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This program contains the latest information up to 3 February 2017.
While program updates and changes until the week prior to the conference may be found on the Update Sheet, Exhibit Buyers' Guide and Addendum distributed in the registration bags, consult the Mobile App for the latest changes. Program updates and changes may be found on the Update Sheet, Exhibit Buyers' Guide, and Addendum distributed in the registration bags.
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 19 March**	**Monday 20 March**	**Tuesday 21 March**	**Wednesday 22 March**	**Thursday 23 March**
General					
Registration	08:00–19:30	07:30–18:00	07:00–19:00	07:30–17:00	07:30–17:00
OFC Career Zone Live Career Event (online kiosks open during registration hours)			10:00–17:00	10:00–17:00	10:00–16:00
Programming					
Short Courses (separate registration required)	09:00–20:00	08:30–17:30			
Workshops (Sunday and Monday morning) and Panels	15:30–18:30	09:00–16:00	14:00–18:30	13:00–17:30	
Technical Sessions		13:30–18:00	14:00–18:30	08:00–17:30	08:00–17:30
Symposium: Overcoming the Challenges in Large-scale Integrated Photonics		13:30–18:00			
Data Center Summit			12:15–18:30		
Rump Session			19:30–21:30		
Symposium: What is Driving 5G, and How Can Optics Help				13:30–18:00	
Poster Sessions				10:00–12:00	10:00–12:00
Postdeadline Papers					18:00–20:00
Exhibition and Show Floor Activities					
Exhibition and Show Floor (Unopposed Exhibit-Only Time)			10:00–17:00 (10:00–14:00)	10:00–17:00 (12:00–13:00)	10:00–16:00 (12:00–13:00)
Product Showcases - Expo Theater III			10:15–10:45	10:15–15:00	10:15–10:45
Show Floor Programming - Expo Theaters II and III			10:15–17:00	10:15–17:00	10:15–16:00
Market Watch - Expo Theater I			10:30–16:00	15:30–17:00	10:30–14:00
Network Operator Summit (formerly Service Provider Summit) - Expo Theater I			10:30–15:00		
Special Events					
OIDA Workshop on Manufacturing Trends for Integrated Photonics (separate registration required)	07:30–19:00				
Lab Automation Hackathon	20:00–22:00				
OIDA Executive Forum		07:30–19:30			
IEEE Women in Engineering “Lunch & Learn” (separate registration required)		12:00–14:00			
Plenary Session			08:00–10:00		
Exhibit Hall Training			11:00–12:00		
Awards Ceremony and Luncheon			12:00–14:00		
OIDA VIP Industry Leaders Speed Meetings Event connecting Industry Executives with Students and Early Career Professionals (separate registration required)			12:00–13:30		
Cheeky Scientist Workshops			13:00–16:00		
Exhibitor Reception			17:30–19:00		
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 2017 Optical Fiber Communication Conference and Exhibition

On behalf of the many individuals, including countless volunteers who are organizing OFC 2017, it is our sincere pleasure to welcome you to Los Angeles, 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 will address recent developments and future challenges in optical communications and networking. Urs Hölzle, Senior Vice President for Technical Infrastructure, Google, Inc., USA will speak on Google's groundbreaking cloud network in terms of reach, scale, and capability; and Meint Smit, Professor at Eindhoven University of Technology, Netherlands will speak about affordable photonic integration and the wide range of applications that the photonic foundry model is enabling; Mischa Dohler, Professor at King's College London, UK will share his joint loves of communications research and music and will look at the disruptive technology approaches combining wireless 5G and next-generation optical networks.

The 2017 conference provides an exceptionally strong technical program consisting of a portfolio of 50 short courses, 500+ contributed and 110+ invited papers, 20 tutorial presentations, 10 workshops, and 6 panels. The range of topics that will be addressed includes advances in deployable optical components, fibers and field installation equipment; passive optical devices and circuits for switching and filtering; active optical devices and photonic integrated circuits; fibers and propagation physics; fiber-optic and waveguide devices and sensors; advances in deployable subsystems and systems; optical, photonic and microwave photonic subsystems; radio-over-fiber, free-space and non-telecom fiber-optic systems; digital and electronic subsystems, digital transmission systems; advances in deployable networks and their applications; control and management of multilayer optical networks; network architectures and techno-economics; optical access networks for fixed and mobile services; and optical devices, subsystems, and networks for Datacom and Computercom.

The main emphasis of the OFC program is on research and development that addresses longer-term issues in optical communications and networking. This year, the technical program includes two symposia: *What is Driving 5G, and How Can Optics Help?* and *Overcoming the Challenges in Large-Scale Integrated Photonics*. Tuesday features a 2-part Data Center Summit on *Open Hardware and Software Platforms*; Session I: *Open Platforms for Optical Innovation* and Session II: SDN & NFV Demo Zone featuring 15 live demonstrations and prototypes of collaborative research projects, pre-commercial products and proof-of-concept implementations in the SDN and NFV space. On Tuesday evening, there is a rump session entitled *Sub \$0.25/Gbps Optics; How and When will Fiber Finally Kill Copper Cable Interconnects in the Data Center (DC)?* organized by Chris Cole, Finisar Corp. and Dan Kuchta, IBM. Poster sessions will be held on Wednesday and Thursday, providing the opportunity for in-depth discussion with presenters.

Hot topics this year include advanced devices and fibers for high-speed data center links; enabling 5G and IoT through next-generation optical access; manufacturing and packaging of photonic and electronic subsystems; multiplexing, transmission and switching techniques for Tb/s networks; new network architectures and applications enabled by SDN and NFV, open hardware and software platforms for cloud scale networks; optical wireless and visible light communications; and silicon and integrated photonics for datacom and telecom.

The OFC Exhibit hosts more than 600 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 (formerly known as Service Provider Summit) form the core of the business-related programming of the meeting. Market Watch includes six panel discussions that will address the current state of the optical industry, market outlook for high bandwidth optical technologies, subsea networking applications, pluggable optics, photonic integration and SDN and optics. The Network Operator Summit includes a keynote address by Zhang Chengliang, Vice President of China Telecom, China on China Telecom's View of the All Optical Network and two panels on next-generation access and metro and optical mobile network access. 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: COBO, Ethernet Alliance, IEEE Cloud computing, IEEE Big Data, MEF, OCP, OIF, ONF, OpenConfig and TIP.

The OFC Short Course program provides attendees with an excellent opportunity to learn about 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 at a variety of educational levels ranging from beginner to expert.

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, Gabriella Bosco, Jörg-Peter Elbers, and Laurent Schares, 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.

Andrew Lord
BT Labs, UK

Shu Namiki
AIST, Japan

Peter Winzer
Nokia Bell Labs, USA

General Information

Conference Services

ATM

There is an ATM machine conveniently located across from the Galaxy concession stand in our West Hall next to Hall A and one is also located in the Concourse walkway leading to the South Hall.

Business Service Center

Concourse Lobby

Image Quest Plus can provide events, vendors and guests at the LACC an array of rapid delivery business services including: copying, digital printing, scanning, visual graphics, communication tools, document finishing services, computer usage, fax services, inbound/outbound shipping and consulting services. For ordering & online help: +1.888.486.7350.

Customer Service Desk

Registration

The Customer Service Desk is open during registration hours and offers translation services in multiple languages.

Conference Information Desk

Registration

The Conference Information Desk services as a "One Stop Shop" for any information concerning the OFC Conference. Staff will be equipped to help you understand the program book, find room locations, and accept small Lost and Found items, and will operate during registration hours.

E-Center

South Lobby

The E-Center provides access to webmail services. Multiple stations allow attendees to check email, identify and locate exhibiting companies, and view a list of accepted postdeadline papers, presentation times and locations. The E-Center Kiosks will be open during registration hours.

Exhibition

Exhibit Halls G-K

The OFC Exhibition is open to all registered attendees. Schedule plenty of time to roam the halls, visit with the hundreds of companies represented and see the latest products and technologies. For more information about what's happening on the exhibit floor, see pages 39-48.

Exhibition Hours

Tuesday, 21 March	10:00–17:00
Wednesday, 22 March	10:00–17:00
Thursday, 23 March	10:00–16:00

Lost and Found

Information Desk

Lost and Found will operate during registration hours at the OFC Information Desk. Please check with Lost and Found if you are missing any items. For after-hours Lost and Found, please go to the OFC Security Office located in Show Office J just outside the Exhibit Hall Entrance (look for security sign).

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

OFC Career Zone Live & Online

South Lobby

The OFC Career Zone connects employers and skilled job seekers from all areas of optical communications.

Choose your method of interaction, online or in person during the conference.

Conference attendees are encouraged to visit the OFC Career Zone Live and be prepared to discuss their futures with representatives from the industry's leading companies.

Job Seekers

OFC Career Zone Live - Meet Participating Companies

Tuesday, 21 March	10:00–17:00
Wednesday, 22 March	10:00–17:00
Thursday, 23 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 Employers/Recruiters

Employers

Didn't sign up for the onsite OFC Career Zone Live? 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 e-mail careercenter@ofcconference.org.

Media Center

Rooms 308A, 308B, 309

The OFC Media Center consists of a Media Room, PR and Media Lounge and private interview space for booking. While the media room itself is restricted to registered media/analysts holding a media badge, the adjoining PR and Media Lounge will provide a place for registered public relations personnel of exhibiting companies to work during the day and interact with attending media.

Media Center Hours

Sunday, 19 March	12:00–16:00
Monday, 20 March	07:30–18:00
Tuesday, 21 March	07:30–18:00
Wednesday, 22 March	07:30–18:00
Thursday, 23 March	07:30–18:00

Advance, Exhibitor and Onsite Registration

South Lobby

Registration Hours

Sunday, 19 March	08:00–19:30
Monday, 20 March	07:30–18:00
Tuesday, 21 March	07:00–19:00
Wednesday, 22 March	07:30–17:00
Thursday, 23 March	07:30–17:00

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Speaker Presentation Room

Room 405

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

Speaker Ready Room Hours*

Sunday, 19 March	13:00–17:00
Monday, 20 March	12:30–18:00
Tuesday, 21 March	10:00–17:00
Wednesday, 22 March	07:00–16:00
Thursday, 23 March	07:00–16:00

*Market Watch and Network Operator Summit speakers should go directly to Expo Theater I in Exhibit Hall G to upload presentations.

Restaurant Reservation Desk and Concierge Kiosk

South Lobby

This kiosk is staffed by local volunteers providing reservations, information and directions.

Show Your Badge & Save

Participants have the benefit of great merchant discounts under our "Show Your Badge Program." Find more information on the OFC website.

Sponsoring Society Exhibits

South Lobby and Exhibit Floor

Catch up on the latest product and service offerings of the OFC sponsoring societies by visiting the IEEE Booths and Member Lounge located in the South Lobby and the OSA booth on the Exhibit Floor. **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 offer complimentary wireless Internet service throughout the Los Angeles Convention Center for all attendees and exhibitors. The wireless internet can be used for checking email, downloading the conference mobile app, and downloading the OFC Technical papers, etc.

SSID: OFC
Password: OFC-2017

Transportation Services

Ground Transportation

SuperShuttle is pleased to offer 10% discount off a round-trip or one way reservation to participants attending the conference. Please refer to the discount **EZGKS**. Discounted reservations must be made on the SuperShuttle website. Discount does not apply to exclusive vans (which are already discounted) or pre-existing reservations. Discounts cannot be applied retroactively. It is valid on select (Booking codes: ATF, EMG, EWC, and VAN) SuperShuttle and ExecuCar services nationwide. SuperShuttle is the nation's leading shared-ride airport shuttle, providing door-to-door ground transportation and provides service to and from 28 major airports in 23 cities.

OFC has secured a special discount with SuperShuttle. A representative from SuperShuttle will be available in South Lobby to assist attendees with their ground transportation to airports.

Hours of Operation

Wednesday, 22 March	09:30–17:00
Thursday, 23 March	09:30–17:00

Car Rentals

Avis Rent-a-Car is pleased to offer low rates with unlimited mileage to participants attending OFC. There are several ways to reserve a car. To make a reservation call Avis at +1.800.331.1600 or book online at Avis.com. On the website enter **AWD # D340737**. If calling, attendees should provide the reservations agent with the Avis Worldwide Discount **(AWD) # D340737** number to ensure you receive the best available car rental rates.

Parking Facilities

The Los Angeles Convention Center has 5,600 public parking spaces available to visitors and located in three convenient parking structures (West Hall Garage, South Hall Garage and Venice Garage). Current daily parking rates are $15.00–$20.00 USD upon entry. There are no in/out privileges. Please note that parking rates and hours of operation are subject to change based on event activity in the LA Live Entertainment District. Please call +1.213.765.4455 to confirm parking rates.

Coat and Baggage Check

South Lobby

A Coat and Baggage Check will operate during registration hours on Tuesday–Thursday of the conference.

Hours of Operation

Tuesday, 21 March	18:00–22:30 (West Lobby for Reception)
Wednesday, 22 March	07:30–17:00
Thursday, 23 March	07:30–18:30

Medical Assistance

Onsite First Aid Station

South Lobby Alcove

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, 19 March	07:00–20:00
Monday, 20 March	07:00–21:00
Tuesday, 21 March	07:00–18:30
Wednesday, 22 March	08:00–20:30
Thursday, 23 March	08:00–20:00

Los Angeles Medical Facilities

Children's Hospital, 4650 Sunset Blvd. Los Angeles +1.323.660.2450; Distance 5.1 mi.

Good Samaritan, 1225 Wilshire Blvd. Los Angeles +1.213.977.2121; Distance 1.7 mi.

California Hospital, 1401 S. Grand Ave. Los Angeles +1.213.478.2411; Distance 0.5 mi.

Emergencies - Contact Security Command Center on house phone at ext. 3000 or call +1.213.765.4605.

Conference Materials

OFC Technical Digest on a USB Slap Band

The OFC 2017 Technical Digest, composed of the 3-page summaries of invited and accepted contributed papers, as well as tutorial presentations slides 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 OFC 2017.

Online Access to Technical Digest and Postdeadline Papers

Technical attendees have EARLY (at least one week prior to the meeting) and FREE continuous online access to the OFC 2017 Technical Digest. These three-page summaries of invited and accepted contributed (regular and postdeadline) papers and tutorial presentation slides can be downloaded individually or by downloading daily .zip files. Postdeadline Papers will be available in a separate .zip file starting Tuesday, 21 March. (.zip files are available for 60 days after the conference).

1. Visit the conference website at http://www.OFCconference.org
2. Select the "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.

The available paper summaries will also be published in OSA Publishing's Digital Library and submitted to the IEEE Xplore Digital Library (www.ieeexplore.ieee.org), provided that the paper is presented by a co-author during the conference.

Short Course Notes

Short Course 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. Notes are not available for purchase separately from the course.

Buyers' Guide

The Buyers' Guide is composed of 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 40% of the sessions at this year's conference are being digitally captured for on-demand viewing and accessible with your technical registration. The pre-selected content represents the full breadth of the OFC program including symposia, oral presentations, and the postdeadline sessions. Session content will be available for on-demand viewing until 26 June 2017. 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, you will be asked to validate your credentials based on your registration record.

Join the Conversation!

Get the latest updates from OFC via Twitter at @OFCConference. Use the hashtag #OFC17 and join in the conversation today!

OFC Conference Mobile App

OFC offers more than 100 sessions featuring 110+ invited speakers and 20 tutorial presentations in the technical conference along with 600+ exhibitors. Manage your conference experience by downloading the OFC 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 mobile app. Locate the session or talk in "Event Schedule" and click on the "Download PDF" link that appears in the description.

IMPORTANT: You will need to log in with your registration email and password to access the technical papers. Access is limited to Full Conference Attendees.

Download the OFC Conference Mobile 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, and Android compatible. Download the 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 2017 Guide will be listed under the "All Events" section of the application.

Conference App Solution Desk

Need assistance? Find an App Coach at the OFC Solution Desk near registration or contact our 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.

Special Events

Workshops

Sunday, 19 March, 15:30–18:30

S1A • Will Machine Learning and Big-data Analytics Relieve Us From the Complexity of System and Network Engineering?
Room: 403A

Organizers: Sethumadhavan Chandrasekhar, *Nokia Bell Labs, USA*; Neil Guerrero Gonzalez, *Universidad Nacional de Colombia, Colombia*; Massimo Tornatore, *Politecnico di Milano, Italy*

Complexity of optical networks is growing rapidly. On a system side, coherent technologies introduced a plethora of adjustable design parameters (modulation formats, symbol rates, among others) to optimize transport systems. On a networking side, dynamic control, as in SDN, promises to enable long-awaited on-demand reconfiguration and virtualization. This variety of "degrees of freedom" does pose challenges when deciding the best system configuration. This workshop examines the application of machine learning and big-data analytics as disruptive solutions to relieve design of future networks/systems from such complexity. These techniques allow to infer, from monitored data (signal quality, traffic samples, etc.), useful characteristics that cannot be easily measured. Speakers from academia, vendors, and operators will debate how beneficial these techniques could be and which are their killer applications.

Speakers:
Satyajeet Ahuja, *Facebook, USA*
Shoukei Kobayashi, *NTT, Japan*
Maurice O'Sullivan, *Ciena, Canada*
Moises Ribeiro, *Universidade Federal do Espírito Santo, Brazil*
Vishnu Shukla, *Verizon & OIF, USA*
Luis Velasco, *UPC, Spain*
Peter Winzer, *Nokia Bell Labs, USA*
Huiying Xu, *Huawei, China*
Darko Zibar, *Technical University of Denmark, Denmark*

S1B • Making the Case for SDM in 2027
Room: 403B

Organizers: Cristian Antonelli, *Università degli Studi dell'Aquila, Italy*; Yoshinari Awaji, *National Inst of Information & Communications Technology, Japan*; Nicolas Fontaine, *Nokia Bell Labs, USA*; Sheryl Woodward, *AT&T, USA*

In the year 2027, after 10 years of exponential internet traffic growth, it will become clear that traditional DWDM transmission systems using a single fiber cannot keep up with demand. Although coherent communications may be a "cheap" commodity, the cost of constantly deploying new line systems will be untenable. Network operators will be looking for dramatic new technologies to evade Shannon's fundamental limits on capacity – space-division multiplexing (SDM) is the prime candidate. But, in what type of network will SDM be most effective (passive, data center, short reach, metro, long haul, submarine, or any unconventional communications frameworks), what level of integration will provide the biggest cost savings (transponders, amplifiers, fibers, switching), how will SDM co-exist/complement existing SMF/DWDM technologies, and is there a killer fiber structure (hollow core, coupled core, few-mode fiber) that outperforms multiple strands of single-mode fiber?

Four teams will present their solutions to a panel of experts—imagine they represent venture capitalists who are looking to capitalize on the next technology wave. Both the audience and the experts will pose questions and decide the winning solutions.

Teams:

- Koji Igarashi, *Osaka University, Japan* (Team Leader)
  Tetsuya Hayashi, *Sumitomo Electric, Japan*
  Katsunori Imamura, *Furukawa Electric, Japan*
  Takayuki Kobayashi, *NTT, Japan*
  Taiji Sakamoto, NTT, Japan
- Dan Marom, *Hebrew University, Israel* (Team Leader)
  Vinayak Dangui, *Google, USA*
  Ezra Ip, *NEC Laboratories America, USA*
  Ming-Jun Li, *Corning, USA*
  Ioannis Tomkos, *Athens Information Technology Center, Greece*
- Roland Ryf, *Nokia Bell Labs, USA* (Team Leader)
  Kazi Abedin, *OFS Labs, USA*
  David DiGiovanni, *OFS Labs, USA*
  Shifu Yuan, *Calient, USA*
  Xiang Zhou, *Google, USA*
- Jochen Schroeder, *Chalmers University of Technology, Sweden* (Team Leader)
  Sander L. Jansen, *ADVA Optical Networking, Germany*
  Peter Krummich, *Technische Universitaet Dortmund, Germany*
  Ben Puttnam, *NICT, Japan*
  Sebastian Randel, *Karlsruhe Institute of Technology, Germany*

S1C • Optical Wireless — Can it Become a Gigabit Wireless Alternative? Capabilities, Opportunities, Challenges and Threats
Room: 404AB

Organizers: Ton Koonen, *Einhoven University of Technology, The Netherlands*; Volker Jungnickel, *Fraunhofer Heinrich-Hertz Institute, Germany*; Thas Nirmalathas, *University of Melbourne, Australia*

Optical wireless communications and networking is seeking to deliver wireless connectivity over the free-space using optical wavelengths in the visible and infrared spectrum. However, optical wireless needs to complement the existing radio technologies, including the rapidly maturing mm-wave and future Terahertz communication systems being under development and research, respectively. Optical wireless can also play a complimentary role for example offloading the burden from the radio technologies in situations such as high-capacity picocells. In the future 5G and 5G-beyond networks, optical wireless may provide crucial roles in meeting the 5G grand challenges such as 1000x throughput, ms latency, 0.01x power consumption, etc. All this needs not only further technical research efforts but also the identification of practical use cases in which optical wireless has unique selling points.

While the technology-oriented research has attracted major attention within the optical communications research community, with demonstrations of multi-Gbit/s wireless transmission and major research projects getting started, it is the use case which paves the way into the market. Besides superior capabilities like bandwidth on demand, support for user mobility and low cost, optical wireless increasingly needs to offer additional features, which are tailored to the identified use cases.

This workshop is intended as a forum that brings together competing ideas and leading experts from research and industry into a collision space and to facilitate a critical debate on the fundamental capabilities of optical wireless technologies and its chance in the very competitive wireless market. This will require putting the focus onto capabilities and opportunities of optical wireless, its key challenges and ways forward towards commercializing the outcomes of the exciting developments in the optical wireless field.

Speakers:
Carsten Behrens, *Deutsche Telekom, Germany*
Harald Haas, *Li-Fi Centre, UK*
Steve Hranilovic, *McMaster University, Canada*
Jean-Paul Linnartz, *Philips Lighting, Netherlands*
Dominic O'Brien, *Oxford University, UK*
Joanne Oh, *Eindhoven, Netherlands*
Maximilian Riegel, *Nokia, Germany*
Nikola Serafimovski, *PureLiFi, UK*
Stan Skafidas, *Nitero/University of Melbourne, Australia*
Ke Wang, *University of Melbourne, Australia*

S1D • Scaling Datacenter Bandwidth: Novel Optics, Advanced Electronics or New Architectures?

Room: 408A

Organizers: Piero Gambini, *STMicroelectronics, Italy*; Ming-Jun Li, *Corning, USA*; Ilya Lyubomirsky, *Facebook, USA*

Bandwidth and power consumption are two key factors to be considered for cost-sensitive datacenter applications. As datacenter switch port bandwidths continue scaling to 400Gb/s and beyond, the datacenter network hardware power dissipation is increasing exponentially. The coming "power crunch" associated with the increased bandwidth will be a major problem for datacenter operators.

- What are the most effective solutions to mitigate the increasing power problem?
- Are there novel optics, for example novel high speed directly modulated lasers (DMLs) or Silicon Photonics technology that reduce power consumption?
- How can we leverage DSP and spectrally efficient modulation techniques, e.g. is it feasible to drive analog optics modules directly from the host ASIC, similar to the 10G SFP+ solution?
- Can novel multi-mode or multi-core fibers provide a new approach?
- What is the role of FEC?
- Is there room for optimizing the FEC triple tradeoff in gain, latency, power to achieve an overall lowest power system design?
- How can we leverage the mature DWDM technology for datacenter applications?
- Are there novel topologies or network architectures that can radically reduce power consumption?
- Is there a role for ROADMs, optical switches, or coherent technology inside the datacenter? Clearly a holistic system view is necessary for finding the optimal solution.

This workshop will bring together experts from optics, fiber, SerDes design, DSP/FEC, and network architecture for an interdisciplinary discussion.

Speakers:
Andy Bechtolsheim, *Arista, USA*
Sudeep Bhoja, *InPhi, USA*
Brad Booth, *Microsoft, USA*
Bruce Chow, *Corning, China*
Peter De Dobbelaere, *Luxtera, USA*
Laura Giovane, *Broadcom, USA*
Chris Kocot, *Finisar, USA*
Benny Mikkelsen, *Acacia, USA*
Brian Taylor, *Facebook, USA*

S1E • III-V + Silicon: To Integrate or to Co-package?

Room: 408B

Organizers: Mike Larson, *Lumentum, USA*; Anders Larsson, *Chalmers University of Technology, Sweden*; Bert Offrein, *IBM, Switzerland*

Silicon photonics provides a path to the cost-effective realization of transceiver chips but lacks a straightforward solution to integrate the light source. Today, co-packaging (hybrid integration) is used commercially, while intense research is pursued on III-V to silicon bonding techniques (heterogeneous integration) and even hetero-epitaxial III-V on silicon growth (monolithic integration).

In this workshop some of the main III-V on silicon integration approaches will be reviewed by leading experts in the field and discussed among the participants. In addition to the technological characteristics, the presentations will address system-level aspects such as functionality, power efficiency, form factor and anticipated cost. What are the prospects and challenges and what is ultimately the best method to combine III-V and silicon technology for future applications?

Questions to be addressed during the workshop are:

- What is generally the best technique for bringing light to the silicon photonics PIC, from cost/size/efficiency/performance perspectives? Is it application dependent?

- For hybrid integration, is there a superior technique for coupling the laser to the silicon photonics PIC? What manufacturing capability (alignment tolerance) is required and what is the typical coupling loss?
- For what applications would an on-chip (heterogeneous or monolithic) integrated light source offer superior performance to hybrid integration, at what cost advantage and why?
- Is on-chip integration of the light source a prerequisite for higher integration density, more channels, reduced footprint, and higher energy efficiency? Is it the inevitable technology for all applications in the future?
- Will further integration of III-V modulator or amplifier material address silicon photonics shortcomings of low electro-optic efficiency and insertion loss? Will silicon ultimately be relegated to passive waveguides only?
- Can hetero-epitaxial growth of III-Vs on silicon ever achieve the material quality needed for high performance on-chip lasers and amplifiers?

Speakers:
John Bowers, *University of California Santa Barbara, USA*
Craig Ciesla, *Kaiam, USA*
Greg Fish, *Juniper, USA*
Richard Grzybowski, *Macom, USA*
Takahiro Nakamura, *PETRA, Japan*
Gunther Roelkens, *Ghent University & IMEC, Belgium*
Lars Zimmermann, *IHP Berlin, Germany*

Monday, 20 March, 09:00–12:00

M1A • Processors and Switches with Integrated Optical Engines — Researchers' Dream or a Commercial Reality Soon?
Room: 403A

Organizers: Dominic Goodwill, *Huawei Technologies Canada Co Ltd, Canada*; Ken Morito, *Fujitsu Laboratories Ltd., Japan*; Sam Palermo, *Texas A&M University, USA*; Thomas Schrans, *Rockley Photonics, USA*

On-board optics or optics-in-packaging - which integration strategy will happen on a large scale in data center and HPC systems? Or indeed will both types of integration co-exist? On-board optics is currently fashionable, but many researchers propose including photonics inside the chip package to increase data rates and decrease energy per bit. Large scale integration reduces cost for many technologies, but yield and other constraints may set practical limits. What are the challenges and benefits of these two approaches? Will cost-driven data center systems and performance-driven engineered systems have radically different solutions? This workshop covers views and expectations from systems builders, perspectives from photonic module suppliers, and assessments from technologists in packaging, high speed circuits and signal integrity, to explore the true benefits and costs.

Speakers:
Frank Flens, *Finisar, USA*
Ali Ghiasi, *Ghiasi Quantum, USA*
Ichiro Ogura, *Photonics Electronics Technology Research Association, Japan*
Marco Romagnoli, *CNIT, Italy*
Katharine Schmidtke, *Facebook, USA*
Marc Taubenblatt, *IBM, USA*

M1B • Connected OFCity Challenge: Optical Innovations for Future Services in a Smart City
Room: 403B

Organizers: Jun Shan Wey, *ZTE, USA*; Denis Khotimsky, *Verizon, USA*; Domaniç Lavery, *University College London, UK*

The *Connected OFCity Challenge* team competition was first held at the OFC 2016 as a representative platform to discuss technological innovations of a smart city project. The OFCity Challenge returns this year to debate technologies concerning future services in a smart city, building upon the results of last year's competition.

This time, the OFCity Council is planning the Septicentennial (700-year anniversary!) celebration in 2023 and once again organizes an open competition to select the best proposal for the preparation and broadcasting of the Septicentennial Concert and three major sports events.

Four multidisciplinary teams consisting of experts from a cross-section of the industry will compete to recommend innovative optical solutions and complementary technologies to realize the required services. Two distinctions, Judges Award and Audience Award, will be handed out at the conclusion of the competition.

Teams:

- Naoto Yoshimoto, *Chitose Institute of Science and Technology, Japan* (Team Leader)
  Ning Chang, *Huawei, China*
  Elaine Wong, *University of Melbourne, Australia*
  Yuki Yoshida, *NICT, Japan*
- Marco Ruffini, *Trinity College Dublin, Ireland* (Team Leader)
  Dave Hood, *Huawei, USA*
  Thomas Pfeiffer, *Nokia Bell Labs, Germany*
- Luca Valcarenghi, *Scuola Superiore Sant'Anna, Italy* (Team Leader)
  Hal Roberts, *Calix, USA*
  Rajesh Yadav, *Verizon, USA*
- Dimitra Simeonidou, *University of Bristol, UK* (Team Leader)
  Harald Haas, *University of Edinburgh, UK*
  Stephen Hilton, *Bristol Futures, UK*
  Sergi Figuerola, *i2CAT in Barcelona, Spain*

Judges Panel:
Rod Tucker (Team Leader, Winner of OFCity 2016 Judges' Award)
Julie Kunstler (OVUM)
Kazuhide Nakajima (Rapporteur, ITU-T Q5/SG15)
Inder Monga (Energy Sciences Network, OFC N2 Subcommittee Chair)
Peter Vetter (Mayor of OFCity 2016)

M1C • Frequency Combs for Communications — Real Potential or Hype?

Room: 404AB

Organizers: Toshihiko Hirooka, *Tohoku University, Sendai, Japan;* Christian Koos, *Karlsruhe Institute of Technology, Germany;* Michael Vasilyev, *University of Texas at Arlington, USA*

Rapid progress in the research and development of optical frequency comb sources has opened new possibilities in communications, ranging from replacing a multitude of parallel lasers by a single multi-line source to employing wideband coherence to enhance nonlinearity mitigation. The workshop will discuss whether these advances can translate into practical systems by addressing key questions including:

- What are the benefits, drawbacks, and challenges of single-source communications?
- Do expected power/complexity reductions justify possible reliability issues (single source failure)? How to increase reliability? What are the options for ultra-narrow linewidth seed laser?
- What power or OSNR per comb line is acceptable? What linewidths are required?
- What are the tradeoffs in comb source choices: fiber versus integrated, mode-locked versus parametric, travelling-wave versus oscillator?
- What are the options for monolithic or hybrid integration with other components, e.g., (de) multiplexers and modulators?
- What are the prospects of using optical frequency combs in data center networks?

Speakers:

Peter Andrekson, *Chalmers University, Sweden*
Nicolas Fontaine, *Nokia, USA*
Hao Hu, *Technical University of Denmark, Denmark*
Tobias Kippenberg, *EPFL, Switzerland*
Masataka Nakazawa, *Tohoku University, Japan*
Stojan Radic, *University of California San Diego, USA*
Jeremie Renaudier, *Nokia, France*
Nicola Sambo, *Scuola Superiore Sant'Anna, Italy*

M1D • Capacity Crunch: When,Where and What Can be Done?

Room: 408A

Organizers: Dmitri Foursa, *TE Subcom, USA*; Qunbi Zhuge, *Ciena Corporation, Canada*; David Millar, *Mitsubishi Electric Research Labs, USA*

Recent theoretical research has indicated that we might soon reach a "capacity crunch," as the limits of conventional single mode fiber transmission systems are approached. While technologies such as spatial diversity, ultra-broadband Raman amplification, optical and digital nonlinearity compensation have been proposed, none has yet demonstrated an ability to overcome these limitations in practical systems. This workshop will examine the conflicts and opportunities that are emerging in optical transmission systems in this context. Key questions will include:

- What are the causes of the theoretical and practical capacity limits?
- How and when will the coming capacity limitations arrive considering the various applications from submarine to metro networks?
- What solutions have been proposed, and how will they address the problems?
- Will the reduction of cost per bit continue by economic solutions such as photonic integration after we reach the "capacity crunch"?

Speakers:

Erik Agrell, *Chalmers University of Technology, Sweden*
Chris Doerr, *Acacia Communications, USA*
Domanic Lavery, *University College London, UK*
Alexei Pilipetskii, *TE SubCom, USA*
Kim Roberts, *Ciena Corporation, Canada*
Peter Winzer, *Nokia Bell Labs, USA*

M1E • White Box Optics: Will it Kill or Encourage Innovations?

Room: 408B

Organizers: Chongjin Xie, *Alibaba Group, USA*; Filippo Cugini, *CNIT, Italy*; David Boertjes, *Ciena, Canada*

Disaggregated networks can bring many benefits to networks operators, including better control of networks, no vendor lock in, and reduced cost. Recently the concept of white box optics is rapidly emerging as can be seen in initiatives such as Open ROADM and Open Line System. However, there is a fear that white box optics may commoditize the industry and squeeze the profit margins for equipment vendors, which will eventually stop the industry from investing on innovations. On the other hand, there is an argue that white box optics may open up closed and proprietary optical networks and give small business and new comers more chances, which will encourage more innovations. This workshop is to bring together experts from equipment vendors and network operators to express their opinions on white box optics and discuss where it will head to.

Speakers:

Martin Birk, *AT&T, USA*
Rick Dodd, *Ciena, Canada*
Niall Robinson, *ADVA, USA*
Peter Roorda, *Lumentum, USA*
Brian Taylor, *Facebook, USA*
Vijay Vusirikala, *Google, USA*
Glenn Wellbrock, *Verizon, USA*
Szilard Zsigmond, *Nokia Corporation, USA*

Symposia

Overcoming the Challenges in Large-Scale Integrated Photonics

Monday, 20 March
Part I 13:30–15:30; Part II 16:00–18:00
Room 403A

Organizers: Po Dong, *Nokia, USA;* Benjamin Lee, *IBM, USA;* Erik Pennings, *7 Pennies, USA*; Takuo Tanemura, *University of Tokyo, Japan*

Integrated photonics provides significant opportunities to develop highly compact and extremely functional components and subsystems for a wide range of communication and sensor applications. However, photonic integration brings with it unique manufacturing and packaging challenges, which can limit the commercial exploitation of novel integration concepts and slow the time-to-market. These challenges can be economic or technical in nature, and are often most apparent during the transition from prototype development to manufacturing. This symposium will provide a balanced view of the promises and challenges of integrated photonics, and it will focus on what is being done to get beyond the many roadblocks in order to enable a much larger market adoption. During the symposium, leaders in the field will address applications in traditional and non-traditional markets for integrated photonics, finding the right fabrication model using MPW or custom processing services, choosing Si versus InP platforms, optical and electrical packaging approaches, and other fundamental component challenges.

Speakers:
John Bowers, *Univ. of California Santa Barbara, USA*
Greg Fish, *Juniper, USA*
Dominic Goodwill, *Huawei, Canada*
Roe Hemenway, *Macom, USA*
Ashok Krishnamoorthy, *Oracle, USA*
Shinji Matsuo, *NTT, Japan*
Pascual Munoz, *VLC, Spain*
Bardia Pezeshki, *Kaiam, USA*
Kevin Williams, *TU Eindhoven, Netherlands*

What is Driving 5G, and How Can Optics Help?

Wednesday, 22 March
Part I 13:30–15:30; Part II 16:00–18:00
Room 403B

Organizers: Björn Skubic, *Ericsson Research, Broadband Technol., Sweden*; Gee-Kung Chang, *Georgia Institute of Technology, USA*; Anna Tzanakaki, *University of Athens, Greece*; Jun Terada, *NTT, Japan*

The vision of 5G is commonly presented as part of the network vision for 2020 and beyond, which in turn embodies a number of services for the future information society in which everything that can connect to this society will do so. The typical services identified span across areas such as enhanced mobile broadband services, media distribution, Smart Cities, and the internet of things (IoT), with massive as well as ultra-reliable and low latency (critical) machine-type communications to support both end-user and operational purposes. Besides new services and applications, 5G will also need to support a wide range of business ecosystems and cooperation models supporting digitalization of industry and trends of business horizontalization. 5G goes far beyond the definition of new radio interfaces. 5G is about a new end-to-end network vision, in which softwarization and virtualization allow a common network infrastructure to be flexibly used for a variety of diverse applications.

The symposium will consist of two sessions. The first session will focus on "What is driving 5G?" with speakers from the 5G community as well as vertical industries that can be benefited adopting the 5G vision. This session will give an overview of the services, applications and ecosystems that are driving 5G and provide some insight on how these can create a new and substantial business opportunity for optical networking and its most advanced technologies. The second session will focus on the role of optics and will include speakers from the optical networking/communications community. This session will give an overview of how optics can play a key role for realizing 5G networks and will cover topics such as evolved x-haul, radio over fiber, distributed cloud connect (including edge/fog computing) and support for tactile (low latency) Internet applications.

Speakers:
Chih-Lin I, *China Mobile Research Inst., China*
Xiang Liu, *Huawei, USA*
Takehiro Nakamura, *NTT Docomo, Inc., Japan*
Anthony Ng'Oma, *Corning, Inc., USA*
Dimitra Simeonidou, *University of Bristol, UK*
Theodore Sizer, *Nokia Bell Labs, USA*
Tao Zhang, *Cisco Systems, Inc., USA*
Jim Zou, *ADVA Optical, Germany*

Panels

Monday, 20 March

Lessons Learned From Global PON Deployment

13:30–15:30
Room: 402AB

Organizers: Frank Effenberger, *FutureWei Technologies, Inc. USA*; Thomas Pfeiffer, *Nokia Bell Labs, Germany*

Passive Optical Networks have seen a dramatic growth over the past decade. There are now many large deployments, such as those in the US, Japan, and China, and the total number of homes passed with PON technology is approaching 200 million. We have also seen an alphabet soup of PON technologies, including B, E, G, 10GE, XG, and TWDM. But the one constant in all of this is that PON development and deployment is as difficult as it is rewarding. This panel brings together representatives of operator and vendor companies that are the driving force behind this wave of ultra-broadband deployment. This will be a great forum to hear of their experiences, discoveries, happy accidents, and expensive lessons.

Panelists:
John Kirby, *AT&T, USA*
Vincent O'Byrne, *Verizon, USA*
Kenichi Suzuki, *NTT, Japan*
Dezhi Zhang, *China Telecom, China*

Transport SDN — What is Ready, What is Missing?

16:00–18:00
Room: 402AB

Organizers: Doug Freimuth, *IBM, USA*; Karthik Sethuraman, *NEC, USA*

The dynamic compute model provided by the cloud has gained acceptance by business and consumer markets. A new network is required to match the resource scalability, faster automated service deployment model and high resource utilization of the cloud. The promise of Transport SDN to fulfill these requirements has been shown in various demonstrations, proof of concepts and by early adopters. The industry is working to define it in standards bodies for production use in NFV, cloud and IoT.

This panel will discuss what it takes to operationalize Transport SDN. We will discuss business drivers, use cases, progress in standards and prototypes shown to date. We will further discuss what can be put into production now, related technologies such as SD-WAN and what the future holds for new Transport SDN capabilities.

Panelists:
Hwa Jung, *Verizon, USA*
Victor Lopez, *Telefonica, Spain*
Naoki Miyata, *NTT Communications, Japan*
Kathy Tse, *AT&T, USA*

Tuesday, 21 March

Coherent Interoperability Beyond QPSK — Is it Needed and What Will it Take?

14:00–16:00
Room: 402AB

Organizers: Marc Bohn, *Coriant GmbH & Co. KG, Germany*; Sebastian Randel, *Nokia Bell Labs, USA*

Within the last decade, coherent DSP technology has emerged as the key enabler for optical transmission at rates from 100 Gbps up to 400 Gbps per wavelength. Today, around seven DSP solutions from different companies are offered, all competing to best answer to the operators needs such as performance, cost, and power. Up to now, this competition seems to drive innovation in the direction of increased speed and capacity as vendors introduce high-performance soft-decision FEC codes, fiber nonlinearity compensation, and probabilistic constellation shaping. With all these advanced features, performance is getting closer and closer to the Shannon limit, making significant performance improvements in the range of >1dB unlikely to occur. At the same time, power consumption is getting more and more important and the timeline of new ASIC generations is following closer and closer the availability of new lower power CMOS process nodes, for which the end of Moore's law has been predicted.

This brings up the question whether the industry as a whole would benefit from a successive standardization of coherent DSPs. Today, pretty much all coherent DSPs include a 100G DP-QPSK mode which is interoperable. However, it uses a hard-decision FEC which cannot compete with more advanced soft-decision FECs. Looking forward, the following questions arise:

- What would it take to standardize higher-order modulation schemes e.g. 16QAM and 64-QAM as well as high-performance FECs?
- Do operators see potential benefits in this?
- Will standardization of coherent DSPs finally be driven by the need for high-capacity short-reach?
- Is the optics market truly unique or will it ultimately be shared among 2-3 players (compare markets like CPU, GPU, LTE, PON, DSL, …)?

On this panel, we want to elude answers to these questions by bringing together speakers from key operators and system vendors.

Panelists:
Marco Bertolini, *Nokia Corporation, Italy*
Dirk van den Borne, *Juniper Networks, Inc., Germany*
Markus Weber, *Acacia Communications Inc., Germany*
Werner Weiershausen, *Deutsche Telekom, Germany*

Direct vs. Coherent Detection for Metro-DCI

16:30–18:30
Room: 402AB

Organizers: Robert Griffin, *Oclaro, UK*; Tom Issenhuth, *Microsoft, USA*

Coherent systems are widely deployed for high capacity long-haul networks, whereas direct detection (DD) implementations with low cost and low power consumption dominate short reach. Both approaches overlap in new fast-growing applications of short reach Metro and data center interconnects (DCI), requiring DWDM transport over distances around 100 km. In 2016 a commercial 100G PAM4 DD solution for 80km DWDM DCI was announced, and single-carrier 400G coherent solutions targeting similar applications have been demonstrated by multiple vendors. Will these solutions happily coexist, will one become the dominant solution over time, or will new alternatives become available? The panel will discuss the merits of different approaches and what progress we can expect as the technologies develop.

Panelists:
Brandon Collings, *Lumentum, USA*
Mark Filer, *Microsoft Corporation, USA*
Radha Nagarajan, *Inphi Corporation, USA*
Atul Srivastava, *NEL-America, USA*

Wednesday, 22 March

Are Electronic & Optical Components Ready to Support Higher Symbol Rates & Denser Constellations?

13:00–15:00
Room: 402AB

Organizers: Rich Baca, *Microsoft, USA*; Gary Nicholl, *Cisco, Canada*

The optical interconnect industry is embracing higher speeds and higher order modulation formats to meet the continuing growth in bandwidth demand. Does the industry have a technology roadmap consistent with these market needs? Are there bottlenecks in the electronics: drivers, TIAs, ADCs, DSPs or the optics: lasers, modulators, detectors? This panel discussion will address these questions with industry experts sharing their view of optimal solutions with constraints such as cost and power consumption, and insight into future innovations that may be needed. Come be a part of the discussion and gain an understanding of what the industry is doing and where it is headed.

Panelists:
Beck Mason, *Oclaro, USA*
Torben Nielsen, *Acadia, USA*
Vasudevan Parthasarathy, *Broadcom, USA*
Kim Roberts, *Ciena, Canada*

Quantum Communication Programs Around the World

15:30–17:30
Room: 411

Organizers: Andrew Lord, *BT Labs, UK*; Masahide Sasaki, *National Inst of Information & Comm Tech, Japan*

In a future where quantum computers will break much current cryptography, quantum communications offers the potential for unbreakable security, through untappable distribution of secret keys over optical fibres and free space, including satellite communications. This panel will take stock of the huge, current worldwide interest in and funding of quantum communications programs including developments in the US, China, Japan and Europe.

What will be the killer applications of quantum communications –will it be for bespoke point to point short-haul secure systems or can it form the basis of unprecedented long-lived security solutions even enabling data storage? Will it extend to core and access networks? Will quantum satellites create secure international communications or will classical, quantum-safe cryptography render quantum communications obsolete before it even starts?

Panelists:
Johannes Buchmann, *Technische Universitat Darmstadt, Germany*
Lijun Ma, *NIST, USA*
Gregoire Ribordy, *ID Quantique, Switzerland*
Qiang Zhang, *University Science and Technology, China*

OIDA Workshop on Manufacturing Trends for Integrated Photonics

Sunday, 19 March, 07:30–19:00
Petree Hall D

Integrated photonics presents significant opportunities to develop compact and highly functional systems for a range of communication and sensor applications. However, it has unique manufacturing challenges which can limit its commercial exploitation. These challenges are most apparent during the transition from research prototyping to product development and volume manufacture.

This workshop will focus on applications for integrated photonics and the manufacturing challenges related to these applications; from product design, device fabrication, integration and packaging, through to test and reliability. Although most applications present their own unique design and manufacturing challenges, this workshop will identify common themes where users can meet their unique set of requirements within a standardized design and manufacturing framework.

Separate registration fees apply.

