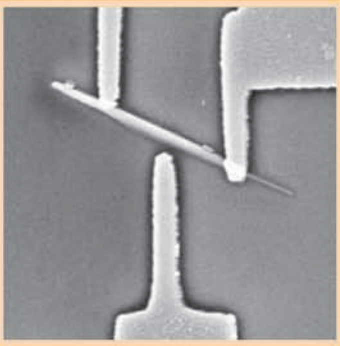
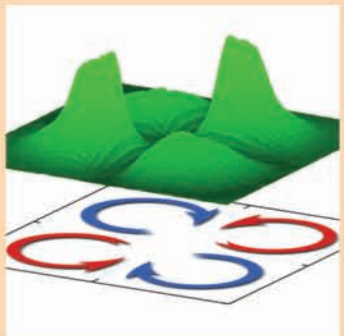
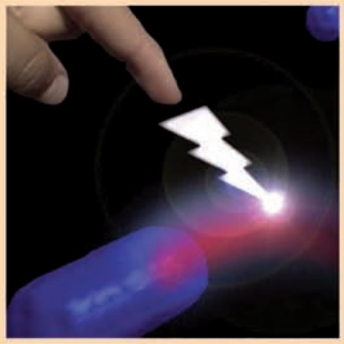
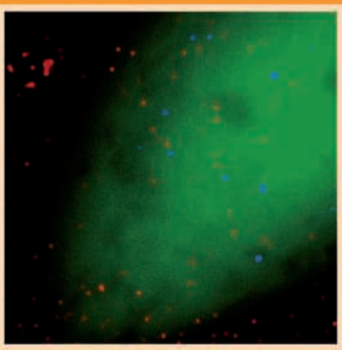
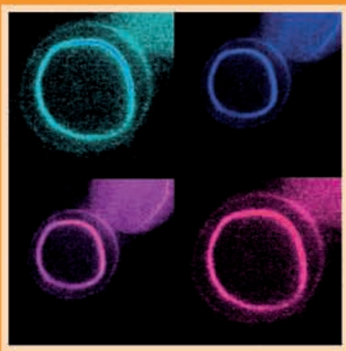
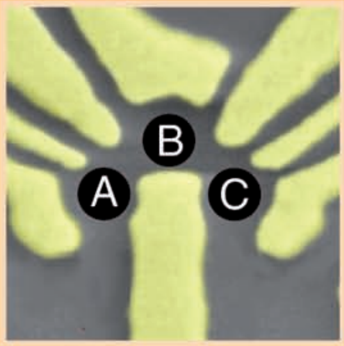
Center for NanoScience

ANNUAL REPORT 2006

CeNS
Center for NanoScience
Ludwig-Maximilians-Universität

2006

was another very successful year for CeNS. Our membership continued to grow with Prof. Achim Hartschuh, who recently joined the LMU Department of Chemistry and Prof. Heinrich Leonhardt at the LMU Department of Biology, becoming full members. As extra-ordinary members we welcome Prof. Andreas Bausch (TU Munich, Physics), Dr. Jens Ebbecke, (Univ. of Augsburg, Physics), Dr. Thomas Franosch (LMU, Physics), Dr. Alexander Gigler and Dr. Markus Lackinger (both LMU, Earth and Environmental Sciences), Dr. Shaila Rössle (LMU, Physical Chemistry), Prof. Enrique Solano (LMU, Physics), and Dr. Albert Zink (LMU, Earth and Environmental Sciences).

CeNS members enjoyed widespread recognition of their work, with Prof. Thomas Carell receiving a Philip Morris Research Award and becoming a Novartis Middle European Lecturer and Prof. Patrick Cramer obtaining a very prestigious Gottfried Wilhelm Leibniz Award of the German Science Foundation. Several awards went to Prof. Peter Hänggi (medal of honour from the Jagellonian University in Krakow and an award for the "Chair of Physics Elena Aizen de Moshinsky" from the National Autonomous University of Mexico) who also continues collecting doctoral degrees *honoris causa* (Tatar State University, Kazan, Russia, and the National Academy of Sciences of Ukraine) and accepted an offer from the National University of Singapore for a visiting professorship. Prof. Ulrich Schubert received calls for full professorships at the Universities of Stuttgart, Hamburg and Jena.

A substantial number of our junior members received outside offers with Ulrich Gerland joining the University of Cologne as associate professor, John Lupton becoming an associate professor at the University of Utah and also receiving the Max Auwärter Prize of the Austrian Physical Society, Wolfgang Parak accepting a full professor position at University of Marburg and Mark Tornow moving as associate professor to University of Braunschweig. Associate professor positions were also offered to Dieter Braun (at the University of Bayreuth) and Friedrich Simmel, (at the University Erlangen-Nürnberg and University of Leipzig), who also received a Young Investigator Award of the Human Frontier Science Program. Here, we are waiting to learn where they will decide to move.

Other awards received by our junior members were an Award of the Swiss Chorafas Foundation to Hendrik Dietz for his thesis work and an award of the Klaus Römer foundation to Irmgard Frank and Don Lamb, respectively. Last not least, our spin-off company attocube systems AG received the 2006 Innovation Award of the State of Bavaria.

CeNS members also competed very successfully in the Initiative for Excellence by the German Government and received five year funding for the Excellence Cluster „Nanosystems Initiative Munich“ (NIM). NIM unites research groups from both Munich universities, LMU Munich and TU Munich, as well as the University of Augsburg, the Max-Planck-Institutes for Quantum Optics and Biochemistry, the Walther-Meißner-Institute of the Bavarian Academy of Sciences, the Munich University of Applied Sciences and the "Deutsches Museum" with nearly 70% of the principal investigators being also CeNS members.

The scientific management of CeNS changed with Eva Natzer leaving for a very attractive position and now coordinating the Natural Science Collections of the State of Bavaria and Marie-Christine Blüm joining us, shortly after completing her Ph.D. in physics at the University of Lausanne. Our special thanks go to Eva Natzer for very successfully coordinating a wide spectrum of CeNS activities and we warmly welcome Marie-Christine Blüm, who quickly became very effective in supporting the CeNS effort.

Hence CeNS educational activities continued smoothly and successfully in 2006, beginning with a largely self-organized Junior Nanotech Network (JNN) activity in which a group of Ph.D. students from CeNS spent a three-week training period at McGill University in Montreal and in turn hosted Ph.D. students from McGill for three weeks in Venice and Munich. Our biannual CeNS workshop in Venice again attracted outstanding lecturers from across the world with Ted Hänsch's talk on "Towards a quantum laboratory on a chip" being a special highlight. Other educational activities included our yearly one-day workshop „CeNS meets industry" and a workshop on "Project management for Ph.D. students" organized jointly with our International Doctorate Program "NanoBioTechnology" (IDK-NBT). These events also provided additional educational activities for the participating Ph.D. students. The continued expansion of nanoscience seminars announced in the "CeNS Weekly"-Newsletter reflects the growing scientific activities as does the increasing number of guest lecturers and researchers from abroad. The international standing of CeNS was again recognized by visits of delegations from abroad, eager to learn our recipes for success. These continue to be based on the voluntary engagement of all CeNS members.

In their yearly general meeting the CeNS members also elected a new board composed of Thomas Bein, Hermann Gaub and myself with Hermann Gaub becoming spokesman. I wish to thank Christoph Bräuchle for his fruitful involvement on the CeNS board during the last six years and am sure that with his active participation on the board of NIM we will continue to have his cherished advice. Equal thanks go to Joachim Rädler for his active service on the CeNS board who now became spokesman of the IDK-NBT. After eight years as spokesman of CeNS I want to thank all members of CeNS for their enthusiastic participation in our creative network. It has been a lot of fun to see CeNS grow without loosing its young spirit. I am certain that this truly collaborative atmosphere will continue to be the trademark of CeNS for the years to come and wish Hermann Gaub as new spokesman of CeNS a joyful time. As coordinator of NIM it will be my pleasure to have continued involvement in many CeNS activities and I am looking forward to a very fruitful interaction of CeNS and NIM.

Munich, June 27, 2007

Jörg P. Kotthaus

Welcome

After all these splendid achievements one might be tempted to lean back and enjoy the success! But knowing the passion of my CeNS-colleagues for science and their unbroken drive for new horizons I am positive that the coming year will be as exciting as ever.

As the new spokesman I see it as my special pleasure to thank the former board members for all their efforts and particularly Jörg Kotthaus for his devotion and all the energy he put into nursing this idea so that it grew into this vivid structure that it is now.

The future looks bright!

Munich, June 27, 2007

Hermann E. Gaub

Content

Mission and Organization

Mission of CeNS

The Center for NanoScience

The Center for NanoScience (CeNS) was founded in 1998 at the Ludwig-Maximilians-Universität (LMU) in Munich. The goal of CeNS was to promote, coordinate, and bundle interdisciplinary research in the field of nanoscience in the Munich area.

CeNS is an association of working groups from basic research and industry and is conceived as a network, joining people from various institutions (LMU Munich, TU Munich, MPI of Biochemistry, Augsburg University and others) and encompassing a variety of disciplines. The researchers cooperate in a horizontal network which is based on voluntary commitment and are supported by a small coordinating team. Currently, about 80 professors and junior group leaders and roughly 200 PhD and Diploma students are members or associates of CeNS.

Joint Research

CeNS consolidates research activities in the fields of nano(bio)science from the areas such as (bio)physics, (bio)chemistry, pharmaceutics, biology, and medicine. The network promotes the mutual understanding and collaboration of researchers from these different disciplines by organizing a great variety of events where the scientists meet and discuss. Mulitdisciplinary cooperations between different groups are supported by CeNS.

Education

CeNS organizes each year a summer or winter school, offers a weekly colloquium, scientific seminars and soft-skill workshops. In addition to the regular Diploma and PhD education, CeNS hosts the International Doctorate Program "NanoBioTechnology" (IDK-NBT) which is funded by the Elite Network of Bavaria.

Transfer to Industry

The creative and unorthodox atmosphere within CeNS efficiently helped to create concepts for and incubate young nano-technological companies: the spin-off companies attocube systems AG, Advalytix AG, ibidi GmbH, Nanion Technologies GmbH, NanoScape AG and Nanotools GmbH, currently employ about 100 mostly young scientists and technologists, working primarily on nano-biotechnological tasks. CeNS offers the creative scientific environment which is essential for these start-up companies and provides well-trained and highly motivated scientists and technologists.

Advalytix
attocube systems
nan]i[on
nanotools
NanoScape
ibidi

Organization

Scientific Board

Spokesman	Prof. J. P. Kotthaus (until 06) / Prof. H. E. Gaub (since 07)	LMU, Physics
Board member	Prof. C. Bräuchle (until 06) / Prof. T. Bein (since 07)	LMU, Chemistry
Board member	Prof. J. O. Rädler (until 06) / Prof. J. P. Kotthaus (since 07)	LMU, Physics

Scientific Advisory Board

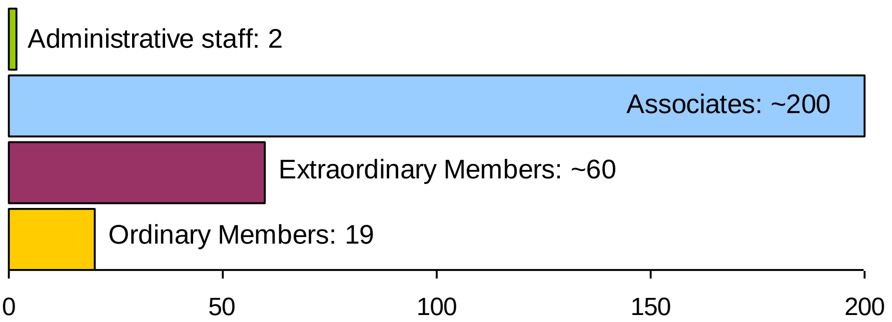
Prof. David Awschalom	University of California, Santa Barbara, USA
Prof. Gerd Binnig	IBM Research Laboratory, Switzerland
Prof. Andreas Engel	Biozentrum, University of Basel, Switzerland
Prof. Teun Klapwijk	Delft University of Technology, Netherlands
Prof. Klaus Müllen	Max Planck Institute for Polymer Research, Mainz

