glazing is particularly significant when applied to contemporary office buildings with highly glazed facades. Often, these buildings suffer from problems of visual discomfort and solar gain. This in turn can lead to poor daylighting since the blinds are regularly left closed for extended periods (Van Den Wymelenberg, 2012). EC glazing could reduce this problem by lessening the dependence on traditional shading devices such as blinds and external shading devices.
Previous research into the application of EC glazing in buildings has been based on scale models, computer simulations and full scale test rooms, with a small number of studies including human participants. Recently, Lee et al (2012) investigated the performance of EC glazing in a conference room in Washington DC, US. However, the transient occupancy patterns of the conference room ruled out a systematic evaluation of user acceptance. Thus there appears to be a paucity of EC performance evaluation in real world settings and over long-term monitoring periods.

Case study outline

A case study is currently underway in two adjacent open plan offices on the De Montfort University campus (Leicester, UK). The rooms have large southeast facing windows, which have been replaced with double-glazed EC panels, manufactured by SAGE Glass – the first installation of its kind in the UK. The control system is zoned so that individual panes can be controlled independently. Figure 1 shows the interior of the two rooms before and after the EC glazing installation.
Each room accommodates four people whose work is administrative in nature, and who are office based for the majority of their working hours.

The programme of monitoring began towards the end of 2012 and will continue for at least 12 months. It will assess the impact of the EC glazing on the physical environment and record the experience of the room occupants.

A reference case will be created by fixing the EC glazing in the clear state and reinstating window blinds. Both rooms will undergo the same changes at the same time, with the response of participants being measured over time. As such this is a within-subject study.
The main challenge of the study design is to achieve a balance between minimising participant burden on one hand, whilst capturing good quality information at regular enough intervals. The need to minimise participant fatigue is particularly important here due to the small number of participants.

The study design includes three main “layers”, each with a different density of observation.

1. A daily experience form allows users to record their experience in very general terms, using a traffic light system; “good”, “bad” or “neutral”. Although recorded at a high frequency, this approach is minimally intrusive. At the same time it provides a coarse data set of occupant perception that can be linked with physical monitoring data.
2. Less frequently, an online questionnaire is administered, which goes into more detail about different aspects of the experience, for example in terms of visual comfort and glare. The questionnaire has been designed to collect a good level of detail while still being short enough to be completed relatively quickly. This is a more traditional approach that will facilitate a deeper analysis of the links between physical conditions in the room and occupant perception of the glazing performance.
3. Finally, even less frequently, one-to-one semi-structured interviews will be carried out in which deeper exploration of the subjective narrative is possible. While this is necessarily more time intensive, it will add important qualitative data that can help put the measurement data from the other levels into context.

Each layer of observation has been carefully designed with the aim of collecting data at a useful level of depth and frequency to enable a realistic picture of the users’ experience to emerge and facilitate meaningful analysis.

Summary

EC glazing has significant potential to transform the way we use glass in architecture. This case study explores that potential by assessing the impact of the technology on end users in a real world setting. By measuring the subjective as well as the non-subjective effects in a typical office setting under normal use, a valuable data set is expected.
This paper explores the challenges of real world research, in particular with regards to balancing the need for data collection with limiting participant burden. A data collection approach is described that has been designed for, and is applied to, a long-term study of EC glazing performance in an office setting.

Acknowledgements

This work is supported by SAGE Electrochromics, Inc. and Saint-Gobain Recherché.

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E.S. Lee, E.S. Claybaugh, M. LaFrance, End user impacts of automated electrochromic windows in a pilot retrofit application, Energy and Buildings 47(2012) 267-284.
K. Van Den Wymelenberg, Patterns of occupant interaction with window blinds: A literature review, Energy and Buildings 51 (2012) 165–176.

Figure 1 – The interior of the case study offices before and after the EC glazing installation

OP38

LIGHTING AND DAYLIGHTING QUALITY: CRITICAL REVIEW OF CRITERIA AND RECOMMENDATIONS AND ITS INSERTION IN BRAZILIAN CONTEXT

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The discussions about lighting quality suggest solutions that incorporate ideas of visual comfort, health, energy efficiency and the relation between architectural design and user behavior. Before evaluating lighting quality, it is still important to determine what criteria are important to quantify light. Recent researches (BOYCE, 2003, OSTERHAUS, 2008; AMORIM, 2011) alert that values found in international standards are modifying illuminance levels due to political and economical reasons disregarding human needs (visibility, performance in tasks, visual comfort, social activities, health, well-being and safety). There has been significant increase in illuminance levels in offices between 1960 and 1970. The main reasons were the improvement in lighting systems and the fast economical boom of undeveloped countries. After 1970, there was a decrease in illuminance levels recommendations because of energetic crisis and an interruption in economical development. The need in the 1970's was to use artificial light in a rational way. When standards, rules and certifications are compared there is not a consensus among light values and this fact gets even worse when these documents are historically analyzed. In Brazil, the highlight is the review of Standard ABNT 5413 ("Illuminance in Interior Environments"), in which was proposed the adoption of ISO/CIE 8995 – Lighting of indoor spaces. This adoption brings advantages in terms of evaluation of quality of light, but it could be interesting to quantify the impact of this Standard in energy efficiency of buildings. Moreover, it is important a more complete discussion of this standard in Brazilian context. On the other hand, it is also essential to point different minimum level of illuminances provided from artificial or daylight. The fact is that human beings react differently to different light sources. In this paper, the intention is to revise the main standards, rules, recommendations, certificates and literature texts about daylighting quality and its insertion in Brazilian context.

OP39

JUST SUFFICIENT LIGHTING CONDITION UNDER HYBRID-LIGHTING OF REAL DAY-LIGHT AND ARTIFICIAL LIGHT

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Lighting designers are required strongly to promote energy efficient lighting because of the global environmental problem. As is well known, one of the most effective ways to energy saving in lighting is active use of daylight. Artificial lighting fixtures should be regarded as secondary lights, except at night, which provide with minimal amount of light when and where daylight is insufficient. This means designers should plan a hybrid-lighting of daylight and artificial light. Yet, unfortunately, the method for the hybrid-lighting has not been established.

The authors have suggested that the method would be a kind of luminance-base lighting design because in such hybrid-lighting designers should estimate the occupants' adaptation level and a luminance image could be a tool for its estimation. In the previous study1) our group conducted an experiment with an imitated office room, where a false window and several lighting fixtures were installed, and tried to know just sufficient lighting condition (JSLC) of various lighting installation with window. From the result we could suggest the possibility to estimate the effect of adaptation by use of a luminance image and a brightness image. However real daylight apparently differs from the light of a false window made from several fluorescent tubes. Therefore the authors conducted an experiment to estimate JSLC of the real hybrid-lighting with an imitated office room with a real side window, from which real daylight entered the room.

We arranged an experimental room 3.75m wide, 6.5m deep and 2.6m high. A window with a venetian blind, through which real daylight entered the room, was installed on the south side wall. The room is made to imitate a small office room. The wall and the ceiling are painted in light gray, and the floor is covered with gray carpet. A desk with a computer display on it and a chair were set in the room. Following lighting conditions were adopted;

1. only real daylight through the window
2. real daylight and a LED task light
3. real daylight, general light by ceiling attached LED fixtures, and a LED task light
4. real daylight, localized general light by ceiling attached LED fixtures, and a LED task light
5. real daylight and wall light by ceiling mounted LED wall washers

The distance of the desk from the window was set as a parameter (1.5m and 4.5m), and the facing direction of the desk was also set as a parameter (facing window, facing the side wall, and facing the opposite wall of the window). The experiment was carried out from 26th August to 9th September in summer, from 25th September to 20th October in autumn, and was planned even in winter. Each experiment started at around 9 o'clock and continued till sunset, and the daylight condition and correct time schedule varied among those experimental days. Twelve persons (7 male and 5 female) participated the experiment.

In the experiment the subject first entered the experimental room with the window-blind fully opened. After 5 minutes adaptation, the subject was asked whether he/she felt glare, and when glare declared, the blind was adjusted till no glare. Then the subject was asked to work with a sheet of paper set before the keyboard and was asked to estimate insufficiency of light, then to work with the monitor on the desk, and then to view the whole room from the corners of the room respectively. When insufficiency declared, artificial light was added till the subject declared JSLC. The lighting condition was measured by illuminance and a luminance image taken from the subject's view point.
We obtained around a thousand case data till now. From those data we obtained tentative results as follows;

JSLC for paper work
The illuminance or the luminance on the paper surface under JSLC was strongly correlated to the average luminance of the luminance image taken from the subject view point as shown in Figure 1. It suggested we could not neglect the effect of adaptation and the effect could be estimated by the average luminance. The authors further examined
brightness values converted from the luminance image like the previous study, and found the brightness value on the paper could be reduced till 7 NB when uniformly illuminated by real daylight. To obtain more consistent index, the authors will try to apply contrast image analysis, which can obtain contrast value between the paper and the background objectively.

JSLC for monitor work
Like the previous study, there was no relation between the luminance of the monitor and the background luminance in JSLC, but was clear relation between the brightness value of the monitor and the background. However large individual difference was observed especially in the high average luminance conditions as shown in Figure 2. The difference of color temperature might influence the result. Further examination will be continued.

JSLC for room appearance
Several cases of JSLC were found to go outside of the borderlines suggested in the previous study. Further analytical study was carried out, and the combination of the contrast image and the approximate image, which are the components of brightness image conversion, was suggested to be a better index to judge JSLC. The analysis will be continued.

1) Nakamura,Y., Suzuo,S. and Aoki,T.:Lighting Design Method Applicable Both to Day Lighting and to Electric Lighting Using Luminance Image, Proceedings of the 27th Session of the CIE South Africa 2011, pp.398-408, 2011

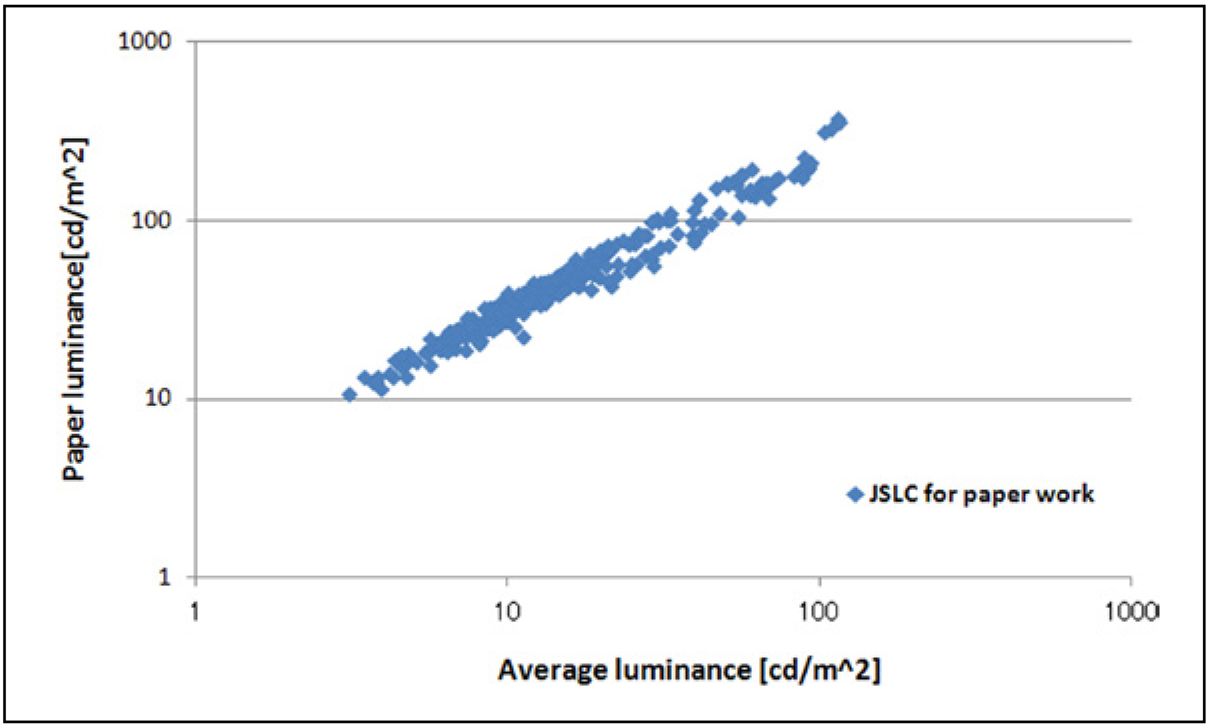

Figure 1 – Relation between paper luminance and average luminance in JSLC

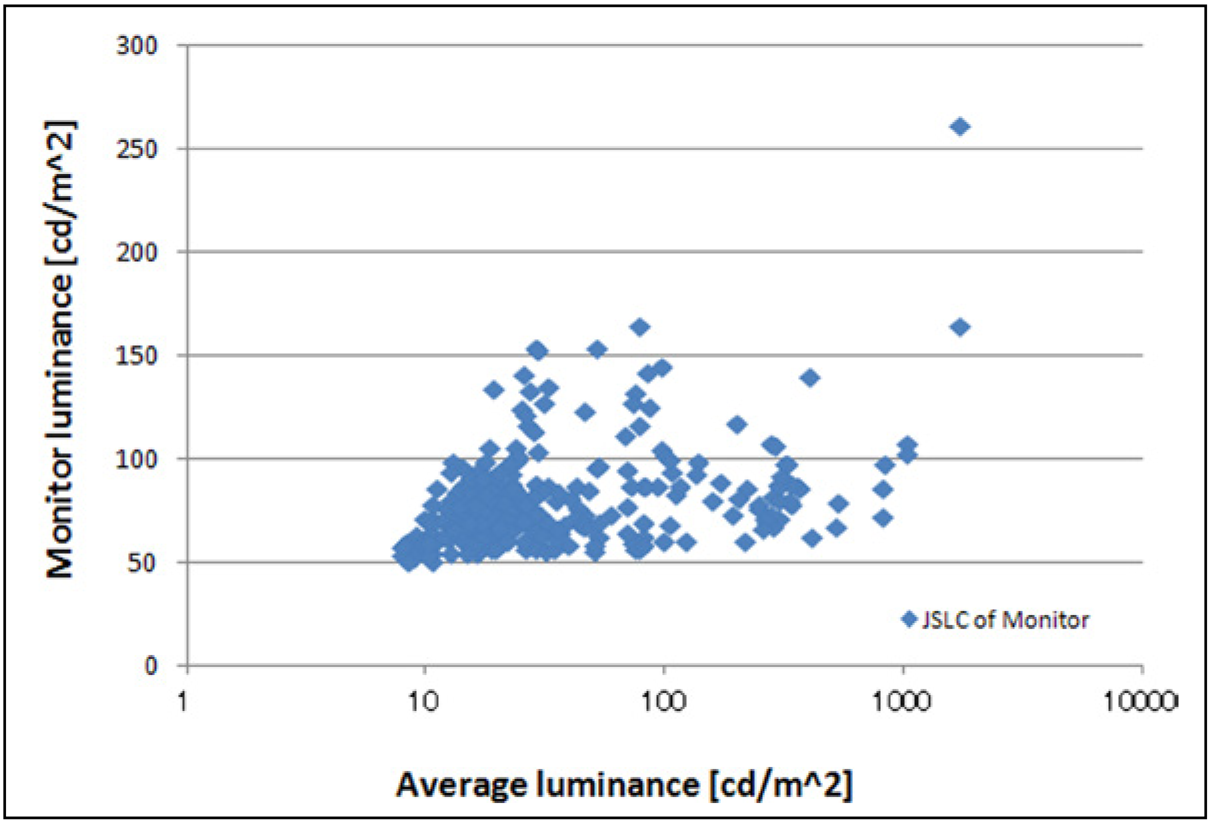

Figure 2 – Relation between monitor luminance and average luminance in JSLC

LED Photometry and Performance of Photometers
(Chair: Armin Sperling, Germany)

OP40

ANALYSIS OF PERFORMANCE PARAMETERS OF ILLUMINANCE METERS PER CIE DS 023 QUALITY INDICES FOR SPECIFIC FIELD MEASUREMENTS

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Illuminance meters and luminance meters are widely used instruments for many types of field measurements. Characterization of performance of these devices was formerly made according to CIE 69:1987 recently updated by the draft standard CIE DS 023/E:2012 which when approved by the CIE national commities, it will be published as a CIE Standard and later on as a joint ISO/CIE Standard. But the problem of user as describe this draft standard is the characteristics of these photometers alone do not allow the estimation of the measurement uncertainty for a specific measurement task even if on the other hand it describes that instruments with "better" characteristics in most cases allow smaller uncertainties than instruments with "worse" properties. Often users do not know according to quality indices evaluate measurement uncertainties of their measurement especially in the field photometric measurements of illuminance or luminance. This ambiguity appears in the field photometric at the verification measurements of illuminance of lighting systems after realisation of lighting project or others measurements. This paper concerns about analysis of measurement uncertainties for specific field measurements of illuminance with different classes of illuminance meters defined by the draft standard CIE DS 023/E:2012. The main aim of research work was made about field measurements for indoor workplaces under well-known conditions. Lighting system parameters (i.e. average illuminance level etc.) and spectrum of used light sources (luminaires) in the measured rooms was known to compare results of measurements with stated expanded uncertainties for 95% coverage interval. Uncertainties of measurement in this specific measurements was investigated for different types of illuminance meters from worse classes to the best classes assuming quality indices prescribed in the draft standard. From results of this work can be assumed or predicted the accuracy of measurement of used illuminance meters with concrete class to avoid ambiguity for user who performs investigated specific measurements.

OP41

INFLUENCE OF CURRENT AND VOLTAGE HARMONIC DISTORTION ON THE POWER MEASUREMENT OF LED LAMPS AND LUMINAIRES

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Solid-state lighting (SSL) products such as LED lamps and luminaires are rapidly replacing other light sources in both consumer and professional markets. This massive transition of the lighting industry relies on the increasing performance of SSL products. Many requirements are set by regulations and certifications in order to guarantee that these products are safe and present a minimum level of light quality together with better energy efficiency. The compliance of the products is based on specific measurement standards, such as the IESNA-LM-79 for photometric and electrical properties. In this standard and other lighting standards, the accepted figure of merit for the energy efficiency of SSL products is the luminous efficacy expressed in lumen per watt (lm/W).

A great body of work has been devoted to improving the measurement of the luminous flux (lm) of LEDs and SSL products. The photometric methods used for incandescent and fluorescent light sources presented some difficulties for LED based lamps and luminaires. The completion of LM-79 in the USA in 2008 was an important milestone as it established relevant photometric test protocols that were well accepted by testing laboratories and lighting manufacturers.
Whereas the measurement of the luminous flux of SSL products can now be achieved with uncertainties of about 2% by testing laboratories, the luminous efficacy is still a difficult parameter to assess because the measurement of the electrical power also presents some challenges that have not yet been studied in depth.

Specific issues appear in the measurement of the electrical power of LED lamps and luminaires. As it has been shown in several reports and publications, many SSL electronic drivers generate harmonic currents in a wide frequency range. In Europe, the emission of harmonic currents by SSL products is not yet regulated. However, many LED lamps were found to exceed the limits set for fluorescent lamps (IEC 61000-3-2), which can potentially be a concern when LED lamps eventually replace the majority of fluorescent lamps. As with other electronic equipment, the impact of harmonic currents emitted by SSL products is well-known by utility companies and manufacturers of electrical distribution equipment. It is quite usual that SSL products generate harmonic currents at frequencies exceeding 100 kHz or 1 MHz, well above the limit of about 2 kHz that is considered in IEC 61000-3-2.

The topic of this paper is to clarify the impact of these harmonic currents on the measurement of the active power itself. When high frequency currents are generated in an electrical circuit, the resulting voltage, current and power readings become very sensitive to two factors: (i) the bandwidth of the measurement devices and (ii) the impedance of the power supply circuit which becomes higher at high frequency due to inductive effects.

The analysis of the electrical network equations of a typical measurement circuit shows that the active power includes a fundamental term at the mains frequency and a series of terms at harmonic frequencies appearing through the coupling of the harmonic currents with the impedance of the power supply circuit (source impedance).
The mathematical expression of the active power is used to give an estimate of the error between the measurement performed with a perfect set-up (infinite measurement bandwidth, null source impedance) and measurements performed with a limited bandwidth and realistic source impedance.

The total harmonic distortion of the current and voltage waveforms (respectively THDi and THDv) are commonly used in electrical engineering to measure the quality of AC electrical distribution circuits. When a piece of equipment, such as an LED lamp, generates harmonic currents in an imperfect electrical distribution circuit, harmonic voltage components appear and distort the sinusoidal voltage waveform.

In this paper, several expressions of the error terms in the active power were established as functions of THDi and THDv. As a result, it is possible to build a criterion to estimate the systematic error induced by THDi and THDv in the measurement of the active power. This criterion can be introduced in standard measurement protocols as a prior requirement to check if the electrical set-up is suited to perform the measurement of the electrical power of a given lamp or luminaire.
In order to verify the relevance of this approach, an experimental set-up was designed to provide accurate measurements of the voltage, current and power of LED lamps. High bandwidth voltage and current probes connected to a fast digitizing oscilloscope were used to measure the current and voltage waveforms. The active power was simultaneously measured by two different methods: a commercial high bandwidth power analyzer on the one hand, and on the other hand, a numerical integration carried out in the time domain.

Using this set-up, it was possible to compare the active power measurements performed with different bandwidths on LED lamps generating high frequency harmonic currents up to about 100 kHz. The active power was typically underestimated by about 5% when the measurement bandwidth was limited to 2 kHz, the IEC-61000-3-2 limit for measuring the power of lighting equipment. The set-up allowed us to study the effects of the source impedance of the measurement of the active power. Again, systematic errors of about 5% to 10% can be introduced with increasing source impedance.

The theoretical and experimental results presented in this paper will help improve the electrical testing protocols used in SSL measurement standards under completion or revision.
The authors are grateful to the French Institut Carnot for providing the financial support for this work that began during the stay of Christophe Martinsons at NIST as a guest researcher in July and August 2012.

OP42

SPECTRAL MISMATCH CORRECTION FACTOR ESTIMATION FOR WHITE LED SPECTRA BASED ON THE PHOTOMETER'S F1' VALUE

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The spectral matching of photometers is important for LED measurements. However there is no general estimation for the spectral mismatch correction factor [1] for the measurement of white LEDs known in the literature until now.

The authors will give a general estimation of the range of possible spectral mismatch correction factors for white LED measurements in function of the quality of the spectral mis match of the photometer. For this purpose a database of 120 different photometers with f1' values in the range of 0.6% up to 9.0% and 300 white LED spectra (Phosphore type as well as RGB type LEDs based on measurements as well as simulations) was used to calculate the spectral mismatch correction factor. From all data a general observation is derived that the minimum and maximum spectral mismatch correction can be calculated based on the f1' value of the photometers.
Regression lines for the 0.95 quantiles were calculated to derive the following approximations:
The spectral mismatch correction factor F* for white LEDs is estimated to lie in the range defined by

$|F^* - 1| < 0.8 * f1'$ For phosphor type white LEDs
$|F^* - 1| < 1.4 * f1'$ For RGB type white LEDs

These estimations of the range of possible spectral mismatch correction factors can also be used for the estimation of the contribution to the measurement uncertainty. As an example the spectral mis match of a photometer with a quality index f1'of 6% will contribute about 8.4% to the combine uncertainty for the measurement of a white LED of RGB type. This uncertainty could only be reduced if the spectrum of the source and the spectral response of the photometer is known.
In their contribution the authors will describe the background of their calculation as well as the data basis (photometers and LED spectra) in detail.

[1] CIE Draft Standard DS 023/E:2012: Characterization of the Performance of Illuminance Meters and Luminance Meters, 2012

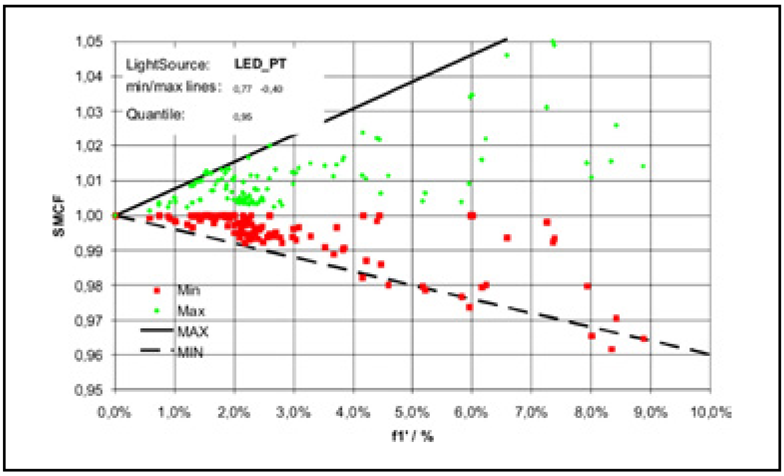

Figure 1 – Minimal and maximal spectral mismatch correction factor for phosphor type white LEDs depending on the f1' value of the photometers used

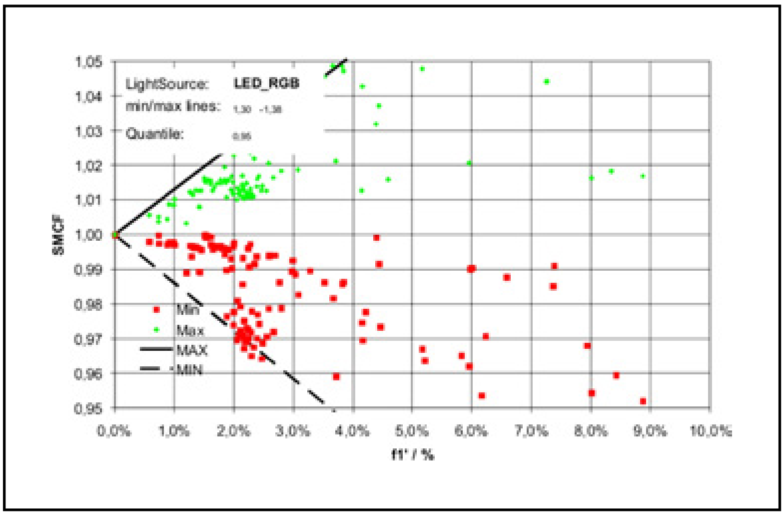

Figure 2 – Minimal and maximal spectral mismatch correction factor for RGB type white LEDs depending on the f1' value of the photometers used

OP43

RADIOMETRIC DETERMINATION OF THE JUNCTION TEMPERATURE OF AN LED

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Junction temperature T_j is an important parameter affecting the lifetime of an LED. In an assembled LED lamp, LEDs are not electrically accessible, thus obtaining T_j is challenging. We have studied the relationship between the junction temperature and spectrum for various LEDs in order to develop a method for determining the junction temperature from the LED spectrum.

The high energy side of an LED spectrum is typically expected to follow the Maxwell-Boltzmann distribution [1]. Although the Maxwell-Boltzmann distribution by itself may not be sufficiently accurate for determining the temperature of blue quantum well LEDs, we have studied the possibility of calibrating the measurements to enable accurate determination of the junction temperature of red, blue and white phosphor LEDs.

Various LEDs were extracted from solid state lamps. The junction temperature – voltage characteristics of the LEDs submerged in an oil bath were determined over a wide temperature range of 30 – 150 °C using short current pulses. Spectra of the LEDs were then measured at varied temperatures. Maxwell-Boltzmann distribution was fitted to the 1 % to 70 % intensity region in the high energy side of the LED spectrum. The fit gave the inverse derivative temperature T_{ID} for the LED. Figure 1 shows an example fit for a set of spectra for a blue LED extracted from a Philips Masterled lamp at various temperatures and the obtained T_{ID} 's. We also studied the characteristic temperatures T_c [1] obtained from the T_{ID} 's. Generally, T_{ID} and T_c deviate from T_j .

Figure 2 shows the relationship between the T_{ID} and T_j for six specimens of the blue Philips Masterled LEDs. There is a linear dependence between the T_j and T_{ID}. The slope is rather similar, 0.804 with a standard deviation of 0.038, for all six LEDs. However, the intercept term is considerably different for all LED specimens varying between -21 and - 116 K. These results indicate that Tj can be obtained for any of the LEDs from the spectrum using the average of the slopes. One measurement e.g. at the room temperature is needed to fix the intercept term. With these conditions, the standard deviation of the radiometrically obtained temperatures at e.g. T_j = 120 °C would be 5 K. We also studied the effect of the current (density) on the temperature determination. Currents were varied by a factor of 2.5. The effect on the inverse derivative temperatures was less than 0.5 % for the blue LEDs.

The measurements were repeated for three red LEDs extracted from an Osram Parathom Classic A80 lamp, and three white LEDs extracted from an Osram Parathom Classic A60 lamp. The slope was 0.826 ± 0.026 for the red LEDs and 0.501 ± 0.029 for the white LEDs. The intercept terms were 20 – 37 K for the red LEDs and -2 – 42 K for the white ones. Detailed results will be presented in the conference.

We conclude that the Maxwell-Boltzmann distribution works satisfactorily with red LEDs and, with calibration, also with some white and blue LEDs. However, LEDs at different wavelengths need to be calibrated separately because the relationship between the T_{ID} and T_j depends heavily on the wavelength. It also varies from a manufacturer to another and, as was noted with the blue Philips LED, the behaviour may even vary considerably between specimens of similar LEDs. Nevertheless, determination of the junction temperature from the LED spectrum seems to give access to LED lifetime estimation via a new method.

Acknowledgement. The work leading to this study was partly funded by the EMRP ENG05 Project „Metrology for Solid
State Lighting.“ The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

[1] Z. Vaitonis, P. Vitta, and A. Zukauskas, “Measurement of the Junction Temperature in High-Power Light-Emitting Diodes from the High-Energy Wing of the Electroluminescence Band,” J. Appl. Phys. 103, 093110 (2008).

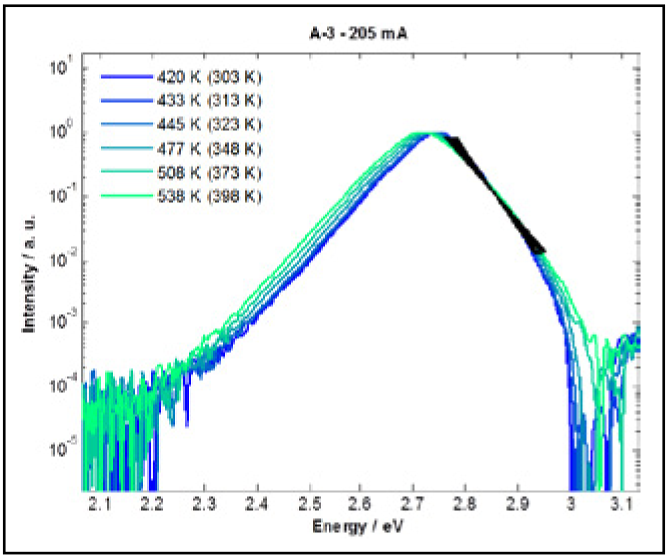

Figure 1 – Spectra of a blue LED extracted from a Philips Masterled lamp at temperatures 303 – 398 K (colored lines), fitted Maxwell-Boltzmann distributions (black lines), and the obtained inverse derivative temperatures T_{ID} (legend). The current of the LED was 205 mA.

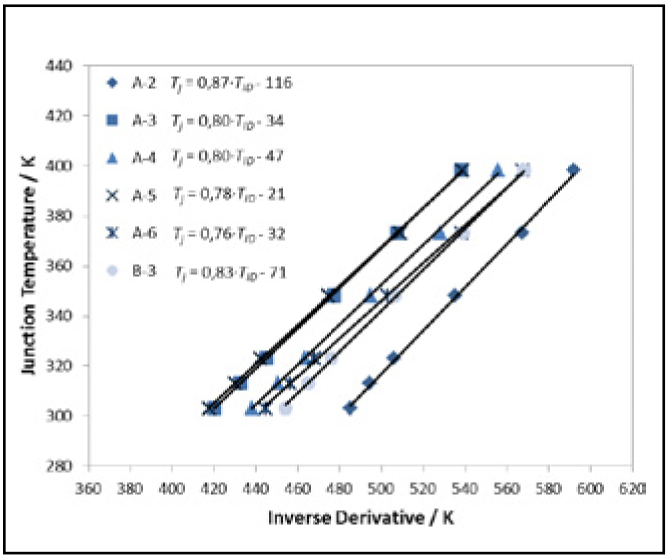

Figure 2 – Relationship between the junction temperatures T_j and the inverse derivative temperatures T_{ID} for six blue Philips Masterled LEDs denoted as A-2, A-3, ..., A-6, B-3.

Lighting the City - Luminaires and Design
(Chair: Peter Schwarcz, Hungary)

OP44

LIGHTING PROPERTIES AND EFFICIENCY OF LUMINAIRES EXCEEDING THEIR LIFE-TIME

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Lighting quality of illuminated premises depend significantly on the state installed luminaires as well as on their luminous, energy related, mechanical and other properties. Unlike light sources which undergo regular replacements, luminaires put into operation are expected to serve for several years or even decades, being maintained by simple cleaning. Lifetime of luminaires is not clearly marked and usually there is no time schedule for replacement of luminaires. As a consequence, in many existing buildings there are still 20 to 50 years old luminaires which are still operated. It is in question whether such luminaires still have acceptable luminous and electrical efficiency for further operation or should be replaced regardless on payback of investments to modernization.

This paper aims to discover current properties of old-type luminaires in comparison to recent technologies and also in comparison to their declared catalogue parameters. To follow the objectives, hundreds of measurements have been performed in lighting laboratories of the Slovak University of Technology. Investigation is focused on the most common fluorescent luminaires with louvres and different kinds of diffusers (smooth, prismatic, pyramidal structured). Luminaires of different age (at least 20 years) have been harvested from buildings during re-construction of their lighting systems. Luminaires have been measured in their actual condition and after cleaning, with actually inserted lamps and with reference lamps. Luminaires have been subjected to measurement of luminous flux and luminous efficiency (in photometric integrator), luminous intensity distribution curve (on goniophotometer), spectral transmittance of diffusers in order to assess the yellowishing effect of UV radiation (by means of spectrophotometer), electrical characteristics of the lamp-ballast system. Fluorescent lamps taken from these luminaires have been separately measured to their luminous flux and efficacy.

As luckily catalogues of measured cluster of luminaires are still available in archives, it was possible to compare the results of measurements to declared values and thus to assess the non-recoverable luminous flux losses (NRLL). NRLL is generally neglected in calculations and it is not included in the maintenance factor according to the CIE 97 publication, estimated to be less than 3 % during the lifetime of a luminaire in normal evironmental conditions. However, if this time is exceeded several times, NRLL affects the optical efficiency (L.O.R.) of luminaire. The results showed that e.g. in case of prismatic or pyramidal diffusers dust deposits in narrow grooves cannot be removed by normal cleaning. Degradation of diffusers due to long-term absorption of UV radiation causes decrease of transmittance. Furthermore, both dust and UV degradation are responsible to changes in the luminous intensity distribution of prismatic covers.
Brief cost analysis of simple luminaire replacement based on comparison of both optical and electrical efficiency of old-type and recent luminaires is also given in the paper. The paper is completed by proposal of determination of nominal lifetime of luminaires upon selected criteria.

OP45

VISUAL MECHANISMS OF DISCOMFORT GLARE SENSATION CAUSED BY LEDS

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LED luminances have increased because of recent innovation in LED technology. It has become important to reduce discomfort glare from LEDs and LED luminaires. Recent studies have suggested that light sources with more short-wavelength radiation increases not only the perception of brightness but also the degree of discomfort glare (Kimura and Ayama, 2011; Bullough, 2009). In order to provide comfortable interior environment, it is important to minimize glare while maximizing the perception of brightness. To this end, we attempted to define the mechanisms of discomfort glare sensation in terms of the spectral sensitivities of retinal receptors. Recent studies suggested S-cones contribute to the sensation of discomfort glare the most among retinal receptors. However, it is reasonable to consider rods, contributing the brightness perception with cones at mesopic light levels, as major contributors to the discomfort glare sensation.

We conducted a glare evaluation experiment by using LEDs with three different spectral power distributions. In the experiment, we used an experimental setup consisting of a 2.0 m * 0.7 m partition (reflectance: 10 %) and a glare light source located behind the partition. In order to change the spectral power distribution (SPD) of the glare source, three types of LEDs (cyan, amber, and white) were used. The partition had five circular holes (visual angle: 2 degrees) at the same height as the subject eyes. Each subject, sitting before the partition, saw the glare source through each of the holes, located at eccentricity angles of 0° (center), 5°, 10°, or 20° off-axis. As ambient lighting, a tri-phosphor fluorescent lamp was used to maintain a constant luminance for the partition surface at a luminance of 0.1 cd/m^2. The independent variables were the spectral power distribution (SPD) and eccentricity angle of the glare source. The dependent variable was measured luminance on the borderline between comfort and discomfort (BCD).

In the experiment, a subject was escorted to the experimental room by an experimenter and seated in front of the partition at a distance of 1 m. After adapting to the background luminance, the subject placed his/her chin on a chin rest. While the subject fixated on the central visual field, a glare source with one of the SPDs was presented at one of the eccentricity angles. The experimenter gradually increases the luminance of the glare source until the subject recognized the luminance of the glare source as the maximum limit of acceptance. Then, the experimenter recorded the source luminance as a BCD luminance for the condition. This procedure was repeated for all the other experimental conditions. In the experiment, 27 subjects (between 19 and 25 in age) participated (16 male and 11 female university students).

Figure 1 illustrates averaged BCD luminances and standard deviations for the four eccentricity angles of the glare sources. BCD luminances for the cyan LED were lower than the white and the Amber LEDs for all the eccentricity angles ($p<0.01$). Interestingly, the cyan BCD luminances were almost constant for all the eccentricity angles while the white and the amber BCD luminances gradually increased as the eccentricity angle increased. The above-described experimental results

confirmed that light sources with more short-wavelength radiations provided higher degrees of discomfort glare.
Based on the experimental data, we discussed which retinal receptors contribute to the discomfort glare sensation. We developed Equation (1) in Figure 2 that defines a modified BCD luminance that corresponds to the glare sensation better than the existing BCD luminance. As Equation (1) indicates, both cones and rods contribute to the sensation of discomfort glare. The influence of S-cones is also counted in the Helmholtz-Kohlrausch effect. The “x” is a factor determining the proportion of cone and rod contributions. The “x” values were different among the eccentricity angles of the glare source in this experiment. They were 0.47, 0.51, 0.37, and 0.42 for 0, 5, 10, and 20 degrees respectively. This is because the proportion of cone and rod differs among the eccentricity angles.

To confirm the consistency of the above-described modified BCD luminance, we conducted additional glare evaluations by using haploscopic glare matching in which 15 young and 16 older (>65 years old) subjects participated. The experimental results confirmed that the mechanisms of the glare sensation derived from the haploscopic glare matching were consistent with Equation (1) although the coefficients in the equation were different.

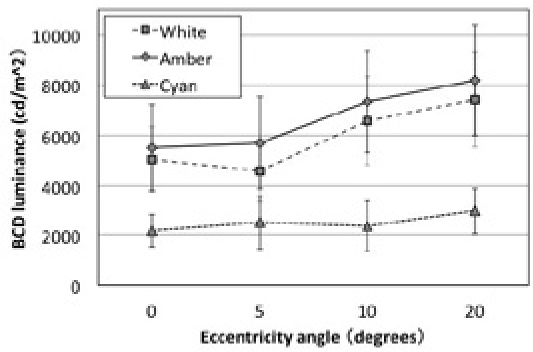

Figure 1. BCD luminances for various eccentricity angles

Figure 1

$$L_{MBCD} = a \cdot 10^{c} \cdot \int I(\lambda)\left\{mV(\lambda) + (1-m)V'(\lambda)\right\} d\lambda \quad (1)$$

$$C = 0.256 - 0.184y - 2.527xy + 4.656x^{3}y + 4.657xy^{4} \quad (2)$$

L_{MBCD} : modified BCD luminance (cd/m^2)
a : a coefficient
c : a coefficient for the Helmholtz-Kohlrausch effect
$I(\lambda)$: spectral power radiation (W/m^2)
$V(\lambda)$: photopic luminous efficacy function
$V'(\lambda)$: scotopic luminous efficacy function
m : a coefficient for cone contribution
x, y : (x, y) chromaticity coordinates

Figure 2. Modified BCD luminance

Figure 2

OP46

THE LUMINAIRE BEAM-SHAPE INFLUENCE ON DISCOMFORT GLARE FROM LED ROAD LIGHTING

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Objective:
Discomfort glare in road lighting has been studied by various groups in the past with traditional road lighting luminaires. Recent years, as a new energy-efficient light source, LEDs are introduced in road lighting at a high pace. However there is a rising concern about discomfort glare caused by LED road luminaires to the road users, namely drivers and pedestrians. To better understand the mechanism of discomfort glare generated by LED sources in a road lighting application, a series of perception experiments have been carried out at Philips Research Lab in Shanghai, such as influence of light source CCT, luminaire beam shape etc. The study of CCT influence on discomfort glare has already been presented in 2012 CIE conference of "Lighting quality and energy efficiency".
In this study, "the luminaire beam shape" influence on discomfort glare is investigated.
Due to the small LED chip and its precise optical control, often LED luminaires are designed to have a beam shape with very sharp cut-off. However, this sharp cut-off could be one of the reasons of discomfort glare sensation of drivers while driving.

Methods:
A laboratory setup is designed to use a multi-source frame with 80 LEDs to mimic the many LED luminaires ahead in the visual field of drivers. The emitting size of each LED was designed and downscaled into the lab settings according to the real flash area of the luminaire in the typical road lighting configurations taken into consideration. The intensity of each LED was modulated according to different beam shapes at the driving speed of 60km/h. A series of experiments were done to evaluate the beam-shape influence on discomfort glare sensation both static and dynamic conditions. In the experiments, the subjects were asked to evaluate the discomfort glare in different lighting situations using De Boer scale. In the static situation, subjects were asked to evaluate the discomfort glare with and without multiple sources in the background scene, in the meanwhile, their pupil size changes were recorded by eye tracking system. In the dynamic situation, subjects were asked to look straight ahead while the multiple LED lights were modulated at different slope of eye illuminance at a given time period.

Results:
From lab experiment, significant difference has been found when the multiple sources ahead is visible in the viewing scene as compared with the invisible situation due to the sharp cut-off beam of LED luminaires in static situation (see Fig.1).
Besides, significant differences have been found with different beam shapes on discomfort glare under dynamic situation (see Fig. 2).

Based on these findings, further application analysis has been done for various types of road class and installation configurations. Results will be presented in the final paper.

Conclusions:
The improperly designed beam shape could be one of the major causes of driver's discomfort glare sensation.

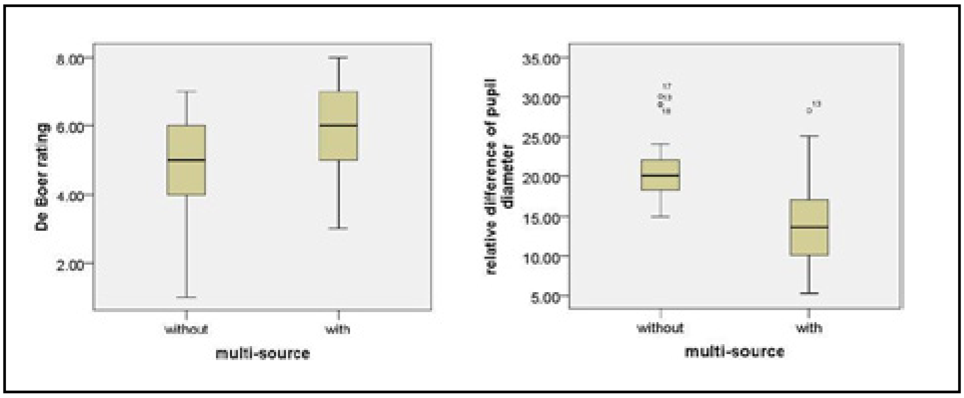

Figure 1 – Boxplot of De Boer rating and relative change of pupil diameter at two background lighting conditions (with multi-source and without multi-source) for static situation

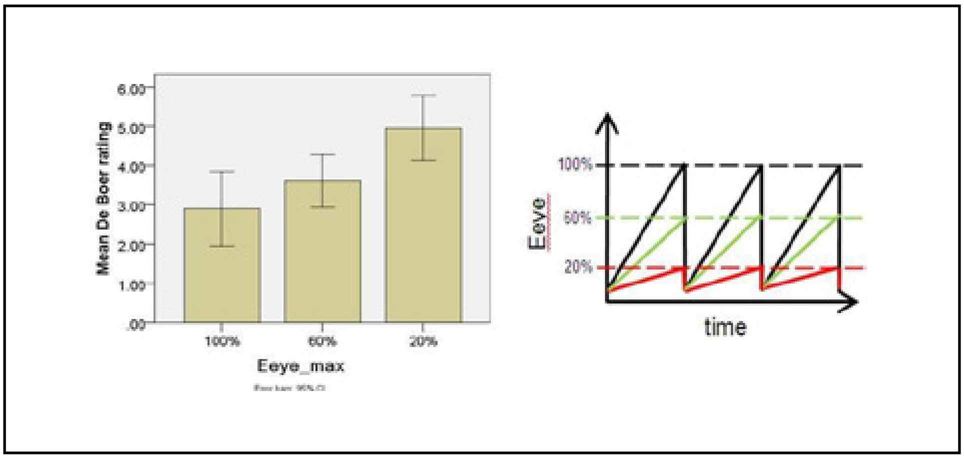

Figure 2 – Mean De Boer rating scores under dynamic lighting conditions with three different beam shapes

OP47

INFLUENCE OF A GLARE SOURCES SPECTRUM ON DISCOMFORT AND DISABILITY GLARE UNDER MESOPIC CONDITIONS

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In the next few years the usage of LED-luminaires for street lighting will increase strongly. At the same time there are complaints about higher glare from LED street lights. As compared to conventional lamps for street lighting (HPS, MHL), there is a higher blue content in the LED-spectrum which could affect glare perception.

It is already known that the colour of light influences discomfort glare /1/, /2/, /3/, /4/, /5/. Some studies focused on the contribution of the blue cone to glare sensitivity. Depending on the setup of the research the results were different /2/, /4/. There are also different functions to describe a discomfort glare sensitivity spectrum /3/, /5/. Considering the differences in excitation of the blue cone from LEDs and HPS-lamps (Fig.1) and the different places of presentation compared to other studies there is a need to investigate this topic for the mentioned application.

Hypothesis: There is an influence of the higher blue content of LEDs on discomfort glare. The more blue there is in the spectrum the higher is the glare rating. However, there is no detectable influence on disability glare (threshold contrast). The glare sensitivity curve in /3/ is suitable to describe the influence of the spectrum on discomfort glare.

To examine the influence of the spectral power distribution on discomfort and disability glare under mesopic conditions an experimental set-up has been designed (Fig. 2). Narrow band stimuli were presented to the subjects to determine the effects of several parts of the visible spectrum on threshold contrast and glare rating. Moreover real existing broadband stimuli with the same size and luminance were presented to verify the results. 28 subjects (20-35 y) took part in this investigation.

For narrow band stimuli a significant influence of the spectral power distribution on discomfort and disability glare could be found. The shorter the wavelength the higher the glare rating and the threshold contrast. For broadband stimuli a significant influence on discomfort glare was detected. The more blue there is in the spectrum the higher is the glare rating. There was no influence on threshold contrast.

/1/De Boer, J.B., Observations on discomfort glare in street lighting; influence of the colours of light. 13. CIE Conference Zürich, 1955
/2/Sivak, M., Schoettle, B., Minoda, T., Flannagan, M. J., Blue content of LED headlamps and discomfort glare, University of Michigan, Report No. UMTRI-2005-2, 2005
/3/ Bullough, J. D., Spectral sensitivity for extrafoveal discomfort glare, Journal of Modern Optics 56:13, 2009 /4/Bodrogi, P., Wolf, N., Khanh, T. Q., Spectral sensitivity and additivity of discomfort glare under street and automotive lighting conditions, 27. CIE Conference, Sun City – South Af-

rica, 2011
/5/Fekete. J., Sik-Lányi, C., Schanda, J., Spectral discomfort glare sensitivity investigations, Ophthalmic and Physiological Optics 2010:30, 2010

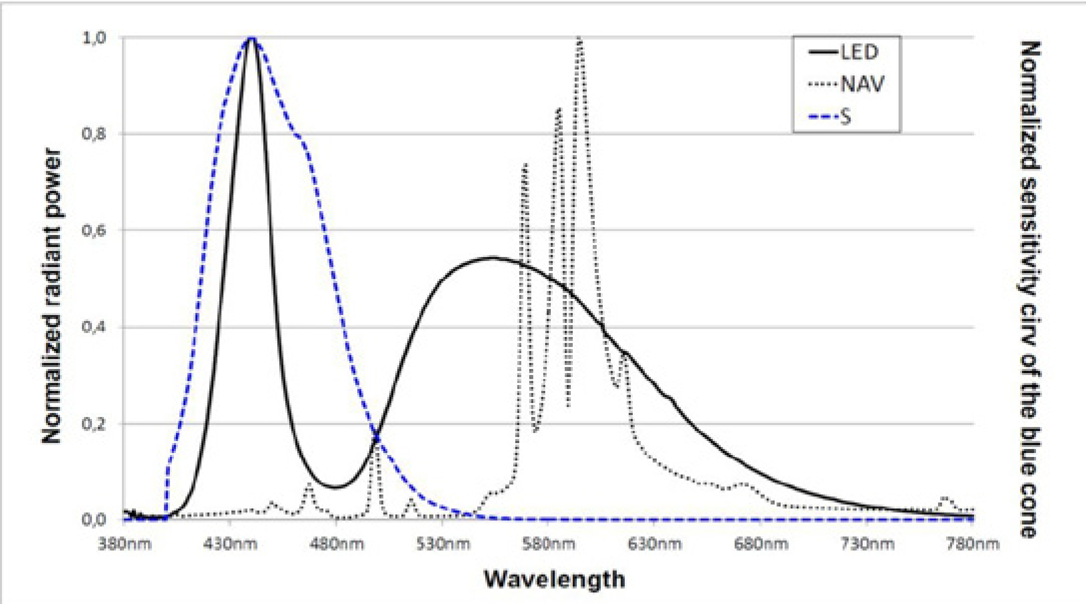

Figure 1 – Excitation of the blue cone from LED and HPS

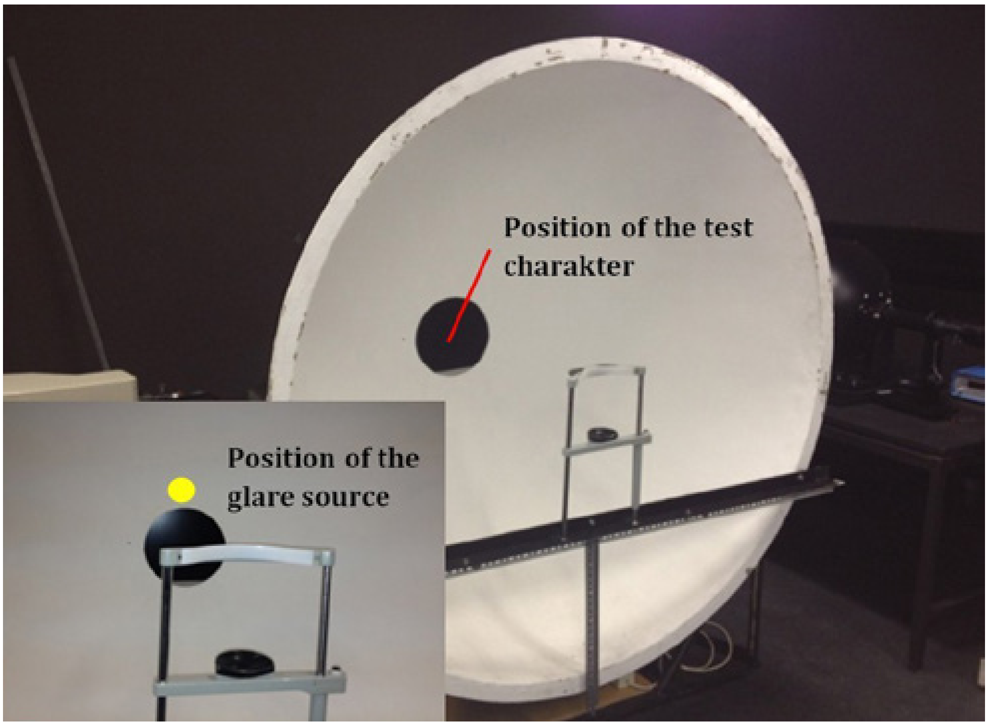

Figure 2 – View of the experimental set-up

Concepts in Lighting Quality
(Chair: Anna Pellegrino, Italy)

OP48

VISUAL QUALITY ASSESSMENT OF LED SPOTS IN COMPARISON TO LOW-VOLTAGE HALOGEN SPOTS

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CONTEXT.

This paper presents the experimental set-up and results of a 3 year long study carried out in the context of the French ADEME (France's environment and energy management agency) Pacte LED project (2009 – 2012).

This project was aimed at assessing whether LEDs could replace 20W and 35W low-voltage halogen lamps, offering similar quality of light.

It started by a photometric benchmark of a number of LED lamps against existing halogen lamps, to identify which characteristics a LED lamp should present to match as close as possible those of an halogen lamp. I was found that special attention should be paid to flux, beam angle, color temperature, and IRC. Moreover to ensure power savings, the LED lamps replacing the 20 W (resp. 35 W) halogen spot should use no more than 5.5 W (resp. 7W).

EXPERIMENTS AND RESULTS.

10,000 lamps with the identified characteristics were produced by the project consortium. The lamps were designed to operate with existing halogen transformers and wall dimmers and to fit in the existing luminaries without any technical adjustment being needed. Then, various tests were conducted to assess the visual quality of those LED lamps:

1. In laboratory;
2. In controlled environments: hotels;
3. In uncontrolled environments: hotels, restaurants, cafes and small shops.

1) TESTS IN LABORATORY

In the laboratory tests, psychovisual experiments were carried out. 80 observers were asked to express their preferences in terms of the lighting quality produced by light sources on different targets (painting, fruits and vegetables), in a paired-comparison protocol. The light sources used included various halogen lamps, various LED lamps, and the LED lamp specially designed during the project. Analyses were carried out using Thurstone law of comparative judgments, case V. On average, observers preferred the lighting produced by halogen lamps, but 74.1 % would be willing to replace halogen lamp by LED lamp. Observers that did not agree to perform this replacement felt that the lighting produced by the LED lamps was too dark and less natural with respect to the one produced by the halogen lamps.

2) TESTS IN CONTROLLED ENVIRONMENT

In the controlled tests, lamps were installed in three Accor hotels in Lyon, France. Hotel guests and staff were then walked through two similar settings (corridors/ hotel rooms/ bathrooms) one of which had halogens and the other had LEDs installed. They didn't know about the installations, but were interviewed in general terms about the light quality. In 66.4 % of the scenes compared in three Accor Hotels, guests and staff were equally pleased with the scenes lit by halogen and LED spots.

3) TESTS IN UNCONTROLLED ENVIRONMENT.

Out of the 10,000 produced LED lamps, 9300 were sent to hotels, restaurants, cafes and small shops throughout France, whose owners were asked to replace existing lamps with the LED lamps. They were given simple instructions to follow, and then asked to evaluate both the ease of installation and the quality of light. In some cases these people (known as ‘demonstrators’) also took the lights home for evaluation in a domestic environment. In terms of the ‘demonstrators’ who were replacing lamps, 89.4% found the light quality offered by the LEDs to be equivalent to or better than that of low-voltage halogen lamps, and 85.5% said that they would be willing to replace their existing halogen lamps with the LEDs.

DISCUSSION.

The results of the tests carried out indicate that end users do see a difference between the light produced by LED lamps and the light produced by halogen lamps (thus the photometric characteristics of the LED lamp do not match exactly those of halogen lamps: especially in terms of spectrum and optics, which is not dichroic for LED lamps), but that the majority of them would be happy with the lighting produced by LED lamp.

The results of these experiments suggest that a wide adoption of LED is foreseeable, and therefore a dissemination of their advantages: energy-efficiency, environmental benefits as shown by Life Cycle Analyses, and short return on investment period.

OP49

ASSESSING COLOR HARMONY IN A ROOM USING LED LIGHTINGS

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Objective:
The purposes of illumination are not only to satisfy the visual performance, but also to extend to mood creations or landscape designs in the way of spatial colored lighting. Color may well be the most important element in an interior space. Its total appearance is affected by the reflection of the surface and light. In addition, colored lighting given in their surroundings can affect users' aesthetic feeling and creates graceful lighting effect to alter the mind and spatial perception. Whenever and wherever color and light apply in an interior, we always strive to achieve color harmony in each room. To analyze the various effects of color related to interior environments, many studies address the psychological properties of color while some more considered about the effect that color has on spatial dimension. Most studies were performed in laboratories using small color patches. The present research is aimed primarily at establishing the nature of color harmony for color spatial light pairs on wall and their relations to colour harmony in paint or wallpaper.

Methods:
This study used high-power full-color RGB LED lamps, a set of digital driver and power supplier, a controller and a personal computer to generate a variety of colored illumination through a unique mixing mechanism of LED. The experiments were divided into two stages. The first stage performed the colorimetric characterization of full colored LED lamps and the characteristics of light source and luminance characteristics. The results were used to establish a platform to control the experimental conditions. At the second stage, a psychophysical experiment was conducted to report the scores of color harmony for 1800 pairs of colored light by five female and five male participants. The results were reported in a six category-point scale (1: extremely poor harmony; 2: remarkably poor harmony; 3: poor harmony; 4: good harmony; 5: remarkably good harmony; extremely good harmony). The test colors plotted in CIELAB color space are given in Figure 2 including the 18 ColorChecker colors ignoring the 6 neutral colors and 100 colors selected to uniformly cover the color space. In total, 1800 color combinations were assessed. Each pair of colored light was presented for a period of 5 seconds during the experiment. The results were used to analyze the impact of lightness difference, hue difference, chroma difference and color difference on color harmony.

Results:
The visual results in terms of the overall mean z-scores of color harmony for the 18 ColorChecker colors are shown in Figure 3. It can be seen that observers scored higher in red colors (CC09 and CC15). In contrast, they scored lower harmony in blue sky (CC03) and foliage color (CC04). The experimental results revealed a stronger color harmony perception as increasing the lightness difference of two colored lights (see Figure 4). In contrast, subjects perceived lower color harmony as larger difference in chroma between two colored lights (see Figure 5). In other

words, close chroma value of two colored lights (little chroma difference) frequently generated high color harmony. Regarding to hue difference of two colored lights, the results showed that two complementary hues were judged as disharmony as shown in Figure 6. This implies that a pair of colored lights with similar hue will highly likely to produce color harmony. Finally, Figure 7 clearly shows that color harmony will be impaired for larger color difference of a pair of colored light. All the effects found here are in good agreement with the color harmony models developed by Ou et al and Szabo et al using surface color patches.

Conclusions:
In this article, various effects on color harmony induced by pairs of colored lights were investigated. The visual results were also compared with those found earlier using surface colors. This implies that the some fundamental color harmony rules also apply to colored LED light.

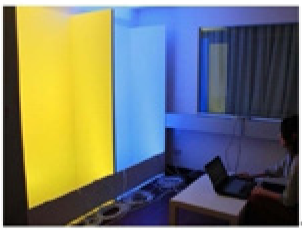
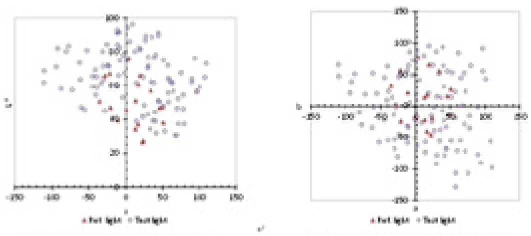


Figure 1 – Experimental setup picture



(a) a*-b* coordinates (b) L*-a* coordinates

Figure 2 – Chromatic coordinates of reference colors and test colors

Figure 1

Lr: Lightness of reference color	Cr: Chroma of reference color
hr: Hue of reference color	Lt: Lightness of test color
Ct: Chroma of test color	ht: Hue of test color
Σ=Lr+ Lt	ΔL= Lt - Lr
ΔC=| Ct - Cr |	ΔH= ht - hr
ΔE: Color difference	ΔLxΔL; ΔCxΔC; ΔHxΔH; ΔExΔE
Lr x Lt; Lr x Ct; Lr x ht	Cr x Lt; Cr x Ct; Cr x ht
hr x Lt; hr x Ct; hr x ht	

Table 1 – Initially selected variables

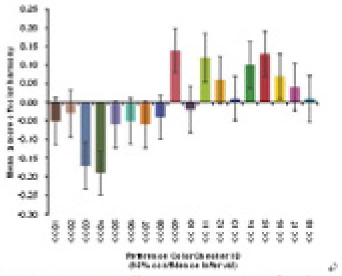


Figure 3 – Overall mean z-score of color harmony for 18 reference colors

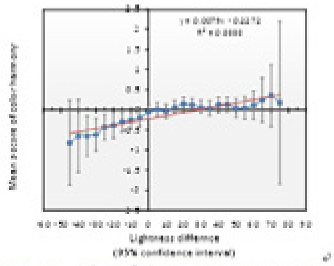


Figure 4 – Plot of the mean z-score as a function of lightness difference

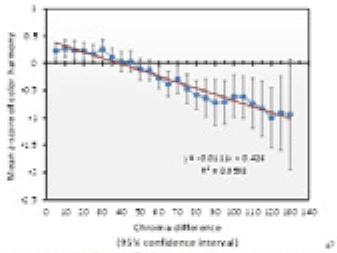


Figure 5 – Plot of the mean z-score as a function of chroma difference

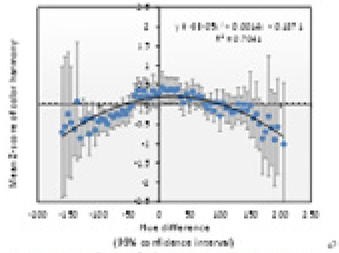


Figure 6 – Plot of the mean z-score as a function of hue difference

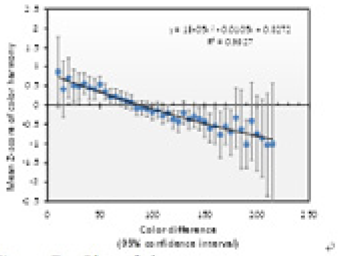


Figure 7 – Plot of the mean z-score as a function of color difference

Figure 2

OP50

EVALUATION OF INDOOR LIGHTING SITUATIONS IN PUBLIC ACCESS BUILDINGS AND OUTDOOR SITUATIONS AT NIGHT BY VISUALLY IMPAIRED PEOPLE

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[1.] Streetlab with Vision Institute, Paris, France.
[2.] CERTU , Lyon, France.

Visual impairment affects about 2 million people in France and in front of the increase of the ageing population, pathologies such as the age-related macular degeneration represent a real concern of public health and concern about 50 % of the world population. Even if devices or technical assistants facilitate the partially-sighted people in their daily life, the environment arrangement in terms of adapted light conditions is essential.

The accessibility of public places requires to consider all forms of deficiencies including visual impairment. National regulations of February 11th 2005 (law) and August 1st 2006 (performance in public spaces and housing) introduce some requirements dealing with lighting levels, glare and visual contrast. However, the knowledge upon which these requirements are based is rather weak.

Among some significant works realized on lighting conditions in real situation with visually impaired people, Certu led some experiments already presented at CIE conferences. When moving, it is necessary to localize the area, to orient towards the wished direction and to detect all kind of obstacles and facilities. The lighting level and uniformity, as well as the choice of light sources orientation and positioning to prevent from glare, are essential points to take into account during the lighting design. This dimension has also been underlined during the CIE workshop on elderly and visually impaired people in July 2011.

Facing the lack of numerous studies and in order to improve the regulations on accessibility, the Ministry of Ecology, Sustainable development and Energy (MEDDE), Certu, RATP (public transportation network of the City and the suburb of Paris) and Streetlab with the Vision Institute decided to launch a project. Its aim consists in assessing different lighting shemes, which would be tested by visually impaired people (and a few well seeing ones) in order to evaluate their performance to achieve some tasks like moving, reaching a specific place, detect a bus shelter...
At first, an indoor experiment was defined, with horizontal (corridors) and vertical (staircases) itineraries. Then, a second experiment was conducted in outdoor and night conditions in order to evaluate urban lighting in tasks of moving. In both studies, participants were tested on their abilities or difficulties to achieve the tasks (objective), and on their feeling and comfort (subjective) in the situations. The visual scenes were all characterized on a photometric aspect (lighting level, uniformity, contrast, glare...)

For each experiment, 40 participants were selected and four groups were identified: visually impaired people with a central vision loss (age-related macular degeneration, Stargardt disease); visually impaired people with a peripheral vision loss (retinitis pigmentosa); well-sighted but long-

sighted people in control group; well-sighted people without longsightedness in another control group. These inclusive criteria were validated and approved by an ophthalmologist. To complete and refine our results, a functional visual assessment was administered to all the participants. It included a vision field, visual acuity and contrast sensitivity examination.

Concerning the experimental conditions, participants had to evaluate seven indoor scenarios (hospital, Vision Institute and metro station) and six outdoor situations at night including the entrance of a subway station (light transitions). We made sure that the different situations were heterogeneous. During the tests, others objective and subjective data were collected. Objective data concerned at the same time experimenter observations in situ as well as quantitative measures. User feedbacks were collected using a questionnaire and allocating appreciation marks concerning the global situation, the lighting atmosphere, the light level, the discomfort when moving, the glare, the darkness, the shadows and the contrasts. For each of these variables, statistical treatments were performed.

The first results (indoor experiment is done, outdoor is still in progress) show that when a situation is preferred, there is no significant difference linked to the visual pathologies. Situations where the light levels were too dark and especially not uniform with transition from dark to very bright places and vice versa gave bad results. Homogeneity is thus essential for visually impaired people. Visual contrast is also a key parameter in order to help in orientation, to detect useful information (handles, steps) and obstacles. There is a trend to appreciate warmer ambiances (lower CCT), with indirect lighting and diffuse materials (avoiding glare), avoiding bright white color on the floor and the walls.

OP51

A STUDY ON THE APPEARANCE OF PAINTINGS IN THE MUSEUM UNDER VIOLET AND BLUE LED

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[2.] Tokosya, Shibuya-ku, Tokyo, Japan.

1.INTRODUCTION

LED lighting systems have recently started to be introduced on museum displays. The characteristics of LEDs, such as lower energy consumption, longer lifetime, smaller size can be great advantages for museum lightings. However, there is not enough practical information about the color rendering and long-term damage on artworks yet, especially for curatorial and technical staffs in museums. This study focuses on the appearance of paintings under LEDs and a new way of using them in museums. In this paper the results of our first and second experiments on the appearance under violet and blue LED compared with the appearance under a halogen lamp will be presented.

2.EXPERIMENTAL PROCEDURES

[Experiment 1]: Experiment1 was done in a mockup model. The floor, ceiling and walls of the space were painted with a matt neutral grey paint, reflectance 0.6. LED/halogen spotlights were attached to a lighting track, 1120mm away from the front wall. As to lighting conditions for LEDs, general color rendering index(Ra) levels were about 95, 90, 59, and correlated color temperature levels were 2700, 3000, 4000, 5000K. A halogen lamp was used as a standard condition and Ra was 100 and color temperature was 2700K only. The painting illuminance levels used were 50, 100, 200, 400 lux. Therefore there were 52 lighting conditions in all. Figure1 shows spectral power distributions of LEDs and halogen at 2700K and 200lux. Three oil painting copies were used for the subjective assessment. These copies were selected to cover a range of subjects, styles and various colors. The paintings were as follows: PaintingA-Portrait of an old master(16thC), PaintingB-Landscape of an impressionist(19thC), Painting C-Abstract(20thC).

The subjects, 10 for each condition, were architectural students aged around 20. All subjects were checked for color vision deficiencies using the Ishihara test.

Subjects were asked to make a visual appraisal of each of the paintings as a whole and some specified details in each paintings, such as lips, skin, sky, red flowers, green plants, brown earth, white cloth and so on. For the assessments of the painting as a whole, eight scales were used, chosen to cover pleasantness and discrimination of detail in the painting. For the assessment of the details, 3 to 5 scales were used. There were nine steps in each assessment scale. „Moistureness“ was an important scale in this experiment because in our pilot study some museum lighting professionals pointed out that the paintings under LEDs seemed to appear a bit drier than the appearance under halogen lamps.

[Experiment 2]: The experiment of the appearance of real pictures in a museum is now underway.

3.RESULTS AND DISCUSSION

[Experiment1]Two major factors were derived from the factor analysis of the assessments of the paintings as a whole. Factor 1 includes pleasantness, colorfulness, detail discrimination, adequacy of the light level, exhilaration, contrastyness, and factor 2 includes moistureness and warmness.

The outputs of logistic regression analyses at 2700K show the relationship between pleasantness of the paintings and their illuminances, and it also show the painting illuminance at which more than half of the subjects take the appearance of the paintings pleasant. There is a tendency that the lower the Ra is, the higher the necessary painting illuminance is to produce pleasant feelings. There is little difference between Ra95 (near ultraviolet-LED at 2700K) and Ra100 (halogen at 2700K) at this painting illuminance value but Ra100 generally get a bit higher appraisal throughout the experiment than LEDs. When the details of the paintings were considered, the relationship between moistureness of the red lips(x:0.41, y:0.38) and Ra, shown in Fig.2, shows an increase in moistureness as the Ra becomes higher, however there is statistically no difference between Ra95 and Ra100. When the paintings were assessed as a whole, there is a increase in moistureness of the paintings in 2700 and 3000K as the Ra becomes higher, but in 4000 and 5000K there is little difference in moistureness among Ra.

4.FUTURE PLAN

An sequent experiment with CIE CRI Test Color Samples under the same LEDs has been already conducted. We will also present the results of the experiment in the museum using real pictures on CIE-france 2012/04.

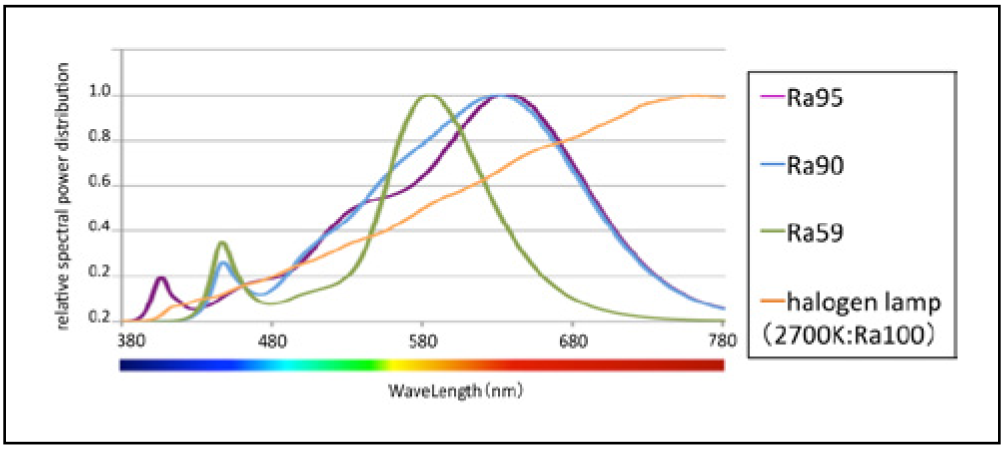

Figure 1 – Spectral power distributions of LEDs and halogen at 2700K / 200lx

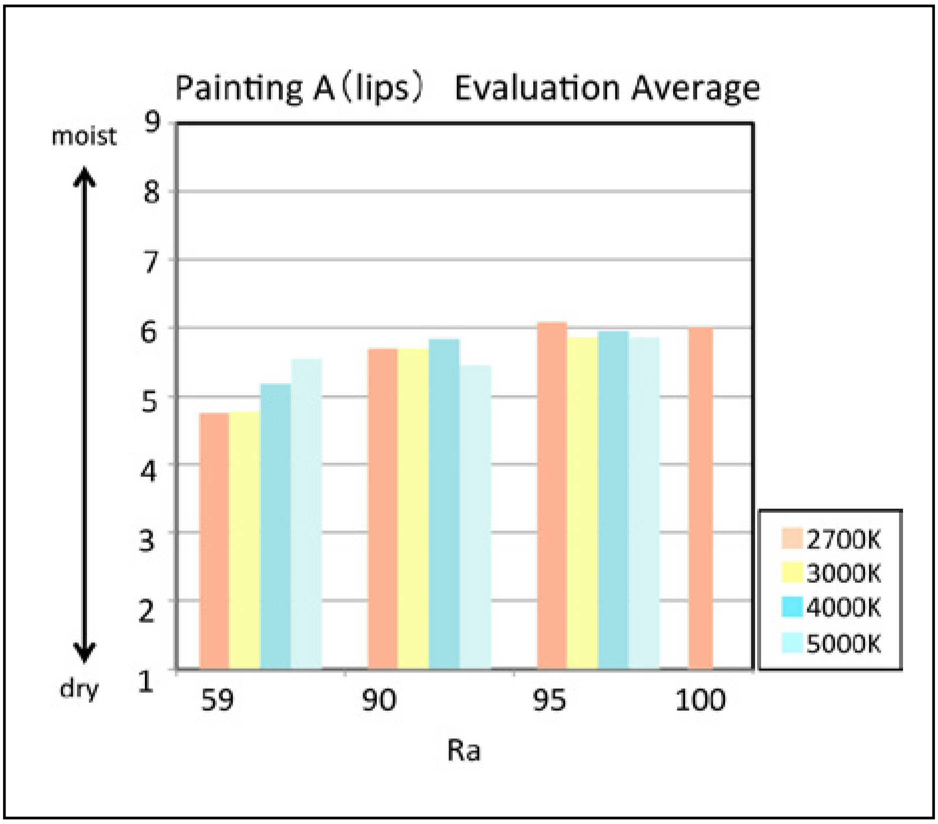

Figure 2 – Moistureness and Ra : red lips

Brightness and Colour, Individual or Shared Percepts

(Chair: Miyoshi Ayama, Japan)

OP52

COLORIMETRIC OBSERVER CATEGORIES AND THEIR APPLICATIONS IN COLOR AND VISION SCIENCES

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The most fundamental aspect of applied colorimetry is the trichromacy of our visual system, resulting from three different cone types in the retina. Trichromacy leads to observer metamerism, in which two stimuli with very different spectral power distribution can produce a color match for a given observer, but will result in a mismatch for another observer with different color vision characteristics (different color matching functions). This variability among observers with normal color vision is not typically taken into account in colorimetry, as it is assumed that a single average observer model can reasonably represent the whole population of color-normal human observers. This model is represented either by the CIE 1931 Standard Colorimetric Observer for small fields (1° - 4°), or by the CIE 1964 Supplementary Standard Colorimetric Observer for larger fields. This approximation has worked reasonably well over the past decades in a large majority of industrial color applications. However, large discrepancies in individual observer color-matches have occasionally been noticed in some of the more recent digital image applications, in particular those involving wide-gamut displays with peaky primaries, and applications involving Light-Emitting Diode (LED) or Laser based light sources. These discrepancies become most evident when two color-reproducing systems with very different spectral characteristics are used for color-matching. As a practical means of accounting for this observer variability, the concept of colorimetric observer categories has been introduced in a recently concluded doctoral thesis research. Each such category represents a unique colorimetric observer model. In this work, eight such categories were derived through statistical analysis of existing experimental and physiological datasets of color-matching functions. An experimental method was developed in order to classify a color-normal human observer as belonging to one of these categories. This observer classification method was first implemented using two displays. It was shown that human observers with normal color vision could be classified into one of these categories based on their color vision. Subsequently, a compact and inexpensive proof-of-concept prototype, described as the Observer Calibrator in this paper, was developed.

While this paper starts with an overview of the derivation of observer categories and the observer classification method, its the main objective is to explore potential benefits of applying the concept of observer categories in various scientific studies and industrial applications of color and vision sciences. Toward this goal, various aspects of practical implementation of an observer dependent color imaging (ODCI) workflow, proposed in the thesis work, will be discussed in detail. This workflow makes it possible to reproduce colors and digital images on an output device according to an observer's category, thus achieving personalized color reproduction. Such capability can potentially be very useful in certain professional applications like color correction (color grading) in cinema post-production, soft- proofing on modern displays, and possibly, in color quality assurance software applications.

Observer classification can also prove to be very useful in scientific studies that include visual experiments involving color stimuli. Such classification may demonstrate important trends in the visual data that have not been revealed or explored so far. For example, it might be possible to better explain outliers in observer data in a psychophysical experiment. With regard to color science, there are many unanswered questions that need to be explored. For example, what are the effects of applying observer categories on suprathreshold color difference judgment data? Can the application of observer categories have an influence on the perceptual uniformity of a color space? Preliminary results obtained during the thesis research encourage us to explore these aspects in more detail.

It must be emphasized that there is no unique way to derive observer categories. It is expected that future research on the topic would yield more optimized categories. Further, whether or not multiple observer models could yield significant benefit in specific industrial applications requires further research. However, it is beyond doubt the concept of observer classification opens up new possibilities and raises interesting questions in the domains of color and vision sciences. Keeping with the spirit of CIE centenary conference, this paper is principally exploratory in nature, aiming to start a thought-provoking dialog in the scientific community on the topics of observer metamerism and colorimetry.

OP53

INDIVIDUAL CHANGES OF BRIGHTNESS PERCEPTION

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In two earlier papers[1,2] the brightness luminance relationship of near white lights, composed of different blue spectra, but of the same green and red spectra, was investigated. It could be shown that colour normal observers can be grouped into three classes, some observers found lights of equal luminance, but different spectral distribution as equally bright, but others found lights with shorter wavelength blue light as brighter, while a third group found the lights with longer wavelength blue component as brighter. Houser reported at the CIE Session in Sun City about the visual optimization of trichromatic light sources by selecting different red components[3].

Above recent results and the findings of Sarkar on different observer types[4], where he has found major differences in the L and M cone fundamentals, moved us to investigate also the possible observed brightness differences if dissimilar red LEDs are used to produce the metameric white lights. An observation booth has been constructed where six different types of LEDs were mounted behind an opal diffuser. The six strings of LEDs could be independently energized from a multi-channel stabilized computer controlled current supply. The six LED types had peak wavelength at 418 nm, 465 nm, 510 nm, 635 nm and 666 nm, respectively. Four metameric white lights have been constructed using these LEDs, with spectral power distributions as shown in Figure 1. The light of the LED strings illuminated at the bottom of the inside black cabinet a white, non-fluorescent paper. With the above settings the reflected light from the white paper produced a luminance in the observers eye of 37,5 cd.m-2.sr-1 ±1,5 cd.m-2.sr-1, of 6527 K ±68 K. All chromaticities were below the Planckian with an average D(u,v)=-0,0044±0,0033. The colour rendering of these lights is very low, for those using the blue LED with the 418 nm peak wavelength it is comparable to a high pressure sodium lamp (but with high CCT white light), the lack of shorter wavelength blue light in the other two sources drives the Ra into negative. Just to avoid any influence of bad colour rendering there are only white and black surfaces in the visual filed of the observer. (Never the less some observers complained to see some discolorations.)

In the middle of the white paper a small mirror was placed that reflected the light of an RGB-LED, which was placed behind a diffuser. This served as the reference light. The luminance and chromaticity of the RGB-LED could be computer controlled and the task of the observer was to match it with the reflected luminance from the white paper (the arrangement was similar as discussed in2). Compared to the previous experiment a main difference was that a continuous spectrometric supervision of the test and reference lights was installed.

Compared to earlier experiments a higher correlated colour temperature was selected, hoping to get better insight into the differences the blue lights could provide, as their relative magnitude was

higher as with the older experiments. Also by using the blue and cyan light of the 465 nm and 510 nm LEDs provided good discrimination between the cone absorption and the possible influence of the rods and of the ipRGCs.
The selection of the two red LEDs should provide possibility to understand whether observers can be categorized as proposed by Sarkar4.
At the time of submitting the Abstract the experiments are still in progress, but one can already see that regarding the influence of the different blue spectral parts the previous results can be confirmed. The picture regarding the influence of the different red components is still not clear enough to draw definite conclusions. These should be presented at the Paris meeting of the CIE.

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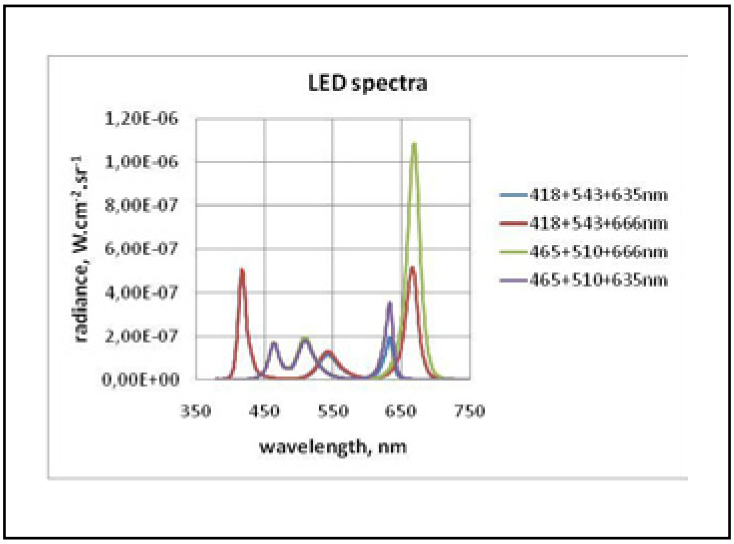

Figure 1

OP54

A PROPOSAL OF PREDICTIVE EQUATION FOR "SPATIAL BRIGHTNESS" CONSIDERING THE EFFECT OF LOOKING AROUND AND ITS APPLICATION TO REAL PROJECT

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In conducting a lighting plan, it is important to grasp how brightness is perceived, which can't simply be measured by photometric quantities like illuminance and luminance; an indicator expressing "Spatial Brightness" is necessary. This research proposes a predictive equation for "Spatial Brightness" which can be measured precisely and easily when planning lighting, and attempts to apply to real project.
The first step is to conduct a fundamental research for "Brightness", when given a free view within a fixed visual target field, and to find its influential factors.

This research considers the effect of adaptation luminance and contrast, as previous studies pointed out as effective factors in senses of brightness. When looking around, view point moves freely, which allows shorter gaze time than time needed for adaptation. We assume that adaptation luminance is equal to average luminance of the whole visual field. For convenience to handle statistical quantities, arithmetic mean of luminance is used as average luminance. Although contrast is expected to reduce "Brightness", in case of luminance distribution of a visual field, luminance variation is more appropriate than simply using contrast.
In order to consider relationship between average luminance of visual field and "Brightness", Experiment 1 evaluated "Brightness" under consistent luminance. Results of this experiment and previous studies showed similarity. Despite minor differences in conditions, "Brightness" when given a free view within a fixed visual target field, can be explained within 0.3rd power of adaptation luminance (=average luminance), which was also used to explain senses of brightness in previous studies. In order to increase practicality, this research adopts 1⁄3rd power of average luminance for its high correlation in a rounded number. Thus, average luminance L and "Brightness" B are expressed as below. B = 21.5×L^1⁄3 (Correlation ratio:0.99) eq.1
(When L=100, B=100)
Experiment 2 was conducted to verify physical quantity expressing luminance variation and to consider its effect on "Brightness. Images with various luminance variations were shown to subjects to evaluate "Brightness". Table 1 shows physical quantities assumed to express luminance variation, and its correlation with luminance variation was observed. Results showed that luminance variation can be expressed by standard deviation of luminance logarithm C of a target visual field.

After correction of C in eq. 1, following equation was found best suited by its high correlation between evaluation and predictive value of "Brightness" given in Experiment 2 (figure 1).
B=(21.5-8.4 × C)×L^1⁄3(Correlation ratio: 0.89) eq. 2
The proposed predictive equation enables to predict "Brightness" in a restricted visual field, which is based on the results of previous studies that considers senses of brightness of a certain visual

target within a visual field. Based on this idea, there is a potential to elaborate into a predictive equation of “Spatial Brightness”. Although further examination on visual field range and resolution to measure luminance distribution are yet to be done, simple use of measured luminance distribution enables the predictive equation to be highly universal.

As for the second step, Experiment 3, conducted in a lighting renovation project of a car dealer, aimed to verify both improvement of lighting environment and reduction of energy use while “Brightness” is maintained. The Great East Japan Earthquake on March 11th 2011 prompted concerns over lack of energy. In such circumstances, an opportunity arose to propose lighting renovation plan. Studies were conducted comparing investigation results before and after renovation.
Following aspects were investigated before and after; luminance distribution, horizontal and vertical illluminance, and reflection rate of materials. In addition, lighting environment evaluation was conducted through five-scale rating method for fifteen items of psychological evaluation, including “Brightness” from both inside and outside the building.

In order to meet the goal, six renovation principles were proposed; 1) use LED, 2) effective usage of light by increasing wall reflectance, 3) effective use of daylight, 4) redesigning of lighting environment accordingly to each function, 5) consider both horizontal and vertical illuminance, 6) consider evaluation from both inside and outside the building.
Results show that “Brightness” and rating scale value of “Brightness” in each space inside the building and its predictive values improved in both day and night. Statistically significant difference was shown at night. Additionally, issues seen before renovation, such as “how inside displayed cars look”, and “whether the shop looks open”, improved.
On the other hand, energy use before and after the renovation (figure 2) decreased by 36% under full use, and ↓50% at day and ↓40% at night under standard use. Usage of LED enables high efficiency, but decreasing planned luminous flux verifies validity of this method using “Brightness”.