Sponsored by: IPIC GoFoton

Presented by: OSA Industry Development Associates CIAN

Lab Automation Hackathon

Sunday, 19 March, 20:00–22:00
Location: 503

Organizers: Nicolas Fontaine, *Nokia Bell Labs, USA;* Jochen Schroeder; *Chalmers University of Technology, Sweden*

Lab work is most efficient when data can be acquired in an automated way, sometimes over long durations, without introducing human error, which 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. Several professionals with 10+ years 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. Bring a laptop to participate in the exercise. There will also be plenty of time for mingling and discussion.

OIDA Executive Forum

Monday, 20 March, 07:30–19:30
Petree Hall D

Held every year in conjunction with OFC, the OIDA Executive Forum features C-level panelists in an informal, uncensored setting discussing the latest issues facing companies in the business. Join more than 150 senior-level executives as they convene to discuss key themes, opportunities, and challenges facing the next generation in optical networking and communications. Highly valued by participants for the frank and open discussions, OIDA Executive Forum sessions explore emerging trends and action plans for tackling today's toughest business challenges.

Separate registration fees apply.

Sponsored by: PICOMETRIX a LUNA company; OSA Industry Development Associates

Media Sponsor: LIGHTWAVE

IEEE Women in Engineering "Lunch & Learn"

Monday, 20 March, 12:00–14:00
Room: 515A

The IEEE Photonics Society and IEEE Communications Society are hosting an inclusive Women in Photonics and Women in Communications Engineering (WICE) "Lunch & Learn", sponsored by IEEE Women in Engineering. This event will provide conference attendees with an opportunity to better hone their interpersonal skills and receive professional advice beyond the classroom or lab, as well as learn from successful women in photonics and optical communications.

The event includes a complementary lunch. All attendees must formally register prior to event.

Visit the IEEE Photonics Society or IEEE Communications Society booths for more details.

Exhibit Hall Training

How to Leverage the Exhibit as a Student or Early Career Professional
Tuesday, 21 March, 11:00-12:00
Room: 402AB

Join professionals in the industry to learn how to leverage the Exhibit Hall throughout the meeting for networking and professional development. This workshop will give you the confidence to walk the floor and engage with exhibitors to enhance your experience.

Hosted by: OSA Foundation

OIDA VIP Industry Leaders Speed Meetings Event

Tuesday, 21 March, 12:00–13:30
Room: 515B
Pre-registration required

This session brings together Industry Executives to share their business experience with Early Career Professionals, Recent Graduates and Students – how they started their careers, lessons learned and using their degree in an executive position. Informal networking during lunch is followed by a transition to "speed meetings" – brief, small-group visits with each executive to discuss industry trends or career topics.

Sponsored by: GoFoton, OSA Industry Development Associates

Data Center Summit: Next Generation Optical Technologies Inside the Data Center

Tuesday, 21 March, 12:15–13:45
Expo Theater II

Moderator: Lisa Huff; *Principal Analyst, Discerning Analytics, USA*

The data center summit panel will focus on next generation optical technologies likely to be used inside the data center. It will include both standard solutions as well as custom ones. Panelists will discuss the following:

- What are the evolving data center requirements?
  - Hyperscale perspective
  - Non-hyperscale perspective
- What will be needed as data centers evolve and grow?
- How are data centers working with optical components suppliers and equipment vendors to achieve their goals?
- What is missing in the ecosystem?

This panel will have members from a cross-section of the value chain – data center operators, equipment suppliers and component suppliers.

Presenters:
Robert Blum, *Director of Strategic Marketing and Business Development, Intel, USA*
Mike Connaughton, *Market Segment Manager, Nexans, USA*
Raju Kankipati, *Product Manager, Arista Networks, USA*
Chongjin Xie, *Senior Director & Chief Optical Network Architect, Alibaba, USA*

Cheeky Scientist Workshops

Tuesday, 21 March, 13:00–16:00
Room: 501B

Cheeky Scientist Isaiah Hankel works with hundreds of graduate students and postdocs daily assisting them to transition to industry by first showing them how to present themselves as business professionals. These programs will provide you with a strong understanding of what it takes to have a tailored industry resume and how to showcase your transferrable skills.

Session I: Industry Resumes: How to Ensure Your Resume Gets to the Top of the Pile
13:00–14:30

Would you like learn how to get your resume seen by hiring managers to get an interview? Come learn the tips and tricks to ensure you don't make the common mistakes. Learn how to layout your resume so the reader can understand what you offer within 7 seconds.

Session II: What are My Transferable Skills? A Common Question
14:30–16:00

Have you ever found yourself asking this this question? You may also not know what types of jobs you should target based on the many transferrable skills you have or may want to develop. This session will show jobseekers how to find out what jobs they should apply to that fit their career goals, personality, and lifestyle.

Hosted by: Cheeky Scientist, OSA Foundation

Data Center Summit: Open Hardware & Software Platforms

Session I: Open Platforms for Optical Innovation

Tuesday, 21 March, 14:00–16:00
Room: 408A

Organizers: Ramon Casellas, *CTTC, Spain*; Daniel King, *University of Lancaster, UK*; Noboru Yoshikane, *KDDI Research, Japan*, Ilya Baldin, *RENCI/UNC Chapel Hill, USA*

Using open hardware and software platforms for designing, deploying and operating large-scale networks is increasingly seen as a viable strategy for large and complex commercial environments. Most recently, the concepts of open hardware and software are being used within the optical infrastructure domain, and this trend is expected to facilitate innovation, design, adoption and control of future optical infrastructure.

Open hardware initiatives, including the Open Compute Platform, Telecom Infrastructure Project, Open ROADM Multi-Source Agreement, Central Office Rearchitected as Datacenter and Open Platform for NFV are defining open hardware platforms and reference implementations. To facilitate their control and operation, software projects such as OpenStack, OpenDayLight, Open Network Operating System, Open Platform for NFV, Open Source Mano and OpenConfig, are providing extensible frameworks and software tools.

Numerous proof-of-concept implementations and distributions across various research projects and early stage commercial initiatives, have demonstrated that rapid innovation is possible on basis of open hardware, interfaces, and software. Increasingly, these implementations and distributions will have to support the growing need for open optical hardware platforms.

The Open Platform Summit will discuss recent trends on open platforms and its applications to the optical networking space. It will comprise two technical sessions; the first session will have invited talks to introduce the audience to the topic area. The second session will comprise interactive table-top SDN & NFV demos selected from proposal submitted through the OFC system.

Speakers:
Saurav Das, *Open Networking Foundation, USA*
Young Lee, *Huawei, USA*
Anees Shaikh, *Network Architect, Google - Open Management Plan for Transport Networks*
Yasushi Sugaya, *Fujitsu, Japan*

Session II: SDN & NFV Demo Zone

Tuesday, 21 March, 16:30–18:30
400 Foyer

The Data Center Summit (OPS) Session II, "SDN & NFV Demo Zone", will provide the OFC audience with the opportunity to see live demonstrations and prototypes of collaborative research projects, pre-commercial products and proof-of-concept implementations in the SDN and NFV space. See page 96 for more details on the demonstrations.

Exhibitor Reception

Tuesday, 21 March, 17:30-19:00
Lucky Strike LA Live
800 W Olympic Blvd

OFC 2017 exhibitors are invited to celebrate the opening of the show. Join your colleagues, customers, and friends for drinks and appetizers.

Conference Reception

Tuesday, 21 March, 18:30-20:00
Concourse Hall

Enjoy food and drinks with your friends and colleagues during the conference. The reception features live music from Ciena's OTN-Speedwagon. Additional tickets may be purchased at registration for US $75.

Rump Session

Tuesday, 21 March, 19:30–21:30
Room: 409AB

Sub $0.25/Gbps Optics; How and When will Fiber Finally Kill Copper Cable Interconnects in the Data Center (DC)?

Organizers: Chris Cole, *Finisar Corp., USA*; Dan Kuchta, *IBM TJ Watson Research Center, USA*

Provocateurs: Andreas Bechtolsheim, *Arista Networks, USA;* Mitch Fields, *Broadcom Ltd., USA;* Tad Hofmeister, *Google, USA;* Benny Koren, *Mellanox Technologies, USA;* Brian Kirk, *Amphenol Corp., USA;* Ashok Krishnamoorthy, *Oracle Corp., USA;* Beck Mason, *Ocalro Inc., USA.;* Brian Welch, *Luxtera Inc., USA*

In the DC, switch interconnects are exclusively fiber-based, but copper cables stubbornly hang on as server interconnects at ~$0.50/Gbps per link. Optical transceivers inside active cables or modules will have to be $0.25/Gbps to match cost. The high volume potential of this application can drive development of disruptive technologies and lower the cost of all DC optics. Yet our industry is moving away from common optics. Previously, focus on a few standard types like SR and LR created a huge 10G common market. Today, Operator and System OEM emphasis on optimizing their individual applications is leading to the proliferation of architectures, rates, link specifications, and form factors, fragmenting the volume of all optics types. This is accompanied by stringent port density and power requirements, making simultaneous optics low cost even more difficult to achieve, prolonging the lifespan of copper cables.

Questions for Discussion:

- What technologies are required to get to sub $0.25/Gbps optical transceivers?
- What happened to the $1/Gbps optics cost target for switch interconnects? Doesn't industry have to hit it first before $0.25/Gbps for server interconnects?
- Are technologies for $0.25/Gbps optics and $1/Gbps optics synergistic or unrelated? Does 0dB loss budget cost less than 4dB loss budget?

- What's the trend in switch-to-server architectures; move them apart as in end-of-row switch topologies or move them closer together as in multiple servers and switch on a card? Is there even a common switch-to-server topology to create a high volume optics market?
- Are optical transceivers inside active cables lower cost compared to inside modules? Are there operational costs that negate this?
- Does matching today's copper cable cost even matter for connecting servers? If in a few lane rate generations, copper cables cannot support useful reaches, won't DC Operators just have to pay more?
- How does the industry get to high volume for any optics type with the current trend of fragmentation of requirements and applications?
- Cloud DC Operators insist on low cost and bleeding edge performance on day one. If they have to make a choice, will they stay at lower cost for lower rate or pay higher cost to move to higher rate?
- Cloud DC Operators have identified power as their most critical requirement yet are restricting technical solutions, for example to SMF only. Are low-power technical solutions like VCSELs being arbitrarily excluded?
- Is Silicon Photonics the answer to sub $0.25/Gbps or $1/Gbps optics?

Format:

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

Photonic Society of Chinese-Americans Workshop & Social Networking Event

The Emerging Technology Enablers for Next Generation Networks

中華光電學會
Photonic Society of Chinese-Americans

Wednesday, 22 March
Room 518
17:00–17:30, Registration and Social Networking
17:30–19:30, Panel Discussions, Q&A

Registration Contacts:

David Li, dli@archcomtech.com, +1.630.308.3362

Genzao Zhang: Genzao_Zhang@emcore.com, +1.626.710.8788

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 10 years. In OFC2017, the panel of the PSC annual event consists of well-respected experts from telcos and OEMs in the optical industry. The latest silicon photonics, data center, access and 5G wireless technologies will be elaborated. The technology trend of converging the fixed and wireless networks and the mainstream technologies will be discussed, as well as the strategies and demand differences for the next generation networks among US, China and the rest of the world markets.

Co-organizers: The Optical Society (OSA), OFC China Office & Wen Global Solutions, and China International Optoelectronic Expo (CIOE)

2017 Sponsors: Auxora, Bandweaver, BUPT, CoAdna, Emcore, EXFO, Fabrinet, FiberCore, Finisar, General Photonics, GoFoton, Hisense, Innolight, Inphi, MACOM, O-Net, Oplink (Molex), OzOptics, SAN-U, Source Photonics

Postdeadline Paper Presentations

Thursday, 23 March, 18:00–20:00
Rooms: 403A, 403B, 408A, 408B

Discover the best and most cutting-edge research in optical communications. The OFC 2017 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.

Authors will be notified of acceptance on Monday, 20 March. Accepted papers will be posted on the mobile app and on the conference website. See page 7 for instructions on accessing a zip file with accepted papers.

Plenary Session

OFC Plenary Session

Tuesday, 21 March, 08:00–10:00
Concourse Hall

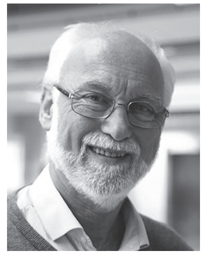
A Ubiquitous Cloud Requires a Transparent Network

Urs Hölzle

Senior Vice President for Technical Infrastructure
Google, Inc., USA

What makes cloud amazing is ubiquity. What makes Cloud ubiquitous is the network. We realized that at Google over a decade back while building the first truly global Cloud infrastructure. Ever since, we have been building a network unparalleled in reach, scale and capability. While we built the network as the backbone of a global super computer, we also turned the network control and management planes into distributed services running on the same Cloud. In the process, we made every network layer, including optical transport, intelligent, fault-tolerant, highly reliable and programmatically manageable to allow for rapid evolution and innovation. We have also applied the lessons of disaggregation, learned from Cloud, widely to our network infrastructure.

Urs Hölzle is Senior Vice President for Technical Infrastructure at Google. In this capacity he oversees the design, installation, and operation of the servers, networks, and datacenters that power Google's services. Through efficiency innovations, Hölzle and his team have reduced the energy used by Google data centers to less than 50% of the industry average. Hölzle grew up in Switzerland and received a master's degree in computer science from ETH Zurich and, as a Fulbright scholar, a Ph.D. from Stanford. While at Stanford (and then a small start-up that was later acquired by Sun Microsystems) he invented fundamental techniques used in most of today's leading Java compilers. Before joining Google he was a professor of computer science at the University of California, Santa Barbara. He is a Fellow of the ACM and a member of the US National Academy of Engineering and the Swiss Academy of Technical Sciences.



Photonic Integrated Circuits for All: How Foundries are Transforming the Prototyping of Exciting New Devices

Meint K. Smit

Professor
Eindhoven University of Technology, Netherlands

In order to provide fabless researchers and developers with access to high-performance photonic integration platforms, the generic micro-electronics foundry model has recently been adapted to photonic integrated circuits. Pioneered in Europe for three different technologies (InP, silicon and silicon nitride), the model is now also being implemented in the United States with the National Photonics Initiative.

The foundry model uses Process Design Kits (PDKs) that allow users to implement complex integrated photonic circuits without detailed knowledge of the underlying photonic integration technologies. This brings the use of photonic ICs within the reach of small companies, and it offers excellent opportunities to introduce integrated photonics into diverse applications, like sensors, security, medical diagnostics, automotive, avionics and metrology. This presentation describes the photonics foundry model and its development in Europe, explains the significant reductions in prototyping costs, and highlights foundry-model developed photonic ICs across a broad range of applications.

Meint K. Smit started research in Integrated Optics in 1981. He invented the Arrayed Waveguide Grating, for which he received a LEOS Technical Achievement award in 1997 and he was closely involved in the introduction of MMI-couplers in semiconductor-based Photonic IC technology. In 2000 he became the leader of the Photonic Integration group at the COBRA Research Institute of TU Eindhoven. His current research interests are in InP-based Photonic Integration and integration of InP circuitry on Silicon. He is the founder of the JePPIX platform, the Joint European Platform for Photonic Integration of Components and Circuits and strongly involved in the development of the InP-based photonic foundry system in Europe. Smit is a LEOS Fellow and he received an ERC Advanced Grant in 2012.

Internet of Skills – Where Communications, Robotics and AI Meet

Mischa Dohler

Professor
King's College, London, UK

Today's internet, accessed by fixed and mobile networks, allows us to transmit files, voice and video across the planet. With the emergence of an ultra-responsive and reliable 'Tactile Internet,' advanced techniques in robotics and artificial intelligence, we predict the emergence of an 'Internet of Skills' which allows the transmission of labor globally. It will invoke an important shift from content-delivery to skillset-delivery networks, where engineers would service cars or surgeons performing critical operations anywhere on the planet. For this to work, however, we require some fundamental laws of physics to be "reengineered." This presentation will look at the disruptive technology approaches in wireless 5G and next-generation optical networks which will allow us to break through the next technology frontier.

Mischa Dohler is full Professor in Wireless Communications at King's College London, driving cross-disciplinary research and innovation in technology, sciences and arts. He is the Director of the Centre for Telecommunications Research, co-founder of the pioneering smart city company Worldsensing, Fellow of the IEEE and the Royal Society of Arts (RSA), and a Distinguished Member of Harvard Square Leaders Excellence. Dohler has pioneered several research fields, contributed to numerous wireless broadband, IoT/M2M and cyber security standards, holds a dozen patents, organized and chaired numerous conferences, was the Editor-in-Chief of two journals, has more than 200 publications, and authored several books.

OFC and Sponsor Awards and Honors

Awards Ceremony and Luncheon

Tuesday, 21 March, 12:00–14:00
Concourse Hall

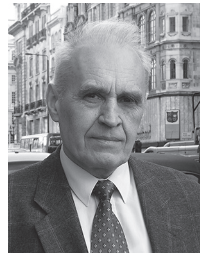
The conference sponsors – IEEE Communications Society, IEEE Photonics Society, and The Optical Society – will present awards and honors in a special Awards luncheon on Tuesday. The lunch is open to anyone who purchases a ticket, but seating is limited. Tickets can be purchased for $45 .00 USD at registration.

OFC will also recognize the winner of the John Tyndall Award and acknowledge all other awards and honors recipients during the plenary session.

John Tyndall Award

The John Tyndall Award is named for the 19th century scientist who was the first to demonstrate the phenomenon of internal reflection. First presented in 1987, the Tyndall Award recognizes an individual who has made pioneering, highly significant, or continuing technical or leadership contributions to fiber optic technology. Corning, Inc. sponsors the award, a prize check and a glass sculpture that represents the concept of total internal reflection. The award is co-sponsored by The Optical Society (OSA) and the IEEE Photonics Society.

The IEEE Photonics Society and OSA will present the 2017 Tyndall Award to Professor Evgeny M. Dianov, Russian Academy of Sciences (RAS), Russian Federation "for pioneering leadership in optical fiber development and outstanding contributions to non-linear fiber optics and optical fiber amplifiers."



Professor Evgeny M. Dianov is Scientific Director of the Fiber Optics Research Center of the Russian Academy of Sciences.

He graduated from Moscow State University in 1960 and began his scientific career in the P.N. Lebedev Physics Institute of the USSR Academy of Sciences (1960-1983), then worked in the General Physics Institute (1983-2006) and in the Fiber Optics Research Center of RAS (2006- present). His research interests include laser physics, nonlinear optics and fiber optics and he has published more than 700 scientific papers and patents. He received the State Prize of the Soviet Union for "Neodymium Glass Lasers" in 1974. In 1994 Prof. Dianov became a Full Member of the Russian Academy of Sciences.

Since 1974 he has been involved with most aspects of fiber optics, including fiber technologies, fiber measurements, nonlinear fiber optics, fiber lasers and optical amplifiers. Main results included new types of optical fibers such as high-strength hermetically metal-coated, dispersion-decreasing, nitrogen-doped and low-loss highly nonlinear fibers; new results in nonlinear fiber optics such as the first observation of soliton self-frequency shift, the discovery of electro-striction mechanism of soliton interaction, generation of a train of fundamental solitons at high repetition rate, the proposal and experimental confirmation of a photovoltaic model of second-harmonic generation in glass fibers; the development of highly efficient Raman fiber lasers and optical amplifiers.

Dianov received the State Prize of the Russian Federation for infrared fibers in 1998 and Vavilov Gold Medal for studies of nonlinear processes in optical fibers and the development of fiber sources of radiation in visible and near IR spectral ranges based on nonlinear phenomena.

IEEE Communications Society 2017 Fellows

Xiang Liu, *Huawei, USA*

Shu Namiki, *National Institute of Advanced Industrial Science and Technology, Japan*

Seb Savory, *University of Cambridge, UK*

IEEE Photonics Society 2017 Fellows

John Ballato, *Clemson, USA*

Chris Cole, *Finisar, USA*

Joseph Ford, *University of California, San Diego, USA*

Xiang Liu, *Huawei R&D, USA*

Shu Namiki, *National Institute of Advanced Industrial Science and Technology (AIST), Japan*

Aydogan Ozcan, *UCLA, USA*

Seb Savory, *University College, UK*

Eric Swanson, *Acacia Communications, Inc., USA*

The Optical Society Fellows

Gabriella Bosco, *Politecnico di Torino, Italy*

Walter F. Buell, *The Aerospace Corporation, USA*

Yijiang Chen, *Jet Propulsion Laboratory, USA*

Aref Chowdhury, *Nokia Corporation, USA*

Ivan B. Djordjevic, *University of Arizona, USA*

Po Dong, *Nokia Bell Labs, USA*

Andrew Forbes, *University of Witwatersrand, South Africa*

JianJang Huang, *National Taiwan University, Taiwan*

Hong Liu, *Google, USA*

Malin Premaratne, *Monash University, Australia*

Leslie A. Rusch, *Universite Laval, Canada*

Seb J Savory, *University of Cambridge, UK*

Perry Ping Shum, *Nanyang Technological University, Singapore*

Kathleen Tse, *AT&T Corp, USA*

Lianshan Yan, *Southwest Jiaotong University, China*

Xinliang Zhang, *Huazhong University of Science and Technology, China*

IEEE/OSA Journal of Lightwave Technology (JLT) Best Paper Award

The IEEE and OSA co-sponsored Journal of Lightwave Technology has instantiated a Best Paper Award. This annual award recognizes the most impactful paper published in JLT 2 to 3 years ago.

Title: **Monolithic Silicon Integration of Scaled Photonic Switch Fabrics, CMOS Logic, and Device Driver Circuits** by: B. G. Lee, A. V. Rylyakov, W. M. Green, S. Assefa, C. W. Baks, R. Rimolo-Donadio, D. M. Kuchta, M. H. Khater, T. Barwicz, C. Reinholm, E. Kiewra, S. M. Shank, S. L. Schow, and Y. A. Vlasov

Copies of these papers will be made available at various places at this conference and will be turned into open-access as well.

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

The Charles Kao Award for Best Optical Communications and Networking Paper is awarded to papers published in the OSA/IEEE Journal on Optical Communications & Networking (JOCN) that open new lines of research, envision bold approaches to optical communication and networking, formulate new problems to solve, and essentially enlarge the field of optical communications and networking. Papers published in the prior three calendar years of JOCN are eligible for the award.

Award Winners and Title of Article: "Software-Defined Optical Networks Technology and Infrastructure: Enabling Software-Defined Optical Network Operations [Invited]", IEEE Journal of Optical Communications and Networking, Vol. 5, No. 10, pp. A274-A282, October 2013.

IEEE ComSoc
IEEE Communications Society

IEEE Photonics Society Fund

The IEEE Photonics Society, in partnership with the IEEE Foundation, is proud to announce the establishment of the IEEE Photonics Society Fund. This fund will be used to enhance the humanitarian and educational initiatives of the Society by providing members and the photonics community with the ability to contribute directly to mission-driven imperatives, such as the Graduate Student Fellowship Program, Women in Photonics and STEM Outreach.

With the establishment of this fund, you too can play a direct role in this vital work.

Visit the IEEE Photonics Society booth or IEEE-Photonics-Fund.org for more information.

The Corning Student Paper Competition

The winners of the Corning Outstanding Student Paper Competition will be announced during the conference.

The top finalist will receive a grand prize of $1,500 USD, and the two runners-up will receive $1,000 USD. This award, endowed through the OSA Foundation by a grant from Corning, recognizes innovation, research excellence and presentation abilities in optical communications.

Congratulations to the 2017 finalists:

Kaoutar Benyahya, *Nokia Bell Labs, France*

Zhe Li, *University College London, UK*

Rafael Puerta, *Technical University of Denmark, Denmark*

Zeinab Sanjabi, *Eznaveh University of Central Florida, USA*

Michael Theurer, *Fraunhofer Heinrich Hertz Institute, Germany*

Jing Wang, *Georgia Institute of Technology, USA*

OSA Foundation

The Paul Anthony Bonenfant Memorial Scholarship

Established in 2011 in memory of Paul Anthony Bonenfant, this scholarship enables undergraduate students enrolled in engineering and/or physical science programs to attend semester-abroad programs offered through their accredited college or university.

The goal of the scholarship is to provide international experience to students as they prepare for professional lives that promote global engagement and collaboration.

This $8,000 USD scholarship will rotate among several universities including The California Institute of Technology, Cornell University, and The Ohio State University. For more information on this scholarship and its recipients, please visit www.osa.org/Bonenfant. The recipient will be announced to OFC attendees by email at the conclusion of the conference.

OSA Foundation

The Tingye Li Innovation Prize

The Tingye Li Innovation Prize, established in 2013, honors the global impact Dr. Li made to the field of Optics and Photonics. This prize is presented to a young professional with an accepted paper that has demonstrated innovative and significant ideas and or contributions to the field of optics. The recipient of this prize receives a $3,000 USD stipend, a special invitation to the Chairs' Reception, and special recognition at the conference.

Congratulations to our 2017 recipient:

Tetsuya Hayashi, *Sumitomo Electric Industries, Ltd., Japan*

OSA Foundation

Short Course Schedule

Sunday, 19 March, 2017

09:00–12:00

SC176: Metro Network: The Transition to Ethernet, Loudon Blair; *Ciena Corp., USA*

SC177: High-Speed Semiconductor Lasers and Modulators, John Bowers; *Univ. of California at Santa Barbara, USA*

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

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

NEW! SC447: The Life Cycle of An Optical Network: From Planning to Decommissioning, Andrew Lord; *BT Labs, BT, UK*

09:00–13:00

SC105: Modulation Formats and Receiver Concepts for Optical Transmission Systems, Peter Winzer, S. Chandrasekhar; *Nokia Bell Labs, USA*

SC114: Passive Optical Networks (PONs) Technologies, Frank J. Effenberger; *Futurewei Technologies, USA*

SC359: Datacenter Networking 101, Cedric Lam, Hong Liu; *Google, USA*

SC384: Background Concepts of Optical Communication Systems, Alan Willner; *Univ. of Southern California, USA*

13:00–17:00

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

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

SC395: Modeling and System Impact of Optical Transmitter and Receiver Components, Harald Rohde, Robert Palmer; *Coriant, Germany*

13:30–16:30

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

SC430: SDN Standards and Applications, Lyndon Y. Ong; *Ciena,USA*

SC433: Photodetectors for Optical Communications, Joe C. Campbell; *Univ. of Virginia, USA*

13:30–17:30

SC203: 100 Gb/s and Beyond Transmission Systems, Design and Design Trade-offs, Martin Birk[1], Benny Mikkelsen[2]; [1]*AT&T Labs, Res., USA,* [2]*Acacia Communications, USA*

SC369: Test and Measurement for Metro and Long-haul Communications, Bernd Nebendahl, Michael Koenigsmann; *Keysight, Germany*

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

17:00–20:00

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

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

SC328: Standards for High-speed Optical Networking, Stephen Trowbridge; *Nokia, USA*

SC372: Building Green Networks: New Concepts for Energy Reduction, Rod S. Tucker; *Univ. Melbourne, Australia*

SC386: The "SDN" Evolution of Wireline Transport due to "Cloud" Services and DCI Innovations, Loukas Paraschis; *Infinera, Inc., USA*

SC428: Link Design for Short Reach Optical Interconnects, Petar Pepeljugoski; *IBM Research, USA*

SC429: Flexible Networks, David Boertjes; *Ciena, Canada*

NEW! SC451: Fiber-based Devices and Sensors, Zuyuan He[1], William Shroyer[2]; [1]*Shanghai Jiao Tong University, China,* [2]*SageRider, Inc., USA*

Monday, 20 March, 2017

08:30–12:30

SC102: WDM in Long-Haul Transmission Systems, Neal S. Bergano; *TE Subcom, USA*

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

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

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

SC390: Introduction to Forward Error Correction, Frank Kschischang; *Univ. of Toronto, Canada*

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

NEW! SC446: Hands-on: Characterization of Coherent Opto-electronic Subsystems, Harald Rohde and Robert Palmer; *Coriant, Germany*

NEW! SC453A: Hands-on Fiber Optic Handling, Measurements, and Component Testing, Chris Heisler[1], Loic Cherel[2], Steve Baldo[3], Keith Foord[4]; *[1]OptoTest Corporation, USA; [2]Data-Pixel, France; [3]Seikoh Giken Company, USA; [4]Greenlee Communications, USA*

09:00–12:00

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

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

SC411: Multi-layer Interaction in the Age of Agile Optical Networking, Ori A. Gerstel; *Sedona Systems, Israel, USA*

NEW! SC442: Free Space Switching Systems: PXC and WSS, David Neilson; *Nokia Bell Labs, USA*

NEW! SC450: Design, Manufacturing, and Packaging of Opto-Electronic Modules, Kevin Williams[1], Arne Leinse[2], Twan Korthorst[3]; *[1]Eindhoven University of Technology, Netherlands; [2]LioniX International, Netherlands, [3]PhoeniX Software, Netherlands*

13:30–16:30

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

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

NEW! SC445: Visible Light Communications — the High Bandwidth Alternative to WiFi, Harald Haas; *LiFi Research and Development Centre, The University of Edinburgh, UK*

NEW! SC448: An Introduction to the Control and Management of Optical Networks, Ramon Casellas; *CTTC, Spain*

13:30–17:30

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

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

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

NEW! SC449: Hands-on: An Introduction to Writing Transport SDN Applications, Ricard Vilalta[1], Karthik Sethuraman[2]; *[1]CTTC, Spain, [2]NEC Corporation of America, USA*

NEW! SC452: FPGA Programming for Optical Subsystem Prototyping, Noriaki Kaneda[1], Laurent Schmalen[2]; *[1]Nokia Bell Labs, USA, [2]Nokia Bell Labs, Germany*

NEW! SC453B: Hands-on Fiber Optic Handling, Measurements, and Component Testing, Chris Heisler[1], Loic Cherel[2], Steve Baldo[3], Keith Foord[4]; *[1]OptoTest Corporation, USA; [2]Data-Pixel, France; [3]Seikoh Giken Company, USA; [4]Greenlee Communications, USA*

NEW! SC454: Hands-on: Silicon Photonic Circuits and Systems Design, Lukas Chrostowski[1],Chris Doerr[2], *[1]University of British Columbia, Canada, [2]Acacia Communications, USA*

Short Course Descriptions

Sunday, 19 March, 2017

09:00–12:00

SC176: Metro Network: The Transition to Ethernet

Instructor: Loudon Blair; Ciena Corp., USA
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe how new services are changing metro network traffic characteristics.
- Describe the impact that these new services will have on metro network traffic patterns and network equipment capacity in both aggregation and core metro networks.
- Describe the meaning of Carrier Ethernet and discuss different implementation approaches.
- Describe the key networking technologies used to build next generation metro networks, including DWDM, OTN, and IP/MPLS.
- Discuss the role of Carrier Ethernet in new metro architectures and how it operates in combination with other key technologies.
- Describe how packet and optical technologies are converging to form packet-optical transport and switching systems.
- Discuss how packet-optical systems may be used in different metro application scenarios, including new cloud network architectures.

Intended Audience:

This course is intended for network architects and planners from service providers, engineering and marketing staff to network equipment providers, technologists with an interest in the evolution of networks, industry analysts, and financial analysts.

SC177: High-Speed Semiconductor Lasers and Modulators

Instructor: John Bowers; Univ. of California at Santa Barbara, USA
Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Compare different technologies.
- Make informed decisions on the design of optical transmitters and their incorporation into optical networks.
- Explain the performance of high-speed transmitters.

Intended Audience:

Attendees should have some knowledge of semiconductor and device physics. A basic knowledge of laser operation is also needed.

SC443: Optical Amplifiers: From Fundamental Principles to Technology Trends NEW!

Instructors: Michael Vasilyev[1], Shu Namiki[2]; *[1]University of Texas at Arlington, USA; [2]National Institute of Advanced Industrial Science and Technology (AIST), Japan*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course will enable you to:

- Define the roles of optical amplifiers in optical communication networks.
- List the key parameters of optical amplifiers important for system design.
- Identify the stimulated emission phenomenon as the common physical process for optical amplification.
- Explain the difference between phase-insensitive amplifiers (PIAs) and phase-sensitive amplifiers (PSAs).
- List several material platforms of optical amplification and key differences in their performances and characteristics.
- Discuss optical amplification technologies such as erbium-doped fiber amplifier (EDFA), fiber Raman amplifier (FRA), semiconductor optical amplifier (SOA), and fiber-optical parametric amplifier (FOPA).
- Describe the practical issues of each of the optical amplification technologies listed above.
- Identify the future trends in research and development of optical communication enabled by advances in optical amplification technologies.

Intended Audience:

This beginner/advanced-beginner course is intended for a diverse audience including newcomers to the field of optical fiber communication, and especially for lightwave system engineers and opto-electronic sub-system designers. Some basic knowledge of optical fiber communication technologies will help in better understanding the course but is not a prerequisite.

SC444: Optical Communication Technologies for 5G Wireless NEW!

Instructor: Xiang Liu; *Futurewei Technologies, Huawei R&D, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe 5G wireless trends and technologies such as massive MIMO and coordinated multipoint (CoMP).
- Identify promising applications of optical communication technologies in future 5G wireless networks.
- Identify recent advances on the common public radio interface (CPRI) and the next-generation fronthaul interface (NGFI) for cloud radio access networks (C-RAN).
- Describe emerging optical communication technologies such as 100+Gb/s coherent, low-cost IM/DD transmission, and associated DSP techniques for high-throughput and low-latency wireless fronthaul and backhaul.
- Discuss emerging network architectures and design tradeoffs among various optical transport and access systems for better converged fiber/wireless networks.

Intended Audience:

This advanced-beginner course is intended for a diverse audience including researchers, engineers, and graduate students. Some basic knowledge of optical networks, wireless networks, optical transmission technologies, photonics, and digital signal processing will help in better understanding the course but is not a prerequisite.

SC447: The Life Cycle of an Optical Network: From Planning to Decommissioning NEW!

Instructor: Andrew Lord; *BT Labs, UK*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify key activities comprising whole-life optical network procurement, design, operation and management.
- Explain the broad time scale for an optical network including reasons for building it and factors affecting how long it should be in operation.
- Appreciate different types of optical network and the range of network operator requirements. Deduce the implications for the solution design.
- List the range of optical network technologies available to build networks, covering legacy through to future roadmap options.
- Understand the need for appropriate resilience and reliability across the network, from devices, sub-systems, network equipment and overall network operation.

- Explore how unpredictable future traffic drives the need for both network flexibility and capacity growth and appreciate that the scope for both flexibility and growth imply increased network cost.
- Appreciate the impact of the quality of the available optical fibre infrastructure on the physical layer system design, including margin allowance.
- Discuss the impact on future networks of new technologies, including flexible transceivers and ROADMs, and finer resolution wavelength grid and a more open contol anad management based around Software Defined Networking (SDN).

Intended Audience:

This advanced-beginner course is intended for a diverse audience – in fact anyone wanting a broad operator-based perspective on the optical network journey. No in-depth knowledge will be required – the objective is sufficient breadth that anyone will be able to see where their field of expertise fits into the overall picture. This is a brand new course for 2017 with entirely new material, much of which is derived from real network deployment experience.

09:00–13:00

SC105: Modulation Formats and Receiver Concepts for Optical Transmission Systems

Instructors: Peter Winzer, S. Chandrasekhar; *Nokia Bell Labs, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the basic concepts behind optical modulation and multiplexing techniques.
- Explain the basic concepts behind advanced optical modulation formats, their performance, and their generation using state-of-the-art opto-electronic components and digital signal processing.
- Explain the basic concepts of optical receiver design, including direct and coherent detection as well as related digital signal processing techniques.
- Recognize and discuss the interplay between modulation format, transceiver design, and transmission impairments.
- Get an insight into future trends in research and product commercialization of optical transport systems enabled by advanced modulation and multiplexing techniques, software-defined transceivers, and flexible WDM architectures.

Intended Audience:

This advanced-beginner course is intended for a diverse audience including lightwave system researchers and engineers as well as opto-electronic subsystem designers. Some basic knowledge of optical modulation and detection technologies will help in better understanding the course but is not a prerequisite. Past attendees will find substantial updates to this course, which we continuously adapt to reflect the latest trends in research as well as in product development, and may hence find it useful to attend again.

SC114: Passive Optical Networks (PONs) Technologies

Instructor: Frank J. Effenberger; *Futurewei Technologies, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Compare the capabilities and advantages of different PON technologies.
- Describe the practical limitations of real-world G-PON and EPON systems for broadband access.
- Explain the motivations behind the Full-Service-Access-Network initiative and the related IEEE P802.3 and P1904 projects.
- Identify the commercial issues surrounding fiber access, and how PON works to address these.
- List and compare the possible future evolution paths that PON technology may take.
- Explain how to plan PON applications and deployments.

Intended Audience:

This course is intended to give engineers a general overview of PON technologies that can serve multiple roles depending on their field. Network planners can use this course to better understand the available systems and their applications. Product designers will gain insight as to the fundamental design trade-offs involved in PON. Academic researchers will see how their specific research can fit into the larger technology domain.

SC359: Datacenter Networking 101

Instructors: Cedric Lam, Hong Liu; *Google, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Define warehouse-scale computer (WSC) and describe its structure.
- Describe the engineering principles and philosophies behind scalable mega-datacenter infrastructures.
- Compare different datacenter cluster topologies and switching technologies.
- Compare the differences and similarities between traditional telecommunication networks and booming data-communication networks.
- Identify the challenges for intra-datacenter and inter-datacenter communications.
- Select suitable optoelectronic interconnect technologies.
- Explain the roles of optics in transmission, multiplexing and switching.
- Describe SDN and NFV.

Intended Audience:

This course is beneficial to optoelectronic engineers, fiber optic transceiver designers and optical transmission engineers who would like to understand the requirements of datacenter networking. It also benefits network engineers with the knowledge of high-speed optical communication technologies used to realize various datacenter network applications. For network planners and architects, this course provides outlooks in optical network technology developments in the next 3 to 4 years.

SC384: Background Concepts of Optical Communication Systems

Instructor: Alan Willner; *Univ. of Southern California, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Discuss the basic concepts of an optical communication system.
- Identify different types of modulation and multiplexing formats.
- Compute a simple optical power budget.
- Explain key differences between direct and coherent detection systems.
- Attend more advanced OFC short courses and understand better the conference technical sessions.

Intended Audience:

This introductory course is intended for an audience with at least some technical background in engineering, physics or related disciplines, and is ideally suited for engineers who want to learn more about optical fiber communication systems. The audience should gain valuable knowledge enabling them to take more advanced courses as well as understand better the conference technical sessions.

13:00–17:00

SC267: Silicon Microphotonics: Technology Elements and the Roadmap to Implementation

Instructor: Lionel Kimerling; *MIT, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify trends in the optical components industry.
- Explain the power of a standard platform.
- Discuss the benefits of electronic-photonic integration.
- Evaluate the latest silicon photonic devices and foundry production of chips for datacom, automotive and sensing applications.
- Summarize the findings of the Integrated Photonics System Roadmap.

Intended Audience:

This course is for executives and technologists in the photonic and electronic hardware industries to include planners, engineers, and scientists participating in the optical components technology supply chain.

SC325: Highly Integrated Monolithic Photonic Integrated Circuits

Instructor: Chris Doerr; *Acacia Communications, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Gain a deeper understanding of photonic integrated circuits (PICs) for telecomm and datacomm.
- Describe the pros and cons of PICs.
- Recognize the most popular material systems, especially silicon photonics and indium phosphide photonics.
- Explain many of the phenomena in PICs.
- Discover the issues that PIC designers face.
- List the main steps in producing a PIC.
- Get an up-to-date view on PICs in the communication industry.
- Separate hype from reality with regard to PICs.

Intended Audience:

This advanced-beginner course is intended for both industry and acadamic participants who want to get a realistic view of PICs in industry today and where they might be going in the next five years. A beginners knowledge of optical communication systems would be very helpful. The participant does not need to know anything about PICs, but some understanding of general optics, such as what is refractive index, is needed.

SC395: Modeling and System Impact of Optical Transmitter and Receiver components

Instructors: Harald Rohde, Robert Palmer; *Coriant, Germany*
Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Numerically model components for coherent transmission systems.
- Detect real life impairments of such components.
- Model, design and characterize optical transceivers.

Intended Audience:

This course is targeted for researchers and students who want to learn how to model transceiver components for coherent optical transmission systems. Basic knowledge of transmission system related mathematics (e.g. Fourier transforms) and basic communication theory knowledge is required.

13:30–16:30

SC216: An Introduction to Optical Network Design and Planning

Instructor: Jane M. Simmons; *Monarch Network Architects, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Compare O-E-O and optical-bypass technology.
- Compare the architectures of various optical network elements.
- Describe the colorless, directionless, contentionless, and gridless attributes of ROADMs.
- Describe the basics of routing traffic, including strategies for load balancing and protection.
- Describe the basics of wavelength assignment.
- List some of the networking principles as well as physical effects that determine where regeneration is required in a network.
- Identify the advantages and disadvantages of Elastic Optical Networks (EONs).
- Discuss the 'hot' topics in network architecture, including Software Defined Networking (SDN), power consumption issues, and Space Division Multiplexing (SDM).

Intended Audience:

This course is intended for network planners and architects in both carriers and system vendors who are involved in planning optical networks and selecting next-generation optical equipment. The discussion of networking elements and algorithms, as well as the discussion of current research areas, should be helpful to vendors who are developing optical systems and to carriers who are modeling network evolution strategies. The course is introductory level, although a basic understanding of networking principles is assumed.

SC430: SDN Standards and Applications

Instructor: Lyndon Y. Ong; *Ciena, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify common service provider SDN Use Cases.
- Explain how SDN can support carrier network virtualization and slicing.
- Discuss the basic architecture of SDN for transport networks.
- Distinguish the roles of SDN SouthBound and NorthBound Interfaces.
- Describe OpenFlow and its extensions for optical networking.
- Understand different approaches to SDN NBI and ONF's Transport API.
- Compare ONF's common model vs. IETF's YANG model approaches.
- Review the status of carrier implementation and testing of Transport SDN APIs.

Intended Audience:

The audience for this course includes system and network architects and engineers in network operators and equipment vendors, as well as researchers wanting to understand directions for introducing SDN into wide area networks. The course assumes some familiarity with optical network technologies and basic understanding of the role of higher layer networks and how they connect to the optical layer.

SC433: Photodetectors for Optical Communications

Instructor: Joe C. Campbell; *Univ. of Virginia, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the fundamental operation of different types of photodetectors and compare their relative merits. Participants will obtain a broad overview of the photodetectors that are widely deployed in optical communications.
- Present the state-of-the-art for p-i-n, avalanche, and single-photon photodiodes. Participants will be "up-to-date" with respect to device performance and the, concomitant, limitations.
- Describe the design guidelines and tradeoffs for specific photodetector applications. This will enable participants to specify appropriate detectors.

Intended Audience:

This course is intended for those interested in the fundamentals of photodetectors. For example, what are the factors that determine the maximum bandwidth of a photodiode? What are the current "champion" results and what are the inherent tradeoffs with other performance parameters? The device physics will be presented at a high level although some background in semiconductor devices will be beneficial. The course is intended for those who are new to the area, while providing useful information to workersin the field.

13:30–17:30

SC203: 100 Gb/s and Beyond Transmission Systems, Design and Design Trade-offs

Instructors: Martin Birk[1], Benny Mikkelsen[2]; [1]*AT&T Labs, Res., USA*, [2]*Acacia Communications, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify key requirements and drivers for 100Gb/s applications.
- List key building blocks of coherent systems.
- Describe the availability and performance of 100Gb/s.
- Discuss 100Gb/s transmission limitations.
- Summarize 100Gb/s standards activities.
- Describe drivers and technologies for systems beyond 100Gb/s.
- Discuss applications of flex rate systems.

Intended Audience:

The course is intended for engineers and technical managers who want an up-to-date overview of 100Gb/s transmission systems, including applications, line-card designs, and fiber transmission limitations. This year this course has been extended to 4 hours to accommodate more questions and more material beyond 100Gb/s. The course requires some understanding of basic optical transmission systems.

SC369: Test and Measurement for Metro and Long-haul Communications

Instructors: Bernd Nebendahl, Michael Koenigsmann; *Keysight, Germany*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe a setup to measure wavelength and polarization dependent properties of DWDM components.
- Determine the required performance of test & measurement equipment to test optical components.
- Measure performance parameters of optical amplifiers and fiber links.
- Compare the quality of various transmitters through the use of EVM measurements.
- Relate details of constellation diagrams to specific device and/or measurement system impairments.
- Identify the root causes of measurement degradation and uncertainty.
- Define test strategies to validate the accuracy of test results.

Intended Audience:

This short course is intended for engineers who start to work or already have experience in manufacturing and development of metro and long-haul communication equipment and components. Attendees should be aware of basic concepts of optical transmission and polarization of light. Research and manufacturing managers as well as technical buyers will get a profound background in order to make optimal decision for their test and measurement needs. Students will extend their knowledge in optimal test concepts for fiber optical testing.