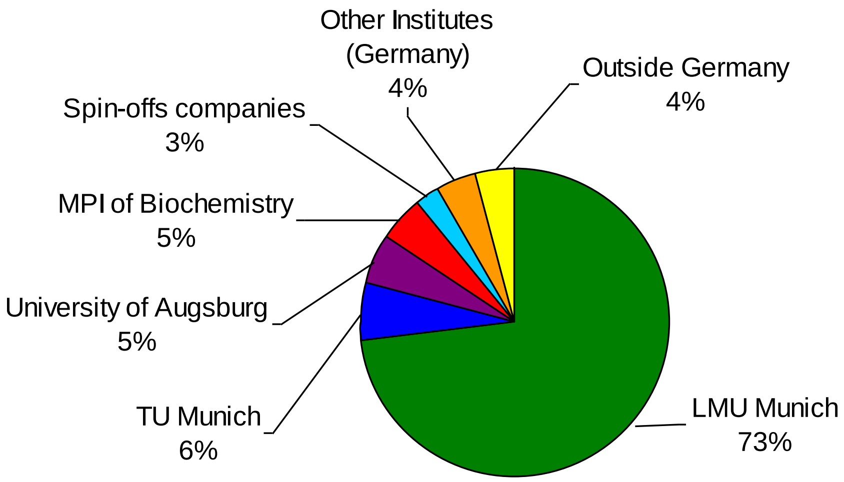
Organization Team

Dr. Marie-Christine Blüm	Scientific Manager
Evelyn Morgenroth	Secretary

Active Members

Ordinary Members	~ 20 full professors at LMU Munich
Extraordinary Members	~ 60 group leaders at LMU and full professors from other institutions
Associates	~ 200 PhD and diploma/Master students





Home Institutions of CeNS Members and Associates

Research Groups

Prof. Andreas Bausch	TU Munich, Biopolymers and Biosensors http://cell.e22.physik.tu-muenchen.de/bausch/index.html
Prof. Jan. C. Behrends	University of Freiburg, Dept. of Physiology II http://www.physiologie.uni-freiburg.de/index_p2.html
Dr. Udo Beierlein	LMU, Molecular Electronics http://www2.nano.physik.uni-muenchen.de/group/people/Beierlein/index.html
Prof. Thomas Bein	LMU, Chemistry and Function in Designed Nanoscopic Spaces http://bein.cup.uni-muenchen.de/index.php
Dr. Martin Benoit	LMU, Cell Biophysics http://www.biophysik.physik.uni-muenchen.de/
Prof. Christoph Bräuchle	LMU, Single Molecule Techniques in Bio- and Nanoscience http://www.cup.uni-muenchen.de/pc/braeuchle/index.html
Dr. Dieter Braun	LMU, Dissipative Biosystems http://www.biophysik.physik.uni-muenchen.de/Braun/
Prof. Thomas Carell	LMU, Biological Chemistry http://www.cup.uni-muenchen.de/oc/carell/
Prof. Hauke Clausen-Schaumann	University of Applied Sciences Munich, NanoBioTechnology http://www.fb06.fh-muenchen.de/fb/queries/vita.php?id=372
Prof. Patrick Cramer	LMU, Institute of Biochemistry http://www.lmb.uni-muenchen.de/cramer/
Dr. Ralf David	LMU, Molecular Biophysics http://www.biophysik.physik.uni-muenchen.de/
Dr. Jens Ebbecke	University of Augsburg, Surface Acoustic Waves and Nanostructures http://www.physik.uni-augsburg.de/exp1/ebbecke/ebbecke_engl.html
Prof. Jochen Feldmann	LMU, Photonics and Optoelectronics http://www.phog.physik.uni-muenchen.de/
Dr. Niels Fertig	Nanion Technologies GmbH http://www.nanion.de/
PD Dr. Irmgard Frank	LMU, Quantum Chemistry http://www.chemie.uni-muenchen.de/pc/frank/index.html
Dr. Thomas Franosch	LMU, Statistical and Biological Physics http://www.theorie.physik.uni-muenchen.de/lsfrey
Prof. Erwin Frey	LMU, Statistical and Biological Physics http://www.theorie.physik.uni-muenchen.de/lsfrey/
Prof. Hermann Gaub	LMU, Biophysics http://www.biophysik.physik.uni-muenchen.de/
Prof. Ulrich Gerland	Cologne University, Biological Physics http://wiki.uni-koeln.de/biologicalphysics/index.php/Main_Page
Dr. Alexander Gigler	LMU, Nanomanipulation http://www.nanomanipulation.de/index.html
Dr. Kay-Eberhard Gottschalk	LMU, Protein Interactions http://www.biophysik.physik.uni-muenchen.de/
Dr. Stefan Griessl	LMU, Nanoscience, STM Group http://theo.krist.geo.uni-muenchen.de/stm/
Dr. Reinhard Guckenberger	MPI of Biochemistry, Scanning Probe Microscopy http://wwwex.biochem.mpg.de/baumeister/spm/
Dr. Zeno Guttenberg	Advalytix AG http://www.advalytix.de/
Dr. Dirk Haft	Attocube Systems AG http://www.attocube.de/
Prof. Peter Hänggi	University of Augsburg, Theoretical Physics http://www.physik.uni-augsburg.de/theo1/hanggi/
Prof. Achim Hartschuh	LMU, Near-Field Optical Microscopy http://www.cup.uni-muenchen.de/pc/hartschuh/
Prof. Wolfgang Heckl	LMU, Scanning Probe Microscopy http://www.nano.geo.uni-muenchen.de/
Prof. Bianca Hermann	LMU, Self-Organized Monolayers of (Bio)Molecules http://www.wmi.badw-muenchen.de/spm/
Dr. Rainer Hillenbrand	MPI of Biochemistry, Nano-Photonics http://www.biochem.mpg.de/en/rg/hillenbrand/
Jun.-Prof. Alexander Holleitner	LMU, Nanoptronics http://www.nano.physik.uni-muenchen.de/nanoptronics/
Jun.-Prof. Thorsten Hugel	TU Munich, Single Molecule Detection and Manipulation http://cell.e22.physik.tu-muenchen.de/Hugel/home.html
Dr. Bernd Irmer	nanotools GmbH http://www.nano-tools.com/
Dr. Ferdinand Jamitzky	LMU, Nanobioinformatics http://theo.krist.geo.uni-muenchen.de/%7efxj/nanobioinformatics/
Dr. Valentin Kahl	ibidi GmbH http://www.ibidi.de/
Prof. Khaled Karrai	LMU, Experimental Nano Optics http://www2.nano.physik.uni-muenchen.de/
Prof. Stefan Kehrein	LMU, Condensed Matter Theory http://www.theorie.physik.uni-muenchen.de/~kehrein/index.html

Dr. Fritz Keilmann	MPI of Biochemistry, Near-Field Spectroscopy http://wwwex.biochem.mpg.de/baumeister/personal/keilmann/
Prof. Roland Kersting	LMU, The Terahertz Group http://www.thz.physik.uni-muenchen.de/
Dr. Thomas Klar	LMU, Nanoparticle Hybrid Systems http://www.phog.physik.uni-muenchen.de/index.html
Prof. Jörg P. Kotthaus	LMU, Nanophysics http://www.nano.physik.uni-muenchen.de/
Dr. Markus Lackinger	LMU, Nanoscience, STM Group http://theo.krist.geo.uni-muenchen.de/stm/
Dr. Pavlos Lagoudakis	Univ. of Southhampton, Hybrid Optoelectronic http://www.soton.ac.uk/~lagous/
Dr. Don C. Lamb	LMU, Fluorescence Applications in Biological Systems http://www.cup.uni-muenchen.de/pc/lamb/index.html
Prof. Ulrich Lemmer	Research University Karlsruhe, Light Technology http://www.lti.uni-karlsruhe.de/english/lemmer.php
Prof. Heinrich Leonhardt	LMU, BioImaging, Fluorescent Nanobodies http://www.biologie.uni-muenchen.de/ou/epigenetics/index.htm
Dr. Heribert Lorenz	LMU, Nanophysics http://www.nano.physik.uni-muenchen.de/
Prof. Axel Lorke	University of Duisburg-Essen, Nanostructures http://fkpme246a.uni-duisburg.de/ag_lorke/index.shtml
Dr. Stefan Ludwig	LMU, Quantum Dots http://www.nano.physik.uni-muenchen.de/
Prof. John Lupton	University of Utah, Organic Seminconductors http://www.physics.utah.edu/~lupton/
Jun.-Prof. Florian Marquardt	LMU, Condensed Matter Theory http://www.theorie.physik.uni-muenchen.de/~florian/
Dr. Eduardo Mendoza	LMU, Systems Biology http://www.softmatter.physik.lmu.de/tiki-index.php?page=GroupMendozaHome
Jun.-Prof. Jens Michaelis	LMU, Physical Chemistry, Nanomechanics http://www.cup.uni-muenchen.de/pc/michaelis/
Prof. Roland Netz	TU Munich, Biological Soft-Matter Theory http://www.ph.tum.de/lehrstuehle/T37/Welcome.html
Dr. Bert Nickel	LMU, Soft Matter Interactions http://softmatter.physik.lmu.de/tiki-index.php?page=GroupNickelHome
Prof. Wolfgang Parak	Philipps University Marburg, Nanomaterials http://www.biophysik.physik.uni-muenchen.de/
Prof. Joachim Rädler	LMU, Soft Condensed Matter Physics http://softmatter.physik.lmu.de/tiki-index.php?page=GroupRaedlerHome
Prof. Matthias Rief	TU Munich, Single Molecules and Molecular Motors http://cell.e22.physik.tu-muenchen.de/gruppematthias/index.html
Dr. Andrey Rogach	LMU, Semiconductor Nanocrystals http://www.phog.physik.uni-muenchen.de/research/sc_nanocrystals/index.html
Dr. Shaila Rössle	LMU, Quantum Chemistry http://www.chemie.uni-muenchen.de/pc/frank/index.html
Dr. Matthias F. Schneider	University of Augsburg, Biological Physics http://www.physik.uni-augsburg.de/exp1/schneider/schneider_research.html
Prof. Ulrich S. Schubert	Eindhoven University of Technology, Macromolecular Chemistry & Nanoscience http://www.schubert-group.com/
PD Dr. Friedrich C. Simmel	LMU, Biomolecular Nanoscience http://www2.nano.physik.uni-muenchen.de/nanobio/
Prof. Enrique Solano	LMU, Quantum Physics http://www.theorie.physik.uni-muenchen.de/~solano/
Dr. Robert Stark	LMU, Nanomanipulation http://www.nanomanipulation.de/index.html
Dr. Stefan Thalhammer	GSF, NanoAnalytics http://www.nanobiomed.de/
Prof. Marc Tornow	TU Braunschweig, Semiconductor Physics http://www.iht.tu-bs.de/EN/forschung.html
Prof. Jan von Delft	LMU, Theory of Meso-and Nanoscopic Physics http://www.theorie.physik.uni-muenchen.de/lsvondelft/
Prof. Ernst Wagner	LMU, Pharmaceutical Biotechnology http://www.cup.uni-muenchen.de/pb/aks/ewagner/
Prof. Frank Wilhelm	University of Waterloo, Quantum Computing http://www.iqc.ca/people/person.php?id=23
Prof. Joost Wintterlin	LMU, Scanning Tunneling Microscopy http://www.cup.uni-muenchen.de/pc/wintterlin/welcome.html
Prof. Achim Wixforth	University of Augsburg, Material Science at the Nanometer Scale http://www.physik.uni-augsburg.de/exp1/willkommen/willkommen.html
Dr. Albert Zink	LMU, NanoBioScience http://www.nano.geo.uni-muenchen.de/index.html

MEMBERS' NEWS

Awards

attocube systems AG

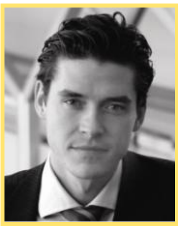
- Innovation Award of the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology

Prof. Thomas Carell

- Philip Morris Research Award
- Novartis Middle European Lecturer

Prof. Patrick Cramer

- Gottfried Wilhelm Leibniz Price of the German Research Foundation

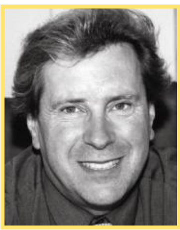


Dr. Hendrik Dietz

- Award of the Swiss Chorafas Foundation

PD Dr. Irmgard Frank

- Award of the Dr. Klaus Römer-Foundation of the Department of Chemistry and Biochemistry, LMU



Prof. Peter Hänggi

- Doctor honoris causa from the Tatar State University, Kazan (Russia) and the National Academy of Sciences of Ukraine
- Medal of honour from the Jagellonian University in Krakow
- Award for the "Chair of Physics Elena Aizen de Moshinsky" from the National Autonomous University of Mexico (UNAM)
- Visiting Professorship, National University of Singapore; 2006 – 2008

Dr. Don Lamb

- Award of the Dr. Klaus Römer-Foundation of the Department of Chemistry and Biochemistry, LMU

Prof. John Lupton

- Max Auwärter Price of the Max Auwärter Foundation, awarded by the Austrian Physical Society

PD Dr. Friedrich Simmel

- Young Investigators Award of the Human Frontier Science Program

New Members

(from left to right on the images)

▪ Prof. Andreas Bausch	Physics, TU Munich
▪ Dr. Jens Ebbecke	Physics, University of Augsburg
▪ Dr. Thomas Franosch	Physics, LMU Munich
▪ Dr. Alexander Gigler	Earth and Environmental Sciences, LMU Munich
▪ Prof. Achim Hartschuh	Physical Chemistry, LMU Munich
▪ Dr. Markus Lackinger	Earth and Environmental Sciences, LMU Munich
▪ Prof. Heinrich Leonhardt	Biology, LMU Munich
▪ Dr. Shaila Rössle	Physical Chemistry, LMU Munich
▪ Prof. Enrique Solano	Physics, LMU Munich
▪ Dr. Albert Zink	Earth and Environmental Sciences, LMU Munich










Clusters of Excellence: NIM and CIPSM

The Excellence Initiative

In 2005, the German government and the German Research Foundation (DFG) initiated the Excellence Initiative to strengthen the science location Germany, to improve its worldwide competitiveness and to unveil top performance in German universities and research institutions.