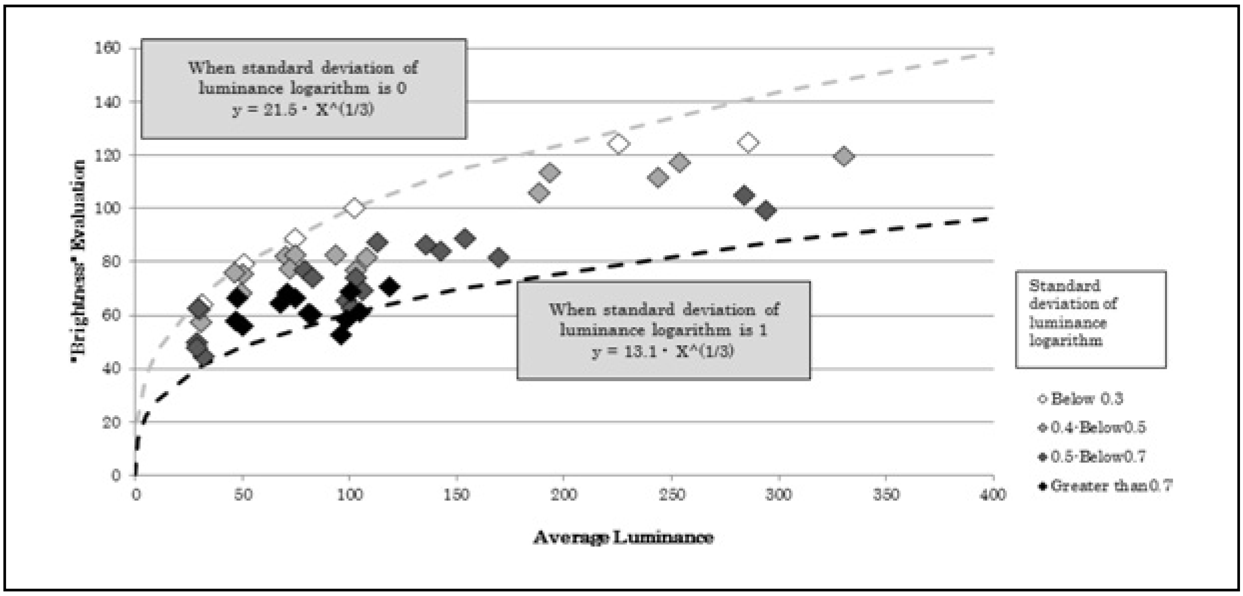

Figure 1 - Average Luminance

Figure 2 - Above: before. Below: after

	Standard Deviation	Var. Coeffi-cient	Luminance Ratio	Luminance Contrast	ΔLuminosity
Luminance values	0.261	0.865	0.314	0.356	0.224
Luminance log.	0.941	0.891	0.153	0.090	0.343

*Var. Coefficient: Std÷Avg *Luminance Ratio: Max÷Min *Luminance Contrast: (Max − Min)÷(Max+ Min) *Δ Luminosity: Max − Min

		Energy Use(W)	Luminance Flux (1000lm) (Maintenance factor 0.8)	Lighting Env. Evaluation			
				From outside	Inside	General	
Before Renovation	Full Use	6300	265				Assumption from equipment used
	Standard Use	5900	252	Subject to comparison with cases below			
After Renovation	Full Use	3800 (↓ 36%)	224				
	Standard Use (day)	2900 (↓50%)	171	+++		++	Usual Use
	Standard Use (night)	3600 (↓40%)	213	++	+++	+++	

(+++: Items ≥80% have statistically significant difference, ++: Items ≥60%, +: Items ≥40%) *( ): Reduction rate

Table 1 – Correlation coefficient between evaluated values of luminance var. and physical quantity of luminance values

Lighting the City - Spaces

(Chair: Dionyz Gasparovsky, Slovakia)

OP55

INTEGRATION OF RHYTHMIC URBAN LIGHTING INTO ARCHITECTURAL CONCEPTS

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Rhythmic phenomena of urban lighting
On one hand, urban lighting expresses itself in a complex visual environment made by the interplay between many separate lighting schemes, as street lighting, shop lighting, traffic lighting, luminous commercials, light from buildings etc. and on the other, a noticable order of patterns appear when urban lighting is observed as luminous formation and rhythm. Without intention, it is like streams of car lights gliding through the streets at night and formation of blinking caution lights for plains on the top of a group of high rise buildings show fragments of topographical layout in the urban landscape. Already in the beginning of the 1920'ies a fascination of urban lighting was expressed by Erich Mendelsohn in the photographical report "AMERIKA. Bilderbuch eines Architekten" and he put the power of urban lighting in words like this: "During the day the city gets loaded with energy, in the night it spreads everything alive. With the criss-cross of car lights, with the luminous shout from business commercials, with the vertical light from high-rise buildings. A light circus, and very seldom, like here, in the rhythm of architecture" [1]

What Mendelssohn means about "rhythm of architecture", the paper behind this abstract is not going more deep into than to presume, that Mendelsohn means the same kind of rhythm in architecture that Steen Eiler Rasmussen write about, when explaining how a building or a façade is experienced as a rhythmic composition. [2] Going down the line of Mendelssohn's words, he experience the change between day and night and different types of electrical light sources as luminous structures and sequences – but also as something none-architectural and chaotic made of natural forces based on both nature and man-made artefacts. Is it possible, though, to integrate the rhythmic patterns of urban lighting into architecture and make them into an aesthetic contribution to the experience of urban environment? And what qualities does such an aesthetic provide?

Examples found:
In Hoxton Square Bar and Kitchen in the Shoreditch area of London, the lights from car head lights sweep through the premises of the bar. There are many bars for people to meet after work in this area, in which this bar distinguish itself by the noticeable rhythmic sequence of pauses and strokes made by the light of the approaching cars. The creation of this concept is made by the frequency of cars coming towards the bar, access for the light to enter by a large window in the rear end of the premises and the situation of a one-way street, which turns right in front of the window. Also the electrical light of the bar is dimmed, so that the light from the cars is a noticeable force, which strikes the bodies of people being in the bar.
Westfriedhof U-bahnstation in München is out of 100 stations in the München underground system. The system has been extended gradually since 1971 containing many different station designs. Westfriedhof U-bahnstation is characterized by 11 huge lampshades coloured on the inside going from blue in one end of the platform, to red in the middle and yellow in the other end of the

platform. Next to the fixed light-zones [3], made by the light coming from the lampshades, the rhythm of shifting daylight-zones entering from above appears clearly in the 'blue' end. Also, the directed light from the lampshades emphasize people movement and the lights from trains and flipping information signs, which is situated outside the light, directed from the lampshades.

The aesthetic of rhythmic integration

The examples above show that it is possible to integrate and mix 'natural' rhythmic phenomena into urban spaces by simple ecological construction of visual perception. By relating to a certain physical lay-out and balancing between perceived intensities it is possible to make rhythmic lighting phenomena appear visible in a certain context. Such ecological balances are well-known within architectural lighting, but what is nonetheless important are the choices made of what to make visible and how. In the cases of Hoxton Square Bar and Kitchen and Westfriedhof U-bahnstation the visibility of luminous rhythmic phenomena contribute to the identity of these urban places, based on the activity of rhythms functioning in a certain place – rhythm thus contribute to both place-telling, time-telling and function-telling aspects.

The French philosophers Gilles Deleuze and Felix Guattari compare the construction of a structure expressed by rhythm with music, art and also animal-made territories. [4] The territory is a time-space based concept (like the bird with its certain pattern of rhythmic singing and moving around in order to maintain its territory) and such concepts create noticeable 'notes' in contexts of complexity, which in the case of urban environment could be interpreted as many visible scales, agendas, things, messages etc. in function at the same time. As the lighting of urban environment make even more now than in Mendelsohn's time, a 'light circus', there is aesthetic potential in regarding the rhythm of urban lighting phenomena as potential actors in architectural concepts. It is a way to connect the powers of urban environment to the people in it, and give them the possibility to discover different powers at work as a place- and time establishing mechanism. The light circus is there - why not make use of it?

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Figure 1

Figure 2

OP56

REINVENTING URBAN SPACES THROUGH LIGHT AND COLOUR: CACILHAS PROJECT

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A challenge for contemporary cities is the implementation of urban policies that are able to reinvent city spaces which are degraded. According to this, it is common the implementation of requalification projects that seek for building a new identity for these spaces with the purpose of developing and promoting tourism and activities related to leisure, culture and knowledge. Those are global models of requalification that associate traditional elements to the present. In this context, elements that have an aesthetic or symbolic component –material or immaterial –-are the most susceptible for a restructuration that adjusts the tradition to modernity. Based on the observation and analysis of an intervention project in the city of Almada in Portugal, we developed a reflection on the idea of how the intervention projects are considering the light and colour in the construction of the new identity of urban spaces. We consider that this issue is fundamental to the reinvention process of the cities because both – light and colour – has a poetic presence but also structure, dynamize and configure places. These elements consider the relation of individuals to space and time and achieve philosophical, religious, social, psychological dimensions, among others, as well as reveal, question and redefine the affinity of individuals with space. The contextualization and use of these elements can transform the city in a scenario that renews and innovates continuously through aspects that shape sensitive places. Nevertheless, in our understanding some intervention projects are disregarding these elements in different scales of perception of the urban space (general, punctual and detail) that can generate spatiality whose environment is less pleasant and responsive to individuals. Regardless of the technological advances and the complexity of some intervention projects the conceptualization of light and color has developed very slowly. From the analysis of the Plan of Rehabilitation of Rua Cândido dos Reis, in the parish of Cacilhas in Almada, and aware of the idea that many values of the urban man remain anchored in ancient archetypes related to light and colour - that are determinant in achieving spaces and in the experience of human beings – we propose a study of colour and light in this requalified area which includes, in particular, the permanent colours (local materials), non-permanent colours (climate, vegetation), light and shadow, textures, aging and renewal of materials. In addition, the main purpose of our communication is to present the study and reflect on the conception that intervention urban projects need to overcome merely the material of objects constructed to project on the constructed shapes and spaces, aesthetic emotional and symbolic values.

Keywords: City. Identity. Light. Colour. Spaciality.

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OP57

IMPRESSION OF LIGHT AND FEELING OF SECURITY IN THE CITY - EXPERIMENTING MESOPIC VISION

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[2.] Sibelga, Brussels, Belgium.

In cities, the widespread use of white lights is giving rise to questions... Is the increased visual effectiveness thought to result from the mesopic model real and does it offset the higher operating costs? Moreover, is it really conceivable for pedestrians to reduce the luminous flux of the lighting during the quiet hours of the night? Finally, is white light really accepted by local residents accustomed for years to an environment lit by high-pressure sodium lamps?

To answer these three questions, Sibelga and Laborelec created an actual test site in the commune of Ixelles, in Brussels.
This lies in a small working-class district dating from the early 19th century and comprises a central street and four perpendicular streets, all with the same morphological and town-planning characteristics.
All these streets were fitted with the same lighting system, mounted on the same lampposts and with a similar layout. The central street was fitted with high-pressure sodium lamps while the four other roads had white light sources (either 3000 K or 5700 K LEDs or 2700 K and 2800 K ceramic burner lamps).

All the lights in the five streets in question were remote controlled using radio frequency and could be adjusted to provide variable levels of illumination.
Over 120 people took part in six test evenings with a threefold objective:
- To determine the compared effectiveness of the white- and yellow-coloured lights in terms of the feeling of security and visual impression;
- To determine the admissible dimming levels from the point of view of pedestrians;
- To determine participants' preferences depending on the colour of the light sources.

One of the main conclusions is that the lighting levels can be lowered between 20 and 40% by using white light (Metal halide or LEDs luminaries) instead of the High Pressure Sodium technology. In term of luminosity, people have shown a preference for cold white light (>4000K). Nevertheless, this kind of light is judged less pleasant by more than 80% of the interrogated people.

The results are interesting in that they show real convergence as the test evenings progressed, despite the apparently random levels that participants experienced. Whether the participants were young or old, male or female, lighting professionals or not, lived in the district or not, the results are comparable. Ultimately, they constitute an important element in extending the debate to cover the relevance of white light in urban environments and the anticipated cost efficiency of dimming systems in cities.

Figure 1

Figure 2

Well-being, Glare and Comfort
(Chair: Alessandro Rizzi, Italy)

OP58

RELATIONS BETWEEN FLICKER, GLARE, AND PERCEPTUAL RATINGS OF LED BILLBOARDS UNDER VARIOUS CONDITIONS

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Objective

Since the rapid growth of application technologies of LED, the controllable lightings or billboards made by LED are more and more popular. Many of these products are pushed to much higher contrast in spatial and/or temporal configurations to attract attentions. However, these manners may produce uncomfortable visual experience for the glare and/or flicker of the LED sources. To investigate these two features of the new lightings or displays, we have systematically performed the imaging luminance, temporal illuminance, and ergonomic experiments on commercial LED billboard lights. Corresponding parameters were calculated from the experiments and studied to find the relations between them.

Methods

A commercial LED billboard was placed in a laboratory for testing the variations of flicker and glare with the lighting property of the billboard. The experiments were performed by displaying a flashing square pattern on the LED billboard. The length of the square was set as 20, 28, 40 or 56 pixels, the digital level was set as 63, 128, 192 or 255, and the flashing frequency was set as 0, 2, 5, 10, 20 or 30 Hz. An illuminance detector with a preamplifier was used to measure the temporal iluminance in front of the billboard. The measured waveforms were processed with a digital low- pass filter, and then the low-pass flicker indexes (LPFI) were calculated. A calibrated DSLR was used as the imaging luminance measurement device (ILMD) to measure the imaging luminance. It was placed at same position of the detector and with same lighting conditions of the former experiments. The CIE-117 unified glare rating (UGR) was calculated from the measured imaging luminance.

Another commercial LED billboard was placed in another laboratory for testing the relations between the flicker, glare, and perceptual ratings under various lighting conditions. The area of the displayed square was set as 25, 50, or 100% of full screen, the average luminance was set as 500, 1000, 2500, or 5000 cd/m^2, and the flashing frequency was set as 0, 3, 6, 9, or 12 Hz. The instruments and procedures for the temporal illuminance and imaging luminance measurements are same as the previous paragraph. Ergonomics experiments on thirteen subjects (ten youths and three elders) were performed to investigate the perceptual ratings of the light properties of the laboratory. The de Boer rating scales of „comfort“ and „flicker“ were examined by the subjects.

Results

The measured temporal illuminance has parasitic components of 240 Hz (from PWM of billboard), 40 Hz (from refreshing rate of billboard), and background illumainnce of about 1.50 lx. After low-pass processed with a vision-like filter, the components above 30 Hz are mostly removed. Then the low-Pass flicker index as a function of average illuminance (Eavg) and flashing frequency (f) is calculated and shown in Fig. 1(a). It can be observed that the LPFI is increased with average illuminance and decreased with frequency except 0 Hz. This feature is fitted with vision experience on flicker, which is progressively significant as contrast of illuminance increased, and dropped as frequency lager than 20 Hz. The shutter speed of the ILMD was set as 0.4“ ~1“ in order to have stable image of the flashing pattern. UGR of the measured luminance images were automatically calculated by our processing software. Fig. 1(b) shows the measured UGR as a function of flashing frequency, average luminance of source (Ls), area of source (A), and background luminance (Lb). It can be observed that UGR is nearly independent on frequency and is a spatial contrast sensitive parameter.

The overall comfort ratings by the subjects were summarized and compared with the measured LPFI and UGR. As shown in Fig. 2(a), after separately linear regressions with log(LPFI) and UGR, the calculated comfort rating is not well fitted with the experiments. The Pearson‘s correlations are 0.64 and 0.47 for fittings with log(LPFI) and UGR, respectively. However, as shown in Fig. 2(b), by linear regression with both log(LPFI) and UGR, the calculated comfort rating is much more fitted with the experiments with Pearson‘s correlation of 0.89. The comfort rating can be written as 7.00 - 0.213*UGR – 2.09*log(LPFI).
This result indicates that the comfort perception on the flashing LED billboard is a combination of flicker and glare, which can be measures and calculated by the novel developed methods. The perceptual flicker rating can written as 5.11 - 0.138*UGR – 2.44*log(LPFI) with Pearson‘s correlation of 0.87. Although the factor corresponding to UGR is smaller than that of comfort rating, the perceptual flicker rating is still influenced by glare.

Conclusions
In summary, we have performed both objective and subjective evaluations on the flashing LED billboards placed in interior spaces. The objective flicker and glare evaluations were carried out by temporal and spatial measurements, respectively. The properties of obtained flicker and glare indexes are matched with physical phenomena. The subjective evaluation results can be expressed by simple equations with objective parameters LPFI and UGR. It is expected that the equations may be improved by much more experiments, and may be used as new evaluation indexes for the flashing LED lighted environments.

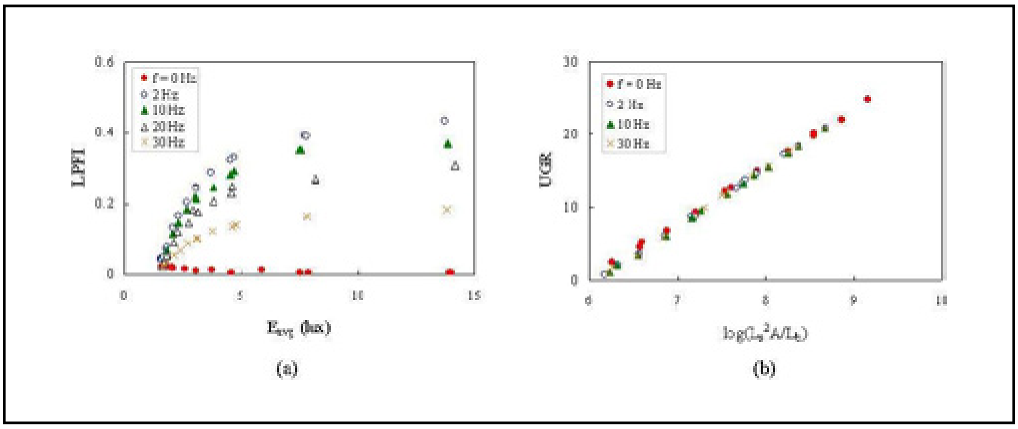

Figure 1 – (a) LPFI as a function of average iluminance and frequency. (b) UGR as a function of source luminance, area of source, background luminance and frequency.

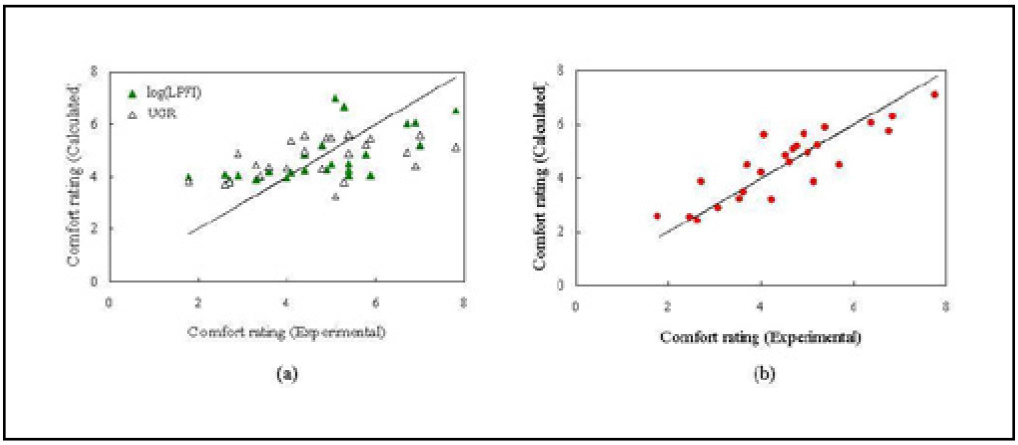

Figure 2 – (a) Comfort ratings calculated from separately linear regressions with log(LPFI) and UGR versus those from experiments. (b) Comfort ratings calculated from linear regressions with both log(LPFI) and UGR versus those from experiments.

OP59

FLICKER AND VISUAL COMFORT EVALUATIONS OF LED PANEL DISPLAY

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This study investigated the discomfort glare produced by the high brightness LED panel and aimed to reduce discomfort feelings by modulating four important factors: flicker frequency, luminance, panel area size and ambient illuminance. Twenty-five conditions were chosen by the orthogonal design. The results show that visual comfort is not affected by ambient illuminance but by flicker frequency, luminance, and area. We concluded that the range of flicker frequency around 8 Hz to 16 Hz is not suitable for LED panel display and the lower luminance the better. There are some evidences pointing out that these four factors have interactions with each other. The interaction must be considered in the future research.

INTRODUCTION

Traditional panels are substituted by high brightness LED panels progressively. However, LED panels not only have high brightness and high directivity but also flash when displaying advertisements. These conditions have led to concerns about glare and light pollution. This study attempts to find the appropriate flicker frequency, luminance, area and ambient illuminance to avoid visual discomfort. The experimental design and the results are presented herein.

METHOD

A LED panel with size of 1.6*1.28 m^2 and with correlated color temperature (CCT) of 6500K was used. Ambient illuminance was provided by fluorescent lamps with CCT of 6500K behind the panel. Figure 1 shows the experimental setup. Observers stared at the center of the panel 5 meters away with their eyes at 1.3 meters height. There are four independent variables with 2 to 5 levels, including flicker frequency (0 Hz, 8 Hz, 16 Hz, 24 Hz, 32 Hz), luminance (505 cd/m^2, 1006 cd/m^2, 2512 cd/m^2, 5063 cd/m^2), area (2.05 m^2, 1.02 m^2, 0.51 m^2) and ambient illuminance (5 lx, 25 lx). Orthogonal design was utilized to select 25 key conditions from totally 120 conditions [1]. The with-in subject design was adopted to avoid inter-subject variations. Each subject experienced the 25 conditions in a random order. 12 subjects (6 males and 6 females) participated in the experiment. 6 subjects are less than 40 years old, and their age averaged 22.34 with a standard deviation (STD) of 3.88. The other 6 subjects are over 40 years old, with an average age of 43.5 and a STD of 2.66. All subjects have normal or rectified vision, with no cataract and familial epilepsy. Under each condition, the participants stared at the LED panel for 30 seconds and filled out the questionnaire at the end of each trial. The experimental data was analyzed in statistical software SPSS.

Questionnaire

There are two questions in the questionnaire, one for flicker comfort rating and the other for glare comfort rating.
De Bore rating scale is used to evaluate visual comfort. It is a 9-point scale with qualifiers at the

odd points: 1 = unbearable, 3 = disturbing, 5 = just permissible, 7 = satisfactory and 9 = just noticeable.

Experimental procedure

1. Fill out the personal information form. It helps the experimenter to screen subjects. View the illustration film (5 min).
   The film gives the details of the experiment and ensures that every subject receives the same instructions.
2. Put the electromyography electrode under the eye and calibrate the signal (2 min). Subject is then asked to close their eyes for adaption (3 min).
3. After adaption, the subject is instructed to stare at the LED panel (30 sec).
4. After the observation, the subject fills out the questionnaire.
5. The subject closes the eyes and rest (1 min).
6. Back to step 3 and experience all conditions.

RESULTS

Table 1 shows the significance analysis of the experiment and posteriori comparisons on the variables that passed the significance test. The greater sign ">" implies a more comfortable situation. The results show that flicker comfort and glare comfort are not significantly influenced by the ambient illuminance but by the flicker frequency, luminance and area. Figure 2 provides the posteriori comparison of flicker frequency versus glare comfort. It is evident that 8 Hz and 16 Hz are more discomfort to subjects. In addition, Pearson correlation coefficient of flicker comfort rating and glare comfort rating is found as large as 0.729, that is to say there is high consistency between them. We also found that females are more critical on comfort rating than males.

CONCLUSION

Flicker frequency, luminance, and panel size are key factors that affect the visual comfort of outdoor LED panel display. Based on the results of the present study, the suggested frequency range is between 0 Hz to 7 Hz or more than 17 Hz. The luminance range of LED panel from 500 cd/m^2 to 1000 cd/m^2 is a better choice for both the flicker and glare comfort concern. Studies of interactions between flicker frequency, luminance and area are in progress.

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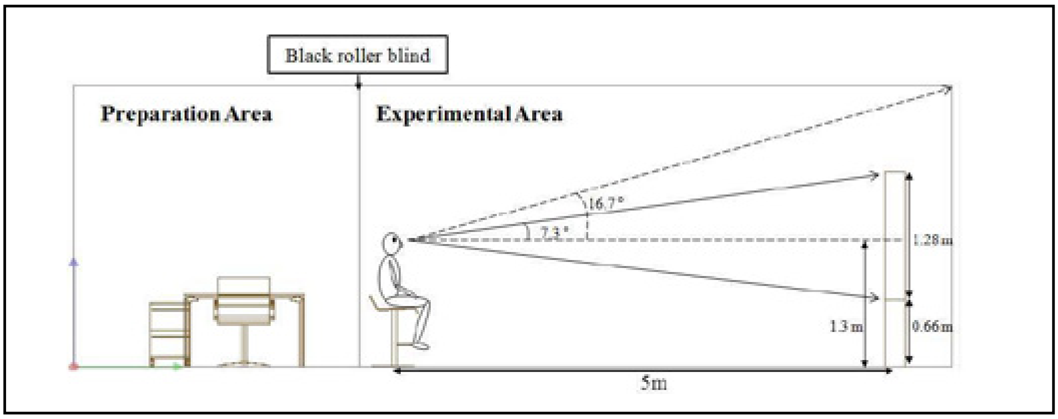

Figure 1 – Experimental setup

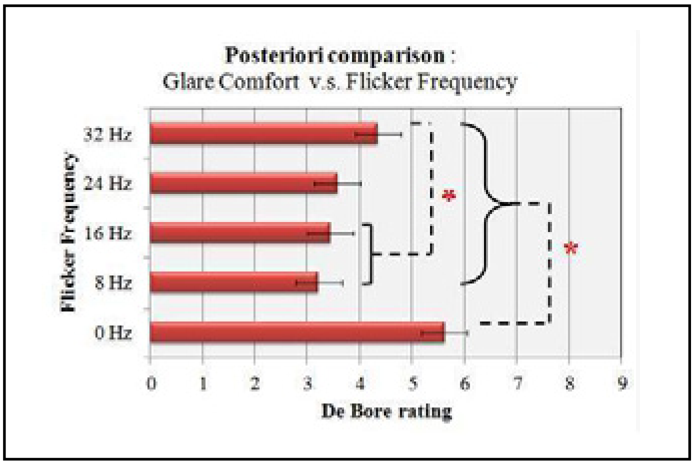

Figure 2 – Posteriori comparison of glare comfort versus flicker frequency

Dependent Variable	Variable	F-value	P-value	Posteriori comparisons for variables that passed the significance test
Flicker Comfort	Flicker frequency	93.536	0.000**	Frequency: 0 Hz > 8 Hz = 16 Hz =24 Hz ; 0 Hz > 32 Hz; 32Hz > 16 Hz Luminance: 505 cd/m^2 > 5063 cd/m^2 Area: 0.51 m^2 > 2.05 m^2
	Luminance	7.870	0.000**	
	Area	4.901	0.008**	
	Ambient illuminance	0.095	0.759	
Glare Comfort	Flicker frequency	29.461	0.000**	Frequency: 0 Hz > 8 Hz = 16 Hz =24 Hz ; 0 Hz > 32 Hz ; 32 Hz > 8 Hz = 16 Hz Luminance: 505 cd/m^2 = 1006cd/m^2 > 2512 cd/m^2 = 5063 cd/m^2 Area: 0.51 m^2 > 2.05 m^2
	Luminance	38.350	0.000**	
	Area	5.717	0.004**	
	Ambient illuminance	1.187	0.277	
Blink Rate	Flicker frequency	1.386	0.239	Luminance: ns
	Luminance	3.329	0.020**	
	Area	1.373	0.255	
	Ambient illuminance	0.729	0.394	
*Significant at p-value = 0.05 or less; ns: not significant				

Table 1 – Significance analysis of the experiment and posteriori comparisons

OP60

INVESTIGATION OF DISCOMFORT GLARE OF RGB LED BILLBOARD AT NIGHT

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Objective:
Mesopic vision is gaining high attention from lighting researchers and industry people re-cently. Most night-time outdoor and traffic lighting scenarios are in the mesopic range [1]. As known as the Purkinje effect, the peak of spectral luminous efficiency shifts to the short-wavelength range in mesopic region. Full color RGB LEDs, which are becoming a popular and energy efficient source for dynamic lighting and displaying information, generally have more wide color gamut than conventional lamps for outdoor lighting like high pressure sodium (HPS) lamps. In addition, achromatic and chromatic color stimuli with same luminance are generally different in brightness (or perceived lightness). The brightness of the latter is higher than the former. The phenomena are well-know and identified with the Helmoholz-Kohlrausch effect (H-K effect) [2]. Those imply that LEDs have a potential risk over conventional lamps in terms of discomfort glare.
Researchers at the Environmental Protection Administration (EPA) in Chinese Taipei are investigating the new technologies and the impacts of light or display must to be used to enhance the positive and reduce the negative effects of LED light, especial in full color RGB LED displays at night. This paper presents results from an ongoing study that compares discomfort glare for different color gamuts of RGB LED billboard using the de Boer rating scale. The RGB LED billboard tested included nine still color pictures at two different ambient illumination levels. The subjective results were also compared with previous discomfort glare equations. Final, the discomfort glare of RGB LED billboard are described to develop a new discomfort glare equation for outdoor in night.

Methods:
Twenty participants with normal color vision joined in the experiments, and all of them passed Farnsworth Munsell Dichotomous D-15 Test. Participants were divided into two groups, one was 18 to 40 years old and the other was older than 40 years. The experiment was conducted in a dark, windowless laboratory. Subjects sat in a chair and were asked to fix their head and watch the billboard on-axis. The eye position, located 5 m away from the apparatus, ensured that subjects‘ eyes were located at the same horizontal angle to the center of the LED array. Each subject was tested individually and was allowed to hold a tablet showing the de Boer discomfort glare rating scale to use as an input device. The experimental setup is illustrated in Figure 1. At the beginning of the experiment the room lights were turned off and the subject was allowed to adapt to the dark room and 4 training pictures with 3 different gamut types were given for 10 minutes. Each session was presented in random order to each subject, and each subject saw a different order than any other subject. For each condition, the subject rated his or her discomfort using the de Boer scale. Once the subject rated the condition, the LED billboard present a middle gray color for a period of 6 to 10 seconds while the experimenter switched to the next testing picture. This

process was repeated until all conditions were presented.
There were 6 sessions in total including 2 surround luminance levels (0.01 cd/m^2, 25 cd/m^2), 3 gamut types (full LED gamut (100LED), standard RGB (069LED), 33% LED gamut (033LED)). There were same 9 pictures for each session. Participants were requested to repeat all sessions three times. The study was based on a randomized factorial design with repeat measures on four factors that include gamut types, observer age, surround luminance and images.

Results:
An analysis of variance based on 10 subjects indicated a significant difference in discomfort glare due to LED gamut (F2, 864 = 29.08, $p < 0.05$), image (F8, 864 = 74.9, $p < 0.05$), age (F1, 864 = 47.97, $p < 0.05$) and sex (F1, 864 = 108.34, $p < 0.05$). There was a significant interaction effect on discomfort glare between gamut and age (F2, 864 = 10.33, $p < 0.05$), as shown in Figure 2. There was a significant interaction effect on discomfort glare between image and age (F8, 864 = 2.09, $p < 0.05$), as illustrated in Figure 3. The interaction between image and sex was also statistical significant (F8, 864 = 2.93, $p < 0.05$).
Although post hoc tests indicate that wide-gamut of RGB LED billboard exhibited the highest discomfort scores (Mean100LED = 4.64; Mean069LED = 4.25; Mean033LED = 3.99), with statistically significant differences detected among three gamut settings. These three mean values represent between "3: disturbing" and "5: just acceptable" in de Boer ratings. Thus, the full color gamut does not cause excessive discomfort glare, yet small color gamut enables more discomfort glare.

Discussion and Conclusions:
Two quantitative methods were used to predict de Boer ratings of discomfort glare for comparison with the actual de Boer subjective ratings. The first method included the Schmidt-Clausen and Bindel's equation [3], and the second method was proposed by Bullough [4]. Results revealed that both methods could not predict well on the actual de Boer rating in this experiment. Finally, we propose a new equation for predicting the discomfort glare of RGB LED Billboard at night.

References
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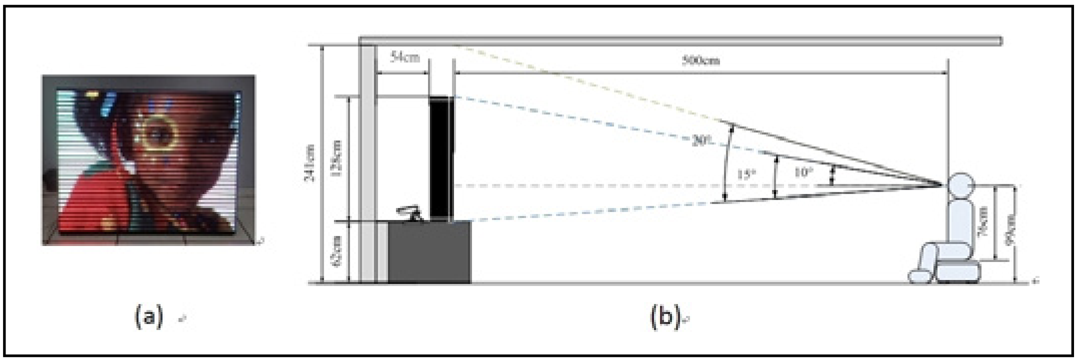

Figure 1 – The Experimental setup. (a) 1.6 x 1.28 m LED billboard with delta RGB arrangement; (b) Viewing dimension.

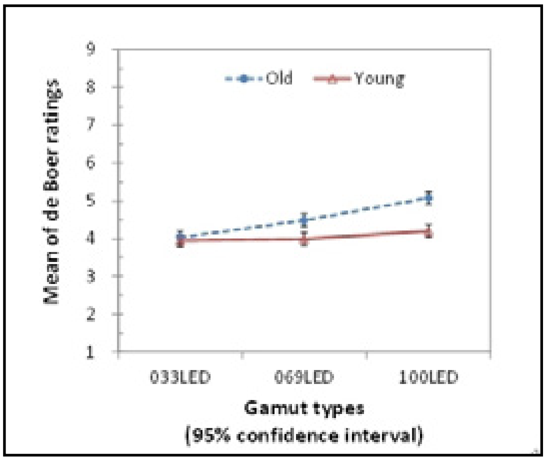

Figure 2 - interaction effect between gamut and age

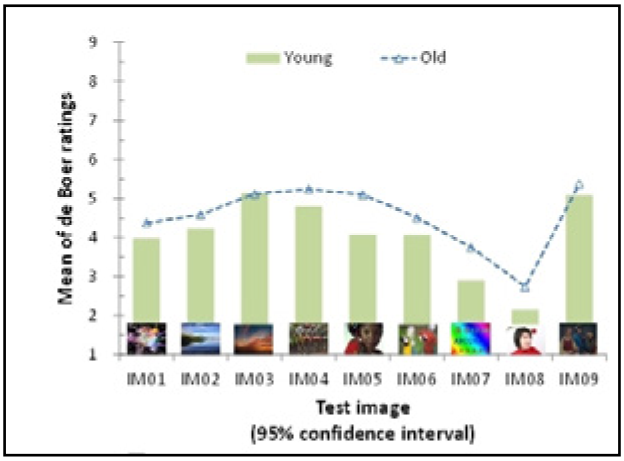

Figure 3 - interaction effect between gamut and age

Keynote: Towards a New Century of Light

(Chair: Yoshi Ohno, United States)

KS02

TOWARDS A NEW CENTURY OF LIGHT

Chain, C.
CERTU, Lyon, France

During the two-day conference, the international community of professionals involved in Light and Lighting will exchange views on the current state of knowledge and practice, resulting from a very long history. For CIE, we celebrate the most recent century of activity. And it is a symbolic moment, like the end of a chapter.
Not the end of a book though. A new chapter is already on its way, and this last keynote presentation will be an opportunity to try and glance into the future, based on the discussions we have had, the talks we have heard, the practical examples we have seen and heard, from the debates, in and out the currents where users, academic researchers, and industrials have shaped. This will thus be an attempt to draft the start of a new chapter and put a mark on the next pages to be written.

Poster Presentations

D1 - Vision and Colour
Colorimetry

PP001

INFORMATION ENTROPY AND THE COLORIMETRY OF SPECTRA

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The application of information entropy (Shannon, 1948) to spectra is discussed, with a focus on recent work in the fields of colour rendering properties of illuminants. White entropy and Spectral entropy are proposed as useful concepts for simplifying and understanding the dynamics relating the challenge of colour rendering to colorimetry. Fig. 1 presents the Planckian locus illuminants as an example of the proposed indices (Colour entropy index = White entropy * Spectral entropy). A further hypothesis relating entropy to colour discrimination is presented, with results comparable to experimental data (see Fig. 2). Allowing for adaptation, it is hypothesised that human colour discrimination is functionally related to the White entropy concept and wavelength.

Shannon CE. A mathematical theory of communication. Bell Sys Labs Tech J, 1948. 27:379-423 Jul, 623-56 Oct. Price LLA. Entropy, colour and colour rendering. J Opt Soc Am A, 2012. In press. Judd DB. Chromaticity sensibility to stimulus differences. J Opt Soc Am, 1932. 22:72-108.

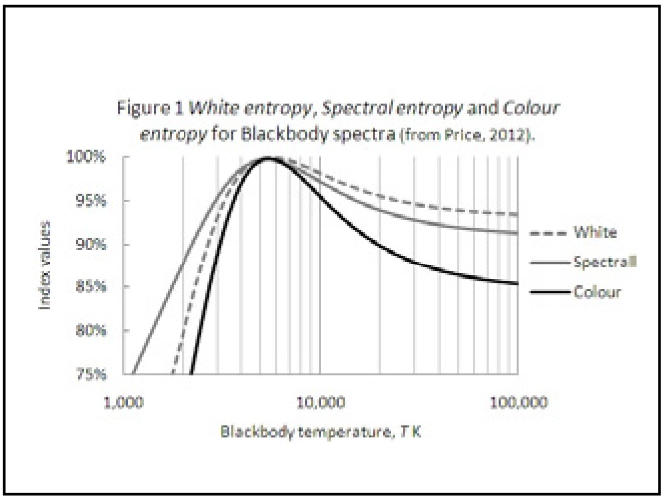

Figure 1

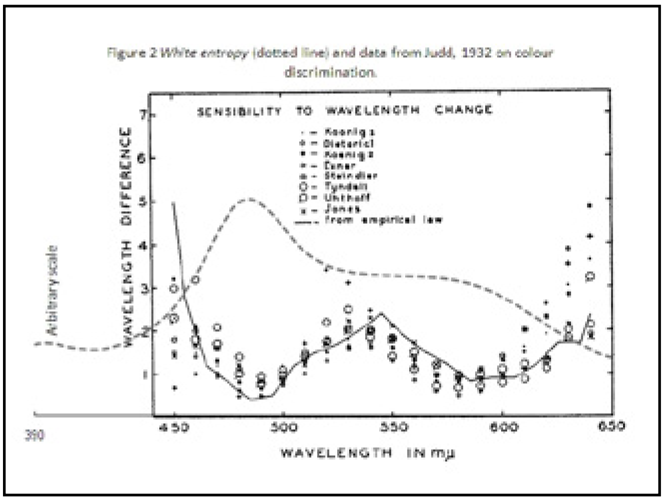

Figure 2

PP002

TOWARDS A FIELD SIZE INDEPENDENT METAMERISM

Polster, S., Schierz, C.
TU Ilmenau, Ilmenau, Germany.

The presentation will give a definition of a field size independent metamerism and describe a method for calculating the visual color shift due to a change in the observer field size, comparing different RGBW-LED-systems.
One of the outstanding characteristics of LED light sources is their compact size, which allows the integration of light sources in confined spaces. Areas that have formerly been lit by one lamp are now lit by a large number of small light sources. There are two ways of incorporating LEDs in order to light large areas. One way is to use only white LEDs of a defined color. In that case the LEDs have to be selected so that they emit exactly the same color in order to give a homogenous impression of the lighted area. The other way is to use sets of LEDs that form a certain color gamut in which all colors can be mixed by controlling the LED output of every single LED with a mixing algorithm. As the spectra of the LED light sources used will always vary to a certain degree it is mainly important to have an exact way to describe the color properties of LEDs. Using a large number of single light sources with differing spectral radiant power distributions the question arises which characteristics the different light sources need to conform to in order to let the surface appear homogenous from any point of view.

Spectra of the same color impression having different radiant power distributions are defined as metamere spectra. However this definition is restricted to color stimuli of a defined observer.* When implementing a large illuminated area the ambition has to be to create a homogenous impression from whatever distance observed. That means the same cluster of LEDs with possibly different spectral power distributions has to give a uniform appearance under any given angle. Therefore, considering the homogenous illumination of large surfaces, the definition of metamerism needs to be stretched to include different observer field sizes. In order to achieve this, the first task at hand is to define color spaces in which metamere spectra are actually mapped to the same color coordinates for a given observer field size. On this basis the calculation of the color shift due to a change in the observer field size will be implemented. Therefore it will be possible to test any sets of RGBW-LEDs for their compatibility for a combined utilization.

An experimental setup was designed to create a database of differing LED spectra with the same stimulus response. The aim was to compare LED spectra with a great variety of different spectral power distributions. In total seven different color-matching experiments were conducted. The compared spectral radiant power distributions ranged from RGB-LED spectra, RGBW-LED spectra to near-continuous LED spectra. The near-continuous Led-spectrum was created by implementing an LED-light source with eight different LEDs spread over the visible spectrum in order to create spectra with a minimum of peaks or dips. In each of the experiments a total of 20 observers made color matches at color temperatures of 3500K, 5000K and 6500K in a 2°-, 5°- and 10°-observer-field. In order to calculate the visual color shift due to a change in the observer field size it is necessary to work with color matching functions that meet the definition of metameres; that means giving the same tristimulus values for those stimuli that match in color for a defined observer. Different color matching functions ranging from the CIE Standard observers from 1931 and 1964 to the cone fundamentals proposed in the technical report CIE 170-1:2006 by the CIE TC1-36 in 2006, were utilized. The color differences between the color coordinates of the reference light sources and the matched test lights were compared and the best fit model for the outcome of the conducted color matching experiments was established. Then this set of color matching functions was refined in a way to fit the existing database. However the presented method of calculating the color shift due to a change in observer field size will work for any given sets of color matching functions for a 2° and 10° observer.

The calculation method in order to estimate the color shift due to a change in the observer field size is simply based on the calculation of a color difference in a given chromaticity diagram. The presented calculation method will focus on the comparison of any two given RGBW-LED-systems that are to be tested for their compatibility with each other. In order to calculate the resulting color difference the algorithm for the color mixture calculation has to be defined. Then
the mix spectra for a certain color coordinate in the 2° chromaticity diagram are calculated for both RGBW-LED- systems. The resulting spectra will give the same color impression in a 2° observer field. Then the color coordinates in the 10° chromaticity diagram will be calculated for both RGBW-mix spectra. The resulting color difference is the indicator for the ability of the different RGBW-LED-systems to be used together in the application of homogenously illuminating a large surface area. The investigation has so far been limited to a comparison between the 2° and 10° field size as the cone fundamentals proposed by TC1-36 did not involve field sizes larger than 10°.

Even so this method has only been validated for the given set of test spectra at three different color coordinates the authors believe that the method should hold for other colors as well. Further investigations are necessary.

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PP003

TESTING A COLOUR-DIFFERENCE FORMULA FOR THE AUTOMOTIVE INDUSTRY USING THE EXPERIMENTAL VISUAL DATASETS EMPLOYED IN CIEDE2000 DEVELOPMENT

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Colour-difference formulas are important tools for objective pass/fail colour decisions in products manufactured by different industries. The goal is these objective decisions based on instrumental colour measurements reliably predict and replace subjective colour-difference evaluations performed by observers' panels [1], as intended by the last two CIE-recommended colour-difference formulas, CIE94 [2] and CIEDE2000 [3].

Currently, the automotive industry is concerned with the development of successful colour-difference formulas for gonioapparent paint materials where different appearance effects (e.g. sparkle, graininess, flop, etc.) play a role in addition to colour [4]. AUDI has proposed the AUDI2000 colour-difference formula [5] for pass/fail decisions in the automotive industry, using materials with solid colours (i.e. homogeneous, non-goniochromatic colours) as well as materials with flop effects. This paper deals only with the performance of the AUDI2000 colour-difference formula (Figure 1) for solid colours. AUDI2000 is based on CIELAB lightness, chroma, and hue differences, with specific weighting functions (SL, SC, SH), where C*ab has been considered here the arithmetical mean of the CIELAB chroma of the two samples in the colour pair, and the parametric factors were assumed as kL=kC=kH=1 (CIEDE2000 reference conditions).
We compare AUDI2000 with CIELAB [6], CIE94, and CIEDE2000 colour-difference formulas, using the experimental datasets with solid colours employed at CIEDE2000 development [7]: four reliable experimental datasets from different laboratories (BFD-P, Leeds, RIT-DuPont, and Witt) on a common scale, and the Combined Weighted dataset (COM-Weighted). To test the performance of different colour-difference formulas we will use the STRESS index [8]. STRESS values are within the range 0-100, low STRESS values indicating good performance of a given formula. From STRESS values, F-tests (95% confidence level) will be performed [8] to ascertain whether or not two colour- difference formulas show statistically significant differences for a given visual dataset.

From STRESS values and F-tests we conclude that: I) AUDI2000 is better (lower STRESS) than CIE94 for the COM- Weighted, BFD-P and Leeds datasets, F-tests indicating that the difference between both formulas is statistically significant for the COM-Weighted and BFD-P datasets. However, AUDI2000 is worse than CIE94 for the RIT-DuPont and Witt datasets, but their differences are not statistically significant for either of these two datasets. In summary, CIE94 and AUDI2000 (with SC and SH functions differing approximately by a factor of 3), are not significantly different for any of the visual datasets tested. II) CIEDE2000 is better than AUDI2000 for all datasets, as might be expected, bearing in mind that CIEDE2000 was optimised for these specific datasets. However, the difference between CIEDE2000 and AUDI2000 is not statistically significant for the BFD-P, RIT-DuPont, and Witt datasets.

Table 1 shows the relevance of each of the weighting functions (SL, SC, SH) proposed in the AUDI2000 and CIE94 colour-difference formulas. If a weighting function is very important in a given formula, when omitted the STRESS value will greatly increase. From all positive values in Table 1, we conclude that all weighting functions in AUDI2000 and CIE94 play a role. For CIE94, the SC function is much more important than the SH function in all datasets, but this cannot be stated for the SC and SH functions in AUDI2000. In addition, the chroma dependence in the SL function of AUDI2000 is very original, and markedly improves this formula. We found that SL functions with chroma dependence may improve the performance of CIE94 (SL =1) for different datasets.

Conclusions

For the visual datasets of solid colour pairs employed at CIEDE2000 development, AUDI2000 without flop terms provides good results in comparison with the ones found from CIE94 and CIEDE2000. In particular, AUDI2000 without flop terms is very similar to CIE94, but adding a chroma-dependent SL function, which may be inspiring in future developments of colour-difference formulas.

Acknowledgements. Research Projects FIS2010-19839 and DPI2011-30090-C02-02, Ministry of Economy and Competitiveness (Spain), with European Regional Development Funds (ERDF) support.

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$$\Delta E_{AUDI2000-NO-FLOP} = \left(\left(\frac{\Delta L^*}{k_L S_L} \right)^2 + \left(\frac{\Delta C^*_{ab}}{k_C S_C} \right)^2 + \left(\frac{\Delta H^*_{ab}}{k_H S_H} \right)^2 \right)^{1/2} \quad ; \quad k_L = k_C = k_H = 1$$

$$S_L = 0.002C^*_{ab} + 0.33 \qquad S_C = 0.014C^*_{ab} + 0.27 \qquad S_H = 0.004C^*_{ab} + 0.30$$

Figure 1

	COM-Weighted	BFD-P	Leeds	RIT-DuPont	Witt
AUDI2000-SL	7.7	4.4	13.3	12.9	10.4
AUDI2000-SC	4.0	4.2	7.7	1.7	1.1
AUDI2000-SH	8.2	7.4	7.0	7.8	8.6
CIE94-SC	14.1	11.2	10.2	15.5	21.7
CIE94-SH	3.7	3.7	0.1	2.1	4.8

Table 1 - Increase of STRESS values when each one of the weighting functions proposed by AUDI2000 and CIE94 are removed at a time, considering the experimental datasets employed at CIEDE2000 development

PP004

COLOUR RENDERING EVALUATION OF THE LED LIGHT SOURCE BY THE RELATIVE EVALUATION

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Objective:

The purpose of our study is to clarify the relationship between colourimetric chromaticity values and subjective evaluation results regarding colour appearance of the test samples under the traditional fluorescence lamps and the white LED lamps, in order to obtain fundamental data for evaluating colour rendering properties of light sources including LEDs.

Methods:

Haploscopic viewing method was employed. The left eye viewed the test colour sample illuminated by the virtual reference light source in the reference viewing booth. The right eye viewed the same test colour sample illuminated by the test light source in right test viewing booth. The observer directly evaluated the colour difference between the two test colour samples using the colour difference scales in the reference viewing booth. The illuminance level of the left and the right booth was kept at 1000lx.

The virtual reference light sources was used three very high colour rendering type fluorescent lamps with CCT 6350K, 4930K, 3060K, and We used the three types of test light sources including the white LED light sources (RGB-primary- colour-LED/LED-RGB, Blue-LED+Yellow-Phospher-LED/LED-BY) and the tri-band type fluorescent lamps (Tri-FL) for each the virtual reference light sources.

The test colour samples were 15 chips, 10 for high and 5 for medial chroma, 40x40mm rectangle shape. The background is covered by N5 sheet. In order to evaluate the difference of colour attribute independently, we employed the three types of colour scales; lightness, chroma, and hue colour scale.

The observers(3 - 6 peoples) were asked the multiple number of a colour difference scale as equivalent to the colour difference between the two test colour samples. The perceived colourimetric value of the test colours under the test light source is compensated with three multiple number values that observer answered, colourimetric difference of the three colour difference scales and colourimetric value of the test colours under the virtual reference light source. On this occasion, we made the color adaptation revision that CIE day light or Planckian radiator assumed standard illuminant. The CCT of reference illuminant is the same as that of test light source.

Results:

The colourimetric values of 15 test colour samples under the test light source and the results given by the subjective evaluation for the test light sources of 6500K, tri-FL, LED-BY and LED-RGB were shown in Fig.1 to Fig.3.

As shown in Fig. 1 and Fig.2, the colourimetric results of Tri-FL and LED-BY were similar to the results of the subjective evaluation.
However, it was shown for LED-RGB that the colourimetric results were slightly different from the subjective results. Colour difference which a subject observed in LED-RGB was considerably larger than the colour difference of standard scale, and Size of the difference was larger than tri-FL and LED-BY.

Conclusions:
Colourimetric result and evaluation result in tri-FL are similar. Similarly, In LED-BY, Colourimetric result and a subjectivity result are similar. The relations of subject results and colourimetric results in Tri-FL almost accord with relations of subject results and colourimetric results in LED-BY. Therefore, we can evaluate the colour rendering evaluation of LED-BY by a colourimetric method in the same way as conventional fluorescent lamps.
In addition, about LED-RGB, chroma of subject colour was appreciated in comparison with chroma of colourimetric value. We suppose that the reason is it. LED-RGB showed the chroma of test colour chip very highly from the chroma difference of the colour scale. Therefore, the observer could not but evaluate very difficult extrapolation. Furthermore, each answer was different greatly by subjects being different than other sources of light. If we suppose this to be the cause that a slightly disagreement produced, we can suppose that we can agree to the evaluation result that a colourimetric results and a subjective results are similar to about test light source LED-RGB.
This research project has been supported by NEDO (New Energy Industrial Technology Development Organization of Japanese Government).

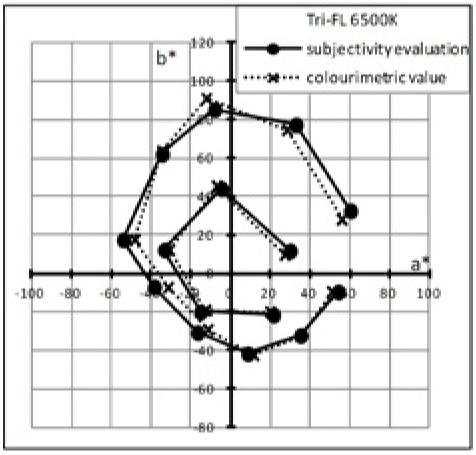

Fig.1 Colourimetric results and subjective results in Tri-FL

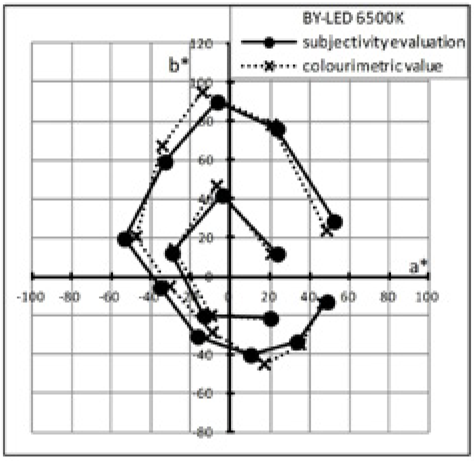

Fig.2 Colourimetric results and subjective results in LED-BY

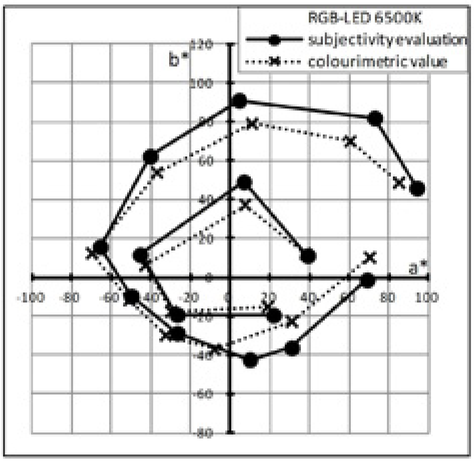

Fig.3 Colourimetric results and subjective results in LED-RGB

Figure 1-3

PP005

AFFECTIVE EVALUATION ON COLOR SAMPLES ILLUMINATED BY LED LIGHT SOURCES - INFLUENCE OF ILLUMINANCE LEVEL

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Introduction

The spectral power distributions of LED light sources are different from those of conventional light sources, therefore the problems of LED illumination on color rendition have been pointed out from subjective estimation.

Chromatic objects look more vivid when illuminance increases, on the other hand they look darker and dull when illuminance decreases(Hunt effect). The lighting environment of a museum is carefully controlled not to give any damage against artworks. In case of an exhibition of Japanese paintings for example, the illuminance level is regulated to constrain at low, under 50 lx in case of the most severe case not to give color fade damage as less as possible.

However, at the view point of appreciation of artworks, low illuminance means the decrease of inherent color appearance of artworks because artworks will lose brightness and colorfulness at low illuminance.

C.Cuttle1) reported that three-band lights were suitable for a museum lighting because they would have the performance of the same visual satisfaction with that of incandescent lamps at equal illuminance.

R.Berns2) studied the performance of a white LED light with red-green-blue prime colors and concluded that the rgb- LED light sources had unique color enhancement effects and those effects might be useful for low illuminance exhibition of artworks at a museum.

The purpose of our study is to examine subjectively the color enhancement effects of LED-RGB illumination compared with other light sources at very low illuminance level and also to investigate the comparison between the subjective color appearance and the calculation analysis of CIECAM02.

Methods

We investigated subjectively the color rendering properties of three kinds of light sources, the conventional fluorescent lamp (FL-WW,Ra60,3500K), the blue LED and yellow phosphor type-LED light source (LED- BY,Ra82,3060K) and the LED light source composed of red, green and blue LEDs (LED-RGB,Ra19,2880K).

The subjective experiment of affective evaluation by semantic differential method (seven categorized scale) on the two-color harmonies (the pairs of color chips) illuminated by each test light source with different illuminance levels was carried out. Ten kinds of the adjective pairs were used for affective evaluation (Table1).

Haploscopic viewing method was employed in the experiment. The left eye viewed the left reference booth illuminated by FL-EDL (Ra96, 3600K) and the right eye viewed the right test booth separately. The inside of the booth was painted by N6. Each observer evaluated color emotion of the test color samples on the right booth compared with color emotion of the reference color samples on the left booth.

Results

The experimental results clearly showed that affective evaluation on the two-color harmonies was strongly influenced by the color rendering properties of the test light sources. Especially we found that if a pair of colors had red or green for each part, affective evaluation by LED-RGB became apparent instead by other light sources. Figure 1 showed the subjective evaluation profiles (average of all subjects) of the pair(a) (a pair of red and green color samples) for each illuminance level. It was shown that the affective evaluation results under LED-RGB were clearly different from those of LED-BY and FL-WW at all illuminance levels.

Figure 2 showed the color gamuts of the special pairs of color samples, namely each color samples had red or green part in the pairs, under 700 lx and 10 lx of each test light sources on the aM-bM chroma coordinates of CIECAM02. As shown in the Fig.2, the color appearance of the test color samples shifted to particularly reddish and greenish direction than yellowish and blueish direction in colorfulness. Moreover the color enhancement effect by LED-RGB was kept from high illuminance level to very low illuminance level. Next, we calculated the gamut area in Fig.2 and showed the numerical values in Table 2. As shown in Fig.2 and Table 2, the gamut area of LED-RGB has the maximum at every illuminace levels, and those of LED-BY and FL-WW were almost the same.

From this study, we confirmed that LED-RGB had color enhancement effect even in very low illuminance and kept the good color rendering properties in low illuminance. Therefore, LED-RGB could be used for color appreciation area, for example a museum or a church, in very low illuminance.

Acknowledgement

We thanks Japan Color Research Institute and KONICA MINOLTA SENSING, INC. for helping us the viewing booth and the luminaires and the measurement instruments.

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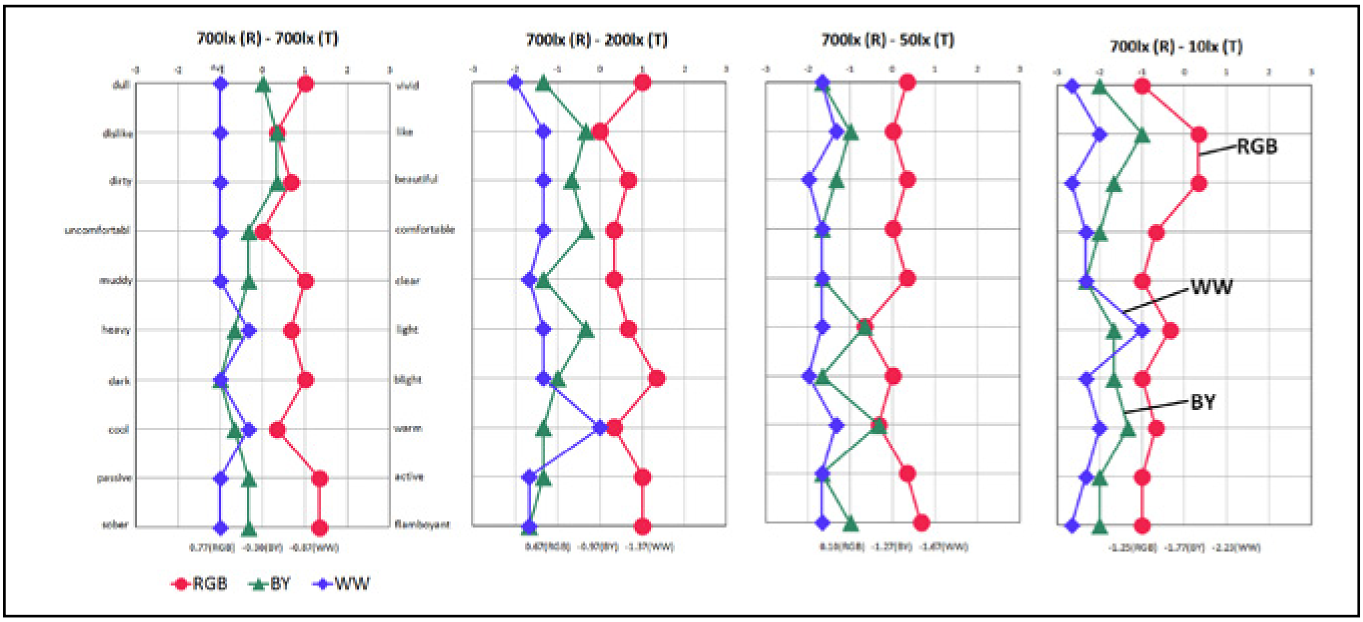

Figure 1 - The subjective evaluation profiles of the pair (a) of colors for each illuminance level

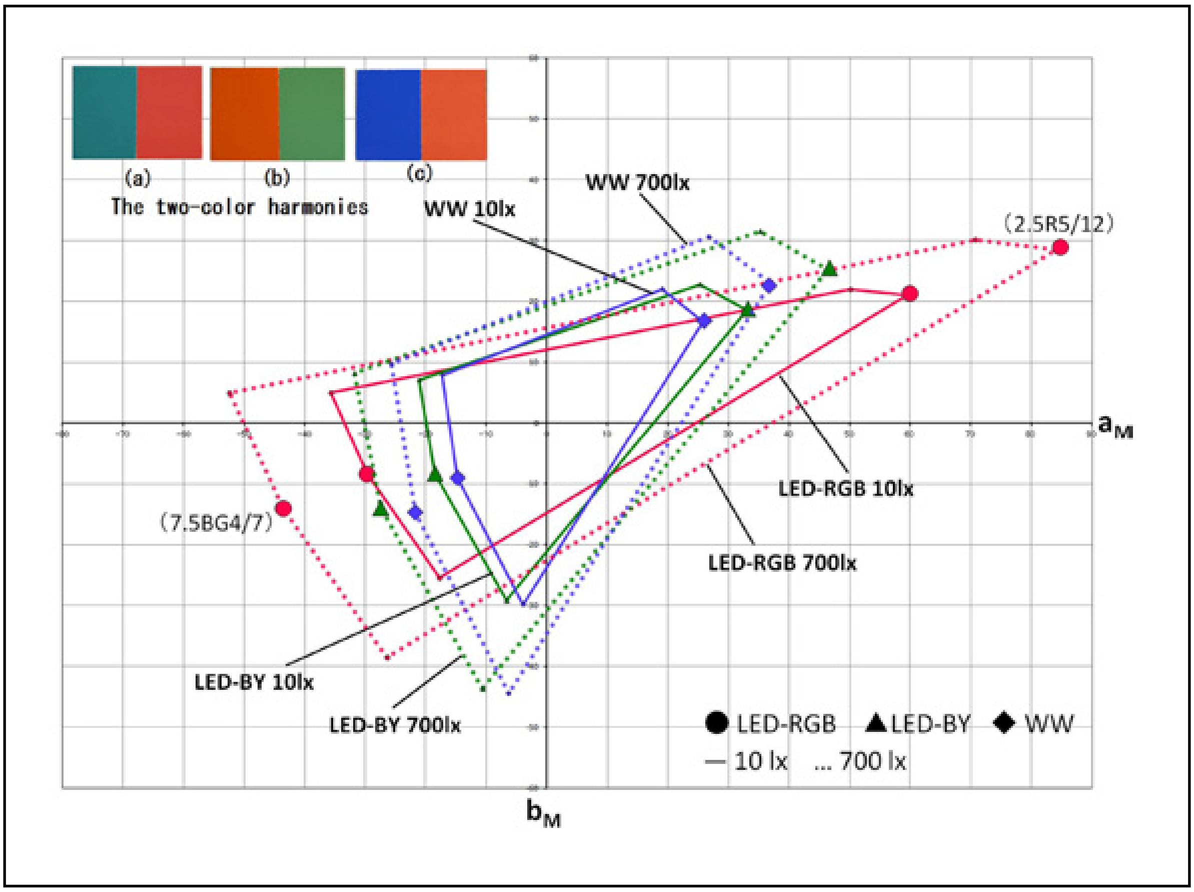

Figure 2 - The color gamuts of the three pairs of color samples on the aM-bM chroma coordinates

adjective	seven categorized scale (-3)strongly......(3)strongly	adjective
dull	strongly(-3)-very(-2)-moderately(-1)-neutral(0)-moderately(1)-very(2)-strongly(3)	vivid
dislike		like
dirty		beautiful
unconfortable		confortable
muddy		clear
heavy		light
dark		bright
cool		warm
passive		active
sober		loud

Table 1 - The pairs of the adjectives for SD evaluation.

	RGB	BY	WW
700 lx	3599	2673	2290
10 lx	1739	1279	1191

Table 2 - The gamut area of aM-bM coordinates of the six color samples of the three pairs of color samples

PP006

SUBJECTIVE ASSESSMENT OF UNIQUE COLOURS AS A TOOL TO EVALUATE THE QUALITY OF WHITE LIGHT SOURCES

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One essential problem in evaluating the quality of a light source is the measure of colour fidelity, meant as the reproduction of the same colours under different sources. The colour rendition of a test source, in comparison with a reference source, is usually measured by the colour difference between sets of colours in the two conditions. The subjective counterpart of these measures is a direct comparison of the colours performed by an actual observer, and this poses methodological problems as regard to either the adaptation state in concurrent observations or the memory influence due to the delayed comparison. This study is directed to solve these problems.

In the first experiment we studied a series of 48 colours, presented singularly in the lower part of a calibrated monitor, divided in two groups, containing 4 unique hues x 6 nuances each: in the case of red, in the first group colours differed in “redness” along the red-white interval, while in the other group along the red-black interval (and similarly for the other hues). A series of seven colours of the same unique hue were presented in the upper part of the monitor, varying towards the white for blackish samples, and towards the black for the whitish ones. They served as a reference to make easier the evaluation of the amount of the tint under consideration. Four observers performed the task of choosing the patch of the series which showed the same redness (or another hue) of the test patch. Interpolation and extrapolation were possible. Each observer repeated the task four times in different periods. Results were recorded in the form of the colourfulness (M’) of the chosen patches, and their mean compared with the colourfulness of the test patch. Linear functions were obtained with slope around 0.7 when the tests where blackish, and around unity when the tests were whitish. In this latter case colourfulness was slightly overestimated for all hues, while in the first case this happened mainly for the red hue. Results showed that evaluation of the hue attribute is consistent among observers.

Given the positive results of this preliminary experiment, a second experiment was performed in which printed papers were used for the evaluation of the hue attribute. Four reference series of ten samples each were printed with colours of each unique hue, the samples were distributed in uniform steps from the most chromatic (with the limitation of our printer) to white, and other four series from the most chromatic to black. Colours were observed in a viewing booth, lit by a LED 6500K source. Two whitish colours per hue were evaluated in a first run, and two blackish colours in a second run. The procedure was the same as before: for the red hue, ten observers were asked to chose the colour of the reference series which showed the same redness (the same way for the other hues) of the test colour. As before, also in this experiment when the test colour was whitish, the reference series was blackish, and the reverse. Results, in terms of colourfulness, were in agreement with the previous ones: subjective evaluations of colourfulness almost always corresponded to instrumental measurement results on the test samples, showing that observers

could consistently evaluate how much tint is perceived in a colour.
The third experiment was devised to see whether evaluation of the hue attribute could consistently be made for mixed colours (in the Hering sense, according to whom a colour appears mixed when two different hues are visible in it). We printed three samples for four mixed hues (all they were almost 50% similar to one hue and 50% to the other hue, according to the NCS notation), the colours were either whitish, or blackish, or highly chromatic. Two experimenters performed the task three times with the four mixed hues, turquoise, purple, orange and lime; it consisted in choosing from the reference series of colours (ten samples of unique hues from the most chromatic to black) the sample which appeared of the same amount of tint as the test sample. Later ten more observers performed the same task twice only with turquoise and purple samples, while ten more observers performed the same task with the other two mixed test colours. The expectation was that the chosen colours from the two reference series had to show the same colourfulness, because the test colour was nominally midway between two consecutive unique hues (e.g. 50% reddish and 50% yellowish). As regard to the whitish and blackish samples the results were in agreement with the expectations, but not for the chromatic ones. In this latter case, considering the orange sample, evaluations of its similarity with red and yellow tints provided values lower than the nominal ones (in terms of NCS notation), moreover yellowness was chosen higher than redness. Analogous results were obtained for the other chromatic samples. This result can appear as an anomaly, therefore it is worth to be more deeply analyzed. The methodology tested in these experiments seemed to give rather coherent and consistent results.

In all the experiments the use of the reference series of samples was very helpful, they showed how much the tint could vary from the most chromatic colour to white (or to black) and make easier to compare the amount of the tint in the test colour in order to chose the corresponding reference sample. Next step will be to remove the reference series of colours and perform the evaluations only on the basis of the redness, blueness, greenness, yellowness, whiteness, and blackness, which all people have in their mind as structures of our colour perception system. This final step could show that it is possible to evaluate consistently all the basic attributes of all colours without the need of direct comparisons, important requirement in the evaluation of colour fidelity relative to the quality of light sources.

PP008

USER EVALUATION OF EIGHT LED LIGHT SOURCES WITH DIFFERENT SPECIAL COLOUR RENDERING INDICES R9

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Objective

The influence of the spectral power distribution of white LED light sources on the colour appearance of objects is under discussion. New metrics are being proposed for improvement of the shortcomings of the Colour Rendering Index (CRI). But as long as CRI is the standard used, there is a possibility to take into account and evaluate the special colour rendering indices R_i, along with the General Colour Rendering index, R_a. Especially R_9 for the strong red test-colour sample, TCS09, is not used for the calculation of R_a, but is especially pertinent since the rendition of saturated red is important for the appearance of skin tones. The aim of this experimental study was to evaluate the influence of R_9 on colour perception of objects illuminated by different white LED light sources available on the market today.

Method

Eight LED retrofit light sources were chosen for these experiments, from a survey of LED products on the Danish market. Here 266 white LED light sources were tested for their photometric and colorimetric properties [1]. The choosen LED light sources has similar correlated colour temperature (CCT) of 2950K +/- 50K and Ra of 80 +/- 3, but varying R9. The measured colorimetric properties of the LED light sources are shown in table 1.

64 test subjects evaluated the LED light sources with R_9 ranging from 3 to 25. The test set-up consisted of four identical blacked out rooms (Figure 1). Each room where divided in two sub-areas by non-translucent fabric. For each sub-area one LED light source lit the white wall, where a Munsell Color chart (Macbeth ColorChecker) was mounted. The LED lights were carefully placed at a distance from the Munsell chart that resulted in a wall illuminance of 115 lx. For each test room the test subjects evaluated two LED light sources against each other.

The experiment consisted of 16 test rounds. For every test round 4 subjects evaluated the set-up starting with one person in each room. The subjects rotated between the rooms systematically to ensure that the experiment was balanced in the order in which the LED light sources were evaluated. Moreover, the location of the LED light sources was changed after each test round. At the end, each of the LED light sources had been evaluated against the seven remaining light sources twice by four test subjects.

Upon evaluation, the test subjects were asked to fill in a questionnaire, about: 1) The colour appearance of the Munsell chart; 2) The appearance of a white paper; 3) The ability to read two lines of text; 4) The appearance of the skin tones on their hand and 5) In which type of room they would locate the light source if given the choice.

The subjects were given 5 minutes to evaluate the two LED sources in each room.

Results

For the selected LED sources it is expected that the special colour rendering indices$_9$ has a pronounced effect on the appearance of skin tones. We expect that a value R_9 below 20 has a major effect on the colour appearance while an R_9 above 20 does not alter the appearance for untrained people to notice a changed color appearance, mainly because of a relatively fast colour adaptation of the eye.

Funding

This work was supported by the Danish Energy Association, ELFORSK grant PSO 342-035.

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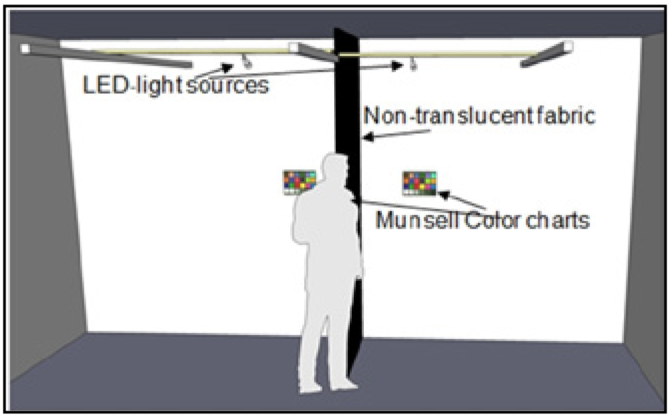

Figure 1 - Sketch showing the test set-up

Light Source	CCT	CRI	R9	Duv(10-3)
1	2988	79.6	17.0	3.2
2	3056	78.8	3.0	1.9
3	2939	81.2	25.5	-5.4
4	2965	79.8	21.6	-4.6
5	2959	81.9	26.7	5.6
6	2909	81.4	23.5	1.6
7	2950	81.3	9.6	-0.78
8	2704	82.8	17.3	8.6

Table 1 - Measured colorimetric properties of the eight LED light sources used in the tests

PP009

SPAN OF FUNDAMENTAL COLORS OF PEOPLE WITH COLOR VISION DEFECT

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Introduction

Specification of span of fundamental colors in a color space (e.g Munsell Colour Space) is useful for conspicuous colouring of objects or creating distinct colour combinations in visual signs. Sagawa and Takahashi (2003) and Itoh and Sagawa (2007) have shown the spans of fundamental colours based on subjective colour-similarity judgement, but not on colour discrimination, and have expressed those as areas of the similar colors in the Munsell Color Space. Data were taken for younger and older people as well as for low vision in order to use the data in a wider application fields. The data collection is still being continued in a systematic way to people with color vision defects who have largely different characteristics from people of normal color vision. The present study aims to show the data on the span of fundamental colours taken for people with colour defects.

Background

CIE published a technical report CIE 196:2011 "CIE Guide to Increasing Accessibility in Light and Lighting" to address the need for providing appropriate lighting for people with special requirements such as older people, people with low vision. Although the report includes useful information concerning visual properties of the visual disabled but still necessary data for increasing lighting accessibility is missing. The present study is able to offer the useful data that will be used for better lighting and signing to people with color vision defects.

Method

Method to measure the span of fundamental color is the same as we used in the measurement for older people and people with low vision (Sagawa and Takahashi, 2003; Itoh and Sagawa, 2007), but the numbers of the reference colors and the test ones were slightly differed to a total of 16 reference colours and of 200 test colors.

The subjects was given one of the 200 test colours and asked to select any from a total of 16 reference colors that were displayed in front of the subject and looks similar to the test one in colour appearance. There was no limitation for the number of selection and no choice was allowed if nothing similar to the test. This trial was continued until all the judgment for the 200 test colours were done.

By collecting the data from a number of subjects the probability of people who judged "similar" was obtained to any combination of the reference and test colors. These probability data were used to specify the area of similarity in the Musnell Color Space to each of the reference colors.
Subjects were all color defects; 6 protanopes and 6 Deuteranopes medically diagnosed. Six more subjects of abnormal trichromats (P and D type) were participated but the data were not included in the present analysis.

Results and Discussion

Figure 1 (a) and (b) shows the areas of two fundamental colors, red (5R5/12) and green (5G5/8) respectively both defined by the 30% similarity (meaning 30% of the subjects judged the colours similar to the reference). Data at the Munsell Value 5 plane are only shown. Three contours drawn by red, green, and black lines in the plane mean the red colour area for protanoeps, deuteranopes, and color normals respectively.

It is clearly shown that the spans of both red or green fundamental colors are largely different from the one shown for color normals in the same figure. The general feature of the protanopes and deuteranopes is that the red and green areas are both intruding to each other i.e. the red area to the green one or the green area to the red one meaning that reddish and greenish colours are being confused each other by those with color defects. Areas of some other fundamental colors are all different from those of color normals.

(Figure (a) and (b) to be inserted)

Figure 1: Areas judged similar to the fundamental color of red defined as 5R5/12 (a) and of green as 5G5/8 (b). Areas contoured by red, green and black line mean the span of protanope, dueteranope, and colour normals respectively.
Data at Munsell Value 5 are shown..

Conclusion

It was concluded that the spans of fundamental colours of people with color vision defects are considerably different from the ones of people with normal colour vision. The difference should be taking into account when we develop visual signs such as traffic signs that are aimed visible even for those who have colour vision defects.

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PP010

THE COLOR OF WHITE LIGHT

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Objectives

Since long it is assumed that a light source with chromaticity coordinates located on the black body locus appears achromatic white to the human eye [1] [2]. Recent studies, however, indicate that this might not be necessarily true [3]. The psychophysical experiment below describes a method of measuring the perceived achromatic white point of quasi-black body spectra of different correlated color temperatures both in a state of no chromatic adaptation and in a state of full chromatic adaptation. In contrast to previous studies, this experiment takes place in a real-life environment where the lighting of the room can be spectrally altered [3].

Methods

The experimental setting is a modernly furnished living room environment. While having colored objects in the room has an impact on the chromatic adaptation of the visual system, it does provide a much more realistic environment than a laboratory viewing booth [4]. The roof of the room is equipped with six wirelessly controlled spectrally tunable LED light fixtures evenly illuminating the floor area and walls until a height of 160cm. After an Ishihara color test and a five minute introduction to the experiment, each of the 25 observers will individually take part in two different tests. The introduction takes place in a dark environment to make sure the visual system of the observer is not influenced by any light source before the experiment starts.

The first part of the experiment provides a two second burst of light at an illuminance level of 250lux. The randomly selected spectrum presented to the observer is selected from a list of quasi-black body spectra where the dominant wavelength of the selected spectrum with a correlated color temperature ranging from 2700K to 10000K corresponds to the dominant wavelength of one of the individual LEDs used in the tunable light fixtures. Changing the relative intensity of that particular wavelength allows the operator to move the color coordinates of the illumination seen by the observer along the isotherm of that particular color temperature. The excitation purity can be used as an expression for the deviation of the shown stimulus from the black body locus. A positive percentage indicates a deviation above the black body locus while a negative percentage indicates one below the curve.

After the burst the observer rates the hue of the stimulus by indicating how much magenta, green, yellow and blue s/he has seen. Each observer returns ten times within a period of one week resulting in 250 measurements. The results of these measurements will tell us the preferred achromatic white point without taking into account the chromatic adaptation of our visual system.
Even after achieving full chromatic adaptation, some light sources appear to have a slight hue. The second part of the experiment aims at finding the achromatic white point and preferred white point at a certain color temperature after complete chromatic adaptation. To achieve this each of the 25 observers is presented with an interactive user interface. The room is illuminated with

a random quasi-black body stimulus of 250lux at a certain correlated color temperature ranging from 2700K to 10000K and a computer keyboard is presented to the observer. By using a combination of keys the observer has the ability to control the movement of the color coordinates of the room lighting along the isotherm of that particular color temperature. The observer is asked to dial-in a fully achromatic white light. Immediately after that s/he is asked to dial in his preferred hue. Each observer returns 5 times resulting in 125 measurements, measurement starting with a randomly selected correlated color temperature.

Results

The results of this experiment will provide valuable information on the perceived achromatic white point and the preferred white point both in a non adapted state and in a state of full chromatic adaptation. By using a realistic living room environment the results of the experiment can be transferred immediately to real-world applications.

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PP011

AN INTELLIGENT COLOR TEMPERATURE CONVERSION FUNCTION WITH MULTI-PRIMARY COLORS FOR INDOOR SOLID-STATE LIGHTING

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Color temperature (CT) represents a color property of a light source or the white point of a display device. However, the chromaticity of many natural and artificial light sources, including daylight, incandescent lamps, display backlight, and etc., is not on this locus. Instead of CT, correlative color temperature (CCT) indicates a light source's characteristics whose the light source chromaticity is off the Planckian locus. Moreover, the ANSI (American National Standard Institute) proposes a standard document (ANSI C78.377) to gauge eight BINs which include warm, normal, and cold modes, for Solid State Lighting (SSL) product. This standard specifies the range of chromaticities recommended for general lighting with indoor SSL products, and guarantees the white light chromaticities of products can be communicated to consumers.

However, displays and lighting require intelligent CT conversion function for user's individual preferences in various applications and different environments in recent years. The CT conversion function is particularly important and requisite in different CT illumination for different applications when the vigorous development of LED lighting comes with multi-primary color (MPC) LEDs. However, when we adopt one LED lighting module of MPC for the various CT illumination in different environmental conditions, how can one be sure that an lighting outcome appears as that we intend in a unknown environmental conditions? In displays, CT conversion is one key approach in the color management system for improving image browsing. Using RGB channel gain to adjust the CT or the white point in displays is a direct and cost effective way to improve image browsing. Similarly, in MPC lighting, changing MPC gain to convert CT is one convenient method. However, maximal brightness reduces when converting from original white point to another.

Our previous study proposes a general color gamut boundary (CGB) theory of an additive multi-primary color system based on color mixing theory. And it can determine the CGB by its apexes in CIExyY space. After determining the xyY coordinates of the three or multiple primaries, the extremes of CGB can be automatically obtained. This methods of constructing the CGB only require the chromaticity coordinates and brightness of the primaries and extraneous light. Further, when we understand the composition of these extremes of CGB, CCT conversion with maximal brightness on the isotemperature line for MPCs display or lighting can be resolve by the same concept that the optimizing point is one of the intersections determined by the lines of gravity-center and the isotemperature line. Similarly, we proposes two methods to determine the optimal converting point in the CT quadrangle which complies with ANSI C78. 377. We take four primary color, red(R), yellow(Y), green(G), blue(B), as an example as figure 1 showing. The outside quadrangle RYGB is the color gamut of lighting. The gamut of inside small quadrangle extends outward from the white point W. We proposes two solutions for CT conversion with maximal brightness in two conditions that the line of center of gravity may or may not intersect with the CT quadrangle. As figure 1 showing, the CT quadrangle A intersects with the line of center of gravity, whereas the quadrangle B does not. When the CT quadrangle A is chosen to be the target CT, the point c is the optimal converting point of the range of CT quadrangle A. because the expanded color gamut from the reference white point (W) first meets the point c, the area of the expanded color gamut is smaller than that meeting other color points in the range of CT quadrangle A. When the CT quadrangle B is chosen to be the target CT, the point d is the optimal converting point of the range of CT quadrangle B. Because the point d is first met by the expanded color gamut from the reference white point, the color gamut area is the smallest under the range of CT quadrangle B. Finally, the simulations based on four primary color show the optimal point with the maximal brightness in the quadrangle of 6500K CT that touches the line of center of gravity as figure 2 showing. The percentage between the maximal and the minimal brightness is about 13% of the minimal brightness. Therefore, this paper propose an intelligent color temperature conversion function to obtain more brightness with multi-primary color LEDs.

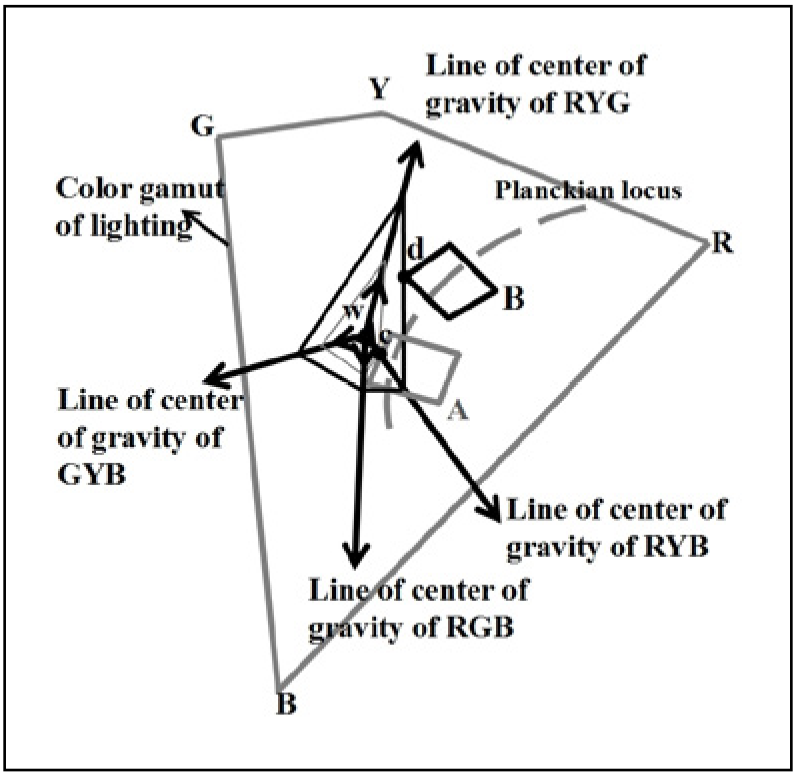

Figure 1 - The optimal converting points of the CT quadrangle A and CT quadrangle B

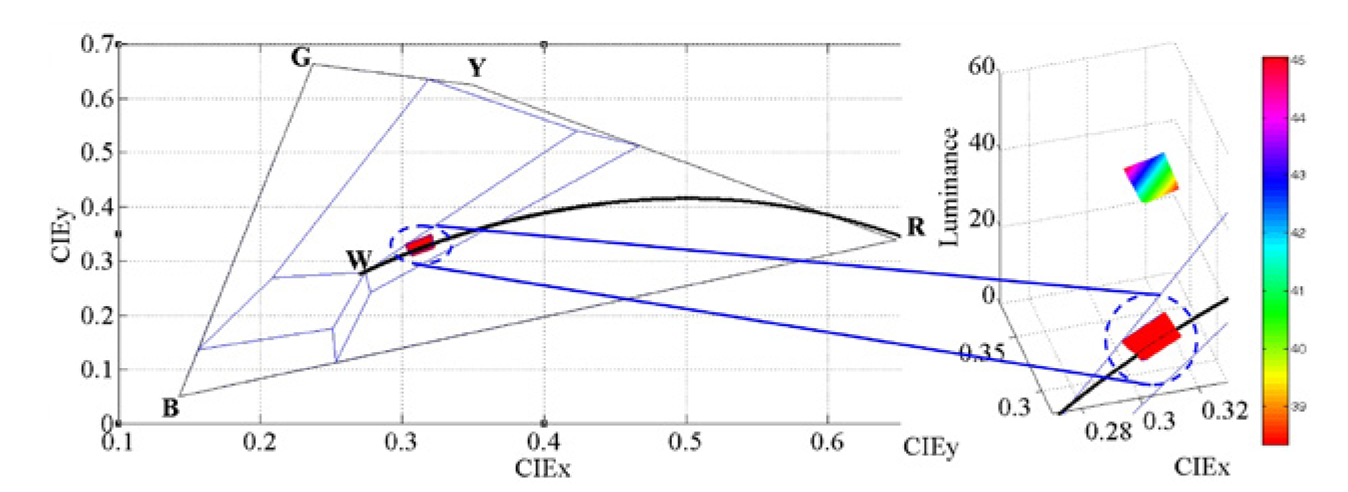

Figure 2 - The percentage between the maximal and the minimal brightness in the quad-rangle of 6500K CT is about 13% of the minimal brightness

PP012

INFLUENCE OF SPECTRAL POWER DISTRIBUTION OF LIGHT SOURCES ON THE COLOUR APPEARANCE OF GONIOCHROMATIC COLOURS

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Introduction

During the last years technologic innovation in all areas has made possible the appearance of effect pigments whose main properties are the change in lightness, hue and chroma depending on the angle of illumination and observation. There is very demanding requeriments to evaluate visually effects colours, for this reason, it is very important to control the illumination to judge visually the colour appearance of these new materials.

New lighting booths have been designed with directional luminous incidence and different viewing positions to do a visual assessment under controlled illumination. Nowadays, in the market, there is a lightweight cabinet named Gonio- Vision-Box® (GVB) whose luminaire is a wLED lantern, and a heavy cabinet named Byko-spectra effect® (BSE) whose luminaire is a fluorescent tube. In both cases, the opto-mechanical design was designed to cover the most number of measurement geometries available in the current multi-gonio-spectrophotometers with different D65 simulators. In a previous work [2], both directional lighting booths were calibrated and analyzed and it was revealed that the two cabinets use light sources with different colorimetric properties.

