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This program contains the latest information up to 14 January 2019.

While program updates and changes until the week prior to the conference may be found on the Update Sheet and Exhibit Buyers' Guide Addendum distributed in the registration bags, consult the OFC Conference App for the latest changes.

Technical Registrants: Download digest papers by visiting ofcconference.org and clicking on the "Download Digest Papers" on the home page. Recorded presentations are available from the same page by clicking "View Presentations."

Conference Schedule

All times reflect Pacific Time Zone	Sunday 3 March	Monday 4 March	Tuesday 5 March	Wednesday 6 March	Thursday 7 March
Registration	07:30–19:00	07:30–18:00	07:00–18:00	07:30–17:00	07:30–16:00
Programming					
Short Courses	09:00–20:00	08:30–17:30			
Workshops	13:00–18:30				
Lab Automation Hackathon	20:00–22:00				
Technical Sessions		08:00–18:30	14:00–18:30	08:00–18:30	08:00–16:00
Symposium: 5G Trials, Pilots, and Demonstrations		08:00–16:00			
Symposium: Future Photonic Devices and Materials for Optical Communications		08:00–16:00			
Symposium: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications			14:00–18:30		
Symposium: Network Automation				14:00–18:30	
OFC Demo Zone		14:00–16:30			
Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program		16:30–19:00			
Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications			14:00–18:30		
Special Session: Quantum Technology and Optical Communications				14:00–18:30	
Open Platform Summit		16:30–19:00			
Data Center Summit, *Expo Theater II*			11:45–13:45		
Panels			14:00–18:30	08:00-10:00	08:00–16:00
Rump Session: Does Approaching Shannon Limit Leave Only Device Developments in Optical Communications?			19:30–21:30		
Poster Sessions				10:30–12:30	10:30–12:30
Postdeadline Papers					16:30–18:30
Exhibition and Show Floor Activities					
Exhibition and Show Floor (Exhibit-Only Time)			10:00–17:00 (10:00–14:00)	10:00–17:00 (12:30–14:00)	10:00–16:00 (12:30–14:00)
OFC Career Zone			10:00–17:00	10:00–17:00	10:00–16:00
Suzanne R. Nagel Lounge			10:00–17:00	10:00–17:00	10:00–16:00
Market Watch - *Expo Theater I*			10:30–16:00	15:30–17:00	10:30–14:00
Network Operator Summit - *Expo Theater I*				10:30–15:00	
Expo Theater II and III Programs			10:15–17:00	10:15–17:00	10:15–16:00
Special Events					
OFC Plenary Session			08:00–10:00		
OIDA VIP Industry Leaders Speed Meetings Event			12:00–13:30		
OFC and Co-Sponsors Awards and Honors Luncheon			12:00–14:00		
Exhibitor Happy Hour			17:00–18:30		
Conference Reception			18:30–20:00		
Photonic Society of Chinese-Americans Workshop & Social Networking Event				17:00–19:30	

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Welcome to the 2019 Optical Fiber Communication Conference and Exhibition

On behalf of the many individuals, including countless volunteers, that have organized OFC 2019, it is our sincere pleasure to welcome you to San Diego, California. OFC is the foremost meeting in optical communications and networking, and this year's conference continues the tradition of providing an excellent program that captures advances in research, development and engineering.

In the plenary session on Tuesday morning, three excellent speakers, Alex Jinsung Choi, *SVP Strategy & Technology Innovation, T-Laboratories Innovation, Deutsche Telekom AG, Germany*; Benny P. Mikkelsen, *Founder and Chief Technology Officer, Acacia Communications, USA*; and Dmitri Dolgov, *Chief Technology Officer, Waymo, USA*, will address recent developments and future challenges in optical communications and networking. Alex will discuss the role of disaggregation, Open Source Software and Open Hardware in the 5G ecosystem. Benny will describe the critical role of electro-photonic integration in tackling capacity and density challenges in optical interfaces. Dmitri will show how the use of custom built sensors and software led to a full fleet of self-driving cars.

The 2019 conference provides an exceptionally strong technical program consisting of a portfolio of 55 short courses, 500 peer-reviewed presentations and 120 invited speakers. The range of hot topics that will be addressed includes 5G, IoT; 100G; 400G; data center networks; photonic, electronic integration; digital signal processing, advanced modulation; disaggregation, open platforms, SDN, NFV; Ethernet; network automation, artificial intelligence, machine learning ; optical interconnects; quantum technologies; sensor devices and systems; silicon, integrated photonics; and wireless, visible light communications.

The OFC Short Course program taught on Sunday and Monday provides a depth of content that is appropriate for beginners to learn the fundamentals, and for seasoned professionals to discover the latest advances in optical communications from some of the leading academic and industrial professionals in the field. The program covers a broad range of topical areas including devices and components, sub-systems, systems and networks.

The main emphasis of the OFC program is research and development that addresses longer-term issues in optical communications and networking. Monday's technical program includes 16 live demonstrations and prototypes of collaborative research projects, pre-commercial products and proof-of-concept implementations presented in the OFC Demo Zone. The technical offerings also include four symposia: "5G Trials, Pilots, and Demonstrations" and "Future Photonic Devices and Materials for Optical Communications" on Monday; "Network Automation" and "Photonics for IoT and Sensing: Manufacturing, Packaging and Applications" on Tuesday. Three special sessions are also scheduled, including, "Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program" on Monday; Special Chairs' Session on "The Role of Optics in Future Data Center and Computing Applications" on Tuesday; and "Quantum Technologies and Optical Communications" on Wednesday. Tuesday evening program includes organizers David Plant, *McGill University, Canada* and Peter Winzer, *Nokia Bell Labs, USA* facilitating the Rump Session, "Does Approaching Shannon Limit Leave Only Device Developments in Optical Communications?" Poster sessions will be held on Wednesday and Thursday, providing the opportunity for in-depth discussion with presenters.

The OFC Exhibit hosts more than 700 exhibitors from all over the world representing every facet of the optical communications market: communication and network equipment, data center interconnects, electronic components and subsystems, fiber cables and assemblies, integrated photonics, test equipment, lasers, optical components, optical fibers, transmitters and receivers, sensors and much more. In addition to meeting with vendors and seeing new products, the Market Watch program and the Network Operator Summit form the core of the business-related programming of the meeting. Market Watch is a three-day series of panel discussions that engages the latest application topics and business issues in the field of optical communications. Presentations and panel sessions feature esteemed speakers from top carriers, system vendors, market analyst firms and component companies. OFC Exhibit programming includes two keynote speeches; the Network Operator Summit Keynote will be given by Genia Wilbourn, *Vice President of Wireline Global Operations, Verizon Communications, USA*; and the Data Center Summit Keynote will be given by Dave Temkin, *Vice President of Networks, Netflix, USA*. Be sure to check out the other programs on the show floor addressing business solutions and emerging technologies. This year many industry groups will present, including AIM Photonics, Broadband Forum/NG-PON2, COBO, Ethernet Alliance, IEEE, ITU, OIF, ON2020, OpenConfig and TIP. Look for three interoperability demo areas on the show: Ethernet Alliance will include a live 400GbE network connecting multiple booths on the show floor, OIF will feature a demo of FlexE and there will also be a multivendor interoperability demo within a fiber-optics network with platform complaint with the Open ROADM MSA.

Organizing a successful OFC conference each year is an enormous task that is undertaken by many dedicated volunteers. We are indebted to the OFC Technical Program Chairs, Po Dong, Junichi Kani, and Chongjin Xie, for their expertise and dedication in coordinating the technical content through OFC's Technical Program committee. The high quality of the OFC program is a direct result of the efforts of the technical program chairs, subcommittee chairs, and technical program committee members, all of whom have dedicated an enormous amount of their valuable time to ensure the quality of the conference, and maintain the highest standards by reviewing and selecting papers, nominating invited speakers and organizing workshops and panels. It is also our pleasure to thank the staff of The Optical Society, whose ceaseless hard work and professionalism make it possible for OFC to continue as the foremost optical communications and networking conference in the world.

Gabriella Bosco
Politecnico di Torino, Italy

Jörg-Peter Elbers
ADVA Optical Networking SE, Germany

Laurent Schares
IBM TJ Watson Research Center, USA

General Information

Customer Service and Conference Information

Please visit the Customer Service and Conference Information desk to get information on:

- Parking
- Coat and Baggage Check
- Restaurant Information
- *Show Your Badge* Promotions
- General Conference Information
- Lost and Found (for after hours Lost and Found, please go to the OFC Security Office located in Show Office D (look for security sign)
- Private Room for Special Needs Use

Exhibition

Exhibit Halls A-H

Schedule plenty of time to roam the Exhibit Hall, visit with the hundreds of companies represented and see the latest products and technologies.

With OFC's dine-out raffle you can enjoy an evening out at one of San Diego's great restaurants.

On **Tuesday, 5 March**, you have the chance to win one of three San Diego restaurant vouchers, each valued between US $25 – 100. To enter, drop your business card at one of the following locations and you are in it to win it:

IEEE Photonics Society / IEEE ComSoc *Booth 3439*

The Optical Society (OSA) *Booth 3039*

The Suzanne R. Nagel Lounge *Booth 6325*

The winners will be announced at the end of the show day (17:00) and notified via email.

Brought to you by: SAN DIEGO convention center

Exhibition Hours

Tuesday, 5 March	10:00–17:00
Exhibit-Only Time	10:00–14:00
Wednesday, 6 March	10:00–17:00
Exhibit-Only Time	12:30–14:00
Thursday, 7 March	10:00–16:00
Exhibit-Only Time	12:30–14:00

First Aid Station

Box Office E

A first aid station will be operated according to the schedule below. In addition, information regarding local medical facilities will be available.

First Aid Station Hours

Sunday, 3 March	08:00–17:00
Monday, 4 March	08:00–17:00
Tuesday, 5 March	08:00–17:00
Wednesday, 6 March	08:00–17:00
Thursday, 7 March	08:00–17:00

Emergencies - Contact Security Command Center on house phone at ext. 5911 or call +1.619.525.5911.

Media Center

Rooms 4, 5A and 5B

The OFC Media Center consists of a Media Room and semi-private interview space for one-on-one interviews and/or briefings with media and analysts. The media room is restricted to registered media/analysts holding a Media badge.

Media Center Hours

Sunday, 3 March	12:00–16:00
Monday, 4 March	07:30–18:00
Tuesday, 5 March	07:30–18:00
Wednesday, 6 March	07:30–18:00
Thursday, 7 March	07:30–16:00

OFC Career Zone

Exhibit Hall C

Looking for a job? Or interested in exploring career options? The OFC Career Zone connects employers and skilled job seekers from all areas of optical communications. Conference attendees are encouraged to visit the OFC Career Zone and be prepared to discuss your future with representatives from the industry's leading companies.

Job Seekers
Meet Participating Companies

Tuesday, 5 March	10:00–17:00
Wednesday, 6 March	10:00–17:00
Thursday, 7 March	10:00–16:00

Register Online at ofcconference.org/careerzone to:

- Search job postings freely
- Post your résumés online confidentially
- Network and schedule interviews with employers/recruiters

Employers

Didn't sign up for the onsite OFC Career Zone? It's not too late.

Participate online at ofcconference.org/careerzone to:

- Post jobs online
- Review résumés before, during or after the conference
- Create alerts to inform you of newly submitted résumés and openings

For more information, call +1.888.491.8833 or email careerzone@ofcconference.org.

OFC Conference App

OFC offers more than 100 sessions featuring 120+ invited speakers and 20+ tutorial presentations in the technical conference along with 700+ exhibitors. Manage your conference experience by downloading the OFC Conference App to your smartphone or tablet. (see steps below).

Schedule

Search for conference presentations by day, topic, speaker or program type. Plan your schedule by setting bookmarks on programs of interest. Technical attendees can access technical papers within session descriptions.

Exhibit Hall

Search for exhibitors in alphabetical order and set bookmark reminders to stop by booths. Tap on the map icon within a description, and you'll find locations on the exhibit hall map. View a daily schedule of all activities occurring on the show floor.

Access Technical Digest Papers

Full technical registrants can navigate directly to the technical papers right from the OFC Conference App. Locate the session or talk in "Event Schedule" and click on the "Download PDF" link that appears in the description.

Important - Log in with your registration email and password to access the technical papers. Access is limited to Full Conference Attendees.

Download the OFC Conference App!

Plan your day with a personalized schedule and browse exhibitors, maps and general show information while engaging with your fellow attendees. iPhone/iPod, iPad, Android, and Kindle Fire compatible. Download the OFC Conference App one of three ways:

1. Search for 'OFC Conference' in the app store.
2. Go to ofcconference.org/app
3. Scan the QR code

The OFC 2019 Guide will be listed under the "download guides" section of the application.

OFC Conference App Help Desk

Need assistance? Contact our OFC Conference App support team, available 24 hours a day, Monday through Friday, and from 09:00 to 21:00 EDT on weekends, at +1.888.889.3069, option 1.

OFC Rise and Shine Morning Run

Wednesday, 6 March, 06:00– 07:00
Bottom of San Diego Convention Center Stairs (front entrance)

Pack your running shoes and meet up for an early morning 3 mile run or walk with fellow OFC colleagues. Light breakfast will be provided at the finish line.

Sponsored by OSA Industry Development Associates

Join the Conversation!

Get the latest updates from OFC via Twitter at @OFCConference. Use the hashtag #OFC19 and join in the conversation today! More social media handles can be found on the OFC Contact Us page at ofcconference.org.

Registration

Exhibit Hall E

Hours:

Sunday, 3 March	07:30–19:00
Monday, 4 March	07:30–18:00
Tuesday, 5 March	07:00–18:00
Wednesday, 6 March	07:30–17:00
Thursday, 7 March	07:30–16:00

Speaker Ready Room

Room 11

All speakers and presiders are required to report to the Speaker Preparation Room at least 1 hour before their sessions begin. Computers will be available to review uploaded slides.

Speaker Ready Room Hours*

Sunday, 3 March	13:00–17:00
Monday, 4 March	07:00–18:00
Tuesday, 5 March	10:00–18:00
Wednesday, 6 March	07:00–18:00
Thursday, 7 March	07:00–16:00

*Market Watch and Network Operator Summit speakers should go directly to Exhibit Hall B in Expo Theater I (#5737) to upload their presentations.

Sponsoring Society Exhibits

Exhibit Hall: IEEE, Booth 3439; OSA, Booth 3039

Catch up on the latest product and service offerings of the OFC sponsoring societies by visiting their booth or member lounge located in the Exhibit Hall. **IEEE** is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. **OSA** is the leading professional association in optics and photonics, home to accomplished science, engineering, and business leaders from all over the world.

Wireless Internet Access

OFC is pleased to provide free wireless Internet service throughout the San Diego Convention Center for all attendees and exhibitors. The wireless internet can be used for checking email, downloading the OFC Conference App, and downloading the OFC Technical Papers, etc.

SSID: OFC
Password: OFC2019

Conference Materials

OFC Technical Digest on a USB Slap Band

The OFC 2019 Technical Digest, composed of the 3-page summaries of invited and accepted contributed papers, as well as, tutorial presentation notes will be on a USB slap band. The Technical Digest USB is included with a technical conference registration. These summaries will also be published in OSA Publishing's Digital Library and submitted to the IEEE Xplore Digital Library, providing the author attends and presents their paper at the conference.

Sponsored by

Online Access to Technical Digest

Technical attendees have EARLY (at least one week prior to the meeting) and FREE continuous online access to the OFC 2019 Technical Digest. These 3-page summaries of tutorial, invited, and accepted contributed papers can be downloaded individually or by downloading daily .zip files. (.zip files are available for 60 days after the conference).

1. Visit the conference website at ofcconference.org
2. Select the purple "Download Digest Papers" button on the right side of the web page
3. Log in using your email address and password used for registration. You will be directed to the conference page where you will see the .zip file links at the top of the page. [Please note: if you are logged in successfully, you will see your name in the upper right-hand corner.]

Access is limited to Full Technical Attendees only. If you need assistance with your login information, please use the "forgot password" utility or "Contact Help" link.

Postdeadline Paper Digest

The Postdeadline Paper Digest includes the 3-page summaries of accepted Postdeadline Papers. Papers will also be available to download online on Tuesday, 5 March. The digests will be available to all technical conference registrants beginning Thursday, 7 March, starting at 10:00 at Registration (Exhibit Hall E). The papers will be presented Thursday, 7 March, 16:30–18:30.

OFC Management advises you to write your name on all of your conference materials (Conference Program, USB Slapband, Buyers' Guide, and Short Course Notes). There is a cost for replacements.

Short Course Notes

Notes typically include a copy of the presentation and any additional materials provided by the instructor. Each course has a unique set of notes, which are distributed on-site to registered course attendees only. An additional fee is required for the notes. Notes are not available for purchase separately from the course.

Buyers' Guide

The Buyers' Guide is composed of the 50-word descriptions and contact information for exhibiting companies, a cross-referenced product-category index, general conference services information and extensive details regarding exhibit floor activities. Guides will be given to every OFC attendee as part of registration.

Captured Session Content

We are delighted to announce that approximately 40 percent of the sessions at OFC 2019 are being digitally captured for on-demand viewing and accessible with your technical conference registration. The pre-selected content represents the full breadth of the OFC 2019 program including Symposia, oral presentations, and the Postdeadline Papers sessions. All captured session content will be live for viewing within 24 hours of being recorded. Just look for the symbol ▶ in the Agenda of Sessions and abstracts to easily identify the presentations being captured.

To access the presentations, select the "View Presentations" button prominently displayed on the conference homepage (www.ofcconference.org). As access is limited to Full Technical Attendees only, you will be asked to validate your credentials based on your registration record.

Code of Conduct

All OFC guests, attendees, and exhibitors are subject to the Code of Conduct policy, the full text of which is available at ofcconference.org/codeofconduct. Conference management reserves the right to take any and all appropriate actions to enforce the Code of Conduct, up to and including ejecting from the conference individuals who fail to comply with the policy.

Special Events and Programming

Workshops

Sunday, 3 March, 13:00–15:30

S1A: Optical Experiments and Testing: With or without FEC?

Room 1

Organizers: Alex Alvarado, *Eindhoven University of Technology, Netherlands*; Yi Cai, *ZTE USA Inc., USA*

Forward error correction (FEC) is a key element in modern fiber optical communications. Yet, FEC is not included in many optical experiments. FEC implementation is typically avoided by using FEC thresholds. These thresholds allow researchers to make claims on post-FEC BER without actually implementing or testing the FEC. Strictly speaking, however, post-FEC BER can only be claimed if it is measured using an actual implementation.

We have heard voices from both sides. One group says, "Thresholds are enough to predict post-FEC BER." The other group says, "You must always implement FEC." In fact, there is not even consensus within the former group. Some believe pre-FEC BER is the right threshold, while others say that the (generalized) mutual information is the correct metric.

In this workshop, we gather together experts from different groups to have a head-to-head discussion on the pros and cons of implementing FEC as well as other advanced coding schemes in optical transmission experiments. The workshop aims at answering the following questions: Can we safely avoid implementing FEC in optical transmission experiments? And if so, what metric should we measure? This workshop will also address other more general questions about FEC. For example, how much more coding gain can we achieve in next generation FEC and at what cost? What are the best technologies for next generation FEC? Should we be considering standardized FEC to enable interoperability in long-haul transmission?

Speakers:
Erik Agrell, *Chalmers University of Technology, Sweden*
Domanic Lavery, *University College London, UK*
Seb Savory, *University of Cambridge, UK*
Laurent Schmalen, *Nokia Bell Labs, Germany*
Weiming Wang, *ZTE Corp., China*

S1B: High Noon: Silicon Photonics vs. Rest of the World

Room 6C

Organizers: Giampiero Contestabile, *Scuola Superiore Sant Anna di Pisa, Italy*; Geert Morthier, *Ghent University, Belgium*; Kenya Suzuki, *NTT Device Innovation Center, Japan*

It is commonly recognized that Si-photonics has evolved from being a research subject to a real fabrication platform. Although some Si-based transceivers are already commercialized, discussions still continue on whether the platform is competitive in other application areas which are still dominated by other technologies.

This workshop aims to discuss how well the silicon photonics platform can penetrate into various areas of optical communications. It will be held in the form of team competitions in which a silicon photonics team will be opposed by an alternative technology team, making the case for III-V, dielectric waveguide, or free-space/micro optics to realize the same target devices:

- Transceivers
- Optical filters
- Optical switches

Speakers:

III-V Transceiver Team
Martin Schell, *Fraunhofer Institut Für Nachrichten - Heinrich-Hertz, Germany*
Martin Zirngibl, *Finisar Corp., USA*

Silicon Transceiver Team
Peter De Dobbelaere, *Luxtera Inc., USA*
Chris Doerr, *Acacia Communications Inc., USA*
Sunil Priyadarshi, *Intel Corp., USA*

Silica Filters (passive) Team
Bart Fondeur, *Lumentum Operations LLC, USA*
Lucas Soldano, *Kaiam, USA*
Hiroshi Takahashi, *Sophia University, Japan*

Silicon Filters (passive) Team
Lukas Chrostowski, *University of British Columbia, Canada*
Andrea Melloni, *Politecnico di Milano, Italy*
Milos Popovic, *Boston University, USA*

Silicon Switches Team
Eric Bernier, *Huawei Technologies R&D, Canada*
Kazuhiro Ikeda, *AIST, Japan*
Ming Wu, *University of California Berkeley , USA*

LCOS Switches Team
Stefano Camatel, *Finisar, USA*
David Neilson, *Nokia Bell Labs, USA*
Roland Ryf, *Nokia Bell Labs, USA*

S1C: Opportunities and Challenges for Optical Switching in the Data Center

Room 6D

Organizers: Paolo Costa, *Microsoft, USA*; Yvan Pointurier, *Nokia Bell Labs, France*; S.J. Ben Yoo, *University of California Davis, USA*

Data center traffic is experiencing double-digit growth, generating high pressure on current switching architectures to keep pace with the bandwidth and energy-efficiency demands for further scaling. Optical switching is often advocated as an enabling technology capable of sustaining the explosive growth of data center networks but several challenges needs to be solved before optical switches can be deployed at scale. The workshop will review the hurdles faced by current electronic switching disciplines and will discuss the roadmap for introducing optical switching. We will explore key device, transmission, and network technologies that scale to realistic network

sizes and will indicate the requirements posed on the underlying components. We will also discuss open challenges associated to the control of large optical data center infrastructures including the design of network controllers and dynamic schedulers for resource allocation and new routing and congestion-control protocols.

Speakers:

Hitesh Ballani, *Microsoft Corp., UK*
Optics for the Cloud: Trends, Challenges and Opportunities

Mike Frankel, *Ciena Corp., USA*
Optical Switching for Link Bandwidth Adaptation in Future Data-center Networks

Benjamin Lee, I*BM TJ Watson Research Center, USA*
Platforms for Integrated Photonic Switching Modules

George Papen, *University of California San Diego, USA*
Control Planes for Optical Switches

Roberto Proietti, *University of California Davis, USA*
Control Plane Solutions for Scalable and Modular Optically Interconnected Datacenters

Eitan Zahavi, *Mellanox Technologies, Israel*
Optical Data Centers – Fundamental and Other System Considerations

S1D: Datacenter Optics Reliability: Can We Standardize Requirements, and Can They be Relaxed Given Redundancies and <~5-Year Lifetimes?

Room 6E

Organizers: Long Chen, *Acacia Communications Inc., USA*; Maura Raburn, *Google Inc., USA*; Hanxing Shi, *Finisar, USA*

Although reliability requirements for data center optics are considered less stringent than for traditional telecom/datacom applications, the industry has yet to agree to a standard. Given the high performance, fast time to market, and low price demands, it has become critical for these requirements to be clearly understood and documented. This workshop will bring major datacenter operators, module suppliers, and component suppliers to the table to address these topics.

Speakers:
Chuck Harrel, *Microsoft, USA*
Bob Herrick, *Intel, USA*
Kenneth P. Jackson, *Sumitomo, Japan*
John Johnson, *Broadcom, USA*
Omer Khayam, *Infinera, USA*
Helmut Knehr, *Telcordia/Ericsson, Sweden*
Osa Mok, *Innolight Technology Corp., China*
Ranjani Muthiah, *Inphi, USA*
Bill Ovenstone, *Lumentum/Oclaro, USA*
Chunchun Sui, *Alibaba, China*
Chris Theis, *Finisar, USA*
Vincent Zeng, *Facebook, USA*

S1E: Will Coherent Optics Become a Reality for Intra-data Center Applications?

Room 6F

Organizers: Fred Bucahli, *Nokia Bell Labs, Germany*; Ken Jackson, *Sumitomo Electric Device Innovations, USA*

Mega-scale data-centers for cloud-based applications drive the need for ever higher bandwidth networks, particularly within the data-center. Optical fiber interconnects play a key role in the realization of these networks providing high data throughputs at relatively low energy and cost per bit over distances that are typically less than 2km. Thus far these optical interconnects have been deployed using intensity modulated, direct detect (IMDD) technologies. Coherent technologies, where the phase of the optical carrier provides higher signal-to-noise ratios, have been used since 2010 for long-haul communications at data rates of 100Gb/s and beyond. In the near future, with the demand for even higher data throughputs, can the IMDD approaches satisfy this need? Will there be opportunities for coherent technologies? This topic has been discussed previously with many experts believing that short reach coherent technology based links are still many years away. This workshop will review recent developments and reexamine the outlook for coherent technologies.

Some of the topics to be explored in this workshop:

- Evolution of datacenters. Which bitrates and distances are required today and in the future?
- What has been standardized or currently under standardization? Are all systems utilized in DCs standardized?
- What are the requirements or corner figures in terms of power consumption, form factors, bitrates, and latency?
- How does direct detect approaches compare to coherent ones---reach, power budget.
- Are there alternative transponder architectures to implement coherent?
- What technologies will yield lowest cost components? Integrated SiPh has been demonstrated and further implementations may be based on MMI couplers instead of full 90° hybrids.
- How do the different market segments view coherent? Data Center operators' view, Access providers' view, Transponder/transceiver Vendors' and Academia's view.

Speakers:
Jingchi Cheng, *Alibaba Group, China*
Chris Cole, *Finisar, USA*
Joseph Kahn, *Stanford University, USA*
Eric Maniloff, *Ciena, Canada*
David Plant, *McGill University, Canada*
Benn Thomsen, *Microsoft Corp., UK*
Winston Way, *Neophotonics, USA*

Sunday, 3 March, 16:00– 18:30

S2A: Super DACs and ADCs - To Interleave or not to Interleave

Room 1

Organizers: Daniel Blumenthal, *University of California Santa Barbara, USA*; Robert Elschner, *Fraunhofer Inst. Nachricht Henrich-Hertz, Germany*; Takayuki Mizuno, *NTT Network Innovation Labs, Japan*

High-speed digital-to-analog (DAC) and analog-to-digital (ADC) conversion is at the heart of high performance digital-coherent optical communication

systems. Today's single-carrier systems are largely determined by available DAC/ADC bandwidths and resolutions that impose limits on useable symbol rates and constellation sizes. Similarly, alternative digital electronic multiplexing techniques also face this frontier. The analog interleaving of multiple converters into a "Super DAC/ADC" multiplexed system is becoming therefore an attractive approach to increase sample rates and bandwidth beyond that of state-of-the-art converters. However, it is not yet clear whether the additional hardware and complexity over traditional (e.g. wavelength-division) multiplexing techniques is justified, and which of the different interleaving concepts (time/frequency, analog electrical/optical) has the potential to make its way into future transmission systems (or into other applications of ultra-highspeed RF/optical waveform synthesis and analysis). In order to raise a discussion on these topics, the workshop wants to provide inputs on the requirements of future transmission systems, whether and how they can be met by traditional DAC and ADC architectures, what the advantages and limits of interleaved super DAC/ADCs are, and how they can be realized.

Speakers:
Peter Schvan, *Ciena, USA*
Fu-Tai Tan, *Infinera, USA*
Hiroshi Yamazaki, *NTT Device Technology Labs, Japan*
Greg Raybon, *Nokia Bell Labs, USA*
Christian Schmidt, *Fraunhofer HHI, Germany*
S. J. Ben Yoo, *University of California Davis, USA*

S2B: Artificial Intelligence for Data Centers Operators and Optical Network Providers - Why and When?
Room 6C

Organizers: Antonio Napoli, *Infinera, Germany*; Danish Rafique, *ADVA Optical Networking, Germany*; Yawei Yin, *Alibaba Group, China*

Artificial Intelligence (AI) and Machine Learning (ML) are ubiquitously emerging at different levels within optical networks. This workshop aims at discussing the potential needs and advantages as well as limitations and risks of AI-driven solutions for a number of use cases. This will include predictive maintenance, impairment estimation, control plane automation and related security issues.

For example, how much benefit do we expect in terms of quality of transmission (QoT) estimation? Can AI effectively boost the way today's network are managed towards fully automated operations, or shall we just expect relatively minor improvements in localized management tools?

Both data center and optical transport networks viewpoints will be discussed, aiming at deployment status and expected potential to optimize network resource usage, introduce proactive solutions and ultimately reduce OPEX costs. What kind of AI-based solutions will be deployed in the short and long term? Which use cases should be prioritized, if at all? Are the system vendors and network operators ready to delegate AI, and thus reduce their control and security, to perform fully automated network operations?

Speakers:
Vittorio Curri, *Politecnico di Torino, Italy*
Jörg-Peter Elbers, *ADVA Optical Networking SE, Germany*
Jianqiang Li, *Alibaba Group, USA*
Victor Lopez, *Telefonica, Spain*
Kim Roberts, *Ciena Corp., Canada*
Rene Schmogrow, *Google, USA*
Takahito Tanimura, *Fujitsu Laboratories Ltd., Japan*
Massimo Tornatore, *Politecnico di Milano, Italy*
Darko Zibar, *Danmarks Teknishe Universitet, Denmark*

S2C: What is a Real Killer Application of SDM, Telecom or Non-Telecom?
Room 6D

Organizers: Rodigro Amezcua-Correa, *University of Central Florida, CREOL, USA*; Haoshuo Chen, *Nokia Bell Labs, USA*; Takemi Hasegawa, *Sumitomo Electric Industries Ltd., Japan*

In the last 10 years we have seen significant advances in research on SDM as a technology to expand the transmission capacity in an energy- and cost- efficient way. Recent hero experiments using SDM fibers (multi-core and/or few-mode) have demonstrated capacities higher than 100-1000 Pbit/s*km per fiber.

Yet, we have not seen such SDM fibers being deployed for telecom use, instead, an increasing amount of standard SMFs is being used. The latter solution is certainly effective in the short term, but not sure in the future.

This situation arises some important questions. What do we do with all this SDM technology? Do we have some valuable application other than telecom? Or do we still have something to do for telecom application?

We have such nice technologies as mode multiplexers, unscrambling light, multimode/multi core amplification, sensing, integrated devices, high power lasers, and all these crazy new optical fibers. In the workshop, experts from several categories of SDM technology will gather and give their ideas on application.

Speakers:

Part 1: SDM Technologies

Nicolas Fontaine, *Nokia Bell Labs, USA*
Spatial Multiplexers for Controlling Thousands Modes

Tetsuya Hayashi, *Sumitomo Electric, Japan*
Multi-core Fiber Technologies for Optical Communications and Sensing

Yong-Min Jung, *University of Southampton, UK*
Multicore Fiber Amplifier/Laser Technology and Potential for Telecom Applications

Siddharth Ramachandran, *Boston University, USA*
OAM Fiber Modes for Telecom, Sensing and Spectroscopy

Pierre Sillard, *Prysmian, France*
State of the Art in Standard Few-mode Fibers

Robert R. Thomson, *Heriot-Watt University, UK*
Title not available

Part 2: Sension/Industrial

Cesar Jauregui, *Friedrich-Schiller-Universität Jena, Germany*
SDM Technology for the Power Scaling of Fiber Laser Systems

Eric Johnson, *Clemson University, USA*
Coherently Coupled Orbital Angular Momentum Beams for Sensing and Communications

Ivo Leite, *Leibniz IPHT, Germany*
Title not available

Sergio G. Leon-Saval, *University of Sydney, Australia*
Mode Multiplexers - beyond Optical Communications

Paul Westbrook, *OFS Labs, USA*
Multicore Fiber Sensors

Part 3: Telecom

Alain Bertaina, *Prysmian, France*
Title not available

Maxim Bolshtyansky, *SubCom, USA*
Potential Benefits Employing SDM in Submarine Networks

Dan Marom, *Hebrew University of Jerusalem, Israel*
Mode Division Multiplexing with Rectangular Core Fiber

Daishi Masuda, *OCC, Japan*
Title not available

Kazuhide Nakajima, *NTT, Japan*
Roadmap of SDM Optical Fiber Link

Peter Winzer, *Nokia Bell Labs, USA*
Scaling Optical Fiber Networks: Challenges and Solutions

S2D: Which One Will Succeed in Data Center Applications, Multi-chip or Monolithic Integrated Optoelectronic Chip?
Room 6E

Organizers: Dominic Goodwill, *Huawei Technologies R&D, Canada*; Yasuhiro Matsui, *Finisar Corp., USA*; James (Zhou) Zhiping, *Peking University, China*

Coherent DSP chips will soon be able to process 100-Gbaud signals. Switch ASICs capacity is scaling to tens of Terabit with a channel rate >100 Gb/s. Proximity integration of DSP/ASIC chips and optical chips are highly demanded in these high-speed and high-capacity applications. On-board optics and optics in packaging with ICs are expected to address this challenge. Silicon photonic technology allows monolithic integration of analog/digital ICs with photonic circuits. However, 2.5D and 3D integration approach based on multiple chips or separate IC and PICs is another feasible technique. This workshop will emphasize on how to integrate photonic chips with electronic ICs for very high baud rate and large capacity. Pros and cons for monolithic or multi-chip integration approaches will be discussed. Advanced packaging techniques such as optics in packaging and on-board optics will be also focused.

Speakers:
Peter De Dobbelaere, *Luxtera, USA*
Chris Doerr, *Acacia Communications, USA*
Frank Flens, *Finisar, USA*
Nick Kucharewski, *Rockely Photonics, USA*
Kazuhiko Kurata, *AIO Core Co. Ltd., Japan*
Vladimir Stojanovic, *University of California Berkeley, USA*
Lars Zimmermann, *IHP, Germany*

S2E: Will Advanced Direct-detection Systems Ever Be the Solution of Choice for Metro and Access Applications?
Room 6F

Cristian Antonelli, *Universita degli Studi dell'Aquila, Italy*; Robert Killey, *University College London, UK*; Lilin Yi, *Shanghai Jiao Tong University, China*

Anticipated traffic requirements for future metro and access applications seem to exceed the scaling capabilities of conventional intensity-modulation (IM) direct-detection (DD) systems. Various advanced DD systems, which include single-sideband modulation with digital signal-signal beating cancellation, Stokes receivers, and Kramers-Krönig receivers, have been recently proposed. These systems, which to various extents rely on the use of digital signal processing, offer increased throughput compared to IMDD systems, and require simpler optical hardware compared to coherent systems. On the other hand, coherent systems have the best cost-per-bit when Terabits per second per transceiver rates are targeted.

This workshop aims primarily to address the question of whether advanced DD systems will ever be realistically considered for commercial metro, access, and data center systems, or whether eventually coherent technology will just take over.

Speakers:
Hacene Caouch, *Arista Networks, USA*
Philippe Chanclou, *Orange Labs LLC, USA*
Vivian Chen, *Nokia Bell Labs, USA*
Annika Dochhan, *Adva Optical Networking, Germany*
Mark Filer, *Microsoft Corp., USA*
Roberto Gaudino, *Politecnico di Torino, Italy*
Songnian Fu, *Huazhong University of Science and Technology, China*
Hoon Kim, *KAIST, Korea*
David Plant, *McGill University, Canada*
Sebastian Randel, *Karlsruhe Institute of Technology, Germany*
Christian Rasmussen, *Acacia Communications Inc., USA*
Takuo Tanemura, *The University of Tokyo, Japan*
Peter Winzer, *Nokia Bell Labs, USA*

Lab Automation Hackathon
Sunday, 3 March, 20:00–22:00
Room 17B

Organizers: Nick Fontaine, *Nokia Bell Labs, USA*; Binbin Guan, *Acacia Communications, USA*; Jochen Schroeder, *Chalmers University of Technology, Sweden*

Lab work is most efficient when data can be acquired in an automated way. Especially when taking measurements over long durations automated acquisition avoids introducing human error and allows researchers to concentrate on the fun part of experimental work. Open source software in easy to learn languages such as Python provides just as much, or more features/interoperability for lab automation than alternative commercial software. In this hackathon several researchers with 10+ years' experience of lab automation will show you the power of using Python to quickly get a lab experiment running and display the measurements in a browser. We will learn from companies that work in photonics how they take advantage of Python to create easy interfaces to their software and hardware. Bring a laptop to participate in the exercise. There will also be plenty of time for mingling and discussion. Light food and drinks will be served.

Symposia

Four symposia are scheduled for OFC 2019. Please refer to the abstract section for full descriptions.

5G Trials, Pilots, and Demonstrations
Monday, 4 March, 08:00–16:00
Room 6F

Organizers: Thomas Pfeiffer, *Nokia Bell Labs, Germany*; Dimitra Simeonidou, *University of Bristol, UK*; Jun Terada, *NTT, Japan*; Shan Wey, *ZTE TX, USA*

Future Photonic Devices and Materials for Optical Communications
Monday, 4 March, 08:00–16:00
Room 6C

Organizers: Roel Baets, *Ghent University, INTEC and IMEC, Belgium;* Joyce Poon, *University of Toronto, Canada*

Photonics for IoT and Sensing: Manufacturing, Packaging and Applications
Tuesday, 5 March, 14:00–18:30
Room 6C

Organizers: William Green, *IBM TJ Watson Research Center, USA*; Paul Westbrook, *OFS Labs, USA*; Kevin Williams, *Technische Universiteit Eindhoven, Netherlands*

Network Automation
Wednesday, 6 March, 14:00–18:30
Room 6F

Organizers: Filippo Cugini, *CNIT, Italy*; Josué Kuri, *Google, USA*; Takafumi Tanaka, *NTT Network Innovation Labs, Japan*; Szilard Zsigmond, *Nokia Corp., USA*

Special Sessions

Three special sessions are scheduled for OFC 2019. Please refer to the abstract section for full descriptions.

Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program
Monday, 4 March, 16:30–19:00
Room 6C

Organizers: Michael Haney, *Advanced Research Projects Agency-Energy, USA;* Alan Liu, *Booz Allen Hamilton, USA*

Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications
Tuesday, 5 March, 14:00–18:30
Room 6F

Organizers: Chongjin Xie, *Alibaba Group, USA;* Junichi Kani, *NTT Access Service Systems Labs, Japan;* Laurent Schares, *IBM TJ Watson Research Center, USA;* Jörg-Peter Elbers, *ADVA Optical Networking SE, Germany*

Quantum Technologies and Optical Communications
Wednesday, 6 March, 14:00–18:30
Room 6C

Organizers: Eleni Diamanti, *CNRS, France;* Werner Klaus, *National Institute of Information and Communications Technology, Japan;* Erwan Pincemin, *Orange Labs, France*

Panels

Six panels are scheduled for OFC 2019. Please refer to the abstract section for full descriptions.

Optical and RF Photonic Signal Processing Based on Frequency Combs
Tuesday, 5 March, 14:00–16:00
Room 3

Organizers: Maurizio Burla, *ETH Zurich, Switzerland*; Victor Krozer, *University of Frankfurt, Germany*

Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics
Tuesday, 5 March, 16:30–18:30
Room 3

Organizers: Efstratios Kehayas, *Gooch & Housego, UK*; Sergio Leon-Saval, *University of Sydney, Australia*

PIC Foundry Commercial Access: Prospects and Challenges
Wednesday, 6 March, 08:00–10:00
Room 1

Organizers: Jeroen Duis, *SMART Photonics B.V., Netherlands*; Dong Pan, *Nano Photonics, USA*

SDM Technology Solutions for Next Generation Submarine Transmission
Wednesday, 6 March, 08:00–10:00
Room 7

Organizers: Takayuki Mizuno, *NTT Network Innovation Labs, Japan*; Lara Garrett, *TE SubCom, USA*

Beyond 400G for Hyperscale Data Centers
Thursday, 7 March, 08:00–10:00
Room 1

Organizers: Katharine Schmidtke, *Facebook Inc., USA*; Xiaoxia Wu, *Juniper Networks Inc., USA*

Network Infrastructure Virtualization and Network Slicing
Thursday, 7 March, 14:00–16:00
Room 7

Organizers: Ramon Casellas, *CTTC, Spain*; Vishnu Shukla, *Verizon Communications, USA*

OFC Demo Zone

Monday, 4 March, 14:00–16:30
Room 6A

The OFC Demo Zone features live demonstrations of research projects and proof-of-concept implementations for software functions as well as software tools in the space of optical communication devices, systems, networks.

OFC Demo Zone covers SDN/NFV researches and additional aspects such as control and optimization of transmission systems, network planning, and device

design, while keeping the emphasis on the software aspects of the research work.

Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?

Monday, 4 March, 16:30–19:00
Room 7

Organizers: Antonio D'Errico, *Ericsson Telecomunicazioni Spa, Italy*; Stephen Grubb, *Facebook Inc., USA;* Albert Rafel, *British Telecommunications, UK*

The event is divided in two parts. In the first part, invited speakers will give their views on Network Disaggregation and how it may drive network deployments in the near future, outlining progress in initiatives such as OpenRoadm, Telecom Infra Project, OpenConfig, and ONF. A debate/discussion will follow addressing the objectives and different strategies leading to the design and deployment of more efficient, more cost-effective, greener and more sustainable network infrastructures, thus achieving a more flexible ICT services evolution in the future.

Telecom and network operators are expected to realize big benefits by disaggregating their metro-core network nodes. The adoption of disaggregation in ICT networks implies a radical change of consolidated paradigms in planning, engineering, deploying, operating and troubleshooting the network.

Network disaggregation represents a dramatic departure from the current way the hardware and software are designed and built, introducing new and not negligible deployment challenges. Disaggregated networks are expected to define a virtuous multi-vendor ecosystem where technology and economic advantages are possible, which can only be achieved if hardware and software components are truly interoperable, therefore making it necessary an effective system integration. Thus a new scenario is emerging following current attempts by the Telecom and Network operators to emancipate themselves from the system vendor lock-in. Vertical integration of network equipment, where vendors provide support during the entire lifecycle of their product, seems to be no longer the common requirement in the Network Disaggregation paradigm.

How system integration and all other mentioned issues can be faced in the disaggregation challenge and how the ICT network market will consequently evolve while maintaining interoperability and reliability is part of the current debate and will be part of the main topics during the Open Platform Summit event.

Speakers:

Andrea Campanella, *ONF, Italy*
Open Source Software and White Box Hardware Driving Optical Network Disaggregation

Mark Filer, *Microsoft, USA*
The Open and Disaggregated Networks Powering the Microsoft Cloud

Akira Hirano, *NTT, Japan*
White Box as a Next Generation Transport Platform?

Scott Mountford, *AT&T, USA*
Opening up Long Distance Optical Networks: Pros, Cons, and Caveats

Tim Stuch, *Facebook, USA*
Opportunities and Challenges of Disaggregation in Subsea Networks

Data Center Summit: The Importance of "Open Transport" DCI Innovations in the Evolution of Metro and Long-haul Optical Networks

Tuesday, 5 March, 11:45–13:45
Theater II, Hall E

Session organized by OFC N5 Program Committee

Moderator: Loukas Paraschis, *Senior Director for Cloud Transport System Engineering, Infinera, USA*

Keynote: 11:45–12:15

Dave Temkin
Vice President of Networks, *Netflix, USA*

The Evolution of Content Delivery at Netflix

Reaching 150 million customers across the world, Netflix's backbone and CDN connects studios around the world and delivers over 100 terabits per second of award-winning movies and TV. Dave's teams are responsible for design, deployment, and operations of all elements of networking at Netflix, from script-to-screen.

Panel 12:15–13:45

This panel will debate the adoption and main similarities and differences in open transport architectures for Inter-data center, metro and long-haul optical networks and review the most important related innovations that enable the "open" optical transport evolution.

Speakers

Kevin Dean, *Chief Marketing Officer, euNetworks Group Limited, UK*

Tad Hofmeister, *Network Architect, Google, USA*

Gaya Nagarajan, *Senior Director, Facebook Network Engineering, USA*

Glenn Wellbrock, *Director of Optical Transport Planning, Verizon, USA*

Yawei Yin, *Optical Network Architect, Alibaba, China*

OIDA VIP Industry Leaders Speed Meetings Event

Tuesday, 5 March, 12:00–13:30
Exhibit Hall A, Booth 6445
Invite-Only event, separate registration required. Contact OIDA@osa.org.

These networking events bring together industry executives to share their business experience – from how they started their careers and lessons learned along the way, to using their degree in an executive position – with early career professionals and students.

Sponsored by GoFoton

Exhibitor Happy Hour

Tuesday, 5 March, 17:00–18:30
Center Terrace, San Diego Convention Center

OFC 2019 exhibitors are invited to celebrate the opening of the show. Join your colleagues, customers, and friends for drinks and light appetizers before heading into the Conference Reception.

Conference Reception

Tuesday, 5 March, 18:30–20:00
Ballroom 20

Celebrate Mardi Gras with friends and colleagues at the conference reception. Tickets for this event are included with all full conference registrations. Additional tickets may be purchased at Registration for US $85.

Sponsored by intel

Rump Session: Does Approaching Shannon Limit Leave Only Device Developments in Optical Communications?

Tuesday, 5 March, 19:30–21:30
Room 6D

Organizers: David Plant, *McGill University, Canada*; Peter Winzer, *Nokia Bell Labs, USA*

Description

In the past 30 years, due to the advances in technologies including TDM, WDM, coding, detection, fiber and optical amplifiers, the capacity of single mode fiber has been increased by 1 million times. Today single mode fiber capacity is close to its fundamental limit, and most of system research is focused on coding and DSP technologies to close just a couple of dB gap to Shannon limit. Although SDM promises a significant increase in fiber capacity, there is still doubt on its real applications. At the same time, with the technology progress in devices and components, the cost and energy consumption per bit keep decreasing at the same speed as that in the past.

Questions for Discussion:

- Does this mean that the future of optical communications leaves only to device developments?
- Are there research topics in the fiber transmission that can continually scale up the capacity, spectral efficiency, or even a new defined parameter?
- On the other hand, the capacity in typical short-reach transmission links are still far off from Shannon limit.
- How do novel transmission technologies help reduce the cost and energy consumption of these links?

Format

- Short introductory presentation by session organizer.
- One slide presentations from diverse group of industry provocateurs.
- Vigorous audience participation after each presentation, with organizer facilitating wide ranging discussion.
- Attendees come prepared with tough questions and insightful comments, and challenge the presenters.

Photonic Society of Chinese-Americans Workshop & Social Networking Event

What Applications are Going to Drive Next Optics Developments?

Wednesday, 6 March 2019
Room 17B
17:00–17:30, Registration and Social Networking
17:30–19:30, Panel Discussion, Q&A

Registration Contact:
Howell Zhao: hzhao@bandweaver.com
+1.805.616.7936
Xuezhe Zheng: xzheng115@gmail.com
+1.858.603.5924

Workshop Registration Fee: Free

To serve our mission of bringing together photonics professionals , enhancing the communication and collaboration in the optical industry, PSC-SC has been organizing technical and social events during OFC in the past 11 years.

In OFC 2019, the panel of the PSC annual event consists of well-respected experts from carriers, services operators and OEMs in the optical industry. The latest AI, 5G applications, autonomous vehicles, sensors and IOT technologies will be elaborated.

Co-organizers: The Optical Society(OSA)/OFC China Office/China International Optoelectronic Expo (CIOE)

中華光電學會
Photonic Society of Chinese-Americans

Postdeadline Paper Presentations

Thursday, 7 March, 16:30–18:30
Rooms 6C, 6D, 6E, 6F

Discover the best and most cutting-edge research in optical communications. The OFC 2019 Technical Program Committee has accepted a limited number of Postdeadline Papers for oral presentation. The purpose of Postdeadline Papers is to give participants the opportunity to hear new and significant material in rapidly advancing areas. Only those papers judged to be truly excellent and compelling in their timeliness were accepted.

Lists of accepted papers with their presentation times will be posted throughout the convention center on Tuesday, 5 March. Please visit ofcconference.org and click the "Download Digest Papers" button to access these papers.

Postdeadline Books will be available outside of the Technical Session rooms.

OFC Plenary Session

Tuesday, 5 March, 08:00–10:00
Ballroom 20BCD

From Self-driving Cars to a Vision for Future Mobility

Dmitri Dolgov, *CTO & VP Engineering, Waymo, USA*

Waymo, formerly the Google self-driving car project, has a mission to make it safe and easy for people and things to move around. It is currently the only company with a fleet of fully self-driving cars on public roads. A suite of sensors, including LiDAR, radar, and cameras, gives Waymo's vehicles a 360 degree view and a detailed 3D picture of the world, and Waymo's self-driving software is tested through billions of miles driven in simulation and over 10 million miles of real-world driving experience.

In this presentation, learn how Waymo's vehicles use their powerful combination of custom-built sensors and software to safely navigate the roads, how they communicate, and how machine learning and artificial intelligence touch every part of Waymo's self-driving system.

Dmitri Dolgov is the CTO at Waymo, a self-driving technology company with a mission to make it safe and easy to move people and things around. Dolgov was one of the original members of the Google self-driving car project, which became Waymo in 2016. In his role at Waymo, Dmitri leads the development of all self-driving hardware and software. Prior to Waymo, Dolgov worked on self-driving cars at Toyota and at Stanford as part of Stanford's DARPA Urban Challenge team. In 2008, he was named one of "AI's ten to watch — the Future of AI" by the IEEE Intelligent Systems Magazine. Dolgov received his Bachelor of Science and Master of Science in physics and math from the Moscow Institute of Physics and Technology and a doctorate in computer science from the University of Michigan.

Tackling Capacity and Density Challenges by Electro-photonic Integrationes

Benny Mikkelsen, *Founder & CTO, Acacia Communications, USA*

Photonic integration and digital signal processing (DSP) are critical technologies to support the ever-increasing need for higher data rates and smaller, cost effective optical interfaces for cloud, access and transport applications. DSP technology offers a step-size increase in data rates by enabling advanced transmission techniques, while compensating for impairments at higher baud rates. Whereas DSP ASICs are riding Moore's law supporting higher density and lower power consumption on a rather predictable time scale, photonic integration provides cost and size reduction by integrating ever-more optical functions. As we move to higher data rates, co-packaging of photonics and electronics - beginning with analog ASICs, then DSP ASICs, and ultimately switch ASICs - could offer additional improvements in power, density and performance. In this talk, we provide an update and outlook of the challenges and opportunities the industry is facing as we scale to higher data rates and smaller form factor optical interfaces.

Benny Mikkelsen is one of the founders of Acacia Communications and also serves as its Chief Technology Officer. Mikkelsen brings to Acacia extensive expertise and experience in optical transmission and technologies. Prior to joining Acacia, Mikkelsen co-founded and served as the vice president of technology at Mintera. Prior to that, he held various engineering positions with Bell Laboratories, a research and scientific development company owned by Alcatel-Lucent USA. Mikkelsen has published more than 200 papers and conference contributions in letters, journals and conferences. Mikkelsen holds a Master of Science and a doctorate in electrical engineering from the Technical University of Denmark.

Towards Open Innovation in 5G

Alex Jinsung Choi, *SVP Strategy & Technology Innovation | T-Laboratories Innovation, Deutsche Telekom AG, Germany*

While it remains difficult to make predictions, especially about the future, one bet seems safe: the exponential Internet traffic growth will continue for the foreseeable future. With 5G, we will see requirements for 100 Gb/s connectivity to base stations. More radical approaches are required by operators to keep network rollout costs under control. This includes the move away from a classical black box approach to disaggregation, to Open Source Software and Open Hardware, and also opening up the closed optical ecosystem. Organizations like TIP, OCP, the Linux Foundation and O-RAN play a critical role in this new ecosystem.

Alex Jinsung Choi is SVP of Strategy & Technology Innovation, Head of T-Laboratories Innovation at Deutsche Telekom AG. In addition, he is member of the Technology & Innovation management board, where he has responsibility for several strategic projects including 5G, Edge, Campus Networks and Cloudification.

In his position, he reports directly to Claudia Nemat, Member of the Board of Management, Technology & Innovation.

Choi has more than 20 years of experience in the mobile telecommunication industry. Prior to joining Deutsche Telekom, he served from 2012 as Chief Technology Officer (CTO) and Head of the Corporate R&D Division and the Technology Strategy Office for SK Telekom in South Korea where he drove forward key strategic and research topics.

OFC and Co-Sponsors Awards and Honors

Awards Ceremony and Luncheon

Tuesday, 5 March, 12:00–14:00
Ballroom 20A

Supported by CORNING

Join conference co-sponsors The Optical Society, IEEE Communications Society, and IEEE Photonics Society for a special luncheon to recognize award and honor recipients from each society. The event is open to anyone who purchases a ticket, but seating is limited. Tickets can be purchased for $45 USD at registration.

The following awards and recognitions will be presented at the Luncheon:

2019 John Tyndall Award

The Optical Society 2019 Fellows

IEEE Communications Society 2019 Fellows

IEEE Photonics Society 2019 Fellows

IEEE/OSA Journal of Lightwave Technology Best Paper Award

IEEE Communications Society Charles Kao Award for Best Optical Communications & Networking Paper

The Corning Outstanding Student Paper Award

The Corning Women in Optical Communications Scholarship

The Corning Women in Optical Communication Travel Grants

The Tingye Li Innovation Prize

James Coleman, 2013 John Tyndall Award winner, serves as Master of Ceremonies during the 2018 event.

From left to right: Claudio Mazzali, Harvey Freeman, 2018 John Tyndall Award winner Peter J. Winzer, Chennupati Jagadish and Alan Willner

WOMEN
IN OPTICAL COMMUNICATIONS

SCHOLARSHIP WINNERS

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Los Angeles, California USA

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Hong Kong, China

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Chaoran Huang, Princeton Univ., Princeton, New Jersey, USA
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Niamh Kavanagh, Tyndall National Institute, Cork, Ireland
Wu Xinru, Chinese Univ. of Hong Kong, Hong Kong, China
Christiane Ebongue, Delaware State Univ., Dover, Delaware, USA
Marija Trajkovic, Eindhoven Univ. of Technology, Eindhoven, Netherlands
Sweta Rani, Indian Inst. of Technology Bombay, Mumbai, India
Honghui Zhang, Chinese Univ. of Hong Kong, Hong Kong, China
Maria A. Faustino, Univ. of the Philippines-Diliman, Quezon, Philippines
Alba Vela, Univ. Politècnica de Catalunya, Barcelona, Spain

Learn More: **osa.org/corningscholarship**
Corning Incorporated Booth #2822 | The Optical Society Booth #3039

CORNING OSA Foundation

Short Course Schedule

Sunday, 3 March, 2019

09:00–12:00

SC177: High-speed Semiconductor Lasers and Modulators
John Bowers, *University of California Santa Barbara, USA*

SC359: Datacenter Networking 101
Hong Liu, *Google, USA*

SC444: Optical Communication Technologies for 5G Wireless
Xiang Liu, *Futurewei Technologies, Huawei R&D, USA*

SC460: Digital Coherent Optical System Performance Basics
John Cartledge[1], Maurice O'Sullivan[2]; *[1]Queen's University, Canada; [2]Ciena, Canada*

SC470: Secure Optical Communications *NEW*
Helmut Grießer[1], Andrew Shields[2]; *[1]ADVA Optical Networking SE, Germany; [2]Toshiba Research Europe Ltd., UK*

09:00–13:00

SC105: Modulation Formats and Receiver Concepts for Optical Transmission Systems
Peter Winzer, Xi (Vivian) Chen; *Nokia Bell Labs, USA*

SC328: New Developments in High-speed Optical Networking: OTN beyond 100G, 100G/200G/400G Ethernet, Flex Ethernet
Stephen Trowbridge, *Nokia, USA*

SC341: Multi-carrier Modulation and Superchannels for Terabit-class Transceivers
Sander L. Jansen[1], Dirk van den Borne[2]; *[1]ADVA Optical Networking, Germany; [2]Juniper Networks, Germany*

SC384: Background Concepts of Optical Communication Systems
Alan Willner, *University of Southern California, USA*

SC395: Modeling and Simulation of Optical Transmitter and Receiver Components
Robert Palmer, Harald Rohde; *Elenion, Germany*

SC432: Hands on: Silicon Photonics Component Design and Fabrication
Lukas Chrostowski, *University of British Columbia, Canada*

13:00–16:00

SC216: An Introduction to Optical Network Design and Planning
Jane M. Simmons, *Monarch Network Architects, USA*

SC433: Introduction to Photodetectors for Optical Communications
Joe C. Campbell, *University of Virginia, USA*

SC459: Space Division Multiplexing Components and Devices
Nicolas Fontaine, *Nokia Bell Labs, USA*

13:00–17:00

SC203: 400 Gb/s and Beyond Transmission Systems, Design and Design Trade-offs
Martin Birk[1], Benny Mikkelsen[2]; *[1]AT&T Labs, USA; [2]Acacia Communications, USA*

SC267: Silicon Microphotonics: Technology Elements and the Roadmap to Implementation
Lionel Kimerling, *MIT, USA*

SC369: Test and Measurement for Signals with Complex Optical Modulation
Michael Koenigsmann, Bernd Nebendahl; *Keysight, Germany*

SC431: Photonic Technologies in the Data Center
Clint Schow, *University of California Santa Barbara, USA*

SC443: Optical Amplifiers: From Fundamental Principles to Technology Trends
Shu Namiki[1], Michael Vasilyev[2]; *[1]National Institute of Advanced Industrial Science and Technology (AIST), Japan; [2]University of Texas at Arlington, USA*

SC450: Design, Manufacturing and Packaging of Opto-Electronic Modules
Twan Korthorst[1], Sylwester Latkowsk[2], Arne Leinse[3], Peter O'Brien[4]; *[1]Synopsys, Netherlands; [2]Eindhoven University of Technology, Netherlands; [3]LioniX International, Netherlands; [4]Tyndall National Institute, Ireland*

SC463: Optical Transport SDN: Architectures, Applications, and Actual Implementations
Achim Autenrieth, Jörg-Peter Elbers; *ADVA Optical Networking SE, Germany*

13:30–17:30

SC445: Optical Wireless for Mobile Communications
Harald Haas, *LiFi Research and Development Centre, University of Edinburgh, UK*

SC451: Optical Fiber Sensors
Zuyuan He[1], William Shroyer[2]; *[1]Shanghai Jiao Tong University, China; [2]SageRider, Inc., USA*

SC452: FPGA Programming for Optical Subsystem Prototyping
Noriaki Kaneda, *Nokia Bell Labs, USA*

17:00–20:00

SC205: Integrated Electronic Circuits for Fiber Optics
Y. K. Chen, *Nokia Bell Labs, USA*

SC385: Optical Interconnects for Extreme-scale Datacenters and HPC
Keren Bergman[1], John Shalf[2]; *[1]Columbia University, USA; [2]Lawrence Berkeley National Laboratory, USA*

SC390: Introduction to Forward Error Correction
Frank Kschischang, *University of Toronto, Canada*

SC408: Space Division Multiplexing in Optical Fibers
Roland Ryf, *Nokia Bell Labs, USA*

SC428: Link Design and Modeling for Intra Data Center Optical Interconnects
Petar Pepeljugoski, *IBM Research, USA*

Monday, 4 March 2019

08:30–12:30

SC102: WDM in Long-haul Transmission Systems
Neal S. Bergano, *Retired, USA*

SC160: Microwave Photonics
Vince Urick, *DARPA, USA*

SC178: Test and Measurement for Data Center/ Short Reach Communications
Greg D. LeCheminant, *Keysight Technologies, USA*

SC357: Circuits and Equalization Methods for Coherent and Direct Detection Optical Links
Alexander Rylyakov, *Elenion, USA*

SC446: Hands-on: Characterization of Coherent Opto-electronic Subsystems
Robert Palmer, Harald Rohde; *Elenion, Germany*

SC453A: Hands-on: Fiber Optic Handling, Measurements and Component Testing
Chris Heisler[1], Steve Lane[2], Julien Maille[2], Steve Baldo[3]; *[1]OptoTest Corporation, USA; [2]Data-Pixel, France; [3]Seikoh Giken Company, USA*

SC454: Hands-on: Introduction to Silicon Photonics Circuit Design
Roel Baets[1], Pieter Dumon[2]; *[1]Ghent University, Belgium; [2]Luceda Photonics, Belgium*

SC468: Advanced FEC Techniques for Optical Communications *NEW*
Laurent Schmalen, *Nokia Bell Labs, USA*

SC473: Photonic Switching Systems *NEW*
Benjamin Lee[1], David Neilson[2]; *[1]IBM, USA; [2]Nokia Bell Labs, USA*

09:00–12:00

SC114: Technologies and Applications for Passive Optical Networks (PONs)
Yuanqiu Luo, *Huawei, USA*

SC261: ROADM Technologies and Network Applications
Thomas Strasser, *Nistica Inc., USA*

SC448: Software Defined Networking for Optical Networks: A Practical Introduction
Ramon Casellas, *CTTC, Spain*

SC461: High-capacity Data Center Interconnects
Sander L. Jansen[1], Dirk van den Borne[2]; *[1]ADVA Optical Networking, Germany; [2]Juniper Networks, Germany*

SC465: Transmission Fiber and Cables
Mike Ellwanger, Christopher Towery; *Corning Optical Communications, USA*

13:30–16:30

SC208: Optical Fiber Design for Telecommunications and Specialty Applications
David J. DiGiovanni, *OFS Labs, USA*

SC217: Optical Fiber Based Solutions for Next Generation Mobile Networks
Dalma Novak, *Pharad, LLC, USA*

SC325: Highly Integrated Monolithic Photonic Integrated Circuits
Chris Doerr, *Acacia Communications, USA*

SC429: Advances in Flexible Photonic Networks and Open Architectures
David Boertjes, *Ciena, Canada*

SC462: Introduction to Pluggable Optics
Sharon Hall[1], Robert Blum[2]; *[1]Lumentum, USA; [2]Intel Corp., USA*

SC464: SDN Inside and in between Data Centers
David Maltz, *Microsoft, USA*

13:30–17:30

SC327: Modeling and Design of Fiber-optic Communication Systems
Rene-Jean Essiambre, *Nokia Bell Labs, USA*

SC347: Reliability and Qualification of Fiber-optic Components
David Maack, *Corning, USA*

SC393: Digital Signal Processing for Coherent Optical Transceivers
Chris Fludger, *Cisco Optical GmbH, Germany*

SC453B: Hands-on: Fiber Optic Handling, Measurements, and Component Testing
Chris Heisler[1], Steve Lane[2], Julien Maille[2], Steve Baldo[3]; *[1]OptoTest Corporation, USA; [2]Data-Pixel, France; [3]Seikoh Giken Company, USA*

SC469: Laboratory Automation and Control Using Python *NEW*
Nicolas Fontaine[1], Binbin Guan[2], Jochen Schröder[3]; *[1]Nokia Bell Labs, USA; [2]Acacia Communications, USA; [3]Chalmers University of Technology, Sweden*

SC472: Hands-on: Controlling and Monitoring Optical Network Equipment with Netconf/YANG *NEW*
Ricard Vilalta[1], Noboru Yoshikane[2]; *[1]CTTC, Spain; [2]KDDI Research, Japan*

Refer to ofcconference.org or the OFC Conference App for course descriptions and more information.

Activities on the Show Floor

The exhibit hall is the perfect place to build and maintain professional contacts and to broaden your knowledge about the companies that lead our industry in product development and technological advances. 700+ exhibits showcase the entire continuum of the supply chain – from communications systems and equipment to network design and integration tools to components and devices. In addition, three exhibit hall theaters feature presentations by experts from major global brands and key industry organizations. Get high-level perspectives on hot topics like Intra and inter data center connectivity, infrastructure and machine learning/automation. Learn about the state of the industry, emerging trends and recommended courses of action for how to tackle today's toughest business challenges.

Exhibition

Halls A-H

Schedule plenty of time to roam the exhibit hall, visit with the hundreds of companies represented and see the latest products and technologies.

Exhibit Hall Regulations

- All bags are subject to search.
- Neither photography nor videotaping is permitted in the exhibit hall without written consent of OFC Show Management. Non-compliance may result in the surrendering of film and removal from the hall.
- Children under 18 are not permitted in the exhibit hall during move-in and move-out.
- Children 12 and under must be accompanied by an adult at all times.
- Strollers are not allowed on the show floor at any time.
- Soliciting in the aisles or in any public spaces is not permitted.
- Distribution of literature is limited to exhibitors and must be done from within the confines of their booths.
- Smoking is only permitted in designated exterior areas of the facility.
- Alcohol is not permitted in the exhibit hall during move-in and move-out.

Exhibit Hall Coffee Breaks

The exhibit floor is the perfect place to build and maintain professional contacts, and these breaks provide ideal networking opportunities. Complimentary coffee will be served at these times:

	Exhibit Hours	Coffee Breaks
Tuesday, 5 March	10:00–17:00	10:00–10:30, 16:00–16:30
Wednesday, 6 March	10:00–17:00	10:00–10:30, 16:00–16:30
Thursday, 7 March	10:00–16:00	10:00–10:30

Expo Theater I, *Exhibit Hall B*

N5 Market Watch and Network Operators Summit Sub-Committee Chair: Lisa Huff; *Principal Analyst, Ovum, USA*

Market Watch

This three-day series of panel discussions engages the latest application topics and business issues in the field of optical communications. Presentations and panel sessions feature esteemed guest speakers from industry, research and the investment community.

The program will be located on the exhibit floor. Attendees can easily attend the sessions and tour the exhibit hall. Audience members are encouraged to participate in the question and answer segments that follow the presentations.

Sponsored by HUAWEI

Market Watch Schedule-at-a-Glance

Tuesday, 5 March	
10:30–12:00	**Panel I: State of the Industry - Analyst Panel**
12:30–14:00	**Panel II: Market Projections for Wireline and Wireless Technologies to Support 5G**
14:30–16:00	**Panel III: High Capacity Long Distance Optical Transport: Challenges and Business Reality**
Wednesday, 6 March	
15:30–17:00	**Panel IV: Optical Fiber Plant Infrastructure - Technologies and Markets**
Thursday, 7 March	
10:30–12:00	**Panel V: What's After 400G Ethernet Inside the Data Center?**
12:30–14:00	**Panel VI: Optical Network Management Using Cognitive Systems - Reality or Hype?**

Please refer to your OFC Buyers' Guide and Addendum for more details on the exhibition and other activities on the show floor, including participating company information, a map of the exhibit hall and specific presentation schedules for many of the programs. Check the OFC Conference App for regular updates to show floor programming.

Network Operator Summit

This dynamic program presents the inside perspective from service providers and network operators–their issues, drivers and how their requirements may impact the future of the industry. Everyone in the supply chain, from equipment manufacturers to components, will want to hear what's next in meeting the needs of all network operators.

N5 Market Watch and Network Operator Summit Sub-Committee Chair: Lisa Huff; *Principal Analyst, Ovum, USA*

Network Operator Summit Schedule-at-a-Glance

Wednesday, 6 March	
10:30–11:00	 **Network Operator Summit: Keynote** Genia Wilbourn, *Vice President of Network & Technology, Wireline Global Operations, Verizon Communications, USA*
11:00–12:30	**Panel 1: The Access Network-Next Generation PON, Mobile and Cable Network Upgrades**
13:30–15:00	**Panel 2: 5G Applications and Networks: Real-World Operator Case Studies**

Activities

Expo Theater II, *Exhibit Hall E*

Sponsored by JUNIPER NETWORKS

Schedule at-a-Glance

Tuesday, 5 March	
10:15–11:15	**Ethernet Alliance:** Interoperability – The Foundation of Ethernet Success
11:45–12:15	 **Data Center Summit:** Keynote David Temkin, *Vice President of Networks, Netflix, USA*
12:15–13:45	**Data Center Summit Panel:** The Importance of "Open Transport" DCI Innovations in the Evolution of Metro and Long-haul Optical Networks
14:00–17:00	**Coherent Equivalence beyond 400G – Milestones and Industry Guidance For Aligning Technology Roadmaps** *Session Sponsored by Juniper*
Wednesday, 6 March	
10:15–11:45	**COBO:** COBO Ecosystem: Post Specifications Release
12:00–14:00	**ON2020:** Defining Key Areas for Industry Roadmap Development
14:15–15:15	**ITU:** Standardization Update on Last Mile Delivery Networks, OTN Beyond 100G and Coherent Optics Interoperability
15:30–17:00	**Innovations with Machine Learning in Optical Networks Drive Process Automation**
Thursday, 7 March	
10:15–11:15	**OIF:** 400ZR Specification Update
11:15–12:15	**OIF:** The Path to Open, Interoperable Optical Networking
12:45–14:15	**How Centralized Should Centralized SDN Control and Orchestration Be?**
14:30–16:00	**High-volume Applications of 3-D Sensing in Consumer and Automotive Markets**

Expo Theater III, *Exhibit Hall G*

Sponsored by ACACIA COMMUNICATIONS, INC.