SC393: Digital Signal Processing for Coherent Optical Systems

Instructor: Chris Fludger; *Cisco Optical GmbH, Germany*
Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Describe the principle building blocks in a coherent optical transceiver.
- Explain the function of frequency and time-domain filters and their advantages and disadvantages.
- Explain the implementation of pulse shaping and CD filters.
- Describe techniques for frequency and carrier phase estimation.
- Summarize the importance of clock recovery and describe clock recovery methods.
- Describe the components of polarization tracking filters.
- Explain how channel parameter estimation may be performed in coherent transceivers.
- Explain the options for achieving flexible capacity including implications for the network.
- Quantify the effectiveness and complexity of non-linear compensation.

Intended Audience:

This course is intended for individuals having an intermediate knowledge of digital lightwave transmission systems. It will be of value for industrial professionals (system designers, managers) who need to understand the different components in digital coherent transceivers, as well as for researchers who are new to the field.

17:00–20:00

SC205: Integrated Electronic Circuits for Fiber Optics

Instructor: Y. K. Chen; *Nokia Bell Labs, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the functions and performance of high-speed electronics for optic fiber terminals and associated designs and implementation of physical layer electronics.
- Describe commonly used circuit architectures and broadband digital, analog and mxied-mode circuits.
- Introduce advanced modulation and signal processing architecture andrelated broadband data converters.

Intended Audience:

This course is intended for engineers, scientists or managers who must make or understand the choice of electronic circuits for optical transmission products or evaluate electronic solutions used in purchased products.

SC217: Optical Fiber Based Solutions for Next Generation Mobile Networks

Instructor: Dalma Novak; *Pharad, LLC., USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the motivation for the integration of next generation mobile communication systems with optical fiber networks.
- Identify the technical challenges related to the application of photonics and optical networking concepts to wireless communications.
- Compare physical layer technologies that enable the integration of wireless and optical networks.
- Identify technologies that can improve the performance of integrated optical and wireless networks.
- Establish the trade-offs with alternative integrated network architectures.

Intended Audience:

This is an advanced beginner course for people working in either the optical or wireless telecommunication fields who wish to broaden their knowledge and learn how optical fiber solutions are playing a role in the realization of emerging integrated optical/wireless networks.

SC328: Standards for High-speed Optical Networking

Instructor: Stephen Trowbridge; *Nokia, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the concepts that form the basis for an OTN based on ITU-T Recommendation G.709, including the capabilities of the OTN standards to manage client signals and wavelengths.
- Describe the mapping mechanisms used by OTN to transport major client signals.
- Describe the structure and format for higher rates of Ethernet.
- Describe the Flex Ethernet implementation agreement and the network configurations that can be supported.
- Identify sources for information about ITU-T G.709, IEEE 802.3 standards, and the Flex Ethernet implementation agreement.

Intended Audience:

This course is intended for anyone who designs, operates, or supports metro and/or long haul optical networks and who need to understand the new interfaces and capabilities specified by standards on OTN, high-speed Ethernet, and Flex Ethernet.

SC372: Building Green Networks: New Concepts for Energy Reduction

Instructor: Rod S. Tucker; *Univ. Melbourne, Australia*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the principles of energy efficiency in telecommunications networks.
- Compare the energy efficiency of different network architectures.
- Compute an estimate of the energy efficiency of network equipment, designs and architectures.
- Identify key factors and leverage points for improving the energy efficiency future networks.
- Describe the key determinants of network energy efficiency.

Intended Audience:

Telecommunications engineers, managers, policy makers, researchers and educators. A basic knowledge of telecommunications networks and equipment will be advantageous but not essential. Little or no knowledge of energy efficiency issues in telecommunications networks is required.

SC386: The "SDN" Evolution of Wireline Transport due to "Cloud" Services and DCI Innovations

Instructor: Loukas Paraschis; *Infinera, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the significant evolution in the Internet wireline transport, due to the proliferation of datacenter based "cloud" service delivery.
- Describe the innovations in interconnecting data-centers (DCI), software defined networking (SDN), and network function virtualization (NFV).
- Determine, beyond any hype, the use-cases and value of SDN and NFV in the "cloud-based" wireline transport.
- Compare the emerging SDN architectures, technologies, and protocols.
- Discuss the DCI innovations in routing and optical transport.
- Identify the synergies of SDN with DCI routing and optical transport.
- Summarize the industry, research, and standards efforts in "cloud" transport.

Intended Audience:

This short course is primarily intended for researchers, students, and industry professionals in optical fiber communication that wish to obtain a perspective on the wireline network transport evolution, with particular focus on the implications of cloud service delivery, and SDN/NFV, and DCI technologies. Past attendees of SC386 will find substantial updates and new information, and are welcomed to attend again.

SC428: Link Design for Short Reach Optical Interconnects

Instructor: Petar Pepeljugoski; *IBM Research, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the components of short multimode fiber links.
- Describe the basic elements of power budget and possible trade-offs.
- List suitable models for various components of the link to be used in the design phase.
- Describe multimode fiber propagation, including launch conditions and connector effects.
- Explain impact of signal dependent noises in multimode links.
- List the advantages and disadvantages of advanced modulation formats in short optical interconnects.

Intended Audience:

This beginner-intermediate course is intended for engineers and scientists working on short optical interconnects in data centers as well as those working on components and subsystems interested in developing an expertise in link design. The course also addresses academic researchers and graduate students with basic knowledge on multimode fiber modeling and propagation, and link power budgeting. Some basic understanding of optical communication systems is helpful, but is not a pre-requisite.

This course is a complement to SC205 and SC327.

SC429: Flexible Networks

Instructor: David Boertjes; *Ciena, Canada*
Level: Beginner

Benefits and Learning Objectives:

This course will enable you to:

- Describe electro-optic technologies used for coherent transmission.
- Discuss network implications of electric field transmitters and coherent receivers.
- Describe flexible grid & flexible modulation format.
- Discuss CD and CDC ROADM technologies.
- Describe capacity optimization & network defragmentation.
- Describe SDN Photonic Network and Control architectures.

Intended Audience:

This course is intended for individuals with a working knowledge of ROADM networks and coherent modems. It will be of value for industrial professionals (system designers, managers) who need to understand the tradeoffs of performance and capacity in the design and deployment of optical networks, as well as for researchers who are new to the field.

SC451: Fiber-based Devices and Sensors NEW!

Instructors: Zuyuan He[1], William Shroyer[2]; [1]*Shanghai Jiao Tong University, China*, [2]*SageRider, Inc., USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify basic devices: fiber Bragg gratings, long period gratings, optical fiber interferometers, resonators.
- Describe typical sensors based on above devices: strain/temperature sensors, refractive index sensors (biomedical sensors), hydrophones, gyroscopes.
- Explain multiplexed fiber-optic sensors and sensor networks: wavelength division multiplexing (WDM), time division multiplexing (TDM), frequency division multiplexing (FDM)
- Summarize basic schemes behind space-resolved measurements in distributed fiber-optic sensors: time domain reflectometry (OTDR), optical frequency domain reflectometry (OFDR), optical coherence domain reflectometry (OCDR).
- Measure the scatterings in optical fiber that work for sensing: Rayleigh scattering, Brillouin scattering, and Raman scattering.
- Discuss the trade-offs in performance: spatial resolution vs sensitivity, distance range vs dynamic range; define key limiting factors.
- Identify the value and recognize the future trends of the applications of fiber sensors by discussing the general application of distributed fiber optic sensing in the oil and gas industry with a primary focus on how DTS (distributed temperature sensing) and DAS (distributed acoustic sensing) are being used to monitor wellbore environments.

Intended Audience:

This advanced-beginner course is intended for an audience including not only researchers and engineers working on the development of optical fiber devices and sensors, but also those trying to apply fiber sensors in diverse areas. Some basic knowledge of optics and physics will help in better understanding the course.

Monday, 20 March, 2017

08:30–12:30

SC102: WDM in Long-Haul Transmission Systems

Instructor: Neal S. Bergano; *TE Subcom, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the tradeoffs made in the design of an amplifier chain.
- Summarize the tradeoffs made in the selection of fiber types.
- Describe Q-factor.
- Discuss the concept of margin in fiber optic transmission systems.
- Identify the important polarization effects in long-haul transmission systems.
- Compare the different methods of performing long-haul transmission experiments.
- Discuss circulating loop experiments.
- Discuss the future trends in long-haul transmission systems.
- Discuss the optical propagation of data signals over long distances.

Intended Audience:

This course is intended for the student who wants an understanding of how information is transmitted over long distances using fiber optic transmission lines, with emphasis on undersea cable transmission systems. This includes new entrants into the fiber optic field with an engineering background, engineers with fiber optics exposure, people in the fiber optic telecommunications industry, and fiber optic research and development management.

SC178: Test and Measurement for Data Center/Short Reach Communications

Instructor: Greg D. Le Cheminant; *Keysight Technologies, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Determine the relationships between BER, eye-diagrams and jitter tests.
- Identify common mistakes that degrade measurement accuracy.
- Define how frequency domain analysis provides insights into time-domain performance.
- Identify ways to increase test efficiencies.
- Develop test strategies to verify compliance to industry standards.
- Compare the different approaches to characterizing jitter and recognize what the results imply in a systems context.
- Identify the essential differences between test methods for NRZ and PAM4 signaling formats.

Intended Audience:

This course is appropriate for engineers, technicians and scientists who have a basic or higher knowledge of high-speed communications systems and signals. A basic knowledge of common laboratory measurement instrumentation will be helpful.

SC327: Modeling and Design of Fiber-Optic Communication Systems

Instructor: Rene-Jean Essiambre; *Bell Labs, Nokia, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Develop a functional understanding of the basic building blocks of fiber-optic communication systems.
- Describe the basic nonlinear effects present in optical fibers.
- List the tools used to characterize system performance.
- Develop a detailed understanding on how to model nonlinear transmission over fibers, especially how to navigate through the numerous pitfalls.
- Choose a suitable technique for modeling a specific transmission system.
- Compare the performance of various amplification technologies.
- Understand the basic technical issues encountered when configuring optical networks.
- Understand the Shannon limit and estimate the ultimate rate of transmission of information over optical fibers.

Intended Audience:

This course is intended for engineers and scientists working on fiber-optic transmission as well as those working on components and subsystems interested in developing an expertise at the fiber transmission level. The course also addresses academic researchers and graduate students with basic knowledge on optical or digital communication. It will allow them to develop a detailed knowledge of fiber-optic transmission modeling and understanding system implications of advanced transmission technologies.

SC341: Multi-carrier Modulation: DMT,OFDM and Superchannels

Instructors: Sander L. Jansen[1], Dirk van den Borne[2]; [1]*ADVA Optical Networking, Germany*, [2]*Juniper Networks, Germany*
Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Describe modulation and detection concepts of different multicarrier modulation formats such as orthogonal frequency division multiplexing (OFDM) and discrete multi-tone (DMT).
- List different flavors of multicarrier modulation and detail the advantages and disadvantages of each modulation method.
- Discuss the state-of-the-art research on high capacity transmission systems and explore the limits of technology of multicarrier modulation.
- List the different OFDM design trade-offs, such as cyclic prefix, FFT-size, etc. with respect to for instance the dispersion tolerance and oversampling.
- Explain why DMT is often preferred over OFDM modulation for cost-effective short distance applications.
- Explain the multi-input, multi-output (MIMO) technique that is required to equalize a polarization division multiplexed (PDM) or a mode division multiplexed signal.
- Describe the different multicarrier modulation formats in the context of short-reach DCI and how to leverage the trade-off between optical performance and system complexity / cost.
- Illustrate the advantage of multicarrier modulation in next-generation 400G/1T transport networks.

Intended Audience:

This course is intended for engineers, researchers and technical managers who would like to gain a better understanding of multicarrier modulation formats and their applications in optical transport networks. Apart from the theory and concepts behind multicarrier modulation, the implementation and system design will be discussed in detail, such that the participants can obtain a good level of understanding for the different design trade-offs. Participants should have a comprehensive knowledge in the field of fiber-optic transmission systems; no previous knowledge of multicarrier modulation systems is required.

SC390: Introduction to Forward Error Correction

Instructor: Frank Kschischang; *Univ. of Toronto, Canada*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Define the key parameters of an error-correcting code.
- Explain the system-level benefits provided by FEC.
- Discuss the existence of fundamental limits (Shannon capacity) on FEC.
- Interpret generator-matrix and parity-check-matrix descriptions of a code.
- Encode and decode a binary Hamming code.
- Describe the key parameters of Reed-Solomon codes and binary BCH codes.
- Combine two or more codes into a product-code or concatenation.
- Combine binary FEC with higher-order modulation.

Intended Audience:

Systems engineers, system operators and managers who need to understand the costs and benefits in applying physical-layer error-control coding in a communications link. No previous background in information theory or algebra is assumed.

SC432: Hands on: Silicon Photonics Component Design & Fabrication

Instructor: Lukas Chrostowski; *University of British Columbia, Canada*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Model select silicon photonic components.
- Create compact models for silicon photonic components.
- Use commercial modelling tools (Lumerical Solutions).
- Design a basic silicon photonic circuit.
- Create a silicon photonic layout and submit for manufacturing.
- Analyze experimental data from real measurements.
- Compare modeling with real-life experimental results.

Intended Audience:

This course is targeted for researchers and students who want to learn how to model and design real silicon photonic components. Familiarity with optics and electromagnetics is a prerequisite. No previous silicon photonic design experience is required.

Participants shall bring their own laptop computers, with the required software pre-installed. Licenses and instructions for installing Lumerical Solutions software, and mask layout software, will be provided prior to the course.

SC446: Hands-on: Characterization of Coherent Opto-electronic Subsystems NEW!

Instructors: Harald Rohde and Robert Palmer; *Coriant, Germany*
Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Describe the properties of key optical components for coherent communication systems.
- Be able to measure those properties and to evaluate the results in the right context.
- Describe component specifications and specify components themselves.

Intended Audience:

This course targets researchers and system designers who want to get a better insight into the depths of component properties and to understand the properties' interdependencies.

SC453A: Hands-on Fiber Optic Handling, Measurements, and Component Testing NEW!

Instructors: Chris Heisler[1], Loic Cherel[2], Steve Baldo[3], Keith Foord[4]; [1]*OptoTest Corporation, USA;* [2]*Data-Pixel, France;* [3]*Seikoh Giken Company, USA;* [4]*Greenlee Communications, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the fundamental optical differences and applications of single-mode fiber (SMF) vs. multimode fiber (MMF), including the different fiber types and fiber sizes.
- Identify and overcome typical pitfalls with testing single and multi-fiber connectors.
- Measure insertion loss (IL) and return loss (RL), while also understanding how these measurements can be affected by wavelength and launch conditions.
- Describe polishing process, the steps involved in creating the proper connector end-face, and the effects of this process on connector performance.
- Explain characterization measurements on passive optical components.
- Measure end face geometry and the value of that measurement as it relates to connectivity.
- Make OTDR measurements while avoiding common pitfalls.

Intended Audience:

This course is valuable to technicians, engineers, and managers interested in measurement and characterization of fiber optic components. Some familiarity with fiber optic test cables and equipment is assumed. Class size is limited to 25.

<u>09:00–12:00</u>

SC208: Optical Fiber Design for Telecommunications and Specialty Applications

Instructor: David J. DiGiovanni; *OFS Labs, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain how certain fiber attributes, like attenuation, modal area and dispersion can impact current and next-generation high speed communications technologies.
- Describe the wide array of optical fibers available and discuss how their designs have been engineered for particular applications.
- Compare the benefits of different materials in fiber design, including different glass dopants.
- Discuss the difference between fibers used for different applications, such as transmission fiber, amplifiers, and sensors.
- Determine whether particular applications can benefit from modified or novel optical fiber.
- Explain the potential offered by fiber engineering which may be exploited to improve existing applications or create new functions.
- Discuss how fiber is used in a wide range of applications, including fusion splicing, fiber management and cabling.

Intended Audience:

This course is intended for the technical community seeking to understand the basics of optical fiber and waveguide design and the opportunities to adapt fiber for specific applications. Basic understanding of optical fiber properties is desirable though not required. The course will provide an understanding of the operating principles of fiber while also exploring the limits of waveguide and materials engineering. Specific designs for high speed transmission, optical amplification and fiber lasers will be studied, among others.

SC385: Optical Interconnects for Extreme-scale Computing

Instructors: John Shalf[1], Keren Bergman[2]; [1]*Lawrence Berkeley National Laboratory, USA,* [2]*Columbia University, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe how new computing technologies enable real-world applications.
- Identify trends in high performance computing architecture.
- Describe innovative technologies on the horizon, such as hybrid memory, optical. interconnects, multicore processors and accelerators, and petascale supercomputers.
- Compare technologies and solutions for real-world applications such climate modeling, biological sciences, and materials discovery.
- Identify opportunities for dramatic improvements in performance for data-movement limited applications.

Intended Audience:

This lecture is designed to introduce students how to use parallel computers to efficiently solve challenging problems in science and engineering, where very fast computers are required either to perform complex simulations or to analyze enormous datasets. The lecture is intended to be useful for students from different backgrounds. The presenter has a strong track record of presenting similar tutorials to academic and industrial audiences, and this material will be accessible by researchers, implementers, innovators, and executives.

SC411: Multi-layer Interaction in the Age of Agile Optical Networking

Instructor: Ori A. Gerstel; *Sedona Systems, Israel*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe IP layer behaviors that affect multi-layer networking.
- Explain types of multi-layer interactions (physical integration, control plane, SDN, mgmt plane).
- Define multi-layer functionality (restoration, reoptimization, disaster recovery,…).
- Quantify the value for multi-layer functionality.
- Describe the interaction between IP layer protection and optical restoration.
- Explain how multi-layer interaction affects the planning process.
- Describe how elastic flexgrid networking benefits from multi-layer interaction.
- Discuss possible centralized/distributed control plane architectures and their pros/cons.

Intended Audience:

The audience for this course includes system and network architects and engineers in network operators and equipment vendors, as well as researchers wanting to understand realistic methodologies for modeling multi-layer networks. The course assumes some familiarity with optical network architectures and basic understanding of the role of higher layer networks and how they connect to the optical layer.

SC442: Free Space Switching Systems: PXC and WSS NEW!

Instructor: David Neilson; *Nokia Bell Labs, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify key capablities and performance metrics of optical switching systems.
- Describe the basic design constraits of free space optical switches.
- Identify and understand the various component technologies that are used to construct these switches.
- Discuss future trends in research and product commercialization of optical switching systems.

Intended Audience:

This advanced-beginner course is intended for a diverse audience including lightwave system and sub system researchers and engineers. Some basic knowledge of classical optics such as lenses, gratings and polarization optics will help in better understanding the course but is not a prerequisite.

SC450: Design, Manufacturing, and Packaging of Opto-Electronic Modules NEW!

Instructors: Kevin Williams[1], Arne Leinse[2], Twan Korthorst[3]; [1]*Eindhoven University of Technology, Netherlands*; [2]*LioniX International, Netherlands*, [3]*PhoeniX Software, Netherlands*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify the distinctive features of packaging and testing for optical integrated modules when compared with discrete optical products and integrated electrical systems.
- Identify the different stages of testing, including the building block methodology used in open-access foundry services.
- Determine the origin of impairments using common measurement methods and describe how test methods can be used to push the yield-performance envelope.
- Recognize common assembly techniques and their impact on chip and multi-chip-module layout and test requirements.
- Determine the motivations for using package and assembly techniques from gold box to glob-top, hermetic to non-hermetic, cooled to uncooled.

Intended Audience:

Course participants will likely already be engaged in either optoelectronic product development, optical systems engineering or photonics research. The course should be of relevance to both systems integrators who are considering the deployment of integrated optical modules and technologists developing integrated optical circuits who are keen to improve their understanding of product specification and evaluation.

A Bachelor or Master level physics or engineering education would provide a solid basis for course participation and a background in semiconductor electronics, optoelectronics and optics will be advantageous. This is the first edition of this highly interdisciplinary course.

13:30–16:30

SC261: ROADM Technologies and Network Applications

Instructor: Thomas Strasser; *Nistica Inc., USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the architectures and network level benefits of ROADM systems from earliest systems to most sophisticated deployments being planned today.
- Define the different ROADM architectures competing in the market.
- Summarize the functional differences between competing ROADM architectures, which will succeed in the long term and why.
- Compare the network economic advantages of ROADM networks.
- Compare the incremental cost of a ROADM to the network level savings it enables.
- Discuss the types of networks that most fully benefit from ROADM technology and why.
- Explain why the advantages of ROADM networks position the technology to have a role in all parts of the network, including data centers.

Intended Audience:

Anyone interested in more fully understanding the functionalities and benefits of ROADMs, including students, researchers, engineers, managers, and executives involved in ROADM development, network design, network planning, and network operations.

SC431: Photonic Technologies in the Data Center

Instructor: Clint Schow; *University of California, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Compare the different optical technologies used in data centers today and identify their strengths and limitations.
- Define the requirements for photonic links at different levels of network hierarchy in terms of reach, power, cost, and density.
- Describe the factors that have driven the current implementation of systems and future trends that will drive technologies.
- Discuss research efforts in the worldwide community aimed at increasing the role of photonics in data centers.
- Explain current networking topologies and identify the technology capabilities that drove their adoption.

Intended Audience:

This course is for anyone interested in learning about the underlying technology platforms that underpin the optical networks in data centers. In particular, network engineers involved in designing next-generation systems, researchers working on photonic interconnects and switching, and managers making product decisions will gain insight into the main strengths, limitations, and future prospects of photonic platforms.

Basic knowledge of fiber optic systems, including fiber transmission basics, optical link budgets, and characterization of high-speed links is beneficial but not required.

SC445: Visible Light Communications — the High Bandwidth Alternative to WiFi NEW!

Instructors: Harald Haas; *LiFi Research and Development Centre, The University of Edinburgh, UK*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the limits to conventional WiFi technology and how light can provide massively higher bandwidth.
- Describe key visible light technologies sucvhc as VLC and LiFi.
- Explain practical limitations of VLC communication links such as strong sun light and non-line of sight conditions.
- Compare different digital modulation techniques used in intensity modulation / direct detection systems in terms of spectrum efficiency and energy efficiency as well as various environmental conditions.
- Discuss pros and cons of angular diversity and multiple input multiple output techniques in VLC systems.
- Summarise methods to achieve multiuser access and to support mobility in LiFi optical attocell networks.
- List practical co-channel interference mitigation techniques in LiFi attocell networks.
- Explain how the downlink capacity of optical attocell networks could be obtained taking into account that effects such as fading do not exist unlike in RF.
- Discuss how LiFi could lead to a merger of the lighting and wireless communication industries.

Intended Audience:

This advanced-beginner course is intended for a diverse audience including lightwave system researchers and engineers as well as photonic device researchers and engineers and optical sub-system designers. The course should also be of interst to reseachers and practitioners in fibre optic communication who see an all-optical future where light also plays a major role in wireless access networks. Some basic knowledge of intensity modulation and direct detection techniques will be useful, but is not a prerequisite. The same applies to basic knowldege of wireless access networks.

SC448: An Introduction to the Control and Management of Optical Networks NEW!

Instructor: Ramon Casellas; *CTTC, Spain*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Define and describe the basic concept(s) of a control plane and its associated functions, such as resource discovery, topology management, path computation, signaling, and routing.
- Identify the objectives & key benefits of a control plane, ranging from the well-known dynamicity, reduction of operational expenses, automation of QoS provisioning and recovery, etc., to newer drivers such as modularity, extensibility and programmability.
- Describe common achitectures, including centralized, distributed and hybrid approaches. Describe their applicability in multi-layer and multi-domain networks by composing into hierarchical and peer models. Compare the main advantages and drawbacks of each architecture.
- Detail existing control plane architectures and protocols, ranging from ASON/GMPLS, PCE, to SDN and ONF OpenFlow.
- Recognize and discuss control plane open issues, missing research and standardization gaps such as common information and data models and highlight the role of de jure and de facto standards as well as OpenSource projects.
- Discuss the new trends including the orchestration of network and IT (computing & storage) resources, and of heterogeneous systems and domains (technological, administrative or network segments)
- Explore the basics and the role of Network Function Virtualization (NFV) and its relationship with SDN.

Intended Audience:

This beginner & advanced-beginner course is intended for a diverse audience, including network researchers, architects and engineers, willing to understand the basic concepts, benefits, architectures and protocols behind the notion of control plane, along with its applicability to both single- and multi-domain/layer networks. The course assumes a basic knowledge of networking (e.g. basic IP networking, concepts of packet switching & circuit switching). Some basic knowledge of network control architectures and protocols will help in better understanding the course but is not a prerequisite. The course will also address new trends in both research and product development, such as the integration of SDN / NFV and orchestration of heterogeneous systems.

13:30–17:30

SC160: Microwave Photonics

Instructor: Vince Urick; *DARPA, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Analyze microwave photonic components, subsystems and systems.
- Discuss, relate and contrast analog and digital fiber optics.
- Design optical systems for microwave applications.
- Identify microwave systems which may benefit from utilizing analog optics.

Intended Audience:

The course attendee should have a basic understanding of lasers, photodetectors, and fiber optics. A bachelor's degree in physics or electrical engineering, or an equivalent level of experience, is prerequisite.

SC347: Reliability and Qualification of Fiber-Optic Components

Instructor: David Maack; *Corning, USA*
Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Describe the importance, tools, methodologies, mathematics and benefits of reliability programs.
- List the requirements, tests, benefits and limitations of qualification programs.
- Identify the strategic and tactical differences between qualification testing and reliability modeling.
- Review the multitude of roles, contributions, tools and functions of a reliability group.
- Discuss and learn what constitutes a complete qualification program and get the author's interpretation of the "letter of the law" for the most popular standards.
- See charts comparing different qualification standards.
- Determine why and when reliability testing and modeling needs to be done.
- Describe the limitation of both reliability modeling and qualification testing.
- Explain how to establish appropriate reliability tests and gather meaningful data.
- Compute the reliability of a device using accelerated testing data.
- Identify information on standards, components, reliability software and other reference materials.

Intended Audience:

This course is intended for a general audience including non-technical persons with no particular background except an interest in or need for knowledge of reliability and qualification of photonic components. It is meant to impart valuable information to audiences of all levels.

SC408: Space Division Multiplexing in Optical Fibers

Instructor: Roland Ryf; *Nokia Bell Labs, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Compare space-division multiplexing to other multiplexing techniques, and list key advantages and potential fields of application.
- Summarize key advantages and limitations of different fiber types for space-division multiplexing.
- Explain the origin of coupling or cross-talk between light paths in multi-mode and multi-core fibers.
- Measure components with multiple-input and/or multiple-output ports and extract key parameters like mode-dependent loss and differential group delay.
- List the key principles used to build mode-couplers and how the insertion loss and the mode dependent loss scale as function of number of mode.
- Design optical components that support multiple modes and explain how the basic design differs from single-mode components.
- Describe digital signal processing techniques to calculate bit-error rate and multiple-input multiple-output impulse responses from raw receiver data.
- Discuss strategies to reduce the complexity of the receiver digital signal processing in space-division multiplexed transmission.

Intended Audience:

This course is intended for engineers, scientists, managers, technicians and students who want to understand space-division multiplexing in optical fibers. Basic knowledge of optics is assumed and basic math knowledge in linear algebra and differential equations is suggested. By the end of the course, the presented techniques will allow the partecipant to design and analyse simple space-division multiplexed systems.

SC449: Hands-on: An introduction to Writing Transport SDN Applications NEW!

Instructors: Ricard Vilalta[1], Karthik Sethuraman[2];
[1]*CTTC, Spain*, [2]*NEC Corporation of America, USA*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Learn and use the necessary open source tools to review and modify models for SDN control of transport networks.
- Develop simple code implementing the models and its applications in a standard REST-based protocol.
- Obtain practical hand-on experience on UML, YANG and JSON for the design of future REST-based interfaces for Control of Carrier Transport Networks.
- Discuss ONF Transport API information model and how to use it for describing multi-domain, multi-technology scenarios.
- Describe ODL/ONOS northbound REST API, and how it might be used to establish T-API connectivity services.

Intended Audience:

This course is targeted for industry and academic researchers who want to learn how to develop SDN Northbound Interfaces focused on Transport SDN and consume the APIs to write applications.
The participants shall bring their own laptop computers, including a pre-loaded virtual machine with all the necessary open source tools.

SC452: FPGA Programming for Optical Subsystem Prototyping NEW!

Instructors: Noriaki Kaneda[1], Laurent Schmalen[2];
[1]*Nokia Bell Labs, USA*, [2]*Nokia Bell Labs, Germany*
Level: Advanced Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Identify key applications and approaches of FPGA prototyping in optical subsystems.
- Describe the key functionalities and capabilities of FPGAs for intended prototyping applications.
- Describe the software and hardware architecture required to synchronize the multiple FPGAs and data converters (ADCs and DACs).
- Define the difference between concurrent and sequential systems in hardware description languages.
- Define the workflow of FPGA projects for implementation ready bit files.
- Design the architecture and write basic codes in hardware description languages to realize selective DSP functionalities.
- Discuss the use of FPGAs and GPUs as simulation utilities for performing low error-rate Monte-Carlo simulations.
- Compare various options for simulating SD-FEC codes and performing error floor analysis using FPGAs and GPUs.

Intended Audience:

The course is intended for the students and engineers who have background and experience in optical subsystems and optical testing but a beginner in the FPGA programming and FPGA prototyping of optical subsystems. The course is intended to give insights to participants on FPGA programming by going through materials that give near hands-on experience. Most of the materials are related to FPGA prototyping of Digital Signal Processing (DSP) and also Forward Error Correction (FEC) algorithms used in coherent optical transceivers.

SC453B: Hands-on Fiber Optic Handling, Measurements, and Component Testing NEW!

Instructors: Chris Heisler[1], Loic Cherel[2], Steve Baldo[3], Keith Foord[4]; [1]*OptoTest Corporation, USA;* [2]*Data-Pixel, France;* [3]*Seikoh Giken Company, USA;* [4]*Greenlee Communications, USA*

Level: Beginner

Benefits and Learning Objectives:

This course should enable you to:

- Explain the fundamental optical differences and applications of single-mode fiber (SMF) vs. multimode fiber (MMF), including the different fiber types and fiber sizes.
- Identify and overcome typical pitfalls with testing single and multi-fiber connectors.
- Measure insertion loss (IL) and return loss (RL), while also understanding how these measurements can be affected by wavelength and launch conditions.
- Understand the polishing process, the steps involved in creating the proper connector endface, and the effects of this process on connector performance.
- Explain characterization measurements on passive optical components.
- Measure end face geometry and the value of that measurement as it relates to connectivity.
- Make OTDR measurements while avoiding common pitfalls.

Intended Audience:

This course is valuable to technicians, engineers, and managers interested in measurement and characterization of fiber optic components. Some familiarity with fiber optic test cables and equipment is assumed. Class size is limited to 25.

SC454: Hands-on: Silicon Photonic Circuits and Systems Design NEW!

Instructors: Lukas Chrostowski[1],Chris Doerr[2], [1]University of British Columbia, Canada, [2]Acacia Communications, USA

Level: Intermediate

Benefits and Learning Objectives:

This course should enable you to:

- Describe common silicon photonic integrated designs.
- Describe how compact models for silicon photonic components are created.
- Explain how to use compact models to model silicon photonic circuits.
- Use commercial modelling tools (Lumerical Solutions).
- Design a basic silicon photonic circuit.
- Design a silicon photonic layout.
- Identify packaging requirements for silicon photonic chips.

Intended Audience:

This course is targeted for researchers and students who want to learn how to model and design silicon photonic circuits. Familiarity with optical communications is a prerequisite. No previous silicon photonic design experience is required.

Participants shall bring their own laptop computers, with the required software pre-installed. Licenses and instructions for installing Lumerical Solutions, and mask layout software, will be provided prior to the course.

NOTES

What's Happening on the Show Floor?

The OFC exhibit floor 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. 600+ exhibits showcase the entire continuum of the supply chain – from communications systems and equipment to network design and integration tools and to components and devices. In addition to the 600+ exhibits, three exhibit hall theaters feature presentations by experts from major global brands and key industry organizations. Learn about the state of the industry, emerging trends and recommended courses of action for how to tackle today's toughest business challenges.

Exhibition

Exhibit Halls G-K

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 the express 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 set-up and teardown.
- 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 set-up and tear-down.

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 in the Exhibit Hall at these times:

	Exhibit Hours	Coffee Breaks
Tuesday, 21 March	10:00–17:00	10:00–10:30, 16:00–16:30
Wednesday, 22 March	10:00–17:00	10:00–10:30, 15:00–15:30
Thursday, 23 March	10:00–16:00	10:00–10:30, 15:00–15:30

Market Watch, *Exhibit Hall G, Expo Theater I* *Sponsored by* HUAWEI

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. See page 40 for schedule and complete information.

Network Operator Summit, *Exhibit Hall G, Expo Theater I* *Sponsored by* JUNIPER NETWORKS

Join your colleagues for this dynamic program that presents the inside perspective from service providers and network operators — their issues, drivers and how their requirements may impact the future of the industry. The program features a keynote speaker and 2 panel discussions.

Other Show Floor Programming, *Exhibit Hall, Expo Theaters II and III* *Expo Theater II Sponsored by* JUNIPER NETWORKS

More than 15 sessions will be held in these theaters covering Intra- and Inter- Data Center Connectivity, Infrastructure Makeover and Networking and SDN/NFV/Open Source. Hear leading experts from many industry groups: COBO, Ethernet Alliance, IEEE Big Data, IEEE Cloud Computing, MEF, OCP, OIF, ONF, OpenConfig, POFTO and TIP.

Product Showcases, *Exhibit Hall K, Expo Theater III*

Exhibitors highlight their newest developments, products and services in 30-minute presentations on the show floor. Refer to page 46 or the OFC Mobile App for presentation schedule.

Poster Presentation, *Exhibit Hall K*

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. See pages 106-109 and 134-137 for abstracts of presentations.

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 Mobile App for regular updates to show floor programming *(see page 8 for details on the app).*

Show Floor Programming and Activities

Expo Theater I, Exhibit Hall G

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.

N5: Network Operator Summit and Market Watch Sub-Committee Chair and Organizer: Lisa Huff, *Discerning Analytics, USA*

Sponsored by:

HUAWEI

Schedule-at-a-Glance

Tuesday, 21 March	
10:30–12:00	**Panel I: State of the Industry — Analyst Panel**
12:30–14:00	**Panel II: Market Outlook for High Bandwidth Optical Technologies**
14:30–16:00	**Panel III: Global Market for Subsea Fiber Optic Networking Applications**
Wednesday, 22 March	
15:30–17:00	**Panel IV: Pluggable Optics – How is the Ecosystem and Value Chain Changing?**
Thursday, 23 March	
10:30–12:00	**Panel V: Photonic Integration Business Case – Reality Check**
12:30–14:00	**Panel VI: SDN and Optics – What is the Business Case?**

Panel I: State of the Industry - Analyst Panel

Moderator: Jim Theodoras, *VP of Global Business Development, ADVA Optical Networking AG, USA*

This Market Watch panel is one of the most highly attended panels at OFC. Industry and financial analysts give their views of the optical communications markets. Both historical data and forecasts will be included. Top trends in all markets will be presented with a focus on specific market data points that are helpful to a wide audience. The entire optical communications value chain will be represented – components, equipment and services.

Panelists:

Alex Henderson; *Senior Analyst, Networking Technology & Optical Equipment, Needham & Company, USA*

Vladimir Kozlov; *Founder and CEO, LightCounting, USA*

Kevin Lefebvre; *Principal Analyst, Ovum, USA*

Mark Rostick; *Director, Intel Capital, USA*

Jimmy Yu; *VP of Optical Transport Market Research, Dell 'Oro Group, USA*

Panel II: Market Outlook for High Bandwidth Optical Technologies

Moderator: Tiejun Xia; *DMTS, Verizon Communications, USA*

The industry is quickly moving beyond current "standard" optical bandwidth, which is represented by 32GBaud. With advancement in electro-optic and DSP components using higher symbol rate transmission, up to 64GBaud has been proved to be a feasible technology and will be commercially available soon. The new high-optical bandwidth technology will significantly decrease the number of components inside modules and systems, moderately increase spectral efficiency by removing guard bands in superchannels, and meaningfully reduce module sizes, power consumption and costs. With this technology, fewer optical carriers are needed to provide 100Gb/s, 200Gb/s and 400Gb/s data equipment interfaces. And to support transport channels, for example, single carrier 400Gb/s-channels will be available. The technology also provides an opportunity to have multiple symbol rates in a module, so that the concept of "liquid bandwidth" can truly be realized. Thus giving the optical channel adaptability that is optimized according to transmission conditions by adjusting its modulation format and symbol rate.

This Market Watch session will provide an overview of market outlook and real benefits of high optical bandwidth technology, review its influence to development in other technology sections, such as high-speed backplane, and address some related challenges in product development, such as high sampling rate. The session will also give a preview of technologies and markets beyond 64 Gaud.

Panelists:

Adam Carter; *Chief Commercial Officer, Oclaro, USA*

Hideki Isono; *Market Segment Director, Fujitsu Optical Components, Japan*

Ron Johnson; *Sr. Director of Architecture and Product Management, Cisco Systems, Inc., USA*

Atul Srivastava; *Chief Technology Officer, NTT Electronics America, USA*

Winston Way; *CTO, Systems, NEOPhotonics Corp, USA*

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Panel III: Global Market for Subsea Fiber Optic Networking Applications

Moderator: Eve Griliches; *Product Line Manager, Cisco Systems, Inc., USA*

Submarine optical networks form the backbone of global communication networks that connect different continents and countries. Conventional submarine networks are mainly for long distance point-to-point links. The rapid growth of the dynamic Internet traffic and IoT services not only lead to exponential bandwidth demand, but also require the network to be more flexible. As a result, submarine optical networks are evolving from the conventional static networks to more flexible ones with different distances and bandwidth requirements. Furthermore, new subsea fiber optic networking applications, such as sensing, scientific observation, security, and oil/gas exploration and production, are adding the opportunities and challenges for subsea fiber optic networks.

This Market Watch session will provide an overview of various technologies and applications in subsea fiber optic networking, such as:

- Trans-oceanic high bandwidth data communication.
- Reconfigurable submarine optical networking and switching.
- Sensing and monitoring of subsea physical structures and systems.
- Control and data transmission between offshore and onshore oil/gas facilities and in subsea tieback system.
- Infrastructure security monitoring and intrusion detection.
- Ocean bottom scientific observation and environmental exploration.

Speakers:

Lisa Bickford; *Sr. Program Manager, Google, Inc., USA*

Rao Lingampalli; *Sr. Manager Optical Network Architecture, Equinix, USA*

Georg Mohs; *Sr. Director System Design and PLM, TE Subcom, USA*

Takaaki Ogata; *Assistant General Manager, NEC Corporation, Japan*

David Smith; *SVP of Network Operations, Hibernia Networks, USA*

Panel IV: Pluggable Optics – How is the Ecosystem and Value Chain Changing?

Moderator: Frank Chang; *Principal Engineer-Optical, Inphi Corp, USA*

Large data centers interconnect bottlenecks are dominated by the switch I/O BW and the front panel BW as a result of pluggable transceiver modules. Recently 50G and beyond transceivers have been developed that significantly reduce power, footprint and cost for three major types of connections: intra- and inter-datacenter, transport client, and metro/access. The detailed designs of the pluggables, however, have many flavors such as: four-wave or four-fiber 28GBd NRZ, two-wave 28GBd PAM4, single-wave 56GBd PAM4, or single-wave DMT, and so on. At the same time, to overcome the front panel BW and the switch ASIC BW limitation one approach is to either move the optics onto the mid-plan or integrate the optics into the switch ASIC. There are many new MSAs in progress to be considered as well including CFP8, QSFP56, QSFP-DD, SFP56 and so on, or even chip on boards directly.

This panel of industry experts will strive to determine the potential winning technology from the wide variety of options as well as answer the following questions:

- What's the realistic price to expect for 100G pluggable to enable mass adoption?
- Is the cost of a $1/Gb/s for high-speed transceivers ultimately achievable in foreseeable future and what will vendor margins look like?
- How can the market serve a reach distance of 2km at one end and 40/80km at the other?
- What are the lessons learned of deploying the PAM4 versus NRZ pluggables?
- Will various demands of different types of data center operators be adequately accommodated with standardized vs. proprietary solutions?
- When will a new 200 & 400G pluggable be commercialized and how much will it cost?
- What's the status of 100G coherent CFP2 and CFP4 pluggable modules?

Speakers:

Bardia Pezeshki; *CEO, Kaiam Corporation, USA*

Chris Pfistner; *VP of Product Line Management, Datacom, Lumentum, USA*

David Piehler; *Sr. Principal Engineer, Dell EMC, USA*

Katharine Schmidtke; *Optical Technology Strategy, Facebook, USA*

Sorin Tibuleac; *Director of System Architecture, ADVA Optical Networking, USA*

Panel V: Photonic Integration Business Case – Reality Check

Moderator: Rick Dodd; *SVP of Open Architecture, Ciena, USA*

Driven by 100Gbps in long haul as well as in data center applications, there is continued progress for companies to commercialize products based on integrated photonics on the InP, GaAs and Silicon platforms. InP and GaAs technologies have dominated the market over the last decade, and recently we have seen successes by vendors to ship integrated products using silicon photonics. This panel brings together experts from key players and continues to

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review the start of the art in photonic integration with a focus on deployment scenarios for both telecom and datacom.

It aims to address the key questions as follows:

- What are the key challenges to realize the high volume and low cost?
- Which technologies offer the best approach to reduce the cost for manufacturability?
- Will Silicon Photonics ever replace the more mature InP and GaAs technologies?
- What are the lessons learned from the experience of deployment?
- How does photonic integration address the emerging application needs?
- Are there any new and noteworthy products being commercialized today?
- What is the status of new developments and standardization of packaging solutions?
- Where are the market opportunities for optical integration technologies?
- How does the outlook or roadmap look like for next 5 years?

Speakers:

Martin Guy; *Sr. Director, Packet Optical Platforms, Ciena, Canada*

Frederick Kish Jr.; *Sr. VP of Optical Integrated Circuit Group, Infinera Corporation, USA*

Radha Nagarajan; *CTO, Optical Interconnect, Inphi Corporation, USA*

James Regan; *CEO, EFFECT Photonics B.V., Netherlands*

Tom Williams; *Sr. Director of Marketing, Acacia Communications, USA*

Panel VI: SDN and Optics – What is the Business Case?

Moderator: Sterling Perrin; *Sr. Analyst- Optical Networking & Transport, Heavy Reading, USA*

The optics industry was one of the first to seize onto the SDN trend, once it moved out of its campus/data center origins. But, translation from optical layer technical work into operator field trials and real-world deployments has been slow relative to other areas, such as in Ethernet and routing. Still, global operator interest in bringing the benefits of SDN down to the optical layer remains high.

This session is designed to move beyond the hype, focus on the optical layer, and assess the real world business benefits of combining SDN and optics.

Some of the questions addressed in this panel will include:

- Of the various optical layer use cases have been floated over the past three years, which ones are showing the most real promise today?
- What role will SDN play in functional disaggregation of optical equipment?
- How do we use SDN to control and manage the overall network – packet layer, OTN and DWDM?
- What are the primary benefits of multilayer optimization and restoration?
- What SDN lessons can telcos/cable companies take from Web 2.0 providers, and where is the path forward decidedly different?
- Does SDN really breathe new life into IP+optical integration or will the next decade look a lot like the last?

Speakers:

Chris Janz; *Technical VP Transmission Product Line, Huawei, Canada*

Thomas Mueller; *Director for Optical & Transport Network Architecture, Juniper Networks, USA*

Steve Vogelsang; *Vice President, Strategy & CTO, IP/Optical Networks, Nokia, USA*

Bill Walker; *Director of Network Architecture – SDN/NFV/Cloud, CenturyLink, USA*

Network Operator Summit (formerly the Service Provider 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: Network Operator Summit and Market Watch Sub-Committee Chair and Organizer: Lisa Huff, *Discerning Analytics, USA*

Sponsored by: JUNIPer NETWORKS

Schedule-at-a-Glance

Wednesday, 22 March

10:00–10:30	**Coffee Break** *Sponsored by Juniper Networks*
10:30–11:00	**Network Operator Summit Keynote**
11:00–12:30	**Panel I: Next-Generation Access and Metro – Where is the Money?**
12:30–13:30	**Networking Lunch** *Sponsored by Juniper Networks*
13:30–15:00	**Panel II: Optical Mobile Network Access**
15:00–15:30	**Coffee Break** *Sponsored by Juniper Networks*

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Keynote Presentation

China Telecom's View of the All Optical Network
Chengliang Zhang, *Vice President, China Telecom Beijing Research Institute, China*

Optical network technologies develop rapidly in China. Revenues from optical products in China account for roughly half of the worldwide market and include systems, devices, components and fiber. Nowadays, with the massive deployment of 100G, FTTx and ROADM devices, the "all optical" target has never been closer. Meanwhile, challenges have arisen. The continuous growth of traffic from data centers and residential users has pushed the optical network needs to 400G for backbone and 10G PON for access. The next generation 5G mobile networks cannot exist without novel optical solutions to carry its backhaul and fronthaul. This presentation will focus on the current deployment situation of the optical network in China Telecom as well as future goals to meet new services' requirements.

Panel I: Next-Generation Access and Metro – Where is the Money?

Moderator: Julie Kunstler; *Principal Analyst, Ovum Inc, USA*

Next-gen EPON is shipping with deployments in North America, China and Japan. XGS-PON has been pushed through the standardization process at lightning speed with initial shipments underway. Next-gen PON has been touted to support the 1G bandwidth craze, MDUs and business services.