Therefore, the purpose of this analysis is to evaluate how the colour appearance of each coloured sample varies in front of the illumination, both in spectral content and geometric position source-observer.

Materials and Method

The goniochromatic set consists of 18 metallic colour samples with three kinds of special-effect pigments at different concentrations: Xirallic Crystal Silver, Xirallic Micro Silver and Iriodin Silver-white 9103. The spectral reflectance was read by the BYK-mac multi-gonio-spectrophotometer at six geometries in accordance with ASTM standards [3-4]. On the other hand, we used the PR-650 tele-spectroradiometer to measure the spectral power distribution (SPD) of the luminaire of each lighting booth (BSE and GVB) by using its corresponding white reference ($BaSO_4$) (Figure 1).

Table 1 summarizes the colorimetric parameters associated with each luminaire installed in both lighting cabinets and those associated with the CIE D65 illuminant. According to Table 1, the fluorescent daylight of the BSE is not a good D65 simulator. In contrast, the wLED lamp of the GVB is a good D65 simulator, though the colour rendering is lower. The spectral data were transformed into CIELAB values for each measurement geometry after doing a chromatic adaptation to D65 based on CAT02 [6] in order to evaluate the perceptible chromatic variability of these colour samples under each lighting booth.

Results

After calculating the CIELAB values for all colour samples at different measurement geometries, we compared the perceptible colour gamut associated with the 18 samples under different light sources of each lighting booth by plotting the chromatic diagrams a* vs. b* and C_{ab}* vs. L*. Figure 2 shows the perceptible chromatic variability of these samples for the six geometries. The perceptible colour gamut under the CIE D65 illuminant, BSE and GVB luminaries are plotted by black, red, and blue dots, respectively. As shown in Figure 2, there are samples with lightness values greater than 100, very typical of effect pigments. On the other hand, the chromatic perception associated with these colour samples changes with the considered light source. The colour difference was calculated based on the CIEDE2000 colour difference formula [5] between the set of CIELAB values obtained under BSE and GVB luminaires after doing the chromatic adaptation. As shown in Table 2, the average colour difference between colour samples is around 2.5 $\Delta E_{CIEDE2000}$. That is a perceptible difference for all colour samples. On the other hand, the maximum differences are related to the measurement geometries (45as-15 and 45as15) closer to the specular direction.

Conclusions

The directional lighting booths for the automotive industry have very different spectral and colorimetric properties. This causes a different perceptible chromatic variability for these new materials with special-effect pigments. Therefore,

due to the very demanding requeriments to evaluate visually effects colours, it is necessary to get new lighting technologies which are able to replicate at spectral level the CIE D65 illuminant.

Acknowledgements

This study was supported by the European Union and Spanish Ministry of Economy and Competitiveness under the grant DPI2011-30090-C02-02.

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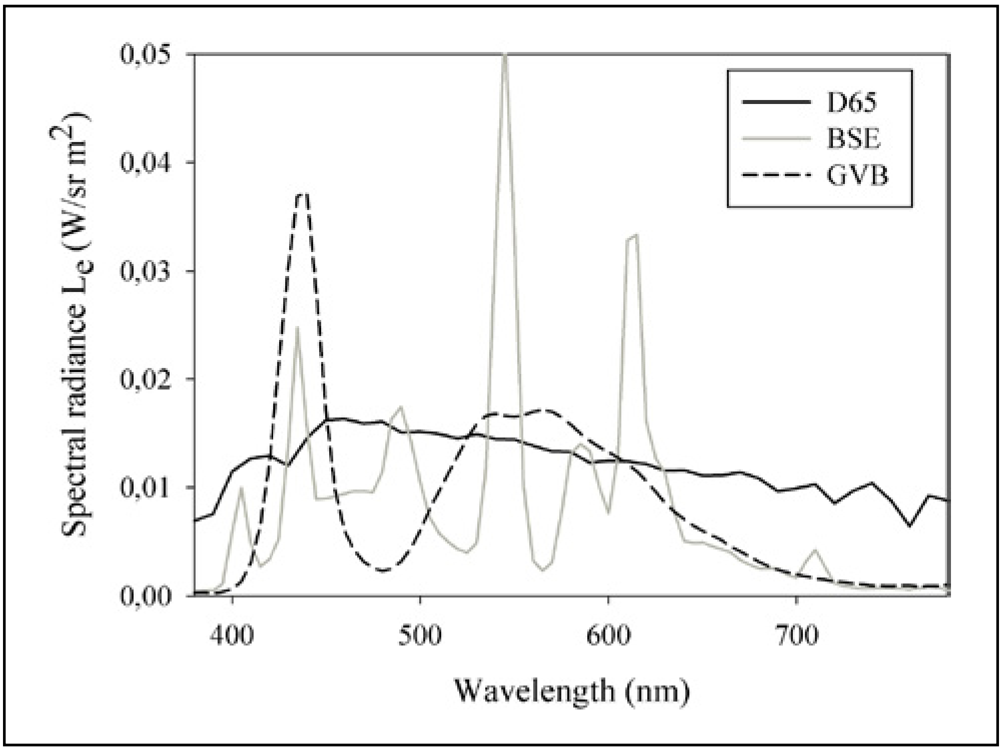

Figure 1

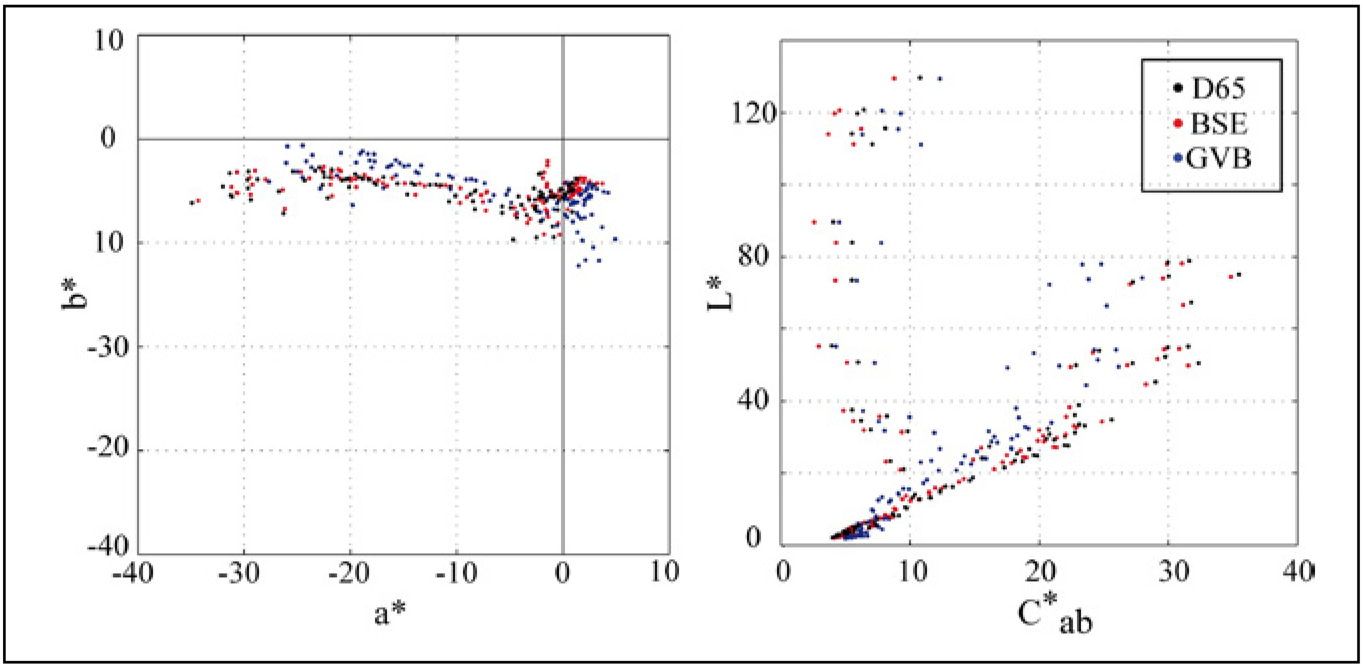

Figure 2

	x	y	Tc (K)	Ra
D65	0.3127	0.3290	6500	99.58
BSE	0.3506	0.3769	4896	86.24
GVB	0.3185	0.3141	6278	69.07

Table 1 - CIE-1931 colorimetric data, correlated colour temperature and general colour rendering index (Ra) of the lamps used in this work

Geometries	45as-15	45as15	45as25	45as45	45as75	45as110	
ΔE	max	6.75	5.39	4.16	3.84	4.63	5.31
ΔE	min	0.92	0.94	0.99	0.92	1.08	1.03
ΔE	mean	2.95	2.82	2.52	2.27	2.34	2.21

Table 2 - Maximum, minimum and average colour difference based on CIEDE2000 calculated for each measurement geometry

D1 - Vision and Colour
Mesopic Vision

PP013

EFFECT OF HIGH LUMINANCE SOURCES TO PERIPHERAL ADAPTATION STATE IN MESOPIC RANGE

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Objective:

CIE has recommended a new photometry system for the mesopic range in the CIE 191. The system is expected to enable lighting industry to develop more energy efficient and/or visual effective outdoor lighting products by taking into account the Purkinje effect to photometry.

However, there are some remaining issues for implementation of the mesopic photometry system. The definition of visual adaptation field is one of them. Although the system requires its user to know the photopic and scotopic luminance of the adaptation field as a representative figure of the adaptation state of observers' eye, the CIE 191 has not defined the shape and size of the field. Many factors regarding adaptation state of human eyes can be separate to two parts in terms of application dependency; the movement of line of sight and other factors (e.g. veiling luminance, spatial neural interactions on retina or visual cortex etc.). The second factors are fundamentally independent from application, while the line of sight usually depends on it.

To evaluate the second factors' effect, a series of vision experiments have been conducted by authors. The experiments showed that surrounding luminance distribution, which is 12 degrees far from a peripheral task point, does not have significant effect to adaptation state at a point on retina that looks at the task point. However, the experiment was conducted only at low luminance levels such as 2,1 cd m^{-2} or 0,42 cd m^{-2} for the surrounding luminance distribution, although outdoor luminaires usually have much higher luminance. Thus, it is still not clear whether such high luminance sources affect the adaptation state significantly or not.

Therefore, this study evaluates the effect of high luminance sources to adaptation state at a peripheral task point in the mesopic range.

Methods:

Vision experiments to measure luminance contrast detection threshold are being conducted to estimate the effect to adaptation state by high luminance sources.

A liquid crystal display (LCD) subtended in 49° x 29° of visual angle is employed to present target stimulus and its background. The target is presented at 10° far from fixation point. A LED source, which has 1,76° diameter, is set as the high luminance source at 20° above the target. The vertical illuminance at subjects' eye caused by the LED source is 5 lx. CCTs of the target, background and the LED source are 5000K.

Fig. 1 shows the adaptation and task conditions. These patterns emulate road lighting scene at night, which has lit road surface and dark sky. Firstly, subjects adapt to the adaptation patterns in the upper row of Fig. 1 for 5 minutes. Then, they observe the task patterns, which are presented for 0,6 seconds. The target is presented for 0,2 seconds while the task patterns are presented. Subjects are asked to answer whether they saw the target or not.

The difference between condition A and C is only the existence of high luminance source in adaptation pattern. If the source affect to adaptation state, task performance at condition C should be different from at condition A significantly. We can also estimate the real adaptation luminance at condition C by comparing task performance at condition C with those at condition A and B.

Results:

So far, preliminary experiments have been conducted. Fig. 2 shows result of a subject. The luminance contrast detection threshold at condition C is significantly higher than at condition A, but lower than at condition B. It means that real adaptation luminance at condition C is between 0,2 cd m^{-2} and 2,0 cd m^{-2}, which are nominal adaptation luminance at condition A and B.

Conclutions:

The result shows that a high luminance source has significant effect to adaptation state at a peripheral task point. It suggests that some light sources in outdoor lighting scenario (e.g. luminaires, headlights of oncoming vehicles, shop windows adjacent to road etc.) could affect the adaptation state that changes luminous efficiency function.

To evaluate the magnitude of the effect of such potential high luminance sources in outdoor lighting, more detailed relation between facial illuminance caused by a source and real adaptation luminance at a peripheral task point should be characterized. Further experiments, results and analysis from this point of view will be discussed in the paper and the presentation.

Acknowledgement:
This study is funded by the New Energy and Industrial Technology Development Organization (NEDO) in Japan.

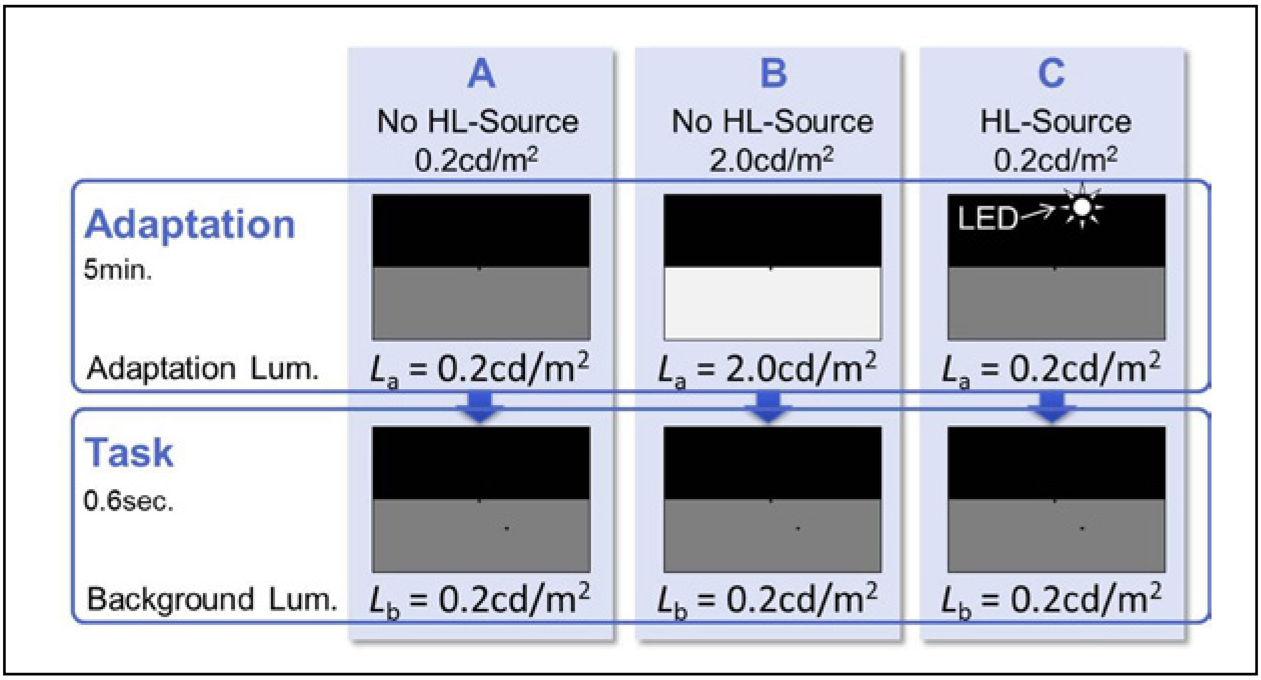

Figure 1 - Adaptation and Task Conditions

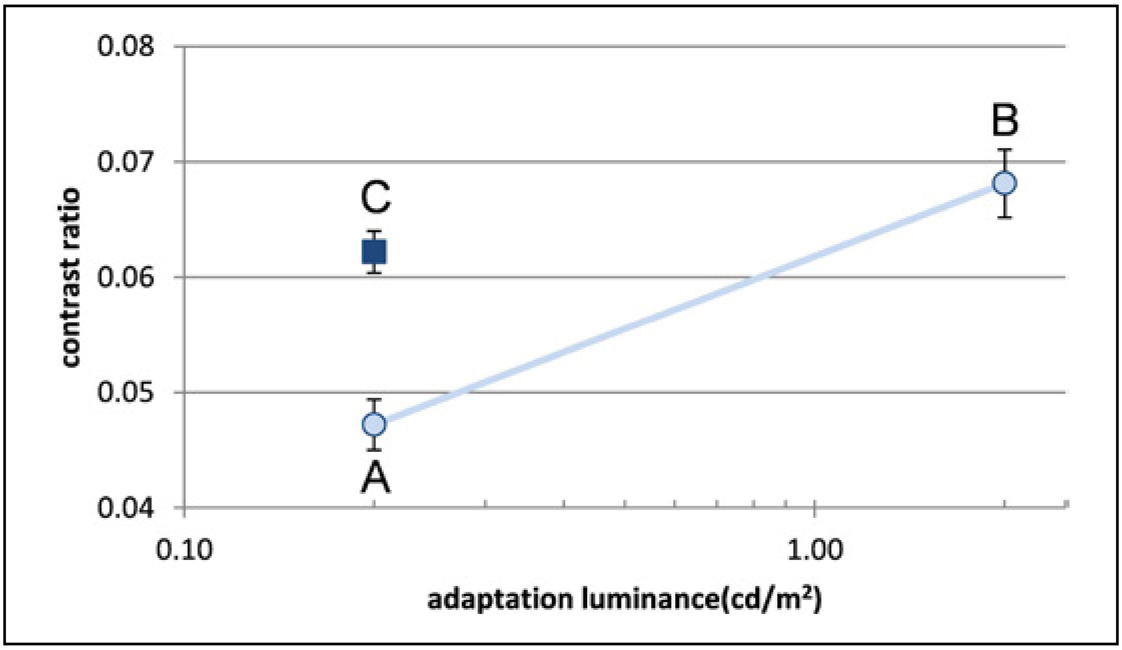

Figure 2 - Luminance Contrast Detection Thresholds of a Subject

D1 - Vision and Colour
Miscellaneous

PP014

PUTTING SHADOW INTO NUMBERS

Yao, H., Li, X.
Yaming Lighting company, Shanghai, China.

Objective:

"Wherever there is light, there is shadow". Each light source creates one shadow per object, and more light sources create more shadows. With the wide application of LED light sources, point-like light source bring in a new term as "multi-shadow". With more than one shadows near an object overlapping with each, lighting quality could be affected. Shadow is part of the lighting, and it plays a very important role in lighting design. Shadows give an image dimension. They add texture and create force lines. There are "wanted" shadows which could create interesting lighting effects; there are also "unwanted" shadows, which could be disturbing and even cause safety issues in certain environment. We could not get rid of shadows, but we could "fill in" shadows by adding light to the dark areas with an extra light source, flattening the visual contrast and making the shadow less obvious. However, how "obvious" is "obvious"? How to quantitatively describe a shadow? How to compare different shadows? How to systematically evaluate shadow effects? Even though there has been some research work as well as practical experiences in controlling shadows, there is not much quantitative research on this subject. In this paper, we try to establish a scientific method to measure, analyze, quantize and evaluate shadows.

Methods:

To make shadows, there are three main participants: the light source, the object, and the projection surface. There are three different scenarios where "multi-shadow" could be observed: multi-shadow could be caused by one single luminaire which is composed of more than one light sources (for example a LED luminaire); multi-shadow could be caused by more than one luminaires; and in a more complicated situation, multi-shadow could be caused by more than one luminaires which are composed of more than one light sources. As the study is in progress, the experiments as well as the results shown here are intended to be preliminary ones. We started our research with the second situation.

Our experiments have been carried out in the High-bay Factory lab at Yaming Lighting Application Center where luminaries could be conveniently adjusted to create different lighting conditions to meet our experimental needs. To simplify the situation, we started with a simple object and two lighting conditions. We taped a piece of rectangular- shaped cardboard on the side wall as object, and turned on 4 and 8 luminaires on the ceiling respectively to create two different shadow images (case A and case B) on the wall. We measured and analyzed the shadows with the ProMetric CCD camera system.

Results:

In both cases, we obtained the luminance distribution images, and mapped out the Cross Section Charts along a horizontal reference line (as shown in graph1 and graph2). The Cross Section Chart is a composite analysis tool. The left side of the Cross Section Chart is composed of the

Bitmap graph and the right side of the chart displays the cross section graph. This display shows the relative percentage values of luminance over the max value at each position across each cross section reference line.

Even though the two shadow images are very similar from the bitmap graph on the left (also observed by the eyes), we noticed distinctive different features on the two cross section graphs, where the shadow image in case B shows more complicated structures than in case A. Each step on the curve reflects one additional shadow. The relative width, height of different features on the luminance percentage curve along well-defined reference lines could give out very rich quantitative information for a multi-shadow.

Conclusions:

Preliminary results are very promising, as different shadows could be quantitatively identified. This research is still in progress, and our next step is to carry out more systematical study on the quantification of shadows. We would identify a few "shadow index" numbers that could be the fingerprint of a given shadow. With these "shadow index", we would expect to be able to evaluate the effects of shadow in lighting design quantitatively.

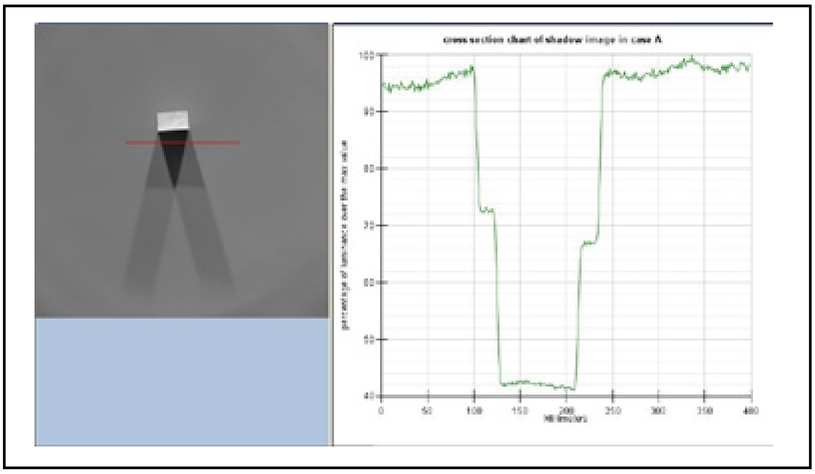

Figure 1

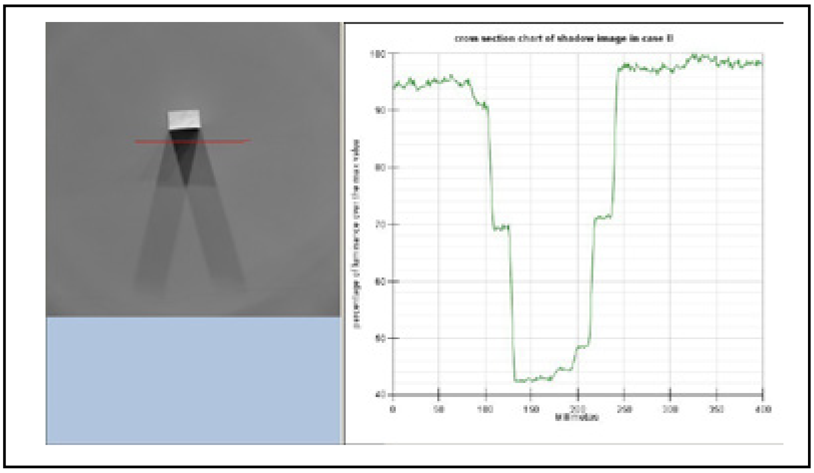

Figure 2

PP015

EILV ONLINE – AN EXCELLENT PRINCIPLE

Liljefors, A.
KTH Architecture, Lighting 1983-2002, Stockholm, Sweden.

eILV opens to the possibility of direct access to terms and definitions according to topical science of related subjects. eILV in main leans upon last printed edition, ILV 1987, now in certain respects not in accordance with topical science. The digital version on line, though, has the great advantage of accomplishing motivated revisions successively.
Comments to terms of eILV show the urgent need for clear terms and definitions in concordance with topical science. Such established terms of eILV will confidently support any professional communication within the area of lighting.

NOTE: Citations below from CIE ILV: 9 pt
Author‘s comments: 10 pt

CIE eILV 2012
a. Now published version edited and rewritten after detailed discussions among the National Committees of current member-countries of CIE. Experts of different topics related to lighting hereby expected to guarantee scientific topicality and reliability. So far though, this elementary claim not fulfilled. This statement developed below by concrete examples:

17-1402 visible radiation
any optical radiation capable of causing a visual sensation directly
b. This term falsified 1905 by Einstein‘s detection of electromagnetic energy composed by not visible photon flows. (ref.1). Vision physiology (ref.2) states no direct connections with photon stimuli 380-780 nm and qualities of visual perception. „Visible radiation“ and any conclusion laid hereupon are pure nonsense.

17-659 light
sensations and perceptions that is specific to vision
view of its ability to excite the human visual system
This term has 2 meanings that should be clearly distinguished. When necessary to avoid confusion between these 2 meanings the term „perceived light“ used in the first sense.
NOTE 2 Light is normally, but not always, perceived as a result of the action of a light stimulus on the visual system. c. Stated ambiguity has its rise in the wrongful assumption of light being visible radiation. The twofold definition of the term light, stating equal physical stimulus and visual perception conflicts with
1. science of physics since 1905 (photons not visible; ref.1).
vision physiology 1930-50 (except for the visible spectrum, no
and qualities perceived; ref.2).
vision‘s physical stimuli being visible radiation still the foundation of CIE Lighting Technology and CIPM Photometry.

17-1222 spectral luminous efficiency (of a monochromatic radiation of wavelength λ) [V(λ) for photopic vision; V'(λ) for scotopic vision] ratio of the radiant flux at wavelength, λm, to that at wavelength, λ, such that both produce equally intense luminous sensations under specified photometric conditions and lm is chosen so that the maximum value of this ratio is equal to 1. NOTES 1-5 no comments
e.The idea of „spectral luminous efficiency" emanates from the base of CIE Lighting Technology

17-1402 visible radiation . any optical radiation capable of causing a visual sensation directly Perceived by a visible spectrum, brightness varies over the part 380-780 nm – from zero by ends over maximum by the middle, ca 580 nm. The logic conclusion hereof – laid upon stated direct connection with brightness and perception – gave rise to extensive
1. characteristic of all
2. radiation that is considered from the point of
2. direct connections with photon stimuli
The false assumption of
NOTE 1
studies of luminous efficacy, performed by member countries of CIE 1913-1923.
These investigations, though, regarded visual judgments of perceived brightness under monochromatic stimuli
of certain effect, each 10 nm over 380-780 nm. Monochromatic stimuli hereby clearly states the V(λ) -curve a special case, valid solely for visual perception by such stimuli.

According to current vision science (ref. 2) visual perception generally founded upon photon stimuli absorbed by cooperation of cones SML, these covering the range 380-780 nm in whole. Thus, Photometry has no relevance to visual perception in general, and should be replaced by a new measurement system laid upon topical science of vision. Modern vision physiology (ref. 2) states visual perception in general performed by a process where direct connections with photon stimuli and perceived qualities do not exist. The vision process relates to photon stimuli 380-780 nm, simultaneously absorbed by cooperation of cones SML. These processes further accounted for by final paper.

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PP016

THE LIGHT DIRECTION AND DIRECTIONAL LIGHT—TOWARDS A NEW QUANTIFICATION OF AN ESSENTIAL LIGHTING QUALITY CRITERION

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Facing the introduction of modern light technologies such as LED and OLED, we rise to the challenge to tap the full potential offered by new lighting concepts in interiors. This is not just a matter of a lamp retrofit or a modern luminaire design; moreover it is a matter of change regarding the evaluation of lighting quality. We have to rethink the usage of the present—well established—quality criteria. These are to be examined carefully towards their applicability regarding LED and OLED, refined and possibly redefined.

The light direction and directional lighting, as being a part of present quality criteria for interior lighting, and its relevance regarding LED and OLED lighting is of particular importance. In LED lighting, we are now facing the problem to use a light source that emits strongly directed light, not comparable to any light source before. Is the directed light of an LED a disadvantage, which needs to be compensated? Or is this the chance of a new quality in interior lighting and needs to considered as a benefit? Are we asking the same questions for OLED lighting regarding an absolutely diffused lighting one day?

In order to answer these questions, research at TU Berlin deals with the light direction and directional lighting in terms of characterisation, measurement and rating and aims at the application in lighting design practice.

To build a new model for characterising the light direction, it is essential to consider this parameter as being related to the entire space. In the present technical point of view the light distribution and levels in interiors are typically related to surfaces, e.g. illuminance at the task area and the luminance distribution at walls and ceilings. However, this approach is unrewarding to describe the light direction, while the rating of the distribution regarding a main light incidence direction and the balance of directional and diffused lighting is based on the spatial perception.

The issue of a spatial characterisation of the illumination was a main part of several prior approaches—all immaterial in today's lighting design practice—which are taken into consideration in creating a new model of light direction. Wilhelm Arndt described a spatial approach for illumination already in 1928 (1). He characterised the 'concentration of light' or 'brightness potential' in a three-dimensional grid in a room and called this indicator "Raumhelligkeit", today well-known as spherical illuminance. He advised the usage of the spatial distribution of this spherical illuminance, as representing the spatial experience, to describe a lit environment. In the same year another spatial approach was published by Heinrich Lingenfelser (2). His model, called "illuminance distribution solid", is a distinguishing component for the quantification of the balance of directional and diffused lighting. For each point in space the solid shows the distribution of illuminance levels—measured in all directions, centred in the point—graphically. The measured levels, representing the illuminance magnitudes in a specific direction, are then connected to a three-dimensional solid. The balance of directional and diffused lighting can be directly identified by the shape of the solid surface; e.g. a spherical shape represents a completely diffused lighting. The

third significant approach is the theory of the light field, extensively illustrated by Geršun in 1939 (3). Comparable in structure to the electromagnetic field, the light field characterises the light distribution in form of flux lines, which visualises the flow of light in the space very well.
After identification of the potentials and limitations of each, all three methods are used to form the basis for a new model to characterise the light incidence at any point in space and subsequently for the whole space. At the first time this model provides a quantification of the light incidence and the balance of directional and diffused lighting, which is essential to achieve high quality LED and OLED lighting. In further research steps this will lead to a new measurable and rateable indicator, which can be taken into account in the lighting design process easily.

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D2 - Measurement
Measurement of Material

PP018

LIGHT DIFFUSING POWER OF TRANSLUCENT GLAZING

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New solutions for energy effective multilayer glazing have been developed during the last few years. Many of them have a diffusing layer or diffusing surface on minimum one side. Also new materials having great thermal insulation ability have been developed, e.g. silica aerogel that are typically sealed between to layers of glass. Most of the translucent insulation materials also have a strong diffusing effect on light. Can this effect be measured? How?
For the purpose of this study Translucent Glazing comprises of all types of facade glazing which diffuse light, although the diffusing effect may be different for each of them.
The selection of glazing can be critical to the success of an architectural project. It is especially important for the visual image of a translucent façade, both inside and outside, and for the light distribution in interiors. The impression of spaciousness and friendliness of interiors, the modeling of objects and human faces as well as the atmosphere of an interior depends strongly on light distribution.

The notion of Light Diffusing Power (LDP) is a new measurement and rating system proposed by Advanced Glazing Ltd http://www.advancedglazings.com/ldp/.
The rating of translucent glazing proposed by Advanced Glazing Ltd is based on measurements of the radiant intensity of light after passing a material sample that is illuminated by a quartz halogen spotlight positioned to make the incident angle of 45 degrees.
The method is not optimal for buildings situated at high latitudes, e.g. Oslo, where the average yearly solar angle at noon is about 30 degrees. Also the way of rating proposed by Advanced Glazing Ltd may be discussed. It takes into consideration only the part of light flux that is diffused upwards, neglecting the rest of it. Such rating depends very much on incidence angle of light. Most translucent materials will diffuse 50% of transmitted light flux upwards if the incidence angle is 0, while the percentage of upward light flux for 45 deg inc. angle may vary from nearly 0 to nearly 50%.

An alternative method is proposed in the paper. It comprises of the usage of a light source that mimics sunlight e.g. the Artificial Sun developed at NTNU Faculty of Architecture, see photo 1. The Artificial Sun enables very even illumination of considerably large surfaces, up to 900 x 900 mm, something that is necessary when full-scale samples of building façade elements are to be evaluated.

The proposed method starts with measurements of angle-dependent luminance on the back side of the sample while it is evenly illuminated on the front side, see figure 1.
It may be observed that materials having very strong diffusing power transmit light quite evenly in all directions; theoretically they are Lambertian's diffusers. On the other hand, materials that have weak diffusing power transmit most light in the direction of incidence light and in directions close to it.

We propose to categorize the light diffusing power of building samples depending on the percentage of light flux transmitted by the sample in the direction of incidence light and directions close to it (up to 5°, 10° or 20° from the direction of incidence light), to the light flux transmitted by the sample in all measured directions.

The following categories are proposed: Very strong, Strong, Moderate and Weak.
The new evaluation method was used in the scientific project "Translucent facades" sponsored by the Norwegian Research Council. The Light Diffusing Power of 7 different building material samples was measured.

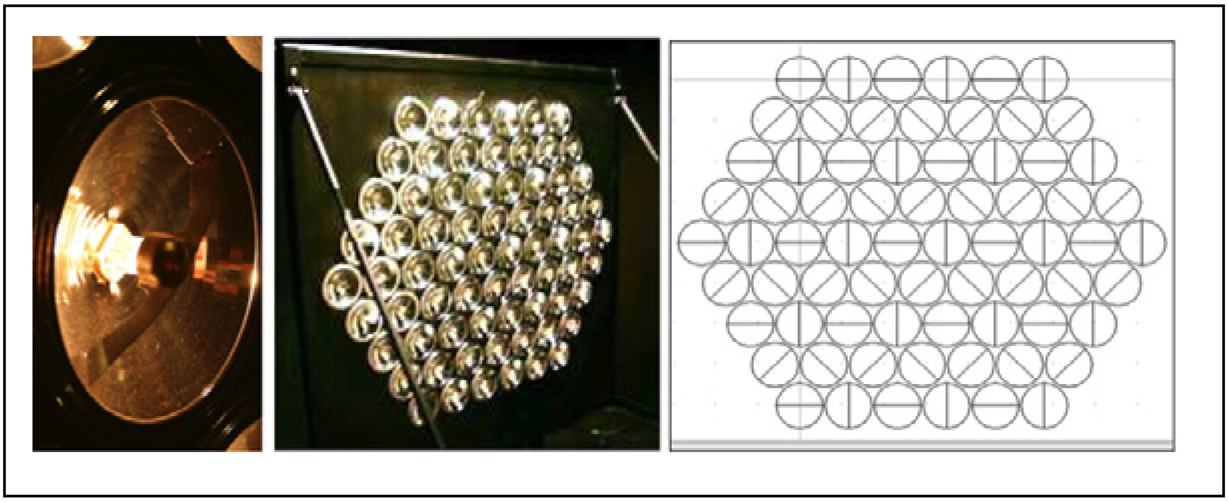

Photo 1 - Artificial Sun, NTNU, Faculty of architecture

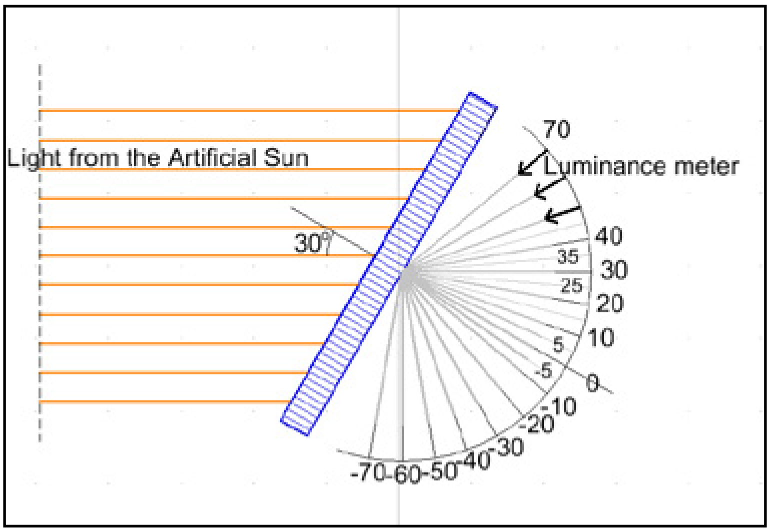

Figure 1 - The measurement method

PP019

EVALUATION OF REFLECTIVE AND TRANSPARENT DISPLAYS USING BRDF/BTDF MEASUREMENT SYSTEM

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To measure the characteristics of newly developed reflective/transparent displays for energy saving, we developed a bidirectional reflectance/transmittance distribution function (BRDF/BTDF) measurement system.

In evaluating the new displays of the reflective and transparent displays, it is important to measure the angular distribution of reflectance and transmittance. We developed BRDF/BTDF measurement system with two configurations. One uses monochromatic light source for fine tuning of wavelength and a photodiode as a detector. The wavelength tunable source consists of a tungsten halogen lamp and a monochromator. The other configuration has a white light source and a spectroradiometer, which offers high speed measurement. A goniometer with two rotation stages for a sample and a detector offers the measurement of BRDF/BTDF.

As an experimental demonstration, we measured BRDF/BTDF of a color reflective display and a transparent display. The experimental data for angle distribution (-60 deg. ~ 60 deg.) at visible wavelength range were obtained. We evaluated the reflection/transmission properties of displays. For the reflective display, the reflection characteristics including regular and diffuse reflections were evaluated. For the transparent display, we obtained angular distribution of transmittance and analyzed the characteristics in terms of haze.

In conclusion, we developed BRDF/BTDF measurement system to evaluate the newly developed displays of reflective and transparent displays. As an experimental example, we measured BRDF/BTDFs of the displays and evaluated the properties. We expect that the BRDF/BTDF system will be useful in evaluating the new reflective/transparent displays.

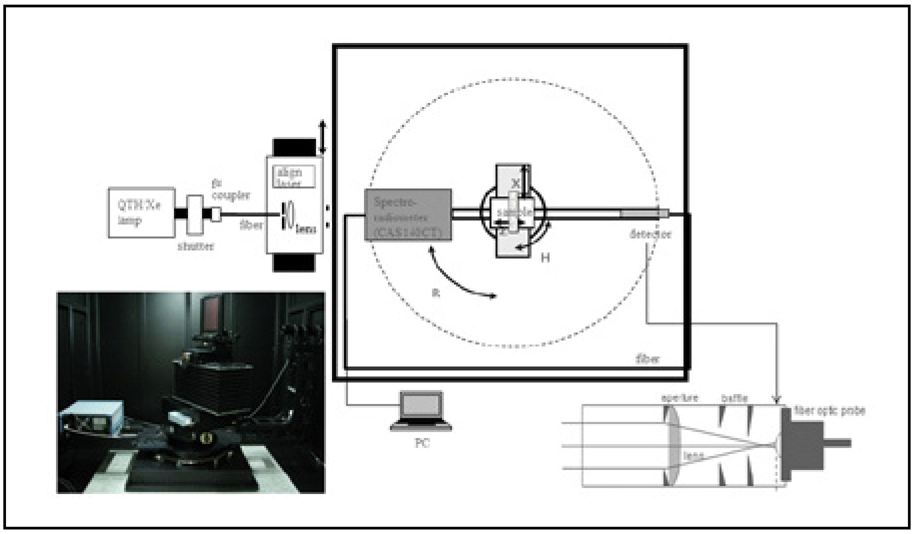

Figure 1 - Schematic design of BRDF/BTDF system

PP020

BI-DIRECTIONAL SCATTERING DISTRIBUTION DATA OF SOLAR SHADING: CHARACTERIZATION AND PERFORMANCES

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1.CONTEXT

Solar shading devices have been used for many years to protect building occupants from the negative effects of solar radiation (diffuse daylight and direct sunlight). Due to increased focus on energy efficiency and better awareness for the beneficial effect of daylight access in buildings solar shading systems have become critical issues to guarantee thermal and visual comfort of occupants.

2.INTRODUCTION

No accurate performance characterization for the comportment of the solar shading is available and used. The most simplified models consider solar shading as a uniform parallel layer which reduces incoming light fluxes by a fixed factor without taking into account the angular-dependent material properties that affect light and energy distribution patterns.

The real situation is indeed more complex. The first issue is that incident radiation is not only direct solar beam radiation but the diffuse sky component also needs to be considered. The second issue is that light interacts with the 'window/solar shading' complex and that multiple reflections and transmissions determine the distribution patterns.These physical phenomena can only be calculated using advanced simulation techniques. For accurate analysis of light and energy radiation ray-tracing techniques are required. The visual performance assessment will be done with simulations and checked to real conditions by comparison to an experimental setup for a typical room.

3.BI DIRECTIONAL SCATTERING DISTRIBUTION FUNCTIONS

The use of bi directional scattering distribution function functions allows a detailed characterizing of the real properties of materials and surfaces.

Bi-directional scattering distribution functions were measured for different solar shading materials (woven shade- screen and aluminium surfaces with different finishes).

The reflected and transmitted components are defined and measured separately as BRDF (Bi-directional reflectance distribution function) and BTDF (Bidirectional transmittance distribution function) as illustrated in figure 1.

4.FORWARD RAY-TRACING SIMULATIONS AND MEASUREMENTS

Most lighting simulation software consider all surfaces as perfect diffuse materials. Directionality of the artificial light source is taken into account by using detailed photometric files for the luminaire but angle-dependent properties of materials are generally ignored.

Specific software applications are able to take various bi-directional scattering distributions for materials into account. Software packages integrating BSDF-data and using forward raytracing algorithms are commonly used in aerospace and automotive industries. The PROSOLIS project of the Belgian Building Research Institute is applying thesetools to the building industry in order to simulate complex fenestration system and daylight redirecting system.

The use of BSDF-Data into the Light Tools software allows to estimatite and visualize direct and diffuse light penetration.

Comparisons of on-site measurements and software simulations will help understanding the modelling of BSDF-data, validating the software and predicting the performances of solar shadings under solar radiation (see figure 2).

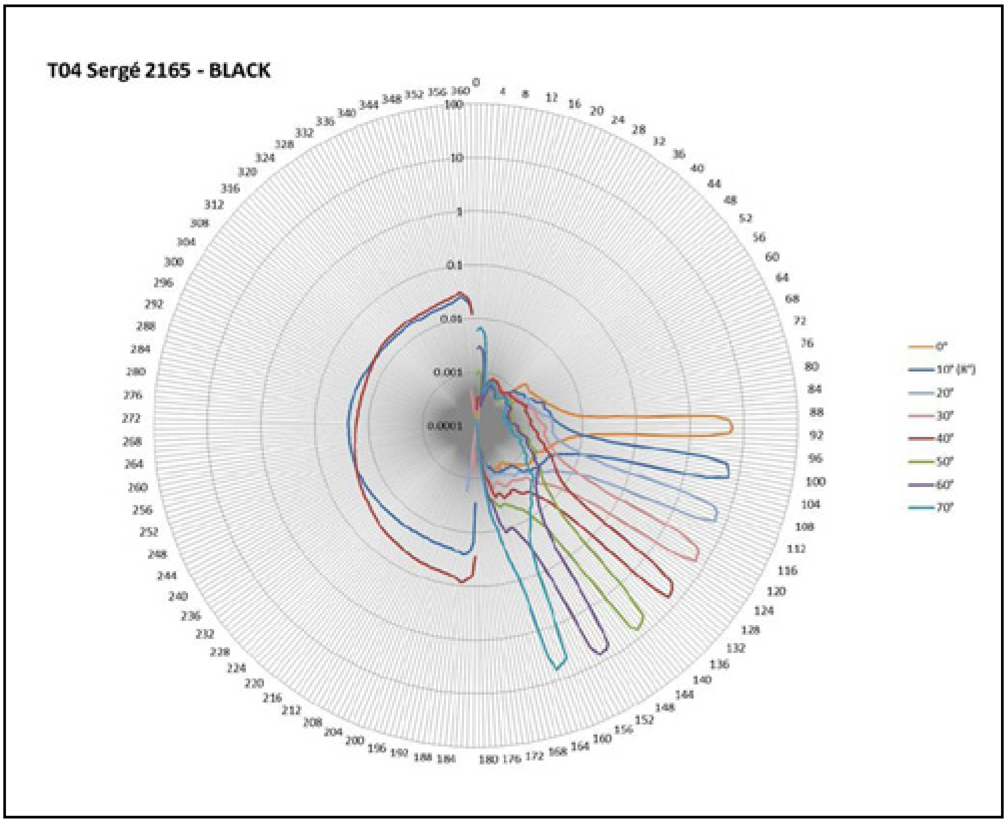

Figure 1 - Representation of BTDF and BRDF in vertical plane for different specific incident angles (0°, 10°, 20°, 30°, 40°, 50°, 60°, 70° for the BSDF – 8° and 40° for the BRDF)

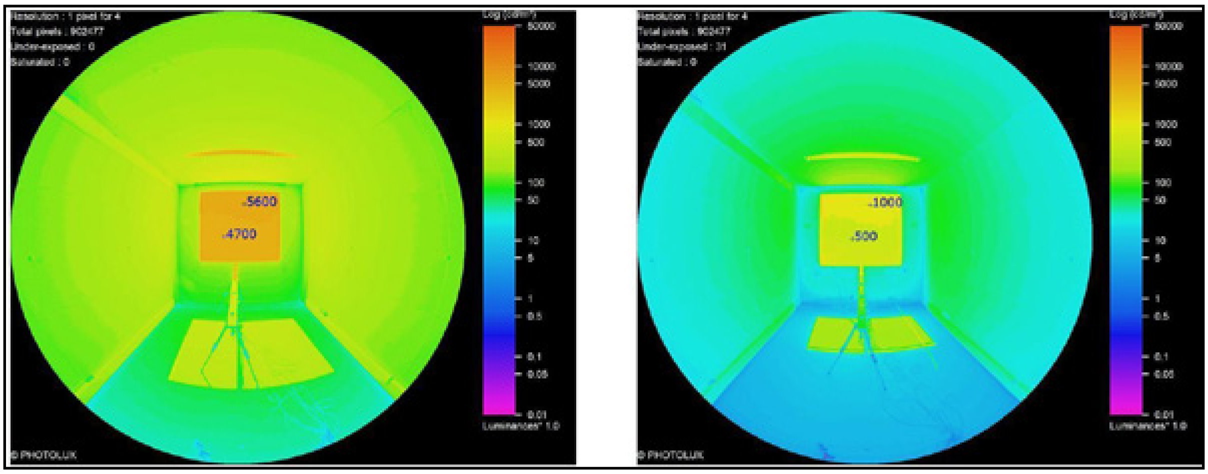

Figure 2 - Luminance maps for a viewpoint in the testroom under clear sky at 10 Augustus and 7 September for different solar shading material

PP021

MEASUREMENT OF TYPICAL ROAD SURFACE REFLECTANCE IN CHINA

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The reflection characteristics of road surfaces are essential for properly designing a lighting installation. CIE (International Lighting Committee) has established a "road surface classification system", which contains reflection tables of representative standard road surfaces and is well adopted by several countries. However, after several decades of developments in road materials, recent studies showed that the reflection characteristics of materials currently used for road surfaces are different from the ones considered in the standard. As a consequence, the CIE r- table needs to be updated to properly evaluate current lighting application on the road from visual performance and energy conservation aspects. This paper reports an experimental set-up for measuring reflectance of selected road samples in China. The experimental set-up consists of a specifically modified goniophotometer applied in a laboratory environment. The road samples are considered representatives for the materials and use conditions currently in use in China according to literature and a field study.

Measurement methodology: Based on literature available on relevant algorithms, laboratory or in-situ measurement systems and methodologies, we built a laboratory measurement system for road surface reflectance. The measurement system is built upon an existing goniophotometer, see Figure 1. A collimated light source is fixed on a rotating arm of the goniophotometer to provide the incident light beam. In the optical path of the incident beam, the light is reflected by Mirror 1 and Mirror 2 to further reduce its angular spread. As a consequence, the light path between the light source and measured sample surface is 11 meters. The position of the light source, Mirror 1 and Mirror 2 are designed so that the main optical axis of the light source is always passing through the center of the road sample.The road sample is installed horizontally on a holder and centered at the intersection of Axis 1 and 2. The luminance meter is also installed on a holder, such that the road sample is seen through Mirror 3, which can be adjusted to insure a 1° angle of observation. Software is programmed to sychronize the goniophotometer and luminance meter, to provide automatic measurements and to save the measurement data.

Trial runs with this measurement system on standard diffuse panels and real asphalt road samples have been carried out. They prove that the system is capable of measuring road surface reflectivity over the full incident angle from 0° to 90°, and with azimuth angles from 0° to 180°. The angular position reproducibility of the goniophotometer is 0.1°. And the measurement reproducibility of the luminance meter is 4%.

Road sample selections: The reflection characteristics of road surfaces are influenced mainly by

their surface material, rock (aggregate) type, traffic volume and age of the surface . By doing a literature study, field survey and interview, we found that alsphalt is the dominant material in road constructions in China. The typical alsphalt recipes are SMA-13 and AC-13. Hence, the samples selected for the measurements are catogorized into material recipe (SMA, AC) and service time (newly made, 2~6 years used). The used road surface samples are all collected from real in-use roads in Shanghai with 2~6 years of service time.

Results and discussions: We currently perform the road reflectance measurements with this system. Some reflectance data will be published and discussed later in the full paper.

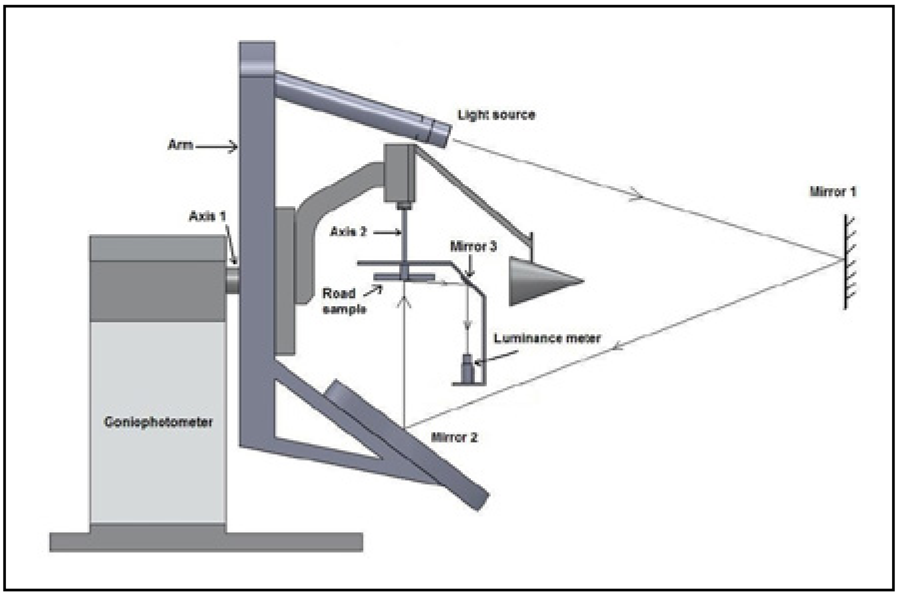

Figure 1 - Schematic diagram of measurement system for road surface reflectance

D2 - Measurement
Measurement of LEDs

PP026

OPTIMAL THERMAL MANAGEMENT OF LED LIGHTING SYSTEMS REGARDING EFFICIENCY AND COSTS

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Thermal impact in packaged high-power LEDs is critical to the reliability and performance of the device. Most significantly, the LED's lifetime at given photometric and colorimetric characteristics can be improved by lowering the junction temperature. The optimal cooling solution depends on the strongly application specific boundary conditions and requirements concerning design, functionality, financial budget and many other aspects.

In this paper, a systematic approach for the achievement of optimal cooling solution of LED lighting systems is presented. For this purpose, a variety of factors, such as thermal conductivities and capacitances, material and geometric properties, fastening methods, are discussed on a concrete example of a LED spotlight. This contribution shows, that the choice of incorrectly specified elements can cause disadvantages, which should be rectified at a more advanced stage of device development by cost-driving and complex measures. The experimental approach to derive the LED junction temperature is determined by transient thermal analysis. A very good agreement is obtained between numerical and experimental results.

PP027

APPLICATION OF LIGHT-EMITTING DIODES IN OPTICAL METROLOGY

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Light-emitting diodes (LEDs) are opening a new era of lighting not only in the everyday life. In science and engineering, LEDs also offer new possibilities to improve the conventional instrumentation and methodology. High spectral power, high directionality, high efficiency and stability, small size, and good availability of LEDs are of particular interest in the field of optical metrology, where light sources are used as a tool for measurement.

In this presentation, we summarize our recent works of LED applications in optical metrology. We classify the applications into three categories. The first category uses the quasi-monochromatic emission property of LEDs to make a spectrally tunable source. Nowadays, a wide area of wavelength can be covered by LEDs of different colours. We present two experimental realizations of tunable sources: one for measuring the differential spectral responsivity of photovoltaic detectors and the other for measuring the normalized spectral responsivity of imaging sensors.

The second category of application is based on the pulsed operation of LEDs. LEDs can be modulated with high bandwidth, and the modulation can be reliably controlled via the power supply. We present two experimental applications of pulsed LEDs: one for measuring the non-linearity of optical detectors with an accuracy level of 10-6, and the other for realizing a controllable flashing light source, which is used to characterize a flashing photometer for effective intensity measurement.

The third category uses the high stability and durability of LEDs to develop the standard calibration sources for photometry and radiometry. We developed a LED-based integrating sphere source for calibration and characterization of luminance meters, colorimeters, and spectro-radiometers. The LEDs attached to the integrating sphere can be flexibly changed to meet the requirement of various applications.

PP028

SPATIAL COLOR DISTRIBUTION OF WHITE LED LUMINAIRES

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The number of SSL products in general lighting applications is rapidly increasing. Therefore higher quality demands are set up for white LEDs. A thorough characterization of luminaires also includes colorimetric data such as the correlated color temperature (CCT) as well as the color rendering index (CRI).

So far, standards have recommended providing spatially averaged values for color quantities [1, 2]. For high power white LEDs, studies [3, 4] have shown that contrary to incandescent lamps the correlated color temperature can vary significantly with the viewing angles θ and φ. For example the so called angular CCT deviation of a white LED with 6.500 K has reached up to 3.000 K [5] whereas in this color temperature region a deviation along the black-body radiation curve of 1.000 K has been found very disturbing. The tolerance threshold for CCT deviations for warm white light sources is much lower [6].

CCT deviation over angle seems to be a relevant quality criterion. Since the spectral power distribution of LED luminaires is depending on the angle of radiation and the optical system, measurement and documentation of a spatial color distribution for LED luminaires should be obligatory. In this study the following setup for measurement of spatial color distributions was used.

The setup (Figure 1) consists of a centric moving mirror goniophotometer combined with an array spectroradiometer. The spectroradiometric detector can be moved in longitudinal direction. For the presented measurements the detector was set in a distance of seven meters. A stray light elimination tube with different apertures is mounted in front of the optical probe of the spectrometer. Depending on the distance between light source and detector, the apertures can be adjusted. A simultaneous characterization of photometric, spectroradiometric and colorimetric data is possible.
So far twenty different warm white LED retrofits have been examined with constant angle φ and varying angle γ (0° to 120°, Δγ = 15°) in the CIE C-gamma coordinate system. CCT deviations from 30 K to 300 K were found. The calculated tolerance thresholds for warm white sources are shown in Table 1 [6].

For some LED samples, with increasing angle γ critical deviations of the correlated color temperature from main beam direction could be observed (one example in Figure 2).

Further results on the spatial color distribution of white LED luminaires will be presented at the conference.

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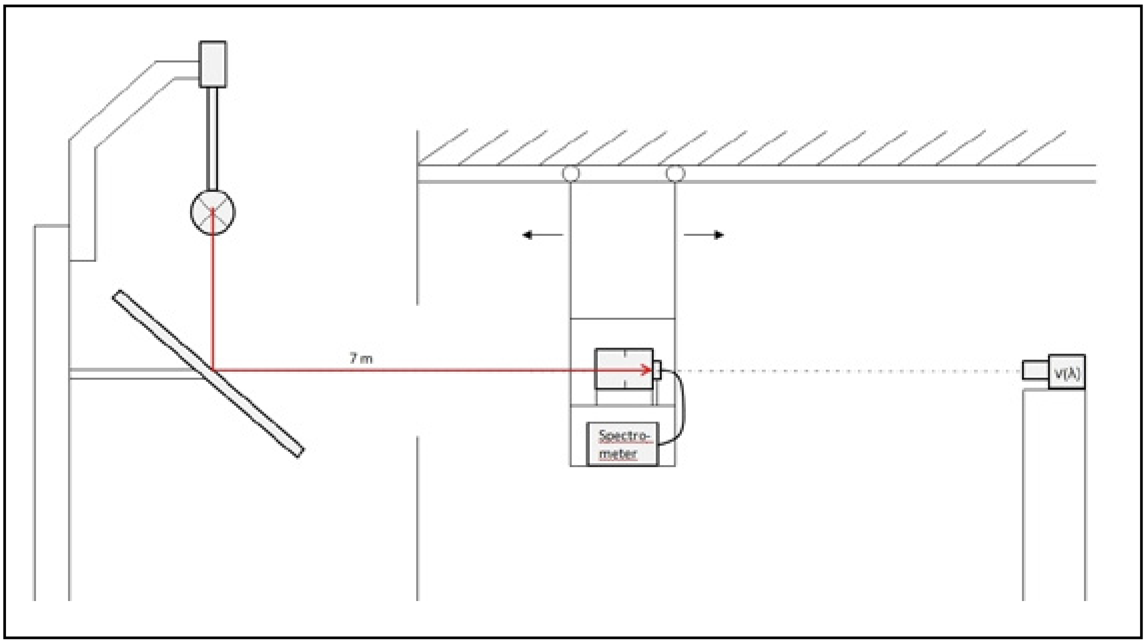

Figure 1 - Measurement Setup

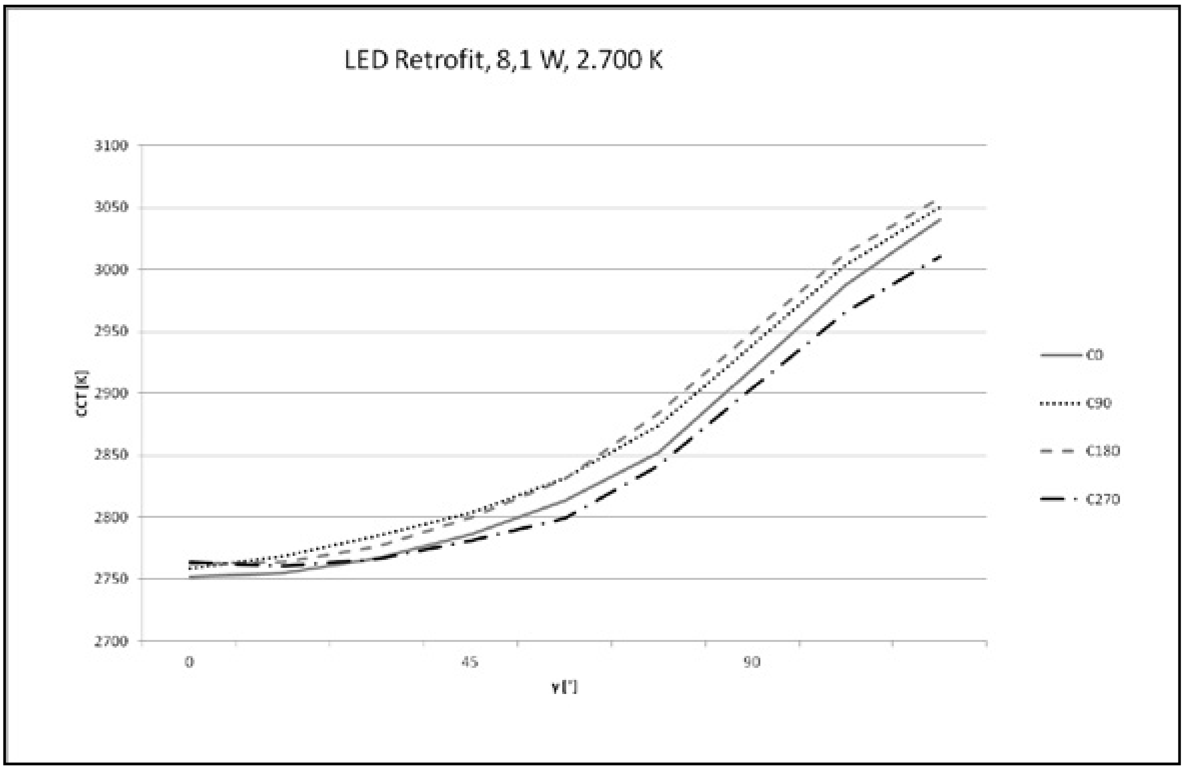

Figure 2 - CCT deviations for a warm white LED sample

	ΔCCT		
CCT	barely recognized	definitely seen	very disturbing
2700	27	60	134
3000	34	76	171

Table 1 - Tolerance thresholds for CCT deviations

PP029

EVALUATION OF LED SOURCE DEGRADATION

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[3] OSP Vatra Corporation LTD, Ternopil, Ukraine.

As is known [1], the value of LED light flow F in the process of LED operation is not constant. This is related to processes within the diodes themselves and requires consideration for their degradation over time.
In view of a wide range of initial LED parameters, the task of predicting them is, in general form, a statistical one, the process of light flow changes over time F(t) being a random, non-stationary one.

The extent of light flow decrease ΔF for any operating time tn with respect to the initial value F0 can be defined as
ΔF(t) = Fmax - F(t) / Fmax = [1 - e-α(t-tmax)] * 100% (1)

F(t) being the value of LED emission flow after t hours of operation;
Fmax being the maximum value of LED emission flow at t=tmax;
α being the degradation coefficient, which is determined on the basis of the expression [2]:

α = -1 / t *ln* F(t) / F0

The main characteristics of the random process of light flow change – density f(F) and integral distribution function F(F) – can be determined in the form [3, 4]
f(F) = 1 / σF * √2π * e-(Fi-mF)/2σF 2 (2)
F(F) = 1 / σF* √2π *∫-∞F e-(Fi-mF)2/σF2 dF (3)

Fi being the random value of light flow F; mF being the mathematical expectancy of casual value F, mF = ∑i=1nFi / n; σF being the standard root-mean-square deviation of random value F; and σF = √DF ; DF being the dispersion of casual value F, DF = ∑ 1n(Fi-mF)2 / n-1
Under conditions of even density of light flow distribution, we get:
f(F) = 1 / F2 - F1 (4)
F1 = mF – β * σF,F2 = mF + β * σF (5)
β being the statistical coefficient, determined by the preset probability limit Ex in accordance with the principle of practical confidence [5].
For that law, the calculated minimal Fμ and maximal Fm values of light flow are determined from the following conditions:
∫-∞Fμ f(F)dF = F(Fμ) =Ex (6)
∫-∞Fm f(F)dF = F(Fm) = 1 -Ex (7)

Ex being the integral probability limit.
By substituting the expressions (4) and (5) into (6) and (7), we get:

$$F\mu = F1 * (1 - Ex) + F2Ex \quad (8)$$

$$Fm = F2 * (1 - Ex) + F1Ex \quad (9)$$

Under these conditions, a LED is deemed to be out of service if its light flow has decreased to a certain end value Fk. Accordingly, the objective of assessing the extent of degradation can be achieved through an experiment lasting until the light flow of all light-emitting diodes goes down to a certain value Fn (fig. 2, a). In this case, the evaluation is performed on the basis of characteristics of observations of a set of time values Tn (Tn1 , Tn2) of achieving in the experimenting of process of level Fn (light circles). Thus, service time values are predicted on the basis of level Fk (dark circles) or of calculated minimal time value Tk1.
An alternative way is to predict the characteristics of light flow distribution for moment of time t' (dark circles) (Fig. 2, b) for the observed light flows for time section t (light circles).
The conducted research has shown that at a constant working temperature the change in the LED power and the frequency of LED switching on practically have no impact on the extent of their degradation. This makes it possible to considerably simplify the conduct of experiments when studying LED light flow over a long period of time.
The use of the developed prediction models and techniques makes it possible to evaluate the extent of LED degradation and to assess, on that basis, the quality of their operation.

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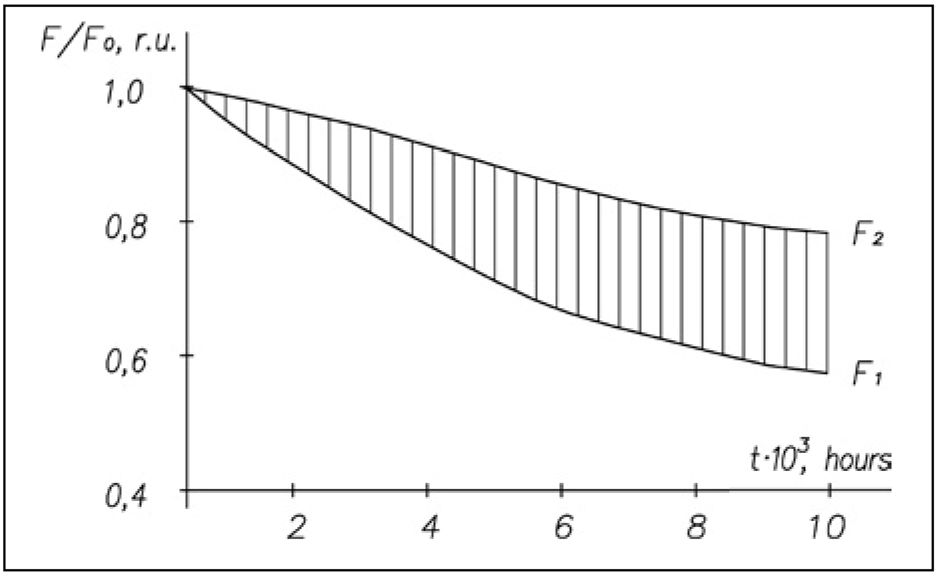

Figure 1 - Dependence of the change of light flux F1 and F2 of the LEDs on the time

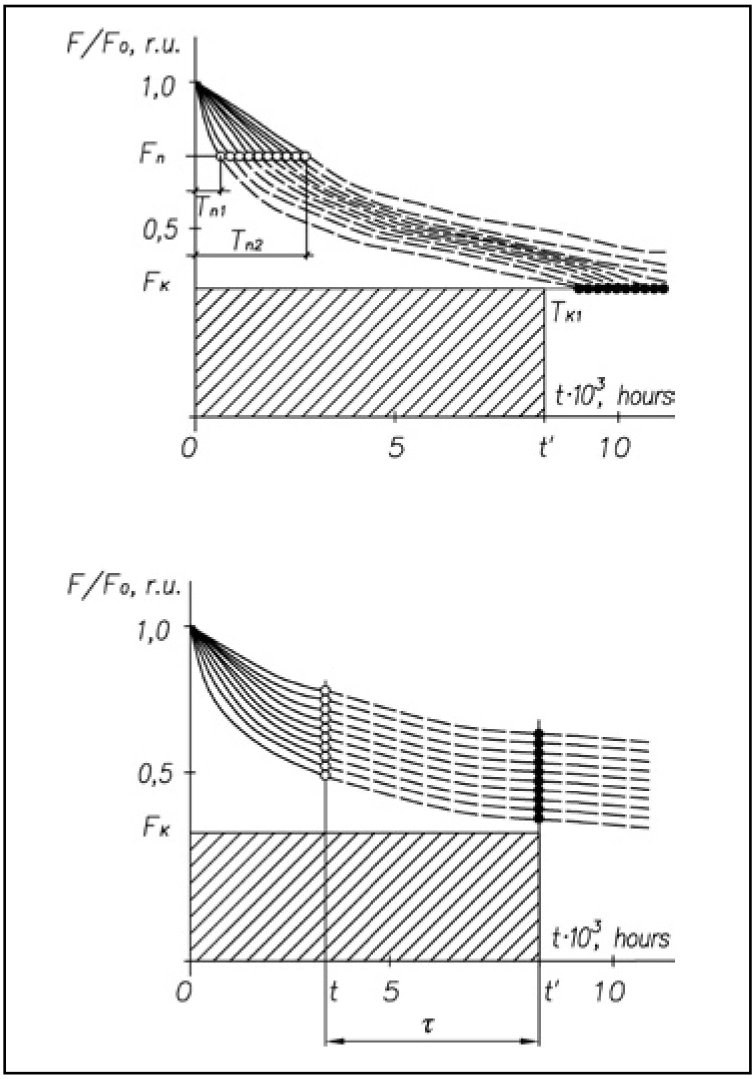

Figure 2 - Experimental curves of LEDs and prediction of aging: the horizontal (a), vertical (b)

PP030

THE FEATURES OF THE TESTING PROGRAM FOR LED LUMINAIRES AT VNISI TESTING CENTRE

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The indoor and outdoor illumination has to be corresponding to the norms, but firstly, they have to be healthy. That means we need to measure to get the characteristics in some numbers, which can to guarantee the quality of product by quantities. That is task for testing centers to check the quality of product at the luminaire market.
The new product needs the new approach in testing program. At Russian lighting market we can meet much different quality and therefore, we have to put barriers for bad, or potentially dangerous, product to be spread in country.
This paper devoted to the two new methodologies for LED luminaire testing program that are in way to be established as an individual optical stands for measurements:
-Stand for additional test of the stability and restorability of luminous and colour parameters of LED luminaires at temperature loading;
-Stand for LED luminaire BLH Radiance measurements.
The new Russian national standard was created by specialists from VNISI in 2010 and was confirmed by GOSSTANDART of Russian Federation in 2011. It is devoted to the luminaries for outdoor and indoor illumination, to the requirements of luminous characteristics and to methods of their testing.

Metrological characteristics and requirements of devices for luminaires colourimetric and photometric parameters measurements are also included in the document.
As an a step of testing there is an additional test to stability and restorability of luminous and colour parameters of LED luminaires at temperature loading included in national Russian standard. Testing is going on at climatic chamber with measurements of CCT (spectral distribution measurements by mini spectrometer and optical fiber putted inside the chamber) and illuminance measurements in some reference plane behind the chamber window by a photometric head, or with optical fiber, which one end is putting inside the chamber too. All measurements at each chamber temperature are compared with results of measurements at 25°C in this climatic chamber. Those results are taken to be equal (CCT) and proportional (luminous flux) to CCT and luminous flux measurements in normal laboratory conditions at 25°C by goniophotometer and spectrometer. The temperature points of measurements inside the climatic chamber are: +25°C, +50°C, +25°C, minus 40°C, +25°C. LED luminaire has positive result of testing if luminous flux decrease is not more than 30 % during the measurement procedure, and CCT change is not more, than + 500°K. The LED luminare, the test instruments and results of testing are presented on Fig.1 and in Table 1. The results of measurements in the climatic chamber are confirming the stability and restorability of colour and luminous characteristics of the LED luminaire [1].

Another type of measurements nowadays is the blue light hazard (BLH) measurements of lighting devices. In order to estimate BLH of LED luminaires we use the new approach of physiolo-

gical effective BLH radiance Lb evaluation [2]. This approach is based on combination of 2 type measurements: one is radiance relative spectral distribution measurements of luminaire luminous body, and the second is irradiance integral measurements by selective photoelectric detector with well known spectral sensitivity (see Fig.2). The main task solved by this way, is a realization of the „alternative“ method of BLH radiance measurement [3] and with taking into account physiological aspects of visual perception.
Approach suggested in the paper and its instrument realization can be applicable for definition of other effective radiant characteristics, Retinal Thermal Hazard for example, but with taking into account conditions of their physiological basis.

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2. Stolyarevskaya, R.I., Bartsev, A.A., Belyaev, R.I. “Methodology of Luminaire BLH Radiance Measurements” PROCEEDINGS of CIE 2012 „Lighting Quality and Energy Efficiency”, pp.215-222, 19 - 21 September 2012, Hangzhou, China
3. CIE standard “Photobiological Safety of Lamps and Lamp Systems” S009/IEC 62471(CIE:2002, IEC:2008)

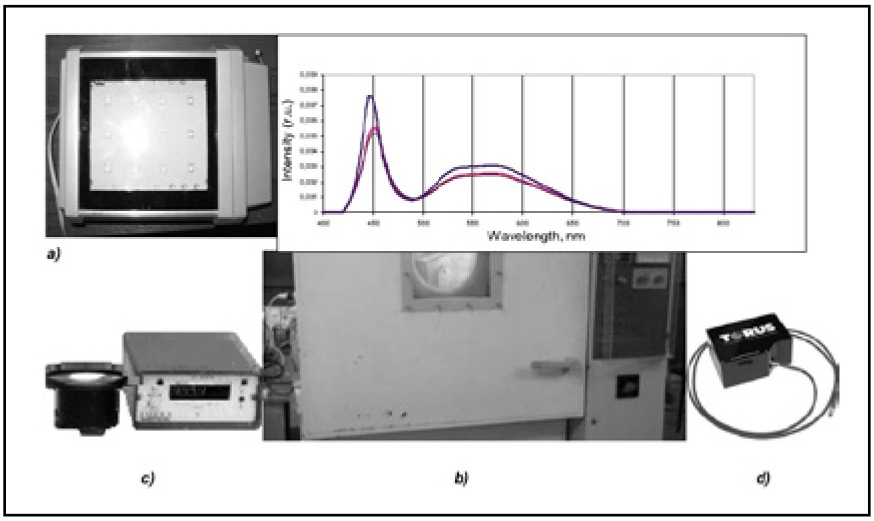

Figure 1 - a) – luminaire on basis of 12 LEDs XR –E 7090 type with driver LPC-20–700 (Meanwell), Φv=620 lm, P=18,9 W; i=0,238 A, it’s spectral distribution at different temperatures b) – climatic chamber; c) – photometric head; d) – minispectrometer

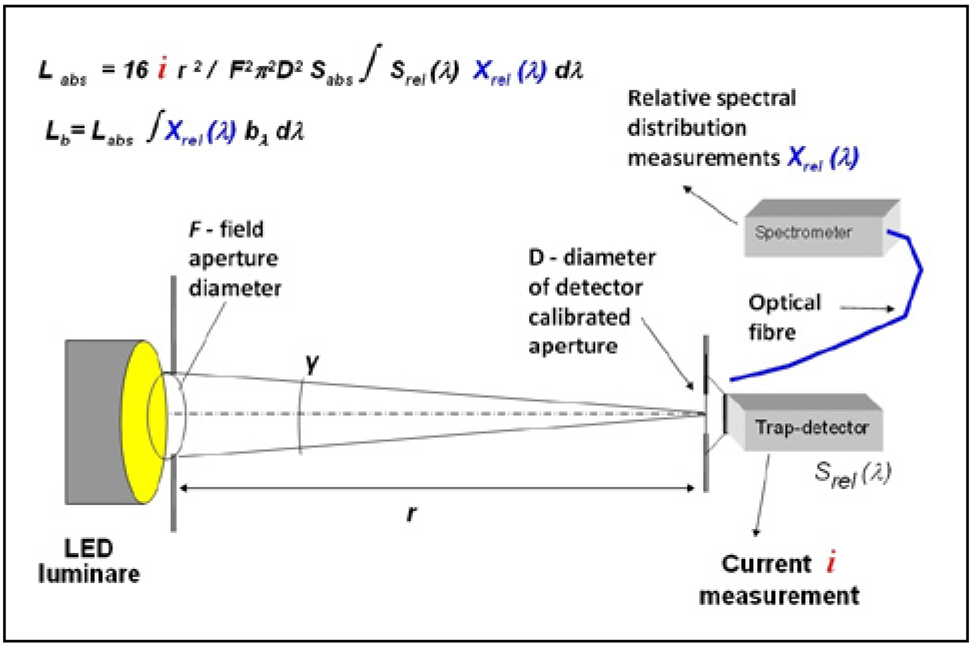

Figure 2 - Measurements and calculation of physiological effective BLH radiance Lb evaluation

Chamber temperature, °C	Luminous flux, rel.un.	Luminous flux, lm	Correlated colour temperature, K
25	1,000	620	7207
50	0,935	-	7360
25	0,997	-	7318
-40	1,183	-	7310
25	1,011	-	7306

Table 1 - Results of test with temperature loading

D2 - Measurement
Measurement Systems

PP032

CHARACTERIZATION OF A PHOTOPIC-SCOTOPIC LUMINANCE METER FOR MEASUREMENTS IN THE MESOPIC REGION

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We present a photopic-scotopic luminance meter characterized for measurements in the mesopic region. Recommended system for mesopic photometry was published by CIE in 2010, and according to this system, the mesopic luminous efficiency function is a linear combination of the photopic and scotopic luminous efficiency functions in the range of 0.005–5 cd/m^2. The ratio in which the functions are combined is determined by the adaptation condition of the observer.

Our instrument is a spot luminance meter with two detection channels for the scotopic and photopic detection. The main parts of the instrument are an objective lens, a field stop defining the field of view, a beamsplitter and two detection channels with a photopic and a scotopic filtering respectively. The signal is measured with silicon photodiodes and a custom-built dual channel switched integrator amplifier. System control and data collection are performed with a portable computer, where luminances from the two channels are combined in an appropriate ratio to obtain a mesopic value.

The instrument is characterized for the relative spectral responsivity of both channels using a radiance source consisting of an integrating sphere with monochromatic light or with a set of 30 individually selectable LEDs with known spectra. The linearity characterization is challenging as the signal levels required for the scotopic end of the range are extremely low. The linearity is characterized with an integrating sphere as the radiance source, by varying the amount of irradiance on the input port of the sphere. This is performed by changing the distance between the incandescent source and the sphere. This preserves the relative spectral distribution of the signal. Power ratios are obtained from the inverse square law and from the monitor detector attached to the sphere.

The results for the spectral responsivities, corresponding spectral matching quality factors f’1 and linearity will be presented at the conference. The work leading to this study was partly funded by the EMRP ENG05 Project „Metrology for Solid State Lighting.“ The EMRP (European Metrology Research Programme) is jointly funded by the EMRP participating countries within EURAMET and the European Union.

PP033

LOW NOISE DETECTION SYSTEM FOR MESOPIC AND SCOTOPIC PHOTOMETRY

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The CIE recommended system for mesopic photometry is based on a linear combination of photopic and scotopic luminous efficiency functions. An instrument has been built in collaboration between Aalto University and CMI capable to measure simultaneously photopic and scotopic luminances over the mesopic range of 0.005 – 5 cd/m^2. The main challenge posed on the detection system of this instrument is the measurement of the low power light levels which can be as low as 0.5 pW with a noise not higher than 1%. The instrument detection system is composed by silicon detector and a custom made switched integrator amplifier.
Each component of the detection system generates noise. The main source of noise of the silicon detector for low photon flux measurements is due to the random thermal generation of carriers in the semiconductor substrate that is proportional to the sensitive area of the detector and its temperature. At room temperature the selected silicon detector with a sensitive area of 3.6 mm x 3.6 mm typically exhibits a shunt resistor value of 500 MΩ and a noise equivalent power of 17 fW/Hz$^{1/2}$ for a responsivity value of about 0.3 A/W at 555 nm. For measurement of light power levels lower than pW with a target noise below 1% the noise contribution of the photodiode itself becomes not negligible. The other source of noise is generated by the electronics that converts the photodiode's photocurrent to a measurable quantity. The traditional method employs a resistor as a feedback of an operational amplifier. The main limit of this approach emerges when the value of the feedback resistor approaches the value of the shunt resistor of the photodiode. In such case the photodiode noise is amplified. Alternatively the switched integrator amplifier uses a feedback capacitor to store the charge generated by the photodiode. The longer it integrates the higher is the output voltage. A custom made dual channel switched integrator with internal 20 bit analog voltage converter has been developed for the mesopic photometer. An on board micro controller generates the timing for the integration and for the ADC conversion and it provides the data communication with a remote host PC. The system has five decades dynamic range, it can reach very high transimpedance values : 6.410 with an integration time of 0.8 second and an integration capacitor of 12.5pF. The noise equivalent power of the detection system at its highest sensitivity setting has been measured to be as low as 35 fW/Hz$^{1/2}$.
A series of measurements where carried out with the two channel photopic - scotopic luminance meter at different luminance levels. The system was developed in the framework of the EMRP ENG05 Project "Metrology for Solid State Lighting". The integration time of the switched amplifier was set to 0.8 s. A numerical integration was performed on 150 samples. The noise is stated as the relative standard deviation of mean (seom) of all the samples. As shown in the table below the power level irradiating the photo detector is around 2 pW at 10 mcd/m^2 and 200fW at 1 mcd/m^2 which is well below the target mesopic lower limit.

The authors acknowledge financial support by the European Metrology Research Programme (EMRP).

Luminance [cd/m^2]	Power [pW]	Relative seom %
0.4	57.5	0.02
0.05	7.5	0.2
0.01	1.8	0.8
0.001	0.2	4

Table 1 - Noise performance of detection system in scotopic-mesopic regime

PP035

EFFECT OF ROTATION AXIS ON THE VALUE OF PHOTOMETER DIRECTIONAL RESPONSE INDEX F2

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Photometer manufacturers use CIE quality indices for describing the performance of their instruments. Quality index f_2 quantifies the matching of the photometer directional response with the cosine function. In order to obtain a cosinusoidal directional response, photometers are equipped with diffusing input optics. The characterization of the directional response is carried out in at least two mutually perpendicular planes by measuring a small light source far away and by changing the angle of incidence on the acceptance area of the photometer. [1]
A method for the uncertainty analysis of quality index f_2 was recently reported using Monte Carlo simulation [2]. The largest contribution to the uncertainty of f_2 was due to the alignment uncertainty (±0.5 mm) of the photometer in the longitudinal direction parallel to the optical axis. The directional response measurements were conducted at a distance of d = 2.5 m from the light source. The axis of rotation was initially set to coincide with the front surface of the photometer diffuser. According to the simulations, the values of f_2 changed if the photometer was displaced from its initial position. The effect was verified by displacing the photometers by up to ±2.0 mm in the measurements. This is analogous with a case, in which the photometer has diffuser offset [3]. The simulations showed that the f_2 of the photometers could be improved by changing the position of the axis of rotation. The virtual minima of f_2 were found with offsets of 41.6 mm, -18.6 mm and -59.4 mm. Positive values here mean that the axis of rotation was inside the photometer. The virtual minima of f_2 were lower by factor of 1.6 – 3.5 compared to the f_2 values measured with correct position of the rotational axis.

The effect was later verified by measuring two different photometers by varying the rotational axis up to ±110 mm. Initial measurements at a distance of d = 2.66 m showed that photometer P1 was a high quality instrument with f_2 = 0.799 ± 0.022 %, whereas photometer P2 was of low quality with f_2 = 12.833 ± 0.024 %. Figure 1 shows the simulated (black curves) and measured (symbols) values of f_2 for both photometers. Due to the high quality matching of P1, its f_2 only increased by varying the rotational axis, as is the case with simulated photometer Pcos with a perfectly cosinusoidal response (dashed line). Due to the mechanical limits of the measurement setup, P2 was finally measured closer to the light source at a distance of d = 1.5 m. Then, the virtual minimum of f_2 was found using an offset of -87 mm, resulting in f_2 = 3.364 %, which is lower by factor of 3.8 compared to the nominal value of f_2.

However, it must be emphasized that although the results are interesting, using such a large offset value in the measurements does not improve the true directional response of the photometer, and should not be used for determining the value of quality index f_2. The effect is caused by the finite measurement distance typically used for the characterization, and disappears at infinity. Using a photometer for illuminance measurements with such an offset value most probably does

not obey the inverse square law either. Although the CIE Publication 69 [1] recommends that the position of the axis of rotation should coincide with the center of the acceptance area of the photometer, it still gives a possibility to describe any other point for this axis. This issue should be addressed in any future version of the CIE Publication, so that the quality index f_2 measured by different manufacturers could be more reliably compared with each other.

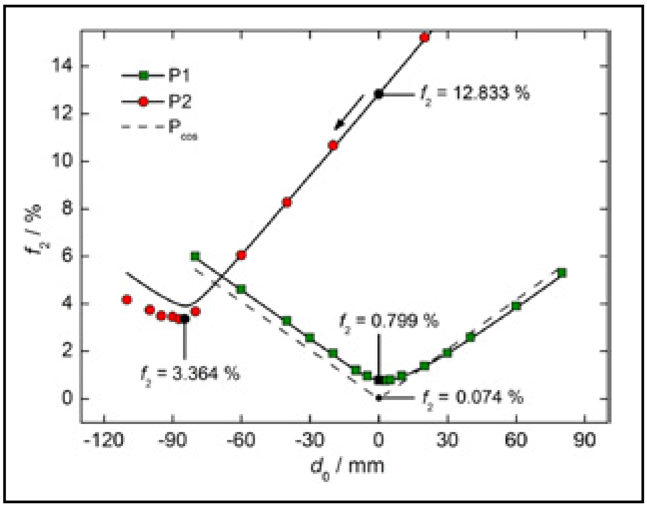

Figure 1 - Measured and simulated f_2 of photometers P1 and P2 as a function of offset d_0. For colors and symbols, see text.

PP036

USING OF CCD BASED FIBRE OPTIC SPECTRORADIOMETERS IN PHOTOMETRIC MEASUREMENTS UNDER DIFFERENT CONDITIONS

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Spectroradiometers are using people who want to measure and investigate spectrum of radiation from the source. This can be done also in the visible part of radiation i.e. spectral measurement of light. It is important in many applications. The spectrum of the light is very important for colorimetry, spectrophotometry and so on. The usage of spectroradiometers is usually mainly oriented into the laboratories condition. In the laboratories are widely used conventional Czerny-Turner single or double spectroradiometers.

Under well-known condition can be performed precise measurements with low uncertainties. But that spectroradiometers are not suitable for measurement in the field measurements due to different reasons (robustness, price, sensitivity on the environment etc.). Therefore it is often impossible to use them for this type of measurement. Requirement of spectroradiometry in the field measurement is increasingly desirable because of new types of lamps (for example LED etc.) and luminaires even more at the measurements under mesopic condition. Necessity of knowledge of spectrum can be very useful for example at the field verification of lighting system, to measurement of performance outdoor lighting systems under mesopic condition and so on. Therefore recently many types of portable spectroradiometers are appearing on the market. It can be found on the market many types of portable spectroradiometers from grid spectroradiometers with fibre optics to the sophisticated types with traditional optics (lenses). As detector they are using CCD array detector. Described spectroradiometers can be used for many applications and user can buy them at the different price levels with different performance and accuracy, especially, if user wants to measure absolute radiometrics or photometrics quantities under different conditions. Portable spectroradiometers can be used in easier way in the field measurements than conventional types.