Schedule at-a-Glance

Tuesday, 5 March	
10:15–10:45	Product Showcase, Optical Intelligence, *Huawei Technologies Canada Co., Ltd.*
11:00–12:30	**OpenConfig:** Simplifying Transport Network Operations with Declarative, Vendor-neutral Configuration Management
12:45–14:15	**IEEE Smart Cities Technical Communities:** Smart Cities Connecting Future Communities
14:30–15:30	**TIP:** The Disaggregated Transport Network
15:45–17:00	**IEEE Future Directions:** Innovation Opportunities in Transport Networks from Network Analytics and Machine Learning

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Wednesday, 6 March	
10:15–10:45	Product Showcase, High Speed Transport and Ultralow Latency, *Huawei Technologies Co., Ltd.*
11:00–11:30	Product Showcase, Next Generation 200G/400G PAM4 Optical Interconnects Break the Barrier of Future Datacenter Bandwidths, *ColorChip*
11:30–12:00	Product Showcase, How to Patent AI and Software Related Inventions in Europe, *European Patent Office*
12:00–12:30	Product Showcase, Performance Improvements of Multi-mode Fiber for Next Generation 100+ Gb/s Data-communications, *YOFC*
12:30–13:00	Product Showcase, Converged Networks for 5G RAN and Broadband Services, *Xilinx Inc.*
13:00–13:30	Product Showcase, Evolution and Productization of PAM4 Technology with In-house Serdes for Wireline Applications, *Xilinx Inc.*
13:30–14:30	**Next-Generation Coherent Architectures – Pluggable vs Multi-haul, a Knockout or a Draw?** *Session Sponsored by Acacia Communications*
15:30–17:00	**AIM Photonics:** Building the Photonic Integrated Circuit (PIC) Ecosystem for the 21st Century

Thursday, 7 March	
10:15–10:45	Product Showcase, Network Transformation and Huawei Optical Network 2.0, *Huawei Technologies USA, Inc.*
11:00–13:00	**POFTO:** POF Symposium
13:15–14:15	**Line Side 100Gb/s DWDM Network Solutions – Debating the Options**
14:30-16:00	**The New Transport Network**

NG-PON2 Roadmap and Evolution

Thursday March 7, 08:00–15:00
Room 17B

The Broadband Forum is hosting this workshop to examine the state and potential of NG-PON2 as a universal platform for residential, business and wireless/5G. Presenters include analysts, component vendors, system vendors and operators.

Suzanne R. Nagel Lounge

Exhibit Hall B, Booth 6325

Named in honor of the first women chair of OFC, Suzanne R. Nagel, the lounge is an inclusive, networking space offering attendees the opportunity to discuss diversity topics, meet colleagues, explore new business opportunities and have professional headshots taken. Attendees can participate in small professional development sessions throughout the week focused on topics ranging from resume writing to navigating the industry.

Lounge Hours

Tuesday, 5 March	10:00–17:00
Wednesday, 6 March	10:00–17:00
Thursday, 7 March	10:00–16:00

Poster Sessions

Wednesday, 6 March, 10:30–12:30
Thursday, 7 March 10:30–12:30
Exhibit Hall B

Poster presentations are an integral part of the technical program and offer an opportunity for lively discussion between the poster presenters and attendees. Beverages and light snacks are served during poster sessions. Refer to ofcconference.org or the OFC Conference App for a list of the poster presentations.

Interoperability Demos

Exhibit Hall, Various Booths

Ethernet Alliance will include a live 400GbE network connecting multiple booths on the show floor, OIF will feature a demo of FlexE and there will be also be a multivendor interoperability demo within a fiber-optics network with platform compliant with the Open ROADM MSA.

Please refer to your OFC Buyers' Guide and Addendum for more details on the exhibition and other activities on the show floor, including participating company information, a map of the exhibit hall and specific presentation schedules for many of the programs. Check the OFC Conference App for regular updates to show floor programming.

FOR ENGINEERS. FROM ENGINEERS.

Like you, we're driven to find a way to solve the challenges surrounding the transition to 400G PAM4.

OFC 2019, exhibit 2631.

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Subcommittees

Track D: Components, Devices and Fiber

OFC D1: Advances in prototypes and product developments of components and subsystems for data centers and optical networks

Bert Jan Offrein, *IBM Research GmbH, Switzerland*, **Subcommittee Chair**
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Jeroen Duis, *SMART Photonics B.V., Netherlands*
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Dominic Goodwill, *Huawei Technologies R&D, Canada*
Kenneth Jackson, *Sumitomo, USA*
Di Liang, *Hewlett Packard Labs, University of California Santa Barbara, USA*
Alan McCurdy, *OFS, Fiber Design & Simulation Group, USA*
Yusuke Nasu, *NTT Photonics Laboratories, Japan*
Samuel Palermo, *Texas A&M University, USA*
Hanxing Shi, *Finisar, USA*
Xiaoxia Wu, *Juniper Networks Inc., USA*

OFC D2: Passive optical devices for switching and filtering

Hiroyuki Tsuda, *Keio University, Japan*, **Subcommittee Chair**
Joel Carpenter, *University of Queensland, Australia*
Haoshuo Chen, *Nokia Bell Labs, USA*
Giampiero Contestabile, *Scuola Superiore Sant Anna di Pisa, Italy*
Nicolas Dupuis, *IBM TJ Watson Research Center, USA*
Richard Jensen, *Polatis Inc., USA*
Joyce K S Poon, *University of Toronto, Canada*
Gunther Roelkens, *Ghent University-imec, Belgium*
Lucas Beda Soldano, *Kaiam Europe Ltd., UK*
Kenya Suzuki, *NTT Device Technology Center, Japan*
Yu Yu, *Wuhan National Lab for Optoelectronics, China*

OFC D3: Active optical devices and photonic integrated circuits

Thomas Schrans, *Rockley Photonics, USA*, **Subcommittee Chair**
Connie J. Chang-Hasnain, *University of California Berkeley, USA*
Yasuhiro Matsui, *Finisar Corporation, USA*
Argishti Melikyan, *Nokia Bell Labs, USA*
Geert Morthier, *Ghent University - imec, Belgium*
Kouji Nakahara, *Oclaro Japan Inc., Japan*
Dong Pan, *Sifotonics, USA*
Frank Peters, *University College Cork, Ireland*
Maura Raburn, *Google, USA*
Erman Timurdogan, *Analog Photonics, USA*
Zhiping Zhou, *Peking University, China*

OFC D4: Fiber and propagation physics

Ming-Jun Li, *Corning Research & Development Corp., USA*, **Subcommittee Chair**
Kazuhiko Aikawa, *Fujikura Ltd., Japan*
John Ballato, *Clemson University, USA*
Wladek Forysiak, *Aston University, UK*
Lara D. Garrett, *TE SubCom, USA*
Tetsuya Hayashi, *Sumitomo Electric Industries Ltd., Japan*
Eric Rodrigue Numkam Fokoua, *University of Southampton, UK*
Bishnu P. Pal, *Mahindra École Centrale Hyderabad, India*
Bera Palsdottir, *OFS Fitel Denmark I/S, Denmark*
Daniel L Peterson, *Verizon Communications Inc., USA*
Axel Schulzgen, *University of Central Florida, USA*

OFC D5: Fiber-optic and waveguide devices and sensors

Nicolas K. Fontaine, *Nokia Bell Labs, USA*, **Subcommittee Chair**
Rodrigo Amezcua Correa, *University of Central Florida, CREOL, USA*
Hui Cao, *Yale University, USA*
Miguel Gonzalez Herraez, *Universidad de Alcala, Spain*
Takemi Hasegawa, *Sumitomo Electric Industries Ltd., Japan*
Clemence Jollivet, *Coherent Inc., USA*
Efstratios Kehayas, *Gooch & Housego, UK*
Sophie LaRochelle, *Universite Laval, Canada*
Sergio G Leon-Saval, *University of Sydney, Australia*
Francesca Parmigiani, *University of Southampton, UK*

Track S: Systems and Subsystems

OFC S1: Digital subsystems and systems for data centers

Sorin Tibuleac, *ADVA Optical Networking, USA*, **Subcommittee Chair**
Fred Buchali, *Nokia Bell Labs, Germany*
Sai Chen, *Alibaba Group, China*
Peter De Dobbelaere, *Luxtera Inc., USA*
Mark McKay Filer, *Microsoft Corp., USA*
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Hongbin Zhang, *Acacia Communications, USA*

OFC S2: Optical, photonic and microwave photonic subsystems

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Hao Hu, *DTU Fotonik, Denmark*
Lu Li, *TE SubCom, USA*
Hiroshi Murata, *Osaka University, Japan*
Ana Pejkic, *University of California San Diego, USA*
Erwan Pincemin, *Orange Labs, France*

OFC S3: Radio-over-fiber, free-space optics and sensing systems

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Gee-Kung Chang, *Georgia Institute of Technology, USA*
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Juan Jose Vegas Olmos, *Mellanox, Denmark*
Rod Waterhouse, *Pharad LLC, USA*

OFC S4: Digital and electronic subsystems

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Benn Thomsen, *Microsoft, UK*
Fan Zhang, *Peking University, China*
Liang Zhang, *Huawei, Germany*

OFC S5: Digital transmission systems

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Johannes Fischer, *Fraunhofer Inst. Nachricht Henrich-Hertz, Germany*
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Antonio Napoli, *Infinera, Germany*
Oleg V. Sinkin, *TE SubCom, USA*
Qi Yang, *State Key Laboratory of Optical Communications, China*
Jianjun Yu, *ZTE TX, Inc. USA*

Track N: Networks, Applications and Access

OFC N1: Advances in system, network and service developments and field trials in commercial data centers and networks

David Weldon Boertjes, *Ciena Corp., Canada*, **Subcommittee Chair**
Bruce Cortez, *AT&T, USA*
Mei Du, *Tata Communications, USA*
Douglas Freimuth, *IBM TJ Watson Research Center, USA*
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Praveen Kumar, *Bharti Airtel Ltd., India*
Georg Mohs, *TE SubCom, USA*
Shuto Yamamoto, *NTT, Japan*
Yu Rong Zhou, *BT, UK*

OFC N2: Architectures and software-defined control for intra-data center networks

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Giada Landi, *Nextworks, Italy*
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Yawei Yin, *Alibaba Group, USA*
Jie Zhang, *Beijing University of Posts & Telecom, China*

OFC N3: Architectures and software-defined control for metro and core networks

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Achim Autenrieth, *ADVA Optical Networking SE, Germany*
Ramon Casellas, *CTTC, Spain*
Angela Chiu, *AT&T Labs, USA*
António Eira, *Infinera, Portugal*
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OFC N4: Optical access networks for fixed and mobile services

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OFC N5: Market Watch, Network Operator & Data Center Summit

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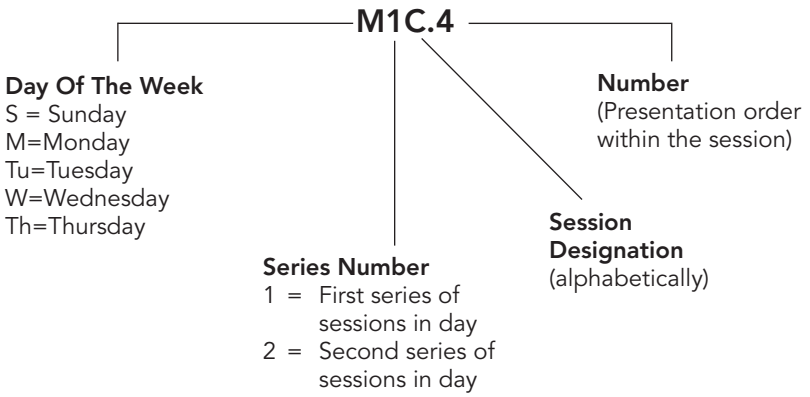
Explanation of Session Codes



The first letter of the code denotes the day of the week (Sunday=Sunday, Monday=M, Tuesday=Tu, Wednesday=W, Th=Thursday). The second element indicates the session series in that day (for instance, 1 would denote the first parallel sessions in that day). Each day begins with the letter A in the third element and continues alphabetically through a series of parallel sessions. The lettering then restarts with each new series. The number on the end of the code (separated from the session code with a period) signals the position of the talk within the session (first, second, third, etc.). For example, a presentation coded M1C.4 indicates that this paper is being presented on Monday (M) in the first series of sessions (1), and is the third parallel session (C) in that series and the fourth paper (4) presented in that session.

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Agenda of Sessions — Sunday, 3 March

	Room 1	Room 6C	Room 6D	Room 6E	Room 6F
09:00–12:00	**SC177, SC359, SC444, SC460, SC470** (additional fee required)				
09:00–13:00	**SC105, SC328, SC341, SC384, SC395, SC432** (additional fee required)				
13:00–15:30	**S1A • Optical Experiments and Testing: With or without FEC?**	**S1B • High Noon: Silicon Photonics vs. Rest of the World**	**S1C • Opportunities and Challenges for Optical Switching in the Data Center**	**S1D • Datacenter Optics Reliability: Can We Standardize Requirements, and Can They be Relaxed Given Redundancies and <~5-Year Lifetimes?**	**S1E • Will Coherent Optics Become a Reality for Intra-data Center Applications?**
13:00–16:00	**SC216, SC433, SC459** (additional fee required)				
13:00–17:00	**SC203, SC267, SC369, SC431, SC443, SC450, SC463** (additional fee required)				
13:30–17:30	**SC445, SC451, SC452** (additional fee required)				
15:30–16:00	**Coffee Break,** *Upper Level Corridors*				
16:00–18:30	**S2A • Super DACs and ADCs - To Interleave or Not to Interleave**	**S2B • Artificial Intelligence for Data Centers Operators and Optical Network Providers - Why and When?**	**S2C • What is a Real Killer Application of SDM, Telecom or Non-telecom?**	**S2D • Which One Will Succeed in Data Center Applications, Multi-chip or Monolithic Integrated Optoelectronic Chip?**	**S2E • Will Advanced Direct-detection Systems Ever Be the Solution of Choice for Metro and Access Applications?**
17:00–20:00	**SC205, SC385, SC390, SC408, SC428** (additional fee required)				
20:00–22:00	**Lab Automation Hackathon,** *Room 17B*				

Key to Shading

Short Courses

Agenda of Sessions — Monday, 4 March

	Room 1	Room 2	Room 3	Room 6C ▶	Room 6D ▶
08:00–10:00	**M1A • Whitebox and OXC**	**M1B • Photonic-based Signal Processing**	**M1C • Advanced Photonics Technology**	**M1D • Symposia: Future Photonics Devices and Materials for Optical Communications 1** ▶	**M1E • Multicore Fibers and Few Mode Fibers** ▶ (Ends at 09:30)
08:30–12:30	**SC102, SC160, SC178, SC357, SC446, SC453A, SC454, SC468, SC473** (additional fee required)				
09:00–12:00	**SC114, SC261, SC448, SC461, SC465** (additional fee required)				
10:00–10:30	**Coffee Break,** *Upper Level Corridors*				
10:30–12:30	**M2A • A.I. in Network Operation**	**M2B • 50G - PON and Beyond**	**M2C • Optical Switching for Datacenter**	**M2D • Symposia: Future Photonics Devices and Materials for Optical Communications 2** ▶	**M2E • Deployable Undersea and Long-haul Systems** ▶
12:30–14:00	**Lunch Break** *(on own)*				
13:30–16:30	**SC208, SC217, SC325, SC429, SC462, SC464** (additional fee required)				
13:30–17:30	**SC327, SC347, SC393, SC453B, SC469, SC472** (additional fee required)				
14:00–16:00	**M3A • High Bandwidth Interconnect** (Ends at 15:45)	**M3B • Optical Switching Technology**	**M3C • Fibers for Short Reach**	**M3D • Symposia: Future Photonics Devices and Materials for Optical Communications 3** ▶	**M3E • Quantum/Nonlinear Optical Processing** ▶
14:00–16:30	**M3Z • OFC Demo Zone,** *Room 6A*				
16:00–16:30	**Coffee Break,** *Upper Level Corridors*				
16:30–18:30	**M4A • High Speed Modulators**	**M4B • Probabilistic Shaping I**	**M4C • Nonlinear and Polarization Effects in Optical Fibers** (Ends at 18:00)	**M4D • Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program** ▶ (Ends at 19:00)	**M4E • Ligo and Lidar** ▶

Key to Shading

Short Courses ▶ Recorded Session

Room 6E	Room 6F	Room 7	Room 8	Room 9
M1F • Enabling Technologies for Data Centers (Ends at 09:45)	**M1G • Symposia: 5G Trials: Vendor's Perspective**	**M1H • Short Reach I**	**M1I • Nonlinearity Mitigation and Modeling** (Ends at 09:30)	**M1J • Optical Amplifiers** (Ends at 09:45)
SC102, SC160, SC178, SC357, SC446, SC453A, SC454, SC468, SC473 (additional fee required)				
SC114, SC261, SC448, SC461, SC465 (additional fee required)				
Coffee Break, *Upper Level Corridors*				
M2F • Ultra-high Speed Devices (Ends at 12:15)	**M2G • Symposia: 5G Trials: Network Operators' and Vertical Industries' Perspective**	**M2H • Advanced Signal Processing** (Ends at 12:15)	**M2I • SDM Transmission I** (Ends at 11:45)	**M2J • Advanced Fiber and Wave Guide Sensing**
Lunch Break *(on own)*				
SC208, SC217, SC325, SC429, SC462, SC464 (additional fee required)				
SC327, SC347, SC393, SC453B, SC469, SC472 (additional fee required)				
M3F • Data Center Operation (Ends at 15:30)	**M3G • Symposia: 5G Trials: Public Sector Initiatives**	**M3H • Coherent Systems for Data Centers**	**M3I • FSO Underwater Communications** (Ends at 15:45)	**M3J • Deployable Technology For Future Networks**
M3Z • OFC Demo Zone, *Room 6A*				
Coffee Break, *Upper Level Corridors*				
M4F • Advanced Wireless Systems (Ends at 18:15)	**M4G • Novel Components for Next Generation PON**	**M4H • Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?** (Ends at 19:00)	**M4I • Transmission Technologies** (Ends at 18:00)	**M4J • Spectrum Efficient Networks**

Agenda of Sessions — Tuesday, 5 March

	Room 1	Room 2	Room 3	Room 6C ▶	Room 6D ▶	Room 6E ▶	Room 6F ▶
07:30–08:00	**Plenary Morning Coffee,** *Upper Level, Ballroom 20 Lobby*						
08:00- 10:00	**OFC Plenary Session,** *Ballroom 20BCD*						
10:00–14:00	**Unopposed Exhibit-only Time,** *Exhibit Hall* (coffee service 10:00–10:30)						
10:00–17:00	**Exhibition and Show Floor,** *Exhibit Hall* (concessions available) **OFC Career Zone Live,** *Exhibit Hall C*						
12:00–14:00	**OFC and Co-Sponsors Awards and Honors Luncheon,** *Upper Level, Ballroom 20A*						
14:00–16:00	**Tu2A • High Speed Silicon Photonics I**	**Tu2B • Optical Solutions for 5G**	**Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs**	**Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1** ▶	**Tu2E • AI in Network Operation 2** ▶	**Tu2F • Short Reach II** ▶ (Ends at 15:45)	**Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1** ▶
16:00–16:30	**Coffee Break,** *Upper Level, Exhibit Hall*						
16:30–18:30	**Tu3A • Laser Driving and VCSELS** (Ends at 18:15)	**Tu3B • PON Standards and Developments**	**Tu3C • Panel: Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics**	**Tu3D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications 2** ▶	**Tu3E • Photonic Integrated Circuits and Novel Technology** ▶	**Tu3F • Wideband Transmission** ▶	**Tu3G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 2** ▶
17:00–18:30	**Exhibitor Happy Hour,** *Center Terrace*						
18:30–20:00	**Conference Reception,** *Ballroom 20BCD*						
19:30–21:30	**Rump Session,** *Room 6D*						

Key to Shading

■ Market Watch/Data Center Summit ▶ Recorded Session

Room 7	Room 8	Room 9
Plenary Morning Coffee, *Upper Level, Ballroom 20 Lobby*		
OFC Plenary Session, *Ballroom 20BCD*		
Unopposed Exhibit-only Time, *Exhibit Hall* (coffee service 10:00–10:30)		
Exhibition and Show Floor, *Exhibit Hall* (concessions available) **OFC Career Zone Live,** *Exhibit Hall C*		
OFC and Co-Sponsors Awards and Honors Luncheon, *Upper Level, Ballroom 20A*		
Tu2H • Silicon Modulator	**Tu2I • Photonic Integration for Data Centers** (Ends at 15:30)	**Tu2J • Filters and Couplers**
Coffee Break, *Upper Level, Exhibit Hall*		
Tu3H • Control of Disaggregated Networks	**Tu3I • Microwave Photonic Chip-scale Subsystems**	**Tu3J • Transmission Fibers and Cables** (Ends at 18:00)
Exhibitor Happy Hour, *Center Terrace*		
Conference Reception, *Ballroom 20BCD*		
Rump Session, *Room 6D*		

Exhibit Hall B, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall G, Expo Theater III
Exhibit Hall Opens 10:00		
■ **MW Panel I: State of the Industry–Analyst Panel** 10:30–12:30 ■ **MW Panel II: Market Projections for Wireline and Wireless Technologies to Support 5G** 12:30–14:00 ■ **MW Panel III: High Capacity Long Distance Optical Transport: Challenges and Business Reality** 14:30–16:00	**Interoperability – The Foundation of Ethernet Success** *Ethernet Alliance* 10:15–11:15 ■ **Data Center Summit: The importance of "Open Transport" DCI Innovations in the Evolution of Metro and Long-Haul Optical Networks** 11:45–13:45 **Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps** *Session sponsored by Juniper* 14:00–17:00	**Product Showcase: Optical Intelligence** *Huawei Technologies Canada Co., Ltd.* 10:15–10:45 **Simplifying Transport Network Operations with Declarative, Vendor-neutral Configuration Management** *OpenConfig* 11:00–12:30 **Smart Cities Connecting Future Communities** *IEEE Smart Cities Technical Communites* 12:45–14:15 **The Disaggregated Transport Network** *TIP* 14:30–15:30 **Innovation Opportunities in Transport Networks from Network Analytics and Machine-Learning** *IEEE Future Directions* 15:45–17:00
Exhibit Hall Closes 17:00		

Agenda of Sessions — Wednesday, 6 March

	Room 1	Room 2	Room 3	Room 6C ▶	Room 6D ▶	Room 6E ▶	Room 6F ▶
07:30–08:00	**Morning Coffee,** *Upper Level Corridors*						
08:00–10:00	**W1A • Panel: PIC Foundry Commercial Access: Prospects and Challenges**	**W1B • Comb Sources and Applications**	**W1C • Nonlinear Processes and Devices**	**W1D • Probabilistic Shaping II** ▶	**W1E • Silicon Photonics Switch** ▶ (Ends at 09:45)	**W1F • Intra and Interdata Center Links** ▶	**W1G • SDN/ NFV** ▶
10:00–17:00	**Exhibition and Show Floor,** *Exhibit Hall* (coffee service 10:00–10:30) **OFC Career Zone Live,** *Exhibit Hall C*						
10:30–12:30	**W2A • Posters Session I,** *Exhibit Hall B*						
12:30–14:00	**Unopposed Exhibit-only Time,** *Exhibit Hall* (concessions available)						
	Lunch Break *(on own)*						
14:00–16:00	**W3A • III-IV Lasers**	**W3B • Novel Device Design**	**W3C • Fiber Lasers** (Ends at 15:15)	**W3D • Special Session: Quantum Technologies and Optical Communications Part 1** ▶	**W3E • High Speed Silicon Photonics II** ▶	**W3F • SDM Transmission II** ▶ (Ends at 15:30)	**W3G • Symposia: Network Automation 1** ▶
16:00–16:30	**Coffee Break,** *Upper Level Corridors and Exhibit Hall*						
16:30–18:30	**W4A • Free Space Optical Communication** (Ends at 18:15)	**W4B • Optical Source and Signal Generation** (Ends at 18:00)	**W4C • Characterization of SDM Fibers** (Ends at 18:15)	**W4D • Special Session: Quantum Technologies and Optical Communications Part 2** ▶	**W4E • Lasers on Si** ▶	**W4F • All-optical Signal Processing** ▶	**W4G • Symposia: Network Automation 2** ▶
17:00–19:30	**Photonic Society of Chinese-Americans Workshop & Social Networking Event,** *Room 17B*						

Key to Shading

■ Market Watch/Network Operator Summit ▶ Recorded Session

Room 7	Room 8	Room 9
Morning Coffee, *Upper Level Corridors*		
W1H • Panel: SDM Technology Solutions for Next Generation Submarine Transmission	**W1I • Radio over Fiber**	**W1J • Datacenter Network Architecture**
Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30) **OFC Career Zone Live,** *Exhibit Hall C*		
W2A • Posters Session I, *Exhibit Hall B*		
Unopposed Exhibit-only Time, *Exhibit Hall* (concessions available)		
Lunch Break *(on own)*		
W3H • Coding and Modulation (Ends at 15:45)	**W3I • Multiplexing and Multichannel Processing** (Ends at 15:45)	**W3J • 5G over Optical Access**
Coffee Break, *Upper Level Corridors and Exhibit Hall*		
W4H • Front Haul Technologies and System Metrics	**W4I • Direct Detection Systems**	**W4J • High-speed PON** **(**Ends at 18:00)
Photonic Society of Chinese-Americans Workshop & Social Networking Event, *Room 17B*		

Exhibit Hall B, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall G, Expo Theater III
Exhibit Hall Opens at 10:00		
■ **Network Operator Summit** **Keynote :** 10:30–11:00 **Panel 1: The Access Network– Next Generation PON, Mobile and Cable Network Upgrades** 11:00–12:30 **Panel 2: 5G Applications and Networks: Real-World Operator Case Studies** 13:30–15:00 ■ **MW Panel IV: Optical Fiber Plant Infrastructure - Technologies and Markets** 15:30–17:00	**COBO Ecosystem: Post Specifications Release** *COBO* 10:15–11:45 **Defining Key Areas for Industry Roadmap Development** *ON2020* 12:00–14:00 **Standardization Update on Last Mile Delivery Networks, OTN Beyond 100G and Coherent Optics Interoperability** *ITU* 14:15–15:15 **Innovations with Machine Learning in Optical Networks Drive Process Automation** 15:30–17:00	**Product Showcase: High Speed Transport and Ultralow Latency** *Huawei Technologies Canada Co., Ltd.* 10:15–10:45 **Product Showcase: Next Generation 200G/400G PAM4 Optical Interconnects Break the Barrier of Future Datacenter Bandwidths** *ColorChip* 11:00–11:30 **Product Showcase: How to Patent AI and Software Related Inventions in Europe?** *European Patent Office* 11:30–12:00 **Product Showcase: Performance Improvements of Multi-mode Fiber for Next Generation 100+ Gb/s Data-communications** *YOFC* 12:00–12:30 **Product Showcase: Converged Networks for 5G RAN and Broadband Services** *Xilinx Inc.* 12:30–13:00 **Product Showcase: Evolution and Productization of PAM4 Technology with In-house Serdes for Wireline Applications** *Xilinx Inc.* 13:00–13:30 **Next-generation Coherent Architectures – Pluggable vs Multi-haul, a Knockout or a Draw?** *Session Sponsored by Acacia Communications* 13:30–14:30 **Building the Photonic Integrated Circuit (PIC) Ecosystem for the 21st Century** *AIM Photonics* 15:30–17:00
Exhibit Hall Closes at 17:00		

Agenda of Sessions — Thursday, 7 March

	Room 1	Room 2	Room 3	Room 6C ▶	Room 6D ▶	Room 6E ▶	Room 6F ▶
07:30–08:00	**Morning Coffee,** *Upper Level Corridors*						
08:00–10:00	**Th1A • Panel: Beyond 400G for Hyper-scale Data Centers**	**Th1B • Multicore and Multimode Amplifiers**	**Th1C • Terahertz/ mmWave Photonics**	**Th1D • Component Implementation and Equalization** ▶	**Th1E • Large-scale Optical Switch** ▶	**Th1F • 5G Fiber Wireless Technology** ▶ (Ends at 09:45)	**Th1G • Security and Monitoring** ▶
10:00–16:00	**Exhibition and Show Floor,** *Exhibit Hall* (coffee service 10:00–10:30) **OFC Career Zone Live,** *Exhibit Hall C*						
10:30–12:30	**Th2A • Posters Session II,** *Exhibit Hall B*						
12:30–14:00	**Unopposed Exhibit-only Time,** *Exhibit Hall* (concessions available)						
14:00–16:00	**Th3A • Evolution of Optical Interconnects**	**Th3B • Detectors**	**Th3C • Microwave Photonic Sub-systems**	**Th3D • SDM Devices** ▶	**Th3E • Hollow Core Fibers** ▶	**Th3F • Coherent PON** ▶ (Ends at 15:45)	**Th3G • Advanced Modulation Formats** ▶ (Ends at 15:45)
16:00–16:30	**Coffee Break,** *Upper Level Corridors*						
16:30–18:30	**Postdeadline Sessions,** *Rooms 6C, 6D, 6E, 6F*						

Key to Shading

■ Market Watch/Network Operator Summit ▶ Recorded Session

Room 7	Room 8	Room 9
Morning Coffee, *Upper Level Corridors*		
Th1H • Machine Learning for Datacenter Networks (Ends at 09:30)	**Th1I • Open Systems and Interoperability**	**Th1J • Quantum Communication and Security**
Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30) **OFC Career Zone Live,** *Exhibit Hall C*		
Th2A • Posters Session II, *Exhibit Hall B*		
Unopposed Exhibit-only Time, *Exhibit Hall* (concessions available)		
Th3H • Panel: Network Infrastructure Virtualization and Network Slicing	**Th3I • Visible Light Communication and Positioning** (Ends at 15:45)	**Th3J • Network Resiliency** (Ends at 15:30)
Coffee Break, *Upper Level Corridors*		
Postdeadline Sessions, *Rooms 6C, 6D, 6E, 6F*		

Exhibit Hall B, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall G, Expo Theater III
Exhibit Hall Opens at 10:00		
■ **MW Panel V: What's After 400G Ethernet Inside the Data Center?** 10:30–12:00 ■ **MW Panel VI: Optical Network Management Using Cognitive Systems - Reality or Hype?** 12:30–14:00	**400ZR Specification Update** *OIF* 10:15–11:15 **The Path to Open, Interoperable Optical Networking** *OIF* 11:15–12:15 **How Centralized Should Centralized SDN Control and Orchestration Be?** 12:45–14:15 **High-volume Applications of 3-D Sensing in Consumer and Automotive Markets** 14:30–16:00	**Product Showcase: Network Transformation and Huawei Optical Network 2.0** *Huawei Technologies USA Inc.* 10:15–10:45 **POF Symposium** *POFTO* 11:00–13:00 **Line Side 100Gb/s DWDM Network Solutions – Debating the Options** 13:15–14:15
Exhibit Hall Closes at 16:00		

Room 1

08:00–10:00
M1A • Whitebox and OXC
Presider: Gangxiang Shen; Soochow Univ., China

M1A.1 • 08:00
Required Link and Node Resource Comparison in Spatial Channel Networks (SCNs) Employing Modular Spatial Channel Cross-Connects (SXCs), Masahiko Jinno[1], Yu Asano[1]; [1]*Kagawa Univ., Japan*. Simulative study shows that modular spatial channel cross-connect (SXC) architectures provide almost the same network spatial resource utilization efficiency when compared to a traditional 1 + 1 matrix-switch based SXC, while yielding considerable reduction in the total node cost in a spatial channel network.

M1A.2 • 08:15
Advantages at Network Level of Contentionless NxM adWSS, Thierry Zami[1], Bruno Lavigne[1]; [1]*Nokia Corporation, France*. When connected to bundle of transponders, 8x24 adWSS can insert/extract more traffic than 8x32 MCS in contentionless OXCs. We quantify this advantage for an Indian core WDM elastic networks transporting 75 GHz-spaced 64 GBaud carriers.

M1A.3 • 08:30
Novel CDC ROADM Architecture Utilizing Low Loss WSS and MCS without Necessity of Inline Amplifier and Filter, Yiran Ma[1], Kenya Suzuki[2], Ian Clarke[1], Ai Yanagihara[2], Patrick Wong[1], Takashi Saida[2], Stefano Camatel[1]; [1]*Finisar Corporation, Australia;* [2]*NTT Device Innovation Center, NTT Corporation, Japan*. A novel CDC ROADM architecture comprising low loss wavelength selective switch and multicast switch is illustrated and experimentally demonstrated. The proposed add/drop structure is designed to eliminate the necessity of additional amplification and filtering.

Room 2

08:00–10:00
M1B • Photonic-based Signal Processing
Presider: Youichi Akasaka; Fujitsu Laboratories of America Inc., USA

M1B.1 • 08:00 Invited
Programmable Schemes on Temporal Processing of Optical Pulses for High-speed Photonic Subsystems, Chester C.T. Shu[1], Qijie Xie[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong*. Modulation-assisted temporal Talbot effect has given birth to different programmable schemes on temporal processing of optical pulses. In this paper, we review our recent work on developing such high-speed pulse processing schemes and their applications.

M1B.2 • 08:30
Noise Mitigation of Random Data Signals Through Linear Temporal Sampling Based on the Talbot Effect, Benjamin G. Crockett[1], Luis Romero Cortes[1], Jose Azana[1]; [1]*INRS, Canada*. Noiseless passive amplification of non-repetitive waveforms, e.g., non-return-to-zero data signals, is achieved up to a factor of 28.5 through a linear Talbot-based lossless temporal sampling process, enabling recovery of signals entirely buried under noise.

Room 3

08:00–10:00
M1C • Advanced Photonics Technology
Presider: Haoshuo Chen; Nokia Bell Labs, USA

M1C.1 • 08:00
Efficient Thermal Cross-talk Effect Cancellation in Photonic Integrated Circuits, Maziyar Milanizadeh[1], Sara Ahmadi[1], Douglas Aguiar[1], Andrea Melloni[1], Francesco Morichetti[1]; [1]*Dipartimento di Elettronica Informazione e Bioingegneria, Politecnico di Milano, Italy*. A novel technique, named Thermal Eigenmode Decomposition, able to cancel the effects of thermal crosstalk in arbitrary photonic circuits with heathers is presented. The mapping of thermal crosstalk is obtained only with electrical measurements

M1C.2 • 08:15
Impact of Optical Lithography Resolution on Silicon Arrayed Waveguide Grating Performance, Jian Wang[1], Kenneth McGreer[1], Kevin Schmidt[1], Madhavi Hegde[1], Jin Hong[1]; [1]*Neophotonics Corporation, USA*. Silicon AWGs fabricated using 193-nm lithography show a substantial performance improvement over those using 248-nm processes in the same foundry. AWG total crosstalk could be suppressed to -30dB through phase error correction in design.

M1C.3 • 08:30 Invited
Photonic Packaging in Europe: The PIX-APP Pilot Line Project, Peter A. O'Brien[1]; [1]*Tyndall National Inst., Ireland*. This talk presents an overview an Open Access Photonic Packaging Pilot Line based on the principle of standardised packaging building blocks. The linkage between packaging, design software, device foundries and testing will also be presented.

Room 6C

08:00–10:00
M1D • Symposia: Future Photonics Devices and Materials for Optical Communications 1

M1D.1 • 08:00 Invited
Tunable Metasurfaces, Harry Atwater[1]; [1]*California Inst. of Technology, USA*. Tunable Metasurfaces

M1D.2 • 08:30 Invited
Topologically Protected Silicon Quantum Circuits, Andrea Blanco-Redondo[1]; [1]*Univ. of Sydney, Australia*. We report experiments showing robustness of correlated and entangled biphoton states generated and guided in silicon quantum circuits with non-trivial topology. These results open new avenues to develop robust quantum qubits for quantum information systems.

Room 6D

08:00–09:30
M1E • Multicore Fibers and Few Mode Fibers
Presider: Kazuhiko Aikawa; Fujikura Ltd., Japan

M1E.1 • 08:00 Invited
Progress on SDM Fiber Research in Japan, Kazuhide Nakajima[1], Takashi Matsui[1], Taiji Sakamoto[1], Saki Nozoe[1], Yukihiro Goto[1]; [1]*Nippon Telegraph & Telephone Corp, Japan*. We describe the progress on space division multiplexing optical fiber research in Japan considering the three phases of "Exploration", "Maximization" and "Realization" with the background of national projects. Further progress is expected towards real deployment.

M1E.2 • 08:30
Chromatic Dispersion Analysis and Compensation in a Large Core-count Few-mode Multi-core Fiber Based on Optical Vector Network Analysis, John van Weerdenburg[1], Simon Rommel[1], Jose Manuel Delgado Mendinueta[2], Werner Klaus[2], Jun Sakaguchi[2], Juan Jose Vegas Olmos[3], Ton Koonen[1], Yoshinari Awaji[2], Idelfonso Tafur Monroy[1], Chigo Maduka Okonkwo[1], Naoya Wada[2]; [1]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands;* [2]*Photonic Network System Laboratory, National Inst. of Information and Communication Technology (NICT), Japan;* [3]*Mellanox Technologies, Denmark*. Chromatic dispersion in a large core-count 3-mode fiber is analyzed, observing up to 0.75 ps/(nm km) variations between mode groups. Furthermore, digital CD compensation is shown to relax the stringent path length matching required in such systems.

Room 6E

08:00–09:45
M1F • Enabling Technologies for Data Centers
Presider: Yue-Kai Huang; NEC Laboratories America Inc., USA

M1F.1 • 08:00 Invited

Enabling Technologies for In-router DWDM Interfaces for Intra-data Center Networks, Kevan P. Jones[1]; [1]*Juniper Networks Inc., Canada*. As intra data center capacities continue to scale, transceiver interfaces are increasing in data rate, often employing multiple optical carriers. We consider an efficient hybrid solution using DWDM capable interfaces and optical switching.

M1F.2 • 08:30

Sparse Volterra Nonlinear Equalizer by Employing Pruning Algorithm for High-speed PAM-4 850-nm VCSEL Optical Interconnect, C. Y. Chuang[1], Wei-Fan Chang[1], Chia-Chien Wei[2], Ching-Ju Ho[1], Cheng-Yu Huang[1], Jin-Wei Shi[5], Lindor Henrickson[3], Young-Kai Chen[4], Jyehong Chen[1]; [1]*Department of Photonics, National Chiao Tung Univ., Taiwan;* [2]*Department of Photonics, National Sun Yat-sen Univ., Taiwan;* [3]*Department of Electrical Engineering, National Chung Hsing Univ., Taiwan;* [4]*DARPA, USA;* [5]*Department of Electrical Engineering, National Central Univ., Taiwan*. A pruned Volterra equalizer that reduces computational complexity by up to 85.2% in 112-Gbps PAM-4 optical interconnects is proposed. The BER performance is competitive with LASSO-based Volterra equalizers, and training time is twice as fast.

Room 6F

08:00–10:00
M1G • Symposia: 5G Trials: Vendor's Perspective
Presider: To be determined

M1G.1 • 08:00 Invited

Requirements of 5G Radio Networks on Optical X-Haul Transport, Francis Dominique[1]; [1]*Mobile Networks, Nokia, USA*. The high data rate and very low latency applications supported by 5G require an appropriate transport network to meet the requirements of these applications. This paper provides an insight to the requirements imposed by 5G radio access networks (RAN) on front/midhaul transport.

M1G.2 • 08:30 Invited

ZTE 5G Transport Solution and Joint Field Trial, Li Mo[1]; [1]*ZTE, China*. In this invited paper, we introduce ZTE's 5G Flexhaul transport solution and describe lab tests and field trials with China Mobile in Shanghai and Beijing, and with Telefonica in Madrid.

Room 7

08:00–10:00
M1H • Short Reach I
Presider: Fan Zhang; Peking Univ., China

M1H.1 • 08:00 Invited

Direct Detection of the Optical Field beyond Single Polarization Mode, William Shieh[1]; [1]*Univ. of Melbourne, Australia*. Direct Detection of the Optical Field Beyond Single Polarization Mode

M1H.2 • 08:30

Clipping-enhanced Kramers-Kronig Receivers, Arthur J. Lowery[1], Tianyu Wang[1], Bill Corcoran[1]; [1]*Electrical and Computer Systems Engineering, Monash Univ., Australia*. Simulations show that strongly clipping signals to the Kramers-Kronig processing's logarithm (limiting their lower extent) substantially improves error rates, enabling < 7-dB carrier-to-signal ratios at achievable SNRs, to support low-latency KP4 FEC.

Room 8

08:00–9:30
M1I • Nonlinearity Mitigation and Modeling
Presider: Rene-Jean Essiambre; Nokia Corporation, USA

M1I.1 • 08:00

Nyquist Filtering and Fiber Nonlinearity Distortions Mitigation of Three-carrier 480Gb/s DP-16QAM with Multiplier-free MAP Detection, Yang Tao[1], Liqian Wang[1], Xue Chen[1], Huan Chen[1], Haoyuan Pan[1], Xiao Luo[1]; [1]*Beijing Univ of Posts & Telecom, China*. A modified multiplier-free MAP detection is proposed for a three-carrier 480Gb/s Nyquist DP-16QAM system. Simulation and experimental results demonstrate its competitive performance on filtering and fiber nonlinearity distortion mitigation with significantly reduced complexity.

M1I.2 • 08:15

Low-Complexity Non-linear Phase Noise Mitigation Using a Modified Soft-decoding Strategy, Dario Pilori[1], Antonino Nespola[2], Pierluigi Poggiolini[1], Fabrizio Forghieri[3], Gabriella Bosco[1]; [1]*DET, Politecnico di Torino, Italy;* [2]*LINKS Foundation, Italy;* [3]*Cisco Photonics Italy srl, Italy.*We propose a modified soft-decoding strategy that takes into account residual nonlinear phase noise. We show the effectiveness of this method in a multi-span experiment with propagation over legacy fibers using uniform and probabilistic-shaped constellations.

M1I.3 • 08:30

Power Spectral Density Estimation in Dispersion Unmanaged Coherent Metro Networks, Matteo Lonardi[1,2], Petros Ramantanis[2], Philippe Jennevé[2], Sébastien Bigo[2]; [1]*Univ. of Parma, Italy;* [2]*Nokia Bell Labs France, France*. We propose a semi-analytical model for predicting nonlinear distortion spectral density in dispersion unmanaged systems. We experimentally demonstrate the model in several heterogeneous metro links proving its accuracy even with various phase estimation techniques.

Room 9

08:00–09:45
M1J • Optical Amplifiers
Presider: Sophie LaRochelle; Universite Laval, Canada

M1J.1 • 08:00

Machine Learning-based Raman Amplifier Design, Darko Zibar[1], Alessio Ferrari[2], Vittorio Curri[2], Andrea Carena[2]; [1]*Danmarks Teknishe Universitet, Denmark;* [2]*Politecnico di Torino, Italy.* A multi-layer neural network is employed to learn the mapping between Raman gain profile and pump powers and wavelengths. The learned model predicts with high-accuracy, low-latency and low-complexity the pumping setup for any gain profile.

M1J.2 • 08:15

Distributed Pumping Architecture to Improve the Noise Performance of Broadband Discrete Raman Amplifier, Md A. Iqbal[1], Lukasz Krzczanowicz[1], Ian Phillips[1], Paul Harper[1], Wladek Forysiak[1]; [1]*Aston Univ., UK*. We report a novel dual-stage broadband discrete Raman amplifier which improves low wavelength noise figure by 3.3dB providing 1.2dB Q^2 factor improvement and 1134km reach extension versus a conventional single-stage design for 18×120Gb/s PM-QPSK transmission.

M1J.3 • 08:30 Invited

Progress in Submarine Optical Amplifiers, Maxim A. Bolshtyansky[1]; [1]*SubCom, USA*. Amplification technology for undersea transmission systems is reviewed. Past, present and future possibilities for amplifier requirements, technical implementation and use cases are discussed.

Room 1

M1A • Whitebox and OXC—Continued

M1A.4 • 08:45
Practical SDM-ROADM Designs for Uncoupled Spatial Channels and Their Switching Capacity, Abhishek Anchal[1], Dan M. Marom[1]; [1]*The Hebrew Univ. of Jerusalem, Israel*. We present SDM-ROADM architectures for independent spatial channel routing and add/drop, investigating C/D/C and degrees of practical directional constraints. These are quantified via the switching capacity metric.

M1A.5 • 09:00 Invited
Whitebox Flavors in Carrier Networks, Victor López[1], Oscar González de Dios[1], Juan Pedro Fernandez Palacios[1]; [1]*Telefonica R&D, Spain*. Disaggregation is a trend that is changing the way to architect and to operate networks. This paper presents the different disaggregation alternatives and which are the different elements in a whitebox ecosystem.

Room 2

M1B • Photonic-based Signal Processing—Continued

M1B.3 • 08:45
Optical Arbitrary Waveform Generator Based on Time-domain Multiplane Light Conversion, Mikael Mazur[2,1], Nicolas K. Fontaine[2], Roland Ryf[2], David T. Neilson[2], Haoshuo Chen[2], Gregory Raybon[2], Andrew Adamiecki[2], Steve Corteselli[2], Jochen Schröder[1]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Crawford Hill Laboratory, Nokia Bell Labs, USA*. We present theoretically lossless optical arbitrary waveform generation based on time-domain multiplane light conversion, with alternating phase modulation and dispersion. We demonstrate the concept by implementing Nyquist shaped QPSK and OOK using phase modulation only.

M1B.4 • 09:00
Optical Matrix Manipulation Based on Frequency Comb Modulation and Dispersed Time Delay, Yuyao Huang[1], Wenjia Zhang[1], Fan Yang[1], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China*. We propose a novel optical matrix manipulation based on frequency comb modulation and dispersed time delay. The sequence autocorrelation is demonstrated at 1.18×10^{11} MAC/s and convolution of binary images is performed at 5.12×10^{11} MAC/s .

Room 3

M1C • Advanced Photonics Technology—Continued

M1C.4 • 09:00
A 300mm CMOS-compatible PECVD Silicon Nitride Platform for Integrated Photonics with Low Loss and Low Process Induced Phase Variation, Sandeep S. Saseendran[1], Tangla D. Kongnyuy[1], Bruno Figeys[1], Federico Buja[1], Benedetto Troia[1], Sarp Kerman[1], Aleksandrs Marinins[1], Roelof Jansen[1], Xavier Rottenberg[1], Deniz Tezcan[1], Philippe Soussan[1]; [1]*IMEC, Belgium*. Low loss PECVD silicon nitride waveguides at 905 nm (0.2 dB/cm) and 532 nm (1.36 dB/cm) wavelengths are reported. Efficacy of phase variation measurements for identifying process conditions for optical phased array fabrication is demonstrated.

Room 6C

M1D • Symposia: Future Photonics Devices and Materials for Optical Communications 1—Continued

M1D.3 • 09:00 Invited
Integrated Phase-change Photonics: A Strategy for Merging Communication and Computing Technologies, David Wright[1], Harish Bhaskaran[2], Wolfram Pernice[3], Santiago Carrillo[1], Emaneuele Gemo[1], Anna Baldycheva[1], Zengguang Cheng[2], Xuan Li[2], Carlos Rios[2,4], Nathan Youngblood[2], Johannes Feldmann[3], Nicos Gruhler[3], Matthias Stegmaier[3]; [1]*Univ. of Exeter, UK;* [2]*Univ. of Oxford, UK;* [3]*Univ. of Muenster, Germany;* [4]*MIT, USA*. We can do much more with light than simply communicate; we can store and process data, and even make computers that operate in a brain-like fashion. We demonstrate such possibilities, using integrated phase-change photonic platform.

Room 6D

M1E • Multicore Fibers and Few Mode Fibers—Continued

M1E.3 • 08:45 Top Scored
Weakly-coupled 6-LP-mode Fiber with Low Differential Mode Attenuation, Marianne Bigot[1], Jean-Baptiste Trinel[1], Hélène Maerten[1], Mathé Van Stralen[2], Igor Milicevic[2], Laurent Bigot[3], Stéphane Plus[3], Adrien Masselot[3], Rémi Habert[3], Christian Simonneau[4], Kaoutar Benyahya[4], Guillaume Labroille[5], Pierre Sillard[1]; [1]*Prysmian Group, France;* [2]*Prysmian Group, Netherlands;* [3]*Université de Lille, France;* [4]*Nokia Bell Labs, France;* [5]*CAILabs SAS, France*. We evidence the impact of small angle light scattering on Differential Mode Attenuation (DMA) in few-mode fibers. Based on this finding, we design and fabricate a weakly-coupled 6-LP-mode fiber with low DMA.

M1E.4 • 09:00
A Novel Ring-core Fiber Supporting MIMO-free 50km Transmission over High-order OAM Modes, Rui Zhang[1,2], Heyun Tan[3], Junwei Zhang[3], Lei Shen[1,2], Jie Liu[3], Yaping Liu[1,2], Lei Zhang[1,2], Siyuan Yu[3]; [1]*State Key Laboratory of Optical Fiber and Cable Manufacture Technology, China;* [2]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, China;* [3]*State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-sen Univ., China*. We design and fabricate a novel ring-core fiber with modulated refractive index profile to suppress the micro-bending induced modal coupling. Two OAM mode-group transmission over 50-km fiber without using MIMO equalization is also experimentally demonstrated.

Room 6E

M1F • Enabling Technologies for Data Centers—Continued

M1F.3 • 08:45
Error-free 100Gbps PAM-4 Transmission over 100m OM5 MMF Using 1060nm VCSELs, Justin Lavrencik[1], Ewa Simpanen[2], Siddharth Varughese[1], Alirio Melgar[1], Varghese A. Thomas[1], Johan Gustavsson[2], Wayne V. Sorin[3], Sagi Mathai[3], Mike Tan[3], Anders Larsson[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Chalmers Univ., Sweden;* [3]*Hewlett Packard Enterprise, USA.* We experimentally demonstrate error-free (BER <10^{-12}) rates beyond 100Gbps over 100m OM5 using unpackaged 1060nm VCSELs. Power penalties of PAM-2/PAM-4 are examined demonstrating OM5 fiber capacity to support wavelengths to 1060nm with only transmitter equalization.

M1F.4 • 09:00 Invited
SDM Fibers for Data Center Applications, Benyuan Zhu[1]; [1]*OFS Laboratories, USA.* We will review the recent progresses on SDM fibers for short-reach transmission links. We will describe the design and properties of multicore fibers and discuss the potential applications for short-reach high-density interconnects in future data centers.

Room 6F

M1G • Symposia: 5G Trials: Vendor's Perspective—Continued

M1G.3 • 09:00 Invited
Network Convergence in 5G Transport, Paola Iovanna[1], Stefano Stracca[1], Fabio Ubaldi[1], Fabio Cavaliere[1], Gemma Vall-llosera[1], Luis Miguel Contreras[2]; [1]*Ericsson, Italy;* [2]*Telefonica, Spain.* A novel network concept for the agnostic transport of mobile and enterprise traffic is described and experimentally validated. It is based on DWDM transmission, deterministic switching and a smart control. Finally, technology enablers are discussed.

Room 7

M1H • Short Reach I—Continued

M1H.3 • 08:45 Top Scored
Modified KK Receiver with Accurate Field Reconstruction at Low CSPR Condition, Shaohua An[1], Qingming Zhu[1], Jingchi Li[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China.* A modified KK receiver based on an exponential operation is proposed to accurately reconstruct the field at a low CSPR in a DD system. We experimentally demonstrate a 2-dB sensitivity improvement after 40-km SMF transmission.

M1H.4 • 09:00
Optimally Partitioned Precoding Assisted Hybrid Constellation Entropy Loading for SSB-DMT Systems, Xi Chen[1], Yizhao Chen[1], Ming Tang[1], Jingxian Cui[2], Songnian Fu[1], Li Xia[1], Deming Liu[1]; [1]*Wuhan National Laboratory for Optoelectronics (WNLO) & Next Generation Internet Access National Engineering Lab (NGIA), School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China;* [2]*Photonics Research Center, Department of Electrical Engineering, The Hong Kong Polytechnic Univ., Hong Kong.* We propose the optimally partitioned precoding to perform hybrid constellation entropy loading. Up to 9% net data rate gain is achieved compared to bit power loading scheme for the SSB-DMT system after 80 km transmission.

Room 8

M1I • Nonlinearity Mitigation and Modeling—Continued

M1I.4 • 08:45
Accurate Non-linearity Fully-closed-form Formula Based on the GN/EGN Model and Large-data-set Fitting, Pierluigi Poggiolini[1], Mahdi Ranjbar Zefreh[1], Gabriella Bosco[1], Fabrizio Forghieri[2], Stefano Piciaccia[2]; [1]*Politecnico di Torino, Italy;* [2]*Cisco Photonics Italy srl, Italy.* We tested the accuracy of a fully-closed-form GN/EGN formula over 1,700 different fully-loaded systems. We improved it greatly through a correction that leverages the large data-set, providing an effective tool for real-time physical-layer-aware network management.

M1I.5 • 09:00
An Efficient Nonlinear Fourier Transform Algorithm for Detection of Eigenvalues from Continuous Spectrum, Vahid Aref[1], Son T. Le[1], Henning Buelow[1]; [1]*Nokia Bell Labs, Germany.* We present an efficient, fast and robust Nonlinear Fourier Transform (NFT) algorithm to detect eigenvalues of the discrete spectrum. It outperforms other known NFT algorithms as it detects the eigenvalues from the continuous spectrum, the numerically more robust part of the nonlinear spectrum.

Room 9

M1J • Optical Amplifiers—Continued

M1J.4 • 09:00
Simple Broadband Bismuth Doped Fiber Amplifier (BDFA) to Extend O-band Transmission Reach and Capacity, Vitaly Mikhailov[1], Mikhail Melkumov[2], Daryll Inniss[1], Aleksandr Khegai[2,3], Konstantin Riumkin[2], Sergei Firstov[2], Fedor Afanasiev[4], Man Yan[1], Yingzhi Sun[1], Jiawei Luo[1], Gabriel Puc[1], Scott Shenk[1], Robert Windeler[1], Paul Westbrook[1], Robert Lingle[1], Evgeny Dianov[2], David DiGiovanni[1]; [1]*OFS Laboratories, USA;* [2]*Fiber Optics Research Center, Russian Academy of Science, Russia;* [3]*A General Physics Inst., Russian Academy of Sciences, Russia;* [4]*Inst. of Chemistry of High-Purity Substances, Russian Academy of Sciences, Russia.* We developed a simple silica-based BDFA with 80nm 6-dB gain-bandwidth flexibly centred within 1305-1325nm, and parameters comparable to EDFAs. The amplifier can extend 400GBASE-LR8 transmission (8×26.6 Gbaud/s PAM-4 channels) beyond 50 km of G.652 fiber.

Room 1

M1A • Whitebox and OXC—Continued

M1A.6 • 09:30
Growing Impact of Optical Filtering in Future WDM Networks, Thierry Zami[1], Ivan Fernandez de Jauregui Ruiz[1], Bruno Lavigne[1], Amirhossein Ghazisaeidi[1]; *[1]Nokia Corporation, France*. Whereas carriers faster than 60 GBaud will soon be deployed in the elastic WDM networks, we examine how 75 GHz-wide channel spacing and filtering impact their performance.

M1A.7 • 09:45
Demonstration of Quasi-Nyquist WDM Networks Using Widely Deployed Wavelength-selective Switches, Ryuta Shiraki[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; *[1]Nagoya Univ., Japan*. We propose novel network architecture that allows quasi-Nyquist WDM networks to be implemented with widely deployed WSSs. Network analyses show a 38% improvement in spectral efficiency. Transmission experiments using 69-channel 400-Gbps signals confirm its feasibility.

Room 2

M1B • Photonic-based Signal Processing—Continued

M1B.5 • 09:15
Orthogonally Polarized Optical Single Sideband Generation Based on Integrated Microring Resonators, Jiayang Wu[1], Xingyuan Xu[1], Thach G. Nguyen[2], Sai T. Chu[3], Brent Little[4], Morandotti Roberto[5], Arnan Mitchell[2], David J. Moss[1]; *[1]Swinburne Univ. of Technology, Australia; [2]RMIT Univ., Australia; [3]City Univ. of Hong Kong, China; [4]Chinese Academy of Science, China; [5]INSR-Énergie, Matériaux et Télécommunications, Canada*. We demonstrate orthogonally polarized RF optical single sideband generation based on integrated dual-polarization-mode microring resonators. A high optical carrier-to-sideband ratio of 59.3 dB and a large RF tuning range of over 20 GHz are achieved.

M1B.6 • 09:30
Demonstration of Tunable Optical Single-sideband Generation of 20-Gbit/s OOK and PAM4 Data Channels, Yinwen Cao[1], Kaiheng Zou[1], Huibin Zhou[1], Ahmed Almaiman[1,2], Peicheng Liao[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Karapet Manukyan[1], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]King Saud Univ., Saudi Arabia*. A tunable optical single-sideband generation using optical frequency combs and nonlinear wave-mixing is experimentally demonstrated for 20-Gbit/s OOK and PAM4 channels. The system performance is investigated by tuning the number and spacing of comb lines.

M1B.7 • 09:45 Top Scored
Carrier to Noise Ratio Improvement by Brillouin Amplification for 64-QAM Coherent Communications, Mark D. Pelusi[1], Takashi Inoue[2], Shu Namiki[2]; *[1]Univ. of Sydney, Australia; [2]National Inst. of Advanced Industrial Science and Technology (AIST), Japan*. The limits of narrowband Brillouin gain improving the carrier-to-noise-ratio (*CNR*) of spectral-lines in coherent communications is evaluated. Extrapolation from experiments with 48Gb/s-64-QAM signals predict allowing an input-*CNR* as low as ≈»19dB/0.1nm for minimal bit-error-rate degradation.

Room 3

M1C • Advanced Photonics Technology—Continued

M1C.5 • 09:15
An Improved Thermo-optic Phase Shifter with AlN Block for Silicon Photonics, Shiyang Zhu[1], Ting Hu[1], Zhengji Xu[1], Yuan Dong[1], Qize Zhong[1], Yu Li[1], Navab Singh[1]; *[1]Inst. of Microelectronics, Singapore*. We demonstrate an improved TO device by inserting a small AlN block between the heater and waveguide, the efficiency and speed are improved from 9.4 to 8.2 mW/p and from 26 to 32 kHz respectively.

M1C.6 • 09:30
3-D PBS & 90 ° Optical Hybrid Circuit Using Novel Planar Polarization Optics, Takayuki Kawashima[1], Toshikazu Ijiro[1], Shojiro Kawakami[1,2]; *[1]Photonic Lattice, Inc, Japan; [2]Autocloning technology, Japan*. We fabricated a novel 3-D PBS & 90 ° hybrid constructed by only stacking glass plates with nanostuctured polarization optics on top. We demonstrated low loss and low phase error sufficient for ICR applications.

M1C.7 • 09:45
Orbital Angular Momentum Mux/Demux Module Using Vertically Curved Si Waveguides, Tomo Amemiya[1], Tomoya Yoshida[2], Yuki Atsumi[2], Nobuhiko Nishiyama[1], Yasuyuki Miyamoto[1], Yoichi Sakakibara[2], Shigehisa Arai[1]; *[1]Tokyo Inst. of Technology, Japan; [2]National Inst. of Advanced Industrial Science and Technology, Japan*. An optical-vortex multiplexer/demultiplexer using vertically curved Si waveguides was developed. Multiplexing/demultiplexing with the lowest crosstalk of 23 dB was demonstrated for five multiple optical vortices.

Room 6C

M1D • Symposia: Future Photonics Devices and Materials for Optical Communications 1—Continued

M1D.4 • 09:30 Invited
Silicon-chip-based Brillouin Lasers and Soliton Microcombs Using an Integrated Ultra-high-Q Silica Resonator, Kerry J. Vahala[1], K-Y Yang[3], D-Y Oh[2], S-H Lee[1], Q-F Yang[1], X Yi[4], B Shen[1], H Wang[1]; *[1]California Institute of Technology, USA; [2]Rockley Photonics, USA; [3]Stanford University, USA; [4]University of Virginia, USA*. A monolithic ultra-high-Q silica resonator featuring an integrated silicon-nitride waveguide is described. The resonator can be configured for either high-coherence Brillouin laser action or stable microwave-rate mode locking over C-band at low pumping power.

Room 6D

M1E • Multicore Fibers and Few Mode Fibers—Continued

M1E.5 • 09:15 Top Scored
Low-loss Uncoupled Two-core Fiber for Power Efficient Practical Submarine Transmission, Yoshiaki Tamura[1], Tetsuya Hayashi[1], Tetsuya Nakanishi[1], Takemi Hasegawa[1]; *[1]Sumitomo Electric Industries Ltd, Japan*. We realized 125-μm-cladding 2-core fiber with 0.162-dB/km attenuation, lowest-ever among uncoupled multi-core fibers, and effective areas of 112μm^2. It can enable 1.34-times higher capacity without increasing power consumption, compared with a state-of-the-art submarine single-mode fiber.

10:00–10:30 Coffee Break, *Upper Level Corridors*

Room 6E

M1F • Enabling Technologies for Data Centers—Continued

M1F.5 • 09:30
K-means Assisted Soft Decision of PAM4 to Mitigate Level Nonlinearity and Level-dependent Noise for VCSEL-based 100-Gbps 100-m MMF Optical Interconnection, Lin Sun[1], Jiangbing Du[1], Ke Xu[2], Bo Liu[3], Zuyuan He[1]; [1]*State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China;* [2]*Department of Electronic and Information Engineering, Harbin Inst. of Technology, China;* [3]*School of Physics and Optoelectronic Engineering in Nanjing Univ. of Information Science & Technology, China.* A likelihood ratio estimation method based on K-means clustering is proposed and experimentally demonstrated for soft decision of PAM4 to mitigate the level nonlinearity and level-dependent noise. Commercial-VCSEL-based 100-Gbps 100-m MMF optical transmission is achieved.

Room 6F

M1G • Symposia: 5G Trials: Vendor's Perspective—Continued

M1G.4 • 09:30 Invited
5G Rural Strategy in India, Soundarkumar Masilamani[1], Prakash Ramasetty[1]; [1]*C-Dot, India.* The talk will provide an overview of the Indian telecom environment, introduction to "Digital India" program, the roadmap for 5G implementation in India and potential key technologies.

Room 7

M1H • Short Reach I—Continued

M1H.5 • 09:15
112GBd Virtual-carrier Assisted Single-sideband PAM4 with Kramers-Kronig Detection and Blind Adaptive IQ Imbalance Compensation, An Li[1], Wei-Ren Peng[1], Yan Cui[1], Yusheng Bai[1]; [1]*Futurewei Technologies, Inc., USA.* We propose a novel IQ imbalance compensation algorithm for virtual-carrier assisted single sideband PAM signal. We demonstrate performance improvement on single-λ 112GBd VSSB-PAM4 with KK receiver and IQ imbalance compensation when there is IQ mismatch.

M1H.6 • 09:30
Towards Low Carrier-to-signal Power Ratio for Kramers-Kronig Receiver, Chuanbowen Sun[1], Di Che[1], Honglin Ji[1], William Shieh[1]; [1]*Univ. of Melbourne, Australia.* We propose a novel scheme to relax the requirement of high carrier-to-signal power ratio for Kramers-Kronig receiver. By adopting low carrier-to-signal power ratios, we obtain optical signal-to-noise ratio improvement of up to 1.9 dB.

M1H.7 • 09:45
Coherent Versus Kramers-Kronig Transceivers in Metro Applications: A Power Consumption Perspective, Tianwai Bo[1], Hoon Kim[1]; [1]*Korea Advanced Inst of Science & Tech, Korea.* We estimate power consumption of coherent and Kramers-Kronig (KK) transceivers with various configurations. We show that KK transceivers consume comparable power with coherent transceiver, but upsampling-free KK transceiver consumes 33% less power than coherent one.

Room 8

M1I • Nonlinearity Mitigation and Modeling—Continued

M1I.6 • 09:15
Experimental Demonstration of Data Transmission Based on the Exact Inverse Periodic Nonlinar Fourier Transform, Jan-Willem Goossens[1,2], Yves Jaouën[2], Hartmut Hafermann[1]; [1]*Huawei Technologies France S.A.S.U., France;* [2]*Communications and Electronics Department, Telecom ParisTech, France.* We design a two-dimensional signal constellation based on the exact periodic inverse nonlinear Fourier transform. Feasibility of continuous transmission with periodic signals is experimentally demonstrated over more than 2000 km.

Room 9

M1J • Optical Amplifiers—Continued

M1J.5 • 09:15
High Gain Bi-doped All Fiber Amplifier for O-band DWDM Optical Fiber Communication, Naresh Kumar Thipparapu[1], Yu Wang[1], Andrey A Umnikov[1], Pranabesh Barua[1], David J. Richardson[1], Jayanta K Sahu[1]; [1]*Univ. of Southampton, UK.* We report a double-pass bismuth-doped fiber amplifier operating in the O-band with a 31dB gain and a 7dB NF for -10dBm input signal. The amplifier power conversion efficiency and gain-coefficient are 11% and 0.06dB/mW, respectively.

M1J.6 • 09:30
Transmission Systems with Constant Output Power Amplifiers at Low SNR Values: A Generalized Droop Model, Jean-Christophe Antona[1], Alexis C. Carbó Meseguer[1], Vincent Letellier[1]; [1]*Alcatel Submarine Networks, France.* We propose a unified model of signal impairment aggregation with fixed-power amplifiers which captures ASE noise accumulation and its combination with nonlinearities. We numerically show discrepancies with AWGN-like models adapted to fixed-gain amplifiers at low SNR values.

10:00–10:30 Coffee Break, *Upper Level Corridors*

Room 1

10:30–12:30
M2A • A.I. in Network Operation
Presider: António Eira; Infinera Corporation, Portugal

M2A.1 • 10:30 Invited
Joint Optimization of Packet and Optical Layers of a Core Network Using SDN Controller, CD ROADMs and Machine-learning-based Traffic Prediction, Gagan Choudhury[1], Gaurav S. Thakur[1], Simon T. Tse[1]; [1]*Advance Technology & Systems, AT&T Labs, USA.* We show significant cost savings and improved robustness by combining machine learning with joint global optimization of IP and optical layers in a core network through the use of SDN, CD ROADMs and DFCC devices.

Room 2

10:30–12:30
M2B • 50G - PON and Beyond
Presider: Naoki Suzuki; Mitsubishi Electric Corporation, Japan

M2B.1 • 10:30 Invited
Optical Strategies for Economical Next Generation 50 and 100G PON, Vincent Houtsma[1], Doutje van Veen[1]; [1]*Nokia Bell Labs, USA.* An overview of optical strategies for economical next-generation 50 and 100G PON is given.

Room 3

10:30–12:30
M2C • Optical Switching for Datacenter
Presider: Paraskevas Bakopoulos; Mellanox, Israel

M2C.1 • 10:30
Express Data Center Interconnection Using a Photonic Cross Connect, Jesse E. Simsarian[1], Young-Jin Kim[1,2], David T. Neilson[1], Flavio Pardo[1], Nagesh Basavanhally[1], Robert Farah[1], Rick Papazian[1], Mark Earnshaw[1], Ed Sutter[1], Sirun Xu[1,3], Marina Thottan[1]; [1]*Nokia Bell Labs, USA;* [2]*Perspecta Labs, USA;* [3]*Rutgers, The State Univ. of New Jersey, USA.* We present measurements of express optical interconnection between data centers using a MEMs photonic cross connect and a packet-optical transport network under the control of a programmable netOS for dynamic traffic steering and resiliency.

M2C.2 • 10:45
Performance Assessment of a Novel Rack-scale Disaggregated Data Center with Fast Optical Switch, Xiaotao Guo[1], Fulong Yan[1], Xuwei Xue[1], George Exarchakos[1], Nicola Calabretta[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* We investigate a novel disaggregated architecture based on nanoseconds optical switches. Results show that under data-traffic from real applications the disaggregated architecture with 0.2 local memory rate and 40Gb/s optical links outperforms the server-centric architecture.

Room 6C

10:30–12:30
M2D • Symposia: Future Photonics Devices and Materials for Optical Communications 2

M2D.1 • 10:30 Invited
Transfer Printing for Heterogeneous Integration, Brian Corbett[1], Ruggero Loi[1], James O'Callaghan[1], Lei Liu[1], Kevin Thomas[1], Agnieszka Gocalinska[1], Emanuele Pelucchi[1], Antonio Trindade[2], Christopher Bower[2], Gunther Roelkens[3], Brendan Roycroft[1]; [1]*Tyndall National Inst., Ireland;* [2]*X-Celeprint Limited, Ireland;* [3]*Ghent University, imec, Belgium.* Transfer-printing provides a highly versatile methodology to heterogeneously and intimately integrate diverse photonic and electronic components in close proximity onto silicon photonics platforms. This technique can enable a manufacturing route to powerful photonic integrated circuits.

Room 6D

10:30–12:30
M2E • Deployable Undersea and Long-haul Systems
Presider: Georg Mohs; TE SubCom, USA

M2E.1 • 10:30 Invited
Field Trial of Machine-learning-assisted and SDN-based Optical Network Management, Shuangyi Yan[1], Faisal Nadeem[2], Alex Mavromatis[1], Qirui Fan[2], Hilary Frank[1], Reza Nejabati[1], Alan Pak Tao Lau[2], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK;* [2]*Department of Electrical Engineering, Hong Kong Polytechnic Univ., Hong Kong.* In this paper, we reported machine-learning based network dynamic abstraction over a field-trial testbed. The implemented network-scale NCMDB allows the ML-based quality-of-transmission predictor abstract dynamic link parameters for further network planning.