Will next-gen PON lead to better profitability for both service providers and vendors? Will next-gen PON become an access solution, meaning shipments in the millions?

Some of the questions addressed in this panel will include:

1. Standards progress – both IEEE and ITU
2. Ecosystem status – are the pieces ready – from components to software
3. Applications for next-gen PON
4. Challenges for next-gen PON
5. What are the forecasts for next-gen PON components and equipment?
6. Profitability in the ecosystem – who will make money and why?

Speakers:

Eddy Barker; *Assistant VP - Member of Technical Staff, AT&T, USA*

Robert Howald; *VP of Network Architechture, Comcast, USA*

Chengbin Shen; *Professor, Shanghai Institute of China Telecom, China*

Ken-Ichi Suzuki; *Group Leader (Senior Research Engineer, Supervisor), NTT Access Network Service Systems Laboratories, NTT Corporation, Japan*

Panel II: Optical Mobile Network Access

Moderator: Željko Bulut, *Product Line Manager, Coriant, USA*

Fixed-Mobile convergence (FMC) has been touted for years as saving capex, opex and simplifying network management. Concurrently, IoT is regarded as a major stimulus for 5G, creating demand for small cells throughout indoor and outdoor urban areas.

Fiber-based metro and access solutions are positioning themselves to support the massive amount of data to be backhauled as IoT ramps.

Will FMC finally happen? Will the two worlds find a common language?

Some of the questions addressed in this panel will include:

1. Will IoT drive Optical Mobile Network Access?
2. What are service providers seeking in terms of solutions?
3. Who are the ecosystem vendors? Who will benefit and why?
4. Are standards needed?
5. How do mobile backhaul and fronthaul need to change to support applications like IoT?

Speakers:

Ray La Chance; *President/CEO, ZenFi, USA*

Tim Doiron; *Principal Analyst, Intelligent Networking practice, ACG Research, USA*

Hyung-Jin Park; *Project Manager, Principal Senior Researcher, Infra Lab, KT R&D Center, South Korea*

Glenn Wellbrock; *Director, Optical Transport Network - Architecture, Design & Planning, Verizon Communications Inc., USA*

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Expo Theater II Programming, *Exhibit Hall K*

Sponsored by Juniper Networks

Schedule-at-a-Glance

Tuesday, 21 March	
10:15–11:45	**OCP: Transforming the Future of Data Centers**
12:15–13:45	**Data Center Summit**
14:00–17:00	**Advancing Optical Interoperability in Open Networks** *Session Sponsored by Juniper*
Wednesday, 22 March	
10:15–11:45	**COBO: On-board Optics — Challenges, Discoveriers and the Path Forward**
12:00–13:30	**Open Config: Open Management and Monitoring of Multilayer Webscale and Carrier Networks**
13:45–15:15	**IEEE Big Data Initiative: Network Analytics in the Next-Generation Optical Transport**
15:30–17:00	**IEEE Cloud Computing: How will Fog Reshape Computing and Networking**
Thursday, 23 March	
10:15–11:45	**TIP: Open Packet DWDM**
12:00–13:30	**ONF: The Path Forward**
15:00–16:00	**Transport SDN: Commercial Applications, Solutions and Innovation Areas**

Transforming the Future of Data Centers

Session organized by OCP
Moderator: Hans-Juergen Schmidtke, *Director of Engineering, Facebook, USA*

Presenters:

Open Network Hardware and Software: Anatomy of Disaggregation
Oleg Berzin, *Sr. Director Technology Innovation, Equinix, USA*

Title TBD
Gaya Nagarajan, *Network Engineering and Architecture, Facebook, USA*

Our Experiences with Datacenter Network Deployments
Srinivasan Ramasubramanian, *Chief Architect, Big Switch Networks, USA*

Data Center Summit: Next Generation Optical Technologies Inside the Data Center

Moderator: Lisa Huff, *Principal Analyst, Discerning Analytics, USA*

Presenters:

Silicon Photonics and the Future of Optical Connectivity in the Data Center
Robert Blum, *Director of Strategic Marketing and Business Development, Intel, USA*

Defining the Link
Mike Connaughton, *Market Segment Manager, Nexans, USA*

Optical Form Factor for Next Generation 400G Switching
Raju Kankipati, *Product Manager, Arista Networks, USA*

Datacenter Requirements on Next Generation Optical Interconnect Technologies
Chongjin Xie, *Senior Director & Chief Optical Network Architect, Alibaba, USA*

Advancing Optical Interoperability in Open Networks

Session Sponsored by Juniper
Moderator:

The following experts will participate in panels and presentations in an interactive setting with the audience:

Nestor Garrafa, *Capacity Planning Senior Consultant, Telxius Cable (A Telefonica Company), USA*

Mike Sabelhaus, *Optical Architect, Fujitsu, USA*

Madhu Krishnaswamy, *Senior Director, Product Line Management, Transport Node, Lumentum, USA*

Domenico DiMola, *Vice President, Optical Engineering, Juniper Networks, USA*

Rehan Zaki, *Senior Optical Product Line Manager, Juniper Networks, USA*

Peter Landon, *Director, Optical Product Line Management, Juniper Networks, USA*

Xiaoxia Wu, *Optical Engineering Staff, Juniper Networks, USA*

On-Board Optics – Challenges, Discoveries and the Path Forward

Session organized by COBO

Presenters:

Robert Blum, *Director of Strategic Marketing and Business Development, Intel, USA*

Ed Frlan, *Senior System Architec, Semtech, USA*

Hugues Tournier, *Senior Manager, Power and Signal Integrity, Ciena, USA*

Nathan Tracy, *Technologist, TE Connectivity, USA*

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Open Management and Monitoring of Multilayer Webscale and Carrier Networks
Session organized by Open Config
Moderator: Steve Plote, *Optics Consulting Engineer, Nokia, USA*

Presenters:

Jaime Gaudette, *Manager, Optical Network Architecture and Development, Microsoft, USA*

Tad Hofmeister, *Network Architect, Google, USA*

Kristian Larsson, *Senior Expert IP Routing & System Management for Terastream, Deutsche Telekom, Sweden*

Dave Miedema, *Senior Technical Advisor, Ciena, USA*

Sushin Suresan, *Product Manager, Engineering, Cisco, USA*

Network Analytics in Next-Generation Optical Transport
Session organized by IEEE Big Data Initiative
Moderator: Loukas Paraschis, *Senior Director Data-Center Transport, Infinera, USA*

Presenters:

Jamie Gaudette, *Manager of Optical Network Architecture and Development, Microsoft , USA*

Anees Shaikh, *Network Architect, Google, USA*

How will Fog Reshape Computing and Networking
Session organized by IEEE Cloud Computing
Moderator: Douglas Zuckerman, *Past President, IEEE Communications Society, USA*

Presenters:

Adam Drobot, *Chairman of the Board, OpenTechWorks, Inc., USA*

Jeff Fedders, *Chief Strategist, Intel Corporation, President of OpenFog Consotrium, USA*

Tao Zhang, *Cisco Systems, Board Director of OpenFog Consortium, USA*

Open Packet DWDM
Session organized by TIP
Moderator: Steve Vogelsang, *Vice President, Strategy & CTO, IP/Optical Networks, Nokia, USA*

Presenters:

Realize Whitebox Networking Gear with Opensource Solutions
Hari Gollapalli, *Director Software Engineer, Snaproute, USA*

Voyager: Toward Open DWDM Transport
Ilya Lyubormirsky, *Optical Engineer, Facebook, USA*

Open Optical Line Systems
Matthew Mitchell, *Vice President of Optical Systems Architecture, Infinera, USA*

The Optical White Box: An Enabler for Open Networking
Raj Nagarajan, *Senior PLM, Lumentum, USA*

Title TBD
Hans-Juergen Schmidtke, *Director of Engineering, Facebook, USA*

ONF: The Path Forward
Session Organized by ONF
Moderator: Steve Plote, *Optics Consulting Engineer, Nokia, USA*

Presenters:

New ONF - Create Open Source and Standards to Accelerate SDN Adoption
Guru Parulkar, *Executive Director of ON.Lab and ONF, USA*

E-CORD: Zero Touch Provisioning for the Enterprise
Marc De Leenheer, *Member of Technical Staff, ON.Lab, USA*

ONF Transport APIs: Advancing Programmability of Transport Networks
Karthik Sethuraman, *Software/SDN Architect, NEC, USA*

SDN and NFV on the Path Towards a Dynamic, Programmable 5G Network
Oguz Sunay, *Chief Technology Officer, Argela, USA*

Transport SDN: Commercial Applications, Solutions and Innovation Areas
Session organized by Huawei

Presenter:

Christopher Janz, *Technical Vice-President, Transmission Product Line, Huawei, China*

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Expo Theater III Programming, *Exhibit Hall K*

Schedule-at-a-Glance

Tuesday, 21 March	
10:15–10:45	**Product Showcase** **DWDM to the Edge** *Huawei USA*
11:00–12:00	**Ethernet Alliance: The Fracturing and Burgeoning Ethernet Market**
12:30–13:30	**MEF: Dynamic Third Network Services for the Digital Economy and Hyper-connected World**
13:45–14:45	**OIF: Enabling Next Generation Physical Layer Solutions**
15:00–16:00	**OIF Interop - The Key to Unlocking the Benefits of SDN**
16:00–17:00	**International Photonic Systems Roadmaps**
Wednesday, 22 March	
10:15–10:45	**Product Showcase** **Innovative OTN Cluster Solution for Cloud Era Transport Networks** *Huawei USA*
11:00–11:30	**Product Showcase** **Industries Standard for Pic's Design** *PhoeniX Software*
11:30–12:00	**Product Showcase** **Challenges in Optoelectronic Integration for Datacom Applications** *Jabil AOC Technologies, USA*
13:00–13:30	**Product Showcase** **Industry's Only All-in-One Spectral & Transport 100G Testing Solution** *EXFO, Canada*
13:30–14:00	**Product Showcase** **400GE from Hype to Reality,** *Xilinx, Inc., USA*
14:00–14:30	**Product Showcase** **400G P4 Programmable Packet Processing for NFV/SDN** *Xilinx, Inc.*
14:30–15:00	**Product Showcase** **Emerging Integrated Optics Based Solutions for Data Center Interconnect** *ColorChip*
Thursday, 23 March	
10:15–10:45	**Product Showcase** **Huawei T-SDN OVPN Solution** *Huawei USA*
11:00–13:00	**POFTO: POF Symposium**
13:30–14:30	**Huawei: Technological Evolution of Next Generation Connect**

Product Showcase
DWDM to the Edge

Dr. Sean Long, *Director, PLM for Transmission Network, Huawei USA, USA*
Tuesday, 21 March, 10:15–10:45

Bandwidth and latency are become critical factors for the new digital services. DWDM to the edge is the best solution to address this concern. The key challenges here are cost and flexibility. Huawei believe DWDM to OLT/Cloud BBU site is a MUST for a future proof network. This presentation introduce our revolutionary solution and latest applications such as CRAN.

The Fracturing and Burgeoning Ethernet Market

Session organized by the Ethernet Alliance
Moderator: *John D'Ambrosia, Ethernet Alliance Chairman, USA*

Presenters: TBD

Dynamic Third Network Services for the Digital Economy and Hyper-connected World

Session organized by the MEF

Presenter:

Ralph Santitoro, *Distinguished Fellow and Director, MEF, Head of SDN/NFV Solutions Practice, Fujitsu Network Communications, USA*

Enabling Next Generation Physical Layer Solutions

Session organized by OIF
Moderator: Steve Sekel, *OIF Physical and Link Layer Interoperability Working Group Chair, Keysight Technologies, USA*

Presenters:

Ed Frlan, *OIF Technical Committee Vice Chair, Semtech, USA*

Karl Gass, *OIF Physical and Link Layer Working Group - Optical Vice Chair, USA*

Tad Hofmeister, *Network Architect, Google, USA*

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OIF Interop – The Key to Unlocking the Benefits of SDN

Session organized by OIF
Moderator: Dave Brown, *Director, Optical Networking Product Marketing, Nokia; Board Member and Vice President of Marketing, Optical Internetworking Forum (OIF), USA*

Presenters:

Victor Lopez, *Technology Expert, Telefonica, USA*

Lyndon Ong, *OIF Market Awareness & Education Co-Chair-Networking, Ciena, USA*

Jonathan Sadler, *OIF Technical Committee Vice Chair, Coriant, USA*

International Photonic Systems Roadmaps

Session organized by IPSR and OIDA
Session Chair: Robert Pfahl, *Roadmapping Director, IPSR, USA*

Presenters:

Wilmer Bottoms, *Co-Chair, Heterogeneous Integration Roadmap (HIR), USA*

Thomas Hausken, *Senior Advisor, OSA-OIDA, USA*

Tom Marrapode, *Director of Advanced Interconnect Technology, Molex, USA*

Peter O'Brien, *Tyndall Institute, Ireland*

Robert C. Pfahl, *Roadmapping Director, IPSR, USA*

Product Showcases

Innovative OTN Cluster Solution for Cloud Era Transport Networks

Nagaraja Upadhya, *Vice President, Fixed Network Product & Solutions, Huawei Technologies USA, Inc., USA*
Wednesday, 22 March, 10:15–10:45

Massive enterprise Cloud applications, VR/AR, Real time Video are driving need for huge capacity, lower latency, flexibility and agility in networks.

As global industry leader, Huawei's Optical innovation Engine continues to drive new solutions such as OTN Cluster that bring huge capacity, smooth scalability, seamless flexibility, cloud era Agility and dynamic capabilities to the transport network.

Industries Standard for Pic's Design

Mitch Heins, *North America Business Development, PhoeniX Software, The Netherlands*
Wednesday, 22 March, 11:00–11:30

The push for greater bandwidth density communications is driving the Industry to integrated solutions using PIC's. PhoeniX Software provides software / services that enable the creation and verification of such complex systems. Learn about the state-of-the-art in design flows and methodologies for integrated photonic and advanced photonic synthesis.

Challenges in Optoelectronic Integration for Datacom Applications

Larry Tarof, *Chief Photonics Scientist, Jabil AOC Technologies, USA*
Wednesday, 22 March, 11:30–12:00

Significant challenges remain in realizing the zettabyte world, which, although market driven, is achievable only through lower cost and greater density. Successful integration paradigms, which must take into account choice of optoelectronic/electronic components, thermal/RF/alignment/coupling at the packaging level, and end-to-end testing solutions, are explored.

Industry's Only All-in-One Spectral & Transport 100G Testing Solution

Jean-Sebastien Tassé and Jean-Marie Vilain, *Product Line Managers*
EXFO, Canada
Wednesday, 22 March, 13:00–13:30

This product showcase will reveal the industry's only and all-in-one 100G commissioning, turn-up and troubleshooting testing solution on a single, versatile platform. EXFO's new FTB-4 Pro platform 4-slot format enables true test orchestration through the unique combination of the FTBx-88200NGE 100G Multiservice tester with iOptics transceiver validation and the Optical Spectrum Analyzer - without the need to swap modules.

400GE from Hype to Reality

Mark Gustlin, *Principal System Architect*
Xilinx, Inc., USA
Wednesday, 22 March, 13:30–14:00

400GE is the new Ethernet speed on the block set to finally become a reality in 2017 after much hype, discussion and standardization effort. This presentation will explore the realities of the 400GE ecosystems, deployment models and why the time for 400GE has arrived.

400G P4 Programmable Packet Processing for NFV/SDN

Harpinder Matharu, *Director of Communications Strategic & Technical Marketing, Xilinx, Inc., USA*
Wednesday, 22 March, 14:00–14:30

This presentation discusses the adoption of P4, the emergent high-level language for packet processing, and will also discuss a record breaking 400 Gb/s line rate implementation built on two programmable technologies – a Xilinx FPGA and a MoSys programmable search engine.

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Emerging Integrated Optics Based Solutions for Data Center Interconnect
Yigal Ezra, *CEO, ColorChip, Israel*
Wednesday, 22 March, 14:30–15:00

ColorChip's unique approach to addressing datacenter requirement for increasing throughput, embraces a multilane Photonic Integrated Circuit, compatible with compact form factors.

This is a groundbreaking integration and packaging technique, used in ColorChip's 100G QSFP28 Single Mode solutions and will be used in ColorChip's 400G roadmap, resulting in cost-effective, compact hyper-scale single-mode, pluggable transceivers and On Board Optics (OBO).

Huawei T-SDN OVPN Solution
Dr. Young Lee, *Technical Director, Network Architecture of SDN, Huawei USA*
Thursday, 23 March, 10:15–10:45

Massive enterprise Cloud applications, VR/AR, real time video are driving need for huge bandwidth, lower latency, flexibility and agility in networks.

Huawei's Optical innovation Engine drives new innovative solutions that address these needs & challenges. This presentation introduces our OTN Cluster & OXC 2.0 that flatten network architecture, bring smooth scalability, and improve flexibility of service while reducing latency.

POF Symposium

Session organized by POFTO
Organizer and Program Chair: Hui Pan, *Chief Economist, POFTO, USA*

Keynote:

Status of GI POF towards Noise-Free 8K Data Transmission
Yasuhiro Koike, *Director, Keio Photonics Research Institute and Professor, Keio University, Japan;* Azusa Inoue, *Keio University, Japan*

Presenters:

IEEE Standards on POF Technology in Automotive Applications
Yoshihiro Tsukamoto, *Manager, Plastic Molding Material Department, Fiber Optics Section, Mitsubishi Rayon Co., LTD, Japan*

Winning the Market for Short-Distance High-Speed Data Links: GigaPOF® in Active Optical Cables
Frank Graziano, *CEO, Board Member, Chromis Fiberoptics, Inc., USA*
Whitney White, *Co-Founder, Board Member, President & CTO, Chromis Fiberoptics, Inc., USA*

POF in Future Access and Home Networks
Eugene Dai, *Principal Transport Architect, Cox Communications, USA*

High Bitrate Transmission over SI-POF
Marco Dietrich, *CTO, ELCON Systemtechnik GmbH, Germany*

Technological Evolution of Next Generation Optical Cross Connect

Session organized by Huawei

Presenter:

Ning Deng, *Lead Engineer, Optical Networks Research, Transmission Network Product Line, Huawei, China*

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Technical Program and Steering Committees

General Chairs

Andrew Lord, *BT Labs, UK*
Shu Namiki, AIST, Japan
Peter Winzer, *Nokia Bell Labs, USA*

Program Chairs

Gabriella Bosco, *Politecnico di Torino, Italy*
Jörg-Peter Elbers, *ADVA Optical Networking SE, Germany*
Laurent Schares, *IBM TJ Watson Research Center, USA*

Subcommittees

Track D: Optical Components, Devices and Fiber

OFC D1: Advances in Deployable Optical Components, Fibers and Field Installation Equipment

Alan F. Evans, *Corning, USA,* **Subcommittee Chair**
Rich Baca, *Microsoft, Inc., USA*
Dirk Breuer, *T-Nova Deutsche Telekom, Germany*
Jose Castro, *Panduit Corp, USA*
Ji Chen, *Finisar Corporation, USA*
Nitin Goel, *Facebook Inc., USA*
Robert Griffin, *Oclaro, UK*
Shin Kamei, *NTT Photonics Laboratories, Japan*
Ashok Krishnamoorthy, *Oracle Corporation, USA*
Jing Li, *Yangtze Optical Fibre & Cable Co, China*
Haruki Ogoshi, *Furukawa Electric, Japan*
Erik Pennings, *7Pennies, USA*
Yongpeng Zhao, *Luster Lightech Corp, China*

OFC D2: Passive Optical Devices and Circuits for Switching and Filtering

Ben Lee, *IBM T. J. Watson Research Center, USA,* **Subcommittee Chair**
Haoshuo Chen, *Nokia Bell Labs, USA*
Mark Feuer, *CUNY City College, USA*
Piero Gambini, *STMicroelectronics, Italy*
Guo-Qiang Lo, *Institute of Microelectronics, Singapore*
Dan Marom, *The Hebrew University of Jerusalem, Israel*
Sylvie Menezo, *CEA-LETI, France*
Joyce Poon, *University of Toronto, Canada*
Jochen Schroeder, *Chalmers University, Sweden*
Hiroyuki Tsuda, *Keio University, Japan*

OFC D3: Active Optical Devices and Photonic Integrated Circuits

Po Dong, *Nokia Bell Labs, USA,* **Subcommittee Chair**
Guang-Hua Duan, *III-V lab, France*
Dazeng Feng, *Mellanox, USA*
Christian Koos, *Karlsruhe Institute of Technology, Germany*
Kazuhiko Kurata, *NEC Corporation, Japan*
Mike Larson, *Lumentum, USA*
Anders Larsson, *Chalmers Tekniska Hogskola, Sweden*
Thomas Schrans, *Rockley Photonics, USA*
Andreas Steffan, *Finisar , Germany*
Takuo Tanemura, *University of Tokyo, Japan*
Zhiping Zhou, *Peking University, China*

OFC D4: Fiber and Propagation Physics

Francesco Poletti, *University of Southampton, UK,* **Subcommittee Chair**
Marianne Bigot, *Prysmian Group, France*
Wladek Forysiak, *Aston University, UK*
Andrea Galtarossa, *University of Padova, Italy*
Ming-Jun Li, *Corning, USA*
Kazuhide Nakajima, *Nippon Telegraph & Telephone Corp (NTT), Japan*
Testuya Nakanishi, *Sumitomo Electric Industries Ltd, Japan*
Axel Schülzgen, *University of Central Florida (CREOL), USA*
Oleg Sinkin, *TE SubCom, USA*
Thierry Taunay, *OFS Laboratories, USA*
Johann Troles, *Universite de Rennes, France*

OFC D5: Fiber-Optic and Waveguide Devices and Sensors

Camille Sophie Bres, *Ecole Polytechnique Federale de Lausanne, Switzerland,* **Subcommittee Chair**
Rodrigo Amezcua-Correa, *University of Central Florida (CREOL), USA*
Maxim Bolshtyansky, *TE Subcom, USA*
Nicolas Fontaine, *Nokia Bell Labs, USA*
Miguel Gonzalez Herraez, *University of Alcalà, Spain*
Takemi Hasegawa, *Sumitomo Electric Industries Ltd., Japan*
Victor Kopp, *Chiral Photonics Inc., USA*
Rogerio Nogueira, *Instituto De Telecomunicacoes, Portugal*
Yasutake Ohishi, *Toyota Technological Institute, Japan*
Karsten Rottwitt, *DTU Fotonik, Denmark*

Track S: Photonic Systems and Subsystems

OFC S1: Advances in Deployable Subsystems and Systems

Tom Issenhuth, *Microsoft, USA,* **Subcommittee Chair**
Marc Bohn, *Coriant GmbH & Co. KG, Germany*
Chris Cole, *Finisar Corporation, USA*
Jonas Geyer, *Acacia Communications, Inc., USA*
Georg Mohs, *TE Subcom, USA*
Lynn Nelson, *AT&T Corp, USA*
Gary Nicholl, *Cisco, Canada*
Katharine Schmidtke, *Facebook, USA*
Henry Sun, *Infinera Corporation, Canada*
Sorin Tibuleac, *ADVA Optical Networking, USA*
Masahito Tomizawa, *NTT Network Innovation Labs, Japan*

OFC S2: Optical, Photonic and Microwave Photonic Subsystems

Leif Oxenlowe, *DTU Fotonik, Denmark,* **Subcommittee Chair**
Jose Azana, *INRS- Energie Materiaux et Telecom, Canada*
Robert Elschner, *Fraunhofer Heinrich Hertz Institute (HHI), Germany*
Toshihiko Hirooka, *Tohoku University, Sendai, Japan*
Leif Johansson, *Freedom Photonics, LLC, USA*
Inuk Kang, *LGS Innovations LLC, USA*
Tsuyoshi Konishi, *Osaka University, Japan*
Ju Han Lee, *University of Seoul, South Korea*
Paul Matthews, *Northrop Grumman Corp, USA*
Colin McKinstrie, *Huawei, USA*
David Neilson, *Nokia Bell Labs, USA*
Michael Vasilyev, *University of Texas at Arlington, USA*

OFC S3: Radio-over-Fiber, Free-Space and Non-telecom Systems

Christina Lim, *University of Melbourne, Australia,* **Subcommittee Chair**
Gee-Kung Chang, *Georgia Tech, USA*
Hwan Seok Chung, *ETRI, South Korea*
Richard DeSalvo, *Harris Corporation, USA*
Tetsuya Kawanishi, *National Institute of Information & Comm Tech (NICT), Japan*
Ton Koonen, *Einhoven University of Technology, The Netherlands*
Jason McKinney, *US Naval Research Laboratory, USA*

Idelfonso Tafur Monroy, *Danmarks Tekniske Universitet (DTU), Denmark*
Dominic O'Brien, *Oxford University, UK*
Rod Waterhouse, *Pharad LLC, USA*

OFC S4: Digital and Electronic Subsystems

Alan Pak Tao Lau, *Hong Kong Polytechnic University, Hong Kong,* **Subcommittee Chair**
Yi Cai, *ZTE Optics Lab, USA*
Liang Dou, *ZTE Beijing, China*
Gernot Goeger, *Huawei Technologies, Germany*
Neil Guerrero Gonzalez, *Universidad Nacional de Colombia, Colombia*
Takayuki Kobayashi, *NTT Network Innovation Laboratories, Japan*
David Millar, *Mitsubishi Electric Research Labs, USA*
Sebastian Randel, *Karlsruhe Institute of Technology (KIT), Germany*
Andre Richter, *VPIphotonics, Germany*
Ben Thomsen, *University College London, UK*
Qunbi Zhuge, *Ciena Corporation, Canada*

OFC S5: Digital Transmission Systems

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Dmitri Foursa, *TE Subcom, USA*
Takeshi Hoshida, *Fujitsu Laboratories Ltd., Japan*
Magnus Karlsson, *Chalmers University, Sweden*
Robert Killey, *University College London, UK*
Takayuki Mizuno, *NTT, Japan*
Colja Schubert, *Fraunhofer Institute Nachricht Heinrich-Hertz (HHI), Germany*
Chandrasekhar Sethumadhavan, *Nokia Bell Labs, USA*
Zhuhong Zhang, *Huawei Technologies Co Ltd, Canada*
Benyuan Zhu, *OFS Laboratories, USA*

Track N: Networks, Applications and Access

OFC N1: Advances in Deployable Networks and Their Applications

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Jean-Luc Auge, *Orange Labs, France*
Fred Bartholf, *Comcast Corporation, USA*
Nitin Batta, *Yahoo, USA*
Dave Boertjes, *Ciena, Canada*
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Herve Fevrier, *Facebook, USA*
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Pat Iannone, *Nokia Bell Labs, USA*
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OFC N2: Control and Management of Optical & Multilayer Networks

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Nicola Ciulli, *Nextworks, Italy*
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Sergi Figuerola, *i2CAT Foundation, Spain*
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Mazen Khaddam, *Cox Communications, Inc., USA*
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Tom Lehman, *University of Maryland, USA*
Nic Leymann, *Deutsche Telekom AG Laboratories, Germany*
Srini Seetharaman, *Infinera, USA*

OFC N3: Network Architectures and Techno-Economics

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Chris Bowers, *Juniper, USA*
Jiajia Chen, *Kungliga Tekniska Hogskolan, Sweden*
Filippo Cugini, *CNIT, Italy*
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Qiong Zhang, *Fujitsu Laboratories of America, USA*

OFC N4: Optical Access Networks for Fixed and Mobile Services

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Ning Cheng, *Huawei Technologies, USA*
Gabriella Cincotti, *Universita degli Studi Roma Tre, Italy*
Volker Jungnickel, *Fraunhofer Heinrich-Hertz Institute, Germany*
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Domanic Lavery, *University College London, UK*
Thomas Pfeiffer, *Nokia Bell Labs, Germany*
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Björn Skubic, *Ericsson, Sweden*
Jun Shan Wey, *ZTE, USA*
Lilin Yi, *Shanghai Jiao Tong University, China*

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

Lisa Huff, *Discerning Analytics, USA,* **Subcommittee Chair**
Lisa Bickford, *Google, USA*
Zeljko Bulut, *Coriant, USA*
Frank Chang, *Inphi Corporation, USA*
Eve Griliches, *Cisco, USA*
Julie Kunstler, *Ovum, USA*
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Andrew Schmitt, *Cignal Active Insight, USA*
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Ting Wang, *NEC Labs, USA*
Tiejun Xia, *Verizon Communications, Inc., USA*

Track DSN: Devices, Systems and Networks

OFC DSN6: Optical Devices, Subsystems, and Networks for Datacom and Computercom

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Peter DeDobbelaere, *Luxtera, USA*
Marco Fiorentino, *Hewlett Packard Enterprise, USA*
Dominic Goodwill, *Huawei Technologies Co Ltd, Canada*
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Explanation of Session Codes

M1C.4

Day Of The Week
S = Sunday
M=Monday
Tu=Tuesday
W=Wednesday
Th=Thursday

Series Number
1 = First series of sessions in day
2 = Second series of sessions in day

Session Designation
(alphabetically)

Number
(Presentation order within the session)

The first letter of the code denotes the day of the week (Sunday=Sunday, Monday=M, Tuesday=Tu, Wednesday=W, Th=Thursday). The third 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 fourth 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.

Invited — Invited Presentation

Tutorial — Tutorial Presentation

Record Presentation

Top Scored — Top Scored Papers

Agenda of Sessions — Sunday, 19 March

	403A	403B	404AB	408A	408B
07:30–19:00	**OIDA Workshop on Manufacturing Trends for Integrated Photonics,** *Petree Hall D* (separate registration required)				
09:00–12:00	**Short Courses: SC176, SC177, SC443, SC444, SC447** (additional fee required)				
09:00–13:00	**Short Courses: SC105, SC114, SC359, SC384** (additional fee required)				
13:00–17:00	**Short Courses: SC267, SC325, SC395** (additional fee required)				
13:30–16:30	**Short Courses: SC216, SC430, SC433** (additional fee required)				
13:30–17:30	**Short Courses: SC203, SC369, SC393** (additional fee required)				
15:30–18:30	**Workshops**				
	S1A • Will Machine Learning and Big-data Analytics Relieve Us From the Complexity of System and Network Engineering?	**S1B • Making the Case for SDM in 2027**	**S1C • Optical Wireless — Can it Become a Gigabit Wireless Alternative? Capabilities, Opportunities, Challenges, and Threats**	**S1D • Scaling Data Center Bandwidth: Novel Optics, Advanced Electronics or New Architectures?**	**S1E • III-V + Silicon: To Integrate or to Co-package?**
17:00–20:00	**Short Courses: SC205, SC217, SC328, SC372, SC386, SC428, SC429, SC451** (additional fee required)				
20:00–22:00	**Lab Automation Hackathon,** *503*				

Key to Shading

Short Courses

Recorded Session

Agenda of Sessions — Monday, 20 March

	402AB	403A ▶	403B ▶	404AB	406AB
07:30–19:30	**OIDA Executive Forum,** *Petree Hall D* (separate registration required)				
08:30–12:30	**Short Courses: SC102, SC178, SC327, SC341, SC390, SC432, SC446, SC453A** (additional fee required)				
09:00–12:00	**Workshops**				
		M1A • Processors and Switches with Integrated Optical Engines — Researchers' Dream or a Commercial Reality Soon?	**M1B • Connected OFCity Challenge: Optical Innovations for Future Services in a Smart City**	**M1C • Frequency Combs for Communications — Real Potential or Hype?**	
09:00–12:00	**Short Courses: SC208, SC385, SC411, SC442, SC450** (additional fee required)				
10:00–10:30	**Coffee Break,** *400 Foyer*				
12:00–13:30	**Lunch Break** *(on own)*				
12:00–14:00	**IEEE Women in Engineering "Lunch & Learn"** (separate registration required), *515A*				
13:30–15:30	**M2A • Panel: Lessons Learned From Global PON Deployment**	**M2B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics I** ▶	**M2C • Coherent Transceivers** ▶	**M2D • SDM Transmission I** (begins at 14:00)	**M2E • Advanced and Open Systems**
13:30–16:30	**Short Courses: SC261, SC431, SC445, SC448** (additional fee required)				
13:30–17:30	**Short Courses: SC160, SC347, SC408, SC449, SC452, SC453B, SC454** (additional fee required)				
15:30–16:00	**Coffee Break,** *400 Foyer*				
16:00–18:00	**M3A • Panel: Transport SDN — What is Ready, What is Missing?**	**M3B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics II** ▶	**M3C • Probabilistic Shaping and Advanced Modulation Formats** ▶	**M3D • High-Speed Subsystems** (ends at 17:45)	**M3E• Radio-over-fiber Systems**

Key to Shading

Short Courses (shaded) ▶ Recorded Session

407	408A	408B	409AB	410	411
OIDA Executive Forum, *Petree Hall D* (separate registration required)					
Short Courses: SC102, SC178, SC327, SC341, SC390, SC432, SC446, SC453A (additional fee required)					
Workshops					
	M1D • Capacity Crunch: When, Where and What Can be Done?	**M1E • White Box Optics: Will it Kill or Encourage Innovations?**			
Short Courses: SC208, SC385, SC411, SC442, SC450 (additional fee required)					
Coffee Break, *400 Foyer*					
Lunch Break *(on own)*					
IEEE Women in Engineering "Lunch & Learn" (separate registration required), *515A*					
M2F • New Fiber Concepts (ends at 15:15)	**M2G • Metro and 5G Transport**	**M2H • Control Architecture and Network Modeling I**	**M2I • Deployable Optical Access and Edge Networks**	**M2J • Optical Frequency Combs and Their Applications**	
Short Courses: SC261, SC431, SC445, SC448 (additional fee required)					
Short Courses: SC160, SC347, SC408, SC449, SC452, SC453B, SC454 (additional fee required)					
Coffee Break, *400 Foyer*					
M3F • Frequency Combs and Waveguide Devices	**M3G • Fibers and Amplifiers for Deployed Networks**	**M3H • TDM and TWDM PON I**	**M3I • Control and Management for Future PON**	**M3J • Optical Characterization and Performance** (ends at 17:30)	**M3K • Optical Data Center Networks**

Agenda of Sessions — Tuesday, 21 March

	402AB	403A ▶	403B ▶	404AB	406AB	407	408A ▶
07:30–08:00	**Coffee Break,** *Concourse Hall Foyer*						
08:00–10:00	**Plenary Session,** *Concourse Hall*						
10:00–14:00	**Unopposed Exhibit-Only Time,** *Exhibit Halls G-K* (coffee service 10:00-10:30)						
10:00–17:00	**Exhibition and Show Floor,** *Exhibit Halls G-K* (concessions available) and **OFC Career Zone Live,** *South Lobby*						
11:00–12:00	**Exhibit Hall Training,** *402AB*						
12:00–13:30	**OIDA VIP Industry Leaders Speed Meetings Event,** *515B* (separate registration required)						
12:00–14:00	**Awards Ceremony and Luncheon,** *Petree Hall D* (additional fee required)						
13:00–16:00	**Cheeky Scientist Workshops,** *501B*						
14:00–16:00	**Tu2A • Panel: Coherent Interoperability Beyond QPSK — Is it Needed and What will it Take?**	**Tu2B • Advanced VCSEL Links** ▶	**Tu2C • SDM Switches** ▶	**Tu2D • Modulation, Detection and DSP for PAM-4 Systems**	**Tu2E • High Bit-rate Transmission Systems** (ends at 15:45)	**Tu2F • Microwave Photonics Enabling Devices** (ends at 15:45)	**Tu2G • Data Center Summit: Open Platforms for Optical Innovation** ▶
16:00–16:30	**Coffee Break,** *400 Foyer; Exhibit Hall*						
16:30–18:30	**Tu3A • Panel: Direct vs. Coherent Detection for Metro-DCI**	**Tu3B • Terehertz Systems** ▶	**Tu3C • VCSELs** ▶	**Tu3D • Linear and Nonlinear Multicarrier Systems**	**Tu3E • Networks Operating in Challenging Environments**	**Tu3F • Reconfigurable Network Elements** (ends at 18:15)	**Tu3G • TDM and TWDM-PON II** ▶
16:30–18:30	**Tu3L • Data Center Summit: SDN & NFV Demo Zone,** *400 Foyer (extended coffee break)*						
17:30–19:00	**Exhibitor Reception,** *Lucky Strike LA Live, 800 W Olympic Blvd*						
18:30–20:00	**Conference Reception,** *Concourse Hall*						
19:30–21:30	**Rump Session,** *409AB*						

Key to Shading

Short Courses   ■ Market Watch/Data Center Summit   ▶ Recorded Session

408B	409AB	410	411
Coffee Break, *Concourse Hall Foyer*			
Plenary Session, *Concourse Hall*			
Unopposed Exhibit-Only Time, *Exhibit Halls G-K* (coffee service 10:00–10:30)			
Exhibition and Show Floor, *Exhibit Halls G-K* (concessions available) and **OFC Career Zone Live,** *South Lobby*			
Exhibit Hall Training, *402AB*			
OIDA VIP Industry Leaders Speed Meetings Event, *515B* (separate registration required)			
Awards Ceremony and Luncheon, *Petree Hall D* (additional fee required)			
Cheeky Scientist Workshops, *501B*			
Tu2H • Silicon Photonic Modulators	**Tu2I • Integrated Circuits for Signal Processing**	**Tu2I • Fibers and Components for Mode Division Multiplexing**	**Tu2K • Operation and Architecture for Optical Access** (ends at 15:45)
Coffee Break, *400 Foyer; Exhibit Hall*			
Tu3H • Tailored Propagation Effects (ends at 18:15)	**Tu3I • Direct-Detection Transmission Systems** (ends at 18:00)	**Tu3J • Fiber-based Spatial Mode Multiplexers**	**Tu3K • Photonic Packaging**
Tu3L • Data Center Summit: SDN & NFV Demo Zone, *400 Foyer (extended coffee break)*			
Exhibitor Reception, *Lucky Strike LA Live, 800 W Olympic Blvd*			
Conference Reception, *Concourse Hall*			
Rump Session, *409AB*			

Exhibit Hall G Expo Theater I	Exhibit Hall K Expo Theater II	Exhibit Hall K Expo Theater III
■ Market Watch **Panel I: State of the Industry — Analyst Panel** 10:30–12:00 ■ Market Watch **Panel II: Market Outlook for High Bandwidth Optical Technologies** 12:30–14:00 ■ Market Watch **Panel III: Global Market for Subsea Fiber Optic Networking Applications** 14:30–16:00	**Transforming the Future of Data Centers** *OCP* 10:15–11:45 ■ Data Center Summit **Next Generation Optical Technologies Inside the Data Center** 12:15–13:45 **Advancing Optical Interoperability in Open Networks** *Session Sponsored by Juniper* 14:00–17:00	**Product Showcase DWDM to the Edge** *Huawei USA* 10:15–10:45 **The Fracturing and Burgeoning Ethernet Market** *Ethernet Alliance* 11:00–12:00 **Dynamic Third Network Services for the Digital Economy and Hyper-connected World** *MEF* 12:30–13:30 **Enabling Next Generation Physical Layer Solutions** *OIF* 13:45–14:45 **The Key to Unlocking the Benefits of SDN** *OIF Interop* 15:00–16:00 **International Photonic Systems Roadmaps** 16:00–17:00

Agenda of Sessions — Wednesday, 22 March

	402AB	403A ▶	403B ▶	404AB	406AB	407	408A ▶
07:30–08:00	**Coffee Break,** *400 Foyer*						
08:00–10:00	**W1A • Photonic/Electronic Integration and Packaging** (ends at 09:45)	**W1B • SDM Multiplexers and 3D Waveguides** ▶	**W1C • Novel Fronthauling Techniques** ▶	**W1D • Control Architecture and Network Modeling II**	**W1E • Tunable Lasers and Transmitters**	**W1F • Advanced Fiber Lasers**	**W1G • Nonlinearity Mitigation and Monitoring** ▶
10:00–17:00	**Exhibition and Show Floor,** *Exhibit Halls G-K* (coffee service 10:00–10:30)						
10:00–17:00	**OFC Career Zone Live,** *South Lobby*						
10:00–12:00	**W2A • Poster Session I,** *Exhibit Hall K*						
12:00–13:00	**Unopposed Exhibit-Only Time,** *Exhibit Halls G-K* (concessions available)						
13:00–15:00	**W3A • Panel: Are Electronic and Optical Components Ready to Support Higher Symbol Rates and Denser Constellations?**	**W3B • Direct- Detection Transceivers** ▶	**W3C • Symposium: What is Driving 5G, and How Can Optics Help I** ▶	**W3D • Inter/Intra Data Center Networks** (ends at 14:45)	**W3E • III-V/Silicon Integrated Devices**	**W3F • Low Cost Systems for Wireless and Non-telecom Applications** (ends at 14:45)	**W3G • Data Center Interconnect Technologies** ▶
13:30–15:00	**IEEE Women in Photonics/WICE Luncheon,** *515A* (separate registration required)						
15:00–15:30	**Coffee Break,** *400 Foyer; Exhibit Hall*						
15:30–17:30	**W4A • Coded Modulation**	**W4B • Microwave Photonic Subsystems** ▶	**W4C • Symposium: What is Driving 5G, and How Can Optics Help II** ▶	**W4D • PAM-4 Inter-data Center Transmission**	**W4E • Photonic and Planar Switches**	**W4F • WDM and SDM Networking**	**W4G • Indium Phosphide Photonic Integration** ▶
17:00–19:30	**Photonic Society of Chinese-Americans Workshop & Social Networking Event,** *518*						

Key to Shading

Short Courses ■ Market Watch/Network Operator Summit ▶ Recorded Session

408B	409AB	410	411
Coffee Break, *400 Foyer*			
W1H • SDN Architecture for Packet and Physical Layer Optical	**W1I • Elastic Optical Networks**	**W1J • Forward Error Correction and Coding** (begins at 08:30)	**W1K • OFDM for Access Networks**
Exhibition and Show Floor, *Exhibit Halls G-K* (coffee service 10:00–10:30)			
OFC Career Zone Live, *South Lobby*			
W2A • Poster Session I, *Exhibit Hall K*			
Unopposed Exhibit-Only Time, *Exhibit Halls G-K* (concessions available)			
W3H • Multicore and Multimode Fibers (ends at 14:45)		**W3I • Control of Multi-layer Networks**	**W3J • Subcarrier Multiplexing and Nonlinear Tolerant Transmission** (13:00–14:00) **W3K • Perspectives in Quantum Communication** (14:00–15:00)
IEEE Women in Photonics/WICE Luncheon, *515A* (separate registration required)			
Coffee Break, *400 Foyer; Exhibit Hall*			
W4H • Evolution of Optical Networks	**W4I • High-speed Interconnects**	**W4J • SDN/NFV and Service Function Chaining**	**W4K • Panel: Quantum Communication Programs Around the World**
Photonic Society of Chinese-Americans Workshop & Social Networking Event, *518*			

Exhibit Hall G Expo Theater I	Exhibit Hall K Expo Theater II	Exhibit Hall K Expo Theater III
■ **Network Operator Summit** **Keynote: China Telecom's View of the All Optical Network** 10:30–11:00 **Panel I: Next-Generation Access and Metro – Where is the Money?** 11:00–12:30 **Panel II: Optical Mobile Network Access** 13:30–15:00 ■ **Market Watch Panel IV: Pluggable Optics — How is the Ecosystem and Value Chain Changing** 15:30–17:00	**On-board Optics — Challenges, Discoveries and the Path Forward** *COBO* 10:15–11:45 **Open Management and Monitoring of Multilayer Webscale and Carrier Networks** *Open Config* 12:00–13:30 **Network Analytics, in the Next-Generation Optical Transport** *IEEE Big Data Initiative* 13:45–15:15 **How will Fog Reshape Computing and Networking** *IEEE Cloud Computing* 15:30–17:00	**Product Showcase Innovative OTN Cluster Solution for Cloud Era Transport Networks** *Huawei Technologies USA* 10:15–10:45 **Product Showcase Industries Standard for Pic's Design** *PhoeniX Software* 11:00–11:30 **Product Showcase Challenges in Optoelectronic Integration for Datacom Applications** *Jabil AOC Technologies* 11:30–12:00 **Product Showcase 400GE from Hype to Reality** *Xilinx, Inc.* 13:30–14:00 **Product Showcase 400G P4 Programmable Packet Processing for NFV/SDN** *Xilinx, Inc.* 14:00–14:30 **Product Showcase Emerging Integrated Optics Based Solutions for Data Center Interconnect** *ColorChip* 14:30–15:00

Agenda of Sessions — Thursday, 23 March

	402AB	403A ▶	403B ▶	404AB	406AB	407	408A ▶
07:30–08:00	**Coffee Break,** *400 Foyer*						
08:00–10:00	**Th1A • Detectors/Receivers**	**Th1B • Silicon Photonics**	**Th1C • SDM Transmission II** ▶ (begins at 08:30)	**Th1D • Advances in Coherent Subsystems** (ends at 09:45)	**Th1E • Visible Light Communications** (ends at 09:45)	**Th1F • Applications of Parametric Nonlinear Processors** (ends at 09:45)	**Th1G • Gratings and Filters**
10:00–16:00	**Exhibition and Show Floor,** *Exhibit Halls G-K* (coffee service from 10:00–10:30)						
10:00–16:00	**OFC Career Zone Live,** *South Lobby*						
10:00–12:00	**Th2A • Posters Session II,** *Exhibit Hall K*						
12:00–13:00	**Unopposed Exhibit-Only Time,** *Exhibit Halls G-K* (concessions available)						
13:00–15:00	**Th3A • Optical Technologies for Radio Access Network I**	**Th3B • Practical Solutions to Tranceiver Integration** ▶	**Th3C • Optical Wireless Systems** ▶ (ends at 14:45)	**Th3D • DSP for Direct-detection Systems**	**Th3E • Waveguide Devices**	**Th3F • Transmission Experiments and Modeling** (ends at 14:45)	**Th3G • Power Efficient Optics** ▶
15:00–15:30	**Coffee Break,** *400 Foyer; Exhibit Hall*						
15:30–17:30	**Th4A • Optical Amplifiers** (ends at 17:15)	**Th4B • Optical Technologies for Radio Access Network II** ▶	**Th4C • DSP for Coherent Systems** ▶	**Th4D • Submarine Transmission Systems** (ends at 17:15)		**Th4E • Novel Applications of Microwave Photonics**	**Th4F • Network Design** ▶
17:30–18:00	**Beverage Break,** *400 Foyer*						
18:00–20:00	**Postdeadline Papers,** *403A, 403B, 408A and 408B*						

Key to Shading

Short Courses ■ Market Watch/Network Operator Summit ▶ Recorded Session

Agenda of Sessions

408B ▶	409AB	410	411
Coffee Break, *400 Foyer*			
Th1H • Advances in Multicore Fiber Technology ▶	**Th1I • Network Architecture Evolution**	**Th1J • Data Analytics and Machine Learning**	**Th1K • Coherent Technologies for Access** (begins at 08:30)
Exhibition and Show Floor, *Exhibit Halls G-K* (coffee service from 10:00–10:30)			
OFC Career Zone Live, *South Lobby*			
Th2A • Posters Session II, *Exhibit Hall K*			
Unopposed Exhibit-Only Time, *Exhibit Halls G-K* (concessions available)			
Th3H • Sensors for Telecom and Biomedical Applications ▶	**Th3I • Novel Photonic Devices**	**Th3J • Nonlinear Mitigation Techniques** (ends at 14:30)	**Th3K • Network Survivability** (ends at 14:45)
Coffee Break, *400 Foyer; Exhibit Hall*			
Th4G • Laser Transmitters ▶	**Th4H • Characterizations of SDM Fibers** (ends at 17:15)	**Th4I • Coherent Optical Signal Processing** (ends at 17:15)	
Beverage Break, *400 Foyer*			
Postdeadline Papers, *403A, 403B, 408A and 408B*			

Exhibit Hall G Expo Theater I	Exhibit Hall K Expo Theater II	Exhibit Hall K Expo Theater III
■ Market Watch **Panel V: Photonic Integration Business Case – Reality Check** 10:30–12:00 ■ Market Watch **Panel VI: SDN & Optics — What is the Business Case?** 12:30–14:00	**Open Packet DWDM** *TIP* 10:15–11:45 **ONF: The Path Forward** 12:00–13:30 **Transport SDN** 15:00–16:00	**Product Showcase Huawei T-SDN OVPN Solution** *Huawei USA* 10:15–10:45 **POF Symposium** *POFTO* 11:00–13:00 **Technological Evolution of Next Generation Optical Cross Connect** *Huawei* 13:30–14:30

Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB	Room 407

Details on all Workshops (both Sunday and Monday) can be found on pages 9-13

10:00-10:30 Coffee Break, *400 Foyer*

12:00–13:30 Lunch Break *(on own)*

13:30–15:30
M2A • Panel: Lessons Learned From Global PON Deployment

Moderators:
Frank Effenberger, FutureWei Technologies, Inc. USA; Thomas Pfeiffer, Nokia Bell Labs, Germany

Passive Optical Networks have seen a dramatic growth over the past decade. There are now many large deployments, such as those in the US, Japan, and China, and the total number of homes passed with PON technology is approaching 200 million. We have also seen an alphabet soup of PON technologies, including B, E, G, 10GE, XG, and TWDM. But the one constant in all of this is that PON development and deployment is as difficult as it is rewarding. This panel brings together representatives of operator and vendor companies that are the driving force behind this wave of ultra-broadband deployment. This will be a great forum to hear of their experiences, discoveries, happy accidents, and expensive lessons.