They provide more flexible solutions for field measurements. But on the other hand many problems occur which should be concerned by the user to avoid errors at the measurement. Errors can be partially corrected by calibrations done before the measurement. Then can be usage of portable spectroradiometers very useful especially using CCD fibre optics spectroradiometers. There exist some problems to ensure good measurement results. It is for example noise of CCD element, linearity of the CCD element, stray light etc. These parameters can significantly influence the measurement. Also people who are performing spectroradiometric measurements usually do measurements without assumption of accuracy of used device. The work about usage of CCD fibre optics spectroradiometer in the field measurements was made.

This paper concerns of usage of portable CCD fibre optics spectroradiometers in the field measurements in many applications. Commercial CCD fibre optics spectroradiometer was used as

illuminance meter or luminance meter which was able to real-time measurement of the spectrum and provide directly from these spectroradiometric measurements absolute photometric or colorimetric quantities. Also it concern comparison of advantages and disadvantages of absolute radiometry between conventional type and CCD fibre optics spectroradiometer. At the end it present results of investigation and research work about possibility of usage of these types of spectroradiometers under mesopic condition.

PP037

AN IMPROVED CCT-TLF CALIBRATION METHOD FOR SPHERE-SPECTRORADIOMETERS

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1.Introduction

Sphere-spectroradiometers are usually calibrated by total spectral radiant flux (TSRF) standards. The difficulty is that only very few national labs can provide TSRF standards with low uncertainties for industries. The correlated color temperature and total luminous flux (CCT-TLF) standards are also used in industry for the calibration of sphere- spectroradiometers. However, the general CCT-TLF calibration method usually has larger uncertainty than the TSRF one. This paper will introduce an improved CCT-TLF calibration method with very low calibration uncertainties and provide the corresponding uncertainty analysis comparing with TSRF calibration method. The results indicate that the uncertainty of the improved CCT-TLF standard is at the same level with TRSF standard. The CCT-TLF standards used in the improved calibration methods can be a cost-effective substitute of TSRF standards for sphere- spectroradiometers.

2.Theory and Calibration Methods

2.1 CCT-TLF and Improved CCT-TLF calibration method

The high quality halogen lamps are usually used as the standards for the calibration of sphere-spectroradiometers. If the correlated color temperature (CCT) and the total luminous flux (TLF) of the standard was calibrated, its TSRF can be calculated according to Planck blackbody function. The calculated TSRF was applied in the calibration of sphere- spectroradiometer, and it is so called general CCT-TLF calibration method. In general CCT-TLF method, the deviation between the calculated TSRF and the real TSRF of the standard leads to much calibration uncertainty. Fig. 1 shows the deviation of the calculated TSRF and the real TSRF of four CCT-TLF standards at four different CCTs. The value of is the ratio of the real TSRF and the calculated TSRF.

Fig. 1 of four CCT-TLF standards

For lower uncertainty calibration, TSRF standard are often used in sphere-spectroradiometers. The difficulty for industries is that only very few national labs can provide TSRF standards with low uncertainties. An improved CCT- TLF calibration method can reach very low calibration uncertainty. In the improved CCT-TLF method, the very low uncertainty photometric standard and an effective correction method was applied. The full paper will introduce the details of this method.

2.2 Calibration Uncertainty Analysis

The typical uncertainties of TSRF standard, general CCT-TLF standard, improved CCT-TLF standard in different wavelength points are listed in Table 1.

Table 1 The standard uncertainties of typical TSRF, general CCT-TLF, and improved CCT-TLF

Standard LampTypeStandard Uncertainty(%)

380nm440nm500nm650nm780nm

Typical TSRFB0.770.640.550.500.50

General CCT-TLFB3.382.110.700.621.39 Improved CCT-TLFB1.050.820.690.611.09

Uncertainty budgets and more detailed analysis will be described in the full paper.

3.Practical Measurement and Measurement Uncertainty Analysis

Typical CFLs, halogen lamps, and LED lamps are measured under both of the calibration methods of the improved CCT-TLF and TSRF. The measurement results, the comparison and the uncertainty analysis will be reported in the full paper.

4.Discussion and Conclusion

The full paper will also give discussion and conclusion for the specified quantities of test lamps such as total luminous flux, color coordinate, CCT, color rendering index, as well as spectral power distribution in different wavelength bands. It will also conclude that the improved CCT-TLF calibration method shows good performance as the TSRF calibration method and the improved CCT-TLF calibration method has cost and realization advantages.

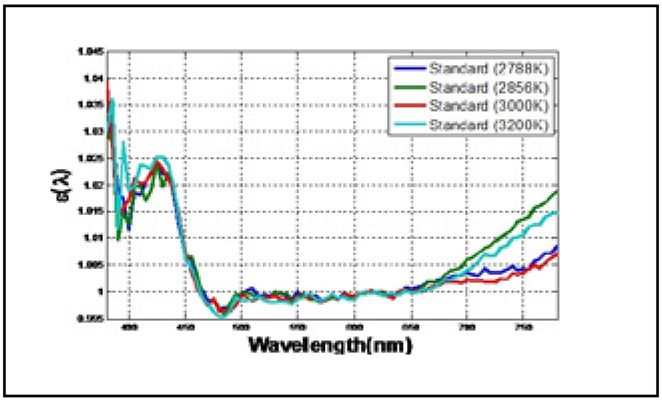

Figure 1 - The ratio of the real TSRF and the calculated TSRF for four CCT-TLF standards

Standard Lamp	Type	Standard Uncertainty(%)				
380nm	440nm	500nm	650nm	780nm		
Typical TSRF	B	0.77	0.64	0.55	0.50	0.50
General CCT-TLF	B	3.38	2.11	0.70	0.62	1.39
Improved CCT-TLF	B	1.05	0.82	0.69	0.61	1.09

Table 1 - The standard uncertainties of typical TSRF, general CCT-TLF, and improved CCT-TLF

PP038

TEST OF AN OPEN HARDWARE COLORIMETER

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One of the most common (and frustrating) situations for a photographer or a graphic designer is to spend hours to enhance a digital photograph with an image processing software, just to realize in the end that the colors appear very differently if seen on another monitor or printout.
The main reason for this situation is that the same RGB triplet, on different devices, can lead to different perceived colors. Consequently, a control of the processing pipeline from a color management point of view is needed, from the acquisition, to the visualization and eventually to the printing.
Ideally, a mapping between the digital color representation and the acquired/reproduced perceived color should exist for each device (acquisition systems, monitors and printers), although it is often impossible in practice, since not all the devices can represent the same color gamut. Thus, a correct profiling of the devices may significantly reduce the perceived color differences.

A common tool used for the profiling of visualization devices is the colorimeter. Different kinds of colorimeters have been proposed, with different specifications and performances. They are based on different working principles, from tristimulus colorimeters to actual spectrophotometers, and their prices range from few hundreds to thousands of Euros.

Despite of this, most of the available devices, independently from their cost, are produced by companies that do not release to the users detailed hardware specifications (electronic schematics, list of components, etc.) neither firmware or driver software source code.
Most of the users do not feel the need of detailed hardware specifications or software source code, but for researchers it may be a great value to obtain detailed hardware schematics and software source code together with the rig. Such a knowledge could be used for academic purposes, to study which algorithms are implemented on the device, but also to exactly understand hardware limitations or to apply customizations for experimental or research purposes.

In this paper we will describe and analyze a recently introduced colorimeter called ColorHug, that may be of particular interest for the research community, since it is an open hardware project and that, consequently, grants the public availability of its hardware schematics and of its firmware and device driver as free software, under the GPLv2 (General Public License version 2).

The ColorHug is a low cost (less than 100€) tristimulus colorimeter device, designed and produced by Hughski Limited, London. It is based on the TCS3200 programmable color light-to-frequency converter produced by TAOS (now AMS-TAOS USA Inc.) and it is internally governed by a PIC18F46J50 microcontroller. It can be easily connected to a computer through a regular USB cable for data read-out and the same connection can be used also for firmware upgrading. Thanks to the software openness of its firmware and drivers, derived by the GPL License, everybody could modify the microcontroller program to change its data read-out and handling behavi-

our.
A part from its hardware and software openness the functions of this device are similar to other commercial devices of the same range, but it is worth to mention its peculiarity of being able to store custom CCMX matrices on the device, that is a not so common feature.
In this work we will present the results of different tests on the ColorHug, evaluating its performance in comparison to other colorimeters and professional tools, but moreover we will also discuss the new opportunities offered to the research community by the open hardware and free software approach.

PP039

GLARE EVALUATION SYSTEM USING PHOTOGRAPHIC PHOTOMETRY

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It is feared that a chronic electricity shortage is encountered by operation stopping the nuclear power plant by the influence of the accident of the Fukushima No. 1 nuclear power plant associated with the Great East Japan Earthquake that occurred on March 11, 2011 in Japan.
Hence the LED luminaires with good energy efficiency have begun to spread rapidly at an earlier stage than expected. On the other hand it often happens that the LED luminaires become problems concerning glare because of their high luminance. There is a possibility to require extra lighting energy to secure the visibility of visual target because the visual performances of eyes lower when large glare is generated (disability glare). Hence it is considered that evaluating the glare appropriately is an important task. Glare can be evaluated by calculating or measuring the equivalent veiling luminance from the light source (Lvl) and the equivalent veiling luminance with the reflected light from the floor or wall (Lve). Lvl can be obtained by calculating the direct illuminance from each luminaire to the view point, using the view point position, luminaire position and luminous intensity distribution data. However, Lve cannot be obtained from illuminance calculation accurately. Moreover the measurement of the equivalent veiling luminance needs to use a special glare lens. However, Lve and Lve cannot be classified accurately by the measurement with the glare lens. Hence it is difficult to evaluate glare accurately. In addition, obtaining the glare lens is difficult now. Hence glare evaluation of LED luminaires has been hardly done in a real environment. Then, we have developed the system capable of measuring the equivalent veiling luminance more easily, at high speed and accurately for glare evaluation by using photographic photometry. We did basic experiment in the laboratory at the beginning, to confirm the measurement accuracy of the equivalent veiling luminance using the photographic photometry technology. Next, we verified the measurement accuracy of the equivalent veiling luminance by using the developed system in the actual field. Fig. 1 shows a luminance distribution of a gymnasium actually measured. Table 1 shows a result of comparing the calculation value from the illuminance distribution of the equivalent veiling luminance and the measurement result by photographic photometry. The table shows the comparative agreement between the calculation result and measurement result concerning the Lvl. This confirms the validity of this system. Concerning the Lve, however, a difference is observed between the calculation result and measurement result. It is estimated that this is because the equivalent veiling luminance by calculation does not include the equivalent veiling luminance with the reflected light from the wall or ceiling face. Hence using this system enables the accurate measurement of the equivalent veiling luminance considering the reflected light, which has been difficult in illuminance calculation. When obtaining the equivalent veiling luminance from the luminance distribution, however, the resolution greatly influences the result of measurement. Fig. 2 shows a result of obtaining the luminance distribution of the same luminaire by the image with different resolution. It is confirmed that the luminance distribution in the luminaire greatly differs as shown in the figure depending on the resolution of the image. Table 2 shows a result of a measurement of the equivalent veiling luminance obtained from each image. The table shows good agreement of the Lve regardless of resolution. It is confirmed, however,

that the Lvl differs greatly depending on the resolution. In the future, we will verify a proper resolution to measure the luminance distribution, to evaluate glare accurately based on human's view angle characteristic.

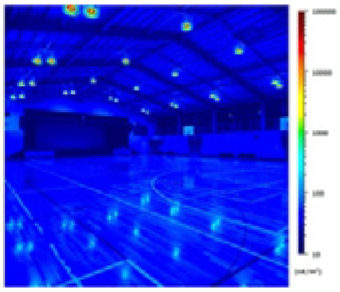

Figure 1 - Image of luminance distribution

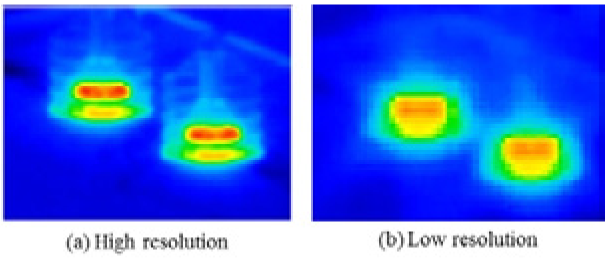

Figure 2 - Comparison of luminance distribution by resolution

	Calculation result from illuminance distribution	Measurement result by photographic photometry
Equivalent veiling luminance with refrected light Lve[cd/m^2]	1.34	2.05
Equivalent veiling luminance from light source Lvl[cd/m^2]	0.55	0.62

Table 1 - Comparison of calculation results of the equivalent veiling luminance

	Low resolution	High resolution
Equivalent veiling luminance with refrected light Lve[cd/m^2]	2.04	2.05
Equivalent veiling luminance from light source Lvl[cd/m^2]	0.41	0.62

Table 2 - Comparison of calculation results of the equivalent veiling luminance

PP040

COMPARISON ON TOTAL LUMINOUS FLUX MEASUREMENT OF SPECTROGONIPHOTOMETER AND GONIPHOTOMETER

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The traditional goniphotometer is always using a silicon detector as photohead. The photohead is made of silicon diode and a series of color filters. The spectral responsivity S(λ) is designed to simulate the relative luminous efficiency function V(λ). Due to the difference existing between the S(λ) and V(λ), the color correct factor is recommended when carrying out a total luminous flux measurement. To calculate the color correct factor, S(λ) should be precisely measured first. However, the blue and red area of S(λ) is not so easy to get because the signal is relatively weak. Another problem is that some lamps (for example, white LEDs) have non-uniform color spatial distribution. That is, the color correct factor is not a constant and depends on the sampling angle, different situation from the tungsten lamp.

The utilizing of a spectrogoniophotometer seems an alternative choice to conquer those issues. The spectrogoniophotometer is using an array spectroradiometer instead of silicon photohead to measure the spectral irradiance and calculate the illuminance by the mathematical function. The measurement process is free of calculating color correct factor and the S(λ) measurement, which many test engineers are not familiar with.

This work is going to show using spectrogoniophotometer to implement the measurement of the total luminous flux, the color spatial distribution, and make a comparison between the spectrogoniophotometer and the traditional goniphotometer.

The spectrogoniophotometer is of a horizontal type. The spectroradiometer is calibrated in situ by a standard luminous intensity lamp and a standard spectral Irradiance lamp. The total luminous flux is given by expression (1). The traditional goniphotometer only replaces the spectroradiometer with a silicon photohead. Other remains the same. The total luminous flux is given by expression (2). If we consider the color correct factor, the expression (2) should be rewritten as the expression (3).

We see little different for the two devices when testing the tungsten lamps. The estimated repeatability of the spectrogoniophotometer and the goniphotometer are both about 0.1 %.
The color correct factor spatial distribution F*(φ, θ) for our goniphotometer can be measured by the spectrogoniophotometer. Figure 1 is one section of F*(φ, θ) of a white LED sample. It shows the variation of F*(φ, θ) for different direction. We recommend considering to introduce F*(φ, θ) when implement a total luminous flux measurement for white LEDs by a goniphotometer.
In conclusion, a spectrogoniophotometer is used to measure the total luminous flux of a light source free of calculating color correct factor and the spectral responsivity S(λ) measurement.

Color spatial distribution is also measured by the spectrogoniophotometer and used for color correct factor spatial distribution F*(φ, θ), which is recommended to introduced for the traditional goniphotometer

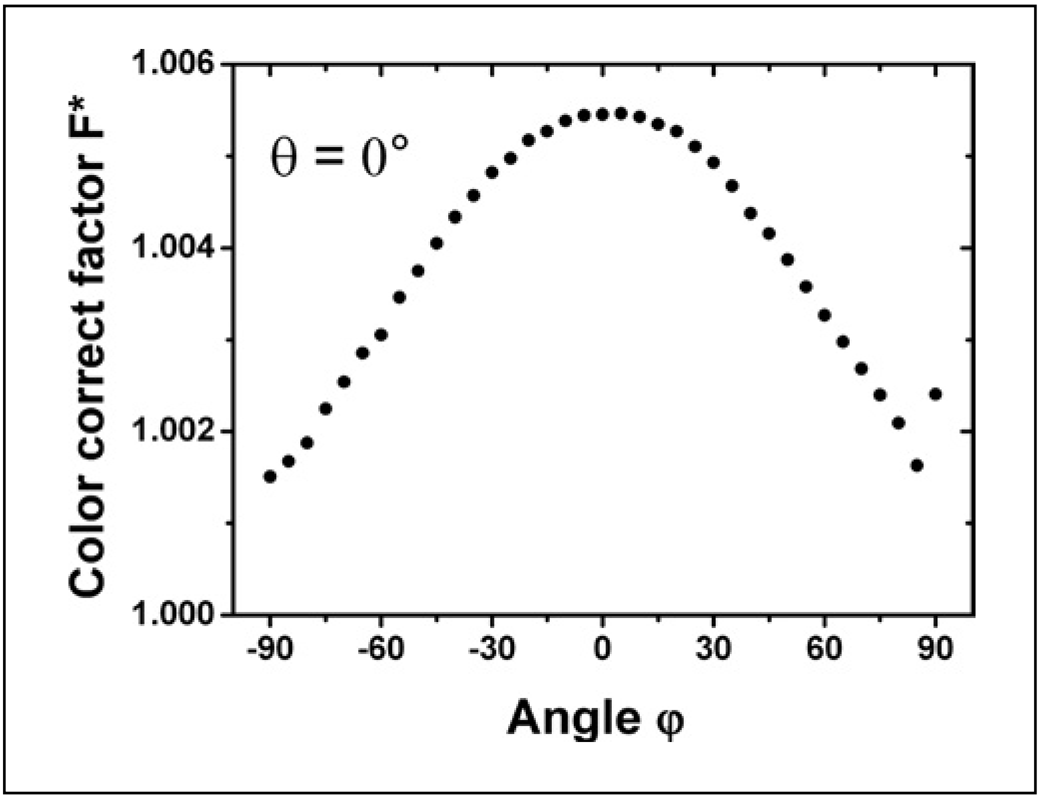

Figure 1 - one section of F*(φ, θ) of a white LED sample

$$\Phi_v = r^2 \cdot \int_{\varphi=0}^{2\pi} \int_{\theta=0}^{\pi} \left(K_m \cdot \int_{\lambda=380}^{780} V(\lambda) S(\lambda,\theta,\varphi) d\lambda \right) \sin\theta d\theta d\varphi \qquad (1)$$

where $S(\lambda,\theta,\varphi)$ is the spectral and spatial distribution of the lamp.

$$\Phi_v = r^2 \int_{\varphi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\varphi,\theta) \sin\theta d\theta d\varphi \qquad (2)$$

where $E(\varphi,\theta)$ is the illuminance spatial distribution of the lamp.

$$\Phi_v = r^2 \int_{\varphi=0}^{2\pi} \int_{\theta=0}^{\pi} F^*(\varphi,\theta) \cdot E(\varphi,\theta) \sin\theta d\theta d\varphi \qquad (3)$$

Where $F^*(\varphi,\theta)$ is the color correct factor spatial distribution and given by $S(\lambda,\theta,\varphi)$.

Figure 2 - the expressions

PP041

IMAGING SPECTROPHOTOMETRY WITH A HIGH STABLE AND MONOCHROMATIC LED-BASED TUNABLE SOURCE

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The use of imaging spectrophotometers for capturing of spectrophotometric quantities with spatial resolution has attracted increasing interest. Capturing spectral frames combines the strength of conventional imaging with that of spectrophotometry to accomplish tasks that each cannot be performed separately. Among the advantages of these imaging techniques it should be noted that it can be used for carrying out certain types of measurements, e.g. reflectance or transmittance evaluation for inhomogeneous samples, that should otherwise be performed by means of scanning methods.

In this paper, we present a new instrumentation for spectrophotometric measurements with using an instrument based on different color LEDs which cover wavelength range from 350 nm through 950 nm. The instrument consists of multiple LEDs, a single-grating monochromator, a small-size integrating sphere, and a CCD camera. Tuning the wavelength could be achieved by a proper selection of LED in accordance with the monochromator setting in the corresponding wavelength. High spectral purity with a narrow spectral bandwidth suitable for the application could be realized. The schematic diagram of the setup and the detailed view of the used integrating sphere are shown in figure 1 (a) and (b) successively. As shown in figure 1 below, the whole setup is compact for practical uses with using a small-size (custom-made) integrating sphere for the purpose of having uniform illumination over the whole sample under test.

In figure 1 (b), port A is used for input radiation, port B is used for attaching the sample to be studied, port C is the output port through which the CCD (monochrome) camera can capture the images (as shown in fig. 1 (a)), and port D is used for attaching a detector for monitoring purposes. The sample is attached tightly to port B so that it is illuminated with highly uniform irradiation, which is one of the main requirements of a precise measurement. The developed instrument can be used in both cw and pulsed mode operation (of the LEDs), which would open up new facilities for a variety of interesting applications.

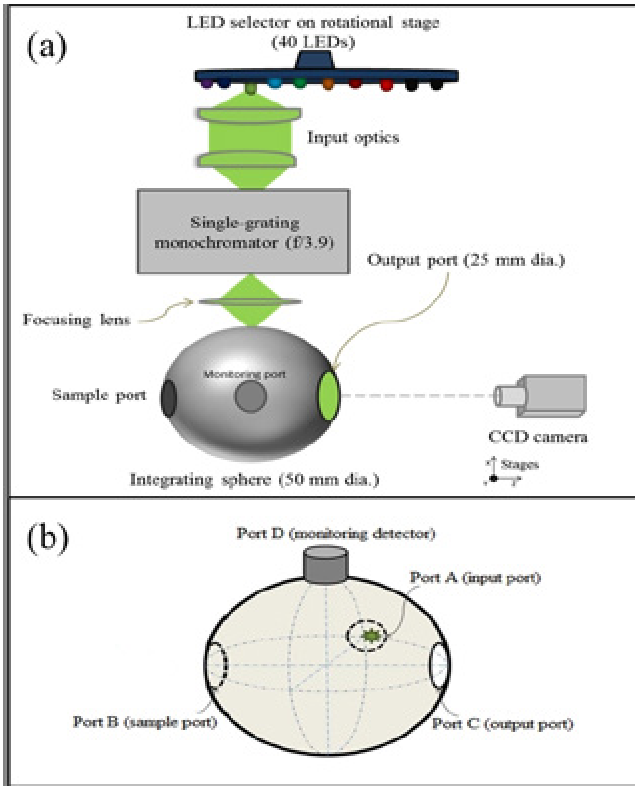

Figure 1 - Schematic diagram of the setup: (a) top view of the whole setup, and (b) detailed view of the used integrating sphere

D2 - Measurement Miscellaneous

PP042

LIGHTING QUALITY AND CHARACTERIZATION OF LAMPS AND LUMINAIRES: BRAZIL GETS READY FOR THE ADVANCEMENT OF SOLID STATE ILLUMINATION

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Objective

Over the past few years has increased the lighting literacy of both producers and consumers. Consumers and traders are more willing to buy the light fixtures that are not only of good quality but also present alleged protocols for lighting and electrical characteristics, as well as the report of conformity to normative documents issued by qualified experts. The Optical Metrology Division of the National Institute of Metrology, Quality and Technology (Inmetro) has started the colorimetric characterization of lamps by implementing correlated color temperature (CCT) and color rendering index (CRI) measurements of incandescent lamps, followed by the CFL, LEDs, and LED lamps and luminaires. Here we present a brief analysis for the verification of the color quality performance of samples of CFL and LED luminaires for public as well as indoor illumination that are sold in the Brazilian market.

Methods

The Robertson method is applied to obtain the CCT. We follow Gardner to derive analytical expression for uncertainty in u and v chromaticity coordinates and an uncertainty in CCT could be achieved. The CRI uncertainties are obtained by applying the ISO Guide Method to derive analytical expressions for the uncertainties following the works of Gardner and A. el Bially et all.
Measurements of the spectral power distribution (SPD) are realized in two distinct setups, according to the lamp or luminaire under test. A setup for spectral reflectance measurements is mounted on an optical table where a CCD spectroradiometer is mounted on a rotating arm allowing measurements over a continuous range of observation angles from a reference tile illuminated by the test lamp. A goniophotometer with rotating mirror arm, used for the photometric characterization, is associated with a CCD spectroradiometer in order to perform the LED luminaires colorimetric measurements. The SPD measurements are carried out in the standard 0°:45° illumination observation geometry from the reflected light of the luminaire on the reference tile. The results are the combination of two parameters: the angle Φ representing the position of the luminaire around its own axis and the angle θ representing the position of the mirror relative to goniophotometer and LED luminaire. There are two sets of measurements, according to the procedure IES LM-79-08. Repeated measurements allows for repeatability and reproducibility analysis for the uncertainty budget. The CCT and CRI calculations take into account the measurements geometry and the procedures in IES LM-79-08.

Results

Figure 1 exemplifies the polar photometric diagram distributions for the SSL luminaire sample C , and Figure 2 shows the corresponding averaged SPD. The colorimetric quantities, CCT and CRI, and the associated uncertainties obtained for a set of fluorescent lamps are shown in Table

1. Table 2 assembles our first results including uncertainties calculations, for SSL luminaires for public lighting. The luminaires and lamps tested are from different trademarks. The expanded measurement uncertainty (U) is declared as the combined standard uncertainty multiplied by a factor of k = 2, which corresponds to a coverage probability of 95,45 %. The experimental values founded for the fluorescent samples are in good agreement with the values given by the traders.

Conclusions

The Optical Metrology Division of Inmetro has developed measurement systems for the determination of CCT and CRI for different light sources. The CCT and CRI calibration services now offered by the laboratory will cover the increasing demand by the Brazilian lighting sector. This work deals with the determination of the CCT and CRI and respective uncertainties of LED luminaires for public lighting, and also with LED lamps and CFLs, available at the Brazilian market. Any attempt to develop energy efficient lighting strategies must, as the first priority, guarantee that the quality of the lighting products is as high as possible. The results for the photometric and colorimetric characterizations presented in this work demonstrate that this is achievable, showing the efforts of Brazilian market in the search for highly efficient lighting products.

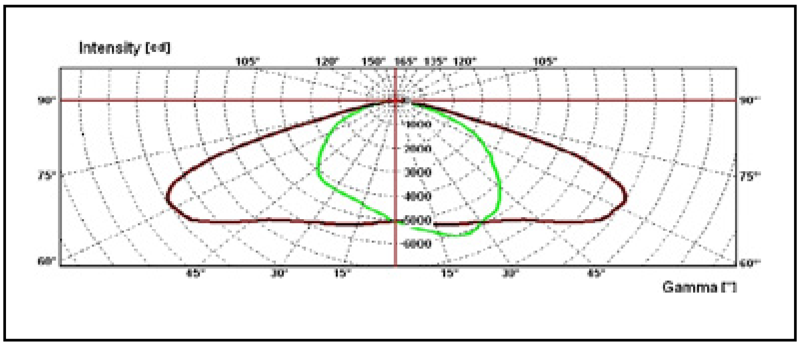

Figure 1 - Polar luminous intensity distribution graph for a SSL luminaire: sample C

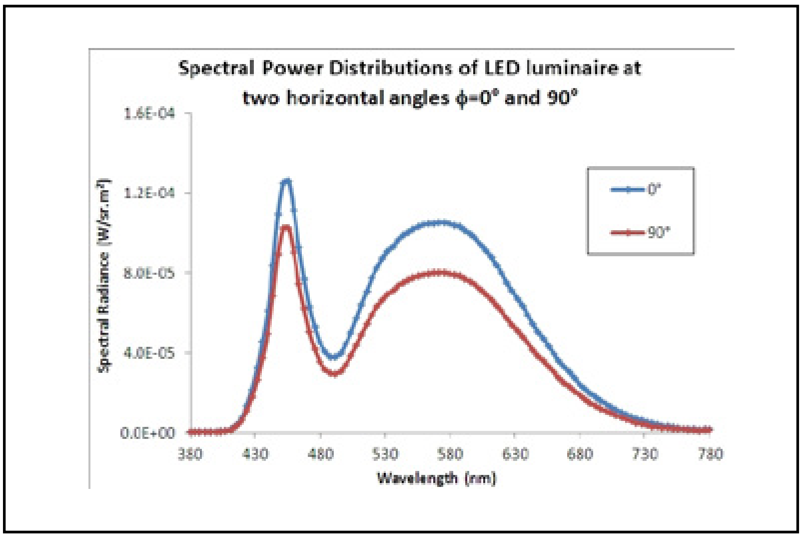

Figure 2 - Averaged SPD obtained for a SSL luminaire: sample C

FLUORESCENT LAMPS	Nominal CCT (K)	Nominal CRI	CCT (K) CCT ± UCCT	CRI Ra ± URa
Sample A - CFL Parallel Triple-Tube 25W	2700	80	2687 ± 32	82 ± 5
Sample B - CFL Triple-Tube 9W	2700	-	2840 ± 33	81 ± 5
Sample C - CFL Triple-Tube 15W	4000	-	4044 ± 44	79 ± 5
Sample D - CFL Triple-Tube 14W	4000	-	4190 ± 57	85 ± 5
Sample E - CFL Parallel Triple-Tube 25W	6400	80	6109 ± 395	76 ± 5
Sample F - CFL Triple-Tube 15W	6400	-	6170 ± 432	76 ± 5
Sample A T8 - 26 mm, with G13 base 40 Watts	3000	52	2973 ± 30	51 ± 4
Sample B T8 - 26 mm, with G13 base 40 Watts	4100	60	4133 ± 57	61 ± 4
Sample C T8 - 26 mm, with G13 base 40 Watts	6500	75	6288 ± 158	75 ± 4

Table 1 - Nominal and measured values of CCT and CRI of samples of compact and tubular fluorescent lamps

SSL LUMINAIRES	Nominal				0 deg. Plane measure				90 deg. Plane measure			
	CCT (K)	UCCT (K)	Ra	URa	CCT (K)	UCCT (K)	Ra	URa	CCT (K)	UCCT (K)	Ra	URa
Sample A 72 LEDs 65 Watts	4500	275	>70	-	4669	83	77	4	4665	83	78	4
Sample B 90 LEDs 125 Watts	5000	300	-	-	4958	138	65	4	4903	146	64	4
Sample C 96 LEDs 100 Watts	-	-	-	-	5244	151	73	4	5292	177	73	4

Table 2 - Nominal and measured values of CCT and Ra of sampled LED luminaires

PP043

REALIZATION OF THE CANDELA AT INMETRO

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ABSTRACT
The measurements system for the illuminance and luminous intensity at Inmetro consists of four standard photometers on trap detector specially constructed at Inmetro for the realization of the candela. We expect to improve the uncertainty associated with photometric calibration and provide calibration of diferent type of standards lamps.

1. INTRODUCTION

The candela, the base unit of luminous intensity of the International System of Units (SI), according to the adopted definition by the Conférence Générale des Poids et Mesures (CGPM) since 1979, has been defined in terms of the watt.
The candela has been realized by many National Metrology Institutes (NMI) following the detector-based method, deduced from the illuminance provided by calibrated detector and the distance from light source to the photometer, whose relative spectral responsivity $s(\lambda)_{rel}$ has been adapted to the spectral luminous efficiency function $V(\lambda)$.
In this article, we present the results for luminous intensity (cd), luminous responsivity (A/lux), and illuminance (lx) based on an absolute cryogenic radiometer through the spectral responsivity power scale at Inmetro.

1. PRINCIPLE OF REALIZATION

A standard photometer consists of a silicon photodiode, a $V(\lambda)$ filter, and a precision aperture. The photometer measures the luminous intensity I_v (cd) when used with a point light source at a distance r from the aperture plane. The luminous intensity I_v is then determined from the following equation

$$I_v = E_v r^2 = (K_m\, i\, F)/((s(555)(A/r^2)) \qquad (1)$$

where i is the output photocurrent, in A; K_m is the maximum spectral luminous efficacy, equal to 683 lm/W; s(555) is the spectral responsivity $s(\lambda)$ at 555 nm, in A/W; A is the aperture area of the photometer, in m^2; r is the distance from the point light source to the aperture plane, in m; F is the spectral mismatch factor and the luminous responsivity is given by the equation

$$s_v = (A\, s(555))/(K_m\, F) \qquad (2)$$

2 MEASUREMENT OF LUMINOUS INTENSITY

The detector-based realization of the candela was realized on a ten meter long photometric bench. At the left side of the photometric bench, the luminous intensity lamp was mounted on stages with six degrees of freedom that allows accurate positioning of the lamp filament. The distance between the filament plane and the aperture surface of standard photometer was fixed.
The photometric measurement was realized with a set of four standard photometers based on a silicon trap detector calibrated against cryogenic radiometer, a high-precision aperture with nomi-

nal value area of 3 mm and a V(λ) filter. A temperature controller filter holder based on Peltier element was used. All components of each standard photometer were individually characterized and the relative spectral responsivity at 555 nm of each standard photometer was well determined.
A set of five luminous intensity standard lamps of type Wi41G at correlated color temperature close to 2856 K (CIE standard illuminant A) was operated with a stable dc power supply.
Photocurrents generated by the standard photometer were amplified with calibrated current voltage converter and the voltage was measured with calibrated digital multimeter. The amplifier conversion factor used was typically 10^6 V/A. The temperature inside the standard photometer and the ambient temperature were set to 25.0 °C and 23 °C , respectively.

3 RESULTS

All standard photometers had spectral mismatch factor close to one and its relative spectral responsivity at 555 nm was evaluated with an relative standard uncertainty of about 0.33 % (k=2). The aperture area was measured with a relative standard uncertainty of 0.085 % (k=2). The luminous responsivity of the standard photometers was determined by using the equation (2) with a relative standard uncertainty of about 0.7% (k=2).
The relative standard uncertainty of the distance measurement was 0.16% (k=2) and photocurrents were measured with a relative standard uncertainty of 0.018% (k=2). The luminous intensity of the lamp was given by the equation (1) and the values were determined with a relative uncertainty of about 0.7% (k=2).

4 CONCLUSIONS

From the obtained results and considering the known values of calibrated luminous intensity lamps by others NMI, it can be stated that a good agreement. In a brief future we expect to improve the uncertainty associated with the detector-based realization of the unit of luminous intensity. At present time, in order to validate the optical power scale traceable to cryogenic radiometer of Inmetro, a bilateral comparison of power spectral responsivity with NIST is going on.

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D3 - Interior Lighting
Glare

PP044

THE DEVELOPMENT OF EVALUATION FOR DISCOMFORT GLARE IN LED LIGHTING OF INDOOR WORK PLACE: THE EFFECT OF THE LUMINANCE DISTRIBUTION OF LUMINOUS PARTS ON SUBJECTIVE EVALUATION

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Objective:
With the improvement in luminous efficiency of LED light source, the general lighting begins to replace the LED luminaires with the existing ones. However, the performance of LED luminaires, including their luminance, area of luminous part, and so on, differs from that of existing luminaires. Therefore, the mere replacement of existing luminaires with LED ones sometimes causes difference in discomfort glare. Because of these factors, the studies of evaluations for discomfort glare in LED lighting have gotten a lot of attention recently.
The design of discomfort glare in lighting of indoor work place uses UGR (Unified Glare Rating). However, it is not clear whether the UGR is applicable to discomfort glare in LED lighting. In our previous studies, it was shown that it was difficult to design using UGR in LED lighting than that in FL one, and there was luminance distribution of luminous part causing it. Because the luminaires used in the experiment differed in the distributions of luminous intensity and the fluxes, however, it was insufficient to conclude that the factor of the results was the luminance distributions. In this paper, we have examined about the affect of the luminance distributions for subjective evaluation of discomfort glare using the luminaires, which the distributions of luminous intensity were close and the luminance distributions had a difference.

Method:
The experiment was performed in a room simulated office room. The room had three walls and no window and its dimensions were: width 2,4m, length 5,0m, ceiling height 2,4m. Figure3 shows the position of each luminaire in the room. The room had a kinds of interior reflection factor: ceiling and wall were 82%, floor was 20%. To simulate an actual office room, the desk, the laptop and chair were placed in the room. It was examined on 20 subjects (10 females, 10 males) varying in age from 25 to 59 years.
In the experiment, a subject was asked to evaluate the degree of discomfort glare under each condition using a scale with seeing fixation point in the centre of the front of wall. There were two positions (P1, P2) evaluated it. For your reference, it was examined to evaluate it in direct view of the luminaire and a whole room. The scale of table 1 was used. The scale was displayed on the laptop, and the evaluation made a verbal response in Japanese. In the analysis, the selected category was converted into a value of UGR with table 1. The value was used as the subjective glare rating in each evaluation. Table 2 shows the conditions employed in the experiment. The conditions were presented in random order and each condition was done once.

Result:
Figure 2 shows the relationship between the UGR and the subjective glare rating with seeing fixation point in each position. The UGR of X-axis is calculated by the information of experimental

room and the distribution of luminous intensity in each condition. The Y-axis is mean of all subjects' data in each condition. The symbols are the conditions of luminance uniformity. According to Fig. 2, the subjective glare rating increased with the UGR, and as the luminance uniformity decreased, the profiles changed in a discomfort way. Fig 2 also indicated that 0,01 of the luminance uniformity differed from the others of that in lower UGR. A similar result in the other evaluations was shown.

From the results, we found that the average luminance was same when the subjective glare rating was different dependently of the luminance distribution of luminous part. The results will facilitate the study of source-independent evaluation for discomfort glare. Further work in this study is on the way to improve the performance of the evaluation for discomfort glare and its application in the luminance distribution of luminous part.
This research project has been supported by NEDO, New Energy Industrial Technology Development Organization of Japanese Government.

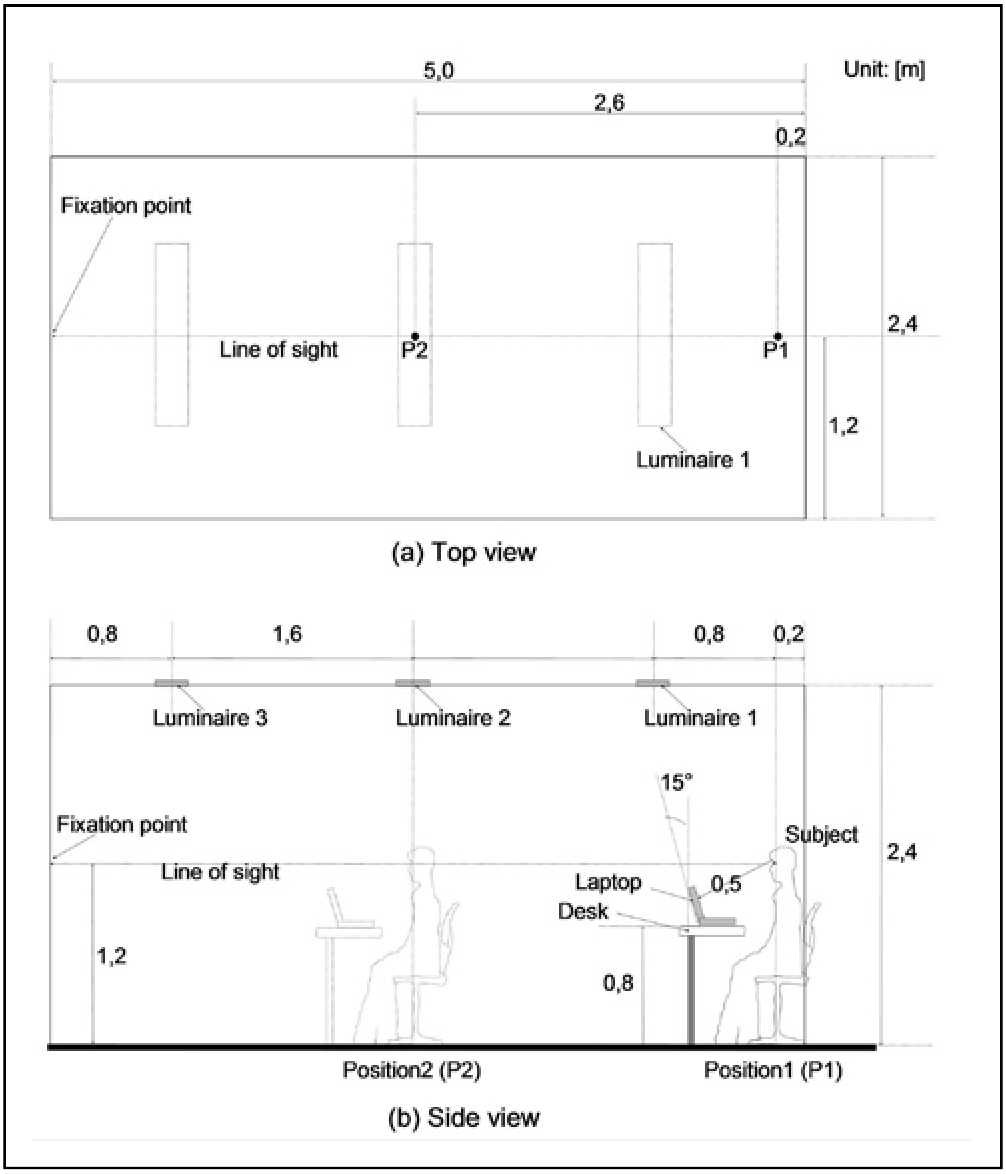

Figure 1 - The sectional view in the experimental room

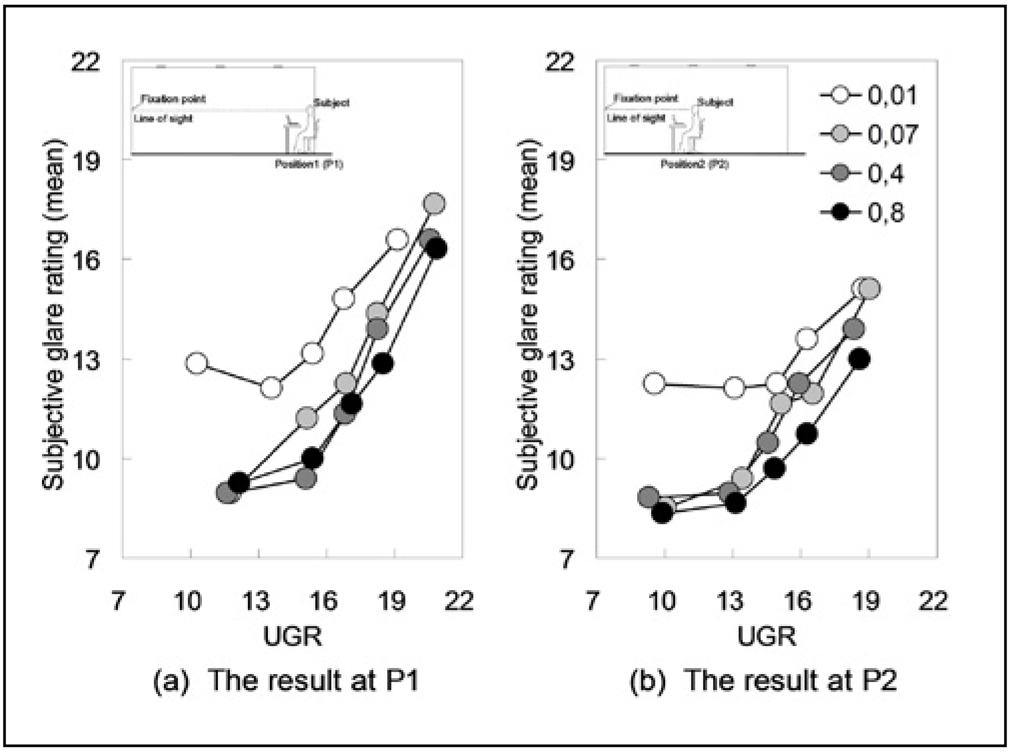

Figure 2 - The UGR versus the subjective glare rating

UGR	Categories
31	Intolerable
28	Just intolerable
25	Uncomfortable
22	Just uncomfortable
19	Unacceptable
16	Just unacceptable
13	Perceptible
10	Just perceptible
7	Imperceptible

Table 1 - The value of UGR correspond to each category.

Horizontal illuminance E (5 conditions)	100 300 500 750 1500 lx
Luminance uniformity U (4 conditions)	0,01 0,07 0,4 0,8

Table 2 - The experimental 20 conditions

PP045

THE DEVELOPMENT OF EVALUATION FOR DISCOMFORT GLARE IN LED LIGHTING OF INDOOR WORK PLACE: THE MODIFICATION OF G-CLASSIFICATION USING LUMINANCE DISTRIBUTION OF LUMINOUS PARTS.

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Objective:
It is one of important factor of designing the comfort lighting space that limiting discomfort glare of indoor work place. In Japan, the G-classification is used to evaluate the discomfort glare of luminaires. G-classification is standardized method by JIS (Japanese Industrial Standards). JIS is local standard in Japan. G-classification is index to evaluate the degree of limited discomfort glare of luminaire, using limit value of one within prescribed vertical angle. Our previous study showed that there were cases that G-classification couldn't evaluate luminaire with distributed luminance, and there was a need for the new G-classification in consideration of the luminance uniformity of luminous parts. In this paper, in order to suggest the new method of G-classification using luminance distribution of luminous parts, we analyzed the previously conducted experiment about discomfort glare, using LED luminaires with several distributed luminance, and investigated the relationship between G-classification and luminance uniformity of luminous parts.

Methods:
The experiments were conducted in the room assumed to be an office room. The dimensions of the room were 2,4m in width, 5m in depth and 2,4m in height, and there was no window in the room. The three same luminaires were set in the room. We prepared the rooms which had two kind of reflectance of the interior. One was: the ceiling, the wall, the floor are 82%, 82%, and 20%. The other was: the ceiling, the wall, the floor are 82%, 51%, and 20%. In the experiments, 16 kinds of the LED luminaires and 5 kinds of the fluorescent lamp luminaires (FL luminaires) were evaluated. The subjects evaluated the discomfort glare with seeing fixation point in the centre of front of wall after their eyes were fully adapted to the lighting conditions. There were two positions (P1, P2) evaluated it. The distance between the position and front of wall was: P1 4,8m, P2 2,4m. The evaluation scale had 9-step (0: imperceptible-8: intolerable) in table 1. In the experiment, we used the category corresponding to Japanese. 20 Japanese subjects (10 females and 10 males) in age from 25 to 59 years participated.

Result:
Figure 1 shows the relationship between the G-classification and the subjective glare rating in reflectance condition of wall 82%. The horizontal axis is the G-classification. The vertical axis is the average of subjective glare rating. The correlation coefficient of FL luminires was 0,9 and that of FL luminiares was 0,45. The result of these indicated that it is difficult to evaluate LED luminaires using G-classification. In order to improve the date spread of subjective glare rating in LED luminaires, we studied the relationship between one and the luminance uniformity, and have developed the new method that G- classification is modified. The modified New G-classification

(n-G-classification) was calculated using the value of the luminance uniformity of luminous parts. Figure 2 shows the relationship between n- G-classification and the subjective glare rating in reflectance condition of wall: 82%. The graph showed a higher correlation coefficient of n-G-classification than one of G- classification. In the case of FL luminaires, the correlation coefficient of both methods was high value. In the case of LED luminaires, the one of n-G-classification was 0,62. The result suggests that the n- G- classification had a correlation better than the G- classification.

Conclusion:

We have studied the relationship between the G-classification and the luminance uniformity of luminous parts. In the case of LED luminaires with distributed luminance, we showed the new method can evaluate better than G- classification.

This research project has been supported by NEDO, New Energy Industrial Technology Development Organization of Japanese Government.

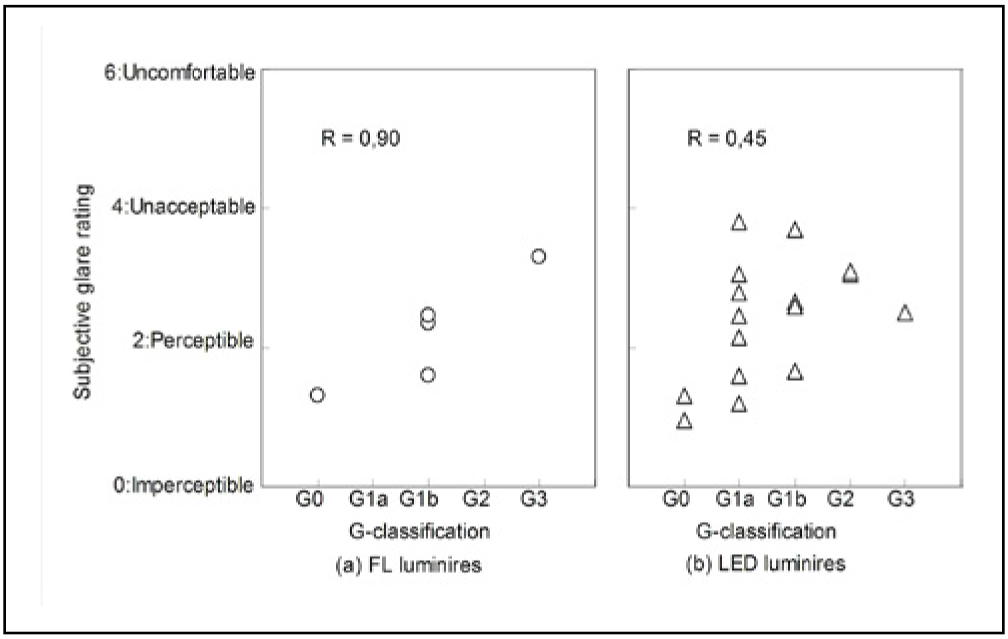

Figure 1 - The G-classification versus the subjective glare rating.(P1,the reflectance of wall: 82%)

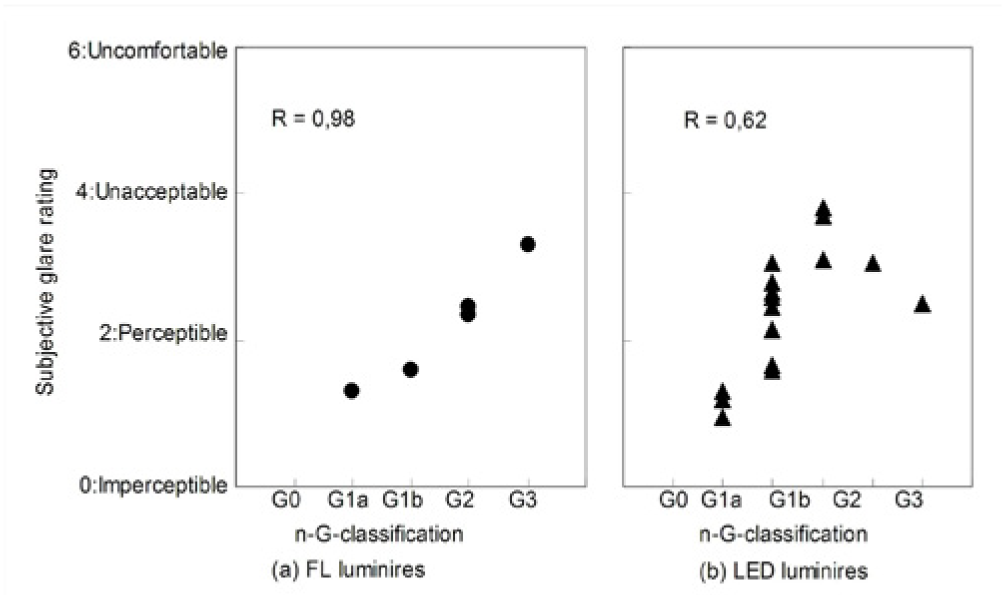

Figure 2 - The n-G-classification versus the subjective glare rating.(P1, the reflectance of wall: 82%)

Scale	Categories
8	Intolerable
7	Just intolerable
6	Uncomfortable
5	Just uncomfortable
4	Unacceptable
3	Just unacceptable
2	Perceptible
1	Just perceptible
0	Imperceptible

Table 1 - The evaluation scale correspond to each category

PP046

A STUDY ON DEVELOPING VEILING GLARE RATING ACCORDING TO CHARACTERISTICS OF REFLECTED IMAGES ON SCREENS AND HUMAN RESPONSES

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Abstract
Lighting is an important environmental factor when considering health and safety, visual comfort and workplace design. There are many different aspects of lighting that can cause visual discomfort, veiling glare especially. Veiling glare can cause visual discomfort because they can reduce the luminance contrast and hence the difficulty of the task. It is therefore quite important to limit the magnitude of veiling glares in offices. In order to prevent the veiling glare, the lighting and screens conditions that can cause the reflected images on screens and veiling glare rating were developed in this study.

Purpose
This study developed the veiling glare rating according to characteristics of reflected images on simulated and real screens. Furthermore, the veiling glare could be reduced or prevented by adapting the conditions of lighting sources, screens, and human.

Background and Motivation
Lighting is an important environmental factor when considering health and safety, visual comfort and workplace design. But how well do we really understand the implications of lighting on these factors, especially in a workplace environment? In recent years, utilization of LED lighting at workplace is increasing. LEDs are small point sources with high intensities and arrays of these individual sources can form luminaires with very different shapes and sizes. Therefore, in illuminating the space with LEDs special care has to be taken to avoid glare. Glare is caused by high luminance or excessive luminance differences in the visual field. Glare is typically classified as one of two main types. (1) Discomfort glare – This is in generic terms defined as a sensation produced by luminance (brightness) within the visual field that is sufficiently greater than that to which the eyes are adapted. Discomfort glare is usually the result of a high luminance of an insufficiently shielded light source or reflection in the field of vision.
(2) Disability glare – Sometimes called 'veiling glares', disability glare is the result of a light source of sufficiently high luminance reflecting off a task surface or directly into the eye and hindering productivity - the result of reduced contrast within the task area. This is inherently less problematic to assess because objective 'visual tests' exist which can record performance under particular lighting layouts and luminance distributions.
Veiling reflections/veiling glare are specular reflections that appear on the object viewed and which reduce the visual task contrast. The determining factors are the specular surface and the geometry between the surface, observer and sources of high luminance (e.g. luminaires, windows, bright walls). Glossy papers, glass surfaces and computer screens are subject to cause veiling glare. In rooms with several computer screens inside the task area special care has to be taken in the positioning of the luminaries to avoid luminous reflections from the screens. In using

portable computers the viewing directions may change in relation to the fixed luminaires and this poses further requirements for lighting design. Veiling glare rating is the base of anti-veiling glare; however, veiling glare rating is not well understood. Hence, this study developed the veiling glare rating according to characteristics of reflected images on simulated and real screens.

Method

In order to build up the veiling glare rating, the systematic procedure was developed (Fig. 1). This procedure started with literature review, followed with setting up experiment layout, classifying reflected images on simulated screens, analyzing conditions of lighting sources that can cause types of reflected image, conducting the experiment design by Taguchi methods, and performing ergonomics evaluation of each selected scenario, and ended with developing veiling glare rating.

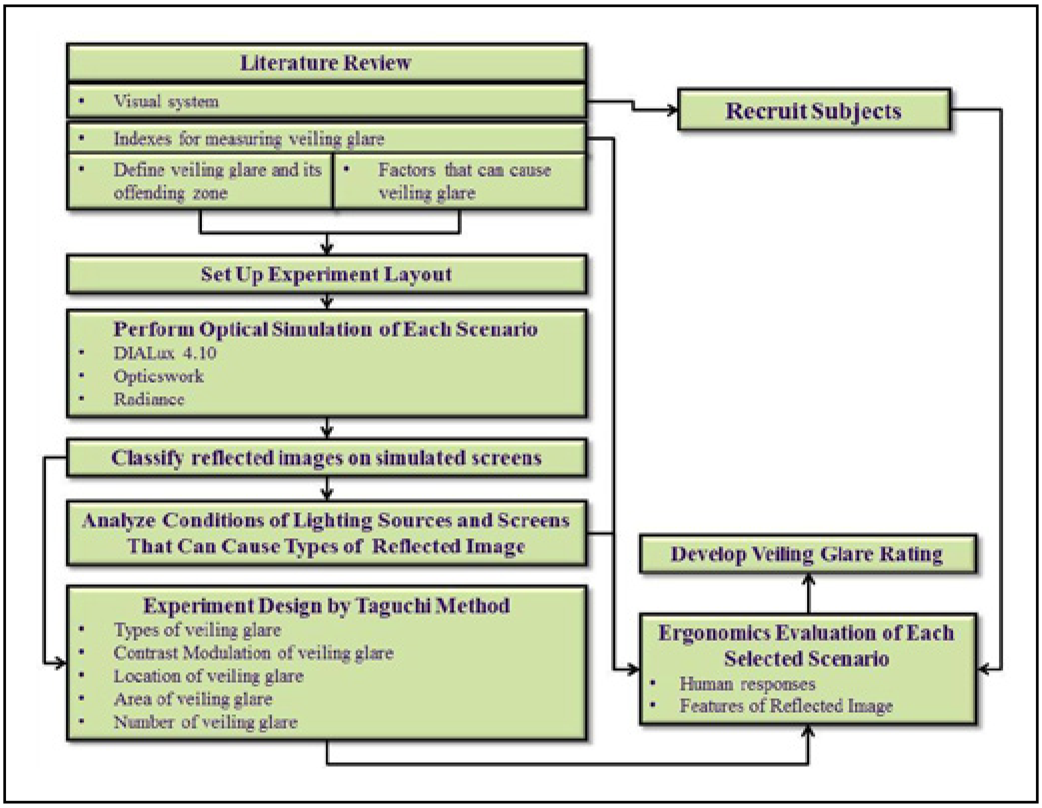

Figure 1 - Systematic procedure for rating veiling glare

PP048

VISUAL COMFORT LIGHTING FOR COMPUTER USE AT HOME

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There are more and more eyestrain related complaints of people using computers at home. Poorly designed lighting may be one of the most important factors causing these complaints. In this paper, we present results of a subjective evaluation of how the vertical luminance distribution in the field of view (FOV) influences visual comfort for computer use at home. The experimental set-up contained a computer screen surrounded with background illumination in a home mock up room. Subjects were asked to tune their preferred luminance level of the background for two typical ambient lighting conditions (i.e., 0lux and 100lux, measured horizontally on the desk) and three typical computer screen luminance levels, corresponding to luminance values typical for movie, game and web surfing. The results show that the background luminance level is a key factor for visual comfort for computer use at home. The most preferred background luminance is linearly related to the averaged screen luminance level for adult eyes.

PP049

SUBJECTIVE RESPONSES TO DIFFERENT LIGHT SOURCES. A STUDY ON LIGHT PREFERENCES AND COMPARISON OF STANDARD LIGHT MEASURES WITH HUMAN INDIVIDUAL ESTIMATES

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We are continuously exposed to natural and artificial light, being light the major Zeitgeber of the circadian system and alterations of the light/dark cycle can have significant effects on human physiology and health [1].
For example use of artificial light in the evening and night hours can delay sleep onset, by suppressing endogenous melatonin which controls nocturnal physiological and behavioural responses.
Individual subjects can show different sensitivity to light [2] and individual performances can also be influenced by chronotype preferences (eveningness vs morningness), and seasonal sensitivity [3].
Although a clear relationship has been shown between light and human psychophysiology, use of artificial light in human environments is based on photometric quantities, as illuminances on visual tasks and luminance, with no study that has addressed comparison between different spectral power distributions and human subjective estimates.
At present several kinds of lighting sources are available for exterior and interior environments. In particular, for indoor environments, fluorescent lamps are still the most spread, while LED applications, especially for new installations are rising.
Since both fluorescents and LEDs are disposable with different CCT, the choice is wide and decision toward a definite technology and colour tone has also an impact in the perception of the environment. In other words, with the same illuminances, the spectral power distribution of the light source affects the brightness as it is suggested by previous researches [4,5].
On changing the SPD of the source, with the same illuminances, other perceptual differences can be detected and people could prefer one source respect to another for various reasons, for example objects can result more detailed or colours appear more harmonious. Furthermore, SPD could have an influence on mood and alertness.
The present study aimed to evaluate individual estimates of different light sources (fluorescent vs LED), specifically addressing subjective evaluation of brightness and agreeableness either of ambient and on visual tasks. Effects on mood and alertness were also evaluated.

METHOD

In the Lighting Laboratory of the Department of Industrial Engineering at the University Federico II of Naples, a test room (3.0 m x 3.0 m x 3.0 m) with neutral gray walls was set up. The lighting equipment consists of four LED luminaires ad two fluorescent luminaires. A table with a chair was located at the centre of the room. LED luminaires can be driven in order to vary both CCT and output luminous flux, while each of fluorescent luminaire mounts 4 lamps, arranged in two couples separately driven. All luminaires are connected in a DALI system and tuned by a digital control

system. SPDs of the fluorescent lamps were detected by means of a spectroradiometer.
Two light scenes with fluorescent lamps were set: warm fluorescent (CCT = 2924 K) and cold fluorescent (CCT = 7010 K), illuminances were measured on the table and were the same and equal to 630 lux. LED luminaires were adjusted in order to obtain other two light scenes with the same CCTs of the fluorescent and the same illuminances on the table.
In this way four light scenes were set up, and named CF (Cold Fluorescent), WF (Warm Fluorescent), CL (Cold LED) and WL (Warm LED). A fifth light scene was set up, which was a mixture of all the sources, equally dimmed in such a way to obtain the same illuminance on the table, and named N (Neutral). See Fig.1.
The light scenes were presented to the subjects in random sequences. In order to avoid sharp changes in the passage from one scene to the subsequent the neutral scene was interposed.
One hundred nine subjects were studied. Mean age of the sample was 27.9 (72 females and 37 males). Written informed consent was obtained from all subjects. Subjects were not colour blind, as tested by Ishihara Color Blindness test. Visual analogue scale (VAS) testing the following items: a) readability of a written text, b) environmental brightness, c) colours perception and d) agreeability of environment, were administered during each of the five light sessions.
Comparison of the five conditions on each of the variables investigated were conducted throughout ANOVA.

RESULTS AND DISCUSSION

Significant differences between the five conditions were found for „readability of a written text“ (df= 4,539 F=11.4, p=0.0001), „environmental brightness“ (df= 4,496 F=21.4, p=0.0001), „colour perception“ (df=4,538 F=14.3, p=0.0001) „agreeability of environment“ (df=4,498 F=3.5 p=0.008). Cold lights were considered by the subjects better compared to the warm ones either when reading a text and evaluating the ambient and the colour. LED resulted better on colour evaluation. Cold light were also reported as giving a higher vigilance, whereas no effect was found for mood. It should however be noted that the „neutral“ light, with a mix of whole components was globally judged as the better one in most of the conditions evaluated, probably this is due to the richness of all wavelengths in the visible range. ACKNOWLEDGEMENT
We thank Zumtobel for providing lighting and control systems.

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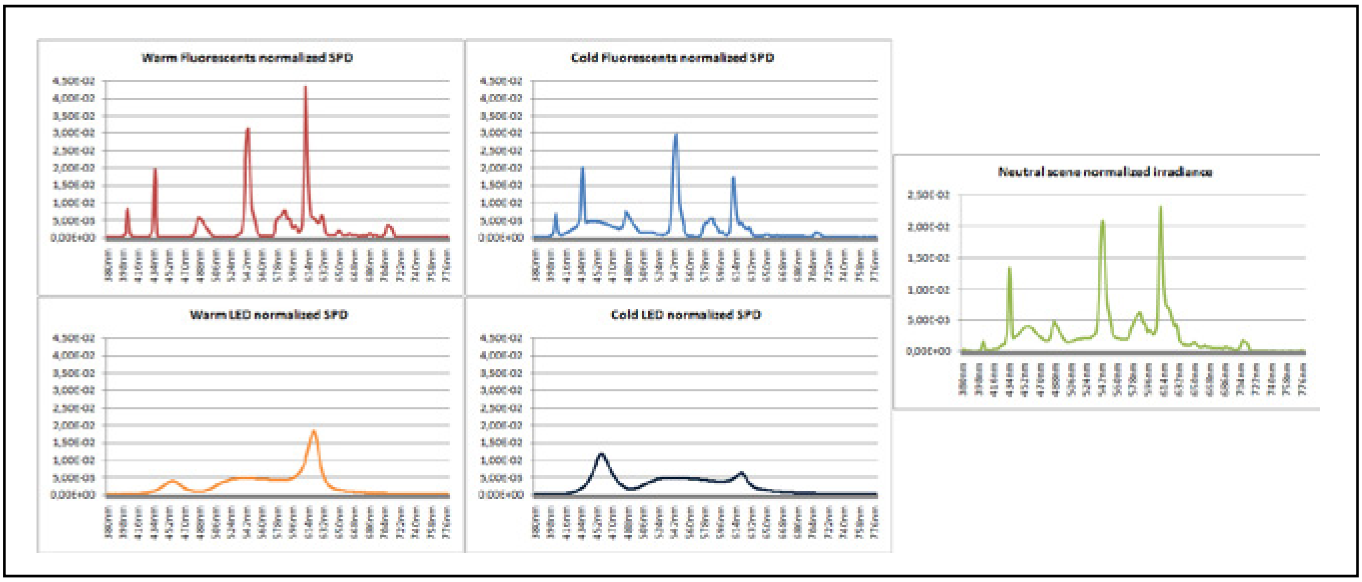

Figure 1 - Spectral characteristics of light scenes

D3 - Interior Lighting
Homes

PP050

AN INVESTIGATION INTO LUMINOUS COMFORT IN THE SUMMER SEASON OF PALESTINIAN DWELLINGS: INHABITANTS' POINT OF VIEW.

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Nowadays, daylighting in buildings is considered as a passive solar design strategy. This paper reviews the results from two field researches (qualitative and quantitative) of environmental (luminous) comfort within two types of buildings; traditional (old) and contemporary (new), in two Palestinian cities (Jericho and Nablus) of two different climatic zones. In the first research, a questionnaire survey was carried out in summer 2009, over 291 dwellings of different times of construction and housing typologies. In the second research, two field measurements (spot and daily) were undertaken in the summer seasons 2010 and 2011, with a clear sky conditions. The environmental parameters were measured in 8 buildings in Jericho (3 traditional & 6 contemporary) and 14 buildings in Nablus (4 traditional and 10 contemporary).

The questionnaire findings have revealed that improving the luminous comfort conditions presents the second preference aspect for Nabulsis. In addition, the field measurements results indicated that although the indoor daylight level, based on ASE8911 and CIE etc, implied discomfort (poor), the occupants expressed their satisfaction with the indoor luminous comfort conditions.
Urban regulations, cultural value (privacy), interior spatial organization and window's size strongly influenced the lighting performance in different living spaces. However, residents of traditional dwellings were more tolerated than who reside in contemporary ones. Designers are invited to review and improve the traditional daylight solutions and strategies into a modern language to enhance both luminous and visual comfort in their designs.

This paper based on a PhD research thesis being carried out under the supervision of Prof. Catherine Semidor and defended in 18 September 2012, Ensap-Bordeaux, France.

Keywords: daylight, comfort, inhabitants' perception, traditional strategies, Palestine.

PP051

TAKING INTO ACCOUNT THE NATURAL LIGHTING IN INTERIOR SPACES OF JEDDAH HISTORICAL HOUSES IN SAUDI ARABIA

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This paper leads to find the advantages of using the mousharbiah in the contemporary middle eastern architecture, it's an investigation on daylighting performance in a residential living rooms of Several buildings in the city of Jeddah in Saudi Arabia. As we know The Arabian Vernacular architecture rich of architectural elements which has been adapted to create their identity, in the same time to reach to the efficiency and quality of life. One of the most remarkable example of this adaptation in the Arabian architecture and hot country called the Moucharbiah (Rowshan). It has effective Specifications which is used for hygrothermal comfort "ventilation and day lighting control", in the same time it works for privacy and security solutions. The Moucharabiah (Rowshan) is a space in between, and which is a closed balcony made of timber lattice of cylinders connected with joints, was developed hundreds of years ago by the Arabian people. The Moucharabiah is made up of three parts, each part has its own benefits and properties.
While its bottom part is opaque, its middle part, at eye height, is made of close meshes net, which admits fresh air. It is based on local materials and techniques and has also a cultural role in that it provides Muslim women with privacy without isolating them from the external environment. The upper part of the it is made of a wide mesh that allows daylight penetration, in the same time the shading system is reducing solar gains in summer but allows sufficient daylight.

A lot of properties can observe it in this element, but is it efficient enough? Is the interior space daylight is enough?!. By working on several interior spaces in Jeddah historical houses, and making some evaluation by using Specialized software which can make calculations for instance: daylight factor, lighting intensity and quantity of solar radiation, or taking instant measures. In addition to what are ways to develop and use this element in contemporary architecture.

PP052

A STUDY ON PREFERENCE AND SUBJECTIVE EVALUATION EXPERIMENT FOR ARCHITECTURAL LIGHTING TYPES AND CORRELATED COLOR TEMPERATURE BY RESIDENTIAL SPACE

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This study examines user needs for residential lighting environments. Two residential space types (109m^2 and 159m^2) were selected, wherein architectural lighting types and correlated color temperature were applied to the living room, bedroom, and corridor. Thus a subjective evaluation of such experiment was conducted.

Tests were conducted on two occasions. The first test evaluated the functional suitability and preference for 55 types of lighting fixtures applied in single residential areas. Lighting variables included the lighting applied area, architectural lighting types, and correlated color temperature. Lighting applied areas included ceilings and walls with the use of the single and combined lighting application methods. Architectural lighting types included the direct ceiling lighting, cove lighting, valance lighting, and cornice lighting. Correlated color temperatures applied to the living room and corridor included the three stages of 3000K, 4000K, and 5500K, and correlated color temperatures applied to the bedroom included five stages including light blue and dark blue. Also, the highly evaluated types in the first evaluation were combined to manufacture 148 types for the second evaluation. 20 experts participated in testing. The five-stage value hierarchy was used for evaluation, and descriptive statistics and factor analysis of the multivariate analysis methods were used for the analysis.

The first test evaluation of suitability and preference for living rooms and bedrooms revealed that the type with valance lighting applied to the wall was highly evaluated. Also, for living rooms, 3000K and 4000K types were preferred. For bedrooms, the lower color temperature earned a higher score. For corridors, in short-length 109m^2 plane type, the combination of downlight and cove lighting was highly evaluated. In the long 159m^2 plane type, the combination of downlight and cove lighting, upward and downward cornice ligthing was highly evaluated.

The second subjective test evaluation revealed that ‘the neat’ atmosphere was closely related to the lighting type, whereas the lower the color temperature was, the more ‘comfortable’ the atmosphere was evaluated.

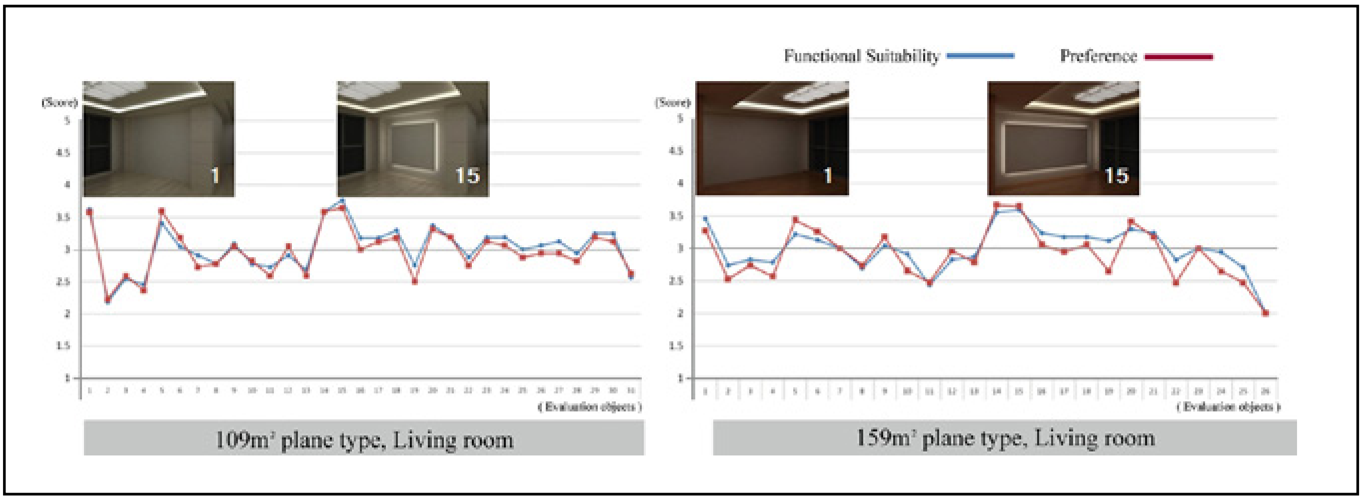

Figure 1 - The results of functional suitability and preference evaluation

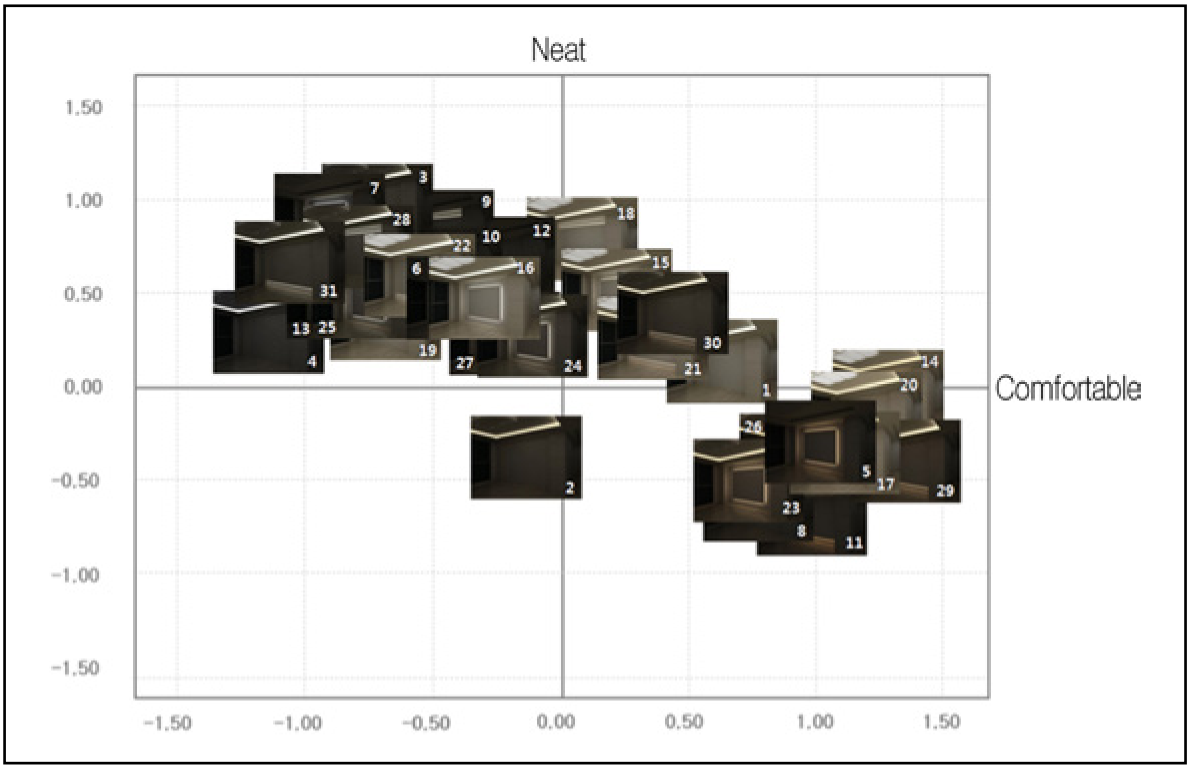

Figure 2 - Analysis of factor plots(109m^2 plane type_Living room)

Division	Living room				
	Ceiling		Wall		
Architectural Lighting	The direct ceiling lighting + Cove lighting	Cove lighting	Valance lighting	Cornice lighting	
				upward	downward
Correlated Color Temperature	2800K, 4000K, 5500K		2800K, 4000K, 5500K		

Factor	Evaluation term	Factor			Factor analysis
		1	2	3	
1	Warm	.903	.003	.044	Comfortable
	Comfortable	.846	.301	.044	
	Soft	.804	.205	-.008	
	Claasical	.722	.031	.130	
	High-class	.622	.446	.320	
2	Simple	.115	.814	-.114	Neat
	Neat	.254	.804	.258	
	Modern	.064	.780	.114	
3	Colorful	.105	.107	.958	Colorful
Eigen value		3.178	2.262	1.133	
Contribution rate		35.309	25.130	12.593	
Cumulative rate		35.309	60.438	73.031	

Table 1 - The compenent of first evaluation object (Living room)

PP053

A STUDY ON THE PERCEPTION CHANGE OF FINISHING MATERIAL BY LIGHTING IN RESIDENTIAL SPACE

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Finishing materials vary in visual effects due to lighting influence, and the perception of finishing material that changes by lighting in residential space produces various atmosphere of space to residents. Therefore, this study has the purpose to identify the degree at which finishing material changes in perception depending on lighting depending on color, texture and pattern the expression elements of finishing material.

The study has been conducted in the following method:
First, it was clarified that lighting element works significantly when finishing material changes in visual effects. Second, ‚modern natural' space and ‚classic natural' space which were evaluated as the most preferred space among recently introduced design trend were planned out in two methods of expressing materials, and at this time, simulation space image was produced with the light source of lighting(LED, 3-phase lamp and halogen) taken as variable.
Third, simulation space was composed as ‚art wall' of living room where finishing materials and lighting are expressed the most diversely and actively, and as for the degree at which the perception of finishing material by each lighting changes, the value (change) of difference when 3 lightings were applied were analyzed comparatively with reference to the conditions where no light source is applied like the circumstance where only living room light is turned ON. Fourth, for evaluation of the perception change of finishing material through simulation space, questionnaire survey was conducted on 100 college students majoring in interior design, and specifically how color, texture and pattern the expression elements of finishing material vary whenever each lighting changes were evaluated. Colors were evaluated with reference to Value, Chroma and Hue, and as for Texture, adjective vocabularies related to visual touch were extracted and proposed as evaluation standard. As for Pattern, the changes of pattern were identified with reference to transparency.

In this study which intended to analyze how differently finishing material formed through the relationship with LED, 3- phase and halogen lamps is perceived, it was found that the color, texture and patterns of finishing material are perceived different from cases where no lighting is applied depending on the difference of lighting even if the same finishing material is applied.
It is anticipated that the results of this study will be utilized as basic data in uplifting the satisfaction of residential space design and presenting design of residential space which is formed with focus on finishing material and lighting through changes of visual perception.

Figure 1 - in case of Halogen of ModernNatural A1

Figure 2 - in case of No Lighting of Modern Natural A1

Space Image		Finishing Material		Space Image		Finishing Material	
Modern-Natural	A1	floor	Basic Material (wood)	Classic-Natural	B1	floor	Basic Material(wood)
		art wall	design wall			art wall	design wall
		ceiling	Basic Material (silk wallpaper)			ceiling	Basic Material (silk wallpaper)
	A2	floor	Basic Material (wood)		B2	floor	Basic Material(wood)
		art wall	design wall/ polishing tile			art wall	wall paper
		ceiling	Basic Material (silk wallpaper)			ceiling	Basic Material (silk wallpaper)

Table 1 - Finishing Material of Modern-Natural and Classic-Natural Simulation Image

PP054

PREFERRED HOME LIGHTING DESIGN

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A major current task of illuminating engineering is to make the SSL lighting acceptable for the general public, i.e. to find an agreeable and efficient home lighting spectrum for the next generation of LEDs, retrofit SSL lamps and new designs of luminairs with LEDs. In the present paper design and first experiments with a full scale home lighting system are described.
At the University of Pannonia two rooms have been equipped with SSL lighting. One room is furnished as a kitchen and dining area, the other as a living room (Figure 1). In both premises LED luminaires were inserted in the ceiling, where the spectrum could be adjusted in 20 channels. In the living room area 3000 K incandescent reference lighting could be switched on, in the kitchen area it was a 4000 K daylight simulation with incandescent lamps.
The LED lightings are fully computer controllable, and a feed-back from the produced illumination to set the intensity of the single narrow band LED sources has been installed.
Into each luminaire 24 LEDs with the same peak wavelength have been built-in (12 LEDs/ PSU channel, 2 channels with the same peak wavelength), 480 LEDs in total. 17 different colour LEDs (with 17 different peak wavelengths) have been used (mainly Osram Golden Dragon LEDs and some from other manufacturers) and 3 kinds of white phosphor LEDs (Osram Oslon LEDs). Figure 2 shows the spectral power distribution of the different LED channels. Extreme blue with 410 nm peak is important because of the further investigation of the effect of S Cone and ipRGC (Intrinsically Photosensitive Retinal Ganglion Cells) excitation on perceived brightness and circadian rhythm. Extreme red with 670 nm and 690 nm peaks are important because of achieving and testing SPDs with extremely high colour rendering index and improving visual contrast. These two peak wavelengths will also help us to approach the SPD of Daylight illuminants. A system monitors the actual spectral power distribution realized on the working plane in the room.
Previously double booth experiments were conducted to test the visual appearance of spectral distributions optimised for current colour fidelity and colour preference programs (CIE 13.3 method, CRI2012, CQS, gamut area, etc.). As not even the 20 channel system is flexible enough to optimise for every colour rendering program, also a virtual reality system was developed, where the test room could be modelled and the light source spectrum, as well as the reflectance spectra of the walls and furniture could be set in 40 spectral channels. We implemented a path tracing. In order to display the image on the monitor, we finally transform the spectrums to 3 representative R, G, B values of the display.
Experiments are in progress on comparing the virtual reality, the booth experiments and the tests performed in the real full size situations, and will be reported at the conference.

Figure 1 - Living room and kitchen area realized at the University of Pannonia

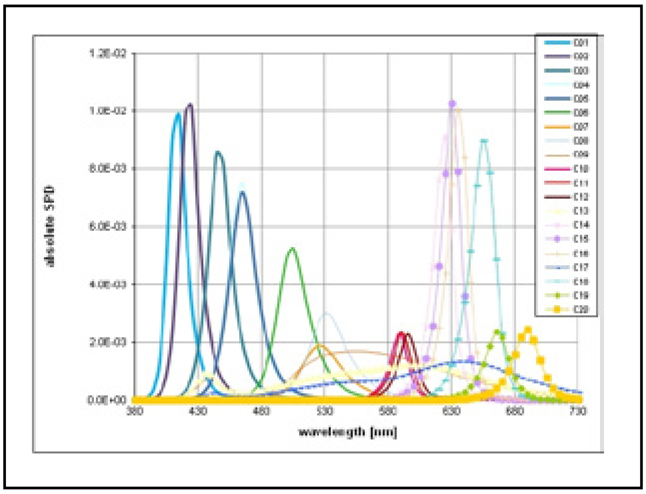

Figure 2 - Spectral power distributions of the LEDs of the test luminaire

PP055

EXPERIMENTAL STUDY ON THE LIGHTING ENVIRONMENT FOR RESIDENTS‘ DOINGS IN LIVINGROOM

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A survey on the actual lighting condition of a livingroom was conducted to determine the optimum environment for the doings in a livingroom. The survey dealt with recent trends and problems in lighting, and lighting uses by doings in living. By using the data from the survey was constructed a full-size mock-up, in which an experiment was conducted on the subjects‘ subjective evaluation in order to find out the optimum conditions for each doing in the livingroom. With the position of the light source, illuminance distribution and color temperature as factors, was evaluated each lighting environment for the three main doings in a livingroom -‘watching TV‘, ‚reading a book‘, and ‚taking a rest.‘

In ‚watching TV‘, the experiment was done to measure the degree of comfort felt by the subjects when they watch static images and moving images, respectably, with different ambient brightness, with or without partial lighting above the TV set, and with different color temperature. In ‚reading a book‘, the comfortableness was estimated by the illuminance ratio of the ambient lighting to the lighting for reading and by the difference in color temperature. And in ‚taking a rest‘, the comfortableness was estimated by means of the ambient brightness, use/no use of a floor stand, and color temperature. This experiment determined the comfortableness for each visual work and the optimum lighting environment against glare.

D3 - Interior Lighting
LEDs

PP056

INFLUENCE OF TECHNICAL PARAMETERS OF LED INDIRECT LIGHTING INSTALLATIONS ON ILLUMINATION PARAMETERS

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Keywords: indirect lighting, light emitting diodes (LEDs), reflection coefficient, illumination parameters

The light emitting diodes (LEDs) are modern light sources used more and more frequently in lighting installations. The luminous efficacy of current best LEDs is equal to or even better than any other light sources. One of the unresolved problems associated with LEDs, though, is related with the glare, especially since LEDs are point light sources with very high luminance. Indirect lighting installations, in which an observer does not see the light source directly, seem to be ideal for the application of LEDs. The one obvious issue with such installations is their low lighting efficiency. In this paper, we present the analysis of the influence of technical parameters of the examined indirect lighting installation on its utilization factor and lighting parameters.
The indirect lighting installations using LEDs were studied first through simulations and then through empirical measurement in a model of the target working space. Previous studies conducted by the authors concluded that computer simulations of indirect lighting installations using LEDs, exploiting two software systems most popular in Poland i.e., Dialux (www.dial.de) and Relux (www.relux.biz), exhibit substantial differences. That is why it was decided to conduct additional simulations using the software developed by the authors, relying on the Monte-Carlo method. The example indirect lighting installation with LEDs was placed in a room where all the surfaces reflect the luminous flux in a diffuse manner. The room was illuminated with one or two rows of LEDs. Individual LEDs were placed on the top of individual diaphragms in a symmetric fashion. The simplicity of the examined lighting installation allowed for more precise analysis of lighting software in terms of lighting results it generates. Moreover, the concluded studies indicate that introduction of additional diaphragms covering LEDs causes substantial decrease in the overall lighting efficiency of the examined installation.

The utility of the given lighting installation was evaluated based on its lighting parameters. According to the European Standard EN 12464-1:2011 Light and Lighting – Lighting of work places – Part 1: Indoor work places, the basic set of lighting parameters includes: average illuminance Em for the target working surface and the illuminance uniformity Uo for the target working surface (calculated as the ratio between the minimum illuminance and the average illuminance Em).
First, we examined the influence of reflection coefficient for the ceiling, walls and the floor on the lighting parameters of the studied installation. The reflection coefficients for the ceiling varied from 0.6 to 0.9, walls – from 0.3 to 0.8, and the floor – from 0.0 to 0.5. It turns out that the reflection coefficient for the ceiling had the critical impact on the lighting efficiency of the installation. When decreased from 0.9 to 0.7, the average illuminance decreased by 30%. The reflection coefficient for the ceiling had negligible impact on the illuminance uniformity, as long as the reflection coef-

ficient for the ceiling remained relatively high. Decreasing the reflection coefficient for the walls impacts the lighting efficiency for the studies installation, though in a less accented manner, while simultaneously causing a clear decrease in the illuminance uniformity.
We also further studied the effect of the diaphragm geometry on the installation lighting parameters. An increase in the width of the diaphragms causes the decrease in the overall installation efficiency and then first increases the illuminance uniformity and then decreases it.
The maximum observed lighting installation efficiency was larger than 50%. This value is considered satisfactory, especially when accompanied by very high lighting uniformity. When used in a room with pastel coloured walls with high reflection coefficient is therefore admissible, though leads to decrease in the lighting efficiency. The lighting efficiency for such installations exceeds 40%, while the illuminance uniformity remains very high. This also allows to solve the basic problem related with application of LEDs in lighting installations, limiting the glare. Additionally, such installations are highly esthetic.