Room 6E

10:30–12:15
M2F • Ultra-high Speed Devices
Presider: Yusuke Nasu; NTT Photonics Laboratories, Japan

M2F.1 • 10:30 Tutorial

Ultra High-speed Quantum-well Semiconductor Lasers, Kazuhisa Uomi[1]; [1]*Lumentum, Japan*. Evolution of ultra high-speed quantum-well semiconductor lasers with breakthrough technology for data-center and 5G-wireless are fully reviewed from pioneer research up to 100GbE/400GbE application, including challenge and advanced approaches for 800GbE and beyond.

Kazuhisa Uomi, Ph.D., JSAP Fellow is the Senior Chief Engineer of Lumentum, specializing in research and development of advanced and state-of-arts semiconductor optical devices for 100GbE, 400GbE, 800GbE and beyond. He has over 38 years of professional experience working in the semiconductor optical devices, from the early stage of the research of quantum well lasers, in Hiroshima University (1980-1982), Hitachi Central Research Laboratory (1983-2000), Opnext (2001-2012), Oclaro (2012-2018) and Lumentum (2018- present). His nickname is "Father of high-speed MQW lasers". He has coauthored 203-papers in technical journals and international conferences. He also submitted 164-patents. He has been involved 40-times on the program committee member/ chair of international conference sponsored by IEEE/SPIE/OSA/JSAP/IEICE.

Room 6F

10:30–12:30
M2G • Symposia: 5G Trials: Network Operators' and Vertical Industries' Perspective

M2G.1 • 10:30 Invited

AT&T's Trials and Path to 5G, Kent G. McCammon[1]; [1]*Converged Access and Device Technology, AT&T, USA*. We report on AT&T's 5G Trials and Deployments featuring Mobile 5G based upon internationally-recognized standards and which cities for AT&T's build plans. Key photonic technologies are described based on AT&T 5G use cases in development.

Room 7

10:30–12:15
M2H • Advanced Signal Processing
Presider: Takahito Tanimura; Fujitsu Laboratories Ltd., Japan

M2H.1 • 10:30

Multi-stage Machine Learning Enhanced DSP for DP-64QAM Coherent Optical Transmission Systems, Mu Xu[1], Junwen Zhang[1], Haipeng Zhang[1], Zhensheng Jia[1], Jing Wang[1], Lin Cheng[1], Alberto Campos[1], Curtis Knittle[1]; [1]*CableLabs, USA*. We propose to improve DSP for coherent-signal recovery with distributed multi-stage machine-learning algorithms. Experiments demonstrate more-than-3-dB and 1-dB improvements in OSNR sensitivities for 40-GBd and 60-GBd DP-64QAM at BER thresholds of 4.5×10^{-3} and 1.6×10^{-2} respectively.

M2H.2 • 10:45

Mode-dependent Probabilistic Shaping for Highly-efficient Weakly Coupled 10-mode Fiber Transmission, Shohei Beppu[1], Daiki Soma[1], Yuta Wakayama[3], Seiya Sumita[1], Koji Igarashi[2,1], Hidenori Takahashi[1], Takehiro Tsuritani[1]; [1]*KDDI Research, Japan;* [2]*Osaka Univ., Japan;* [3]*KDDI Corp., Japan*. We newly introduced mode-dependent probabilistically shaped (PS-) QAM signals for modal XT limited weakly coupled few-mode fiber transmission and the 16% higher aggregated SE over 81-km transmission than that of QPSK signals was obtained.

Room 8

10:30–11:45
M2I • SDM Transmission I
Presider: Werner Klaus; National Inst of Information & Comm Tech, Japan

M2I.1 • 10:30

Outage Probability Due to Intercore Crosstalk in Weakly-coupled MCF Systems with OOK Signaling, Tiago F. Alves[1], João L. Rebola[1,2], Adolfo V. Cartaxo[1,2]; [1]*Instituto de Telecomunicações, Portugal;* [2]*ISCTE - Instituto Universitário de Lisboa, Portugal*. The outage induced by intercore-crosstalk in multicore-fiber systems employing on-off-keying signaling is theoretically and experimentally characterized. It is shown that a crosstalk level below -16 dB is required to obtain an outage probability below 10^{-4}.

M2I.2 • 10:45

Mode-multiplexed Transmission within and across Mode Groups of a Multimode-fiber, Steffen Wittek[1,2], Roland Ryf[1], Nicolas K. Fontaine[1], Karthik Choutagunta[1,3], Mikael Mazur[1,4], Haoshuo Chen[1], Juan Carlos Alvarado-Zacarias[1,2], Mark Capuzzo[5], Rose Kopf[5], Al Tate[5], Hugo Safar[5], Christian Bolle[5], David T. Neilson[1], Ellsworth Burrows[1], Kwangwoong Kim[1], Marianne Bigot[6], Frank Achten[7], Pierre Sillard[6], Adrian Amezcua-Correa[6], Joseph M. Kahn[3], Jochen Schröder[4], Rodrigo Amezcua Correa[2], Joel A. Carpenter[8]; [1]*Nokia Bell Labs, USA;* [2]*Univ. of Central Florida, CREOL, USA;* [3]*Ginzton Laboratory, Stanford Univ., USA;* [4]*Photonics Laboratory, Chalmers Univ. of Technology, Sweden;* [5]*Nokia Bell Labs, USA;* [6]*Prysmian Group, France;* [7]*Prysmian Group, Netherlands;* [8]*The Univ. of Queensland, Australia*. We show mode-multiplexed transmission over individual mode groups up to 9 groups of a 27 km long graded-index multimode fiber. We also investigate transmission distances up to 500 km using a recirculating loop arrangement for the first 6 mode groups using QPSK and 16-QAM signals.

Room 9

10:30–12:30
M2J • Advanced Fiber and Wave Guide Sensing
Presider: Nicolas Fontaine; Nokia Bell Labs, USA

M2J.1 • 10:30

Monitoring of Remote Seismic Events in Metropolitan Area Fibers Using Distributed Acoustic Sensing (DAS) and Spatio-temporal Signal Processing, Hugo Martins[1], María R. Fernández-Ruiz[1], Luis Costa[1], Etham Williams[2], Zhongwen Zhan[2], Sonia Martin-Lopez[1], Miguel Gonzalez Herraez[1]; [1]*Universidad de Alcalá, Spain;* [2]*California Inst. of Technology, USA*. Remote seismic activity is monitored with DAS using a pre-existent fiber installation in an urban area. Background noise, which greatly exceeds the amplitude of the monitored seismic signals, is eliminated via 2D (spatio-temporal) signal processing.

M2J.2 • 10:45

Real-time Interrogation of Multiplexed FBG Strain Sensors Based on a Thermally Tunable Microring Resonator Array, Fan Yang[1], Wenjia Zhang[1], Shuangxiang Zhao[1], Qingwen Liu[1], Jifang Tao[2], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Shandong Univ., China*. A high-resolution integrated multi-wavelength FBG interrogator is proposed based on a microring resonator array. Two-channel strain sensing is demonstrated with the dynamic stain resolution of 30 nε/ √Hz over 100 Hz to 1 kHz.

Room 1

M2A • A.I. in Network Operation—Continued

M2A.2 • 11:00
Multi-agent Deep Reinforcement Learning in Cognitive Inter-domain Networking with Multi-broker Orchestration, Xiaoliang Chen[1], Baojia Li[2], Roberto Proietti[1], Zuqing Zhu[2], S. J. Ben Yoo[1]; *[1]Univ. of California Davis, USA; [2]Univ. of Science and Technology of China, China.* This paper proposes, for the first time, a cognitive inter-domain networking framework with multi-broker orchestration and multi-agent deep reinforcement learning for multi-domain optical networks. Simulation results show >17% blocking reduction compared to the baselines.

M2A.3 • 11:15
Slice-scaling Strategy Based on Representation Learning in Flex-grid Optical Networks, Jingwen Nan[1], Hui Yang[1], Ao Yu[1], Yajie Li[1], Huifeng Guo[2], Tao Peng[2], Jie Zhang[1]; *[1]Beijing Univ. of Posts and Telecom., China; [2]ZTE, China.* We propose a slice-scaling strategy adapting to dynamic demands based on representation learning in flex-grid optical networks. Experiments show our strategy has lower latency than others when dealing with the slice-scaling problem.

Room 2

M2B • 50G - PON and Beyond—Continued

M2B.2 • 11:00
Elastic Optical Transmission of 50 Gb/s/lambda OFDM Based Mobile Fronthaul via DSP-aided Sub-band Spreading, You-Wei Chen[1], Peng-Chun Peng[2], Jhih-Heng Yan[3], Shuyi Shen[1], Qi Zhou[1], Long Huang[1], Siming Liu[1], Rui Zhang[1], Kai-Ming Feng[3], Gee-Kung Chang[1]; *[1]School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA; [2]Department of Electro-Optical Engineering, National Taipei Univ. of Technology, Taiwan; [3]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan.* Even suffering from two 20-dB attenuated RF fading notches, a 50-Gpbs sub-band spreading OFDM enhanced intensity-modulation mobile fronthaul is experimentally demonstrated over 25-km fiber transmission with a superior EVM performance over the widely-adapted OFDM signals.

M2B.3 • 11:15
Improved Dispersion Tolerance for 50G-PON Downstream Transmission via Receiver-side Equalization, Tao Minghui[1], Jianyu Zheng[1], Xiaolong Dong[2], Kuo Zhang[2], Lei Zhou[2], Huaiyu Zeng[3], Yuanqiu Luo[3], Shengping Li[1], Xiang Liu[3]; *[1]Huawei Technologies, China; [2]Huawei Technologies, China; [3]Futurewei Technologies, USA.* We experimentally show that the dispersion penalty of a 50-Gb/s NRZ signal under 85-ps/nm dispersion can be reduced to below 1 dB via receiver-side equalization, showing the promise of supporting 50G-PON downstream transmission over 20-km SSMF at the 1342-nm wavelength.

Room 3

M2C • Optical Switching for Datacenter—Continued

M2C.3 • 11:00 Invited
A Practical Approach to Optical Switching in Data Centers, William Mellette[1,2]; *[1]Univ. of California San Diego, USA; [2]inFocus Networks, USA.* Optical switching can address the energy and bandwidth scaling challenges facing data center networks, but its adoption is impeded by the cost and complexity of associated hardware and control mechanisms. This paper discusses an approach that reduces cost and complexity by co-designing the hardware and overall network architecture.

Room 6C

M2D • Symposia: Future Photonics Devices and Materials for Optical Communications 2—Continued

M2D.2 • 11:00 Invited
3D Printing in Photonic Integration, Philipp Dietrich[1]; *[1]Karlsruhe Inst. of Technology, Germany.* 3D Printing in Photonic Integration

Room 6D

M2E • Deployable Undersea and Long-haul Systems—Continued

M2E.2 • 11:00 Top Scored
50G BPSK, 100G SP-QPSK, 200G 8QAM, 400G 64QAM Ultra Long Single Span Unrepeatered Transmission over 670.64km, 653.35km, 601.93km and 502.13km Respectively, Xu Jian[1], Jiekui Yu[1], Qianggao Hu[1], Ming Li[1], Jiasheng Liu[1], Qing Luo[1], Liyan Huang[1], Jie Luo[2], Hongyan Zhou[2], Lei Zhang[2], Shugang Jia[3], Xiaohong Zhang[3], Haitao Chen[3]; *[1]ACCELINK, China; [2]Yangtze Optical Fiber and Cable Joint Stock Limited Company, China; [3]NOKIA Shanghai Bell Co., Ltd, China.* We demonstrate record single-carrier 50Gb/s, 100Gb/s, 200Gb/s and 400Gb/s unrepeatered transmission over 670.64km, 653.35km, 601.93km and 502.13km respectively. Using optimized Raman amplifiers, cascaded RGUs, ultra low-loss & 130-μm^2 A_{eff} fibers, and optimal modulation format.

M2E.3 • 11:15
Field Trial Demonstration of Real-time 400GbE Optical Transport over Both Conventional and Non-contiguous Superchannels Using Configurable Modulation Formats, Yu Rong Zhou[1], Kevin Smith[1], Mike Gilson[1], Weiwei Pan[2], Wei Huang[2], Lihong Shen[2], Wei Peng[2], Kunxu Peng[2], Paul Brooks[3], Chris Cole[4], Chengpin Yu[4]; *[1]BT, UK; [2]Huawei Technologies, UK; [3]Viavi Solutions, Germany; [4]Finisar, USA.* We report successful field trial demonstration of real-time 400GbE traffic transported over optical superchannel of both conventional and non-contiguous spectral configurations using configurable modulation formats (200G DP-16QAM/DP-QPSK/DP-8QAM). Stable long term error free performance was demonstrated.

Room 6E

M2F • Ultra-high Speed Devices—Continued

Room 6F

M2G • Symposia: 5G Trials: Network Operators' and Vertical Industries' Perspective—Continued

M2G.2 • 11:00 Invited

5G Trials in Japan, Yukihiko Okumura[1]; [1]*NTT DoCoMo, Japan.* Symposium.5G Trials

Room 7

M2H • Advanced Signal Processing—Continued

M2H.3 • 11:00

Subcarrier Power Loading for Coherent Optical OFDM Optimized by Machine Learning, Maximilian Schaedler[1], Maxim Kuschnerov[1], Stephan Pachnicke[2], Christian Blümm[1], Fabio Pittala[1], Changsong Xie[1]; [1]*Huawei Munich Research Center, Germany;* [2]*Chair of Communications, Kiel Univ. (CAU), Germany.* Enhanced power loading based on machine learned subcarrier interactions and nonlinear SNR progression is proposed to improve BER performance in optical coherent OFDM systems, achieving a gain of 0.5 dB in OSNR vs. classical schemes.

M2H.4 • 11:15

Dual-polarization On-line 256 and 512 QAM Digital Coherent Transmission, Masato Yoshida[1], Keisuke Kasai[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We demonstrate the first dual-polarization on-line 5 Gbaud, 256 and 512 QAM coherent transmissions using an FPGA-based transmitter and receiver. Error-free operation with 14% overhead FEC was achieved for 256 QAM-160km and 512 QAM-20km transmissions.

Room 8

M2I • SDM Transmission I—Continued

M2I.3 • 11:00 Invited

Mode-division-multiplexing Systems for High-capacity Optical Transport Network, Yutaka Miyamoto[1], Kohki Shibahara[1], Takayuki Mizuno[1], Takayuki Kobayashi[1]; [1]*NTT Network Innovation Laboratories, Japan.* This paper reviews the recent technical challenges on mode-division multiplexing (MDM) transport systems for high-capacity Optical Transport Network. Desired features and issues of the MDM system are discussed for long-haul transmission performance over 1,000 km.

Room 9

M2J • Advanced Fiber and Wave Guide Sensing—Continued

M2J.3 • 11:00

Hybrid Polarization Pulling and Pushing Effects for Eliminating Brillouin Gain Fluctuation in Golay-coded BOTDA Sensor, Yin Zhou[1], Lianshan Yan[1], Zonglei Pan[1], Xinpu Zhang[1], Wei Pan[1], Bin Luo[1]; [1]*Southwest Jiao-Tong Univ., China.* A scheme based on hybrid polarization pulling and pushing effects is utilized for eliminating Brillouin gain fluctuation in Golay-coded BOTDA sensor. Maximum Brillouin gain fluctuation is reduced from ~ 0.31% to ~ 0.04%.

M2J.4 • 11:15

A Rapid LiDAR without Mutual Interferences, Il-Pyeong Hwang[1], Chang-Hee Lee[1,2]; [1]*Korea Advanced Inst of Science & Tech, Korea;* [2]*Electrical Engineering, Chongqing Univ. of Technology, China.* We propose a LiDAR without mutual interference for the autonomous vehicles. By using a true random light and a fast correlation measurement method, it is possible to realize a fast LiDAR without a mutual interference.

Room 1

M2A • A.I. in Network Operation—Continued

M2A.4 • 11:30
Self-learning Approaches for Real Optical Networks, Marc Ruiz[1], Fabien Boitier[2], Patricia Layec[2], Luis Velasco[1]; *[1]Universitat Politecnica de Catalunya, Spain; [2]Nokia - Bell Labs, France.* Self-learning approaches to facilitate the deployment of ML algorithms in real networks are analyzed and their performance evaluated through an illustrative use case. Results show large benefits of collective self-learning with centralized retraining.

M2A.5 • 11:45
Building Network Nervous System with Multilayer Telemetry to Realize AI-assisted Reflexes in Software-defined IP-over-EONs for Application-aware Service Provisioning, Hongqiang Fang[1], Wei Lu[1], Lipei Liang[1], Bingxin Kong[1], Zuqing Zhu[1]; *[1]Univ of Science and Technology of China, China.* We design and experimentally demonstrate a network nervous system that can leverage multilayer telemetry to realize artificial intelligence (AI) assisted network reconfigurations (i.e., reflexes) in a software-defined IP over elastic optical network, for application-aware provisioning.

M2A.6 • 12:00
Routing Based on Deep Reinforcement Learning in Optical Transport Networks, José Suárez-Varela[1], Albert Mestres[1], Junlin Yu[2], Li Kuang[2], Haoyu Feng[3], Pere Barlet-Ros[1], Albert Cabellos-Aparicio[1]; *[1]Universitat Politècnica de Catalunya, Spain; [2]Network Research Department, Huawei Technologies Co., Ltd., China; [3]Ottawa Optical System Competency Centre, Huawei Technologies Co., Ltd., Canada.* This paper addresses the use of Deep Reinforcement Learning for automatic routing in Optical Transport Networks at the electrical-layer level. We propose a DRL-based solution that achieves both high performance and fast learning.

Room 2

M2B • 50G - PON and Beyond—Continued

M2B.4 • 11:30 Invited
Exploiting General Purpose Hardware in Optical Access Networks, Sangyeup Kim[1], Takahiro Suzuki[1], Jun-ichi Kani[1], Jun Terada[1]; *[1]NTT Corporation, Japan.* Given the paradigm shift demanded by the widening variation in service requirements, we introduce an edge-server architecture that utilizes commodity hardware to create especially advanced DSP-oriented optical access with maximized system flexibility and server utilization.

M2B.5 • 12:00
SVM-modified-FFE Enabled Chirp Management for 10G DML-based 50Gb/s/λ PAM4 IM-DD PON, Xin Miao[1], Meihua Bi[1,2], Jiasheng J. Yu[2], Longsheng Li[1], Weisheng Hu[1]; *[1]Shanghai Jiao Tong Univ., China; [2]College of Communication Engineering, Hangzhou Dianzi Univ., China.* We propose a novel machine learning based equalization algorithm for bandwidth-limited IM-DD PON in C-band. 50Gb/s/λ PAM4 transmission is demonstrated over 20km SSMF using a 10G-class transmitter with 21dB loss budget without amplification.

Room 3

M2C • Optical Switching for Datacenter—Continued

M2C.4 • 11:30 Tutorial
Enabling Technologies for Optical Data Center Networks: Spatial Division Multiplexing, Lena Wosinska[1,2], Erik Agrell[2], Rui Lin[1], Jiajia Chen[1]; *[1]KTH Royal Inst. of Technology, Sweden; [2]Chalmers Univ. of Technology, Sweden.* Spatial-division multiplexing (SDM) offers scaling up the transmission capacity, while reducing the number of fibers and patch cords, which simplifies cabling complexity. This tutorial will address challenges and recent developments of SDM techniques for optical datacenters.

Lena Wosinska received Ph.D. degree in Photonics and a Docent degree in Optical Networking from KTH Royal Institute of Technology, Sweden, where she is currently a Full Professor of Telecommunication. She is the founder and leader of the Optical Networks Lab. Her current research interests include optical datacenter networks, optical network design, control, reliability and security. She has been involved in many professional activities including serving in panels evaluating project proposals, being General Chair and Co-Chair of IEEE, OSA and SPIE conferences and workshops, Associate and Guest Editor of IEEE, OSA, Elsevier and Springer journals. Currently she is serving on the Editorial Board of Springer PNET Journal and Wiley Transactions on ETT.

Room 6C

M2D • Symposia: Future Photonics Devices and Materials for Optical Communications 2—Continued

M2D.3 • 11:30 Invited
Silicon Photonic MEMS: Exploiting Mechanics at the Nanoscale to Enhance Photonic Integrated Circuits, Niels Quack[1], Hamed Sattari[1], Alain Takabayashi[1], Yu Zhang[1], Pierre Edinger[2], Carlos Errando Herranz[2], Kristinn Gylfason[2], Xiaojing Wang[2], Frank Niklaus[2], Moises Jezzini[3], How Yuan Hwang[3], Peter A. O'Brien[3], Marco A. Porcel[4], Cristina Lerma Arce[5], Saurav Kumar[6], Banafsheh Abasahl[7], Peter Verheyen[7], Wim Bogaerts[6]; *[1]EPFL, Switzerland; [2]KTH Royal Institute of Technology, Sweden; [3]Tyndall National Institute, Ireland; [4]VLC Photonics, Spain; [5]Commscope, USA; [6]University of Ghent, Belgium; [7]IMEC, Belgium.* In this paper, we will discuss recent achievements in the development of MEMS enabled systems in Silicon Photonics and outline the roadmap towards reconfigurable general Photonic Integrated Circuits.

M2D.4 • 12:00 Invited
Indium Phosphide Membrane Photonics on Silicon, K. Williams, V. Pogoretskiy, J. Van Engelen, N. Kelly, J. van der Tol, Y. Jiao, *TU Eindhoven, Eindhoven, Netherlands.* Energy-efficiency, bandwidth density and speed requirements drive miniaturisation in photonics and the intimate integration with silicon technologies. IMOS - the integration of InP membranes on silicon - is an active, scalable nanophotonic platform to achieve this.

Room 6D

M2E • Deployable Undersea and Long-haul Systems—Continued

M2E.4 • 11:30 Invited
Facebook Perspective on Submarine Wet Plant Evolution, Herve Fevrier[1]; *[1]Facebook Inc., USA.* Because of an ever-increasing demand for capacity, submarine cable system design is evolving and the wet plant equipment design and technology are facing new challenges.

M2E.5 • 12:00
Selection of Amplifier Upgrades Addressed by Quality of Transmission and Routing Space, Alessio Ferrari[1], Alberto Tanzi[2], Stefano Piciaccia[2], Gabriele Galimberti[2], Vittorio Curri[1]; *[1]Politecnico di Torino, Italy; [2]Cisco Photonics, Italy.* We propose and compare strategies addressed by quality of transmission and quality of service to address the upgrades of amplification sites. We perform an offline physical layer assessment to deliver traffic independent results.

Room 6E

M2F • Ultra-high Speed Devices—Continued

M2F.2 • 11:30 Invited

Ultra-high Bandwidth InP IQ Modulator for beyond 100-GBd Transmission, Yoshihiro Ogiso[1], Josuke Ozaki[1], Yuta Ueda[1], Hitoshi Wakita[2], Munehiko Nagatani[2], Hiroshi Yamazaki[2], Masanori Nakamura[3], Takayuki Kobayashi[3], Shigeru Kanazawa[1], Takuro Fujii[2], Yasuaki Hashizume[1], Hiromasa Tanobe[1], Nobuhiro Nunoya[1], Minoru Ida[2], Yutaka Miyamoto[3], Mitsuteru Ishikawa[1]; *[1]NTT Device Innovation Center, Japan; [2]NTT Device Technology Laboratories, Japan; [3]NTT Network Innovation Laboratories, Japan.* We present an ultra-high bandwidth IQ modulator with an electro-optic bandwidth of around 80 GHz at a half-wave voltage of 1.5 V, which is a promising modulator for beyond 100-GBd transmission.

M2F.3 • 12:00

Dual-drive Plasmonic Transmitter with Co-designed Driver Electronics Operated at 120 GBd On-off Keying, Benedikt Baeuerle[1], Wolfgang Heni[1], Yuriy Fedoryshyn[1], Claudia Hoessbacher[1], Ueli Koch[1], Arne Josten[1], Tatsuhiko Watanabe[1], Christopher Uhl[2], Horst Hettrich[3], Delwin Elder[4], Larry Dalton[4], Michael Möller[2,3], Juerg Leuthold[1]; *[1]ETH Zurich, Switzerland; [2]Chair of Electronics and Circuits, Saarland Univ., Germany; [3]MICRAM Microelectronics GmbH, Germany; [4]Department of Chemistry, Univ. of Washington, USA.* A plasmonic dual-drive transmitter with co-designed driver electronics featuring 120 GBd on-off keying, with a single ended drive voltage of 450mV and BER performance of 5x10^-7 is demonstrated in a 500m direct detection transmission scheme.

Room 6F

M2G • Symposia: 5G Trials: Network Operators' and Vertical Industries' Perspective—Continued

M2G.3 • 11:30 Invited

Regulatory Aspects for 5G to Enable New Business Models, Walid Mathlouthi[1]; *[1]Google, USA.* Symposium.5G Trials

M2G.4 • 12:00 Invited

VaaSI; Vehicle as a Social Infrastructure, Yuji Inoue[1]; *[1]Toyota InfoTechnology Center, Japan.* Connected-car will become a new social infrastructure not only for automated mobility but more importantly for the social and/or local public services by its powerful ICT capabilities. This new role is named as VaaSI, Vehicle as a Social Infrastructure.

Room 7

M2H • Advanced Signal Processing—Continued

M2H.5 • 11:30 Invited

Signal Processing Techniques for Nonlinear Fourier Transform Systems, Alan Pak Tao Lau[1], Gai Zhou[1], Chao Lu[2], Tao Gui[3,1], P.K.A. Wai[2], Terence Chan[4]; *[1]Photonics Research Center, Department of Electrical Engineering, Hong Kong Polytechnic Univ., Hong Kong; [2]Photonics Research Center, Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong; [3]Huawei Tech. Co., China; [4]Inst. for Telecommunications Research, School of Information Technology and Mathematics, Univ. of South Australia, Australia.* Nonlinear fiber-optic transmissions based on Nonlinear Fourier Transform (NFT) is an emerging area in optical communications with more and more experiments demonstrating their potentials. We review recent developments in signal processing techniques for NFT systems.

M2H.6 • 12:00 Top Scored

120-GBaud 32QAM Signal Generation Using Ultra-broadband Electrical Bandwidth Doubler, Fukutaro Hamaoka[1], Masanori Nakamura[1], Munehiko Nagatani[1,2], Takayuki Kobayashi[1], Asuka Matsushita[1], Hitoshi Wakita[2], Hiroshi Yamazaki[1,2], Hideyuki Nosaka[1,2], Yutaka Miyamoto[1]; *[1]NTT Network Innovation Laboratories, Japan; [2]NTT Device Technology Laboratories, Japan.* We propose an electrical spectrum synthesis technique using digital pre-processing with an interband crosstalk compensation and newly developed ultra-broadband electrical bandwidth doublers. A 120-GBaud PDM-32QAM signal (net rate: 954.2 Gb/s) has been successfully generated.

Room 8

M2I • SDM Transmission I—Continued

M2I.4 • 11:30 Top Scored

Demonstration of Potential 130.8 Tb/s Capacity in Power-efficient SDM Transmission over 12,700 km Using Hybrid Micro-assembly Based Amplifier Platform, Alexey V. Turukhin[1], Milen Paskov[1], Mathew Mazurczyk[1], William Patterson[1], Hussam G. Batshon[1], Oleg V. Sinkin[1], Maxim A. Bolshtyansky[1], Bruce Nyman[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; *[1]TE SubCom, USA.* We demonstrate feasibility of power efficient full C-band 130.8 Tb/s SDM transmission over transoceanic distance using MCF and a compact amplifier platform. Power efficiency is improved by using modulation format with optimal spectral efficiency.

Room 9

M2J • Advanced Fiber and Wave Guide Sensing—Continued

M2J.5 • 11:30 Invited

Silicon Photonic Gas Sensing, William Green[1], Eric J. Zhang[1], Chi Xiong[1], Yves Martin[1], Jason Orcutt[1], Martin Glodde[1], Laurent Schares[1], Tymon Barwicz[1], Chu C. Teng[2], Nathan Marchack[1], Elizabeth Duch[1], Swetha Kamlapurkar[1], Sebastian Engelmann[1], Nigel Hinds[1], Tom Picunko[1], Russell Wilson[1], Gerard Wysocki[2]; *[1]IBM T. J. Watson Research Center, USA; [2]Department of Electrical Engineering, Princeton Univ., USA.* We present a photonic chip sensor platform for near-infrared laser absorption spectroscopy, which incorporates an uncooled III-V laser and detector, on-chip methane reference cell, and 30cm-long evanescent field waveguides, integrated on a silicon photonics substrate.

M2J.6 • 12:00

Design, Fabrication and Experimental Demonstration of Subwavelength Grating Slot Microring Resonator for Sensing Applications, Zhengsen Ruan[1], Jian Wang[1]; *[1]Huazhong Univ. of Scien and Technol, China.* Racetrack micro-ring resonator (MRR) based on subwavelength grating slot (SWGS) waveguide is proposed and experimentally demonstrated. A very high sensing sensitivity of 132 nm/RIU is achieved, which is, respectively improved by 65% compared to the standard strip waveguide-based devices.

Room 1

M2A • A.I. in Network Operation—Continued

M2A.7 • 12:15
Reinforcement Learning Based Multi-tenant Secret-key Assignment for Quantum Key Distribution Networks, Yuan Cao[1,2], Yongli Zhao[1], Jun Li[2], Rui Lin[2], Jie Zhang[1], Jiajia Chen[2]; [1]*Beijing Univ. of Posts and Telecommunications, China;* [2]*KTH Royal Inst. of Technology, Sweden*. We propose a reinforcement learning based online multi-tenant secret-key assignment algorithm for quantum key distribution networks, capable of reducing tenant-request blocking probability more than half compared to the benchmark heuristics.

Room 2

M2B • 50G - PON and Beyond—Continued

M2B.6 • 12:15
92 and 50 Gbps TDM-PON Using Neural Network Enabled Receiver Equalization Specialized for PON, Vincent Houtsma[1], Elaine Chou[2], Doutje van Veen[1]; [1]*Nokia Bell Labs, USA;* [2]*Electrical Engineering, Stanford Univ., USA*. Investigation of NN-based equalizers for 50 & 92-Gbps IM/DD NRZ/PAM-4 TDM-PON. NN is universally trained for OLT-receiver for different fiber reaches and ONU wavelength-variations. Care was taken to avoid overestimation of performance due to overfitting.

Room 3

M2C • Optical Switching for Datacenter—Continued

Room 6C

M2D • Symposia: Future Photonics Devices and Materials for Optical Communications 2—Continued

Room 6D

M2E • Deployable Undersea and Long-haul Systems—Continued

M2E.6 • 12:15 Top Scored
Real-time 16QAM Transatlantic Record Spectral Efficiency of 6.21 b/s/Hz Enabling 26.2 Tbps Capacity, Stephen Grubb[2], Pierre Mertz[1], Ales Kumpera[3], Lee Dardis[4], Jeffrey Rahn[4], James O'Connor[4], Matthew Mitchell[2]; [1]*Infinera Corporation, USA;* [2]*Facebook, USA;* [3]*Infinera Canada, Canada;* [4]*Infinera Corporation, USA*. Real-time, error-free 16QAM transmission at a record spectral efficiency of 6.21 b/s/Hz enables transatlantic (6,644 km) fiber capacity of 26.2 Tbps, using precision, multi-carrier common wavelocking; digitally synthesized subcarriers; near-Nyquist pulse shaping; and large-area, positive dispersion fiber.

12:30–14:00 Lunch Break *(on own)*

Room 6E	Room 6F	Room 7	Room 8	Room 9
M2F • Ultra-high Speed Devices—Continued	**M2G • Symposia: 5G Trials: Network Operators' and Vertical Industries' Perspective—Continued**	**M2H • Advanced Signal Processing—Continued**	**M2I • SDM Transmission I—Continued**	**M2J • Advanced Fiber and Wave Guide Sensing—Continued**

M2J.7 • 12:15
Brillouin Optical Time Domain Analysis Incorporating with Backward Rayleigh Light Detection, Haijun He[1], Lianshan Yan[1], Wei Pan[1], Bin Luo[1]; [1]*Southwest Jiaotong Univ., China.* An approach of backscattering Rayleigh light detection has been prosed to compensate the nonlocal effect in BOTDA. A hotspot has been measured accurately at the end of the 39-km sensing fiber. Brillouin frequency shift error of 13MHz induced by 2dBm probe power has been corrected.

12:30–14:00 Lunch Break *(on own)*

Room 1

14:00–15:45
M3A • High Bandwidth Interconnect
Presider: Bert Offrein; IBM Research GmbH, Switzerland

M3A.1 • 14:00 Invited
Optical PAM4 Signaling and System Performance for DCI Applications, Reza Motaghian[1]; [1]*Amazon, USA*. Three different PAM4-based transmission systems are demonstrated for enhancing the receiver sensitivity, increasing the capacity, and extending the reach over SMF/MMF. The measured BERs are presented as a function of OMA for system performance comparison.

M3A.2 • 14:30
Using a Hybrid Si/III-V Semiconductor Laser to Carry 16- and 64-QAM Data Signals over an 80-km Distance, Kaiheng Zou[1], Zhewei Zhang[2],Peicheng Liao[1], Huolei Wang[2], Yinwen Cao[1], Ahmed Almaiman[1], Ahmad Fallahpour[1], Naresh Satyan[3], George Rakuljic[3], Moshe Tur[4], Amnon Yariv[2,5], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Department of Applied Physics and Materials Science, California Inst. of Technology, USA;* [3]*Telaris Inc., USA;* [4]*School of Electrical Engineering, Tel Aviv Univ., Israel;* [5]*Department of Electrical Engineering, California Inst. of Technology, USA*. We have demonstrated the use of a hybrid Si/III-V semiconductor laser to carry 20-Gbaud 16- and 64-QAM data signals over an 80-km fiber. The high coherence of the laser enables below FEC threshold performance after transmission.

M3A.3 • 14:45
50-Gbps Receiver Subsystem Using Ge/Si Avalanche Photodiode and Integrated Bypass Capacitor, Sungbong Park[1], Yann Malinge[1], Olufemi Dosunmu[1], Gregory Lovell[1], Seth Slavin[1], Kelly Magruder[1], Yimin Kang[2], Ansheng Liu[1]; [1]*Intel Corporation, USA;* [2]*Consultant, USA*. A 50-Gbps receiver subsystem consisting of a Ge/Si avalanche photodiode and integrated metal-insulator-metal capacitor is presented which demonstrates 32 GHz receiver bandwidth, -16 dBm OMA sensitivity at BER of 2E-4, and 8 dBm optical overload.

Room 2

14:00–16:00
M3B • Optical Switching Technology
Presider: Richard Jensen; Polatis Inc., USA

M3B.1 • 14:00 Tutorial
Photonic Switching in Datacenters and Computing Systems, S. J. Ben Yoo[1]; [1]*Univ. of California Davis, USA*. We will discuss technologies, architectures, and control plane/data plane of photonic switching in data centers and computing systems. Scalability, throughput, latency, energy-efficiency, and system-wide impacts on data-systems will also be covered.

S. J. Ben Yoo is a Distinguished Professor at the University of California Davis. His research includes future computing, cognitive networking, and photonic integrated systems. Prior to 1999, he was a Senior Research Scientist at Bellcore and led the MONET testbed experimentation efforts. Prof. Yoo is Fellow of IEEE, OSA, and a recipient of the DARPA Award for Sustained Excellence, the Bellcore CEO Award, and the UC Davis Research Faculty Awards.

Room 3

14:00–16:00
M3C • Fibers for Short Reach
Presider: Bera Palsdottir; OFS Fitel Denmark I/S, Denmark

M3C.1 • 14:00 Invited
Optical Fibers for Short-reach High-density Interconnects, Scott R. Bickham[1]; [1]*Corning Optical Communications, USA*. Data centers are striving to meet the challenge of delivering more bandwidth density. In this paper, we discuss reduced diameter fiber designs that enable smaller cables and higher density interconnects for on-board and co-packaged optics.

M3C.2 • 14:30
Graded-index Standard Single-mode Fiber for VCSEL Transmission around 850 nm, Adrian Juarez[1], Xin Chen[1], Jason Hurley[1], Maria Thiermann[2], Jeff Stone[1], Ming-Jun Li[1]; [1]*Corning Research & Development Corp, USA;* [2]*Corning Optical Communications GmbH & Co. KG, Germany*. Graded-index standard single-mode fiber offers few-mode operation around 850 nm with better modal bandwidth over step-index fiber. We investigated feasibility of VCSEL transmission through link model analysis and demonstrated 100 m VCSEL transmission at 25Gb/s.

M3C.3 • 14:45
Characterization of 30 μm Core Diameter Multimode Fiber for 200 Gb/s PM-16QAM Transmission at 1550 nm, John D. Downie[1], Xiaojun Liang[1], Jason Hurley[1], Xin Chen[1], Ming-Jun Li[1]; [1]*Corning Research & Development Corp, USA*. We measure MPI and 1550 nm transmission of 200 Gb/s signals over long span and link lengths using 30 μm core diameter multimode fiber (MMF). MPI is reduced and reach increased compared to OM4 MMF.

Room 6C

14:00–16:00
M3D • Symposia: Future Photonics Devices and Materials for Optical Communications 3

M3D.1 • 14:00 Invited
Quantum Si Ph, Dirk Englund[1]; [1]*MIT, USA*. Quantum Si Ph

M3D.2 • 14:30 Invited
Integrated LiNbO3 Photonics and Applications, Marko Loncar[1]; [1]*Harvard Univ., USA*. I will present our integrated LiNbO3 nanophotonics platform, featuring sub-wavelength scale light confinement and dense integration of optical and electrical components. Examples include integrated LN electro-optic modulators that can be driven directly by a CMOS circuitry, and electro-optic and Kerr frequency combs.

Room 6D

14:00–16:00
M3E • Quantum/Nonlinear Optical Processing
Presider: Lu Li; SubCom, USA

M3E.1 • 14:00 Invited
Nonlinear Fourier Transform for Nonlinear Fibre Channels, Sergei K. Turitsyn[1]; [1]*Aston Univ., UK*. The nonlinear Fourier transform is a transmission and signal processing technique that takes into account inherent nonlinear properties of fibre-optic channels. I will discuss its potential applications in the general context of nonlinear communication theory.

M3E.2 • 14:30
Giant Enhancement in Signal Contrast Using Integrated All-optical Nonlinear Thresholder, Chaoran Huang[1], Thomas Ferreira de Lima[1], Aashu Jha[1], Siamak Abbaslou[1], Bhavin Shastri[1,2], Paul Prucnal[1]; [1]*Princeton Univ., USA;* [2]*Queen's Univ., Canada*. We experimentally demonstrate, for the first time, an all-optical nonlinear thresholder on a silicon photonic integrated circuit. This thresholder enhances signal amplitude contrast 40-fold and improves receiver sensitivity by 10 dB.

M3E.3 • 14:45
Wideband Complexity-enhanced Chaos Generation with Electro-optic Phase Modulation and Dual Optical Feedback, Anke Zhao[1], Ning Jiang[1], Chenpeng Xue[1], Shiqin Liu[1], Kun Qiu[1]; [1]*Univ of Electronic Science & Tech China, China*. We numerically and experimentally demonstrated the generation flat-spectrum wideband chaos with efficient bandwidth of several tens of GHz and perfect time delay signature suppression using external-cavity semiconductor laser subject self-phase modulation and dual optical feedback.

Room 6E

14:00–15:30
M3F • Data Center Operation
Presider: Yawei Yin; Alibaba Group, USA

M3F.1 • 14:00 Invited
Data Models for Optical Devices in Data Center Operator Networks, Eric Breverman[1], Vijay Vusirikala[1], Nancy El-sakkary[1], Anees Shaikh[1], Tad Hofmeister[1]; [1]*Google, USA.* Standardized, vendor agnostic data models deliver major operational benefits. OpenConfig has been implemented on multiple platforms and is an ideal data model to take advantage of these benefits. This document provides an overview.

M3F.2 • 14:30 Invited
Top Down Approach in Controlling and Managing Optical DC Networks, Jamie Gaudette[1]; [1]*Microsoft Corp, USA.* Top Down Approach in Controlling and Managing Optical DC Networks

Room 6F

14:00–16:00
M3G • Symposia: 5G Trials: Public Sector Initiatives
Presider: To be determined

M3G.1 • 14:00 Invited
Test Bed and Trials for 5G Content Delivery in England, Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK.*

M3G.2 • 14:30 Invited
5G Rural Trials in Scotland, Harald Haas[1], Stefan Videv[1], Sovan Das[1], John Fakidis[1], Hamish Stewart[1]; [1]*School of Engineering, Univ. of Edinburgh, UK.* We introduce new optical wireless backhaul technology using solar cells as data receivers. We argue that this new technology can be reliable and low-cost. We introduce a real-world pilot use case within the UK 5G project 'RuralFirst'.

Room 7

14:00–16:00
M3H • Coherent Systems for Data Centers
Presider: Fotini Karinou; Microsoft Research Ltd, UK

M3H.1 • 14:00 Tutorial
Data Center Interconnect Systems with Coherent Detection, Radhakrishnan Nagarajan[1]; [1]*Inphi Corporation, USA.* In this tutorial we will discuss the characteristics of between-datacenter optical interconnects, with distances of the order of 100km, and the cost-effective strategies to implement these very high speed optical links.

Radhakrishnan Nagarajan is Inphi's Chief Technology Officer (Optical). Prior to Inphi, he was with Infinera, as a Fellow, working on the development of large-scale photonic integrated circuits.

Dr. Nagarajan is a Fellow of the IEEE, OSA and IET. In 2006, he shared the IEEE/LEOS Aron Kressel Award for his work on commercializing large-scale photonic integrated circuits. He has been awarded 147 US patents, and authored/coauthored over 185 technical papers and five book chapters. He received his B.Eng. from the National University of Singapore, his M.Eng. from the University of Tokyo, and Ph.D. from UC, Santa Barbara, all in Electrical Engineering.

Room 8

14:00–15:45
M3I • FSO Underwater Communications
Presider: Hyun-Do Jung; Electronics and Telecom Research Inst., Korea

M3I.1 • 14:00 Invited
Visible Diode Lasers for High Bitrate Underwater Wireless Optical Communications, Boon S. Ooi[1], Xiaobin Sun[1], Omar Alkhazragi[1], Yujian Guo[1], Tien Khee Ng[1], Mohamed-Slim Alouini[1]; [1]*King Abdullah Univ of Sci & Technology, Saudi Arabia.* This talk provides an overview of the latest underwater wireless optical communication (UWOC) research from the system to the device level. Besides, studies investigating underwater channel characterization are also described.

M3I.2 • 14:30
Leveraging LED Technology in Consumer Electronics Towards Gb/s Indoor Visible Light Communication, Bernhard Schrenk[1], David Löschenbrand[1], Hannes Hübel[1], Thomas Zemen[1]; [1]*AIT Austrian Inst. of Technology, Austria.* SMD-LEDs intended for illumination can support modulation efficiencies of 5.98 bits/symbol and data rates of 350 Mb/s as indoor VLC receivers in combination with laser-sourced pencil beams. Gb/s operation is feasible through R/G/B channel bonding.

M3I.3 • 14:45
40-Gbit/s Visible Light Communication Using Polarization-multiplexed R/G/B Laser Diodes with 2-m Free-space Transmission, L. Y. Wei[1], Chin-Wei Hsu[1], Chi Wai Chow[1], Chien-Hung Yeh[2]; [1]*National Chiao Tung Univ., Taiwan;* [2]*Feng Chia Univ., Taiwan.* We demonstrate a recorded 40.665-Gbit/s visible-light-communication (VLC) system using polarization multiplexed red/green/blue (R/G/B) laser-diodes (LDs) with 2-m free-space transmission. Bit-and-power-loading orthogonal-frequency-division-multiplexed (OFDM) signal is employed.

Room 9

14:00–16:00
M3J • Deployable Technology for Future Networks
Presider: Patrick Iannone; Nokia Bell Labs, USA

M3J.1 • 14:00 Invited
Nonlinear Mitigation Enabling Next Generation High Speed Optical Transport beyond 100G, Kim Roberts[1], Maurice O'Sullivan[1], Michael Reimer[1], Michael Hubbard[1]; [1]*Ciena Corporation, Canada.* We consider methods for containment of the effects of optical nonlinearities in coherent optical transmission. These are distinguished according to their practicality and effectiveness.

M3J.2 • 14:30 Invited
Closer to Shannon, Christian Rasmussen[1]; [1]*Acacia Communications Inc., USA.* Despite the sophistication of existing optical transport solutions, substantial additional capacity and reach gains can be achieved through improvements in the areas of implementation penalty, nonlinear propagation, forward error correction, and modulation.

Room 1

M3A • High Bandwidth Interconnect—Continued

M3A.4 • 15:00 Invited

Tb/s-Class Optical Engines Utilizing InP Coherent Receiver and Transceiver Photonic Integrated Circuits, Gloria Hoefler[1], Ryan Going[1], S Wolf[1], C Berry[1], P Studenkov[1], M Lu[1], V Lal[1], P Evans[1], H Tsai[1], S Corzine[1], J Zhang[1], B Behnia[1], J Tang[1], T Vallaitis[1], J Osenbach[1], M Kuntz[1], A Hosseini[1], T Frost[1], L Chuang[1], M Montazeri[1], H Mousavi[1], S Porto[1], S Buggaveeti[1], X Xu[1], Jeffrey Rahn[1], T Butrie[1], A Karanicolas[1], M Ziari[1], David Welch[1], Fred A. Kish[1]; [1]*Infinera Corporation, USA.* We report on the development of state of the art optical engines based upon multi-channel C&L Band tunable InP PICs operating up to 1 Tb/s per wave and with aggregate PIC capacities of 4.9 Tb/s

M3A.5 • 15:30

Monolithically-integrated 50Gbps 2pJ/bit Photoreceiver with Cherry-hooper TIA in 250nm BiCMOS Technology, Hector Andrade[1], Takako Hirokawa[1], Aaron Maharry[1], Alexander Rylyakov[2], Clint Schow[1], James F. Buckwalter[1]; [1]*Univ. of California Santa Barbara, USA;* [2]*Elenion Technologies, USA.* We report a monolithically-integrated photoreceiver with a pseudo-differential Cherry-Hooper transimpedance amplifier (TIA) in a 250 nm BiCMOS process. High sensitivity 50 Gbps operation in demonstrated, and the TIA architecture is analyzed.

Room 2

M3B • Optical Switching Technology—Continued

M3B.2 • 15:00 Invited

Low-loss, Low-crosstalk Large-scale Silicon Photonics Switch, Keijiro Suzuki[1], Ryotaro Konoike[1], Satoshi Suda[1], Hiroyuki Matsuura[1], Shu Namiki[1], Hitoshi Kawashima[1], Kazuhiro Ikeda[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan.* We review research progress on the strictly-non-blocking optical switches based on the silicon photonics. The current switching performances including loss, crosstalk, bandwidth, and polarization insensitivity are summarized and their future prospects are discussed.

M3B.3 • 15:30

High-efficient Black-box Calibration of Large-scale Silicon Photonics Switches by Bacterial Foraging Algorithm, Guangwei Cong[1], Noritsugu Yamamoto[1], Takashi Inoue[1], Makoto Okano[1], Yuriko Maegami[1], Morifumi Ohno[1], Koji Yamada[1]; [1]*AIST (Natl Inst of Adv Indust Sci&Tech), Japan.* Black-box calibration algorithm is highly required for various large-scale silicon photonics devices. We demonstrated bacterial-foraging algorithm to calibrate random phase errors in 32×32 matrix switch by simulating switch as black-box, which promised ≦2min calibration time.

Room 3

M3C • Fibers for Short Reach—Continued

M3C.4 • 15:00

Wide Band Multimode Fiber with a 30 μm-Core and Fluorine-doped Cladding to Support Error-free 4×25 Gb/s SWDM Transmission over 250 Meters, Yinping Liu[1], Lin Ma[1], Wufeng Xiao[2], Runhan Wang[2], Zuyuan He[1,2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, China.* We propose multimode fiber with a 30 μm-core and fluorine-doped cladding to achieve large bandwidth covering 850-940 nm. In experiment, Error-free 4×25 Gb/s SWDM transmission using commercial transceiver is demonstrated over 250 meter-long fiber.

M3C.5 • 15:15

Modal Chromatic Dispersion Compensating Fiber Channels Using 100G Multimode Optical Transceivers, Asher S. Novick[1], Jose M. Castro[1], Rick J. Pimpinella[1], Bulent Kose[1], Paul Huang[1], Fei Jia[1], Brett Lane[1]; [1]*Panduit, USA.* Using 100G multimode transceivers, we measure bit error rate over 300 m of dispersion and non-dispersion compensating multimode fiber channels. For both 100GBASE-SR4 and 100GSWDM4 transceivers, all lanes showed performance advantages on dispersion compensating fiber.

M3C.6 • 15:30 Top Scored

Ultralow Loss Hollow-core Conjoined-tube Negative-curvature Fiber for Data Transmission, Xiao-cong Wang[1,2], Dawei Ge[3], Wei Ding[1], Ying-ying Wang[2], Shou-fei Gao[2], Xin Zhang[2], Yi-zhi Sun[1], Ying-chao Xin[3], Juhao Li[3], Zhangyuan Chen[3], Pu Wang[2]; [1]*CAS Inst. of Physics, China;* [2]*Inst. of Laser Engineering, Beijing Univ. of Technology, China;* [3]*State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking Univ., China.* We present a hollow-core conjoined-tube negative-curvature fiber with unique merits of ultralow loss of 2 dB/km at telecom band and launch-insensitive response to the data transmission in 10-Gb/s OOK test.

Room 6C

M3D • Symposia: Future Photonics Devices and Materials for Optical Communications 3—Continued

M3D.3 • 15:00 Invited

Graphene Photonics for Optical Communications, Marco Romagnoli[1]; [1]*Photonic Networks and Technologies Lab, CNIT, Italy.* Graphene is a post-processed single platform compliant with silicon photonics or other platforms based on passive waveguides. Results on high speed optical modulators on both SOI and SiN and large bandwidth detectors will be shown.

M3D.4 • 15:30 Invited

Long-term Stable Electro-optic Polymers for Hybrid Integration, Shiyoshi Yokoyama[1], Guo-Wei Lu[1], Xiaoyang Cheng[1], Feng Qiu[1]; [1]*Kyushu Univ., Japan.* The high-temperature-resistant electro-optic polymer is used to demonstrate 100 Gbit/s OOK and 112 Gbit/s PAM4 modulations. The polymer is performed on the silicon Mach-Zehnder interferometer toward possible hybrid silicon and polymer photonic platform.

Room 6D

M3E • Quantum/Nonlinear Optical Processing—Continued

M3E.4 • 15:00 Tutorial

Subsystem Requirements for Photonic Integrated Quantum Information Processing, Saikat Guha[1]; [1]*Univ. of Arizona, USA.*

Room 6E

M3F • Data Center Operation—Continued

M3F.3 • 15:00
Flexible Resource Allocation Using Photonic Switched Interconnects for Disaggregated System Architectures, Ziyi Zhu[1], Yiwen Shen[1], Yishen Huang[1], Alexander Gazman[1], Maarten Hattink[1], Keren Bergman[1]; *[1]Columbia Univ., USA.* We present an optically connected disaggregated system architecture that supports dynamic resource allocation, leveraging the optical spatial switching capability of silicon photonic microring-based interconnects and demonstrate compute nodes on-request access to remote memory and PCIe-based resources.

M3F.4 • 15:15
Experimental Assessment of SDN-enabled Reconfigurable OPSquare Data Center Networks with QoS Guarantees, Xuwei Xue[1], Fu Wang[1], Fernando Agraz[2], Albert Pagès[2], Bitao Pan[1], Fulong Yan[1], Salvatore Spadaro[2], Nicola Calabretta[1]; *[1]TU/e, Netherlands; [2]Universitat Politècnica de Catalunya, Spain.* An SDN-controlled DCN enabling QoS-driven network-slice reconfiguration and packet priority updating is experimentally assessed. Network-slice can be reconfigured within 150 ms to decrease packet loss. The measured ToR-to-ToR latency of high-priority packets is 260.55 ns.

Room 6F

M3G • Symposia: 5G Trials: Public Sector Initiatives—Continued

M3G.3 • 15:00 Invited
COSMOS: Optical Architecture and Prototyping, Jiakai Yu[1], Tingjun Chen[2], Craig Gutterman[2], Shengxiang Zhu[1], Gil Zussman[2], Ivan Seskar[3], Daniel C. Kilper[1]; *[1]Univ. of Arizona, USA; [2]Columbia Univ., USA; [3]Rutgers Univ., USA.* The COSMOS testbed provides an open-access and programmable multi-layer beyond 5G wireless platform built on an advanced optical x-haul network supporting mobile edge cloud base band processing and applications.

M3G.4 • 15:30 Invited
5G Research and Testbeds in Brazil, Moises Ribeiro[1]; *[1]Universidade Federal do Espírito Santo, Brazil.* A conjunctural analysis for 5G challenges and opportunities in Brazil is presented. The EU-Brazil initiatives to provide testbeds in the 5G ecosystem is discussed focusing on an Industry 4.0 wireless cloud-robotics showcase from FUTEBOL project.

Room 7

M3H • Coherent Systems for Data Centersv

M3H.2 • 15:00
A Low-complexity Adaptive Equalizer for Digital Coherent Short-reach Optical Transmission Systems, Jingchi Cheng[1], Chongjin Xie[3], Ming Tang[2], Songnian Fu[2]; *[1]Alibaba Group, China; [2]Huazhong Univ. of Sci. & Tech., China; [3]Alibaba Group, USA.* We propose a novel adaptive equalization algorithm for short-reach digital coherent systems targeting intra-datacenter applications. Its performance is similar to conventional method, while the number of real multipliers is reduced by ~65%.

M3H.3 • 15:15
Single Carrier vs. OFDM for Coherent 600Gb/s Data Centre Interconnects with Nonlinear Equalization, Christian Blümm[1], Maximilian Schaedler[1], Maxim Kuschnerov[1], Fabio Pittala[1], Changsong Xie[1]; *[1]Huawei, Germany.* Single lambda coherent 600Gb/s solutions based on single carrier modulation or OFDM with and without bit and power loading are experimentally assessed. Volterra nonlinear equalization architectures are optimized for the most performant schemes.

M3H.4 • 15:30 Invited
400G and Beyond: Coherent Evolution to High-capacity Inter Data Center Links, Eric S. Maniloff[1], Sebastien Gareau[1], Michael Moyer[1]; *[1]Ciena Corporation, Canada.* Coherent data transmission applications to the data center interconnect space are presented. We discuss methods of increasing the data rate beyond 400Gb/s, and the improvements in signal-to-noise ratio requirements when Ethernet optimized transport is used.

Room 8

M3I • FSO Underwater Communications—Continued

M3I.4 • 15:00
Experimental Demonstration of an Underwater Wireless Optical Link Employing Orbital Angular Momentum (OAM) Modes with Fast Auto-alignment System, Chengkun Cai[1], Yifan Zhao[1], Jieying Zhang[1], Lulu Wang[1], Jian Wang[1]; *[1]Wuhan National Laboratory for Optoelectr, China.* We experimentally demonstrate an underwater optical wireless link employing orbital angular momentum (OAM) modes with fast auto-alignment system to overcome signal fluctuations. The results show that the fast auto-alignment system succeeds to provide stable outputs.

M3I.5 • 15:15
Net Data Rate of 14.6 Gbit/sUnderwater VLC Utilizing Silicon Substrate Common-anode Five Primary Colors LED, Jianyang Shi[1], Xin Zhu[2], Fumin Wang[1], Peng Zou[1], Yingjung Zhou[1], Junlin Liu[2], Fengyi Jiang[2], Nan Chi[1]; *[1]Fudan Univ., China; [2]Nanchang Univ., China.* We demonstrate a net data rate of 14.6 Gbit/s DFT-S OFDM over 1.2m of UVLC. A self-designed Silicon substrate five primary colors LED is employed to improve system performance. To the best of our knowledge, this is the first time that 14Gb/s signal transmission is experimentally achieved with LED in the underwater optical wireless communication.

M3I.6 • 15:30
High-bandwidth Low-cost High-speed Optical Fiber Links Using Organic Light Emitting Diodes, Priyanka de Souza[1], Nikos Bamiedakis[1], Kou Yoshida[2], Pavlos Manousiadis[2], Graham A. Turnbull[2], Ifor D. Samuel[2], Richard V. Penty[1], Ian H. White[1]; *[1]Univ. of Cambridge, UK; [2]Univ. of St. Andrews, UK.* Record-high 200 Mbps transmission using an OLED with a 31 MHz 3 dB bandwidth using a 3-tap feedforward equaliser is achieved, demonstrating the potential of such devices for use in low-cost polymer optical fiber links.

Room 9

M3J • Deployable Technology for Future Networks—Continued

M3J.3 • 15:00 Invited
Next Generation Silicon Photonic Interconnect Solutions, Marc Bohn[1], Peter Magill[1], Michael Hochberg[1], Dominick Scordo[1], Ari Novack[1], Matt Streshinsky[1]; *[1]Elenion Technologies, USA.* Silicon Photonics is expected to be the technology platform to address next-generation optical interconnect solutions. By leveraging existing semiconductor production infrastructure and processes as well as building complex optical system-on-chip solutions, SiPh enables opportunities for a wide range of new applications.

M3J.4 • 15:30
Field Test of Installed High-density Optical Fiber Cable with Multi-core Fibers toward Practical Deployment, Takehiro Tsuritani[1], Daiki Soma[1], Yuta Wakayama[2], Yuichi Miyagawa[2], Mikoto Takahashi[2], Itsuro Morita[1], Koichi Maeda[3], Kohei Kawasaki[3], Toshikazu Matsuura[3], Masayoshi Tsukamoto[3], Ryuichi Sugizaki[3]; *[1]KDDI Research, Inc., Japan; [2]KDDI Cooperation, Japan; [3]Furukawa Electric, Japan.* A field trial of high-density 0.92-km 200-fiber cable with 5-core fibers (5CFs) was conducted for reliability tests. No degradation of cable attenuation of 5CFs was observed even after installation into underground conduits and aerial area.

Room 1	Room 2	Room 3	Room 6C	Room 6D
M3A • High Bandwidth Interconnect—Continued	**M3B • Optical Switching Technology—Continued**	**M3C • Fibers for Short Reach—Continued**	**M3D • Symposia: Future Photonics Devices and Materials for Optical Communications 3—Continued**	**M3E • Quantum/Nonlinear Optical Processing—Continued**

M3B.4 • 15:45
Silicon Photonic Wavelength and Mode Selective Switch for WDM-MDM Networks, Liangshun Han[1], Bill P. Kuo[1], Nikola Alic[1], Stojan Radic[1]; [1]*Univ. of California San Diego, USA.* A novel wavelength and mode selective switch for wavelength-division multiplexing and mode-division multiplexing networks was proposed and demonstrated on a silicon wafer. The fabricated chip integrated 20 thermo-optic elements, with a footprint of 2.3×1.4 mm^2.

M3C.7 • 15:45 Top Scored
Polarization Effects on Thermally Stable Latency in Hollow-core Photonic Bandgap Fibres, Eric Rodrigue Numkam Fokoua[1], Wenwu Zhu[1,2], Yong Chen[1], Seyed Reza Sandoghchi[1], Thomas D. Bradley[1], Marco N. Petrovich[1], David J. Richardson[1], Francesco Poletti[1], Radan Slavik[1]; [1]*Univ. of Southampton, UK;* [2]*School of Optoelectronic Engineering and Instrumentation Science, Dalian Univ. of Technology, China.* Hollow-Core fibers were recently demonstrated to have propagation time through them completely insensitive to changes in temperature. Here, we consider polarization dependent behaviour of these fibers and show how it can alter the fibre design.

16:00–16:30 Coffee Break, *Upper Level Corridors*

NOTES

Room 6E	Room 6F	Room 7	Room 8	Room 9
M3F • Data Center Operation—Continued	**M3G • Symposia: 5G Trials: Public Sector Initiatives—Continued**	**M3H • Coherent Systems for Data Centersv**	**M3I • FSO Underwater Communications—Continued**	**M3J • Deployable Technology for Future Networks—Continued**

M3J.5 • 15:45
Accurate Fault Location Based on Deep Neural Evolution Network in Optical Networks for 5G and beyond, Xudong Zhao[1], Hui Yang[1], Huifeng Guo[2], Tao Peng[2], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecom., China;* [2]*ZTE, China.* This paper presents an accurate fault location method based on deep neural evolution network in optical networks. Experiments indicate that the proposed method improves the accuracy of fault location when confronted with large-scale alarm sets.

16:00–16:30 Coffee Break, *Upper Level Corridors*

NOTES

Room 6A

14:00–16:30
M3Z • OFC Demo Zone

M3Z.1
Demonstration of Advanced Open WDM Operations and Analytics, Based on an Application-extensible, Declarative, Data Model Abstracted Instrumentation Platform, Abhinava Sadasivarao[1], Sharfuddin Syed[1], Biao Lu[1], Sachin Jain[4], Ashok Kunjidhapatham[4], Paulo Gomes[5], Radhakrishna Valiveti[1], Loukas Paraschis[1], Jag Brar[3], Kannan Raj[2]; [1]*Infinera Corporation, USA;* [2]*Oracle Cloud Infrastructure, USA;* [3]*Oracle Cloud Infrastructure, USA;* [4]*Infinera India Private Limited, India;* [5]*Infinera Corporation, Portugal.* We demonstrate a novel application-flexible data-model-abstracted and declarative software instrumentation platform that advances open-WDM multivendor operations and analytics. We validate its functional extensibility by implementing software-agent-based service provisioning and monitoring, and leveraging multiple open-source technologies.

M3Z.2
Demonstration of Continuous Improvement in Open Optical Network Design by QoT Prediction Using Machine Learning, Martin Bouda[1], Shoichiro Oda[2], Yuichi Akiyama[2], Denis Paunovic[3], Takeshi Hoshida[2], Paparao Palacharla[1], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America Inc., USA;* [2]*Fujitsu Laboratories Ltd., Japan;* [3]*Fujitsu Network Communications, Inc., USA.* We demonstrate for the first time an interactive process with QoT prediction learning design server for multi-vendor optical networks using vendor-neutral optical model parameter learning from real BER measurements, enabling continuous improvement in network efficiency.

M3Z.3
Standardized Northbound Interface Testing Automation on the Open and Disaggregated Optical Transport Equipment, Yawei Yin[1], Tao Wang[2], Liang Dou[2], Shuai Zhang[2], Ming Xia[1], Chongjin Xie[1]; [1]*Alibaba Group, USA;* [2]*Alibaba (China) Co., Ltd., China.* The proposed demonstration will showcase a live testing of the northbound API on optical DCI equipment which is compliant with the NETCONF network configuration protocol and OpenConfig YANG data models

M3Z.4
ODTN: Open Disaggregated Transport Network. Discovery and Control of a Disaggregated Optical Network through Open Source Software and Open APIs., Andrea Campanella[1], Hiroki Hokui[2], Arturo Mayoral[7], Dai Kashiwa[2], Oscar González de Dios[9], Dominique Verchere[3], Quan Pham Van[3], Alessio Giorgetti[4,5], Ramon Casellas[8], Roberto Morro[10], Lyndon Ong[6]; [1]*Open Networking Foundation, Italy;* [2]*NTT Telecommunications, Japan;* [3]*Nokia Bell Labs, France;* [4]*Scuola Superiore Sant'Anna, Italy;* [5]*CNIT, Italy;* [6]*Ciena, USA;* [7]*Universitat Politécnica de Catalunya, Spain;* [8]*CTTC/CERCA, Spain;* [9]*Telefonica, Spain;* [10]*TIM, Italy.* ONOS discovers and manages a topology made of Transponders and dedicated OLS, using standard protocols (NETCONF/RESTCONF) and models (OpenConfig/TAPI). The demo is a joint collaboration, towards production deployment, between 3 operators and 2 equipment vendors.

M3Z.5
Demonstration of Container-based Microservices SDN Control platform for Open Optical Networks, Quan Pham Van[2], Quang-Huy Tran[1], Dominique Verchere[2], Patricia Layec[2], Trung Thieu-Huu[2], Djamal Zeghlache[1]; [1]*RS2M, Telecom-sudparis, France;* [2]*NOKIA Bell Labs, France.* We demonstrate a microservices SDN control platform that provides network control plane as a service with the capabilities to instantiate, upgrade, automated and on-demand deployment of the control components such as the controller and its applications.

M3Z.6
P4 In-band Telemetry (INT) for Latency-aware VNF in Metro Networks, Filippo Cugini[1], Paul Gunning[2], Francesco Paolucci[3], Piero Castoldi[3], Andrew Lord[2]; [1]*CNIT, Italy;* [2]*British Telecom Laboratories, UK;* [3]*Scuola Superiore Sant'Anna, Italy.* A first demonstration of P4-based virtual network function (VNF) for latency-critical services is presented. The VNF exploits P4 In-band telemetry to dynamically enforce per-packet QoS priority according to cumulated latency performance.

M3Z.7
Autonomic NFV Network Services on Top of Disaggregated Optical Metro Networks, Pau R. Esmerats[1], Ramon Casellas[2], Lluis Gifre[3], Alba P. Vela[1], Marc Ruiz[1], Ricardo Martinez[2], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Spain;* [3]*Universidad Autónoma de Madrid (UAM), Spain.* Control and orchestration of metro network to support dynamic provisioning and reconfiguration of services based on Virtual Network Functions are demonstrated through a CDN example. Interaction among CASTOR MDA, OSM, and ONOS is exhibited.

M3Z.8
Experimental Demonstration of a 5G Network Slice Deployment Exploiting Edge or Cloud Data-centers, Andrea Sgambelluri[1], Marco Capitani[2], Silvia Fichera[1], Koteswararao Kondepu[1], Alessio Giorgetti[1], Francesco Giannone[1], Barbara Martini[3,1], Fabio Ubaldi[4], Paola Iovanna[4], Giada Landi[2], Luca Valcarenghi[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy;* [2]*Nextworks, Italy;* [3]*CNIT, Italy;* [4]*Ericsson Telecomunicazioni, Italy.* The demo shows the 5G-TRANSFORMER architecture capability to deploy 5G network slices exploiting edge or cloud data-centers in minutes. Different slice deployments are shown to affect the performance of a dictionary mobile-app supported by them.

M3Z.9
Open Optical Network Planning Demonstration, Jean-Luc Auge[2], Gert Grammel[3], Vittorio Curri[1], Esther Le Rouzic[2], Gabriele Galimberti[4], James Powell[5]; [1]*Polito, Italy;* [2]*Orange Labs, France;* [3]*Juniper, Germany;* [4]*Cisco, Italy;* [5]*Telecom Infra Project, USA.* Planning optical networks in a multi-vendor environment calls for open and vendor agnostic simulation tools to compare different scenarios in "what-if?" analysis and determine the best performing solution. The PSE-Group in the Telecom Infra Project aims to facilitate network planning based on GN-model and parametrized engineering.

M3Z.10
Zero-touch Provisioning of Distributed Video Analytics in a Software-defined Metro-haul Network with P4 Processing, Bogdan Andrus[1], Silviu A. Sasu[1], Thomas Szyrkowiec[1], Achim Autenrieth[1], Mohit Chamania[1], Johannes Fischer[2], Stephan Rasp[3]; [1]*ADVA Optical Networking SE, Germany;* [2]*Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany;* [3]*SeeTec AG, Germany.* We demonstrate automated network service provisioning and virtual network function orchestration with P4-based VNF acceleration. Zero-touch provisioning of distributed computing resources at the edge and central office is validated with a video analytics use case

M3Z.11
Open Device Model Comparison and Support for OpenConfig and OpenROADM, Calvin Wan[1], Catherine Yuan[1], Yanbing Li[1], Qiong Zhang[2], Kirsten Rundberget[1]; [1]*FNC, USA;* [2]*FLA, USA.* A challenge facing vendors and service providers is the ability to support a growing number of device models with minimum cost and fast time to market. We demonstrate a software solution embracing diverse device models.

M3Z.12
Biological Attractor Selection and SDN Control Interworking in the Virtual Packet Optical Node Network Control, Chiaki Hara[1], Kodai Yarita[1], Satoru Okamoto[1], Naoaki Yamanaka[1]; [1]*Keio Univ., Japan.* Biological Attractor Selection (BAS) is a promised network control technology to ensure environmental fluctuation. This demonstration shows BAS and software defined networking control interworking for controlling the virtual packet optical node network.

M3Z.13
NFDMLab: Simulating Nonlinear Frequency Division Multiplexing in Python, Marius Brehler[2], Christoph Mahnke[3], Shrinivas Chimmalgi[1], Sander Wahls[1]; [1]*TU Delft, Netherlands;* [2]*TU Dortmund, Germany;* [3]*n/a, Germany.* Fiber-optic transmission based on nonlinear frequency division multiplexing (NFDM) has received much attention in recent years. We introduce NFDMLab, an open source software package for simulating NFDM transmissions written in the Python language.