A very prominent part of this initiative are the Clusters of Excellence, joining different research groups to work out a common scientific focus.

Together with researchers from other institutions, CeNS members successfully applied for funding of two clusters of excellence: the Nanosystems Initiative Munich (NIM), whose application was coordinated by CeNS, and the Munich Center for Integrated Protein Science (CIPSM). Both clusters were awarded with substantial funding for a five-year period which has started in November 2006.

Nanosystems Initiative Munich (NIM)

The overarching vision guiding the research in this cluster is to design, fabricate and achieve control of a broad range of artificial and multi-functional nanoscale systems, and to unlock their potential for possible applications in fields as diverse as future information technologies, the life sciences, or combinations of both.

In the Nanosystems Initiative Munich about 60 research groups in physics, biophysics, physical chemistry, biochemistry, pharmaceutics, biology, electrical engineering and medical science in the Munich area work together.

Together with the Ludwig-Maximilians-University (LMU) as coordinating university, the cluster of excellence also involves the Technical University of Munich (TUM), the University of Augsburg, the Munich University of Applied Sciences (FHM), the Walther-Meißner Institute at the Bayerische Akademie der Wissenschaften, the Max Planck Institutes of Biochemistry and Quantum Optics, and the Center for New Technologies at the Deutsches Museum.

Coordinator
Prof. Jörg P. Kotthaus (LMU, CeNS)

Deputy Coordinator
Prof. Gerhard Abstreiter (TUM)

www.nanosystems-munich.de

Center for Integrated Protein Science (CIPSM)

The scientists of CIPSM study proteins in their natural context by analyzing their structure, function and dysfunction. The resulting new overall understanding shall lead to the development and exploration of novel therapeutic targets and their medical application.

To achieve this goal, interactive research in different disciplines, including chemistry, physics, biology and molecular medicine is essential. CIPSM brings together scientists from the Ludwig Maximilians University (LMU) and the Technical University of Munich (TUM), as well as from the Max Planck Institutes of Biochemistry and Neurobiology, and the National Research Center for Environment and Health (GSF).

The main goal of CIPSM is "to catalyze the transition from classical protein science scattered over the Munich region to a new systemic protein science that is expected to dominate research in the molecular life sciences beyond the funding period."

Coordinator
Prof. Thomas Carell (LMU, CeNS)

Deputy Coordinator
Prof. Arne Skerra (TUM)

www.cipsm.uni-muenchen.de

Education

Workshops & Seminars

In addition to the weekly CeNS Colloquium where invited speakers and CeNS members present their research to the interdisciplinary audience of CeNS, a large scientific workshop for all CeNS members was held in Venice from September 25th to 29th. Furthermore, the workshops “CeNS meets Industry” and a Soft-Skills-Seminar were organized in Munich.

CeNS Workshop in Venice, September 25 - 29, 2006

Emerging Nanosystems - From Quantum Manipulation to Nanobiomachines

140 participants; location: Venice International University on San Servolo, Italy

Invited speakers & titles of their presentations:

Gerhard Abstreiter, TU Munich	Manipulating and controlling semiconductor quantum dots
Thomas Basché, Universität Mainz	Electronic excitation energy transfer between two single molecules
David F. Bensimon, ENS Paris	Single molecule studies of chromatine remodelling factors
Piet Brouwer, Cornell University	Current-induced magnetization dynamics in nanoscale magnets
Harold Craighead, Cornell	Nanostructures for biomolecular analysis
Thomas W. Ebbesen, Strasbourg	Surface plasmon photonics
Enrico Gratton, University of Illinois	Particle tracking in 3D: Chromatin structure and dynamics
Theodor W. Hänsch, LMU München	Towards a quantum laboratory on a chip
Paul Hansma, UCSB	High speed AFM & the molecular mechanics of bone fracture
Kevin Hennessy, UCSB/ETH Zurich	Coupled excitons and photons in photonic nanocavities
Justin Molloy, MRC London	Single molecule mechanical and optical studies: in vitro and inside live mammalian cells
Vahid Sandoghdar, ETH Zürich	On the coupling of a single emitter to photons
Christoph F. Schmidt, Göttingen	Eg5: a four-headed mitotic kinesin motor
William Shih, Harvard University	DNA-based molecular containers
Ulrich B. Wiesner, Cornell	Nanohybrids and nanobiohybrids
Erik Winfree, Caltech	Algorithmic self-assembly of DNA
Eli Yablonovitch, UCLA	The impedance-matching predicament: A hurdle in the race toward nano-electronics

VENICE INTERNATIONAL UNIVERSITY

Workshop 2006, San Servolo, Venice

CeNS Center for NanoScience Ludwig-Maximilians-Universität

“CeNS meets Industry 06“ & CeNS Summer Party - June 23, 2006

At this annual workshop, invited speakers from business and industry reported about their career, their jobs and their professional surrounding. The event offered the opportunity for Diploma and PhD students and PostDocs to talk to qualified representatives about the requirements and chances for a career in the industrial environment.

Speakers:

▪ Dr. Eckart Neuhaus	Advalytix / Olympus Life and Material Science Europa GmbH
▪ Dr. Dirk Lumma	Siemens Management Consulting
▪ Dr. Omar Stern	General Electric Company
▪ Dr. Ismail Moarefi	Crelux GmbH
▪ Dr. Andreas Pohl	Bain & Company Germany, Inc.

The event “CeNS meets Industry” was followed by the traditional CeNS Summer Party.

“Project Management for PhD-Students” - August 7, 2006

Workshop organized by CeNS and the International Doctorate Program “NanoBioTechnology” of the Elite Network of Bavaria

Elitenetzwerk Bayern

Speaker:

Dr. David Hoeflmayr, International Vice President of debitel AG

Subtitle: Planning, self management, successful graduation

The seminar addressed graduate students and project leaders of scientific groups. By alternating lecture parts and individual exercises, the participants were invited to directly link the proposed models to their own problems and experiences. In free discussions the particular basic conditions, success criteria, and auxiliary tools of academic projects were compiled.

Topics included:

- Project definition
- Project planning
- Scheduling
- Recourse management
- Communication

Junior Nanotech Network (JNN)

Self-organized PhD exchange program between Bavaria and Québec

This symmetrical exchange project brought together 20 PhD students from CeNS and the McGill Institute for Advanced Materials, Montréal, Québec. The program combined lectures from internationally renowned speakers with an extended period of laboratory work.

Organizers:

Prof. Hermann Gaub, CeNS
Prof. Peter Grütter, McGill Institute for Advanced Materials

Schedule:

June / July 2006
Students from CeNS visited McGill University in Montréal, Canada

September / October 2006
The Canadian partners went together with the German students to the CeNS workshop in Venice and then stayed in the labs in Munich for two weeks

Program:

- **Education:** One week of lectures held by internationally renowned speakers
- **Research:** Two weeks of hands-on experiments which were conceived, realized and supervised by the host students
- **Intercultural exchange:** Joint activities in the evening; housing at the hosts' homes

Hands-on experiments

Scientific discussions

Stimulating lectures

International Doctorate Program "NanoBioTechnology"

The scholarships of the International Program NanoBioTechnology (IDK-NBT) are granted to outstanding PhD students working at CeNS in the interdisciplinary fields of nanobiotechnology. The IDK-NBT has been established in 2004/05 by CeNS and is financed by the Elite Network of Bavaria. The members of the program are expected to participate in international conferences as well as in exchange programs with other NanoBioTechnology Centers. Furthermore, they are strongly encouraged to propose and organize scientific and soft-skill workshops as well as social events.

Organizational Board

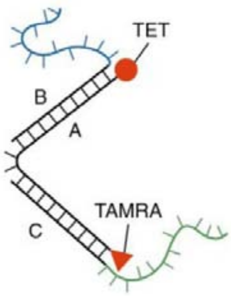
Spokesman	**Prof. Joachim Rädler**
Vice-Spokesman	**Prof. Christoph Bräuchle**
Coordinator	**Dr. Marie-Christine Blüm**
Coordinator (Finances)	**Dr. Moritz Ehrl**
Students' Representative	**Sebastian Geiger**
Vice students' Representative	**Julia Schmitz**

Selection Committee

Prof. Christoph Bräuchle, Prof. Patrick Cramer, Prof. Joachim Rädler, PD Dr. Friedrich Simmel

Main Subjects

- Nano2Bio: Application of Nanotechnology to Biology
- Bio2Nano: Biology inspired Nanotechnology



Curriculum / Activities

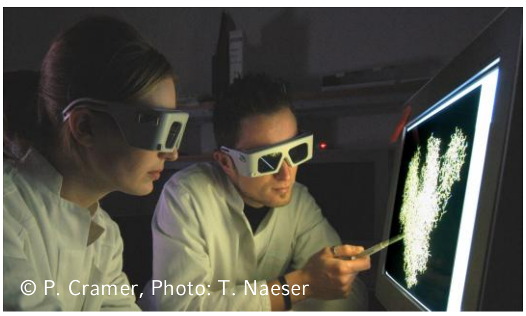
- Lecture Series on NanoBioTechnology
- Lectures and Seminars on nano(bio-)sciences held by CeNS members
- Scientific Workshops and Seminars (also in cooperation with CeNS)
- Soft-Skill Workshops (partly organized by the students)
- Social Events

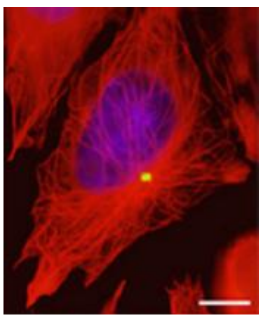
Members

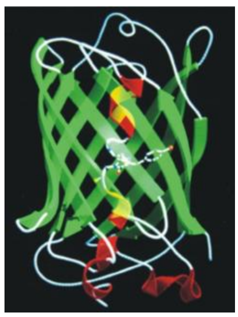
- 12 new scholarships per year / total of approx. 30 active members by 2006/2007
- Memberships: regular stipends and members with external stipends
- Female students: ~ 30 %
- International students: ~ 30 %
  (Australia, Czech Republic, Italy, The Netherlands, Poland, Rumania, Spain, Turkey)

International Mobility

Travels to cooperation & exchange partners and conferences abroad, e.g. UCSB, Caltech, University of Oxford, McGill University







Research

Nano-Bio-Sciences

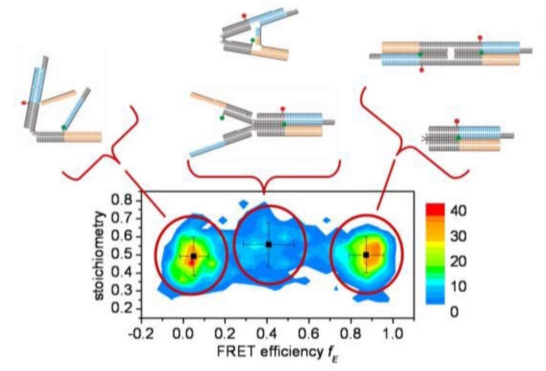
Single Molecule Investigations of a DNA Nanomachine

PD Dr. Fritz Simmel (LMU, Biomolecular Nanoscience)
Dr. Don Lamb (LMU, Fluorescence Applications in Biological Systems)

The self-assembly properties of DNA makes it an ideal building block for the construction of nanomachines. Nanomachines function as individual units and are thus best understood by studying them individually. Hence, the groups of Friedrich Simmel and Don C. Lamb have joined together to investigate the function of DNA tweezers using single molecule spectroscopy.