Moreover, we studied the impact of the asymmetric placement of LEDs in the room on the lighting parameters of the examined installation. Studies indicate that even the high placement asymmetry of LEDs does not cause substantial
loss in efficiency and illuminance uniformity. This allows architects to design different types of indirect lighting installations using LEDs.
The empirical verification of the computer simulations for lighting installations with LEDs was based on a developed model of the room (scale of 1:5). The average illuminance observed empirically in the model and obtained in computer simulations differed by only 3%. The measured and calculated illuminance uniformity values were also very similar and high, exceeding 0.8.

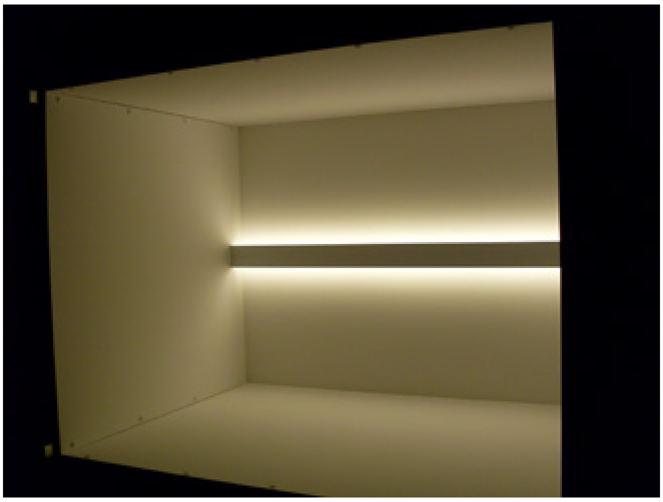

Figure 1 - Model of the room (scale of 1:5) - view from the floor

Figure 2 - Model of the room (scale of 1:5) - view from the ceiling

PP057

A STUDY ON SPACING TO HEIGHT RATIO OF CONVENTIONAL FLUORESCENT LUMINAIRES AND LED FLAT LUMINAIRE

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1. OBJECTIVE

Nowadays conventional fluorescent luminaires is replaced with LED Flat Luminaires because they are thought to offer many advantages, including luminaires efficacy, tenability of the spectrum, lower energy savings, appearance and quality of lighting, environmental benefits and cost effectiveness. In order to compare spacing to height ratio of conventional fluorescent luminaires and LED Flat Luminaires, we should be evaluated using a Popular Lighting Calculation Software like the NLReport. In this paper, we investigated the spacing to height ratio of luminaires and estimated luminaires number in interior environment.

2. METHODS

The Study aimed at identifying the spacing to height ratio and estimated luminaires number of conventional
fluorescent luminaires and LED Flat Luminaires. The identification process followed a step-by-step approach, as follows. In the first part of the experiment, the Luminous Intensity Distribution measurements of Luminaires were carried out with Gonio-Spectroradiometer. In the second part of experiment, we calculated the spacing to height ratio and the Luminaires number of conventional fluorescent luminaires and LED Flat Luminaires in the interior environment using Lighting Calculation Lumen method and NLReport Software. And we determined assuming their spacing to height ratio value. Analyses are realized on the LED Flat Luminaires and compared with conventional fluorescent luminaires in terms of Luminaires number at approximately equivalent light output (Target illuminance 500 lx) in the same interior environment (10m x 10m x 2.7m). The last measurements were focused on optical Performance of conventional fluorescent luminaires and LED Flat Luminaires using by Lighting Software: illuminance, illuminance uniformity. Optical performance of LED Flat Luminaires was compared with respect to that of conventional fluorescent luminaires.

3. RESULTS

Conditions of Luminous Intensity Distribution of Luminaires tests are relying on the standard IESNA LM-79-08. We acquire the Luminous Intensity Distribution (IES File) using the Gonio-Spectroradiometer. We analyse the spacing to height ratio results for the LED Flat Luminaires against the baseline of conventional fluorescent Luminaires. The spacing to height ratio of LED Flat Luminaires is around 1.42:1 to 1.49:1. The spacing to height ratio of conventional fluorescent Luminaires is around 1.27:1. LED Flat Luminaires is a more Spacing Performance alternative than conventional fluorescent Luminaires.

4. CONCLUSIONS

The results of this paper showed that the spacing to height ratio of LED Flat Luminaires is around

1.42:1 to 1.49:1.The LED Flat Luminaires tested is a more spacing performance effective than conventional fluorescent luminaires. Number of conventional fluorescent luminaires need more than LED Flat Luminaires in the same interior environment. Optical property of LED Flat Luminaires was compared with respect to optical performance of conventional fluorescent luminaires. The Result showed that optical performance of LED Flat Luminaires has high uniformity than that of conventional fluorescent luminaires. LED Flat luminaires still a relative new solution in the general lighting and can compete with a longstanding technology to their high performance.

	Type	Power Consumption	Total LuminousFlux	SHR Maximum
1	Conventional Luminaires	93	5638	1.27 : 1
2	LED Flat Lumianires 1	83	4319	1.47 : 1
3	LED Flat Lumianires 2	71	4340	1.42 : 1
4	LED Flat Lumianires 3	47	4885	1.49 : 1
5	LED Flat Lumianires 4	49	4336	1.46 : 1

Table 1 - Spacing to height ratio of conventional fluorescent luminaires and LED Flat Luminaires

PP058

COMPARISON BETWEEN FLUORESCENT AND LED LIGHTING ON VISIBILITY AND VISUAL COMFORT IN SCHOOL CLASSROOMS

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There currently is much emphasis on replacing fluorescent lighting with LED-based lighting, also in schools. However, the difference between LEDs and traditional light sources is not fully understood yet for most applications. There is a basic concern about light quality with the new LED light sources, which are different from traditional fluorescent sources in many aspects. The aim of our study was to evaluate the impact of fluorescent and LED lighting on visibility and visual comfort for students in school classrooms when watching a projector screen. 19 students aged from 9 to 16 years participated in the experiment. Two types of luminaires (i.e., one with fluorescent lamps and one with LED sources) were used at an ambient lighting condition (i.e., 300 lux). The students seated at 5 different positions and performed some tasks on a projector screen that had 5 different luminance levels. The students were asked to tune the contrast of the letters on the projection screen to (1) a value that corresponded for them to the visibility threshold of the letters, and (2) a value that corresponded to a comfortable threshold for reading the text. A paired-sample T-test performed on the result indicated no significant difference in the contrast visibility threshold and in the comfortable contrast value between the fluorescent and LED based ambient lighting.

PP059

SUBJECTIVE PREFERENCES FOR LED LIGHTING IN OFFICE

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CIE Colour Rendering Index (CRI) has been used for over 40 years and has been widely accepted. Despite of its prominence, CIE CRI has numerous deficiencies, and the problems of CIE CRI became serious enough to require revision for the metric after the emergence of white light from Light Emitting Diodes. Various alternative metrics have been proposed for accessing color characteristics of light sources to the CIE TC 1-69, which is currently working on to find a new metric or metrics. The proposed metrics cover different aspects of colour quality. To be able to suggest people's judgement of colour quality, well-designed user preference experiments are needed. Moreover, LEDs provide huge opportunities to adjust the lighting according to actual needs in the working place. However, end-users' requirements, expectations and preferences for office lighting applications based on LEDs are not well-known.

This paper presents 1) experiments performed in tests booths at Aalto University to study user lighting requirements and preferences to be able to suggest preferred spectral distribution for SSL products and 2) setup of further detailed investigations being carried out in real office environment.

Small-scale experiments were performed in test booths to restrict the range for optimal solutions for the full scale experiments to be performed in real office environment. In the small scale experiment 21 different LED spectra simulated for various combinations of existing and proposed color rendering metrics were tested at 2700K, 4000K, and 6500K. Sixty observers evaluated the lit scenes and evaluations were based on questionnaires and objective measurements. The results provided a first estimate on the preferred lighting spectra within office environment.

Based on the results of small-scale experiments, as a next phase of acceptance studies, large scale experiments are being conducted in real office rooms. In these experiments, the test persons are totally immersed in the lit environment, do office related tasks and perform evaluation of the lit environment. The objective is to determine optimum light source spectral power distribution (SPD) for different working situations by 1) the exploration of lighting preferences and requirements in office environment, and 2) optimization of SPDs for user preference, acceptance, and energy savings.

PP060

USER PREFERENCES IN INDOOR LED LIGHTING

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The objective of the study was to identify different visual elements of LED lighting including sufficiency of light, pleasantness and color rendering. Visual elements were both measured and evaluated by user study. Another goal of the study was to test the guidelines set in the latest European indoor lighting standard EN 12464-1 (issued June, 2011) in an office experiment, and to compare the luminous values to the subjects' preferences.

LEDs are currently one of the fastest growing lighting solutions: and thanks to their flexibility and application prospects, they are now leading the way towards market dominance. Individual LEDs are as small and compact as point sources and their luminance is very high. LED luminaire may be a source for discomfort glare which may cause a decline in employees' performance. Another very important aspect of LED lighting is the color rendering capabilities and the color of the light. The general scene, and light color are also examined within this study with the main aim of identifying which settings are perceived as energizing and activating, and which are seen as stressful and hectic.

The user test took place during the last week of October, with a typical autumn pale daylight. The questionnaire was designed to evaluate light sufficiency and pleasantness, direct and reflected glare, light color (correlated color temperature) and color rendering capabilities. The test subjects evaluated two different positions in the room. Subjects would arrive in their reserved times along the day, and would be directed to the test room. They were then given a brief about the test for 2 minutes without discussing major technical specifications and concepts. They were asked to stay in the room for 5 minutes for their eyes to adapt to the lighting conditions before they can assess them. A dense instruction sheet was printed in black text and an official size 12, Times New Roman font over a regular matt A4 office paper. Subjects were asked to read these instructions thoroughly before they start giving their feedback. In addition to giving them the necessary information about the test, this sheet was also meant to simulate a typical reading task taking place in office environments.

The test subjects would start by assessing the situation at desk 1. They first have to fill in their personal information including the date, their age and gender, and the estimated number of hours they usually work in a similar environment. Following that, subjects were asked to look around the room and make themselves familiar with the different room elements with regard to visibility and color. Subjects were then asked to browse the pages of the glossy booklet and experience the different text and pictures before they settle on an assigned page and start reading it in full. To expand on the simulation of the office environment and tasks forward, they were asked to type in a given paragraph from the test they had read. They were asked to do so with a similar size 12, Times New Roman font configuration, and as fast as they can. This was meant to introduce a usual office task pressure to make the simulation somewhat complete.

By that time, the subjects would have been exposed to a regular work experience, and their res-

ponses should reflect, to a large extent, what employees would perceive the lighting with. From this point forward, they would have to start evaluating the conditions through their responses to the survey. They were also asked to give their comments in free words after the formal questionnaire. After the evaluation, subjects were asked to select their favorite light settings by adjusting the dimmers to their convenience. They were then requested to write their selection in the assigned place on the survey paper, then leave the room and wait outside. The test was then repeated with table 2, which was positioned differently relative to luminaires. In average, the whole process lasted between 45 to 65 minutes.

The first part of the questionnaire included three questions evaluating light sufficiency and pleasantness. The second part included two questions evaluating glare and reflections. The third part included four questions meant for assessing color rendering and natural appearances. Subjects were given the choice on a scale from “1: I disagree totally” to “7: I agree totally”, and passing via the neutral “4: I neither agree nor disagree”.

From the results of the experiment presented, and the conclusions withdrawn from their explanations, a set of recommendations was driven:
1) Sufficient and pleasant light is perceived to be the light that produces higher luminance rather than following the standards of illuminance. In this regard it is wise to focus on creating pleasant lighting for the room scene rather than delivering light only for the task area
2) Neutral to cooler light color temperatures were preferred over warmer light
3) Giving control to the employees over the lighting conditions not only by dimming, but also by changing the color of light would result in affecting their moods positively.

PP061

A STUDY OF THE SUSTAINED PUPIL RESPONSE UNDER A VARIETY OF LED ILLUMINATIONS

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Introduction

Melanopsin-expressing retinal ganglion cells (mRGCs) which are maximally photoreceptive around 490 nm and rods having a peak sensitivity at 507 nm, have been shown to drive the pupil response. The light emitted by white LEDs shows a peculiar spectral power distribution with a sharp spectral component in the short visible wavelengths associated with a yellow light component emitted by fluorescence. Here we investigate whether the deficit of energy of LEDs in the vicinity of 490 nm could weaken the pupillary constriction in comparison to conventional light sources of similar colour temperature.

Methods

Illuminations
Five lights, two commercial LED sources
Commercial „Warm White“ (WW), 2842 K
Commercial „Cool White“ (CW), 5290 K
and three metameric illuminations
Incandescent (INC), 2555 K
WW+Amber+Green (WW-A-G-LEDs), 2561 K
Multi-Color-LEDs, 2579 K
have been prepared (Figure 1) and made available in a large light booth where observers were allowed to practice reading and writing.

Pupil measurements
The study involved 9 subjects aged 24-65 years.
Each observer was presented the 10 illuminations (five lights at 100 and 210 lux) during one session. The presentation started with three minutes of practicing subjective visual tests which allows the subject to adapt to light. Then the subject was instructed that the video recording of his eye would start and asked to gaze at the cam-recorder during 45 seconds. A LabView program was written to measure the pupil diameter in every view.
A series of 1100 images (15 seconds duration) was extracted from the video, close to the end of the video record when the pupil aperture has stabilised. Every image of the recorded video was analysed using a specially developed LabView program that measures the pupil diameter and

controlled in order to eliminate oddities (blinkings and out-of- range values).

Results

The pupil diameter decreases with the light level (Figure 2). The magnitude of the decrease varies among subjects. On average, there was a 29% reduction of area between 100 and 210 lux.

The cool white light constricts the pupil at most, for 8 out of 9 subjects, whichever light level (Figure 2). In general, the higher the colour temperature raises, the more the pupil constricts. On average, there was a reduction of area between incandescent and LED „Cool White“ (12% at 100 Lux and 17% at 200 Lux).

The commercial LED “Warm White”, having an intermediate colour temperature, is not as efficient as one would expect (Figure 2). Its light dilates the pupil more than expected according to the rule related to the colour temperature. The pupil gain that follows is estimated at 14% of the surface. This observation is possibly linked to the energy gap of the spectrum around 490 nm.

From three metameric lights, at any light level and for most observers, it is the warm white light corrected by adding green and amber which leads to greater pupil dilation, and the incandescent light that leads to smaller dilation. This effect is more noticeable at 210 lux than at 100 lux for most observers.

The study of correlations between the size of the pupil and the spectral profile of the light distribution aims to explain and connect the pupil size to the power content in a particular region of the spectrum. A careful examination of the correlations between the spectral profile of the light and the size of the pupil reveals the involvement of spectrally selective mechanisms responsible for controlling the pupil. Some specific individual trends appear. The majority of subjects, mostly young, follow a similar trend, with strong antagonistic influences of receptor responses, while a few observers, mostly older, show shifted responses. The origin, frequency and magnitude of inter-individual variations of the spectral selectivity of responses deserve further study.

Discussion and conclusion

Whereas careful stabilisation of the pupil response has been achieved through allowing for a three minute adaptation time and eliminating eye blinkings and out-of-range measurements, we cannot ignore that the pupil aperture is under the effect of individual parameters including age. Nevertheless, the reduction of the pupil size with the luminous level, with the colour temperature and with the deficit of energy around 490 nm has been observed for 8 out of 9 observers. It is probably the amount of energy available in this wavelength range that favours the pupil constriction.

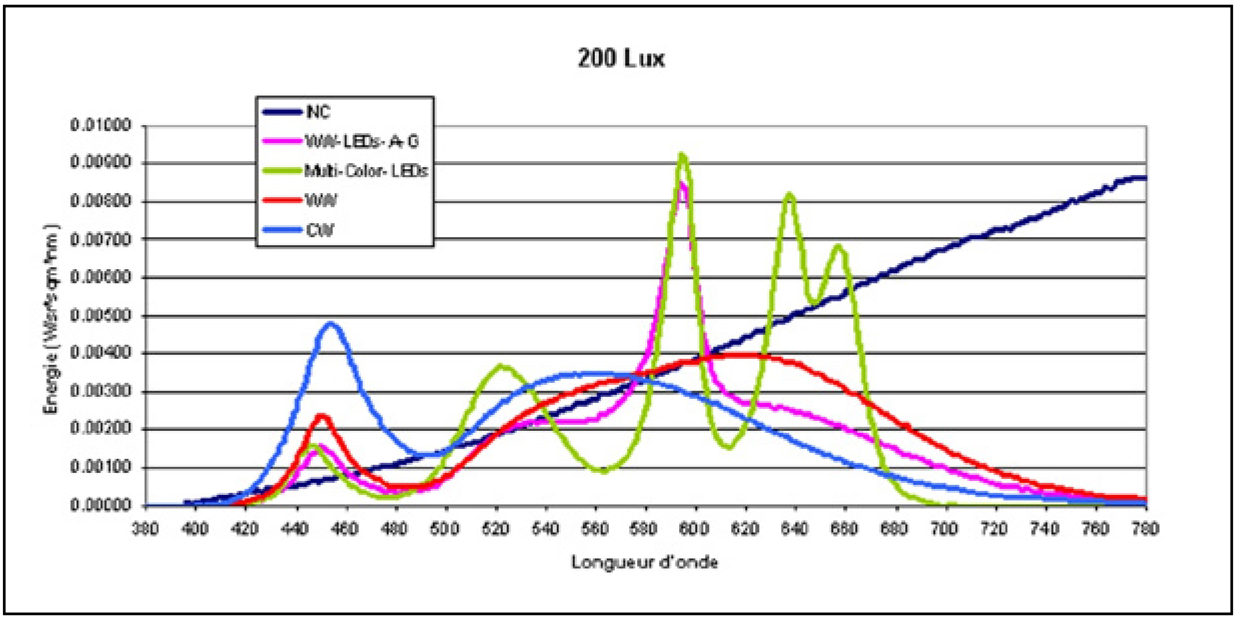

Figure 1 - Spectral power distribution of the five illuminations

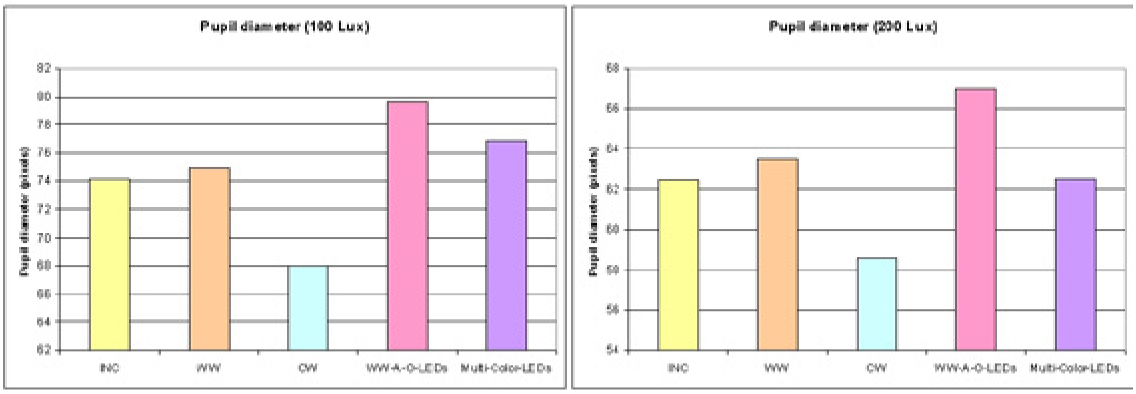

Figure 2 - Average pupil diameter of 9 observers under 5 illuminations at 2 illuminance values

D3 - Interior Lighting
Museums

PP062

DESIGN OF LED (LIGHTING EMITTING DIODES) FOR MUSEUM LIGHTING APPLICATION

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Saving energy in lighting application is gathering much more attention than ever before. As the rapid development of LED technology increases, solid-state lighting has given a smooth transition toward the new generation of lighting solutions. LEDs have been widely sought-after in home lighting, office workplaces, museums, schools, hospitals, etc. LED light sources compared to traditional light sources have many distinct and advantageous characteristics, such as longer lifetime, higher luminous efficacy, dimmable light capabilities, and rich color options; however, in the practical applications, some of LEDs lighting behaves not very well in its color rendering, as well as its harmonized user experience during long time exposure under LED lighting condition. Therefore, how we evaluate the quality of LED lighting, and how we build and design a high efficiency, good color rendering, and comfortable visual sense specialized in the LED lighting products is critical.

This research aims to evaluate the LEDs quality to that of LEDs specifically in a museum setting. The first booth will consist of a four-channel LED lighting platform is proposed to generate a matching of the daylight spectrum. The light platform is combined with four different channels of LEDs (two of the channels are in cold and warm white LEDs respectively). Each channel of light output is dimmable by an electronic board controller, and programmable by the computer to set the light intensity, thereby realizing from 2600k to 6500k in high efficiency, full spectrum and color rendering as well. Also, to create a better visualization of the distinct characteristics of the LED lighting compared to traditional light sources, the second booth is installed as a reference platform with both halogen tungsten lamps and daylight florescent lamps, via interchanging the switch to simulate the warm light and cool white illumination environments. With a traditional light booth and LED booth under the darkroom, we will have a window in front of the each booth, so observers can view the objects for visual perception either at one time for visual perception of doing comparison experiments or individual properties of the lighting conditions towards human subject. The walls inside the booths are painted with almost perfect reflecting diffusing material to create the uniform illumination environment to shine the color of objects such as paintings, drawings, or photographs, for evaluation of the quality of LED lighting.

Based on our designed LED booth with its comparison traditional light booth, we can practice both the physical measurement as well as its visual experiment.
A virtual reality simulation of natural light: light of morning sun, daylight at noon, sunset glow and evening light can be implemented. The performance of LED lighting simulation, such as luminous efficacy, illuminance, spectral distribution, color temperature, color rendering index, and C/P (ratio of circadian and photopic quantities) can be measured by a power meter, luxmeter and CCD spectroradiometer. It also makes a match with the traditional light sources. Moreover, spectral reflectance of criteria objects selected from several typical paints or materials used in art works can

be measured to determine the UV and IR damage degree on the materials, and color appearance and color rendering of LED lighting sources as well as conventional lamps taking into account color adaption of environmental light.

In addition, human factor experiments of visual perception can be done for evaluation of LED lighting simulating the natural light at different time-phase and traditional lighting, and the consistence comparing with physical measurement in the LED lighting booth and the traditional lighting booth. Detailed structure of lighting booths, data of physical measurement, results of visual perception and comparative analysis, will be given in the paper.

PP063

LIGHT EMITTING DIODES IN MUSEUM LIGHTING - COLOR QUALITY REQUIREMENTS FOR VISITORS' ACCEPTANCE

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In museum lighting the two most important requirements are colour fidelity and art preservation. Up to now the use of halogen lamps and metal halide lamps with short wavelength cut-off filters were the standard techniques to solve these requirements. Applying these light sources, museums as well as lighting designers have to found the compromise between minimizing irreversible damage of artwork and technical factors as preferred colour appearance and energy efficiency. With the possibility of finely tuneable LED light sources the use of LED lighting offers a good alternative, as it is easy to satisfy the art preservation requirements, by selecting LEDs with little (or no) UV and IR content. It is more difficult to solve the colour fidelity question.
Our laboratory has the task within an EU project to find best colour fidelity lighting for the new LED based indoor lighting system of Sistine Chapel. In the present paper steps to accomplish this task are described:

1. To show coloured paintings/frescos the first demand is to show them in a light as the artist has seen them. For a renaissance painting this would mean daylight. The curators of the Vatican Museum insisted to use lower correlated colour temperature radiation, preferable between 3000 K and 4000 K. Thus our task was determining equivalent colours for these colour temperatures. This was accomplished by using CAT02 chromatic adaptation transform for the colours in question.

2. Another part of our investigations is to determine ideal colour temperature for fresco lighting between 3000K and 4000K. This can be investigated on-site based on visual observations of a professional group (curators, restaurateurs, artist, colour experts), by illuminating frescoes with tuneable LED light sources. Test SPDs have to be optimized to produce the same illuminance level on frescoes and have same colour fidelity values. Distance from Planckian has to be fixed for the SPDs with different CCT.

3. A pilot study showed that the pigments used in present colour rendering and colour preference programs differ from the pigments used in renaissance frescos. Thus a colour fidelity metric was developed using correct fresco reflectance spectra. Investigations for this were performed on 16th Century frescos.

4. LED spectral power distribution has to be optimized for this special colour fidelity metric. Possible maximum values of achievable colour fidelity index have to be determined for LED light sources containing white phosphor LEDs and 4, 5, 6 kinds of supplementary narrow band LEDs. Possible peak wavelength combinations have to be investigated by varying blue and red peak wavelengths in the spectra.

Visual tests are needed to check visual differences between the colour appearances of frescoes in case of different LED combinations. Acceptable LED spectrum with minimal LED peak wavelengths has to be identified.

5. For final check reflectance spectral measurements have to be performed within the Sistine Chapel as well. This will be done using a spectroradiometer, two imaging luminance and colorimeters and special light sources for providing the needed illumination of the different surface parts. To prepare this task colour measurements were done on reproductions found in books and on the Internet, marking the critical places of measurement. As a by-product the colour fidelity of these reproductions was determined as well.

6. Based on the lighting system prepared for another museum lighting (Lenbachhaus) was further developed to provide for every major colour of the Michelangelo frescos the smallest possible colour shift.

7. A stability tests of the applied LEDs was performed to determine what temporal stability of the installation can be expected. The stability tests will also include temperature dependence investigations to give guidelines for the appropriate cooling system.

PP064

USING LED SOURCES FOR WORKS OF ART LIGHTING

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Nowadays, the use of Solid State Lighting (SSL) in work of art exposition and in particular in showcases, is becoming more and more frequent. LED luminaries fit inside a showcase for their small dimensions and shapes, and are very attractive for museum managers because their low impact on energy consumption and promised UV and IR control. But their impact on conservation and perception is not always well known: the color perception they give is very difficult to predict and standard methods, for calculating their color rendering, fail. CIE is working on it and several experiments are underway.

The goal of this study is not to suggest new methods for color rendering calculation in LED lighting, but to give practical indications to lighting designers when using LED sources in art exposition about the expected color perception and the conservation performances.
The study follows two different approaches: an objective characterization of the elements of exposition (LED sources, works of art) and a subjective characterization of works of arts perception. We considered:

- two different LED sources (of cold and warm Correlated Color Temperature), widely used in works of arts exposition,
- two different "traditional" lights of the same color temperature (CCT) of LEDs (incandescent lamp and a fluorescent tube),
- six different hues (three cold and three warm colors) of tempera paints.

The spectral reflection factor of tempera paints was measured with a Perkin Elmer double beam spectrometer, while the spectral intensity distribution of all four lights with a Pritchard spectrophotometer.
Four different works of light were made with definite rules in arrangement, harmony and spatial density of colors in order to obtain two cold dominant and two warm dominant paints.
The aim was to correlate spectral and colorimetric properties of tempera paints, with the works of arts perception when lighted by LED and "traditional" sources.
The conservation properties of light sources were analyzed too, evaluating the lighting dose (the product of illuminance and time of exposition) necessary to cause a variation of $\Delta E=1$ in the first three scales of blue wool reference samples.

Then, a subjective experiment was performed using two especially made observation boxes.
During the test, 25 subjects observed two equal polychromatic cold or warm paints, comparing concurrently their perception with LED and traditional sources (incandescent or fluorescent). In each trial the same two images were compared when lighted by the two sources (LED and Traditional) of the same CCT, at equal illuminance values and illuminance uniformity. So every subject performed 4 different trials: cold images lighted by cold and warm sources and the same for warm

images, during each trial the subject had to fill a 40 entries questionnaire in order to investigate his perception.

Then the descriptive results of the questionnaire were compared with objective evaluations (color coordinates, saturation, color differences...). Therefore, not only the perception of a single color was investigated, but also the subjective evaluation of the image rendered as a whole and how the ratios among colors are affected by different light spectra.
The results showed a different behavior when cold or warm CCT LEDs light cold or warm images. In order to give to lighting designers and museum manager useful directions, when LED lighting is involved in art exposition, a guideline
is proposed. Among several other suggestions, when LED are compared with traditional, it is possible to say:

- Warm CCT LED improves the perception of spatial uniformity of a paint, especially in cold paints
- LEDs are perceive as colder light (even if the color temperature is the same) when they light images of opposite dominant: i.e. when a warm LED lights a cold image, or a cold LED lights a warm image, is perceived as a colder light than a the traditional light (incandescent or fluorescent) of the same CCT
- Warm and cold CCT LED improve color perception of cold paints -Warm CCT improve brilliance of cold paints

The study is a first step of a more complex investigation about the use of LED lighting in Museum that involves INRIM; Politecnico di Torino and the Conservation and Restoration Centre “La Venaria Reale”.

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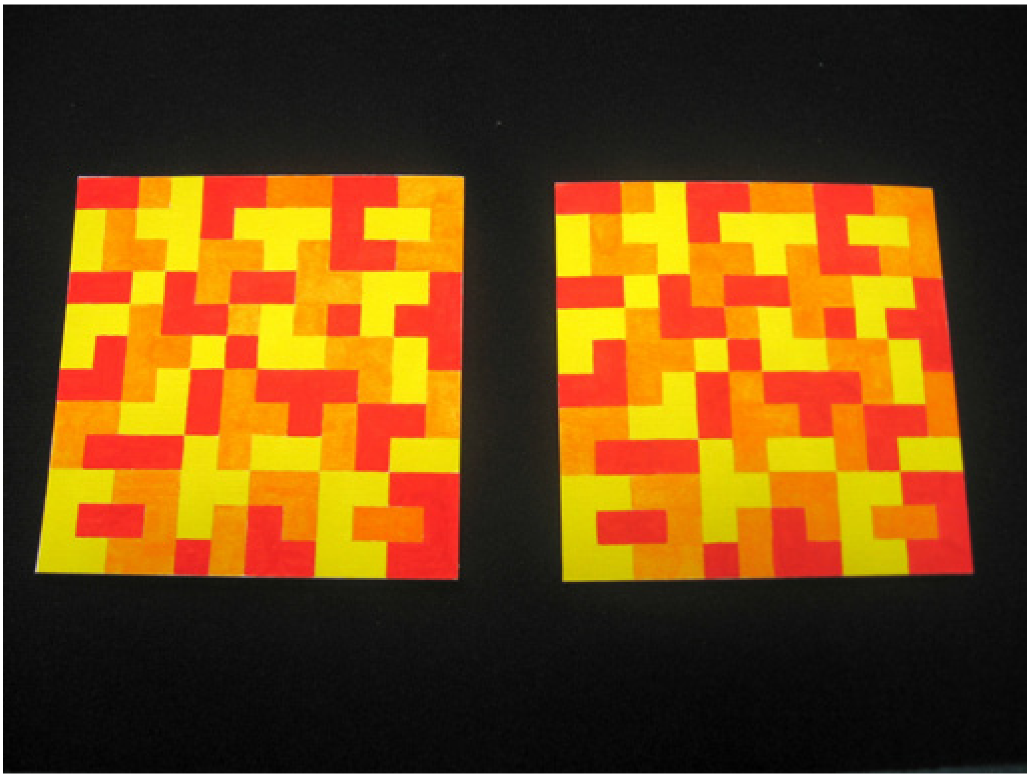

Figure 1 - the two equal warm dominant paints used in the subjective experiment

Figure 2 - the two observation boxes with the warm paints on. Note the fluorescent tube that lights the paint

PP065

SUBJECTIVE AND OBJECTIVE ASSESSMENT ON LED LIGHTING QUALITY FOR MUSEUM SHOWCASES

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At present, the use of Solid State Lighting (SSL) in museum interior design, and in particular in showcases, is becoming increasingly more frequent.
To address the visitor's attention towards the displayed objects, showcases are often internally lighted, with several advantages and drawbacks concerning the conservation and fruition of museum collections. According to a proper object fruition and visual comfort, lighting systems within showcases should provide high colour rendering, appropriate light quantity and distribution, as well as avoiding glare and visual distraction effects. Additionally, small size and different spatial arrangement of light sources are relevant to showcases and all these criteria seem to be potentially fulfilled by the latest LED generations.

Nevertheless their impact on visual perception is not completely known, due to dramatic differences from traditional lighting technology. Particularly, the implication of LED features on visual comfort, such as high luminous intensity and small emitting area, needs more investigation.
This paper presents the results of an experimental study on testing the performance of several LED lighting systems inside typical museum showcases.
The main goal of the research was to assess the lighting quality perceived by visitors for LEDs with different colour temperature, spatial arrangement and illuminance level on exhibits inside the showcase. In particular, the assessment of lighting and visibility conditions was focused on objective and subjective measurements, respectively based on luminance metrics and evaluation surveys through questionnaire.

A "free-standing island" showcase was selected among other typologies as it is frequently used for temporary exhibits. Since it can be viewed from more sides, light pointing is also challenging. Two types of white LED with same luminescence method (blue LED + phosphor deposition) and different colour temperature (3200 K and 6900 K) were used in three light fitting layouts inside the showcase. More specifically, LED sources were positioned on the base corners of the exhibition volume (layout 1- lighting from below), in the middle of each side of the basement (layout 2 - lighting from below) and at the top corners of the exhibition volume (layout 3 - lighting from above). During the experiment, LED sources were dimmed in order to achieve different illuminance values on the exhibit's surfaces (50 lx, 150 lx, 300 lx). A coloured enamel statuette was inserted in the exhibition volume as target to assess objects visibility.

The assessment of lighting and visibility conditions was firstly focused on luminance based lighting quality metrics, evaluating light distribution on exhibit and in showcase, and assessing discomfort glare for visitors. A single observation point was assumed in this phase of the study, with the line of sight directed towards the centre of the target (figure 1). Luminance images of the exhibition volume were acquired using an Imaging Luminance Measurement Device (ILMD). The luminance images corresponding to each layout were then processed to obtain synthetic and comparable information about visibility conditions.

Concerning the evaluation survey, the questionnaire was based on four sections. In the first and second section semantic differential scales were used to assess respectively the lighting quality of the whole exhibition volume and the exhibit. The third section was related to reflections on showcase's glazing panels caused by LED fittings, whilst the fourth section concerned the assessment of direct glare using a category scale corrisponding to UGR values.

A panel of 26 observers (mainly painting restorers from 20 to 30 years old) was involved in the study; each observer was engaged in several trials concerning the different light fitting layouts.
The main findings were related to quality and quantity factors such as the pleasantness of the lighting scene and the colour/detail discrimination on the target with respect to illuminance values, correlated colour temperature of LED sources and their spatial arrangement (light fitting layouts).
A relationship between the subjective evaluation of glare and the correlated colour temperature of LED sources was found, and the impact of LED spatial arrangement over glare was outlined.
Further research on the validity of UGR is currently being carrying out, comparing the glare rank order obtained by the subjective survey with the UGR results obtained by luminance metrics.

PP066

MUSEUM OBJECTS ON THE INTERNET, IN PRINT AND IN REALITY

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It was never possible to visit all the big museums around the world, printed copies and recently images on the Internet provided a possibility to get some – if only faint – impression of the objects of art. With increasing printing quality and better understanding of the visual perception questions of digital colour reproduction one has hoped to be able to provide image quality in print and on the Internet that gets nearer to reality. To test present day colour quality we studied how well is colour reproduced for the frescos of the Sisitine Chapel in the Vatican. (This location was selected as we hope that by the presentation of this work in Paris we will have the colorimetric values of the original frescos as well.)

Images have been collected both from books and publications from the Internet, and some critical areas of the images have been colorimetrically evaluated. In this research we selected 14 frescos of Sistine Chapel, measuring always the same points of the frescos, taking the pictures from the two reproduction books and from two Internet providers. An Eye-One spectrophotometric colorimeter was used for the hard-copy measurements. Data have been transformed to the CIELAB system for colour difference evaluation. For the Internet images were loaded into Photoshop and supposing sRGB colour the internal L*, a*, b* representation of the system was used.. Objects of skin, hair, grass, sky, foliage, clothes etc. were measured. Approximately 3000 measurements were made. We compared the measured values of the pictures of the two books and the two Internet sources. Figure 1 shows for example the points of brown hair in different pictures. Figure 2 shows for example the points of skin in different pictures painted by Michelangelo. As can be seen the colours used by different painters and in different frescos overlap considerably. The determination of the colour differences to the originals is still under way at the time of submitting this Abstract. From the Internet and hard-copy comparisons one can state that the quality of colour reproduction in the Internet has became much better as found a few years ago, when we tested the fort-copy and hard-copy artifacts of some Leonardo and van Gough pictures1,2.

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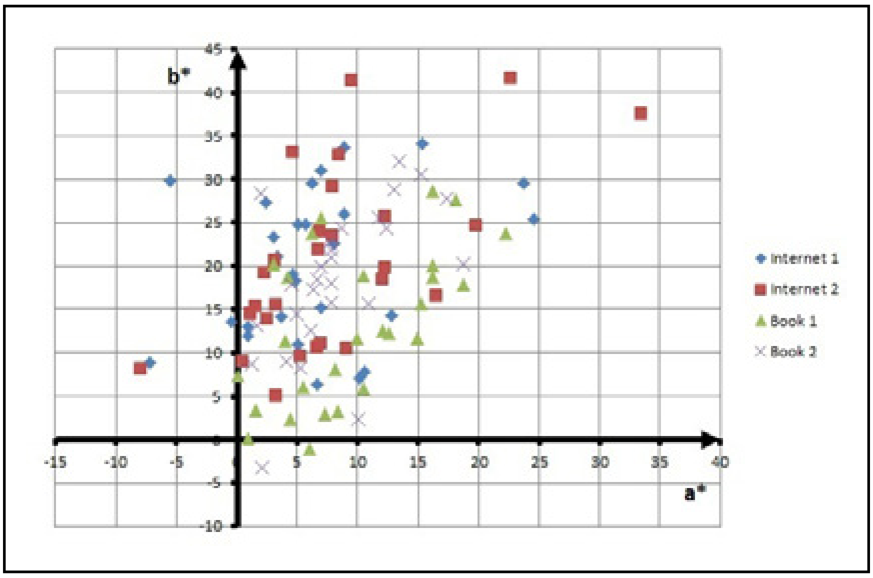

Figure 1 - Colours of brown hair

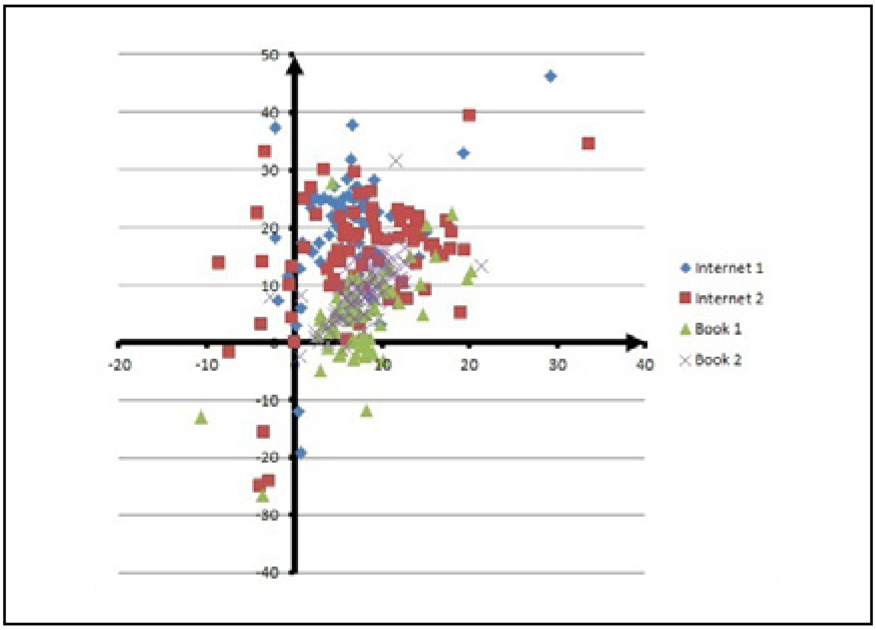

Figure 2 - Skin colours painted by Michelangelo

PP067

DYNAMIC LIGHTING SYSTEM WITH LOW CORRELATED COLOUR TEMPERATURE AND HIGH COLOUR RENDERING INDEX FOR MUSEUM LIGHTING OF FRAGILE ARTIFACTS

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Objective

Illumination of fragile and irreplaceable historical objects exhibited to the public presents multiple challenges. The colour rendering is often of high importance due to the aesthetic and artistic nature of the objects. The light level and blue light content must be low in order not to excessively degrade the objects through photochemical reactions, considering that the spectral sensitivity of most materials increases dramatically with shorter wavelengths. Changes in temperature and humidity due to on/off cycles of lighting can also be harmful to the exhibited objects. Further considerations are the increased need for energy efficiency in general, and the decreasing availability of traditional incandescent light sources with high colour rendering.

Methods

We present a LED lighting system for illumination of historical artifacts in display cases at museums and other exhibitions, which can replace 3-5 Watt incandescent light bulbs with a correlated colour temperature (CCT) around 2200 K, with a decrease in energy consumption of up to 80 %. The design is based on further development of a system that was built in collaboration with the Royal Danish Collections at the treasury at Rosenborg Castle, in Copenhagen, Denmark [1]. An example of a display case can be seen in Figure 1. We expect to be able to install the optimized system in a similar exhibition. Simulations show colour rendering index (CRI) at low CCT for a broad range of LED pulse width modulation (PWM) settings (see Figure 2). These simulations show an improvement of the colour rendering index compared to the system described above.
The system is built as a tri-colour LED system. It is comprised of an extreme warm white LED at 2233 K with a Ra of 83.9 and a R9 of 29.7, a cyan LED at 505 nm and a deep red at 663 nm (peak). This combination enables spectra which are very close to the blackbody radiator for low CCT and high Ra and R9. Since the system is free of metamerisms all possible linear combinations have been simulated and characterized with regards to CCT, Ra, R9, chromaticity distance (Duv). The characterization of the colour rendering properties according to the colour quality scale will also be investigated. Some of the results are shown in Figure 2 as a function of the two variables which describe the PWM values for the cyan and red LED. Depicted is the general colour rendering index - Ra (Figure 2a), the special CRI R9 – strong red (Figure 2b), the CCT (Figure 2c) and the Duv (Figure 2d). Here it is seen that the resulting CCT range from 2200 to 2600 K with Ra ranging from 90 to 99. This is combined with low Duv values and high R9 values, signifying that red, golden and white objects are rendered satisfactory.

Discussion

Low CCT incandescent lighting has traditionally been chosen for this application due to the low content of damaging low wavelength radiation and attractive colour rendering of reddish and golden objects. However, the rendition of blue coloured objects is severely limited in incandescent

lighting at very low CCT, due to the low content of blue light in the spectral power distribution. Increasing the CCT is problematic since short wavelength light has an exponentially greater deteriorating effect on fragile artifacts. Accordingly there is a tradeoff between the colour rendering performance and conservational concerns with regards to this type of lighting.
With the LED lighting system presented in this paper, we hope to decrease the problems associated with this tradeoff, as the blue content will be moved towards longer wavelengths, while maintaining acceptable light quality. Furthermore, the CCT will be tunable, and makes it possible for curators to find an optimum between sufficient colour rendering of blue toned objects and minimization of the degradation caused by low wavelength light. Secondarily it has been suggested that the preferred chromaticity of low CCT illumination is situated below the Planckian locus. This can be accommodated by the system and will be investigated further.
Due to the distance between the differently coloured light sources, a patented hemispherical diffusing reflector is used for colour mixing. This enables a very high degree of uniformity in the lighting field and minimizes coloured shadows in the display cases.

Conclusion
With the presented LED system it is possible to achieve warm white light to replace low wattage incandescent bulbs. Colour rendering properties of the light have very high values of Ra and R9 comparable to that of incandescent bulbs. Furthermore it is possible to tune the CCT of the light source for specific needs.
This work is supported by the Danish Agency for Science, Technology and Innovation under the Danish Lighting Innovation Network.

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[1]A. Thorseth, D. D. Corell, P. B. Poulsen, S. S. Hansen, and C. Dam-Hansen, „Museum lighting for golden artifacts, with low correlated color temperature, high color uniformity and high color rendering index, using diffusing color mixing of red, cyan, and white-light-emitting diodes," in International Society for Optics and Photonics, 2012, pp. 82781N-- 82781N.

Figure 1 - An example of the display case, containing gold objects, illuminated by the LED system installed at Rosenborg Castle in Copenhagen

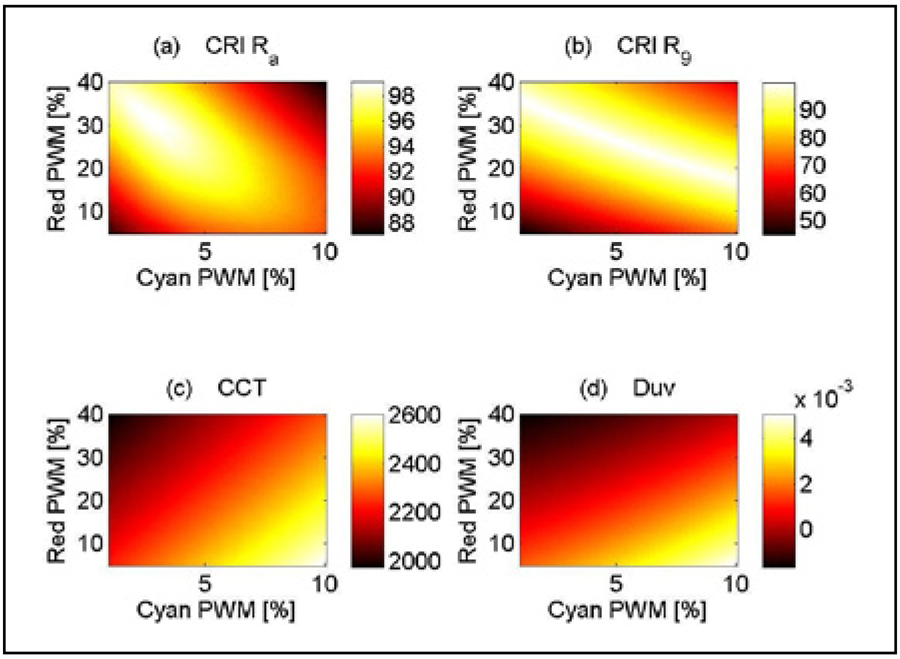

Figure 2 - Properties of the tri-colour system in the relevant PWM ranges

D3 - Interior Lighting
Daylight

PP069

EFECT OF COLOUR TEMPERATURE ON HUMAN DEPENDING ON WEATHER, DAYLIGHT AND TIME - FIELD STUDY IN A SCHOOL

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1. Motivation

The increasing demand for energy efficiency represents a challenge for the development of lighting systems and lighting design. Besides increasing efficiency of lighting and lamps, lighting control becomes used more often to save additional energy. The biggest saving potential is the use of daylight. Therefore currently a lot of systems are used that measure daylight entry in the interior and add artificial light in a way that a constant lighting level is achieved.

But daylight has more advantages. From many studies which where conducted at office workplaces, we know that there is a strong preference for workplace illumination with daylight. On the one hand this involves the view out of a window and on the other hand the daylight itself. In addition to the continuous light spectrum of daylight, the constant changing in light colour, light direction and intensity adds up to a very special characteristic.

Light, especially daylight, also fulfils a non-visual function. It acts as a clock for the human circadian rhythm. Responsible for that are receptors on the retina of the human eye, which react primarily on bluish light. Many current studies focus on the effect of light colour on the well-being and performance of humans - and on long-term effects. As a result dynamic lighting controls for artificial light are developed. Often the dynamics are based on typical variation of natural daylight or on the human performance curve.

2. Problem

Both approaches for the use of lighting control of artificial light over time have different goals: the reduction of energy consumption on the one hand and the support of the human circadian rhythm on the other hand. Both have disadvantages from a user point of view and are rarely accepted.

One main reason for this is usually the light colour.

Different colour combinations of the interior lighting with daylight, which vary depending on daytime or weather are the result of automated lighting control. Depending on the room shape, window openings and seating position different adaptation states are the outcome, influencing the evaluation of the light colour and light colour combinations. Changes in habitual lighting conditions affect user perception of the current lighting situation.

The aim of this thesis is to investigate the effect of light colour and light colour combinations in terms of user acceptance, lighting quality and energy efficiency - and to implement the results in recommendations on control strategies for artificial light.

3. Theoretical framework

Previous knowledge about the effect of light colour and light colour combination goes back to the ‚40s, when the fluorescent lamps were introduced. Starting with this new technology it was possible to choose the colour of lighting in interior rooms.

The question of how different colour temperatures should be used in practice was first investigated by Kruithof . He found that colour temperature - depending on illumination level - must be within certain limits, otherwise it will be felt unpleasant. Moreover, according to Kruithof a low illumination level of lighting belongs to a low colour temperature and
a high illumination level belongs to a high colour temperature. Until today the work of Kruithof is highly accepted among experts.
But Kruithof‘s results are also subject to scientific criticism. For example Davis, Bodmann, Newsman, Cockram, Boyce and others could present results later that contradict the simple context of the „Kruithof curve“. They revealed that for the preference of an illumination in the interior the illumination level is a more important factor than the light colour itself. Every lighting situation, but especially the light colour, is judged individually highly differentiated and emotionally.
In the project „Harmonious light“ Fleischer investigated the effect of light condition changes on the human emotional state. In addition the study observed the effect of external factors such as weather, activity or the circadian rhythm corresponding to the daytime or the sky situation. The findings suggest that dynamic lighting systems have a positive effect on people’s mood. Moreover, Aldworth and Bridges could proof that variable lighting options are usually preferred over static situations.
Essential requirements for control strategies of dynamic lighting systems have been formulated by Bieske. She conducted studies on the variation of light colour.
In the context of this work, the fundamental studies on the effect of light colour and light colour variation can be expanded - to provide evidence of the effect of local light colour combinations depending on various parameters such as time of day, daylight and weather.

4. Method
This paper presents a field study which was set up in a school in Innsbruck (Austria).
Within the field study different lighting scenarios (colour temperatures) are examined in dependence on the parameters day time, weather and daylight.
The effect is evaluated from teachers and pupils of two classrooms in particularly with regard to the three optimization goals: user acceptance, light quality and energy efficiency.
In order to come to a clear conclusion about the user acceptance subjective assessments of users are recorded and their behavior is observed.
The method in detail will be explained in the full paper and at the conference. Also first results can be shown at the conference, since the first field test period will end in march 2013.

5. Outlook
The study should provide new insights of the perception and the effect of light colour on people. Based on the findings recommendations are formulated for control algorithms, which should then be tested in practice.

PP070

SIMULATION OF ANNUAL DAYLIGHT PERFORMANCE UNDER HONG KONG REPRESENTATIVE SKIES FOR USINE LIGHTING ENERGY INTELLIGENTLY

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This on-going study simulates annual daylight availability of building facades in high-density Hong Kong under Hong Kong Representative Sky (HKRS) predicted by irradiance data from Typical Meteorological Year (TMY) data. Rather than basing on the traditional static simulation only under CIE overcast sky, the annual daylight availability on building facades under HKRS in high-density Hong Kong can provide the „real“ daylight performance during a whole year for using artificial lighting energy intelligently.

Hong Kong Representative Sky consists of sky type 1, 8 and 13 based on CIE General Sky type defined from 2-year sky scans data[1]. Hourly HKRS during a whole year can be predicted based on the irradiance data from TMY data by using the similar methodology in our previous study, which predicted three sky types from satellite images[2]. Then the absolute values of sky luminance distribution can be approximately estimated from CIE standard general sky model. By using RADIANCE software, hourly daylight availability on building facades in typical urban districts in Hong Kong can be simulated for a whole year. With the annual daylight performance, designers and users can use artificial lighting intelligently for energy saving.

1.Ng, E., et al., Defining standard skies for Hong Kong. Building and Environment, 2007. 42(2): p. 866-876.
2.He, J.Z. and E. Ng, Using satellite-based methods to predict daylight illuminance for subtropical Hong Kong. Lighting Research & Technology, 2010. 42(2): p. 135-147.

PP071

A REVIEW OF HISTORICAL CHANGES IN JAPANESE REGULATIONS AND STANDARDS FOR SUNLIGHT AND DAYLIGHTING

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Daylight including direct sunlight contributes to maintaining good physiological and psychological conditions. Receiving daylight is a human fundamental need, and it is essential to secure favourable daylit environments indoors and outdoors. However, high density of buildings and an increase of high-rise buildings make it difficult to ensure sunlight-rich dwelling environments in inner-city areas. Besides, window sizes are likely to be reduced in architectural design for high thermal performance of buildings. This paper outlines historical changes in Japanese regulations and standards for sunlight and daylighting as an example, and presents challenges for future development or revision of daylighting legislation that considers physiological actions of daylight.

Japanese Building Standards Act provides regulations on daylighting, overshadowing of surrounding sites and the building height for environmental hygienic safety both indoors and outdoors. For daylighting, habitable rooms must, in principle, have windows or any other daylight openings, and the ratio of the effective area thereof to the floor area must be a specified ratio or more. The habitable room is defined as a room that is continuously used for dwelling, working, meeting, entertaining or any other similar purposes. The daylighting regulation is applied to living rooms, dining rooms, bedrooms, studies, drawing rooms, classrooms, nursery rooms, meeting rooms, sickrooms, guestrooms and so on. The shadow regulation aims at ensuring sufficient sunlight in surrounding sites of a medium-/high-rise building. But it does not ensure sunlight for the said building. It restricts the duration and extent of shadowing by the said building between 8 a.m. and 4 p.m. true solar time (between 9 a.m. and 3 p.m. true solar time within the areas of Hokkaido) on the winter solstice. Local governments may designate use districts to which the shadow regulation is applied. The use district is an area prescribed by the City Planning Law, which also regulates the type of building in each use district. The shadow regulation may be applied to the following districts: category 1 and 2 low-rise exclusive residential, category 1 and 2 medium-to-high-rise exclusive residential, category 1 and 2 residential, quasi-residential, neighborhood commercial and quasi-industrial districts, and districts where the use is not assigned. The Building Standards Act had a provision for sunlight that reaches openings of habitable rooms in residential buildings, but it was abolished in the year 1998. Design criteria for sunlight duration are not established. Urban congestion has led a relaxation of regulations and standards for sunlight as well as daylighting.
Architectural Institute of Japan (AIJ) has published a standard entitled „Academic Standards for Design and Maintenance of Windows and Openings on Interior Lighting and Visual Environment“ against the relaxation of regulations on sunlight and daylighting. It provides criteria for design and maintenance of windows and openings for daylighting in order to ensure good performance of luminous and visual environments in interiors. It also presents methods of calculating and measuring daylight factor. Moreover, at present, a new standard for daylighting is under development in AIJ.

Abstracts

Entry of sunlight into interiors should be properly controlled for good visual and thermal environments and high energy efficiency of buildings. However, appropriate exposure to sunlight is of critical importance in terms of human physiology as well as psychology. It is well known that ultraviolet radiation from the sun is effective in production of vitamin D in the skin. Sunlight also regulates biological rhythms and serves to maintain sound autonomic and sleep- wake systems. In addition, perception of sunlight brings about vigour, cheer and comfort.

Some daylighting standards other than Japanese ones provide criteria for sunlight duration. In further development of standards for indoor environmental criteria, inclusion of criteria for sunlight duration is proposed for reducing the prevalence of Seasonal Affective Disorder (SAD). SAD is an emotional disorder whose onset depends on the season. Winter depression is the most common type, but cases of summer depression are also reported. The exact cause of SAD is unknown. The frequency of winter depression is considered to be relevant to sunshine duration. Bright light treatment is effective against winter depression, and studies have shown effective dosage and timing of light. Nevertheless, little is known about the minimum daily light exposure to prevent winter depression, much less about the correlation between preventing effects and sunlight exposure levels. Under the present scientific circumstances, it would be premature to set sunlight criteria for SAD in consensus-based standards.

Human needs for sunlight and daylighting can be explained relatively easily in terms of lighting for visual tasks and heating with objective measures. However, they include many complicated factors such as maintaining good biological rhythms, obtaining a good mood and satisfaction in daily life, and preserving overall mental and physical health. Although research results on non-visual effects of optical radiation are being accumulated, knowledge is insufficient yet to set standards for non-visual physiological functioning of daylight in indoors and outdoors. Even if sunlight is strongly required in dwellings from health aspects, it is often difficult to be successful at both enjoying plenty of sunlight and the convenience of city life in high-density urban areas. Practically, there are several incompatible matters to be solved in daylighting standardization.

PP072

DAYLIGHT AND SOLAR ACCESS AT URBAN SCALE : A METHODOLOGY AND ITS APPLICATION TO A HIGH DENSITY DEVELOPMENT IN BRUSSELS

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1.CONTEXT

Larger urban areas in the world experience rapid population growth. Brussels in no exception to this and its growth rate is one of the highest in Europe. This means there is a need for extra surfaces for all activities including working, retail and leisure, however in particular for housing. As open space is scares in historical cities the only option is to increase the density of the existing urban fabric. Higher densities are certainly a way towards a more sustainable environment but there are limits that are specific for each case and climate.

This study focuses on lighting aspects and proposes a methodology to evaluate daylight in an urban context for urban design, planning and policy. More generally it is necessary to raise the awareness for the beneficial effect of daylight not only inside the buildings but also for our outdoor places.

2.INTRODUCTION

This study was done in the framework of an impact assessment of a significant urban development project around one of the main axis of Brussels ('Rue de la Loi/Wetstraat') linking the national parliament to the Schuman square where the seat of most important European institutions are located (European Commission and Council). The main tasks included analyzing sunlight access, daylight, views as well as wind conditions in the streets and public open spaces surrounding buildings and evaluating if the proposed siting and massing of new buildings is appropriate in relationship to neighbouring areas.

The area is actually a mono-functional zone of office buildings along a one way four lanes wide busy traffic road. The Brussels authorities have been working since a few years in order to define a strong and future proof vision for the development of this zone. An international competition was organized and a winning team headed by Christian de Portzamparc was designated. This proposal fixed a general strategy for the site and integrated two important aspects that were requested by the authorities: increasing density and introducing mixed functions.

Three configurations were studied. As reference case the existing situation was used. A first alternative consisted to raise all buildings by a few floors in order to increase surfaces by 20%. A second alternative was worked out that follows the chosen strategy. This alternative results in a configuration which varies height of buildings depending of a three fixed setbacks and allows for a limited number of tall buildings. Another important feature is that this configurations steps away from the traditional enclosed building blocks. Recessed volumes and variable setbacks and heights are encouraged instead of a perfect alignment with the property line. Also some spaces are left open providing pleasing public places ('pocket parks') and passages through building blocks.

3.METHODOLOGY

Mostly very simplified methods and tools are used for determining daylight performances at the stage of a massing plan. Main limitations are linked with the possibilities of existing simulation tools and the uncertainties about buildings and surface properties. However considerable progress has been made in recent years concerning simulation methods and calculation times are getting realistic allowing us to better understand and describe the lighting comfort.

Incident radiation is not only direct solar beam radiation but the diffuse sky component also needs to be considered, especially knowing that overcast sky conditions are predominant in Northern European climate. Two set of criteria are proposed to determine daylighting performance in urban context. One criterion is related to diffuse light the other to direct sunlight. Of course both components are occurring simultaneously in reality but analysing these components separately allows identifying their relative impact and different variations.

For diffuse skylight a Sky View Factor ('SVF) is used and for direct sunlight the maximal sunlight duration ('MSD') is determined.

3.1Diffuse light: Sky View Factors (SVF)

The evaluation of illumination levels under overcast sky conditions will be estimated by using Sky view Factors. A Sky View factor is defined as the percentage of the sky hemisphere that is viewed directly from one point. A grid of points has been calculated to evaluate the different alternatives in comparison with the existing reference condition.

This method doesn't intent to determine absolute illumination levels as it implicitly supposes that the sky has a uniform luminance distribution and that no inter-reflections of light happen on surfaces. This is a serious simplification but it can be argued that at this stage building geometry and facades are not well defined. A series of measurements on site were carried out to check the real conditions in comparison to the simulations and to estimate the order of magnitude of variations. When calculation sky view factors on facade planes it is also possible to estimate a daylight potential for the buildings.

3.2Direct sunlight: Maximal Sunshine Duration (MSD)

Direct sunlight is also important. We compared the different alternatives using the maximal sunshine duration or MSD. This is the total hours that direct sunlight hits a point over a given time period. This cumulative measure could be determined over a period of a day, a month or even a year. In this study we chose to calculate the MSD for three reference dates, 21th December, 21th of March and 21th of June and to realize false colour maps for the visualization and comparison.

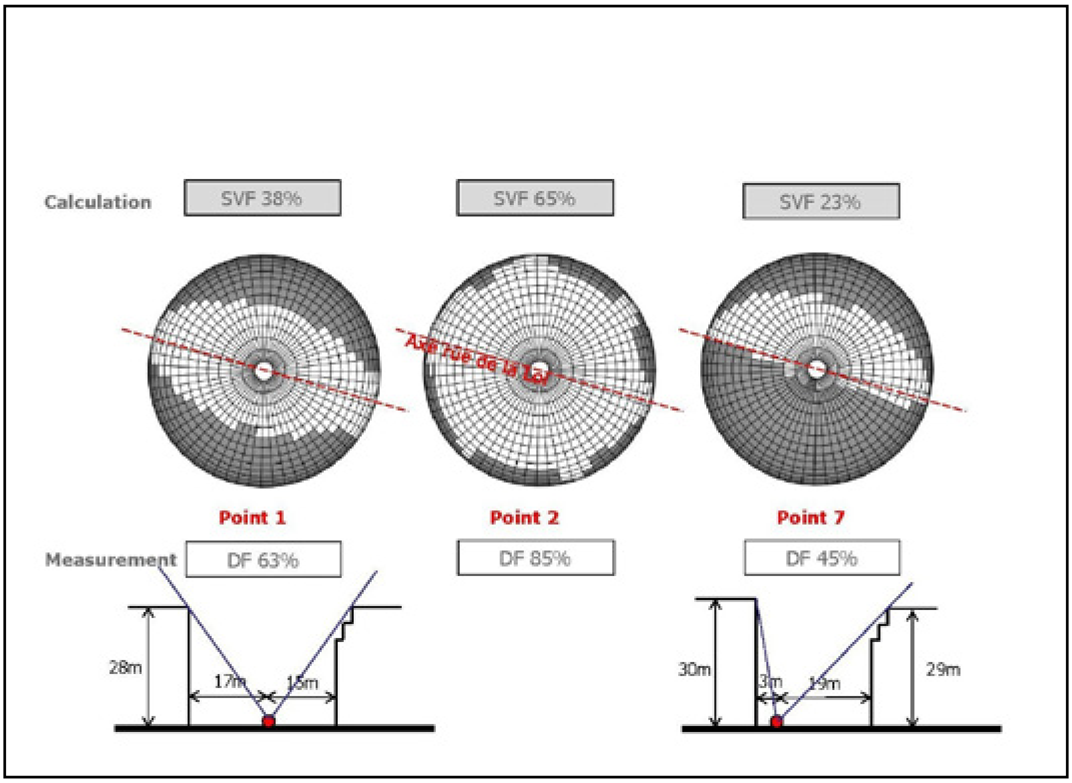

Figure 1 - Sky View Factors and measured daylight factors for a set of reference points

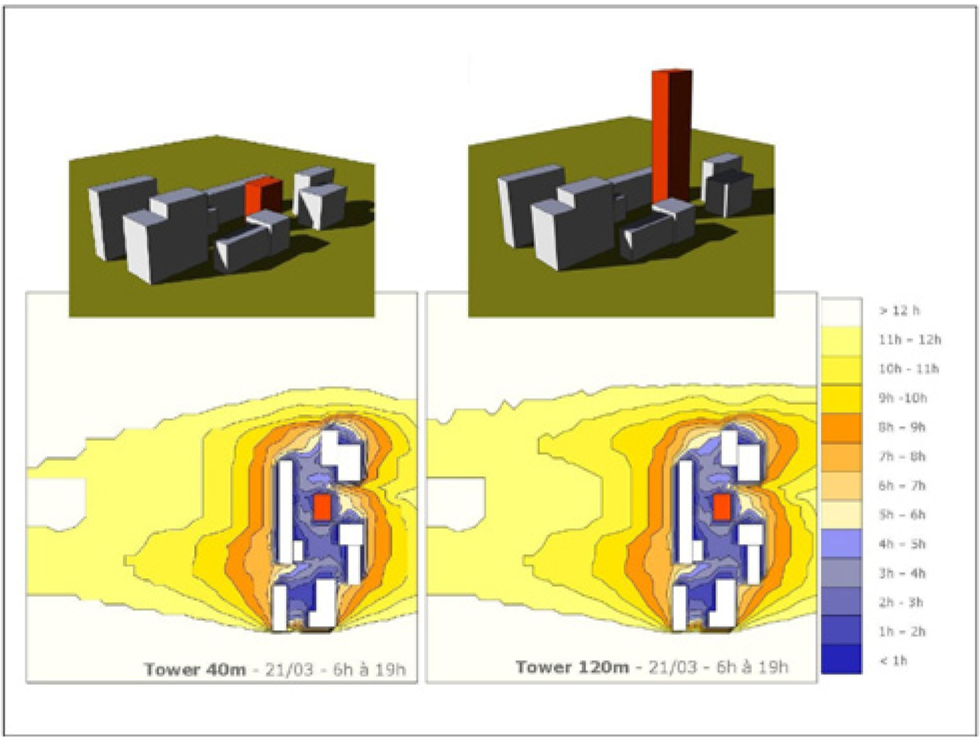

Figure 2 - Sunshine Duration maps - Comparison between a high and a low building in an urban setting

PP073

DAYLIGHTING DESIGN TOOL FOR ARCHITECTS

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The daylighting characteristics of buildings are greatly effected by the decisions of the architectural designers. The design decisions made at the conceptual design phase determine approximately 80% of the energy as well as the daylighting characteristics of the future building. Engineers and consultants have on approx. 20% chance to influence the basic energetic characteristics of the design at the later design stages. The task of the architects are not simple, because their work is influenced by various connected – as well as contradicting - design factors to be considered: building code, program provided by the investor, aesthetics, design standards, environmental aspects, costs, etc.

It is crucially important to provide adequate tools for the architectural designers to help their design decisions at the early design stages as well as to provide invaluable feedback about the daylighting realted aspects of their design decisions. Architects will consider, and can implement in their everyday practice only those tools that:

- provide practical design feedback and able to support design decisions, even at the early design stages,
- provide accurate results about the daylighting characteristics of the design and design alternatives,
- don't require any in-depth studies in the field of daylighting and energy analyses,
- don't require to involve additional engineers or consultants – such as lighting or energy experts,
- provide results in a "short" time (range of 15 minutes – instead of days),
- don't require additional costs and budget.

There are various, existing daylighting design tools, however none of the conventional tools can fully fulfil all the above listed requirements.

Most of the existing daylighting tools, diagrams and software applications offer an "implicit" calculation method. This practically means that they require precise details and dimensions about the openings and based on this input data they can determine the daylighting efficiency or characteristics of the designed building or interior space. The most important shortcoming of the implicit calculation methods is that these can not be effectively applied at the conceptual architectural design stages, because here the exact size, location or position of the openings are usually unknown. A series of calculations has to be completed using openings of different sizes and/or locations to get closer to the characteristics of the optimal daylighting system of a specific architectural design.

The advantage of the "explicit" calculation methods that these can provide specific opening characteristics in one go. In other words there is no need to run a series of calculations but one calculation.

The conventional, graphical daylighting diagrams and tables can consider only a limited input

parameter for the basis of the calculations. These methods can not consider the surface properties of the internal walls and surfaces, the characteristics and type of glazing or the geometry of skylights and dimensions of light-wells.
There are various software applications developed to calculate daylight measurements, however these require a detailed architectural design and can not be applied at the early design stages. These applications may also require expert knowledge, and extra time and budget.
A possible solution appears by implementing the accuracy of model measurements, the consistency of graphical diagrams and the speed of software applications. A series of model measurements have been carried out in the artificial sky.

The most convenient, reliable and precise solution to describe and follow the illuminance distribution and efficiency of daylighting systems is by model measurements in the artificial sky. Interiors of any geometry, surfaces of any quality, any structure or form of opening can be examined by physical model measurements. The series of model measurements in the artificial sky are providing illuminance values. Using these measured values the daylight factor can be determined in the reference plane. The measured values reflect all the physical characteristics of the actual daylighting system (dimensions of the transparent surfaces, obstructions, fenestration, dimensions and surface characteristics of the interior space).

Considering various curves of various measurements, interpolating in between the values, it is possible to calculate the illuminance and its distribution - considering all the different features of the daylighting system. All the information of the illuminance distribution curves, representing the characteristics of the openings can be traced, translated and stored in matrixes. Using various matrixes of various measurements, completing interpolation in between the values, it is easy to calculate the illuminance and its distribution considering all the various features of the daylighting system. The results of the measurements can be summarized in form of a computer software. This computer software is already available for rooms with side-lights for free download for all visitors. The model measurements of the sky- lights are already completed and the corresponding software development is in progress.

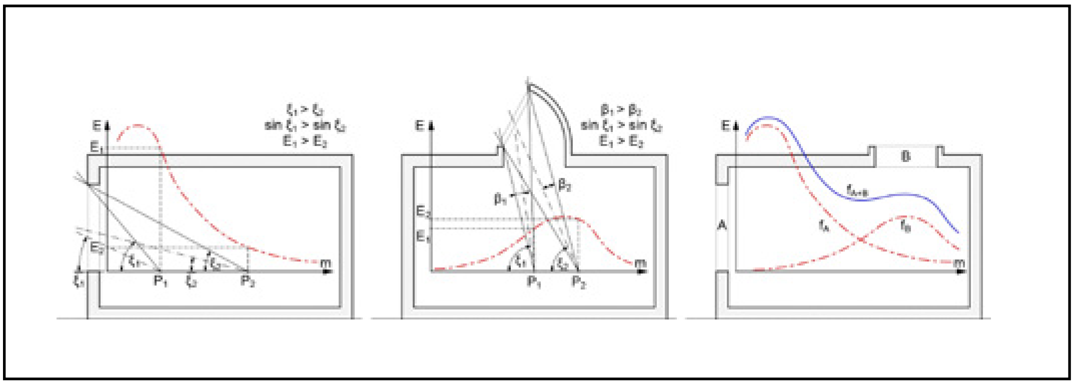

Figure 1 - Characteristics of sidelights, skylights and combined lighting systems

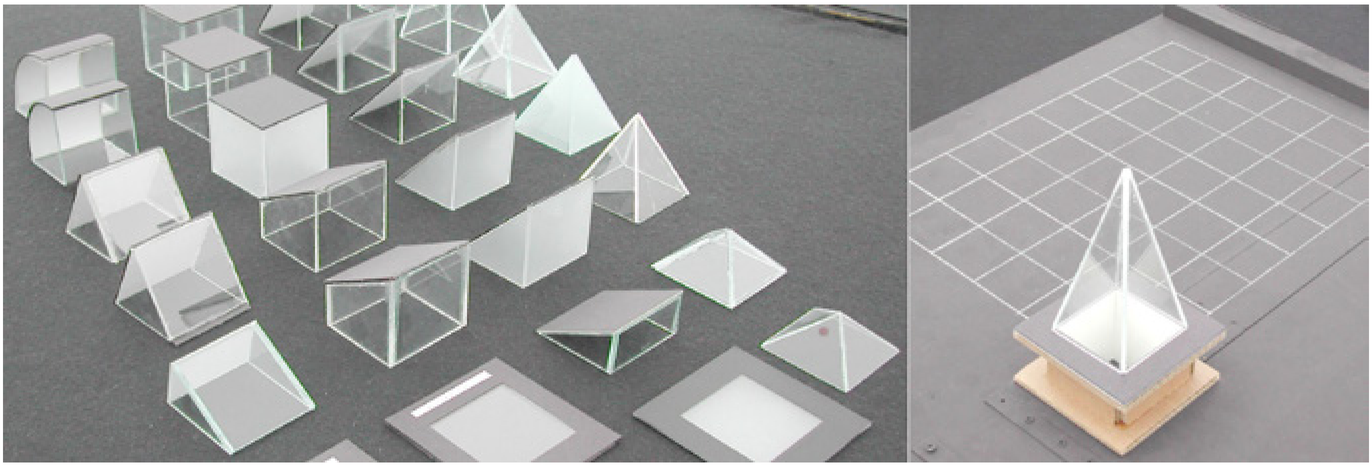

Figure 2 - Model measurements of skylights in the artificial sky

PP074

SKY CLASSIFICATION METRICS FOR HIGH DYNAMIC RANGE IMAGES

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In the field of daylight, photographic record of the sky vault has been approached by several studies (ROY et al., 1998; CHAMAIDI, 2006; PEREIRA, 2008). Recent development of techniques and technologies has contributed to broaden the usage possibilities of photographic records, such as the High Dynamic Range Imaging (HDRI), that is a powerful tool to register the light distribution in the built environment. At first, the studies involving HDRI pointed at the difficulties inherent to the process of capturing high contrast scenes, just like the recording of clear skies (STUMPFEL et al., 2004; REINHARD et al., 2006). Recent studies (INANICI; NAVVAB, 2006; CHENEY; INANICI, 2008; INANICI, 2009) addressed the possibility of capturing sky vault luminances using this technique with single-lens-reflex cameras and fisheye lenses. The characterization of the sky type is extremely important to the daylight studies, since it regards the patterns of daylight availability and distribution in a given region. However, the classification is still made with subjective methods, as there is no established metrics to compare images with mathematical models. This paper investigates the possibility of objective analysis among real and forecasted sky luminance distribution. The used images have been collected in places where the viewing obstruction of the sky vault was minimal, aiming at the correct interpretation and comparison of the data of the HDRI and the predictive models. Two cameras were placed on tripods and pointed at the zenith. After the shots, the images were compiled using the software Photosphere 1.8.7u (WARD, 2012) and stored in the Radiance RGBE format (.hdr extension). With the HDR Toolbox library compiled by Banterle et al. (2011), a MATLAB routine was elaborated, comparing the HDRI and the predictive models adopted in the ISO 15469:2004 / CIE S 011/E:2003 standard. Six accuracy metrics were used: the mean squared error (MSE); the mean absolute error (MAE); the mean absolute percentage error (MAPE); the symmetric mean absolute percentage error (sMAPE); the mean percentage error (MPE); and the Pearson's correlation (R). A set of two hundred HDRI was evaluated. First of all it is noticeable the unique behavior of each metrics, as shown in the tables. All basic formulas presented some accuracy errors in detecting certain complex skies, but these deviations were similar for both cameras. The results showed in the images indicated that the most stable one is the sMAPE, which presented a more heterogeneous distribution of the sky patterns, in accordance with the variety registered on the HDRI set. Thus, the initial hypothesis is that the sMAPE seems to be the most appropriate metrics for a primary evaluation of the data sampling and amplitude present on the HDRI.

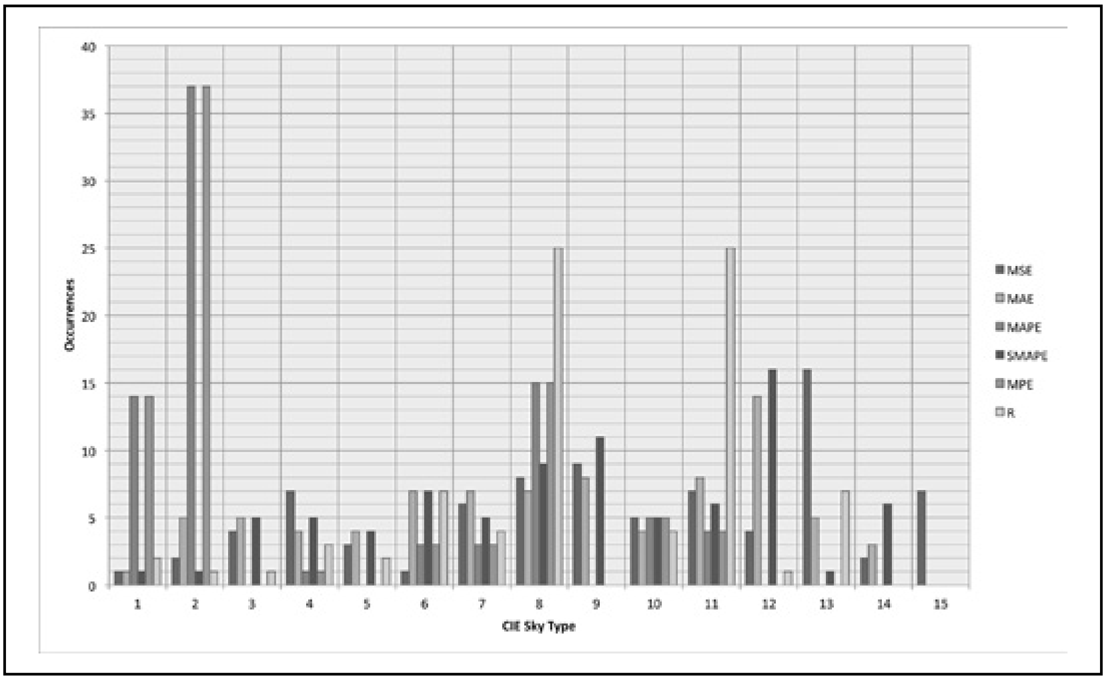

Figure 1 - Sky occurrence distribution for Nikon d60

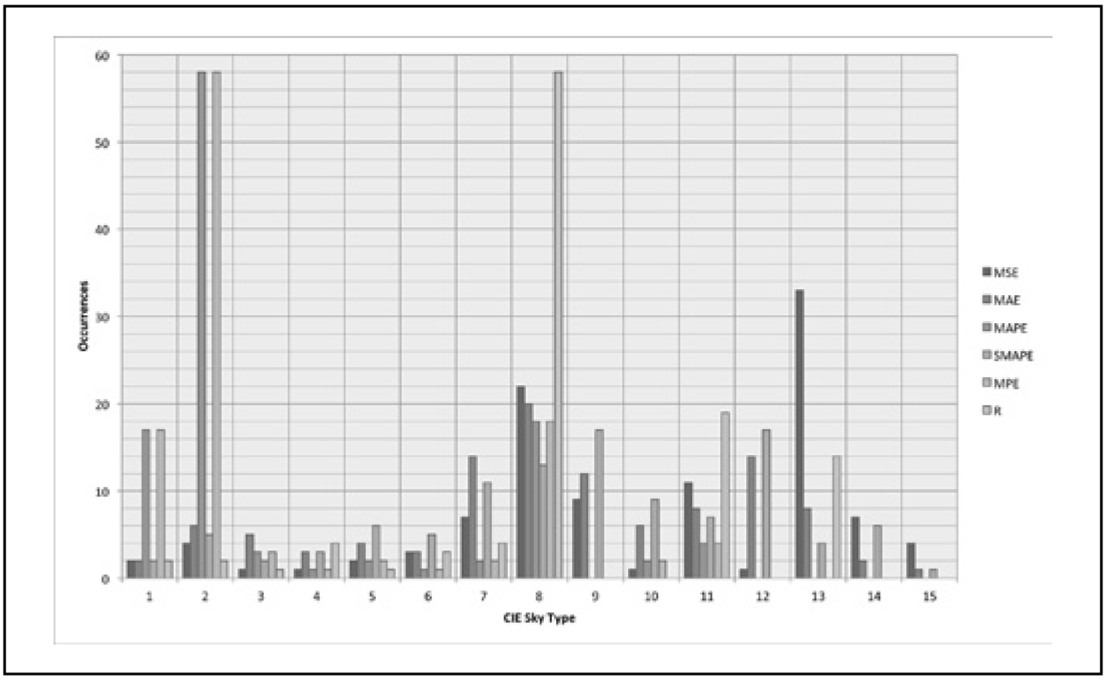

Figure 2 - Sky occurrence distribution for Canon EOS Rebel Xsi

Nikon d60	MSE	MAE	MAPE	sMAPE	MPE	R
Arithmetic Mean	51,69%	53,99%	71,38%	76,82%	71,38%	58,84%
Geometric Mean	38,43%	48,84%	67,93%	76,54%	67,93%	57,29%
Median	47,35%	51,98%	77,80%	77,08%	77,80%	57,68%
Standard Deviation	32,96%	22,61%	20,17%	6,48%	20,17%	13,32%
Variance	10,73%	5,05%	4,02%	0,41%	4,02%	1,75%
Sums of Squares of Deviations	880,02%	413,93%	329,44%	34,02%	329,44%	143,72%

Tabel 1 - Statistical results for Nikon d60

Canon EOS Rebel Xsi	MSE	MAE	MAPE	sMAPE	MPE	R
Arithmetic Mean	42,91%	52,60%	72,91%	74,84%	72,91%	51,44%
Geometric Mean	29,18%	47,38%	70,48%	74,37%	70,48%	49,85%
Median	36,83%	54,69%	77,67%	76,13%	77,67%	51,78%
Standard Deviation	30,79%	21,77%	17,24%	8,05%	17,24%	12,74%
Variance	9,39%	4,69%	2,49%	0,64%	2,94%	1,61%
Sums of Squares of Deviations	1014,24%	507,04%	318,01%	69,37%	318,01%	173,76%

Tabel 2 - Statistical results for Canon EOS Rebel Xsi

PP075

RESEARCH ON PREFERABLE LUMINANCE CONTRAST OF WINDOW AND WALL AT DAYTIME

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There is a problem in the power supply in Japan since the earthquake that happened on March 11, 2011. It is necessary to use the daylight for the lighting energy reduction.
Before the earthquake, there was a trend that the smaller the window and give priority to energy conservation. The low thermal insulation performance of the glass surface is a factor of the cooling load. It also contributes to the energy efficiency of artificial lighting. However, artificial lighting that is turned off by power outages reminded the importance of window. There is a need for active use of daylight and the securing of the opening.

The problem when using the daylight is the luminance of the sky and the surrounding buildings seen from the window. Excessively high luminance may cause glare and the impression of the room becomes dark. That is, in order to achieve a comfortable visual environment, it is necessary to control the luminance of the window section depending on the luminance of the room wall. There are several studies about glare, because discomfort level and perceived level are mixed in the evaluation criteria, it is unclear which level should be chosen when designing. The purpose of this study is revealing the preferable luminance contrast of window and wall.
Test space was created on the 7th floor of the office building in Tsukuba. The window is located on the north side, about 60% of the views is the sky, the rest is composed of mountains and white building. The experimenters has changed to „the transmittance of the window glass“ , „ interior reflectance „ and „the size of the window.“ Subjects to adjust the output of the luminaire in the room until you feel preferably luminance contrast of windows and walls. Age of the subjects in their 20s, the number is 18 people. Luminance distribution of the state in which the subject has been adjusted is measured by a CCD camera, and calculates the average luminance of the window portion and the wall portion.

According to the results, the preferred luminance contrast tended to vary depending on the reflectivity of the interior. The preferred luminance contrast increases as the interior reflectance is low. On the other hand, there was no effect of the size of the window. In previous studies, the effect of the size of the window has been reported is different from the our findings. Also, if they have the same luminance of the window, the glare should be higher when the low interior reflectivity, previous research can not explain our findings on luminance contrast. When designing the luminance of the window based on the glare index, there is a possibility that excessively suppressed.

PP076

PROPOSAL OF SIMPLE DAYLIGHTING PERFORMANCE INDICES FOR REGULATIONS:VALIDATION WITH ON-SITE MEASUREMENT CAMPAIGN.

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A model for regulation for minimum daylighting of building is proposed based on geometric parameters, which could be easily estimated by design teams, and easily verified on site, after construction, by clients. This model is coherent with the methods proposed by CIE: the Daylight Factor approach (*) and the Climate based calculation method (**).
This procedure was chosen due to the specific context of regulation, in comparison with the detailed assessment process for optimal design. It was found indeed that DF coefficients, and climate based models are very sensitive to the values of input parameters, which are often unknown at the design stage, or mistaken. Furthermore, they are rarely verified on site after construction, due to difficulties in the measurement procedures for DF assessment, or to the comparison of achieved long term performance issues by comparison to the calculated ones.
Although DF values are the most common coefficients used by architects and engineers, this observations suggests that regulation related to daylighting could use a more simple model, with performance indices which could be easily verified on-site, without performing detailed daylight measurements.

The major challenge is to verify that the proposed simplified model
a) correlates well with on-site DF measurements
b) correlates well with observed quality of daylight in a building.

For these reasons, a campaign of field assessment of daylighting was launched, dealing with more than 50 existing spaces in buildings in the area of Copenhagen.
Geometric, photometric and light measurements were conducted for buildings with various, but realistic, daylighting schemes. A panel of professionals was also invited to rate the quality of daylight, to verify that the findings are coherent with observations.
The result is a set of "good sense "rules, with a set of minimum values of building descriptors, to avoid situations where daylighting would be insufficient, or inappropriate.
The rules take into account 7 parameters
1. The level of obstructions in the street (angle)
2. The absorption of light by the façade component
3. The size of the window area (m^2)
4. Room depth (m)
5. Average absorption of light in room
6. Building thickness (m)
7. Ceiling height (m)

(*) DF is the ratio of the illuminance indoor, at a specific location, to the simultaneous illuminance outdoor, in an unobstructed area, under standard overcast conditions.

(**)CIE-TC 3-47: Climate-Based Daylight Modelling
This study was conducted with a specific grant from the Danish Energy Agency (Energistyrelsen).

PP077

HOLLOW LIGHT GUIDES: 50 YEARS OF RESEARCH, DEVELOPMENT, MANUFACTURE AND APPLICATION

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The paper provides a historical overview of key emergence and development stages of a new branch of lighting science and technology.
The paper covers developments from mirror slit hollow light guides with reflective internal surfaces, through to prismatic light guides, and then to the creation of installations like “Heliobus” and “Arthelio”, where natural sky and sunlight, as well as light from artificial sources enters and disperses within buildings. In recent years short hollow end- to-end light guides are widely applied for channelling natural light. The paper explores new prospects and directions for further development of hollow light guides, which offer new efficient and effective avenues of improvement for lighting installations.

Hollow light guides present an important opportunity to increase the safety and efficiency of lighting installations, giving them new forms and aesthetic appearances.
The production of hollow light guides is a complex scientific and technological effort. It involves the development of new metric methodologies, alternative photometric devices, radically new optical systems, new materials and light sources, as well as the creation of completely new efficient lighting installations. This developing branch of science accounts for over one hundred patents, several hundred peer reviewed articles, two major books, eight PhD theses, and two CIE publications developed by two technical committees within Division 3CIE.