M3Z.14
Dynamic Virtual Network Function Placement over a Software-defined Optical Network, Sebastian Troia[1], Alessio Giorgetti[2], Andrea Sgambelluri[2], Guido Maier[1]; [1]*Politecnico di Milano, Italy;* [2]*Scuola Superiore Sant'Anna/CNIT, Italy.* We demonstrate how to dynamically place Virtual Network Functions over a software defined optical network integrating IT computing and real IP over WDM resources, thus allowing exchange of real traffic.

M3Z.15
Failure Disposal by Interaction of the Cross-layer Artificial Intelligence on ONOS-based SDON Platform, Bing Zhang[1], Yongli Zhao[1]; [1]*Beijing Univ. of Posts and Telecomm, China.* We propose a new architecture introducing AI to span the control layer and the data layer in SDON. This demonstration shows the cooperation of the AI engines in two layers in dealing with failure disposal.

M3Z.16
The Net2Plan-OpenStack Project: IT Resource Manager for Metropolitan SDN/NFV Ecosystems, Miquel Garrich Alabarce[1], Manuel Hernández-Bastida[1], César San-Nicolás-Martínez[1], Francisco Javier Moreno-Muro[1], Pablo Pavon-Marino[1,2]; [1]*Universidad Politécnica de Cartagena, Spain;* [2]*E-lighthouse Networks Solutions, Spain.* We demonstrate an open-source Net2Plan extension interfacing multiple OpenStack instances for enabling multi-datacenter IT resource management, with multi-tenant slicing in an ETSI-OSM orchestrated and ONOS-controlled IP over WDM transport network.

16:00–16:30 Coffee Break, *Upper Level Corridors*

NOTES

Room 1

16:30–18:30
M4A • High Speed Modulators
Presider: Kouji Nakahara; Oclaro Japan Inc., Japan

M4A.1 • 16:30 Invited

A Guide for Material and Design Choices for Electro-optic Modulators, Rubab Amin[1], Zhizhen Ma[1], Mohammad Tahersima[1], Rishi Maiti[1], Mario Miscuglio[1], Hamed Dalir[2], Volker J. Sorger[1]; [1]*George Washington Univ., USA;* [2]*Omega Optics Inc., USA.* Here we discuss a) fundamental performance vectors of electro-optic modulators, and b) showcase recent development of heterogeneous-integrated emerging EO materials into Si-photonics to include an ITO-based MZM, a Graphene hybrid-plasmon and the first TMD-MRR modulator.

Room 2

16:30–18:30
M4B • Probabilistic Shaping I
Presider: Alex Alvarado; Eindhoven Univ. of Technology, Netherlands

M4B.1 • 16:30

Rate-adaptive Probabilistic Shaping Enabled by Punctured Polar Codes with Pre-set Frozen Bits, Shajeel Iqbal[1], Metodi P. Yankov[1,2], Søren Forchhammer[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Fingerprint Cards A/S, Denmark.* We propose to pre-set the frozen bits of a rate-adaptive punctured polar-coded system to pseudo-random sequences. The many-to-one probabilistic shaping gains are improved up to 2 dB (~160 km) w.r.t. the standard punctured polar-coded system.

M4B.2 • 16:45

Polar-coded Modulation for Joint Channel Coding and Probabilistic Shaping, Toshiki Matsumine[1,2], Toshiaki Koike-Akino[2], David Millar[2], Keisuke Kojima[2], Kieran Parsons[2]; [1]*Yokohama National Univ., Japan;* [2]*Mitsubishi Electric Research Laboratories, USA.* We propose joint channel coding and constellation shaping based on polar-coded modulation. Proposed shaping method offers more than 0.6 dB gain without the need of external distribution matcher and the increase of decoding complexity.

Room 3

16:30–18:00
M4C • Nonlinear and Polarization Effects in Optical Fibers
Presider: Eric Numkam Fokoua, University of Southampton, UK

M4C.1 • 16:30

Investigation of Optical Phase Characteristics of Stokes and Transmitted Light in Fiber Brillouin Scattering, Shiori Nozawa[1], Shiro Ryu[1]; [1]*Meiji Univ., Japan.* We have experimentally investigated optical phase characteristics of Stokes and transmitted light in fiber Brillouin scattering. We observed abrupt phase changes for the Stokes light and the phase noise increase for the transmitted light.

M4C.2 • 16:45

Spontaneous Raman Scattering Effects in Multicore Fibers: Impact on Coexistence of Quantum and Classical Channels, Rui Lin[1,3], Lin Gan[3], Aleksejs Udalcovs[2], Oskars Ozolins[2,1], Xiaodan Pang[1], Li Shen[3], Ming Tang[3], Sergei Popov[1], Songnian Fu[3], Weijun Tong[5], Deming Liu[3], Thiago F. Silva[4], Guilherme B. Xavier[6], Jiajia Chen[1]; [1]*The Royal Inst. of Technology (KTH), Sweden;* [2]*Networking and Transmission Laboratory, RISE Acreo AB, Sweden;* [3]*School of Optics and Electronic Information, Huazhong University of Science and Technology, China;* [4]*Optical Metrology Division, National Inst. of Metrology, Quality and Technology, Brazil;* [5]*R&D Center, Yangtze Optical Fiber and Cable Joint Stock Limited Company (YOFC), China;* [6]*Institutionen för Systemteknik, Linköpings Universitet, Sweden.* We measure spontaneous Raman scattering (SRS) effects in C-band and observe trench-assisted MCF is robust to SRS noise, making it possible to run quantum channels in the neighboring and/or the same core as data channels.

Room 6C

16:30–19:00
M4D • Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program

M4D.1 • 16:30 Invited

ENLITENED Program Overview, Michael Haney[1]; [1]*ARPA-E, USA.* ENLITENED Program Overview

M4D.2 • 16:45 Invited

Dynamically Switched WDM Source for Energy-proportional Interconnect for Datacenters, Ming Wu[1]; [1]*Univ. of California Berkeley, USA.* Dynamically Switched WDM Source for Energy-proportional Interconnect for Datacenters

Room 6D

16:30–18:30
M4E • Ligo and Lidar
Presider: Nicolas Fontaine; Nokia Bell Labs, USA

M4E.1 • 16:30 Tutorial

The Basics of How the Advanced LIGO Detector Works, Stanley E. Whitcomb[1], Eric Gustafson[1]; [1]*LIGO Laboratory, California Inst. of Technology, USA.* This tutorial will cover the basics physics and engineering of how the Advanced LIGO interferometers work. It will include a discussion of some of the decisions made and will highlight several of the lesser known subsystems.

Stan Whitcomb is Chief Scientist of the LIGO Laboratory, operated by Caltech and MIT through funding from the National Science Foundation. Since joining Caltech in 1980, he has been involved in nearly every aspect of LIGO—concept development, prototype sensitivity demonstration, detector design and installation, commissioning, data analysis, and management.

Room 6E

16:30–18:15
M4F • Advanced Wireless Systems
Presider: Idelfonso Tafur Monroy; Danmarks Tekniske Universitet, Netherlands

M4F.1 • 16:30 Invited
FSO SpaceComm Links and its Integration with Ground 5G Networks, Jose M. Estaran Tolosa[1], Yvan Pointurier[1], Sébastien Bigo[1]; [1]*Nokia Bell Labs France, France*. Space communications and free-space optics are powerful technologies increasingly regarded to enhance, jointly, our networks and digital experiences. We explain why, elaborating on the opportunities and challenges – from application and technical standpoints – in the 5G+ context.

Room 6F

16:30–18:30
M4G • Novel Components for Next Generation PON
Presider: Derek Nesset; Huawei Technologies R&D, Germany

M4G.1 • 16:30 Invited
APDs for Future Optical Access Systems beyond 25G, Mohand Achouche[1], Jean Decobert[1], Nicolas Vaissiere[1], Florence Martin[1], Catherine Fortin[1], Jean-Francois Paret[1], Delphine Lanteri[1], Karim Mekhazni[1], Harry Gariah[1], Christophe Caillaud[1], Fabrice Blache[1]; [1]*III-V Lab, France*. We report a robust Zinc diffused planar junction InGaAs/InAlAs APD with a responsivity of 10A/W at 1550nm with an associated record low dark current of 8nA, a f_{3dB} of 20GHz and a Gain x bandwidth product > 300GHz.

Room 7

16:30–19:00
M4H • Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?

The event is divided in two parts. In the first part, invited speakers will give their views on Network Disaggregation and how it may drive network deployments in the near future, outlining progress in initiatives such as OpenRoadm, Telecom Infra Project, OpenConfig, and ONF. A debate/discussion will follow addressing the objectives and different strategies leading to the design and deployment of more efficient, more cost-effective, greener and more sustainable network infrastructures, thus achieving a more flexible ICT services evolution in the future.

Telecom and network operators are expected to realize big benefits by disaggregating their metro-core network nodes. The adoption of disaggregation in ICT networks implies a radical change of consolidated paradigms in planning, engineering, deploying, operating and troubleshooting the network. Network disaggregation represents a dramatic departure from the current way the hardware and software are designed and built, introducing new and not negligible deployment challenges. Disaggregated networks are expected to define a virtuous multivendor ecosystem where technology and economic advantages are possible, which can only be achieved if hardware and software components are truly interoperable, therefore making it necessary an effective system integration. Thus a new scenario is emerging following current attempts by the Telecom and Network operators to emancipate themselves from the system vendor lock-in. Vertical integration of network equipment, where vendors provide support during the entire lifecycle of their product, seems to be no longer the common requirement in the Network Disaggregation paradigm.

How system integration and all other mentioned issues can be faced in the disaggregation challenge and how the ICT network market will consequently evolve while maintaining interoperability and reliability is part of the current debate and will be part of the main topics during the Open Platform Summit event.

Room 8

16:30–18:00
M4I • Transmission Technologies
Presider: Oleg Sinkin; TE SubCom, USA

M4I.1 • 16:30
A Polarization Change Monitor by Eigenvalue Analysis in Coherent Receiver, Tong Ye[1], Xiaofei Su[1], Ke Zhang[1], Zhenning Tao[1], Guoxiu Huang[2], Hisao Nakashima[2], Takeshi Hoshida[2]; [1]*Fujitsu R&D Center, China;* [2]*Fujitsu Laboratories Ltd., Japan*. A method is proposed to monitor polarization change of optical link. Several-hundred-krad/s polarization change was monitored within errors less than 20 and 50 krad/s in back-to-back and transmission experiments, respectively.

M4I.2 • 16:45
Laser Frequency Jitter Tolerance and Linewidth Requirement for ≥ 64Gbaud DP-16QAM Coherent Systems, Rui Zhang[1], Wen-Jr Jiang[2], Konstantin Kuzmin[2], Reggie Juluri[2], Gee-Kung Chang[1], Winston Way[2]; [1]*Georgia Inst. of Technology, Georgia;* [2]*Neophotonics, USA*. Equalization-enhanced phase noise-dominated optical carrier frequency jitter tolerance and linewidth requirement for ≥ 64Gbaud DP-16QAM dispersion-unmanaged coherent systems have been investigated. The implication to future 100 Gbaud systems is delineated.

Room 9

16:30–18:30
M4J • Spectrum Efficient Networks
Presider: Qiong Zhang; Fujitsu Laboratories of America Inc., USA

M4J.1 • 16:30
Maximizing Optical Network Capacity through SNR-availability Based Provisioning, Inwoong Kim[1], Xi Wang[1], Olga Vassilieva[1], Paparao Palacharla[1], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America, USA*. We present a new SNR-availability based provisioning scheme to maximize capacity while satisfying target service availability in optical networks employing fine tunable modulations such as probabilistically shaped mQAM, and show up to 36% capacity gain.

M4J.2 • 16:45
Deployment Strategies to Enable Cost-effective Flex-grid in Large Scale Metro Applications, Bruno J. Pereira[1], António Eira[1], Julia Larikova[2,3]; [1]*Infinera Portugal, Portugal;* [2]*Infinera USA, USA;* [3]*Northwestern Univ., USA*. High baud rate channels present a significant problem in large scale high degree count metro core networks. We consider deployment strategies specifically optimized for flex-grid to overcome traditional approaches with 6.25GHz granularity.

Room 1

M4A • High Speed Modulators—Continued

M4A.2 • 17:00
Efficient Optical Modulator by Reverse-biased III-V/Si Hybrid MOS Capacitor Based on FK Effect and Carrier Depletion, Qiang Li[1], ChongPei Ho[1,2], Shinichi Takagi[1], Mitsuru Takenaka[1]; *[1]Univ. of Tokyo, Japan; [2]Japan Society for Promotion of Science Fellowship, Japan.* We present efficient optical phase modulation based on Franz-keldysh effect and carrier depletion in reverse-biased III-V/Si hybrid MOS capacitor. The high modulation efficiency and small capacitance enables significant improvement in modulation bandwidth and modulation energy.

M4A.3 • 17:15
56-Gbit/s Operations of Mach-Zehnder Modulators Using 300-μm-long Membrane InGaAsP Phase Shifters and SiN Waveguides on Si, Takuma Aihara[1], Tatsurou Hiraki[1], Takuro Fujii[1], Koji Takeda[1], Tai Tsuchizawa[1], Takaaki Kakitsuka[1], Hiroshi Fukuda[1], Shinji Matsuo[1]; *[1]NTT, Japan.* Mach-Zehnder modulators using 300-μm-long membrane phase shifters and SiN waveguides, in which InGaAsP core is buried with InP, are fabricated on Si. Devices exhibit 56-Gbit/s NRZ signal modulations with clear eye-openings.

Room 2

M4B • Probabilistic Shaping I—Continued

M4B.3 • 17:00 Invited
Partition-based Probabilistic Shaping for Fiber-optic Communication Systems, Tobias Fehenberger[1], David Millar[1], Toshiaki Koike-Akino[1], Keisuke Kojima[1], Kieran Parsons[1]; *[1]Mitsubishi Electric Research Labs, USA.* Various aspects of distribution matchers (DMs) with constant and variable composition are reviewed. LDPC-coded fiber simulations of 64QAM shaped via a multiset-partition DM show significantly increased reach and information rate over a constant-composition DM.

Room 3

M4C • Nonlinear and Polarization Effects in Optical Fibers—Continued

M4C.3 • 17:00 Invited
Highly Nonlinear Fiber for Optical Parametric Amplifier, Shigehiro Takasaka[1]; *[1]Furukawa Electric, Japan.* We review highly nonlinear fibers and techniques for practical parametric amplifiers. Characteristics of fibers for wideband amplification over C-band, quasi-phase-matching technique for flat and 20dB gain, and polarization insensitive configuration avoiding SBS are discussed.

Room 6C

M4D • Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program—Continued

M4D.3 • 17:00 Invited
Toward Optical Networks Using Rapid Amplified Multi-wavelength Photonic Switches, Benjamin G. Lee[1], Nicolas Dupuis[1], Fuad Doany[1], Laurent Schares[1], Nicolas Boyer[2], Nathalie Normand[2], Herschel Ainspan[1], Christian Baks[1], Jonathan Proesel[1], Isabel De Sousa[2], Mounir Meghelli[1], Marc Taubenblatt[1]; *[1]IBM TJ Watson Research Center, USA; [2]IBM Bromont, Canada.* We report on efforts to develop optical and electrically packaged photonic switch modules in monolithically integrated CMOS technology and to interface these modules with an FPGA-based control plane facilitating reconfiguration in tens of nanoseconds.

M4D.4 • 17:15 Invited
LEED: A Lightwave Energy-efficient Datacenter, George Papen[1], Yeshaiahu Fainman[1], Joseph Ford[1], William Mellette[1], Shayan Mookherjea[1], George Porter[1], Alex Snoeren[1], Saman Saeedi[2], John Cunningham[2], Ashok Krishnamoorthy[2], Michael Gehl[3], Christopher DeRose,[3], Paul Davids[3], Douglas Trotter[3], Andrew Starbuck[3], Christina Dallo[3], Dana Hood[3], Andrew Pomerene[3], Anthony Lentine[3]; *[1]Univ. of California San Diego, USA; [2]Axalume Inc., USA; [3]Sandia National Laboratory, USA.* The Lightwave Energy-Efficient Datacenter (LEED) consists of: 1) A novel optically-switched datacenter architecture, 2) a "Rotor" optical switch that reconfigures the network topology in less than 20 microseconds, and 3) Enhanced link margin burst-mode interconnects that can accommodate an optical switch without the need for optical amplification.

Room 6D

M4E • Ligo and Lidar—Continued

Room 6E

M4F • Advanced Wireless Systems—Continued

M4F.2 • 17:00 Top Scored

Daylight Operation of a High-speed Free-space Quantum Key Distribution Using Silica-based Integration Chip and Micro-optics-based Module, Heasin Ko[1], Joong-Seon Choe[1], Byung-Seok Choi[1], Kap-Joong Kim[1], Jong-Hoi Kim[1], Yongsoon Baek[1], Chun Ju Youn[1]; *[1]Electronics and Telecom Research Inst, Korea*. We developed a high-speed quantum key distribution system integrated with a compact self-developed silica-based planar lightwave circuit chip and a micro-optics-based polarization module. Our system can generate average secure keys at the rate of 701.22 kbps over a free-space link of 275 m in daylight by using effective noise filtering systems.

M4F.3 • 17:15

Resilient MMW-RoF Network Enabled by Implementation of Tomlinson-harashima Precoding, Shuyi Shen[1], You-Wei Chen[1], Qi Zhou[1], Shuang Yao[1], Rui Zhang[1], Yahya M. Alfadhli[1], Gee-Kung Chang[1]; *[1]Georgia Inst. of Technology, USA*. Tomlinson-Harashima precoding is proposed to relax the requirements of device bandwidth, linearity, and power consumption for resilient MMW-RoF network. A 16.8-dB BER improvement is experimentally demonstrated by the proposed precoding scheme subjecting to bandlimited operations.

Room 6F

M4G • Novel Components for Next Generation PON—Continued

M4G.2 • 17:00

A Tandem of EMLs as Low-cost OTDR, Bernhard Schrenk[1], Fotini Karinou[2]; *[1]AIT Austrian Inst. of Technology, Austria; [2]Microsoft Research Ltd., UK*. A polarization-immune coherent OTDR is realized through EML technology. Multiple reflections with an ORL of 42.5dB can be resolved in 20ms with <10% error. Using just two EMLs, Fresnel reflections can be acquired within 2ms.

M4G.3 • 17:15

Remote Wavelength Tracking of Strongly Chirped Tunable 10G MEMS-VCSEL for Port-agnostic WDM Fronthaul, Jim (Shihuan) Zou[1], Mohmmed A. Houri[1,2], Hung-Kai Chen[3], Michael Eiselt[1]; *[1]ADVA Optical Networking SE, Germany; [2]Faculty of Physics and Astronomy, Friedrich-Schiller-Universität Jena, Germany; [3]Bandwidth10 Ltd., USA*. We successfully demonstrated the centralized wavelength control in a passive port-agnostic WDM fronthaul system for tracking a remotely tunable MEMS-VCSEL transceiver, which exhibited strong chirp due to the low-frequency pilot tone modulation.

Room 7

M4H • Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?—Continued

Speakers:

Andrea Campanella, *ONF, Italy*
Open Source Software and White Box Hardware Driving Optical Network Disaggregation

Mark Filer, *Microsoft, USA*
The Open and Disaggregated Networks Powering the Microsoft Cloud

Akira Hirano, *NTT, Japan*
White Box as a Next Generation Transport Platform?

Scott Mountford, *AT&T, USA*
Opening up Long Distance Optical Networks: Pros, Cons, and Caveats

Tim Stuch, *Facebook, USA*
Opportunities and Challenges of Disaggregation in Subsea Networks

Room 8

M4I • Transmission Technologies—Continued

M4I.3 • 17:00

WDM Transmission of 600G Carriers over 5,600 km with Probabilistically Shaped 16QAM at 106 Gbaud, Miao kong[2], Jianjun Yu[1], Hungchang Chien[1], Kaihui Wang[2], Li Zhao[2], Jianyang Shi[2], Benyuan Zhu[4], Xiaolong Pan[3], Xiangjun Xin[3], Xinying Li[2], Yan Xia[5], Bing Ye[5]; *[1]ZTE TX Inc., USA; [2]Fudan Univ., China; [3]Beijing Univ. of Posts and Telecommunications, China; [4]OFS, USA; [5]ZTE Corp., China*. We experimentally demonstrated 600G per-wavelength (848-Gbps coded line rate) probabilistically shaped 16QAM coherent WDM transmission over 5,600-km ultra-low-loss fibers with Raman amplification above the 27.5% SD-FEC threshold of 0.8 NGMI, attaining 27% transmission-distance improvement compared with regular-16QAM.

M4I.4 • 17:15 Top Scored

1.04 Tbps/carrier Probabilistically Shaped PDM-64QAM WDM Transmission over 240 km Based on Electrical Spectrum Synthesis, Masanori Nakamura[1], Fukutaro Hamaoka[1], Munehiko Nagatani[1,2], Hiroshi Yamazaki[1,2], Takayuki Kobayashi[1,2], Asuka Matsushita[1], Seiji Okamoto[1], Hitoshi Wakita[2], Hideyuki Nosaka[1,2], Yutaka Miyamoto[1]; *[1]NTT Network Innovation Laboratories, Japan; [2]NTT Device Technology Laboratories, Japan*. We demonstrate 1.04-Tbps/carrier net-rate 125-GHz-spaced 9-WDM (9.3-Tbps) transmission over 240-km using 120-GBd probabilistically shaped PDM-64QAM generated by electrical spectrum synthesis technique with in-house ultra-broadband bandwidth doublers with the spectral efficiency of 8.3 bps/Hz.

Room 9

M4J • Spectrum Efficient Networks—Continued

M4J.3 • 17:00

Spectrum Trading between Virtual Optical Networks Embedded in an Elastic Optical Network, Shifeng Ding[1], Xiaodong Fu[2], Boping Jiang[2], Sanjay Bose[3], Gangxiang Shen[1]; *[1]Soochow Univ., China; [2]Zhongtian Broadband Technology, China; [3]IIT Guwahati, India*. We propose a spectrum trading (ST) scheme to trade spectra between virtual networks embedded in an elastic optical network (EON) for efficient spectrum utilization and better client quality of service. An integer linear programming (ILP) model and a heuristic algorithm are developed. Results show the effectiveness of the proposed scheme.

M4J.4 • 17:15

A Comparison of Impairment Abstractions by Multiple Users of an Installed Fiber Infrastructure, David J. Ives[1], Shuangyi Yan[2], Lidia Galdino[3], Daniel Elson[3], Francisco J. Vaquero-Caballero[1], Gabriel Saavedra[3], Rui Wang[2], Domanic Lavery[3], Reza Nejabati[2], Polina Bayvel[3], Dimitra Simeonidou[2], Seb J. Savory[1]; *[1]Univ. of Cambridge, UK; [2]Univ. of Bristol, UK; [3]UCL, UK*. We compare three independent impairment abstractions of an installed fibre infrastructure. Abstractions agreed to within 1.3dB despite being obtained from different nodes using different terminal equipment. Validation using a DWDM virtual topology was within 1.4dB.

Room 1

M4A • High Speed Modulators—Continued

M4A.4 • 17:30 Tutorial

Design of Very High Speed InP Modulators, Urban Westergren[1]; [1]*Applied Physics, Photonics unit, KTH Royal Inst. of Technology, Sweden.* Electroabsorption modulators based on InP have been proven useful for fiberoptical communication at speeds beyond 100Gbit/s serial transmission. The key to the high modulation speeds is the combination of semiconductor technology, photonics, and microwave engineering.

Urban Westergren received his PhD degree in Electrical Engineering in 1992 from KTH Royal Institute of Technology, Sweden. In 2012 he was appointed professor in optoelectronic integrated circuits at KTH. The research has lately focused on electroabsorption modulators for use in transmitters for fiberoptical communication at speeds from 100Gb/s. He was the coordinator of the EU project HECTO throughout the project duration 2006-2010, and the designer of the monolithic light transmitters with lasers and distributed modulators (DBF-TWEAM). HECTO ended with field trials of a complete fiberoptical communication system with 112Gbit/s serial transmission using On-Off Keying over 42km.

Room 2

M4B • Probabilistic Shaping I—Continued

M4B.4 • 17:30

Optimum Bit-level Distribution Matching with at most $O(N^3)$ Implementation Complexity, Yohei Koganei[1], Kiichi Sugitani[2], Hisao Nakashima[1], Takeshi Hoshida[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fujitsu Kyushu Network Technologies, Japan.* An algorithm of distribution matching which could be effectively implemented for short block lengths of around 100 bit or less is proposed, enabling better performance than the constant composition schemes with the same block lengths.

M4B.5 • 17:45

Simplified Bit-level Shaping with High Spectral Efficiency and High Throughput, Yizhao Chen[1], Xi Chen[1], Ming Tang[1], Hexun Jiang[1], Yating Xiang[1], Tianhao Tong[1], Songnian Fu[1], Deming Liu[1]; [1]*School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China.* We propose a simplified bit-level shaping method by optimizing the structure of product distribution matcher for high spectral efficiency and high throughput. Simulation and experimental comparisons based on 64QAM demonstrate the efficiency of our method.

Room 3

M4C • Nonlinear and Polarization Effects in Optical Fibers—Continued

M4C.4 • 17:30

Suppression of Nonlinear Crosstalk in a Polarization Insensitive FOPA by Mid-stage Idler Removal, Vladimir Gordienko[1], Filipe Ferreira[1], Vitor Ribeiro[1], Nick Doran[1]; [1]*Aston Univ., UK.* We experimentally demonstrate a modification to the looped architecture of polarization-insensitive fiber optical parametric amplifier which shows a nonlinear crosstalk reduction by over 4.5dB with negligible penalty on amplifier performance.

M4C.5 • 17:45

Statistical Distribution of the Possible Maximum Rate of Polarization Rotation in Optical Fiber Transmission Line, Yoshihiro Kanda[1], Hitoshi Murai[1], Hironori Sasaki[1]; [1]*Oki Electric Industry Co., Ltd., Japan.* We reveal that the possible maximum rate of polarization rotation at each instant follows the Maxwell distribution. The average value of the distribution is proportional to the square root of the fiber length.

Room 6C

M4D • Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program—Continued

M4D.5 • 17:30 Invited

Seamless Hybrid-integrated Interconnect NEtwork (SHINE), Shaoliang Yu[1], Haijie Zuo[1], Xiaoxin Wang[2], Xiaochen Sun[3], Jifeng Liu[2], Juejun Hu[1], Tian Gu[1]; [1]*Massachusetts Inst. of Technology, USA;* [2]*Dartmouth College, USA;* [3]*LaXense Inc., USA.* We describe an optical communication technology scalable across chip-, board-, and rack-interconnect levels for data centers. The approach claims high energy efficiency, large bandwidth density, and is compatible with standard area-bonding and pick-and-place chip assembly.

M4D.6 • 17:45 Invited

Multi-wavelength Optical Transceivers Integrated on Node (MOTION), Daniel Kuchta[1], Jonathan Proesel[1], Fuad Doany[1], Wooram Lee[1], Timothy Dickson[1], Herschel Ainspan[1], Mounir Meghelli[1], Petar Pepeljugoski[1], Xiaoxiong Gu[1], Michael Beakes[1], Mark Schultz[1], Marc Taubenblatt[1], Paul Fortier[2], Catherine Dufort[2], Eric Turcotte[2], Marc-Olivier Pion[2], Charles Bureau[2], Frank Flens[3], Greta Light[3], Blake Trekell[3], Kevin Koski[3]; [1]*IBM TJ Watson Research Center, USA;* [2]*IBM Bromont, Canada;* [3]*Finisar, USA.* We report on efforts to develop a high speed, low cost, low energy chip scale optical module for co-packaging on a first-level organic substrate for HPC and Data Center applications.

Room 6D

M4E • Ligo and Lidar—Continued

M4E.2 • 17:30

Large-scale Silicon Photonic Phased Array Chip for Single-pixel Ghost Imaging, Yusuke Kohno[1], Kento Komatsu[1], Yasuyuki Ozeki[1], Yoshiaki Nakano[1], Takuo Tanemura[1]; [1]*The Univ. of Tokyo, Japan.* We develop large-scale optical phased array (OPA) with 128 phase shifters integrated on a compact silicon chip for single-pixel ghost imaging application. By using speckle illumination pattern generated from OPA, calibration-free robust imaging is demonstrated.

M4E.3 • 17:45

MWIR Solid-state Optical Phased Array Beam Steering Using Germanium-silicon Photonic Platform, Mathias Prost[1], Yi-Chun Ling[1], Semih Cakmakyapan[1], Yu Zhang[1], Kaiqi Zhang[1], Junjie Hu[1], Yichi Zhang[1], S. J. Ben Yoo[1]; [1]*Univ. of California, Davis, USA.* We demonstrate a chip-scale germanium-silicon optical phased array fabricated on a Bi-CMOS compatible platform capable of beam steering in the mid-infrared wavelength. We achieved beam steering angle up to 12.7° with beam divergence of 0.47°×2.86°.

Room 6E

M4F • Advanced Wireless Systems—Continued

M4F.4 • 17:30

132-Gb/s Photonics-aided Single-carrier Wireless Terahertz-wave Signal Transmission at 450GHz Enabled by 64QAM Modulation and Probabilistic Shaping, Xinying Li[2,1], Jianjun Yu[2,3], Li Zhao[2], Wen Zhou[2], Kaihui Wang[2], Miao Kong[2], Gee-Kung Chang[1], Ying Zhang[4], Xiaolong Pan[4], Xiangjun Xin[4]; *[1]Georgia Inst. of Technology, USA; [2]Shanghai Inst. for Advanced Communication and Data Science, Fudan Univ., China; [3]ZTE TX Inc, USA; [4]Beijing Univ. of Posts and Telecommunications, China.* We experimentally demonstrate 132-Gb/s (12-Gbaud) photonics-aided single-carrier PDM-64QAM-PS5.5 THz-wave signal transmission at 450GHz over 20-km fiber-optics and 1.8-m wireless distance with BER under 4×10^{-2}. The employment of probabilistic-constellation-shaping significantly improves transmission capacity and system performance.

M4F.5 • 17:45

32 GBd 16QAM Wireless Transmission in the 300 GHz Band Using a PIN Diode for THz Upconversion, Carlos Castro[1], Simon Nellen[1], Robert Elschner[1], Isaac Sackey[1], Robert Emmerich[1], Thomas Merkle[2], Björn Globisch[1], David de Felipe[1], Colja Schubert[1]; *[1]Fraunhofer Heinrich Hertz Inst., Germany; [2]Fraunhofer-Institut für Angewandte Festkörperphysik, Germany.* We demonstrate THz wireless transmission of 32 GBd QPSK and 16QAM signals using a broadband PIN photodiode. Using an electronic THz receiver operating at 300 GHz, error-free transmission is achieved at 100 Gb/s net rate.

Room 6F

M4G • Novel Components for Next Generation PON—Continued

M4G.4 • 17:30 Tutorial

Photonic Integrated Circuits for NG-PON2 ONU Transceivers, Antonio L. Teixeira[1,2]; *[1]DETI, Instituto de Telecomunicacoes, Portugal; [2]PICadvanced SA, Portugal.* A revision on access ONU optics for existing technologies and standards will be made. Based on the limitations and potential opportunities design rules, techniques and technologies will be addressed objectivating introduction of PICs in access.

Antonio Teixeira, received his PhD from Aveiro in 1999, EC MIT Sloan School and PG in quality. Professor UA from 1999, senior standards expert 2009-13 in Nokia Siemens Networks and Coriant (2013/14) (In FSAN, ITU-T, IEEE 802.3). Dean of Doctoral school of the UA and in 2014 he co-founded PICadvanced.

Room 7

M4H • Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?—Continued

Room 8

M4I • Transmission Technologies—Continued

M4I.5 • 17:30 Invited

Performance and Impairments of Submarine Systems, Dmitri Foursa[1]; *[1]SubCom, USA.* This work summarizes effects and factors that limit capacity of submarine systems. Techniques for minimizing nonlinear impairments and maximizing information rate are presented. Capacity limitations arising from practical considerations are also discussed.

Room 9

M4J • Spectrum Efficient Networks—Continued

M4J.5 • 17:30 Invited

Optical Network Design towards beyond 100 Gbaud, João Pedro[1], Nelson Costa[1]; *[1]Infinera, Portugal.* This paper overviews key challenges and network design solutions to cost-effectively exploit next-generation line interfaces operating at increasingly higher symbol rates.

Room 1

M4A • High Speed Modulators—Continued

Room 2

M4B • Probabilistic Shaping I—Continued

M4B.6 • 18:00
Joint Source–channel Coding via Compressed Distribution Matching in Fiber-optic Communications, Tsuyoshi Yoshida[1,2], Magnus Karlsson[3], Erik Agrell[3]; *[1]Mitsubishi Electric Corporation, Japan; [2]Graduate School of Engineering, Osaka Univ., Japan; [3]Fiber Optic Communications Research Center (FORCE), Chalmers Univ. of Technology, Sweden.* The variability of source entropy due to data idling is inconsistent with most studies' assumptions in probabilistic shaping. We propose a distribution matcher sensitive to the source entropy, and discuss its impacts on fiber-optic communications.

M4B.7 • 18:15
Multi-rate Prefix-free Code Distribution Matching, Junho Cho[1], Peter J. Winzer[1]; *[1]Nokia Bell Labs, USA.* We propose a multi-rate prefix-free code distribution matching (PCDM) algorithm that implements a fixed-length probabilistic constellation shaping. It uses various small codebooks in an adaptive manner, thereby improving the shaping performance of PCDM.

Room 3

M4C • Nonlinear and Polarization Effects in Optical Fibers—Continued

Room 6C

M4D • Special Session: Integrated Photonics for Energy Efficient Datacenters: The ARPA-E ENLITENED Program—Continued

M4D.7 • 18:00 Invited
TeraPHY: A High-density Electronic-photonic Chiplet for Optical I/O from a Multi-chip Module, Roy Meade[1], Shahab Ardalan[1], Michael Davenport[1], John Fini[1], Chen Sun[1], Mark Wade[1], Alexandra Wright-Gladstein[1], Chong Zhang[1]; *[1]Ayar Labs, USA.* In this work, we provide an overview of System-in-Package (SiP) integration of an electronic-photonic chiplet fabricated in a commercial CMOS foundry. Assembly considerations, including co-packaging in a standard multi-chip module (MCM) package with a System-on-Chip (SoC), thermals, and fiber attach will be reviewed.

M4D.8 • 18:15 Invited
PINE: An Energy Efficient Flexibly Interconnected Photonic Data Center Architecture for Extreme Scalability, Keren Bergman[1], Madeleine Glick[2], John Shalf[3], George Michelogiannakis[3], Manya Ghobadi[4], Larry Dennison[5]; *[1]Columbia Univ., USA; [3]Lawrence Berkeley National Lab, USA; [4]MIT, USA; [5]NVIDIA, USA.* Data centers are increasingly bottlenecked by the energy and communications costs of interconnection networks. We introduce the PINE architecture that leverages embedded photonics to deeply disaggregate compute/memory resources and flexibly compose application-tailored interconnectivity.

M4D.9 • 18:30 Invited
INTREPID: Developing Power Efficient Analog Coherent Interconnects to Transform Data Center Networks, Clint Schow[1], Katharine E. Schmidtke[2]; *[1]Univ. of California Santa Barbara, USA; [2]Facebook Inc., USA.* The INTREPID program is developing power efficient coherent optics for package-level integration with future switch ICs as a path to realizing higher-radix switches for flatter networks while enabling new architectures incorporating optical routing and switching.

M4D.10 • 18:45 Invited
Photonics in the Package for Extreme Scalability (PIPES), Gordon A. Keeler[1]; *[1]DARPA, USA.* The DARPA PIPES program seeks innovation in components, architectures, and electronic-photonic integration to enable efficient optical signaling that can overcome the interconnect bottlenecks limiting system performance for emerging sensors, machine learning, and data analysis needs.

Room 6D

M4E • Ligo and Lidar—Continued

M4E.4 • 18:00
Two-dimensional Beam Steering Device Based on VCSEL Slow-light Waveguide Array with Amplifier Function, Keisuke Kondo[1], Xiaodong Gu[1], Zeuku Ho[1], Akihiro Matsutani[2], Fumio Koyama[1]; *[1]FIRST, Tokyo Inst. of Technology, Japan; [2]Semiconductor and MEMS Processing Center, Tokyo Inst. of Technology, Japan.* We demonstrated two-dimensional beam steering by using VCSEL-based slow-light waveguide array with large angular dispersion of 1.8°/nm, which showed potential to achieve resolution point of over 10,000 dots. We obtained chip gain of 18.4 dB.

M4E.5 • 18:15
Serpentine Optical Phased Array Silicon Photonic Aperture Tile with Two-dimensional Wavelength Beam Steering, Bohan Zhang[1], Nathan Dostart[2], Anatol Khilo[1], Michael Brand[2], Kenaish Al'Qubaisi[1], Deniz Onural[1], Daniel Feldkhun[2], Milos Popovic[1,2], Kelvin Wagner[2]; *[1]Boston Univ., USA; [2]Univ. of Colorado, Boulder, USA.* We propose and demonstrate a passive microphotonic phased-array aperture that wavelength-steers a beam in 2-D, showing 14,000 resolvable spots. It is tileable into larger apertures with fill factor above 50%, an improvement of 16x over previous work.

Room 6E

M4F • Advanced Wireless Systems—Continued

M4F.6 • 18:00 Top Scored

Low-cost Analogue Coherent TDMA Receiver with All-optical Synchronization to Free-running Optical Carriers, Bernhard Schrenk[1], Fotini Karinou[2]; [1]*AIT Austrian Inst. of Technology, Austria;* [2]*Microsoft Research Ltd, UK.* All-optical locking of an EML is exploited for fast frequency tracking of coherently received data packets with 2.7μs guard interval. Homodyne analogue 64QAM-OFDM radio-over-fiber transmission is demonstrated in TDMA over >35dB loss budget.

Room 6F

M4G • Novel Components for Next Generation PON—Continued

Room 7

M4H • Open Platform Summit: Will Disaggregation Drive Core Network Deployments in 2025?—Continued

Room 8

M4I • Transmission Technologies—Continued

Room 9

M4J • Spectrum Efficient Networks—Continued

M4J.6 • 18:00

Inter-core Crosstalk Impact on Migration Planning from Elastic Optical Networks to Spectrally-spatially Flexible Optical Networks, Piotr Lechowicz[1], Rubén Rumipamba-Zambrano[2], Jordi Perelló[2], Salvatore Spadaro[2], Krzysztof Walkowiak[1]; [1]*Faculty of Electronics, Department of Systems and Computer Networks, Wroclaw Univ. of Science and Technology, Poland;* [2]*Universitat Politècnica de Catalunya, Spain.* We study inter-core crosstalk (ICXT) impact on migration planning toward spectrally-spatially flexible optical networks considering 22-core multi-core fiber. Results reveal, 55-70% of links need to be upgraded when ICXT ranges from -68.2 to -43.4 dB/km.

M4J.7 • 18:15 Top Scored

SDN-enabled Scaling up/down of SDM Super-channels Exploiting Spatial Modes with Adaptive MIMO Equalization and Modulation Format Assignment, Raul Muñoz[1], Noboru Yoshikane[2], Josep Maria Fàbrega[1], Laura Rodríguez[1], Ricard Vilalta[1], Daiki Soma[2], Shohei Beppu[2], Seiya Sumita[2], Ramon Casellas[1], Ricardo Martinez[1], Takehiro Tsuritani[2], Itsuro Morita[2]; [1]*CTTC, Spain;* [2]*KDD Research, Japan.* We propose a heuristic and experimentally demonstrate dynamic scaling up/down of SDM super-channels to increase/decrease the capacity by exploiting the spatial modes. We deploy mode-adaptive MIMO equalization and modulation format assignment controlled by SDN.

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E

07:30–08:00 Plenary Morning Coffee, *Upper Level, Ballroom 20 Lobby*

08:00–10:00 OFC Plenary Session, *Ballroom 20BCD*

10:00–14:00 Unopposed Exhibit-only Time, *Exhibit Hall* (coffee service 10:00–10:30)

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall* (concessions available)
OFC Career Zone Live, *Exhibit Hall C*

12:00–14:00 OFC and Co-Sponsors Awards and Honors Luncheon, *Upper Level, Ballroom 20A*

14:00–16:00 Tu2A • High Speed Silicon Photonics I

Presider: Di Liang; Hewlett Packard Labs, University of California Santa Barbara, USA

Tu2A.1 • 14:00
APSUNY Process Design Kit (PDKv3.0): O, C and L Band Silicon Photonics Component Libraries on 300mm Wafers, Erman Timurdogan[1], Zhan Su[1], Ren-Jye Shiue[1], Christopher V. Poulton[1], Matthew J. Byrd[1], Simon Xin[1], Michael R. Watts[1]; [1]*Analog Photonics, USA.* An updated process design kit (APSUNY PDKv3.0) is introduced with verified passive and active O+C+L band silicon photonics component libraries, which includes 50Gbaud (100Gbps) capable modulators, high yield splitters and detectors on 300mm SOI wafers.

14:00–16:00 Tu2B • Optical Solutions for 5G

Presider: Jianjun Yu; ZTE USA Inc., USA

Tu2B.1 • 14:00 Invited
5×510 Gbps Single-polarization Direct-detection WDM Transmission over 80 km of SSMF, Son T. Le[1], Karsten Schuh[1], Roman Dischler[1], Fred Buchali[1], Laurent Schmalen[1], Henning Buelow[1]; [1]*Nokia Bell Labs, Germany.* We demonstrate 5-channel WDM DD transmissions over 80 km of SSMF with a net data rate per channel of 432 Gbps using either Kramers-Kronig detection or a low-complexity interference cancellation scheme

14:00–16:00 Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs

Recent developments have shown a strongly growing interest in the application of optical frequency combs (OFC) to high-speed optical and RF-photonics signal processing. For example, highly stable OFCs have been recently employed, besides massively parallel communications, for other advanced functions such as nonlinear impairment mitigation, high-purity microwave signal generation, optical beamforming, all-optical Fourier transformation, sensing, and more. The scope of this panel session is to provide a focused overview on recent advances on this topic and its multiple applications to all-optical processing and microwave photonic subsystems.

Speakers:

Cristina de Dios, *Universidad Carlos III de Madrid, Spain*
Versatile OFCs Based on EO Modulation of Efficient Diode Laser Sources: Close to the Application

14:00–16:00 Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1

Tu2D.1 • 14:00 Invited
Technology and Market for 3D Sensing, Julie Eng[1]; [1]*Finisar Corp., USA.* Technology and Market for 3D Sensing

14:00–16:00 Tu2E • AI in Network Operation 2

Presider: Josue Kuri; Google, USA

Tu2E.1 • 14:00 Invited
On-Board Artificial Intelligence on Edge Computing in Optical Transport Networks, Yongli Zhao[1], Boyuan Yan[1], Wei Wang[1], Yi Lin[2], Jie Zhang[1]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Huawei Technologies Co., Ltd., China.* On-board artificial intelligence (AI) is proposed based on edge computing to support performance monitoring, physical impairment evaluation, alarm message filter and so on. Some experiments have been done to verify the performance of above applications.

14:00–15:45 Tu2F • Short Reach II

Presider: Xi Chen; Nokia Bell Labs, USA

Tu2F.1 • 14:00
Demonstration of 100-Gb/s/λ PAM-4 Transmission over 45-km SSMF Using One 10G-class DML in the C-band, Jiao Zhang[2,1], Jianjun Yu[1], Xinying Li[2], Yiran Wei[2], Kaihui Wang[2], Li Zhao[2], Wen Zhou[2], Jiangnan Xiao[2], Xiaolong Pan[3], Xiangjun Xin[3], Liwei Zhang[4], Yun Zhang[4]; [1]*ZTE TX Inc., USA;* [2]*Fudan Univ., China;* [3]*Beijing Univ. of Posts and Telecommunications, China;* [4]*ZTE Corp, China.* We experimentally demonstrated single-lane 100-Gb/s PAM-4 signal transmission over 45-km SMMF based on joint algorithm and optical filtering technique using 10-GHz DML. 107.5-Gb/s PAM-4 signal transmission over 10-km without optical filtering can also be achieved.

07:30–08:00 Plenary Morning Coffee, *Upper Level, Ballroom 20 Lobby*

08:00–10:00 OFC Plenary Session, *Ballroom 20BCD*

10:00–14:00 Unopposed Exhibit-only Time, *Exhibit Hall* (coffee service 10:00–10:30)

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall* (concessions available)
OFC Career Zone Live, *Exhibit Hall C*

12:00–14:00 OFC and Co-Sponsors Awards and Honors Luncheon, *Upper Level, Ballroom 20A*

14:00–16:00
Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1

Data-center and high-performance computing technologies are rapidly evolving to accommodate emerging applications such as artificial intelligence, data-centric workloads and IoT. Hardware acceleration, new memory technologies, high-capacity low-latency networking, and programmatic control are key enablers to optimize application performance and improve resource scalability. In this session, industry leaders and cutting-edge researchers will discuss the evolution of data center and computing architectures, related hardware and the role of optics in this context.

Speakers:
Part I: Architecture Evolution

Invited **Alibaba Datacenter Architecture: Today and the Future,** Zheng Cao, *Alibaba Group, China.* Alibaba datacenter is running one million servers and serves various businesses, e.g. Taobao, Alipay, and Alibaba Cloud. This talk introduces current Alibaba datacenter architecture and future developing directions regarding higher performance and resource utilization.

14:00–16:00
Tu2H • Silicon Modulator
Presider: Erman Timurdogan; Analog Photonics, USA

Tu2H.1 • 14:00 Invited
Silicon Photonic Modulators for High-capacity Coherent Transmissions, Wei Shi[1], Jiachuan Lin[1,2], Hasan Sepehrian[1,2], Sasan Zhalehpour[1], Zhuhong Zhang[2], Leslie Rusch[1]; [1]*Department of Electrical and Computer Engineering & Center for Optics, Photonics, and Lasers (COPL), Université Laval, Canada;* [2]*Huawei Technologies Canada Co., Ltd., Canada.* We discuss system-orientated design and optimization of all-silicon modulators for high-baud-rate (up to 84GBaud) coherent transmissions. We achieved single-carrier net-600Gb/s DP-32QAM, net-400Gb/s DP-16QAM over 1520km; and 800Gb/s super-channel using a silicon-modulator optical frequency comb.

14:00–15:30
Tu2I • Photonic Integration for Data Centers
Presider: Sorin Tibuleac; ADVA Optical Networking, USA

Tu2I.1 • 14:00
A 25-Gbps x 4 ch, Low-power Compact Wire-bond-free 3D-stacked Transmitter Module with 1.3-μm LD-array-on-Si for On-board Optics, Toshiki Kishi[1], Hitoshi Wakita[1], Kota Shikama[1], Munehiko Nagatani[1], Shigeru Kanazawa[2], Takuro Fujii[1], Hidetaka Nishi[1], Hiroshi Ishikawa[1], Yuko Kawajiri[1], Atsushi Aratake[1], Hideyuki Nosaka[1], Hiroshi Fukuda[1], Shinji Matsuo[1]; [1]*NTT Device Technology Laboratories, Japan;* [2]*NTT Device Innovation Center, Japan.* A 4-channel wire-bond-free 3D-stacked transmitter module consisting of a 65-nm CMOS cascode shunt LD driver, 1.3-μm LD-array-on-Si, and LTCC interposer achieves simultaneous 4-channel 25-Gbps error-free transmission over 1.2-km-long SSMF, with power consumption of 2.67 mW/Gbps.

14:00–16:00
Tu2J • Filters and Couplers
Presider: Hiroyuki Tsuda; Keio Univ., Japan

Tu2J.1 • 14:00
Integrated-photonic Tunable Demultiplexer for Variable Channel Number Optical OFDM Signals, Koichi Takiguchi[1], Hideaki Masaki[1], Taiki Taguchi[1]; [1]*Ritsumeikan Univ., Japan.* We report a tunable OFDM demultiplexer whose major element is a star coupler-based optical DFT circuit. Variable channel number 20 to 100 Gsymbol/s OFDM signals were demultiplexed by selecting delay lines into the star coupler.

Show Floor Programming

Product Showcase: Optical Intelligence
Huawei Technologies Canada Co., Ltd.
10:15–10:45, *Theater III*

Interoperability – The Foundation of Ethernet Success
Ethernet Alliance
10:15–11:15, *Theater II*

■ **MW Panel I:**
State of the Industry–Analyst Panel
10:30–12:30, *Theater I*

Simplifying Transport Network Operations with Declarative, Vendor-neutral Configuration Management
OpenConfig
11:00–12:30, *Theater III*

■ **Data Center Summit:**
The importance of "Open Transport" DCI Innovations in the Evolution of Metro and Long-Haul Optical Networks
11:45–13:45, *Theater II*

■ **MW Panel II:**
Market Projections for Wireline and Wireless Technologies to Support 5G
12:30–14:00, *Theater I*

Smart Cities Connecting Future Communities
IEEE Smart Cities Technical Communites
12:45–14:15, *Theater III*

Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps
Session sponsored by Juniper
14:00–17:00, *Theater II*

Room 1

Tu2A • High Speed Silicon Photonics I—Continued

Tu2A.2 • 14:15
An All-silicon Transmitter with Co-designed Modulator and DC-coupled Driver, Yangjin Ma[1], Christopher Williams[1], Mostafa Ahmed[1], Abdellatif Elmoznine[1], Daihyun Lim[1], Yang Liu[1], Ruizhi Shi[1], Tam Huynh[1], Jose Roman[1], Abdelrahman Ahmed[1], Leonardo Vera[1], Yaojia Chen[1], Alexandre Horth[1], Hang Guan[1], Kishore Padmaraju[1], Matthew Streshinsky[1], Ari Novack[1], Rafid Sukkar[1], Rick Younce[1], Alexander Rylyakov[1], Dominick Scordo[1], Michael Hochberg[1]; *[1]Elenion Technologies, USA.* We present a co-designed silicon traveling wave modulator with a SiGe driver with 6Vpp effective swing. 34GBaud DP-16QAM is demonstrated with comparable ROSNR performance to a commercial CFP2-ACO.

Tu2A.3 • 14:30 Invited
Reliable Heterogeneous and Monolithic Integrated Silicon Photonics, Robert Herrick[1], Catherine Jan[1], Neil Caranto[1], Daehwan Jung[2], Justin Norman[2], Jennifer Selvidge[2], Kunal Mukherjee[2], John E. Bowers[3]; *[1]Reliability Dept., Intel Corporation, USA; [2]Dept. of Material Science, Univ. of California, USA; [3]Dept. of ECE, Univ. of California, USA.* We will present reliability and performance data from Intel silicon photonics lasers, based on heterogeneous bonding of InP on silicon, and also reliability of quantum dot lasers grown on silicon substrates in collaboration with UCSB.

Room 2

Tu2B • Optical Solutions for 5G—Continued

Tu2B.2 • 14:30
Experimental Verification of Equalization Enhanced Phase Noise in Kramers-Kronig Transmissions, Son T. Le[1], Karsten Schuh[1]; *[1]Nokia Bell Labs, Germany.* We experimentally investigate, for the first time, the impact of laser phase noise in a 30 Gbaud 64 QAM DD transmission system with Kramers-Kronig receiver, showing significant impacts of phase-to-amplitude noise conversion and EEPN

Room 3

Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs—Continued

Marko Loncar, *Harvard University, USA*
Electro-Optic and Kerr Frequency Combs in Lithium Niobate

Andrey Matsko, *OEwaves, USA*
Optical Frequency Combs for RF Signal Generation

Scott Papp, *NIST, USA*
Microresonator Frequency Combs for Synthesis Across the Microwave and Optical Domains

Alan E. Willner, *University of Southern California, USA*
Reconfigurable Optical Signal Processing Functions using Frequency Combs

Xiaoxiao Xue, *Tsinghua University, China*
High-efficiency Kerr Frequency Combs for RF Signal Processing

Room 6C

Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1—Continued

Tu2D.2 • 14:30 Invited
Photonic Terahertz Solutions for Sensing, Spectroscopy and Wireless Communication, Björn Globisch[1], Simon Nellen[1], Lars Liebermeister[1], Robert B. Kohlhaas[1], Martin Schell[1]; *[1]Photonic Components, Fraunhofer Heinrich-Hertz-Inst., Germany.* We present all-fiber coupled pulsed and continuous wave optoelectronic terahertz systems for applications in sensing, spectroscopy and wireless communication. Up to 6.5 THz bandwidth and > 90 dB peak dynamic range can be obtained.

Room 6D

Tu2E • AI in Network Operation 2—Continued

Tu2E.2 • 14:30
Machine Learning for QoT Estimation of Unseen Optical Network States, Tania Panayiotou[1], Giannis Savva[1], Behnam Shariati[2], Ioannis Tomkos[3], Georgios Ellinas[1]; *[1]KIOS Research and Innovation Centre of Excellence, Univ. of Cyprus, Cyprus; [2]Universitat Politecnica de Catalunya, Spain; [3]Athens Information Technology, Greece.* We apply deep graph convolutional neural networks for Quality-of-Transmission estimation of unseen network states capturing, apart from other important impairments, the inter-core crosstalk that is prominent in optical networks operating with multicore fibers.

Room 6E

Tu2F • Short Reach II—Continued

Tu2F.2 • 14:15 Top Scored
120-Gb/s DP-QPSK Transmission Using Polarization-Diversity Stokes-Analyzer-Based Coherent Receiver, Shota Ishimura[1,2], Takuo Tanemura[2], Kohsuke Nishimura[1]; *[1]KDDI Research, Inc., Japan; [2]School of Engineering, The Univ. of Tokyo, Japan.* We propose a simple polarization-diversity coherent receiver by taking advantage of the features of the Stokes analyzer. Using a prototype of the receiver, we successfully transmitted 120-Gb/s DP-QPSK signals over a 100-km SMF.

Tu2F.3 • 14:30
Polarity-header Optical OFDM for IM/DD Communication Systems, Jie Lian[1], Maite Brandt-Pearce[1]; *[1]Univ. of Virginia, USA.* Polarity-header optical OFDM modulation for bandlimited noncoherent optical communication systems improves the spectral efficiency, providing a better bit error rate performance and higher achievable data rate compared with benchmark schemes.

Room 6F

Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1—Continued

Invited **Microsoft Cloud Hardware Futures,** Jeff Cox, *Microsoft Corp., USA*. In this session Microsoft will discuss the 5-year future evolution of network, optical, and compute technologies utilized within our datacenters, availability zones, and regional infrastructure designs.

Invited **High Performance Computing in Japan and the Role of Optics in Future,** Tomohiro Kudoh, *Tokyo University, Japan*. First, network architecture and interconnection technology used in Japanese supercomputers will be explained. Then how optics can contribute to future computing systems, considering change of balance between computation and communication, will be discussed.

Invited **The Role of Optics in Evolving Google's Cloud,** Hong Liu, *Google, USA*. The optical layer has evolved and expanded rapidly to significantly shape and differentiate Google's compute infrastructure. We will present an overview and future roadmap, including the critical role of optics in enabling new compute capabilities.

Room 7

Tu2H • Silicon Modulator—Continued

Tu2H.2 • 14:30 Top Scored
Silicon Photonics Carrier Depletion Modulators Capable of 85Gbaud 16QAM and 64Gbaud 64QAM, Jianying Zhou[1], Jian Wang[1], Likai Zhu[1], Qun Zhang[1,2], Jin Hong[1]; *[1]NeoPhotonics, USA; [2]ECET Department, Minnesota State Univ., USA*. We achieved high performance silicon photonics carrier-depletion Mach-Zehnder modulation with a commercial foundry by optimizing doping and device design. We demonstrated IQ modulator operating at 85Gbaud 16QAM and 64Gbaud 64 QAM with >25dB extinction ratio.

Room 8

Tu2I • Photonic Integration for Data Centers—Continued

Tu2I.2 • 14:15
104 Gbaud OOK and PAM-4 Transmission over 1km of SMF Using a Silicon Photonics Transmitter with Quarter-rate Electronics, Jochem Verbist[1,2], Mads Lillieholm[3], Joris Van Kerrebrouck[1], Srinivasan Ashwyn Srinivasan[4], Peter De Heyn[4], Joris Van Campenhout[4], Michael Galili[3], Leif K. Oxenløwe[3], Xin Yin[1], Johan Bauwelinck[1], Gunther Roelkens[2]; *[1]IDLab, Ghent Univ. - IMEC, Belgium; [2]Photonics Research Group, Ghent Univ. - imec, Belgium; [3]DTU Fotonik, Technical Univ. of Denmark, Denmark; [4]imec, Belgium*. We present a silicon photonics transmitter using four GeSi EAMs driven at 26 Gbaud with 1.2Vpp to realize the fastest reported single-wavelength PAM-4 transmission on silicon at 208 Gb/s over 1km of SMF.

Tu2I.3 • 14:30 Invited
Stokes Vector Modulation and Detection with Monolithic InP Photonic Integrated Circuits, Yoshiaki Nakano[1], Takuo Tanemura[1], Samir Ghosh[1], Mohiyuddin N. Kazi[1]; *[1]The Univ. of Tokyo, Japan*. Stokes-vector modulation direct-detection (SVM-DD) formats are expected as costeffective methods to transmit multi-level signals in short-reach links. In this talk we review our novel SV modulator and receiver circuits realized on monolithic InP platforms, which possess compact non-interferometric configurations, relatively simple fabrication procedures, and compatibility with other active photonic components.

Room 9

Tu2J • Filters and Couplers—Continued

Tu2J.2 • 14:15
Low-loss and Fabrication-tolerant Si Four-wavelength Multiplexer Using Higher-order Mode for 100/400GbE, Junya Takano[1], Takeshi Fujisawa[1], Takanori Sato[1], Yusuke Sawada[1], Taiji Sakamoto[2], Takashi Matsui[2], Kyozo Tsujikawa[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; *[1]Hokkaido Univ., Japan; [2]NTT Access Network Service Systems Laboratories, Japan*. A Si four-wavelength multiplexer for 100/400GbE composed of (a)symmetric directional couplers and a rib-waveguide mode-converter is experimentally demonstrated. Proposed device is fabrication-tolerant due to the removal of 1600-GHz filter used in conventional two-stage Mach-Zehnder multiplexers.

Tu2J.3 • 14:30 Invited
Tunable Filters in the Evolving Optical Communication Network, Glenn D. Bartolini[1], Michael J. Cahill[1]; *[1]II-VI Photonics, USA*. Tunable optical filters are a key enabler of flexible, high density and high bandwidth optical communication systems. We describe the evolution of fundamental technologies and applications for tunable optical filters in dynamic, reconfigurable networks.

Show Floor Programming

Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps
Session sponsored by Juniper
14:00–17:00, *Theater II*

The Disaggregated Transport Network
Telecom Infra Project (TIP)
14:30–15:30, *Theater III*

■ **MW Panel III:**
High Capacity Long Distance Optical Transport: Challenges and Business Reality
14:30–16:00, *Theater I*

Room 1

Tu2A • High Speed Silicon Photonics I—Continued

Tu2A.4 • 15:00 Top Scored

80-km Transmission with Silicon Micro-ring Modulators and Kramers-Kronig Direct Detection, Yeyu Tong[1], Qiulin Zhang[1], Xinru Wu[1], Chester C.T. Shu[1], Hon Ki Tsang[1]; [1]*Electronic Engineering, The Chinese Univ. of Hong Kong, Hong Kong.* Single sideband signals generated by micro-ring modulators were demonstrated for 80-km standard single-mode fiber transmission with Kramers-Kronig direct detection. The integrated transmitter with KK receiver is suitable for future low-cost, low-power and low-footprint datacenter interconnects.

Room 2

Tu2B • Optical Solutions for 5G—Continued

Tu2B.3 • 14:45

Transmission of 90 Gbd 32 QAM over 480 km of SSMF with Kramers-Kronig Detection, Karsten Schuh[1], Son T. Le[1], Roman Dischler[1], Fred Buchali[1]; [1]*Nokia Bell Labs, Germany.* We demonstrate transmission at record symbol rate of 90 GBd with Kramers-Kronig detection at a line rate of 450 Gb/s (360 Gb/s net rate) with 32 QAM. We show successful transmission over 480 km SSMF.

Tu2B.4 • 15:00 Invited

Enabling Technologies for 5G-oriented Optical Networks, Xiang Liu[1], Ning Deng[2], Min Zhou[2], Yin Wang[2], Minghui Tao[3], Lei Zhou[2], Shengping Li[3], Huaiyu Zeng[1], Sharief Megeed[1], Andy Shen[1], Frank Effenberger[1]; [1]*Futurewei Technologies, Inc., USA;* [2]*Huawei Technologies, China;* [3]*Huawei Technologies, China.* We review enabling technologies in optical transport and access networks, such as mobile-optimized-OTN and eCPRI-PON, to better support the upcoming 5G wireless networks with high bandwidth efficiency, low latency, accurate synchronization, and flexible network slicing.

Room 3

Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs—Continued

Room 6C

Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1—Continued

Tu2D.3 • 15:00 Invited

Shifting Fiber Optic Sensing Performance and Cost Paradigms with Integrated Photonics, Pim Kat[1], Rolf Evenblij[1]; [1]*Technobis, Netherlands.* Fiber Optic Sensing grows increasingly favorable towards demanding environments and applications by utilizing innovative PIC technology for next generation systems, allowing full advantage from miniature, low cost and power, and functionally aggregated solutions.

Room 6D

Tu2E • AI in Network Operation 2—Continued

Tu2E.3 • 14:45

Out-of-field Generic ML Training with In-field Specific Adaptation to Facilitate ML Deployments, Behnam Shariati[1], Marc Ruiz[1], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain.* A two-phase strategy to facilitate ML algorithm deployment in real networks is demonstrated: out-of-field training uses data from simulation and testbed experiments with generic equipment whereas in-field adaptation is applied to support heterogeneous equipment.

Tu2E.4 • 15:00 Invited

Autonomous Network Diagnosis with AI, Akira Hirano[1]; [1]*NTT Network Innovation Laboratories, Japan.* We propose novel autonomous network diagnosis platform. We will discuss some requirements from network operators toward such direction and how to meet such requirements with novel mechanisms. We also present PoC demonstration.

Room 6E

Tu2F • Short Reach II—Continued

Tu2F.4 • 14:45

Optical Amplifier-free 100 Gbit/s/lamda PAM-N Transmission and Reception in O-band over 40-km SMF with 10-G Class DML, Fan Li[1], Dongdong Zou[1], Qi Sui[2], Jianping Li[2], Xingwen Yi[1], Liangchuan Li[3], Zhaohui Li[1]; [1]*Sun Yat-Sen Univ., China;* [2]*Jinan Univ., China;* [3]*Huawei Technologies Co., Ltd., China.* Pre-equalization with different Rx FFE tap-coefficients is investigated for different bandwidth PAM-N, also nonlinear-distortions is compensated by LUT. 100Gbit/s PAM-N is successfully transmitted over 30-km SMF with 10-G class DML with BER under 3.8×10-3.

Tu2F.5 • 15:00 Invited

Beyond 1Tb/s Datacenter Interconnect Technology: Challenges and Solutions, Xiang Zhou[1], Ryohei Urata[1], Hong Liu[1]; [1]*Google, USA.* We discuss challenges and solutions for beyond 1Tb/s intra-datacenter bandwidth scaling, with a focus on the FlexPAM-based direct detection and the baud-rate DSP enabled coherent detection.

Room 6F

Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1—Continued

Room 7

Tu2H • Silicon Modulator—Continued

Tu2H.3 • 14:45
SiPh Self-coherent Transmitter Circuit with On-chip CSPR Control Capability Based on a Tunable Power Splitter, Zhenping Xing[1], David Patel[1], Eslam Elfiky[1], Meng Xiang[1], Rui Li[1], Md Ghulam Saber[1], Luhua Xu[1], Michael Hui[1], David Plant[1]; *[1]McGill Univ., Canada.* We present a novel CSPR controllable silicon photonic transmitter circuit based on a tunable power splitter for VSB self-coherent transmissions. 112 Gb/s 16 QAM over 80 km at a BER below 3.8×10^{-3} has been achieved.

Tu2H.4 • 15:00
Sub-fJ/bit Operation of 100 GBd Plasmonic IQ Modulators, Wolfgang Heni[2], Yuriy Fedoryshyn[2], Benedikt Baeuerle[2], Arne Josten[2], Claudia Hoessbacher[2], Andreas Messner[2], Christian Haffner[2], Yannick Salamin[2], Ueli Koch[2], Tatsuhiko Watanabe[2], Delwin Elder[1], Larry Dalton[1], Juerg Leuthold[2]; *[1]Department of Chemistry, Univ. of Washington, USA; [2]Inst. of Electromagnetic Fields (IEF), ETH Zurich, Switzerland.* A 100 GBd QPSK (200 Gbit/s) plasmonic IQ modulator operating with sub-1V drive voltages and low 0.6 fJ/bit electrical energy consumption is shown. Furthermore, 100 GBd 16QAM (400 Gbit/s) operation with 2 fJ/bit is demonstrated.

Room 8

Tu2I • Photonic Integration for Data Centers—Continued

Tu2I.4 • 15:00 Top Scored
400 Gbps PAM-4 Signal Transmission Using a Monolithic Laser Integrated Silicon Photonics Transmitter, Kangping Zhong[1], Jinyu Mo[1], Richard Grzybowski[3], Alan Pak Tao Lau[2]; *[1]Macom Technology Solutions Inc, China; [2]Eletrical Engineering, the Hong Kong Polytechnic University, Hong Kong; [3]MACOM Technology Solutions Inc., USA.* In this paper, we experimentally demonstrated a 400 Gbps PAM-4 monolithic laser integrated silicon photonics CWDM4 transmitter for 400GE short reach applications. 4x106 Gbps (400GE) PAM-4 signal transmission over 2 km of SMF with BER lower than KP4-FEC threshold is achieved.

Room 9

Tu2J • Filters and Couplers—Continued

Tu2J.4 • 15:00
Broadband-tunable Cascaded Vernier Silicon Photonic Microring Filter with Temperature Tracking, Yang Ren[1], David Perron[1], Fnu Aurangozeb[1], Zhiping Jiang[2], Masum Hossain[1], Vien Van[1]; *[1]Univ. of Alberta, Canada; [2]HUAWEI Canada Research Centre, Canada.* We report a 4th-order Vernier silicon microring filter consisting of two cascaded stages with 32 nm tuning range and better than 30 dB isolation. On-chip thermistors allow device temperature to be tracked with ±0.1°C accuracy.

Show Floor Programming

Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps
Session sponsored by Juniper
14:00–17:00, *Theater II*

The Disaggregated Transport Network
Telecom Infra Project (TIP)
14:30–15:30, *Theater III*

■ **MW Panel III:**
High Capacity Long Distance Optical Transport: Challenges and Business Reality
14:30–16:00, *Theater I*

Room 1

Tu2A • High Speed Silicon Photonics I—Continued

Tu2A.5 • 15:15
64-GBd DP-bipolar-8ASK Transmission over 120 km SSMF Employing a Monolithically Integrated Driver and MZM in 0.25-µm SiGe BiCMOS Technology, Gilda Raoof Mehrpoor[1,4], Carsten Schmidt-Langhorst[2], Benjamin Wohlfeil[1], Robert Elschner[2], Danish Rafique[1], Robert Emmerich[2], Annika Dochhan[1], Iria Garcia Lopez[3], Pedro Rito[3], Despoina Petousi[3], Dietmar Kissinger[3], Lars Zimmermann[3], Colja Schubert[2], Bernhard Schmauss[4], Michael Eiselt[1], Joerg-Peter Elbers[1]; *[1]Advanced Technology, ADVA Optical Networking SE, Germany; [2]Fraunhofer Heinrich Hertz Inst., Germany; [3]IHP GmbH, Germany; [4]LHFT, Friedrich-Alexander Univ. of Erlangen-Nuremberg, Germany.* We demonstrate 64-GBd signal generation up to bipolar-8-ASK utilizing a single MZM, monolithically integrated with segmented drivers in SiGe. Using polarization multiplexing, 300-Gb/s net data rate transmission over 120 km SSMF is shown.

Tu2A.6 • 15:30
A Single-mode Expanded Beam Separable Fiber Optic Interconnect for Silicon Photonics, Dirk Schoellner[1], Mike Hughes[1], Darrell Childers[1], Dan Kurtz[1], Ke Wang[1], Shubhrangshu Sengupta[1]; *[1]US Conec Ltd., USA.* An expanded beam optical interconnect is introduced that provides a separable connection between photonic integrated circuit and single-mode fiber. Insertion loss data are provided and stability through solder reflow is demonstrated.

Room 2

Tu2B • Optical Solutions for 5G—Continued

Tu2B.5 • 15:30 Invited
Low-complexity Self-coherent Transceivers for Metro, Access and Interdata Center Applications, Robert Killey[1], M. Sezer Erkılınç [2], Wenting Yi[1], Polina Bayvel[1]; *[1]Univ. College London, UK; [2]HHI Fraunhofer, Germany.* Low-complexity transceivers offering high spectral efficiency and dispersion tolerance will be required for short-haul links operating at 100 Gb/s per wavelength and beyond. Recent developments in self-coherent transceivers are described and future research directions suggested.