A pair of DNA tweezers is a nanomachine consisting of two arms of double-stranded helical DNA attached via a flexible single-strand DNA hinge. By addition of a "fuel" DNA strand, the tweezers are closed and upon removal of the fuel strand, the tweezers can be opened. Fluorophores were attached to both arms of the tweezers such that the conformation of the tweezers could be investigated using single pair Fluorescence Resonance Energy Transfer (FRET) and pulsed interleaved excitation. In the open state, only a single conformation was observed with both arms of the DNA well separated. Fluctuations bringing the arms close together were rarely observed which is expected from the Coulomb repulsion of the two arms. Single molecule investigations of the closed state resolved three subconformations which were not observable in ensemble measurements. The three subconformations correspond to the properly closed tweezers, fully open tweezers, and partially open tweezers. The fully open conformation comes from tweezers that have bound separate fuel strands to each arm, which allows the tweezers to remain in the open configuration.

The intermediate state is a mixture of at least two species: dimers that are linked together by a fuel strand and tweezers that could not close correctly due to steric hindrances. The detailed understanding of these subconformations gained from the single molecule experiments provides testable suggestions as how to improve the function of DNA tweezers. More importantly, the results show how vital single molecule experiments will be for the development of nanodevices.



A two dimensional histogram of FRET efficiency versus stoichiometry showing three subpopulations of DNA tweezers in the closed state along with schematics showing what constructs lead to the various conformations. The left subconformation is attributed to open DNA tweezers that have bound two fuel strands. The middle conformation is a mixture of incompletely labeled dimers of DNA tweezers and tweezers where the fuel strand has bound to both arms simultaneously and static hindrances do not allow the tweezers to close properly. The third subpopulation arises from properly closed tweezers and perhaps dimers of closed tweezers.

B. K. Müller, A. Reuter, F. C. Simmel and D. C. Lamb
Single-Pair FRET Characterization of DNA Tweezers
Nano Letters 6, 2814 (2006)

Multifunctional Polymer Microcapsules as Potential Drug Delivery Systems

Dr. Andrey Rogach (LMU, Semiconductor Nanocrystals)
Prof. Joachim Rädler (LMU, Soft Condensed Matter Physics)
Dr. Martin Benoit (LMU, Cell Biophysics)
Prof. Wolfgang Parak (Philipps University Marburg, Nanomaterials)

In a collaborative project of the CeNS scientists A. Rogach, J. Rädler, M. Benoit and W. Parak, a combination of atomic force microscopy (AFM) and optical microscopy has been used for the investigation of capsule uptake by cells. Positively and negatively charged polymer microcapsules were chosen as model particles, because their interaction with cells had already been investigated in detail. AFM measurements allowed the recording of adhesion forces on a single-molecule level. Due to the micrometer size of the capsules, the number of ingested capsules could be counted by optical microscopy. The combination of both methods allowed combined measurement of the adhesion forces and the uptake rate for the same model particle. As a demonstration of this system, the correlation between the adhesion of positively or negatively charged polymer microcapsules onto cell surfaces and the uptake of these microcapsules by cells has been investigated for several cell lines. We have found a correlation between both processes, which is in agreement with adsorption-dependent uptake of the polymer microcapsules by cells.

CdTe nanocrystals capped by short-chain thiol molecules can easily be prepared in aqueous solution. They possess a single narrow emission band and can potentially be used as luminescence sensors and ions probes. In a collaborative project of A. Rogach and W. Parak, we have studied the effect of pH and various ions, including physiology important cations such as calcium(II), manganese(II) and iron(III), on the luminescence intensity of CdTe nanocrystals capped by thioglycolic acid. Quenching of luminescence of CdTe nanocrystals by Ag(I)-cations points out their use in cellular studies as fluorescent labels and quenching agents, respectively. Micromolar amounts of Hg(II) ions caused quenching of the emission of CdTe nanocrystals, while at increasing Hg(II) concentration alloyed $Cd_xHg_{1-x}Te$ nanocrystals were formed, followed by appearance of a near-infrared luminescence band. Luminescence of both - bare CdTe nanocrystals and CdTe nanocrystals embedded into polymer microcapsules - was found to be pH sensitive within the pH range between 4 and 6.

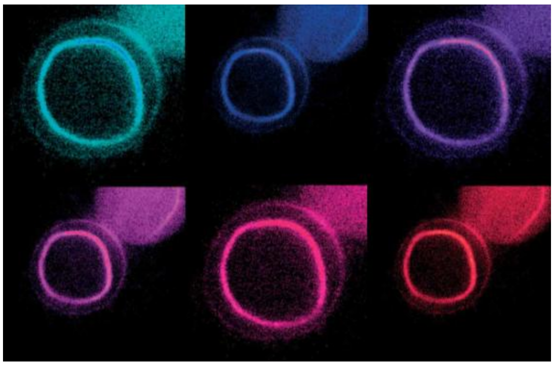
A. Munoz Javier, O. Kreft, A. Piera Alberola, C. Kirchner, B. Zebli, A. S. Susha, E. Horn, S. Kempter, A. Skirtach, A. L. Rogach, J. Rädler, G. B. Sukhorukov, M. Benoit, W. J. Parak
Combined Atomic Force Microscopy and Optical Microscopy Measurements as a Method to Investigate Particle Uptake by Cells, Small 2, 394 (2006)

A. S. Susha, A. Munoz Javier, W. J. Parak, A. L. Rogach
Luminescent CdTe Nanocrystals as Ion Probes and pH Sensors in Aqueous Solutions
Coll. Surf. A 281, 40 (2006)

Micromechanics of Actin Bundles

Prof. Andreas Bausch (TU Munich, Biopolymers and Biosensors)
Prof. Erwin Frey (LMU, Statistical and Biological Physics)

Despite the importance of F-actin bundle mechanical properties to many cytoskeletal processes, quantitative investigations of their mediation by actin binding proteins (ABPs) remain scarce. The groups of Prof. Bausch and Prof. Frey directly measure the bending stiffness of F-actin crosslinked by three ABPs that are ubiquitous in eukaryotes and observe distinct regimes of bundle bending stiffness that differ by orders of magnitude depending on ABP type, concentration, and bundle size. The reported behaviour is reproduced quantitatively by a molecular-based mechanical model in which ABP shearing competes with F-actin extension/compression. A generic scaling parameter identifying the relevant bundle bending stiffness regimes is presented. The results shed new light on the potential role of ABPs in associated cellular processes and demonstrate how single molecule properties determine mesoscopic material properties. Moreover, the observed mechanics of fiber bundle bending are completely general, with broad implications not only for cytoskeletal mechanics but also for the rational design of functional materials.



A mesoscopic model system was developed to determine the micromechanical properties of cytoskeletal bundles.

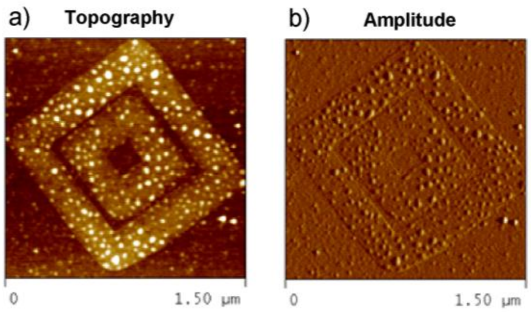
M. M. A. E. Claessens, M. Bathe, E. Frey and A. R. Bausch
Actin-binding proteins sensitively mediate F-actin bundle stiffness
Nature Materials 5, 748 (2006)

„Münchner Physiker bestimmen erstmals Faserbündel im Zellskelett"
August 24, 2006 - Joint Press release of TUM and LMU

Template-Guided Assembly of Magnetic Nanoparticles

Prof. Ulrich Schubert (Eindhoven U. of Technology, Macromolec. Chemistry & Nanoscience)
Dr. Andrey Rogach (LMU, Semiconductor Nanocrystals)
Prof. Jochen Feldmann (LMU, Photonics and Optoelectronics)

A successful collaboration on the assembly of nanostructures consisting of Fe_3O_4 particles was established between the Laboratory of Macro-molecular Chemistry and Nanoscience in Eindhoven, Netherlands (Prof. U. S. Schubert) and the Photonics and Optoelectronics Group at LMU Munich (Dr. A. Rogach, Prof. J. Feldmann) where the magnetic nanoparticles were synthesized. The magnetic properties can be potentially used for magnetic storage applications, whereby these concepts rely critically on the ability to localize these particles in a regular fashion. Therefore, suitable structuring methods have to be found that allow the site-selective placement of (individual) Fe_3O_4 particles, preferable by self-assembly schemes. A potentially interesting approach to achieve this nanoparticle organization is the local chemical functionalization of a self-assembled monolayer of n-octadecyltrichlorosilane (OTS), where the top functional methyl groups can be electro-chemically oxidized into reactive acid functions.



Topography (a) and amplitude (b) tapping mode SFM image of Fe_3O_4 nanoparticles selectively deposited on a rhombic surface template, inscribed on the OTS substrate by electro-oxidative nanolithography. The nanoparticles assemble preferentially on the patterned area.

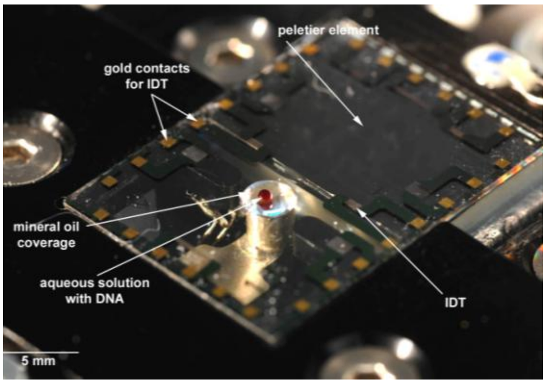
The group of Macromolecular Chemistry and Nanoscience used this approach to create areas to preferentially bind Fe_3O_4 particles. These particles can be dispersed in aqueous solutions and assemble on the hydrophilic, –COOH terminated surface patterns that can be inscribed on the OTS monolayer with a conductive scanning force microscope (SFM) tip by the application of a sufficiently high bias voltage. This versatile approach is moreover applicable also to other particle systems or other nano-objects, e.g. carbon nanotubes, molecular building blocks and the surface templates can be used as templates to locally conduct chemical reactions. Therefore, the used patterning approach of electro-oxidative lithography is regarded as a versatile approach towards nanofabrication.

S. Hoeppener, A. S. Susha, A. L. Rogach, J. Feldmann, U. S. Schubert
Guided Self-Assembly of Fe_3O_4 Nanoparticles on Chemically Active Surface Templates Generated by Electro-Oxidative Nanolithography
Current Nanosci. 2, 135 (2006)

Programmable Lab-on-a-Chip System

Dr. Stefan Thalhammer (GSF, NanoAnalytics)
Prof. Achim Wixforth (University of Augsburg & Advalytix AG)

Over the past decade, advances in molecular biology have helped to enhance understanding of the complex interplay between genetic, transcriptional and translational alterations in e.g. human cancers. These molecular changes are the basis for an evolving field of high-throughput cancer discovery techniques using microscopic amounts of patient-based material. To be able to reproducibly and reliably handle, process and analyze such small samples, many laboratories all over the world are intensively investigating the applicability of so-called "labs-on-a-chip" for this purpose.



Lab-on-a-chip: transport of sample volumes in their "virtual" reaction vessels is performed via surface acoustic waves, propagated by interdigital transducers (IDT). Aqueous solution with genetic material (red droplet) is covered with mineral oil to avoid evaporation. A spot heating device and a Peletier element are precisely controlling the temperature profile necessary for polymerase chain reaction (PCR).

Dr. Stefan Thalhammer and Prof. Achim Wixforth collaborate on an acoustic driven lab-on-a-chip for cytogenetic applications. By combining different platform elements, like microdissection-, nanofluidic-DNA amplification and detection modules, the chip can be in future adapted to patient-specific applications. Atomic force microscopy (AFM) based manipulation as well as laser based isolation of cells down to single chromosomes can be performed to extract minute amount of genetic material. In contrast to many other lab-on-a-chip approaches, the fluidic handling is done on the planar surface of a chip, the fluids being confined in "virtual" reaction chambers and "virtual" test tubes in the form of free droplets. The droplets, the fluidic tracks and the reaction sites are defined at the chip surface by a monolayer chemical modification of the surface.