Panelists:

John Kirby, *AT&T, USA*

Vincent O'Byrne, *Verizon, USA*

Kenichi Suzuki, *NTT, Japan*

Dezhi Zhang, *China Telecom, China*

13:30–15:30
M2B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics I

Presiders: Po Dong; Nokia, USA; Erik Pennings; 7 Pennies, USA

Integrated photonics provides significant opportunities to develop highly compact and extremely functional components and subsystems for a wide range of communication and sensor applications. However, photonic integration brings with it unique manufacturing and packaging challenges, which can limit the commercial exploitation of novel integration concepts and slow the time-to-market. These challenges can be economic or technical in nature, and are often most apparent during the transition from prototype development to manufacturing. This symposium will provide a balanced view of the promises and challenges of integrated photonics, and it will focus on what is being done to get beyond the many roadblocks in order to enable a much larger market adoption. During the symposium, leaders in the field will address applications in traditional and non-traditional markets for integrated photonics, finding the right fabrication model using MPW or custom processing services, choosing Si versus InP platforms, optical and electrical packaging approaches, and other fundamental component challenges.

Speakers (in speaking order)

Roe Hemenway, *Macom, USA*

Dominic Goodwill, *Huawei, Canada*

Pascual Munoz, *VLC, Spain*

John Bowers, *Univ. of California Santa Barbara, USA*

13:30–15:30
M2C • Coherent Transceivers

Presider: Benn Thomsen; Univ. College London, UK

M2C.1 • 13:30

FPGA-based Real-Time Receiver for Nyquist-FDM at 112 Gbit/s Sampled with 32 GSa/s, Benedikt Baeuerle[1], Arne Josten[1], Marco Eppenberger[1], Edwin Dornbierer[1], David Hillerkuss[1], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland.* We demonstrate an efficient multi-format real-time Nyquist-FDM receiver implemented on a single FPGA. The single-polarization receiver with only 8/7 oversampling receives 56 Gbit/s 4QAM and 112 Gbit/s 16QAM transmitted over 300 km SSMF.

M2C.2 • 13:45

Simple Frequency-domain Hybrid-QAM Superchannel with Path-fitted Pre-filtering and Collaborative-subcarrier Frequency Self-tuning for Flexible ROADM Systems, Takahiro Kodama[1], Masashi Binkai[1], Tsuyoshi Yoshida[1]; [1]*Optical Communication Technology Department, Mitsubishi Electric Corporation Information Technology R&D Center, Japan.* Flexible spectral efficiency was demonstrated by a frequency-domain hybrid-QAM based 400 Gb/s superchannel with path-fitted pre-filtering. Subcarrier frequency tuning was also evaluated through offline emulation of laser frequency drift, and mitigated a 2.1 dB Q degradation.

14:00–15:30
M2D • SDM Transmission I

Presider: Cristian Antonelli; Universita degli Studi dell'Aquila, Italy

13:30–15:30
M2E • Advanced and Open Systems

Presider: Lynn Nelson; AT&T Labs, USA

M2E.1 • 13:30 Invited

Open Undersea Cable Systems for Cloud Scale Operation, Tim Stuch[1], Jamie Gaudette[1]; [1]*Microsoft, USA.* A true open cable system is designed specifically to operate in a disaggregated, vendor agnostic manner. We outline Microsoft's approach to open cable systems and discuss the technical challenges.

13:30–15:15
M2F • New Fiber Concepts

Presider: Oleg Sinkin; TE SubCom, USA

M2F.1 • 13:30 Invited

SDM for Power Efficient Transmission, Yu Sun[1], Oleg V. Sinkin[1], Alexey v. Turukhin[1], Maxim A. Bolshtyansky[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; [1]*TE SubCom, USA.* We discuss the principles behind the use of space division multiplexing for power efficient transmission in optical fiber communication systems. Experimental demonstration of these principles are realized in a multicore fiber transmission system.

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10:00-10:30 Coffee Break, *400 Foyer*

12:00–13:30 Lunch Break *(on own)*

13:30–15:30
M2G • Metro and 5G Transport
Presider: Jiajia Chen; Kungliga Tekniska Hogskolan, Sweden

M2G.1 • 13:30
Techno-economic Analysis of Transmission Technologies in Low Aggregation Rings of Metropolitan Networks, Tamara Jimenez[1], Victor Lopez[2], Felipe Jimenez Arribas[2], Oscar Gonzalez de Dios[2], Juan Pedro Fernandez-Palacios[2]; [1]*Optical Communications Group, Univ. of Valladolid, Spain;* [2]*Telefonica I+D, Spain.* A techno-economic comparison of dark fiber and passive architectures to evolve low aggregation metro rings of 1G is presented. Results demonstrate that there are alternatives more cost-effective than just migrating to 10G.

M2G.2 • 13:45
Integrating Wireless BBUs with Optical OFDM Flexible-grid Transponders in a C-RAN Architecture, Avishek Nag[1], Yi Zhang[1], Luiz DaSilva[1], Linda Doyle[1], Marco Ruffini[1]; [1]*Trinity College Dublin, Ireland.* We propose a case study on hardware-level virtualisation of C-RAN BBUs and optical flex-grid OFDM transponders, showing cost savings of integrating fixed and mobile network devices in a realistic converged network scenario.

13:30–15:30
M2H • Control Architecture and Network Modeling I
Presider: Sergi Figuerola; i2CAT Foundation, Spain

M2H.1 • 13:30 Tutorial
ONF SDN Architecture and Standards for Transport Networks, Lyndon Y. Ong[1]; [1]*Ciena Corporation, USA.* This talk reviews ONF SDN standards development for transport networks, focusing on the Transport API (TAPI) NorthBound Interface. This includes basic concepts and modeling, TAPI open source SDK and recent TAPI interop testing, in the context of related industry work such as IETF YANG models.

Lyndon Ong is Principal, Network Architecture at Ciena Corporation and a Ciena Technical Fellow. He currently chairs the Open Transport Working Group of the Open Networking Foundation (ONF), and has been a major contributor to work on SDN architecture and APIs and optical control plane. He is an active member of the Optical Internetworking Forum (OIF), previously serving as Technical Committee Chair and on its Board of Directors, and an active participant in IETF. Dr. Ong joined Ciena in 2001, after previous stints at Nortel Networks, Bay Networks and Bellcore. He received his doctorate from Columbia University in 1991.

13:30–15:30
M2I • Deployable Optical Access and Edge Networks
Presider: Weisheng Hu; Shanghai Jiao Tong Univ., China

M2I.1 • 13:30
Antenna, Spectrum and Capacity Trade-off for Cloud-RAN Massive Distributed MIMO over Next Generation PONs, Irene Macaluso[1], Bruno Cornaglia[2], Marco Ruffini[1]; [1]*Univ. of Dublin Trinity College, Ireland;* [2]*Vodafone, Italy.* We propose a cost-optimal antenna vs. spectrum resource allocation strategy for mobile 5G MD-MIMO over Next-Generation PONs. Comparing wavelength overlay and shared wavelength approaches, split-PHY leads to solutions with higher mobile capacity than fronthaul.

M2I.2 • 13:45
Demonstration of Radio and Optical Orchestration for Improved Coordinated Multi-point (CoMP) Service over Flexible Optical Fronthaul Transport Networks, Jiawei Zhang[1,2], Hao Yu[1], Yuefeng Ji[3], Hui Li[2], Xiaosong Yu[1], Yongli Zhao[1], Han Li[3]; [1]*State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts & Telecom, China;* [2]*Beijing Advanced Innovation Centre for Future Internet Technology, Beijing Univ. of Technology , China;* [3]*China Mobile Research Inst., China.* We propose an SDN-enabled orchestration for the convergence of radio and optical networks in the 5G. Improved coordinated multi-point service is experimentally demonstrated in the cloud radio over flexible optical fronthaul transport networks (C-RoFlex) testbed.

13:30–15:30
M2J • Optical Frequency Combs and Their Applications
Presider: Jose Azana; INRS-Energie Materiaux et Telecom, Canada

M2J.1 • 13:30 Invited
Computation-free Signal Mapping to Fourier Domain, Bill Kuo[1], Vahid Ataie[1], and Stojan Radic[1]; [1]*Univ. of California, San Diego, USA.* Conventional lightwave receiver incorporates high-speed Fast Fourier Transform (FFT) computation core in order to aid carrier recovery and perform channel equalization. This talk examines a computation-free FFT alternative architecture and discussed its implications.

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M2A • Panel: Lessons Learned From Global PON Deployment—Continued

M2B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics I—Continued

Presentations selected for recording are designated with a ▶. Visit www.ofcconference.org and select the View Presentations link.

M2C • Coherent Transceivers—Continued

M2C.3 • 14:00 ▶
Colorless C-Band WDM System Enabled by Coherent Reception of 56-GBd PDM-16QAM Using an High-bandwidth ICR with TIAs, Robert Emmerich[1], Robert Elschner[1], Carsten Schmidt-Langhorst[1], Gijs v. Elzakker[2], Jan Hoffmann[2], Andreas Umbach[2], Colja Schubert[1]; [1]*Fraunhofer Heinrich Hertz Inst., Germany;* [2]*Finisar Germany GmbH, Germany.* We demonstrate error-free 80-km transmission of a 400-Gb/s channel in a colorless coherent C-band WDM system using a high-bandwidth micro-ICR. The WDM channels are colorlessly combined at the transmitter and colorlessly split/detected at the receiver.

M2C.4 • 14:15 ▶
A Memory Polynomial Based Digital Pre-distorter for High Power Transmitter Components, Ginni Khanna[1], Bernhard Spinnler[2], Stefano Calabrò[2], Erik De Man[2], Uwe Feiste[2], Tomislav Drenski[3], Norbert Hanik[1]; [1]*Technical Univ. of Munich, Germany;* [2]*Coriant R&D GmbH, Germany;* [3]*Socionext Europe GmbH, UK.* An adaptive digital pre-distortion method based on memory polynomials to compensate for non-linearities in high power optical transmitters is presented. Gains up to 2dB for DP-64QAM are achieved beyond linear pre-distortion

M2D • SDM Transmission I—Continued

M2D.1 • 14:00
12 Mode, MIMO-free OAM Transmission, Kasper Ingerslev[1], Patrick Gregg[2], Michael Galili[1], Francesco Da Ros[1], Hao Hu[1], Fangdi Bao[1], Mario A. Usuga Castaneda[1], Poul Kristensen[3], Andrea Rubano[4], Lorenzo Marrucci[4], Siddharth Ramachandran[2], Karsten K. Rottwitt[1], Toshio Morioka[1], Leif K. Oxenlowe[1]; [1]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [2]*Electrical and Computer Engineering Department, Boston Univ., USA;* [3]*OFS-Fitel, Denmark;* [4]*Dipartimento di Fisica, Università di Napoli Federico II, Italy.* Simultaneous MIMO-free transmission of a record number (12) of orbital angular momentum modes over 1.2 km is demonstrated. WDM compatibility of the system is shown by using 60 WDM channels with 25 GHz spacing and 10 GBaud QPSK.

M2D.2 • 14:15
5Tb/s Transmission Over 2.2 km of Multimode OM2 Fiber with Direct Detection Thanks to Wavelength and Mode Group Multiplexing, Kaoutar Benyahya[1], Christian Simonneau[1], Amirhossein Ghazisaeidi[1], Nicolas Barré[3], Pu Jian[3], Jean-François Morizur[3], Guillaume Labroille[3], Pierre Sillard[2], Jérémie renaudier[1], Gabriel CHARLET[1]; [1]*Nokia Bell Labs Paris Saclay, France;* [2]*Prysmian Group, France;* [3]*CAILabs, France.* We demonstrate 5Tb/s bidirectional transmission (2.5Tb/s in each direction) over 2.2km of OM2 fiber using selective excitation of 4 mode groups and WDM multiplexing with DMT modulation and direct detection.

M2E • Advanced and Open Systems—Continued

M2E.2 • 14:00 Invited
Lessons Learned from Open Line System Deployments, Valey Kamalov[1], Vinayak Dangui[1], Tad Hofmeister[1], Bikash Koley[1], Chris Mitchell[1], Matt Newland[1], John O'Shea[1], Cody Tomblin[1], Vijay Vusirikala[1], Xiaoxue Zhao[1]; [1]*Google, Inc., USA.* We present on the design and operational aspects of our open line system approach for overcoming cost, capacity and flexibility limitations. Dramatic growth of datacenter traffic was supported by separation of the terminal equipment from the optical layer allowing the introduction of multi-vendor, best-of-breed coherent terminal equipment.

M2F • New Fiber Concepts—Continued

M2F.2 • 14:00 Invited
Phosphate Glass Fibers for Optical Amplifiers and Biomedical Applications, Daniel Milanese[1,2], Diego Pugliese[1], Nadia G. Boetti[3], Edoardo Ceci-Ginistrelli[1], Davide Janner[1], Vincenzo M. Sglavo[5], Chiara Vitale-Brovarone[1], Joris Lousteau[4]; [1]*Department of Applied Science and Technology, Politecnico di Torino, Italy;* [2]*IFN, CNR, Italy;* [3]*Applied Photonics, Istituto Superiore Mario Boella, Italy;* [4]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [5]*Department of Industrial Engineering, Università di Trento , Italy.* Phosphate glass optical fibers were designed and fabricated for applications in the fields of remote sensing and biomedicine. Main results are reported together with the recent developments.

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M2G • Metro and 5G Transport—Continued

M2G.3 • 14:00 Invited

Benefits of Programmability in 5G Transport Networks, Muhammad Rehan Raza[1], Matteo Fiorani[1], Ahmad Rostami[2], Peter Ohlen[2], Lena Wosinska[1], Paolo Monti[1]; [1]*KTH Royal Inst. of Technology, Sweden;* [2]*Ericsson AB, Sweden.* This paper shows how programmability can improve operators' revenues and it presents a dynamic resource slicing policy that leads to more than one order of magnitude better resource utilization levels than convectional (static) allocation strategies.

M2H • Control Architecture and Network Modeling I—Continued

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M2I • Deployable Optical Access and Edge Networks—Continued

M2I.3 • 14:00 Invited

The Evolution of Outside Plant Architectures Driven by Network Convergence and New PON Technologies, Kevin L. Bourg[1]; [1]*Corning Optical Communications, USA.* We show that convergence of access networks together with new PON standards drive lower bandwidth cost, which in turn due to elasticity of demand results in larger number of users. According to Metcalf's law that came into existence in 1980's and explained the wide adoption of Ethernet cards, increase in network value will scale quadratically with the number of users, thus making convergence and new PON standards so valuable to network operators.

M2J • Optical Frequency Combs and Their Applications—Continued

M2J.2 • 14:00

Towards an Integrated-photonics Optical-Frequency Synthesizer With <1 Hz Residual Frequency Noise, Daryl T. Spencer[1], Aaron Bluestone[2], John E. Bowers[2], Travis C. Briles[1], Scott Diddams[1], Tara Drake[1], Robert Ilic[3], Tobias Kippenberg[4], Tin Komljenovic[2], Seung H. Lee[5], Qing Li[3], Nathan Newbury[1], Erik Norberg[6], Dong Y. Oh[5], Scott Papp[1], Pfeiffer Martin Hubert Peter[4], Laura Sinclair[1], Kartik Srinivasan[3], Jordan Stone[1], Myoung-Gyun Suh[5], Luke Theogarajan[2], Kerry Vahala[5], Nicholas Volet[2], Daron Westly[3], Kiyoul Yang[5]; [1]*National Inst of Standards & Technology, USA;* [2]*Univ. of California Santa Barbara, USA;* [3]*National Inst. of Standards and Technology, USA;* [4]*Ecole Polytechnique Federale de Lausanne, Switzerland;* [5]*California Inst. of Technology, USA;* [6]*Aurrion Inc., USA.* We introduce an architecture for optical-frequency synthesis using photonic-chip frequency combs and a heterogeneously integrated CW laser. The Kerr dual-comb that we describe offers a microwave-optical link to discipline the laser to an RF clock.

M2J.3 • 14:15

Comb-Assisted Real-time Discrete Fourier Transform Processor, Huan Hu[1], Daniel Esman[1], Vahid Ataie[1], Eduardo Temprana[1], Bill Kuo[1], Nikola Alic[1], Stojan Radic[1]; [1]*UCSD, USA.* We present a high-speed flexible photonic-assisted Discrete Fourier Transform (DFT) processor based on a dual, phase-locked optical parametric combs. A 25-point DFT at 500 Million-DFT-point per second throughput is achieved relying on slow, 20 MS/s Analog to Digital Converter (ADC).

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M2A • Panel: Lessons Learned From Global PON Deployment—Continued

M2B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics I—Continued

M2C • Coherent Transceivers—Continued

M2C.5 • 14:30 Tutorial

Digital Coherent Transceivers: From Algorithm Design to Economics, Maxim Kuschnerov[1]; [1]*Huawei Technologies Duesseldorf GmbH, Germany.* The divide between generic 100G coherent interfaces and differentiated solutions is widening. A DSP invest in the age of white box transmission is a careful decision, discussed from a technological and economic point of view.

Maxim Kuschnerov is a Senior R&D Manager at Huawei Technologies in Munich working on innovation projects. He earned his doctorate in 2011 from the University of the Bundeswehr on digital signal processing for optical DSPs. In 2010, he joined Nokia Siemens Networks in R&D, developing 100Gb/s transceivers. In parallel, he was a project lead for developing space division multiplexing network technology based on solid core and hollow core fibers. In 2014, he moved to product line management at Coriant creating the Groove G30 data center interconnect product and managing the ultra-long haul transport system hiT 7300.

M2D • SDM Transmission I—Continued

M2D.3 • 14:30 Invited

Signal Processing Techniques for DMD and MDL Mitigation in Dense SDM Transmissions, Kohki Shibahara[1], Takayuki Mizuno[1], Doohwan Lee[1], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan.* Methodologies for DMD and MDL mitigation in SDM transmission are reviewed. We clarify frequency selective channels over a multicore few-mode fiber with experimental evaluations, and their impact on signal transmission from a signal processing perspective.

M2D.4 • 15:00

Partial MIMO-based 10-Mode-Multiplexed Transmission over 81km Weakly-coupled Few-mode Fiber, Daiki Soma[1], Yuta Wakayama[1], Koji Igarashi[2,1], Takehiro Tsuritani[1]; [1]*KDDI Research, Inc., Japan;* [2]*Osaka Univ., Japan.* A 10-mode-multiplexed 10-Gbaud DP-QPSK WDM signals transmission over 81 km weakly-coupled few-mode fiber has been successfully demonstrated using 2x2 or 4x4 partial MIMO equalizer with reduced receiver DSP complexity.

M2E • Advanced and Open Systems—Continued

M2E.3 • 14:30 Top Scored

Single-Carrier 61 Gbaud DP-16QAM Transmission using Bandwidth-limited DAC/ADC and Narrow Filtering Equalization, Yann Loussouarn[1], Erwan Pincemin[1], Serge Gautier[1], Yang Chen[2], Wushuang Yuan[2], Yang Hong[2], Xiong Wei[2], Zhangde Jiang[2]; [1]*Orange Labs, France;* [2]*Huawei Technologies, China.* We demonstrate 400 Gbps metro WDM transmission with 61 Gbaud single-carrier DP-16QAM real-time transceiver prototype over respectively 200 km, 300 km and 500 km of G.655, G.652, and G.654 super-large area and ultra-low loss fibers using bandwidth-limited DAC/ADC (<15 GHz) and MLSE-based narrow filtering equalization.

M2E.4 • 14:45

Experimental Characterization of Submarine "Open Cable" using Gaussian-noise Model and $OSNR_{WET}$ Parameter, Pascal Pecci[1], Sebastien Dupont[1], Suwimol Dubost[1], Stéphane Ruggeri[1], Olivier Courtois[1], Vincent Letellier[1]; [1]*ASN, France.* With the coherent era, a new parameter called $OSNR_{WET}$ is experimentally studied for "open cable" characterization. A +/-0.3dB maximum deviation from the average is found for 3 modulation formats, 3 channel spacings and 3 distances.

M2E.5 • 15:00

Real-Time Investigation and Prediction of Transmission Penalties for PDM-8QAM/16QAM Super-Channels in Flexible Grid DWDM Networks, Jie Pan[1], Sorin . Tibuleac[1]; [1]*Adva Optical Networking, USA.* Real-time transmission penalties of PDM-8QAM and PDM-16QAM super-channel system are investigated for various system configurations in a ROADM enabled flexible grid link. Gaussian noise model is verified in systems with both filtering and cross-talk penalties.

M2F • New Fiber Concepts—Continued

M2F.3 • 14:30 Invited

Advances in Optical Fibers Fabricated with Granulated Silica, Jonas Scheuner[1], Alexander M. Heidt[1], Sönke Pilz[2], Philippe Raisin[1], Ali El Sayed[2,1], Hossein Najafi[2], Manuel Ryser[1], Thomas Feurer[1], Valerio Romano[1,2]; [1]*Universitat Bern, Switzerland;* [2]*Bern Univ. of Applied Sciences, Switzerland.* The sol-gel based granulated silica preform fabrication method is presented as a versatile "rapid prototyping" platform for specialty optical fiber production, enabling arbitrary geometries, large flexibility of doping composition and concentration, and homogeneous dopant distributions.

M2F.4 • 15:00

Low-loss Splice of Large Effective Area Fiber Using Fluorine-doped Cladding Standard Effective Area Fiber, Takemi Hasegawa[1], Masato Suzuki[1], Yoshiaki Tamura[1], Yoshinori Yamamoto[1]; [1]*Sumitomo Electric Industries Ltd, Japan.* Ultra-low dissimilar splice loss of 0.08dB between A_{eff}-enlarged fiber (148μm²) and standard A_{eff} fiber (83μm²) was realized, by applying a ring core profile to A_{eff}-enlarged fiber and fluorine doped cladding to standard A_{eff} fiber.

Room 408A

M2G • Metro and 5G Transport—Continued

M2G.4 • 14:30
Dynamic Placement of BaseBand Processing in 5G WDM-based Aggregation Networks, Francesco Musumeci[1], Giuseppe Belgiovine[1], Massimo Tornatore[1]; [1]*Politecnico di Milano, Italy.* We propose and compare different baseband-processing-placement strategies in optical aggregation networks. Proper trade-off between baseband-resources consolidation and network blocking can be obtained by dynamically adapting location of processing resources to traffic conditions.

M2G.5 • 14:45
Core VNT Adaptation Based on the Aggregated Metro-flow Traffic Model Prediction, Fernando Morales[1], Marc Ruiz[1], Luis Velasco[1]; [1]*Universitat Politècnica de Catalunya, Spain.* Aggregation of metro-flow traffic models is proposed to obtain valid core traffic predictive models for core VNT reconfiguration when metro and core networks are independently controlled. Exhaustive simulation results reveal large optical transponders usage savings.

M2G.6 • 15:00
Metro Transport, from Mesh to Hub, Qingya She[1], Tomohiro Hashiguchi[2], Kirsten Rundberget[1], Weisheng Xie[1]; [1]*Fujitsu Networks Communications Inc., USA;* [2]*Fujitsu Laboratories Ltd, Japan.* We discuss the realistic challenges of network operation and new services for carriers' metro transport networks. A new metro transport architecture is proposed and evaluated.

Room 408B

M2H • Control Architecture and Network Modeling I—Continued

M2H.2 • 14:30
Distributed vs. Centralized PCE-based Transport SDN Controller for Flexi-Grid Optical Networks, Ricardo Martínez[1], Ramon Casellas[1], Ricard Vilalta[1], Raul Muñoz[1]; [1]*Ctr Tecnologic de Telecoms de Catalunya, Spain.* We validate the use of a centralized PCE architecture as an SDN controller to compute and configure flexi-grid optical networks. Besides presenting new PCEP extensions, performance evaluation compares PCE-based solution with traditional distributed signaling approach.

M2H.3 • 14:45
Cascading of Tenant SDN and Cloud Controllers for 5G Network Slicing using Transport API and Openstack API, Arturo Mayoral López de Lerma[1], Ricard Vilalta[1], Raul Muñoz[1], Ramon Casellas[1], Ricardo Martinez[1], Victor Lopez[2]; [1]*CTTC, Spain;* [2]*Global CTO, Telefonica, Spain.* Cascading of network and cloud resources is defined as the recursive hierarchical abstraction and virtualization of resources. Cascading is expected to an enabler for 5G Network Slicing. We provide a demonstration of the proposed concept.

M2H.4 • 15:00 Invited
Managing Service Quality in a Software Defined Network, Jennifer M. Yates[1]; [1]*AT&T, USA.* Service Quality Management (SQM) technologies enable service providers to manage customer experience. In this paper, we focus on SQM innovations and how they apply to software defined networks.

Room 409AB

M2I • Deployable Optical Access and Edge Networks—Continued

M2I.4 • 14:30 Invited
Experiences and Future Perspective of China Telecom on Optical Access Networks, Chengbin Shen[1]; [1]*Shanghai Inst. of China Telecom, China.* As the largest FTTx operator in the world, China Telecom faced with technical and engineering issues during FTTx deployment and operation. In the paper, China Telecom's experience and technical innovation on FTTx networks were given. Moreover, China Telecom's vision on future FTTH network, including PON technology upgrade, software-defined access networks and central office re-architecture as edge DC, were presented.

M2I.5 • 15:00
Uncompressed 8K Ultra-high Definition Television Transmission over 100G Ethernet in Broadcasting Station, Junichiro Kawamoto[1], Takuya Kurakake[1]; [1]*Japan Broadcasting Corporation, Japan.* For live television production, we developed a system for transmitting a 257-Gb/s 8K ultra-high definition television signal using two 100-Gb/s Ethernet lines. Packet-error-rate was evaluated to satisfy broadcasting requirements; stable 8K transmission was successfully performed.

Room 410

M2J • Optical Frequency Combs and Their Applications—Continued

M2J.4 • 14:30 Invited
High Capacity MCF Transmission with Wideband-Comb, Benjamin J. Puttnam[1], Ruben S. Luis[1], Georg Rademacher[1], Jun Sakaguchi[1], Werner Klaus[1], Erik Agrell[2], John Marciante[3], Y. Awaji[1], Naoya Wada[1]; [1]*National Inst Info & Comm Tech (NICT), Japan;* [2]*Signals and Systems, Chalmers Univ. of Technology, Sweden;* [3]*RAM Photonics, LLC, USA.* We describe experiments combining high core-count, homogeneous single-mode multi-core fibers with a wideband comb for high-capacity transmission without high-order MIMO reception and demonstrate wideband transmission with coded modulation up to 12,300 km.

M2J.5 • 15:00
Ultrafast Demultiplexing of Optical Time-division Multiplexed Signals by Parallel Opto-Electronic Time-frequency Domain Sampling, Takahide Sakamoto[1], Guo-Wei Lu[1], Naokatsu Yamamoto[1]; [1]*National Inst of Information & Comm Tech, Japan.* We demonstrate demultiplexing of ultrafast optical time-division multiplexed (OTDM) signals by parallel time-frequency domain sampling. With a loop-assisted coherent matched detector configuration, all subchannels of 4x20-Gb/s Gaussian-/Nyquist-shaped OTDM-QPSK signals were simultaneously demultiplexed and detected.

Room 411

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M2A • Panel: Lessons Learned From Global PON Deployment—Continued	**M2B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics I—Continued**	**M2C • Coherent Transceivers—Continued**	**M2D • SDM Transmission I—Continued**	**M2E • Advanced and Open Systems—Continued**	**M2F • New Fiber Concepts—Continued**

Room 404AB — M2D • SDM Transmission I—Continued

M2D.5 • 15:15
3x10 Gb/s Mode Group-multiplexed Transmission over a 20 km Few-Mode Fiber Using Photonic Lanterns, Huiyuan Liu[1], He Wen[1,2], Juan Carlos Alvarado Zacarias[1], Jose Antonio-Lopez[1], Ning Wang[1], Pierre Sillard[3], Adrian Amezcua-Correa[3], Rodrigo Amezcua Correa[1], Guifang Li[1,2]; [1]*CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA;* [2]*The College of Precision Instruments and Opto-electronic Engineering, Tianjin Univ., China;* [3]*Prysmian Group, France.* We experimentally demonstrate 3x10 Gb/s mode group-multiplexed transmission with direction detection in a step-index few-mode fiber over a record reach of 20 km, enabled by low crosstalk photonic lanterns as mode group (de) multiplexers.

Room 406AB — M2E • Advanced and Open Systems—Continued

M2E.6 • 15:15
Shake Before Break: Per-Span Fiber Sensing with In-Line Polarization Monitoring, Jesse E. Simsarian[1], Peter Winzer[1]; [1]*Nokia Bell Labs, USA.* Fast state-of-polarization transients induced by transmission-fiber disturbances can indicate an imminent fiber break even in the absence of transmission errors. We present a simple in-line polarization monitoring scheme that detects fiber disturbances, enabling proactive protection.

15:30–16:00 Coffee Break, *400 Foyer*

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

M2G • Metro and 5G Transport—Continued

M2G.7 • 15:15 Top Scored

Cost-Effectiveness Assessment of Transport Networks based on Disaggregated Optical Platforms, Joao Santos[1], Nelson Costa[1], João Pedro[1,2]; [1]*Coriant Portugal, Portugal;* [2]*Instituto de Telecomunicações, Portugal.* This paper compares the routing performance between disaggregated and proprietary optical line systems. Network simulations show that disaggregated solutions attain minimal traffic blocking while reducing OEO interface count with respect to multi-vendor deployments.

M2H • Control Architecture and Network Modeling I—Continued

M2I • Deployable Optical Access and Edge Networks—Continued

M2I.6 • 15:15

Strategies for VNF Placements in Large Provider Networks, Ashwin Gumaste[1], Sidharth Sharma[1], Tamal Das[1], Aniruddha Kushwaha[1]; [1]*Indian Inst. of Technology, Bombay, India.* We examine three strategies of VNF placement in a provider network: static service chains; seamless VNF duplication and VNF-dynamic-splitting. A constrained optimization applied to a large provider evaluates these strategies and showcases cost-latency trade-off.

M2J • Optical Frequency Combs and Their Applications—Continued

M2J.6 • 15:15

Mitigation of Electrical Bandwidth Limitations using Optical Pre-sampling, Zihan Geng[1], Bill Corcoran[1,3], Andreas Boes[2,3], Arnan Mitchell[2,3], Leimeng Zhuang[1], Yiwei Xie[1], Arthur Lowery[1,3]; [1]*Dept. of Electrical and Comp. System Eng., Monash Univ., Australia;* [2]*School of Engineering, RMIT Univ., Australia;* [3]*Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Australia.* We propose a novel method to improve a system degraded by a low receiver electrical bandwidth. With optical pre-sampling, 4-dB sensitivity improvement at the 7% hard FEC limit is experimentally demonstrated.

15:30–16:00 Coffee Break, *400 Foyer*

Room 402AB

16:00–18:00
M3A • Panel: Transport SDN - What is Ready, What is Missing?
Moderators: Doug Freimuth; IBM, USA; Karthik Sethuraman; NEC, USA

The dynamic compute model provided by the cloud has gained acceptance by business and consumer markets. A new network is required to match the resource scalability, faster automated service deployment model and high resource utilization of the cloud. The promise of Transport SDN to fulfill these requirements has been shown in various demonstrations, proof of concepts and by early adopters. The industry is working to define it in standards bodies for production use in NFV, cloud and IoT.

This panel will discuss what it takes to operationalize Transport SDN. We will discuss business drivers, use cases, progress in standards and prototypes shown to date. We will further discuss what can be put into production now, related technologies such as SD-WAN and what the future holds for new Transport SDN capabilities.

Panelists:

Victor Lopez, *Telefonica, Spain*

Naoki Miyata, *NTT Communications, Japan*

Kathy Tse, *AT&T, USA*

Room 403A

16:00–18:00
M3B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics II
Presiders: Benjamin Lee; IBM, USA; Takuo Tanemura; Univ. of Tokyo, Japan

Integrated photonics provides significant opportunities to develop highly compact and extremely functional components and subsystems for a wide range of communication and sensor applications. However, photonic integration brings with it unique manufacturing and packaging challenges, which can limit the commercial exploitation of novel integration concepts and slow the time-to-market. These challenges can be economic or technical in nature, and are often most apparent during the transition from prototype development to manufacturing. This symposium will provide a balanced view of the promises and challenges of integrated photonics, and it will focus on what is being done to get beyond the many roadblocks in order to enable a much larger market adoption. During the symposium, leaders in the field will address applications in traditional and non-traditional markets for integrated photonics, finding the right fabrication model using MPW or custom processing services, choosing Si versus InP platforms, optical and electrical packaging approaches, and other fundamental component challenges.

Speakers (in speaking order)

Shinji Matsuo, *NTT, Japan*

Ashok Krishnamoorthy, *Oracle, USA*

Bardia Pezeshki, *Kaiam, USA*

Greg Fish, *Juniper, USA*

Kevin Williams, *TU Eindhoven, Netherlands*

Room 403B

16:00–18:00
M3C • Probabilistic Shaping and Advanced Modulation Formats
Presider: Takeshi Hoshida; Fujitsu Laboratories Ltd., Japan

M3C.1 • 16:00
Spectrally-Efficient Single-carrier 400G Transmission Enabled by Probabilistic Shaping, Yanjun Zhu[1], An Li[1], Wei-Ren Peng[1], Clarence Kan[1], Zhihong Li[1], Samina Chowdhury[1], Yan Cui[1], Yusheng Bai[1]; [1]*Futurewei Technologies, Inc, USA.* We report experimental results of Probabilistically Shaped 64QAM (PS-64QAM) Single-Carrier 400G transmission over SSMF, in a 50 GHz wavelength grid. Up to 300% reach enhancement over regular 64QAM is achieved, thanks to probabilistic shaping.

M3C.2 • 16:15
Experimental Comparison of PM-16QAM and PM-32QAM with Probabilistically Shaped PM-64QAM, Luca Bertignono[1], Dario Pilori[1], Antonello Nespola[2], Fabrizio Forghieri[3], Gabriella Bosco[1]; [1]*Politecnico di Torino, Italy;* [2]*Istituto Superiore Mario Boella, Italy;* [3]*Cisco Photonics Italy , Italy.* We experimentally compare the performance of uniformly distributed and probabilistically shaped constellations with either the same asymptotic mutual information or the same FEC overhead, in order to assess the achievable shaping gain.

Room 404AB

16:00–17:45
M3D • High-Speed Subsystems
Presider: Qunbi Zhuge; Ciena Corporation, Canada

M3D.1 • 16:00 Invited
Advanced Algorithm for High-baud Rate Signal Generation and Detection, Zhang Junwen[1], Jianjun Yu[1], Hung-Chang Chien[1]; [1]*ZTE (Tx), USA.* We review recent progress on the high-baud rate signal generation and detection, and the corresponding advanced algorithms used in the transmitter- and receiver-side for signal pre- and post- equalization and compensation, respectively.

Room 406AB

16:00–18:00
M3E • Radio-over-fiber Systems
Presider: Rod Waterhouse; Pharad, LLC, USA

M3E.1 • 16:00 Invited
Techniques for Highly Linear Radio-over-Fiber Links, Thomas R. Clark[1], Jean H. Kalkavage[1], Eric J. Adles[1]; [1]*JHU/APL, USA.* Hybrid fiber-wireless systems offer the promise of efficient high capacity fiber-optic class data delivery to mobile and fixed wireless devices. Achieving this promise will require systems employing highly linear techniques.

Room 407

16:00–18:00
M3F • Frequency Combs and Waveguide Devices
Presider: Camille-Sophie Bres; Ecole Polytechnique Federale de Lausanne, Switzerland

M3F.1 • 16:00
Experimental Investigation of the Effect of EDFA-generated ASE Noise Added to the Pump of a Kerr Frequency Comb, Peicheng Liao[1], Changjing Bao[1], Arne Kordts[2], Karpov Maxim[2], Pfeiffer Martin Hubert Peter[2], Lin Zhang[3], Yinwen Cao[1], Ahmed Almaiman[1], Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Moshe Tur[4], Tobias Kippenberg[2], Alan Willner[1]; [1]*Electrical Engineering, Univ. of Southern California, USA;* [2]*Ecole Polytechnique Federale de Lausanne, Swaziland;* [3]*Precision Instrument and Opto-electronics Engineering, Tianjin Univ., China;* [4]*Electrical Engineering, Tel Aviv Univ., Israel.* We experimentally investigate the effect of EDFA-induced pump ASE noise on cavity-soliton Kerr combs for 64-QAM transmission. We find that all comb optical carrier-to-noise ratios (OCNRs) are similar with a fixed pump OCNR and comb linewidths almost remain unchanged.

M3F.2 • 16:15
High-Efficiency WDM Sources Based on Microresonator Kerr Frequency Combs, Xiaoxiao Xue[1,2], Pei-Hsun Wang[2], Yi Xuan[2], Minghao Qi[2], Andrew Weiner[2]; [1]*Tsinghua Univ., China;* [2]*Purdue Univ., USA.* We report on microcombs that achieve ~30% conversion efficiency (~200 mW on-chip comb power excluding the pump), with 40 lines between 1513 nm – 1586 nm with an average 7 dBm per comb line.

Room 408A

16:00–18:00
M3G • Fibers and Amplifiers for Deployed Networks
Presider: Alan Evans; Corning Incorporated, USA

M3G.1 • 16:00 Tutorial

The State of the Art of Modern Non-SDM Amplification Technology in Agile Optical Networks: EDFA and Raman Amplifiers and Circuit Packs, Gregory Cowle[1]; [1]*Lumentum, USA.* This tutorial will review the fundamental technology used in conventional EDFA and Raman amplifiers used in modern agile optical networks. Technology trends of circuit pack integration, EDFA miniaturization and gain switchable amplifiers will be discussed.

Gregory J. Cowle directs the amplification research and development team in Lumentum. He received The B.E. and B.Sc. from the University of New South Wales, Australia, and the Ph.D. from the University of Southampton, U.K.. Dr Cowle's career has focused on fiber lasers and amplifiers, with experience at Telstra Research Laboratories, The University of Sydney, The University of Southampton, Corning Incorporated, and he is currently with Lumentum (previously JDSU).

Room 408B

16:00–18:00
M3H • TDM and TWDM PON I
Presider: Ning Cheng; Huawei Technologies NA Co Ltd, USA

M3H.1 • 16:00 Top Scored

First Demonstration of Symmetric 100G-PON in O-band with 10G-Class Optical Devices Enabled by Dispersion-supported Equalization, Lei Xue[1], Lilin Yi[1], Honglin Ji[1], Peixuan Li[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* We demonstrate the first symmetric 100G-PON based on 10Gbps optical devices supporting 0-20 km reach in O-band. Dispersion-supported equalization enables 25.78-Gb/s NRZ-OOK modulation/detection based on DMLs/APDs with a combined 3-dB bandwidth of 5 GHz.

M3H.2 • 16:15

64-Gbit/s PAM-4 20-km Transmission Using Silicon Micro-ring Modulator for Optical Access Networks, Yung Hsu[1], Ta-Ching Tzu[3], Tien-Chien Lin[1], C. Y. Chuang[1], Xinru Wu[2], Jye-Hong Chen[3], Chien-Hung Yeh[4], Hon Ki Tsang[2], Chi-Wai Chow[3]; [1]*Inst. of EO Engineering, National Chiao Tung Univ., Taiwan;* [2]*Department of Electronic Engineering, The Chinese Univ. of Hong Kong, Hong Kong;* [3]*Department of Photonics and Inst. of Electro-Optical Engineering, National Chiao Tung, Univ., Taiwan;* [4]*Department of Photonics, Feng Chia Univ., Taiwan.* We demonstrate the feasibility of using silicon-micro-ring-modulators for 50-Gbit/s and 64-Gbit/s pulse-amplitude-modulation-4 (PAM-4) communications in a 20-km single-mode-fiber (SMF) link with Volterra-filtering. The integrated transmitter may be used in passive–optical-access-networks with 20-km-reach and 64-split-ratio.

Room 409AB

16:00–18:00
M3I • Control and Management for Future PON
Presider: Thomas Pfeiffer; Nokia Corporation, Germany

M3I.1 • 16:00 Invited

Dynamic Wavelength Allocation and Rapid Wavelength Tuning for Load Balancing in λ-tunable WDM/TDM-PON, Yumiko Senoo[1], Kota Asaka[1], Jun-ichi Kani[1]; [1]*Access Network Service Systems Laboratories, NTT, Japan.* Dynamic load balancing (DLB) among OLT-ports can keep good user experience by preventing heavy users from occupying the bandwidth. To realize DLB, we present a dynamic wavelength allocation algorithm and a rapid wavelength tuning sequence.

Room 410

16:00–17:30
M3J • Optical Characterization and Performance
Presider: Leif Oxenlowe; DTU Fotonik, Denmark

M3J.1 • 16:00

Polarimetry of Polarization-Modulated Signals Based on Polarization-Selective RF Power Detection, Reinhold Noe[1,2], Benjamin Koch[1,2], Vitali Mirvoda[1]; [1]*Paderborn Univ., Germany;* [2]*Novoptel GmbH, Germany.* A novel polarimeter identifies the main polarization axes of polarization-modulated, nominally unpolarized signals such as PDM-QPSK, PDM-QAM, PS-QPSK. It measures the electrical AC power detected behind several polarization analyzers and calculates the axes iteratively.