The paper is accompanied by an array of diagrams and illustrations.
Key words: hollow light guides, mirror slit hollow light guides, prismatic hollow light guides, lighting installations, health and safety of lighting systems

PP079

ASSESSMENT OF DAYLIGHT CONDITIONS IN OFFICE BUILDINGS WITH THE INTEGRATION OF EXTERNAL BLINDS

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The use of solar control devices contributes to the energy efficiency of buildings during the summer period and controls daylight levels throughout the year; however, it can result in increased heating loads in winter due to limited solar gains. Especially in modern office buildings with extensive glass surfaces, sun protection is essential and is often realized as unmovable blinds mounded on the exterior of facades.

The objective of the proposed paper is to present the results of an experimental analysis regarding the impact of integrating external blinds on the transparent elements of the building envelope on the formation of indoor daylight conditions. The analysis is based on data derived from recording the illuminance on the working plane of two building models constructed for this purpose. The building cells are orientated due south and have identical geometrical and optical characteristics, with the exception of solar shading: one has no solar protection, while the other is shaded with unmovable horizontal blinds mounded on the external side of the window façade.
The evaluation parameters referred to both quantity and quality of daylighting. More specifically, as regards daylight quantity, the distribution of illumination on characteristic points of the working surface of the two models is studied for the two building cells for a period of one year. Moreover, the differentiation of daylight levels caused by the movement of the slats was studied.
The quality of daylighting prevailing in the examined cells was approached by studying the uniformity of daylight distribution, as well as by conducting an in situ visual comfort survey among persons who used the space and filled in relative questionnaires.

The presentation of results for the two building cells, as well as their intercomparison, indicate the contribution of external blinds to the formation of daylight levels and visual comfort in office spaces.

PP081

DESIGN OF LATERAL OPENINGS FOR NATURAL ILLUMINATION IN RESIDENTIAL BUILDINGS IN BRAZIL: ANALYSIS OF THE BUILDINGS CODES AND SUGGESTIONS OF NEW PARAMETERS TO THE CITY OF BRASÍLIA.

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In residential building, daylight is usually brought to the interior of a room by lateral openings, which must to be well designed to provide minimal illumination to the environment. However, the correct measurement of these openings is dependent on the knowledge of natural light behavior on the project site, as well as the opening orientation and other factors. In every city of Brazil, building codes regulate construction of residential buildings. In theory, these codes should grant minimal quality standards including that of daylight through lateral openings. In the majority of Brazilian cities building codes, lateral opening dimension is solely calculated as a proportion of the floor area of the room. These calculations do not take in consideration the local sky conditions, the orientation or amount on incoming solar radiation, potentially resulting in inadequate dimensions (Fernandes, 2009). Some of the measures adopted by the Brasilia building codes are merely copied from other Brazilian cities and their review based on the Brazilian legislation to determine, by simple comparison e sampling, which values were the best to be adopted (Buson, 1998). Lamounier (2012) evaluated the natural illumination performance in kitchens and bathrooms with light wells in 5 Brazilian cities using the actual codes and verified the inefficiency of these indications. None of the analyzed places resulted in the minimal lighting level required. The objective of this study is to analyze the Brazilian building codes and present new parameter indications for the city of Brasilia. The recommendations for residential lateral opening of 27 Building Codes from all Brazilian capitals were compared to the daylight conditions generated in Brasilia by computer simulation of dynamic measures and provision of improvement in opening dimensions parameters for this city. The method includes the elaboration of computer models of the evaluated environments, taking in consideration the recommended dimensions of the Brasilia building codes e simulated using DaySim software. To establish the minimal daylight required, the Brazilian Norm of Building Performance (NBR 15.575) was used, which stated a minimum of 60 lux of natural lighting in residential environments. The analyzes of daylight autonomy (DA) were generated using graphics from the results of the simulations, from which will be possible to conclude if the opening dimensions proposed by the city codes reach the minimal daylight level recommended and also will allow for the proposal of new recommendations for the city of Brasilia.
key words: daylight, buidings codes, lateral openigns for natural illumination.

PP083

EVALUATION WINDOW LIGHTING CONSIDERING THE CIRCADIAN EFFECT

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Window light is a very essential part of a modern building. Natural light is extremely beneficial to human health and people lack of exposure to natural light are readily subjected to diseases. Therefore, window light is getting more and more attention these years.
The basic function of a window is obviously to allow the natural sunlight to enter a room, which illuminates the indoor environment, and meanwhile as a heat provider in winter. For people indoor, seeing the scene such as the sky, cloud and green trees outside through the windows make them feel active, which is beneficial to maintain their status of pleasure physiologically and psychologically, and improve their work performance, especially for those under constant huge working pressure .However, more important is that, natural light stimulates effectively the human visual system, metabolic system and circadian rhythm. Exposure to appropriate amount of natural light helps to prevent possible diseases. Especially, natural light is by far the most important entraining cue of circadian rhythm. While the spectral intensity and incident light direction of window light from natural light fluctuate according to the actual time points in daytime and seasons, which synchronizes the circadian rhythm to outside environment, regulates various variables of body and ultimately promotes organism homeostasis.

Circadian rhythm is a biological cycle that has a period of about a day. Body temperature, hormonal levels, sleep, cognitive performance and many other physiological variables exhibit such daily oscillations. Normalization of circadian rhythm is crucial to human health, because this system regulates a series of gene involves in occurrence and development of disease, especially cancer. Disorder of circadian rhythm is adverse and even lethal to human. In mammals including human, a pacemaker in the hypothalamus called the suprachiasmatic nucleus (SCN) drives these rhythms. Lesions of the SCN abolish circadian rhythms. Because the intrinsic period of the SCN oscillator is not exactly 24 h, it drifts out of phase with the solar day unless synchronized or ‘entrained’ by sensory inputs. Intrinsically photoreceptive retinal ganglion cells (ipRGCs) are the most important circadian rhythm participants. When light reaches the eyes, convey light signals directly to the SCN via the retinohypothalamic tract eliciting circadian alterations by modulating SCN activity. When we experience a sudden change in light cycle, as in air travel to a new time zone, we suffer an unpleasant mismatch between our biological rhythms and local solar time (‘jet lag’). Normal synchrony is restored over several days as the rising and setting of the sun resets our biological clock. This is the most classical case demonstrating the rhythm alteration.

However, in modern building, many offices and rooms were made without windows which enable the sunlight to enter because of the restriction of structure. Living under a circumstance with 24-hour, constant and low illumination(less than 500lx) probably induce negative impacts on mental health and emotions of human. The regular illuminating system contains short-wave blue light that impair human retina after a long period exposure, which alters subsequently circadian rhythm. Under constant artificial lighting, people feel fatigued easily and result in reduction of working efficiency. Meanwhile, the regular lighting system is fixed on the ceiling, which reflects the light into people's eyes. Therefore, an artificial window on the wall of a window-less room, that is a simulating window, which simulates the natural day light penetrating a window, is possible to change these poor conditions.

We made use of four channels of LED(cool white, warm white, red and blue) which are controlled by DMX512 via a computer. We simulated a view of the West-lake scene from a window toward the east. Luminances and color temperatures of trees, clouds, the sky and lake water on the simulating window approach the natural environment as closely as possible by driving dynamically each LED sub-source.

To evaluate the consistency of lighting view on the simulating window and the natural view, we took advantage of the image extraction to differentiate trees, clouds, the sky, lake water and city building— the five scenes. Luminance and color temperatures of the five parts were measured by a spectroradiometric luminance meter, and parameters of different time point from 6:00AM to noon till 7:00PM were recorded, these data were compared with those recorded under natural conditions.

The size of the dynamically controlled simulating window was 3.0m×1.5m. In a human trial, a subject kept sitting by a desk 3m away from the simulating window and facing to it, which stimulate the perception of their ipRGCs of retina in eyes daytime.
The effective irradiation field and exposure irradiation from the window on retina of the subject were recorded via a behavior recorder fastened on their head, The result suggested that the high luminance-scene of the simulating window improved the stimulation of non-visual system of the subjects working indoor chronically, because the induced stimulation to circadian rhythm is 2-3 times to the ambient light.

We analyzed the method of evaluation of multi-scene field, and compared the circadian rhythm variables of the simulating window with the visual variables. We also compared chromaticity and luminance of the dynamically controlled simulating window and C/P (C/P refers to the ratio of effects of circadian rhythm to photopic vision, which used to evaluate the non-visual effects of a light source)with the natural environment, and evaluated the string jump and flicker of light influencing the visual comfort level, and then made case analysis of circadian rhythm and illumination variables of the subject under window lighting in daily working conditions.

PP084

A CLIMATE-BASED GRAPHICAL TOOL TO PREDICT THE DAYLIGHT AVAILABILITY WITHIN A ROOM AT THE EARLIEST DESIGN STAGES

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The need for reducing energy consumption is today a key issue when approaching the conception and designing phases of a building construction. Electric lighting, particularly for non-residential building, plays a major role in determining the building energy demand, and its relative influence is increasing as a consequence of the progressive decreasing of HVAC consumption due to stricter requirements recently introduced into national and international codes and regulations.
In the field of lighting, the need for a more rational use of resources results in an increased use of daylight and its conscious integration with the electric lighting fittings, even through the use of control systems. The importance of daylight and sunlight for both building energy performance and ambient quality implies the need of a more accurate design approach which takes into account the dynamic behavior of daylight. In response to this, a new series of metrics has been proposed in literature(1)(2), the 'climate-based daylight metrics CBDM', which are parameters able to account for the dynamic variation of daylight and sunlight conditions during the course of the year. Addressing a daylighting design based on CBDM allows assessing daylight availability within a space with higher accuracy than an analysis based on the daylight factor only, in terms of both determining quantity and quality of daylight and of verifying potential visual and thermal discomfort problems due to direct sunlight penetrating into a room. A dynamic approach allows a more conscious architectural design which is integrated with the design site and its climate conditions, also accounting for the effect of the orientation.

Nevertheless, while the dynamic daylighting design approach is becoming more and more diffuse within the scientific community, it still results hard to be correctly understood and applied by the designers. Actually, most of daylighting design tools presently available are based on Radiance and expert skills are therefore needed to carry out simulations. As a result, designers still have troubles to adopt a dynamic approach since the early design stages and throughout the whole design process.

Within this frame, the paper presents a graphical tool which could be used by the design team since the earliest design stages to predict the daylight amount within an indoor space, as expressed through the values of Dynamic Daylight Performance Metrics DDPM (namely the group of Daylight Autonomies, the group of Useful Daylight Illuminances and the Annual Light Exposure).

The tool was built to visualize the results of huge database of DDPM data obtained from a parametric study which was carried out to assess the daylight amount for a sample office room with different characteristics: room orientation, depth and window area, as well as obstruction angle. The task illuminance was set to 500 lux, according to international standards. The analysis was repeated for three sites, representative of different climate conditions (Turin and Palermo - Ita-

ly - and Berlin – Germany). For each case-study the DDPM values were calculated through the Radiance-based software Daysim.
Results which were obtained are intended to provide architects and designers with more detailed information about the consequences on daylighting due to different architectural solutions, as well as, the other way around, with strategies to guarantee a desired energy and/or environmental performance.

For this reason the aim of the tool is to allow practitioners, designers and decision makers to quickly verify the influence of preliminary design solutions on daylight availability within the room and it can be applicable for simple environments. For a given combination of room depth, obstruction angle and window-to-wall ratio, designers can identify the daylighting condition as expressed by each DDPM and assess the influence on the daylight condition due to changing of these room architectural characteristics. The graphical tool can by used by practitioners according to two different approaches: according to the first approach, the design team has the chance to identify, for the specific space under examination, the corresponding daylighting performance which can be expected, based on the values of the DDPM. According to the second approach, the design team can use the tool to identify which combinations of the room architectural features (depth, window area and obstruction angle) would provide the standard-based or user defined performance objective.

Even if the study does not cover every possible building configuration it makes available a set of data and correlations that can be useful to inform designers on the impact of their architectural choices during the very first stages of the building design process, when the use of simulation tools for more detailed calculation is still premature.
This paper presents the graphical tool which was developed and some results concerning the effectiveness of its application, as well as some comparison with other prediction tools which could be used by the design team to approach the daylighting design since the early design stages.

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D3 - Interior Lighting Controls

PP085

DEVELOPMENT OF AUTOMATIC LIGHTING CONTROL SYSTEM USING BRIGHTNESS IMAGE

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The illuminance in the office building in Japan has common 750 lx. In those offices, only the ambient lighting system is used and the task light is not needed to use, which is called general lighting. However, in addition to the demand of energy saving, it fell into electric power shortage with the stop of the nuclear power plant by the great earthquake in March, 2011. Therefore, power saving and energy saving are strongly called for in the field of office lighting.
The Task Ambient Lighting (TAL) is validated for energy saving in office building. In Japan, although introduction of TAL began from the 1980s, it has not spread in this present time. It is because the ambient lighting illuminance of about 300 lx is felt dark to the illuminance of 750 lx in the general office.
Then, authors started development of the automatic control system of light environment using the brightness image, and it succeeded in making comfortable nature and energy-saving nature compatible.
In this paper, the outline of the system, the simulation result of its energy-saving effect and an experimental result are reported.

The automatic control system consists of the following three systems greatly.
System1: Luminance measurement system
a. Measure indoor luminance for every surface of surrounding wall and every definite period of time, and obtain luminance images.
System2: Light environment assessment system
a. Change into brightness images based on the luminance images, and compute distribution of the brightness measure value of the space.
b. Deduce a required lighting control value by comparing this brightness images with the brightness images of the target set up beforehand.
System3: Light environment control system
a. Carry out dimmer control of the lighting automatically according to a lighting control value.

By using this control method, lighting output can be suppressed low and large energy saving can be attained, without feeling shortage of brightness in the space using daylight. The brightness image used here is developed by Nakamura expresses the measurement of the brightness perception which people feel and it is acquired from luminance image through wavelet transform. A measurement value is denoted by 13 steps of NB (Natural scale Brightness) in values from 1 to 13, which are 13: very bright, 11: bright, 9: a little bright, 7: mean, 5: a little dark, 3: dark, 1: very dark.
About such automatic control technology, the actual proof examination is done in the laboratory

shown in Fig. 1. Recessed lighting fixtures with louver are installed. Lamps are used efficient type with dimmer control and can be individually controlled in 5-100% of range.
Five cameras to measure the luminance on the surface of a wall and the upper surface of a desk are installed, and brightness images can be converted from the measured luminance.
Lightings near the surface of a wall are dimmed so that the brightness value computed from the measured luminance image may serve as NB of 7.
Moreover, lightings in the center of the room are dimmed so that upper surface of the desk arranged in the central part of the room may be set to NB of 5.
Control value is determined taking the influence of both lights into consideration.

Fig.2 shows an example of simulation results performed in advance. The results derived from the condition on the clouded sky day of the winter and at noon. The left figure shows the brightness image obtained by day-lighting only, and the right figure shows the brightness image obtained from the mixed lighting of a daylight and artificial light so that it might be set to NB of 7 at the wall. The result shows that appropriate brightness value can be achieved by artificial light even in the space with day-lighting. The lighting power consumption at this time can be shown in Table 1, and can attain large energy saving compared with the general illumination system of 750lx. The figure in TAL system includes the power consumption of 5 sets task light with 11W per set.

Thus, it became clear that the lighting control system which we have developed could attain large energy-saving . Moreover, this system is built in an actual laboratory and the energy-saving effect and the result of the subject experiment to brightness are reported.

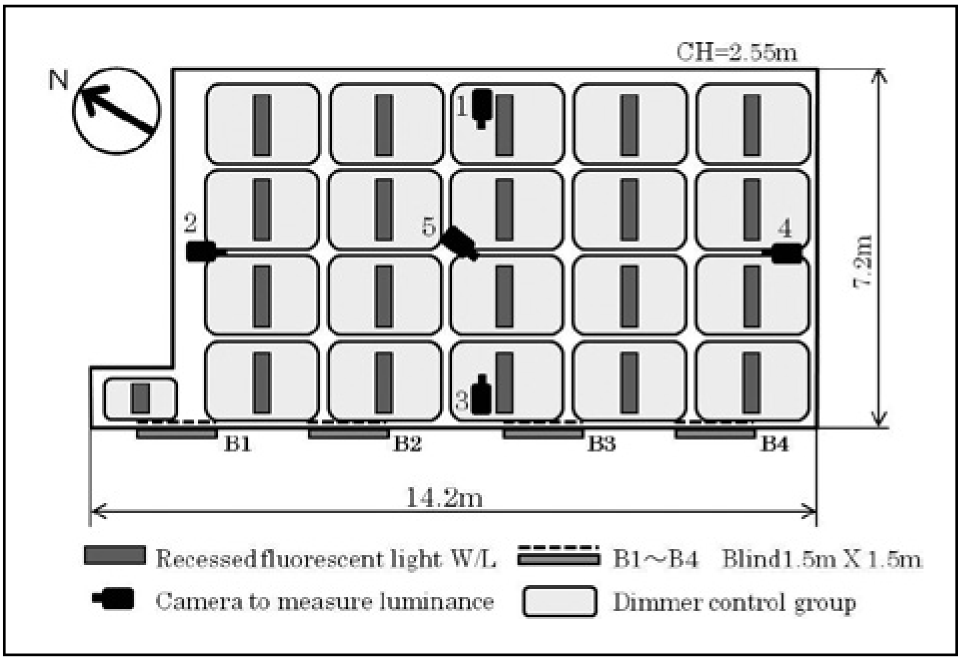

Figure1 - Layout of an experimental room

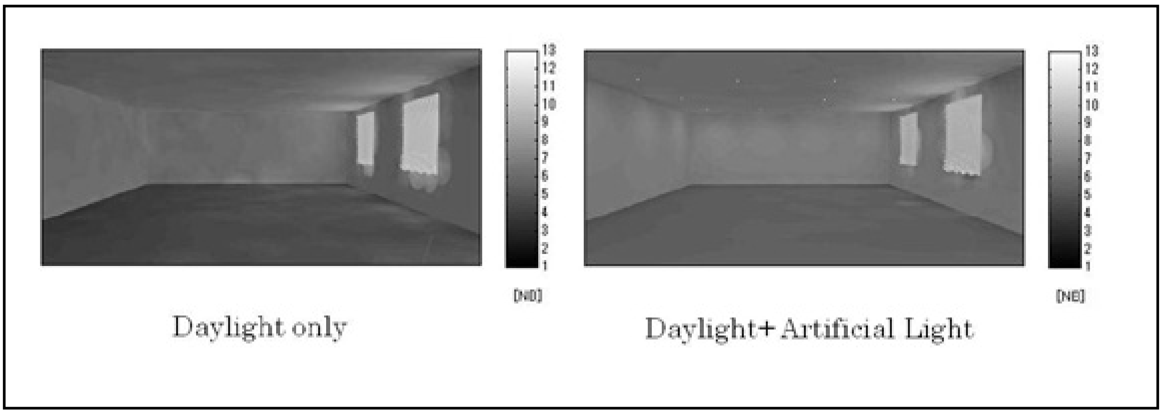

Figure 2 - Brightness image

	General Lighting at 750lx	TAL controlled by Brightness Image
Power Consumption(W)	1374	267.7

Table 1 - Comparison of Electric Power Consumption

PP086

ENERGY HARVESTING SOURCES FOR INTELLIGENT LED LIGHTING SYSTEMS

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Modern lighting control systems in buildings are composed of numerous wired sensors and actuators that are installed and deployed on buildings. With the rise of wireless communications technologies, the miniaturization of sensor devices and the advancements of energy harvesting technologies [1] to increase the lifetime of embedded devices, the modern lighting systems are evolving toward intelligent lighting control systems based on wireless sensor and actuator networks (WSN) [2].

This paper presents a survey of energy harvesting technologies to design autonomous smart sensors and actuators for intelligent LED lighting control systems oriented to near zero-energy buildings as shown in Figure 1. Different illuminance and occupancy smart sensor nodes are characterized experimentally to determine the energy efficiency and node autonomy from multiple sources such as sunlight outdoor, indoor artificial LED lighting with different color temperatures, Color Rendering Index (CRI), and according to the distance between the light source and the solar cell. One of the great challenges for the implementation of autonomous sensors in LED lighting systems lies in the proper characterization of the building to determine the residual energy sources that could be used properly depending on the node operational conditions throughout the day. This information is important to determine the devices location based on residual energy harvesting technologies that should be tailored to different areas of the building such as windows, office ceiling, common areas, stairwells, bathrooms etc.

Experimental results in this work involve solar cell characterization based on amorphous silicon, monocrystalline silicon, and thin film Dye Sensitized (DSSC) technology to optimize the size of harvesters and solar cells for autonomous nodes with ultra-low power consumption and small duty cycles. Additional tests involve harness the heat produced by a LED heat sink radiator in the luminaire for a thermoelectric harvester module [3] as shown in Figure 2. Additionally, a set of small current transformers are evaluated as another method to capture energy from the LED lighting system based on electromagnetic induction in the wires.
Finally we conclude with a discussion of wireless communications technologies for ultra low power and short range autonomous nodes for LED lighting control systems based on specifications such as Enocean [4] and standards such as IEEE 802.15.4 [5], ZigBee [6], 6LoWPAN [7] and Bluetooth [8] for smart lighting systems that employ autonomous smart sensors for interoperable, energy efficiency and high quality sensor networks for intelligent LED lighting control systems.

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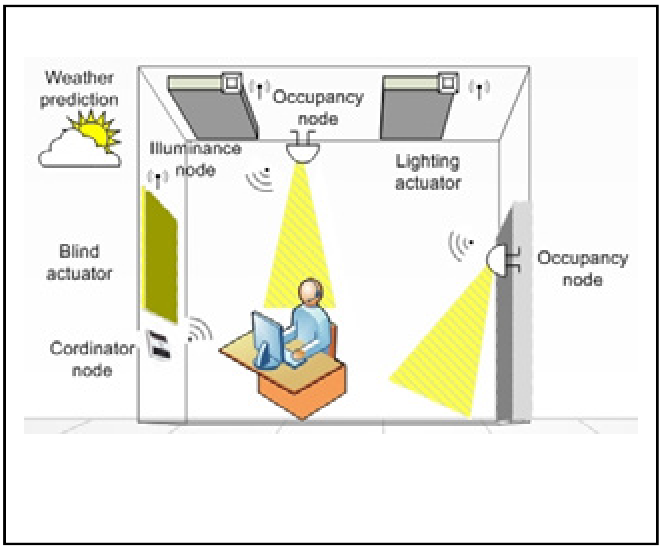

Figure 1 - Lighting control systems oriented to near zero-energy buildings

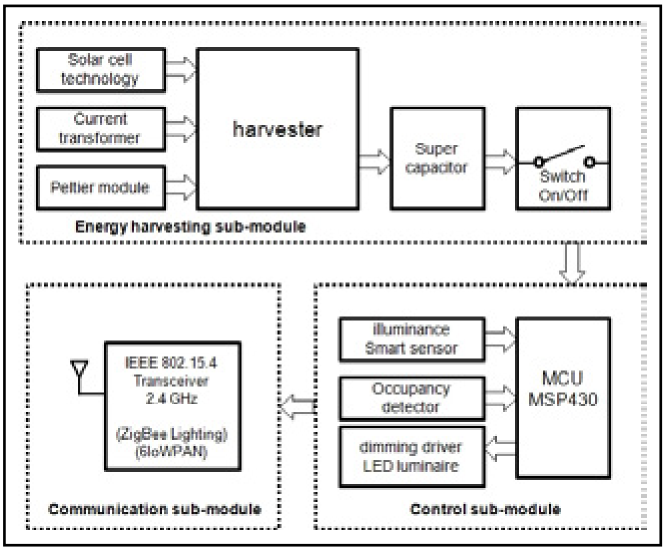

Figure 2 - Main blocks for an autonomous sensor node in a smart lighting system

PP087

EFFECTS ON ENERGY SAVINGS OF PERSONAL LIGHTING CONTROL SYSTEM IN AN OFFICE BUILDING IN JAPAN - PART 1 OUTLINE OF THE MEASUREMENT AND EFFECTS ON LOWERING ELECTRICAL POWER CONSUMPTION FOR LIGHTING

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1. INTRODUCTION

It has been said that energy use for lighting accounts for about 20% of the total energy use in Japanese office buildings (Japan Luminaires Association. 2009.). Turning off artificial lighting has a large impact on lowering energy use in office buildings because it relates to reducing the load for air-conditioning. However, Japanese office buildings have not made progress in energy saving for lighting.

In the most of Japanese office buildings, it is quite usual that the occupants live together with the others in a deep-plan office space with largely divided control unit of ceiling luminaires. In such cases, it is difficult to switch on/off the ceiling luminaires as the individual demands because switching on/off the luminaires changes not only the lighting environment in the area where the occupant who controlled the luminaire occupies but also that in the surrounding area. In some cases, ceiling luminaires are controlled by using occupancy sensors. It can be expected that turning off or reducing lumen output of the ceiling luminaires in the areas from where the occupants are absent. However, it has been reported that the ceiling luminaires could not be turned off than estimated in the cases where the occupants come and go frequently (M. Homma. 2010). Some lighting control systems that can turn off the lights surely in the area from where the occupants are absent are required.

The purpose of this study is to examine the effects of the personal lighting control system on the quality of lighting environment of the office space and lowering energy use for lighting. In this paper, the outline of the measurement and the effects on energy savings of personal lighting control system for ceiling luminaires are reported.

2. METHOD

Figure 1 shows the plan of the measured office space. The office space was divided into four areas and the ceiling light switches of different types –two kinds of push-button system and one push-button telephone- were distributed to each area. The occupants could switch on/ off the ceiling luminaires near their seats by pushing the button settled on their desks. In the most cases, one ceiling lighting fixture was shared with more than one occupant. The number of the occupants who could switch on/ off the light per lighting fixture ranged from 1 to 2. Also, the number of the controllable ceiling luminaires per head ranged from 1 to 3.

Field measurements were conducted twice to examine the effects of personal lighting control system for ceiling luminaires on energy conservation by comparing the electrical power consumption for lighting before installing the personal lighting control system and that after installing the system. The first measurement, before installing the personal lighting control system, was conducted

during 11th June and 15th June, 2012. And the second measurement was conducted during 17th July and 20th July, 2012, the second week after installing the personal lighting control system.
In the measurement, electrical power consumption for ceiling luminaires was measured at intervals of 1 minute and the number of the occupants who took their seats in each area was counted at intervals of 5 seconds during working hours (9 a.m.-7 p.m.). Also, the timings when each occupant switched on/off the ceiling luminaires were recorded at intervals of 1 minute.
Moreover, the occupants evaluated the visual environment in the office space and the ceiling light switch. The results of the questionnaire and the occupants' response to personal light switch are reported in Part 2.

3. RESULTS

Figure 2 shows the comparison of the electrical power consumption for ceiling luminaires before installing the personal lighting control system and that after installing the system in area A as an example. It can be seen that electrical power consumption for ceiling luminaires after installing the personal lighting control system was halved compared with that before installing the system. However, electrical power consumption both before and after installing the personal lighting control system was almost constant during working hours. Before installing the personal lighting control system, the ceiling luminaires were switched on/off all together, so the ceiling lights could not be switched off before all of the occupants left the office space. On the other hand, it could be expected that the occupants switched on/off the ceiling lights frequently in accordance with their presence by personal switch for ceiling lights. However, most of the occupants switched off the ceiling luminaires only when they left the office. It could be concluded that once the ceiling light was switched on, most of the occupants did not change the state of the lighting.

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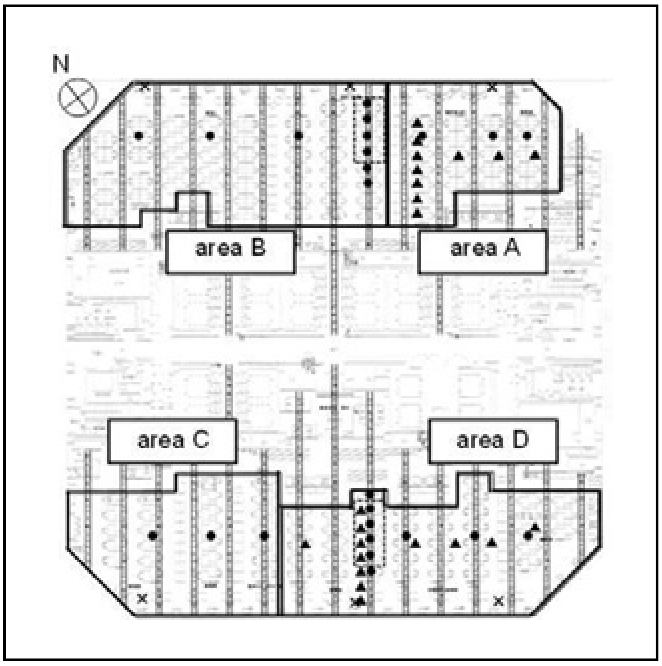

Figure 1 - Measured office space

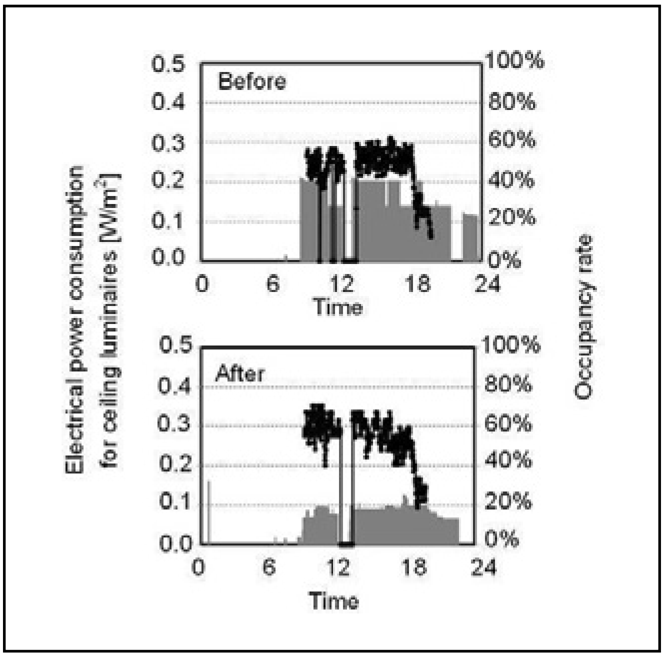

Figure 2 - Electrical power consumption for ceiling luminaires (area A as example)

PP088

EFFECTS ON ENERGY SAVINGS OF PERSONAL LIGHTING CONTROL SYSTEM IN AN OFFICE BUILDING IN JAPAN - PART 2 EVALUATION OF LIGHTING ENVIRONMENT AND OCCUPANTS' RESPONSE TO PERSONAL LIGHTING CONTROL SYSTEM

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1.Introduction

In this study, field measurement was conducted in an office building which introduced personal lighting control system. Part 1 of this paper has reported that electrical power consumption for lighting has been reduced by 44% in average by installing the personal lighting control system compared with before installing the system. However, the percentage of reduction in electrical power consumption for lighting varied from area to area. In some areas, the electrical power consumption for lighting in working hours on weekdays was reduced in proportion to the percentage of the occupants who took their seats. On the other hand, there could be seen some areas whose electrical power consumption for lighting was much higher than those in other areas although the percentages of the occupants who were present were almost the same.

In part 2, the relationship between the occupants' response to the personal lighting control system and the state of ceiling luminaires was analyzed in detail. Also, the results of the questionnaire survey, identifying the occupants' evaluation of the lighting environment in the office space and their operation of the personal lighting control system are shown. From the results of this study, the optimal design for personal lighting control system with considerations of energy savings can be proposed.

2. Method

Field measurements were conducted twice, before and after installing the personal lighting control system. Two kinds of questionnaire were prepared. The first one was the questionnaire on the lighting environment in the office space. Questionnaire on the lighting environment was asked to the occupants three times for each measurement, in the daytime on a sunny day and that on a cloudy day and at night, to consider the difference in the light environment due to weather and time. In the questionnaire, brightness on the desk, discomfort glare of the ceiling luminaires, satisfaction level of the whole office space etc. were asked.

The second one was the questionnaire regarding the operation of the personal lighting control system. It was carried out only in the second measurement that was conducted after installing the personal lighting control system. In the questionnaire, when and why they changed the state of the ceiling luminaires was asked. Also the reasons why they didn't switch the ceiling luminaire off in the case when they left their seats and how they felt the operation of the lighting by the other occupants were asked.

3.Results

Figure1 shows an example of the relationship between the occupants' presence (whether hi/she took the seat or not) and the state of the ceiling luminaires which were controlled by them. The data were obtained in the second week after the personal lighting control system was installed to see the actual conditions under the occupants accustomed with the system. It could be seen that once the ceiling luminaires were turned on, they were rarely switched off. It was identified that the occupants seldom switched off the lighting during working hours. Also it can be said that the reduction in electrical power consumption for lighting was not for the occupants switched on/off the ceiling luminaires frequently in accordance with their presence but for the ceiling luminaires were turned off in the area where the occupants were absent.

From the results of questionnaire, it was identified that the percentage of the occupants' who were satisfied with the operability of the switch was 30% in the areas A and D, 40% in the area B and 70% in the area C. Also, about half of the occupants answered that the switches for the ceiling luminaires were necessary for each occupant, because they

could switch the lighting at any time depending on their demands for lighting. However, the occupants seldom switched the lighting . the reasons why they did not switch the ceiling luminaires were also asked to the occupants. More then half of the occupants answered that they could not switch the lighting because they shared the same luminaire with the others and worried about the influence on the lighting environment of the others in the case when they switch off the common luminaires. Meanwhile, they also answered that they did not care about the others' operations.

For the effective use of the personal lighting control system, it is necessary for each occupant to recognize the difference between their own conjectures on the others' operations of luminaires and the others' response to that. Also, the relations between the controllable luminaire and the occupants who control the luminaire should be considered for proper use of the personal lighting control system.

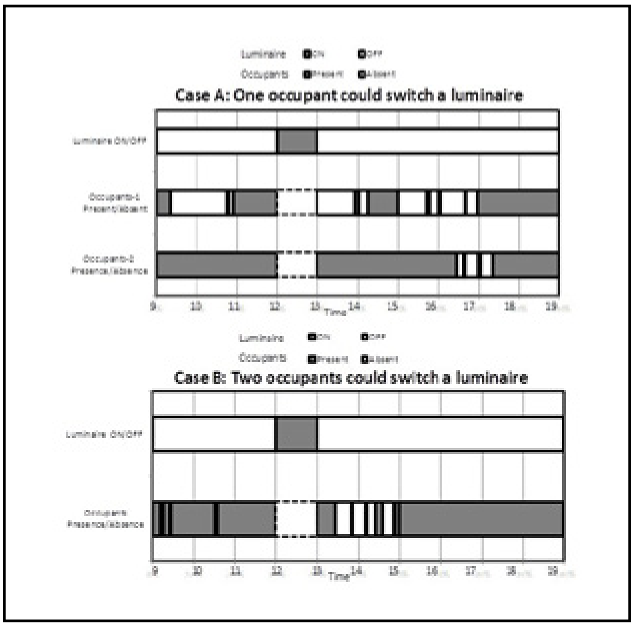

Figure 1

PP089

RESEARCH ON EVALUATION OF ENERGY CONSUMPTION OF INTELLIGENT LIGHTING CONTROL SYSTEM

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Intelligent lighting control system is a convenient control method commonly applied in lighting design, which achieves flexible, convenient, friendly user experience and stable lighting environment.
Theoretically, in certain illuminance requirement, intelligent lighting control system saves energy due to additional sunlight compared with manual control system.
In order to quantify energy-saving effect of intelligent lighting control system applied to certain venues, this article illustrates a contrast experiment between two office spaces of similar working conditions equipped with intelligent control system based on Digital Address Light Interface (DALI) standard.
The lighting energy consummation and lighting environment parameters are precisely measured in this contrast experiment so as to assess the difference between these two lighting control methods.
The challenge in this experiment is to decouple the energy consummation and lighting control methods. The experimental result will be directly affected by such parameters as lighting environment requirement, lighting control habits, outdoor lighting environment conditions, etc. In order to reduce the interference, two selected adjacent offices facing towards north are both of 24m^2 without direct sunlight. Office working time starts from 7:30am and ends at 6:00pm. Computers with LCD are used as routine working tools.
6 sets of triple T8 fluorescent lamp with dimming Ballast based on DALI are installed in the office ceiling. The desk surface horizontal illuminance is 360lx in average, 380lx maximum and 275lx minimum. An illuminance meter, a curtain controler and a 5-key control panel are installed in both offices.
In one office, all lamps are controlled by the illuminance meter, while meanwhile to a control group, the other office is set to be simulating manual control.
Variables include working time, illuminance standard, electrical shuttle, timing controller and infrared body sensors.
In order to measure energy consummation, two multi-function electrical meters are installed to power distribution system of the two offices.
All data collected are transferred to a compact gateway, which is accessible via the internet. All equipments for this experiment were settled in Sept. 2012.
As per result from lighting environment satisfaction survey and different control strategy, the control modes have been shifting monthly with uninterrupted record of energy consumption in two offices.
Base on collected data, compared with office space with manual control system, office space with intelligent control system consumes 2% to 8% less energy as per different experimental viables.

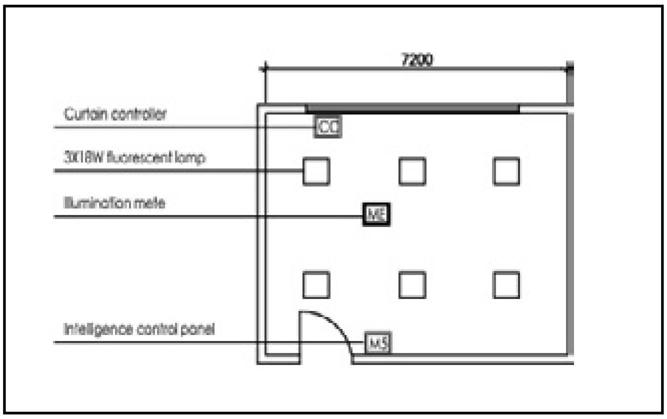

Figure 1 - Plan of office space

PP090

SMART LIGHTING CONTROL USING HUMAN MOTION TRACKING FROM DEPTH CAMERAS

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This paper presents a smart lighting control system using depth cameras based on human motion tracking. Recently, conventional lighting bulbs get replaced by LED lighting devices because LED lightings consumers lower powers and are easier to control than conventional lightings. Therefore, there have been many research activities to achieve energy savings using LED lighting and to provide convenient methods to users by fusing IT technologies (Paradiso, 2011). There have been several projects to combine sensor systems for smart LED lighting control (Daeho Kim, 2011). Estimated human location using ultra sonic sensors or IR sensors is used to control LED lighting ON/OFF. However, it is difficult to estimate correct location, moving trajectories, and the number of people in the space. Also, it is difficult to control lighting systems using general 2D cameras because it is sensitive to lighting condition change. Depth information, however, can be acquired independent to lighting condition change from depth camera like Kinects and it is relatively easy to detect human independent of clothing, and skin colors. Therefore, a smart lighting room is equipped with a TV set, a table and a desk and controlled by human activities. Figure 1 shows a schematic diagram of the smart lighting living room used in our experiments. There are four activity modes such as walking around, studying, dialog, and watching TV. Table 1 describes specifications of four activities and its lighting conditions. LED flat panel lightings are used to control color temperature and illuminance. Multiple depth cameras were used to detect human subject motion. Because the background information does not need in human detection, background depth pixel was removed using threshold values. After removing background objects, connected components are detected to evaluate foreground blobs. Each human location is estimated in image space through each center of foreground blob components. The trajectories from multiple cameras were projected to a global trajectory maps using perspective transformation. Figure 2 shows an example of detected person and its representation in the global trajectory maps.Experimental results show accurate estimation of human location and high energy saving using lighting control based on human activity recognition.

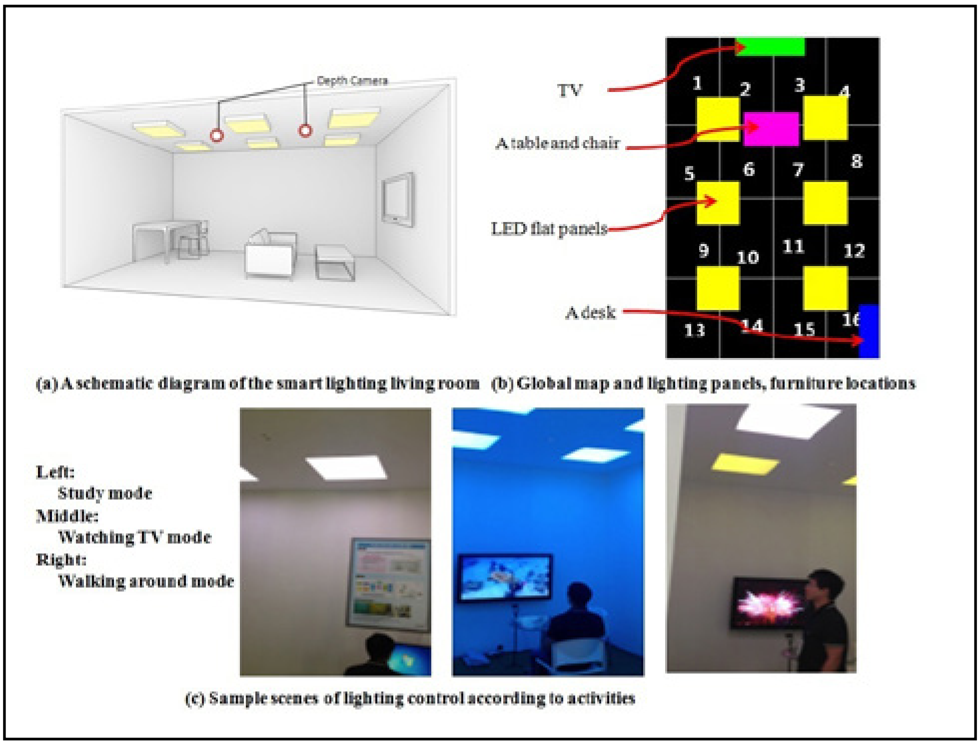

Figure 1 - A schematic diagram of the smat lighting living room and lighting panels and furniture locations on the global map and captured sample scenes in different actitivy modes

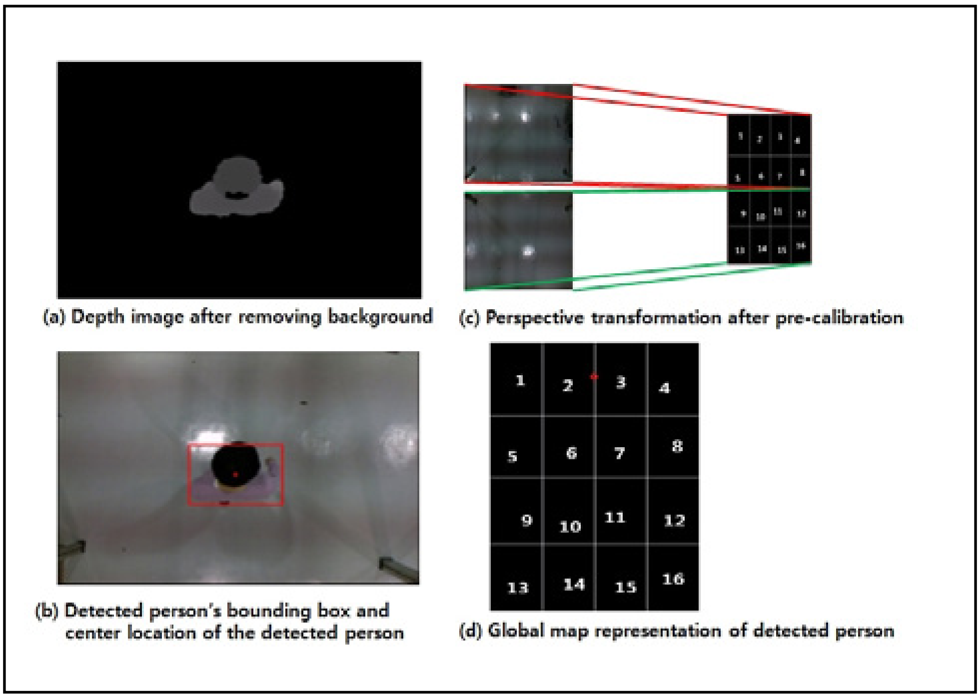

Figure 2 - Person detection from depth camera and projection to global map

Activity mode	Detection condition	Lighting control
Study mode	a a participant stay near the desk	7000K color temperature, 650 lux
Dialog mode	two persons stay near by the table	5000K color temperature, 400lux
Watching TV mode	a person sits on the sofa, which is in front of the TV set	all the lighting panels colors are synchronized with the dominant colors of the TV screen images
Walking mode	None of other mode conditions	Closest lighting panel is turned into 6500K color temperature

Tabel 1 - Activity mode and its lighting condition

D3 - Interior Lighting Energy Efficiency

PP091

LIGHTING QUALITY VERSUS ENERGY EFFICIENCY

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Rapidly evolving twenty-first century lighting technology is outpacing our codes and best practices. To embrace these new technologies and reevaluate fundamental design concepts in the commercial lighting industry, this work seeks to appraise the effectiveness of current lighting standards, and to propose a novel interpretation of “high quality, energy efficiency light” for the modern technological environment.

The European standard for office lighting, EN 12464-1, sets limits on minimum illuminance and uniformity of task areas, surrounding areas, backgrounds, walls and ceilings [1]. If a design meets the standard exactly, it could theoretically consume 90% less power than the reference building used in the German building energy standards DIN V 18599 and EnEV 2009 [2]. Exactly matching all the levels set in EN 12464-1 is no easy task, as stray light from fluorescent fixtures will usually result in wall illuminances well above the minimum. However, current LED luminaires emit light in exactly defined directions with very little stray light. This begs the question, what happens if a lighting environment meets the EN 12464-1 standards exactly? Will the lighting quality still be sufficient?

A strict adherence to the European standard may take the quality element out of lighting engineering. A typical lighting design according to EN 12464-1 heavily relies on power consumption by taking “acceptable“ minimum illuminances as maximum values without sufficiently considering a lighting solution’s holistic quality. Indeed, power consumption is important to any lighting installation, but power consumption is not the only measure of energy efficiency. In a practical lighting system, the input is electric power, and the output is lighting quality. Therefore, a more practical gauge of a lighting system is:

Degree of System Efficiency=(Quality of Lighting Installation)/(Energy Consumption)

Another question arises: what defines lighting quality? Many have attempted to answer this with previous research, but the only general agreement is that lighting quality is hardly quantifiable. Lighting quality exists somewhere within the intersection of ergonomic, economic, and efficient operation, making energy efficiency an important element of lighting quality and vice versa [3], [4], [5]. Lighting engineers must consider these complex correlations simultaneously. This research focuses on optimizing lighting quality and efficiency by seeking for an optimal luminous distribution in office spaces. Dependent measures include architectural integration, acceptance and perceived lighting quality, summarized as subjective evaluation of lighting quality. These measures are integral to the hypotheses of this experiment:

- A decreased illuminance level in surrounding areas is sufficient if wall and ceiling luminance is increased.
- Different wall/ceiling luminous distributions (with a fixed average luminance) lead to different subjective levels of acceptance.

- Appropriate luminance distributions in a room can increase subjective lighting quality without increasing energy consumption.
- Appropriate luminance distributions can decrease energy consumption without decreasing subjective lighting quality.
- Optimizing the luminance distribution in the field of view and lowering the illuminance in surrounding areas will save energy and increase light quality.

The research takes place in a unique custom made mockup of a cell office aiming to an exact isolation of independent variables. Diffuse acrylic, backlit by over 1300 controllable LED panels, make up three walls and ceiling to control luminance distributions in the visual field. The fourth wall contains a simulated window with adjustable CCT. Six high- resolution projectors in the ceiling provide defined illuminance distributions on the workplane. Since the projectors have almost no stray light the provided illuminance is restricted to the workplane. All components can be balanced to provide the exact distribution needed independently from each other. The test room contains a double desk to enable subjects to evaluate various lighting conditions. In each case, the dependant variable is the subjective evaluation of
lighting quality. Independent variables are luminous distributions including desktop illuminance, background luminance, wall luminance and luminance in the field of view.
Assuming that the hypotheses prove true, one can expect the following outcomes:

- Subjective evaluation of lighting quality will not change as the horizontal surrounding illuminance decreases, allowing a decreased level of energy consumption.
- Subjective evaluation of lighting quality will increase using appropriate luminance distributions without changing the energy consumption.
- Lighting solutions using the right luminous distribution will decrease energy consumption without changing subjective evaluation of lighting quality.

If conclusively observed, the results will support improved definitions of lighting quality, including required luminance distributions within the field of view to address the quality of a lighting solution in a holistically. This experiment will show that newer technologies need newer standards to maintain optimality and thus pave the road for future improvement.

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PP093

DEVELOPMENT OF THE METHOD TO EVALUATE ECONOMICAL EFFICIENCY OF A LIGHTING SYSTEM

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A tool with which economical efficiency of a lighting system can be evaluated when different types of luminaires are used in the same space. Using this tool makes it possible to evaluate economical efficiency of lighting systems when they are newly installed or replaced. By using this method initial costs, annual maintenance and repair costs, annual electric charges of each lighting system can be determined. Since it is possible to evaluate the cost of an entire lighting system using different types of luminaires, the economical efficiency of lighting systems of multi-purpose spaces or tunnels can be evaluated with ease.

PP094

THE REQUIREMENTS FOR THE LIGHTING ENERGY PERFORMANCE ASSESSMENT OF NON- RESIDENTIAL AND RESIDENTIAL BUILDINGS CONSIDERING ASSUMPTION OF BUILDING USAGE CONDITIONS

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Objective:
The energy reduction by equipment technologies in non-residential buildings and in residential buildings has been more and more important. The present trend for assessment energy-saving performance is toward using an annual primary energy amount of consumption by the building equipment, and lighting equipment is not an exception. From the viewpoint of LCCO2 by the lighting equipment, emitted CO2 resulting from the energy consumption of building usage occupies most. Therefore, assessment by the lighting energy amount of consumption at the time of usage is especially important.
However, in order to perform assessment by the lighting energy amount of consumption at the time of usage, it is necessary to make assumption of the usage condition appropriately.
At present, in Japan, considering trend described above, the energy-saving standard for both non-residential building and residential building is to be revised, and within 2012, the detailed of assessment method including lighting is also to be decided. For making assessment method, various researches have been carried out, and obtained effective results for lighting energy assessment.
Based on these backgrounds, the purpose of this study is to clarify the requirements for the lighting energy performance assessment of non-residential and residential buildings considering assumption of building usage conditions.

Method:
On the non-residential buildings, based on the concept that the lighting control system is important for assessment of lighting energy performance considering usage conditions, office buildings including various lighting control systems were investigated and relationship between condition of the systems and lighting energy consumption were analyzed. On the residential buildings, the simulations of the lighting energy consumption at the time of usage were carried out and the relationship among the room arrangement, life activities, and energy consumption were analyzed.

Result:
- In assessment of non-residential building lighting energy performance considering usage condition, focusing on the lighting control system is important, and to categorize factor such as outdoor factor (daylighting control), human related factor (sensor control, zoning control, timer control and so on), and to arrange conditions of mutual controls based on the factors on are effective.
- In assessment of the lighting energy performance of non-residential building, it is necessary for distinguishing lighting control systems and lighting system such as TAL.

- About the effect of daylighting control in the non-residential building, consideration of the usage of blind control should be considered.
- In assessment of residential building lighting energy performance considering usage condition, while the general cost for energy performance assessment is lower than non-residential buildings, the usage conditions are more complex than non-residential buildings. Therefore, while setting up the condition of usage for assessment lighting energy performance finely as much as possible, it is required to simplify the other conditions.
- Since the latest lighting control systems have been improving, the design cases of installing excessive lighting at first and controlling at the time of usage later are increasing. In order to assess the energy consumption performance of lighting appropriately and to prevent excessive lighting design, it is necessary to consider both at the time of designing and at the time of usage.

Conclusions:
In this research, the requirements for the lighting energy performance assessment of non-residential and residential buildings considering assumption of building usage conditions are clarified from the investigation and simulations for making Japanese building energy saving standard.

PP095

UNRAVELLING EFFICACY, MAINTENANCE AND LIGHTING ENERGY FOR THE END USER

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Despite lighting professionals, whether they are involved with the fundamental science of the interactions between light and the cognitive functions of humans, the measurement of light, the development of light sources, lighting-related product design, lighting designs or the actual installation of lighting systems, being familiar with all of the terms used to describe both lighting quality and energy efficiency there are still plenty of opportunities for confusion. The customers and end users are often in an even more disadvantageous position as they are usually not familiar with many of the rather esoteric terms, quantities and units. Thus, it is easy to understand why customers are disappointed when they do not see the well-publicised advances in the performance of light sources reflected in the energy efficiency of lighting installations. Conveying quantitative measures of lighting quality to end users is even more difficult.

The authors have therefore undertaken a review of numerous factors influencing the efficiency of lighting systems including: light source efficacy; gear efficiency; luminaire light output ratio (LOR); lamp lumen maintenance factor (LLMF); luminaire maintenance factor (LMF); room surface maintenance factor (RSMF); lamp survival factor (LSF), to establish a series of examples that may be used to illustrate quantitatively how these factors determine the impact of the conversion of light source efficacy into the predicted illuminance in an installation, i.e. from light source lumens generated to lux delivered.

These concepts can be illustrated by considering the energy required to deliver a functional unit, an approach that is used in life cycle analysis. For a functional unit of 1,000,000 lm.h, and light source output of 10,000 lm, a functional unit would be delivered in 1,000 h. A 150 W ceramic metal halide lamp with initial output of 14,000 lm would produce approximately 10,000 lm at 4,000 h (LLMF ~0.7). Electronic ballasts for HID lamps are more efficient than the corresponding electromagnetic ballasts. Whereas the efficiency of latter would typically be approximately 0.80 to 0.90, the former would fall in the range 0.85 to >0.93 [1]. There is an additional benefit in using electronic ballasts in that the lamp lumen maintenance when operating such a lamp is higher than when it is operated on an electromagnetic ballast. This is reflected in the energy required to deliver one functional unit. This energy changes throughout the life of the lamp as the lumen maintenance decreases. Figure 1a illustrates the difference in energy required to deliver one functional unit for a typical 150 W ceramic metal halide lamp after 2,000 h operation when operated on an electronic (efficiency 0.92) or an electromagnetic ballast (efficiency 0.88).

Power balances are frequently used by light sources technologists to show the role various loss mechanisms play in the conversion of input power to luminous output [2], [3]. The equivalent diagrams for the conversion of input power into luminous output for lighting systems are rarely displayed. Figure 2 is a schematic presentation of the power balance for a lamp, gear and luminaire assembly. The lighting designer has to take into account not only the losses in the lamp control gear but also those losses associated with the luminaire, i.e. light output ratio and luminaire maintenance factor, the lamp (lamp lumen maintenance factor & lamp survival factor) and the degradation of the room surfaces over time. While the characteristics of the light source, control gear and the luminaire are beyond the influence of the end user once their selection has been made, the maintenance factors for the luminaire and the room surface are directly under the control of the end user.

Figure 1b shows the difference in the energy required to deliver one functional unit for the lamp shown in Figure 1a operated on an electronic ballast with luminaire maintenance factors 0.90 and 0.80. Figure 1c illustrates the corresponding difference for the lamp with luminaire & room surface maintenance factors of 0.90 and 0.80. These diagrams show that the advantages of using an electronic ballast can be outweighed by failing to maintain the cleanliness of the luminaire and/or allowing the room surface maintenance factor to fall.

There are costs associated with cleaning luminaires and maintaining room surfaces such that their reflectances are close to the values used in the original design calculations and the end user must decide upon the strategy for maintenance and lamp replacement based on a cost-benefit analysis. It would, however, be advantageous if the end user was presented with the options and corresponding consequences by the lighting designer in advance such that the preferred maintenance and lamp replacement schedule could be incorporated into the installation design.

ACKNOWLEDGEMENTS
The authors thank Stewart Langdown and John Stocks for their valuable feedback and advice.
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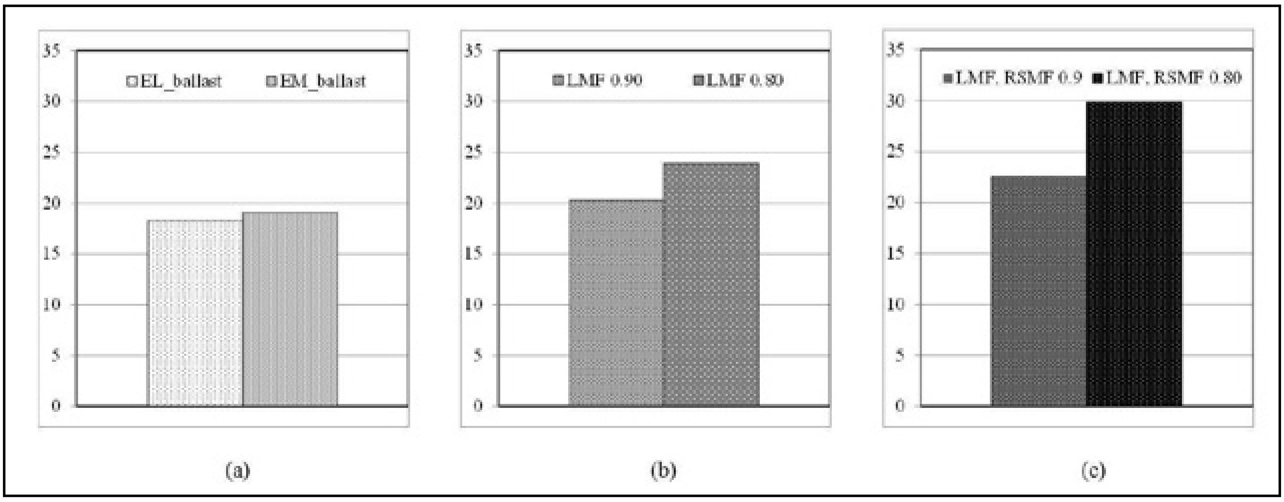

Figure 1 - Energy required by the light source & gear combination to deliver one functional unit/kW.h

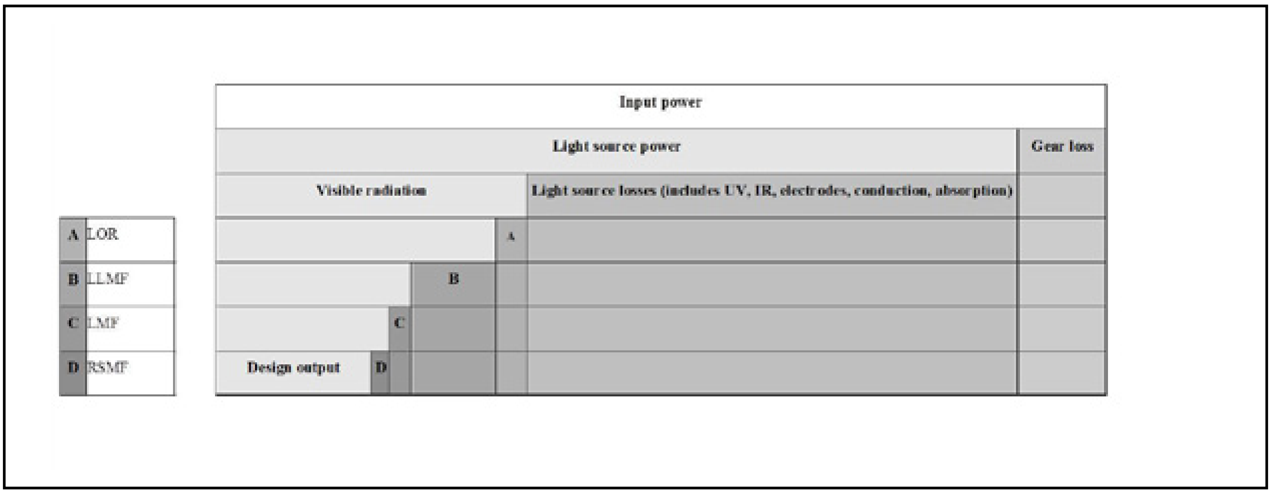

Figure 2 - Schematic power balance for a lamp, gear & luminaire combination showing the progression from input power to design output

PP097

SOFTWARE CALCULATION TOOL FOR LIGHT SAVINGS IN THE BUILDINGS

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This paper deals with a problem how to calculate possible savings by using daylight and artificial light together. It solves calculations of artificial lighting systems dimming in the buildings which depend on the level of daylight on the working area. The problem was being discussed because the clients of lighting engineers wondered if the dimming is worth installing. The software could be used so that it meets the requirements of recommended decreasing in consumption of lighting systems in the current buildings.

D3 - Interior Lighting
Lighting Design

PP098

LIGHTING DESIGN BASED ON HUMAN PRINCIPLES

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Abstract

Light is essential to human animals, plants and to the ecosystem [Hollwich & Dieckhues 1980, Pauley 2004]. As a result of a delay in knowledge about man and light have the use of artificial light been developed merely for a visual support and in a general way. Recent findings about melanopsin and ipRGC reveal that light are important from a psychological, physiological and visual perspective as well [Brainard & Hanifin 2005]. Better practice should start now is requested from the medical field [Pauley 2004]. Since the human body strive towards homeostatic balance as an answer to external and internal triggers and since electromagnetic radiation (EMR) is such a strong trigger for almost all human behaviours and tissues through the diurnal rhythm [Brainard & Hanifin 2005] is the way we design the complementary artificial light for the indoor environment of the highest importance. The human senses are the utmost part of the central nervous system (CNS) and great differences can be seen in the sensitivity in to the CNS [Ingvar 1980]. Seeing is exceedingly irregular. The results vary widely both between subjects and between successive operations by the same subject from moment to moment in a day and/or from day to day. [Luckiesh and Moss 1931, Ronchi 2009, Säter 2011, 2012]. The Lighting design process is described in 4 basic steps [Säter 2012]. The user centred lighting design process (UCLDP) is a process where the user is shown an intense care through all steps of the process. UCLDP uses all four steps in the LDP. Recommendations for the UCLDP were developed. [Säter 2012]. The recommendations lead to a lighting design that gives input to melanopsin and ipRGC close to daylight, enhance homeostatic balance for the individual and have the possibility to follow the constant changes in the experience of visual comfort for the individual [Säter 2012].

The often used static predesigned level of light is here changed towards recommendations for a flexible lighting application that can be adapted to daylight, the actual space and the specific individuals need for visual comfort at the moment.

Keywords: User centred lighting design; recommendations for lighting design;

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PP102

RELATION BETWEEN THE GRID FOR CALCULATION/MEASUREMENT AND RESULTING LUMINOUS PARAMETERS FOR ILLUMINATION OF INDOOR WORKPLACES

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At the preparation of the lighting project (for both Indoor and Outdoor workplaces) is necessary to respect the applicable legislative or regulatory requirements regarding with of qualitative and quantitative parameters of light according to standards (for example in Europe EN 12464 part 1 for indoor workplaces and part 2 outdoor workplaces). The basic parameters are undoubtedly maintained illuminance level at the work place and uniformity of the illuminance in the room. Aslo other parameters should be concerned UGR, Ra index, plan of maintainance of lighting system characterised by the maintainance factor (MF) etc. as prescribed by the standards. In Slovakia these standards are mandatory under the law of ministry of health. Therefore it is necessary to do good lighting project to ensure lighting conditions for ensuring visual comfort i.e. well-being of persons with short-term or long-term staying in the workplaces. Verification of lighting project is performed by the field photometric measurement of parameters prescribed by the standards mentioned before. Measurements are fundamental for judging of Public Health Authority if lighting system is proper designed or not and persons who are staying in the workplace have proper lighting condition for their work. Due to unexpected errors in the project to remove them is usually too costly. To avoid this situation it can be done by the measurement of each parameter. People who carry out field photometric measurements are authorised by Public Health Authority. They should ensure good measurement practice. In practice there are many problems which can influence results of measurements of parameters of illumination of lighting system and difference between design of project and reality can be significant. Research work is needed to investigate what negatively influence results of measurement. It is not existing unified procedure for practice photometric measurements. Therefore people who are doing different measurement at which they predict or assume different influences which negatively obstruct results. Unfortunately they usually underestimate many facts which can significantly influence the results for example evaluation of maintenance factor according to document CIE No. 97:2005, definition of the measurement grid, evaluations of the expanded measurement uncertainty and so on. Preliminary investigations have been done and work is going on till now. This paper concerns about finding of main influences which can negatively impact to the field photometric measurements for verification of lighting project. The problem is that standards prescribe the concrete values of parameters but they do not sufficiently describe procedure how to do it and at the end how to evaluate and to express what they measured. In some countries exist papers or standards how to carry out measurement but it appears another problem about interpretation of the results because of accuracy of used instruments at the measurement, errors of measurement, error of number of the points in the illumination grid etc. Accuracy of the measurement mainly depends on choosing of appropriate measurement grid, photometric devices used at the measurement and others. Verification photometric measurement should be performed in the specified grid uniformly spread in the measured plane. In practice measurement grids vary from the measurement to measurement. Even more,

increasingly, starts at different levels discussion about evaluation and expression of uncertainties of measurements in photometry. Usually people who perform photometric measurements avoid computation of uncertainty of measurement, because it is time consuming, too hard and so on. But according to metrology convenience when somebody performs measurement should properly analyze whole process of the measurement, explore all possible contribution of errors and express result of the measurement with stated expanded uncertainty for 95% confidance interval. These measurements are reliable and can be judged properly when some problems occur. Therefore investigation of described problems has done. The first investigation was performed about quantification of the differences between computed parameters in the lighting project proposal and the reality i.e. measured parameters by the stated procedure according to methodic of ministry of health of Slovak republic. The investigation was made for many known rooms (workplaces) from the level of designing of lighting project through realisation to practical photometric measurement in known illuminance grid stated in the project. The aim of the research is to evaluate of tolerance of the computation in the lighting project which should be sufficient for people who do lighting projects. Measured deviation was evaluated from theoretically designed lighting project. The second investigation was made about accuracy of photometric field measurement of the indoor parameters by varying of proposals of measurement grids to simulate differences between measurements. From results of these measurements was stated possible measurement uncertainty which can occur in the real photometric measurements and it is usually underestimated by peoples who are performing measurements. Paper brings results of the first investigations performed on the carried out known and unknown indoor lighting projects to investigate accuracy of the measurement with the conclusions and visions what should be done in the future to aware people who design and verificate lighting projects to do best practice.

12																		
11		-18,5	-24,7	-20,2	-24,2	-24,0	-25,9	-27,9	-33,1	-30,5	-29,3	-27,6	-25,9	-24,7	-24,1	-17,4	-11,7	
10		-4,3	-14,7	-15,5	-15,3	-16,0	-18,5	-19,5	-26,3	-23,1	-22,7	-20,2	-19,6	-17,8	-14,0	-5,4	0,7	
9		6,6	-6,3	-7,5	-7,9	-8,9	-8,7	-12,2	-18,7	-16,9	-15,3	-13,8	-12,3	-10,1	-8,4	1,9	7,6	
8		10,8	-1,3	-1,7	-2,5	-3,6	-5,8	-7,3	-13,7	-12,0	-10,0	-8,3	-6,2	-3,5	-0,5	-12,5	7,9	
7		13,3	1,7	0,9	0,5	-1,0	-3,0	-3,4	-11,1	-9,1	-7,3	-5,3	-2,6	0,2	3,5	9,3	11,4	
6		12,6	2,0	0,3	-0,1	-1,4	-3,8	-4,3	-11,3	-9,2	-7,2	-4,6	-3,1	-0,8	3,4	10,4	11,3	
5		8,0	-1,7	-2,6	-3,7	-5,1	-7,0	-8,0	-14,4	-12,4	-10,2	-8,3	-6,7	-3,5	-0,1	7,6	7,5	
4		-2,3	-11,9	-11,4	-10,7	-11,0	-14,2	-14,3	-20,8	-17,7	-16,2	-14,2	-13,2	-10,7	-7,1	1,2	4,9	
3		-16,3	-23,2	-22,8	-23,1	-23,6	-25,4	-24,5	-30,5	-27,8	-25,6	-23,0	-22,1	-20,3	-18,5	-8,8	-5,4	
2		-28,6	-34,7	-34,9	-34,2	-34,4	-36,4	-36,4	-40,8	-38,7	-36,7	-34,4	-32,8	-31,8	-29,4	-22,6	-22,2	
1	↑	-39,1	-42,2	-41,6	-41,7	-40,9	-42,4	-43,4	-47,0	-44,9	-43,1	-40,6	-39,3	-38,2	-36,6	-31,1	-30,4	
0	+	→																
Č.b.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Figure 1

PP103

HIGH DYNAMIC RANGE (HDR) IMAGES FROM SMART PHONES FOR LIGHTING RESEARCH OFFICE SPACES

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The aim of thIs paper is to assess the feasibility of the IphotoLux, an app for smart phones (simplified version of the Photolux Luminance mapping system developed by the building sciences laboratory- LASH- at ENTPE), to produce luminance maps that could be use to calculate light at the eye, in a first step to develop a methodology for a larger scale population study of office workers in Brisbane, Australia. To this end, a correlation between HDR images from a calibrated digital camera, data collected using daysimeters, actigraphs and HDR images from IphotoLux of office spaces under different lighting conditions is done to determine correction factors.

Methodology: Office spaces with different lighting characteristics (light intensity, spectrum of lamps, windows, view, etc) located around a university campus in Brisbane, Australia are use for the study. Measurements are taken place during a 3 weeks period in summer. In each space 3 sets of HDR images (morning, midday and afternoon) using Nikon Coolpix 8400 HDR calibrated Digital Camera + Fisheye lens, and Iphone with Iphotolux + fish lens for iphone are taken. In addition, data from a daysimeter device and actigraph (Philips-Respironics Actiwatch) are also collected throughout the day.

The data is compared and correlated, and correction factors determine in order to document photometric protocol.

PP104

GLOBAL ILLUMINATION ALGORITHM USED IN COMPUTER AIDED ARCHITECTURAL DESIGN PRESENTATION

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This paper presents a new, groundbraking computer aided solution to improve architectural design sharing, collaboration and presentation, using a custom global illumination algorithm.
The technology and methods used throughout the various phases of the architectural design development and coordination processes greatly effects the content, quality and efficiency of the design presentation and communication. The development of computer hardware and software applications gradually changing not only the tools, but also the workflow methods used in the AEC industry. BIM (Building Information Modeling) initiated a major shift in the last decade in the architectural design development and interdisciplinary collaboration. Thanks to the integrated, virtual model approach, BIM not only offers significant productivity increase of the documentation processes, but also opens up brand new possibilities for design collaboration and client presentation. BIM also enables AEC software vendors to develop new approaches and techniques not only for design collaboration but also for interactive project presentations.

The new, free and standalone software application not only enables interactive design walkthrough but also improves design communication and presentation workflows in three major fields:

- Exploring the design: designers can explore the building project in a 3D environment with real-time 3D navigation support. Design concepts and alternatives can also be explored during an interactive walkthrough. Easy-to-use, 3D navigation techniques can be developed to help the interactive project presentation.
- Communicating the design: interactive project presentation packages can be created at any stage of the design development process in minutes. There is no need to invest additional time and money to provide a professional 3D experience for viewers. BIM models include all types of design element information and also provide accurate measurements within the interactive 3D environment. The visibility of the architectural layers can be controlled, various 3D representation methods can be selected.
- Sharing the design: model based projects can be shared by virtually anyone. Standalone presentation packages can be created and opened on all the common software platforms.

Using this model based design explorer application architects can quickly share their creative ideas and projects at any stage of the design development process. During the conceptual design phase the building volumes are formed, but the openings are not yet created. The artificial lighting systems are not yet designed either, such design will only be available later at the tender or construction documentation phases. To be able to explore the interior spaces of the design, it is necessary to ensure certain generic illumination for the interior spaces. The presented software application uses a so-called global illumination algorithm to resolve this issue. This practically means that all surfaces in the building interiors are illuminated regardless of the available openings and lighting fixtures. This algorithm ensures a realistic surface illumination: the edges of surfaces and corners receive slightly less illumination than the other parts of the surfaces. The global illumination algorithm ensures that all internal spaces and rooms of the BIM project model are automatically illuminated, ensuring better viewing experience when exploring the design.

The software application provides viewers a natural, interactive, game-like experience to explore architectural projects at any stage of the design development process and helps the interpretation and understanding of architectural projects of any complexity:

- viewers will experience a professional, 3D project presentation and will benefit from a real-time exploration of the architectural design without having to install any architectural software,
- additional element information can be displayed, accurate measurements can be carried out and various view modes can be initiated (including wire-frame, hidden-line and even stereo viewing mode),
- the interactive design model viewer application is completely free of charge and the architectural design can be viewed on all the common desktop, tablet and smartphone operating systems including Microsoft Windows, Apple OS X and iOS and Google Android devices.

Figure 1 - Interior space with global illumination displayed on a tablet device

PP105

HOW TO CHOOSE SIMULATION PARAMETERS TO IMPROVE ACCURACY?

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1.Introduction:

In many fields of industry, simulations are getting more and more important. Optical design and light propagation modeling would be significantly harder and less precise without simulations. As the LEDs are becoming more and more popular, simulations also required in order to satisfy their diverse professional applications.

At modern light sources, the manufacturer provides the luminous intensity distribution database files for the simulations in international standard formats or with "Ray Files", which define millions of guided ray vectors. This file contains all photometrical information about the light source. Thus, the software can calculate with these vectors quickly and easily.

The aim of this paper is to answer some questions about simulations, using a professional light-modeling and simulation software at the BUTE–MOEI. For example, how may traced rays are required to achieve accurate results? What is the relationship between the traced rays and the simulation time? What is the effect of complex geometries to the simulation results? Can we improve accuracy with implementing a measured spectral power distribution?

2.Calculation methods of optical simulation software:

Modern optical simulation algorithms can be separated into three sub-categories based on their used calculating methods [1]:

Sequential ray tracing: the algorithm substitutes the light source with directed rays and guides these rays through the pre-defined optical elements in a determined order. Ray tracing is capable of simulating a wide variety of optical effects such as reflection and refraction, scattering, and dispersion phenomena.

Non-sequential ray tracing: similar to the one above, but in this case ray tracing is arbitrary, and the rays can reach one surface in multiple times and, so ray scattering is allowed.

Finite-difference time-domain: mainly used in the design of micro-optical systems where there are optical elements at a size of the wavelength of light.

The mathematical algorithms applied by our non-sequential ray tracing software are mainly confidential but generally based on the Monte Carlo method. Using this method, deterministic problems can be solved with the sequence of random events applying probability density functions for the unknown parameters.

In contrast to deterministic methods, due to the random sampling, the Monte Carlo method needs less computation and less boundary condition to the geometries. Thus, simulation time is significantly shorter and for the evaluations statistical estimation methods are applied [2].

As a ray reaches a surface, its further path depends on the pre-defined structural and optical properties, what the following equation (BRDF - Bidirectional Reflectance Distribution Function) [3] describes: $f_r(\omega_i,\omega_0)=(dL_r(\omega_0))/(dE_i(\omega_i))=(dL_r(\omega_0))/(L_i(\omega_i)\cos\theta_i d\omega_i)$,

where: ω_i - Vector directed to the light source, ω_0 - Vector directed to the observer (sensor), L –

Luminance, E - Illuminance, i – Incoming parameter, r – Reflected parameter θ – Angle between surface normal and the ray

3.Correlation between traced ray number and simulation time

With the increase of the number of traced rays the simulation time also grows linearly. However, in order to get properly accurate simulation results, the applied ray number should be sufficient.

4.Effect of traced ray number on the simulation accuracy

As the simulation time increases with the number of traced rays it is important to apply the sufficient number of rays for accuracy. We have simulated various photometric quantities without defined optical geometries to determine the stability of the results (Fig. 1).

The results show that the sufficiently precise and time efficient simulation requires more than 1 million traced rays in the case when there isn't any defined geometry in the simulation, which could influence the path of the rays. Above 1 million rays we didn't find significant variation in the simulation results, the standard deviation of the results was around zero.

5.Effect of optical geometries on the simulations

We also need to examine how many traced rays are required in order to get accurate results in case of complex geometries. Due to the more difficult calculations, the simulation time shall be longer.

During the experiments, we applied 10 surfaces with defined optical parameters (reflection, transmission, etc.) between the light source and the illuminance sensor. The simulations have been conducted with 1, 5, 7, 10 and 15 million traced rays.

The difference between the results was very small. The average value was slightly higher at 1 million rays, and the standard deviation was bigger at 1 and 5 million rays. Thus we can say that complex geometries require above 5 million traced rays.

6.Improving simulation accuracy with measured spectral power distribution

The Ray file doesn't contain any information about the spectral power distribution of the light source, thus the simulation can be supplemented with the measured spectral power distribution of the LED.

The simulation results show that implementation of the spectral power distribution improved the results by 1-2 %. Therefore, its effect is significant.

7.Summary

We made several simulations to examine correlations between the numbers of traced rays and other parameters. The sufficient number of traced rays can be determined depending on the applied geometries. Beside this we can also implement spectral measurement results to improve accuracy.

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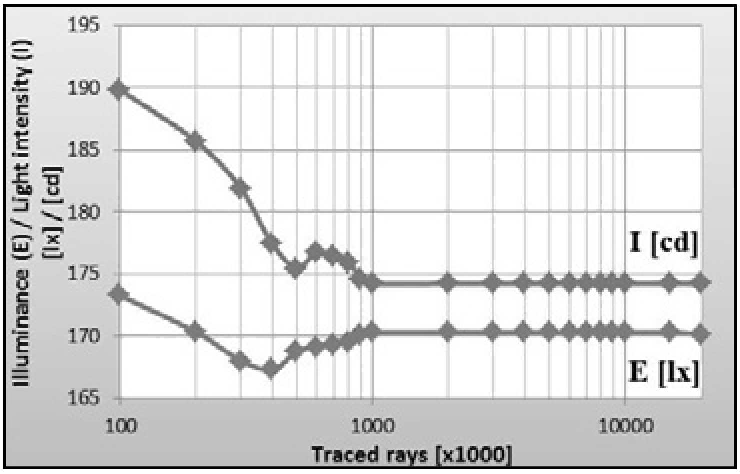

Figure 1 - Simulated illuminance and luminous intensity, in function of the number of traced rays

D4 - Lighting and Signalling for Transport
LEDs

PP106

THE FIELD EXPERIMENTS OF THE HIGH S/P RATIO LED STREET LIGHTING

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This study's goal is to develop safe and efficient LED street lighting .
We evaluated LED that emitted white light whose S/P ratio was high at mesopic vision levels. on field experiments using high-S/P ratio LED lamps in the real street lighting contexts. We thus designed a set of field experiments in which we investigated the influence of lamp spectral distributions on the brightness of spaces using LED lamps and fluorescent lamps installed in an actual road.

In the experiments, we used 20 W fluorescent luminaires (FL4200) with a correlated color temperature (CCT) of 4,200 K and an S/P ratio of 1.47, typically used for street lighting in Japan. We also used two LED luminaries: LED5000 (CCT: 5,000 K, S/P: 1.65) and LED8000 (CCT: 8,000 K, S/P: 2.07). LED5000 and LED8000 have the same luminous intensity distribution while FL4200 has slightly different luminous intensity distribution from the others. To maintain consistency among all the three lamps' luminous intensity distributions, we placed an ND filter on the top of each fluorescent lamp.
The experiments were carried out on an asphalt-paved two-lane roadway with a width of 7 m in a private facility. This roadway is not affected by artificial lighting in adjacent areas. Two poles were installed along the roadway at a spacing of 30 m. The lighting instruments were attached to the poles at a height of 4.5 m. The average horizontal illuminances of the FL4200, LED5000, and LED8000 were 1.29 lx, 1.28 lx, and 1.26 lx, respectively. The observed targets were a clothed dummy (mannequin), a color poster, a landscape picture, and a Macbeth color checker placed on the roadway.

We conducted two experiments: an absolute evaluation and a relative evaluation. In the absolute experiment, subjects evaluated the street spaces illuminated by three light sources individually. In the relative evaluation, subjects compared two spaces illuminated by different lamps. Nine statements, related to the requirements for street spaces, were adopted in each evaluation. These statements were "(1) the street appears bright", "(2) the street surface is clearly visible", "(3) the street appears safe", "(4) I would support using such street lighting for crime prevention", "(5) this street surface appears uniformly illuminated", "(6) I like the light source color", "(7) the light source doesn't produce glare", "(8) colors on the street look natural", and "(9) colors look pleasant." For each statement, each subject scored in five agreement levels. They were "-2: strongly disagree", "-1: disagree", "0: neutral", "+1: agree", and "+2: strongly agree."
Subjects were 43 inhabitants who lived in Fukui Prefecture. They were 24 young people (12 males and 12 females, 22 years old on average) and 19 older people (19 males, 49 years old). No information on lighting instruments or the objectives of the experiment was given to any of the subjects.

Scores obtained from the absolute evaluation were averaged for each of the lighting conditions. Additionally, a t-test was applied to each of paired experimental conditions based on all the averaged scores. The results of the t-tests indicated that the space illuminated by LED8000 tended to appear to the subjects (1) brighter, (2) more visible, (3) safer, and (5) more evenly illuminated than the space illuminated by FL4200. (4) The subjects tended to think that they would like to support the use of LED8000 for crime prevention than FL4200. (6) However, the light source of LED8000 tended to appear more glaring than FL4200. There were no statistically significant differences between the space illuminated by the LED8000 and LED5000 for all the sentences. This means that LED5000 also appeared to provide good lighting. In addition, object colors illuminated by LED5000 appeared even better than LED8000. The light sources of LED5000 appeared less glaring than that of LED8000.

We applied chi- squared tests to the results of the relative evaluation. The statistical analyses showed that the subjects found the space illuminated by LED8000 to be better than that by LED5000 for all sentences except for glare.

Based on the above-described results, LED8000, which emits higher short-wavelength radiation, provides brighter spaces and a better feeling of security than LED5000 or FL4200. In addition, although the luminous distributions of all the three luminaries were almost the same, the roadway surface illuminated by LED8000 appeared the most evenly illuminated. As recent studies on the mesopic vision already showed, this is because LED8000 has a higher S/P ratio

There are few reports

than LED5000 or FL4200. Therefore, light sources with high S/P ratios, e.g., LED8000 in this experiment, should be recommended for street lighting at mesopic light levels.

PP107

STUDIES ON TUNNEL LIGHTING VISIBILITY AND ENERGY-SAVING EFFECT IN HIGH-OVERALL- UNIFORMITY (APPLICATION OF LED IN TUNNEL LIGHTING)

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1. Introduction

In recent years, LED has become widespread in the world as light source. LED is characterized by long-life-cycle and control flexibility. Utilizing the characteristics, overall uniformity of road surface can be raised by installing lamps with small luminous flux at short intervals. Energy can be saved if road surface luminance can be reduced corresponding to rise of road surface luminance uniformity. However, its evaluation is difficult with conventional standards. Concerning visibility of tunnel lighting under high degree of uniformity, we implemented operation evaluation on visual environment, energy-saving effect, etc., by 1)calculating revealing power to elucidate correlation with conventional standards (overall uniformity and average road surface luminance), 2) conducting on-sight test (actual tunnel) to confirm difference of lighting installations by conventional design and high-uniformity design and 3) finally, we evaluated the visibility and energy savings in the actual tunnel using LEDs. As a result, it was confirmed that average road surface luminance can be reduced while ensuring visibility. In this paper, we report the results of the study.

2. Relation between overall uniformity and average road surface luminance for ensuring visibility

An average value of total revealing power (define as TRPave) under the condition of different spacing between luminaires in a typical tunnel (one-way traffic, two lanes, height of lamps of 5 m, distribution of luminous intensity of BZ5) was obtained by calculation. Next, relation between average road surface luminance and overall uniformity to give a constant TRPave was obtained (Fig. 1). Fig. 1 shows that when overall uniformity rises, average road surface brightness required to obtain the same TRPave drops. For example, when TRPave = 90%, the condition of average road surface luminance of 3.2 cd/m^2 and overall uniformity of 0.4 and the condition of average road surface luminance of 2.25 cd/m^2 and overall uniformity of 0.7 give equal visibility by evaluation using TRPave. In other words, it can be said that possibility of reduction of road surface luminance of about 30% is suggested by improvement of overall uniformity from 0.4 to 0.7.

3.Evaluation experiment of visual environment and visibility of objects with different uniformity

Visibility test was conducted on site concerning visibility of an object on the road with different visual environment and reflectance under lighting environments shown in Table 1.

1) Subjective assessment was implemented on eight items such as unevenness of road surface and wall, visibility of the leading vehicle, etc. Next, 2) visibility (in clean air) of targets (size: 20 cm square, reflectance: 20, 30, 40%) from a stopped car was assessed in 5 levels from “Visible (5)” to “Invisible (1)”. Then, 3) reflectance for visibility boundary (called threshold reflectance) was obtained from the visibility level (VL) for visibility assessment of 3 (“scarcely visible”), and TRPave

was calculated by equation (1).
TRPave values in lighting environment of high and low uniformity zones calculated from on-site test as 85% (road surface luminance: 1.4cd/m^2) and 84 %(road surface luminance: 2cd/m^2), respectively, almost coincided with each other, so that it was confirmed that visibility level can be ensured by improving overal uniformity from 0.4 to 0.8 even when road surface luminance is reduced by about 30%.

$$TRP=RPs(\rho s) + RPrs(\rho rs) \quad (1)$$

RPs (ρ): Cumulative existence probability (%) of a target of reflectance ρS in the case of silhouette vision
RPrs (ρ): Cumulative existence probability (%) of a target of reflectance ρS in the case of reverse silhouette vision
ρs: Threshold reflectance of a target in silhouette vision (%)
ρrs: Threshold reflectance of a target in reverse silhouette vision (%)

4. Application example and energy-saving effect of high uniformity tunnel lighting using LED

Based on the evaluation result described above, we have implemented as a trial in the actual tunnel using LED tunnel illumination appliances. The site condition was one-way traffic, two lanes, design speed of 100 km/h, average road surface luminance of 3.2 cd/m^2, and overall uniformity of 0.8 (Photograph 2). From the results of visual environment assessment, visibility of target and TRP, it was confirmed that visibility was secured at a certain level compared with a conventional installation using low pressure sodium: NX (4.5 cd/m^2, overall uniformity of 0.5). The energy-saving effect of the installation estimated from the result of this test is about 30%.

5. Conclusion

In this study, more than about 30% energy saving compared with conventional lighting system was found possible in tunnel lighting while maintaining visibility by raising overall uniformity. This can be realized by appropriately combining average road surface luminance and overall uniformity using LED. If efficiency of LED is improved by future technology innovation, energy-saving effect will grow ever greater. In case road surface luminance is reduced, however, comprehensive evaluation of visibility of vehicles and visual environment in tunnels is required.