Room 3

Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs—Continued

Room 6C

Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1—Continued

Tu2D.4 • 15:30 Invited
Photonic Integrated Circuit Based Sensing Modules with Hybrid Integration in the Silicon Nitride TriPleX™ Platform, Arne Leinse[1], Douwe Geuzebroek[1]; *[1]LioniX International, Netherlands.* Silicon-Nitride based photonic integrated circuits enable biophotonic sensing platforms, allowing integration of multiple sensor elements over a broad wavelength range. Combined with (hybrid) integration of sources and detectors make it suitable for high end desktop and single use disposable applications.

Room 6D

Tu2E • AI in Network Operation 2—Continued

Tu2E.5 • 15:30
Field Demonstration of Real-time Optical Network Diagnosis Using Deep Neural Network and Telemetry, Takafumi Tanaka[1], Seiki Kuwabara[1], Hideki Nishizawa[1], Tetsuro Inui[1], Shoukei Kobayashi[1], Akira Hirano[1]; *[1]NTT Network Innovation Laboratories, Japan.* We demonstrate network diagnosis using deep neural network in the field fiber. Accurate and rapid optical fiber bend estimation is achieved with the help of streaming telemetry implemented in a whitebox packet transponder.

Room 6E

Tu2F • Short Reach II—Continued

Tu2F.6 • 15:30
4×288Gb/s Orthogonal Offset Carriers Assisted PDM Twin-SSB WDM Transmission with Direct Detection, Yixiao Zhu[1], Pengfei Wang[1], Mingxuan Jiang[1], Fan Zhang[1]; *[1]Peking Univ., China.* We demonstrate 4×288Gb/s direct detection transmission of WDM PDM Twin-SSB signals with orthogonal offset carriers. With Kramers-Kronig detection or joint signal-signal beat interference cancellation, the BERs of all the channels are below 20% HD-FEC Threshold.

Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1—Continued

Tu2H • Silicon Modulator—Continued

Tu2H.5 • 15:15
110 Gbit/s On-off Keying Transmitter Based on a Single-drive Polymer Modulator, Shiyoshi Yokoyama[1], Gui-Wei Lu[1,2], Xiaoyang Cheng[1], Feng Qiu[1], Andrew M. Spring[1]; *[1]Kyushu Univ., Japan; [2]Tokai Univ., Japan.* We demonstrate a 110Gbit/s OOK transmission using a hybrid silicon and polymer EO modulator with BER below FEC threshold. It has high thermal-stability, >100G operation bandwidth, 3.5dB extinction ratio and low driving-voltages of 3.5V.

Tu2H.6 • 15:30
Integrable Thin Film Lithium Niobate (TFLN™) on Silicon Electro-optic Modulators, Vincent Stenger[1], Andrea Pollick[1], Carl Acampado[1]; *[1]SRICO Inc., USA.* A thin film lithium niobate on silicon modulator is demonstrated with 2.5V Vpi, 50 GHz bandwidth, and < 0.5 dB/cm loss. An optimized design features < 5mm length, < 2V Vpi and 60 GHz bandwidth.

Tu2I • Photonic Integration for Data Centers—Continued

Tu2I.5 • 15:15
Genetic Algorithm Optimization of Multi Core Fibre Transmission Links Based on Silicon Photonic Transceivers, Alessandro Ottino[1], Arsalan Saljoghei[1], Tetsuya Hayashi[2], Tetsuya Nakanishi[2], Craig Kochis[3], Peter De Dobbelaere[3], Georgios Zervas[1]; *[1]Univ. College London (UCL), UK; [2]Optical Communications Laboratory, Sumitomo Electric Industries, Ltd., Japan; [3]Luxtera Inc., USA.* We demonstrate a genetic algorithm based system that can optimize optical interconnects using silicon photonic multi-core fibre coupled transceiver. The GA selects 48 parameters to deliver a minimum 6.94×10^{-16} BER on channels with diverse losses.

Tu2J • Filters and Couplers—Continued

Tu2J.5 • 15:15
Efficient Optical I/O in Standard Silicon Photonics Process, Argishti Melikyan[1], Ting-Chen Hu[1], Kwangwoong Kim[1], Yves Baeyens[1], Mark Earnshaw[1], Po Dong[1]; *[1]Nokia/Bell Labs, USA.* We demonstrate grating coupler based, efficient optical I/Os for silicon pho- tonic(SiPh) chip-to-fiber and chip-to-chip applications. Standard single-mode fiber(SSMF)- to-chip interface experimentally shows coupling efficiency of -1.3dB. The reported I/Os are fabricated in standard SiPh process.

Tu2J.6 • 15:30
Trident Shape SOI Metamaterial Fiber-to-chip Edge Coupler, Min Teng[1], Ben Niu[1], Kyunghun Han[1], Sangsik Kim[1], Yi Xuan[1], Yun Jo Lee[1], Minghao Qi[1]; *[1]Purdue Univ., USA.* We propose a fiber-to-chip edge coupler based on trident-shaped dielectric metamaterial. Experiment shows < 2 dB/facet coupling loss with high NA fiber and near 0.5 dB/facet coupling loss using lensed fiber at the best polarization.

Show Floor Programming

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14:30–15:30, *Theater III*

■ **MW Panel III:**
High Capacity Long Distance Optical Transport: Challenges and Business Reality
14:30–16:00, *Theater I*

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E
Tu2A • High Speed Silicon Photonics I—Continued	**Tu2B • Optical Solutions for 5G—Continued**	**Tu2C • Panel: Optical and RF Photonic Signal Processing Based on Frequency Combs—Continued**	**Tu2D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Application 1—Continued**	**Tu2E • AI in Network Operation 2—Continued**	**Tu2F • Short Reach II—Continued**
Tu2A.7 • 15:45 **Multi-core Fiber Socket-assisted Packaging for 84-channel Ultra-dense Silicon Photonics IO,** Gligor Djogo[1], Stephen Ho[1], Haque Moez[1], Erden Ertorer[1], Jianzhao Li[1], Jun Liu[2], Xiaolu Song[2], Jing Suo[2], Peter R. Herman[1]; *[1]Univ. of Toronto, Canada; [2]Huawei Technologies Co., Ltd., China.* A femtosecond-laser 3D structured silica chip with alignment sockets has permitted precise and compact packaging of multi-core fiber for edge coupling to silicon photonic chips, with average single-pass loss of ~5.6 dB over 84 channels.				**Tu2E.6 • 15:45** **Optical Signal Tracking for Robust PAM4 Deployment in Filterless Metro Network Scenarios,** Behnam Shariati[1], Francesco Fresi[2], Marc Ruiz[1], Filippo Cugini[2], Luis Velasco[1]; *[1]Universitat Politecnica de Catalunya, Spain; [2]CNIT, Italy.* Highly accurate and reliable optical signal tracking is proposed that estimates sub-GHz laser drift failures by analyzing spectra acquired by cost-effective coarse-granular OSAs. Its application on PAM4 systems in filterless metro networks brings added robustness.	

16:00–16:30 Coffee Break, *Upper Level Corridors and Exhibit Hall*

Room 6F	Room 7	Room 8	Room 9
Tu2G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 1—Continued	**Tu2H • Silicon Modulator—Continued**	**Tu2I • Photonic Integration for Data Centers—Continued**	**Tu2J • Filters and Couplers—Continued**
	Tu2H.7 • 15:45 **Characterizations of Semiconductor Optical Amplifiers for 64Gbaud 16-64QAM Coherent Optical Transceivers,** Jianying Zhou[1], Likai Zhu[1], Dave Wong[1], Huiling Wang[1], Marcel Boudreau[1], Jibin Sun[1], Jun Huang[1], Ping Wang[1], Guijun Ji[1], Jin Hong[1]; [1]*NeoPhotonics, USA.* We demonstrated semiconductor optical amplifiers capable of operating at 64Gbaud for 16-64QAM modulation with large dynamic ranges. The full characterizations of SOA as transmitter booster and receiver pre-amplifier for 400Gb/s to 600Gb/s applications were reported.		**Tu2J.7 • 15:45** **Broadband and Polarization Insensitive Surface Optical Coupler Using Vertically Curved Waveguides Fabricated with ArF-immersion Lithography,** Tomoya Yoshida[1], Yuki Atsumi[1], Emiko Omoda[1], Yoichi Sakakibara[1]; [1]*Electronics and Photonics Research Inst., National Inst. of Advanced Industrial Science and Technology (AIST), Japan.* Vertically-curved Si waveguide using 45nm-node ArF-immersion lithography and ion implantation bending method showed <2.5dB minimum coupling loss, >130nm/0.5dB spectrum bandwidth for 5μm-MFD fiber coupling in both TE- and TM-polarization with very small polarization dependence.

16:00–16:30 Coffee Break, *Upper Level Corridors and Exhibit Hall*

Show Floor Programming

Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps
Session sponsored by Juniper
14:00–17:00, *Theater II*

The Disaggregated Transport Network
Telecom Infra Project (TIP)
14:30–15:30, *Theater III*

■ **MW Panel III:**
High Capacity Long Distance Optical Transport: Challenges and Business Reality
14:30–16:00, *Theater I*

Innovation Opportunities in Transport Networks from Network Analytics and Machine-Learning
IEEE Future Directions
15:45–17:00, *Theater III*

Room 1

16:30–18:15
Tu3A • Laser Driving and VCSELS
Presider: Samuel Palermo; Texas A&M Univ., USA

Tu3A.1 • 16:30 Invited
High Capacity VCSEL Links, Stephen E. Ralph[1]; [1]*School of ECE, Georgia Inst. of Technology, USA*. Recent advances and remaining challenges for high capacity VCSEL based links are reviewed. A path to 800Gbps and greater single fiber links is described.

Room 2

16:30–18:30
Tu3B • PON Standards and Developments
Presider: Elaine Wong; Univ. of Melbourne, Australia

Tu3B.1 • 16:30 Tutorial
The Outlook for PON Standardization: 2019-2022, Jun Shan Wey[1]; [1]*ZTE (TX) Inc., USA*. This tutorial will review the driving forces shaping the new generations of PON systems in the coming years; and discuss the course of action in ITU-T and IEEE standards bodies to address the impending requirements.

After receiving a Ph.D. from the University of Maryland, College Park, Shan has devoted her career to optical communications R&D, and in particular PON standardization. She is currently a Director of Fixed Networks Technology Strategy and Standards at ZTE USA. Her prior affiliations include Terabeam, Myrio, Siemens, Nokia Siemens Networks, and Coriant. She is active in FSAN, ITU-T Q2/SG15, and IEEE 802.3ca; as an editor of G.sup.5GP (PON for 5G transport), G.9806 (BiDi PtP optical access), and the first edition of G.989.2 (NG-PON2 PMD). Shan chaired the OFC 2018 Optical Access Networks Subcommittee and is a designated Program Chair for OFC 2020.

Room 3

16:30–18:30
Tu3C • Panel: Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics

Photonics is expected to play a key role in space applications as optics and fiber-optics penetrates into satellite payloads and photonic components and sub-systems become integral functional parts of telecommunication, on-board signal distribution and/or remote sensing instrumentation. The FCC has received more than 15 applications for constellations with several confirmed inter-satellite link designs relying on laser communications. On the other hand, space instrument science increasingly uses optics and photonics (e.g. fiber-based instruments) for Earth observation and astronomical exploration with operational requirements in extreme environments. The panel will discuss the technology development requirements, qualification deltas, cost targets and ground-based infrastructure required for volume manufacturing and/or integration of space photonic hardware. We will also analyze the challenges in designing and developing new generation of photonic instruments.

Speakers:

Don Cornwell, *NASA-HQ, USA*
Laser Communications and Astrophysics in 2030

Melanie Ott, *NASA-GSFC, USA*
Developing and Qualifying Space Hardware

Rizwan Parvez, *BRIDGESAT, USA*
Building High-speed Data Links from Space to Ground

Elisabetta Rugi, *Thales Alenia Space CH, Switzerland*
Laser Terminals for the Masses

Room 6C

16:30–18:30
Tu3D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications 2

Tu3D.1 • 16:30 Invited
Towards 1 Billion Sensors: Distributed Fibre Sensing as a Pervasive IOT Contributor, Chris Minto[1,2], Etienne Rochat[2,3]; [1]*OptaSense, UK;* [2]*Fiber Optic Sensing Association, USA;* [3]*Omnisens, Switzerland*. Fiber Optic Sensing creates thousands of virtual sensors over long distances. In 2017 we recorded 3 million sensors providing temperature, strain or acoustics covering >30,000km. This paper introduces these technologies and plots a future of >1bn of connected sensors.

Room 6D

16:30–18:30
Tu3E • Photonic Integrated Circuits and Novel Technology
Presider: Maura Raburn; Google, USA

Tu3E.1 • 16:30 Invited
Realities and Challenges of III-V/Si Integration Technologies, John E. Bowers[1], Duanni Huang[1], Daehwan Jung[1], Justin Norman[1], Minh Tran[1], Yating Wan[1], Weiqiang Xie[1]; [1]*Univ. of California Santa Barbara, USA*. The complexity of photonic integrated circuits has progressed rapidly, but serious problems remain to be solved to enable widespread application in Tbps transceivers and optical scanners. A summary of progress, problems and potential solutions is provided.

Room 6E

16:30–18:30
Tu3F • Wideband Transmission
Presider: Antonio Napoli; Infinera Corporation, Germany

Tu3F.1 • 16:30
Impact of the Number of Channels on the Induced Nonlinear Distortions in Ultra-wideband SOAs, Aymeric Arnould[1], Dylan Le Gac[1], Amirhossein Ghazisaeidi[1], Patrick Brindel[1], Mathilde Makhsiyan[2], Karim Mekhazni[2], Fabrice Blache[2], Helene Debregeas[2], Mohand Achouche[2], Gabriel Charlet[1], Jeremie Renaudier[1]; [1]*Nokia Bell Labs, France;* [2]*III-V lab, France*. We report on the impact of wavelength division multiplexed (WDM) channel count onto the nonlinear distortions induced by an ultra-wideband (UWB) semiconductor optical amplifier (SOA). We demonstrate experimentally that UWB SOA devices are well suited for wideband WDM signal amplification.

Tu3F.2 • 16:45 Top Scored
107 Tb/s Transmission of 103-nm Bandwidth over 3x100 km SSMF Using Ultra-wideband Hybrid Raman/SOA Repeaters, Jeremie Renaudier[1], Aymeric Arnould[1], Dylan Le Gac[1], Amirhossein Ghazisaeidi[1], Patrick Brindel[1], Mathilde Makhsiyan[2], Agnes Verdier[2], Karim Mekhazni[2], Fabrice Blache[2], Helene Debregeas[2], Aurelien Boutin[3], Nicolas K. Fontaine[1], David T. Neilson[1], Roland Ryf[1], Haoshuo Chen[1], Mohand Achouche[2], Gabriel Charlet[1]; [1]*Nokia Bell Labs, France;* [2]*III-V Lab, France;* [3]*Kylia, France*. We report on the ultra-wideband transmission of 254 PCS-64QAM channels over 300 km of SSMF. We demonstrate a 107-Tb/s transmission throughput over a continuous 103 nm optical bandwidth using backward Raman pumping and SOA technology.

Room 6F

16:30–18:30
Tu3G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 2

Speakers:
Part II: Hardware Evolution

Invited **How AI and Data Science Drive the Need for Novel Connectivity,** Larry Dennison, *Nvidia, USA*. Two emerging applications, AI and Data Science, see both performance and economic benefit from networked accelerators such as GPUs, FPGAs and custom ASICs. We explore the application requirements for novel direct accelerator-to-accelerator communication networks.

Invited **Evolution of Data Center Switches and Optical Interconnects,** Mitchell Fields, *Broadcom Inc., USA*. For several generations of data centers, interconnect bandwidth growth was enabled by enhancements to electrical and optical technologies. This presentation explores the past, present, and potential future enabling technologies for data center interconnects.

Invited **High-density Silicon Photonics for In-package Optics,** Andrew Rickman, *Rockley Photonics, USA*. Silicon-photonics-based In-Package Optics promises to overcome the barriers of cost, density and power that impede progress in datacenter networks. Adopting a multi-micron technology platform improves the prospects of simultaneously meeting the requirements of performance and manufacturability.

Room 7

16:30–18:30
Tu3H • Control of Disaggregated Networks
Presider: Filippo Cugini; CNIT, Italy

Tu3H.1 • 16:30 Invited
Optical Network Control & Management Plane Evolution - A Large Datacenter Operator Perspective, Vijay Vusirikala[1], Eric Breverman[1], Tad Hofmeister[1], Anees Shaikh[1], Nancy El-sakkary[1]; [1]*Google, USA*. Legacy management technologies and concepts are a major blocker to efficiently building and operating a large scale optical network. We provide an overview of new, modern device management technologies and discuss deployment and operational efficiencies that they enable.

Room 8

16:30–18:30
Tu3I • Microwave Photonic Chip-scale Subsystems
Presider: Hiroshi Murata; Mie Univ., Japan

Tu3I.1 • 16:30
0-40 GHz-Tunable RF Receivers on Chip Exploiting a Noise-cancelling Architecture and a Silicon Photonic Modulator, Daniel Onori[1], Benjamin G. Crockett[1], Alireza Samani[2], David Plant[2], Jose Azana[1]; [1]*Énergie, Matériaux et Télécommunications, Institut National de la Recherche Scientifique, Canada;* [2]*Electrical and Computer Engineering, McGill Univ., Canada*. A widely-tunable RF receiver based on a novel digital feed-forward noise cancellation technique and a silicon photonic modulator is presented. Its capabilities, in terms of bandwidth, linearity, and on-chip integration trough silicon-on-insulator technology are analyzed.

Tu3I.2 • 16:45
Microwave Photonic Links: Optimizing SiP Modulator Design and Operation, Christian G. Bottenfield[1], Varghese A. Thomas[1], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA*. We experimentally demonstrate improved microwave photonic link performance by optimizing integrated modulator biases and show that plasma-dispersion modulators may achieve intrinsic linearity on par with lithium niobate modulators with link SFDRs greater than 100 dB-$Hz^{2/3}$.

Room 9

16:30–18:00
Tu3J • Transmission Fibers and Cables
Presider: Wladek Forysiak; Aston Univ., UK

Tu3J.1 • 16:30 Invited
Practical Aspects of G.654.E Fibers for Terrestrial Long Haul Transmission, Yoshinori Yamamoto[1]; [1]*Sumitomo Electric Industries, Ltd., Japan*. We review G.654.E fibers with low loss and large A_{eff} for terrestrial long haul transmissions in particular emphasis on addressing practical issues on terrestrial cabling, low splice loss, and applicability of Raman amplification.

Show Floor Programming

Coherent Equivalence Beyond 400G – Milestones And Industry Guidance For Aligning Technology Roadmaps
Session sponsored by Juniper
14:00–17:00, *Theater II*

Innovation Opportunities in Transport Networks from Network Analytics and Machine-Learning
IEEE Future Directions
15:45–17:00, *Theater III*

Room 1

Tu3A • Laser Driving and VCSELS—Continued

Tu3A.2 • 17:00 Top Scored

A 50Gb/s PAM-4 Retimer-CDR + VCSEL Driver with Asymmetric Pulsed Pre-emphasis Integrated into a Single CMOS Die, Shang Hu[1], Tingyu Yao[1], Bozhi Yin[1], Lei Zhao[1], Chunyu Song[1], Patrick Chiang[1], Nan Qi[2]; *[1]Fudan Univ., China; [2]Inst. of Semiconductors, Chinese Academy of Sciences, China.* A 50 Gb/s PAM-4 Retimer-CDR + VCSEL driver is fully-integrated in a 40nm CMOS process. Measurement results demonstrate wide optical eye openings using a 16GHz bandwidth VCSEL, achieving > 4 dB extinction ratio and < 8 pJ/bit energy efficiency.

Tu3A.3 • 17:15

VCSEL with Bi-layer Oxidized Aperture Enables 140-Gbit/s OFDM Transmission over 100-m-long OM5 MMF, Wei-Li Wu[1,2], Cheng-Yi Huang[1,2], Huai-Yung Wang[1,2], Yu-Hong Lin[1,2], Cheng-Han Wu[3], Hao-Chung Kuo[4], Wood-Hi Cheng[5], Chao-Hsin Wu[1], Milton Feng[6], Gong-Ru Lin[1,2]; *[1]Graduate Inst. of Photonics and Optoelectronics, and Department of Electrical Engineering National Taiwan Univ., Taiwan; [2]NTU-Tektronix Joint Research Center, National Taiwan Univ. and Tektronix Inc., Taiwan; [3]Graduate Inst. of Electronics Engineering, and Dept. of Electrical Engineering, Taiwan; [4]Dept. of Photonics, National Chiao-Tung Univ., Taiwan; [5]Graduate Inst. of Optoelectronic Engineering, Dept. of Electrical Engineering, National Chung Hsing Univ., Taiwan; [6]Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA.* A few-mode 850-nm VCSEL chip directly modulated by 16-QAM OFDM data at 140 Gbit/s is demonstrated to enable error-free transmission over 100-m-long OM5 MMF with 3.1-dB power penalty compared to the back-to-back case.

Room 2

Tu3B • PON Standards and Developments—Continued

Room 3

Tu3C • Panel: Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics—Continued

Paul Serra, **MIT, USA**
Miniaturizing Laser Terminals

John Shuster, *LEOSAT, Netherlands*
Optical Networks in the Sky

Morio Toyoshima, *NICT, Japan*
Space Photonics: Trends, Applications and Societal Impact

Room 6C

Tu3D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications 2—Continued

Tu3D.2 • 17:00 Invited

Laser Eyes for Driverless Cars: The Road to Automotive LIDAR, Cibby Pulikkaseril[1], Stanley Lam[1]; *[1]Baraja, Australia.* Automotive LIDAR is one of the primary sensors for fully autonomous vehicles, and the performance requirements of these sensors places challenges on the optical technologies used in the device. We analyze the requirements for automotive LIDAR and then suggest a novel taxonomy of classifying different beamsteering methods.

Room 6D

Tu3E • Photonic Integrated Circuits and Novel Technology—Continued

Tu3E.2 • 17:00

Fully Integrated Stokes Vector Receiver for 400 Gbit/s, Moritz Baier[1], Francisco M. Soares[1], Axel Schoenau[1], Y Durvasa Gupta[1], David Melzer[1], Martin Schell[1]; *[1]Fraunhofer HHI, Germany.* We propose and demonstrate a new photonic integrated circuit (PIC) design for Stokes vector reception. Its accuracy is 2.5° across the entire Poincaré sphere and almost than the entire C-band.

Tu3E.3 • 17:15

Demonstration of Ge/Si Avalanche Photodetector Arrays for Lidar Application, Yu Li[1,2], Xianshu Luo[1], Gang Liang[1], Guo-qiang Lo[1]; *[1]Advanced Micro Foundry Pte. Ltd., Singapore; [2]Inst. of Microelectronics, ASTAR, Singapore.* We report Ge-on-Si APD arrays with up to 10-by-10 pixels at 1550nm. Our demonstration reveals highly uniform responsivity of ~3.3 A/W with <7% variation. The bandwidth is 9GHz and 0.7GHz for single and 10×10 array.

Room 6E

Tu3F • Wideband Transmission—Continued

Tu3F.3 • 17:00

74.38 Tb/s Transmission over 6300 km Single Mode Fiber with Hybrid EDFA/Raman Amplifiers, Maria Ionescu[1], Domaniç Lavery[2], Adrian Edwards[1], Eric Sillekens[2], Lidia Galdino[2], Daniel Semrau[2], Robert Killey[2], Wayne Pelouch[3], Stuart Barnes[1], Polina Bayvel[2]; *[1]Xtera, UK; [2]Electrical and Electronic Engineering, Univ. College London, UK; [3]Xtera, USA.* Transmission of 306×35 GBd, dual polarization, 64-ary geometrically shaped channels over 90×70 km of SMF was demonstrated, achieving a net throughput of 74.38 Tb/s. A combination of hybrid fiber spans and EDFA/Raman amplifiers enabled a continuous gain bandwidth of 10.8 THz.

Tu3F.4 • 17:15

Performance Estimation of Discrete Raman Amplification within Broadband Optical Networks, Lukasz krzczanowicz[1], Mohammad Al-Khateeb[1], Md A. Iqbal[1], Ian Phillips[1], Paul Harper[1], Wladek Forysiak[1]; *[1]Aston Univ., UK.* The nonlinear impact of discrete Raman amplifiers on transmission in wideband systems is analyzed theoretically and tested experimentally. At double EDFA bandwidth, predicted reach of >3400km, indicates a distance penalty of ~30% versus EDFA systems.

Tu3G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 2—Continued

Tu3H • Control of Disaggregated Networks—Continued

Tu3H.2 • 17:00 Invited
ONOS-Controlled Disaggregated Optical Networks, Alessio Giorgetti[1,4], Ramon Casellas[5], Roberto Morro[2], Andrea Campanella[3], Piero Castoldi[1,4]; [1]*Scuola Superiore Sant Anna di Pisa, Italy;* [2]*TIM, Italy;* [3]*ONF, USA;* [4]*CNIT, Italy;* [5]*CTTC, Spain*. State-of-art, potentials and limitations of the ONOS controller applied to disaggregated optical networks are reported. Focus is on the on-going ODTN project. Results of experimental demonstrations are reported to prove the feasibility of proposed approach.

Tu3I • Microwave Photonic Chip-scale Subsystems—Continued

Tu3I.3 • 17:00 Invited
Microwave Photonic Subsystems-on-chip, Siva Yegnanarayanan[1], Dave Kharas[1], Jason Plant[1], Cheryl Sorace-Agaskar[1], Paul Juodawlkis[1]; [1]*Massachusetts Inst. of Tech Lincoln Lab, USA*. Microwave photonic subsystems are rapidly evolving from discrete to chip-scale implementations, enabled by the tight integration of active/passive photonic integrated circuits into multi-chip-modules. This paper reviews the recent advances in this field.

Tu3J • Transmission Fibers and Cables—Continued

Tu3J.2 • 17:00
Long-term Latency Measurement of Deployed Fiber, Florian Azendorf[1], Annika Dochhan[1], Ralf-Peter Braun[2], Michael Eiselt[1]; [1]*ADVA Optical Networking, Germany;* [2]*Deutsche Telekom, Germany.* Using a Correlation-OTDR we measured the latency of fibers in a deployed cable and calculated the time coefficient of the fiber temperature changes. Annual temperature variations of 25K were estimated for the deployed fiber.

Tu3J.3 • 17:15
Observation and Compensation of Guided Acoustic-wave Brillouin Scattering in Modulated Channels, Milen Paskov[1], Maxim A. Bolshtyansky[1], Jin-Xing Cai[1], Carl Davidson[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; [1]*TE SubCom, USA.* We explore the SNR penalty introduced by GAWBS over trans-oceanic distances. A digital compensation technique is proposed, and its limitations are investigated. In simulations we demonstrate an uncompensated penalty of 0.4 dB after 7000 km.

Room 1

Tu3A • Laser Driving and VCSELS—Continued

Tu3A.4 • 17:30 Invited

Tunable Laser Drivers for Next Generation WDM-Based PON Networks, Tao Zhang[1]; [1]*Google, USA*. This paper reviews the tunable lasers and their driving circuits to address challenges of the biasing and wavelength excursion reduction for next generation TWDM-PON systems, including NG-PON2 and the recent Super-PON effort in IEEE802.3.

Tu3A.5 • 18:00

53-Gbaud PAM4 Differential Drive of a Conventional EA/DFB toward Driver-amplifier-less Optical Transceiver, Koichiro Adachi[1], Takayoshi Fukui[1], Masato Shishikura[1], Akira Nakanishi[1], Atsushi Nakamura[1], Takanori Suzuki[1], Shigehisa Tanaka[1]; [1]*Lumentum, Japan*. 53-Gbaud-PAM4 differential drive of a conventional EA/DFB was demonstrated. Almost the same waveform as single-ended drive was confirmed with outer ER of 4.1 dB and TDECQ of 1.63 dB by differential drive with 0.57 V_{pp}/lane.

Room 2

Tu3B • PON Standards and Developments—Continued

Tu3B.2 • 17:30 Invited

Lessons Learned from NG-PON2 Systems Developments and Deployment, Hal Roberts[1], Nicholas Proite[1], Pete Lee[1], Christopher Smith[1]; [1]*Calix Inc., USA*. TWDM-PON introduced the first standardized use of DWDM channels in burst mode and as such introduced new optical challenges. How these challenges were met, and the lessons learned along the way will be described.

Tu3B.3 • 18:00

Real-time Rogue ONU Identification with 1D-CNN-based Optical Spectrum Analysis for Secure PON, Yanlong Li[2,1], Nan Hua[2,1], Chen Zhao[2,1], Haotao Wang[2,1], Ruijie Luo[2,1], Xiaoping Zheng[2,1]; [1]*Department of Electronic Engineering, Tsinghua Univ., China;* [2]*BNRist, China*. We proposed a real-time optical spectrum analysis method with one-dimensional convolutional neural network to identify rogue ONUs in PON. Experimental results show that 100% rogue ONU identification accuracy is achieved within 12.6 milliseconds on average.

Room 3

Tu3C • Panel: Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics—Continued

Room 6C

Tu3D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications 2—Continued

Tu3D.3 • 17:30 Invited

Mid-infrared Dual-comb Spectroscopy with Interband- and Quantum-cascade Lasers – Recent Progress towards Integrated Photonics Chemical Sensing, Gerard Wysocki[1]; [1]*Princeton Univ., USA*. This paper will present recent results in chemical sensing using a chip-scale mid-infrared dual-comb spectroscopy systems and their potential for future system integration.

Tu3D.4 • 18:00 Invited

Integrated Nanophotonic Biosensors for Point-of Care Diagnostics and Bioanalytical Applications, Filiz Yesilkoy[1], Alexander Belushkin[1], Yasaman Jahani[1], Roland Terborg[2], Xiaokang Li[1], Valerio Pruneri[2], Hatice Altug[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland;* [2]*The Inst. of Photonic Sciences, Spain*. In an effort to address the requirements of next-generation healthcare systems, including personalized medicine, point-of-care diagnostics, and global health surveillance, I will introduce imaging-based portable nanoplasmonic biosensors integrated with microfluidic systems for various bioanalytical applications.

Room 6D

Tu3E • Photonic Integrated Circuits and Novel Technology—Continued

Tu3E.4 • 17:30 Invited

Computationally-optimized Ultra-compact Nanophotonics, Rajesh Menon[1]; [1]*Univ. of Utah, USA*. Computational techniques, such as nonlinear optimization, when guided by manufacturing constraints, can result in highly practical, robust, CMOS-compatible, ultra-compact (on the order of the wavelength) and multi-functional integrated- photonics components.

Tu3E.5 • 18:00 Invited

Large-scale Monolithic Optical Phased Arrays, Hossein Hashemi[1]; [1]*Univ. of Southern California, USA*. This paper covers architectures, devices, recent advancements, and selected remaining challenges towards large-scale monolithic optical phased arrays with emphasis on silicon process.

Room 6E

Tu3F • Wideband Transmission—Continued

Tu3F.5 • 17:30 Invited

Recent Advances in Ultra-wideband WDM Transmission Based on Semiconductor Optical Amplifiers, Jeremie Renaudier[1]; [1]*Nokia Bell Labs, France*. We report on the use of semiconductor optical amplifiers to enlarge optical bandwidth of next generation WDM systems. We review recent results, including lab demonstration and field trial, based on novel 100+nm-wide SOA device.

Tu3F.6 • 18:00

PDM-16QAM WDM Transmission with 2nd-order Forward-pumped Distributed Raman Amplification Utilizing Incoherent Pumping, Takayuki Kobayashi[1], Masahito Morimoto[2], Haruki Ogoshi[2], Junji Yoshida[2], Shigehiro Takasaka[2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*Furukawa Electric Co., Ltd., Japan*. We experimentally shows second-order forward Raman pumping scheme combined with incoherent- and coherent- light sources can achieve 1.6-dB Q-improvement of PDM-16QAM signal in WDM configuration while keeping low RIN transfer after 1,760-km standard SMF transmission.

Tu3G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 2—Continued

Tu3H • Control of Disaggregated Networks—Continued

Tu3H.3 • 17:30 Top Scored

Enabling Network Slicing across a Disaggregated Optical Transport Network, Ramon Casellas[1], Alessio Giorgetti[2], Roberto Morro[3], Ricardo Martinez[1], Ricard Vilalta[1], Raul Muñoz[1]; [1]*CTTC, Spain;* [2]*Scuola Santa'Anna Pisa, Italy;* [3]*TIM, Italy.* We propose and implement a network virtualization architecture for open optical (partially) disaggregated networks, based on a device hypervisor and OpenConfig and OpenROADM data models, in support of 5G network slicing over interconnected NFVI-PoPs

Tu3H.4 • 17:45

OpenConfig Control of 100G/400G Filterless Metro Networks with Configurable Modulation Format and FEC, Francesco Paolucci[1], Andrea Sgambelluri[1], Robert Emmerich[2], Alessio Giorgetti[1], Piero Castoldi[1], Colja Schubert[2], Johannes Fischer[2], Filippo Cugini[3]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*Heinrich Hertz Inst., Fraunhofer Inst. for Telecommunications, Germany;* [3]*CNIT, Italy.* OpenConfig YANG extensions are proposed to enable dynamic selection of transmission parameters of 100G/400G transmitters with coherent reception in a filterless metro network. Data and control plane experimental validations exploiting the ONOS controller are provided.

Tu3H.5 • 18:00

Submilisecond Control/Monitoring of Disaggregated Optical Node through a Direct Memory Access Based Architecture, Kiyo Ishii[1], Shigeyuki Yanagimachi[2], Akio Tajima[2], Shu Namiki[1]; [1]*National Inst. of Advanced Industrial Science and Technology, Japan;* [2]*System Platform Research Laboratories, NEC Corporation, Japan.* Sharing and updating the monitoring and configuration data of disaggregated optical components through DMA enables a fast, flexible, and scalable node or network control architecture. Control plane communication cycle of 400 us is experimentally demonstrated.

Tu3I • Microwave Photonic Chip-scale Subsystems—Continued

Tu3I.4 • 17:30 Tutorial

Programmable Integrated Optical Signal Processors: Toward Next-generation Signal Processing Engine in Communication Devices, Leimeng Zhuang[1]; [1]*imec USA (Florida), USA.* Having programmable integrated optical signal processors in communication devices means the potential for performing software-defined signal processing tasks with order-of-magnitude improvement in bandwidth, latency, and power efficiency. I review worldwide efforts on this exciting topic.

Leimeng Zhuang is dedicated to R&D activities of implementation and application of photonic integrated circuits (PICs). He is currently with imec USA (Florida), working on PIC solutions for imaging, sensing, and communication systems, such as LiDAR, THz imager, Nyquist-WDM ROADM, and general-purpose optical signal processors.

Tu3J • Transmission Fibers and Cables—Continued

Tu3J.4 • 17:30 Invited

Technical Considerations for Pairing Very Low Loss Fiber and Cable, Jon Fitz[1]; [1]*Prysmian Group, USA.* Very Low Loss single-mode fibers offer improvements in optical loss and/or latency. However, capturing their full benefit requires careful selection of both cable design and loss specifications. This paper outlines technical considerations to guide this process.

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E
Tu3A • Laser Driving and VCSELS—Continued	**Tu3B • PON Standards and Developments—Continued**	**Tu3C • Panel: Space Photonics: Disruptive Satellite Laser Communications and Astrophotonics—Continued**	**Tu3D • Symposia: Photonics for IoT and Sensing: Manufacturing, Packaging and Applications 2—Continued**	**Tu3E • Photonic Integrated Circuits and Novel Technology—Continued**	**Tu3F • Wideband Transmission—Continued**
	Tu3B.4 • 18:15 **In-service Software Updating without Packet Loss for a Time-critical Function on Optical Access Network System,** Takumi Harada[1], Takashi Yamada[1], Hirotaka Ujikawa[1], Hiroyuki Uzawa[1], Jun-ichi Kani[1], Jun Terada[1]; *[1]NTT Access Network Service System Laboratories, Japan.* We propose an in-service software updating method for optical access network equipment. The method is implemented and confirmed to update OLT software within 15 micro-seconds without packet loss.				**Tu3F.7 • 18:15** **Pilot Aided Compensation of Relative Phase Noise in Raman Amplified Coherent Transmission System with Forward Pumping,** Govind Vedala[1], Youichi Akasaka[2], Tadashi Ikeuchi[2], Rongqing Hui[1]; *[1]The Univ. of Kansas, USA; [2]Fujitsu Laboratories of America, Inc, USA.* We demonstrate pilot aided compensation of Relative Phase Noise (RPN) in a forward pumped Raman amplified fiber system which effectively eliminates the error floor that arises when conventional phase noise compensation algorithms track RPN

17:00–18:30 Exhibitor Happy Hour, *Center Terrace*

18:30–20:00 Conference Reception, *Ballroom 20BCD*

19:30–21:30 Rump Session, *Room 6D*

Tu3G • Special Chairs' Session: The Role of Optics in Future Data Center and Computing Applications 2—Continued

Tu3H • Control of Disaggregated Networks—Continued

Tu3H.6 • 18:15
Multi-layer Service Provisioning over Resilient Software-defined Partially Disaggregated Networks, Arturo Mayoral[1], Victor López[2], Manuel López Bravo[2], Diego Garcia Montes[2], Oscar González de Dios[2], Alejandro Aguado Martin[3], Rafal Szwedowski[4], Konrad Mrówka[4], Fabio Marques[5], Zdravko Stevkovski[5], Quan Pham Van[7], Dominique Verchere[7], Lubo Tancevski[6], Juan Pedro Fernandez Palacios[2]; [1]*Theory of Signal and Telecommunications, Universitat Politécnica de Catalunya, Spain;* [2]*Telefonica I+D/Global CTIO, Spain;* [3]*Universidad Politécnica de Madrid, Spain;* [4]*ADVA Optical Networking, Germany;* [5]*Infinera, Portugal;* [6]*Nokia (US/Plano), USA;* [7]*Nokia Bell Labs, France.* This paper demonstrates a partially disaggregated network solution, completely based on standard interfaces integrated into the Software Defined Transport Network architecture. A proof-of-concept of multi-layer service provisioning over resilient disaggregated multi-vendor testbed is presented.

Tu3I • Microwave Photonic Chip-scale Subsystems—Continued

Tu3J • Transmission Fibers and Cables—Continued

17:00–18:30 Exhibitor Happy Hour, *Center Terrace*

18:30–20:00 Conference Reception, *Ballroom 20BCD*

19:30–21:30 Rump Session, *Room 6D*

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00 W1A • Panel: PIC Foundry Commercial Access: Prospects and Challenges

The generic foundry approach leads to a revolution in micro and nanophotonics, just as it did in microelectronics thirty years ago. Generic integration leads to a drastic reduction in the entry costs for developing Photonic Integrated Circuits. Integrated circuits using generic integration open up a whole new range of applications including data communications, fiber-to-the-home, fiber sensors, gas sensing, medical diagnostics, metrology and consumer photonics. Present prospects and challenges of Silicon and InP-based photonic foundry technology are being addressed.

Speakers:

Philippe Absil, *IMEC VZW, Belgium*

Luc Augustin, *SMART Photonics B.V., Netherlands*

Graham Barry, *Huawei Lab, UK*

Robert Blum, *Intel Corp., USA*

Albert Hasper, *PHIX Photonics Assembly, Netherlands*

Michael Hochberg, *Elenion Technologies LLC, USA*

Edward Preisler, *Tower Jazz, USA*

08:00–10:00 W1B • Comb Sources and Applications

Presider: Frank Peters; Univ. College Cork, Ireland

W1B.1 • 08:00 **Tutorial**

Optical Frequency Combs: General Concepts as Well as on-chip and Quantum Perspectives, Christian Reimer[1]; [1]*Harvard Univ., USA*. I will give an overview over the working principles and applications of laser-based, electro-optic and Kerr frequency combs. I will then discuss on-chip frequency combs, including basic techniques for their numerical simulation, and highlight some of the recent achievements as well as ongoing challenges. Finally, I will summarize recent research showing that optical frequency combs can possess powerful quantum properties, which can find applications in quantum communications and computation.

Christian Reimer is an early-career physicist working in the field of nonlinear optics, integrated photonics and quantum optics, having worked on integrated classical and quantum frequency combs, as well as mode-locked lasers. He received graduate degrees from the Karlsruhe Institute of Technology in Germany, Heriot-Watt University in Scotland, and

08:00–10:00 W1C • Nonlinear Processes and Devices

Presider: Francesca Parmigiani; MICROSOFT Research, Cambridge, UK

W1C.1 • 08:00 **Top Scored**

Electrically Driven Photonic Integrated Soliton Microcomb, Arslan Raja[1], Andrey S. Voloshin[2], Hairun Guo[1], Sofya E. Agafonova[2,3], Junqiu Liu[1], Alexander S. Gorodnitsky[2,3], Maxim Karpov[1], Nikolay G. Pavlov[2,3], Erwan Lucas[1], Ramzil R. Galiev[2,4], Artem E. Shitikov[2,4], John D. Jost[1,5], Michael L. Gorodetsky[2,4], Tobias Kippenberg[1]; [1]*École Polytechnique Fédérale de Lausanne, Switzerland;* [2]*Russian Quantum Center, Russia;* [3]*Moscow Inst. of Physics and Technology, Russia;* [4]*Faculty of Physics, M.V. Lomonosov Moscow State Univ., Russia;* [5]*MicroR Systems Sarl, Switzerland*. We demonstrate via self-injection locking an electrically driven soliton microcomb by coupling a multi-frequency laser diode to a chip-scale high-Q Si3N4 microresonator. This approach offers a pathway for an integrated and ultra-compact microcomb source for high-volume applications e.g. coherent telecommunication and data-center interconnects.

W1C.2 • 08:15 **Top Scored**

Ultralow-power Chip-based Soliton Microcombs for Photonic Integration, Junqiu Liu[1], Arslan Raja[1], Maxim Karpov[1], Nils Engelsen[1], Hairun Guo[1], Tobias Kippenberg[1], Anton Lukashchuk[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland*. Using the photonic Damascene reflow process, we present single soliton formation in 99-GHz-FSR silicon nitride microresonators of Q-factor exceeding 15 million, with less than 10 mW optical power.

08:00–10:00 W1D • Probabilistic Shaping II

Presider: Timo Pfau; Acacia Communications Inc., USA

W1D.1 • 08:00 **Invited**

Non-orthogonal WDM Systems with Faster Than Nyquist Technology, Liangchuan Li[1], Zhiyu Xiao[1], Ling Liu[1], Yanzhao Lu[1]; [1]*Huawei Technologies Co. Ltd., China*. We propose the concept of non-orthogonal WDM and review the principle of FTN. Performance comparison between FTN and constellation shaping is presented. Simulation results of FTN-CS-QAM are shown to support the evolution of 400G WDM

08:00–09:45 W1E • Silicon Photonics Switch

Presider: Giampiero Contestabile; Scuola Superiore Sant Anna di Pisa, Italy

W1E.1 • 08:00

Fast and Wide-range Wavelength Locking Based on a Two-layer Neural Network in a Silicon Microring Switch, Qingming Zhu[1], Shaohua An[1], Ruiyuan Cao[1], Yuye Ling[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China*. We propose and experimentally demonstrate a neural-network-based wavelength locking algorithm for a 1 × 2 silicon microring switch. The wavelength locking is performed at a 20-nm/ms locking speed over a full free spectral range.

W1E.2 • 08:15 **Top Scored**

A Nonblocking 4×4 Mach-Zehnder Switch with Integrated Gain and Nanosecond-scale Reconfiguration Time, Nicolas Dupuis[1], Fuad Doany[1], Russell Budd[1], Laurent Schares[1], Christian Baks[1], Dan Kuchta[1], Takako Hirokawa[1], Benjamin G. Lee[1]; [1]*IBM TJ Watson Research Center, USA*. We present a silicon photonic switch assembly integrating a nonblocking 4×4 Mach-Zehnder switch and a flip-chipped SOA array. The switch provides close to net-neutralloss in the full C-band for all states and shows nanosecond-scale reconfiguration time.

08:00–10:00 W1F • Intra and Interdata Center Links

Presider: Katharine Schmidtke; Facebook Inc., USA

W1F.1 • 08:00 **Invited**

Energy Consumption Modelling of Coherent Transmission in Data Centers, Rodney S. Tucker[1]; [1]*Univ. of Melbourne, Australia*. We analyze energy consumption of coherent transmitters and receivers for intra- and inter-data center links and model trends in energy consumption of global-scale data center networks as the volume of traffic increases.

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00 W1G • SDN/NFV

Presider: Ramon Casellas; CTTC, Spain

W1G.1 • 08:00 Invited

Applications of SDN-enabled Optical Transport Networks and Cloud/Edge Computing Technology, Noboru Yoshikane[1]; [1]*KDDI Research, Japan.* This paper reviews the current R&D status of edge computing technology. Furthermore, this paper introduces remote control of an industrial robot performing surface blending by jointly employing SDN-enabled optical transport networks and cloud/edge computing.

08:00–10:00 W1H • Panel: SDM Technology Solutions for Next Generation Submarine

The field of submarine system design is always in search of new cost-effective, power-efficient, and highly reliable approaches to increasing overall cable capacity. Significant recent advances have been made in this area by the addition of transmission bands and fiber pairs per cable, and by new design paradigms for power-efficient optimization of total cable capacity.

Multi-core fiber technology could be the next likely step in undersea cable design to support the rapid increases in internet capacity, with up to 500 Tbit/s per fiber demonstrated over trans-Pacific distances in the laboratory. Multi-core fiber solutions also provide higher physical density, a key characteristic for space-limited submarine equipment. The power-efficient and cost-effective amplification approaches required for multi-core fiber transmission systems are an ongoing area of research.

The focus of this panel will be the challenges and solutions for implementing massive spatial and spectral multiplexing SDM technology within the unusual design constraints of undersea cable systems. Speakers from fiber and optical component suppliers, submarine system providers, and network owners will present their views on the evolution of high-capacity submarine transmission systems, and whether multi-core transmission technologies will play a role in that future.

Speakers:

Olivier Courtois, *Alcatel Submarine Networks, France*

Herve Fevrier, *Facebook, USA*

08:00–10:00 W1I • Radio over Fiber

Presider: Rod Waterhouse; Pharad LLC, USA

W1I.1 • 08:00

Physical-layer Confidentiality by Chaotic Encoding in Radio-over-fiber Systems, Alvaro Morales Vicente[1], Dimitrios Konstantinou[1], Simon Rommel[1], Ulf Johannsen[1], Chigo Maduka Okonkwo[1], Idelfonso Tafur Monroy[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* Confidential wireless transmission of a 150Mb/s chaotic encoded signal with an artificial signal to noise ratio of 0dB is experimentally demonstrated at 28GHz. The chaos is generated by a digitally implemented Duffing oscillator system.

W1I.2 • 08:15

Low-noise Radio over Plastic Optical Fiber for TV Broadcasting in Ultrahigh-definition Era, Azusa Inoue[1], Yasuhiro Koike[1]; [1]*Keio Univ., Japan.* We develop plastic optical fibers that significantly improve TV transmission qualities compared with conventional multimode fibers despite their higher attenuation. This improvement is attributed to mode coupling that is closely related to microscopic core-material properties.

08:00–10:00 W1J • Datacenter Network Architecture

Presider: Ken-ichi Kitayama; Graduate School for the Creation of New, Japan

W1J.1 • 08:00 Invited

Slotted Optical Datacenter Network with Sub-wavelength Resource Allocation, Konstantinos (Kostas) Christodoulopoulos[2], Konstantinos Kontodimas[1], Lars Dembeck[2], Emmanouel Varvarigos[1]; [1]*National Technical Univ. of Athens, Greece;* [2]*Nokia Bell Labs, Germany.* We describe the dynamic resource allocation problem in a slotted Datacenter network and present fast scheduling solutions to solve it. We then review scalability related issues.

Room 1

W1A • Panel: PIC Foundry Commercial Access: Prospects and Challenges—Continued

Room 2

W1B • Comb Sources and Applications—Continued

the National Institute of Scientific Research (INRS) in Canada. He is currently a postdoctoral fellow at Harvard University, working on integrated photonics with thin-film Lithium Niobate, a new low-loss nonlinear photonic platform for ultra-fast electro-optic modulators, on-chip Kerr and electro-optic frequency combs, as well as quantum photonics.

Room 3

W1C • Nonlinear Processes and Devices—Continued

W1C.3 • 08:30 Invited

New Insights on Modulation Instability in Optical Fibers, Arnaud Mussot[1], Corentin Naveau[1], Florent Bessin[1], Pascal Szriftgiser[1], Matteo Conforti[1], Alexandre Kudlinski[1], Stefano Trillo[2]; [1]*Univ. of Lille, France;* [2]*Univ. of Ferrara, Italy.* We provide the first longitudinal characterization in phase and amplitude of the nonlinear stage of Modulation Instability in optical fibers by means of a heterodyne optical time domain reflectometer. This original setup allows to report the symmetry breaking of the process due to an initial condition change.

Room 6C

W1D • Probabilistic Shaping II—Continued

W1D.2 • 08:30

Blind Polarization Demultiplexing and Equalization of Probabilistically Shaped QAM, Stefanos Dris[1], Saleem Alreesh[1], Andre Richter[1]; [1]*VPIphotonics GmbH, Germany.* A novel, two-stage algorithm for polarization demultiplexing and equalization of probabilistically shaped QAM is presented. It operates blindly, requiring no knowledge of the channel or transmitted sequence. Performance is validated under realistic PMD conditions.

W1D.3 • 08:45

MAP Detection of Probabilistically Shaped Constellations in Optical Fiber Transmissions, Shaohua Hu[2], Wenjing Zhang[2], Xingwen Yi[1], Zhaohui Li[1], Fan Li[1], Xinning Huang[3], Mingyue Zhu[2], Jing Zhang[2], Kun Qiu[2]; [1]*Sun Yat-sen Univ., China;* [2]*Univ. of Electronic Science and Technology of China, China;* [3]*Xi'an Inst. of Optics and Precision Mechanics of CAS, China.* We present the theoretical analysis and experimental demonstration of MAP detection that outperforms the conventional detection for probabilistically shaped constellations in optical fiber transmissions. Larger BER improvements are observed for the stronger shaped constellations.

Room 6D

W1E • Silicon Photonics Switch—Continued

W1E.3 • 08:30 Invited

Silicon Photonic Devices for Optical Switching in Wavelength, Polarization and Mode, Yikai Su[1], Yong Zhang[1], Ciyuan Qiu[1], Huanying Zhou[1], Xinhong Jiang[1], Qingming Zhu[1], Yu He[1]; [1]*Shanghai Jiao Tong Univ., China.* We present our recent work on thermal-optical switching on silicon chips, including two nanobeam switches with wavelength tuning, and a mode and polarization selective switch having a 748-Gb/s capacity on a single wavelength.

Room 6E

W1F • Intra and Interdata Center Links—Continued

W1F.2 • 08:30

Comparison of Coherent and IMDD Transceivers for Intra Datacenter Optical Interconnects, Jingchi Cheng[1], Chongjin Xie[3], Yizhao Chen[2], Xi Chen[2], Ming Tang[2], Songnian Fu[2]; [1]*Alibaba Group, China;* [2]*Huazhong Univ. of Sci. & Tech., China;* [3]*Alibaba Group, USA.* We experimentally evaluated the performance of 400G coherent and IMDD transceivers for intra-datacenter interconnects, and showed that coherent transceivers can achieve a higher power budget with comparable ASIC power consumption.

W1F.3 • 08:45

Achievable Rate Comparison between Entropy and Bit Loading in a 100-Gb/s DM-DD DMT System, Di Che[2,1], William Shieh[2]; [1]*Nokia Bell Labs, USA;* [2]*The Univ. of Melbourne, Australia.* We propose an efficient entropy loading (EL) scheme with NGMI target based on look-up tables. We reveal the EL superiority on channel coding over bit loading in a 100-Gb/s DM-DD DMT system, proving EL as the best capacity-approaching modulation for band-limited transceiver.

W1G • SDN/NFV—Continued

W1G.2 • 08:30
Transport API Extensions for the Interconnection of Multiple NFV Infrastructure Points of Presence, Ricard Vilalta[1], Arturo Mayoral López-de-Lerma[2], Victor López[3], Konrad Mrówka[4], Rafal Szwedowski[4], Stephan Neidlinger[4], Antonio Felix[5], Zdravko Stevkovski[5], Lubo Tancevski[6], Ajay Singh[6], Ricardo Martinez[1], Ramon Casellas[1], Raul Muñoz[1]; *[1]CTTC, Spain; [2]Universitat Politècnica de Catalunya, Spain; [3]Telefónica I+D, Spain; [4]Adva Optical Networking, Germany; [5]Infinera, Portugal; [6]Nokia, USA.* We present the provisioning of constrained connectivity services and protection/restoration scenarios using Transport API for the interconnection of multiple NFV infrastructure points of presence, which is needed for the uptake of NFV at telecom operators.

W1G.3 • 08:45
Multi-operator Orchestration of Connectivity Services Exploiting Stateful BRPC and BGP-LS in the 5GEx Sandbox, Andrea Sgambelluri[1], Olivier Dugeon[2], Karine Sevilla[2], Fabio Ubaldi[3], Paolo Monti[4], Oscar González de Dios[5], Francesco Paolucci[1]; *[1]Scuola Superiore Sant'Anna, Italy; [2]Orange Labs, France; [3]Ericsson Research, Italy; [4]KTH Royal Inst. of Technology, Sweden; [5]TID Telefonica, Spain.* QoS-based connectivity coordinated by the 5GEx Multi-domain Orchestrator exploiting novel stateful BRPC is demonstrated for the first time over a multi-operator multi-technology transport network within the European 5GEx Sandbox, including Segment Routing and optical domains.

W1H • Panel: SDM Technology Solutions for Next Generation Submarine—Continued

Tetsuya Hayashi, *Sumitomo Electric Industries Ltd., Japan*

Emmanuel Le Taillandier de Gabory, *NEC Corp., Japan*

Robert Lingle, *OFS, USA*

Erwan Pincemin, *Orange Labs France Telecom, France*

Oleg Sinkin, *TE SubCom, USA*

Vijay Vusirikala, *Google, USA*

W1I • Radio over Fiber—Continued

W1I.3 • 08:30 Invited
ARoF-fed Antenna Architectures for 5G Networks, Ulf Johannsen[1], Simon Rommel[1], Ali Al-Rawi[1], Dimitrios Konstantinou[1], Thomas Bressner[1], Idelfonso Tafur Monroy[1], Bart Smolders[1]; *[1]Technische Universiteit Eindhoven, Netherlands.* 5G mm-wave communications requires a highly densified network of radio access stations to ensure sufficient coverage. Low-complexity nodes based on C-RAN and ARoF fronthaul combined with advanced antenna concepts offer a suitable and potentially low cost technology for single and multi-beam 5G applications.

W1J • Datacenter Network Architecture—Continued

W1J.2 • 08:30 Invited
Novel Lambda-rich Torus DC Network: From Underlying Principles to Candidate Technologies, Salah A. Ibrahim[1], Toshikazu Hashimoto[1]; *[1]NTT Device Technology Laboratories, Japan.* We review the principles and technologies required for realizing a dynamic optical DC network comprising a few thousands of nodes based on new exploitation of λ resources and burst-mode transmission to enable scheduling-free optical flows/packets without collision

Room 1

W1A • Panel: PIC Foundry Commercial Access: Prospects and Challenges—Continued

Room 2

W1B • Comb Sources and Applications—Continued

W1B.2 • 09:00
Expansion and Phase Correlation of Gain-switched Optical Frequency Combs through FWM in an SOA, Prajwal Doddaballapura Lakshmijayasimh[1], Aleksandra Kaszubowska[2], Eamonn P. Martin[1], Pascal Landais[1], Prince M. Anandarajah[1]; [1]*School of Electronics Engineering, Dublin City Univ., Ireland;* [2]*Trinity College Dublin, CONNECT Research Centre, Ireland.* A novel technique to expand gain-switched combs, by employing a phase modulator and an SOA is proposed. We demonstrate two separate gain-switched combs that are combined, expanded (42-lines) and phase-correlated through FWM phenomena in SOA.

W1B.3 • 09:15
Foundry-fabricated Dual-DFB PIC Injection-locked to Optical Frequency Comb for High-purity THz Generation, Mu-Chieh Lo[1], Shi Jai[2], Deming Kong[2], Toshio Morioka[2], Leif K. Oxenløwe[2], Hao Hu[2], Guillermo Carpintero[1]; [1]*Universidad Carlos III de Madrid, Spain;* [2]*DTU Fotonik, Denmark.* We present the first comb injection-locked heterodyne source based on generic foundry-fabricated PIC. The generated 0.4-THz carrier with Hz-level linewidth over 10-meter wireless link suggests the generic approach is a cost-effective solution for THz communications.

Room 3

W1C • Nonlinear Processes and Devices—Continued

W1C.4 • 09:00 Top Scored
Wide-band Intermodal Wavelength Conversion in a Dispersion Engineered Highly Nonlinear FMF, Georg Rademacher[1], Ruben S. Luis[1], Benjamin J. Puttnam[1], Yoshinari Awaji[1], Masato Suzuki[2], Takemi Hasegawa[2], Naoya Wada[1]; [1]*National Inst. of Information & Comm Tech, Japan;* [2]*Sumitomo Electric Industries, Japan.* We demonstrate wide-band (>40-nm in C+L-bands) intermodal wavelength conversion of 24.5-GBaud QPSK, 16- and 64-QAM signals with <1-dB OSNR penalty, using a newly designed highly nonlinear few-mode fiber with similar chromatic dispersion profiles amongst modes.

W1C.5 • 09:15 Top Scored
Ultra-broadband Bragg Scattering Four Wave Mixing in Silicon Rich Silicon Nitride Waveguides, Cosimo Lacava[1], Thalia Dominguez Bucio[1], Ali Z. Khokhar[1], Peter Horak[1], Yongmin Jung[1], Frederic Gardes[1], David J. Richardson[1], Periklis Petropoulos[1], Francesca Parmigiani[2,1]; [1]*Univ. of Southampton, UK;* [2]*Microsoft Research UK, UK.* We show the first demonstration of Bragg scattering inter-modal four-wavemixing in silicon-rich SiN waveguides. We report wavelength conversion using two spatial modes, exhibiting a maximum efficiency of -15-dB over a flat-bandwidth in excess of 30-nm.

Room 6C

W1D • Probabilistic Shaping II—Continued

W1D.4 • 09:00
Shaping Factor Detuning for Optimized Phase Recovery in Probabilistically-Shaped Systems, Fabio A. Barbosa[1], Darli A. Mello[1]; [1]*Univ. of Campinas, Brazil.* We propose to optimize the phase recovery performance in probabilistically-shaped systems by detuning the shaping factor of the Maxwell-Boltzmann distribution. The results indicate tangible gains in the mutual information without increasing complexity.

W1D.5 • 09:15 Top Scored
Experimental Analysis of Laser Phase Noise Tolerance of Uniform 256QAM and Probabilistically Shaped 1024QAM, Takeo Sasai[1], Asuka Matsushita[1], Masanori Nakamura[1], Seiji Okamoto[1], Fukutaro Hamaoka[1], Yoshiaki Kisaka[1]; [1]*NTT, Japan.* We experimentally compare laser linewidth tolerance of US-256QAM and PS-1024QAM. US-256QAM has higher achievable information rate (AIR) with <5% pilot symbol and 40 kHz linewidth, while PS-1024QAM realizes higher AIR than US-256QAM with narrower linewidth.

Room 6D

W1E • Silicon Photonics Switch—Continued

W1E.4 • 09:00
Silicon Polarization Splitter and Rotator with Tolerance to Width Variations Using a Nonlinearly-tapered and Partially-etched Directional Coupler, Yong Zhang[1], Qingming Zhu[1], Yu He[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China.* A silicon polarization splitter and rotator is experimentally demonstrated using a nonlinearly-tapered directional coupler. Adiabatic polarization splitting and rotating are achieved over a length of 129 μm. Fabrication tolerance to waveguide widths is also verified.

W1E.5 • 09:15
High Extinction Ratio and Broadband O-band Polarization Splitter and Rotator on Silicon-on-insulator, Eslam Elfiky[1], Yun Wang[1], Santiago Bernal[1], Claude Gamache[2], Eric Panorel[2], Amar Kumar[1], Alireza Samani[1], Maxime Jacques[1], Ping-Chiek Koh[3], David Plant[1]; [1]*McGill Univ., Canada;* [2]*Lumentum, Canada;* [3]*Lumentum, USA.* We experimentally demonstrate a silicon photonic O-band polarization splitter and rotator. The wafer-level extinction ratio over 80 nm bandwidth has an average of 21.82 dB and 19.05 dB for the upper and lower ports, respectively.

Room 6E

W1F • Intra and Interdata Center Links—Continued

W1F.4 • 09:00 Tutorial
Direct-detection Technologies for Intra- and Inter-data Center Optical Links, Mathieu Chagnon[1]; [1]*Transmission and DSP, Nokia Bell Labs, Germany.* We present the evolution of fiber-optic communication systems, review the phenomena limiting the bitrate and reach of intensity modulation–direct detection-based systems, overview proposals for DSP-enabled direct detection, and conclude with coherent-lite for short reaches.

Mathieu Chagnon obtained his Ph.D. from McGill University, Canada. He made seminal contributions in the field of short-reach direct-detect systems, demonstrating new transceiver architectures, designing multi-dimensional self-beating signaling schemes, and developing novel digital signal processing algorithms. He has authored more than 100 papers and gave Invited and Tutorial talks at major conference venues. He is now a researcher in Optical Transmission and DSP at Nokia Bell Labs, Germany.

W1G • SDN/NFV—Continued

W1G.4 • 09:00
VNF Chaining across Multi-PoPs in OSM Using Transport API, Anderson Bravalheri[1], Abubakar Siddique Muqaddas[1], Navdeep Uniyal[1], Ramon Casellas[2], Reza Nejabati[1], Dimitra Simeonidou[1]; *[1]High Performance Networks Group, Department of Electrical and Electronic Engineering, Univ. of Bristol, UK; [2]CTTC/CERCA, Spain.* Management and Network Orchestration (MANO) systems permit simultaneous orchestration of compute and network resources. Here, we experimentally demonstrate the integration of Transport API based WIM with Open Source MANO (OSM), for NFV orchestration over optical networks.

W1G.5 • 09:15
Proof-of-concept Validation of SDN-controlled VCSEL-based S-BVTs in Flexi-grid Optical Metro Networks, Ricardo Martínez[1], Ramon Casellas[1], Michela Svaluto Moreolo[1], Josep Maria Fàbrega[1], Ricard Vilalta[1], Raul Muñoz[1], Laia Nadal[1], Juan Pedro Fernandez Palacios[2]; *[1]Ctr Tecnologic de Telecoms de Catalunya, Spain; [2]Telefónica I+D, GTCO, Spain.* We model via YANG an adaptive, modular and programmable VCSEL-based S-BVT for optical flexi-grid metro networks. Discussion and experimental validation of the PCECC T-SDN controller interfaces for automatic provisioning of flexi-grid connections are provided.

W1H • Panel: SDM Technology Solutions for Next Generation Submarine—Continued

W1I • Radio over Fiber—Continued

W1I.4 • 09:00
Optical Heterodyne Millimeter-wave Analog Radio-over-fiber with Photonic Integrated Tunable Lasers, Colm Browning[1], Amol Delmade[1], Yi Lin[1], Douwe Geuzebroek[2], Liam P. Barry[1]; *[1]Dublin City Univ., Ireland; [2]Lionix International, Netherlands.* Analog radio-over-fiber links enforce strict laser requirements for optical heterodyne systems. Experimental results show the successful implementation of two free-running, un-correlated micro-ring resonator based tunable lasers in a 60GHz A-RoF heterodyne system over 25km.

W1I.5 • 09:15
Full-duplex Transmission of Nyquist-SCM Signal over a Seamless Bidirectional Fiber–wireless System in W-band, Pham Tien Dat[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Van-Dien Nguyen[2,4], Tan Hung Nguyen[2], Tetsuya Kawanishi[3]; *[1]Network System Research Institute, NICT, Japan; [2]Danang Univ. of Science and Technology, Viet Nam; [3]Waseda Univ., Japan; [4]Industrial Univ. of Ho Chi Minh City, Viet Nam.* We experimentally demonstrate a seamless full-duplex fiber–wireless system in the W-band for Nyquist-SCM signal transmission. Satisfactory performance is confirmed for 45-Gb/s and 20-Gb/s signal transmission over the downlink and uplink directions.

W1J • Datacenter Network Architecture—Continued

W1J.3 • 09:00 Invited
OPTUNS: Optical Edge Datacenter Network Architecture and Prototype Testbed for Supporting 5G, Maria C. Yuang[1], Po-Lung Tien[1], Wei-Zhang Ruan[1], Tien-Chien Lin[2], Shao-Chun Wen[2], Po-Jen Tseng[2], Che-Chang Lin[2], Ching-Nien Chen[3], Chun-Ting Chen[1], Yi-An Luo[1], Meng-Ru Tsai[1], Shan Zhong[4]; *[1]National Chiao Tung Univ., Taiwan; [2]Delta Electronics, Taiwan; [3]CYNTEC, Taiwan; [4]Bandwidth Express LLC, USA.* We present the architecture/testbed of an SDN-based optical-tunnel-network system (OPTUNS) for 5G edge-datacenters. Benchmarking results show that, compared to electrical-spine-leaf datacenter-network, OPTUNS achieves 82.6% power saving and significantly lower mean/p99 latency under high traffic load/locality.

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E
W1A • Panel: PIC Foundry Commercial Access: Prospects and Challenges—Continued	**W1B • Comb Sources and Applications—Continued**	**W1C • Nonlinear Processes and Devices—Continued**	**W1D • Probabilistic Shaping II—Continued**	**W1E • Silicon Photonics Switch—Continued**	**W1F • Intra and Interdata Center Links—Continued**
	W1B.4 • 09:30 Invited **Towards Integrated Microcomb Systems for Hertz-scale Accuracy Optical Signal Generation,** Kerry J. Vahala[1]; [1]*California Inst. of Technology, USA*. The history and physics of soliton microcombs are briefly overviewed. Several applications under active investigation are described including recent demonstrations of dual-comb spectroscopy and optical frequency synthesis to Hertz-level absolute accuracy over C-band.	**W1C.6 • 09:30** **Few-mode Degenerate Four Wave Mixing in a Few-mode Semiconductor Optical Amplifier,** Yousef Alahmadi[1,3], He Wen[1], Patrick LiKamWa[1,2], Guifang Li[1,2]; [1]*CREOL, College of Optics and Photonics,, Univ. of Central Florida, USA;* [2]*The Department of Electrical Engineering and Computer Science, Univ. of Central Florida, USA;* [3]*King Abdulaziz City for Science and Technology, Saudi Arabia*. We demonstrate few-mode degenerate four wave mixing in a few-mode semiconductor optical amplifier with high efficiency and large bandwidth for the first time	**W1D.6 • 09:30** **Probabilistic Shaping of Set-partition mQAM,** Inwoong Kim[1], Olga Vassilieva[1], Paparao Palacharla[1], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America, USA*. We propose novel probabilistic shaping of set-partition mQAM signals to extend the entropy range below 2 bits/symbol and demonstrate a performance gain of 0.45dB compared to time-domain hybrid QAM at the same achievable information rate.	**W1E.6 • 09:30** **Dual-microring Resonator Based 8×8 Silicon Photonic Switch,** Yishen Huang[1], Qixiang Cheng[1], Yu-Han Hung[1], Hang Guan[2], Ari Novack[2,1], Matthew Streshinsky[2], Michael Hochberg[2], Keren Bergman[1]; [1]*Columbia Univ., USA;* [2]*Elenion Technologies, USA*. First demonstration of a dual-microring 8×8 silicon-photonic switch in a compact 4 mm^2 footprint shows 4.4-8.4 dB end-to-end on-chip loss, -16.75 dB first-order switching crosstalk, and 40 GHz switching bandwidth capable of high-data-rate datacenter transmissions.	
		W1C.7 • 09:45 **3D Shape Sensing Utilizing SBS in Multi-core Fiber,** Zhen Guo[1,2], Chen Xing[1,2], Changjian Ke[1,2], Keyuan Yang[1,2], Deming Liu[1,2], Zhenggang Lian[3]; [1]*School of Optical and Electronic Information, Huazhong Univ. of Sci. & Tech., China;* [2]*National Engineering Laboratory for Next Generation Internet Access System, Huazhong Univ. of Sci. & Tech., China;* [3]*Yangtze Optical Electronic Co., Ltd., China*. 3D shape sensing utilizing stimulated Brillouin scattering in multi-core fiber is experimentally demonstrated. A 1.7-m helical curve can be reconstructed with a RMSE of 0.0200 m when the spatial resolution is 20 cm.	**W1D.7 • 09:45** **On the Performance Metric and Design of Non-uniformly Shaped Constellation,** Shaoliang Zhang[1], Fatih Yaman[1], Eduardo Mateo[2], Ivan Djordjevic[3], Kohei Nakamura[2], Takanori Inoue[2], Yoshihisa Inada[2]; [1]*NEC Laboratories America Inc, USA;* [2]*Submarine Network Division, NEC Corporation, Japan;* [3]*ECE, Univ. of Arizona, USA*. Asymmetric information is shown to be more accurate in characterizing the performance of quadrant folding shaped (QFS) M-QAM. The performance difference of QFS M-QAM schemes strongly depends on the FEC coding rate, and the optimum FEC coding rate is found to be around ~0.8, which is independent of QFS M-QAM and the designed rates.		