This interdisciplinary project, sponsored by the Bavarian Research Foundation and the Cluster of Excellence "Nanosystems Initiative Munich" (NIM), is conducted by the Institute of Radiation Protection at the GSF, the Department of Experimental Physics at University of Augsburg, the Medizinisch Genetisches Zentrum MGZ Munich, Advalytix AG, Brunnthal, and the Deutsches Museum Munich.

„Minilabor aus Augsburg: Krebsdiagnose schneller"
July 7, 2006 - Augsburger Allgemeine Zeitung & Neu-Ulmer Zeitung

„Minilabor als Werkzeug zur Genanalyse"
July 19, 2006 - Der Standard, Austria

Electrical Control of Förster Energy Transfer

Prof. John Lupton (University of Utah, Organic Seminconductors)
Dr. Andrey Rogach (LMU, Semiconductor Nanocrystals)
Prof. Jochen Feldmann (LMU, Photonics and Optoelectronics)

Combination of inorganic semiconductor nanoparticles with organic dye molecules allows us to impart new optoelectronic functionality on an artificial hybrid system. An interdisciplinary collaboration between J. M. Lupton (University of Utah), A. Rogach and J. Feldmann (LMU) with materials chemistry group of Prof. Horst Weller at the University of Hamburg showed for the first time the feasibility of electrically tailoring one of the most fundamental processes occurring in nature: excitation energy transfer. The electronic resonance between a single emitting semiconductor nanoparticle and an adjacent dye absorber is controlled by applying an external electric field which shifts the emission of the nanocrystal due to the quantum confined Stark effect. Besides offering a new parameter for optoelectronic device control (FRET), the work also provides unique insight into the disorder limitation of resonant dipole-dipole coupling in disorder broadened samples.

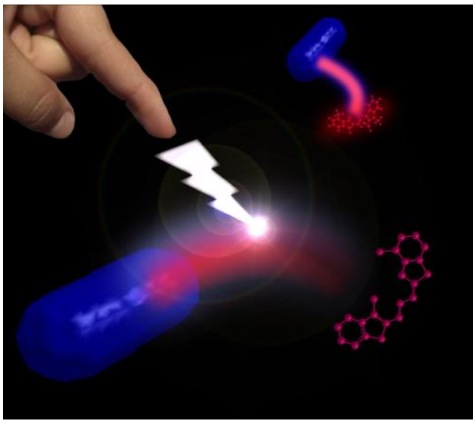


Illustration of the electrical control of Förster energy transfer.

K. Becker, J. M. Lupton, J. Müller, A. L. Rogach, D. V. Talapin, H. Weller and J. Feldmann
Electrical control of Förster energy transfer
Nature Mat. 5, 777 (2006)

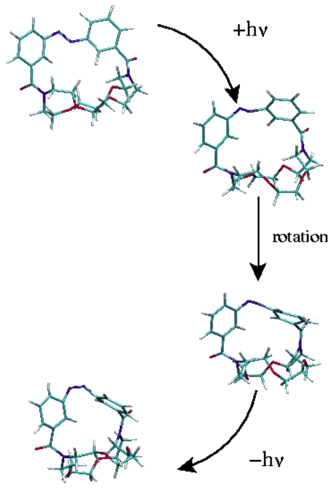
Simulation of Ultrafast Photoreactions in Nanosystems

PD Dr. Irmgard Frank (LMU, Quantum Chemistry)
Prof. Hermann Gaub (LMU, Biophysics)

The group of Irmgard Frank investigates the excited state dynamics of nanosystems using first-principles molecular dynamics. On the basis of the Car-Parrinello concept, this approach allows to simulate the dynamics of a nanosystem consisting of some hundred atoms. The bonding between the atoms is described quantummechanically using density functional theory, which makes it possible to model not only molecular structures but also chemical reactions.

With this approach the photoisomerization of azobenzene was studied together with Hermann Gaub who uses the photoreaction of this molecule for the construction of light-driven molecular motors. It was possible to show that the isomerization is a rotation, not an inversion. This is in contrast to the conclusion drawn from previous experiments using a capped azobenzene in which a rotation was believed to be impossible.

The simulations which show the full reaction dynamics as it occurs spontaneously upon excitation, clearly demonstrate that also in the capped system the flexibility within the system is still high enough for the rotation to occur. Also the striking phenomenon that the quantum yield of the reaction is even increased by the capping could be explained on the basis of the quantum chemical calculations.



The isomerization of a capped azobenzene: snapshots from a first-principles molecular dynamics run. Upon excitation, the double bond (shown in blue) spontaneously isomerizes. Due to the specific quantumchemical nature of the bonds, this rotation is possible even if the two ends of the azobenzene moiety are connected by a crown ether.

C. Nonnenberg, H. Gaub and I. Frank
First-Principles Simulation of the Photoreaction of a Capped Azobenzene - The Rotational Pathway Is Feasible, ChemPhysChem, 7, 1455 (2006)

Laser-Induced Release of Encapsulated Materials inside Living Cells

Prof. Wolfgang Parak (Philipps University Marburg, Nanomaterials)

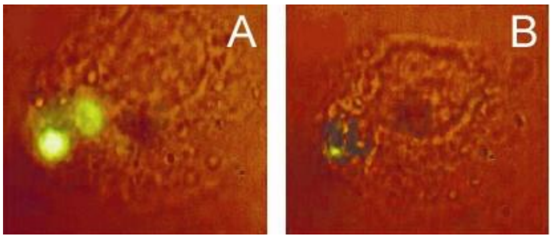
Together with the Max Plank Institute in Golm the Parak group has developed a transport vehicle for local release of chemicals. The chemicals are encapsulated in the cavity of a polymer container. The wall of this capsule contains gold nanoparticles. When these particles are irradiated with a laser, the gold gets heated which causes a local destruction of the container wall. In this way, the container wall is opened and the chemicals can diffuse out. This technique was demonstrated in vitro by releasing fluorescence-labeled dextrane inside cells upon light stimulation.

A. G. Skirtach, A. Muñoz Javier, O. Kreft, K. Köhler, A. Piera Alberola, H. Möhwald, W. J. Parak, G. B. Sukhorukov
Laser-Induced Release of Encapsulated Materials inside Living Cells
Angew. Chem. 118, 4728 (2006)

„Türöffner für Medikamente"
July 26, 2006 - Münchener Merkur

„Tödliche Kost für Tumorzellen"
August 8, 2006 - Münchner Merkur

„Molekulare Kriegslist"
August 23, 2006 - Süddeutsche Zeigung



Release of encapsulated AF-488-labeled dextran inside a living cell upon laser illumination. Superimposed fluorescence and transmission signals from a cell and capsules before (A) and after (B) illumination by laser light. The capsule appears filled (A) before illumination. The corresponding image of the same capsule after illumination (B) shows that, although there is some leftover fluorescence in the walls of the capsules, most polymer molecules had left the interior of the capsule.

Self Organized Blood Clotting

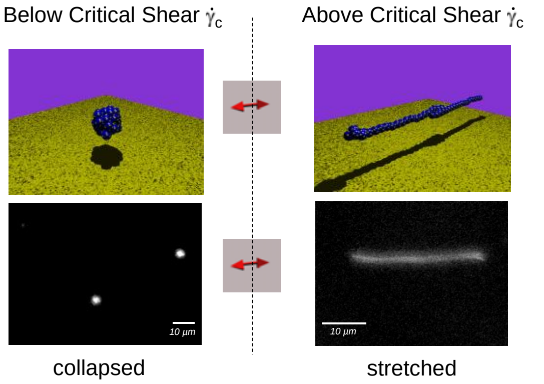
Dr. Matthias F. Schneider (University of Augsburg, Biological Physics)
Prof. Achim Wixforth (University of Augsburg, Material Science at the Nanometer Scale)
Prof. Roland Netz (TU Munich, Biological Soft-Matter Theory)

An interdisciplinary approach between biophysics, nanotechnology, theoretical physics and physiology conducted by M. F. Schneider (Biological Physics Group Augsburg), A. Wixforth (Experimental Physics I, Augsburg), R. Netz (TUM) and S. W. Schneider (University of Münster) has led to new insights into one of the crucial mechanisms of blood clotting under high flow conditions. The scientists solved an old puzzle in physiology: how can an increasing shear rate trigger an increase in adhesion of blood platelets? A phenomenon in clear contradiction to our daily experience, but crucial for life since mechanical vessel damage by elevated shear rates is taking place at all times in our body.

Using computer simulations including hydrodynamic interactions the researchers were able to mimic the critical stretching transition of collapsed von Willebrand factor (VWF) into its stretched conformation. Furthermore they unravelled the origin of the high shear unfolding of VWF. Scaling arguments predict a dependency of the critical shear rate following $\gamma_{crit} \propto a^{-3}$, where a is the actual size of the monomer. Due to the fact that this size is unusually large, the shear rate of VWF is in a reasonable range.

This is an excellent example how the understanding of the physical properties of an object solves a whole ballpark of mysterious observations with just one strike.

With the help of computer simulations the researchers currently try to understand the impact on mutations of VWF on its hydrodynamic behavior to get new insight in the origin of VWF related diseases.



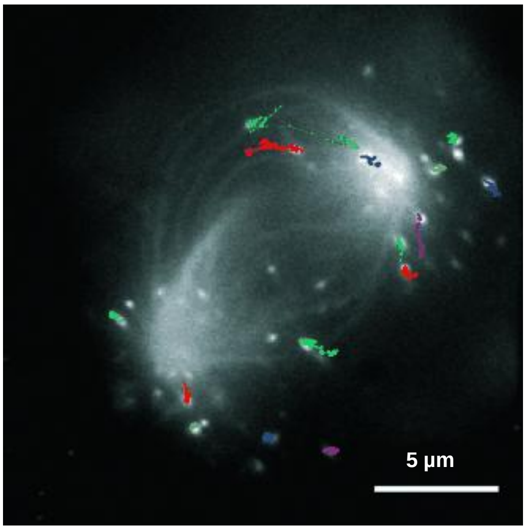
Under low shear flow conditions VWF is in a collapsed state with most of his binding sites buried inside (left). When a critical value is reached the protein elongates and starts to bind very efficiently to the surface (right). Only in the latter state VWF is hemostatically active.

A. Alexander-Katz, M. F. Schneider, A. Wixforth, S. W. Schneider, R. R. Netz
Shear Flow-Induced Unfolding of Polymeric Globules
Phys. Rev. Lett. 97, 138101 (2006)

Synthetic pDNA, dsRNA and siRNA Viruses for Targeted Therapy

Prof. Christoph Bräuchle (LMU, Single Molecule Techniques in Bio- and Nanoscience)
Prof. Ernst Wagner (LMU, Pharmaceutical Biotechnology)
Prof. Joachim Rädler (LMU, Soft Condensed Matter Physics)

The availability of nucleic acids (NA) such as small interfering RNA or plasmid DNA as novel molecular tools opens a new therapeutic perspective, once appropriate pharmaceutical carriers have been designed. Natural viruses are very effective in NA delivery. By incorporating virus-like delivery functions we optimize synthetic NA/polymer complexes (polyplexes) towards "synthetic viruses".



Polyplex distribution during mitosis. PEI/DNA complexes are transported on astral microtubules towards the poles of the spindle apparatus with peak velocities of 0.9 µms^{-1}.

Targeting polyplexes to tumors requires tumor cell binding ligands such as epidermal growth factor (EGF) which trigger receptor-mediated endocytosis. Biooptical studies performed in collaboration with the Bräuchle lab [Bausinger 2006] demonstrated uptake of polyplexes, involvement of actin cytoskeleton followed by dynamic transport along microtubules. As observed by the single particle tracking, in the early times of the uptake the polyplexes show free and confined diffusion as well as slow transport processes localized with the actin filaments beneath the cell membrane.

Later on and after deeper penetration into the cell the polyplexes show fast transport with molecular motors such as kinesins and dyneins along microtubules.

The observation of successful gene expression assumes that the transgene delivered by the polyplex becomes accessible to the transcriptional machinery. The transfection efficiency is cell-cyle dependent, a fact that is described to the breakdown of the nuclear membrane during cell division. In mitosis, polyplexes move along the microtubules of the spindle apparatus as shown in the figure, and distribute at the poles of the spindle apparatus.

Uptake for EGFR-targeted polyplexes resulted in localization in perinuclear vesicles within 10 minutes. Nanoparticles can be designed to contain a polyethylene glycol shield as reported in collaboration with the Rädler lab [DeRouchey 2006]. The concept has been extended into therapy. EGFR targeted polyplexes containing double stranded RNA (poly Inosine Cytidine) induced rapid cell killing in EGFR overexpressing tumors. Mice with glioblastoma tumors treated with the "synthetic RNA virus" showed complete tumor regression and were cured [Shir 2006].