M3J.2 • 16:15

In-service Crosstalk Monitoring for Dense Space Division Multiplexed Multi-core Fiber Transmission Systems, Takayuki Mizuno[1], Akira Isoda[1], Kohki Shibahara[1], Yutaka Miyamoto[1], Saurabh Jain[2], Shaif-ul Alam[2], David J. Richardson[2], Carlos Castro[3], Klaus Pulverer[3], Yusuke Sasaki[4], Yoshimichi Amma[4], Katsuhiro Takenaga[4], Kazuhiko Aikawa[4], Toshio Morioka[5]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*Univ. of Southampton, UK;* [3]*Coriant R&D GmbH, Germany;* [4]*Fujikura Ltd., Japan;* [5]*Technical Univ. of Denmark, Denmark.* We present in-service inter-core crosstalk monitoring for MCF transmission systems. We transmit 54-WDM PDM-16QAM signals over 111.6-km 32-core DSDM transmission line incorporating cladding-pumped 32-core MC-EYDFA, and demonstrate –30 dB crosstalk monitoring without affecting transmission performance.

Room 411

16:00–18:00
M3K • Optical Data Center Networks
Presider: Adel Saleh; Univ. of California Santa Barbara, USA

M3K.1 • 16:00 Tutorial

Optical Technologies in Support of Computing Systems, George Papen[1]; [1]*Univ. of California, San Diego, USA.* The design of a modern datacenter is constrained by both technology and economics. This tutorial discusses some of these constraints and how optical components may be used in future datacenters to address some of these issues.

George C. Papen is a professor of Electrical and Computer Engineering at the University of California at San Diego. His research is in systems applications of optics in computing and communication. Current research topics include the development of robust optical interconnects for applications within computing systems and developing coding techniques to mitigate signal impairments in optical communication systems.

Room 402AB

M3A • Panel: Transport SDN - What is Ready, What is Missing?—Continued

Room 403A

M3B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics II—Continued

Room 403B

M3C • Probabilistic Shaping and Advanced Modulation Formats—Continued

M3C.3 • 16:30 Invited

Flexible Optical Transmission Close to the Shannon Limit by Probabilistically Shaped QAM, Fred Buchali[1], Wilfried Idler[1], Laurent Schmalen[1], Qian Hu[1]; [1]*Nokia Bell Labs, Germany.* We are reviewing the application of probabilistic shaping in long haul optical transmission systems and investigate the linear, nonlinear and implementation limits for this format in comparison to pragmatic QAM formats.

Room 404AB

M3D • High-Speed Subsystems—Continued

M3D.2 • 16:30

A Simplified Dual-Carrier DP-64QAM 1 Tb/s Transceiver, David Millar[1], Lidia Galdino[2], Robert Maher[2], Milutin Pajovic[1], Toshiaki Koike-Akino[1], Domanic Lavery[2], Gabriel Saavedra[2], Daniel Elson[2], Kai Shi[2], Mustafa S. Erkilinc[2], Eric Sillekens[2], Robert Killey[2], Benn C. Thomsen[2], Keisuke Kojima[1], Kieran Parsons[1], Polina Bayvel[2]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*Univ. College London, UK.* A 1Tb/s net bitrate transceiver using a low complexity dual-carrier architecture with free running lasers and DP-64QAM, enabled by pilot-aided DSP and low-rate LDPC, is shown to achieve transmission over 400km with 100km amplifier spacing.

M3D.3 • 16:45

246 GHz Digitally Stitched Coherent Receiver, Kai Shi[1], Eric Sillekens[1], Benn C. Thomsen[1]; [1]*Univ. College London, UK.* Phase estimation and 4×2 MIMO equalization techniques are experimentally compared for digital frequency stitching in ultra-wideband coherent reception, using time multiplexing and a single conventional dual polarization coherent receiver, to simultaneously detect a 5×46GBaud super-channel.

Room 406AB

M3E • Radio-over-fiber Systems—Continued

M3E.2 • 16:30

60-Gbps W-Band 64QAM RoF System with T-Spaced DD-LMS Equalization, Xinying Li[1,2], Jianjun Yu[1,3], Yuming Xu[1,2], Xiaolong Pan[4], Fu Wang[4], Zhipei Li[4], Bo Liu[4], Lijia Zhang[4], Xiangjun Xin[4], Gee-Kung Chang[2]; [1]*Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [2]*Georgia Inst. of Technology, USA;* [3]*ZTE (TX) Inc., USA;* [4]*Beijing Univ. of Posts and Telecommunications, China.* We experimentally demonstrate the generation and transmission of 60-Gb/s (10-Gbaud) 91-GHz 64QAM-modulated mm-wave signal over 20-km SMF-28 and 3-m wireless distance, with BER under 2×10^{-2}. Receiver-based T-spaced DD-LMS equalization significantly improves the system performance.

M3E.3 • 16:45

Real-Time Demonstration of over 20Gbps V- and W-Band Wireless Transmission Capacity in one OFDM-RoF System, Xinying Li[1,2], Xin Xiao[1], Yuming Xu[2], Kaihui Wang[2], Li Zhao[2], Jiangnan Xiao[2], Jianjun Yu[1,2]; [1]*ZTE (TX) Inc., USA;* [2]*Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China.* With real-time reception, we experimentally demonstrate the generation and wireless delivery of V-band (57-GHz) and W-band (91-GHz) OFDM-16QAM signals, both with 6.02-GHz-bandwidth (24.08-Gb/s net bit rate) and a BER below the SD-FEC threshold of 2×10^{-2}.

Room 407

M3F • Frequency Combs and Waveguide Devices—Continued

M3F.3 • 16:30

Cavity-less 50GHz Frequency Comb Generation by Comb Pitch Multiplication, Bofang Zheng[1], Qijie Xie[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, USA.* A cavity-less optical frequency comb with accurate 50-GHz comb pitch is achieved using a 10-GHz RF source via the temporal Talbot effect. The comb is implemented as a Nyquist-shaped 32-GBaud 16-QAM data transmitter.

M3F.4 • 16:45

Regeneration of Noise Limited Frequency Comb Lines for 64-QAM by Brillouin Gain Seeded via SSB Modulation, Mark D. Pelusi[1], Amol Choudary[1], Takashi Inoue[2], David Marpaung[1], Benjamin Eggleton[1], Shu Namiki[2]; [1]*CUDOS/Univ. of Sydney, Australia;* [2]*National Inst. of Advanced Industrial Science and Technology (AIST), Japan.* We demonstrate noise suppression from parametrically generated optical frequency comb-lines with low 10GHz-pitch by using narrowband Brillouin amplification pumped self-seeded via single-sideband modulation (SSB). Comb-line carrier performance close to a reference laser is achieved for 96Gb/s-DP-64QAM.

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

M3G • Fibers and Amplifiers for Deployed Networks—Continued

M3H • TDM and TWDM PON I—Continued

M3H.3 • 16:30 Invited

DSP-Based Multi-Band Schemes for High Speed Next Generation Optical Access Networks, Jinlong Wei[1]; [1]*Optical Technology Department, Huawei Technologies Duesseldorf GmbH, European Research Center, Germany.* 40-Gb/s/λ long reach multi-band CAP PONs using 10G-class transceivers were demonstrated with transmission over an 80-km (90-km) SMF and a link power budget of 33 dB (29 dB) considering a FEC threshold BER of 3.8×10^{-3} .

M3I • Control and Management for Future PON—Continued

M3I.2 • 16:30

Feasibility Demonstration of Low Latency DBA Method with High Bandwidth-efficiency for TDM-PON, Saki Hatta[1], Nobuyuki Tanaka[1], Takeshi Sakamoto[1]; [1]*NTT Corporation, Japan.* We propose a DBA method with an adaptive DBA cycle for TDM-PON based MFH and campus LANs. Experiments show that the method achieves minimum latency of 60 µs and high bandwidth efficiency, depending on traffic.

M3I.3 • 16:45

Virtual Dynamic Bandwidth Allocation Enabling True PON Multi-Tenancy, Amr Elrasad[1], Nima Afraz[1], Marco Ruffini[1]; [1]*CONNECT, Trinity College Dublin, the Univ. of Dublin, Ireland.* We propose a virtual-DBA architecture enabling true PON multi-tenancy, giving Virtual Network Operators full control over capacity assignment algorithms. We achieve virtualization enabling efficient capacity sharing without increasing scheduling delay compared to traditional (non-virtualized) PONs.

M3J • Optical Characterization and Performance—Continued

M3J.3 • 16:30

Real-time Path Monitoring of Optical Nodes, Takayuki Kurosu[1], Satoshi Suda[1], Kiyo Ishii[1], Shu Namiki[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan.* We demonstrate a novel method for monitoring internal paths of optical nodes exploiting light labeling technique. The optical paths of a 2x2 wavelength cross connect could be monitored in 2ms without affecting transmission performance.

M3J.4 • 16:45

All-optical Reconfigurable Time-lens Based Signal Processing, Jeonghyun Huh[1], Jose Azana[1]; [1]*INRS, Canada.* All-optical reconfigurable time-to-frequency conversion and temporal magnification of optical waveforms is proposed and experimentally demonstrated using a XPM-based time lens by exploiting chirp rates being directly proportional to the peak power of a parabolic pump pulse.

M3K • Optical Data Center Networks—Continued

Room 402AB

M3A • Panel: Transport SDN - What is Ready, What is Missing?—Continued

Room 403A

M3B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics II—Continued

Room 403B

M3C • Probabilistic Shaping and Advanced Modulation Formats—Continued

M3C.4 • 17:00
On the Impact of Probabilistic Shaping on SNR and Information Rates in Multi-Span WDM Systems, Tobias Fehenberger[1], Alex Alvarado[2], Georg Böcherer[1], Norbert Hanik[1]; [1]*Technical Univ. of Munich (TUM), Germany;* [2]*Univ. College London, UK.* Numerical simulations and the EGN model show that probabilistic shaping decreases SNR due to modulation-dependent nonlinear effects. This SNR loss, however, is less important than the rate increase from shaping, resulting in an overall gain.

M3C.5 • 17:15
100-Gb/s Complex Direct Modulation over 1600-km SSMF Using Probabilistic Transition Estimation, Di Che[1], Feng Yuan[1], William Sheih[1]; [1]*Univ. of Melbourne, Australia.* We demonstrate single-channel 100-Gb/s polarization-multiplexed PAM-4 with 2 independent directly modulated lasers using only 12.5-GHz electrical bandwidth. By probabilistic transition estimation, this complex-modulated PAM system achieves a record distance of 1600 km.

M3C.6 • 17:30 Invited
On the Use of GMI to Compare Advanced Modulation Formats, Shaoliang Zhang[1]; [1]*NEC Laboratories America Inc, USA.* A variety of advanced modulation formats, including set-partitioning M-QAM, time-hybrid QAM, multi-dimensional formats, geometric- and probabilistic-shaped constellation, are compared by means of GMI metric.

Room 404AB

M3D • High-Speed Subsystems—Continued

M3D.4 • 17:00 Invited
Extreme Speed Power-DAC: Leveraging InP DHBT for Ultimate Capacity Single-carrier Optical Transmissions, Agnieszka Konczykowska[1], Jean-Yves Dupuy[1], Filipe Jorge[1], Muriel Riet[1], Virginie Nodjiadjim[1]; [1]*III-V Lab, joint laboratory of Nokia Bell Labs, TRT and CEA/LETI, France.* With 100-Gbaud operation and 4-Vpp swing, InP DHBT Power-DAC enabled experiments with different types of E/O modulators. Single-carrier 100-GBd PAM-4 DD transceiver for datacenters and 1.08 Tb/s transmitter (90-GBd PDM-64QAM) were demonstrated.

M3D.5 • 17:30
First Demonstration of an All Analog Adaptive Equalizer for Coherent DP-QPSK Links, Nandakumar Nambath[1], Mehul Anghan[1], Nandish Thaker[1], Rakesh Ashok[1], Rashmi Kamran[1], Arvind Kumar Mishra[2], Shalabh Gupta[1]; [1]*Indian Inst. of Technology, Bombay, India;* [2]*Sterlite Technologies Ltd., India.* For the first time, an all analog CMA equalizer for DP-QPSK transmission systems has been demonstrated. The experiment with an 8-Gb/s link shows promise for low power analog processing based receivers for short-reach DP-QPSK links.

Room 406AB

M3E • Radio-over-fiber Systems—Continued

M3E.4 • 17:00
Optically Generated Single Sideband Radio-over-Fiber Transmission of 60Gbit/s Over 50m at W-Band, Rafael Puerta[1], Simon Rommel[1], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1,2]; [1]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [2]*ITMO Univ., Russia.* 60Gbit/s single side-band multi-band CAP radio-over-fiber transmission at W-band is demonstrated. A spectral efficiency of 3.8bit/s/Hz and bit error rates below 3.8×10^{-3} are achieved after 50m wireless transmission.

M3E.5 • 17:15
Capacity Enhancement for Hybrid Fiber-wireless Channels with 46.8Gbit/s Wireless Multi-CAP Transmission over 50m at W-Band, Simon Rommel[1], Rafael Puerta[1], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1,2]; [1]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [2]*ITMO Univ., Russia.* Transmission of a 46.8Gbit/s multi-band CAP signal is experimentally demonstrated over a 50m W-band radio-over-fiber link. Bit error rates below 3.8×10^{-3} are achieved, employing nine CAP bands with bit and power loading.

M3E.6 • 17:30
W-Band 16QAM-Modulated SSB Photonic Vector Mm-Wave Signal Generation by One Single I/Q Modulator, Xinying Li[1,2], Yuming Xu[1], Jiangnan Xiao[1], Kaihui Wang[1], Jianjun Yu[1,2]; [1]*Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [2]*ZTE (TX) Inc., USA.* Adopting asymmetrical-single-sideband-modulation enabled by one single I/Q modulator, we experimentally demonstrate a novel scheme for photonic generation of W-band 16QAM-modulated photonic vector mm-wave signal, which can be transmitted over 80-km SMF-28 without optical dispersion compensation.

Room 407

M3F • Frequency Combs and Waveguide Devices—Continued

M3F.5 • 17:00 Invited
Nitride-based Devices at Telecom Wavelengths, Eva Monroy[1]; [1]*INAC-PHELIQS, CEA-Grenoble, France.* This presentation reviews the progress towards the development of a new technology which relies on intersubband transitions in GaN/AlN nanostructures to achieve ultra-fast optoelectronic devices operating at telecommunication wavelengths.

M3F.6 • 17:30
Bandgap Engineering in Nonlinear Silicon Nitride Waveguides, Clemens Krueckel[1], Attila Fulop[1], Peter A. Andrekson[1], Victor Torres-Company[1]; [1]*Chalmers Univ. of Technology, Sweden.* We show that controlling the bandgap of SiN provides an additional degree of freedom for engineering waveguides for nonlinear optics. We show an optimized structure with gamma*max Leff = 0.17 rad/W and absence of nonlinear loss.

Room 408A

M3G • Fibers and Amplifiers for Deployed Networks—Continued

M3G.2 • 17:00

Erbium Doped Fiber Amplifier with Passive Temperature Compensation, Lijie Qiao[1], Alan Solheim[1], Qinlian Bu[2], Yong Luo[2], Chengpeng Fu[2], Weiqing Zhang[2], Menghui Le[2]; [1]*GC Photonics Inc., Canada;* [2]*Accelink Technologies Co., Ltd., China.* Abstract: A commercially viable technique for passive temperature compensation in EDFAs based on a MZ interferometer with a variable splitting ratio is developed and described. It allows system engineers to simultaneously achieve better gain flatness, small size, low power consumption and heat production

M3G.3 • 17:15

Low-loss Fiber-bundle-type Fan-in/Fan-out Device for 6-mode 19-core Fiber, Kota Shikama[1], Yoshiteru Abe[1], Hirotaka Ono[1], Atsushi Aratake[1]; [1]*NTT Device Technology Laboratories, Nippon Telegraph and Telephone Corporation, Japan.* We describe a low-loss fiber-bundle-type fan-in/fan-out device for 6-mode 19-core fiber, which achieves physical-contact connection. We suppress the mode-dependent loss of the device by accurately arranging fibers and utilizing a precise rotational alignment mechanism.

M3G.4 • 17:30 Invited

G.654.E Fibre Deployments in Terrestrial Transport System, Shikui Shen[1], Guangquan Wang[1], Haijun Wang[1], Yongtao He[1], Shuo Wang[1], Chenfang Zhang[1], Chunxu Zhao[1], Jing Li[2], Hao Chen[3]; [1]*China Unicom, China;* [2]*YOFC, China;* [3]*Corning Optical Communication China., China.* Multi-vendors G.654.E fibres field trials for 400G terrestrial transport systems were demonstrated. The evaluation works carried out by China Unicom for high bitrate terrestrial transport application are introduced. Test results in factories and fields are analyzed detailed.

Room 408B

M3H • TDM and TWDM PON I—Continued

M3H.4 • 17:00

4×28 Gb/s PAM4 Long-Reach PON Using Low Complexity Nonlinear Compensation, Xiang Li[1], Shiwei Zhou[2], Fan Gao[2], Ming Luo[1], Qi Yang[1], Qi Mo[2], Yu Yu[2], Songnian Fu[2]; [1]*WRI, China;* [2]*School of optical and electronic information, Huazhong Univ. of Science and Technology, China.* We demonstrate a 4×28 Gb/s PAM4 Long-reach-PON over 80 km fiber with more than 33 dB power budget. A low complexity nonlinearity compensation using sparse Volterra filtering is applied with excessive optical dispersion compensation.

M3H.5 • 17:15

40 Gbps PON with 23 dB Power Budget using 10 Gbps Optics and DMT, Chuan Qin[1,2], Vincent Houtsma[1], Doutje Van Veen[1], Jeffrey Lee[1], Hungkei Chow[1], Peter Vetter[1]; [1]*Nokia, Bell Labs, USA;* [2]*Univ. of California Davis, USA.* We investigate a symmetrical 40 Gbps PON using 10-Gbps class optical components. We demonstrate transmission at 40 Gbps, with 23-dB power budget and 4.6×10^{-3} BER after 10-km SSMF transmission using discrete multitone IM-DD.

M3H.6 • 17:30

Demonstration of 25Gbit/s per Channel NRZ Transmission with 35 dB Power Budget using 25G Ge/Si APD for Next Generation 100G-PON, Yong Guo[1], Yongjia Yin[1], Yingxiong Song[2], Mengyuan Huang[3], Yingchun Li[2], Guohua Kuang[1], Zhiming Fu[1], Xingang Huang[1], Pengfei Cai[3], Zhuang Ma[1], Mingsheng Li[1], Dong Pan[3]; [1]*ZTE Corporation, China;* [2]*Shanghai Univ., China;* [3]*SiFotonics Technologies, USA.* We accomplished the first demonstration of 25Gbit/s NRZ transmission for 100G-PON by leveraging state-of-art 25G Ge/Si APD. Measurement results prove that 35dB power budget is achievable. Comparisons between 25G and 10G APD receivers are performed.

Room 409AB

M3I • Control and Management for Future PON—Continued

M3I.4 • 17:00 Tutorial

Programmable Access and Edge Cloud Architecture, Peter Vetter[1]; [1]*Nokia Bell Labs, USA.* We will discuss how converged access deployment will become more flexible thanks to a data center like approach for central offices, in which the control will be disaggregated from access functions in the data plane implemented on servers or specialized hardware.

Peter Vetter is Head of the Fixed Networks Research Lab in Bell Labs. He is globally responsible in Nokia for research on optical and copper access, access hardware platforms, and access architectures. After a PhD at Ghent University and a post-doc at Tohoku University, he joined the research center of Alcatel (now part of Nokia Bell Labs) in Antwerp in 1993. Since 2009, he is based in Murray Hill, New Jersey.
 Throughout his career, he researched access architectures and platforms, optical access, high speed interconnect and liquid crystal displays. He was also co-founder of an internal venture that produced the first FTTH product in Alcatel. He is a Bell Labs Fellow and has co-authored over a hundred international papers.

Room 410

M3J • Optical Characterization and Performance—Continued

M3J.5 • 17:00

Optical Spectrum Analysis with a Resolution of 6 fm based on a Frequency-Swept Microwave-photonic Source, Beibei Zhu[1], Min Xue[1], Shilong Pan[1]; [1]*Nanjing Univ Aeronautics & Astronautics, China.* A full-polarization optical spectrum analyzer is proposed based on a frequency-swept microwave-photonic source and balanced photodetection. A resolution of 0.75 MHz (6 fm) and a dynamic range of >57 dB were experimentally achieved.

M3J.6 • 17:15

On-chip Simultaneous Multi-channel Ultra-wideband Radio Frequency Spectrum Analyzer, Ming Ma[1], Rhys Adams[2], Lawrence R. Chen[1]; [1]*McGill Univ., Canada;* [2]*Department of Physics, Vanier College, Canada.* We demonstrate how to harness mode-selective excitation of nonlinear optical effects to perform simultaneous multi-channel RF spectrum analysis for both 640 GHz and 160 GHz waveforms using a single integrated silicon photonic device.

Room 411

M3K • Optical Data Center Networks—Continued

M3K.2 • 17:00

Novel Intra- and Inter-datacenter Converged Network Exploiting Space- and Wavelength-dimensional Switches, Koh Ueda[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; [1]*Nagoya Univ., Japan.* We propose a novel network architecture that enables intra- and inter-datacenter converged flow management. By adopting our proposed single large-scale optical circuit switch, intra- and inter-datacenter traffic can be transported without any blocking.

M3K.3 • 17:15

Does it Make Sense to Put Optics in Both the Front and Backplane of a Large Data-center?, Aniruddha Kushwaha[1], Tamal Das[1], Ashwin Gumaste[1]; [1]*Indian Inst. of Technology, Bombay, India.* We propose a dual optical architecture, with optics in both the front plane (connecting servers within a rack) and in the backplane (connecting TOR switches). The architecture is shown to scale to a million servers.

M3K.4 • 17:30

Bit-Parallel All-to-all and Flexible AWGR-based Optical Interconnects, Paolo Grani[1], Gengchen Liu[1], Roberto Proietti[1], S. J. Ben Yoo[1]; [1]*Univ. of California, Davis, USA.* This paper demonstrates bit-parallel, all-to-all communication with AWGR for on-board optical interconnects. A flexible bandwidth allocation is also presented. Trade-off studies optimize the bit-parallelism and achieve up to 3.5× higher energy efficiency compared to the single-bit case.

Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB	Room 407

M3A • Panel: Transport SDN - What is Ready, What is Missing?—Continued

M3B • Symposium: Overcoming the Challenges in Large-Scale Integrated Photonics II—Continued

M3C • Probabilistic Shaping and Advanced Modulation Formats—Continued

M3D • High-Speed Subsystems—Continued

M3E • Radio-over-fiber Systems—Continued

M3E.7 • 17:45
Fast Statistical Estimation in Highly Compressed Digital RoF Systems for Efficient 5G Wireless Signal Delivery, Mu Xu[1,2], Xiang Liu[2], Naresh Chand[2], Frank Effenberger[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Huawei R&D USA, Futurewei Technologies, USA.* A fast data compression algorithm is proposed for wireless-signal delivery in a digital RoF system supporting mobile fronthaul. Combined with resampling and advanced modulation formats, data-transmission efficiency is improved by 5 times in experimental demonstrations.

M3F • Frequency Combs and Waveguide Devices—Continued

M3F.7 • 17:45
Mode-selective Wavelength Conversion of Multicarrier, Multilevel Modulation Signals in a Multimode Silicon Waveguide, Ying Qiu[2], Xiang Li[1], Ming Luo[2], Jing Xu[2], Qi Yang[1], Shaohua Yu[1]; [1]*WRI, China;* [2]*Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology , China.* We design and fabricate a multimode silicon waveguide to achieve mode-selective wavelength conversions of 100-Gb/s optical signals. Experimental results show that less than 2 dB power penalties are observed after wavelength conversion for both modes.

NOTES

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

M3G • Fibers and Amplifiers for Deployed Networks—Continued

M3H • TDM and TWDM PON I—Continued

M3H.7 • 17:45

25Gb/s PAM4 Burst-Mode System for Upstream Transmission in Passive Optical Networks, Marco Dalla Santa[1], Cleitus Antony[1], Mark Power[1], Anil Jain[1], Peter Ossieur[1], Giuseppe Talli[1], Paul D. Townsend[1]; [1]*Tyndall National Inst., Ireland.* A 25Gb/s PAM4 burst-mode upstream transmission is demonstrated over 25km of fiber using 10G components and a linear burst-mode TIA with a 14.7dB dynamic range and with differential chromatic dispersion equivalent to 25km of fiber.

M3I • Control and Management for Future PON—Continued

M3J • Optical Characterization and Performance—Continued

M3K • Optical Data Center Networks—Continued

M3K.5 • 17:45

Emulation of a 16×16 Optical Switch Using Cascaded 4×4 Dilated Hybrid MZI-SOA Optical Switches, Minsheng Ding[1], Adrian Wonfor[1], Qixiang Cheng[1], Richard Penty[1], Ian H. White[1]; [1]*Department of Engineering, Univ. of Cambridge, UK.* We demonstrate the first cascaded operation of integrated 4x4 hybrid MZI-SOA optical switches. Experimental studies emulate a 16×16 hybrid switch with 15dB IPDR for 1dB penalty and 43% reduced power consumption than equivalent SOA-based switches.

NOTES

Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB	Room 407

07:30–08:00 Coffee Break, *Concourse Hall Foyer*

08:00–10:00 Plenary Session, *Concourse Hall*

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

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall G-K* (concessions available)

10:00–17:00 **OFC Career Zone Live,** *South Lobby*

11:00–12:00 OSAF Exhibit Hall Training, *402AB*

12:00–13:30 OIDA VIP Industry Leaders Networking Event, *515B* (invite-only; separate registration required)

12:00–14:00 Awards Ceremony and Luncheon, *Petree Hall D* (additional fee required)

13:00–16:00 OSAF Cheeky Scientist Workshops, *501B*

14:00–16:00 Tu2A • Panel: Coherent Interoperability Beyond QPSK — Is it Needed and What Will it Take?

Moderators: Marc Bohn; Coriant GmbH & Co. KG, Germany; Sebastian Randel; Karlsruhe Institute of Technology, Germany

Within the last decade, coherent DSP technology has emerged as the key enabler for optical transmission at rates from 100 Gbps up to 400 Gbps per wavelength. Today, around seven DSP solutions from different companies are offered, all competing to best answer to the operators needs such as performance, cost, and power.

Up to now, this competition seems to drive innovation in the direction of increased speed and capacity as vendors introduce high-performance soft-decision FEC codes, fiber nonlinearity compensation, and probabilistic constellation shaping. With all these advanced features, performance

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14:00–16:00 Tu2B • Advanced VCSEL Links

Presider: Xuezhe Zheng; USA

Tu2B.1 • 14:00 Invited

Future of Short-Reach Optical Interconnects based on MMF Technologies, Jonathan Ingham[1]; [1]*Foxconn Interconnect Technology, USA.* Important aspects of current and future optical interconnects over multimode optical fiber are reviewed, with an emphasis on links using short-wavelength VCSELs and PAM-4 modulation.

14:00–16:00 Tu2C • SDM Switches

Presider: Jochen Schroeder; Chalmers Tekniska Hogskola, Sweden

Tu2C.1 • 14:00

Silicon-based Reconfigurable Optical Add-drop Multiplexer for Hybrid MDM-WDM Systems, Daoxin Dai[1], Shipeng Wang[1]; [1]*Zhejiang Univ., China.* A on-chip reconfigurable optical add-drop multiplexer for mode-division-multiplexing (MDM) and wavelength-division-multiplexing (WDM) simultaneously is proposed and demonstrated for the first time. It integrates a mode demultiplexer, four tunable microring resonator switches, and a mode multiplexer.

14:00–16:00 Tu2D • Modulation, Detection and DSP for PAM-4 Systems

Presider: Gernot Goeger; Huawei, Germany

Tu2D.1 • 14:00

Amplifier-less Transmission of 56Gbit/s PAM4 over 60km using 25Gbps EML and APD, Kang Ping Zhong[1], Xian Zhou[1], Yiguang Wang[1], Jiahao Huo[1], Hongyu Zhang[2], Li Zeng[2], Changyuan Yu[1], Alan Pak Tao Lau[1], Chao Lu[1]; [1]*The Hong Kong Polytechnic Univ., Hong Kong;* [2]*Huawei, China.* In this paper, we experimentally demonstrated 56Gbit/s PAM4 signal optical amplifier-less transmissions over a record distance 60km using 25Gbps EML and APD. Compared to PD-based receiver, improvements of 7dB and 50% in terms of receiver sensitivity and transmission distance were achieved.

14:00–15:45 Tu2E • High Bit-rate Transmission Systems

Presider: Benyuan Zhu; OFS Laboratories, USA

Tu2E.1 • 14:00

Single-Carrier 216 Gbit/s, 12 Gsymbol/s 512 QAM Coherent Transmission over 160 km with Injection-locked Homodyne Detection, Yixin Wang[1], Keisuke Kasai[1], Masato Yoshida[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We demonstrate a pol-mux, 12 Gsymbol/s 512 QAM coherent transmission. An injection-locked homodyne-detection circuit enabled precise optical-phase locking, and 216 Gbit/s-data were successfully transmitted over 160 km with a potential spectral efficiency of 12 bit/s/Hz.

14:00–15:45 Tu2F • Microwave Photonics Enabling Devices

Presider: JGee-Kung Chang; Georgia Institute of Technology, USA

Tu2F.1 • 14:00

Over 40 Gb/s Dynamic Bidirectional All-optical Indoor Wireless Communication Using Photonic Integrated Circuits, Ketemaw Addis Mekonnen[1], Chin Wan Oh[1], Johan van Zantvoort[1], Nicola Calabretta[1], Eduward Tangdiongga[1], A. Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* We demonstrate a novel all-optical system using optical cross-connect and reflective modulator photonic chips to realize bidirectional dynamic indoor wireless networks equipped with localization and tracking functionalities, with over 40 Gb/s data capacity per user.

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

07:30–08:00 Coffee Break, *Concourse Hall Foyer*

08:00–10:00 Plenary Session, *Concourse Hall*

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

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12:00–14:00 Awards Ceremony and Luncheon, *Petree Hall D* (additional fee required)

13:00–16:00 OSAF Cheeky Scientist Workshops, *501B*

Room 408A

14:00–16:00
Tu2G • Data Center Summit: Open Platforms for Optical Innovation

Organizers: Ramon Casellas, CTTC, Spain; Daniel King, University of Lancaster, UK; Noboru Yoshikane, KDDI Research, Japan, Ilya Baldin, RENCI/UNC Chapel Hill, USA

Using open hardware and software platforms for designing, deploying and operating large-scale networks is increasingly seen as a viable strategy for large and complex commercial environments. Most recently, the concepts of open hardware and software are being used within the optical infrastructure domain, and this trend is expected to facilitate innovation, design, adoption and control of future optical infrastructure.

Open hardware initiatives, including the Open Compute Platform, Telecom

continued on page 81

Room 408B

14:00–16:00
Tu2H • Silicon Photonic Modulators

Presider: Zhiping Zhou; Peking Univ., China

Tu2H.1 • 14:00 Invited
High Speed Silicon Photonic Modulators, Xi Xiao[1], Miaofeng Li[1], Lei Wang[1], Daigao Chen[1], Qi Yang[1], Shaohua Yu[1]; [1]*State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts & Telecommunications, China.* We review the progress on high speed silicon photonic modulators based on dispersion plasma effect. We present the demonstrations of silicon-based 90 Gbaud intensity modulator, 100G CWDM4 transmitter, I-Q modulator and optical frequency comb generator.

Room 409AB

14:00–16:00
Tu2I • Integrated Circuits for Signal Processing

Presider: Leif Johansson; Freedom Photonics, LLC, USA

Tu2I.1 • 14:00 Tutorial
Photonic Integrated Circuit for Optical Signal Processing, Michael Watts[1]; [1]*Massachusetts Inst. of Technology, USA.* Abstract not available.

Michael R. Watts is a principal investigator in the Research Laboratory of Electronics (RLE) and a member of the Electrical Engineering and Computer

continued on page 81

Room 410

14:00–16:00
Tu2J • Fibers and Components for Mode Division Multiplexing

Presider: Testuya Nakanishi; Sumitomo Electric Industries Ltd, Japan

Tu2J.1 • 14:00 Invited
MIMO-less Space Division Multiplexing with Elliptical Core Optical Fibers, Giovanni Milione[1], Ezra Ip[1], Philip Ji[1], Yue-Kai Huang[1], Ting Wang[1], Ming-Jun Li[2], Jeffery Stone[2], Gaozhu Peng[2]; [1]*NEC Laboratories America Inc, USA;* [2]*Corning Incorporated, USA.* MIMO-less space division multiplexing with elliptical core optical fibers is reviewed. Real-time, bi-directional, and Tb-scale data rates with direct detection over the spatial modes/cores of km-scale, few mode/multi-core elliptical core optical fibers are demonstrated.

Room 411

14:00–15:45
Tu2K • Operation and Architecture for Optical Access

Presider: Jun Shan Wey; ZTE, USA

Tu2K.1 • 14:00 Invited
FTTH Deployment - Google Fiber's Perspective, Cedric Lam[1]; [1]*Google, USA.* In this paper, we review the experiences and challenges learned through six years of operations of Google Fiber.

Show Floor Programming

Transforming the Future of Data Center
OCP
10:15–11:45
For more details, see page 44

Product Showcase
Huawei
10:15–10:45
For more details, see page 46

■ Market Watch
Panel I: State of the Industry — Analyst Panel
10:30–12:00
For more details, see page 40

The Fracturing and Burgeoning Ethernet Market
Ethernet Alliance
11:00–12:00
For more details, see page 46

■ Data Center Summit
Next Generation Optical Technologies Inside the Data Center
12:15–13:45
For more details, see page 16

■ Market Watch
Panel II: Market Outlook for High Bandwidth Optical Technologies
12:30–14:00
For more details, see page 40

Dynamic Third Network Services for the Digital Economy and Hyper-connected World
MEF
12:30–13:30
For more details, see page 46

Enabling Next Generation Physical Layer Solutions
OIF
13:45–14:45
For more details, see page 46

Advancing Optical Interoperability in Open Networks
Session Sponsored by Juniper
14:00–17:00
For more details, see page 44

Room 402AB

Tu2A • Panel: Coherent Interoperability Beyond QPSK - Is it Needed and What Will it Take?—Continued

is getting closer and closer to the Shannon limit, making significant performance improvements in the range of >1dB unlikely to occur. At the same time, power consumption is getting more and more important and the timeline of new ASIC generations is following closer and closer the availability of new lower power CMOS process nodes, for which the end of Moore's law has been predicted.

This brings up the question whether the industry as a whole would benefit from a successive standardization of coherent DSPs. Today, pretty much all coherent DSPs include a 100G DP-QPSK mode which is interoperable. However, it uses a hard-decision FEC which cannot compete with more advanced soft-decision FECs. Looking forward, the following questions arise:

- What would it take to standardize higher-order modulation schemes e.g. 16QAM and 64-QAM as well as high-performance FECs?
- Do operators see potential benefits in this?
- Will standardization of coherent DSPs finally be driven by the need for high-capacity short-reach?
- Is the optics market truly unique or will it ultimately be shared among 2-3 players (compare markets like CPU, GPU, LTE, PON, DSL, …)?

On this panel, we want to elude answers to these questions by bringing together speakers from key operators and system vendors.

Panelists:

Marco Bertolini, *Nokia Corporation, Italy*

Dirk van den Borne, Juniper Networks, Inc., Germany

Markus Weber, *Acacia Communications Inc., Germany*

Werner Weiershausen; *Deutsche Telekom, Germany*

Room 403A

Tu2B • Advanced VCSEL Links—Continued

Tu2B.2 • 14:30

First Demonstration of PAM4 Transmissions for Record Reach and High-capacity SWDM Links Over MMF Using 40G/100G PAM4 IC Chipset with Real-time DSP, Frank Chang[1]; [1]*Inphi Corporation, USA.* We experimentally demonstrate, for the first time, link BERs under KP4 FEC threshold at 42.5Gbps over 550m high bandwidth OM4 using single 850nm VCSEL and at aggregated 212.5Gbps over 300m wideband multimode fiber using SWDM TOSAs from 850 to 940nm, employing newly developed PAM4 ICs and direct detection, with novel Ge/Si APD or wideband PIN ROSA.

Room 403B

Tu2C • SDM Switches—Continued

Tu2C.2 • 14:15

Channel Passband Broadening via Strong Mixing in Cascaded Few-mode Fiber Wavelength-selective Switches, Miri Blau[1], Dan M. Marom[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* Strong mixing in FMF statistically reduces group delay spread. We demonstrate that it also statistically broadens the passband of cascaded FMF WSS, since the channel edge transition of a single WSS is mode dependent.

Tu2C.3 • 14:30

SDM-Compatible Dynamic Gain Equalizer using Spatial and Planar Optical Circuit, Mitsumasa Nakajima[1], Kenya Suzuki[1,2], Keita Yamaguchi[1], Hirotaka Ono[1,2], Hiroki Kawahara[2], Mitsunori Fukutoku[2], Takayuki Mizuno[2], Yutaka Miyamoto[2], Toshikazu Hashimoto[1]; [1]*NTT Device Technology Labs., NTT, Japan;* [2]*NTT Network Innovation Laboratories, NTT, Japan.* We propose a gain equalizer array for SDM amplifiers using a spatial and planar optical circuit platform and demonstrate gain equalizing of multicore Er-doped fiber amplifier over 30-nm wavelength range with ±0.8 dB accuracy.

Room 404AB

Tu2D • Modulation, Detection and DSP for PAM-4 Systems—Continued

Tu2D.2 • 14:15

Single-lane 180 Gb/s SSB-Duobinary-PAM-4 Signal Transmission over 13 km SSMF, Qiang Zhang[1], Nebojsa Stojanovic[1], Tianjian Zuo[2], Liang Zhang[2], Cristian Prodaniuc[1], Fotini Karinou[1], Changsong Xie[1], Enbo Zhou[2]; [1]*Huawei Technologies Duesseldorf GmbH, Germany;* [2]*Huawei Technologies Co. LTD, China.* A 90 GBaud single sideband duobinary PAM-4 signal is generated using bandwidth pre-compensation and duo-binary pulse shaping employing a 92 GSa/s DAC. Transmission over 13 km of SSMF is achieved in 50 GHz channel enabled by dispersion pre-compensation at the transmitter.

Tu2D.3 • 14:30

A 64 Gb/s PAM-4 Transimpedance Amplifier for Optical Links, Bart Moeneclaey[1], Jochen Verbrugghe[1], Elad Mentovich[2], Paraskevas Bakopoulos[3], Johan Bauwelinck[1], Xin Yin[1]; [1]*Ghent Univ., Belgium;* [2]*Mellanox Technologies, Israel;* [3]*School of Electrical & Computer Engineering, Greece.* We present a 64 Gb/s PAM-4 transimpedance amplifier with 180 mW power consumption. By switching between four gain modes, modulation amplitudes between -7 dBm and at least -0.2 dBm yield a BER lower than 10^{-3}.

Room 406AB

Tu2E • High Bit-rate Transmission Systems—Continued

Tu2E.2 • 14:15

Single-carrier 400G Based on 84-GBaud PDM-8QAM Transmission over 2,125 km SSMF Enhanced by Pre-equalization, LUT and DBP, Junwen Zhang[1], Jianjun Yu[1]; [1]*ZTE tx, USA.* Single-carrier 400G based on 84-GBaud 8QAM is generated and pre-processed with pre-equalization and Look-up-Table pre-distortion. Thanks to the receiver-side DBP fiber nonlinearity compensation, WDM transmission over 2,125 km SSMF with EDFA-only amplification is enabled.

Tu2E.3 • 14:30 Invited

Fast DAC Solutions for Future High Symbol Rate Systems, Xi Cen[1]; [1]*Nokia Bell Labs, USA.* We review electronic digital-to-analog converter (DAC) technologies with sampling rates beyond 200 GSa/s and analog electrical bandwidths of 100 GHz using digital bandwidth interleaving. These allow the all-electronic generation of up to 195-GBaud electrical and 180-Gbaud optical modulation formats.

Room 407

Tu2F • Microwave Photonics Enabling Devices—Continued

Tu2F.2 • 14:15

All-optical Signal Upconversion using Optically-Injected DFB Laser and Embedded Optoelectronic Oscillator for Radio-over-fiber Applications, Ji Tao[2], Peng Wang[2], Long Huang[2], Guo-Wei Lu[1]; [1]*Tokai Univ., Japan;* [2]*Nanjing Univ., China.* We propose all-optical signal upconversion scheme using optically-injected DFB in combine with embedded optoelectronics oscillator for RoF application. The low-noise LO provided by OEO and near-SSB modulation implemented by injection locking enables high-performance in transmission.

Tu2F.3 • 14:30

Long-reach MMWoF using Single-sideband Modulated Dual-Mode VCSEL with 16-QAM OFDM at 8 Gbit/s, Cheng-Ting Tsai[1], Yu-Chieh Chi[1], Peng-Chun Peng[2], Gong-Ru . Lin[1]; [1]*National Taiwan Univ., Taiwan;* [2]*National Taipei Univ. of Technology, Taiwan.* 39-GHz millimeter-wave-over-fiber (MMWoF) based long-reach PON with a dual-mode VCSEL transmitter under single-sideband modulation is demonstrated for 8-Gbit/s 16-QAM OFDM transmission over 50-km single-mode fiber and 1-m free-space with BER of 3.6×10^{-3}.

Tuesday, 21 March

Room 408A

Tu2G • Data Center Summit: Open Platforms for Optical Innovation—Continued

Infrastructure Project, Open ROADM Multi-Source Agreement, Central Office Rearchitected as Datacenter and Open Platform for NFV are defining open hardware platforms and reference implementations. To facilitate their control and operation, software projects such as OpenStack, OpenDayLight, Open Network Operating System, Open Platform for NFV, Open Source Mano and OpenConfig, are providing extensible frameworks and software tools.

Numerous proof-of-concept implementations and distributions across various research projects and early stage commercial initiatives, have demonstrated that rapid innovation is possible on basis of open hardware, interfaces, and software. Increasingly, these implementations and distributions will have to support the growing need for open optical hardware platforms.

The Open Platform Summit will discuss recent trends on open platforms and its applications to the optical networking space. It will comprise two technical sessions; the first session will have invited talks to introduce the audience to the topic area. The second session will comprise interactive table-top SDN & NFV demos selected from proposal submitted through the OFC system.

Speakers:

Saurav Das, *Open Networking Foundation, USA*

Young Lee, *Huawei, USA*

Anees Shaikh, *Network Architect, Google - Open Management Plan for Transport Networks*

Yasushi Sugaya, *Fujitsu, Japan*

Room 408B

Tu2H • Silicon Photonic Modulators—Continued

Tu2H.2 • 14:30

Efficient Single-drive Push-pull Silicon Mach-Zehnder Modulators with U-shaped PN Junctions for the O-Band, Zheng Yong[1], Wesley D. Sacher[1], Ying Huang[2], Jared C. Mikkelsen[1], Yisu Yang[1], Xianshu Luo[2], Patrick Dumais[3], Dominic Goodwill[3], Hadi Bahrami[3], Guo-Qiang Lo[2], Eric Bernier[3], Joyce K. Poon[1]; [1]*Univ. of Toronto, Canada;* [2]*Inst. of Microelectronics, A*STAR, Singapore;* [3]*Huawei Technologies Canada Co. Ltd, Canada.* We demonstrate silicon Mach-Zehnder modulators with efficient ($V_\pi L$ = 0.46V•cm at a bias of -0.5V) and low-loss phase-shifters for the O-band. A 2-mm long device had a 3-dB bandwidth of 13GHz and supported 24Gb/s modulation.

Room 409AB

Tu2I • Integrated Circuits for Signal Processing—Continued

Science Department (EECS) at the Massachusetts Institute of Technology. Professor Watts' research focuses on photonic microsystems for low-power communications, sensing, and microwave-photonics applications. His current interests include the modeling, fabrication, and testing of large-scale implementations of microphotonic circuits, systems, and networks that are being integrated, directly or through hybrid techniques, with CMOS electronics for high-speed transmitting, switching, and routing applications of digital signals. Additional interests include large-scale microphotonic sensing and imaging arrays, along with optical phased arrays, nanophotonic antennas, nonlinear optics, and manipulations of optical-electromagnetic fields on-chip.

Room 410

Tu2J • Fibers and Components for Mode Division Multiplexing—Continued

Tu2J.2 • 14:30

MIMO-Free Transmission over Six Vector Modes in a Polarization Maintaining Elliptical Ring Core Fiber, Lixian Wang[1], Reza M. Nejad[1], Alessandro Corsi[1], Jiachuan Lin[1], Younès Messaddeq[1], Leslie Rusch[1], Sophie LaRochelle[1]; [1]*COPL, Univ. Laval, Canada.* We demonstrate an elliptical ring core fiber featuring vector modes with high stability and linear polarization states. We achieve six vector mode channel transmission over 0.9 km of 32 Gbaud QPSK without MIMO/PDM signal processing.