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30)
OFC Career Zone Live, *Exhibit Hall C*

Room 6F

W1G.6 • 09:30
VNF Availability Model for Service Provider Networks, Sidharth Sharma[1], Aniruddha Kushwaha[1], Ashwin Gumaste[1], Admela Jukan[2]; *[1]Indian Inst. of Technology, Bombay, India; [2]TU Braunschweig, Germany.* We consider designing provider networks with VNFs of lower availability than telecom equipment while maintaining an overall high-availability services infrastructure. An optimization model and corresponding performance results are showcased.

W1G.7 • 09:45 Top Scored
Enabling Heterogenous Low Latency and High-bandwidth Virtual Network Services for 5G Utilizing a Flexible Optical Transport Network, Thierno Diallo[1], Arash Farhadi Beldachi[1], Abubakar Siddique Muqaddas[1], Renato Souza Silva[1], Reza Nejabati[1], Anna Tzanakaki[1], Dimitra Simeonidou[1]; *[1]High Performance Networks Group, Department of Electrical and Electronic Engineering, Univ. of Bristol, UK.* For the first time, we demonstrate a 5G network orchestration system supporting low latency and high bandwidth virtual network services over a flexible time slotted optical transport network.

Room 7

W1H • Panel: SDM Technology Solutions for Next Generation Submarine—Continued

Room 8

W1I • Radio over Fiber—Continued

W1I.6 • 09:30
Novel Hybrid Radio-over-fiber Transmitter for Generation of Flexible Combination of WDM-ROF/WDM Channels, Pengyu Guan[1], Sebastian Rodriguez[1], Edson Porto da Silva[1,2], Francesco Da Ros[1], Michael Galili[1], Mads Lillieholm[1], Toshio Morioka[1], Leif K. Oxenløwe[1]; *[1]Technical Univ. of Denmark, Denmark; [2]Federal Univ. of Campina Grande, Brazil.* We propose a transmitter capable of seamlessly generating any combination of WDM-ROF/WDM channels and demonstrate the highest WDM-ROF channel-number from a single laser-modulator pair with 100-km SSMF plus 0.5-m wireless transmission at 12×2.5-Gb/s and 10×4-Gb/s.

W1I.7 • 09:45 Top Scored
150-Watt Power-over-fiber Feed for Bidirectional Radio-over-fiber Systems Using a Double-clad Fiber, Nana Tajima[1], Daisuke Kamiyama[1], Motoharu Matsuura[1]; *[1]Univ. of Electro-Communications, Japan.* We experimentally demonstrate bidirectional radio-over-fiber transmission with 150-W power-over-fiber feed using a double-clad fiber for optically powered remote antenna units. We successfully achieve good signal transmission performances under the high power optical feeding.

Room 9

W1J • Datacenter Network Architecture—Continued

W1J.4 • 09:30
Achieving Ultralow-latency Optical Interconnection for High Performance Computing (HPC) Systems by Joint Allocation of Computation and Communication Resources, Ruijie Luo[1], Yufang Yu[1], Nan Hua[1], Zhizhen Zhong[1], Jialong Li[1], Xiaoping Zheng[1], Bingkun Zhou[1]; *[1]Tsinghua Univ., China.* We propose joint allocation of computation resource and optical transmission time slices to realize ultralow-latency optical interconnection in time-synchronized HPC systems. Results show that over 80% reduction in buffering time is achieved at high load.

W1J.5 • 09:45
Flat, Highly Connected Optical Network for Data Centers, Michael Y. Frankel[1], Vladimir Pelekhaty[1], John P. Mateosky[1]; *[1]Ciena Corporation, USA.* A novel flat optical DC network approach using only low radix electrical switches and high data rate optical links is investigated. Compared to Clos, it provides resilience and ~40% hardware savings with ~60% higher throughput.

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30)
OFC Career Zone Live, *Exhibit Hall C*

10:30–12:30
W2A • Poster Session I

W2A.1
56Gb/s PAM-4 VCSEL Transmitter with Quarter-rate Forwarded Clock Using 65nm CMOS Circuits, Jeongho Hwang[1], Hyungrok Do[1], Hong-Seok Choi[1], Gyu-Seob Jeong[1], Daehyun Koh[1], Sungwoo Kim[2], Deog-Kyoon Jeong[1]; [1]*ISRC, Seoul National Univ., Korea;* [2]*SK Hynix, Korea.* A 56Gb/s PAM-4 VCSEL transmitter is demonstrated in 65nm CMOS. This paper also discusses different kinds of clocking architecture.

W2A.2
Low-loss and Highly Reliable Low-profile Coupler for Silicon Photonics, Tsutaru Kumagai[1], Tetsuya Nakanishi[1], Tetsuya Hayashi[1], Kenichiro Takahashi[1], Manabu Shiozaki[1], Atsushi Kataoka[1], Takashi Murakami[1], Tomomi Sano[1]; [1]*Sumitomo Electric Industries, Ltd., Japan.* We demonstrate low-profile fiber coupler for silicon photonics with stress-free fiber bending technique, which achieves low insertion loss of <0.5 dB and Telcordia-1221GR-CORE-complying high reliability even with severe fiber bending radius of around 2 mm.

W2A.3
Terabit Interconnects with a 20-GHz O-band Passively Mode Locked Quantum Dot Laser Grown Directly on Silicon, Xinru Wu[1], Songtao Liu[2], Daehwan Jung[2], Justin Norman[2], MJ Kennedy[2], Hon Ki Tsang[1], Arthur Gossard[2], John E. Bowers[2]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*Univ. of California Santa Barbara, USA.* A 20-GHz passively mode-locked quantum dot laser directly grown on a silicon substrate is demonstrated as an on-chip wavelength division multiplexing (WDM) source for 4.1 Tb/s data transmission using 64 Nyquist WDM channels.

W2A.4
Ultra-compact DWDM Filter Tunable across the C-band, Simon Bélanger-de Villers[1], Dominic Hould[1], Wei Shi[1]; [1]*Université Laval, Canada.* We demonstrate a third-order cascaded microring filter with 2.5 µm-radius resonators, showing a flat-top response and a 35-nm free spectral range. Continuous wavelength tuning over the C-band has been achieved.

W2A.5
Benefits of a Coupled-core Wavelength-selective Switch, Miri Blau[1], Dan M. Marom[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* The system benefits of strongly-mixing mode-division multiplexed transmission extend to passband broadening of few-mode WSS cascades. We design and analyze a WSS with directly integrated seven-core supermodes.

W2A.6
Air Trenches-assisted Highly Selective, Fully Flexible SOI Filtering Element, Giannis Poulopoulos[1], Giannis Kanakis[1], Panagiotis Toumasis[1], Giannis Giannoulis[1], Dimitrios Kalavrouziotis[2], Dimitrios Apostolopoulos[1], Hercules Avramopoulos[1]; [1]*ICCS-NTUA, Greece;* [2]*Mellanox, Israel.* We demonstrate a SOI fully flexible filtering element based on serial coupled ring resonators exhibiting 12-116 GHz bandwidth tunability, ER values up to 37.5 dB, high bandwidth tuning efficiency of 3.95 GHz/mW and compact footprint.

W2A.7
Flexible Photonic Spectral Shaping at Ultrahigh Resolution of 125MHz, Tomer Yeminy[1], Sagie Asraf[2], Dan Sadot[1], Zeev Zalevsky[2]; [1]*Ben Gurion Univ. of the Negev, Israel;* [2]*Faculty of Engineering, Bar Ilan Univ., Israel.* We experimentally demonstrate a proof of concept resolution-enhanced flexible spectral shaper, using a spectral encoding block with high resolution features before the spatial diffractive element. Ultrahigh 125MHz resolution is obtained, refining present limit of 0.8GHz.

W2A.8
Waveguide Si-Ge Avalanche Photodiode Based on Hole-generated Impact Ionization, Zhibin Jiang[1], Yu Yu[1], Yilun Wang[1], De Zhou[1], Wentao Deng[1], Xinliang Zhang[1]; [1]*Wuhan National Lab for Optoelectronics, China.* We report a waveguide Si-Ge avalanche photodiode using zero-change foundry processing. A 182 GHz gain-bandwidth product with a responsivity of 11.2 A/W at 1550 nm is experimentally demonstrated through hole-generated impact ionization.

W2A.9
Efficient Graphene Phase Modulator Based on a Polarization Multiplexing Optical Circuit, Haowen Shu[1], Qingzhong Deng[1], Ming Jin[1], Yuansheng Tao[1], Xingjun Wang[1], Zhiping Zhou[1]; [1]*Peking Univ., China.* An efficient graphene phase modulator on a silicon-on-insulator platform is proposed based on a CMOS-compatible polarization multiplexing optical circuit. The dual-polarizations enhanced modulation efficiency is 0.184 V•mm with a device dimensions of 75µm x 320µm.

W2A.10
High-speed Silicon Electro-optic Modulator Based on a Single Multimode Waveguide, Gangqiang Zhou[1], Linjie Zhou[1], Yuyao Guo[1], Shuhuang Chen[1], Zhiming Fu[2], Liangjun Lu[1], Jianping Chen[1]; [1]*Shanghai Jiaotong Univ., China;* [2]*ZTE Photonics Technology Corporation, China.* We report a novel silicon intensity modulator that exploits the different modulation efficiency between two TE modes in a multimode waveguide. On-off key modulation was successfully demonstrated with an extinction ratio of 5.5 dB at a data rate of 32 Gb/s.

W2A.11
Aluminum Nitride Ultralow Loss Waveguides and Push-pull Electro-optic Modulators for Near Infrared and Visible Integrated Photonics, Shiyang Zhu[1], Qize Zhong[1], Ting Hu[1], Yu Li[1], Zhengji Xu[1], Navab Singh[1]; [1]*Inst. of Microelectronics, Singapore.* We demonstrate AlN waveguide with ultralow loss of 0.42 dB/cm, push-pull MZI modulator with $V_p \times L_p$ of 59 V×cm and speed of 140 MHz, and dual-ring modulator with E_r of 12 dB and speed of 4 GHz.

W2A.12
Single Mode, Low-loss 5-tube Nested Hollow-core Anti-resonant Fiber, Md Selim Habib[2], Jose Enrique Antonio-Lopez[3], Christos Markos[1], Axel Schulzgen[2], Rodrigo Amezcua Correa[2]; [1]*DTU Fotonik, Technical Univ. of Denmark, Denmark;* [2]*CREOL, The College of Optics and Photonics, Univ. of Central Florida, USA.* A 5-tube nested hollow-core anti-resonant fiber is proposed to simultaneously achieve ultra-low loss (< 1dB/km), broader transmission window, lower bend loss, and larger higher-order mode suppression than fibers with a different number of cladding tubes

W2A.13
Multi-functional Multi-core Fiber with a Low-latency Core and Conventional Silica Cores, Yuto Sagae[1], Takashi Matsui[1], Yoko Yamashita[1], Masaki Wada[1], Taiji Sakamoto[1], Kyozo Tsujikawa[1], Kazuhide Nakajima[1]; [1]*NTT, Japan.* We propose a novel multi-functional multi-core fiber (MF-MCF) composed of low-latency core and conventional silica-cores. MF-MCF can offer fast channel, and which is also expected to be management channels for realizing the advanced signal processing.

W2A.14
Dust Insensitive Single Mode Multi Fiber Connector with Expanded Beam, Sho Yakabe[1]; [1]*Sumitomo Electric Industries, Ltd., Japan.* Multi-fiber connector with expanded beam has been developed by fusion splicing of GRIN lens and SMF fiber. This new connector reduced the increase in average insertion loss after dust test to 0.35 dB and made it possible to reduce the increase in average connection loss to 0.06 dB by air blow cleaning.

W2A.15
Towards Early Detection of Red Palm Weevil Using Optical Fiber Distributed Acoustic Sensor, Yuan Mao[1], Islam Ashry[1], Yousef Al-Fehaid[2], Abdulmoneim Al-Shawaf[2], Mansour Al-Bagshi[2], Salman Al-Brahim[3], Tien Khee Ng[1], Boon S. Ooi[1]; [1]*King Abdullah Univ. of Sci & Technology, Saudi Arabia;* [2]*Center of Date Palms and Dates, Saudi Arabia;* [3]*Office of the Ministry of Environment, Water, and Agriculture, Saudi Arabia.* Red palm weevil (RPW) is a severe danger to the dates farming. We use optical fiber distributed acoustic sensor (DAS) as a solution to the detection of RPW via sensing the RPW activities sound.

W2A.16
Wavelength-locked Doubly-resonant Cavity Fibre Brillouin Ring Laser for BOTDA Sensing, Leonardo Rossi[1,2], Diego Marini[1], Filippo Bastianini[3], Gabriele Bolognini[1]; [1]*CNR, IMM Inst., Bologna, Italy;* [2]*Università degli Studi di Bologna, Italy;* [3]*Sestosensor srl, Italy.* A doubly-resonant cavity Brillouin ring laser coupled with a wavelength locking system is presented and evaluated as a tunable pump-probe source for BOTDA sensing, exhibiting low RIN (~-145 dB/Hz) and narrow pump-locked bandwidth (~200 Hz).

W2A.17
High Frequency Current Sensor System Using a 4ch CWDM MUX Module and DeMUX ROSA, Hyoung-Jun Park[1], Hyun Jin Kim[1], Dong Hoon Son[1], Sung Chang Kim[1], Youngbeom Jung[2], In-Jin Seo[2]; [1]*Electronics & Telecomm Res. Inst., Korea;* [2]*Smart Power Distribution Lab, KEPCO Research Inst., Korea.* We proposed a high frequency current sensor for partial discharge detection and the signal processing board equipped with 4ch DeMUX ROSA for 4 channel partial discharge diagnosis. From the experimental results, it was confirmed that the detection data of partial discharge on the 22.9kV XLPE cable can be transmitted well

W2A.18
Discriminative Determination Based on Long-period Gratings Inscribed in Few-mode Fibers, Bing Li[1], Xuan Zhan[1], Ming Tang[1], Lin Gan[1], Liang Huo[1], Li Shen[1], Songnian Fu[1], Weijun Tong[2], Deming Liu[1]; [1]*School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China;* [2]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, China.* We achieved the fabrication of long period gratings in few-mode fibers with micro-tapered method. By establishing coupling among spatial modes, discriminative sensing of temperature and strain was realized with the relative error under 3%.

W2A.19
Coupled 7-Core Erbium Doped Fiber Amplifier and its Characterization, Takafumi Ohtsuka[1], Masato Tanaka[1], Hirotaka Sakuma[1], Takemi Hasegawa[1], Tetsuya Hayashi[1], Hedehisa Tazawa[1]; [1]*Sumitomo Electric Industries, Ltd., Japan. We demonstrate a coupled 7-core erbium-doped-fiber amplifier (EDFA) with the gain of higher than 15 dB and noise figure (NF) of 4.5 to 5.2 dB. The NF is lower than the previously reported coupled-multicore EDFA.*

W2A • Poster Session I—Continued

W2A.20
Optical Signal-to-noise Ratio Prediction Using Neural Networks for Multicast Light-trees in Optical Networks, Lu Zhang[1], Xin Li[1], Tao Gao[1], Ying Tang[1], Yongjun Zhang[1], Shanguo Huang[1]; *[1]Beijing Univ. of Posts and Telecommunications, China.* An adaptive method based on neural networks is proposed, which can simultaneously predict the signal-to-noise ratio at all destination nodes of one multicast light-tree. Results show the method is fast and has high accuracy.

W2A.21
On the Latencies in a Hybrid Optical Packet Switching Network in Data Center, Artur Minakhmetov[1], Archana Nagarajan[1], Luigi Iannone[1], Cedric Ware[1]; *[1]Telecom Paristech, France.* Hybrid Optical Packet Switching is a prominent solution for boosting a Data Centers' performance. We reaffirm this hypothesis by studying network latencies and showing that hybrid switching delivers the best performance compared to all-electronic one.

W2A.22
Deep Reinforcement Learning for BBU Placement and Routing in C-RAN, Zhengguang Gao[1], Jiawei Zhang[1], Shuangyi Yan[2], Yuming Xiao[1], Dimitra Simeonidou[2], Yuefeng Ji[1]; *[1]Beijing Univ. of Posts and Telecomm, China; [2]Univ. of Bristol, UK.* The paper proposes a deep reinforcement learning (DRL) based policy for BBU placement and routing in C-RAN. The simulation results show DRL-based policy reaches the near-optimal performance with a significantly reduced computing time.

W2A.23
Gap Analysis on Open Models for Partially-disaggregated SDN Optical Transport Environments, Miquel Garrich Alabarce[1], César San-Nicolás-Martínez[1], Francisco Javier Moreno-Muro[1], Arturo Mayoral[2], Oscar González de Dios[3], Victor López[3], Alessio Giorgetti[4], Andrea Sgambelluri[4], Dominique Verchere[5], Lubo Tancevski[5], Pablo Pavón-Mariño[1,6]; *[1]Dept. of Information and Communication Technologies (TIC), Technical Univ. of Cartagena, Spain; [2]Universitat Politècnica de Catalunya, Spain; [3]gCTIO, Telefonica I+D, Spain; [4]Scuola Superiore Sant'Anna / CNIT, Italy; [5]NOKIA Bell Labs Paris-Saclay, France; [6]E-lighthouse Networks Solutions, Spain.* We report an analysis of completeness and suitability of OpenConfig, OpenROADM and OpenDevice models, for physical-impairment aware network planning, and a proof-of-concept in a partially disaggregated testbed exposing equipment information to Net2Plan through ONOS.

W2A.24
Verification of High Performance and Wide Applicability of Seamlessly Expandable and Limitless OXC, Ryota Hashimoto[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; *[1]Nagoya Univ., Japan.* The performance is analyzed of a highly cost-effective OXC that allows hitless port-count expansion to meet traffic-growth at minimum cost. Numerical experiments verify the OXC offers excellent routing capability even though it uses small-degree WSSs.

W2A.25
Resilient Fiber-based Quantum Key Distribution (QKD) Networks with Secret-key Re-allocation Strategy, Hua Wang[1], Yongli Zhao[1], Xiaosong Yu[1], Bowen Chen[2], Jie Zhang[1]; *[1]Beijing Univ. of Posts and Telecomm, China; [2]Soochow Univ., China.* Fiber-based QKD is a promising solution for enhancing the security of information networks. A secret-key re-allocation strategy is proposed and verified for the failure recovery of key provisioning services in resilient fiber-based QKD networks.

W2A.26
Single-wavelength Symmetric 50 Gbit/s Equalization-free NRZ IM/DD PON with up to 33 dB Loss Budget and Fiber Transmission over >40 km, Robert Borkowski[1], Harald Schmuck[1], Giancarlo Cerulo[2], Helene Debregeas[2], René Bonk[1]; *[1]Nokia Bell Labs, Germany; [2]III-V Lab, France.* We demonstrate burst-mode upstream and continuous-mode downstream transmission in a 50G TDM-PON system, achieving up to 33-dB loss budget with a maximum of 77-km SMF transmission before any equalization. The system is enabled by semiconductor optical amplifiers at the transceivers.

W2A.27
Novel Time Synchronization Scheme in Delay-division-multiplexing OFDM-PON Using Sub-nyquist Sampling, Min Yu[1], Fumin Liu[2], Wei-Lun Chen[1], Chun-Ting Lin[3], Lei Zhou[2], LiMing Fang[2], Chia Chien Wei[1]; *[1]National Sun Yat-sen Univ., Taiwan; [2]Advanced Optical Access Network Research Center, Huawei Technologies, China; [3]National Chiao Tung Univ., Taiwan.* We propose a novel time synchronization scheme in a DDM-OFDM-PON under the constraint of sub-Nyquist sampling. In a 25-Gb/s DDM-PON, the scheme can acquire precise delays, making the delay-related penalty in SNR <0.2 dB.

W2A.28
Low-latency Transmission of Fronthaul Traffic over XG(S)-PON with Fixed-elastic Bandwidth Reservations, David Eugui[1], José Alberto Hernández Gutiérrez[1]; *[1]Universidad Carlos III de Madrid, Spain.* This article overviews the transport of fronthaul traffic along with residential traffic on an XG(S)-PON using both fixed and dynamic transmission windows in the PON's DBA.

W2A.29
Experimental Characterization of Back-scattering Interference Limits for Fronthaul Employing Bitrate Variable Transceivers Based on OFDM and Direct Detection, Josep M. Fabrega[1], Michela Svaluto Moreolo[1], Laia Nadal[1]; *[1]Ctr Tecnologic de Telecoms de Catalunya, Spain.* We experimentally assess the impact of back-scattering when featuring DD-OFDM bidirectional transmission over a single fiber. Results show that different functional split options can be supported for signal/scattering ratios >16dB and received optical power around -24dBm.

W2A.30
Using Light-trails as an Optical Backhaul for 5G, Ashwin Gumaste[1], Sidharth Sharma[1], Biswanath Mukherjee[2]; *[1]Indian Inst. of Technology, Bombay, India; [2]University of California Davis, USA.* We propose the use of light-trails – a shared wavelength bus architecture for plausible use as 5G backhaul. Network design for metro, pico, and femto cells is considered and results obtained from simulations.

W2A.31
Demonstration of an Analogue Domain Processing IC for Carrier Phase Recovery and Compensation in Coherent Links, Rakesh Ashok[1], Sarath Manikandan[1], Shivangi Chugh[1], Sandeep Goyal[1], Rashmi Kamran[1], Shalabh Gupta[1]; *[1]IIT Bombay, India.* We demonstrate a carrier phase recovery and compensation technique for low power coherent optical interconnects. Experimental results from an analogue processing IC developed for this purpose for QPSK and 16-QAM signals have been presented.

W2A.32
Transmission Link Optimization for Coherent 4 Tb/s Extended Reach (ZR) Transmission, Fred Buchali[1], Karsten Schuh[1], Mathieu Chagnon[1], Henning Buelow[1]; *[1]Nokia Bell Labs, Germany.* We optimize the transmission system for a coherent 4Tb/s-transmission over Extended Reach distances (ZR). In a lab experiment we show that one SOA is sufficient for a successful transmission, which should be placed at transmitter side and allows transmission over 106km.

W2A.33
4×96 Gbit/s PAM8 for Short-reach Applications Employing Low-cost DML without Pre-equalization, Li Di[1], Lei Deng[1], Yao Ye[1], YuCheng Zhang[1], Mengfan Cheng[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1]; *[1]Huazhong Univ. of Sci. & Tech., China.* We demonstrate 4×96-Gbit/s PAM8 transmission enabled by low-cost DMLs with the narrowest 3-dB bandwidth of 13.5-GHz for the first time. Thanks to the optimized Volterra equalizer, 15-km SSMF distance is achieved without optical amplification and pre-equalization.

W2A.34
Performance Enhancement of 112 Gb/s PAM-4 Amplifier-free 40km Transmission with Record Sensitivity Using O-band 25G- class Directly Modulated Laser, Weiyu Wang[1], Huanlu Li[1], Zhike Zhang[2], Pengchao Zhao[1], Dajun Zang[1], Ninghua Zhu[3], Yuchun Lu[1]; *[1]Huawei Technologies Co. Ltd., China; [2]State Key Laboratory of Advanced Optical Communications System and Networks, School of Electronics Engineering and Computer Science, Peking Univ., China; [3]State Key Laboratory on Integrated Optoelectronics, Inst. of Semiconductors, Chinese Academy of Sciences, China.* An amplifier-less transmission of a single-wavelength 112Gb/s PAM4 signal over 40km using O-band 25G class DML and advanced DSP with a record receiver sensitivity of -12dBm@ HD-FEC is experimentally demonstrated. It also beats the KP4 FEC limit for the first time.

Show Floor Programming

COBO Ecosystem: Post Specifications Release
COBO
10:15–11:45, *Theater II*

Product Showcase: High Speed Transport and Ultralow Latency
Huawei Technologies Canada Co., Ltd.
10:15–10:45, *Theater III*

■ **Network Operator Summit Keynote :**
10:30–11:00, *Theater I*

Product Showcase: Next Generation 200G/400G PAM4 Optical Interconnects Break the Barrier of Future Datacenter Bandwidths
ColorChip
11:00–11:30, *Theater III*

■ **Network Operator Summit Panel 1: The Access Network–Next Generation PON, Mobile and Cable Network Upgrades**
11:00–12:30, *Theater I*

Defining Key Areas for Industry Roadmap Development
ON2020
12:00–14:00, *Theater II*

Product Showcase: Converged Networks for 5G RAN and Broadband Services
Xilinx Inc.
12:30–13:00, *Theater III*

Product Showcase: Evolution and Productization of PAM4 Technology with In-house Serdes for Wireline Applications
Xilinx Inc.
13:00–13:30, *Theater III*

W2A • Poster Session I—Continued

W2A.35
First Demonstration of an FPGA-controlled Multiplane OAM-wavelength Packet Switch, Justine C. Borromeo[2], Muhamman N. Malik[3], Nicola Andriolli[3], Ning Zhang[4], Charalambos Klitis[4], Martin Lavery[4], Gianni Preve[1], Veronica Toccafondo[1], Rosula Reyes[2], Piero Castoldi[3], Marc Sorel[4], Antonella Bogoni[3,1], Mirco Scaffardi[1]; [1]*CNIT, Italy;* [2]*Ateneo de Manila, Philippines;* [3]*Scuola Superiore Sant'Anna, Italy;* [4]*Univ. of Glasgow, UK.* We report the first demonstration of an OAM-wavelength photonic integrated packet switch, controlled by a FPGA-based scheduler suited for multiplane architectures. We show error-free transmission at 20 Gb/s in multiple OAM-wavelength configurations.

W2A.36
Reconfigurable Microwave Photonic Spectral Shaper, Jia Ge[1], Daniel A. Garon[1], Qidi Liu[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* A reconfigurable RF spectral shaper for dynamic wideband frequency component manipulation is experimentally demonstrated. Spectral functions including positive and negative slopes, low-pass, parabolic, inverted-parabolic functions, as well as triangular and saw-tooth functions have been achieved.

W2A.37
Selective Mark or Space Level Amplitude Regeneration Using Blue Chirp Spectral Slicing in a QD-SOA, Motoharu Matsuura[1], Genma Ito[1]; [1]*Univ. of Electro-Communications, Japan.* We present a selective amplitude regeneration of mark or space level using spectral slicing in a QD-SOA. By controlling the input signal power, we achieve significantregeneration effect specialized for either mark or space level.

W2A.38
Experimental Analysis of Noise Transfer in Optical Phase Conjugation Process in Nonlinear SOA, Aneesh Sobhanan[1], Karthik Vijay Annur Myilswamy[1], Lakshmi Narayanan Venkatasubramani[1], R David Koilpillai[1], Deepa Venkitesh[1]; [1]*Indian Inst. of Technology, Madras, India.* We experimentally evaluate the noise transfer properties during the phase conjugation process in nonlinear SOA by varying the OSNR of the input signal. OSNR retention is observed for both the signal and the conjugate.

W2A.39
Real-time FPGA Demonstration of Hybrid Bi-directional MMW and FSO Fronthaul Architecture, Yahya M. Alfadhli[1], Peng-Chun Peng[2], Hyunwoo Cho[1], Siming Liu[1], Rui Zhang[1], You-Wei Chen[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Department of Electro-Optical Engineering, National Taipei Univ. of Technology, Taiwan.* We experimentally demonstrate a converged hybrid bi-directional mobile fronthaul by integrating MMW and FSO links with real-time FPGA processing. We achieve long-term stability under practical 5G operation scenarios with EVM variations of <0.7% for 16-QAM.

W2A.40
Mitigation of Effects of Angle-of-arrival Fluctuation and Pointing Error on Airborne Free-space Optical Systems, Vuong V. Mai[1], Hoon Kim[1]; [1]*Korea Advanced Inst. of Science & Tech, Korea.* We propose an energy-efficient adaptive beam control technique, where beam sizes are adjusted without iterations at both transmitter and receiver using variable-focus lenses, to mitigate the performance degradation caused by angle-of-arrival fluctuations and pointing errors.

W2A.41
5G NR Multi-beam Steering Employing a Photonic TTD Chip Assisted by Multi-core Fiber, Maria Morant[1], Ailee Trinidad[2], Eduward Tangdiongga[2], Ton Koonen[2], Roberto Llorente[1]; [1]*Nanophotonics Technology Center, Universitat Politècnica de València, Spain;* [2]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands.* Beam steering demonstration employing integrated optical ring resonators (ORRs) and multi-core fiber with multiple beams at 17.6GHz and 26GHz obtains 103.5° beam separation. A 4×1 beamforming system provides up to 16.8Gbps with 20° beam steering.

W2A.42
Power Loading Based on Portfolio Theory for Densified Millimeter-wave Small-cell Communications, Shuyi Shen[1], Bernardo A. Huberman[2], Lin Cheng[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*CableLabs, USA.* We experimentally demonstrate a novel scheme of power loading based on portfolio theory for millimeter-wave small-cell densification. By exploiting the statistical characteristics of interference, this approach improves the average throughput by 91% and reduces the variance.

W2A.43
High Accuracy Non Ambiguity ToF Lidar System Based on Pseudo-random Noise Code and Phase Detection Method, Yubin Zang[1], Hongwei Chen[1], Sigang Yang[1], Minghua Chen[1]; [1]*Tsinghua Univ., China.* By utilizing PRN code and phase detection method under 1GHz subcarrier modulation, an improved ToF Lidar is proposed which achieves millimeter accuracy under extremely low SNR over 60 meters without ambiguity in distance ranging.

W2A.44
Machine Learning Aided In-phase/Quadrature Skew and Imbalance Calibration for Coherent Optical Transmitters, Xiaoxiao Dai[1], Ming Luo[1], Xiang Li[1]; [1]*State Key Lab. of Optical Comm. Tech, China.* We apply artificial neural network to guide the calibration of IQ time skew and amplitude imbalances for coherent optical transmitters with heterodyne detection and modified real-value constant module algorithm. 12.8 dB performance improvement is observed after only three calibration steps.

W2A.45
50-Gb/s PAM4 over 50-km Single Mode Fiber Transmission Using Efficient Equalization Technique, Xizi Tang[1], Shuangyue Liu[1], Xuekai Xu[1], Jia Qi[1], Mengqi Guo[1], Ji Zhou[2], Yaojun Qiao[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, School of Information and Communication Engineering, Beijing Univ. Posts & Telecommunications, China;* [2]*Department of Electronic Engineering, College of Information Science and Technology, Jinan Univ., China.* We experimentally demonstrate a C-band 50-Gb/s PAM4 transmission over 50-km single mode fiber using efficient equalization technique. Without any optical amplifier and chromatic dispersion compensation, the receiver sensitivity reaches -7.5 dBm at BER of 10^{-3}.

W2A.46
Identification of Soft Failures in Optical Links Using Low Complexity Anomaly Detection, Siddharth Varughese[1], Daniel J. Lippiatt[1], Thomas Richter[2], Sorin Tibuleac[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*ADVA Optical Networking, USA.* We demonstrate one-class SVM employing readily available receiver side DSP features to detect soft link failures. The technique was able to detect inferior lasers, faulty ROADMs, OSNR degradation and inter-channel interference with <4% classification error.

W2A.47
Faster-than-nyquist DMT QPSK/16-QAM Signal Transmission with Iterative Detection and Sphere Decoder, Yixiao Zhu[1], Xiaoke Ruan[1], Fan Zhang[1]; [1]*Peking Univ., China.* We experimentally demonstrate 40Gbaud faster-than-Nyquist DMT QPSK/16-QAM signal transmission with bandwidth compression ratio of 0.7 and 0.88, respectively. The performance of iterative detection and sphere decoder for inter-carrier interference mitigation are investigated in both simulation and experiment.

W2A.48
Power Control Strategies in C+L Optical Line Systems, Alessio Ferrari[1], Dario Pilori[1], Emanuele Virgillito[1], Vittorio Curri[1]; [1]*Politecnico di Torino, Italy.* Following the LOGO paradigm, we propose and test frequency-dependent power control strategies and show that 50% pre-tilting for the L-band and flat launch for the C-band is a good strategy as predicted by the GGN-model.

W2A.49
Low Complexity Sub-band Digital Back Propagation, Seiji Okamoto[1], Kengo Horikoshi[1], Masanori Nakamura[1], Asuka Matsushita[1], Fukutaro Hamaoka[1], Yoshiaki Kisaka[1]; [1]*Nippon Telegraph & Telephone Corp, Japan.* We propose sub-band digital back propagation (DBP). We confirmed performance improvement by 4 sub-band DBP with 10-WDM 64-Gbaud 64QAM transmission over 840 km. Total FFT/IFFT size becomes approximately one quarter of full-band DBP.

W2A.50
Wiener-Hopf Method for b-Modulation, Sander Wahls[1], Shrinivas Chimmalgi[1], Peter J. Prins[1]; [1]*Technische Universiteit Delft, Netherlands.* A numerical method for the generation of fiber inputs in nonlinear frequency division multiplexing (NFDM) systems based on b-modulation is provided. The method is parallelizable, does not suffer from error propagation, and converges exponentially.

W2A.51
Improving DML-based OFDM Transmission by a Filter-aided Neural Network Equalizer, Chia Chien Wei[1], Wei-Hsiang Huang[1], Chung-Wen Wang[1], Hidenori Taga[2], Takehiro Tsuritani[2]; [1]*National Sun Yat-sen Univ., Taiwan;* [2]*Photonic Transport Network Laboratory, KDDI Research Inc., Japan.* We propose a filter-aided NN to compensate 10G-DML-based OFDM transmission, avoiding low-frequency SNR degradation. After 100- and 150-km SMF, the data rates are increased by 95 and 130% to achieve ~40 and 32 Gbps, respectively.

W2A.52
Fast and Format-transparent Polarization Tracking Scheme Based on Nonlinear Principal Component Analysis Criterion, Qian Xiang[1], Yanfu Yang[1], Qun Zhang[1], Yong Yao[1]; [1]*Harbin Inst. of Technology, Shenzhen, China.* A fast and format-transparent polarization tracking recovery scheme based on nonlinear principal component analysis criterion is proposed. Simulation and experimental results indicate that our scheme shows fast polarization tracking capability, compared with ICA

12:30–14:00 Unopposed Exhibit-only Time,
Exhibit Hall (concessions available)
Lunch Break *(on own)*

NOTES

Room 1

14:00–16:00
W3A • III-IV Lasers
Presider: Yasuhiro Matsui; Finisar Corporation, USA

W3A.1 • 14:00
850 nm VCSELs for 50 Gb/s NRZ Error-free Transmission over 100-meter OM4 and up to 115 °C Operation, Hsiao-Lun Wang[1], Wenning Fu[1], Junyi Qiu[1], Milton Feng[1]; [1]*Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA.* 850-nm multi-mode oxide-VCSELs with record performance of 50-Gb/s (RT) and 44-Gb/s (85°C) NRZ error-free transmission over 100-meter OM4 are demonstrated. The L-I-V, optical bandwidth and BER of 30 GHz VCSEL are characterized up to 115°C

W3A.2 • 14:15
Ultra-fast Zn-diffusion/Oxide-relief 940 nm VCSELs, Chen-Lung Cheng[1], Mikel Agustin[2], Joerg Kropp[2], Nikolay Ledentsov[2], Zuhaib Khan[1], Jin-Wei Shi[1], Nikolay Ledentsov Jr[2]; [1]*National Central Univ., Taiwan;* [2]*VI Systems GmbH, Germany.* We demonstrate 940nm VCSELs with record-high 3-dB E-O bandwidths as 40 (32) GHz under room-temperature (85C^0) operation. It achieves error-free 60Gbps (room-temperature) and 50Gbps (85 C^0) OOK transmission over 1m and 100m OM5 fiber, respectively.

W3A.3 • 14:30
25-30 Gbps Error-free Data Transmission with Large Oxide Aperture Diameter 980 nm VCSELs, James Lott[1]; [1]*Technische Universität Berlin, Germany.* Using a simplified 980 nm vertical cavity surface emitting laser (VCSEL) epitaxial design we achieve record error free 25 and 30 Gbps data transmission at operating optical output powers of 23 and 17 mW, respectively.

Room 2

14:00–16:00
W3B • Novel Device Design
Presider: Nicolas Dupuis; IBM TJ Watson Research Center, USA

W3B.1 • 14:00 Invited
Fully Reconfigurable Waveguide Bragg Gratings for Programmable Photonic Signal Processing, Jianping Yao[1], Weifeng Zhang[1]; [1]*Ottawa Univ., Canada.* Fully reconfigurable silicon-based waveguide Bragg gratings for programmable photonic signal processing are discussed. Two waveguide grating structures are introduced and their experimental verifications are provided.

W3B.2 • 14:30
Inverse Design and Demonstration of Ultracompact Silicon Polarization Rotator, Weijie Chang[1], Yingquan Ao[1], Longhui Lu[1], Songnian Fu[1], Lei Deng[1], Mengfan Cheng[1], Li Xia[1], Deming Liu[1], Minming Zhang[1]; [1]*Huazhong Univ. of Science and Technology, China.* An ultra-compact silicon polarization rotator based on inverse-designed subwavelength structures is proposed and experimentally exhibited high performance with high extinction ratio of 19 dB, a footprint of 1.2 × 7.2 μm^2 and only one-step etching.

Room 3

14:00–15:15
W3C • Fiber Lasers
Presider: Takemi Hasegawa; Sumitomo Electric Industries Ltd, Japan

W3C.1 • 14:00 Invited
High Peak Power Mamyshev Oscillators, Frank W. Wise[1]; [1]*Applied Physics, Cornell Univ., USA.* Recent progress in scaling the peak power of femtosecond-pulse fiber oscillators will be reviewed. So-called Mamysehv oscillators achieve peak powers an order of magnitude higher than those of prior fiber lasers.

W3C.2 • 14:30
Real-time Multi-regime Programmable Mode-locked Fiber Laser Enabled by Human-like Algorithm, Guoqing Pu[1], Lilin Yi[1], Li Zhang[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* The first real-time programmable mode-locked fiber laser, automatically locking on multiple regimes enabled by the proposed human-like algorithm is demonstrated, achieving the fastest cold boost and recovery time of 0.22 s and 14.8 ms respectively.

Room 6C

14:00–16:00
W3D • Special Session: Quantum Technologies and Optical Communications Part 1

W3D.1 • 14:00 Invited
An Introduction to Quantum Computing and Its Application, Bo Ewald[1]; [1]*D-Wave Systems, Canada.* This presentation will introduce the ideas and principles that have enabled the first quantum computers. We'll briefly review the technologies and architectures, then dive a little more deeply into how the world's first commercial quantum computer works.

W3D.2 • 14:30 Invited
Special Session: Quantum Technologies, Dirk Englund[1]; [1]*MIT, USA.*

Room 6D

14:00–16:00
W3E • High Speed Silicon Photonics II
Presider: Kenneth Jackson; Sumitomo, USA

W3E.1 • 14:00 Tutorial
Silicon Photonics, Hybrid Integration, and Frequency Combs: Technologies for High-bandwith Communications, Christian Koos[1]; [1]*Karlsruhe Inst. of Technology KIT, Germany.* High Bandwidth Silicon Photonics Systems

Room 6E

14:00–15:30
W3F • SDM Transmission II
Presider: Takayuki Mizuno; NTT Network Innovation Laboratories, Japan

W3F.1 • 14:00 Tutorial
Modeling of Multiple-mode Propagation in Fibers for Space-division Multiplexing, Cristian Antonelli[1]; [1]*Universita degli Studi dell'Aquila, Italy.* This tutorial reviews the modelling of the main propagation effects in fibers for SDM transmission. Addressed specifically are random mode coupling, modal dispersion, mode-dependent loss, and nonlinear distortions, as well as their impact on system performance.

Cristian Antonelli received his PhD degree in Electrical Engineering from the University of L'Aquila in 2006. During his graduate studies, he worked on the "Hinge Model" for the time dynamics of PMD within a collaboration with AT&T Labs. In 2006 he spent six months at MIT, performing research on the theory of mode-locked fiber lasers. Since 2007 he was a senior research scientist at CNISM and later at the University of L'Aquila, where he became an assistant professor in 2014. His work focuses on the modelling and characterization of fiber-optic communication systems, including SDM. Cristian Antonelli has served on the committees of several major international conferences and he is currently serving as an AE for the IEEE/OSA JLT.

Room 6F

14:00–16:00
W3G • Symposia: Network Automation 1

W3G.1 • 14:00 Invited
Zero Touch Operation Across Multiple Layers and Datacenter Operation, Andrew Leong[1]; *[1]Facebook Inc., USA.*

W3G.2 • 14:30 Invited
Application of Probabilistic Constellation Shaping and Gaussian Model for Network Self-optimization, Marco Bertolini[1], Bruno Lavigne[2], Thierry Zami[2], Yuan-Hua Kao[3], Oriol Bertran-Pardo[1]; *[1]Nokia Corp., Italy; [2]Nokia Corp., France; [3]Nokia Corp., USA.* In this paper we review the concepts of probabilistic constellation shaping and of Gaussian modeling for fiber propagation to outline network self-optimization techniques to maximize capacity over the system lifetime.

Room 7

14:00–15:45
W3H • Coding and Modulation
Presider: Yi Cai; ZTE TX, Inc., USA

W3H.1 • 14:00
Low-complexity, Low-PAPR Polarization-time Code for PDL Mitigation, Tomofumi Oyama[1], Guoxiu Huang[1], Hisao Nakashima[1], Yoshitaka Nomura[1], Tomoo Takahara[1], Takeshi Hoshida[1]; *[1]Fujitsu Laboratories Ltd., Japan.* We apply a polarization-time (PT) code based on number theory for PDL mitigation. The PT code has comparable PDL mitigation performance to the best PT codes reported so far, and higher tolerance to fiber nonlinearities.

W3H.2 • 14:15
FPGA-based Real-time Soft-decision LDPC Performance Verification for 50G-PON, Mingwei Yang[1], Xiang Liu[2], Linlin Li[2], Ivan Djordjevic[1]; *[1]Univ. of Arizona, USA; [2]Futurewei Technologies, USA.* We have studied the combined use of the mother LDPC code from ongoing industrial standards and soft-decision to further improve the performance of the FEC. Through experimental measurements based on a real-time FPGA platform, we found that this approach offers ~1.3 dB more gross coding gain.

W3H.3 • 14:30
First Experimental Verification of Improved Decoding of Staircase Codes Using Marked Bits, Bin Chen[1], Yi Lei[1,2], Sjoerd Peter van der Heide[1], John van Weerdenburg[1], Alex Alvarado[1], Chigo Maduka Okonkwo[1]; *[1]Eindhoven Univ. of Technology, Netherlands; [2]Beijing Univ. of Posts and Telecommunications, China.* Experimental validation for improved staircase decoding via marked bits is shown for the first time. Using a single-span hybrid-amplified recirculating loop experiment, we demonstrate reach increases of up to 240 km.

Room 8

14:00–15:45
W3I • Multiplexing and Multichannel Processing
Presider: Ana Pejkic; Univ. of California San Diego, USA

W3I.1 • 14:00 Invited
Enhanced Optical Communications through Joint Time-frequency Multiplexing Strategies, Tsuyoshi Konishi[2], Takuya Murakawa[2], Tomotaka Nagashima[2], Satoshi Shimizu[3], M Hasegawa[2], Kuninori Hattor[4], Naoya Wada[3], H Uenohara[5], Takahiro Kodama[6], Gabriella Cincotti[1]; *[1]Univ. Roma Tre, Italy; [2]Graduate School of Engineering, Osaka Univ., Japan; [3]NICT, Japan; [4]NTT Electronics, Japan; [5]Tokyo Inst. of Technology, Japan; [6]Graduate Faculty of Interdisciplinary Research, Univ. of Yamanashi, Japan.* We demonstrate an ultimate flexible approach for simultaneous OFDM and N-OTDM transmission, using intermediate grids between time and frequency axes. We achieve open eye diagrams, and performance below the FEC limit in an 89.2-km field-trial.

W3I.2 • 14:30
Experimental Generation and Time Multiplexing of Data-carrying Nyquist Sinc Shaped Channels from a Single Microresonator-based Kerr Frequency Comb, Fatemeh Alishahi[1], Ahmad Fallahpour[1], Kaiheng Zou[1], Yinwen Cao[1], Arne Kordts[2], Maxim Karpov[2], Martin H. Pfeiffer[2], Peicheng Liao[1], Ahmed Almaiman[1], Huibin Zhou[1], Karapet Manukyan[1], Tobias Kippenberg[2], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]EPFL, Switzerland.* We experimentally achieve optical time multiplexing of multiple Nyquist channels. A single microresonator Kerr comb allows the generation of multiple Nyquist sinc-shaped pulse trains. TDM of pulse trains are obtained through wavelength conversion inside a PPLN.

Room 9

14:00–16:00
W3J • 5G over Optical Access
Presider: Volker Jungnickel; Fraunhofer HHI, Germany

W3J.1 • 14:00 Invited
Optical Access Technology for B5G MFH/MBH, Kohsuke Nishimura[1], Shota Ishimura[1], Abdelmoula Bekkali[1], Kazuki Tanaka[1], Haruhisa Hirayama[1], Yu Tsukamoto[1], Shinobu Nanba[1], Masatoshi Suzuki[1]; *[1]KDDI Research, Inc., Japan.* The paper overviews recent trends in mobile front/backhaul (MFH/MBH) toward Beyond-5G (B5G) era, covering functional split of base station functions, Radio-over-Fiber and related transmission schemes, and digital coherent transmission schemes.

W3J.2 • 14:30
First Demonstration of Bandwidth-allocation Scheme for Network-slicing-based TDM-PON toward 5G and IoT Era, Hiroyuki Uzawa[1], Kazuaki Honda[1], Hirotaka Nakamura[1], Yukio Hirano[2], Kenichi Nakura[2], Seiji Kozaki[2], Atsushi Okamura[2], Jun Terada[1]; *[1]NTT Corporation, Japan; [2]Mitsubishi Electric Corporation, Japan.* We propose a bandwidth allocation scheme for converging 5G mobile fronthaul and IoT networks on a TDM-PON. Experiments show that the scheme can simultaneously provide low-latency transmission, bandwidth guarantee, and auto-discovery process.

Show Floor Programming

Next-generation Coherent Architectures – Pluggable vs Multihaul, a Knockout or a Draw?
Session Sponsored by Acacia Communications
13:30–14:30, *Theater III*

■ **Network Operator Summit Panel II: 5G Applications and Networks: Real-World Operator Case Studies**
13:30–15:00, *Theater I*

Standardization Update on Last Mile Delivery Networks, OTN Beyond 100G and Coherent Optics Interoperability
ITU
14:15–15:15, *Theater II*

Room 1

W3A • III-IV Lasers—Continued

W3A.4 • 14:45
85°C Operation of Single-mode 850 nm VCSELs for High Speed Error-free Transmission up to 1 km in OM4 Fiber, Junyi Qiu[1], Xin Yu[1], Milton Feng[1]; [1]*Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA.* Single-mode 850 *nm* oxide-confined VCSELs with integrated mode-selective filter are developed. The fabricated devices have demonstrated 32 *Gb/s* (room temperature) & 26 *Gb/s* (85°C) error-free transmission over 500 *m* OM4 fiber, and 28 *Gb/s* (room temperature) & 22 *Gb/s* (85°C) over 1 *km* OM4 fiber.

W3A.5 • 15:00
Full C-band Wavelength Demultiplexer with Optical Gain for Use in Wavelength Selective Switch, Ryosuke Togashi[1], Xiaodong Gu[1], Takahiro Sakaguchi[1], Bocheng Cao[2], Junichi Shimizu[2], Fumio Koyama[1]; [1]*Tokyo Inst. of Technology, Japan;* [2]*Huawei Technologies Japan K.K., Japan.* A full C-band wavelength demultiplexer based on Bragg reflector waveguide is demonstrated with optical gain. Current injection into the device improved the demultiplexed resolution and compensated the device insertion loss at the same time.

Room 2

W3B • Novel Device Design—Continued

W3B.3 • 14:45 Top Scored
50GHz Silicon Cascaded Mach-zehnder Wavelength Filter and Automatic Phase Error Correction, Liangshun Han[1], Bill P. Kuo[1], Ana Pejkic[1], Nikola Alic[1], Stojan Radic[1]; [1]*Univ. of California San Diego, USA.* We demonstrate a silicon photonic 50GHz 16-channel cascaded Mach-Zehnder wavelength filter with over 26dB extinction ratio. An automatic phase error correction method was also proposed and implemented to guarantee filter transfer characteristic.

W3B.4 • 15:00
First Experimental Demonstration of Wavefront-matching-method-designed Silicon Mode Converters, Yusuke Sawada[1], Takeshi Fujisawa[1], Takanori Sato[1], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan.* Ultrasmall TE_0-TE_1 and TE_1-TE_2 mode converters based on Si-wire waveguides designed by wavefront matching (WFM) method are demonstrated both theoretically and experimentally. This is the first demonstration of WFM-designed Si waveguide devices.

Room 3

W3C • Fiber Lasers—Continued

W3C.3 • 14:45
A Mode Locked Fiber Laser with Switchable High-order Modes Using Intracavity Acousto-optic Mode Converter, Jiafeng Lu[1], Linghao Meng[1], Fan Shi[1], Xianglong Zeng[1]; [1]*Shanghai Univ., China.* We demonstrate a mode-switchable generation of $LP_{11a/b}$ modes via a dual-resonant acousto-optic mode converter. Within the configuration of mode-locked intracavity laser output, this approach has very potential applications in mode division multiplexing system, particle manipulation.

W3C.4 • 15:00
All-fiber Orbital Angular Momentum Laser Generated with Titled Fiber Bragg Grating Pair Written in Few-mode Ring-core Fiber, Kang Yang[1,2], Yange Liu[1]; [1]*Nankai Univ., China;* [2]*Handan Univ., China.* An all-fiber method of orbital angular momentum (OAM) beams laser generated is proposed. The laser cavity is formed by a pair of few-mode ring-core fiber based titled fiber Bragg gratings.

Room 6C

W3D • Special Session: Quantum Technologies and Optical Communications Part 1—Continued

W3D.3 • 15:00 Invited
Large-scale Integrated Quantum Photonic Technologies for Communications and Computation, Mark G. Thompson[1]; [1]*Univ. of Bristol, UK.* Quantum photonics has emerged as a promising approach to realizing large-scale and complex quantum technologies. Here we overview recent developments presenting circuits comprising hundreds of photonic components integrated into single coherent quantum systems.

Room 6D

W3E • High Speed Silicon Photonics II—Continued

W3E.2 • 15:00
A 4×40 Gb/s O-band WDM Silicon Photonic Transmitter Based on Micro-ring Modulators, Stelios Pitris[1,2], Miltiadis Moralis-Pegios[1,2], Theoni Alexoudi[1,2], Yoojin Ban[3], Peter De Heyn[3], Joris Van Campenhout[3], Nikos Pleros[1,2]; [1]*Dept. of Informatics, Aristotle Univ. of Thessaloniki, Greece;* [2]*Center for Interdisciplinary Research & Innovation, Aristotle Univ. of Thessaloniki, Greece;* [3]*imec, Belgium.* We present an O-band micro-ring-based silicon-photonic 4-channel WDM transmitter with 6.75 nm-channel spacing for high-speed optical interconnects and demonstrate 4×40 Gb/s data generation operation featuring an energy efficiency of 24.84 fJ/bit/RM under 1.82 Vpp drive.

Room 6E

W3F • SDM Transmission II—Continued

W3F.2 • 15:00 Top Scored
Full C-band 3060-km DMD-unmanaged 3-mode Transmission with 40.2-Tb/s Capacity Using Cyclic Mode Permutation, Kohki Shibahara[1], Takayuki Mizuno[1], Hiroto Kawakami[1], Takayuki Kobayashi[1], Masanori Nakamura[1], Kota Shikama[2], Kazuhide Nakajima[3], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*NTT Device Technology Laboratories, Japan;* [3]*NTT Access Network Service Systems Laboratories, Japan.* We demonstrate the longest three mode-multiplexed full C-band transmission over 3060 km. The cyclic mode permutation technique enabled DMD-unmanaged transmission across 4.4-THz optical bandwidth over FMF having DMD of > 33.7 ps/km.

Room 6F

W3G • Symposia: Network Automation 1—Continued

W3G.3 • 15:00 Invited

Fault Management Based on Machine Learning, Luis Velasco[1], Danish Rafique[2]; *[1]Universitat Politecnica de Catalunya, Spain; [2]ADVA Optical Networking, Germany.* Machine Learning (ML) brings many benefits for network operation. In this paper, basic ML concepts and its integration into existing network control and management planes are reviewed. Case studies covering fault management are illustrated.

Room 7

W3H • Coding and Modulation—Continued

W3H.4 • 14:45

Nonbinary Polar Coding for Multilevel Modulation, Semih Cayci[1], Toshiaki Koike-Akino[1], Ye Wang[1]; *[1]Mitsubishi Electric Research Labs, USA.* We investigate nonbinary polar-coded modulations, which achieve a significant performance gain of at least 1 dB compared to binary counterparts at a short block-length of 2048 bits.

W3H.5 • 15:00

Partially Ordered Statistics Demapping for Multi-dimensional Modulation Formats, Djalal Falih Bendimerad[1], Huijian Zhang[1], Ingmar Land[1], Hartmut Hafermann[1]; *[1]Huawei Technologies France, France.* We propose a very-low complexity and high-performance algorithm for soft-demapping of multi-dimensional modulation formats. We assess its performance over the linear channel for four 8D formats, generated using binary arithmetics. This solution outperforms current algorithms in terms of complexity without loss in performances.

Room 8

W3I • Multiplexing and Multichannel Processing—Continued

W3I.3 • 14:45

Low-speed DSP Assisted Dispersion Compensation-free IM/DD Optical OFDM Transmission over 100 km-SMF Using Time- and Frequency-domain Sparse-subcarrier Multiplexing, Takahiro Kodama[1], Tatsuya Miyazaki[1], Masanori Hanawa[1], Akihiro Maruta[2], Naoya Wada[3], Gabriella Cincotti[4]; *[1]Univ. of Yamanashi, Japan; [2]Osaka University, Japan; [3]NICT, Japan; [4]Univ. Roma Tre, Japan.* Time- and frequency-domain sparse-subcarrier IM/DD optical OFDM system is proposed for dispersion-tolerant transmission. We show a BER improvement for four-subcarrier x 10 Gb/s/subcarrier OFDM, using duo-binary coding and MLSE over 100-km transmission without dispersion compensation.

W3I.4 • 15:00

SOI-ring Based Analog Phase Processing for Chromatic Dispersion Compensation in A-IFoF Fronthaul, Konstantina Kanta[1], Panagiotis Toumasis[1], Giannis Poulopoulos[1], Nikos Iliadis[1], Nikos Argyris[1], Giannis Giannoulis[1], Dimitrios Apostolopoulos[1], Hercules Avramopoulos[1]; *[1]ICCS-NTUA, Greece.* We demonstrate a SOI ring-based, analog phase processing method to manage the dispersion induced power fading of DSB IFoF. Experimental results in an IFoF/V-band Fronthaul link, revealed improved EVM performance of 1 Gbaud QPSK signals.

Room 9

W3J • 5G over Optical Access—Continued

W3J.3 • 14:45

Proactive Dynamic Network Slicing with Deep Learning Based Short-term Traffic Prediction for 5G Transport Network, Qize Guo[1], Rentao Gu[1], Zihao Wang[1], Tianyi Zhao[1], Yuefeng Ji[1], Jian Kong[2], Riti Gour[2], Jason Jue[2]; *[1]Beijing Laboratory of Advanced Information Network, Beijing Univ. of Posts and Telecomm, China; [2]Dept. of Computer Science, The Univ. of Texas at Dallas, USA.* We propose a proactive dynamic network slicing scheme by the deep-learning based short-term traffic prediction approach for 5G transport network. The demonstration shows the utilization efficiency improved from 46.33% to 71.53% under the evaluated scenario.

W3J.4 • 15:00

Demonstration of ONU Activation for In-service TDM-PON Allowing Uninterrupted Low-latency Transport Links, Rene Bonk[1], Robert Borkowski[1], Michael Straub[1], Harald Schmuck[1], Thomas Pfeiffer[1]; *[1]Nokia Bell Labs, Germany.* We propose an upstream-traffic-disruption-free ONU activation method enabling low-latency services over TDM-PON. We demonstrate ranging using only 5-µs-long empty window independent from fiber length, a significant improvement over 250/450-µs quiet windows required in conventional ranging.

Show Floor Programming

Next-generation Coherent Architectures – Pluggable vs Multihaul, a Knockout or a Draw?
Session Sponsored by Acacia Communications
13:30–14:30, *Theater III*

■ **Network Operator Summit Panel II: 5G Applications and Networks: Real-World Operator Case Studies**
13:30–15:00, *Theater I*

Standardization Update on Last Mile Delivery Networks, OTN Beyond 100G and Coherent Optics Interoperability
ITU
14:15–15:15, *Theater II*

Room 1

W3A • III-IV Lasers—Continued

W3A.6 • 15:15
Demonstration of 100 Gbps per Lambda PAM4 Transmission with 1310 nm and 1330 nm Directly Modulated Lasers, Mingshan Li[1], YuJing Chen[1], Yu Yan Liang[1], Huanlin Zhang[1], Elsie Marentes[1], Qin Li[1], Yi Wang[1], Jun Zheng[1]; [1]*Applied Optoelectronics Inc., USA.* 100Gbps per lambda PAM4 transmission with 1310 nm and 1330 nm directly modulated lasers is demonstrated. Dispersion penalty after transmission through 2km SMF is less than 1 dB measured in TDECQ or receiver sensitivity change.

W3A.7 • 15:30
Carrier Diffusion Effect in Gain Chip and 60 mW Tunable External Cavity Laser with Diffusion-limited Gain Chip and Polymer-based Waveguide Grating, Dong Churl Kim[1], Young-Tak Han[1], Donghoon Lee[1], Seok-Tae Kim[1], Soojeong Jeon[1], Sangho Park[1], Jang-Uk Shin[1], Yong-Hwan Kwon[1], Jong-Hoi Kim[1], Yongsoon Baek[1], Ho-Sung Cho[2]; [1]*Electronics & Telecomm Res. Inst., Korea;* [2]*ELDIS, Korea.* In a tunable external cavity laser (T-ECL) module with a diffusion-reduced gain chip and a polymer waveguide grating, we have obtained P_{out} of 60 mW and 50 mW at 20 °C and 40 °C, respectively.

Room 2

W3B • Novel Device Design—Continued

W3B.5 • 15:15
Deep Neural Network Inverse Modeling for Integrated Photonics, Mohammad Tahersima[1], Keisuke Kojima[1], Toshiaki Koike-Akino[1], Devesh Jha[1], Bingnan Wang[1], Chungwei Lin[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Labs, USA.* We propose a deep neural network model that instantaneously predicts the optical response of nanopatterned silicon photonic power splitter topologies, and inversely approximates compact (2.6 x 2.6 um2) and efficient (above >92%) power splitters for target splitting ratios.

W3B.6 • 15:30
4-port Integrated Stokes Vector Receiver Circuit for Multi-level 3D Signal Detection and OSNR Monitoring, Takahiro Suganuma[1], Samir Ghosh[1], Yoshiaki Nakano[1], Takuo Tanemura[1]; [1]*Univ. of Tokyo, Japan.* A novel Stokes vector (SV) receiver circuit with 4-port configuration integrated on a compact InP chip is fabricated to demonstrate SV retrieval with various intensity and degree-of-polarization as well as application to in-band OSNR monitoring.

Room 3

W3C • Fiber Lasers—Continued

Room 6C

W3D • Special Session: Quantum Technologies and Optical Communications Part 1—Continued

W3D.4 • 15:30 Invited
Special Session: Quantum Technologies, Yu-Ao Chen[1]; [1]*Univ. of Science and Technology of China, China.*

Room 6D

W3E • High Speed Silicon Photonics II—Continued

W3E.3 • 15:15
A Compact 100G-ER4 ROSA Realized by Hybrid Integration of SOA and Lensed PIN-PDs for QSFP28 Transceivers, Young-Tak Han[1], Donghoon Lee[1], Jang-Uk Shin[1], Sangho Park[1], Seok-Tae Kim[1], Sang-Moon Shin[2], Hong-Beom Kim[2], Byoungdon Yoon[2], Yongsoon Baek[1]; [1]*Electronics & Telecomm Res. Inst., Korea;* [2]*ARTECH, Korea.* With hybrid integration of SOA and lensed PIN-PD chips on a silica-based AWG platform, we have developed a novel compact 100G-ER4 ROSA for QSFP28 transceivers with sensitivities below -27 dBm at a BER of 1×10^{-12}.

W3E.4 • 15:30
100Gbps CWDM4 Silicon Photonics Transmitter for 5G Applications, Haijiang Yu[1], Jonathan Doylend[1], Wenhua Lin[1], Kimchau Nguyen[1], Wei Liu[1], David Gold[1], Avsar Dahal[1], Catherine Jan[1], Robert Herrick[1], George Ghiurcan[1], Summer Hollingsworth[1], Randolph Romero[1], Michael Favaro[1], Liang Qiu[1], Daniel Zhu[1], Yuliya Akulova[1]; [1]*Intel, USA.* A 100Gbps CWDM4 silicon photonics transmitter with four heterogeneously integrated distributed feedback lasers on 20 nm wavelength grids has been demonstrated for 5G wireless front-haul applications over a temperature range of -20°C to 95°C

Room 6E

W3F • SDM Transmission II—Continued

W3F.3 • 15:15
80-Channel WDM-MDM Transmission over 50-km Ring-core Fiber Using a Compact OAM DEMUX and Modular 4×4 MIMO Equalization, Junwei Zhang[1], Yuanhui Wen[1], Heyun Tan[2], Jie Liu[1], Lei Shen[3], Maochun Wang[4], Jiangbo Zhu[5], Changjian Guo[4], Yujie Chen[1], Zhaohui Li[1], Siyuan Yu[1,5]; [1]*School of Electronics and Information Engineering, State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-sen Univ., China;* [2]*School of Physics, State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-sen Univ., China;* [3]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, State Key Laboratory of Optical Fiber and Cable Manufacture Technology, China;* [4]*South China Academy of Advanced Optoelectronics, South China Normal Univ., China;* [5]*Photonics Group, Merchant Venturers School of Engineering, Univ. of Bristol, UK.* 8-OAM modes each carrying 10 wavelengths with 2.56-Tbit/s aggregated capacity and 10.24-bit/s/Hz spectral efficiency have been transmitted over 50-km specially designed ring-core fiber, using a compact OAM mode sorter and only modular 4×4 MIMO equalization.

Room 6F

W3G • Symposia: Network Automation 1—Continued

W3G.4 • 15:30 Invited

Optical Zero Touch Networking - A Large Operator Perspective, Eric Breverman[1], Vijay Vusirikala[1], Sean Ngai[1], Nancy El-sakkary[1], Anees Shaikh[1], Tad Hofmeister[1]; [1]*Google, USA.* A key area of innovation in optical networking has been enabling modern, vendor-agnostic APIs on devices. We provide specifics of how these new capabilities enable deployment and operational efficiencies.

Room 7

W3H • Coding and Modulation—Continued

W3H.6 • 15:15

Energy-efficient Soft-assisted Product Decoders, Christoffer Fougstedt[1], Alireza Sheikh[1], Alexandre Graell i Amat[1], Gianluigi Liva[2], Per Larsson-Edefors[1]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*German Aerospace Center (DLR), Germany.* We implement a 1-Tb/s 0.63-pJ/bit soft-assisted product decoder in a 28-nm technology. The decoder uses one bit of soft information to improve its net coding gain by 0.2 dB, reaching 10.3-10.4 dB, which is similar to that of more complex hard-decision staircase decoders.

W3H.7 • 15:30

ASIC Design Exploration of Phase Recovery Algorithms for M-QAM Fiber-optic Systems, Erik Börjeson[1], Christoffer Fougstedt[1], Per Larsson-Edefors[1]; [1]*Chalmers Univ. of Technology, Sweden.* We develop circuit implementations and explore design optimizations for one blind and one pilot-based carrier phase-recovery algorithm, where the former algorithm is shown to dissipate 1.8–4.5 pJ/bit and the latter 0.5–0.3 pJ/bit, using 16 to 256QAM.

Room 8

W3I • Multiplexing and Multichannel Processing—Continued

W3I.5 • 15:15

Repetition Rate Stabilization of a Mode-locked Laser-PIC Optical Frequency Comb Using Harmonic Injection Locking, Ricardo Bustos Ramirez[1], Michael E. Plascak[1], Ashish Bhardwaj[2], Gloria Hoefler[2], Fred A. Kish[2], Peter J. Delfyett[1]; [1]*CREOL, The College of Optics and Photonics, Univ. of Central Florida, USA;* [2]*Infinera Corporation, USA.* We present an all-optical technique to divide millimeter-Wave range (20-80GHz) optical frequency combs down to microwave regime (10GHz) using harmonic injection locking of a chip-scale MLL achieving a repetition rate stability of 10^-10 a 1s.

W3I.6 • 15:30

Electrically Programmable Equivalent-phase-shifted Waveguide Bragg Grating for Multichannel Signal Processing, Jianping Yao[1], Weifeng Zhang[1]; [1]*Univ. of Ottawa, Canada.* A silicon-based on-chip electrically programmable equivalent-phase-shifted waveguide Bragg grating implemented through nonuniform spatial sampling to introduce an equivalent phase shift is designed, fabricated and characterized, and its application in multichannel signal processing is experimentally demonstrated.

Room 9

W3J • 5G over Optical Access—Continued

W3J.5 • 15:15

Load-aware Dynamic Traffic Migration Enabling Low Latency in Hierarchical Edge Cloud-based 5G Fronthaul, Chuang Song[1], Min Zhang[1], Luyao Guan[1], Lin Zhang[1], Danshi Wang[1], Yueying Zhan[2], Suzhi Cao[2], Shaojun Wu[2], Jianhua He[2]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China;* [2]*Technology and Engineering Center for Space Utilization, Chinese Academy of Science, China.* We present a load-aware-based dynamic traffic migration strategy for achieving low latency in hierarchical-edge-cloud-based optical fronthaul network. The experimental results demonstrate the proposed strategies achieve a five-fold delay reduction and release 22.7% burden of fronthaul bandwidth.

W3J.6 • 15:30

Wavelength-shifted Protection for WDM-PON with AMCC Scheme for 5G Mobile Fronthaul, Kazuaki Honda[1], Hirotaka Nakamura[1], Kyosuke Sone[2], Goji Nakagawa[2], Yoshio Hirose[2], Takeshi Hoshida[2], Jun Terada[1]; [1]*NTT Access Network Service Systems Laboratory, NTT Corporation, Japan;* [2]*Fujitsu Limited, Japan.* We propose wavelength-shifted protection using an auxiliary management and control channel (AMCC) scheme against feeder fiber faults for WDM-PON without additional active devices. Its validity is demonstrated on an AMCC evaluation platform for 50-ms operation.

Show Floor Programming

■ **MW Panel IV:**
Optical Fiber Plant Infrastructure - Technologies and Markets
15:30–17:00, *Theater I*

Innovations with Machine Learning in Optical Networks Drive Process Automation
15:30–17:00, *Theater II*

Building the Photonic Integrated Circuit (PIC) Ecosystem for the 21st Century
AIM Photonics
15:30–17:00, *Theater III*

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E
W3A • III-IV Lasers—Continued	**W3B • Novel Device Design—Continued**	**W3C • Fiber Lasers—Continued**	**W3D • Special Session: Quantum Technologies and Optical Communications Part 1—Continued**	**W3E • High Speed Silicon Photonics II—Continued**	**W3F • SDM Transmission II—Continued**
W3A.8 • 15:45 **Narrow Linewidth InAs/InP Quantum Dot DFB Laser,** Tali Septon[1], Sutapa Gosh[1], Annette Becker[2], Vitalii Sichkovskyi[2], Florian Schnabel[2], Anna Rippien[2], Johann Peter Reithmaier[2], Gadi Eisenstein[1]; [1]*Electrical Engineering, Technion, Israel;* [2]*Inst. of Nanostructure Technologies and Analytics (INA), Univ. of Kassel, Germany.* Narrow linewidth InAs/InP QD DFB lasers with linewidths of less than 50kHz at 20°C which broadens to less than 80kHz at 80°C were demonstrated using delayed self- heterodyne as well as by optical frequency comb interferometry.	**W3B.7 • 15:45** **Ultra-compact and Polarization-insensitive MMI Coupler Based on Inverse Design,** Yingjie Liu[1], Zhiyu Li[1], Shuai Wang[1], Nan Zhang[1], Yong Yao[1], Jiangbing Du[2], Zuyuan He[2], Qinghai Song[1], Ke Xu[1]; [1]*Harbin Inst. of Technology, Shenzhen, China;* [2]*Shanghai Jiao Tong Univ., China.* We experimentally demonstrate a polarization-insensitive MMI coupler with a footprint of 2.4×2.4 μm². It allows for >90% transmission efficiency for both TE and TM polarized optical wave with a wavelength range from 1480 ~ 1560 nm.			**W3E.5 • 15:45** **A Directly Modulated Quantum Dot Microring Laser Transmitter with Integrated CMOS Driver,** Yang-Hang Fan[1], Di Liang[2], Ashkan Roshan-Zamir[1], Chong Zhang[2], Binhao Wang[2], Marco Fiorentino[2], Raymond Beausoleil[2], Samuel Palermo[1]; [1]*Texas A&M Univ., USA;* [2]*Hewlett-Packard Enterprise, USA.* We demonstrate an integrated heterogeneous quantum-dot laser transmitter directly modulated by a CMOS driver. Utilizing a developed co-simulation laser model enables the design of an asymmetric 2-tap equalizer to achieve a record 12 Gb/s operation.	