R. Bausinger, K. von Gersdorff, K. Braeckmans, M. Ogris, E. Wagner, C. Bräuchle, A. Zumbusch
The transport of nanosized gene carriers unraveled by live-cell imaging
Angew. Chem. 118, 1598 (2006)

J. DeRouchey, G. F. Walker, E. Wagner, and J. O. Rädler
Decorated Rods: A bottom-up self-assembly of monomolecular DNA complexes
J. Phys. Chem. 110, 4548 (2006)

A. Shir, M. Ogris, E. Wagner, and A. Levitzki
EGF Receptor-Targeted Synthetic Double-Stranded RNA Eliminates Glioblastoma, Breast Cancer, and Adenocarcinoma Tumors in Mice.
PloS Med 3, e6 (2006)

"Trojan Horse Approach Developed To Kill Brain Tumors From Within"
October 24, 2006 - PhysOrg.com

Scanning Near-Field Optical Microscopy (SNOM)

Dr. Reinhard Guckenberger (MPI of Biochemistry, Scanning Probe Microscopy)
Dr. Rainer Hillenbrand (MPI of Biochemistry, Nano-Photonics)
Dr. Fritz Keilmann (MPI of Biochemistry, Near-Field Spectroscopy)

Compared to the confocal laser scanning microscope, SNOM achieves a higher resolution and allows to acquire a topographical signal simultaneously with the optical signal which facilitates interpretation of the images. In 2006 we performed model calculations on how to concentrate light at a metal tip in a setup which minimizes exposure of the sample to light. This minimization is important in fluorescence applications in order to reduce bleaching of fluorophores. Fluorescence is very useful in biological research as it allows easy identification of labeled spots. We modified our SNOM and performed experiments to realize the theoretical findings. The groups of R. Hillenbrand and F. Keilmann develop scattering-type near-field optical microscopy (s-SNOM) that allows nanoscale resolved optical imaging along with topography, simultaneously at visible and mid-infrared frequencies. Together with the group of R. Guckenberger it could be demonstrated that s-SNOM enables ultra-high resolution infrared imaging of even sub-10 nm particles. Those objects 1000 times smaller than the applied infrared wavelength (10 µm) are undetectable by standard far-field infrared microscopy since the weak nanoparticle signals are buried far below the background level. Combined with spectroscopic mapping, s-SNOM opens the door to exciting applications: noninvasive and label-free chemical identification of individual nanocrystals or biomolecules via their infrared fingerprint spectra from which many fields of nano and life sciences could benefit.

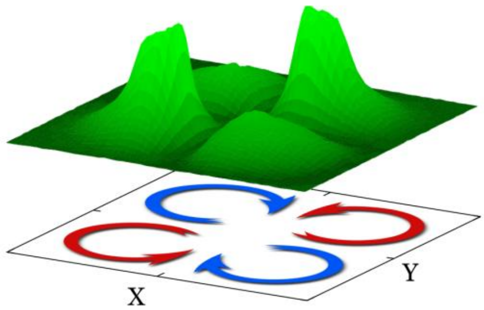
A. Cvitkovic, N. Ocelic, J. Aizpurua, R. Guckenberger and R. Hillenbrand
Infrared Imaging of Single Nanoparticles via Strong Field Enhancement in a Scanning Nanogap
Phys. Rev. Lett. 97, 060801 (2006)

N. A. Issa and R. Guckenberger
Optical Nanofocusing on Tapered Metallic Waveguides
Plasmonics 2, 31 (2007), published online Dec. 2006

The Use of Microfluidics in Selecting Chiral Molecules

Prof. Peter Hänggi (University of Augsburg, Theoretical Physics)

Almost all molecules that are of biological relevance possess a handedness or chirality: like a single glove they do not coincide with their mirror image. This innocuously looking asymmetry between chiral partners (or enantiomers) causes huge difference in their biological properties and functionality. For example, humans can only digest one chiral form of sugars or amino acids; the taste and smell of different enantiomers may drastically differ, and one partner may be beneficial while the other can be toxic.



The (green) density of right handed particles is higher in right handed eddies (indicated by the red arrows) than in left handed eddies (blue).

Nature manages to synthesize only one particular chiral substance in enzymatic reactions; in contrast, chemical reactions in vitro often result in fifty-fifty racemic mixtures of enantiomers. The separation then requires a second complicated chemical step. Therefore, the separation of enantiomers presents a prominent challenge in molecular biology and belongs to the "Holy Grail" of organic chemistry.

Recently, M. Kostur, M. Schindler, P. Talkner, and P. Hänggi [Chiral separation in microflows, Phys. Rev. Lett. 96, 014502 (2006)] suggest an intriguing, novel sorting scenario that is based on tiny differences between the forces that enantiomers sense in a microfluidic flow pattern. The key idea is that with an appropriately prepared microfluidic flow a right handed eddy acts differently on a left handed chiral particle than on its right handed partner. The result is that different enantiomers finally reside on different attractors in the fluid. Interestingly enough, however, the separation efficiency is enhanced by the presence of ubiquitous irregular, thermal Brownian motion which in turn shoves each of the two chiral species into their corresponding, most stable attractor. For suitable flow patterns these specific attractors are well separated in space so that the different enantiomers residing there can conveniently be selected out. This provides the desired and efficient sorting mechanism.

Marcin Kostur, Michael Schindler, Peter Talkner, Peter Hänggi
Chiral Separation in Microflows
Phys. Rev. Lett. 96, 014502 (2006)

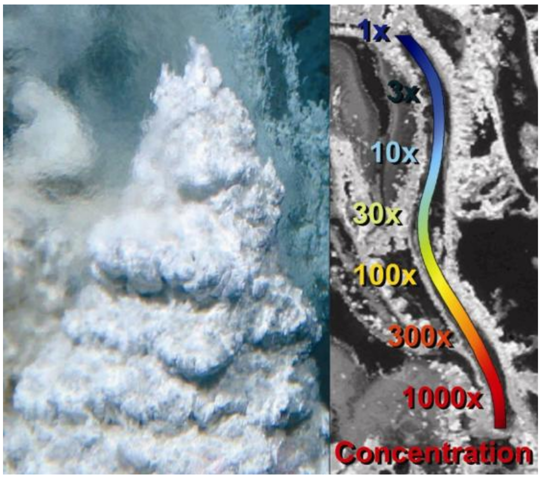
„Trennung chiraler Moleküle in Mikrofluiden"
February 7, 2006 – Chemie.de

"Chirale Moleküle in Mikrofluiden getrennt"
March 1, 2006 - CHemie plus

Understanding Thermophoresis of Biomolecules

Dr. Dieter Braun (LMU, Dissipative Biosystems)

The major success of this year in Braun's lab was the fundamental microscopic understanding of thermophoresis. Stefan Duhr and Dieter Braun found an analytical formula to predict the movement of DNA or polystyrene beads in a temperature without fitting parameters. The study appeared on the cover of Proceedings of the National Academy of Sciences. With this theory, thermophoresis can be now used as quantitative tool for biomolecule analysis; most importantly the charge of particles in solution can be determined since the major driving force is the nanoscopic solvation layer of molecules in water. The breakthrough was possible with the interdisciplinary application of infrared heating in microfluidic chambers under fluorescence imaging. Such multi-disciplinarity is typical for many things that happen at CeNS. Two other articles were published in Physical Review Letters showing that thermophoresis results in an exponential concentration depletion, which motivates a Boltzmann approach of local equilibrium which was the basis for the above mentioned theoretical work.



Nanoscience goes Evolution. Small RNA Molecules are million-fold accumulated in deep-ocean vents by a combination of thermal convection and thermophoresis. The latter is molecule drift along a thermal gradient, understood in detail now from the temperature dependence of the molecule-water interface. The findings make an origin of life on early earth much more plausible.

The second article described DNA accumulation in counterflow of thermophoresis and fluid flow, well described with a one dimensional diffusion model.

First application of thermophoresis was to determine the size of nanocrystals from the Wolfgang Parak group. This allows a fast analysis of particle size without the need for calibrations. Stefan Duhr and Philipp Baaske have won the #1 Price in the initial idea stage of the Businessplan competition with a proposal to measure melting curves within very short time (< 150 ms).

S. Duhr and D. Braun
Why molecules move along a temperature gradient
PNAS 103, 19678 (2006)

S. Duhr and D. Braun
Thermophoretic Depletion Follows Boltzmann Distribution
Physical Review Letters 96, 168301 (2006)

S. Duhr and D. Braun
Optothermal Molecule Trapping by Opposing Fluid Flow with Thermophoretic Drift
Physical Review Letters 97, 038103 (2006)

"Some like it cold"
November 28, 2006 - LMU Press release

Simulation of Nanosystems under Extreme Tensile Load

PD Dr. Irmgard Frank (LMU, Quantum Chemistry)
Jun.-Prof. Jens Michaelis (LMU, Nanomechanics)
Prof. Christoph Bräuchle (LMU, Single Molecule Techniques in Bio- and Nanoscience)

Siloxanes are an extremely versatile material and, among many other applications, represent the basis for adhesives. In collaboration between the groups of Jens Michaelis, Christoph Bräuchle, and Irmgard Frank the failure of such materials was investigated both experimentally and theoretically. With single molecule atomic force microscopy (AFM) experiments the force necessary to break a single polymer strand could be determined. This force is unexpectedly low in view of the strong Si-O bond and the corresponding potential.

With Car-Parrinello molecular dynamics an explanation for these low rupture forces could be provided. Several effects are relevant, particularly the redistribution of kinetic energy at finite temperatures within the polymer chain. In addition, it could be shown that the low resistance to tensile stress of silicon materials compared to hydrocarbon polymers is due to a different rupture mechanism. The breaking of a Si-O bond leads to the formation of highly reactive ions which have a similar effect like strong acids or bases and readily attack neighboring polymer chains.

E. M. Lupton, F. Achenbach, J. Weis, C. Bräuchle and I. Frank
Modified Chemistry of Siloxanes under Tensile Stress: Interaction with Environment
J. Phys. Chem. B, 110, 14557 (2006)

Nano-Sciences

Nonlinear Dynamics in Optomechanical Systems

Prof. Khaled Karrai (LMU, Experimental Nano Optics)
Jun.-Prof. Florian Marquardt (LMU, Condensed Matter Theory)

The interplay of light and matter can be studied in so-called optomechanical systems. In such systems, a micron size cantilever is made to move in response to the forces induced by light bouncing off a mirror attached to the cantilever. Particularly strong effects are seen when the light intensity is resonantly enhanced, by storing the light inside an optical cavity that is illuminated by a laser. A few years ago, such a setup has been employed by Constanze Metzger and Khaled Karrai at the LMU to cool down a cantilever from room temperature down to 18 K, a work which has received widespread attention [C. Höhberger-Metzger and K. Karrai, Nature 432, 1002 (2004)].

However, cooling the mechanical motion is not the only interesting effect that may be observed in such a system. If the frequency of the laser light is blue-detuned from the cavity resonance, this may actually lead to a decrease in the mechanical damping rate, and ultimately to self-sustained oscillations of the cantilever. These oscillations arise when the average power lost through mechanical dissipation is precisely balanced by the power fed into the cantilever from the radiation field. The nonlinear dynamics in this regime can become very intricate, with an array of possible dynamical attractors for a given set of fixed experimental parameters [F. Marquardt et al., Phys. Rev. Lett. 96, 103901 (2006)].

Recent experiments in the group of Khaled Karrai, performed by Alexander Ortlieb, Ivan Favero, and Constanze Metzger have explored this dynamics systematically (some of the results can be found in the diploma thesis of A. Ortlieb, 2006). In particular, they were able to record not only the average transmission of the cavity but also the amplitude of the cantilever oscillations, in their dependence on tunable parameters.

In order to interpret the results, a new theoretical model had to be developed and implemented as a numerical code, providing the full attractor diagram that can be compared against experiment. This task was accomplished by Clemens Neuenhahn and Max Ludwig, two undergraduate students at the LMU, working under the supervision of Florian Marquardt. The results of this joint experimental and theoretical work are currently being prepared as a manuscript for publication.

Florian Marquardt, J. G. E. Harris, and S. M. Girvin
Dynamical Multistability Induced by Radiation Pressure in High-Finesse Micromechanical Optical Cavities
Phys. Rev. Lett. 96, 103901 (2006)

Spectroscopic Near-Field Microscopy in the Mid Infrared

Dr. Fritz Keilmann (MPI of Biochemistry, Near-Field Spectroscopy)
Dr. Rainer Hillenbrand (MPI of Biochemistry, Nano-Photonics)

Mid-infrared illumination enables a unique chance for microscopy because it provides specific material contrasts due to molecular vibration, and thus chemical recognition, and also due to electron motion that allows conductivity mapping. Scattering-type near-field microscopy using monochromatic laser illumination can resolve optical contrasts at 20 nm spatial resolution independently of the wavelength.