Room 411

Tu2K • Operation and Architecture for Optical Access—Continued

Tu2K.2 • 14:30

Multi-dimensional Quasi-passive Reconfigurable (MD-QPAR) Node for Future 5G Optical Networks, Ke Wang[1,2], Apurva Gowda[2], Yingying Bi[2], Leonid G. Kazovsky[2]; [1]*School of Engineering, RMIT Univ., Australia;* [2]*Department of Electrical Engineering, Stanford Univ., USA.* A multi-dimensional quasi-passive reconfigurable node is proposed and demonstrated for dynamic power and wavelength allocations in future 5G optical network applications. The traffic delay is reduced by >95% and the power penalty is negligible.

Show Floor Programming

Enabling Next Generation Physical Layer Solutions
OIF
13:45–14:45
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Advancing Optical Interoperability in Open Networks
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The Key to Unlocking the Benefits of SDN
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15:00–16:00
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Room 402AB

Tu2A • Panel: Coherent Interoperability Beyond QPSK - Is it Needed and What Will it Take?—Continued

Room 403A

Tu2B • Advanced VCSEL Links—Continued

Tu2B.3 • 14:45

Demonstration of SWDM Transmission over OM4 Multimode Fiber with Modal Dispersion Compensation, Xin Chen[1], Jason Hurley[1], Dong Gui[1], Yao Li[1], Jeffery Stone[1], Ming-Jun Li[1]; [1]*Corning Incorporated, USA.* We propose simple wavelength-band modal dispersion compensation approach for extended reach SWDM up to 600m and demonstrate experimentally 40G transmission over 450m OM4 MMF with modal dispersion compensation fiber and 4-channel MUX/DEMUX devices.

Tu2B.4 • 15:00 Invited

Universal Photonic Interconnect for Data Centers, Michael R. Tan[1], Paul Rosenberg[1], Wayne V. Sorin[1], Sagi Mathai[1], Georgios Panotopoulos[1], Glenn Rankin[1]; [1]*Hewlett Packard Enterprise, USA.* Tb/s class, co-packaged CWDM optical engine based on 4 wavelength VCSELs around 1um is presented. The capability to scale bandwidth and link distance > 2km using single mode VCSELs and standard SMF28 fiber is demonstrated.

Room 403B

Tu2C • SDM Switches—Continued

Tu2C.4 • 14:45

Beam-Steering All-optical Switch for Multi-core Fibers, Hans Christian H. Mulvad[1], Andrew Parker[2], Bryan King[2], Daryl Smith[2], Mate Kovacs[2], Saurabh Jain[1], John R. Hayes[1], Marco Petrovich[1], David J. Richardson[1], Nick Parsons[2]; [1]*Optoelectronics Research Centre , UK;* [2]*Polatis Ltd, UK.* We report on the development of the first multi-lane all-optical switch with directly integrated multi-core fibers. A 3-port single-sided beam-steering switch connecting 4-core fibers shows core-to-core losses below 2.2 dB with less than 1-dB variation.

Tu2C.5 • 15:00 Tutorial

Switching and Multiplexing Technologies for Mode-division Multiplexed Networks, Roland Ryf[1]; [1]*Advanced Photonics, Nokia Bell Labs, Holmdel, NJ, USA.* Mode-division multiplexing adds a new dimension on top of conventional wavelength-division multiplexed networks. In this tutorial we will review the implications on switching architectures and multiplexing technologies for combined mode and wavelength multiplexed optical networks.

continued on page 84

Room 404AB

Tu2D • Modulation, Detection and DSP for PAM-4 Systems—Continued

Tu2D.4 • 14:45

Eye Deskewing Algorithms for PAM Modulation Formats in IM-DD Transmission Systems, Nebojsa Stojanovic[1], Qiang Zhang[1], Cristian Prodaniuc[1], Fotini Karinou[1]; [1]*Huawei, Germany.* We propose several algorithms for eye deskewing in IM-DD transmission systems that use EMLs and VCSELs for data modulation. The performance of linearly equalized signals with irregular eye diagrams is significantly improved after deskewing.

Tu2D.5 • 15:00

Nonlinear Equalizer for 112-Gb/s SSB-PAM4 in 80-km Dispersion Uncompensated Link, Noriaki Kaneda[1], Jeffrey Lee[1], Young-Kai Chen[1]; [1]*Nokia Bell Labs, USA.* We present a blindly adaptive nonlinear channel equalizer that effectively compensates nonlinearity in SSB-PAM4 transceiver components. The proposed scheme is demonstrated over 56GBaud PAM4 transmission over 80km dispersion uncompensated link with low BER near 10^{-4}.

Room 406AB

Tu2E • High Bit-rate Transmission Systems—Continued

Tu2E.4 • 15:00

Experimental Demonstration of Single Carrier 400G/500G in 50-GHz Grid for 1000-km Transmission, Yi Yu[1], Yanzhao Lu[1], Ling Liu[1], Yuanda Huang[1], Xie Wang[1], Liang-Chuan Li[1]; [1]*Transmission Technology Research Department, Huawei Technologies Co., Ltd., China.* In this paper, we experimentally demonstrated 400G/500G single-carrier in 50-GHz grid for 1000-km G.654 fiber transmission with Raman amplifier. 43.125-Gbaud PDM-64QAM (400G net) and PDM-128QAM (500G net) achieved spectral efficiency of 8 and 10 bit/s/Hz.

Room 407

Tu2F • Microwave Photonics Enabling Devices—Continued

Tu2F.4 • 14:45

Novel Detection in V-band MIMO OFDM RoF Systems using ADCs with Sub-Nyquist Sampling, Yao-Lun Huang[2], Chia Chien Wei[1], Chun-Ting Lin[2], Chi-Hsiang Lin[2]; [1]*National Sun Yat-sen Univ., Taiwan;* [2]*National Chiao Tung Univ., Taiwan.* A novel detection scheme in MIMO-OFDM-RoF systems is proposed. Via pre-processing, data are received using sub-Nyquist-sampling ADCs without MIMO demodulation and extra DSP. Based on 5/32-GSample/s sampling rate, 50-Gbps 2×2 MIMO-OFDM-RoF transmission was successfully demonstrated.

Tu2F.5 • 15:00 Invited

Towards Programmable Microwave Photonics Processors, Jose Capmany[1], Daniel Perez[1], Ivana Gasulla Mestre[1]; [1]*Universidad Politecnica de Valencia, Spain.* We present the concept of software-defined microwave photonics programmable processor and describe recent efforts carried towards its implementation using photonic waveguide meshes in a similar way as Field Programmable Gate Arrays are employed in electronics.

Room 408A

Tu2G • Data Center Summit: Open Platforms for Optical Innovation—Continued

Room 408B

Tu2H • Silicon Photonic Modulators—Continued

Tu2H.3 • 14:45 Top Scored
A 44Gbps High Extinction Ratio Silicon Mach-Zehnder Modulator with a 3D-Integrated 28nm FD-SOI CMOS Driver, Zheng Yong[1], Stefan Shopov[1], Jared C. Mikkelsen[1], Robert Mallard[2], Jason C. Mak[1], Sorin P. Voinigescu[1], Joyce K. Poon[1]; [1]*Univ. of Toronto, Canada;* [2]*Innovation Park at Queen's Univ., CMC Microsystems, Canada.* We present a silicon electro-optic transmitter consisting of a 28nm UTBB FD-SOI CMOS driver flip-chip integrated onto a Mach-Zehnder modulator. At 44 Gbps, the extinction ratio was 6.4 dB at the modulator quadrature operation point.

Tu2H.4 • 15:00 Top Scored
Silicon Photonics Modulator Architectures for Multi-level Signal Generation and Transmission, Alireza Samani[1], Mathieu Chagnon[1], Eslam Elfiky[1], David Patel[1], Maxime Jacques[1], Venkat Veerasubramanian[1], David Plant[1]; [1]*McGill Univ., Canada.* We present two SiP modulator architectures for PAM-4 signal generation. We demonstrate the transmission of 56 Gbaud PAM-4 over 1 km of SMF. An 84 Gbaud PAM-4 generation below KP4 FEC threshold is also achieved.

Room 409AB

Tu2I • Integrated Circuits for Signal Processing—Continued

Tu2I.2 • 15:00 Top Scored
80Gb/s PDM-QPSK PIC-to-PIC Transmission based on Integrated Hybrid Silicon/III-V Wavelength-tunable Transmitter and Monolithic Silicon Coherent Receiver, Guilhem de Valicourt[2], Michael Eggleston[2], Chen Zhu[2], Jeffrey Lee[2], Chia-Ming Chang[2], Jeffrey Sinsky[2], KW Kim[2], Young-Kai Chen[2], Anaelle Maho[1], Romain Brenot[1], Po Dong[2]; [1]*III-V Lab, France;* [2]*Nokia Bell Labs, USA.* We reported the first hybrid III-V/Si integrated QPSK wavelength-tunable transmitter based on high-speed ring modulators (BW~23GHz). 80 Gbit/s PDM-QPSK signal transmission over 100 km with said integrated hybrid transmitter as well as a fully packaged silicon-based coherent receiver is demonstrated.

Room 410

Tu2J • Fibers and Components for Mode Division Multiplexing—Continued

Tu2J.3 • 14:45
Strongly-Coupled Five-mode Ring-core Fiber for MDM Transmission with MIMO DSP, Takayoshi Mori[1], Taiji Sakamoto[1], Masaki Wada[1], Azusa Urushibara[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*NTT Corporation, Japan.* The group delay spread reduction induced by a constant bend is experimentally confirmed using a five-mode ring-core fiber. Five spatial modes were successfully transmitted using a low-loss multiplexer composed of a five-core bundle.

Tu2J.4 • 15:00
DMGD-Compensated Links, Pierre Sillard[1], Denis Molin[1], Marianne Bigot[1], Adrian Amezcua-Correa[1], Koen de Jongh[1], Frank Achten[1]; [1]*Prysmian Group, France.* DMGD-compensated links based on few-mode and multi-mode fibers are investigated taking into account the impact of process variability. A 50µm-diameter-core multimode-fiber link with values ≤40ps/km for the first 36 usable spatial modes is reported.

Room 411

Tu2K • Operation and Architecture for Optical Access—Continued

Tu2K.3 • 14:45
In-Service Location of Multiple Fiber Faults in WDM/SCM-PONs with Low-frequency Stepwise Sweep and l1 Regularization, Gustavo C. do Amaral[1], Joaquim D. Garcia[1], Bruno F. Santos[2], Patryk Urban[3], Jean Pierre von der Weid[1]; [1]*Center for Telecommunication Studies, Pontifical Catholic Univ. of Rio, Brazil;* [2]*Electrical Engineering, Pontifical Catholic Univ. of Rio de Janeiro, Brazil;* [3]*Ericsson Research, Ericsson AB, Sweden.* We present a monitoring technique that can be directly integrated in the transceiver for WDM/SCM-PON applications. It is based on the detection of the back-scattered signal from a baseband tone and interpretation with the LASSO operator for multiple fault detection.

Tu2K.4 • 15:00 Invited
Challenges and Technology Innovations for Interconnections in Smart Cities, Rodney S. Tucker[1]; [1]*Univ. of Melbourne, Australia.* Ubiquitous wireless connectivity and pervasive ultra-high-speed broadband access networks underpin smart cities and smart nations. This paper examines some of the challenges and technological trade-offs that face governments and communities seeking to enhance public communications infrastructure.

Show Floor Programming

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The Key to Unlocking the Benefits of SDN
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Room 402AB

Tu2A • Panel: Coherent Interoperability Beyond QPSK - Is it Needed and What Will it Take?—Continued

Room 403A

Tu2B • Advanced VCSEL Links—Continued

Tu2B.5 • 15:30

4×50Gb/s NRZ Shortwave-Wavelength Division Multiplexing VCSEL link over 50m Multimode Fiber, Tam N. Huynh[1,2], Fuad Doany[1], Daniel Kuchta[1], Deepa Gazula[3], Edward Shaw[3], Jason O'Daniel[3], Jim Tatum[3]; [1]*IBM T.J. Watson Research Center, USA;* [2]*R&D, Coriant Advanced Technology, USA;* [3]*Finisar Corp., USA.* We demonstrate for the first time a 4x50Gb/s NRZ SWDM VCSEL link over 50m OM4 multimode fiber achieving error free operation (BER<1E-12). Transmission of 4×44Gb/s SWDM over 100m OM4 fiber with error free is also presented.

Room 403B

Tu2C • SDM Switches—Continued

Roland Ryf is a Distinguished Member of Technical Staff at Nokia Bell Labs, Holmdel, NJ. He received the diploma and the Ph.D. in physics from the Swiss Federal Institute of Technology (ETH) Zürich, Switzerland, working on nonlinear optics and optical parallel processing. After joining Bell Labs in May 2000 he has been working on MEMS based large port-count optical cross-connect switches, high resolution optical wavelength filters, mutlimode wavelength-selective switches and amplifiers, and numerous first experimental demonstration of long distance high capacity space-division multiplexed transmission over multimode fibers and coupled-core multicore fibers. Dr. Ryf authored/coauthored over 200 journal and conference publications and holds 40 patents.

Room 404AB

Tu2D • Modulation, Detection and DSP for PAM-4 Systems—Continued

Tu2D.6 • 15:15

Transmission of 56-Gb/s PAM-4 Signal over 20 km of SSMF Using a 1.55-µm Directly-Modulated Laser, Minsik Kim[1], Sunghyun Bae[1], Hoon Kim[1], Yun Chul Chung[1]; [1]*KAIST, USA.* We demonstrate the transmission of 56-Gb/s PAM-4 signal over 20-km long SSMF by using a 1.55-µm DML without optical dispersion compensation. Instead, a linear electric equalizer is used for the compensation of dispersion-induced waveform distortions.

Tu2D.7 • 15:30 Invited

Recent Advances in Short Reach Systems, Kang Ping Zhong[1], Xian Zhou[1], Yiguang Wang[1], Tao Gui[1], Yanfu Yang[1], Jinhui Yuan[1], Liang Wang[2], Wei Chen[3], Hongyu Zhang[3], Jiangwei Man[3], Li Zeng[3], Changyuan Yu[1], Alan Pak Tao Lau[1], Chao Lu[1]; [1]*The Hong Kong Polytechnic Univ., Hong Kong;* [2]*CUHK, Hong Kong;* [3]*Huawei, China.* In this paper, we review recent advances in high speed optical short reach transmission systems. Recent progress on advanced modulation formats, DSP, transmission schemes and devices are discussed.

Room 406AB

Tu2E • High Bit-rate Transmission Systems—Continued

Tu2E.5 • 15:15

WDM Transmission of 16-Channel Single-carrier 128-GBaud PDM-16QAM signals with 6.06 b/s/Hz SE, Junwen Zhang[1], Jianjun Yu[1], Hung-Chang Chien[1]; [1]*ZTE Tx Inc, USA.* We experimentally demonstrate the WDM transmission of 16-channel single-carrier 1.024 Tb/s signals based on 128-GBaud all-ETDM PDM-16QAM signals over 320-km stand single-mode-fiber with EDFA-only amplification with joint transmitter and receiver-side signal processing.

Tu2E.6 • 15:30

800 Gbit/s Dual Channel Transmitter with 1.056 Tbit/s Gross Rate, Karsten Schuh[1], Fred Buchali[1], Wilfried Idler[1], Tobias A. Eriksson[1], Wolfgang Templ[1], Lars Altenhain[2], Ulrich Duemler[2], Rolf Schmid[2], Michael Moeller[2]; [1]*Nokia Bell Labs, Germany;* [2]*MICRAM Microelectronic GmbH, Germany.* We demonstrate generation of a 44 Gbaud 64 QAM dual polarization dual channel signal from one laser achieving a gross rate of 1.056 Tbit/s. Fiber transmission reach of 730 km over SSMF is also demonstrated.

Room 407

Tu2F • Microwave Photonics Enabling Devices—Continued

Tu2F.6 • 15:30

Experimental Beam Displacement Tracking and Correction of Data-carrying Orbital-angular-momentum Beams in a Free-space Optical Link, Long Li[1], Runzhou Zhang[1], Guodong Xie[1], Yongxiong Ren[1], Zhe Zhao[1], Zhe Wang[1], Cong Liu[1], Haoqian Song[1], Kai Pang[1], Robert Bock[2], Moshe Tur[3], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*R-DEX System, USA;* [3]*School of Electrical Engineering, Tel Aviv Univ., Israel.* We experimentally demonstrate beam displacement tracking and correction using orbital-angular-momentum (OAM) beams based position detection over a 400-Gbit/s OAM-multiplexed link. Power penalties <3 dB are achieved with the displacement up to ±10 mm.

Room 408A

Tu2G • Data Center Summit: Open Platforms for Optical Innovation—Continued

Room 408B

Tu2H • Silicon Photonic Modulators—Continued

Tu2H.5 • 15:15
Dual Polarization O-Band Silicon Photonic Intensity Modulator for Stokes Vector Direct Detection Systems, Eslam Elfiky[1], Mohammed Sowailem[1], Alireza Samani[1], Mohammed Osman[1], David Patel[1], Mathieu Chagnon[1], David V. Plant[1]; [1]*McGill Univ., Canada.* We present an O-band dual-polarization silicon photonic intensity-modulator for short reach direct-detection applications. We demonstrate 112 Gb/s DP-OOK transmission over 10 km at a BER of 6.6x10-6 using a Stokes vector direct-detection receiver.

Tu2H.6 • 15:30
Tapless Locking of Silicon Ring Modulators for WDM Applications, Argishti Melikyan[1], KW Kim[1], Young-Kai Chen[1], Po Dong[1]; [1]*Nokia/Bell Labs, USA.* Novel method for tapless locking of silicon ring modulators for WDM applications is discussed. Wavelength locking with an athermal operation over the temperature variations of 6C is demonstrated at the data rates of 10 Gbit/s.

Room 409AB

Tu2I • Integrated Circuits for Signal Processing—Continued

Tu2I.3 • 15:15
Dual-Core Polarization Diverse Silicon Photonic Add/Drop Switch Supporting 400Gb/s PDM-16QAM, Dominic Goodwill[1], Chunshu Zhang[1], Patrick Dumais[1], Dritan Celo[1], Jia Jiang[1], Xuefeng Tang[1], Zhuhong Zhang[1], Fei Zhao[2], Xin Tu[2], Chunhui Zhang[2], Shengyong Yan[2], Jifang He[2], Ming Li[2], Wanyuan Liu[2], Yuming Wei[2], Dongyu Geng[2], Hamid Mehrvar[1], Eric Bernier[1]; [1]*Huawei Technologies Canada, Canada;* [2]*Huawei Technologies, China.* We implement a silicon photonic 16-port add-or-drop, with on-chip polarization diversity including polarization splitter rotators and dual switch cores. PDL, DGD of express and add were 0.3dB, <0.1ps and 1.1dB, <3ps respectively. 200Gb/s and 400Gb/s PDM-16QAM signals were transmitted, with 0.1dB ROSNR penalty at 200Gb/s.

Tu2I.4 • 15:30
Full C-band Nyquist-WDM Interleaver Chip, Zihan Geng[1], Leimeng Zhuang[1], Bill Corcoran[1,2], Benjamin Foo[1], Arthur Lowery[1]; [1]*Dept. of Electrical and Comp. System Eng., Monash Univ., Monash Univ., Australia;* [2]*Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Australia.* We experimentally demonstrate full C-band coverage of a Nyquist-filtering interleaver for super-channel multiplexing. We show N-WDM super-channel multiplexing with zero guard-band, 12.5-GHz spacing, 0.08 roll-off, and a Q fluctuation <0.3-dB across C-band.

Room 410

Tu2J • Fibers and Components for Mode Division Multiplexing—Continued

Tu2J.5 • 15:15
Reducing Group Delay Spread in a 9-LP mode FMF using Uniform Long-period Gratings, Huiyuan Liu[1], He Wen[1,2], Rodrigo Amezcua Correa[1], Pierre Sillard[3], Guifang Li[1,2]; [1]*CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA;* [2]*The College of Precision Instruments and Opto-elecronic Engineering, Tianjin Univ., China;* [3]*Prysmian Group, France.* We experimentally demonstrate, for the first time, reducing group delay spread in graded-index few-mode fibers with many LP modes using simple, uniform long-period gratings which have only one grating period.

Tu2J.6 • 15:30
Experimental Verification of Mode-Dependent Loss Reduction by Mode Coupling Using Long-Period Grating, Azusa Hasegawa-Urushibara[1], Takayoshi Mori[1], Taiji Sakamoto[1], Masaki Wada[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*NTT Corporation, Japan.* Experiments reveal, for the first time, the mode-dependent loss (MDL) reduction effect of mode-coupling in long-period-grating. MDL is reduced effectively even if the transmission system has a large differential-mode-attenuation.

Room 411

Tu2K • Operation and Architecture for Optical Access—Continued

Tu2K.5 • 15:30
Compact and Low Cost Superimposition of AMCC with Magneto-optic VOA, Goji Nakagawa[2], Kyosuke Sone[2], Setsuo Yoshida[1], Shoichiro Oda[1], Motoyuki Takizawa[2], Tomoo Takahara[1], Yoshio Hirose[2], Takeshi Hoshida[1]; [1]*Fujitsu Laboratories Limited, Japan;* [2]*Fujitsu limited, Japan.* We have proposed optical superimposition scheme employing a magneto-optic VOA as a simple and low cost implementation of AMCC system and experimentally confirmed lower power penalty in AMCC superimposition.

Show Floor Programming

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Tu2A • Panel: Coherent Interoperability Beyond QPSK - Is it Needed and What Will it Take?—Continued

Tu2B • Advanced VCSEL Links—Continued

Tu2B.6 • 15:45 Top Scored
4λ x 100Gbps VCSEL PAM-4 Transmission over 105m of Wide Band Multimode Fiber, Justin Lavrencik[1], Siddharth Varughese[1], Varghese A. Thomas[1], Gary Landry[2], Yi Sun[3], Roman Shubochkin[3], Kasyapa Balemarthy[3], Jim Tatum[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Finisar, USA;* [3]*OFS, USA.* We demonstrate 100 Gbps PAM-4 transmission over 105m of wideband-MMF for each of four wavelengths from 850nm to 940nm using 25G VCSELs and thereby demonstrate an architecture that enables 400G over a single MMF.

Tu2C • SDM Switches—Continued

Tu2D • Modulation, Detection and DSP for PAM-4 Systems—Continued

16:00–16:30 Coffee Break, *400 Foyer; Exhibit Hall*

NOTES

Room 408A

Tu2G • Data Center Summit: Open Platforms for Optical Innovation—Continued

Room 408B

Tu2H • Silicon Photonic Modulators—Continued

Tu2H.7 • 15:45
Characterization of Electro-optic Bandwidth of Ultra-high Speed Modulators, Xi Chen[1], Sethumadhavan Chandrasekhar[1], Gregory Raybon[1], Po Dong[1], Borui Li[1], Andrew Adamiecki[1], Peter Winzer[1]; [1]*Nokia Bell Labs, USA.* We propose and demonstrate a method for measuring the bandwidth of electro-optic modulators up to 100 GHz using an RF synthesizer, a Mach-Zehnder modulator, a photodiode, and an optical spectrum analyzer.

Room 409AB

Tu2I • Integrated Circuits for Signal Processing—Continued

Tu2I.5 • 15:45
K-band RF Multi-beamformer Using Si_3N_4 TTD for Home-satellite Communications, Netsanet Tessema[1], Zizheng Cao[1], Johan van Zantvoort[1], Ketemaw Addis Mekonnen[1], Ailee M. Trinidad[1], Eduward Tangdiongga[1], Bart Smolders[1], A. Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* An optically controlled multi-RF beamformer for targeting more than one satellite is presented. Two beams in K-band of 6 Gbps each are generated by a 2x1 beamformer attached to a wavelength-dependent ring-based optical chip.

Room 410

Tu2J • Fibers and Components for Mode Division Multiplexing—Continued

Tu2J.7 • 15:45
Experimental Analysis of the Modal Evolution in Photonic Lanterns, Juan Carlos Alvarado Zacarias[1,2], Bin Huang[1,2], Nicolas K. Fontaine[2], Haoshuo Chen[2], Roland Ryf[2], Jose Antonio-Lopez[1], Rodrigo Amezcua Correa[1], Zeinab Sanjabi Eznaveh[1]; [1]*Univ. of Central Florida, USA;* [2]*Nokia Bell Labs, USA.* We experimentally analyze the modal evolution in a 10 mode-selective photonic lantern along the tapered transition using a swept-wavelength interferometer. Mode conversion to HOM's occurs closer to the beginning of the photonic lantern taper.

Room 411

16:00–16:30 Coffee Break, *400 Foyer; Exhibit Hall*

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International Photonic Systems Roadmaps
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Room 402AB

16:30–18:30
Tu3A • Panel: Direct vs. Coherent Detection for Metro-DCI
Moderators: Robert Griffin; Oclaro, UK; Ampalavanapillai Nirmalathas; University of Melbourne, Australia

Coherent systems are widely deployed for high capacity long-haul networks, whereas direct detection (DD) implementations with low cost and low power consumption dominate short reach. Both approaches overlap in new fast-growing applications of short reach Metro and data center interconnects (DCI), requiring DWDM transport over distances around 100 km. In 2016 a commercial 100G PAM4 DD solution for 80km DWDM DCI was announced, and single-carrier 400G coherent solutions targeting similar applications have been demonstrated by multiple vendors. Will these solutions happily coexist, will one become the dominant solution over time, or will new alternatives become available? The panel will discuss the merits of different approaches and what progress we can expect as the technologies develop.

Panelists:

Brandon Collings, *Lumentum, USA*

Mark Filer, *Microsoft Corporation, USA*

Radha Nagarajan, *Inphi Corporation, USA*

Atul Srivastava, *NEL-America, USA*

Room 403A

16:30–18:30
Tu3B • Terahertz Systems
Presider:

Tu3B.1 • 16:30 Tutorial

THz Communication Systems, Tadao Nagatsuma[1]; [1]*Osaka Univ., Japan.* This talk reviews latest advances in THz communications based on photonics technologies and compares it with other competitive technologies such as THz transceivers enabled by electronic devices as well as free-space light-wave communications.

Tadao Nagatsuma received B.S., M.S., and Ph.D. degrees in electronic engineering from Kyushu University in 1981, 1983, and 1986, respectively. From 1986 to 2007, he was with Nippon Telegraph and Telephone Corporation. Since 2007, he has been a Professor at Graduate School of Engineering Science, Osaka University. His research interests include millimeter-wave and terahertz photonics and their applications to wireless communications, sensing, and measurement. He is a Fellow of the IEEE, and the Institute of Electronics, Information and Communication Engineers (IEICE), Japan. He currently serves as an Associate Editor of the IEEE Photonics Technology Letters, and a Director of the IEICE.

Room 403B

16:30–18:30
Tu3C • VCSELs
Presider: Kazuhiko Kurata; PETRA, Japan

Tu3C.1 • 16:30 Invited

High-bandwidth and Low-dimensional VCSELs for Optical Interconnects, James Lott[1]; [1]*Technische Univ., Berlin, Germany.* With bandwidths exceeding 30-GHz, error-free bit rates exceeding 50-Gb/s, and energy efficiencies approaching 100-fJ/b, via innovative grating reflectors, added materials, and unusual device geometries methods to further enhance the performance 980-nm communication VCSELs are explored.

Room 404AB

16:30–18:30
Tu3D • Linear and Nonlinear Multicarrier Systems
Presider: Alan Pak Tao Lau; Hong Kong Polytechnic Univ., Hong Kong

Tu3D.1 • 16:30 Invited

Nonlinear Frequency-Division Multiplexing in the Focusing Regime, Xianhe Yangzhang[1], Mansoor Yousefi[2], Alex Alvarado[1], Domanic Lavery[1], Polina Bayvel[1]; [1]*Department of Electronic and Electrical Engineering, Univ. College London, UK;* [2]*Communications and Electronics Department, Telecom ParisTech, France.* Achievable rates of the nonlinear frequency-division multiplexing (NFDM) and wavelength-division multiplexing (WDM) subject to the same power and bandwidth constraints are computed as a function of transmit power in the standard single-mode fiber. NFDM achieves higher rates than WDM.

Room 406AB

16:30–18:30
Tu3E • Networks Operating in Challenging Environments
Presider: Patrick Iannone; Nokia Bell Labs, USA

Tu3E.1 • 16:30 Invited

Enabling E-Science Applications with Dynamic Optical Networks Secure Autonomous Response Networks, Ralph Koning[1], Ameneh Deljoo[1], Stojan Trajanovski[1], Ben de Graaff[1], Paola Grosso[1], Leon Gommans[2], Tom van Engers[1], Frank Fransen[3], Robert Meijer[3], Rodney Wilson[4], Cees de Laat[1]; [1]*Univ. of Amsterdam, Netherlands;* [2]*Airfrance-KLM, Netherlands;* [3]*TNO, Netherlands;* [4]*Ciena, Canada.* Secure Autonomous Response NETworks (SARNET) is a framework for automated response against attacks on computer network infrastructures. The framework addresses several cyber-security problems at three crucial levels: strategic, tactical and operational.

Room 407

16:30–18:15
Tu3F • Reconfigurable Network Elements
Presider: David Neilson; Nokia Bell Labs, USA

Tu3F.1 • 16:30

Monolithically Integrated WDM Cross-connect Switch for High-performance Optical Data Center Networks, Nicola Calabretta[1], Wang Miao[1], Ketemaw Addis Mekonnen[1], Kristif Prifti[1], Kevin Williams[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* The switching performance of a photonic integrated WDM cross-connect switch is assessed with 40Gb/s NRZ-OOK, 20Gb/s PAM4 and data-rate adaptive DMT traffic. Results show limited penalty for single/WDM channels and > 10dB power dynamic range.

Tu3F.2 • 16:45

Cascaded All-optical Sub-Channel Add/Drop Multiplexing from a 1-Tb/s MB-OFDM or N-WDM Superchannel with Ultra-low Guard-bands, Mengdi Song[1], Erwan Pincemin[1], Benedikt Baeuerle[2], Arne Josten[2], David Hillerkuss[2], Juerg Leuthold[2], Roy Rudnick[3], Dan M. Marom[3], Shalva Ben-Ezra[4], Jordi Ferre Ferran[5], Dimitrios Klonidis[6], Ioannis Tomkos[6]; [1]*Orange Labs, France;* [2]*ETH Zurich, Switzerland;* [3]*The Hebrew Univ. of Jerusalem, Israel;* [4]*Opsys Technologies, Israel;* [5]*W-Onesys, Spain;* [6]*Athens Information Technologies, Greece.* We show cascaded 100-Gb/s Sb-Ch add/drop from a 1-Tb/s MB-OFDM or N-WDM Sp-Ch having ultra-low inter-Sb-Ch guard-bands within a recirculating loop via a hierarchical ROADM using high-resolution filters, showcasing up to 1000-km transmission reach and five ROADM node passages for the add/drop Sb-Ch when hybrid Raman-EDFA is used.

Room 408A

16:30–18:30
Tu3G • TDM and TWDM-PON II
Presider: Lilin Yi; Shanghai Jiao Tong Univ., China

Tu3G.1 • 16:30 Top Scored
Suppression of Burst-Mode Operation Induced Laser Wavelength Drift for Upstream Transmission in TWDM-PON by Using an Integrated Heater for Thermal Control, Xuming Wu[1], Dekun Liu[1], Huafeng Lin[2], Xiang Liu[3]; *[1]Huawei Technologies, China; [2]Huawei Technologies, China; [3]America Fixed Access Laboratory, Huawei Technologies, USA.* We propose and experimentally demonstrate substantial suppression of the wavelength drift of a 10-Gb/s burst-mode directly-modulated laser for TWDM-PON upstream transmission by using an integrated heater for thermal compensation, reducing the drift by 4.6 times to 5 GHz.

Tu3G.2 • 16:45 Top Scored
50-Gb/s/λ TDM-PON Based on 10G DML and 10G APD Supporting PR10 Link Loss Budget after 20-km Downstream Transmission in the O-band, Tao Minghui[1], Lei Zhou[1], Huaiyu Zeng[1], Shengping Li[1], Xiang Liu[1]; *[1]Huawei, China.* We experimentally demonstrate a 50-Gb/s/λ TDM-PON based on PAM4/DMT modulation respectively. By using digital signal processing and 10G-class optoelectronics, -20 dBm/-18 dBm receiver sensitivity is achieved in the O-band after 20-km downstream transmission.

Room 408B

16:30–18:15
Tu3H • Tailored Propagation Effects
Presider: Francesco Poletti; Univ. of Southampton, UK

Tu3H.1 • 16:30 Tutorial
Hollow Core Optical Fibers and Their Applications, David J. Richardson[1]; *[1]Univ. of Southampton, UK.* I review the current state-of-the-art in hollow core optical fibers describing in the process the different structural forms and associated guidance mechanisms possible, their key physical attributes and the steadily increasing range of end applications.

David Richardson joined the Optoelectronics Research Centre (ORC) at Southampton University in 1989. Since 2000 he has been Deputy Director of the ORC with responsibility for optical fibre and laser related research. He has published more than 400 technical journal papers and produced more than 30 patents during his time at Southampton. Professor Richardson is a Fellow of the IEEE, OSA and the IET and was made a Fellow of the Royal Academy of Engineering in 2009. He received a Royal Society Wolfson Research Merit Award in 2013 for his optical communications research.

Room 409AB

16:30–18:00
Tu3I • Direct-Detection Transmission Systems
Presider: Sethumadhavan Chandrasekhar; Nokia Bell Labs, USA

Tu3I.1 • 16:30
IM-DD MDM-WDM Transmission over 120-km Weakly-coupled FMF Enabled by Wavelength Interleaving, Yu Tian[1], Juhao Li[1], Zhongying Wu[1], Paikun Zhu[1], Yuanxiang Chen[1], Qi Mo[2], Fang Ren[3], Zhengbin Li[1], Yongqi He[1], Zhangyuan Chen[1]; *[1]Peking Univ., China; [2]Wuhan Research Inst. of Posts and Telecommunications, China; [3]Univ. of Science and Technology Beijing, China.* Wavelength-interleaved (WI) scheme is proposed to mitigate modal crosstalk during weakly-coupled few-mode fiber (FMF) transmission, based on which 2×3×10-Gb/s IM-DD MDM-WDM transmission over 120-km 2-mode FMF without MIMO processing has been experimentally demonstrated.

Tu3I.2 • 16:45
4×200Gb/s Twin-SSB Nyquist Subcarrier Modulation WDM Transmission over 160km SSMF with Direct Detection, Yixiao Zhu[1], Xiaoke Ruan[1], Zeyu Chen[1], Mingxuan Jiang[1], Kaiheng Zou[1], Chenjia Li[1], Fan Zhang[1]; *[1]Peking Univ., China.* We demonstrate a spectrally-efficient 4×200Gb/s WDM transmission based on twin-SSB Nyquist subcarrier modulation with signal-signal beat interference cancellation. The BER achieves 6.5×10^{-3} (<20% HD-FEC) after 160km SSMF transmission.

Room 410

16:30–18:30
Tu3J • Fiber-based Spatial Mode Multiplexers
Presider: Nicolas Fontaine; Nokia Corporation, USA

Tu3J.1 • 16:30 Invited
The Photonic Lantern, Sergio G. Leon-Saval[1,2]; *[1]Univ. of Sydney, Australia; [2]School of Physics, Sydney Astrophotonic Instrumentation Laboratory, Australia.* Photonic lanterns are all-optical transition devices that allow for broadband low-loss interface between multimode, few-mode and single-mode systems, thus allowing a waveguide transition from one to other as required by the optical system.

Room 411

16:30–18:30
Tu3K • Photonic Packaging
Presider: Piero Gambini; STMicroelectronics, Italy

Tu3K.1 • 16:30 Top Scored
High Efficient Suspended Coupler Based on IME's MPW Platform with 193nm Lithography, Lianxi Jia[1], Tsung-Yang Liow[1], Chao Li[1], Xianshu Luo[1], Xiaoguang Tu[1], Ying Huang[1], Haifeng Zhou[1], Mingbin Yu[1], Guo-Qiang Lo[1]; *[1]Inst. of Microelectronics, Singapore.* We realized the state-of-the-art coupling loss less than -1.3dB/facet with cleaved single-mode-fiber. A uniformity of 0.4dB across wafers has also been confirmed, the best performance to our knowledge realized in public-available silicon photonics platform.

Tu3K.2 • 16:45 Invited
Subwavelength Index Engineered Waveguides and Devices, Pavel Cheben[1]; *[1]National Research Council Canada, Canada.* We report our advances in development of subwavelength engineered structures for integrated photonics, specifically high-efficiency fiber-chip couplers, broadband surface grating couplers and ultra-broadband nanophotonic beam splitters.

Show Floor Programming

Advancing Optical Interoperability in Open Networks
Session Sponsored by Juniper
14:00–17:00
For more details, see page 44

International Photonic Systems Roadmaps
16:00–17:00
For more details, see page 47

Room 402AB

Tu3A • Panel: Direct vs. Coherent Detection for Metro-DCI—Continued

Room 403A

Tu3B • Terahertz Systems—Continued

Room 403B

Tu3C • VCSELs—Continued

Tu3C.2 • 17:00

Temperature Dependent Analysis of 50 Gb/s Oxide-confined VCSELs, Curtis Wang[1], Michael Liu[1], Milton Feng[1], Nick Holonyak[1]; [1]*Univ. of Illinois at Urbana-Champai, USA.* Temperature dependent analysis of a high speed 850 nm oxide-confined VCSEL with 50 Gb/s error-free capability and a -3 dB modulation bandwidth of 24.7 GHz at 85 °C is reported.

Tu3C.3 • 17:15

Amplitude Noise Suppression and Orthogonal Multiplexing Using Injection-locked Single-mode VCSEL, Vladimir Lyubopytov[2], Tuomo von Lerber[3], Matti Lassas[3], Mohammadreza Malekizandi[1], Arkadi V. Chipouline[1], Franko Küppers[1]; [1]*TU Darmsatdt, Germany;* [2]*Dpt. Photonics Engineering, Technical Univ. of Denmark (DTU), Akademivej Building 343, 2800 Kgs. Lyngby, Denmark, Finland;* [3]*Department of Mathematics and Statistics, Univ. of Helsinki, P.O. Box 68 (Gustaf Hällströmin katu 2b)FI-00014 Helsinki, Finland, Finland.* We experimentally demonstrate BER reduction and orthogonal modulation using an injection locked single-mode VCSEL. It allows us suppressing an amplitude noise of optical signal and/or double the capacity of an information channel.

Room 404AB

Tu3D • Linear and Nonlinear Multicarrier Systems—Continued

Tu3D.2 • 17:00

Introducing the Fast Inverse NFT, Vishal Vaibhav[1], Sander Wahls[1]; [1]*TU Delft, Netherlands.* In optical fiber communication, the nonlinear frequency division multiplexing scheme requires a fast inverse nonlinear Fourier transform (NFT). We present two algorithms with $O(N(K+\log^2N))$ complexity for N samples of a signal comprising K eigenvalues.

Tu3D.3 • 17:15

50-Gb/s PDM-DMT-SSB Transmission over 40km SSMF using a Single Photodetector in C-band, Jiahao Huo[1,2], Xian Zhou[1,2], Kang Ping Zhong[2], Tao Gui[3], Yiguang Wang[2], Liang Wang[4], Jinhui Yuan[2], Hongyu Zhang[5], Keping Long[1], Changyuan Yu[2], Alan Pak Tao Lau[3], Chao Lu[2]; [1]*Univ. of Science & Technology Beijing (USTB), China;* [2]*Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., China;* [3]*Department of Electrical Engineering, The Hong Kong Polytechnic Univ., China;* [4]*Department of Electronic Engineering, The Chinese Univ. of Hong Kong, China;* [5]*Fixed Network Research and Development Department, Huawei Technologies Co Ltd, China.* We experimentally demonstrated transmission of 50-Gb/s PDM-DMT-SSB signal over 40km SSMF in C-band using a single photodetector. The DMT signal in another polarization is placed at the guard band of the SSB-OFDM signal.

Room 406AB

Tu3E • Networks Operating in Challenging Environments—Continued

Tu3E.2 • 17:00

First Field Trial Demonstration of Hitless Defragmentation with Signals Overlap in Elastic Optical Networks, Francesco Fresi[1], Gianluca Meloni[2], Tommaso Foggi[2], Filippo Cugini[2], Luca Potì[2]; [1]*TeCIP, Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* We experimentally demonstrate for the first time hitless spectrum defragmentation exploiting signals overlap in a field trial. Spectrum resources are shared without signals loss. The defragmentation procedure was successfully verified through 32Gbaud PM-QPSK-TFP signals over 1320km installed fiber.

Tu3E.3 • 17:15

SDN/NFV-based Deployment of Data Receiving-storing-resending Function for Highly Reliable Transmission, Fangke Xiao[1], Fang Zhang[1], Wei Guo[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* This paper proposes an architecture to automatically deploy a data receiving-storing-resending function based on SDN/NFV to reduce data loss during transmission interruption. Experiment result shows this can effectively reduce data loss and improve transmission reliability.

Room 407

Tu3F • Reconfigurable Network Elements—Continued

Tu3F.3 • 17:00 Invited

Reconfigurable Photonic Signal Processing Circuits, Andrea Melloni[1]; [1]*Politecnico di Milano, Italy.* Complex photonic integrated circuits can deliver advanced functionalities but they also require advanced control techniques. We show control strategies for such complex circuits and application to implement signal processing, routing, tuning and locking.

Room 408A

Tu3G • TDM and TWDM-PON II—Continued

Tu3G.3 • 17:00

40 Gb/s/λ Optical Amplified PAM-4 PON with Transmission over 30 km SMF using 10-G Optics and Simple DSP, Jinlong Wei[1], Elias Giacoumidis[2]; [1]*Optical Technology Department, Huawei Technologies Duesseldorf GmbH, European Research Center, Germany;* [2]*Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), School of Physics, Univ. of Sydney, Australia.* We experimentally demonstrate 40-Gb/s/λ PAM-4 transmission over a 20-km (30-km) SMF using only 10-G optics and simple post-nonlinear equalizations with a link power budget of 38 dB (30.7 dB) at a threshold BER of 10^{-3}.

Tu3G.4 • 17:15

Demonstration and Application of 37.5 Gb/s Duobinary-PAM3 in PONs, Robbert van der Linden[1,2], Nguyen-Cac Tran[2], Eduward Tangdiongga[1], A. Koonen[1]; [1]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands;* [2]*Genexis B.V., Netherlands.* Duobinary-PAM3 enables up to 37.5Gb/s with 10G receivers. It has less linearity requirements on transmitters and gains 2dB sensitivity compared to equal-bitrate PAM8. In a 10G flexible modulation scheme, DB-PAM3 enables 190% network utilization increase.

Room 408B

Tu3H • Tailored Propagation Effects—Continued

Presentations selected for recording are designated with a ▶. Visit www.ofcconference.org and select the View Presentations link.

Room 409AB

Tu3I • Direct-Detection Transmission Systems—Continued

Tu3I.3 • 17:00 Invited

Direct-detection Solutions for 100G and Beyond, Michael H. Eiselt[1], Nicklas Eiselt[1], Annika Dochhan[1]; [1]*ADVA Optical Networking SE, Germany.* Pulse amplitude modulation (PAM-4) and discrete multi-tone (DMT) transmission are contenders for metro-reach and inter data center transmission. While commercial signal processing components are available, chromatic fiber dispersion effects need to be considered.

Room 410

Tu3J • Fiber-based Spatial Mode Multiplexers—Continued

Tu3J.2 • 17:00

All-fiber Mode-locked Vortex Laser with a Broadband Mode Coupler, Xianglong Zeng[1], Teng Wang[1], Fan Shi[1], Feng Wang[1], Fufei Pang[1], Sujuan Huang[1], Tingyun Wang[1]; [1]*Shanghai Univ., China.* We experimentally demonstrated all-fiber passively mode-locked vortex lasers using a broadband mode selective coupler, which can deliver femtosecond optical vortex pulses with topological charges of OAM±1, ±2.

Tu3J.3 • 17:15 Top Scored

Annular Core Photonic Lantern Spatial Mode Multiplexer, Zeinab Sanjabi Eznaveh[1], Juan Carlos Alvarado Zacarias[1], Jose Antonio-Lopez[1], Yong-min Jung[2], Kai Shi[3], Benn C. Thomsen[3], David Richardson[4], Sergio G. Leon-Saval[5], Rodrigo Amezcua Correa[1]; [1]*CREOL, Univ. of Central Florida, USA;* [2]*Optoelectronic Research Center, UK;* [3]*Univ. College London, UK;* [4]*Southampton Univ., UK;* [5]*Univ. of Sydney, Australia.* We demonstrate an all-fiber, ring core photonic lantern to generate high quality OAM modes up to the second order at 1550nm. We achieved low-loss coupling of the lantern OAM modes into a ring core fiber.

Room 411

Tu3K • Photonic Packaging—Continued

Tu3K.3 • 17:15

Metamaterial Waveguides with Low Distributed Backscattering in Production O-Band Si Photonics, Bo Peng[1], Chi Xiong[1], Marwan Khater[1], Asger Jensen[1], William M. Green[1], Tymon Barwicz[1]; [1]*IBM T.J. Watson Research Center, USA.* We report on the first measurement of distributed backscattering in metamaterial (subwavelength grating) waveguides. We find distributed backscattering to be < -50 dB/mm in samples fabricated using a CMOS-integrated Si photonic production process.