16:00–16:30 Coffee Break, *Upper Level Corridors and Exhibit Hall*

Room 6F	Room 7	Room 8	Room 9
W3G • Symposia: Network Automation 1—Continued	**W3H • Coding and Modulation—Continued**	**W3I • Multiplexing and Multichannel Processing—Continued**	**W3J • 5G over Optical Access—Continued**
			W3J.7 • 15:45 **A 4-channel Beamformer for 9-Gb/s MMW 5G Fixed-wireless Access over 25-km SMF with Bit-loading OFDM,** Yu Tang[1,2], Min-Yu Huang[2], You-Wei Chen[2], Peng-Chun Peng[3], Hua Wang[2], Gee-Kung Chang[2]; *[1]Beijing Jiaotong Univ., China; [2]Georgia Inst. of Technology, USA; [3]National Taipei Univ. of Technology, Taiwan.* An MMW 5G-FWA system is experimentally demonstrated with bit-loading OFDM and a 4-channel beamforming receiver. 9 Gb/s data rate is achieved after 25-km transmission with similar BER performance of 0° and 60° incident angles.

16:00–16:30 Coffee Break, *Upper Level Corridors and Exhibit Hall*

Show Floor Programming

■ **MW Panel IV:**
Optical Fiber Plant Infrastructure - Technologies and Markets
15:30–17:00, *Theater I*

Innovations with Machine Learning in Optical Networks Drive Process Automation
15:30–17:00, *Theater II*

AIM Photonics: Building the Photonic Integrated Circuit (PIC) Ecosystem for the 21st Century
AIM Photonics
15:30–17:00, *Theater III*

Room 1

16:30–18:15
W4A • Free Space Optical Communication
Presider: Mona Hella; Rensselaer Polytechnic Inst., USA

W4A.1 • 16:30 Invited
Converging Underwater and FSO Ground Communication Links, Antonio Jurado-Navas[1], José María Garrido-Balsells[1], Miguel Castillo-Vázquez[1], Antonio García-Zambrana[1], Antonio Puerta-Notario[1]; [1]*Ingeniería de Comunicaciones, Universidad de Málaga, Spain*. We propose a new combined underwater-atmospheric optical communication link for providing a high speed optical connectivity between onshore and sumerge systems. New average BER expressions are derived when assuming amplify-and-forward (AF) relay.

Room 2

16:30–18:00
W4B • Optical Source and Signal Generation
Presider: Liang Zhang; Huawei Technologies Duesseldorf GmbH, Germany

W4B.1 • 16:30 Tutorial
Optical Injection Locking: From Principles to Applications, Zhixin Liu[1]; [1]*Univ. College London, UK*. This tutorial reviews the operation principles and engineering techniques to obtain stable optical injection locking for features including modulation bandwidth enhancement, optical carrier recovery, chirp reduction and their applications in optical communication systems.

Zhixin Liu is with the Department of Electronics and Electrical Engineering at University College London (UCL) in the UK. His research interests include optical transceivers (modulation, clock recovery, laser dynamics), coherent optical signal processing (optical injection locking, frequency and phase locking, multiplexing/demultiplexing schemes), and their applications in optical communication systems.

Room 3

16:30–18:15
W4C • Characterization of SDM Fibers
Presider: Tetsuya Hayashi; Sumitomo Electric Industries Ltd., Japan

W4C.1 • 16:30 Invited
Modal Dynamics in Spatially Multiplexed Links, Karthik Choutagunta[2,1], Roland Ryf[2], Nicolas K. Fontaine[2], Steffen Wittek[2,3], Juan Carlos Alvarado-Zacarias[2,3], Mikael Mazur[2,4], Haoshuo Chen[2], Rene-Jean Essiambre[2], Rodrigo Amezcua Correa[3], Tetsuya Hayashi[5], Yoshiaki Tamura[5], Takemi Hasegawa[5], Toshiki Taru[5], Joseph M. Kahn[1]; [1]*Stanford Univ., USA;* [2]*Nokia Bell Labs, USA;* [3]*CREOL, The Univ. of Central Florida, USA;* [4]*Photonics Laboratory, Chalmers Univ. of Technology, Sweden;* [5]*Sumitomo Electric Industries, Ltd., Japan*. We investigate the vibration sensitivity of spatially multiplexed links by measuring the mode-coupling dynamics of a four-core coupled-core fiber and a reference single-mode fiber. We show that the speed of dynamics increases with mode count.

Room 6C

16:30–18:30
W4D • Special Session: Quantum Technologies and Optical Communications Part 2

W4D.1 • 16:30 Invited
Special Session: Quantum Technologies, Andrew Shields[1]; [1]*Toshiba Cambridge Research Lab, UK*.

Room 6D

16:30–18:30
W4E • Lasers on Si
Presider: Geert Morthier; Ghent Univ., Belgium

W4E.1 • 16:30 Invited
III-V Quantum Dot Lasers Monolithically Grown on Silcion, Huiyun Liu[1]; [1]*Univ. College London, UK*. We review the direct growth of III-V quantum dot laser on Si substrates. A low threading dislocation density, on the order of $10^5 cm^{-2}$, for III-V epilayer on Si has been achieved.

Room 6E

16:30–18:30
W4F • All-optical Signal Processing
Presider: Robert Elschner; Fraunhofer Inst Nachricht Henrich-Hertz, Germany

W4F.1 • 16:30 Invited
Multi-channel All-optical Signal Regeneration, Lu Li[1,3], Pallavi Patki[1,2], Taras Lakoba[4], Michael Vasilyev[1]; [1]*Univ. of Texas at Arlington, USA;* [2]*Infinera Corp., India;* [3]*SubCom, USA;* [4]*Univ. of Vermont, USA*. We discuss simultaneous and independent 2R regeneration of many WDM channels, enabled by a group-delay-managed nonlinear medium, in which high intra-channel nonlinearity can be accumulated without suffering from the nonlinear inter-channel crosstalk.

Room 6F

16:30–18:30
W4G • Symposia: Network Automation 2

W4G.1 • 16:30 Invited
Programmability and End-to-end Automation for Telecommunication Operators (TELCOs), Paul Gunning[1]; [1]*BT Applied Research, UK.* Networking equipment with OpenAPIs admit automation of end-to-end services that span optical and packet domains. Adoption will be considered and proportionate to match *business logic* that lubricates and couples several architectural domains in a TELCO; and constrained by scarcity of programmers adept at effecting the necessary automation.

Room 7

16:30–18:30
W4H • Fronthaul Technologies and System Metrics
Presider: Shuto Yamamoto; NTT Network Innovation Laboratories, Japan

W4H.1 • 16:30 Invited
Optical Network Technologies for 5G Mobile Network, Jun Terada[1]; [1]*NTT Access Service Systems Laboratories, Japan.* This paper describes optical network technologies to accommodate various types of 5G base stations.

Room 8

16:30–18:30
W4I • Direct Detection Systems
Presider: Fred Buchali; Nokia Bell Labs, Germany

W4I.1 • 16:30
BER Improvement of IM/DD Higher-order Optical PAM Signal with Precise Nonlinearity Compensation, Nobuhiko Kikuchi[1], Riu Hirai[1], Takayoshi Fukui[2]; [1]*Hitachi Ltd, Japan;* [2]*Oclaro Japan, Japan.* We introduce a precise Tx-side non-linear distortion compensation scheme for higher-order PAM signals, and experimentally show its effectiveness in 28 GBaud PAM-8 and 40 GBaud THP(Tomlinson Harashima Precoding)-PAM6 signals with more than 2-dB sensitivity improvement.

W4I.2 • 16:45
84 GBd Faster-than-nyquist PAM-4 Transmission Using Only Linear Equalizer at Receiver, Qian Hu[1], Karsten Schuh[1], Mathieu Chagnon[1], Fred Buchali[1], Henning Buelow[1]; [1]*Nokia Bell Labs, Germany.* Based on Tomlinson-Harashima precoding, we demonstrate 84 GBd PAM-4 transmission in an intensity-modulation direct-detection system with 33 GHz brick-wall bandwidth limitation. BER below 7% hard-decision FEC threshold is achieved using only linear equalizer at receiver.

Room 9

16:30–18:00
W4J • High-speed PON
Presider: Lilin Yi; Shanghai Jiao Tong Univ., China

W4J.1 • 16:30
Burst-mode Equalization Strategies in 25 Gbps US-PON Using Duobinary and 10G-class APD for 20-km in C-band, Pablo Torres-Ferrera[1], Valerio Milite[1], Valter Ferrero[1], Maurizio Valvo[2], Roberto Mercinelli[2], Roberto Gaudino[1]; [1]*Politecnico di Torino, Italy;* [2]*Telecom Italia (TIM), Italy.* 25 Gbps burst-mode upstream duobinary transmission in C-band using 10G optoelectronics and APD-based adaptive equalization receiver is analyzed and experimentally demonstrated. We show a memory-aided alternative that avoids the long training preambles (>2600 bits) needed in commonly proposed memoryless approaches.

W4J.2 • 16:45
Variable Gain SOA Pre-amplifier for Optical Equalization of a 25Gb/s Burst-mode PON Upstream with 10G Optics, Marco Dalla Santa[1], Cleitus Antony[1], Giuseppe Talli[1], Paul D. Townsend[1]; [1]*Tyndall National Inst., Ireland.* Variable gain SOA based pre-amplification is demonstrated providing 27dB of optical power equalization in a 25Gb/s PON upstream receiver without fast gain adjustment of electrical amplifiers, supporting a 33.5dB power budget over 25km of SMF.

Show Floor Programming

■ **MW Panel IV:**
Optical Fiber Plant Infrastructure - Technologies and Markets
15:30–17:00, *Theater I*

Innovations with Machine Learning in Optical Networks Drive Process Automation
15:30–17:00, *Theater II*

AIM Photonics: Building the Photonic Integrated Circuit (PIC) Ecosystem for the 21st Century
AIM Photonics
15:30–17:00, *Theater III*

Room 1

W4A • Free Space Optical Communication—Continued

W4A.2 • 17:00
Violet Laser Diode Based 25-Gbps Point-to-point and 12-Gbps MEH/BBEHP Converted White Lighting QAM-OFDM Link, Chia-Yu Su[1,2], Wei-Chun Wang[1,2], Huai-Yung Wang[1,2], Li-Yin Chen[3,4], Gong-Ru Lin[1,2]; *[1]National Taiwan Univ., Taiwan; [2]Department of Electrical Engineering, Taiwan; [3]National Sun Yat-sen Univ., Taiwan; [4]Department of Photonics, Taiwan.* Violet laser diode based point-to-point 64-QAM-OFDM optical wireless transmission at 25.2 Gbps is color converted with a novel short-lifetime MEH/BEHP polymer phosphor to achieve spatially diffused white-lighting and short-reach 16-QAM-OFDM communication at 12.8 Gbps.

W4A.3 • 17:15 Top Scored
200 Gbit/s Free-Space Optics Transmission Using a Kramers-Kronig Receiver, Abel Lorences-Riesgo[1], Fernando P. Guiomar[1], Artur N. Sousa[1], Antonio L. Teixeira[1], Nelson J. Muga[1], Paulo P. Monteiro[1]; *[1]Instituto de Telecomunicaçoes, Portugal.* We experimentally demonstrate the transmission of a dual-carrier 25 Gbaud 8/16/32QAM signal over a 55-m free-space optics link using a 35-GHz bandwidth photodiode. Evaluation of the link performance over hourly periods shows minor variations.

Room 2

W4B • Optical Source and Signal Generation—Continued

Room 3

W4C • Characterization of SDM Fibers—Continued

W4C.2 • 17:00 Top Scored
Experimental Investigation of Static and Dynamic Crosstalk in Trench-assisted Multi-core Fibre, Hui Yuan[1], Arsalan Saljoghei[1], Tetsuya Hayashi[2], Tetsuya Nakanishi[2], Eric Sillekens[1], Lidia Galdino[1], Polina Bayvel[1], Zhixin Liu[1], Georgios Zervas[1]; *[1]Univ. College London, UK; [2]Sumitomo Electric Industries Ltd, Japan.* We investigate the time-dependent crosstalk characteristics of trench-assisted multi-core fibers in a temperature controlled environment. Results indicate that temperature, PRBS length, modulation format and signaling rate impact the intensity and volatility of inter-core crosstalk.

W4C.3 • 17:15
Dynamic Crosstalk Study in a Few-mode-multi-core Fiber, Benjamin J. Puttnam[1], Georg Rademacher[1], Ruben S. Luis[1], Hideaki Furukawa[1], Andrew Ross-Adams[2], Simon Gross[2], Michael Withford[2], Nicolas Riesen[5], Yusuke Sasaki[3], Kunimasa Saitoh[4], Kazuhiko Aikawa[3], Yoshinari Awaji[1], Naoya Wada[1]; *[1]National Inst Info & Comm Tech (NICT), Japan; [2]Dep. of Physics and Astronomy, Macquarie Univ, Australia; [3]Fujikura Ltd, Japan; [4]Graduate School of Information Science and Technol, Hokkaido Univ., Japan; [5]School of Engineering, Univ. of South Australia, Australia.* We investigate crosstalk fluctuations between cores and modes in a few-mode-MCF, observing almost 20dB power fluctuations for CW signals. We then measure increased crosstalk penalty for LP_{11} modes compared to the more confined LP_{01} modes.

Room 6C

W4D • Special Session: Quantum Technologies and Optical Communications Part 2—Continued

W4D.2 • 17:00 Invited
Telecom Compatible Quantum Key Distribution - Learning from Classical Coherent Communication, Christoph Marquardt[1]; *[1]Max Planck Inst., Germany.* Quantum key distribution (QKD) enables secure cryptography that is safe against future attacks by quantum computers. We show recent advances in continuous variable QKD and highlight similarities and differences to classical coherent communication.

Room 6D

W4E • Lasers on Si—Continued

W4E.2 • 17:00
A Low-noise High-channel-count 20 GHz Passively Mode Locked Quantum Dot Laser Grown on Si, Songtao Liu[1], Daehwan Jung[2], Justin Norman[3], MJ Kennedy[1], Arthur Gossard[3], John E. Bowers[1]; *[1]Electrical and Computer Engineering, Univ. of California Santa Barbara, USA; [2]Inst. for Energy Efficiency, Univ. of California Santa Barbara, USA; [3]Materials Department, Univ. of California Santa Barbara, USA.* We report a low noise high-channel-count 20 GHz passively mode locked quantum dot laser grown on CMOS compatible silicon substrate. The laser demonstrates a record low timing jitter value of 82.7 fs (4 – 80 MHz) and a narrow RF 3-dB linewidth of 1.8 kHz as well as 58 wavelength channels within 3 dB optical bandwidth (80 lines within 10 dB).

W4E.3 • 17:15
Coherent and Incoherent Optical Feedback Sensitivity of High-coherence Si/III-V Hybrid Lasers, Zhewei Zhang[1], Huolei Wang[1], Naresh Satyan[2], George Rakuljic[2], Christos T. Santis[1], Amnon Yariv[1,3]; *[1]Department of Applied Physics and Materials Science, California Inst. of Technology, USA; [2]Telaris Inc, USA; [3]Department of Electrical Engineering, California Inst. of Technology, USA.* We demonstrate that high-coherence Si/III-V hybrid lasers are much more robust than conventional III-V DFB lasers against both coherent and incoherent optical feedback by examining the frequency noise power spectral density of the lasers.

Room 6E

W4F • All-optical Signal Processing—Continued

W4F.2 • 17:00 Top Scored
Demonstration of Tunable and Reconfigurable Optical Nyquist Channel Aggregation of QPSK-to-16QAM and BPSK-to-4PAM Using Nonlinear Wave Mixing and a Kerr Frequency Comb, Ahmad Fallahpour[1], Fatemeh Alishahi[1], Kaiheng Zou[1], Yinwen Cao[1], Ahmed Almaiman[2,1], Arne Kordts[3], Maxim Karpov[3], Martin H. Pfeiffer[3], Karapet Manukyan[1], Huibin Zhou[1], Peicheng Liao[1], Moshe Tur[4], Tobias Kippenberg[3], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]King Saud Univ., Saudi Arabia; [3]Ecole Polytechnique Federale de Lausanne, Swaziland; [4]Tel Aviv Univ., Israel.* A tunable and reconfigurable optical Nyquist channels aggregation is experimentally demonstrated. The proposed method two aggregate lower order modulation formats into a single higher order one. Two 16 Gbaud QPSK Nyquist pulses aggregated to a 16 QAM Nyquist pulse.

W4F.3 • 17:15
Wavelength Conversion of 10 Gbit/s Data from 2000 to 1255 nm Using an AlGaAsOI Nanowaveguide and a Continuous-wave Pump in the C Band, Deming Kong[1], Minhao Pu[1], Yong Liu[1], Yi Zheng[1], Elizaveta Semenova[1], Kresten Yvind[1], Leif K. Oxenløwe[1], Michael Galili[1], Hao Hu[1]; *[1]DTU Fotonik, Technical Univ. of Denmark, Denmark.* We demonstrate wavelength conversion over 744 nm in an AlGaAsOI nanowaveguide using a 17.5-dBm continuous-wave pump. We convert 10 Gbit/s NRZ-OOK and Nyquist PAM 4 signals at a conversion efficiency of −28 dB.

W4G • Symposia: Network Automation 2—Continued

W4H • Fronthaul Technologies and System Metrics v

W4I • Direct Detection Systems—Continued

W4J • High-speed PON—Continued

W4G.2 • 17:00 Invited

Evolution of Network Automation, Vijoy Pandey[1]; [1]*Cisco, USA.* Cross-domain multi-layer automation requires a rethink on how to build e2e automation frameworks utilizing a system-wide view and a difficult organizational, process, skill-set journey for most companies. This talk will focus on the four phases of that journey that any organization can (and should) undertake towards Zero Touch Automation.

W4H.2 • 17:00 Invited

High-speed Transport and Aggregation for Ethernet Fronthaul with Low and Bounded Delay, Raimena Veisllari[1], Steinar Bjornstad[1,2], Mickael Fontaine[1], Carla Raffaelli[3]; [1]*TransPacket AS, Norway;* [2]*NTNU, IIK, Norway;* [3]*UNIBO, DEI, Italy.* 3-node integrated packet/circuit Ethernet network experiment demonstrates aggregation and add/drop of 10Gb/s fronthaul links on a 100Gb/s path. Bounded 5.9µs maximum end-to-end delay and 1.24µs PDV is achieved, even when combining with less delay-sensitive traffic.

W4I.3 • 17:00

200 Gbit/s (68.25 Gbaud) PAM8 Signal Transmission and Reception for Intra-data Center Interconnect, Fan Li[1], Zibin Li[1], Qi Sui[2], Jianping Li[2], Xingwen Yi[1], Liangchuan Li[3], Zhaohui Li[1]; [1]*Sun Yat-Sen Univ., China;* [2]*Jinan Univ., China;* [3]*Huawei Technologies Co., Ltd., China.* In this paper, single carrier, single polarization 200 Gbit/s signal transmission for intra- DCI is demonstrated. Enabling by pre-equalization, adaptive-notch-filter and look-up-table, the BER of 68.25 Gbaud PAM8 signal is below 2.7×10-2 after 1-km SMF transmission.

W4I.4 • 17:15

Demonstration of 260-Gb/s PS-PAM-8 IM/DD for Datacenter Interconnects, Jiao Zhang[2,1], Jianjun Yu[1], Li Zhao[2], Jianyang Shi[2], Kaihui Wang[2], Xinying Li[2], Miao Kong[2], Xiaolong Pan[3], Bo Liu[3], Xiangjun Xin[3], Liwei Zhang[4], Yun Zhang[4], Wen Zhou[2]; [1]*ZTE TX Inc., USA;* [2]*Fudan Univ., China;* [3]*Beijing Univ. of Posts and Telecommunications, China;* [4]*ZTE Corp, China.* We experimentally demonstrated single-lane EML-based IM/DD 106-Gbaud PAM-4 and PS-PAM-8 signals transmission over 1-km NZDSF based on Pre-EQ and clipping technique. 260-Gb/s PS-PAM-8 signal transmission can be achieved.

W4J.3 • 17:00 Invited

Electronic Circuits for High Speed PON beyond 25G, *Xin Yin[1], Joris Lambrecht[1], Gertjan Coudyzer[1], Jochem Verbist[1], Hannes Ramon[1], Peter Ossieur[1], Guy Torfs[1], Johan Bauwelinck[1];* [1]*IDLab, imec - Ghent University, Belgium.* Tightly integrated and co-optimized electronic and photonic integrated circuits are key to meet the scalability and performance requirements for next-generation optical access. We address the challenges, design considerations and methodology for such circuits at >25G rates.

Room 1

W4A • Free Space Optical Communication—Continued

W4A.4 • 17:30
Demonstration of Independent Turbulence Mitigation of Two 100-Gbit/s QPSK Orbital-angular-momentum Multiplexed Beams Using Wavefront Shaping and Controlled Scattering, Runzhou Zhang[1], Hao Song[1], Zhe Zhao[1], Haoqian Song[1], Jing Du[1], Cong Liu[1], Kai Pang[1], Long Li[1], Ari N. Willner[1], Robert W. Boyd[2], Moshe Tur[3], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]Univ. of Rochester, USA; [3]Tel Aviv Univ., Israel.* We experimentally demonstrate using wavefront shaping and controlled scattering to mitigate different-strength turbulence effects (D/r0=2.4, 6.0) in a 200-Gbit/s orbital angular momentum (OAM)-multiplexed link.

W4A.5 • 17:45 Top Scored
Demonstration of Both Mode and Space Diversity in a 100-Gbit/s QPSK Free-space Optical Link to Increase System Tolerance to Turbulence, Long Li[1], Haoqian Song[1], Runzhou Zhang[1], Zhe Zhao[1], Cong Liu[1], Kai Pang[1], Hao Song[1], Jing Du[1], Ari N. Willner[1], Ahmed Almaiman[1,2], Brittany Lynn[3], Robert Bock[4], Moshe Tur[5], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]King Saud Univ., Saudi Arabia; [3]Space & Naval Warfare Systems Center, USA; [4]R-DEX Systems, USA; [5]School of Electrical Engineering, Tel Aviv Univ., Israel.* We experimentally demonstrate the use of mode and space diversity with 2 modes and 2 aperture pairs to enhance system reliability under turbulence for a 100-Gbit/s QPSK FSO link, achieving BERs of $<3.8\times10^{-3}$ under various emulated turbulence realizations.

Room 2

W4B • Optical Source and Signal Generation—Continued

W4B.2 • 17:30
64-GBd PDM-256QAM and 92-GBd PDM-64QAM Signal Generation Using Precise-digital-calibration Aided by Optical-equalization, Asuka Matsushita[1], Masanori Nakamura[1], Kengo Horikoshi[1], Seiji Okamoto[1], Fukutaro Hamaoka[1], Yoshiaki Kisaka[1]; *[1]NTT Corporation, Japan.* We propose to precisely distribute equalization for transceiver imperfection between digital and optical domain. 1.7- and 4.6-dB OSNR tolerance improvements were confirmed for PDM-256QAM and PDM-64QAM signals with net-rates of 793 and 851 Gbps/carrier.

W4B.3 • 17:45
Performance of Lasers with Excess Low-frequency FM-noise Profiles in Digital Coherent Optical Systems, Mustafa A. Al-Qadi[1], Govind Vedala[1], Rongqing Hui[1]; *[1]Univ. of Kansas, USA.* We show that for the same spectral linewidth, lasers with high FM-noise at low frequency outperform those with white FM-noise in a coherent system. Digital carrier-recovery has to be optimized based on laser FM-noise profile.

Room 3

W4C • Characterization of SDM Fibers—Continued

W4C.4 • 17:30 Invited
Impact of Modulation Format on Dynamic Channel Crosstalk Behavior in Multi-core Fibers, Georg Rademacher[1], Ruben S. Luis[1], Benjamin J. Puttnam[1], Yoshinari Awaji[1], Naoya Wada[1]; *[1]National Inst. of Information & Comm Tech, Japan.* We present a study on the relation between the spectral occupation of crosstalk-generating signals and the resulting dynamic crosstalk behavior. We show performance fluctuations induced by varying crosstalk power when transmitting carrier supported modulation formats.

Room 6C

W4D • Special Session: Quantum Technologies and Optical Communications Part 2—Continued

W4D.3 • 17:30 Invited
Why do I Believe That Quantum Key Distribution (QKD) is Finally about to Reach Telecom Markets and Grow out of Its Present Exotic Standing? Momtchil Peev[1]; *[1]Optical and Quantum Communications, Huawei Technologies Duesseldorf GmbH, Germany.* QKD has had for decades the stigma of practical irrelevance. A new wave of interest in Quantum Technology coupled with emerging practical application scenarios is paving the way for a radical change in its future.

Room 6D

W4E • Lasers on Si—Continued

W4E.4 • 17:30 Top Scored
Sub-kHz Linewidth Extended-DBR Lasers Heterogeneously Integrated on Silicon, Duanni Huang[1], Minh Tran[1], Joel Guo[1], Jon Peters[1], Tin Komljenovic[1], Aditya Malik[1], Paul Morton[2], John E. Bowers[1]; *[1]Univ. of California Santa Barbara, USA; [2]Morton Photonics, USA.* We demonstrate single-mode E-DBR lasers with 1kHz linewidth and >37mW output power, and ring-assisted E-DBR lasers with 500Hz linewidth, by heterogeneously integrating III-V gain material with a 15mm long ultra-low loss silicon waveguide-based Bragg reflector.

W4E.5 • 17:45 Top Scored
High-performance Hybrid-integrated Silicon Photonic Tunable Laser, Yongkang Gao[1], Shing Lee[1], Ronak Patel[1], Jiann-Chang Lo[1], Jibin Sun[1], Likai Zhu[1], Jianying Zhou[1], Jin Hong[1]; *[1]NeoPhotonics, USA.* We report a silicon photonic tunable laser for coherent communication, with output power reaching 140 mW across the C-band, linewidth narrower than 80 kHz, SMSR larger than 50 dB, and precise gridless frequency tuning.

Room 6E

W4F • All-optical Signal Processing—Continued

W4F.4 • 17:30
Channel Selective Wavelength Conversion by Means of Inter Modal Four Wave Mixing, Omar Anjum[1], Kyle Bottrill[1], Peter Horak[1], Yongmin Jung[1], Masato Suzuki[2], Yoshinori Yamamoto[2], Takemi Hasegawa[2], David J. Richardson[1], Francesca Parmigiani[3], Periklis Petropoulos[1]; *[1]Optoelectronics Research Center, UK; [2]Sumitomo Electric Industries, Japan; [3]Microsoft Research, UK.* We experimentally demonstrate a means to selectively enhance wavelength conversion of WDM channels on a 100 GHz grid exploiting nonlinear effects between the spatial modes of a few mode fibre.

W4F.5 • 17:45
WDM Amplification of One Pump HNLF Based Phase Sensitive Amplifier with Static Pump Phase Tuning, Youichi Akasaka[1], Yinwen Cao[2], Shigehiro Takasaka[3], Kenji Yamauchi[3], Koichi Maeda[3], Haoqian Song[2], Ryuichi Sugizaki[3], Alan E. Willner[2], Tadashi Ikeuchi[1]; *[1]Fujitsu Laboratories of America Inc., USA; [2]Univ. of Southern California, USA; [3]Furukawa Electric, Japan.* We experimentally demonstrate WDM capable Raman-assisted low-noise phase-sensitive amplifier with up-to ~26dB gain for 35 channels at 40GHz spacing using FBG phase tuning of single pump. 16QAM constellation shows gain linearity for multi levels formats.

W4G • Symposia: Network Automation 2—Continued

W4G.3 • 17:30 Invited

Intent Based Network Operation, Andrea Campanella[1]; [1]*ONF, USA*. Intent Based Networking defines high level policies (what) for the network, translated to configuration (how) by underling systems. An overview is given then focus goes to ONOS helping network automation through intents. Finally challenges are discussed.

W4H • Fronthaul Technologies and System Metrics v

W4H.3 • 17:30 Tutorial

Demystifying Transceiver and Line Characterization Metrics, Loren Berg[1]; [1]*Ciena Corporation, USA*. With the introduction of variable rate coherent transceivers and their often complex modulation schemes operating over a dynamic line system, the need to monitor performance is crucial. Various metrics (GOSNR, Q, SNR, EVM) have been proposed and many are used to monitor performance. It is therefore important to understand the nature of these metrics and how they may be used in the assessment of performance.

Loren Berg graduated with a B.Sc. and M.Sc. in Electrical Engineering from Queen's University in Kingston, Ontario, Canada in 1989 and 1991 respectively. Since then he has been involved in the design of many generations of optical transmission systems with Nortel and eventually Ciena. For the last 5 years he has been working on submarine system upgrades using coherent modem technology. Currently, Loren is an Advisor in the field of Autonomous Photonics Networks for Ciena.

W4I • Direct Detection Systems—Continued

W4I.5 • 17:30 Top Scored

92-Gbaud PAM4 Transmission Using Spectral-shaping Trellis-coded-modulation with 20-GHz Bandwidth Limitation, Shuto Yamamoto[1], Akira Masuda[1], Hiroki Taniguchi[1], Yoshiaki Kisaka[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan*. We propose a simple nonlinear trellis-coded-modulation to realize spectral-shaping for short-reach IM-DD transmission. Simulation results show the improvement of bandwidth-limitation and chromatic-dispersion tolerances. Experimental results show the achievement of 7% HD-FEC threshold in 184-Gb/s transmission.

W4I.6 • 17:45

255-Gbps PAM-8 Transmission under 20-GHz Bandwidth Limitation Using NL-MLSE Based on Volterra Filter, Akira Masuda[1], Shuto Yamamoto[1], Hiroki Taniguchi[1], Masanori Nakamura[1], Yoshiaki Kisaka[1]; [1]*NTT, Japan*. 85-Gbaud PAM-8 transmission with BER below HD-FEC limit under 20-GHz bandwidth limitation is achieved applying NL-MLSE based on Volterra filter. NL-MLSE also achieves 3.84-Tbps O-band transmission using 4-λ LAN-WDM and SDM over 2-km 4-core fiber.

W4J • High-speed PON—Continued

W4J.4 • 17:30

Equalization and Interoperability Challenges in Next Generation Passive Optical Networks, Sylvain Barthomeuf[1,2], Fabienne Saliou[1], Luiz Anet Neto[1], Gael Simon[1], Fabrice Bourgart[1], Philippe Chanclou[1], Didier Erasme[2]; [1]*Orange Labs, France;* [2]*Telecom ParisTech, France*. To reach higher line rates in interoperability conditions, we experiment the possibility to have a unified set of channel equalization coefficients for different transmitted wavelengths, received optical power, and optical receivers.

W4J.5 • 17:45

High-speed Train Cell-less Network Enabled by XGS-PON and Impacts on vRAN Split Interface Transmission, Anas El Ankouri[1], Luiz Anet Neto[1], Gael Simon[1], Hugues LeBras[1], Ali Sanhaji[1], Philippe Chanclou[1]; [1]*Orange Labs, France*. We successfully demonstrate a transmission of a high layer split mobile interface for cell-less, high-speed train network applications using a commercially available XGS-PON. Operation is also demonstrated for an 1GbE interface.

Room 1

W4A • Free Space Optical Communication—Continued

W4A.6 • 18:00
Delay-tolerant Repetition-coding for Optical Wireless Communications, Tingting Song[1], Ke Wang[2], Ampalavanapillai Nirmalathas[1], Christina Lim[1], Elaine Wong[1], Kamal Alameh[3]; *[1]The Univ. of Melbourne, Australia; [2]RMIT Univ., Australia; [3] Edith Cowan Univ., Australia.* Delay-tolerant orthogonal-filters based repetition coded optical wireless communications are proposed to solve the critical issue of different channel lengths. 2.5 Gbps orthogonal-filtered 2PAM transmission is experimentally demonstrated, showing the robustness against channel blockage and up to 1.2-meter optical delay.

Room 2

W4B • Optical Source and Signal Generation—Continued

Room 3

W4C • Characterization of SDM Fibers—Continued

W4C.5 • 18:00 Top Scored
Characterization of Long Multi-mode Fiber Links Using Digital Holography, Mikael Mazur[2,1], Nicolas K. Fontaine[2], Roland Ryf[2], Haoshuo Chen[2], David T. Neilson[2], Marianne Bigot[3], Frank Achten[4], Pierre Sillard[3], Adrian Amezcua-Correa[3], Jochen Schröder[1], Joel A. Carpenter[5]; *[1]Chalmers Univ. of Technology, Sweden; [2]Crawford Hill Laboratory, Nokia Bell Labs, USA; [3]Prysmian Group, France; [4]Prysmian Group, Netherlands; [5]The Univ. of Queensland, Australia.* We propose to use digital holography to characterize long multi-mode fiber links. A four segment 26.5km fiber span supporting 45 spatial modes is analyzed, showing the evolution of both mode-dependent loss and cross talk.

Room 6C

W4D • Special Session: Quantum Technologies and Optical Communications Part 2—Continued

W4D.4 • 18:00 Invited
Implementation Security Certification of a Quantum Key Distribution System through Device Characterization, Akihisa Tomita[1]; *[1]Graduate School of Information Science and Technology, Hokkaido Univ., Japan.* It is indispensable for social deployment of quantum key distribution to certificate the security on the installed systems, or "implementation security." In this talk, we will present several case studies on the implementation security certification.

Room 6D

W4E • Lasers on Si—Continued

W4E.6 • 18:00 Invited
III-V/Si PICs Based on Micro-transfer-printing, Gunther Roelkens[1], Jing Zhang[1], Grigorij Muliuk[1], Jeroen Goyvaerts[1], Bahawal Haq[1], Camiel Op de Beeck[1], Alexandros Liles[1], Zheng Wang[1], Soren Dhoore[1], Sulakshna Kumari[1], Joan Juvert[1], Joris Van Campenhout[2], Bart Kuyken[2], Dries Van Thourhout[1], Brian Corbett[3], Antonio Trindade[4], Christopher Bower[4], Roel G. F. Baets[1]; *[1]INTEC, Ghent Univ. - imec, Belgium; [2]imec, Belgium; [3]Tyndall National Inst., Ireland; [4]X-Celeprint, Ireland.* III-V opto-electronic devices (photodiodes, etched facet lasers) are micro-transfer-printed onto silicon waveguide circuits. An alignment-tolerant interface for evanescently-coupled devices is proposed enabling III-V/Si heterogeneously integrated PICs using micro-transfer-printing.

Room 6E

W4F • All-optical Signal Processing—Continued

W4F.6 • 18:00 Invited
Manipulation and Optical Processing of WDM Signals Using Optical Time Lenses, Leif K. Oxenløwe[1]; *[1]DTU Fotonik, Denmark.* We describe flexible processing of WDM signals without separating the individual WDM channels and processing them individually. We describe WDM regeneration, flexible WDM grid manipulation and a TDM-to-WDM conversion for cheaper energy-efficient PON systems

W4G • Symposia: Network Automation 2—Continued

W4G.4 • 18:00 Invited

Possibility to Eliminate Network Operation Center (NOC), Ravi Kumar Pattamatta[1]; [1]*RIL, India*. Event Based Correlation: Single TT/W.O thru enriched alarm for single fiber cable cut, for different interface down alarms on different network technologies. Topology Based Correlation: Identification of exact restoration path incase of multiple node isolations by grouping of those alarms within the geo fencing network topology.

W4H • Fronthaul Technologies and System Metrics v

W4I • Direct Detection Systems—Continued

W4I.7 • 18:00 Invited

Beyond 200Gbps per Lane Intensity Modulation Direct Detection (IM/DD) Transmissions for Optical Interconnects: Challenges and Recent Developments, Xiaodan Pang[1,4], Oskars Ozolins[2,1], Lu Zhang[1,3], Aleksejs Udalcovs[2], Rui Lin[1], Richard Schatz[1], Urban Westergren[1], Shilin Xiao[3], Weisheng Hu[3], Gunnar Jacobsen[2], Sergei Popov[1], Jiajia Chen[1]; [1]*KTH Royal Inst. of Technology, Sweden;* [2]*NETLAB, RISE Research Inst. of Sweden, Sweden;* [3]*State Key Laboratory of Advanced Optical Communication System and Networks, Shanghai Jiao Tong Univ., China;* [4]*Infinera, Sweden*. All parts of an IM/DD system are being stretched to the limit as the single lane data rate approaches 200 Gbps and beyond. We report the recent developments on the key enablers conquering this target.

W4J • High-speed PON—Continued

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00 Th1A • Panel: Beyond 400G for Hyper-scale Data Centers

With 400G optics deployments on the horizon, what will be required next by hyperscale data centers? Do pluggable optical modules continue to scale to 800G/1.6T, or are new solutions required? What are the key technologies and enablers for next generation data center interconnect? What are the critical limitations and possible solutions?

Panelists from hyperscale data centers, system companies, and module manufacturers, will share their views of what's beyond 400G for hyperscale data centers.

Speakers:

Andy Bechtolsheim, *Arista Networks, USA*

Chris Cole, *Finisar, USA*

Peter De Dobbelaere, *Luxtera, USA*

Hong Liu, *Google, USA*

Clint Schow, *University of California Santa Barbara, USA*

Rob Stone, *Broadcom Inc., USA*

Min Sun, *Tencent, China*

08:00–10:00 Th1B • Multicore and Multimode Amplifiers

Presider: Takemi Hasegawa; Sumitomo Electric Industries Ltd, Japan

Th1B.1 • 08:00 Invited

Reduction in Power Consumption in Multi-core Amplifier, Emmanuel Le Taillandier de Gabory[1], Hitoshi Takeshita[1], Keiichi Matsumoto[1], Shigeyuki Yanagimachi[1]; [1]*System Platform Research Laboratories, NEC Corporation, Japan*. We report advances in low power consumption multi-core amplifiers. We namely show recent advances concerning core pumping, cladding pumping and hybrid pumping technologies for power efficient optical amplification with erbium doped multi-core fiber amplifiers.

08:00–10:00 Th1C • Terahertz/ mmWave Photonics

Presider: Daniel Blumenthal; Univ. of California Santa Barbara, USA

Th1C.1 • 08:00 Tutorial

Terahertz Photonics - An Overview, Hartmut G. Roskos[1]; [1]*Physics Department, Goethe-Univ. Frankfurt, Germany*. Free-space communication, with its ever increasing need for higher bandwidth, is pushing the frequency of the carrier wave into the terahertz frequency regime. It has developed into a technology driver for sub-THz devices and systems. An overview will be given of the state-of-the-art of relevant optoelectronic, all-electronic and passive devices of THz photonics, and applications will be described both pertaining to communication but also to other fields such as THz imaging and sensing.

Hartmut G. Roskos studied physics at the Technical Universities of Karlsruhe and Munich. He received his PhD degree in 1989 from TU Munich. He then was a post-doc at AT&T Bell Laboratories, Holmdel, USA, where THz phenomena became the focus of his research. From 1991 to 1996, he was with RWTH Aachen where he obtained the Habilitation degree in 1996 for his work on coherent phenomena in solid-state physics.

08:00–10:00 Th1D • Component Implementation and Equalization

Presider: Qunbi Zhuge; Shanghai Jiao Tong Univ., China

Th1D.1 • 08:00 Invited

On the Analysis and Emulation of Nonlinear Component Characteristics, Andre Richter[1], Stefanos Dris[1], Nuno Andre[1]; [1]*VPIphotonics, Germany*. We present theoretical background and implementation considerations of Volterra series based nonlinear component models. We demonstrate the advantage of combining frequency and time domain representations and present an efficient way to find high-order filter taps.

08:00–10:00 Th1E • Large-scale Optical Switch

Presider: Kenya Suzuki; NTT Device Innovation Center, Japan

Th1E.1 • 08:00 Invited

Large Scale Silicon Photonics Switches Based on MEMS Technology, Ming C. Wu[1], Tae Joon Seok[2,1], Kyungmok Kwon[1], Johannes Henriksson[1], Jianheng Luo[1]; [1]*Univ. of California Berkeley, USA;* [2]*Gwangju Inst. of Science and Technology, Korea*. We review the recent developments in large-scale silicon photonic switches, focusing on MEMS-based switches that enables high port-count (128x128), low optical loss (0.05 dB/port), low crosstalk, broadband operation, sub-microsecond response time, and low power consumption.

08:00–09:45 Th1F • 5G Fiber Wireless Technology

Presider: Gee-Kung Chang; Georgia Inst. of Technology, USA

Th1F.1 • 08:00 Invited

Photonics-aided Mm-wave Communication for 5G, Xinying Li[1], Jianjun Yu[2,3], Gee-Kung Chang[1]; [1]*Electrical and Computer Engineering, Georgia Inst. of Technology, USA;* [2]*Shanghai Inst. for Advanced Communication and Data Science, Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [3]*ZTE (TX) Inc., USA*. To meet the eMBB challenges in 5G, we have systematically explored the potential of the photonics-aided mm-wave communication in terms of the wireless transmission capacity and distance it can accommodate.

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00
Th1G • Security and Monitoring

Presider: Achim Autenrieth; ADVA Optical Networking SE, Germany

Th1G.1 • 08:00
Blockchain-based Efficient Recovery for Secure Distributed Control in Software Defined Optical Networks, Yongshen Liang[1], Hui Yang[1], Qiuyan Yao[1], Shaoyong Guo[1], Ao Yu[1], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecomm, China*. This paper presents a blockchain-based high-efficiency security strategy with blockchain ledger-based recovery algorithm for software-defined optical networks. Numerical results show the proposed strategy has less recovery latency and superior network performances.

Th1G.2 • 08:15
Distributed Blockchain-based Trusted Control with Multi-controller Collaboration for Software Defined Data Center Optical Networks in 5G and Beyond, Hui Yang[1], Yajie Li[1], Shaoyong Guo[1], Jian Ding[2], Young Lee[2], Jie Zhang[1]; [1]*Beijing Univ. of Posts & Telecom, China;* [2]*Huawei, China*. We present a distributed blockchain-based trusted control (BlockTC) architecture with multi-controller credible routing for software defined data center optical network in 5G and beyond. The feasibility and efficiency of architecture are verified on our testbed.

08:00–9:30
Th1H • Machine Learning for Datacenter Networks

Presider: Yvan Pointurier; Nokia Bell Labs, France

Th1H.1 • 08:00
Using Active Learning to Decrease Probes for QoT Estimation in Optical Networks, Dario Azzimonti[1], Cristina Rottondi[1], Massimo Tornatore[2]; [1]*IDSIA, Switzerland;* [2]*Electronics, Information and Bioengineering, Politecnico di Milano, Italy*. We use active learning to reduce the number of probes needed for machine-learning-based QoT estimation. When building an estimation model based on Gaussian processes, only QoT instances that minimize estimation uncertainty are iteratively requested

Th1H.2 • 08:15 Top Scored
Deep-NFVOrch: Deep Reinforcement Learning Based Service Framework for Adaptive vNF Service Chaining in IDC-EONs, Baojia Li[1], Wei Lu[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China*. By leveraging deep reinforcement learning (DRL), we design Deep-NFVOrch as a novel service framework with resource pre-deployment to achieve adaptive virtual network function (vNF) service chaining in inter-datacenter elastic optical networks (IDC-EONs).

08:00–10:00
Th1I • Open Systems and Interoperability

Presider: Bruce Cortez; AT&T, USA

Th1I.1 • 08:00 Tutorial
Open Transport Infrastructure (TIP), Luis Martin Garcia[1]; [1]*Facebook Inc., UK*. Open Transport Infrastructure (TIP)

08:00–10:00
Th1J • Quantum Communication and Security

Presider: Eleni Diamanti; Universite Pierre et Marie Curie, France

Th1J.1 • 08:00
Inter-core Crosstalk Impact of Classical Channels on CV-QKD in Multicore Fiber Transmission, Tobias A. Eriksson[1], Benjamin J. Puttnam[1], Georg Rademacher[1], Ruben S. Luis[1], Masahiro Takeoka[1], Yoshinari Awaji[1], Masahide Sasaki[1], Naoya Wada[1]; [1]*National Inst. of Information and Communications Technology (NICT), Japan*. Crosstalk-induced excess noise is experimentally characterized for continuous-variable quantum key distribution, spatially multiplexed with WDM PM-16QAM channels in a 19-core fiber. The measured noise-sources are used to estimate the secret key rates for different wavelength channels.

Th1J.2 • 08:15
Precise Noise Calibration for CV-QKD, Hans Brunner[1], Stefano Bettelli[1], Lucian C. Comandar[1], David Hillerkuss[1], Chi-Hang F. Fung[1], Dawei Wang[1], Spiros Mikroulis[1], Andreas Poppe[1], Momtchil Peev[1]; [1]*German Research Center, Huawei Technologies Duesseldorf GmbH, Germany*. A receiver setup capable of measuring optical power with an extremely high sensitivity of approximately -200 dBm/Hz at 1550 nm (40 dB below shot noise) is analyzed and demonstrated in a continuous-variable quantum-key-distribution prototype device.

Th1A • Panel: Beyond 400G for Hyper-scale Data Centers—Continued

Th1B • Multicore and Multimode Amplifiers—Continued

Th1B.2 • 08:30
Improvement of the Pump Recycling Ratio of Turbo Cladding Pumped MC-EDFA with Paired Spatial Pump Combiner and Splitter, Hitoshi Takeshita[1], Keiichi Matsumoto[1], Shigeyuki Yanagimachi[1], Emmanuel Le Taillandier de Gabory[1]; *[1]NEC Corporation, Japan.* We used paired prototypes of spatial pump combiner and splitter to improve the pump recycling ratio of turbo cladding pumped MC-EDFA from 12% to 42%. This enables a potential 1.2dB improvement of the optical gain.

Th1B.3 • 08:45
Impact of MDM-EDFA Saturation Effects on Mode Scaling for Capacity Increases, Steffen Jeurink[1], Peter M. Krummrich[1]; *[1]TU Dortmund, Chair for High Frequency Technology, Germany.* We investigate modal gain differences of a graded-index EDFA for different mode counts in a system upgrade scenario. We find that the mode dependent gain can decrease with the number of modes.

Th1C • Terahertz/mmWave Photonics—Continued

Since 1997, he is a full professor at Goethe-University, Frankfurt, Germany.

He spent sabbaticals at University of California Santa Barbara in 2005, Osaka University in 2009/2010, and the University of Rochester in 2014. In 2009, OC Oerlikon AG awarded his group jointly with the Ferdinand-Braun-Institute (FBH), Berlin, Germany, a 5-year endowed professorship which led to the establishment of a JointLab for THz Photonics of FBH and Goethe University; the center is now led by Prof. Dr. Viktor Krozer.

He is a Topical Editor of Optics Letters. His research areas include ultrafast optical and THz spectroscopy, s-SNOM nanoscopy, THz device physics, and applications of THz radiation.

Th1D • Component Implementation and Equalization—Continued

Th1D.2 • 08:30
Receiver DSP Highly Tolerant to Transmitter IQ Impairments, Pavel Skvortcov[1], Christian Sanchez-Costa[1], Ian Phillips[1], Wladek Forysiak[1]; *[1]Aston Inst. of Photonic Technologies, Aston Univ., UK.* A novel DSP equalization structure providing high tolerance to transmitter IQ impairments is proposed. Two-fold tolerance improvement for gain and quadrature error, bias offsets and skew is demonstrated both numerically and experimentally.

Th1D.3 • 08:45
Experimental Demonstration of Reduced-size LUT Predistortion for 256QAM SiP Transmitter, Sasan Zhalehpour[1], Jiachuan Lin[2], Hasan Sepehrian[2], Wei Shi[1], Leslie Rusch[1]; *[1]COPL, Universite Laval, Canada; [2]Canada Research Center, Huawei Technologies Canada, Canada.* We experimentally demonstrate a predistortion method combining a linear equalizer and nonlinear reduced-size lookup table (LUT) for a silicon based IQ modulator at 20 Gbaud 256QAM. We achieve BER well below the 20% FEC-threshold.

Th1E • Large-scale Optical Switch—Continued

Th1E.2 • 08:30 Top Scored
Polarization-diversity 32 × 32 Si Photonics Switch with Non-duplicate Diversity Circuit in Double-layer Platform, Keijiro Suzuki[1], Ryotaro Konoike[1], Nobuyuki Yokoyama[1], Miyoshi Seki[1], Minoru Ohtsuka[1], Shigeru Saitoh[1], Satoshi Suda[1], Hiroyuki Matsuura[1], Koji Yamada[1], Shu Namiki[1], Hitoshi Kawashima[1], Kazuhiro Ikeda[1]; *[1]Natl Inst of Adv Industrial Sci & Tech, Japan.* We demonstrate a polarization-diversity 32×32 Si-photonics switch by newly introducing a SiN overpass circuit onto our non-duplicate polarization-diversity path-independent insertion-loss switch circuit. An average PDL in a sampled connection setting was evaluated as 3.2 dB.

Th1E.3 • 08:45
Integrated Reconfigurable 4×4 Optical Unitary Converter Using Multiport Directional Couplers, Ryota Tanomura[1], Rui Tang[1], Samir Ghosh[1], Takuo Tanemura[1], Yoshiaki Nakano[1]; *[1]The Univ. of Tokyo, Japan.* We demonstrate novel silicon photonic 4×4 reconfigurable optical unitary converter, comprising multiport directional couplers and phase shifter arrays. By optimizing the phase shift with simulated annealing algorithm, reconfigurable mode sorting and switching are experimentally realized.

Th1F • 5G Fiber Wireless Technology—Continued

Th1F.2 • 08:30 Top Scored
Demonstration of 5G Trial Service in 28 GHz Millimeter Wave Using IFoF-based Analog Distributed Antenna System, Minkyu Sung[1], Joonyoung Kim[1], Eon-Sang Kim[1], Seung-Hyun Cho[1], Young-Jun Won[2], Byoung-Chul Lim[2], Sung-Yeop Pyun[3], Joonki Lee[1], Jong Hyun Lee[1]; *[1]Optical Network Research Group, Electronics and Telecom Research Inst., Korea; [2]Fiber Radio Technologies (FRTeK), Korea; [3]KT Cooperation, Korea.* We report the successful demonstration of 5G trial service using IFoF-based analog DAS during Pyeongchang Winter Olympics. 5G connected car, one of the 5G key services, is successfully demonstrated through IFoF-based DAS in Pyeongchang area

Th1F.3 • 08:45
Experimental Demonstration of mmWave Multi-beam Forming by SiN Photonic Integrated Circuits for Elastic RF-optical Networking, Hongbo Lu[1], Yichi Zhang[1], Yi-Chun Ling[1], Gengchen Liu[1], Roberto Proietti[1], S. J. Ben Yoo[1]; *[1]Univ. of California Davis, USA.* We present a two-beam 24-GHz mmWave spatial-division multiplexing demonstration using multi-layer SiN photonic integrated circuits for elastic RF-Optical 5G networking. The total system throughput can reach 8-Gbps over 1 GHz bandwidth with 16-QAM signals.

Th1G • Security and Monitoring—Continued

Th1G.3 • 08:30
Optimization of Secure Quantum Key Distribution Backbones in Core Transport Networks, Federico Perderzolli[1], Marco Savi[1], Domenico Siracusa[1], Elio Salvadori[1]; [1]*FBK CREATE-NET, Italy.* We present a Mixed Integer Linear Programming formulation to perform optimal placement of Quantum Key Distribution devices to protect active/planned traffic at minimal cost, thus securing active core transport networks.

Th1G.4 • 08:45
Experimental Demonstration of End-to-end Key on Demand Service Provisioning over Quantum Key Distribution Networks with Software Defined Networking, Yuan Cao[1], Yongli Zhao[1], Xiaosong Yu[1], Lijie Cheng[1], Ziqin Li[1], Guojun Liu[2], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecommunications, China;* [2]*Global Energy Interconnection Research Inst. Co,. Ltd., China.* We experimentally demonstrate end-to-end key on demand (KoD) service provisioning over quantum key distribution networks with software defined networking (SDN), achieving efficient and flexible on-demand secret-key rate allocation for end-to-end data security.

Th1H • Machine Learning for Datacenter Networks—Continued

Th1H.3 • 08:30
Scheduling with Flow Prediction Based on Time and Frequency 2D Classification for Hybrid Electrical/Optical Intra-datacenter Networks, Ao Yu[1], Hui Yang[1], Qiuyan Yao[1], Yajie Li[1], Huifeng Guo[2], Tao Peng[2], Haibin Li[2], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecomm, China;* [2]*ZTE Corporation, China.* This paper first presents a 2D traffic classification-based flow prediction method and a corresponding resource allocation algorithm supported by B-RNN in intra-datacenter networks. Results show that the proposed method improves prediction accuracy and network performance.

Th1H.4 • 08:45
Machine Learning-based Traffic Prediction for Optical Switching Resource Allocation in Hybrid Intra-data Center Networks, Mihail Balanici[1], Stephan Pachnicke[1]; [1]*Kiel Univ., Germany.* This work presents a highly accurate traffic prediction model based on nonlinear autoregressive neural networks for efficient forecasting of heavy traffic streams in intra-data center networks. Its deep-learning version guarantees a prediction error of 10^{-10}.

Th1I • Open Systems and Interoperability—Continued

Th1J • Quantum Communication and Security—Continued

Th1J.3 • 08:30
Experimental Investigation of Heterodyne Quantum Key Distribution in the S-band Embedded in a Commercial DWDM System, Sebastian Kleis[1], Joachim Steinmayer[2], Rainer H. Derksen[2], Christian G. Schaeffer[1]; [1]*Helmut Schmidt Univ, Univ. of FAF Hamburg, Germany;* [2]*Coriant R&D GmbH, Germany.* The tolerance of continuous-variable quantum key distribution to co-propagating DWDM channels is investigated. For the experiments, the quantum channel is operated in the S-band and multiplexed with a commercial C-band DWDM system. It is shown that compared to previously proposed configurations, the number of co-propagating channels can be doubled.

Th1J.4 • 08:45
High Bit-rate Quantum Communication Chips, Taofiq Paraiso[1], Thomas Roger[1], Innocenzo De Marco[1], Davide G. Marangon[1], James Dynes[1], Marco Lucamarini[1], Zhiliang Yuan[1], Andrew Shields[1]; [1]*Toshiba Research Europe Ltd., UK.* We present novel photonic integrated circuits for high-bandwidth quantum communications. We demonstrate integrated quantum key distribution transmitters and quantum random number generators with record performances, paving the way for practical deployment of quantum communication technologies.

Th1A • Panel: Beyond 400G for Hyper-scale Data Centers—Continued

Th1B • Multicore and Multimode Amplifiers—Continued

Th1B.4 • 09:00
Low-crosstalk Few-mode EDFA for Single-mode Fiber Trunk Lines and Networks, Ning Wang[1], Inwoong Kim[2], Olga Vassilieva[2], Tadashi Ikeuchi[2], He Wen[1], Jose Enrique Antonio-Lopez[1], Juan Carlos Alvarado-Zacarias[1], Pierre Sillard[3], Cedric Gonnet[3], Huiyuan Liu[1], Shengli Fan[1], Md Selim Habib[1], Rodrigo Amezcua Correa[1], Guifang Li[1]; *[1]Univ. of Central Florida, CREOL, USA; [2]Fujitsu Laboratories of America, Inc., USA; [3]Prysmian Group, France.* We propose a low-crosstalk few-mode EDFA based on the unitary property of the coupling matrix of symmetric photonic lanterns and experimentally demonstrate a three-channel few-mode EDFA with a 20 dB gain and crosstalks below -10 dB.

Th1B.5 • 09:15
L-band Randomly-coupled 12 Core Erbium Doped Fiber Amplifier, Masaki Wada[1], Taiji Sakamoto[1], Shinichi Aozasa[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; *[1]NTT Corporation, Japan.* We demonstrate a cladding-pumped L-band randomly-coupled 12-core EDFA for the first time. Flat spectra and low mode dependent loss of 1.9 dB or less in the 1570 to 1605 nm range are achieved.

Th1C • Terahertz/ mmWave Photonics—Continued

Th1C.2 • 09:00 Top Scored
Integrated Dual-DFB Laser for 408 GHz Carrier Generation Enabling 131 Gbit/s Wireless Transmission over 10.7 Meters, Shi Jai[1], Mu-Chieh Lo[3], Lu Zhang[2], Oskars Ozolins[4,2], Aleksejs Udalcovs[4], Deming Kong[1], Xiaodan Pang[2], Xianbin Yu[5], Shilin Xiao[6], Sergei Popov[2], Jiajia Chen[2], Guillermo Carpintero[3], Toshio Morioka[1], Hao Hu[1], Leif K. Oxenløwe[1]; *[1]DTU Fotonik, Denmark; [2]KTH Royal Inst. of Technology, Sweden; [3]Universidad Carlos III de Madrid, Spain; [4]NETLAB, Research Inst. of Sweden AB, Sweden; [5]Zhejiang Univ., China; [6]Shanghai Jiao Tong Univ., China.* A monolithically integrated dual-DFB laser generates a 408 GHz carrier used for demonstrating a record-high single-channel bit rate of 131 Gbit/s transmitted over 10.7 m. 16-QAM-OFDM modulation and specific nonlinear equalization techniques are employed.

Th1C.3 • 09:15
Photonic Generation of Dual-band Coherent Radar Signals in S- and X-Band, Yitian Tong[1]; *[1]Shanghai Jiao Tong Univ., China.* Based on phase-locked dual combs, dual-band coherent radar signals at S- and X-band are generated with large modulation bandwidth and flexible tunability. The system performance is evaluated through measuring the range resolution of two targets.

Th1D • Component Implementation and Equalization—Continued

Th1D.4 • 09:00 Tutorial
High-speed DAC/ADC and ASIC Technologies, Tomislav Drenski[1]; *[1]Socionext Europe GmbH, Germany.* Achievements and challenges for continuous scaling of high-speed DAC/ADC for optical communication systems will be reviewed. Future requirements for ASIC technologies of ultra-long haul coherent transceivers and shorter reach low-cost IM/DD transceivers will be discussed

Tomislav Drenski holds a Dipl. Ing. degree from the FHTE Esslingen in Electronic/Microelectronics. From 1995 to 1999 he worked in R&D at NEC Japan on BiCMOS RFIC's for high-speed wireless communication, receiving the NEC Research Prize in 1997. In 1999 he joined Socionext Europe GmbH (former Fujitsu Semiconductor) designing RF front ends for GPS and wireless applications. From 2005 he was project lead to roll-out WiMAX systems in Europe and Far East/Asia regions. Since 2009 he has worked in a variety of marketing and project manager roles and is currently responsible for direct detect 100G standard product developments and business developments enabling 400G to T-bit transceiver solutions based on high-speed ADC/DAC.

Th1E • Large-scale Optical Switch—Continued

Th1E.4 • 09:00 Invited
Recent Developments in High Radix Optical Switching, Nick J. Parsons[1]; *[1]HUBER+SUHNER Polatis Inc., UK.* Low loss all-optical circuit switches enable network automation directly at the fiber layer. We review recent advances in free-space beam-steering technology and examine the prospects and challenges presented in scaling beyond 384x384 non-blocking fiber ports.

Th1F • 5G Fiber Wireless Technology—Continued

Th1F.4 • 09:00 Top Scored
Real-time 100-GS/s Sigma-delta All-digital Radio-over-fiber Transmitter for 22.75-27.5 GHz Band, Haolin Li[1], Michiel Verplaetse[1], Jochem Verbist[1], Joris Van Kerrebrouck[1], Laurens Breyne[1], ChiaYi Wu[1], Laurens Bogaert[1], Xin Yin[1], Johan Bauwelinck[1], Piet Demeester[1], Guy Torfs[1]; *[1]Univ. Ghent-imec, Belgium.* We present the first real-time 100-GS/s FPGA-based sigma-delta modulator to enable all-digital radio-over-fiber transmission in the 22.75-27.5GHz band. 4.68Gb/s (2.34Gb/s) 64-QAM is transported over 10-km SSMF at 1562nm with 6.46% (4.73%) EVM.

Th1F.5 • 09:15
Crosstalk-free AWGR-based 2-D IR Beam Steered Optical Wireless Communication System for High Spatial Resolution, Xuebing Zhang[1], Chao Li[1], Yuqing Jiao[1], Henrie van den Boom[1], Eduward Tangdiongga[1], Zizheng Cao[1], Ton Koonen[1]; *[1]Eindhoven Univ. of Technology, Netherlands.* By creating polarized orthogonality between the odd and even channels, crosstalk-free OWC link is realized with spectral overlap. This technique can tolerate the wavelength misalignment between AWGRs and lasers, which relaxes the design of high port-count AWGRs and wavelength stable lasers.

Th1G • Security and Monitoring—Continued

Th1G.5 • 09:00 Tutorial

State of the Art and Best Practices for Optical Network Self Monitoring and Optimization, Marc Lyonnais[1]; [1]*CTO Office, Ciena, Canada*. This tutorial will look into the best use case where proof of concepts have been executed to provide a glimpse of what to expect in the future of the automation in Networking.

Marc Lyonnais is responsible for advanced research network architecture programs in Ciena's CTO group. Over the last decade, he became heavily involved in the area of Open Networking, next generation programming and network behavior as well as high throughout appliances such as Multi 100G Data Transfer Nodesand P4 devices.

Th1H • Machine Learning for Datacenter Networks—Continued

Th1H.5 • 09:00 Invited

Predictive Analytics in Hybrid Optical/Electrical DC Networks, Zuqing Zhu[1], Wei Lu[1], Lipei Liang[1], Bingxin Kong[1]; [1]*Univ. of Science and Technology of China, China*. We explain how to leverage knowledge-defined networking (KDN) to realize automatic network control and management (NC&M) for orchestrating the IT and bandwidth resources in a hybrid optical/electrical datacenter network (HOE-DCN).

Th1I • Open Systems and Interoperability—Continued

Th1I.2 • 09:00

Open Design for Multi-vendor Optical Networks, Jean-Luc Auge[1], Vittorio Curri[2], Esther Le Rouzic[1]; [1]*Orange Labs, France;* [2]*Polito, Italy*. We review physical layer models to design and simulate open line systems, enabling vendor interoperability. An open algorithm that takes into account different engineering choices is presented and used to optimize power on a WDM link.

Th1I.3 • 09:15

Interoperable CFP-DCO and CFP2-DCO Pluggable Optic Interfaces for 100G WDM Transmission, Erwan Pincemin[1], Yann Loussouarn[1], Mike Pan[2], Glenn Miller[2], Alan Gibbemeyer[2], Benny Mikkelsen[2], Alberto Gaibazzi[3], Winston Way[3], Tooru Yamasaki[4], Akihiro Hayashi[4], Kazutomo Fujiyama[4]; [1]*Orange Labs, France;* [2]*Acacia Communications, USA;* [3]*Neophotonics Corporation, USA;* [4]*Fujitsu Optical Components Corporation, Japan*. For the first time, interoperability is demonstrated at 100G with modern CFP-DCO and CFP2-DCO interfaces using the newly standardized Staircase FEC between three vendors and two DSP-ASIC providers. Inter-workable 100G WDM transmission (up to 1200 km) and passive point-to-point interconnection (up to 135 km) are shown.

Th1J • Quantum Communication and Security—Continued

Th1J.5 • 09:00

O-band Differential Phase-shift Quantum Key Distribution in 52-channel C/L-Band Loaded Passive Optical Network, Bernhard Schrenk[1], Michael Hentschel[1], Hannes Hübel[1]; [1]*AIT Austrian Inst. of Technology, Austria*. A cost-effective QKD transmitter is evaluated in a 16km reach, 2:16-split PON and yields 5.10^{-7} secure bits/pulse. Co-existence with 20 down- and 1 upstream channel is possible at low QBER degradation of 0.93% and 1.1%.

Th1J.6 • 09:15

Physical Encryption Secure Optical Communications Based on Distributed Private Chaos Synchronization, Ning Jiang[1,2], Anke Zhao[1], Chenpeng Xue[1,2], Jianming Tang[2], Kun Qiu[1]; [1]*Univ. of Electronic Science & Tech China, China;* [2]*School of Electronic Engineering, Bangor Univ., UK*. A physical encryption scheme converting messages into noise-like signals is proposed, whose features include inherent transparency to modulation formats, bidirectional transmission suitability, plug-and-play in conventional optical communication systems and use of existing dispersion compensation modules.

Room 1	Room 2	Room 3	Room 6C	Room 6D	Room 6E
Th1A • Panel: Beyond 400G for Hyper-scale Data Centers—Continued	**Th1B • Multicore and Multimode Amplifiers—Continued**	**Th1C • Terahertz/ mmWave Photonics—Continued**	**Th1D • Component Implementation and Equalization—Continued**	**Th1E • Large-scale Optical Switch—Continued**	**Th1F • 5G Fiber Wireless Technology—Continued**
	Th1B.6 • 09:30 Top Scored **Characterization of Coupled-core Fiber Amplifiers Using Swept-wavelength Interferometer,** Juan Carlos Alvarado Zacarias[1,3], Charles Matte-Breton[2,3], Roland Ryf[3], Nicolas K. Fontaine[3], Haoshuo Chen[3], Steffen Wittek[1,3], Hirotaka Sakuma[4], Takafumi Ohtsuka[4], Tetsuya Hayashi[4], Takemi Hasegawa[4], Sophie LaRochelle[2], Rodrigo Amezcua Correa[1]; *[1]CREOL, The College of Optics & Photonics, USA; [2]COPL, Universite Laval, Canada; [3]Nokia Bell Labs, USA; [4]Sumitomo Electric Industries, Ltd., Japan.* We present a characterization technique for coupled space-division multiplexed (SDM) amplifiers, that can measures the complex transfer matrix over the whole wavelength range of interest of an amplifier under nominal input spectrum and power condition. The measurements are essential for the performance estimation of an SDM system.	**Th1C.4 • 09:30** **Broadband and Continuous Beamformer Based on Switched Delay Lines Cascaded by Optical Ring Resonator,** Ailee Trinidad[1], Zizheng Cao[1], Johan van Zantvoort[1], Eduward Tangdiongga[1], Ton Koonen[1]; *[1]Technical Univ. of Eindhoven, Netherlands.* A beamforming chip is realized on indium phosphide (InP) employing cascaded optical ring resonators and switched delay lines for wide bandwidth applications. 6.7 Gbps transmission in the K-band (17-22 GHz) is achieved up to 23.1 ps steering on a 4 GHz-wide OFDM signal.		**Th1E.5 • 09:30** Top Scored **240x240 Wafer-scale Silicon Photonic Switches,** Tae Joon Seok[1,2], Kyungmok Kwon[2], Johannes Henriksson[2], Jianheng Luo[2], Ming C. Wu[2]; *[1]Gwangju Inst. of Science and Technology, Korea; [2]Univ. of California Berkeley, USA.* We report on 240x240 silicon photonic MEMS switches on 4cm x 4cm dies realized by wafer-scale integration and reticle stitching. The maximum on-chip loss is measured to be 9.8dB and the crosstalk is below -70dB.	**Th1F.6 • 09:30** **Electro-optic Device in InP for Wide Angle of Arrival Detection in Optical Wireless Communication,** Simone Cardarelli[1], Nicola Calabretta[1], Sebastian Koelling[1], Ripalta Stabile[1], Kevin Williams[1]; *[1]Technical Univ. of Eindhoven, Netherlands.* An optical beam steering component for indoor localization is introduced. Detection of the angle of arrival between the proposed device and a receiving optical fiber is shown for a 60° angle range.
	Th1B.7 • 09:45 **High Spatial Density 6-mode 7-core Multicore L-band Fiber Amplifier,** Yong-min Jung[1], Masaki Wada[2], Taiji Sakamoto[2], Saurabh Jain[1], Ian Davidson[1], Pranabesh Barua[1], John Hayes[1], Shaif-ul Alam[1], Kazuhide Nakajima[2], David J. Richardson[1]; *[1]Optoelectronics Research Centre (ORC), UK; [2]NTT Access Network Service Systems Laboratories, NTT Corporation, Japan.* We present high spatial density SDM amplifier (i.e. 6-mode, 7-core multicore fiber amplifier) supporting 42 spatial channels. More than 17 dB average gain is obtained in the L-band with less than 5.4dB differential modal gain.	**Th1C.5 • 09:45** **93-GHz Signal Beam Steering with True Time Delayed Integrated Optical Beamforming Network,** Yuan Liu[1], Brandon Isaac[1], Jean Kalkavage[2], Eric Adles[2], Thomas Clark[2], Jonathan Klamkin[1]; *[1]Univ. of California Santa Barbara, USA; [2]The Johns Hopkins Univ. Applied Physics Laboratory, USA.* A 93-GHz beam steering experiment based on a 1x4 phased array antenna was demonstrated, achieving beam steering angles of −51°, ±34° ,±17° and 0°. An integrated optical beamforming network chip with true time delays was employed.		**Th1E.6 • 09:45** **LCoS-based Photonic Crossconnect,** Haoshuo Chen[1], Nicolas K. Fontaine[1], Roland Ryf[1], David T. Neilson[1]; *[1]Nokia Bell Labs, USA.* We demonstrate a 16 x 16 photonic crossconnect using LCoS steering, with an average insertion loss of 4 dB, which allows alignment error to be corrected and demonstrates power splitting for increased network functionality.	