We have established two ways of achieving local mid-infrared maps that carry a broad spectrum at each pixel. The first one is sequential: a separate image is taken for each wavelength of a tunable laser, and the set of images is processed off-line to determine the spectral map. Convincing spectral images could be taken from a crowded assembly of polymer and virus particles on Si substrate. A drawback, however, is both the long duration of data taking, and the uncertainties induced by sample drift and tip erosion. These are circumvented in a second method that employs a coherent frequency-comb beam covering the wavelength range of 9 - 12 µm to illuminate the microscope tip. The scattering is analyzed by multi-heterodyne detection using a slightly detuned frequency-comb for reference. By employing a new method of background-signal suppression we could demonstrate true near-field interaction and material-specific local infrared spectra. However, a routine applicability of infrared-spectroscopic near-field microscopy has to await considerably higher power of the frequency-comb beam.

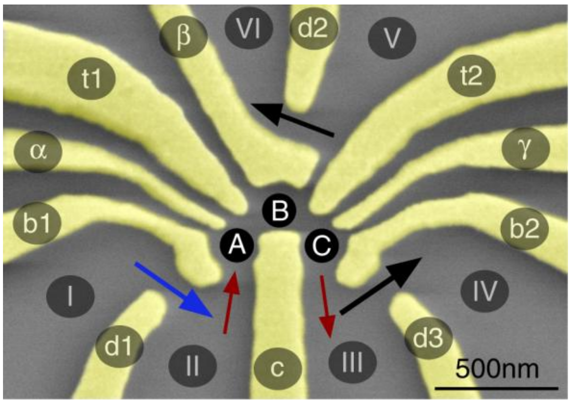
M. Brehm, T. Taubner, R. Hillenbrand, F. Keilmann
Infrared spectroscopic mapping of single nanoparticles and viruses at nanoscale resolution
Nano Lett. 6, 1307 (2006)

M. Brehm, A. Schliesser, F. Keilmann
Spectroscopic near-field interaction using frequency combs in the mid-infrared
Optics Express 14, 11222 (2006)

Transport Spectroscopy on Quantum Dots

Prof. Jörg P. Kotthaus (LMU, Nanophysics)
Dr. Stefan Ludwig (LMU, Quantum Dots)

Reducing the length scales of transistors well below 100 nanometers is one of the present key efforts in semiconductor industry. At the same time the behavior of such tiny devices is increasingly influenced by phenomena obeying the fundamental laws of quantum mechanics. Various gate-controlled nanoscale devices are fabricated in our clean room with electron beam lithography starting from GaAs/AlGaAs heterostructures that contain a two-dimensional electron system and are grown at the MPI Stuttgart, U. Regensburg and the Walter Schottky-Institut of TU Munich.



SEM-picture of the gate layout of a serial triple quantum dot (QD). The yellow regions are gold gates on the surface of a AlGaAs/GaAs heterostructure containing a two-dimensional electron system (2DES) 120 nm below the surface. The gates can be negatively biased to locally deplete the 2DES and define 3 QDs (A, B, C) and three additional quantum point contacts (black and blue arrows) used as charge sensors of the QDs. Transport measurements through the triple QD are possible with current flowing along the red arrows.

A first observation of the Kondo effect in a double quantum dot (QD) charged with one and two electrons could be explained in detail in a fruitful collaboration with Mikhail Kiselev as guest professor at CeNS in Jan v. Delft's group, and Boris Altschuler (Columbia U.). A new quantum ratchet in a double QD was realized in collaboration with Vadim Khrapay, an Alexander von Humboldt fellow visiting from the Russian Academy of Sciences in Chernogolovka. The energy source for the ratchet is a strongly biased quantum point contact in an electrically isolated circuit. It drives a current through a nearby but unbiased double QD in a direction chosen by the control of the quantum states in the double dot.

As a further step towards a quantum-dot based quantum computer a serial triple QD was fabricated and the full control of its quantum mechanical states in the regime of few electrons charging the device demonstrated. This ongoing work aims at exploring coherent quantum transport phenomena that may be utilized to couple distant quantum bits and profits strongly from collaborations with the groups of Lloyd Hollenberg (U. Melbourne) in Australia and Andy Sachrajda (NRC Ottawa) supported by visits at CeNS. Stimulating interactions with members and other guests of the theory groups of Jan von Delft and Peter Hänggi further aid our efforts.

V. S. Khrapai, S. Ludwig, J. P. Kotthaus, H. P. Tranitz, and W. Wegscheider
A double-dot quantum ratchet driven by an independently biased quantum point contact
Phys. Rev. Lett. 97, 176803 (2006)

D. M. Schröer, A. K. Hüttel, K. Eberl, S. Ludwig, M. N. Kiselev, and B. L. Altshuler
Kondo effect in a one-electron double quantum dot: Oscillations of the Kondo current in a weak magnetic field
Phys. Rev. B 74, 233301 (2006)

Surface Polariton Photonics

Dr. Rainer Hillenbrand (MPI of Biochemistry, Nano-Photonics)

The group of R. Hillenbrand applies scattering-type Scanning Near-Field Optical Microscopy (s-SNOM) to study electromagnetic surface waves formed by coupling of infrared light to optical lattice vibrations (phonons) in polar crystals. Besides the fundamental mechanisms of phonon-photon coupling on structured crystal surfaces, the group explores their potential for detecting, manipulating and transporting infrared light in subwavelength-scale dimensions (phonon photonics). One interesting application is the so called superlens. It is a thin slab of a material supporting surface polaritons that enables optical imaging with enhanced resolution.

Applying s-SNOM, the group obtained the first direct near-field infrared images generated by surface phonon polaritons on a SiC superlens.

T. Taubner, D. Korobkin, Y. Urzhumov, G. Shvets, and R. Hillenbrand
Near-field microscopy through a SiC superlens
Science 313, 1595 (2006)

„Die Physik überlistet"
September 15, 2006 - Süddeutsche Zeitung

„Eine Infrarotlupe überwindet optische Grenzen"
October 4, 2006 - Frankfurter Allgemeine Zeitung

Electronic and Structural Properties of Organic Field Effect Transistors

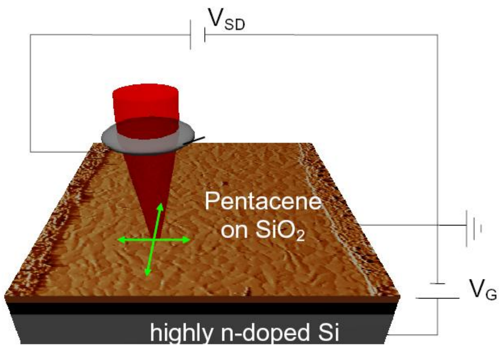
Dr. Bert Nickel (LMU, Soft Matter Interactions)
Dr. Udo Beierlein (LMU, Molecular Electronics Group)

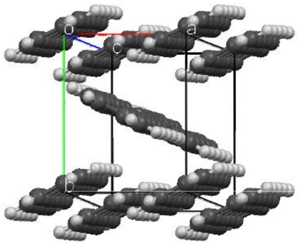
Pentacene field effect transistors have been produced using clean room facilities and an ultra-high vacuum deposition system for organic molecules. In order to study the charge injection and charge transport, transistor transport curves have been measured and modeled in collaboration with the group of P. Lugli (TUM). These experiments are complemented by photo response measurements of such devices under illumination by a focused laser beam with a spatial resolution of micrometer. The spatially resolved photo response maps reveal inhomogeneous contact properties. In order to resolve the molecular structure of the organic film, crystal truncation rod measurements have been performed at HASYLAB, Hamburg.

Furthermore, x-ray reflectivity experiments on pentacene thin films have been performed to complement band structure measurements by photoelectron emission in collaboration with the group of N. Koch (HU Berlin).

N. Koch, I. Salzmann, J. P. Rabe, A. Vollmer, H. Weiss, B. Nickel
Evidence for Electron Band Dispersion in Pentacene
Phys. Rev. Lett. 96, 156803 (2006)

C. Erlen, P. Lugli, M. Fiebig, B. Nickel
Transient TCAD simulation of three-stage organic ring oscillator
Journal of Computational Electronics 5, 345 (2006)





Left: Setup of the photo response experiment. A field effect transistor is scanned by a focused laser beam and the photo response is recorded. The texture is an AFM micrograph of a pentacene transistor.
Right: Molecular structure of the pentacene film, as resolved from x-ray diffraction experiments.

Interference and Interactions Combined Lead to New Features in Electronic Interferometers

Jun.-Prof. Florian Marquardt (LMU, Condensed Matter Theory)

Quantum transport through nanostructures has been studied for some time now, with the emphasis both on interference effects and interactions. Nevertheless, in some cases even quite elementary features seem to have escaped notice so far when it comes to the interplay of interference and (strong) interactions.

An example illustrating this theme was discovered recently in a joint theoretical work by Volker Meden (University of Göttingen) and Florian Marquardt (LMU/CeNS). When two quantum dots are placed in parallel between a source and a drain electrode they can form an interferometer. A setup of this type had been realized already some years ago by CeNS researchers [Holleitner, Decker, Qin, Eberl and Blick, PRL 87, 256802 (2001)]. Now the recent theoretical analysis shows that new features will arise if one is able to induce a sufficiently strong electrostatic coupling between the two dots. In that case (beyond a certain critical coupling strength) the plot of conductance vs. gate voltage should show two novel, sharp conductance peaks. These have been termed "correlation-induced resonances", as they are due to the effects of strongly correlated electrons moving inside the interferometer. The group of Stefan Ludwig at the LMU now plans to set up experiments which may finally reveal these effects and thereby open a new window onto the physics arising from the interplay of interference and interactions.

V. Meden and F. Marquardt
Correlation-Induced Resonances in Transport through Coupled Quantum Dots
Phys. Rev. Lett. 96, 146801 (2006)

Dimensionally Constrained Spin Relaxation: Transition from 2D to 1D

Jun.-Prof. Alexander W. Holleitner (LMU, Nanoptronics)

For efficient information processing scheme based upon the electron spin it is important to explore carrier spin relaxation mechanisms in nanostructures as a function of dimensionality. In two and three dimensions elementary rotations do not commute, with significant impact on the spin dynamics if the spin precession is induced by spin-orbit coupling. Spin-orbit coupling creates a randomizing momentum-dependent effective magnetic field; the corresponding relaxation process is known as the D'yakonov-Perel' mechanism. In an ideal one-dimensional system, however, all spin rotations are limited to a single axis, and the spin rotation operators commute. In the regime approaching the one-dimensional limit, a progressive slowing and finally a suppression of the D'yakonov-Perel' spin relaxation have been predicted. In collaboration with the group of David Awschalom at the University of California, Santa Barbara (UCSB) we reported on spin dynamics of electrons in narrow two-dimensional n-InGaAs channels as a function of the wire width.

We found that electron-spin relaxation times increase with decreasing channel width, in accordance with recent theoretical predictions. Surprisingly, we detected the suppression of the spin relaxation rate for widths that are an order of magnitude larger than the electron mean free path. We found the spin diffusion length and the wire width to be the relevant length scales for explaining the observed effects.