Installtations	Low overall uniformity zone	High overall uniformity zone
Light source	Fluorescent lamp	LED
Spacing(m)	11.4	2.7
Height (m)	4.8	5.2
Average road surface luminance (cd/m^2)	3.2	2.25
Overall uniformity	0.4	0.8
TRPave (%)	90	90

Table 1 - Condition of installtations

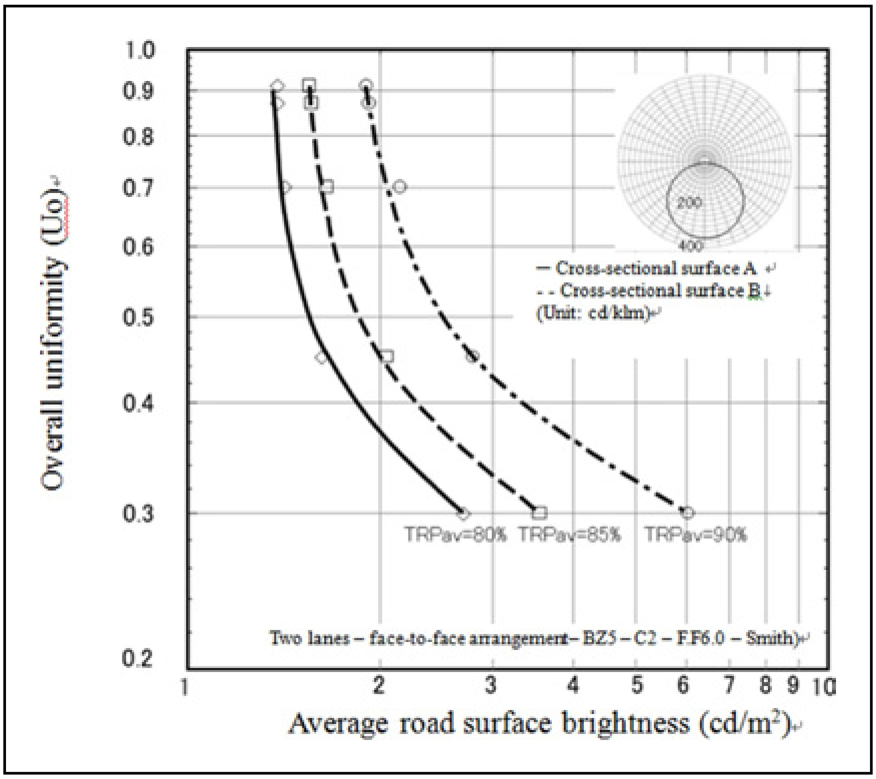

Figure 1 - Relation between road surface luminance and overall uniformity for TRPave to be constant

Figure 2 - Examples of tunnel installation (left: low uniformity, right: high uniformity)

PP108

A SET OF QUALITY CRITERIA FOR SELECTION AND INSTALLATION OF LED ROAD LIGHTING

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When the authority in charge of managing different types of roads comprehensively plans to introduce a LED road lighting system, it should consider two possible cases: the one is to retrofit the luminaires being used with LED luminaires and the other to initially design a lighting system for the newly constructed road. In addition, the LED luminaire products from a number of manufacturers must be evaluated in their propriety.

Standards to determine the requirements for lighting installation and criteria for introduction of LED luminaires for each standard road condition were set up, which can apply to both cases of replacement and new installation. Standard installation requirements that can be applied when retrofitting the luminaires were determined and a design method that can be applied when installing a new lighting system. The utilization factors of LED luminaires on the market were calculated, on the basis of which the required luminous flux were estimated to classify by wattages the LED luminaires whose proprieties are to be evaluated according to the road conditions. Also, the utilization factors of the LED luminaires were analyzed with the data from the road lighting simulation to evaluate their applicability to the road types and installation requirements.

PP109

PERCEPTION OF HUMAN SKIN IN STREET LIGHTING UNDER FIVE TYPES OF LED SPECTRA.

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Abstract :
A panel of observers has been invited to rate and compare the quality of 5 spectra of LED sources used for street lighting, on 30 subjects. Vertical illuminance on faces was 14 lx (+/- 3 lx) . All 30 subjects did not have the same type of skin. 60% were from the European Caucasian type (clear skin), 23 % from the Asian one, 17% were from the Sub- Saharan type (dark skin). All subjects were also acting as observers. Correlated Colour temperature of sources was 2200K , 2700K, 3200K, 4000K, 4800K. This was obtained by mixing coolwhite, warmwhite and red LEDs (for the 2200 K and 2700 K sources only). The extreme stimuli (2200K and 4800K) were rejected by all participants. When presented in pairs (Thurstone protocole), 75% of observers preferred the 3200K stimulus, 61% the 4000 K stimulus, 59% preferred the 2700K stimulus. People with Asian skin was found to be preferred under CCT of 3200 K and below, for Sub-saharan skin type it was 3200K and above, and for Caucasian around 3200 K.

Introduction:
New light sources for public lighting are now proposed based on Solid State Lighting rtechnologies (LEDs). Luminous efficacy is often comparable with the ones of arc type lamps, and one significant interest in street lighting stands in their continuous spectrum distribution: light is emitted all along the visual spectrum, without narrow peak of emission, and with only one major gap around 490 nm (although light is still emitted is this region). Colour Rendering Indices are good for street lighting applications (typically in the 70-85 range). Light is white and correlated colour temperature (CCT) can be adjusted in selecting the appropriate right white LED, although higher luminous efficacies are obtained with CCT above 4000 K. This ability of selecting values of CCT is a major attractive aspects of LED technology for street lighting. In cities, light is not only being used to improve perception of roads, boardwalks and furniture, but also to see pedestrians. One of the interesting aspect is the perception of pedestrian faces. What would be the best CCT for optimal vision of faces of pedestrian? And how would this be affected by the skin type?

Protocole
One street luminaire was installed in a large theatre scene (20 x 10 m in size, 12 m in height, with all surfaces being totally black. The street luminaire was equipped with Cool White LEDs (CCT 4800K, CRI 81) , Warm White LEDs (2800 K, CRI 74) and red LEDs (630 nm) . The height of the light source was fixed at 3 metre, which is a height consistent with public lighting in pedestrian streets. A subject was invited to stand below the luminaire, slightly behind see details of position in figure 1). The azimuth angle of lighting was about 47° from the observation axis, to allow reasonable vision of the face. Values of vertical illuminances was maintained constant for all configuration: 16 lx in the direction of the light sources, 11 lx in the direction of the observers. A panel of

4 observers was installed 6 meters away to judge the quality of lighting on the face of the subject. They were sitting next to each other, in front a table to allow them to fill the questionnaires which was given to them.

Stimuli

Five spectra where proposed, corresponding to values of CCT on the face of the subject equal to: 2200K , 2700K, 3200K, 4000K, 4800K. This was obtained by mixing coolwhite, warmwhite and red LEDs (for the 2200 K and 2700 K sources). The spectra of the light incident on the subject skin are presented in figure 2.

Protocole:

During the experiment, the participants are separated in two groups : one person named “subject” and four others named “observers”. The subject is exposed to the different lights, placed under the experimental lamp.. The subject

wears a black tee shirt. Each participant play in turn the role of the subject. Thirty subjects participated: 20 women and 10 men. The average age is 22 (from 19 to 28 years old). Five had sub-saharian skin, 7 asian, and 18 caucasian. The spectral reflectance of the skin of each participant recorded.

Firstly, participants stayed in the room for 20 minutes to get adapted to the low level of light. The room was dark (black surfaces with iilluminance exceeding 10 lx only in the luminaire area.

Two colour temperatures are proposed in alternance, every 10 secondes, leading to the proposal of ten pairs of colour temperatures in 5 minutes. Each pair is run 3 times to allow time for observers to compare and choose Ten pairs of lights are presented with a given subject. The 4 observers had to select, for each pair, which of the two proposed CCT (A or B) is provide the most appropriate vision of the face of the subject. When all the pairs are passed one of the observers becomes subject and the former subject becomes observer. 5 min are needed to pass a sequence of 10 pairs.

Results

116 views were collected. These views are classified in the following way :

- 70 about a subject with Caucasian type skin (white coloured skin)
- 27 about a subject with Asian type skin
- 19 about a subject with African type skin (black coloured skin)

The extreme stimuli (2200K and 4800K) were rejected by all participants. 75% of observers preferred the 3200K stimulus, 61% the 4000 K stimulus, 59% preferred the 2700K stimulus. People with Asian skin was found to be preferred under CCT of 3200 K and below, for Sub-saharan skin type it was 3200K and above, and for Caucasian around 3200 K.

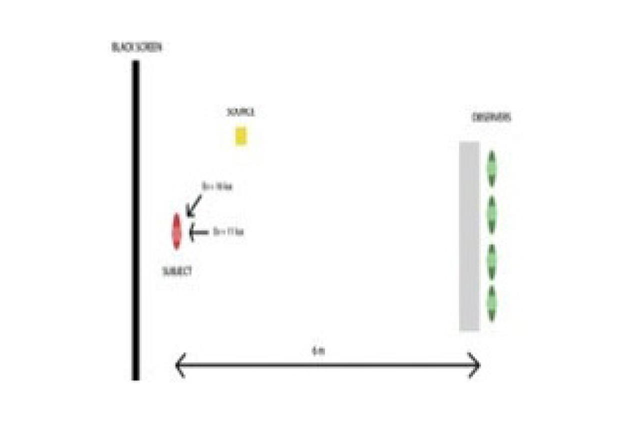

Figure 1 - Experimental set-up, showing position of light source, subject and observers

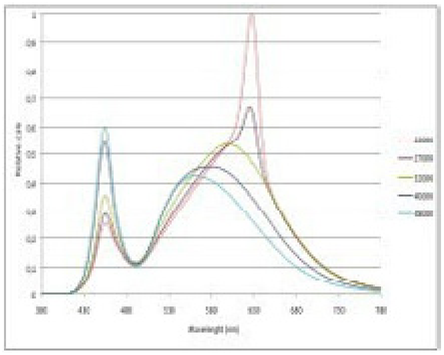

Figure 2 - Spectral distribution of the five stimuli, obtained by mixing 3 categories of LEDs: cool-white, warm white and red

D4 - Lighting and Signalling for Transport
Road Lighting

PP110

MEASURING THE IMPACT OF LIGHTING ON INTERPERSONAL JUDGEMENTS OF PEDESTRIANS AT NIGHT-TIME

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Lighting in residential roads is provided to meet primarily pedestrians' needs for safety and perceived safety. One element of safety is inter-personal judgements: evaluations made regarding the intent of other pedestrians, e.g. whether or not they present a threat. While the need to make judgements about threat was recognised by those who established the basis for design criteria, subsequent research within the lighting community has tended to target only facial recognition.
Past studies carried out to investigate how the spectral power distribution (SPD) of lighting affects facial recognition have had mixed results: of six known studies, three suggested that SPD does affect facial recognition, while the others concluded there is no effect. Further investigation of experimental design appears to be required [1] and this has led to the current proposal.
Four experiments are being carried out from which to interpret how lighting may affect visual cues to inter-personal judgements. Past work suggests that visual cues as to intent include facial expression [2], body posture [3] and gaze direction [4], but the performance of these tasks under low light levels and different spectra has yet to be examined. This article presents results from these experiments.

1. Gaze direction. The literature suggests that another person looking at you is perceived to present a threat. This test will determine whether ability to recognise gaze direction (eye or head movement) is affected by low light levels.

2. Recognition of facial expressions and body postures. There are seven universally recognised facial expressions (happy, sad, surprise etc) and four body postures. Pilot studies suggest that judgements of intent based on these expressions/postures may not be consistent, with some within- and between-subject variance. Thus initially the ability to recognise these expressions/postures at low light levels will be examined. Databases of the standard expressions and postures have been validated under good lighting conditions, i.e. high luminances, but not the low luminances typical of road lighting.

3. Judgement of threat based on facial expression and body posture. While this task is the more directly relevant to investigation of inter-personal judgements, pilot studies reveal inconsistent results. A further problem is that there is no right answer – an angry expression does not lead with certainty to a threat decision and this may add noise to the data.

4. Facial recognition. For benchmarking with past studies of lighting, a fourth test investigates facial recognition. In an attempt to develop the methodology used in past studies this test uses target faces of constant size, limited observation duration, and more precise recognition criterion.

Target images are photographs drawn from standard databases, these presented on a non-self-

illuminated display screen (i.e. an e-reader) so that the dominant spectrum is that of the test light source. The targets are presented for 1 s, the fixation suggested in eye tracking studies of pedestrians. This study examines the effects of the level and spectrum of lighting, using three vertical illuminances on the target faces (0.6, 6.0 and 60 lux) and three types of lamp (HPS, MH and LED), these being chosen to determine whether any effect is best characterised by S/P ratio or CRI. Test participants are drawn from younger and older age groups.

Caminada and van Bommel [5] proposed a requirement to recognise the face of an approaching pedestrian at a distance of 4 m, suggested to be the minimum distance at which an alert subject would be able to take evasive or defensive action if threatened. Others have suggested larger distances and that once inter-personal distance is reduced below 15 m, the space in which we have time to react to avoid trouble, or simply an undesirable situation, becomes reduced beyond comfortable levels [6]. One limitation of past studies of facial recognition is that they have not addressed the inter-personal distance at which it might be desirable to make judgements about other pedestrians. It is possible that at near distances any effect of SPD is not significant because the face is of a large size. At further distances, where the face is smaller, then an improvement due to SPD may be of benefit. Thus, alongside evaluation of interpersonal judgements, this study is investigating the relationship between distance and inter-personal judgements [7]. Three inter-personal distances are evaluated in trials: the 4 m minimum distance suggested by Caminada and van Bommel; 10 m, the optimum distance suggested by Caminada and van Bommel; and 30 m, the boundary of action space suggested by Cutting and Vishton.

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PP111

CRITICAL PEDESTRIAN TASKS: USING EYE-TRACKING WITHIN A DUAL TASK PARADIGM

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Existing design criteria for road lighting provide recommended horizontal illuminances for different types of highway. Recommended illuminances for residential streets range between 2 lux and 15 lux. However, there appears to be little empirical basis for these illuminances [1]. One requirement for establishing an empirical basis for recommended illuminances on residential roads is understanding what visual tasks are important to pedestrians after dark. There is little previous research investigating critical pedestrian tasks. In one recent study it was found that pedestrians spent 40%-50% of their time looking at the pavement [2]; however, the authors acknowledged that it was difficult to confirm whether a person was actually attending to the object their gaze was fixated on or that it was important for the task of walking.

This issue raises questions over how to reliably determine what visual tasks are important to pedestrians in residential roads. The current study used eye-tracking within a dual-task paradigm. Attention is a finite resource: the visual tasks required when walking down a street use some attentional capacity but it is unlikely they use all or even most of the capacity available under normal circumstances as it is not a cognitively taxing task. Therefore the eye movements we make that are relevant to the task of walking on a street will be intermingled with eye movements that are not relevant to that task, and periods in which our vision may not be connected to our mental processes, e.g. if we are daydreaming. Research has shown that introducing additional tasks that use up attentional capacity can reduce task-unrelated thoughts and the effects of visual 'distractors' that focus our visual attention away from the task in hand [3]. This finding applies equally well to internal distracters (e.g. when we experience "mind wandering") as external distracters. Using up attentional capacity in task-relevant processing can reduce instances of task-unrelated thoughts [4]. These findings show that the allocation of attention to task-unrelated stimuli and thoughts can be reduced by increasing the load on the attention mechanism, e.g. through increased cognitive processing produced by a concurrent dual-task.

The current research used a dual-task approach to determine the important visual tasks of pedestrians. Eye tracking equipment was used to monitor eye movements and fixations whilst participants walked down a road in two sessions: once during daytime and once after dark. The route walk was divided into two sections: low obstacle density and high obstacle density street. Whilst walking along the test route, participants were also given a concurrent cognitive task. It was proposed that noting the instances when performance on the secondary task was interrupted (e.g. a delayed or incorrect response) would identify the instances when the pedestrian was distracted by something critical to their walking task. Participants were questioned about their experience during the experiment immediately after their final test session, and again shortly afterwards whilst reviewing the fixation-point video captured by the eye tracking equipment.
The results will be used to identify critical visual tasks for pedestrians, through analysis of fre-

quency/duration of observation, distance of observation and eye-related metrics including pupil dilation, mean number of saccades and mean number of fixations (overall and at categorised regions of interest). The questions targeted are:

- The low obstacle density street will produce results indicative of easier visual tasks involved in walking, relative to the high obstacle density.
- The high obstacle density street will produce more fixations and a greater proportion of looking time regions of interest that are thought to be important in walking safely on a street
- Regions of interest for walking down a street are likely to include the immediate pavement area, pavement edges, areas further ahead of the participant to provide visual information for strategic planning of travel, and other pedestrians
- The after-dark sessions are expected to produce results indicative of more difficult visual tasks involved in walking, relative to the daylight sessions.

The methods used in this study will allow more confident conclusions about the visual tasks that are important to pedestrians at night, compared with previous research.

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PP112

THE APPLICATION OF ADAPTIVE LIGHTING IN URBAN AREAS

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The Northwest Energy Efficiency Alliance (NEEA) and the City of Seattle partnered to evaluate the future of solid state street lighting in the Pacific Northwest with a three night demonstration in Seattle's Ballard neighborhood in March 2012. The study evaluates the effectiveness of LED streetlights on nighttime driver object detection visibility as function of color temperature and light distribution. Adaptive standards (tuning of streetlights during periods of reduced vehicular and pedestrian activity) are also evaluated at three different levels: 100% of full light output, 50% of full light output, and 25% of full light output.
There are two data collection methods to this study: subjective and objective. The results from both of the methods are used to justify the use of adaptive street lighting.

Study Setup

The demonstration took place in Seattle's Ballard neighborhood along 15th Avenue NW, between NW65th Street and NW 80th Street. The 15 block stretch is divided into six evaluation test areas with approximately one test area per two blocks. The luminaires for each test area included 105 Watt LED systems at 3500K, 4100K and 5000K color temperature, an asymmetric 4100K LED system, a 250 Watt HPS system and the existing 400W HPS system. The LED luminaries are equipped control system to dim the lights on command.
The demonstration took place over the course of two evenings. Each evening, three groups of participants evaluated the entire test site. The first group evaluated all of the lights at 100% of full light output, the second group evaluated all of the LED lights at 50% of full light output, and the final group evaluated all of the LED lights at 25% of full light output. The first night of general participant testing the pavement was dry. On the second night, the pavement was artificially wetted. The wet conditions provided a method to evaluate how driving visibility is affected under the common rainy conditions found in the Pacific Northwest. The roadway was closed for both nights of evaluation.
The participants completed both a subjective survey and participated in an objective object detection task. The subjective survey evaluated the participant comfort, feelings of safety and overall impression of the roadway. During the objective testing, the participants were located in a vehicle and their ability to detect a small target in the roadway was measured from the moving vehicle. The vehicle was also outfitted with a photometric system that measured the visual environment.

Results

The results of the subjective survey indicate a preference for the incumbent HPS streetlights, while still showing acceptance of the LED luminaires. At the lower light levels, some participants noted the lighting as too dark on the sidewalks. As seen in the sidewalk evaluations, the vertical illuminance is significantly below the requirements for all of the LED based conditions. This is further exacerbated by the impact of dimming. This is valuable information in that perhaps the

sidewalk and the roadway lighting systems should be exclusive from one another. In many designs across the country, sidewalk lighting is intended to be covered by the roadway lighting. The results of this demonstration may suggest that separate dimming control may be valuable where the backlight illuminating the sidewalk is dimmed separately from the roadway.

The results from the objective evaluation, shown in Figure 1, indicate that the LED 4100K (symmetric and asymmetric) luminaires have the highest detection distance of all of the test areas with a value of approximately 130 feet. At the lowest light level of 25 percent of full light output during the dry pavement test, the LED 4100K luminaires did not have a significantly different detection distance compared to the same luminaires at 100 percent of full light output. As this distance is within the reach of the headlamps, it indicates that the headlamps are probably the primary mode of detection in this condition. The roadway is located in an urban area that had significant influence from the signage and other facilities along the roadway edge.
The wet roadway conditions did show an impact of the lighting system dim level on the object visibility. This is shown in Figure 2. Here the detection distance was significantly reduced under the wet roadway conditions.

Conclusions
The results indicate that the performance and acceptance of the new LED systems is at least on par with the existing HPS system. However, care must be considered for the sidewalks. Lighting of the sidewalks was a significant aspect of use acceptance and consideration should be given to a specialized sidewalk lighting system. Similarly, using adaptive dimming must be used with care for the sidewalks and separate dimming may be considered. Dimming on the wet roadway conditions also showed an impact and adaptive lighting is not recommended in these wet conditions.

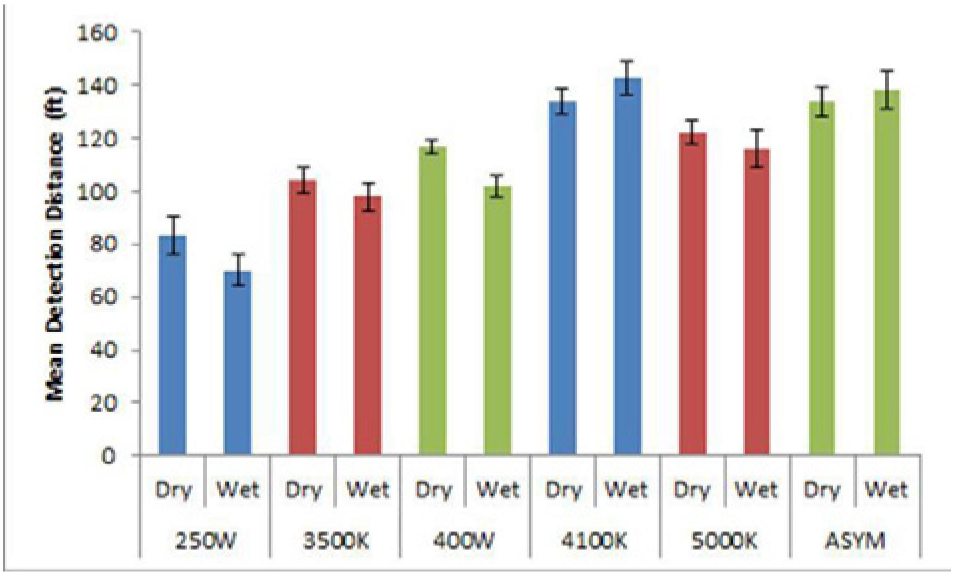

Figure 1 - Target Detection Performance under varying Light Sources and Road Conditions

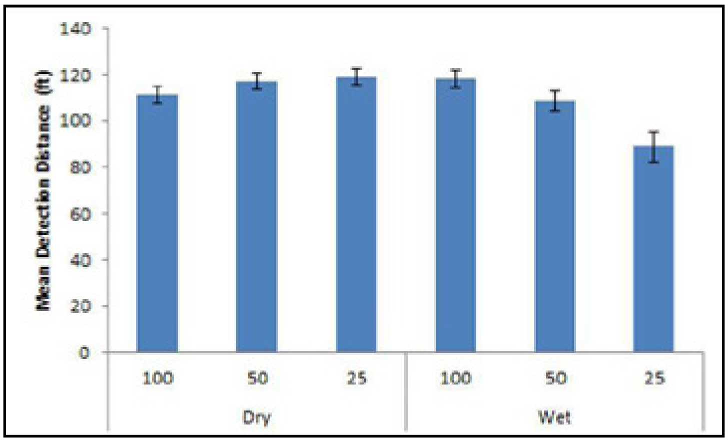

Figure 2 - Target Detection Performance in Varying Dimming Levels and Road Conditions

PP113

CALCULTION OF THE OPERATION TIME OF ROAD LIGHTING

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Proper road lighting of cities helps to increase personal safety and to avoid traffic accidents. Depending on various criteria, taking into account visual conditions, traffic situations and other influencing conditions, target lighting parameters are defined for different road lighting classes as minimum values. These should be maintained under any circumstances, including availability of natural daylight. On the other hand it is important to conserve energy for lighting wherever possible. In public lighting it means that with regard to local conditions, switching and dimming of the lighting system should be tailored to actual needs.
Currently there are no widely used recommendations on when to switch on and off the lighting. Setting of control devices like timers or photodetectors is usually made upon experience of local staff. If target values of luminance or illuminance are to be satisfied, control of lighting system should consider particular lighting class of a given road section what itself is a complication because topology of road lighting network is in no correlation with lighting classes (except of individually controlled luminaires).

This paper aims to propose a definition of starting and ending times for operation of road lighting. Daily method is intended to be used for setting of control devices while annual method is intended for calculation of energy consumption and energy efficiency of the system. Daily approach is based on selection of empirical formulae for calculation of solar declination and time equation in order to calculate the time of sunrise and sunset. Illuminance levels from daylight during transient periods of sunrise and sunset are measured at the Slovak University of Technology and results of these separately performed investigation are used to determine the time spans between sunrise and sunset on one side and times when certain light levels corresponding to particular road lighting classes are reached on the other side. Summing up daily values, annual operation times are calculated.
The paper also concerns lighting systems with regulators and dimmers where several light levels (corresponding to certain power consumptions) with individual durations are set. Calculation of the total operation time incorporates these different levels.

PP114

IN DEPTH INVENTORY FOR A HIGHER QUALITY OF STREET LIGHTING

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ORES is the grid operator responsible for the installation and the maintenance of the street lighting in the south part of Belgium. This management was done for years without a detailed view of the entire lighting points.
In order to increase the quality level of the street lighting, ORES starts a huge inventory of all the 400000 luminaires installed on his territory. The goal is to improve the maintenance speed, enhance the security on the roads thanks to a higher lighting quality and optimize the maintenance process.

A database was build with all the informations collected in the field. Several teams traversed the territory with a special vehicle recording, for each light point, the GPS position, the type of luminaire, the type of lamp, the height of the luminaire, a picture of the luminaire,...
Now, the technicians have access, in the field, to this database when they have to make the maintenance. They can view the previous defaults, validate the maintenance actions and order spare parts. On the other hand, the final users (the municipalities and local people) have access to an internet website where they can mention defect luminaires.

In the future, another aspect of the quality level of street lighting will be studied in cooperation with Laborelec. The conformity with the lighting levels required by the standards could be measured on site with a vehicle equiped with luxmeters. These onsite measurements will allow to make a cartography of the lighting points, focus the relighting efforts on the critical streets and follow the ageing of the installations.

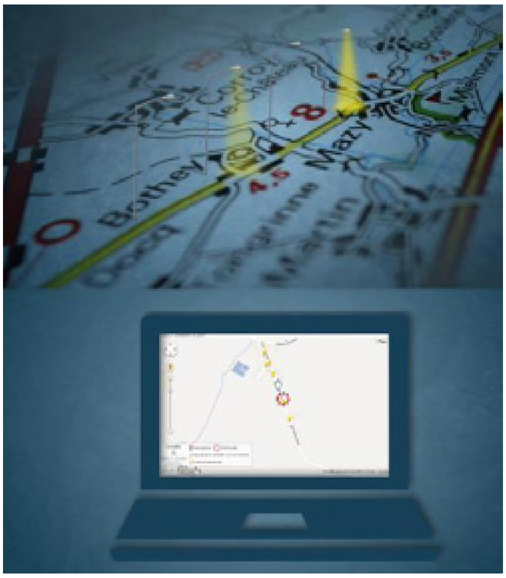

Figure 1 - The final users (the municipalities and local people) have access to an internet website where they can mention defect luminaires

PP115

RENEWAL OF STREET AND ROAD LIGHTING IN SWEDISH MUNICIPALITIES

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The objective of this study was to identify factors that constitute possible barriers or incentives for new or reinvestments in more energy efficient street and road lighting (SRL) in Swedish municipalities. Focus was on planning and decision making processes, responsibilities, organisation and stakeholder's involvement.

A questionnaire study with a number of semi-structured questions was carried out in twelve municipalities from three size classes in different geographical locations in Sweden. The official responsible for the SRL was interviewed in each of the municipalities.
The result showed that the small municipalities had the most energy efficient SRL and also had the lowest percentage of high pressure mercury (Hg) lamps remaining. All four small municipalities stated that energy savings were the main reason for substitution of the Hg lamps. In the medium sized and large municipalities the EU Directive was given as the main motive by four municipalities while the remaining four municipalities stated that their main motive was the need to replace old and obsolete SRL.

The result is an indication that coordination and cooperation between planning sectors and different organisational levels may be a factor that contributes to a more proactive planning in municipalities and that such processes are easier to accomplish in small municipalities.

PP116

COMPARISON OF DIFFERENT LIGHT SOURCES ON PEDESTRIAN AND BICYCLE ROAD

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Light measurements on a pedestrian and bicycle road in Stockholm were compared in light distribution and illuminance. Light sources were 125 W mercury vapour, 70 W ceramic metal halide and 25 W LED. Changing from mercury vapour to LED on the pedestrian and bicycle road saves 80% energy. Comparisons in illuminance, luminance, the luminance distribution, and spectral distribution between the light sources were measured in the field. The results show large differences in light distribution on the road surface and also some individual differences between the LED lamps. Photos on the luminance distribution of the different light sources will be presented. Measurements on bicycle speed for the three different light sources will also be incorporated in the study.

PP117

RESEARCH ON TESTING METHODS OF RELATIVE PARAMETERS OF OVERPASS LIGHTING SAFETY BY HDR IMAGE

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As an important part of night lighting environment, the quality of city overpass lighting is significant for protecting the traffic safety in the night, improving the efficiency of transportation and providing a good visual environment for the drivers.

The article analyzed the relevant indicators of Overpass lighting safety. Combined with the visual characteristics of the driver, we proposed the important measurement of affecting the overpass area lighting security. It is threshold increment, which is closely related with the visual adaptation and change in vision. We cited more effectiveness and persuasive basis than others as measurements.

In this paper, a luminance information obtainment method based on high dynamic range images was used to acquire the threshold increment. With floating-point value, the High Dynamic Range Image (HDR image) is an image of very wide range brightness and can store the luminance of the scenes. The R, G, B floating-point value of the HDR image can be read through own-developed software. And through the experiment, the functional relationship between the R, G, B floating-point values and the RGB values of the 1931 CIE-RGB system can be calculated. Then, according to the CIE documents, the RGB values can be conversed to the XYZ values of the 1931 CIE-XYZ system. Thus the luminance value, namely the Y value, can be gained. As for the illuminance value, it can be gained according to the relationship between the luminance and the illuminance. Based on these theories, the method of obtaining the luminance information from the lighting environment through HDR Images was established.

The traditional method is time-consuming, traffic-blocking and inconvenient. And obtaining the luminance information through low dynamic range images has a limitation on the luminance range recorded. Using HDR images to obtain the luminance information can conquer the disadvantages and the limitations and is more convenient.

We tested the Balitai overpass in Tianjin with both traditional methods and the parameters extracting of the light environment from a high dynamic range image and study the accuracy of it. This study provides the basis for environmental testing and research on the overpass light.

PP118

A STUDY ON THE LIMIT OF LIGHTING POWER DENSITY FOR ROAD LIGHTING

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It is important that the road lighting be designed efficiently in consideration of efficiency, light distribution, conditions for installation and maintenance factors of luminaires. Standards regulating the maximum lighting power density of a unit area were devised to decide the efficiency of a road lighting design.
The data of actual energy use in road lighting was analyzed by measuring the performances of the existing road lighting facilities in use. Since the requirements of lighting performance vary to the road types and road lighting classes, standard road conditions were set up on the basis of the assumed general road conditions. Energy uses per unit area were calculated according to each road lighting class and lamp used by means of the computing simulation. The analysis showed that difference in energy use depends on the install conditions, light distribution of the luminaire and other various factors.
Recommended were maximum limits of energy use applicable according to the road lighting classes and the road lighting energy measured and calculated thereupon. The limited values were verified through comparing them with the energy used in actual road lighting.

PP119

OPTIMISING VISIBILITY IN STREET LIGHTING BY OPTIMISING AND COMPARING LUMINOUS INTENSITY DISTRIBUTIONS

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European road lighting standards are mainly based on the minimum and average illuminance or luminance as well as their uniformities in the road area. These values depend on the street's road classes and its characteristics given by EN 13201.
Figure 1 shows two street lighting scenes for two different streets of the same street class, which both fulfil the EN 13201 requirements but show completely different results regarding the visibility of a given test object. The right street provides good visibility whereas the left example demonstrates how bad visibility can be although the EN requirements are reached. In both cases the target is a grey card with a reflectance of 0.07 and a size of 0.3 m x 0.3 m. According to studies [1, 2], this degree of reflectance can be used as representation for dark pedestrian clothing. Related studies [3,4] have shown that high luminance uniformities do not assure high visibility performance, but have a positive effect on target detection. Other studies [5] compare visibility performance under different overall and longitudinal uniformity conditions to recommended luminance and uniformity conditions of CIE Publication No. 115 [6]. They show that streets with poor luminance uniformities show more areas of inadequate visual conditions based on visibility level (VL) than installations with adequate uniformities. However, this approach does not take into account the optimisation of uniformities. Comments [7] on this study indicate that the effect of uniformity on visual performance remains unclear.

A step further would be to use luminous intensity distributions (LID) which are optimised for providing best available visibility for specific, actual street lighting geometries. In the past visibility optimisation based LID approaches were difficult to realise in practice. Nowadays LEDs provide possibilities to adapt light distributions accurately to a given geometry. Thus, light distributions specially designed for a certain street lighting arrangement can provide optimal visibility and contrast at high energy efficiency.
The present study compares simulations of four optimised LIDs to conventional street lighting LIDs. The optimised LIDs are determined by simulation to achieve comparable illumination levels for typical residential road geometry. The four simulated LID differentiate, each being optimised for one specific road lighting quality criterion, such as L (max U0), Eh (max U0 and U1), Ev (max U0) and VL or C. Conventional LIDs are based on standard bat wing distributions, found through analysis of 25 residential roads.
A prototype LED fixture with indecently controlled modules for illumination of different areas on the road surface was developed to realize the simulated LIDs. Each module is driven by DMX protocol for dimming and there is the possibility to choose between four optics from narrow to wide beam characteristics.
These adaptive LED street lighting fixtures are used in a laboratory setup to analyse the possibility to implement the simulations of optimised LIDs in field. Besides this, this experimental set-up can be used to validate the benefits for visibility in street lighting by using individual optimised LID

for the given street lighting criteria.
The complete setup is scaled 1:2 to a real street lighting measurement arrangement in a given residential road. The specifications are according to EN 13201 and ANSI IESNA RP-8-00 2005 requirements. Thus, the observer's viewing distance is set to 30 m. The measurement field's geometry is defined to 12.3 m x 3 m with the fixture's height of 3 m. The reflectance range of the setup room's walls, ceiling and floor, is $0.01 \leq \rho \leq 0.1$. The used objects for target detection approaches have squared size with edges of 10 cm and $\rho = 0.05$; 0.1; 0.2; and 0.4.
At the current state the simulation tool for LID design has been completed and the simulation assessment will be completed in the coming months. The laboratory setup will be in use for the first measurements at the beginning of 2013.
First simulations show that optimisation on uniformity has a positive impact on target object contrast. With the results of the simulations and measurements, it is expected to get more insight into further improvement (of visibility) through optimising for object contrast having a specified inhomogeneity of luminance. During the presentation the studies will be presented in detail and results will be reported.

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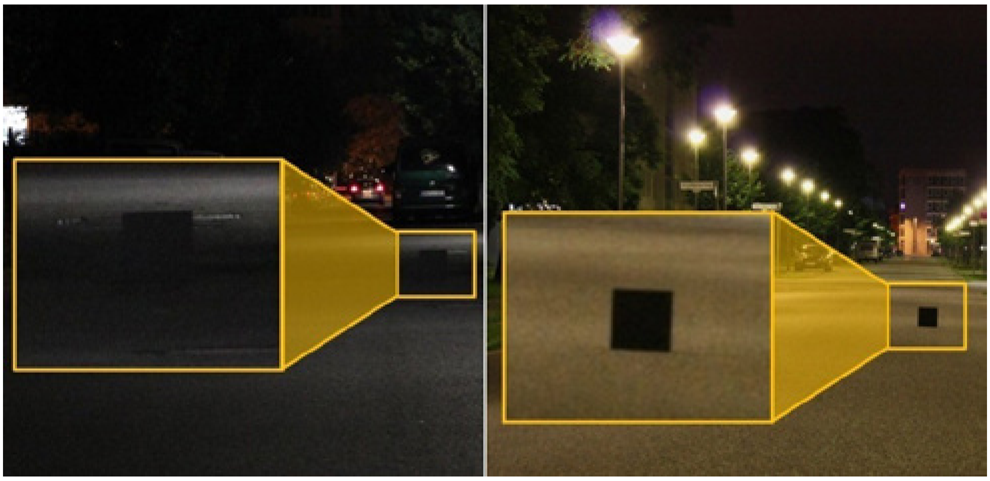

Figure 1 - Two residential roads are both fulfilling the requirements of EN 13201, but giving a complete different target visibility

PP120

APPLICATION OF ROAD LIGHTING ENERGY EFFICIENCY EVALUATION SYSTEM IN PRACTICE

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Energy efficiency criterion is introduced to the road lighting practice, for both design of new and evaluation of existing systems. In the progress of conducted research, classification and evaluation system were introduced.

In this paper, in the introduction the overview of road lighting energy efficiency classification and evaluation is presented. Road lighting energy efficiency measures used in the system: power (energy) density and normalized power (energy) density are introduced too.

Then, for a typical road cross sections: single and dual carriage ways and luminaire layouts: single sided, staggered, opposite and central, calculation procedures of the energy efficiency measures are presented.

Finally, application of the energy efficiency evaluation system for existing road lighting is presented. Use of the system is presented for lighting of selected streets in Stockholm and Warsaw. Opportunities for the system development for lighting energy efficiency evaluation of existing roads are indicated.

PP121

ENVIRONMENTAL COMPATIBILITY IN ROAD LIGHTING AN INSTRUMENTED DRONE MEASURES THE UPWARD SPILL LIGHT

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2. AIDI, Milano, Italy.

1Compatibility of road lighting with environment and energy saving

In order to reduce the negative effects of road lighting for astronomy, up to now laws (e.g. [1]) and regulations [2, 3], prescribed upper limits for the luminous flux emitted upward by the luminaires (ULOR), considered the sole cause of the artificial sky luminance.

This was also the approach of Divisions 4 and 5 of CIE in publication 126 and in the recent draft revision of publication 150, which prescribe 0 upward emissions (in practice, cutoff luminaires), with no consideration for the upward reflections and for the higher energy consumptions of cutoffs.

The measurements recently carried out in Italy follow the measurements on lit towns already available and clarify the influence of the different factors, which produce the negative effects of road lighting, and are representative of a new approach to the compatibility of road lighting with the environment.

2Upward emissions and reflections of road lighting

Up to now, CIE publications did not consider the upward unavoidable reflections of the illuminated surfaces as a negative effects for astronomy. The reason is probably more psychological than technical: at far distance, the luminaires, being bright and small, are perceived more disturbing than the lit roads, dark but large, even if the reflections of the road are higher than the emissions of the luminaires. Moreover, the astronomers do not consider the real problem, the effects on sky luminance, which is of course higher for the reflections, higher than the emissions.

With the sponsorship of ENEA, the National Agency for Energy in Italy, and the participation of INRIM, the National Metrological Institute, and of AIDI, the Italian Lighting Association, some measurements of both the upward spill light of the road lighting installations and of the reflections of the illuminated surfaces, were carried out on four pilot road light installations, with cutoff and shallow glass luminaires, metal halide lamps and LEDs. Measurements of illuminance, luminance and uniformity have been carried out on the four pilot installations following the normative requirements. A small helicopter, equipped with visual luminancemeters, flew repeatedly over the installations performing measurements of upward emitted radiation at different heights.

These lighting installations included a single luminaire. In this way, the measurements can be easily extended to installations composed by any number of that luminaire placed in any position: figure 1 shows a pilot installation as seen by the helicopter.

The luminous intensity distribution of a virtual luminaires, representative of the upward emissions and reflections of the lighting installation, was calculated starting from the measurements values. Figure 2 shows the luminous intensity distribution on a C plane the virtual luminaire with clear evidence of diffusing character.

3Measurement results

The data on the lighting installations were calculated extending the measures to an indefinite number of the same luminaires, all installed on the edge of a road at the reported spacing.

Some comments are in order.

- Measured and calculated illuminances are in good agreement, authorizing the extension of the results to all installations according to the calculations, without any need for more measurements.
- The luminous flux emitted by the luminaires (ULOR) is very low, 5-10% of the total luminous flux emitted and reflected upward: actually, the reflections always prevail.
- The differences between the calculated and measured luminance are probably due to the great sensitivity of the luminaires to the orientation during the installation and/or to the difference between the reflection matrix of the road surface used in the calculations and in the measurements. For this reason, the evaluation of the costs was based on the calculated luminances.
- Installations with cutoff luminaires need more poles.
- The comparison of the costs for installation and energy is referred to a road luminance of 1 cd/m^2.
- Light pollution is higher with cutoff luminaires, which emit and reflect upward a higher luminous flux. -The ULOR of cutoff luminaires reported in table 1 is due to the reflections of the pole.

4Concluding remarks

This research confirms the measurements carried out on lit towns form a hill teams [5] and the evaluations reported in 1973 by Waldrum [6] on the diffusing character of a lit village.

The consideration of the measurements described in this paper in the revision of CIE publication 126 AND 150 could contribute to the reduction of the costs for installation, save energy and also reduce the artificial luminance of the sky.

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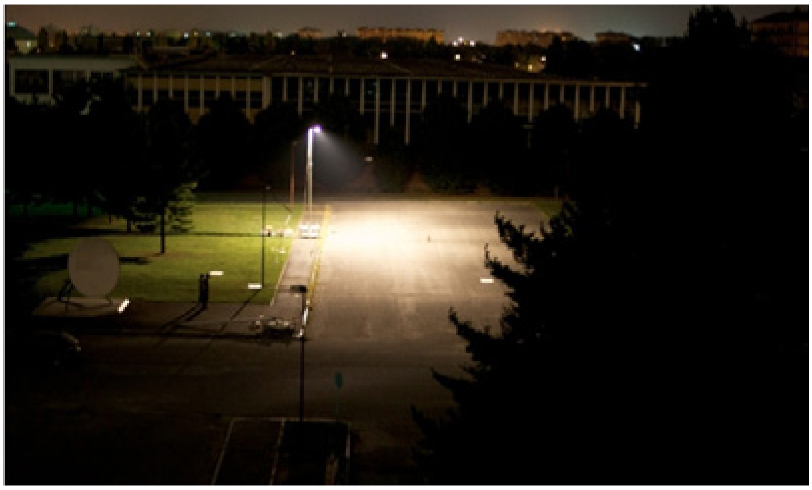

Figure 1 - A one pole installation from the helicopter

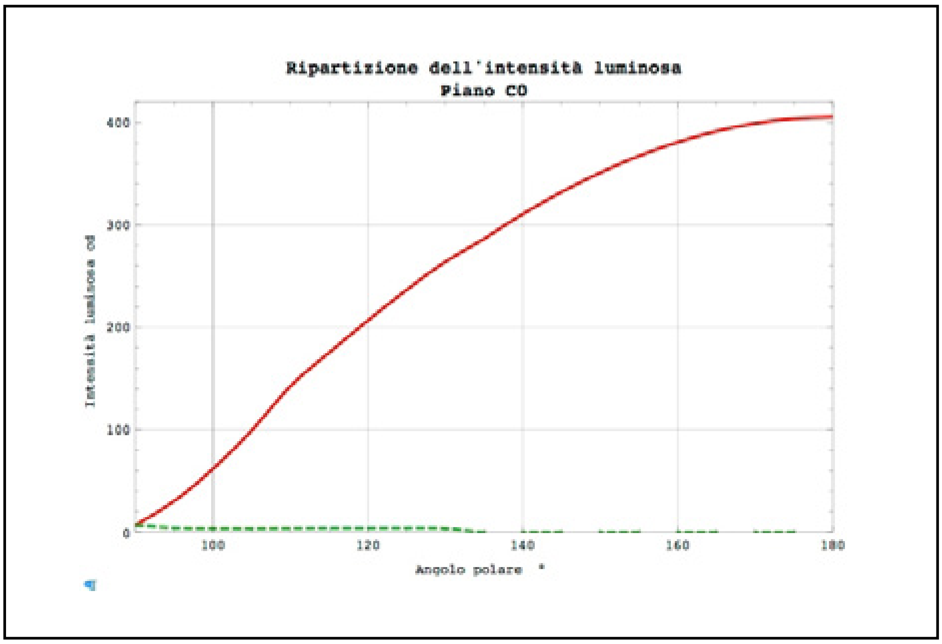

Figure 2 - A C-meridian of a virtual luminaire for the simulation of the total luminous flux emitted and reflected upward by a luminaire

PP123

THE EFFECT OF ONCOMING CAR HEADLIGHTS ON PEDESTRIAN VISIBILITY

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Introduction

One of the important factors in striving towards sustainable urban living is the safety of pedestrians. This safety is influenced by many factors, one of which is the ability of drivers to see pedestrians. During the night, pedestrian visibility becomes more difficult, especially on two-way streets, where headlamps of cars from the opposite direction cause glare to drivers. Newer types of headlamps are using LEDs and Xenon which are glarier than older halogen types. This study examines the effect of on-coming car headlamps on pedestrian night time visibility. Detection distance was used as a measure of visibility. The detection distance was measured in the presence and in the absence of on-coming car headlamps in an unlit street. Pedestrians wore three different clothing colours; white, yellow and, black.

Methodology

In this experiment male drivers between the age of 18 and 28 were used as subjects. All drivers underwent an eye exam to test their visual acuity and color blindness using an Ishihara color test. Any subject that did not score 6/6 on his Visual Acuity exam was excluded from the experiment. An isolated street in one of the university campuses was used as a test site. The width of the street was 7.1 m and it had empty land towards the north east. During the testing, the participants drove a test vehicle towards the pedestrian location and identified when they could see a pedestrian Each driver performed four rounds of testing. The pedestrian location was fixed and all streetlights were turned off. Each driver was asked to fix the car speed between 35 and 40 km/hour, keep the car on the right lane and focus on the centre of the street directly ahead. The drivers used a Mitsubishi Pajero 2010 with xenon-HID headlamps. In all rounds the pedestrians were not moving because this was considered a more critical case than that of a moving pedestrian who tends to be more easily detected. The pedestrian stood on the left sidewalk and changed his clothing randomly in each round. Three different clothing colours were used; white, black and yellow. There was no pedestrian present at the second round, so as to keep the driver guessing. In all rounds, an Audi A4 2008 with xenon-HID headlamps was placed on the second lane in the opposite direction to the subject car. The headlamps of the standing car remained off, except during the 4th round when the headlamps were turned on. For each lap, when the driver indicated that he saw a pedestrian, the location was entered into a GPS HPS 72H instrument (Garmin 2009).

Conclusion and Recommendations

In this study, the detection distance of pedestrians in the presence of on-coming car headlights was found to be around half of the detection distance in the absence of on-coming car headlights. The reduction in the detection distance was more pronounced when the pedestrian wore black clothing whereby the detection distance was reduced by 60% as shown in Figure 1, and table 1. The current IES/ANSI roadway lighting standards (RP-8- 2005) does not consider the full street configuration. For example, the street is not classified based on how many lanes it has (i.e. is it a two way street or a one way street). On the other hand, drivers' visibility is significantly reduced in the presence of on-coming car headlight. This situation is very common on two way streets. Under such circumstances, the light levels should be higher. Despite this fact, ANSI/IESNA RP 8.00 (IESNA 2005) does not consider such an effect in its design recommendation for street lighting. Whereas, the CIE 115 technical report (CIE 2010) does consider the separation of carriageways in its selection of M lighting class. It does not, however, consider any glare blocking element along the separation line.

Recommendations:

Based on the result presented here, the following recommendations were developed:

a-Two-way streets with pedestrians should have a median with glare blocking elements. The glare blocking elements could be soft-scape or hardscape as long as it is high enough to prevent oncoming cars' headlamps from being visible by drivers from the opposite direction.

b-The speed limit in two-way streets should be lower than one way street considering the influence of oncoming car headlamps, especially in the absence of glare blocking elements along the median of the street.

c-Street lighting design standards should take into account the street design and configuration. For example, two way streets with no glare blocking element should have higher light levels than one way streets, and higher than a two way street with glare blocking elements.

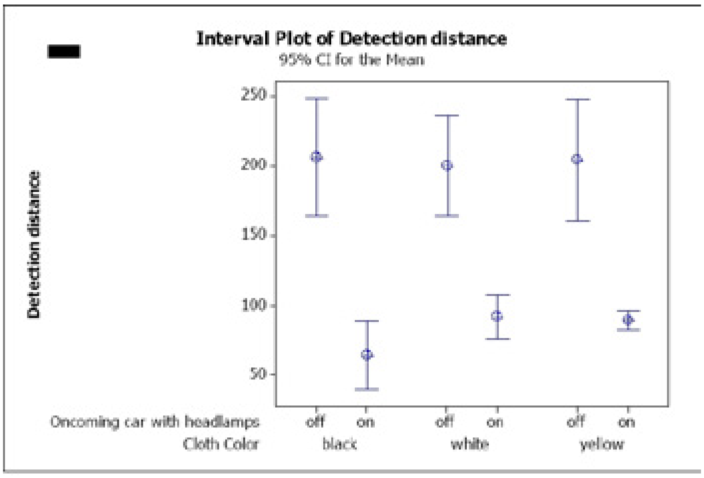

Figure 1 - Comparison of DD when oncoming car headlamps were off versus on for all three colored clothing

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cloth Color	2	571	1823	911	0.24	0.789
Head lamps	1	228553	225828	225828	59.09	0.000
Cloth Color*Headlamps	2	3294	3294	1647	0.43	0.652
Error	62	236940	236940	3822		
Total	67	469358				

Table 1 - Data set analysis of Variance for Detection Distance

PP125

DRIVER VISUAL FIELD ANALYSIS

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This project is the consideration of the driver visual field while travelling at night both in lighted and unlighted areas. The results indicate that the visual field of the driver is significantly influenced by lighting, the presence of other vehicles, the roadway geometry and the desired direction of travel. Participants drove a specific route located around the Virginia Tech Transportation Institute. This route included lighted areas both in urban and highway settings, unlighted areas, commercial environments, differing roadway geometry and areas with high pedestrian activity. The participants wore an eye-tracking device while they were driving. This device recorded video of the visual scene and eye location. The vehicle also used a luminance based camera system to record the luminance of the driving environment.

The breadth and scope of the visual field was measured using the eye tracker and the video system. The results indicate that in general, the driving environment significantly impacted the field of view of the driver. The presence of other vehicles, traffic signals, the roadway geometry and the lighting system all changed the apparent visual field. As an example, Figure 1 shows the visual field for a driver on a freeway in a slight right curve. The red dots indicate glances to a location in the image. Most of the glances are to the edge line of the roadway the vehicle is traversing. However, glances to the other lane also exist. It was found that most of these other glances were a result of a passing vehicle. As another example, Figure 2 indicates that eye glances for a vehicle in a left curve with an exit to the right. The drivers were expected to use the exit. Here the results show that the visual field is significantly widened. It is expected that the drivers were both glancing to the left to traverse the curve as well as observe other vehicles but were also glancing to the right to monitor were they were intending to drive.

These results indicate that the visual field is a very dynamic aspect of driving and is significantly influenced by the situational aspects of the driving environment. The presence of other vehicles, roadway geometry and direction of travel have as much of an impact on the driver visual field as does the lighting system. The application of Mesopic factors and the assessment of lighting for safe travel must consider this visual field. These results indicate that a much more comprehensive consideration must be given to this aspect of driving and the overall impact on the lighted environment.

Figure 1 - Glance Pattern in a Right Curve

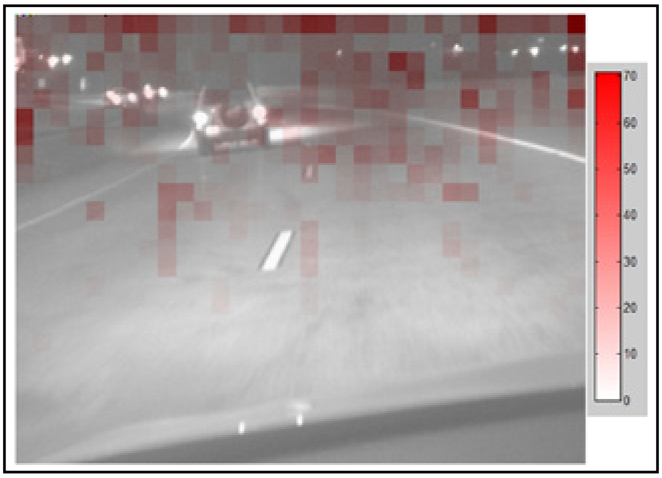

Figure 2 - Glance Pattern in a Left Curve with a Right Exit

D4 - Lighting and Signalling for Transport Road Surface / Objects

PP126

RELATIONSHIP BETWEEN LUMINANCE DISTRIBUTIONS OF ROAD SURFACE AND VISIBILITY IN STREET LIGHTING DESIGN

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1. Introduction

Since the adequate level of luminous flux of LED has became available as the general light source, LED lights spread quickly for indoor and outdoor lighting. Compared with conventional lighting tools such as fluorescent lamp, incandescent lamp and HID, the light source luminance of LED light is extremely high and the irradiated area is very narrow. Therefore it causes glare, scattering inside the eyeball, and reduction in sensitivity for pedestrian if the traditional illumination design method of street lighting is used with LED lights. In this situation, the visibility of pedestrian is significantly reduced and it is difficult to find barriers on the road surface because of the non-uniform luminance distribution in the visual field.

Our previous paper showed evacuees' performance could be predicted by visual conditions such as the luminous environment (road illuminance) and evacuee's visual acuity. Travel speed is determined by visual acuity regardless of age, with or without smoke. Whether adaptation is complete or not, travel speed decreases if the evacuee's visual acuity is less than 0.25. The visual acuity reaches 0.25 for young subjects under the condition that road surface reflectance is 0.43, the road illuminance distribution is nearly homogeneous and the average illuminance is more than 3[lx]. We finally construct a calculation model to predict travel speed and psychological state in uniform illuminated environment based on an evacuee's visual acuity. Simmons researched the travel speed under various non-uniform illuminance conditions, and showed that the illuminance distribution of floor surface didn‘t affect the travel speed. But he didn‘t carry out the visibility test under the non-uniform illuminance condition.

LED has a big potential to use in street lighting, but it is difficult to illuminate the road uniformly. If we want to predict the visibility and performance in LED street lighting using our previous research model, we should know the relationship between visibility/performance and illuminance distribution. The purpose of this research is the establishment of the appropriate utilization method of LED lights in street lighting. The relationship between illuminance distributions of road surface and visibility is dealt with in this paper.

2. Experiment

We examined subjective experiments with a scale model equipment of 1:10, which is 25m long by 5m wide by 5m high in the actual size. The road surface reflectance is 0.2 and the side reflectance is 0.1. This equipment is able to keep the illuminant conditions from entering the outside light. and has one luminous ceiling with a dimmer control, which maximum size is 24.5m by 4.5m (in the actual size, as the case may be). The size, setting position and luminous flux of the experimental illuminants are easily changed by light-blocking panels and sheets on the ceiling light.

Table 1 shows the experimental conditions. The illuminant length is 4.5m as same as the original ceiling light. We set two illuminant widths (0.1m and 0.5m) for the experimental parameter. The illuminants are set parallel, and we select from three installation intervals among illuminants (20m, 10m and 5m)

Five levels of average illuminance on the road surface are set by reference to previous researches: 0.1, 0.3, 1, 3 and 10[lx]. Under 3[lx] or less that visibility and travel speed begin to decrease, we also set uniform illuminance conditions using the original ceiling light. Figure 1 and 2 show illuminance distributions under 1[lx] of average illuminance on the road surface. The illuminance distribution of the central under the illuminant condition of 0.5m width and 5m interval is similar to one under the uniform condition.

A Subject adapts the illuminance level as same as the average illuminance on the road surface in a front chamber for 5 minutes. After that, the subject watches the street lighting made in this experimental equipment, and evaluates the visibility of road surface (1=no problem, 2=a little difficult to see, 3= difficult, 4=very difficult, 5=unable to see) and the fear of walking the street (1=no problem, 2= a little uneasy, 3=uneasy, 4=significantly uneasy). We put three different reflectance gray sheets on the road surface of center per 5m intervals. Their luminance contrast with road are 0.10, 0.34 and 0.57. In order to measure the visibility threshold of the subject, the subject answers the farthest visible gray sheet by reflectance.

In order to grasp qualitative relationship between illuminance distribution and visibility, three subject number is limited to three. All experimental conditions were showed to the subjects once in random order.

3. Results

In analyzing experiment results, non-uniform illuminance distribution is quantified by the space frequency characteristic which is represented as the illuminance range from the maximum to the minimum and the cycle per unit distance. Although there is considerable variation among three subjects' results, we extract the application range of illuminance distribution and average illuminance on road surface which can obtain visibility similar to uniform condition.

4. Conclusions

LED lights are not only energy-saving but also easily-worked for varied lighting equipments. Therefore we can adjust design of LED appropriately to a completely different design method for street lighting from the standard design method with other traditional light sources. The range in application of the illuminance distribution and average illuminance on the road surface which is equivalent of visibility to the uniform conditions will be beneficial as materials for the street lighting design with LED lights.

PP127

LUMIROUTE : OPTIMISATION OF ROAD SURFACES REFLECTION PROPERTIES AND LIGHTING

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3. Spie Batignolles énergie - Borja, Toulouse, France.
4. CERTU, Lyon, France.

For the 5th edition of the call for proposals launched by the French Ministry of Ecology, Sustainable Development, Transport and Housing (MEDDTL) to support actions in favour of innovation, „Lumiroute“ project driven by Malet, manufacturer of road surfaces with the partnership of Spie Batignolles énergie - Borja and of the lighting manufacturer Thorn, was named the winner in the theme: „ Materials and sustainable equipment“.
A significant reduction of energy consumption is made possible thanks to the optimisation of the association ‘road surface – luminaires’. The aim of Lumiroute project is to prove it on site with a practical experiment during several years.
This unprecedented collaboration between the world of light and the manufacturers of road surfaces will benefit, from an environmental perspective, to the development of eco-districts. The project theoretically allows a reduction in power consumption by more than 40% compared to the current high performance modern lighting facilities used widely.
Indeed, the conventional technique of optimisation of a lighting design by focusing only on the choice of optical and electrical control is no more sufficient. Until now, the real nature and the changes of road surfaces over time were ignored in lighting (essentially by lack of solution to overcome them). However the road surface is a key element in lighting calculations. In fact, adapting optical part and light distributions of luminaires to different types of road surfaces initially and along their lifetime is a challenge. This is the trend in order to limit energy consumption and also obtrusive light realised in a very promising research.

Technical Summary of the Project for the CIE presentation.

The design of functional road lighting installations is defined mainly by the luminance level and uniformity of the road surface. Electrical power consumption thus depends directly upon optical parts of the luminaires adapted to the reflection properties – brightness and specularity – of the road surface.

The first step of the project was therefore to identify the best promising associations between different road surfaces samples, provided by Malet, and a lot of available or simulated light distributions of luminaires, provided by Thorn. Then a process that allows managing the luminous flux and the light distribution in space of the luminaires to the aging of the road surface is defined in order to maintain the standard requirements needed with minimum waste of light and energy. Luminaires using LEDs and variable light distribution lead to this best optimisation.
The results of the preliminary study are satisfactory and the winning project is currently being

tested on a real site under the authority of the Scientific and Technical Network of MEDDTL: the CERTU.
The evaluation is based, not only on photometric requirements of lighting level and uniformity, but also on glare evaluation, energy consumption, slipperiness of the road surface, acoustic impact, and financial feasibility of the project.

If the results of the experiment are conclusive, the Ministry will issue a „certificate of successful completion or label“ validating definitively this project.

Luminaires + Road surface = optimised road lighting

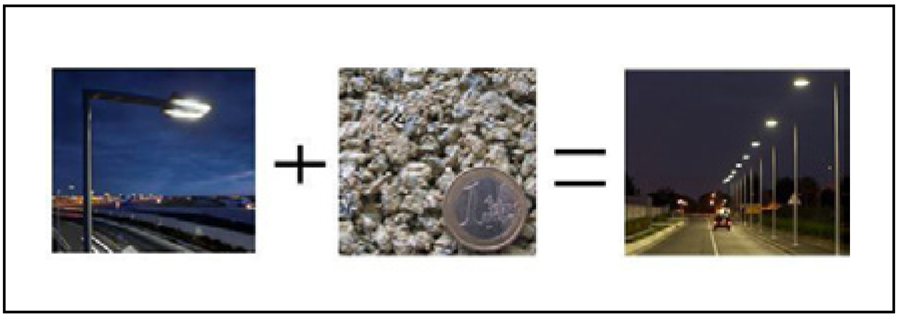

Figure 1 - Luminaires + Road surface = optimised road lighting

PP128

THE STUDY OF REFLECTANCE FACTOR'S DISTRIBUTION OF FALLEN OBJECTS AND THE INFLUENCE ON VISIBILITY

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[2.] West nippon expressway company limited, Osaka, Japan.
[3.] Panasonic corporation, Tokyo, Japan.
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[5.] Nexco-east engineer company limited, Tokyo, Japan.

It is important for road lighting to ensure visibility which is required for traffic safety, and the critical object with the size of 20x20cm and reflectance factor of 20% is used for visibility study. The reflectance factor was found from the study of pedestrians' clothes by Smith. Since 90% of the clothes have reflectance factors with less than 20%, it has been believed that 90% or more objects could be recognized visibly by ensuring the visibility of objects with less than 20% reflectance under silhouette vision. However there would be no pedestrians for the case of motorways, which means the reflectance factors of the critical object should be targeted to fallen objects on road rather than pedestrians.

The study was made to find the actual reflectance factors of fallen objects on the motorways in Japan 40 years ago, and it was found that the cumulative probability of the existence with less than 20% reflectance accounts for 70% and there were more objects with 20% or more reflectance than the study done by Smith. This result shows reversed silhouette vision should be considered for the evaluation of visibility of fallen objects. The further study was made 10 years ago to investigate the reflectance factors of fallen objects (5,700 samples) for two seasons and motorways, and the cumulative probability of the existence with less than 20% reflectance was found to be 65%. Fig.1 shows the result of both study, and the distributions were not very much different as far as fallen objects on motorways. Therefore, it is appropriate that "NEXCO Curve" based on the actual study above mentioned, shown in Fig.2, be applied to study visibility of fallen objects on motorways.

Since there are more objects with higher reflectance factors on motorways, visibility can be evaluated appropriately by using total revealing power (TRP) which is the addition of probability of correct perception of both silhouette and reversed silhouette vision. We calculated the TRP for some case of a tunnel section by using Curve A and B in Fig.2.
Table 1 shows the average TRP, and TRP of Curve A is 87% while TRP of Curve B is 72%. This difference is due to less low reflectance objects in Curve B. Therefore, the TRP tends to be small in case of road lighting design based on silhouette vision where relatively more percentages of higher reflectance objects are expected. It is necessary that pro-beam lighting, which is effective for high reflectance, would be considered in order to improve TRP.
We propose the need of reflectance factors based on actual field data since motorways have different distributions from general road, and it is important that total visual design be performed considering the distribution of the reflectance factors and reversed silhouette vision.

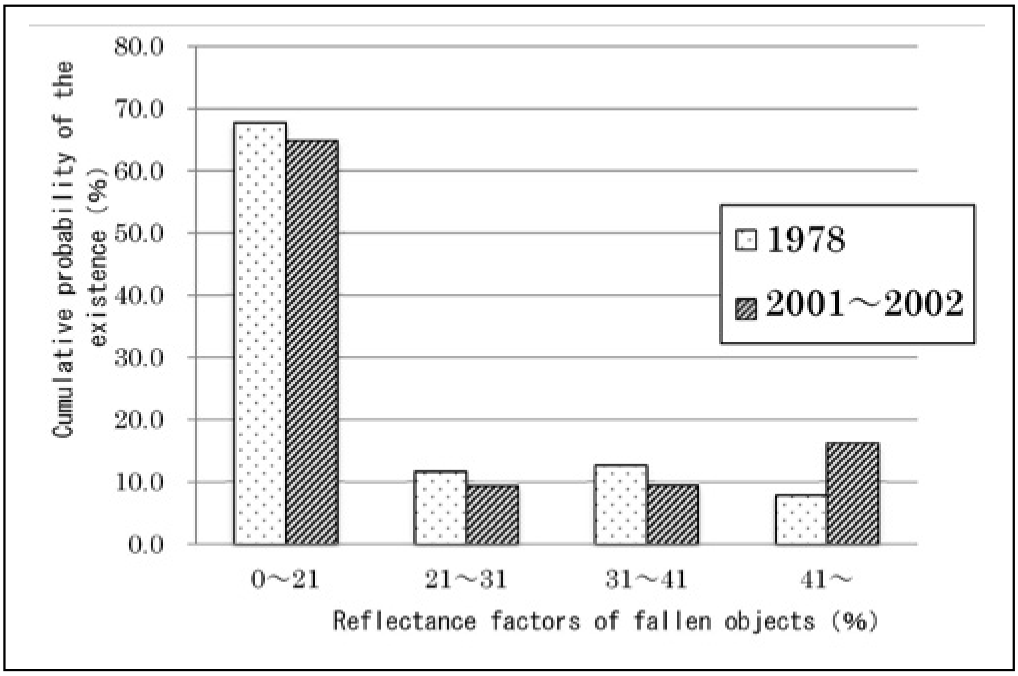

Figure 1 - Distribution of reflectance factors of fallen objects

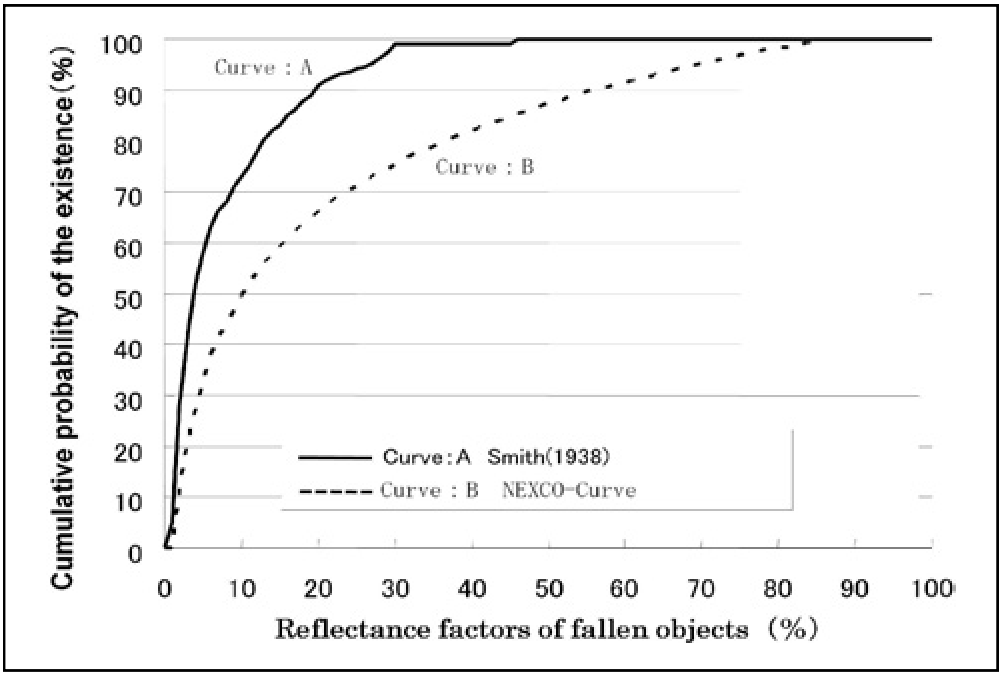

Figure 2 - Cumulative probability of the existence

	Overall uniformity ratio	Longitudinal uniformity ratio	TRP ave(%)
A(Smith)	0.60	0.69	87
B(NEXCO)	0.60	0.69	72

Table 1 - Example of TRP for Curve A and B

PP129

APPROXIMATION OF ROAD SURFACE LUMINANCE COEFFICIENT

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Luminance coefficient is the most important characteristic of a road surface. It is used in computations of lighting design criteria specified by the lighting standards, namely, an average luminance, overall and longitudinal luminance uniformity on a road. Presently, this characteristic is presented in the r-tables of reduced luminance coefficient for different types of road surfaces. The report suggests an analytical approximation, based on ellipsoid of revolution model, of the relationship between luminance coefficient and incident and observation angles. This approach leads to sufficient decrease of data needed for description of luminance coefficient and further computations, and makes the measurements of the luminance coefficient less laborious due to reduction of number of parameters to be measured.

D4 - Lighting and Signalling for Transport
Tunnel Lighting

PP131

VISIBILITY OF THE CRITICAL OBJECT AND ENERGY EFFICIENCY OF PRO-BEAM LIGHTING FOR TUNNEL INTERIOR LIGHTING

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4. Nippon expressway research institute company limited, Machida, Tokyo, Japan.

In CIE publication No.88 (2004), road surface luminance for the tunnel interior lighting is recommended to secure mainly visibility of the critical object. Also, CIE publication No.31 (1976) shows that visibility of the critical object depends on uniformity of the road surface luminance distribution. This result was derived from research of visibility for road lighting conditions by Narisada (1971). Road surface luminance recommended by CIE is value in the condition of uniformity 0.4. Therefore, in the condition of higher uniformity, there is possibility that lower road surface luminance is able to be adopted, and energy saving for the tunnel interior lighting is expected.

On the other hands, in the conditions of heavy traffic volume and high design speed, visibility of the preceding cars is important too. And it depends on the vertical illuminance of the rear end of the preceding cars (2011). In other words, in case of decreasing road surface luminance as uniformity becomes higher, vertical illuminance for the identification of the rear end of the preceding cars becomes critical factor. Therefore, pro-beam lighting system, which is able to derive higher vertical illuminance of the rear end of the preceding cars than symmetrical lighting system, is useful for conditions mentioned above. However, even if visibility of the preceding cars is assured by pro-beam lighting system, it is worried visibility of critical object worsen. Generally, visibility of the critical object for tunnel lighting is estimated based on visibility of silhouette vision which is situation that road surface luminance is higher than luminance of critical object. Because, the relationship between the reflectance of the object and the revealing power by Smith (1938) is adopted to estimate visibility of the critical object.

The total revealing power considered both visibility of silhouette vision and reversed silhouette vision was suggested by Harris et al (1951). And, Okada et al (2005) showed visibility of the critical object is roughly constant, even if vertical illuminance increases. On the other word, visibility of the critical object is secure even if pro-beam lighting system is adopted for tunnel interior lighting. So, we studied the visibility of the critical object of pro-beam lighting system for tunnel interior by total revealing power. Firstly, lighting characteristics, road surface luminance, vertical luminance and equivalent veiling luminance and so on, were measured in the practical tunnel installed two types of luminaires which have luminous intensity distribution for pro-beam lighting system and symmetrical lighting system each other. These lighting situations are shown in figure 1 and figure 2. Then, the luminance difference thresholds of silhouette vision and reversed silhouette vision were calculated using these results of measurement by simulation model of the luminance difference threshold for non-uniformity luminance distribution suggested by Narisada (1977) and contrast polarity factor suggested by Adrian (1989). Then, total revealing power, which calculated

using the relationship between the reflectance of the object and the revealing power investigated on express high way in Japan (2007), of both lighting systems is considered. And, results of the observation experiments on the visibility of the critical object took place in the practical tunnel mentioned above were investigated too. Furthermore, energy efficiency of pro-beam lighting system is studied. These results show in our full paper in detail.

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Figure 1 - Pro-beam lighting system

Figure 2 - Symmetric lighting system

PP132

VISIBILITY EVALUATION OF TUNNEL LIGHTING TAKING VEHICLE HEADLAMPS IN CONSIDERATION

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Introduction

Historically, visibility of objects on the road in road lighting has been considered with silhouette vision as a general rule and road lighting has not been designed with consideration of influence of headlamps of vehicles. It is estimated that visibility of objects is reduced due to lowering of contrast with background road surface when they are illuminated by an vehicle headlamp. The pro-beam lighting system is a system of directing maximum optical axis to the same direction of driving to highlight objects themselves (reverse silhouette vision) by raising vertical illuminance of objects and vehicles on the road (CIE88, 2004). However, since pro-beam lighting system is said to require more electricity than symmetrical lighting system in order to secure road surface luminance, it has had a challenge from view point of energy-saving. Since performance of vehicle headlamps is expected to improve further by technology innovation of LED, etc., establishment of integrated visibility evaluation method can be said to be an urgent challenge. This is a report of theoretical and experimental study with Revealing Power (Waldram,1938) as a visibility of tunnel lighting installation for which vehicle headlamps are taken in consideration.

Theoretical Study

Theoretical study was conducted under the conditions shown in Table 1.
(Calculation of Total Revealing Power (Harris et al.1951, Karasawa et al.2007))
Threshold reflection factor (ρS (%)) of target of 20cm square for silhouette vision is calculated with luminance difference threshold (ΔLmin), obtained from its background luminance (Lb) and equivalent veiling luminance (Leq) from the luminaire, and vertical luminance (Ev) at a point (Equation 1).

$\rho S = \pi *(Lb-\Delta Lmin)/ Ev$ (%)(1)

Cumulative probability of the reflection factors (Ps__threshold) corresponding to this ρS (%) is obtained from the reflection factor surveyed in 2002 with fallen objects on express highways in Japan (Sugawara et al.2002). In the same manner, cumulative probability of the reflection factors (PRS_threshold)is obtained from threshold reflection factor (ρRS (%)) for reverse silhouette vision. Total Revealing Power (TRP) is the total sum of cumulative probability of the reflection factors of target visible by silhouette vision and reverse silhouette vision (Equation 2).

$TRP = RPS + RPRS$ (%)(2)

When vertical illuminance (Ev_HL; 13 lx at the height of 0.1 m of a target) of a vehicle headlamps is added to this, threshold reflection factor for silhouette vision becomes as shown in equation 3 below.

ρ S_HL = π*(Lb-ΔLmin)/(Ev+Ev_HL) (%)(3)

Total area ratio (TAR) is the percentage area of a portion or portions of the road surface where Revealing Power is higher than a specified percentage value (for instance 70%) for the whole road surface area (Narisada et al. 2003). From Table 1, when cases where headlamp is on and off are compared concerning TAR of symmetrical lighting system and pro-beam lighting system (TRP≥70%) (field factor 6), while it is 63% for symmetrical lighting system and 68% for pro-beam lighting system when headlamp is off, it was 50% for symmetrical lighting system when headlamp is on, about 20% lower than when headlamp is off (Fig. 1). On the other hand, it was 70% for pro-bean lighting system showing little difference. In other words, in the case of symmetrical lighting system, it is suggested that visibility of lighting installations is reduced by vehicle headlamp.

Experiments in an actual tunnel

In Shiratori tunnel of Takamatsu express highway, the visibility of targets of 20cm square with the reflection factor of 5 - 30% was evaluated in the zone where two types of lighting system (symmetrical and pro-beam). Visibility of targets was assessed in 5 levels from “invisible” to “highly visible”. Table 2 shows the result of visibility of targets with the vehicle headlamp on and off for the two lighting systems. While result of evaluation for pro-beam lighting system shows little change by on and off of headlamp, visibility of targets was reduced by turning headlamp on except for reflection factor of 5% in the case of symmetrical lighting system. These results support the result of theoretical study.

Conclusions

It is important to take vehicle headlamp in consideration in road lighting design. In the present study, symmetrical lighting system showed tendency of reducing visibility of object on the road by addition of vehicle headlamp. Although pro-beam lighting system is considered to be one of the solutions because visibility is not reduced by headlamp, it is required to perform comprehensive evaluation verifications on the visual performance and the environments.

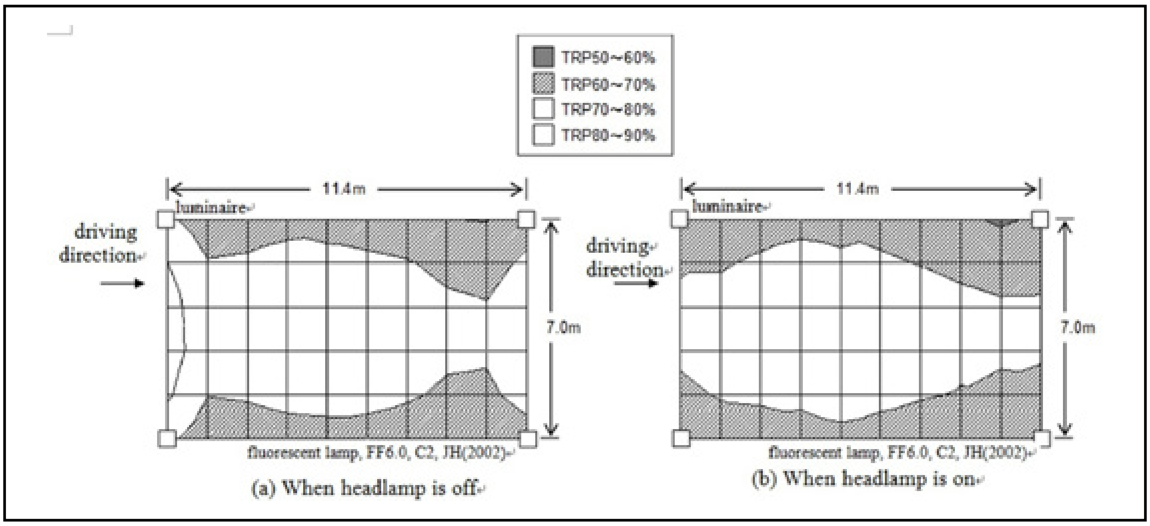

Figure 1 - TRP distribution of fluorescent lamp

Figure 2 - Tunnel lighting (left: when headlamp is off, right: when headlamp is on, fluorescent lamp)

	Symmetrical lighting system	Pro-beam lighting system
Number of lanes	2 lanes (3.5m×2)	
Light source (Kind, wattage)	Fluorescent lamp (50W×2)	Ceramic metal halide lamp (35W)
Lighting installation conditions (height, spacingl) (m)	4.8m, 11.4m	4.8m, 20m
Arrangement	Opposite	
Vertical illuminance (lx)	18/31	71/84
Average road surface luminance (cd / m^2)	2.25/2.25	0.76/0.76
TAR (TRP≥70%) (%) (field factor 6.0)	63/50	68/70

Table 1 - Calculation results for lighting systems

		Symmetrical lighting system	Pro-beam lighting system
Optical property	Vertical illuminance (lx)	18/31	110/123
	Average road surface luminance(cd/m^2)	1.1/1.1	0.8/0.8
Result of question-naire on visibility	target reflection factor 5%	1.5/2.9	2.8/2.9
	target reflection factor 10%	2.3/1.8	4.3/4.3
	target reflection factor 20%	4.0/1.0	4.6/4.7
	target reflection factor 30%	4.1/1.3	4.8/4.8

Table 2 - Optical measurement in an actual tunnel and result of questionnaire

PP133

DETERIORATION PREDICTION IN CONSIDERATION OF THE DIFFERENCE IN LIGHTNING TIME OF A TUNNEL LIGHTING EQUIPMENT.

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In the infrastructure assetmanagement, it is an important issue to make a decision on the optimum maintenance strategy which can minimize life cycle cost. In addition, it is necessary to predict the repair demand of civil engineering facilities in the future and formulate the budget planning for maintenance and repair. When carrying out asset management, the deterioration prediction model of civil engineering facilities plays an important role, in order to estimate life cycle cost and repair demand.

Time-related deterioration always follows also about various kinds of road incidental facilities installed on the highway, so the deterioration forecasting is required. For example, as for the tunnel lighting equipment which is one of the road incidental facilities, we would like to estimate deterioration path and expected life time, and to determine the optimal replacement timing based on estimation result. About the expected life time of it, generally, the value (catalog value) which each maker calculated by various examinations exists. However, in the actual lighting under severe environment like in a tunnel, many cases where deterioration is progressing early exist rather than a catalog value. Therefore, it is necessary to utilize actual inspection data and to calculate the expected life time based more on the actual condition. Furthermore, tunnel lighting differs in lighting time with lighting classification or an installation position and it is pointed out that an expected life time is different by that cause.

Therefore, in this study the authors formulate deterioration process of tunnel lighting based on Weibull hazard model, and propose a its estimation method using actual visual inspection data.
Moreover it estimated that based on the visual inspection data of lightning of tunnels in service. The estimation result is shown in the table. When estimating, the kind of lighting (a fluorescent light and a sodium lamp) and the difference in lighting time were used as an characteristic variable. So it became possible to estimate the survivor function and expected life span (line in which survival probability is below 50%) by difference of each deterioration characteristic. As a result, as shown in figure, it turned out that the expected life time of a fluorescent light is short as compared with a sodium lamp. Moreover, about the sodium lamp, it was shown clearly that an expected life time becomes short as average candlelight became long.

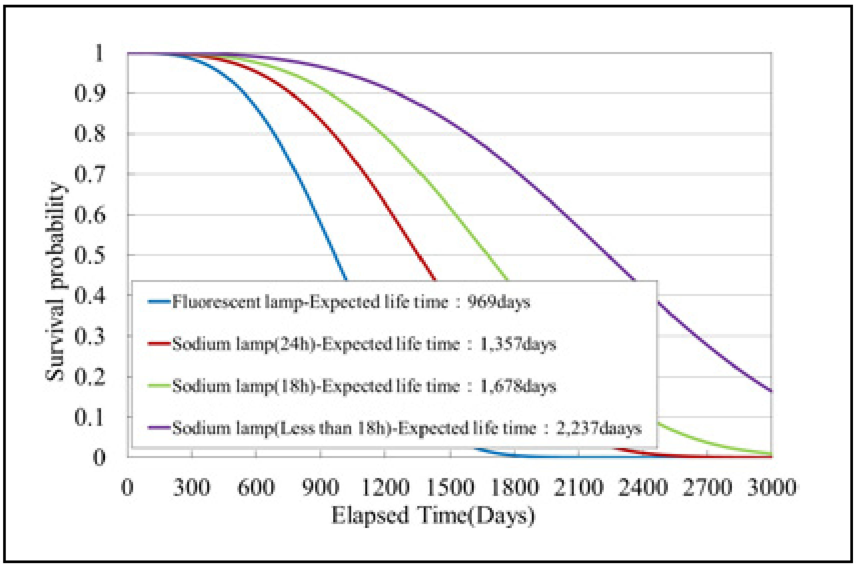

Figure 1 - Survivor function

	constant term β1	1:Fluorescent lamp 0:Sodium lamp β2	1:Lighting Time 24h 0:Otherwise β3	1:Lighting Time 18h 0:Otherwise β4	Acceleration parameter α
estimator	-25.56	1.80	1.63	0.94	3.27
t value	-52.27	20.46	22.30	11.27	50.39
log likelihood	-11737.5				
likelihood ratio	0.9977				

Table 1 - Estimation results

D4 - Lighting and Signalling for Transport
Miscellaneous

PP134

LUMINANCE RANGE AND ARRANGEMENT OF PANELS AGAINST GLARE SENSATION IN NIGHTTIME FOR CIVIAL AIRCRAFT COCKPIT LIGHTING DESIGN

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The safety in nighttime flying highly depends on the reasonable lighting design. The luminance range of luminous devices, such as the display screens, panels and PBAs (illuminated push button and switches), should guarantee the discrimination of the information delivered by themselves as well as the visual comfort for the pilots. The glare in the visual field during nighttime flying is a potentially insecure problem for the pilots as it destroys the adaptation level and causes psychological discomfort. With this object, we will conduct a study to establish the proposed luminance range and arrangement of the panels which are prone to cause glare in the cockpit based on the typical windshield form.

Experiments upon participants' visual performance, subjective evaluation along with physiological monitoring will be designed to explore the influence of glare sensation from panels and their reflections on the windshield. Key parameters including the location, orientation, size, luminance etc. of the panels and their reflections on the windshield will be selected as variables. Typical visual and body tasks will be arranged and fulfilled by ergonomics software. Together with the subjective evaluation and measurement of the physiological parameters, multiple dependent variables can be obtained to be used as the indexes to reflect the effects of glare, such as the detection rate, reaction time, rating score, level of sight distraction and some electrophysiological parameters. The whole experiments will be operated with highly simulated apparatus within a simulated cockpit in a dark room, as shown in Fig. 1.

According to the experiment results, the relationship between the independent variables and the multiple indexes can be established. And based on this, the luminance range and the arrangement of the luminous devices on the panels will be proposed, which can be used as the guidelines and verification of the lighting design for the commercial aircraft cockpit.

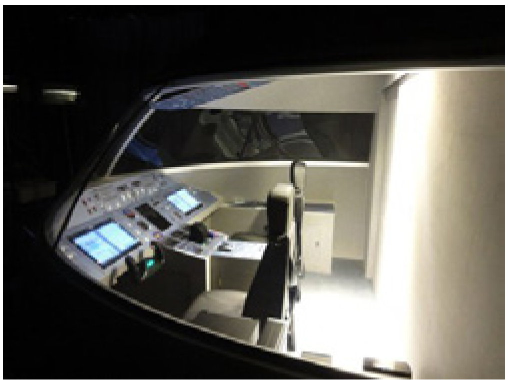

Figure 1

D5
Exterior Lighting

PP136

RHYTHM OF LIGHT CREATED BY STATIC LIGHT PATTERNS

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1.INTRODUCTION

It is natural that we discuss rhythm in relation to lighting caused by variations in daylight, circadian rhythm and time- controlled changes in illumination. However, this paper aims to show that we also can discuss and plan light with departure in rhythm created by static light patterns. A conscious light planning with rhythm in consideration is beneficial for spatial understanding, architectural experience and orientation. This paper shows a possible way to work with rhythm of illumination in spatial analysis and provides a ground for developing future studies and a notification system for rhythm analysis in lighting design.

The following questions will be answered:
-How is it possible to speak about rhythm by static patterns of light?
-Which methods of rhythm analysis are available and can be further developed?
Rhythm is usually connected with movement and the passage of time. However, distribution of light creates, together with light level and colour of light, a rhythm that we experience when walking or driving through a space. In lighting, rhythm deals with distance: the extension of light and distinct pauses of darkness that appear between the illuminated areas. Repetition of illuminated areas is seen as patterns, with distances in length, width and height. Uniform lighting does not have rhythm in the same way as non-uniform lighting does. Imagine a night view with a row of streetlights of equal distance between luminaires, illuminating the facades along the street. If some of the facades are darker and less reflective than others or if the row of buildings is broken by a path with vegetation, we will have a pause in the rhythm.