10:00–16:00 Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30)
OFC Career Zone Live, *Exhibit Hall C*

Room 6F

Th1G • Security and Monitoring—Continued

Room 7

Th1H • Machine Learning for Datacenter Networks—Continued

Room 8

Th1I • Open Systems and Interoperability—Continued

Th1I.4 • 09:30 Invited

Interoperability and High-capacity Transmission Using Multi-core Fiber with Standard Cladding Diameter, Takashi Matsui[1], Kazuhide Nakajima[1]; [1]*Access Network Service Systems Labs, Nippon Telegraph and Telephone Corporation, Japan*. We show multi-core fiber (MCF) with standard cladding diameter that enables us to utilize standard fiber technologies, and demonstrate multi-vendor interoperability and the potential of 100 Pbit/s-km capacity of the standard cladding MCF.

Room 9

Th1J • Quantum Communication and Security—Continued

Th1J.7 • 09:30

Digital Coherent 20-Gbit/s DP-PSK Y-00 Quantum Stream Cipher Transmission over 800-km SSMF, Ken Tanizawa[1], Fumio Futami[1]; [1]*Tamagawa Univ., Japan*. We demonstrate secure fiber-optic transmission utilizing quantum-noise signal masking by 2^{17}-level random phase modulation. Masking of 157 signal phase levels at a BER of HD-FEC threshold is achieved without significant impacts on the transmission performance.

Th1J.8 • 09:45

Multi Scrolls Chaotic Encryption for Physical Layer Security in CO-OFDM, Yongtao Huang[1], Yuanxiang Chen[1], Kaile Li[1], Yitong Li[1], Jie Ma[1], Jianguo Yu[1]; [1]*Beijing Univ. of Posts and Telecommunications, China*. We propose a novel 3 dimension (3D) multi scrolls chaotic encryption for physical layer security in CO-OFDM. A key space of 10^{324} is created to enhance the security level of OFDM data encryption with lower encryption complexity.

10:00–16:00 Exhibition and Show Floor, *Exhibit Hall* (coffee service 10:00–10:30)
OFC Career Zone Live, *Exhibit Hall C*

10:30–12:30
Th2A • Poster Session II

Th2A.1
Novel Opto-electronical Probe Card for Wafer-level PIC Testing, Tobias Gnausch[1], Armin Grundmann[1], Thomas Juhasz[1], Thomas Kaden[1], Robert Büttner[1], Thilo von Freyhold[1]; *[1]Jenoptik Optical Systems, Germany.* A novel alignment insensitive, opto-electronical probe card for wafer level PIC testing to use with common high volume wafer probers and automated test equipment is presented to reduce cost and cycle time.

Th2A.2
High Density 8 Lane 2x200Gb/s Optical Transceivers Using MEMS-aligned TROSA Architecture, Bardia Pezeshki[1], Robert Kalman[1], Ramsey Selim[1], Lucas B. Soldano[1]; *[1]Kaiam Corp., USA.* We demonstrate 8 lane compact optical transceivers running at 50Gb/s using EMLs with PAM4 encoding. MEMS-alignment of lasers and a compact PLC with integrated vertical deflection mirrors enables simple low-cost assembly and high density.

Th2A.3
Efficient Low-loss Adaptive Optical Filters Based on Silicon Oxycarbide - Liquid Crystal Hybrid Technology, Lars Baudzus[1], Peter M. Krummrich[1]; *[1]Chair for High Frequency Technology, TU Dortmund, Germany.* We present results from experimental investigations on adaptive optical filters based on a silicon oxycarbide - liquid crystal hybrid technology and show that the transmission characteristics can be adjusted by low voltage digital driving signals.

Th2A.4
A Broadband Mode Divider with Arbitrary Branching Ratio Based on Wavelength-insensitive Coupler, Misa Kudo[1], Takeshi Fujisawa[1], Taiji Sakamoto[2], Takashi Matsui[2], Kyozo Tsujikawa[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; *[1]Hokkaido Univ., Japan; [2]NTT Corporation, Japan.* A broadband TE_0-TE_1 mode divider with arbitrary-branching-ratio based on multimode wavelength-insensitive coupler is proposed for flexible mode manipulation in mode-division-multiplexing system. Measured spectra of fabricated devices in Si-photonics platform are in excellent agreement with theory.

Th2A.5
Phase Insensitive High Order Mode Pass Filter with Low Reflection for Two-mode Division Multiplexing, Min Teng[1], Yun Jo Lee[1], Abdullah Al Noman[1], Yi Xuan[1], Ziyun Kong[1], Yingheng Tang[1], Minghao Qi[1]; *[1]Purdue Univ., USA.* A TE0 block TE1 pass filter is proposed and experimentally demonstrated on SOI platform over C band. The filter suffers negligible reflection and is theoretically immune to phase dependent spectral fluctuation under dual-modes concurrent input.

Th2A.6
All-Si Metasurface Polarizing Bandpass Filter Mass Produced on 12 Inch Wafer, Zhengji Xu[1], Yuan Dong[1], Chi Kuo Tseng[1], Ting Hu[1], Jinchao Tong[2], Qize Zhong[1], Larry Sim[1], Keng Heng Lai[1], Ying Lin[1], Dongdong Li[1], Yu Li[1], Vladimir Bliznetsov[1], Yuan Hsing Fu[1], Shiyang Zhu[1], Qunying Lin[1], Dao Hua Zhang[2], Dim Lee Kwong[1], Yuandong Gu[1]; *[1]A*STAR, Inst. of Microelectronics, Singapore; [2]Nanyang Technological Univ., Singapore.* We report all-Si metasurface based polarizing bandpass filter (PBF) fabricated on 12 inch wafer, employing CMOS-compatible 193nm ArF DUV immersion lithography and ICP etch. The fabricated metasurface PBF work on dual short wave infrared bands.

Th2A.7
4-Channel C-Band WDM Transmitter Based on 10 GHz Graphene-silicon Electro-absorption Modulators, Chiara Alessandri[1,2], Inge Asselberghs[1], Peter De Heyn[1], Steven Brems[1], Cedric Huyghebaert[1], Joris Van Campenhout[1], Dries Van Thourhout[2,1], Marianna Pantouvaki[1]; *[1]imec, Belgium; [2]Ghent Univ., Belgium.* We demonstrate three 4-channel WDM transmitters, each based on four graphene-silicon electro-absorption modulators with passivated graphene, achieving ~2.6dB insertion loss, ~5.5dB extinction ratio for 8V voltage swing and ~10GHz 3dB-bandwidth at 0V DC bias.

Th2A.8
Femtosecond Timing Jitter of Quantum Dot Semiconductor Comb Lasers with Self-injection Feedback Locking, Youxin Mao[1], Jiaren Liu[1], Zhenguo Lu[1], Chunying Song[1], Philip J. Poole[1]; *[1]National Research Council Canada, Canada.* An analysis of phase noise and timing jitter in an external cavity self-injection feedback locking (ECSIFL) 25 GHz InAs/InP quantum dot coherent comb laser (CCL) is presented. Femtosecond timing jitter of the CCL with ECSIFL is experimentally demonstrated.

Th2A.9
Butt-coupled Waveguide Germanium Avalanche Photodiodes with Lateral SAM Structures, Hideki Ono[1]; *[1]PETRA, Japan.* Butt-coupled lateral SAM structure waveguide Ge-APDs based on Si photonics technology were fabricated and evaluated. The excellent responsivity exceeding 20 A/W independent of polarization at the wavelength of 1600nm was experimentally demonstrated for TWDM-PON applications.

Th2A.10
Pseudomorphic GeSn/Ge Multiple-quantum-well on Silicon for Photo Detection and Modulation at 2 μm Wavelength Range, Shengqiang Xu[1], Wei Wang[1], Yuan Dong[1], Yi-Chiau Huang[2], Saeid Masudy-Panah[1], Hong Wang[3], Xiao Gong[1], Yee-Chia Yeo[1]; *[1]National University of Singapore, Singapore; [2]Applied Materials Inc., USA; [3]Nanyang Technological Univ., Singapore.* Pseudomorphic GeSn/Ge multiple-quantum-well p-i-n photodiodes were studied at 2 μm range. Direct current and radio frequency measurements were performed to investigate the electrical and optical property of GeSn/Ge MQWs for photo detection and electro-absorption modulation.

Th2A.11
Enhanced Nonlinearity Compensation Efficiency of Optical Phase Conjugation System, Abdallah A. Ali[1], Mohammad Al-Khateeb[1], Tingting Zhang[1], Filipe Ferreira[1], Andrew D. Ellis[1]; *[1]Aston Inst. of Photonic Technologies, UK.* We experimentally demonstrate enhanced efficiency of nonlinearity compensation, by 13dB, when deploying mid-link optical phase conjugation in discretely-amplified systems. Our demonstration is based on dispersion-loading, using standard transmission fiber, which enhances the reach by 75km.

Th2A.12
Design and Fabrication of a High Precision Dual-row Optical Fiber Array., Shijia Yan[1], Henghuan Yang[2], Changjian Ke[1], Zhujun Wan[1, 3]; *[1]Huazhong Univ. Sci. & Tech., China; [2]Shanghai Fujusheng industry Co., Ltd., China; [3]Shenzhen Huazhong University of Science and Technology Research Institute, China.* A high-precision dual-row fiber array (FA) is proposed to ensure the positioning accuracy of two rows of optical fibers. The fabricated 2×10-channel FA samples show maximum insertion loss of <1.23dB and worst uniformity of <1.00dB.

Th2A.13
Optical Phase Conjugation Enhanced Direct Detection with Kramers–Kronig Receiver, Honghui Zhang[1], Qiulin Zhang[1], Chaoran Huang[2], Chester C.T. Shu[1]; *[1]Department of Electronic Engineering and Center for Advanced Research in Photonics, The Chinese Univ. of Hong Kong, Hong Kong; [2]Lightwave Communication Research Laboratory, Department of Electrical Engineering, Princeton Univ., USA.* We demonstrate performance enhancement of a Kramers-Kronig direct-detection system by utilizing mid-span optical phase conjugation. The optimum Q factor is improved by 1.8 dB. The optimum carrier-to-signal power ratios at different launched powers are analyzed. <audio controls="controls" style="display: none;"> </audio>

Th2A.14
Higher-gain Broadband Single-mode Chromium-doped Fiber Amplifiers by Tetrahedral-chromium Enhancement, Liu Chun-Nien[1], Jhuo-Wei Li[1], Chun-Chuen Yang[2], Charles Tu[1], Wood-Hi Cheng[1]; *[1]Graduate Inst. of Optoelectronic Engineering, National Chung Hsing Univ., Taiwan; [2]Department of Physics, Chung Yuan Christian Univ., Taiwan.* The net gains of 5.1 for a 300-nm broadband single-mode Cr-doped crystalline core fiber are in demonstration with thermal annealing. The gain improvement was mainly achieved by enhancing the tetrahedral chromium (Cr^{4+}(tetra))-ions up to 17% in the SMCDCCF annealing.

Th2A.15
Direct Measurement of Polarization Dependency of Mode Conversion in a Long Period Grating, Lars E. Grüner-Nielsen[2], Neethu M. Mathew[1], Karsten Rottwitt[1]; *[1]DTU Fotonik, Denmark; [2]Danish Optical Fiber Innovation, Denmark.* A thermal induced long period grating mode converter with high bandwidth, and low loss is presented. Polarization dependency of the mode conversion is measured using spatial and spectral (S^2) imaging and found to be low.

Th2A.16
Ultra-high Resolution Distributed Strain Sensing Based on Phase-OTDR, Tao Liu[1], Hao Li[1], Fan Ai[1], Jin Wang[1], Cunzheng Fan[1], Yiyang Luo[1], Zhijun Yan[1], Deming Liu[1], Qizhen Sun[1]; *[1]Huazhong Univ. of Science and Technology, China.* We demonstrate an ultra-high resolution distributed strain sensor assisted with Rayleigh-scattering enhanced optical fiber and phase noise compensation scheme, realizing a static strain resolution of 1.89 nε and dynamic resolution of 97.5 pε/√Hz over 1Hz.

Th2A.17
Rail Crack Detection by Analyzing the Acoustic Transmission Process Based on Fiber Distributed Acoustic Sensor, Cunzheng Fan[1], Fan Ai[1], Yijie Liu[1], Zhijie Xu[1], Geng Wu[1], Wei Zhang[1], Chen Liu[1], Zhijun Yan[1], Deming Liu[1], Qizhen Sun[1]; *[1]Huazhong Univ. of Science and Technology, China.* A method for rail crack detection by analyzing sound wave generated by the interaction between wheel and crack is proposed. Field tests verify the feasibility with maximum locating error of 2.1m.

Th2A.18
Brillouin Optical Time Domain Analyzer Fiber Sensor Based on FPGA Accelerated Support Vector Regression, Huan Wu[1,2], Hongda Wang[1], Chester Shu[1], Chiu S. Choy[1], Chao Lu[2]; *[1]Department of Electronic Engineering, The Chinese Univ. of Hong Kong, Hong Kong; [2]Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong.* Support vector regression and its FPGA implementation have been employed in a BOTDA system to extract temperature information. Post-processing for 96,100 BOTDA data points along 38.44-km fiber can be completed within 0.5 seconds.

Th2A • Poster Session II—Continued

Th2A.19
Distributed Sub-tree Based Multi-class Multicast Service Aggregation in Elastic Optical Data Center Networks, Ying Tang[1], Xin Li[1], Tao Gao[1], Lu Zhang[1], Yongjun Zhang[1], Shanguo Huang[1]; [1]*Beijing Univ. of Posts and Telecomm, China*. We propose a distributed sub-tree based multicast service aggregation scheme considering the class of each multicast service including public and secure types. It achieves low spectrum and transceiver consumptions and has a wide application scope.

Th2A.20
Machine Learning Based Traffic Pattern Aware Topology Reconstruction to Optimize Application Performance in Optical DCNs, Cen Wang[1], Hongxiang Guo[1], Xiong Gao[1], Yanhu Chen[1], Jian Wu[1]; [1]*Beijing Univ. of Posts & Telecom, China*. We proposed a traffic pattern aware topology reconstruction strategy via CNN and spectral clustering to support correlative traffic in parallel computing. Simulation and experiment have verified the efficiency of such strategy by accelerating the computing jobs.

Th2A.21
Demonstration of a Multivendor Path Computation with Optical Feasibility Combining GMPLS and Open Source, Luay Alahdab[1,2], Esther Le Rouzic[1], Julien Meuric[1], Jean-Luc Auge[1], Cedric Ware[2], Khalifa Ndiaye[1]; [1]*Orange Labs, France;* [2]*LTCI, Télécom ParisTech, Université Paris-Saclay, France*. Openness and interoperability are a challenge in optical networks especially when it comes to lightpath optical performance estimation. We propose to use a vendor-agnostic open-source tool and extend the OSPF-TE protocol with the required parameters.

Th2A.22
Multi-failure Resilient and Cost-effective Hyper-scale Transport Networks for the 5G-era, Bodhisattwa Gangopadhyay[1], João Pedro[1,2], Stefan Spaelter[1]; [1]*Infinera, Portugal;* [2]*Instituto de Telecomunicações, Portugal*. This paper exploits an hyper-scale network architecture involving high-density transponders, fast protection switching, shared regeneration for optical restoration and proposes algorithms for routing, grooming and statistical simulation for resource dimensioning targeting high availability in a time-effective manner.

Th2A.23
Comprehensive Performance Study of Elastic Optical Networks for Distributed Datacenter with Survivability, Xiao Luo[1], Chen Shi[2], Xue Chen[1], Yang Li[1], Yang Tao[1]; [1]*Beijing Univ. of Posts & Telecom, China;* [2]*Iowa State Univ., USA*. We present a criterion to measure network performance comprehensively and a reinforcement learning based network resource assignment strategy with enhanced survivability. Numerical results show the validity of criterion and superior performance of the proposed strategy.

Th2A.24
Routing without Routing Algorithms: An AI-based Routing Paradigm for Multi-domain Optical Networks, Zhizhen Zhong[1], Nan Hua[1], Zhigang Yuan[1], Yanhe Li[1], Xiaoping Zheng[1]; [1]*Tsinghua Univ., China*. We first propose a novel multi-domain routing paradigm that transforms the routing problem from heuristic-algorithm-based computation to artificial-intelligence-based data analytics. Numerical results prove that our proposal can achieve excellent routing accuracy, and significant signaling reduction.

Th2A.25
Adaptive Traffic Data Augmentation Using Generative Adversarial Networks for Optical Networks, Shuai Li[1], Jin Li[1], Min Zhang[1], Danshi Wang[1], Chuang Song[1], Xinghua Zhen[1]; [1]*Beijing Univ. of Posts and Telecommunications, China*. We propose an adaptive traffic data augmentation technique based on generative adversarial networks trained with partial experimental data for optical networks and verify that the augmented traffic is similar to experimental traffic under diverse scenarios.

Th2A.26
Identification of Sagging Aerial Cable Section by Distributed Vibration Sensing Based on OFDR, Tatsuya Okamoto[1], Daisuke Iida[1], Hiroyuki Oshida[1]; [1]*NTT, Japan*. We measure vibration waveforms along an installed aerial optical fiber cable and identify a sagging cable section. This is the first demonstration of telecom optical fiber cable maintenance by distributed vibration sensing.

Th2A.27
Mobility-aware 5G Midhaul Network Design for Optimizing Edge Computing Resources, Nannan Wang[1], Xi Wang[1], Paparao Palacharla[1], Tadashi Ikeuchi[1], Weisheng Xie[2]; [1]*Fujitsu Laboratories of America Inc., USA;* [2]*Fujitsu Network Communications, USA*. We present a 5G midhaul design algorithm for connecting suitable groups of distributed units to each central unit based on the mobility patterns of connected vehicles, with the goal of minimizing edge computing resources.

Th2A.28
Silicon Microring IQ Modulator Enabled Single Sideband OFDM Transmission, Yelong Xu[1], Mingyang Lyu[1], Leslie Rusch[1], Wei Shi[1]; [1]*Université Laval, Canada*. We experimentally demonstrate SSB-OFDM signal generation with over 18-dB sideband suppression ratio using a silicon microring IQ modulator. Transmission of 31.4 Gb/s over 20-km SSMF is achieved well below the FEC threshold.

Th2A.29
Symmetric Long-reach 16-QAM Transmission Using Lite Coherent Receiver for Next-generation Optical Access Network, Qi Zhou[1], Jiale He[1], Shuyi Shen[1], Rui Zhang[1], Shuang Yao[1], Yahya M. Alfadhli[1], You-Wei Chen[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA*.We propose and experimentally demonstrate a low-cost symmetric long-reach high-capacity access structure enabled by a lite coherent receiver. 50-Gb/s/λ 16-QAM transmission with 40.1-dB link-budget is achieved to surpass specifications in NG-PON2.

Th2A.30
Direct Detection of Pilot-assisted PAM Signals for DCI and Metro Networks, Cai Li[1], Chao Yang[1], Ming Luo[1], Zhixue He[1], Xiang Li[1], Shaohua Yu[1]; [1]*Wuhan Research Inst. of Posts and Tech, China*. We propose a pilot-assisted direct detection scheme with digital carrier regeneration in DCI and metro networks to realize 112-Gb/s CFP-LR4-100G optical module, 56-Gb/s duobinary and PAM-4 signals over 160-km, 640-km and 720-km SSMF transmission, respectively.

Th2A.31
System Performance Evaluation of a Nanoseconds Modular Photonic Integrated WDM WSS for Optical Data Center Networks, Kristif Prifti[1], Anas Gasser[2], Netsanet Tessema[1], Xuwei Xue[1], Ripalta Stabile[1], Nicola Calabretta[1]; [1]*TU/e Eindhoven Univ. of Technology, Netherlands;* [2]*VUB, Belgium*. The system performance of a photonic integrated WDM wavelength selective switch is assessed with 10, 20 and 40 Gb/s NRZ-OOK. Results show lossless operation, limited penalty for 8 WDM channels and > 8dB power dynamic range.

Th2A.32
120-Gbit/s/pol./l IM-DD Transmission over 55-km SSMF with 10-GHz-Bandwidth Intensity Modulator, Single PD, and a Pair of DAC and ADC with 20 GSa/s, Ken Kakizaki[1], Shinya Sasaki[1]; [1]*Chitose Inst. of Science and Tech., Japan*. We successfully demonstrate 120-Gbit/s/pol./l bare-rate IM-DD transmission over 55.6-km SSMF with 10-GHz-bandwidth devices such as an intensity modulator, a single PD, and 20-GSa/s DAC/ADC using novel combination of CAP and CDM scheme.

Th2A.33
AMI for Nonlinearity Mitigation in O-band Transmission, Natsupa Taengnoi[1], Kyle Bottrill[1], Cosimo Lacava[1], David J. Richardson[1], Periklis Petropoulos[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK*. We utilise the alternate mark inversion (AMI) scheme to mitigate the nonlinearity in O-band transmission. The results after transmission over 60km of SMF show that AMI outperforms the duobinary and on-off keying formats.

Show Floor Programming

400ZR Specification Update
OIF
10:15–11:15, *Theater II*

Product Showcase: Network Transformation and Huawei Optical Network 2.0
Huawei Technologies USA Inc.
10:15–10:45

■ **MW Panel V: What's After 400G Ethernet Inside the Data Center?**
10:30–12:00, *Theater I*

POF Symposium
POFTO
11:00–13:00, *Theater III*

The Path to Open, Interoperable Optical Networking
OIF
11:15–12:15, *Theater II*

■ **MW Panel VI: Optical Network Management Using Cognitive Systems - Reality or Hype?**
12:30–14:00, *Theater I*

How Centralized Should Centralized SDN Control and Orchestration Be?
12:45–14:15, *Theater II*

Th2A • Poster Session II—Continued

Th2A.34
Nonlinear Noise Monitoring in Coherent Systems Using Amplitude Modulation Pilot Tone and Zero-power Gap, Zhiping Jiang[1], Xuefeng Tang[1]; [1]*Huawei Technology Canada, Canada.* We propose a new method to monitor fiber nonlinear noise power using amplitude modulation pilot-tone and zero-power gap. The direct nonlinear noise monitoring was verified experimentally in multi-channel transmission over a 600-km SSFM link.

Th2A.35
Reduction of Nonlinear Distortion in SOA-based Wavelength Conversion System by Post-blind-compensation Based on Machine Learning Clustering, Yi Lin[1], Elias Giacoumidis[1], Sean O'Duill[1], Aravind Anthur[1], Liam P. Barry[1]; [1]*Dublin City Univ., Ireland.* Nonlinearities in SOA-based wavelength conversion are experimentally tackled using post-blind-compensation based on machine learning clustering for coherent 16/64-QAM signals. We show that K-means outperforms fuzzy-logic since it tackles more effectively non-circularly-symmetric Gaussian noise and nonlinearity.

Th2A.36
Dual-function Frequency and Doppler Shift Measurement System Using a Phase Modulator Incorporated Lyot Filter, Qidi Liu[1], Mable P. Fok[1]; [1]*The Univ. of Georgia, USA.* A microwave photonic dual-function system capable of measuring both instantaneous frequency and Doppler frequency shift is experimentally demonstrated. The system consists of a tunable Lyot loop filter that enhances spectral resolution and reduces measurement error.

Th2A.37
Experimental Demonstration of an Optical Neuron with a Logistic Sigmoid Activation Function, George Mourgias-Alexandris[1], Apostolos Tsakyridis[1], Nikolaos Passalis[1], Anastasios Tefas[1], Nikos Pleros[1]; [1]*Aristotle Univ. of Thessaloniki, Greece.* We experimentally demonstrate an optical neuron using an optical logistic Sigmoid activation function. Successful thresholding at 4 different power levels was achieved yielding a 100% improvement compared to state-of-the-art, employing a sequence of 100psec long pulses.

Th2A.38
Speckle-based BPSK/QPSK Demodulator, Adam C. Scofield[1], George A. Sefler[1], Thomas J. Shaw[1], Daniele M. Monahan[1], George C. Valley[1]; [1]*The Aerospace Corporation, USA.* BPSK and QPSK RF signals are demodulated without carrier frequency knowledge. The demodulator employs compressive sensing recovery methods and uses speckle within a multimode fiber to perform the requisite random signal projections.

Th2A.39
Multicarrier Entropy-power Loading Enabled the Capacity-approaching for Optical Wireless Channel, Zexin Chen[1], Chenhui Xie[1], Songnian Fu[1], Li Xia[1], Xiang Li[2], Daojun Xue[2], Zhixue He[2], Ming Tang[1], Deming Liu[1]; [1]*Huazhong Univ. of Science & Technology, China;* [2]*State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts and Telecommunications, China.* We propose water-filling (WF) strategy based multicarrier entropy-power loading technique to approach the Shannon capacity of optical wireless channel with colored SNR. The normalized gap for the OFDM based VLC system is reduced to 9.31%.

Th2A.40
Probabilistically Shaped 256-QAM-OFDM Transmission in Underwater Wireless Optical Communication System, Xiaojian Hong[1], Chao Fei[1], Guowu Zhang[2], Sailing He[1]; [1]*Zhejiang Univ., China;* [2]*McGill Univ., Canada.* We experimentally demonstrated PS-256-QAM-OFDM for 35m underwater-wireless-optical-communication (UWOC) system. Compared with bit-power loading scheme, 27.8% capacity improvement is achieved. To the best of our knowledge, this is the first time to employ PS-QAM in UWOC.

Th2A.41
Demonstration of Enhanced Tolerance to Turbulence and Misalignment of a 10-Gbit/s QPSK Free-space Optical Link by Utilizing Two Aperture Pairs Combined with Detecting Multiple Modes, Haoqian Song[1], Long Li[1], Kai Pang[1], Runzhou Zhang[1], Kaiheng Zou[1], Zhe Zhao[1], Jing Du[1], Hao Song[1], Cong Liu[1], Yinwen Cao[1], Ari N. Willner[1], Robert Bock[2], Brittany Lynn[3], Moshe Tur[4], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*R-DEX Systems, USA;* [3]*Space & Naval Warfare Systems Center, USA;* [4]*School of Electrical Engineering, Tel Aviv Univ., Israel.* A 10-Gbit/s optical wireless link is demonstrated and investigated under misalignment and emulated turbulence. Up to 10-dB power penalty reduction is realized by utilizing two aperture pairs combined with detecting two OAM modes.

Th2A.42
KK Heterodyne Detection of Mm-wave Signal at D-band, Mingming Zhao[2], Jianjun Yu[1], Yingjun Zhou[2], Kaihui Wang[2], Can Wang[1,2], Jiangnan Xiao[2], Xiaolong Pan[3], Xiangjun Xin[3], Bo Liu[3]; [1]*ZTE USA Inc., USA;* [2]*Fudan Univ., China;* [3]*Beijing Univ. of Posts and Telecommunications, China.* We have realized 80-Gb/s 16-QAM signal at D-band wireless delivery over 3.47-m with KK heterodyne coherent detection, and for our knowledge this is the first time to realize the KK heterodyne coherent detection at D-band.

Th2A.43
Impact of Carrier-phase Estimation on Noise Transductions for Optical Performance Monitoring, Francisco Javier Vaquero Caballero[1], David J. Ives[1], Robert J. Vincent[1], Charles Laperle[2], Andrew Shiner[2], Michael Reimer[2], Douglas Charlton[2], Maurice O'Sullivan[2], Seb J. Savory[1]; [1]*Univ. of Cambridge, UK;* [2]*Ciena, Canada.* The impact of CPE the estimation linear and nonlinear noises is studied. Using previously reported second-order statistical metrics, CPE increases the maximum error from 0.16dB to 0.59dB whereas alternative metrics give 0.26dB independent of CPE.

Th2A.44
Deep Learning Enabled Simultaneous OSNR and CD Monitoring for Coherent Transmission System, Chunxiao Wang[1], Songnian Fu[1], Ming Tang[1], Li Xia[1], Deming Liu[1]; [1]*School of Optical and Electronic Information, Huazhong Univ. of Sci&Tech, China.* We demonstrate long short-term memory neural network (LSTM-NN) enabled simultaneous OSNR and CD monitoring with features of modulation-format and baud-rate insensitive. The mean absolute errors (MAEs) of simultaneous monitoring are below 0.1dB and 0.64ps/nm, respectively.

Th2A.45
Fiber Nonlinear Noise-to-signal Ratio Estimation by Machine Learning, Ke Zhang[1], Yangyang Fan[1], Tong Ye[1], Zhenning Tao[1], Shoichiro Oda[2], Takahito Tanimura[2], Yuichi Akiyama[2], Takeshi Hoshida[2]; [1]*Fujitsu R&D Center Co., Ltd., China;* [2]*Fujitsu Laboratories Ltd., Japan.* A machine learning-based estimation method for fiber nonlinear noise-to-signal ratio is proposed, which does not require channel state information. The generalization problem of machine learning model from homogeneous to inhomogeneous cases is also investigated.

Th2A.46
160 Gb/s 256QAM Transmission in a 25 GHz Grid Using Kramers-Kronig Detection, Yingjun Zhou[1,2], Jianjun Yu[1,4], Yiran Wei[1], Rui Deng[2], Li Zhao[1,2], Nan Chi[1], Gee-Kung Chang[2], Yun Zhang[3]; [1]*Fudan Univ., China;* [2]*Georgia Inst. of Technology, USA;* [3]*ZTE Corp., China;* [4]*ZTE (TX) Inc, USA.* We experimentally demonstrated a 20 Gbaud 256QAM over 20 km of SSMF in a 25 GHz grid employing Kramers-Kronig scheme to reconstruct optical phase. To the best of our knowledge, this is the first time that 256QAM format is implemented in a Kramers-Kronig single-sideband direct detection system.

Th2A.47
Impact of Nonlinear Impairments in MDM Transmissions Using Rescaled Multimode Fibers, Marius Brehler[1], Peter M. Krummrich[1]; [1]*Chair for High Frequency Technology, TU Dortmund, Germany.* We show that the nonlinear impairments in mode-division multiplexing systems scale opposite to the spatial density of modes in multimode fibers with a constant numerical aperture.

Th2A.48
Automated Alignment between Channel and Filter Cascade, Camille Delezoide[1], Patricia Layec[1], Sébastien Bigo[1]; [1]*Nokia Bell Labs, France.* We propose a new and cost-efficient method based on receiver-side spectrum monitoring to mitigate filter impairments. We experimentally demonstrated up to 3dB-reduction in filter penalties for 32GBd PDM-QPSK signals.

Th2A.49
Reduced Complexity Nonlinearity Compensation via Principal Component Analysis and Deep Neural Networks, Yuliang Gao[1], Ziad A. El-Sahn[1], Ahmed Awadalla[1], Demin Yao[1], Han Sun[1], Pierre Mertz[2], Kuang-Tsan Wu[1]; [1]*Infinera Canada, Canada;* [2]*Infinera Corporation, USA.* We demonstrate a novel fiber nonlinearity post-equalization algorithm using principal component analysis and neural networks. We achieve ~0.46 dBQ improvement for 21 Gbaud DP-8QAM transmission over ~13,000 km deployed fiber with over 90% complexity reduction.

Th2A.50
MIMO Nonlinear Equalizer Based on Inverse Volterra Series Transfer Function for Coherent SDM Systems, Vassiliki Vgenopoulou[1], Nikolaos P. Diamantopoulos[2,3], Ioannis Roudas[4], Stylianos Sygletos[5]; [1]*Physics, Univ. of Patras, Greece;* [2]*Athens Information Technology, Greece;* [3]*NTT Device Technology Labs, NTT Corporation, Japan;* [4]*Electrical and Computer Engineering, Montana State Univ., USA;* [5]*ASTON Univ., UK.* We propose a novel MIMO Volterra-based nonlinear equalizer. Simulation results revealed a ~0.8 dB Q^2-factor improvement, after transmitting 6×32 Gbaud PM-16QAM signals carried by 6 spatial modes over 1,040 km of an FMF link.

Th2A.51
Joint Equalization Scheme of Ultra-fast RSOP and Large PMD in Presence of Residual Chromatic Dispersion, Wei Yi[1], Zibo Zheng[1], Nan Cui[1], Liyuan Qiu[1], Xiaoguang Zhang[1], Nannan Zhang[1], Wenbo Zhang[1], Lixia Xi[1]; [1]*Beijing Univ. of Posts and Telecomm, China.* We propose a new Kalman filter structure for joint equalization of ultra-fast RSOP, large PMD and residual CD, which provides excellent performance for PMD (> 200ps), RSOP (up to 3Mrad/s) and residual CD (~ ±820ps/nm)

12:30–14:00 Unopposed Exhibit-only Time, *Exhibit Hall* (concessions available)

NOTES

Room 1

14:00–16:00
Th3A • Evolution of Optical Interconnects
Presider: Dominic Goodwill; Huawei Technologies R&D, Canada

Th3A.1 • 14:00 Invited
HPC Interconnects at the End of Moore's Law, John Shalf[1]; [1]*Lawrence Berkeley National Laboratory, USA.* The tapering of lithography advances that have been associated with Moore's Law will substantially change requirements for future interconnect architectures for large-scale datacenters and HPC systems.

Room 2

14:00–16:00
Th3B • Detectors
Presider: Dong Pan, Nano Photonics, USA

Th3B.1 • 14:00
Highly Sensitive, 112 Gb/s O-band Waveguide Coupled Silicon-germanium Avalanche Photodetectors, Alireza Samani[1], Olivier Carpentier[1], Eslam Elfiky[1], Maxime Jacques[1], Amar Kumar[1], Yun Wang[1], Laurent Guenin[1], Claude Gamache[2], Ping-Chiek Koh[3], David Plant[1]; [1]*McGill Univ., Canada;* [2]*Lumentum LLC, Canada;* [3]*Lumentum LLC, USA.* We present two different waveguide coupled SiGe APDs. We report 25 Gb/s error free operation with -12 dBm input power. Additionally, 112 Gb/s PAM-4 operation below the KP4-FEC threshold of 2.0×10^{-4} is reported.

Th3B.2 • 14:15
35Gb/s Ultralow-voltage Three-terminal Si-Ge Avalanche Photodiode, Binhao Wang[1], Zhihong Huang[1], Xiaoge Zeng[1], Di Liang[1], Marco Fiorentino[1], Raymond Beausoleil[1]; [1]*Hewlett Packard Enterprise, USA.* We demonstrate a 35Gb/s three-terminal waveguide silicon-germanium avalanche photodiode using a lateral interdigitated multiplication region. A breakdown voltage of -6V, a bandwidth of 18.9GHz, and a multiplication gain of 15 are achieved.

Room 3

14:00–16:00
Th3C • Microwave Photonic Sub-Systems
Presider: Jose Azana; INRS-Energie Materiaux et Telecom, Canada

Th3C.1 • 14:00 Invited
Microwave Signal Analysis and Processing Based on Frequency Shifting Loops, Hughes Guillet de Chatellus[1,2]; [1]*Univ. Grenoble Alpes, France;* [2]*CNRS, France.* We demonstrate the interest of frequency shifting loops for microwave photonics. This simple architecture allows both spectral analysis in real time, and the generation of arbitrary signals with state of the art performance.

Room 6C

14:00–16:00
Th3D • SDM Devices
Presider: Rodrigo Amezcua Correa; Univ. of Central Florida, CREOL, USA

Th3D.1 • 14:00 Invited
Ultrafast Laser Processes for Photonics, Robert R. Thomson[1], Debaditya Choudhury[1], Calum Ross[1]; [1]*Inst. of Photonics and Quantum Sciences, Heriot Watt Univ., UK.* Space division multiplexing (SDM) has the potential to dramatically increase the information capacity of single optical fibres. I will review how ultrafast laser processing techniques can be used to fabricate interconnect components for SDM applications.

Room 6D

14:00–16:00
Th3E • Hollow Core Fibers
Presider: Daniel Peterson; Verizon Communications Inc, USA

Th3E.1 • 14:00 Tutorial
Advances in Hollow Optical Fiber Technologies and Applications, Francesco Poletti[1]; [1]*Univ. of Southampton, UK.* This talk will review 20 years of advances in hollow core optical fiber technology for a non-specialist audience, focusing on physical guidance mechanims, current and ultimate performance, and on applications in communications and more broadly.

Francesco Poletti leads the Hollow Core Fibre and Compound Glass and Fibre groups at the Optoelectronics Research Centre (ORC), University of Southampton (UK). His research interests focus on the development and application of novel optical fibers, including hollow core, mid-IR and nonlinear versions. After working on optical network design at Marconi, he joined the ORC in 2003, where he obtained a PhD in 2007. His work on hollow fibers was awarded Fellowships from the Royal Society and the Royal Academy of Engineering in 2009, and an ERC consolidator grant in 2016. He has over 340 research papers and 10 patents.

Room 6E

14:00–15:45
Th3F • Coherent PON
Presider: Junwen Zhang; CableLabs, USA

Th3F.1 • 14:00 Top Scored
200-Gb/s/λ PDM-PAM-4 PON with 29-dB Power Budget Based on Heterodyne Coherent Detection, Jiao Zhang[2,1], Jianjun Yu[1], Kaihui Wang[2], Xin Xiao[1], Wen Zhou[2], Li Zhao[2], Xiaolong Pan[3], Bo Liu[3], Xiangjun Xin[3]; [1]*ZTE TX Inc, USA;* [2]*Fudan Univ., China;* [3]*Beijing Univ. of Posts and Telecommunications, China.* We experimentally demonstrated single-lane EML-based IM/DD 106-Gbaud PAM-4 and PS-PAM-8 signals transmission over 1-km NZDSF based on Pre-EQ and clipping technique. 260-Gb/s PS-PAM-8 signal transmission can be achieved.

Th3F.2 • 14:15 Top Scored
Demonstration of Bidirectional Real-time 100 Gb/s (4×25 Gb/s) Coherent UDWDM-PON with Power Budget of 44 dB, Ming Luo[1], Danyu Wu[2], Weizhong Li[1], Tao Zeng[1], Lei Zhou[2], Lingheng Meng[1], Zhixue He[1], Cai Li[1], Xiang Li[1]; [1]*Wuhan Research Inst. of Posts and Telecommunications, China;* [2]*Inst. of Microelectronics of Chinese Academy of Science, China.* We experimentally demonstrate the real-time of 4×25-Gb/s coherent UDWDM-PON at 12.5-GHz spacing over 50-km standard single mode optical fiber. The downlink power budget can be more than 44 dB, and support more than 1000 subscribers.

Room 6F

14:00–15:45
Th3G • Advanced Modulation Formats
Presider: Magnus Karlsson; Chalmers Tekniska Hogskola, Sweden

Th3G.1 • 14:00 Invited
Approaching Shannon Limit with Advanced Modulation and Coding Techniques, Hussam G. Batshon[1]; [1]*SubCom, USA.* This paper discusses different modulation format design techniques that help approaching Shannon capacity limit. It also discusses the different metrics that can be used to characterize these formats.

Room 7

14:00–15:45
Th3H • Panel: Network Infrastructure Virtualization and Network Slicing

Network Slicing is used to unify and extend the concepts of optical network virtualization and (network) function virtualization. It has emerged as a key enabler for 5G deployment and dynamic networking and its applicability domains include intra-datacenter networks as well as the access, aggregation/metro and core network segments. In this context, the network and infrastructure is "sliced", with end-users being provided an abstracted topology view of the physical, underlying network. The granularity level of control given to tenants depends on operators' policy.

This panel aims at discussing these concepts from multiple perspectives, with emphasis on the optical domain:

i) Operators' view of this trend, actual applicability to optical networks, associated challenges, use cases and business models;
ii) Requirements and network architectures enabling the virtualization and slicing, including dynamic management and orchestration of slices and their lifetime management;
iii) Industry status, testing and emerging standards. Ongoing and planned Deployments.

The take-away message is related to the role of the optical technology in network virtualization and network slicing, including to what extent next generation programmable hardware for optics should support some form of virtualization and its performance trade-off.

Speakers:

Achim Authenrieth, *ADVA Optical Networking SE, Germany*
Optical Network Virtualization and 5G Network Slicing – Bridging the Gap

Kalyani Bogineni, *Verizon Communications, USA*
5G Deployment Architecture Options

Room 8

14:00–15:45
Th3I • Visible Light Communication and Positioning
Presider: Ton Koonen; Technische Universiteit Eindhoven, Netherlands

Th3I.1 • 14:00 Invited
Microwave Photonics for Optical Fiber Sensors, Salvador Sales[1], David Barrera[1], Javier Hervas[1], Javier Madrigal[1]; [1]*PRL ITEAM, Universitat Politecnica Valencia, Spain.* Optical fiber sensors have been extensively deployed in the last decades thanks to their intrinsic advantages. Microwave Photonics interrogation techniques provide robust schemes against environmental changes with good repeatable performance.

Room 9

14:00–15:30
Th3J • Network Resiliency
Presider: Takafumi Tanaka; NTT Network Innovation Laboratories, Japan

Th3J.1 • 14:00 Tutorial
Challenges and Solution on Supporting Sub-second Restoration in Centralized SDN Control Architectures in L1 Optical Transport Networks, Fred Gruman[1], Abinder Dhillon[1], Sanjay Gera[1]; [1]*Fujitsu Network Communications Inc, USA.* An SDN architecture is presented that centralizes control functions for L1 optical networks while also supporting sub-second restoration. An extension to this architecture for L0 optical networks is also discussed.

Fred Gruman is a product planner at Fujitsu Network Communications (FNC) responsible for operational requirements for Fujitsu's disaggregated optical transport system product line including control plane, management interfaces, open data models and data communication protocols. He is an active contributor to the Open ROADM MSA forum.

Prior to this position, Fred was responsible for the GMPLS control plane solutions on embedded products. At Xtera Communications, he was responsible for the software system engineering of long haul DWDM solutions.

Fred has a B.S. in electrical engineering from Texas A&M University and a M.S. in electrical engineering from MIT.

Show Floor Programming

How Centralized Should Centralized SDN Control and Orchestration Be?
12:45–14:15, *Theater II*

Line Side 100Gb/s DWDM Network Solutions – Debating the Options
13:15–14:15, *Theater III*

High-volume Applications of 3-D Sensing in Consumer and Automotive Markets
14:30–16:00, *Theater II*

The New Transport Network
14:30–16:00, *Theater III*

Room 1

Th3A • Evolution of Optical Interconnects—Continued

Th3A.2 • 14:30 Invited

Evolution of Pluggable Optics and What Is Beyond, Jeffery J. Maki[1]; *[1]Juniper Networks Inc., USA.* Need to support higher speeds of Ethernet at high radix on datacenter switches is prompting new pluggable optic form factors, on-board optics and co-packaging of optics with switch ASICs to fulfill the evolutionary need.

Room 2

Th3B • Detectors—Continued

Th3B.3 • 14:30

Novel CMOS-compatible Ultralow Capacitance Hybrid III-V/Si Photodetectors Tested up to 32 Gbps NRZ, Yannick Baumgartner[1,2], Marc Seifried[1], Charles Caer[1], Pascal Stark[1], Daniele Caimi[1], Jerome Faist[2], Bert J. Offrein[1], Lukas Czornomaz[1]; *[1]IBM Research - Zurich, Switzerland; [2]ETH Zurich, Inst. of Quantum Electronics, Switzerland.* We demonstrate the monolithic integration of CMOS-compatible ultralow capacitance hybrid III-V/Si photodetectors and test these devices up to 32Gbps NRZ. The lateral photodiodes are suitable for ultrafast optical communication without using a transimpedance amplifier.

Th3B.4 • 14:45

Photodetector with Monolithically Integrated SOA for Pre-amplification of High-speed Signals with 56GBd and Above, Patrick Runge[1], Shahram Keyvaninia[1], Marko Gruner[1], Alexander Schindler[1], Frederik Schröder[1], Ronald Kaiser[1], Felix Ganzer[1], Sven Mutschall[1], Angela Seeger[1], Jens Stephan[2], Günter Unterbörsch[2]; *[1]Fraunhofer Institut, Germany; [2]Finisar Germany GmbH, Germany.* We demonstrate an InP-based photodetector with a monolithically integrated SOA. The device allows the detection of signals with 14dB less optical input power, without using electrical amplification. Due to the short carrier lifetime in the SOA, amplification without pattern effects for signals with a symbol rate of 56GBd is achieved.

Room 3

Th3C • Microwave Photonic Sub-Systems—Continued

Th3C.2 • 14:30 Top Scored

Microcomb-based Photonic Local Oscillator for Broadband Microwave Frequency Conversion, Xingyuan Xu[1], Mengxi Tan[1], Jiayang Wu[1], Thach G. Nguyen[2], Sai T. Chu[3], Brent E. Little[4], Morandotti Roberto[5], Arnan Mitchell[2], David J. Moss[1]; *[1]Swinburne Univ. of Technology, Australia; [2]RMIT Univ., Australia; [3]City Univ. of Hong Kong, China; [4]Chinese Academy of Science, China; [5]INRS, Canada.* We report a broadband microwave mixer based on an integrated micro-comb source, with a photonic local oscillator at 48.9 GHz, a conversion efficiency of −6.8 dB and a spurious suppression ratio of over 43.5 dB.

Th3C.3 • 14:45

All-optical Microwave I/Q Mixer Based on Cascaded Phase Modulator and Dual-drive Mach–Zehnder Modulator, Mingzheng Lei[2,1], Zhennan Zheng[2,1], Jinwang Qian[2,1], Xinlu Gao[2], Shanguo Huang[1]; *[1]Lab Info Photonics & Optical Comm, China; [2]Beijing Univ. Posts Telecommun., China.* We propose and experimentally demonstrate an all-optical microwave I/Q mixer based on cascaded electro-optic modulators. Proposed mixer suppresses the image signal by 49.84 dB and is suitable for antenna remoting applications.

Room 6C

Th3D • SDM Devices—Continued

Th3D.2 • 14:30

Low-loss 19 Core Fan-in/Fan-out Device Using Reduced-cladding Graded Index Fibers, Juan Carlos Alvarado Zacarias[1], Jose Enrique Antonio-Lopez[1], Md Selim Habib[1], Stefan Gausmann[1], Ning Wang[1], Daniel Cruz-Delgado[1], Guifang Li[1], Axel Schulzgen[1], Adrian Amezcua-Correa[2], Louis-Anne Demontmorillon[2], Pierre Sillard[2], Rodrigo Amezcua Correa[1]; *[1]CREOL, The College of Optics & Photonics, USA; [2]Prysmian Group, France.* We demonstrate a 19-core fan-in/fan-out device with low insertion loss using reduced-cladding graded index fibers and micro-structured preform. The average insertion loss for a pair of devices spliced to 3m of 19 core trench-assisted multicore fiber is 1.27 dB.

Th3D.3 • 14:45

Ultra-low Crosstalk Fused Taper Type Fan-in/Fan-out Devices for Multicore Fibers, Lin Gan[1], Jiajun Zhou[1], Li Shen[1], Xiancong Guo[1], Yanlin Wang[1], Chen Yang[2], Weijun Tong[2], Li Xia[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1]; *[1]Next Generation Internet Access National, China; [2]Yangtze Optical Fiber and Cable Joint Stock Limited Company, China.* We achieved fan-in/fan-out devices for 7-core multicore fibers with ultra-low crosstalk under -62 dB. The maximum insertion loss and Fresnel reflection are less than 1.2 dB and -58 dB, respectively.

Room 6D

Th3E • Hollow Core Fibers—Continued

Room 6E

Th3F • Coherent PON—Continued

Th3F.3 • 14:30

Real-time Demonstration of an Integrated Metro-access Network Carrying Live VR Traffic Based on Multi-carrier Modulation and Simplified Sub-band Coherent Detection, Yansi Le[1], Huaiyu Zeng[2], Ning Deng[1], Sharief Megeed[2], Andy Shen[2], Zhenhua Dong[1], Zhiyong Feng[1], Tianhai Chang[1], Xiang Liu[2]; *[1]Huawei Technologies Co., Ltd., China; [2]Futurewei Technologies, USA.* We present an integrated metro-access networking scheme based on Alamouti-coded multi-carrier modulation and simplified sub-band coherent detection, and experimentally demonstrated it with real-time DSP in a 300-km communication link carrying live VR traffic, showing error-free performance with a low end-to-end latency of 1.5 ms.

Th3F.4 • 14:45

Colorless Coherent Passive Optical Network Using a Frequency Comb Local Oscillator, Md Mosaddek Hossain Adib[1], Juned N. Kemal[1], Christoph Füllner[1], MD Salek Mahmud[1], Abderrahim Ramdane[3], Christian Koos[1,2], Wolfgang Freude[1], Sebastian Randel[1]; *[1]Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology, Germany; [2]Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany; [3]Center for Nanosciences and Nanotechnologies (CNRS), Paris-Sud Univ., France.* We propose a colorless coherent PON architecture alleviating the need for wavelength locking of the ONU lasers. Using two different types of comb sources, we demonstrate error-free reception at -25 dBm received power over bandwidths of 600 GHz and 1 THz, respectively.

Room 6F

Th3G • Advanced Modulation Formats—Continued

Th3G.2 • 14:30 Tutorial

Transmission of Flexible High Spectral Efficiency and Noise Tolerant Modulation Formats, Sethumadhavan Chandrasekhar[1]; [1]*Nokia Bell Labs, USA*. This tutorial will cover methods for flexible high spectral efficiency and rate adaptive transmission, such as probabilistic constellation shaping and hybrid modulation. It will also examine formats that are resilient to fiber non-linearities but trading spectral efficiency.

Sethumadhavan Chandrasekhar joined Nokia Bell Labs, Holmdel, NJ, in 1986. His current interests include coherent optical transmission systems for high spectral efficiency transport and networking beyond 100Gb/s, multi-carrier superchannels, and software-defined transponders for efficient end-to-end optical networking. He is a Fellow of the IEEE, a Fellow of the Optical Society of America, and Fellow, Nokia Bell Labs.

Room 7

Th3H • Panel: Network Infrastructure Virtualization and Network Slicing—Continued

Gagan Choudhury, *AT&T Labs, USA*
SDN Controller to Enable Network Slicing and Efficient Sharing of Resources

Lydon Ong, *Ciena Corp., USA*
Likely Talk on ONF or OIF Activities

Jonathan Sadler, *Coriant, USA*
Virtual Topologies and APIs: Overcoming Information Loss

Ricard Vilalta, *CTTC, Spain*
Optical Network Virtualization and Slicing in Open Source MANO

Room 8

Th3I • Visible Light Communication and Positioning—Continued

Th3I.2 • 14:30 Top Scored

Demonstration of High Precision 3D Indoor Positioning System Based on Two-layer ANN Machine Learning Technique, Jiale He[1,3], Chin-Wei Hsu[2], Qi Zhou[3], Ming Tang[1], Songnian Fu[1], Deming Liu[1], Lei Deng[1], Gee-Kung Chang[3]; [1]*Huazhong Univ. of Sci&Tech (HUST), China;* [2]*National Chiao Tung Univ., Taiwan;* [3]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA*. We experimentally demonstrate a high precision 3D indoor visible light positioning system utilizing two-layer machine learning technique. The measured average positioning resolution of <1cm in an unit volume of 0.9 × 1 × 0.4 m^3.

Th3I.3 • 14:45

Accuracy Enhancement of Indoor Visible Light Positioning Using Point-wise Reinforcement Learning, Zhuo Zhang[1], Huayang Chen[1], Xuezhi Hong[1], Jiajia Chen[1,2]; [1]*South China Normal Univ., China;* [2]*Royal Inst. of Technology, Sweden*. A point-wise reinforcement learning (PWRL) algorithm is proposed for a multi-detector based visible light positioning system. Experimental results demonstrate that the average positioning error is reduced up to 70% by employing the proposed PWRL.

Room 9

Th3J • Network Resiliency—Continued

Show Floor Programming

How Centralized Should Centralized SDN Control and Orchestration Be?
12:45–14:15, *Theater II*

Line Side 100Gb/s DWDM Network Solutions – Debating the Options
13:15–14:15, *Theater III*

High-volume Applications of 3-D Sensing in Consumer and Automotive Markets
14:30–16:00, *Theater II*

The New Transport Network
14:30–16:00, *Theater III*

Th3A • Evolution of Optical Interconnects—Continued

Th3A.3 • 15:00
A 4-lane 400 Gb/s Silicon Photonic Transceiver for Intra-datacenter Optical Interconnects, Eslam Elfiky[1], Alireza Samani[1], Md Samiul Alam[1], Mohammed Sowailem[1], Olivier Carpentier[1], Maxime Jacques[1], Laurent Guenin[1], David Patel[1], David Plant[1]; [1]*McGill Univ., Canada*. We present a four-lane silicon photonic transceiver for intra-datacenter optical interconnects. A net rate of 400 Gb/s is achieved at a bit error rate below the KP-4 forward error correction threshold of $2.4x10^{-4}$.

Th3A.4 • 15:15
Fabric-wide, Penalty-optimized Path Routing Algorithms for Optical Integrated Switches, Qixiang Cheng[1], Yishen Huang[1], Meisam Bahadori[1], Ji Zhou[1], Madeleine Glick[1], Keren Bergman[1]; [1]*Columbia Univ., USA*. We propose a generic path routing algorithm that opts for the most favorable switch configuration set by an algorithmically-defined weighting-factor, which optimizes fabric-wide penalties and corrects for fabrication variations. Results demonstrate significant power penalty improvements.

Th3B • Detectors—Continued

Th3B.5 • 15:00
UTC-PD-integrated HEMT for Optical-to-millimeter-wave Carrier Frequency Down-conversion, Yuya Omori[1,2], Tomotaka Hosotani[1,2], Taiichi Otsuji[1,2], Katsumi Iwatsuki[2], Akira Satou[1,2]; [1]*Research Inst. of Electrical Communication, Tohoku Univ., Japan;* [2]*Research Organization of Electrical Communication, Tohoku Univ., Japan*. We newly developed an InGaAs HEMT integrated with a uni-traveling-carrier photodiode (UTC-PD) structure as a carrier frequency down-converter from optical to wireless data signals. We demonstrate the performance enhancement by the UTC-PD integration and also verify its feasibility for the practical use in future full coherent networks.

Th3B.6 • 15:15
Efficiency of Waveguide Uni-traveling-carrier Photodiodes for Microwave Signal Generation, Brandon Isaac[1], Yuan Liu[1], Sergio Pinna[1], Jonathan Klamkin[1]; [1]*Univ. of California Santa Barbara, USA*. The power conversion efficiency of uni-traveling-carrier photodiodes (UTC-PDs) and their limitations for generating microwave signals are discussed. The model is validated with experimental results from a fabricated waveguide UTC-PD that demonstrates a 60-GHz bandwidth.

Th3C • Microwave Photonic Sub-Systems—Continued

Th3C.4 • 15:00
Optical Self-heterodyne Generation of Dual–band Linear Frequency Modulated Microwave Pulses, Luis Ernesto Ynoquio Herrera[1], Pedro Tovar[1], Ricardo M. Ribeiro[2], Vladimir B. Jabulka[2], Jean Pierre von der Weid[1]; [1]*Puc-Rio, Brazil;* [2]*Fluminense Federal Univ., Brazil*. Photonic generation of dual-band chirped microwave pulses by self-heterodyne beat is presented. Six combinations of S, C, X and Ku bands were synthesized with 2,000-6,000 time-bandwidth products. Linear frequency modulation was verified for all bands.

Th3C.5 • 15:15
Simultaneous Measurements of Doppler-frequency-shift and Angle-of-arrival of Microwave Signals Based on Polarization-diversified Heterodyning, Peng Li[1], Lianshan Yan[1], Jia Ye[1], Xia Feng[1], XiHua Zou[1], Wei Pan[1], ZhiYu Chen[2], Tao Zhou[2]; [1]*Southwest Jiaotong Univ., China;* [2]*Southeast China Research Inst. of Electronic Equipment, China*. Simultaneous measurements of the Doppler-frequency-shift (DFS) and angle-of-arrival (AOA) of microwave signals is proposed. DFS between ±100-KHz with <±20-Hz error and AOA from 53.13° to 90° with <±0.51°error are experimentally achieved.

Th3D • SDM Devices—Continued

Th3D.4 • 15:00
Demonstration of Distributed Stress Sensor Based on Mode Coupling in Weakly-coupled FMF, Junchi Jia[1], Juhao Li[1], Dawei Ge[1], Yuyang Gao[1], Yu Yang[1], Yichi Zhang[2], Zhengbin Li[1], Zhangyuan Chen[1], Yongqi He[1]; [1]*Peking Univ., China;* [2]*Fiberhome Fujikura, China*. We propose a distributed stress sensing mechanism based on mode coupling in weakly-coupled FMF. The scheme is experimentally demonstrated over 5.27-km FMF with a spatial resolution of 13.9-m and a stress resolution of 0.046-kg/cm.

Th3D.5 • 15:15
All-fiber Orbital Angular Momentum (OAM) Functional Devices for Mode-division (De)Multiplexing in Conventional Graded-index Multimode Fiber, Wei Zhou[1], Han Cao[1], Lulu Wang[1], Jian Wang[1]; [1]*HUST, China.* We propose and fabricate all-fiber orbital angular momentum (OAM) functional devices for mode-division (de)multiplexing in conventional graded-index multimode fiber, based on which OAM±01, OAM±11 and OAM±21 (de)multiplexing in OM3 fiber is successfully demonstrated in the experiment with favorable mode-crosstalk performance

Th3E • Hollow Core Fibers—Continued

Th3E.2 • 15:00
Novel Antiresonant Hollow Core Fiber Design with Ultralow Leakage Loss Using Transverse Power Flow Analysis, Gregory T. Jasion[1], David J. Richardson[1], Francesco Poletti[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK*. By analyzing transverse power flows in hollow core Nested Antiresonant Nodeless Fibers (NANFs), we devise a simple and realistically achievable structural improvement that promises over two orders of magnitude lower leakage loss than current state-of-the-art.

Th3E.3 • 15:15
Free Space Based Hollow Core Fiber Interconnection and Associated In-line Components, Hyuntai Kim[1], Yongmin Jung[1], Yong Chen[1], Shuichiro Rikimi[1], Francesco Poletti[1], David J. Richardson[1]; [1]*Univ. of Southampton, UK*. We present compact, low-loss optical interconnection devices based on micro-collimator technology for hollow core fibers. Exemplar functional optical components (i.e. isolator and bandpass filter) are fabricated with low backreflection (<-47dB) and high modal purity (>20dB).

Th3F • Coherent PON—Continued

Th3F.5 • 15:00 Invited
Coherent ONU Designs for 50 Gb/s/λ PON, M. Sezer Erkilinç[1], Domanic Lavery[2], Polina Bayvel[2], Robert Killey[2], Seb J. Savory[3], Colja Schubert[1]; [1]*Photonic Networks and Systems, Fraunhofer HHI, Germany;* [2]*Dept. of EE Engineering, Univ. College London, UK;* [3]*Department of Engineering, Univ. of Cambridge, UK.* The required complexity of coherent technology has always been a showstopper in optical access networks. Here, the recent compelling research activities in low-complexity coherent PON are reviewed, and their feasibility for 50 Gb/s/λ is investigated.

Room 6F

Th3G • Advanced Modulation Formats—Continued

Room 7

Th3H • Panel: Network Infrastructure Virtualization and Network Slicing—Continued

Room 8

Th3I • Visible Light Communication and Positioning—Continued

Th3I.4 • 15:00 Invited

Visible Light Communications: From Theory to Industrial Standardization, Murat Uysal[1]; [1]*Center of Excellence in Optical Wireless Communication Technologies (OKATEM), Ozyegin Univ., Turkey.* Visible light communication builds upon the ubiquitous presence of LEDs and exploits the existing illumination infrastructure for wireless access. In this paper, we first provide an overview of this promising technology, then discuss its commercialization potential and present ongoing international standardization activities.

Room 9

Th3J • Network Resiliency—Continued

Th3J.2 • 15:00

Survivable VNF Placement and Scheduling with Multipath Protection in Elastic Optical Datacenter Networks, Tao Gao[1], Xin Li[1], Weixia Zou[1], Shanguo Huang[1]; [1]*Beijing Univ. of Posts & Telecom, China.* We propose a multipath protection-based virtual network function placement and scheduling scheme in elastic optical datacenter networks. It outperforms conventional protection methods in terms of spectrum and computing resource utilization as well as blocking probability.

Th3J.3 • 15:15 Top Scored

Service Provisioning Framework with Dynamic Margin Management for Optical Transport Networks, Daniela A. Moniz[1,2], João Pedro[1,2], Joao Pires[2]; [1]*Infinera Portugal, Portugal;* [2]*Instituto de Telecomunicações, Portugal.* This paper proposes a service provisioning framework exploiting awareness of current optical performance and OTN-switching to efficiently operate transport networks with reduced margins. Simulation results highlight reductions in number of line interfaces and rerouting events.

Show Floor Programming

How Centralized Should Centralized SDN Control and Orchestration Be?
12:45–14:15, *Theater II*

Line Side 100Gb/s DWDM Network Solutions – Debating the Options
13:15–14:15, *Theater III*

High-volume Applications of 3-D Sensing in Consumer and Automotive Markets
14:30–16:00, *Theater II*

The New Transport Network
14:30–16:00, *Theater III*

Room 1

Th3A • Evolution of Optical Interconnects—Continued

Th3A.5 • 15:30 Invited

InP PIC's Scalability for Datacenter Applications, Boudewijn Docter[1], Karen Solis-Trapala[1], Aaron Albores-Mejia[1]; [1]*EFFECT Photonics B.V., Netherlands*. InP PIC fabrication platforms have seen an accelerated development over the recent years. Monolithic integration allows novel concepts in packaging and testing technology. Altogether they enable a ready to scale cost-effective InP PIC ecosystem.

Room 2

Th3B • Detectors—Continued

Th3B.7 • 15:30

1-λ, 16-parallel Lanes, 50-Gbaud on-off Keying Multi-core Fiber Communication Directly Coupled to High Speed 2D-photodetector Array, Toshimasa Umezawa[1], Atsushi Matsumoto[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[1,2]; [1]*National Inst. of Information & Comm Tech, Japan;* [2]*Waseda Univ., Japan*. We present a newly developed high-speed 16-pixel photodetector array device operated at 50-Gbuad which circumvents the need for fiber splicing, including its receiving performance when coupled to 16-multi-core fibers, assuming next-generation short-range optical fiber communications.

Th3B.8 • 15:45

Two-dimensional Van Der Waals Heterostructure Tunneling Photodiodes on Silicon Nitride Waveguides, Yun Gao[1], Guodong Zhou[1], Hon Ki Tsang[1], Chester C.T. Shu[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong*. We fabricated h-BN/MoS_2/graphene van der Waals heterostructures on silicon nitride waveguides for use as high-speed infrared tunnel photodiodes. We measured 28-GHz bandwidth, 0.24-A/W responsivity, and on/off ratio larger than 10,000.

Room 3

Th3C • Microwave Photonic Sub-Systems—Continued

Th3C.6 • 15:30

A Novel Self-interfere Cancellation Technique Based on Operating-point-optimized Optical IQ Modulator for Co-frequency Co-time Full Duplex Wireless Communication, Xiaolei Li[1], Lei Deng[1], YuCheng Zhang[1], Li Di[1], Mengfan Cheng[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1]; [1]*Huazhong Univ. of Sci.&Tech., China*. We propose a novel self-interference-cancellation technique by using an optical IQ modulator and a training-based optimization method. 35 dB cancellation ratio and 11 dB modulation gain for 100 MHz OFDM signal are achieved experimentally.

Th3C.7 • 15:45

Photonic-assisted Modulation Classification for RF Signals Using Probabilistic Neural Network, Jia Ye[1], Pei Deng[1], Peng Li[1], Lianshan Yan[1], Wei Pan[1], XiHua Zou[1], Ming Hao[1]; [1]*Southwest Jiaotong Univ., China*. A photonic-assisted modulation classification for RF signals using PNN is proposed and experimentally demonstrated. The approach achieves >97% classification accuracy at -1~15 SNR with 160 training samples for each SNR value and modulation format.

Room 6C

Th3D • SDM Devices—Continued

Th3D.6 • 15:30

Polarization Dependence of Mode-group Selective Air-clad Photonic Lantern, Neethu Mariam Mathew[1], Lars E. Grüner-Nielsen[2], Michael Galili[1], Mads Lillieholm[1], Mario A. Castaneda[1], Karsten Rottwitt[1]; [1]*DTU, Denmark;* [2]*Danish Optical Fiber Innovation, Denmark*. Polarization dependence of loss and cross talk of an air-clad photonic lantern is experimentally investigated. Polarization dependence of two SDM 10 Gbits/s channels transmitted up to 20 km without any MIMO processing is further investigated.

Th3D.7 • 15:45

Cladding Pump Recycling Device for 19-core EDFA, Shigehiro Takasaka[1], Koichi Maeda[1], Kohei Kawasaki[1], Kazuaki Yoshioka[1], Ryuichi Sugizaki[1], Masayoshi Tsukamoto[1]; [1]*Furukawa Electric, Japan*. We confirm that cladding pump collection ratios of pump recycling devices for 19-core EDFAs are almost the same with the 7-core devices. A 19-core EDFA with cladding pump recycling has increased gain and unchanged NF.

Room 6D

Th3E • Hollow Core Fibers—Continued

Th3E.4 • 15:30 Invited

Anti-resonant Hollow Core Fibers, Jonathan C. Knight[1]; [1]*Univ. of Bath, UK*. Hollow core fibers based on antiresonant confinement have demonstrated attractive properties including ultrashort pulse delivery, low attenuation at mid-infrared wavelengths, and damage-free delivery of light in the ultraviolet. Their potential for future development is discussed.

Room 6E

Th3F • Coherent PON—Continued

Th3F.6 • 15:30

80-km Reach 28-Gb/s/λ RSOA-based Coherent WDM PON Using Dither-frequency-tuning SBS Suppression Technique, Daeho Kim[1], Byung Gon Kim[1], Tianwai Bo[1], Hoon Kim[1]; [1]*Korea Advanced Inst of Science & Tech, Korea*. We experimentally demonstrate 80-km transmission of 28-Gb/s QPSK signal in loopback-configured coherent WDM-PON using RSOAs. Dither frequency is tuned to suppress the SBS and minimize the adverse effect of broadened linewidth on carrier phase estimation.

16:00–16:30 Coffee Break, *Upper Level Corridors*

16:30–18:30 Postdeadline Sessions, *Rooms 6C, 6D, 6E, 6F*

Room 6F

Th3G • Advanced Modulation Formats—Continued

Th3G.3 • 15:30
400G/channel 50-GHz WDM Coherent Transmission: PS 64QAM vs Hybrid 32/64QAM, Jianjun Yu[1], Miao Kong[2], Hungchang Chien[1], Kaihui Wang[2], Jianyang Shi[2], Xinying Li[2], Xiaolong Pan[3], Xiangjun Xin[3], Xiaoqiang Wei[4], Bing Ye[4], Yufei Chen[4], Yan Xia[4]; *[1]ZTE TX Inc, USA; [2]Fudan Univ., China; [3]Beijing Univ. of Posts and Telecommunications, China; [4]ZTE Corp, China.* We experimentally demonstrated that PS-64QAM outperformed hybrid-32/64QAM by 37.5% in a 400G per channel 50-GHz WDM system, which enabled a 990-km transmission link consisting of SSMF and EDFA-only amplification.

Room 7

Th3H • Panel: Network Infrastructure Virtualization and Network Slicing—Continued

Room 8

Th3I • Visible Light Communication and Positioning—Continued

Th3I.5 • 15:30
Real-time Demonstration of Software Reconfigurable Dynamic Power-and-subcarrier Allocation Scheme for OFDM-NOMA Based Multi-user Visible Light Communications, Jin Shi[1], Yang Hong[2,3], Rui Deng[1,4], J He[1], Lian-Kuan Chen[2], Gee-Kung Chang[4]; *[1]Hunan Univ., China; [2] The Chinese Univ. of Hong Kong, China; [3] Univ. of Southampton, UK; [4]Georgia Inst. of Technology, USA.* For the first time, we experimentally demonstrated a novel software-reconfigurable dynamic power-and-subcarrier allocation scheme for real-time multi-user OFDM-NOMA VLC. It is markedly adaptive to dynamic demand while maintaining better user fairness and system flexibility.

Room 9

Th3J • Network Resiliency—Continued

16:00–16:30 Coffee Break, *Upper Level Corridors*

16:30–18:30 Postdeadline Sessions, *Rooms 6C, 6D, 6E, 6F*

Show Floor Programming

How Centralized Should Centralized SDN Control and Orchestration Be?
12:45–14:15, *Theater II*

High-volume Applications of 3-D Sensing in Consumer and Automotive Markets
14:30–16:00, *Theater II*

The New Transport Network
14:30–16:00, *Theater III*

Key to Authors and Presiders

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