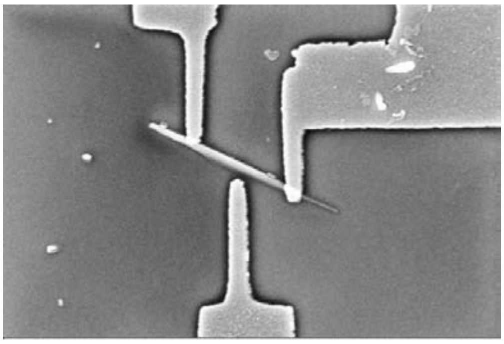
A. W. Holleitner, V. Sih, R. C. Myers, A. C. Gossard, and D. D. Awschalom
Suppression of Spin Relaxation in Submicron InGaAs Wires
Phys. Rev. Lett. 97, 036805 (2006)

H. Knotz, A. W. Holleitner, R. C. Myers, A. C. Gossard, D. D. Awschalom
Spatial Imaging and Mechanical Control of Spin Coherence in Strained GaAs Epilayers
App. Phys. Lett. 88, 241918 (2006)

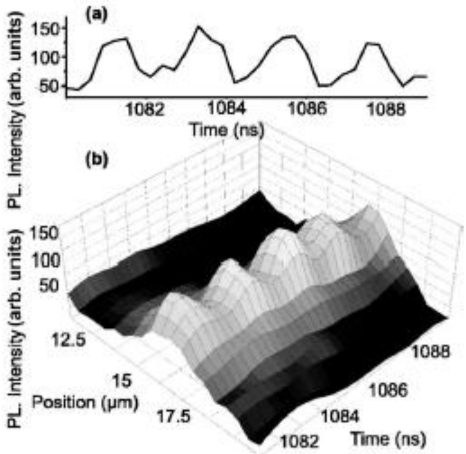
Surface Acoustic Waves and Semiconductor Nanostructures

Dr. Jens Ebbecke (University of Augsburg, Surface Acoustic Waves and Nanostructures)
Prof. Achim Wixforth (University of Augsburg, Material Science at the Nanometer Scale)

Surface acoustic waves (SAW) are used to control charges in semiconductor nanostructures. One example is the bipolar transport of electrons and holes towards self assembled quantum dots. The resulting emission of light has an intensity oscillation with a frequency given by the SAW frequency. A reduction of the emitting quantum dots will lead to a single photon source. Furthermore, single walled carbon nanotubes have been contacted and the SAW modulates turnstile-like the interface barriers which results in a quantized charge transport. Finally, self-organized GaN nanowires have been contacted and an acoustoelectric charge transport has been realized.



Contacted GaN nanowire for acoustoelectric transport measurements.



Temporal intensity evolution integrated over a distance of 2 μm. An enhanced beating of the signal with a periodicity given by the surface acoustic wave frequency is visible.

C. Bödefeld, J. Ebbecke, J. Toivonen, M. Sopanen, H. Lipsanen, A. Wixforth
Experimental investigation towards a periodically pumped single-photon source
Phys. Rev. B 74, 035407 (2006)

K. M. Seemann, J. Ebbecke, A. Wixforth
Alignment of carbon nanotubes on pre-structured silicon by surface acoustic waves
Nanotechnology 17, 4529 (2006)

Drift Mobility of Long-Living Excitons in Coupled GaAs Quantum Wells

Jun.-Prof. Alexander W. Holleitner (LMU, Nanoptronics)
Prof. Jörg P. Kotthaus (LMU, Nanophysics)

Photo-generated electron-hole pairs in quantum well devices can be manipulated in lifetime and position via a mesoscopic voltage-controlled electrostatic landscape. Whereas exciton ionization and spatial separation of electron-hole pairs by large in-plane electric fields enable us to store and release optical images at will, the quantum-confined Stark effect allows us to create long-living excitons and study their dynamics on mesoscopic length scales.

We employed the quantum confined Stark effect in a coupled double quantum well to generate spatially indirect excitons with lifetimes exceeding 1 sec and to study their motion induced by a controlled spatial variation of the out-of-plane electric field.

Macroscopic drift of excitons was studied in a time-of-flight experiment employing a laterally graded electrostatic potential induced via a current-carrying resistive gate. This allowed us to determine the drift mobilities of such long-living excitons. Across several hundreds of microns we observed a drift mobility of > 105 cm^2/eVs for temperatures below 10 K. With increasing temperature the excitonic mobility decreased due to exciton-phonon scattering. In the project we closely collaborated with D. Schuh of the University of Regensburg.

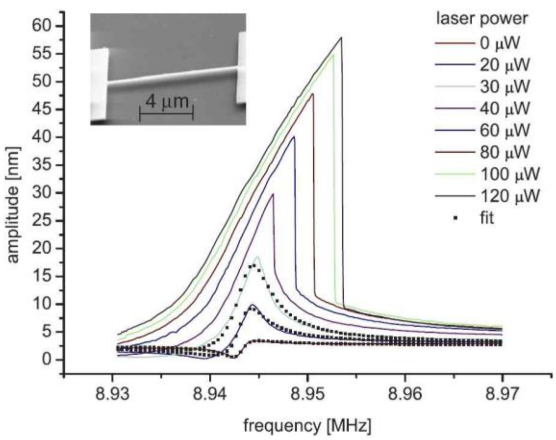
A. Gärtner, A. W. Holleitner, D. Schuh, J. P. Kotthaus
Drift mobility of long-living excitons in coupled GaAs quantum wells
Appl. Phys. Lett. 89, 052108 (2006)

Non-Linear Operation of Nanomechanical Systems Combining Photo-Thermal Excitation and Magneto-Motive Detection

Prof. Khaled Karrai (LMU, Experimental Nano Optics)
Prof. Jörg P. Kotthaus (LMU, Nanophysics)

Nanoelectromechanical systems realized by lithographic techniques form freestanding objects in silicon and other materials with thickness and lateral dimensions down to about some 10 nanometers. Shrinking mechanical devices in thickness, width and length leads to reduced mass, increased resonant frequency, and lowered force constants of these systems. Therefore nanomechanical systems are both fascinating objects for fundamental studies in the quantum regime and promising for a large variety of applications such as extremely sensitive sensors and actuators. Advances in the field include improvements in fabrication processes, new methods for actuating and detecting motion at the nanoscale.

In the cooperation of the groups of J. P. Kotthaus and K. Karrai the non-linear behaviour of a nanomechanical beam resonator was investigated by photo-thermal excitation at 4 K. The actuation mechanism is based on a pulsed diode laser focused onto the centre of the beam resonator. Thermally induced stress caused by the different thermal expansion coefficients of the Si/Au-bi-layer system periodically deflects the resonator. Magnetomotively detected amplitudes up to 150 nm are reached at the fundamental resonance mode at a frequency of 8.9 MHz. The photo-thermal excitation at 4 K should be applicable up to the GHz regime; the operation in the non-linear regime can be used for performance enhancement of nanomechanical systems, and the combination of photo-thermal excitation and magneto-motive detection avoids undesired cross talk.



Resonance curves for different laser actuation powers. The beam resonator is driven into the non-linear regime which is described by the Duffing-equation. The response of the first three curves fits well to a Lorentzian function with an appropriate phase difference between the driving force and the amplitude response. Inset: SEM image of a doubly clamped free standing Au/Si-bi-layer resonator.

D. R. König, C. Metzger, S. Camerer and J. P. Kotthaus
Non-linear operation of nanomechnical systems combining photothermal excitation and magneto-motive detection
Nanotechnology 17, 5260 (2006)

Superconducting Flux Qubits

Dr. Frank Wilhelm (University of Waterloo, Quantum Computing)

We discuss a novel method to read out a superconducting flux qubit at the flux degeneracy point, using a charge measurement through a single charge transistor. The interaction is based on the Aharonov-Casher geometric phase. The read-out cycle indicates one of the states by a fluorescence-like cycle. We discuss how to efficiently implement this scheme with the transistor in the radio frequency mode.

F. K. Wilhelm and K. Semba
Superconducting quantum bits: Status and prospects
M. Nakahara, S. Kanemitsu, M.M. Salomaa, and S. Takagi (eds.), "Physical Realizations of Quantum Computing", World Scientific, 38–108 (2006)

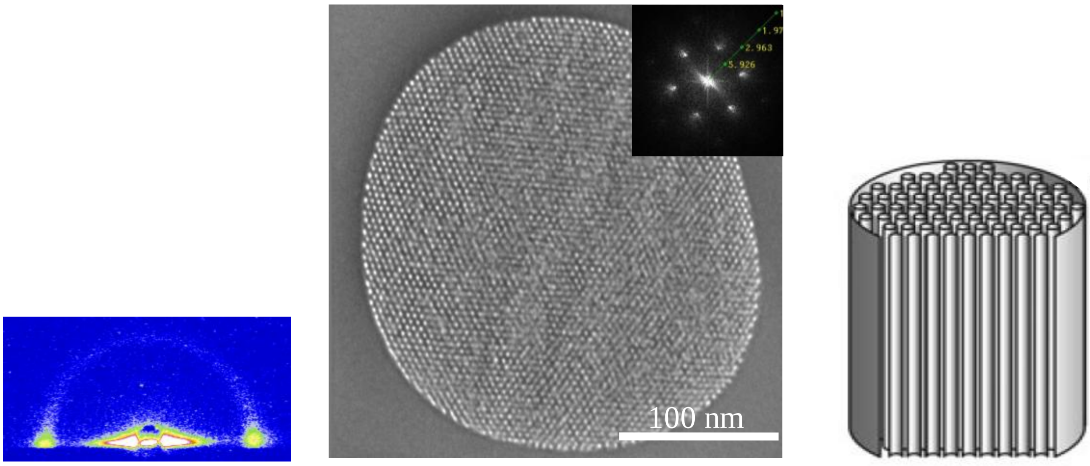
Andreas Käck, Göran Wendin, and Frank K. Wilhelm
Efficient Read-out of Flux Qubits at Flux Degeneracy
Quant. Inf. Proc. Vol. 5, No.6, 563- 575(13), Springer (2006)

Tuning the Structure and Orientation of Hexagonally Ordered Mesoporous Channels in Anodic Alumina Membrane Hosts

Prof. Thomas Bein (LMU, Chemistry and Function in Designed Nanoscopic Spaces)

Oriented nanochannels are attractive synthetic targets for the subsequent encapsulation of nanoscale wire arrays. It has recently been shown that periodic mesoporous materials can be synthesized within the regular, larger channels of anodic alumina membranes (AAMs), resulting in some control over the morphology of the mesoporous system. Aiming at a greater understanding of the mechanism and the ability to tune these complex hierarchical structures at will, we present a combined 2D small angle X-ray scattering (SAXS) and transmission electron microscopy (TEM) study, showing that highly ordered hexagonal mesoporous structures with adjustable orientation can be formed in the AAMs with the templates cetyltrimethylammonium bromide (CTAB), the triblock-copolymer Pluronic123 and decaethylene glycol hexadecyl ether (Brij56) under the conditions of the EISA (evaporation-induced-self-assembly) method. We demonstrate that when using the ionic surfactant CTAB, the hexagonally structured mesopores were solely oriented along the AAM-channels (columnar orientation, see Figure). When using the non-ionic surfactants P123 or Brij 56 it was possible to control the formation of two possible orientations (circular or columnar) by tuning the Si/surfactant-ratio of the initial synthetic mixtures as well as the humidity present during the EISA-process.

B. Platschek, N. Petkov, T. Bein
Tuning the structure and orientation of hexagonally ordered mesoporous channels in anodic alumina membrane hosts: A 2D small-angle X-ray scattering study
Angew. Chem. Int. Ed. 45, 1134 (2006), emphasized as VIP paper



Scheme, plan-view transmission electron micrograph and small angle X-ray scattering of oriented hexagonal mesoporous silica in anodic alumina channels.

Publications

Selected Publications

A. Alexander-Katz, M.F. Schneider, A. Wixforth, S.W. Schneider, R. Netz
Shear Flow-Induced Unfolding of Polymeric Globules
Phys. Rev. Lett. 97, 138101 (2006)

A.R. Bausch and K.Kroy
A bottom-up approach to cell mechanics
Nature Physics 2, 231 (2006)

R. Bausinger, K. von Gersdorff, K. Braeckmans, M. Ogris, E. Wagner, C. Bräuchle, A. Zumbusch
The transport of nanosized gene carriers unraveled by live-cell imaging
Angew. Chem. 118, 1598-1602 (2006)

K. Becker, J. M. Lupton, J. Müller, A. L. Rogach, D. V. Talapin, H. Weller and J. Feldmann
Electrical control of Förster energy transfer
Nature Mat. 5, 777 (2006)

K. Becker and J. M. Lupton
Efficient Light Harvesting in Dye-endcapped Conjugated Polymers Probed by Single Molecule Spectroscopy
J. Am. Chem. Soc. 128, 6468 (2006)

S. Beyer and F. C. Simmel
A DNA signal translator for the controlled release of a protein by an aptamer
Nucleic Acids Research 34, 1581-1587 (2006)

A. Biebersdorf, R. Dietmüller, A. S. Susha, A. L. Rogach, S. K. Poznyak, D. V. Talapin, H. Weller, T. A. Klar and J. Feldmann
Semiconductor Nanocrystals Photosensitize C60 Crystals
Nanoletters, 6, 1559 (2006)

S. Boeckle, J. Fahrmeir, W. Roedl, M. Ogris, and E. Wagner
Melittin analogs with high lytic activity at endosomal pH enhance transfection with purified targeted PEI polyplexes
J. Control. Rel. 112, 240 (2006)

C. Bödefeld, J. Ebbecke, J. Toivonen, M. Sopanen, H. Lipsanen, A. Wixforth
Experimental investigation towards a periodically pumped single-photon source
Phys. Rev. B 74, 035407 (2006)

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