2.PREVAILING KNOWLEDGE

Connections and similarities between rhythm and architecture are described by Dyrssen (Dyrssen, 1995). Similarly, Hopsch describes spatial 'rhythmisation' of form sequences (Hopsch, 2008). Repetition of forms creates rhythmic patterns in architecture (Rasmussen, 1959). Lefebvre has developed a theory for rhythmic analysis that deals with repetition of dimensions and frequency in city environments, including cyclic rhythms regarding place, time and energy (Lefebvre, 2004). Madsen developed the term light zones to describe the spatial units made from light within the space. Consequently, Madsen describes dark zones as pauses in an illuminated space (Madsen, 2006). Lighting designers and architects like Millet and Michel describe rhythm in lighting in similar ways (Millet, 1996, Michel, 1996). The relationship between rhythm and lighting is also confirmed by Bülow's PhD thesis on light and rhythm in architecture (Bülow, 2007). Bülow describes a case study where the rhythm is created by a pedestrian walking beneath differently coloured luminaires on a subway platform.

3.DEVELOPING A NOTIFICATION SYSTEM FOR RHYTHM ANALYSIS

There are several established methods for spatial analysis that are useful for rhythm analysis, for example the combination of the mapping methods of Lynch (Lynch, 1960) and Branzell's sketching method of experienced spatial extension and directions (Branzell, 1995). Lynch method focuses in finding paths, key nodes, borders, transitions, areas and landmarks. Additionally, Trieb's method for town analysis can be used as a guide to find the height for the luminaire placements (Trieb and Markelin, 1977). Furthermore, Cullen's serial visions method, in which one draw or take a photo of each substantially new view during a movement in space helps to analysis sequences (Cullen, 1961). With these methods as a base, a notification system for rhythm analysis in illumination is planned to be developed (see table).

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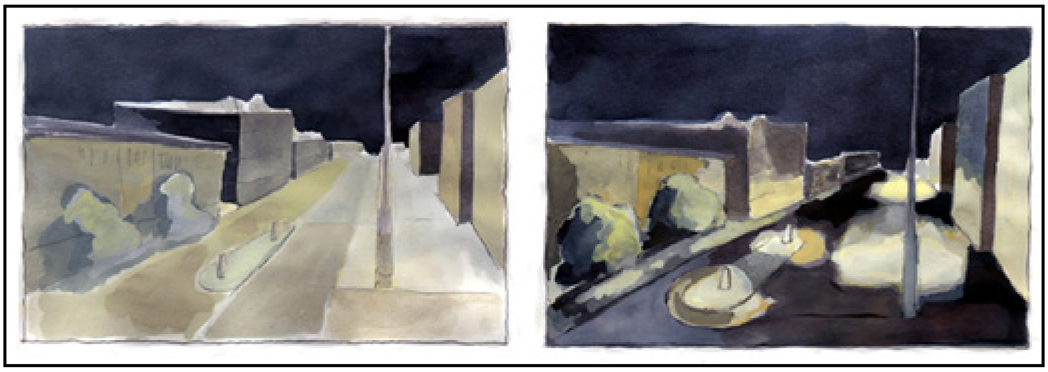

Figure 1 - Uniformity vs. non-uniformity

Figure 2 - Light topography

Uniformity vs. non-uniformity of distribution of light
Dynamic of light (light levels)
Distances between light zones/luminaires in length and width
Light topography (e.g. height of luminaire placement)
Directions of light
Spread of light
Sizes of light zones
Numbers of light zones/luminaires in groups
Compound and separated light zones
Vertical and horizontal light patterns
Asymmetry and symmetry of light zones/luminaire placements
Dark zones ("pauses")
Soft and hard contrasts(gradients and transitions)
Accents, like landmarks and important nodes

Table 1 - The notification system is planned to include:

PP137

SUBJECTIVE IMPRESSIONS AS QUALITY INDICATORS OF AMBIENT LIGHTING

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Manufacturers broadly recommend LED technology for application in all areas of urban lighting. Even though LED lighting has justified its expectations in the field of architectural lighting, for street and ambient lighting further research is still needed, due to the fact that some independent analyses showed that the declared LED performance regarding their life and energy efficiency is questionable. Another questionable point is represented by the statements of the LED manufacturers that LEDs cause subjective impressions which are better than in the case of conventional lamps. In order to evaluate the latter statement, a survey was recently conducted in Belgrade.
Research dealing with subjective impressions in urban lighting is scarce and often inadequate in terms of 1) set-ups, which include different lighting types but without a common condition like the requested illuminance level or colour of light, 2) respondents who are not familiar with the field of lighting and the commonly used terms, and 3) the questionnaires, which do not include all of the relevant aspects. Therefore, our research was based on a comprehensive comparison of the subjective impressions of ambient lighting realized by metal-halide (MH) and LED lighting installations with comparable illuminance level and colour of light. In our opinion, the comparison between lighting installations realized by high-pressure sodium (HPS) and LED luminaires would not be sensible in ambient lighting where colour of light and colour rendering greatly influence the quality of the illuminated space. The research included educated participants able to understand the specific photometric terminology: 49 respondents with healthy eye sight and familiar with the field of lighting through courses they took at the Faculties of Architecture or Electrical Engineering (University of Belgrade).

The case study was carried out in a Belgrade park, on a paved pedestrian lane of sufficient length. The lane is located in the center of the park and in its immediate surroundings there are no other public lighting luminaires.

The pilot installation was realized on the existing public lighting poles 3.8 m high, from which the existing luminaires with HPS lamps were previously removed. The same type of luminaire was used for both lighting types. Luminaires contained a matt diffuser which disabled recognition of the light source. Therefore, the respondents did not know the type of lamp used in either lighting installation. The first four luminaires in a row (representing lighting type 1) had warm white (3000 K) 70 W MH lamps with a ceramic discharge tube (luminaire power: 80 W). The second sequence of four luminaires (representing lighting type 2) was realized with LEDs (32 warm white (3000 K) diodes). Since the power of each LED luminaire was 53 W, energy savings of 34% were achieved. On the two existing poles located between the two lighting installations no luminaires were installed in order to eliminate the influence of one type of lighting on the other.

Both lighting types were realized by lamps of excellent colour rendering (CRI>80). The matt diffu-

ser equally influenced the reduction of glare for both lighting types, which was in favour of the LED installation because in practice LED chips are often visible and cause intensive glare.
In order to enhance the validity of the comparison of the subjective indicators, it was necessary for the basic photometric indicator, illuminance level of the pedestrian lane, to be approximately equal in both cases. For lighting type 1 the illuminance level was 11.1 lx, and for lighting type 2 it was 10.9 lx (the number of LED chips was chosen as to enable the illuminance level to be practically equal in both cases).

The survey was conducted using a questionnaire with 13 questions identical for both lighting types, which were answered by encircling one of the offered answers 1–5 (1 for absolutely unacceptable and 5 for absolutely acceptable). Each of the first twelve questions was related to the subjective impression of a single aspect of lighting (illuminance level, uniformity, recognition of pedestrians, illumination of human faces, colour of light, colour rendering, presentation of landscape elements, glare, feeling of security and pleasantness of the ambient), while the thirteenth question was devoted to the overall lighting impression.

The analysis of the obtained results showed that the average mark for all 12 questions amounted to 4.16 for lighting type 1 and 3.28 for lighting type 2. Since the average mark for question 13 (regarding the overall impression) amounted to 4.25 for lighting type 1 and 3.25 for lighting type 2, an exceptional consistency in the answers of the respondents was noticed.
The respondents rated their impression of lighting type 1 (with MH lamps) as better regarding all aspects! The ratio of the marks for each question given to lighting type 1 versus lighting type 2 belongs to the range of 1.19 – 1.53, the average ratio being 1.27, with only one exception: the question referring to the subjective experience of glare, for which both lighting types received approximately the same mark.

As most significant, the respondents marked questions regarding the feeling of security and comfort in the ambient, and then questions referring to the illuminance level and uniformity.
The direct question ″Which lighting type do you prefer?” confirmed the overall impression of the respondents about the two lighting types. Even 44 out of 49 respondents (89.8%) preferred lighting type 1 with conventional MH lamps.

PP139

INVESTIGATION ON RESIDENTIAL LIGHTING STATUS IN PART AREA OF CHINA

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It is known that about 20% of the electricity generated in the world is dedicated to lighting applications. Of these, residential lighting plays a crucial role for its impact on issues such as energy saving, environmental protection as well as individual health. In the design of residential light environments, the amount of illumination required, color temperature, and spectral power distribution of lamps are all important considerations. Therefore it is highly required to understand the lighting condition and energy efficiency level. In this work, practical investigation of residential lighting situations was carried out in part area of China and the results are reported.

The investigation was lasted 5 months from November 2011 to March 2012, and involved 475 households with features of different eras, layouts and styles in China. The investigated houses covered that of staffs and students of Dalian Polytechnic University, covering provinces of Liaoning, Zhejiang, Hebei, Shanxi, Henan, Inner Mongolia, etc. There were 275 questionnaires for resident-self measurement and 145 questionnaires for household measurement. The number of effective questionnaires is 401. The contents of residential investigation include the family structure, residential type, residential pattern of the plan, lighting arrangement plan, illuminance level measurement in each room of residence, color temperature, uniformity of illuminance, brightness ratio between two rooms, light source saving energy and control mode, lighting power consumption. Figure 1 shows the family structure, household type, architectural time and residential area. We performed a statistical analysis on the use of the light source of incandescent lamp, fluorescent tube, compact fluorescent lamp and LED. The percentage of above light source is 50%, 20% -30%,10%-20%,1% -4% respectively, which are utilized in five function rooms including living room, bedroom, kitchen, dining-room and toilet.

The daily total power consumption of residential lighting is calculated by the product of the lamps total power and the work day. An average of energy consumption is 434W. The maximum value of power consumption is 1800 W, minimum of 60.5 W, and middle value is 370 W. The lighting power consumption is distributed universally in the range of 200 W -600 W.
As to lighting conditions, the average illuminance, color temperature and uniformity radio of illuminance in each residential room were investigated. The illuminance in five rooms was measured by illuminance meter at five test points, one point in the room center and other four points apart from wall distance are 70cm, the height is 80cm. 60% percentage of illuminance value in five rooms is between 0 Lx and 50Lx, 20% in the range of 50Lx-100Lx. It is found that the proportion of living-room illuminance meeting the national standards only accounted for 11.6%, the bedroom occupied 8.3%, the kitchen occupied 4%, the dining-room occupied 4.1%, and the toilet accounted for 7.8%. The illuminance level illuminance should be greatly improved. The color temperature of light source is divided into 4 levels: white, warm white, warm yellow, cold white. White light is used most in the proportion of 60%-80% in five function rooms, followed by warm white and warm yellow, cold white is used at least with less than 6%.

At the same time, the existing lighting problems in residential lighting situation proposed by residents are summarized. More than 40% of people think brightness is not yet adjusted. More than 35% of people think that lamps are not convenient to clean, and 30% of people think that brightness is uncomfortable and there is a high power consumption of lighting, about 23% of people thinks lamps have a short life and light color can't be regulated.

In a summary, the actual situations of residential lighting environment were investigated in this study. It is found that CFL is widely used in residential lighting, followed by fluorescent tube lamp, LED is mainly used for indoor scattered lighting, as an auxiliary illuminant. The value of illuminance in living room, bedroom, kitchen, dining-room and toilet in many households are below the national standards. The investigated results are reference to enhance the illumination quality of residences.

Family structure	Households	%	House type	Households	%	Building year	Households	%	House area	Households	%
Two generations of children	208	51.9	Buildings	336	83.8	Nearly 10 years	289	72.1	Less than 70 m^2	62	15.5
Couple generation	76	19.0	Bungalow	56	14.0	The 1990's	72	18.0	70 m^2 - 120 m^2	245	61.1
Three generations of childre	79	19.7	Cottage	3	0.7	The 1980's	12	3.0	120 m^2 - 150 m^2	55	13.7
Live alone	17	4.2				The 1970's	3	0.7	More than 150 m^2	19	4.7
Others	17	4.2									
Unknown	4	1.0	Unknown	6	1.5	Unknown	25	6.2	Unknown	20	5.0

Figure 1 - Basic situation of investigated households

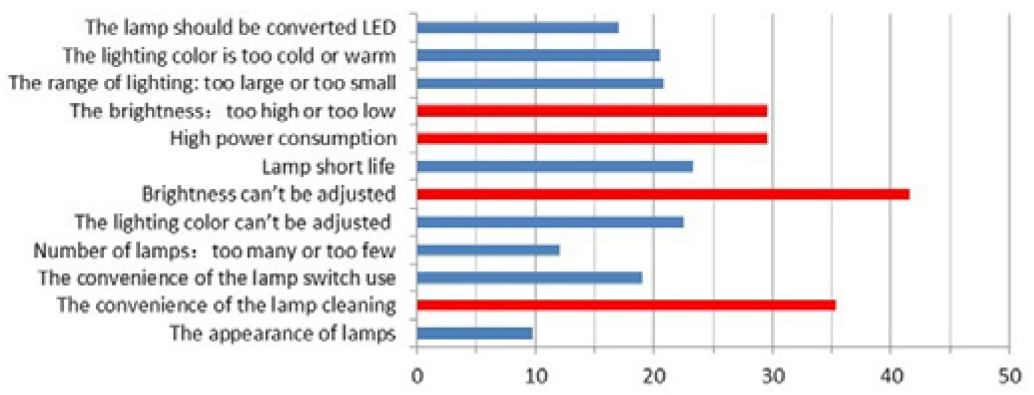

Figure 2 - Proposed problems in residential lighting

PP141

THE QUALITATIVE EVALUATION OF LIGHT QUALITY IN URBAN SQUARE LIGHTING

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With the improvement of people's life quality and the development of lighting and control technology, dynamic lighting with its multiple colors is widely used in various fields of social life and creates a colorful life for us. Currently these technology just use simple and fixed light colour control strategy and algorithm to realize light colour change, they don't interact with human activity and emotion. so far we know the light color directly impact on human psychological feelings: warm light color can make people feel warmer and exciter, cool light color make people quiet and calm. red color is easiest to stimulate people a sense of excited, cyan color is easiest to cause people calm.
By means of indoor perception experiment, we build up the quantitive relationship between dynamic light color and human emotion. In our experiment, we select 20 responds, we also select some typical color LED source to stimulate our responds and ask they feedback and comments, then we identify three main dimensions of human emotions relate to ligh color changing, one is human active and inspire, other is human feeling about life style, the third is the human comfort and relax, we also identify the range of light color directly relevant to human active and inspire, life style feeling and comfort/relax feeling.

according to our perception experiment finding, we can create the light color changing control strategy for urban square lighting to enhance human inspire, comfort and relax, it can enhance lighting atmosphere in urban suqare, at the same time, it also can create health lighting environment and improve light quality of urban landscape lighting

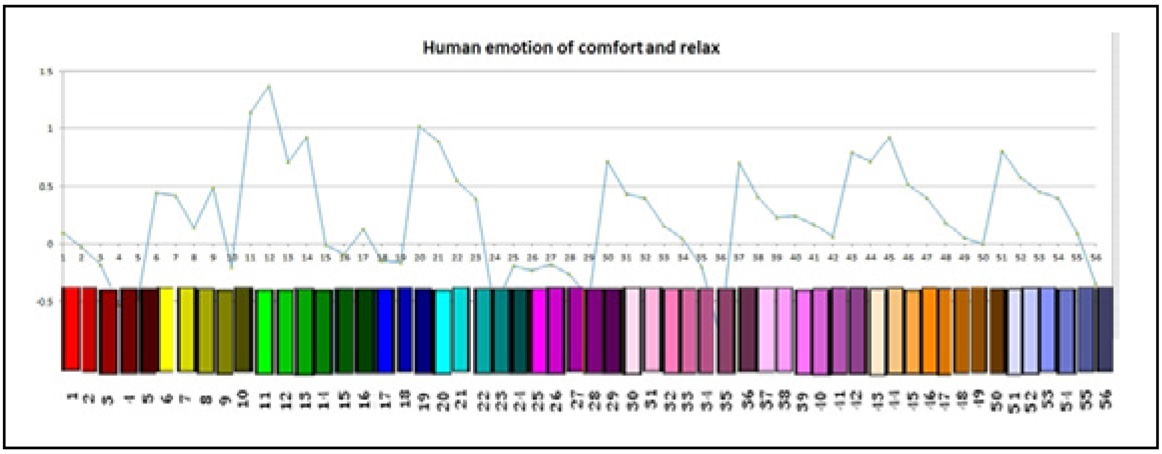

Figure 1 - Human comfort feeling and different light color

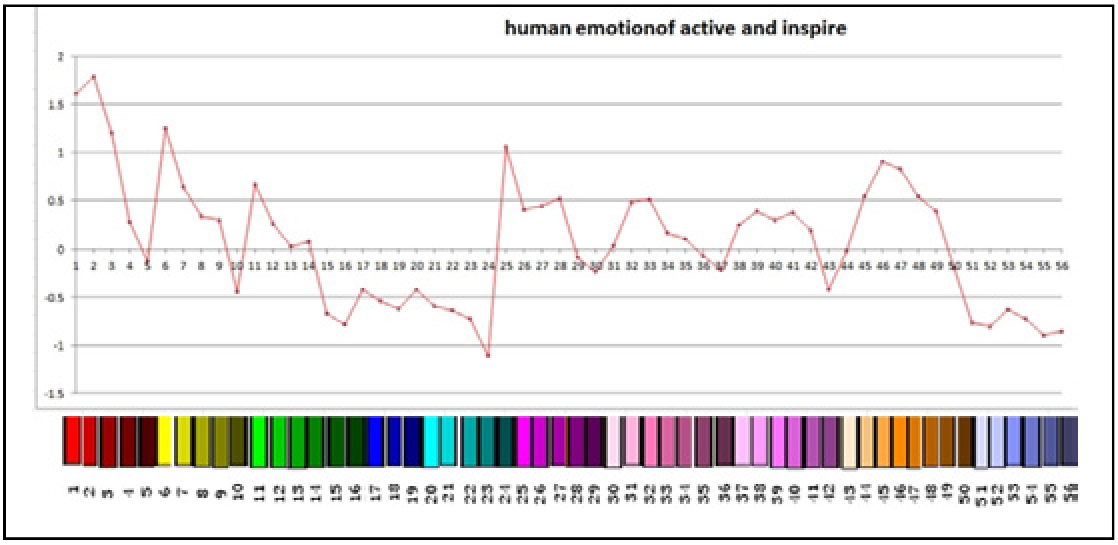

Figure 2 - Human inspiring feeling and different light color

light color	color light intensity	huma emotion
cyan	50%	lonely; peaceful; calm
blue	56%	quite
pink	63%	flat;mild;gentle
green	70%	slack; leisure/comfort
brown	76%	relax
purple	82%	fashion
orange	88%	temprate
yellow	93%	active
red	100%	Enthusiastic

Table 1 - The mapping between light color and human emotion

PP143

LIGHT AND PARTICIPATION NIGHT EXPLORATORY WALKING

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How to perceive better the feelings of the inhabitants in front of their night environnement? How to understand how they move at night, where they feel comfortable, where they are afraid...
This preliminary understanding of the "night field" is necessary to construct a project based ion the real used of the places.
Different techniques of participation do exist.
The object of the presentation is to talk about the technique of the "night exploratory walking".
This method seems to be quite interesting to reveal the complexity of the cities, all theirs dimensions and the senses (view, smell, hearing but also memory of the place)
In terms of lighting, this method seems to be suited to the night situation, because it's particularly difficult to make speak the inhabitants on that subject, except the context.
The lecture will be the occasion to talk about a few experiences of night exploratory walking organized by Isabelle Corten of Radiance35.

The first one was in 2009 in the "Cité des Coteaux" in Mulhouse in en collaboration project with Luminocité and the town planner Nicolas Michelin. This neighbourhood constructed in 1958 is suffering now of urban disqualification. The exploratory walking was the first stage to understand the needs of the inhabitants.
The second and third were in Brussels in 2010, in 2 neighbourhoods (Saint-Josse and Molenbeek) where requalification urban projects are planned.

The next ones were in Lausanne (Switzerland) in 3 different neighbourhoods, one next to the city rail station, the others one in an district where exist an vitalising program and the last one in an social house district.
The lecture will demonstrate how it's important to take time for this social approach before to design the project and conclude with the asssesment and perspectives of this method.


Voulez-vous découvrir la nuit autrement ?
La Ville de Lausanne a choisi l'agence Radiance35 pour élaborer son Plan Lumière.
Pour appréhender le territoire du quartier des Boveresses, les concepteurs lumière de l'agence proposent une méthode proche du « quotidien » et de l'usage.
La ville est multiple et fait appel aux différents sens ainsi qu'à la mémoire, il y a donc lieu de réaliser une évaluation critique de l'environnement la plus complète possible.
Pour expérimenter l'usage de l'espace public, Radiance35 invite les « acteurs locaux » à une rencontre directe avec la nuit par le biais de l'expérience collective qu'est la marche exploratoire.
Qu'est-ce que la marche exploratoire ?
Des groupes (d'environ 10 à 20 personnes), constitués d'usagers du quartier (habitants, commerçants, travailleurs, représentants de la collectivité publique, etc) parcourent à la nuit tombée, le territoire à analyser, accompagnés d'urbanistes qui recueillent les ressentis.
Tous les participants échangent, de manière totalement libre, pour essayer d'apporter ensemble la réponse la plus juste à une meilleure vie dans l'environnement urbain nocturne d'aujourd'hui.
La marche en elle-même, comme expérience collective, est un outil de revalorisation du quartier. Pour les habitants, porter un autre regard sur leur environnement est un premier pas de réappropriation du quartier.
Venez participer à l'expérience collective de la marche exploratoire
aux Boveresses le 1 er septembre 2012 à 21h30

Figure 1

D6
Photobiology

PP145

ECO-FRIENDLY COLOR TUNABLE LED OFFICE LIGHTING INCORPORATING CIRCADIAN PHYSIOLOGY

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INTRODUCTION

Great East Japan Earthquake occurred in March 2011. It raises a question about the safety of nuclear power plants in national scale and forces them to stop the operation. As a result, Japan has been under energy crisis and it may last for some more years.
Under the situation, office lighting has been attracting attention as a source of energy saving. Based on Japanese Industry Standard, general office lighting has been designed so that horizontal illuminance on a desk can be 750 lx or more. In most offices, the illuminance level is not reduced all through the day even if it's late evening. This lighting standard in Japanese office could consume more energy than ones in western countries and there have been some arguments if we should reduce the illuminance level or not.
The lighting standard has mainly been considered from the viewpoint of visibility. Recently, however, many studies have revealed Non Image Forming effects of light on circadian rhythm (sleep/wake, melatonin and core body temperature). Now it is well known that light is an essential cue of circadian synchronization and promotes alertness in daytime. Therefore, lowered lighting without enough consideration could lead to deterioration of productivity and health status.
Meanwhile, LED lighting fixtures have rapidly been acquiring the popularity in Japanese office lighting. In addition to contributing to energy saving, LED has another advantage in the effect on circadian rhythm. Many scientific evidences prove that short wavelength light is essential for circadian regulation. Consequently, color tunable LED lighting system which can create circadian rhythmicity of short wavelength light could be ideal in order to achieve a good balance between energy saving and healthy lighting.
The aim of this study is to examine the potential of energy saving office lighting with color tunable LED lighting system in the effects on productivity and circadian rhythm.

METHODS

The effects of diurnal office lighting conditions on task performances, physiological and psychological parameters were examined in experiments with 2-day protocol.
Ten healthy subjects participated in the experiment. Three lighting conditions were employed. The first one is simulated general office lighting condition in Japan (GL), which is constant lighting of 750 lx (5000K) on a desk from 9:00AM to 6:00PM. The second one is simple energy saving condition (DL), which is constant lighting of 400 lx (5000K). The third one is energy saving lighting condition with color tunable function (CT). The illuminance and color temperature are kept at 750 lx and 6000 K respectively from 9:00AM to 2:00PM, then they were lowered gradually and were finally 400 lx and 4000 K respectively at 6:00PM in CT.
Each subject spent 2 consecutive days in the experimental room in all conditions. Task performance test (sorting task), EEG alertness test (KDT and CNV) and subjective evaluation were re-

peatedly carried out from 9:00AM to 6:00PM. Saliva sampling for analysis of melatonin secretion was carried out every 30-minute from 7:30PM to 1:00AM. Rectal temperature was measured from 7:30PM to wake-up time. The subjects went to bed after final saliva sampling at 1:00AM and woke up at 7:30AM. All these measurements were carried out under same time schedule in both days but polysomnography was measured during subjects' sleeping just in the second day.

RESULTS AND DISCUSSION

The amplitude of CNV (Contingent Negative Variation) early component in DL was significantly lower than one in GL and CT. In the results of KDT (Karolinska Drowsiness Test), alpha-wave power in DL was significantly higher than ones in other conditions. These results suggested that alertness lowered due to less light exposure through out the day in DL. Significant difference of sorting task performance in three lighting conditions couldn't be found but number of selective errors in CNV paradigm was significantly higher in DL than others. It could be considered that this poor performance was caused by the lowest alertness level in DL. Salivary melatonin concentration in CT was significantly higher than ones in other conditions on the 2nd night. Dim Light Melatonin Onset (DLMO) on the 2nd night advanced from ones on the 1st night in GL and CT but delayed in DL. The biggest advancement of DLMO was found in CT among all conditions. Higher CCT lighting which has bigger portion of short wavelength light in morning can be considered to contribute to creating these positive effects in CT.

CONCLUSION

Poor alertness and task performance under simply dimmed diurnal lighting (DL) can cause direct negative effects on office workers' productivity. Furthermore, delay of circadian phase could be a negative effect on circadian synchronization and it also could be an indirect negative effect on their productivity. Considering these effects, although simply dimmed office lighting easily makes big energy saving, the illuminance level should be carefully considered.

Meanwhile, almost no negative effects on all indices were found in energy saving condition with color tunable LED lighting (CT) compared to general office lighting (GL). In addition, the bigger advancement of circadian phase could improve circadian synchronization and it possibly creates positive effects on their sleep, health status directly and productivity indirectly.

Considering circadian physiology, photo-biological circadian effect of office lighting should be more essential in morning than in afternoon. Consequently, employing timer-controlled system and higher CCT lighting in morning are recommended and lighting in late afternoon should have greater priority to be dimmed for energy saving. From these view points, LED lighting featuring color tunable function has a promising potential in creation of human centered and eco-friendly office lighting.

PP146

RESEARCH TREND ON QUANTIFICATION SYSTEM FOR BIOLOGICAL CLOCK

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Objective:
The action that light influences on human physiology is not quite understood, compared to visual sensation. Therefore, we focused on suppression of melatonin as already having much knowledge among the studies for action how light influences on human physiology. If the knowledge for suppression of melatonin can be mathematized, we might be able to find there is a similarity between this action and action for other physiological amounts. Therefore, in this report, we aim to clarify a difference in various methods and characteristics to quantify suppression of melatonin.

Methods:
As a quantification method for suppression of melatonin, we compared German Prestandard (DIN V 5031-100), the method by Rea et al. of Rensselaer Polytechnic Institute, and the method by Takahashi et al. of Chiba University. The comparative method was conducted by a calculation comparing evaluation value for various light sources. We used blackbody radiation, 2 types of CIE standard illuminant, 14 types of fluorescent lamp, and 4 types of white LED for Blue-Yellow as the light sources. We also set the illuminance as 100 lx.

Results:
In German Prestandard, it was indicated that the higher correlated color temperature is, the larger action quantity (biological action factor) becomes. Because white LED has a high-intensity radiation in short wavelength area, a large action could be suggested but it was indicated that white LED has almost the same action quantity as identical correlated color temperature of fluorescent lamp. German Prestandard has a characteristic as calculation simplicity. However, the practicality could be inferior since it does not consider a light intensity. In addition, it was reported that Abney‘s law (additivity rule) can not be established in suppression of melatonin, but it does not take the action into consideration.
With the method by Rea et al. of Rensselaer Polytechnic Institute, as well as German Prestandard, it was also indicated that the higher correlated color temperature is, the larger action quantity becomes as overall tendency. However, the relationship was discontinuous around 4000 K. This is because 2 types of relational expression were used differently depending on spectral distribution of light source. It might be necessary to examine whether there would be a tendency of discontinuous mechanism as the higher correlated color temperature is, the larger action quantity becomes. The method by Rea et al. could be more practical with consideration of light intensity and pupil contraction. Furthermore, even though it considers an action in where Abney‘s law cannot be established, it would be necessary to examine whether the method is appropriate or not.
In the method by Takahashi et al. of Chiba University, as well as German Prestandard, it was again indicated that the higher correlated color temperature is, the larger action quantity becomes as overall tendency. Like the method by Rea et al., a relationship between correlated color temperature and action quantity did not become discontinuous despite of consideration for the cha-

racteristic as Abney‘s law cannot be established. This is because the method by Takahashi et al. uses relational expression differently depending on whether light source is monochromatic light or broadband light while the method by Rea et al. uses 2 types of relational expression differently depending on amount of short-wavelength component and long-wavelength component in light source. The method by Takahashi et al. can be more practical due to considering light intensity and pupil contraction. In addition, although it considers that Abney‘s law cannot be established, it would be a disadvantage not indicating a method to distinguish monochromatic light and broadband light.

Conclusions:
Difference and characteristic for various methods to quantify suppression of melatonin were indicated. Although a calculation simplicity of German Prestandard is attractive, the method by Rea et al. or Takahashi et al. is also attractive to be applied in practical environment as considering light intensity and pupil contraction. Furthermore, it was indicated that Abney‘s law cannot be established in suppression of melatonin and there is a quantification method with consideration of the characteristic. More detailed study might be necessary to identify whether such action really exists and in what situation the action can be functioned.

References:
1. DIN V 5031-100 (2009) Optical radiatin physics and illuminating engineering - Part 100: Non-visual effects of ocular light on human beings - Quantities, symbols and action spectra
2. Rea MS, Figueiro MG, Bierman A, Bullough JD (2010) Circadian light, J Circadian Rhythms, 8, 2
3. Takahashi Y, Katsuura T, Shimomura Y, Iwanaga K (2011) Prediction model of light-induced melatonin suppression, J Light & Vis Env, 35, 2, 123-135

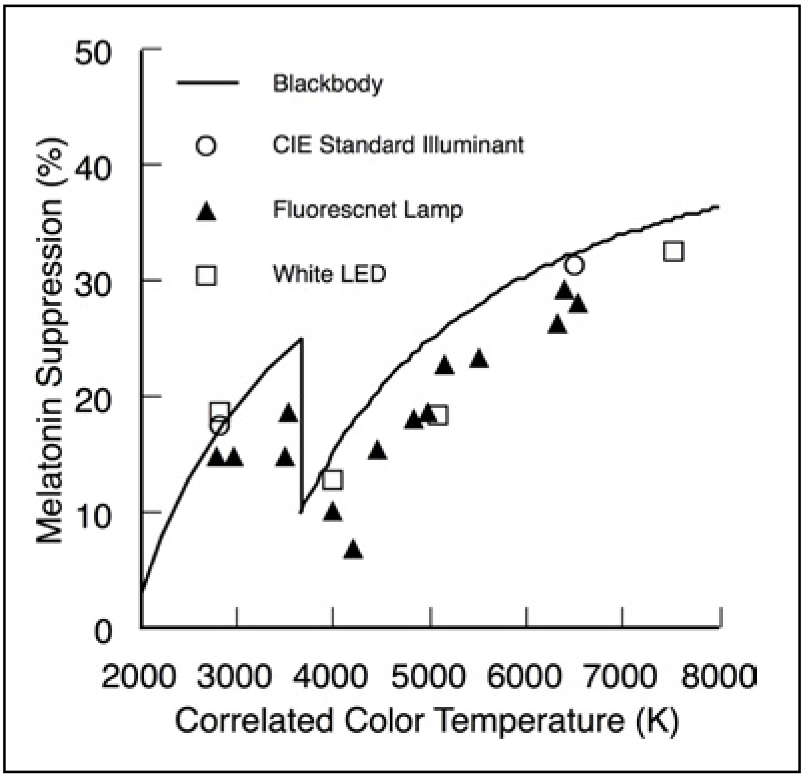

Figure 1 - Calculation result for melatonin suppression % based on method by Rea et al.

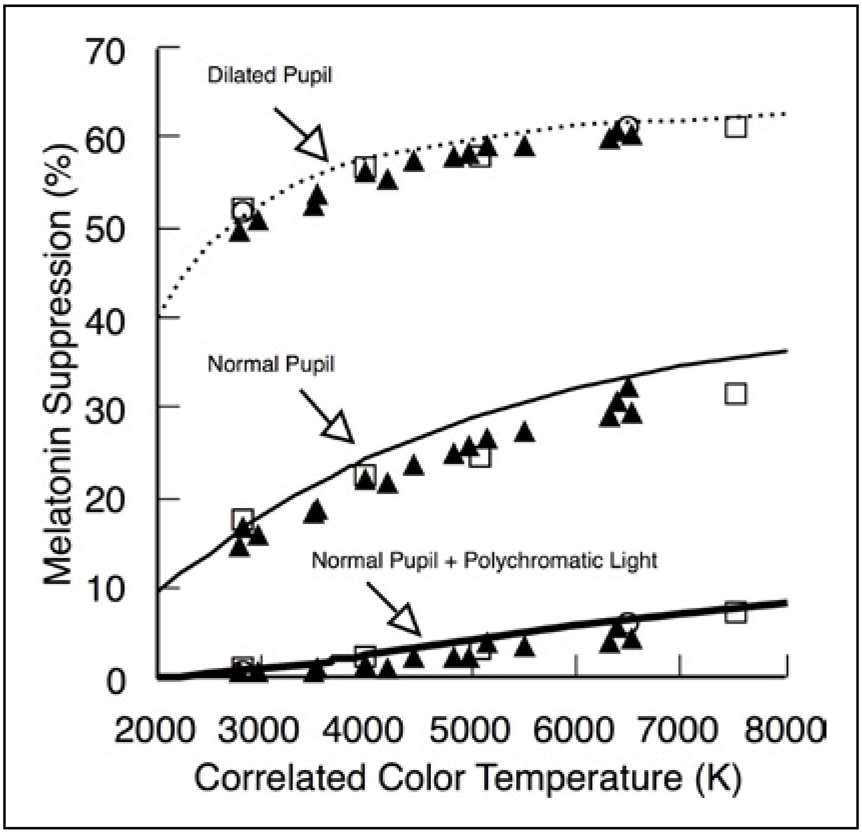

Figure 2 - Calculation result for melatonin suppression % based on method by Takahashi et al.

PP149

COMPUTER AIDED DESIGN (CAD) FOR APPLYING UPPER ROOM UVGI FIXTURES TO CONTROL AIRBORNE DISEASE TRANSMISSION

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Upper room ultraviolet germicidal irradiation (UVGI) systems are a recognized engineering control to interrupt the transmission of airborne pathogens such as Mycobacterium tuberculosis (TB) and influenza viruses. However, the application of this air cleansing technology has been challenging because of the lack of computer aided design (CAD) lighting software. Additionally, there has been no standard protocol for goniometric measurement of these specialized germicidal UVGI fixtures, which are based on standard fluorescent lighting technology. Research has been completed on the development of a CAD –based UVGI tool through modification of professional lighting software. Additionally, a method for capturing the UV gonioradiometric measurements in an radiometric data file has been developed and used to validate the UVGI-CAD tool. The UV gonioradiometric method is being used by CIE Technical Committee 6-52 to develop a technical report on UVGI fixture radiometric data for use in lighting design software. This paper reports on these advances and describes how the UVGI-CAD tool can be used to develop an average UVGI fluence in the upper room. Human exposure to UVGI is hazardous. It is virtue of the CAD-UVGI tool that it can predict eye level irradiance in the design phase to minimize or eliminate this risk. A case study is used to illustrate predictions of fluence and eye level safety measurements for a range of spaces, based on the multi-centered Tuberculosis Ultraviolet Shelter (TUSS) study.

PP152

COMBINED EFFECTS ON SLEEPING EFFICIENCY OF LIGHTING ENVIRONMENT IN THE DAYTIME AND THAT IN THE NIGHTTIME

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1. Introduction

It has been indicated that continuous excessive light exposure might disturb human circadian rhythm and cause sleep disorder, mental illness etc. Proper lighting environment from a viewpoint of circadian rhythm should be identified.

In our previous study, the effects on sleeping efficiency and task performance under variable lighting conditions combining with desktop illuminance and correlated color temperature during the daytime were examined. The results showed that sleeping efficiency was slightly improved by lowering both the desktop illuminance and the color temperature in the afternoon compared with the stationary lighting condition from morning till evening. In that experiment, the illuminance on the desk in the subjects' living room during nighttime was controlled to be lower than 200 lx, and the correlated color temperature was set at 2700 K in their bedrooms, because lighting fixtures with low color temperature after sunset were recommended from a viewpoint of circadian rhythm. However, in most of Japanese houses, lighting fixtures with high color temperature are installed. In actual situations, the lighting environment of houses at night might vary among individuals and the preferable effects on sleeping efficiency of the lighting conditions in the daytime might be canceled.

In this study, the combined effects of the lighting environment in office during the daytime and that in houses after returning home on sleeping efficiency were investigated. The sleeping efficiency might be improved much more by interactions of the lighting environment during the daytime and that in the nighttime. From the results of our experiments, preferable combinations of the lighting conditions during the daytime and those in the nighttime can be proposed from a viewpoint of sleeping efficiency.

2. Method

The experimental chamber assuming an office space was used to simulate the lighting conditions in offices during working hours. Eight university age male students participated in the experiment as the subjects. The students who lived alone in the areas within walking distance from the university were selected as the subjects to keep the amount of the light exposure for a whole day almost the same. In the experiment, the subjects stayed in the experimental chamber from 9 to 18 o'clock doing several kinds of VDT tasks. The amount of the light to which the subjects were exposed during the daytime was about 3,300 lx*h in total for each condition.

The lighting conditions during working hours in the experimental room are shown in Figure-1. One stationary experimental condition and two variable experimental conditions with desktop illuminance were examined. The illuminance of the stationary condition S was fixed at 400 lx during the daytime. For the variable experimental condition V1, the desktop illuminance was set at 750 lx at the starting time of the experiment and lowered gradually into 200 lx from 9 to 18 o'clock. For the variable experimental condition V2, the desktop illuminance was set at 500 lx in the morning and lowered gradually into 200 lx from 12 to 18 o'clock. The color temperature was set at 5000 K in each condition.

After the daytime experiment, the subjects were asked to go back home and spend their time in the living room as possible as they could. They were not permitted to watch TV and PC monitor. Also, the subjects were not allowed to drink alcohol and take caffeine during the experiment.
The subjects were asked to wear Actiwatch (Philips respironics) from 9 o'clock in the morning, the starting time of the experiment, until they got up next morning to evaluate the sleeping efficiency.

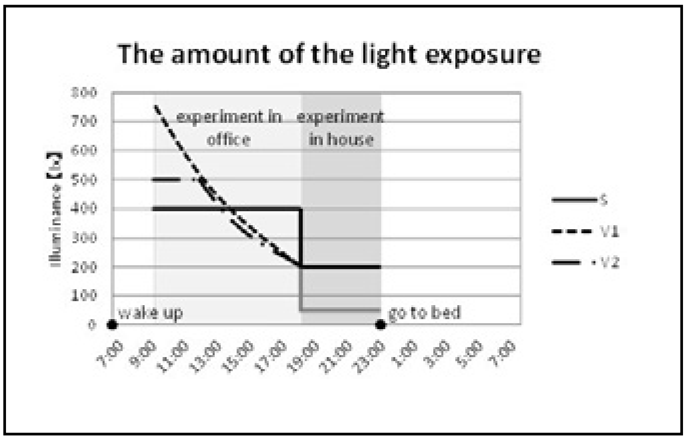

Figure 1

PP153

A STUDY ON DEVELOPMENT AND PERFORMANCE OF LIGHT SOURCE'S UV-IR WAVELENGTH BLOCKING FILTER

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Objective

Among the light sources that are used today, halogen lamp is still being used despite the fact it has low efficiency as its color rendering index goes up. In fact, radiations of UV and IR give affects to human and as well as the display artifacts in the museums. This happens to put limitations of irradiance on subject in the general exhibition, art gallery and museum lightings.
Accordingly, this study developed a filter for preventing damages on the illuminated object. This filter blocks IR and radiates only visible light by using alternating deposition filter in two substances, which have features in low refraction (SiO2) and high refraction (TiO2); also, durability has been added to protective film. The UV and IR filter gives an excellent color rendering index property and as well as a longer life time for both the lamp and the illuminated object.

Methods

Tests have been carried out by using papers such as newspapers or blue-prints that generally has rapid pace of getting damaged; damaged values were detected by the application of similar illuminance (lx) conditions, which were 17,640 lx for general halogen lamp and 17,715 lx for a halogen lamp mounted with the damage wavelength blocking filter. The distance between the light source and the sample was 30 cm, and the illuminance (lx) values were stabilized with 17,600 lx to 17,700 lx.
The UV radiation measurement was carried out by placing a halogen lamp in a UD-36 (310 ~ 400 nm; TOPCON Company, Japan) chamber for 500 hour. As well, to test damage occurrence level within the visible spectral range (380 ~ 400 (nm)), the sample was illuminated with a halogen lamp having the damage wavelength blocking filter.
Next, the sample being sensitive to temperature such as blue-blue silk went through IR radiation dependent temperature test having 25 ± 1 °C for ambient temperature and 65 % and lower for relative humidity. A general halogen lamp's illuminance surface temperature was 39.5 °C and relative humidity was 31 %, and a halogen lamp's illuminance surface with the damage wavelength blocking filter had 32 °C for temperature and 44 % for relative humidity. Furthermore, temperature rising level of dichroic mirror that is affected by the damage wavelength blocking filter's IR reflectance has been measured through the Infrared Thermal Camera after aging a halogen lamp for an hour. In addition, when connecting dichroic mirror sensor directly onto the Temperature Measuring Meter, a halogen lamp with the damage wavelength blocking filter's mirror temperature was 189 °C in the IR Thermal Camera and 188.8 °C in the Temperature Measuring Meter.

Results

In the simulation results of development of the damage wavelength blocking filter, the blocking effect took place typically in the 18th layer, 22nd layer, 28th layer, and 34th layer. The optimal design conditions were obtained by considering the thicknesses for every Refractive Index and

Physical layer, and as well as the transmittance level of visible light.
For the test result of UV radiation measurement, a halogen lamp with the damage wavelength blocking filter showed much lower damaged occurrence level within the visible spectral range (380 ~ 400 nm) than a halogen lamp without it. Moreover, the test result of IR radiation dependent temperature test in the illuminance surface temperature of 39.5 °C for a general halogen lamp and 32 °C for a halogen lamp with the damage wavelength blocking filter showed 7.5 °C of difference, which indicates humidity level decreases as temperature level rises. In fact, the test result through the Infrared Thermal Camera and the Temperature Measuring Meter proved that the temperature of dichroic mirror rises when IR is blocked by the damage wavelength blocking filter.

Conclusion
The application of the developed filter for a lamp preserves the object in a good condition without discoloration, fading, or thermal damage by transmitting only pure visible light, and simultaneously can maximize the exhibition effect on subject by maintaining high color rendering index of a halogen lamp, which is being used the most as the exhibition lightings currently.
This technology is expected to have considerable effects on limited effort for blocking irradiance damage on illuminated objects caused by light radiation in the general exhibition, art gallery and museum.

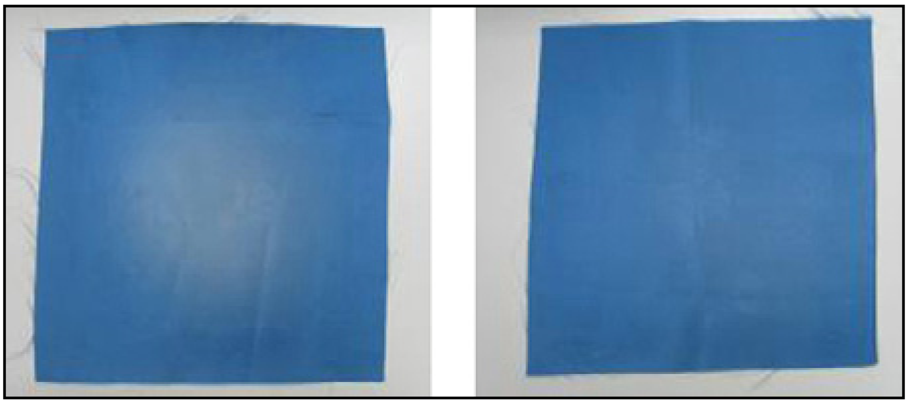

Figure 1 - A general halogen lamp vs a halogen lamp mounted with the damage wavelength blocking filter (testing time: 2 000 hrs , material: blue silk)

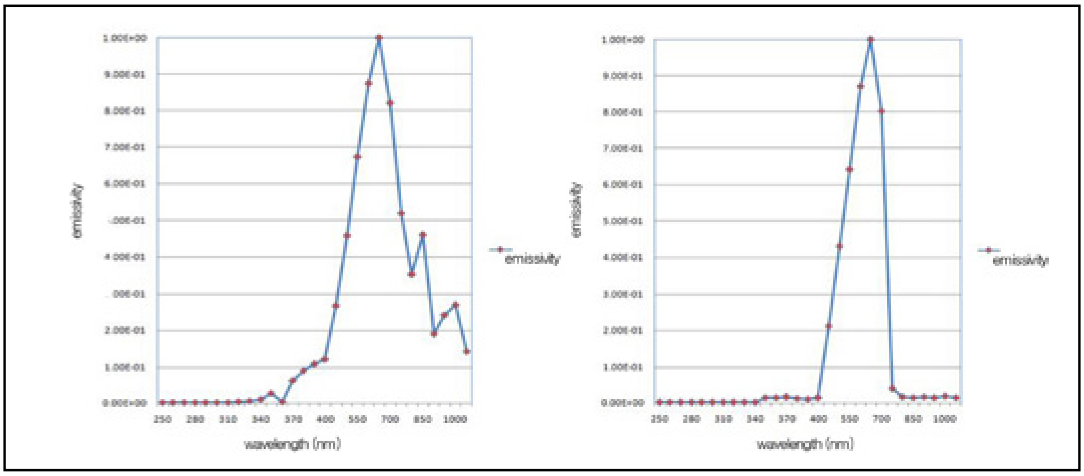

Figure 2 - Emissivity comparison between a general halogen lamp and a halogen lamp mounted with the damage wavelength blocking filter (Note: See Table 1, 2)

Wave-length (nm)	250	260	270	280	290	300	310	320	330	340
Emissivity	1.17E-03	2.00E-03	1.04E-03	1.11E-03	1.14E-03	1.32E-03	1.93E-03	3.32E-03	5.56E-03	9.66E-03
Wave-length (nm)	350	360	370	380	390	400	450	500	550	600
Emissivity	2.67E-02	4.03E-03	6.26E-02	8.89E-02	1.08E-01	1.22E-01	2.66E-01	4.58E-01	6.74E-01	8.75E-01
Wave-length (nm)	650	700	750	800	850	900	950	1000	1050	
Emissivity	1.00E+00	8.20E-01	5.20E-01	3.52E-01	4.60E-01	1.90E-01	2.41E-01	2.68E-01	1.43E-01	

Table 1 - Emissivity of a general halogen lamp

Wavelength (nm)	250	260	270	280	290	300	310	320	330	340
Emissivity	6.13E-04	1.05E-03	5.18E-04	5.12E-04	4.71E-04	3.75E-04	3.30E-04	2.60E-04	2.25E-04	2.07E-04
Wavelength (nm)	350	360	370	380	390	400	450	500	550	600
Emissivity	1.45E-02	1.41E-02	1.52E-02	1.24E-02	9.88E-03	1.30E-02	2.12E-01	4.32E-01	6.41E-01	8.72E-01
Wavelength (nm)	650	700	750	800	850	900	950	1000	1050	
Emissivity	1.00E+00	8.02E-01	3.83E-02	1.60E-02	1.47E-02	1.56E-02	1.47E-02	1.82E-02	1.44E-02	

Table 2 - Emissivity of a halogen lamp mounted with the damage wavelength blocking filter

PP154

LIGHT IN THE BODY – BODY IN THE LIGHT. REVISIONING THE BALANCE OF LIGHT AND DARK

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Without light there is no life – and there is no light without darkness. The Rhythms of light and dark are existential to all life. Our planet is kept alive through the rhythmic interplay of sun and moon which bestows us with day and night, with light and darkness. Life grows in the dark; the foetus in the womb, the seed in the earth. Our body systems are based on this interplay of light and dark.
In my presentation I would like to advocate the importance of a balance of the polarities of light and dark for our wellbeing. The rhythms of day and night have structured our lives on earth since more than 4 billion years. And it has been just recently – a fraction of a second in earth time – that we have developed the use of artificial light. The abundant and extensive use of which has caused a major change, which is not only beneficial for human life but also bringing along many human diseases. We have fallen out of the natural rhythm which is causing an imbalance in our life rhythms. What does this mean for our health and how can we regain a healthy balance for our body-mind-soul? Looking East, to the Indian tradition, as well as to modern physics we can receive some answers and try to adopt them for our lives.

In the West we live in an overly materialistic and technically oriented world. Thus the technologies in lightning and the use of artificial light have been amazing. From lightning the myriad of electronic devises to lightning our living and working spaces, our shopping malls, streets, cities – we illuminate every corner of our physical world. With light we accentuate spaces and we extend the days and shorten the nights. Thereby 'tricking' the natural cycles of day and night. The nights are lit not only in the cities but more and more in the country side, to the extent that we often do not see the stars anymore. Our obsession with light is further mirrored from the world of advertising to the explosive growth of solariums and tanning studios. In those white men and women expose themselves to UV-light waves in the name of health and status symbols.

The imbalance caused by this overemphasis of and on the light is further reflected in our imbalanced behaviour towards matter: our body and our food. Not only do we sunbath in artificial light, we also grow a majority of our vegetables in artificial light and without earth and savour 'lite' and diet food which only seems to increase the general overweight problem as well as the number of diseases. Short, we treat our selves with the same materialistic and mechanistic attitude that has so much shaped our world in the industrialized West.
Light has to do with 'enlightment', that is consciousness. The Eastern thinking is holistic: everything is part of something greater, everything is alive, has a consciousness and a soul, and is carried by an underyling life force (breath, prana or Chi). The Western thinking is still mechanistic and linear; it is based on separating, categorizing and emphasizing matter over mind (and spirit) - although this is slowly changing as can be seen in Modern physics.
What Eastern civilizations have known for thousands of years is today confirmed by our Western science: that everything is energy and has a consciousness! We are surrounded by a bioelectri-

cal field through which an information exchange takes place: with the speed of light, information is absorbed and released. Constantly we are in communication and interaction with everything. Quantum physics has revealed us the heart of matter, which is energy and information. And those subatomic particles have only meaning in their relation to everything else, but not isolated in themselves.
Biophotonic researchers have shown that the cells of all living organisms emit light quants, so-called biophotons that the cell communication is based on light thus implies the human being is a light system which is regulated through
impulses. Our wake and sleep patterns are regulated by brain cells that respond to light and dark signals. Physiologically exposure to light activates our being awake whereas exposure to darkness activates our sleep.

On a more psychological and symbolic level, we can say that light is consciousness. Symbolized by the sun, it has been associated with the masculine principle, the visible, knowledge, information, inspiration and with spirit. On the other hand darkness, often symbolized by the dark phase of the moon, has been associated with matter, the feminine principle, the invisible, the unknown, the unconscious, and the less understood often feared aspects of life. We tend to negate the qualities of the dark in favour of the light. But the web of life is woven with the treads of light and dark – equally balanced they dance the dance of the creative matrix. To honour the dark is to bring consciousness (light) to it.

Looking East, to the ancient tradition of India, we can learn a lot from their rich mythology as well as their philosophy of Yoga. In the yogic tradition the balance of light and dark – of body and spirit is crucial. To see the light is to see the shadow.
The core of all yogic practices is union: the balance of polarities, such as dark/light, spirit/matter, male/female etc. Meditation (experiencing the inner light); breathing technique (pranayama) and body movements (asanas) are means of attaining this union. Through conscious breathing we bring light into our body, nourishing our organs, our blood, and all our bodily systems. Bringing light into the body is bringing consciousness to matter and vis versa: we become aware of the life-force in ourselves and in everything around us, attuning us to the natural rhythms in and around us. The practice of Yoga is in accordance with the cycles and rhythms of the sun and the moon. And in the rich imaginative world of myth the archetypes of Surya and Chandra (symbols of sun of moon) show us how to live in harmony with the light and dark.

Figure 1 - coyright Alex Grey

PP155

BALANCING BENEFITS WITH EXPOSURE RISKS OF ULTRAVIOLET EMISSIONS FROM LAMPS

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The ultraviolet radiation emission from lamp products are used for a variety of applications, from excitation of fluorescent pigments in fabrics, paints and paper to insect traps and germicidal radiation. We examined the UV emissions of a wide variety of lamp products with an analysis of irradiances and exposure durations at typical use distances for realistic exposures of the eyes and skin. It was found that the UV-A (315-400 nm) emitted from lamp products posed no realistic health risk when considering the time-weighted exposures. Safely installing ultraviolet germicidal irradiation (UVGI) can pose practical problems for upper-air disinfection; proper fixture design and lamp height becomes critical. It is also concluded that lamp safety standards should also better clarify the risks of UV-A exposures and then essence of time-weighted averaging of potential exposures. The risks of ocular exposure UV-A radiation require a better understanding and it is emphasized that UV-A absorbed by the eye's crystalline lens is re- emitted as harmless fluorescence, thus protecting the retina and protecting the lens from direct photochemical damage and over-heating.

PP156

MELANOPIC ASSESSMENT OF LIGHT – STANDARDIZATION ACTIVITIES

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The assessment of light with respect to its biological effects is essential for the proper description of research studies as well as for the lighting design in applications like offices, schools, nursing homes, and others. A first step to describe the biologically effective part of the visual spectrum has been achieved with the pre-standard DIN V 5031- 100 in Germany in June 2009. It has been used in applications and for descriptions of products. E.g. test houses have used this standard to include a rating on biological action factors of lamps into their test results and customer informations. For practical applications the definition of quantities for the assessments of biologically effective lighting were still missing. This was the reason for a revision of the pre-standard which will be republished as DIN SPEC 5031-100 in early 2013.

The revised version comprises detailed specifications of radiometric quantities based on melanopic assessment. The first and most obvious change is in wording. The fuzzy term “biological” is replaced by “melanopic” to clearly show that the assessment of light described in DIN SPEC 5031-100 is based on effects mediated by melanopsin expressing retinal ganglion cells. The relevant action spectrum is s(mel).
The melanopic rated radiometric quantity X(mel) is defined as
X(e,mel) = Integral (X * s(mel)) (1 ; for proper reading of equation 1 see attached image)
and the melanopic action factor a(mel,v) of a light source is defined as the ratio of its melanopic and photopic radiometric quantity
a(mel,v) = X(e,mel) / X(v) (2 ; for proper reading of equation 2 see attached image)

A “melanopic daylight equivalent” K(mel) is defined which allows to relate the photometric quantities relevant for biological effects of light to the comparable photometric quantity of daylight. The melanopic daylight equivalent is defined as the luminous efficacy of radiation divided by the melanopic action factor for standard illuminant D65. K(mel) = K(m) / a(mel,v,D65) (3 ; for proper reading of equation 3 see attached image)

This allows the definition of melanopic rated “photometric” quantities like melanopic illumination levels, melanopic luminance and others. An important quantity for lighting design may be the melanopic light output ratio of a luminaire, which is also defined in the reviewed standard. Almost simultaneously to the revised standard a technical report on design guidelines for biologically effective illumination will be issued by DIN as DIN SPEC 67600 in early 2013.
In parallel to the activities of standards committee FNL 27 at DIN in Germany, the European WG 13 at CEN/TC 169 is working on a European standard. Some committee members are active in both working groups. This ensures an efficient collaboration and proper alignment of activities in Germany and on European level.

The presentation will report latest progress of standardization activities on biological effects of light, show details of the new standard DIN SPEC 5031-100 and give examples for assessment of melanopic rated quantities used in realized applications.

References:

1. Standard DIN SPEC 5031-100:2013. Optical radiation physics and illuminating engineering — Part 100: Non-visual effects of ocular light on human beings — Quantities, symbols and action spectra. Beuth Verlag, Berlin (to be published early 2013)
2. Technical Report DIN SPEC 67600:2013. Biologisch wirksame Beleuchtung – Planungsempfehlungen“, Beuth Verlag, Berlin (to be published in German, early 2013)

remark:
as the abstract submission system does not support greek letters and mathematical formulas, the definitions used above in the abstract had to be modified for readability and are not compliant to the symbols and definitions used in the cited standard.
For proper reading of the equations see attached images.

$$X_{\mathrm{e,mel}} = \int_{\lambda_{\mathrm{u}}}^{\lambda_{\mathrm{o}}} X_{\lambda}(\lambda) \cdot s_{\mathrm{mel}}(\lambda) \cdot d\lambda \qquad \text{Equ. (1)}$$

$$a_{\mathrm{mel,v}} = \frac{X_{\mathrm{e,\,mel}}}{X_{\mathrm{v}}} \cdot K_{\mathrm{m}} \qquad \text{Equ. (2)}$$

$$K_{\mathrm{mel}} = \frac{K_{\mathrm{m}}}{a_{\mathrm{mel,v,D65}}} \qquad \text{Equ. (3)}$$

Figure 1 - used equations as image to ensure proper readability

PP157

RELATION BETWEEN THE PROFILE OF MOOD STATES AND LIGHTING ENVIRONMENT EVALUATION

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1. Background and purpose of this study

In order to obtain comfortable lighting environment, it is necessary to consider visual lighting and atmospheric lighting in lighting design. This study aims to clarify the relation between profile of mood states (POMS) and light environment evaluation using statistical analysis as focusing on mood states in the atmospheric lighting design.

2. Experimental method

80 student subjects participated in the experiments in 2009 and 120 student subjects participated in 2010. Four fluorescent lamps were installed on the ceiling in a climate chamber (2.91m width, 3.31m depth, and 2.30m height). Lighting power was conditioned at two levels: 25% and 100%. Room temperature and humidity were kept at 25°C and 50%. The mean horizontal illuminance among the seats was 342 lx in the Dark and 2238 lx in Light conditions.
Figure 1 presents the experimental procedures. Six subjects entered the room and sat at the table and answered questionnaires in the first lighting condition. Then the lighting level was changed and subjects answered the questionnaires in the second lighting condition. The Dark-to-Light experiment was conducted in 2009. The Light-to- Dark experiment was conducted in 2010.

3. Questionnaire items

Questionnaire items are as follows.
(a) Basic attributes (16 items) (b) Residential attributes (16 items) (c) Environmental evaluation (6 items) (d) POMS (40 items) (e) Semantic differential scales (SD) evaluation of the atmosphere (32 items) (f) Light environment evaluation (9 items) (g) Environmental consciousness (10 items)
POMS used in the clinical psychology gives an integral score between 0 and 4 to each questionnaire item. The results are expressed in six mood scales; T(Tension)-A(Anxiety), D(Depression-Dejection), A(Anger)-H(Hostility), V(Vigor), F(Fatigue), and C(Confusion).

4. POMS aggregate results and pattern classification

Characteristics of the subjects in this experiment had a high Fatigue and Confusion while they had a low Depression, Anger and Vigor. As a result of the cluster analysis of the response pattern to each POMS factor, the feature was most apparent when the patterns were categorized in five groups. As shown in Table 1, Pattern 1 was high Vigor, Pattern 2 high Fatigue, Pattern 3 overall lower score, Pattern 4 low Vigor, and Pattern 5 plotted around 40 points.

5. Relationship between light environment evaluation and POMS

Table 2 shows the result of the test of goodness-of-fit concerning the relationship between the light environment evaluations and the lighting conditions, and the illuminance change orders (Light-to-Dark and Dark-to-Light) for all subjects, Pattern 1 (P1), and Pattern 4 (P4). Figure 2 shows the result of the average of difference between the light environment evaluations in the Dark and Light conditions by the POMS patterns. In Pattern 1, the evaluation of performance concerning the lighting conditions did not change compared with the whole. In Pattern 4, the evaluations of brightness for writing, glare, lighting comfort, and lighting preference did not change compared with the whole. In Pattern 1, the evaluation of brightness for writing concerning the illuminance change orders changed compared with the whole. In Pattern 4, the evaluations of brightness for writing, lighting comfort, and lighting preference did not change compared with the whole.

6. Conclusion

This study clarified the relation between the subjects' mood states during the preceding week and the light environment evaluation in the experimental room conditioned at two levels of lighting. The light environment evaluation concerning brightness, brightness for writing, uniformity of lighting, glare, color, comfort, preference, and

performance changed according to the level of lighting and the order of lighting for the all subjects. POMS response patterns could be categorized in five groups. In high vigor Pattern 1, the evaluations of brightness for writing, comfort, preference changed according to illuminance level. In low vigor Pattern 4, most evaluations did not change according to illuminance level and the order of lighting.

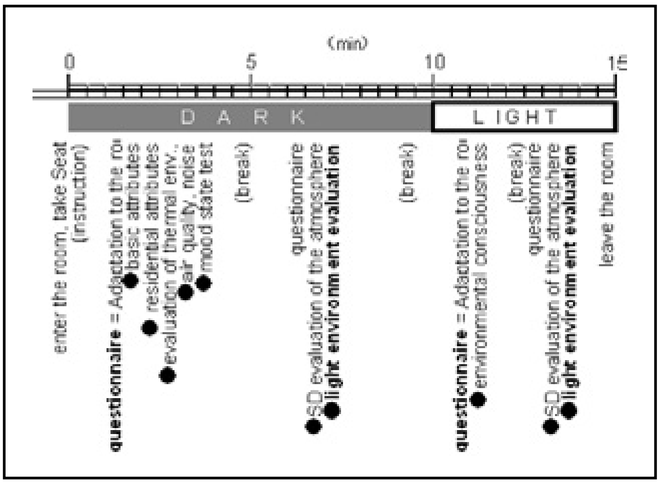

Figure 1 - Experimental procedure (D-to-L exp.)

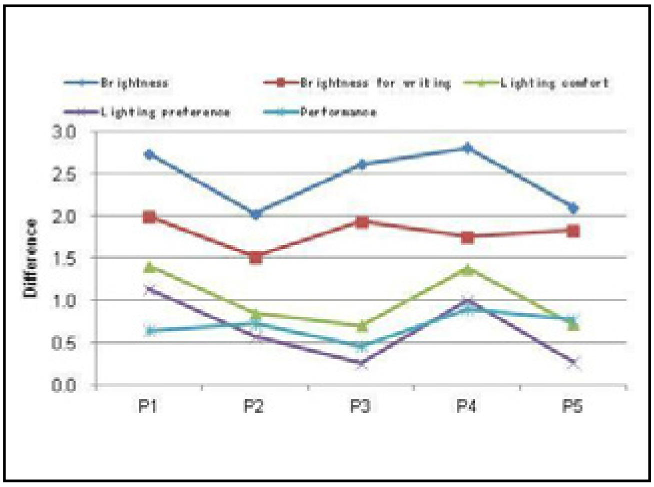

Figure 2 - The average of difference between light environment evaluations in the Dark and Light conditions

Pattern	Number	T-A	D	A-H	V	F	C
P1	51	23.0	11.4	15.9	44.0	22.5	29.1
P2	66	36.7	26.3	31.0	43.5	55.0	45.3
P3	54	27.9	12.7	12.2	16.9	34.7	43.7
P4	21	59.1	46.6	59.3	31.5	76.8	60.7
P5	18	47.6	50.5	43.5	34.5	42.8	57.5

Table 1 - Average score of the POMS factors and the number of patterns

	Relationship between the lighting conditions (p-value)			Relationship between the illuminance change orders (p-value)		
	All	P1	P4	All	P1	P4
Brightness	0.0001	0.0001	0.0357	0.0001	0.0001	0.0467
Brightness for writing	0.0001	0.0040	0.1838	0.0001	0.0029	0.3069
Uniformity of brightness	0.0146	0.1652	0.2250	0.0008	0.1193	0.4283
Glare	0.0001	0.0010	0.1002	0.0001	0.0015	0.0295
Light colour preference	0.0001	0.0516	0.1697	0.0004	0.0522	0.3870
Lighting waver	0.2548	0.2207	0.8489	0.0518	0.2192	0.5290
Lighting comfort	0.0016	0.0287	0.3776	0.0035	0.0475	0.5290
Lighting preference	0.0063	0.0426	0.6165	0.0179	0.0772	0.6642
Performance	0.0005	0.0540	0.0050	0.0001	0.0316	0.0040

Table 2 - Relationship between light environment evaluations and the lighting conditions, and the illuminance change orders

PP159

SPECTRAL REFLECTANCE MEASUREMENTS ON VERVET MONKEY PELTS

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The School of Physiology at the University of the Witwatersrand, Johannesburg, South Africa, are involved in a project on the thermoregulatory benefits of grooming in vervet monkeys (Chlorocebus pygerythrus). The overall aim of this project is to assess the thermoregulatory properties of vervet monkey pelts and determine how these properties are affected by grooming (grooming is defined as an individual cleaning or maintaining their, or another group member's, fur and body using their hands and mouths). The purpose of the study is also to find an ultimate explanation for the function of grooming in primates, as well as other mammals.
An animal's pelt plays an important role in thermoregulation. The conductive and reflective properties of a pelt allow an animal to regulate solar heat load. The pelt controls the heat transferred to (keeping them cool in warm temperatures) and from the body (keeping them warm in cold temperatures); the vervet monkeys are subjected to a highly variable climate (i.e. -5oC to +40oC). It is predicted that the maximum thermoregulatory benefits afforded by an animal's pelt are maintained through grooming - the pelt is kept free of dirt and ectoparasites and sufficient loft is sustained for effective thermoregulation.

The study includes the examination of the spectral reflectance, thermal conductance and radiant heat load of the vervet monkey pelts to determine whether the presence or absence of simulated grooming affects thermoregulatory efficiency.
The Photometry and Radiometry laboratory of the National Metrology Laboratory of South Africa is involved in the spectral reflectance measurements of the pelts across a wavelength range of 380 nm to 1 500 nm. Experiments with different orientation of the pelts are performed. The measurements are also performed at different geometries to establish the best method to be used for these measurements.
The colour of the pelts varies from light grey to a darker grey and a large number of measurements are made to make provision for the variation in colour.
Our paper will present the results using different methods, including geometry, when analyzing the spectral reflectance of the pelts in different orientations. The variation in the colour and the reflectance obtained for the different colours will be discussed.

PP160

LED LIGHT SUPPLEMENT TECHNIQUE FOR INDOOR PLANTS

Zou, N., Jiang, J., Fang, Y., Niu, Y.
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In the field of agriculture, it is known light is the essential condition to all plants. The effects of light on plant growth can be divided as two types including indirect and direct actions. Indirect action refers to photosynthesis. Plants must grow in strong light for a long time to synthetic enough photosynthetic products for growth needs. Therefore, Photosynthesis is a kind of „high energy reaction“. Direct action refers to the light effect on plant formation. Plant formation only needs weak light in a short time, which is a kind of "low energy reaction". Natural light environment can't promote the growth of plants day and night. As a result light supplement technique is highly required and beneficial to flowering and fruit as well as control height and nutrients of indoor plants growth. On the other hand, in recent years LED light sources are widely used in all aspects of life such as general lighting, special lighting and so on. It can not only turn this colorful world to more gorgeous, but also meet the all living creatures' demand for light , with its high luminous efficiency, long life, energy conservation and environmental protection etc properties. LEDs have rich wavelength, therefore are in accord with spectral range on photosynthesis and plant formation. Either pure monochromatic light or compound spectrum can be acquired by means of selection and combination of different LED sources. Since plant can be lighted balanced at specific wavelength, LED is very suitable for plant growing in controlled facilities environment.

In this paper, an intelligent LED light supplement lamp is designed and experimentally demonstrated on indoor plants. Taking the above-mentioned advantages into consideration, a LED light supplement lamp has intelligent control and monitoring functions. The control system is mainly composed of temperature sensor, illumination sensor and working mode setting circuit. Control circuit consists of LED and buzzer connected with intelligent control system, the working process is shown in Fig.1. Master can select mode through the work mode setting circuit according to needs. Optional model contains illumination mode and time pattern. Illumination model is that signals collected by illumination sensor contrast with standard range set in controller. Then the drive circuit control bright and dark of the supplement light. Time pattern is based on timing function of SCM. The designed LED light supplement lamp lights a specific color namely red, green, blue or red and blue mixed in certain time. What's more, it can monitor and display temperature all the time. Single chip microcomputer dealing with collected signal, buzzer will sound when the display value is lower than the pre set value.

Fig.1 Diagram of LED light supplement lamp for plants

Fig.2 The state of the plant growth in different lighting environment

Based on the designed control system, two groups of lettuce were selected for experiments. One group of lettuce was illuminated by the designated light from 8:00 to 18:00 and another one was under normal indoor lighting condition at the same time. In this process, the experimental data

was collected every two days a time. The collected data includes illumination at leaf surface and the height of the plant. In additional, the length of the roots would be measured and recorded once a week. The different lighting environments by green, red, blue and mixed lighting are shown in Fig2. (a) (b) (c) (d) respectively. Comparing the two groups of lettuce it is found that the one under the designated light grow more flourish than the other.

In a summary, LED can be utilized to make up for the deficiency of the natural light to promote plant growth. The intelligent LED light supplement technique has potential applications on fast growing indoor planting.

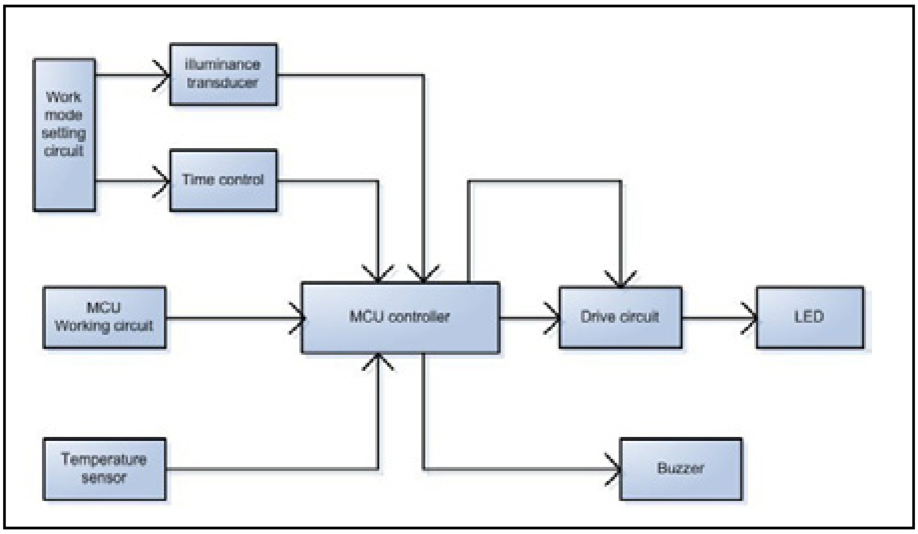

Figure 1

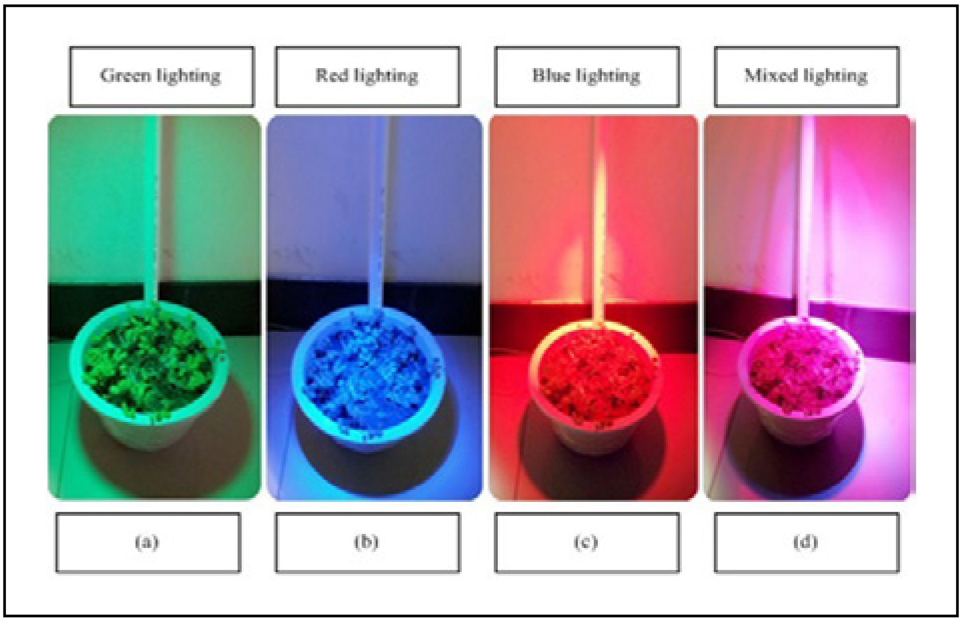

Figure 2

PP161

OPTIMAL ILLUMINATION OF PLANTS IN GROWTH CHAMBERS WITH LOW ENERGY DEMAND

Škoda, J., Krbal, M., Sumec, S., Baxant, P., Parma, M.
Brno University of Technology, Brno, Czech Republic.

The article deals with illumination plants and refers to differences in illumination if the lighting system is designed for optimum plant growth or for the best visual appearance. The common denominator in these both cases is energy consumption, which should be minimized. The main part of the article is dedicated to the illumination in growth chambers. Where the choice of a suitable light source plays a crucial role for the later development of cultivated plants. Spectral sensitivity of plants is vastly different from the spectral sensitivity of the human eye. Therefore it is necessary to choose light sources with different spectral distributions for good growth of flora. The most appropriate types of resource not only in terms of energy efficiency are discussed in this article.

D8
Image Technology

PP162

EVALUATION OF ILLUMINATION USING DIGITAL PHOTOGRAPHY

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Our laboratory is developing an application LumiDISP for evaluation of illumination and light sources using digital photography for a long time. Thanks to the precise calibration of camera we achieved the precision adequate to the standard measuring instruments. Calibration includes spectral characteristics of the sensor, geometric properties of the lens, and the mechanical behavior of the camera itself. However, the indisputable advantage is the speed and efficiency of the measurement and the following analysis of the data. For example instead of a large number of individual measurements using the luminance meter just take one picture a room, subsequently can be easily subtracted brightness at arbitrary point. This paper presents the abilities of created software and shows several examples of its application. Currently the application is used for the measurement of public lighting in Brno, it can be used to evaluate discomfort glare in the room using the methodology UGR, another module provides an assessment of LED panels for variable traffic signs. Other research institutes use this tool to capture the brightness of the sky in order to evaluate light pollution.

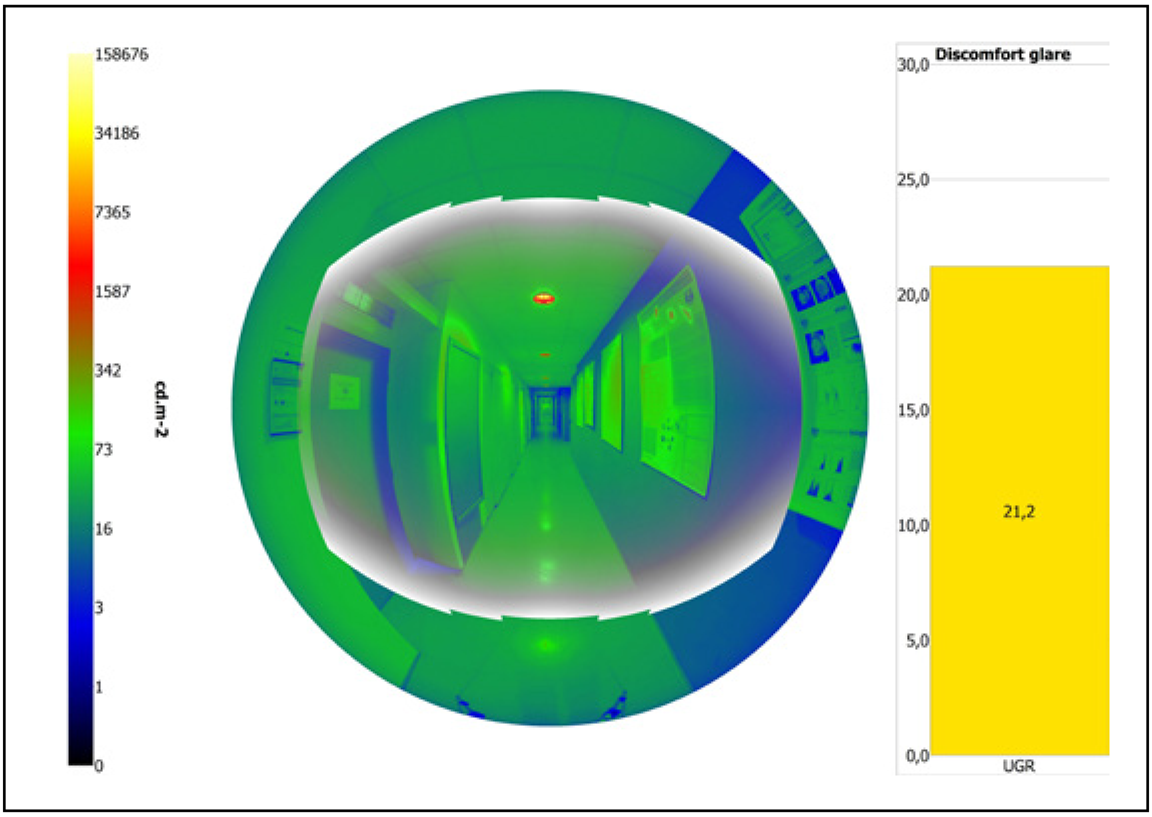

Figure 1 - Result of discomfort glare analysis

PP163

TOWARD A VALID IMAGE PROCESSING SYSTEM THROUGH COLOUR STANDARDS

Richard, N., Ledoux, A., Capelle-Laizé, A., Fernandez- Maloigne, C.
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Image processing standards have produced spaces and difference metrics to manage colour acquisition, reproduction and exchange between systems. In parallel, the image processing domain starting from signal theory evolves to become closest from the mathematical domains, with Gaussian and vectorial hypothesis far from the psychovisual or physical colour point of view. Due to this way of developments, it becomes harder to validate image processing results in regard to the human perception or physical reality.

Obviously, starting from colour standards, new ways of expression for image processing are possible. For example, the perceptual colour spaces and associated metrics was produced from the ordering of colour pairs through psychovisual experiments in controlled environments. In the same way, the mathematical morphology is based on the ability to order scalars or vectors, without constraints to do it, only property resulting of the ordering quality. So great parallels could be done and exploit to propose new image processing schemes, available on a colour point of view. We show in this work how to construct a complete scheme for the colour mathematical morphology, based only on the existing colour distance functions and perceptual colour spaces, giving a valid colour image processing system under these standards. We show then results and more complex operators (gradient, Laplacian, Hit-Or-Miss Transform, segmentation process). As this approach is based on colour distance functions, it allows comparing their behaviour in front of the ordering and morphological objectives, giving new solutions to complete the validation for new colour spaces or distance functions.

To show that such construction is only a question of initial hypothesis in the image processing chain construction, we show how to extend the formalism to multispectral imagery. Then we develop some scientific questions to solve in such ways, in particular on this question of the muti-spectral distance function and how to validate it. We conclude on the link between the notion of Non-Flat Structuring Element in Mathematical Morphology and the classical linear filtering, and how the non-linear way of expression offers solutions for some classical image operations.

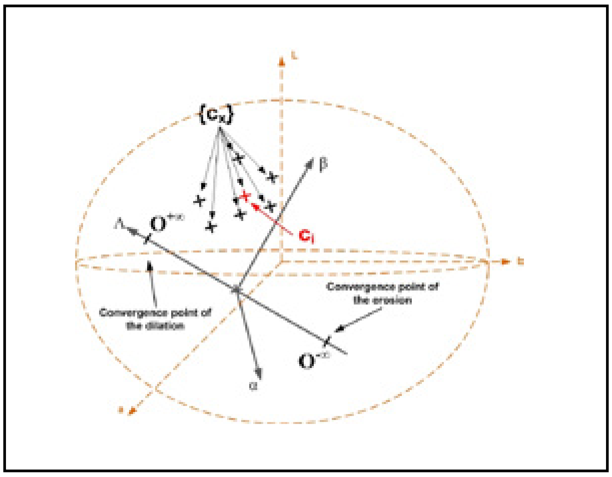

Figure 1 - To be correct with the colour standards, the colour ordering question by distance functions induces the notion of colour convergence coordinates. The extremum inside the colour set will chosen by intersection of ellipsoides from by the colour distance to these colour convergence coordinates (O+, O-) and the colour coordinates (Ci) of the spatial origin of the structuring element.

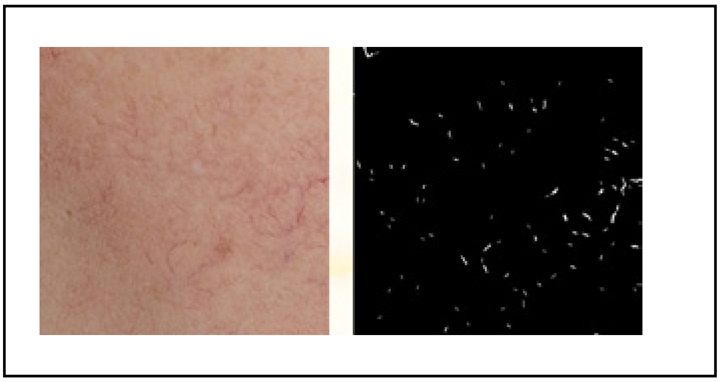

Figure 2 - From the colour mathematical morphology formalism, the Hit-Or-Miss Transform allows to extract shapes from templates defined by vectorial contrast and spatial support. As all the formalism is based on perceptual distances, the used vectorial contrast is valid under this condition.

PP164

EYE-TRACKING FOR 3D-APPLICATION: GAZE-POINT DETECTION TAKING INTO CONSIDERATION DISPARITY

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High quality three-dimensional video technology is spreading significantly in all spheres of life: entertainment, medicine, advertisement, etc. The idea of creation 3D image is based on showing two slightly different images to left and right eyes, to achieve effect of natural viewing world with binocular parallax. Producers of 3D video is trying to produce such a disparity that customers could enjoy feeling of presence, new quality of video presentation and do not have visual discomfort. From other point of view human visual system is working in another way with its latency and selective sensitivity. Three-dimensional space is derived geometrically by comparing the small differences between the two retinal images that result from the slightly different points of the two eyes caused by their 6.5 cm separation. The disparities result from surface form and depth as well as the direction and distance of gaze, the torsion of the eyes. In our experiment, we tried to investigate if the most prominent object always attracts viewers attention and the features of human visual system are more sensitive to object‘ location in space, than its color and size.

Commercially available video was shown to 10 participants with normal vision in conditions close to free watching. To follow participant‘s gaze-points during watching video eye-tracker Tobii TX-120 with capability to work with 3D glasses and large freedom of head movement was chosen. The distance between eye-tracker and display was 63 cm, which was calculated according to requirements of eye-trackers‘ producer. The eyes of subjects were located no more than 70 cm far from eye-tracker, in such a way that the distance between participant and monitor was 2H of screen. As settings of eye-tracker were set up the same for all subjects, the position of subjects with different height was adjusted with special chair, that allows changing its level and fix angle of rotation. Calibration of device was done before test to adjust position of each observer.
Gaze positions of left and right eyes were recorded simultaneously by eye-tracker during watching video; disparity was calculated for each fixation point. Disparity map was obtained for each video frame and it was verified whenever point with the greatest value of disparity coincides with the gaze point.

Results pointed out, that disparity is important parameter in humans attention, but
not all the time people follow the most disparity salient object, other parameters as color and size can have more impact. The application of saliency tools for 2D images needs to be adopted for 3D video and takes into account depth information.
In our study, relationship between the given disparity of the video and disparity perceived by viewer was investigated, based on this data prediction of the sensitivity to the disparity can be done. This result can be used in studies dedicated to visual fatigue from watching 3D imaging, where extended level of disparity is considered one of discomfort cause.

PP165

DEVELOPMENT OF GENERIC COLORIMETRY SYSTEM FOR LIGHTING ENVIRONMENT BY USING CCD CAMERA

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1. Building Research Institute, Tsukuba, Ibaraki, Japan.
2. Kansai University, Suita, Osaka, Japan.
3. Institute of Technologists, Gyoda, Saitama, Japan.
4. National Institute for Land and Infrastructure Management, Tsukuba, Ibaraki, Japan.

Several studies have pointed out that measuring the distribution of horizontal illuminance was not enough to evaluate an impression of architectural lighting environment. The retinal image of human eye is formed by light which is reflected by some object's surface or is emitted by light source. A photometric value that represents this kind of light intensity is luminance of object's surface, not horizontal illuminance. Therefore, the impression of lighting environment should be correlated to the luminance and color distribution over the entire visual field. Many studies discussed the relationship between lighting impression and luminance distribution. Especially, an evaluating method of brightness impression for a room is examined well by many researchers. Those studies suggested several methods to calculate the brightness impression, which is immeasurable by horizontal illuminance, by measuring the luminance distribution. That is, evaluation or design of a lighting environment must be based on the distribution of luminance and color in the next step. Although several colorimetric systems with CCD camera and fish-eye lens have been developed by each research institute or manufacturer, not all the systems might provide us the photometric accuracy precisely. To examine the relationship between impression of lighting environment and distribution of luminance and color, photometric accuracy of colorimetric system with CCD should be guaranteed. Since it is not easy to calibrate the colorimetric system, most of the researcher and designer cannot use the system easily. The purpose of the study is to develop a generic colorimetry system which is composed by commercial digital camera and fish-eye lens and to provide a convenient calibration method for general user. In this paper, we examined the algorism to convert CCD camera signal values into the CIEXYZ tristimulus values and confirmed the photometric accuracy.

We constructed the colorimetric system composed by CCD camera (TXG13c, Baumer), fish-eye lens (FE185C046HA-1, FUJINON) and laptop computer. To manipulate the camera image we programed image processing software using Visual C++ and OpenCV1.0. Ordinary camera colorimetric system would convert the RGB values of the each pixel into the XYZ tristimulus values. One of the problems for this conversion is that the relationship between them is non-linier, because the images are compressed at when a camera generates the RGB image from original raw data. We constructed the calculation algorism used raw data of CCD which is proportional to the photometric value linearly. Since the XYZ values are represented by linear combination of the values of raw data, the conversion matrix could be obtained accurately and easily. To estimate the conversion matrix, we examined not only the method to minimize the absolute errors of XYZ value, but also the method to minimize the relative errors of u'v' chromaticity which is more important to recognize the color difference in human visual system. When we checked luminance and

chromaticity of color chart measured by our colorimetric system under several illuminations which is different in spectrum, we could confirm the accuracy of measurement.

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SPECIAL THANKS TO

Benoît Mosset for the design of the CIE100YEARS logo
RATP for their invitation to the exhibit and their contribution to the *Paris by Night Tour*
ERCO for financing the registration of students to the conference

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Comprehensive Schedule CIE Centenary

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MNHN</td></tr>
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