Show Floor Programming

Room 402AB

Tu3A • Panel: Direct vs. Coherent Detection for Metro-DCI—Continued

Room 403A

Tu3B • Terahertz Systems—Continued

Tu3B.2 • 17:30
Coherent Radio-over-Fiber THz Communication Link for High Data-Rate 59 Gbit/s 64-QAM-OFDM and Real-time HDTV Transmission, Andreas Stohr[1], Maria Freire Hermelo[1], Matthias Steeg[1], Boris Shih[3], Anthony Ng'oma[2]; [1]*Universität Duisburg-Essen, Germany;* [2]*Science and Technology Dept., Corning Incorporated, USA;* [3]*Corning Research Center Taiwan, Corning Incorporated, Taiwan.* We report a coherent Radio-over-Fiber (CRoF) THz communication link supporting both, off-line high data-rate 59 Gbit/s transmission using a record spectral efficient 64-QAM-OFDM modulation as well as real-time HDTV transmission at 328 GHz carrier frequency.

Tu3B.3 • 17:45 Top Scored
Demonstration of 352 Gbit/s Photonically-enabled D-Band Wireless Delivery in one 2x2 MIMO System, Rafael Puerta[1], Jianjun Yu[2,3], Xinying Li[2,3], Yuming Xu[3], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1,4]; [1]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [2]*ZTE (TX) Inc, USA;* [3]*Fudan Univ., China;* [4]*ITMO Univ., Russia.* First demonstration of photonically-enabled independent side-bands D-Band wireless transmission up to 352 Gbit/s with a BER below 3.8×10^{-3}. These results were achieved by means of advanced DSP and antenna polarization multiplexing (2x2 MIMO).

Room 403B

Tu3C • VCSELs—Continued

Tu3C.4 • 17:30 Tutorial
High-Capacity VCSEL Links, Daniel Kuchta[1]; [1]*IBM TJ Watson Research Center, USA.* This tutorial will cover the use and application of directly modulated Vertical Cavity Surface Emitting Lasers (VCSELs), for Data Centers and High Performance Computing (HPC) applications. Topics will include, advances in modulation formats, packaging, and fibers.

Daniel M. Kuchta is a Research Staff Member in the Communications and Computation Subsystems Department at the IBM Thomas J. Watson Research Center. He received B.S., M.S., and Ph.D. degrees in Electrical Engineering and Computer Science from the University of California at Berkeley in 1986, 1988, and 1992, respectively. He subsequently joined IBM at the Thomas J. Watson Research Center, where he has worked on high-speed VCSEL characterization, multimode fiber links, and parallel fiber optic link research. Dr. Kuchta is an author/coauthor of more than 135 technical papers and inventor/co-inventor of at least 20 patents.

Room 404AB

Tu3D • Linear and Nonlinear Multicarrier Systems—Continued

Tu3D.4 • 17:30
200-Gb/s Polarization-multiplexed DMT using Stokes Vector Receiver with Frequency-Domain MIMO, Di Che[1], Feng Yuan[1], William Sheih[1]; [1]*Univ. of Melbourne, Australia.* We propose frequency-domain MIMO equalization for the Stokes vector direct detection with OFDM modulation, verified by a 50-Gbaud polarization-multiplexed DMT experiment. The algorithm can be generalized to other OFDM-based Stokes-space modulation systems.

Tu3D.5 • 17:45
Transmit Filter Optimization for Improved Performance of Time-frequency Packing System, Qian Hu[1], Fred Buchali[1], Laurent Schmalen[1], Wilfried Idler[1], Roman Dischler[1], Vahid Aref[1], Henning Buelow[1]; [1]*Nokia Bell Labs, Germany.* The performance of time-frequency packing system is improved with transmit filter optimization. 0.2 dB gain in OSNR penalty is experimentally demonstrated at spectral efficiency of 6.98 bits/s/Hz with no additional complexity on the system.

Room 406AB

Tu3E • Networks Operating in Challenging Environments—Continued

Tu3E.4 • 17:30
Demonstration of Survivable vSD-EON Slicing with Automatic Data Plane Restoration to Support Reliable Video Streaming, Jie Yin[1], Jiannan Guo[1], Bingxin Kong[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China.* We design and experimentally demonstrate a network slicing system which can not only construct vSD-EONs dynamically for upper-layer applications but also recover their data plane services automatically and timely during substrate link failures.

Tu3E.5 • 17:45
Joint Progressive Recovery of Optical Network and Datacenters after Large-scale Disasters, Sifat Ferdousi[1], Ferhat Dikbiyik[2], Massimo Tornatore[1], Biswanath Mukherjee[1]; [1]*Univ. of California Davis, USA;* [2]*Sakarya Univ., Turkey.* Effective post-disaster cloud-network recovery can significantly improve users' access to important cloud services. We propose a joint progressive recovery strategy for optical network and datacenters to maximize content reachability to users at each repair stage.

Room 407

Tu3F • Reconfigurable Network Elements—Continued

Tu3F.4 • 17:30
Optical Tunable Filter for Gridless ROADM, Masaki Niwa[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; [1]*Nagoya Univ., USA.* We fabricate an optical tunable filter for gridless signal drop in ROADMs. Its effectiveness is confirmed by experiments on 10-Gbaud intensity-modulated signals with 50-GHz spacing and 32-Gbaud dual-polarization QPSK and 16QAM signals with 33.3-GHz spacing.

Tu3F.5 • 17:45
Silicon-photonics Polarization-Insensitive Broadband Strictly-non-blocking 8 × 8 Blade Switch, Keijiro Suzuki[1], Ken Tanizawa[1], Satoshi Suda[1], Hiroyuki Matsuura[1], Takashi Inoue[1], Kazuhiro Ikeda[1], Shu Namiki[1], Hitoshi Kawashima[1]; [1]*AIST, Japan.* We present a 1-RU silicon photonics 8×8 switch with a low PDL (<0.5 dB) and a broad operating bandwidth (35 nm at -20 dB crosstalk). 32-Gbaud DP-QPSK WDM transmission was demonstrated with no OSNR penalty.

Room 408A

Tu3G • TDM and TWDM-PON II—Continued

Tu3G.5 • 17:30
EVM Reduction in Digital Mobile Fronthaul by Sample Bits Interleaving and Uneven PAM4, Haiyun Xin[1], Kuo Zhang[1], Hao He[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* We propose a digitial MFH system exploiting sample bits interleaving and uneven PAM4. Digitized LTE-A signal transmission is experimentally demonstrated via 25Gbps fiber link. The results indicate that, ~13dB EVM reduction can be achieved, compared with evenly-spaced PAM4.

Tu3G.6 • 17:45
Real-Time Burst-mode Operation of an Integrated SOA-PIN/TIA Receiver for 25 Gbit/s/λ and Faster T(W)DM-PON, Robert Borkowski[1], Wolfgang Poehlmann[1], Romain Brenot[2], Rene Bonk[1], Philippe Angelini[2], Christophe Caillaud[2], Mohand Achouche[2], Fabrice Blache[2], Michel Goix[2], Karim Mekhazni[2], Bernadette Duval[2], Jean-Yves Dupuy[2], Jean F. Paret[2], Thomas Pfeiffer[1]; [1]*Nokia Bell Labs, Germany;* [2]*III-V Lab, France.* First real-time 25-Gbit/s burst-mode operation of an integrated SOA-PIN/TIA receiver for future generation T(W)DM-PON is presented. The device has a 2.7-dB better sensitivity than APD photoreceiver and 13-dB better than PIN photoreceiver at this bitrate.

Room 408B

Tu3H • Tailored Propagation Effects—Continued

Tu3H.2 • 17:30 Invited
Tailoring the Response of Stimulated Brillouin Scattering in Fibers, John Ballato[1], Peter Dragic[2]; [1]*Clemson Univ., USA;* [2]*Electrical and Computer Engineering, Univ. of Illinois - Urbana - Champaign, USA.* This paper describes how thoughtful consideration of the materials from which the fibers are made can have marked effects on stimulated Brillouin scattering mitigation; more so than achievable through complex microstructuring of the optical fiber.

Room 409AB

Tu3I • Direct-Detection Transmission Systems—Continued

Tu3I.4 • 17:30 Top Scored
112 Gb/s/λ WDM Direct-detection Nyquist-SCM Transmission at 3.15 (b/s)/Hz Over 240 km SSMF Enabled by Novel Beating Interference Compensation, Zhe Li[1], Mustafa S. Erkilinc[1], Kai Shi[1], Eric Sillekens[1], Lidia Galdino[1], Benn C. Thomsen[1], Polina Bayvel[1], Robert Killey[1]; [1]*Univ. College London, UK.* We experimentally demonstrate 112Gb/s/channel 35GHz-spaced WDM direct-detection SSB Nyquist-SCM transmission over a record distance of 240km SSMF using a novel beating interference compensation method, which offers a 7.6dB required OSNR improvement, and 200% reach enhancement.

Tu3I.5 • 17:45 Top Scored
Kramers-Kronig PAM Transceiver, Cristian Antonelli[1], Antonio Mecozzi[1], Mark Shtaif[2]; [1]*Universita degli Studi dell'Aquila, Italy;* [2]*Tel Aviv Univ., Israel.* We propose a new transceiver scheme using PAM transmission in combination with direct detection and digital reconstruction of the optical phase. This allows digital compensation of chromatic dispersion and provides a significant improvement in terms of spectral efficiency.

Room 410

Tu3J • Fiber-based Spatial Mode Multiplexers—Continued

Tu3J.4 • 17:30 Invited
Adiabatic Mode Multiplexers, Tim A. Birks[1], Stephanos Yerolatsitis[1], Kerrianne Harrington[1]; [1]*Univ. of Bath, UK.* We describe mode multiplexers that rely on adiabatic propagation along optical fibre structures (photonic lanterns) that change gradually along their lengths. Spatially-separated single-mode waves evolve adiabatically into individual pure modes occupying a common multimode core.

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Room 411

Tu3K • Photonic Packaging—Continued

Tu3K.4 • 17:30 Invited
High Throughput Photonic Packaging, Tymon Barwicz[1], Ted W. Lichoulas[2], Yoichi Taira[1], Yves Martin[1], Shotaro Takenobu[4], Alexander Janta-Polczynski[3], Hidetoshi Numata[5], Eddie L. Kimbrell[2], Jae-Woong Nah[1], Bo Peng[1], Robert Leidy[6], Marwan Khater[1], Swetha Kamlapurkar[1], Sebastian Engelmann[1], Paul Fortier[3], Nicolas Boyer[3]; [1]*IBM TJ Watson Research Center, USA;* [2]*AFL Telecommunications, USA;* [3]*IBM Bromont, Canada;* [4]*Asahi Glass Co, Japan;* [5]*IBM Research - Tokyo, Japan;* [6]*Global Foundries, USA.* We have demonstrated photonic packaging compatible with standard, high-throughput, microelectronics assembly lines. We show a 1.3dB fiber-to-chip loss and 1.1dB chip-to-chip loss. We discuss the rationale behind this approach and compare to other packaging directions.

Show Floor Programming

Room 402AB

Tu3A • Panel: Direct vs. Coherent Detection for Metro-DCI—Continued

Room 403A

Tu3B • Terahertz Systems—Continued

Tu3B.4 • 18:00
Modulation Optimization for D-band Wireless Transmission Link, Xinying Li[1,2], Yuming Xu[1], Jiangnan Xiao[1], Kaihui Wang[1], Jianjun Yu[1,2]; [1]*Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [2]*ZTE (TX) Inc., USA.* High-performance high-frequency mm-wave amplifier and other components, particularly those at D-band, are difficult to manufacture. We optimize modulation format for one 150-GHz D-band vector-mm-wave system and demonstrate OFDM can better tolerate imperfect-gain-characteristic of D-band amplifier.

Tu3B.5 • 18:15 Top Scored
Single Channel 106 Gbit/s 16QAM Wireless Transmission in the 0.4 THz Band, Xiaodan Pang[1], Shi Jia[2,5], Oskars Ozolins[1], Xianbin Yu[3], Hao Hu[2], Leonardo Marcon[4], Pengyu Guan[2], Francesco Da Ros[2], Sergei Popov[4], Gunnar Jacobsen[1], Michael Galili[2], Toshio Morioka[2], Darko Zibar[2], Leif K. Oxenlowe[2]; [1]*NETLAB, Acreo Swedish ICT, Sweden;* [2]*DTU Fotonik, Technical Univ. of Denmark, Denmark;* [3]*College of Information Science and Electronic Engineering, Zhejiang Univ., China;* [4]*School of ICT, KTH Royal Inst. of Technology, Sweden;* [5]*School of Electronic Information Engineering, Tianjin Univ., China.* We experimentally demonstrate a single channel 32-GBd 16QAM THz wireless link operating in the 0.4 THz band. Post-FEC net data rate of 106 Gbit/s is successfully achieved without any spatial/frequency multiplexing.

Room 403B

Room 404AB

Tu3D • Linear and Nonlinear Multicarrier Systems—Continued

Tu3D.6 • 18:00
FPGA-based Layered/Enhanced ACO-OFDM Transmitter, Qibing Wang[1], Binhuang Song[1], Bill Corcoran[1], David Boland[1], Leimeng Zhuang[1], Yiwei Xie[1], Arthur Lowery[1]; [1]*Monash Univ., Australia.* We present an FPGA-based QPSK-encoded 9.375 Gb/s layered/enhanced ACO-OFDM transmitter giving a high spectral efficiency. The measured Q-factor is greater than 13 dB after 20-km standard single-mode fiber transmission.

Tu3D.7 • 18:15
Gaussian Process Regression for WDM System Performance Prediction, Jesper Wass[1,2], Jakob Thrane[1,2], Molly Piels[1], Rasmus Jones[1], Darko Zibar[1,2]; [1]*DTU Photonics, Technical Univ. of Denmark, Denmark;* [2]*MLytico, Denmark.* Gaussian process regression is numerically and experimentally investigated to predict the bit error rate of a 24 × 28 GBd QPSK WDM system. The proposed method produces accurate predictions from multi-dimensional and sparse measurement data.

Room 406AB

Tu3E • Networks Operating in Challenging Environments—Continued

Tu3E.6 • 18:00 Invited
What To Do When There's No Fiber: The DARPA 100Gb/s RF Backbone Program, Ted Woodward[1]; [1]*Strategic Technology Office, Defense Advanced Research Projects Agency (DARPA), USA.* Intermediate results from a project to deliver 100 Gb/s communication links over ranges of 100 to 200 km in air-to-ground or air-to-air environments are described.

Room 407

Tu3F • Reconfigurable Network Elements—Continued

Tu3F.6 • 18:00
Low Phase Noise CO-MB-OFDM Optical Burst Transmitter for Time and Spectral Optical Aggregation, Bing Han[1], Paulette Gavignet[1], Erwan Pincemin[1], Thierry Guillossou[1], Michel Cresseaux[2], Dominique Le Brouster[2], Benoît Haentjens[2], Yves Jaouen[3]; [1]*Orange Labs, France;* [2]*Vectrawave, France;* [3]*Télécom ParisTech, France.* We demonstrate experimentally the feasibility of a low phase noise CO-MB-OFDM burst transmitter for time and spectral optical aggregation based on our proposition of a 100 kHz linewidth and 100 ns switching time laser source.

16:30–18:30 Tu3L • Data Center Summit: SDN & NFV Demo Zone, *400 Foyer (Extended Coffee Break)*

17:30–19:00 Exhibitor Reception, *Lucky Strike Live LA, 800 W Olympic Blvd* (Exhibitor badge required)

Room 408A

Tu3G • TDM and TWDM-PON II—Continued

Tu3G.7 • 18:00
Directly Modulated and ER Enhanced Hybrid III-V/SOI DFB Laser Operating up to 20 Gb/s for Extended Reach Applications in PONs, Valentina Cristofori[1], Francesco Da Ros[1], Mohamed E. Chaibi[2], Yunhong Ding[1], Laurent Bramerie[2], Alexandre Shen[3], Antonin Gallet[3], Guang-Hua . Duan[3], Leif K. Oxenlowe[1], Christophe Peucheret[2]; [1]*DTU Fotonik, Technical Univ. of Denmark, Denmark;* [2]*FOTON Laboratory, Univ. of Rennes 1, France;* [3]*Nokia-Thales-CEA, III-V Lab, France.* We demonstrate error-free performance of an MRR filtered DML on the SOI platform over 40- and 81-km of SSMF. The device operates up to 17.5 Gb/s over 81 km and 20 Gb/s over 40 km.

Tu3G.8 • 18:15
Requirements on Resolution and Sampling Jitter of ADC in 10G-Class Optics and MLSD based NG-EPON, Zhengxuan Li[1], Qianwu Zhang[1], Yong Guo[2], Yongjia Yin[2], Tingting Xu[1], Ying-Chun Li[1], Jian Chen[1], Yingxiong Song[1], Min Wang[1]; [1]*Shanghai Univ., China;* [2]*ZTE Corporation, China.* The impact of sampling jitter and resolution of ADC on the performance of MLSD-based NG-EPON is analyzed. 30-dB loss budget is achieved in 25-Gb/s/λ applications using 25-Gb/s, 3-bit ADC with ±2.5-ps timing jitter tolerance.

Room 408B

Tu3H • Tailored Propagation Effects—Continued

Tu3H.3 • 18:00
Tailoring Nonlinear Frequency Generation in Graded-index Multimode Fibers, Mohammad Amin Eftekhar[1], Zeinab Sanjabi Eznaveh[1], Jose Antonio-Lopez[1], Miroslav Kolesik[2], Axel Schulzgen[1], Frank W. Wise[3], Demetrios N. Christodoulides[1], Rodrigo Amezcua Correa[1]; [1]*CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA;* [2]*College of Optical Sciences, The Univ. of Arizona, USA;* [3]*Applied and Engineering Physics, Cornell Univ., USA.* We demonstrate that frequency generation in multimode graded-index fibers can be tailored through appropriate fiber design. This is achieved by exploiting a geometric parametric instability which can be utilized for developing novel fiber light sources.

Room 409AB

Tu3I • Direct-Detection Transmission Systems—Continued

Room 410

Tu3J • Fiber-based Spatial Mode Multiplexers—Continued

Tu3J.5 • 18:00
10-Mode Photonic Lanterns Using Low-index Micro-structured Drilling Preforms, Bin Huang[2,1], Juan Carlos Alvarado Zacarias[2,1], Nicolas K. Fontaine[2], Haoshuo Chen[2], Roland Ryf[2], Francesco Poletti[3], John R. Hayes[3], Jose Antonio-Lopez[1], Rodrigo Amezcua Correa[1], Guifang Li[1]; [1]*Univ. of Central Florida, USA;* [2]*Nokia Bell Labs, USA;* [3]*Univ. of Southampton, UK.* We demonstrate low mode-dependent loss 10-mode photonic lanterns using low-index micro-structured drilling preforms. The adiabaticity requirement for lantern tapering can be alleviated by the proposed solution leading to improved performances.

Tu3J.6 • 18:15 Top Scored
Mode-selective Photonic Lanterns from Multicore Fibres, Stephanos Yerolatsitis[1], Kerrianne Harrington[1], Robert Thomson[2], Tim A. Birks[1]; [1]*Univ. of Bath, UK;* [2]*Heriot-Watt Univ., UK.* We report mode-selective photonic lanterns made from multicore fibres with several dissimilar cores. Six-mode and ten-mode multiplexers are demonstrated. Such designs potentially offer the maximum possible number of multiplexed modes in mode-selective photonic lanterns.

Room 411

Tu3K • Photonic Packaging—Continued

Tu3K.5 • 18:00
Thermally Expanded Core Fiber with a 4-μm Mode Field Diameter Suitable for Low-loss Coupling with Silicon Photonic Devices, Takuya Oda[1], Keisuke Hirakawa[1], Kentaro Ichii[1], Satoshi Yamamoto[1], Kazuhiko Aikawa[1]; [1]*Advanced Technology Laboratory, Fujikura Ltd., Japan.* We developed thermally expanded core fibers with a 4-μm mode field diameter. The connection loss with conventional single-mode fibers is below 0.2 dB. The coupling loss with silicon devices can be below 1.5 dB/facet.

Tu3K.6 • 18:15
Low-loss On-chip Prism-waveguide Coupler to High-Q Micro-resonator and Optical Frequency Comb Generation, Guangyao Liu[1], Kuanping Shang[1], Siwei Li[1], Tiehui Su[1], Yu Zhang[1], Shaoqi Feng[1], S. J. Ben Yoo[1], Roberto Proietti[1], Vladimir Ilchenko[2], Wei Liang[2], Anotoliy Savchenkov[2], Andrey Matsko[2], Lute Maleki[2]; [1]*Electrical Engineering and Computer Science, Univ. of California, Davis, USA;* [2]*OEwaves Inc., USA.* We design, fabricate and characterize first on-chip prism-like waveguide coupler to high-Q ($Q>10^{10}$) micro-resonator with record 1.1dB coupling loss at 1550nm and demonstrate an integrated optical frequency comb generation unit based on this coupler.

Show Floor Programming

16:30–18:30 Tu3L • Data Center Summit: SDN & NFV Demo Zone, *400 Foyer (Extended Coffee Break)*

17:30–19:00 Exhibitor Reception, *Lucky Strike Live LA, 800 W Olympic Blvd* (Exhibitor badge required)

400 Foyer

16:30–18:30
Tu3L • Data Center Summit: SDN & NFV Demo Zone

Tu3L.1
SDN Control Framework with Dynamic Resource Assignment for Slotted Optical Datacenter Networks, Giada Landi[3], Ioannis Patronas[1], Konstantinos Kontodimas[2], Muzzamil Aziz[4], Konstantinos Christodoulopoulos[2], Angelos Kyriakos[1], Marco Capitani[3], Amirreza F. Hamedani[4], Dionysis Reisis[1], Emmanuel Varvarigos[2], Paraskevas Bakopoulos[1], Hercules Avramopoulos[1]; [1]*National Technical Univ. of Athens, Greece;* [2]*Computer Engineering and Informatics Department, Univ. of Patras, Greece;* [3]*Nextworks, Italy;* [4]*Gesellschaft für wissenschaftliche Datenverarbeitung mbH , Germany.* An SDN control framework is demonstrated enabling slotted operation for dynamic resources assignment in optically-switched datacenters. The demonstration includes the SDN controller with scheduler plugins and north-/southbound interfaces, and the SDN agent communicating to data-plane.

Tu3L.2
Fully Automated Peer Service Orchestration of Cloud and Network Resources using ACTN and CSO, Ricard Vilalta[1], Young Lee[2], Haomian Zheng[3], Yi Lin[3], Ramon Casellas[1], Arturo Mayoral[1], Ricardo Martinez[1], Raul Muñoz[1], Luis Miguel Contreras Murillo[4], Victor Lopez[4]; [1]*CTTC, Spain;* [2]*Huawei Technologies USA R&D Center, USA;* [3]*Huawei Technologies Co., China;* [4]*Telefónica Global CTO, Spain.* This demo proposes the fully automated establishment of a network service using a peer inter-CSO interface in ACTN. The underlying network resources have been abstracted and virtualized in order to provide a network slice.

Tu3L.3
Demonstration of the Benefits of SDN Technology for All-optical Data Centre Virtualisation, Chris R. Jackson[1], Reza Nejabati[1], Fernando Agraz[2], Albert Pagès[2], Michael Galili[3], Salvatore Spadaro[2], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK;* [2]*Universitat Polit`ecnica de Catalunya, Spain;* [3]*Danmarks Teknisken Universitet, Denmark.* An integrated software stack made up of extended OpenStack, OpenDaylight and custom OpenFlow agents enabling Virtual Data Centre deployment on an all-optical architecture employing hollow-core fibre, TDM fast switches and a circuit switched backplane.

Tu3L.4
E2E Transport API Demonstration in Hierarchical Scenarios, Victor Lopez[2], Itay Maor[3], Karthik Sethuraman[4], Arturo Mayoral López de Lerma[1], Lyndon Y. Ong[9], Rafal Szwedowski[8], Fabio Marques[5], Anurag Sharma[6], Francesco Bosisio[7], Oscar Gonzalez de dios[2], Ori Gerstel[3], Felipe Druesedau[4], Ricard Vilalta[1], Hector Silva[9], Achim Autenrieth [8], Nuno Borges[5], Chris Liou[6], Giorgio Cazzaniga[7], Juan Pedro Fernandez-Palacios[2]; [1]*CTTC, Spain;* [2]*GCTO, Telefónica I+D, Spain;* [3]*Sedona Systems, Israel;* [4]*NEC, USA;* [5]*Coriant GmbH, Germany;* [6]*Infinera, USA;* [7]*SM Optics, Italy;* [8]*ADVA, Germany;* [9]*Ciena, USA.* We validate the Transport API interoperability with a hierarchical orchestration layer. The demonstration shows the end-to-end provision of connections based on the topology and connectivity services of the Transport API.

Tu3L.5
Demonstration of a SDN-based Spectrum Monitoring of Elastic Optical Networks, Matteo Dallaglio[2], Quan Pham Van[1], Fabien Boitier[1], Camille Delezoide[1], Dominique Verchere[1], Patricia Layec[1], Arnaud Dupas[1], Nicola Sambo[2], Sébastien Bigo[1], Piero Castoldi[2]; [1]*Nokia Bell Labs, France;* [2]*Scuola Superiore Sant'Anna, Italy.* We demonstrate optical channel monitoring capabilities executed as SDN applications. To guarantee Quality of Transmission, diagnostic is performed by dynamically selecting the list of optical parameters to be monitored and by adjusting their polling rates.

Tu3L.6
INDIRA: 'Application Intent' Network Assistant to Configure SDN-based High Performance Scientific Networks, Anu Mercian[1], Mariam Kiran[1], Eric Pouyoul[1], Brian Tierney[1], Inder Monga[1]; [1]*ESnet Lawrence Berkeley National Labs, USA.* We demonstrate INDIRA ((Intelligent Network Deployment Intent Renderer Application)), an interactive network assistant that will help us configure a data path between two scientific end-point groups (EPGs) to optimize the transfer of elephant data flows.

Tu3L.7
APP Store Installed in ONOS-based Multi-layer and Multi-domain Transport SDN Platform with Novel TE Abstraction, Yongli Zhao[1], Boyuan Yan[1], Wei Wang[1], Haomian Zheng[2], Yi Lin[2], Young Lee[3], Huiying Xu[2], Ruiquan Jing[4], Yunbin Xu[5], Guoying Zhang[5], Jie Zhang[1], Yuefeng Ji[1]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Huawei Technologies Co., China;* [3]*Huawei Technologies, USA Research Center, USA;* [4]*China Telecom Beijing Research Inst., China;* [5]*China Academy of Information and Communication Technology, China.* An APP store is demonstrated over multi-layer and multi-domain transport software defined networks (T-SDN) platform, which is developed based on IETF ACTN standard. A novel traffic engineering (TE) abstraction method is used with different applications demonstrated.

Tu3L.8
Open and Disaggregated Multi-layer Networks, Marc De Leenheer[1], Ayaka Koshibe[1], Yuta Higuchi[2], Naoki Shiota[2], Helen Wu[3], Toru Furusawa[4], Tom Tofigh[5], Guru Parulkar[1,6]; [1]*ON.Lab, USA;* [2]*NEC, Japan;* [3]*Harvard Univ., USA;* [4]*NTT Communications, Japan;* [5]*AT&T, USA;* [6]*Stanford Univ., USA.* Disaggregation of both packet and optical networks is driving innovation in transport networks. We demonstrate a proof of concept and detail our plans for a field trial in a major service provider.

Tu3L.9
Automation of Optical Provisioning on Multi-vendor Metro Optical Platforms, Marco Rizzi[1]; [1]*Facebook, USA.* This demonstration is going to automate provisioning of multivendor optical platforms supporting API based configurations, using transport interfaces such as NETCONF or REST.

Tu3L.10
Intent-based In-flight Service Encryption in Multi-layer Transport Networks, Mohit Chamania[1], Thomas Szyrkowiec[1], Michele Santuari[2], Domenico Siracusa[2], Achim Autenrieth[1], Victor Lopez[3], Pontus Sköldström[4], Stephane Junique[4]; [1]*ADVA Optical Networking, Germany;* [2]*CREATE-NET Research Center, Italy;* [3]*Telefonica I+D, Spain;* [4]*ACREO Swedish ICT AB,, Sweden.* We demonstrate multi-layer encrypted service provisioning via the ACINO orchestrator. ACINO combines a novel intent interface with an ONOS-based SDN orchestrator to facilitate encrypted services at IP, Ethernet and optical network layers.

Tu3L.11
Demonstration of NFV Content Delivery using SDN-enabled Virtual Infrastructures, ALI Hammad[1], Jaume Marhuenda[1], Shuangyi Yan[1], Reza Nejabati[1], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK.* We will demonstrate the composition and operation of a virtual infrastructure (VI) for NFV content delivery. The demonstrated VI will be controlled through SDN controller. Furthermore, an infrastructure replanning mechanism will be also demonstrated.

Tu3L.12
Software-programmed Optical Networking with Integrated NFV Service Provisioning, Victor Mehmeri[1,2], Xi Wang[2], Shrutarshi Basu[3], Qiong Zhang[2], Paparao Palacharla[2], Tadashi Ikeuchi[2], Idelfonso Tafur Monroy[1], Juan José Vegas Olmos[1], Nate Foster[3]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Fujitsu Laboratories of America, USA;* [3]*Cornell Univ., USA.* We showcase demonstrations of "program & compile" styled optical networking as well as open platforms & standards based NFV service provisioning using a proof-of-concept implementation of the Software-Programmed Networking Operating System (SPN OS).

Tu3L.13
Performance-assured Network Function Virtualization for Open and Disaggregated Optical Transport Systems, Ryousei Takano[1], Takahiro Hirofuchi[1], Hirokazu Takahashi[3], Norio Sakaida[3], Katsuhiro Shimano[3], Kiyo Ishii[1], Satoshi Suda[1], Shu Namiki[1], Tomohiro Kudoh[1,2]; [1]*AIST, Japan;* [2]*Univ. of Tokyo, Japan;* [3]*NTT Network Innovation Laboratories, Japan.* A performance-assured Network Function Virtualization (NFV) method for software-based packet processing on an open and disaggregated optical transport network systems will be demonstrated. Our technique improves NFV operations by leveraging cache memory allocation and monitoring.

Tu3L.14
An End-to-End Programmable Platform for Dynamic Service Creation in 5G Networks, Ahmad Rostami[1], Allan Vidal[1], Mateus A. Santos[1], Muhammad Rehan Raza[2], Farnaz Moradi[1], Bertrand Pechenot[3], Zere Ghebretensae[1], Paolo Monti[2], Peter Ohlen[1]; [1]*Ericsson Research, USA;* [2]*KTH Royal Inst. of Technology, Sweden;* [3]*Acreo, Sweden.* We demonstrate how SDN and NFV can bring end-to-end programmability to heterogeneous technology domains including optical transport, radio and cloud networks, which can in turn be leveraged for agile and resource-optimized service creation.

Tu3L.15
A Multi-operator Network Service Orchestration Prototype: The 5G Exchange, Andrea Sgambelluri[1], Andrea Milani[2], Janós Czentye[3], Javier Melian[4], Wint Y. Poe[5], Francesco Tusa[6], Oscar Gonzalez de dios[7], Balazs Sonkoly[3], Molka Gharbaoui[10], Francesco Paolucci[10], Elisa Meini[6], Giovanni Giuliani[2], Aurora Ramos[4], Paolo Monti[1], Luis Miguel Contreras Murillo[7], Ishan Vaishnavi[5], Carlos Jesús Bernardos Cano[8], Róbert Szabó[9]; [1]*KTH Royal Inst. of Technology, Sweden;* [2]*Hewlett Packard Enterprise (HPE), Italy;* [3]*Budapest Univ. of Technology and Economics BME, Hungary;* [4]*Atos Spain SA, Spain;* [5]*Huawei Technologies Duesseldorf GmbH, Germany;* [6]*Univ. College London, UK;* [7]*Telefonica, Spain;* [8U]*niversidad Carlos Iii De Madrid, Spain;* [9]*Ericsson Research, TrafficLab, Hungary;* [10]*Sant'Anna di Pisa, Italy.* In the context of the 5GEx Project, a Multi-domain Orchestrator is in charge of creating, deploying, and terminating Network Services spanning across multiple-operators. This live demo showcases the main functionalities of the 5GEx system.

18:30–20:00 Conference Reception, *Concourse Hall*

19:30–21:30 Rump Session: Sub $0.25/Gbps Optics; How and When Will Fiber Finally Kill Copper Cable Interconnects in the Data Center (DC)?, *409AB*

NOTES

07:30–08:00 Coffee Break, *400 Foyer*

Room 402AB

08:00–09:45
W1A • Photonic/Electronic Integration and Packaging
Presider: Peter Dedobbelaere; Luxtera Inc, USA

W1A.1 • 08:00 Invited
Microprocessor Chip with Photonics I/O, Chen Sun[1,3], Mark Wade[2], Yunsup Lee[1], Jason Orcutt[3], Luca Alloatti[3], Michael Georgas[3], Andrew Waterman[1], Jeffrey Shainline[2], Rimas Avizienis[1], Sen Lin[1], Benjamin Moss[3], Rajesh Kumar[2], Fabio Pavanello[2], Amir Atabaki[3], Henry Cook[1], Albert Ou[1], Jonathan Leu[3], Yu-Hsin Chen[3], Krste Asanovic[1], Rajeev Ram[3], Milos A. Popovic[2], Vladimir Stojanovic[1]; [1]*EECS, Univ. of California, Berkeley, USA;* [2]*ECEE, Univ. of Colorado, Boulder, USA;* [3]*EECS, Massachusetts Inst. of Technology, USA.* In this work, we provide an overview of the technology and architecture of a microprocessor chip with optical I/O. Zero-change photonics integration enabled the chip to be fabricated in a commercial electronics CMOS foundry.

Room 403A

08:00–10:00
W1B • SDM Multiplexers and 3D Waveguides
Presider: Haoshuo Chen; Nokia Bell Labs, USA

W1B.1 • 08:00
Scrambling-type Three-mode Multiplexer Based on Cascaded Y-branch Waveguide with Integrated Mode Rotator on PLC Platform, Takeshi Fujisawa[1], Yoko Yamashita[1], Taiji Sakamoto[2], Takashi Matsui[2], Shuntaro Makino[1], Kyozo Tsujikawa[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan;* [2]*NTT, Japan.* A novel scrambling-type mode multiplexer is proposed for future large-mode-number mode-division-multiplexing. 3-mode multiplexer design based on silica PLC shows low-loss and small wavelength dependence multiplexing is possible and a proof-of-concept device is fabricated.

W1B.2 • 08:15
One chip, PLC Three-mode Exchanger Based on Symmetric and Asymmetric Directional Couplers with Integrated Mode Rotator, Takeshi Fujisawa[1], Eri Taguchi[1], Taiji Sakamoto[2], Takashi Matsui[2], Yoko Yamashita[1], Kyozo Tsujikawa[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan;* [2]*NTT, Japan.* A three-mode exchanger composed of symmetric and asymmetric directional couplers is proposed for mode-division-multiplexing system. Theoretical design shows low-loss and highly efficient mode exchanging is possible. Fabricated device exhibits successful mode exchanging for LP_{01} mode.

Room 403B

08:00–10:00
W1C • Novel Fronthauling Techniques
Presider: Hwan Seok Chung; ETRI, Korea

W1C.1 • 08:00
Experimental Demonstration of a Period-one (P1) Nonlinear Dynamic Modulated Optical OFDM Signal Employing to a Millimeter Wave (MMW) Mobile Fronthaul Uplink, Jhih-Heng Yan[1], Yu-Han Hung[2], Kun-Lin Shieh[2], Yi-Ting Liao[3], Sheng-Kwang Hwang[2,4], Kai-Ming Feng[1,3]; [1]*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan;* [2]*Department of Photonics, National Cheng Kung Univ., Taiwan;* [3]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan;* [4]*Advanced Optoelectronic Technology Center, National Cheng Kung Univ., Taiwan.* For the first time, a period-one (P1) nonlinear dynamic modulated MMW OFDM signal is employed to mobile fronthaul uplink. A proof-of-concept experimental demonstrations show successfully retrieved signals after 1.5-m wireless and 25-km SMF transmissions.

W1C.2 • 08:15
Millimeter-wave Radio Bundling for Reliable Transmission in Multi-section Fiber-Wireless mobile Fronthaul, Lin Cheng[1], Feng Lu[1], Jing Wang[1], Mu Xu[1], Shuyi Shen[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA.* We propose a reconfigurable millimeter-wave radio bundling method to improve system efficiency and transmission reliability in multi-section fiber-wireless mobile fronthaul. A multi-point multi-section experiment demonstrates improved signal quality and reliability.

Room 404AB

08:00–10:00
W1D • Control Architecture and Network Modeling II
Presider: Werner Weiershausen; Deutsche Telekom Technik GmbH, Germany

W1D.1 • 08:00 Tutorial
YANG, Netconf, Restconf - What is This All About and How is it Used for Multi-layer Networks, Carl Moberg[1]; [1]*Cisco Systems, USA.* Abstract not available.

Specializes in driving product life cycles of network equipment and software. Understands network technologies as well as the software involved. Experienced in communicating technical concepts to customers and peers.

Room 406AB

08:00–10:00
W1E • Tunable Lasers and Transmitters
Presider: Anders Larsson; Chalmers Tekniska Hogskola, Sweden

W1E.1 • 08:00
A Direct Comparison between Heterogeneously Integrated Widely-tunable Ring-based Laser Designs, Linjun Liang[1,2], Jared Hulme[1], Rui-Lin Chao[1,3], Tin Komljenovic[1], Jin-Wei Shi[1,3], Shuisheng Jian[2], John E. Bowers[1]; [1]*Univ. of California Santa Barbara, USA;* [2]*Inst. of Lightwave Technology, Beijing Jiaotong Univ., China;* [3]*Department of Electrical Engineering, National Central Univ., Taiwan.* Four ring-based tunable lasers are demonstrated in the heterogeneous silicon platform. Except for double-sided CRR structure, the other three show comparable narrow-linewidth (~200kHz) and output power (~10mW) across entire wide-tuning ranges (~40nm) with SMSR (>40dB).

W1E.2 • 08:15 Top Scored
Full C-band, Mode-hop-free Wavelength-Tunable Laser Diode with a Linewidth of 8 kHz and a RIN of -130 dB/Hz, Keisuke Kasai[1], Masataka Nakazawa[1], Yasunori Tomomatsu[2], Takashi Endo[2]; [1]*Research Inst. of Electrical Communication, Tohoku Univ., Japan;* [2]*Koshin Kogaku Co., Ltd., Japan.* We demonstrate a wavelength-tunable external-cavity laser diode with a linewidth of less than 8 kHz and a RIN below -130 dB/Hz. The oscillation wavelength can be tuned over the full C-band without mode hopping.

Room 407

08:00–10:00
W1F • Advanced Fiber Lasers
Presider: Rodrigo Amezcua Correa; Univ. of Central Florida, CREOL, USA

W1F.1 • 08:00
6kW Yb-doped Laser Fiber Fabricated by Chelate Precusor Doping Technique, Aoxiang Lin[1], Xuan Tang[1], Huan Zhan[1], Qi Li[1], Yuying Wang[1], Kun Peng[1], Li Ni[1], Xiaolong Wang[1], Cong Gao[1], Zhanonian Jia[1], Yuwei Li[1], Ani You[1], Jianjun Wang[1], Feng Jing[1], Honghuan Lin[1]; [1]*China Academy of Engineering Physics, China.* By chelate precursor doping technique, a 30µm-core Yb-doped alumino-phosphosilicate fiber was fabricated and presented 6.03kW laser output at 1080nm. The slope efficiency is 68.37% and the M^2 factor is ~2.38 when stably running at 5.16kW.

W1F.2 • 08:15
Dual-Emission Band All-Fiber Laser based on Theta Cavity with Thulium- and Holmium-Doped Fibers, Svyatoslav Kharitonov[1], Camille-Sophie Bres[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland.* We present first dual-wavelength all-fiber laser, based on isolator-free theta cavity with two fiber Bragg mirrors and thulium- and holmium-doped fibers. Laser provides 350mW total power with 8% slope efficiency, and linewidth less than 0.1nm.

07:30–08:00 Coffee Break, *400 Foyer*

Room 408A

08:00–10:00
W1G • Nonlinearity Mitigation and Monitoring

Presider: Robert Killey; Univ. College London, UK

W1G.1 • 08:00

Experimental Investigation of Nonlinear Signal Distortions in Ultra-wideband Transmission Systems, Gabriel Saavedra[1], Mingming Tan[2], Daniel J. Elson[1], Lidia Galdino[1], Daniel Semrau[1], Md Asif Iqbal[2], Ian Phillips[2], Paul Harper[2], Naoise MacSuibhne[2], Andrew Ellis[2], Domanic Lavery[1], Benn C. Thomsen[1], Robert Killey[1], Polina Bayvel[1]; [1]*Univ. College London, UK;* [2]*Aston Univ., UK.* The impact of nonlinear interference (NLI) is experimentally investigated in the ultra-wide bandwidth regime. For signal bandwidths up to 7.3 THz it is confirmed that NLI continues to accumulate as predicted by the Gaussian Noise model.

W1G.2 • 08:15

Pilot Based Cross Phase Modulation Power Estimation, Ying Zhao[1], Zhenning Tao[1], Shoichiro Oda[2], Yasuhiko Aoki[3], Takeshi Hoshida[2]; [1]*Fujitsu research & development center, China;* [2]*Fujitsu Laboratories Ltd., Japan;* [3]*Fujitsu Limited, Japan.* An inter-channel cross phase modulation power estimation method is proposed based on angular squeezing of polarization diversified pilot tones. Simulation and experiment verify the estimator successfully indicates the power of the cross phase modulation impairment.

Room 408B

08:00–10:00
W1H • SDN Architecture for Packet and Physical Layer Optical

Presider: Hiroaki Harai; National Inst of Information & Comm Tech, Japan

W1H.1 • 08:00 Invited

Segment Routing for Network Optimizations, Walid Wakim[1]; [1]*Cisco Systems, Inc., USA.* Segment Routing (SR) simplifies network design and operations, enabling opex reduction in networks. SR achieves this simplification through the increased utilization of available bandwith and elimination of distributed protocols such as LDP and RSVP-TE. Optimization around capacity during link failures with Tactical SR-TE, will be discussed.

Room 409AB

08:00–10:00
W1I • Elastic Optical Networks

Presider: João Pedro; Coriant, Portugal

W1I.1 • 08:00

Mixed Channel Traffic Grooming in Shared Backup Path Protected IP over Elastic Optical Network, Fengxian Tang[1], Longfei Li[1], Bowen Chen[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*IIT Guwahati, India.* For mixed channel traffic grooming in shared backup path protected IP over elastic optical network, we develop an auxiliary graph based heuristic algorithm allowing working and protection traffic flows to share common optical channels. Results show that the scheme is efficient in greatly improving capacity and transponder utilization.

W1I.2 • 08:15

Signal Overlap for Efficient 1+1 Protection in Elastic Optical Networks (EONs), Filippo Cugini[1], Nicola Sambo[2], Tommaso Foggi[1], Marc Ruiz[3], Luis Velasco[3], Piero Castoldi[2]; [1]*CNIT, Italy;* [2]*Scuola Superiore Sant'Anna, Italy;* [3]*Optical Communications Group (GCO), Universitat Politcnica de Catalunya (UPC), Spain.* An innovative transmission technique enabling signal overlap is introduced for spectrally-efficient 1+1 protection. Simulation results show that the proposed technique successfully reduces the overall amount of occupied spectrum resources.

Room 410

08:30–10:00
W1J • Forward Error Correction and Coding

Presider: Yi Cai; ZTE (TX) Inc., USA

Room 411

08:00–10:00
W1K • OFDM for Access Networks

Presider: Jun-ichi Kani; NTT Access Service Systems Laboratories, Japan

W1K.1 • 08:00 Invited

Frequency Division Multiplexing for Very High Capacity Transmission in Bandwidth-Limited Systems, Alberto Gatto[1], Paola Parolari[1], Pierpaolo Boffi[1]; [1]*Politecnico di Milano, Italy.* FDM is shown to achieve high capacity facing system bandwidth limitations and exploiting its flexibility to allocate the subcarriers, also with an effective combination with MDM, in different applications, including PONs and mobile fronthaul.

Show Floor Programming

Wednesday, 22 March

Room 402AB

W1A • Photonic/Electronic Integration and Packaging—Continued

W1A.2 • 08:30
Low Crosstalk Simultaneous 12 ch x 25 Gb/s Operation of High-density Silicon Photonics Multichannel Receiver, Tsuyoshi Aoki[1,2], Tomoyuki Akiyama[1,2], Akio Sugama[2], Akinori Hayakawa[1,2], Hidenobu Muranaka[2], Takasi Simoyama[1], Shinsuke Tanaka[1], Motoyuki Nishizawa[1], Nobuaki Hatori[1], Yohei Sobu[1], Yanfei Chen[2], Toshihiko Mori[1,2], Shigeaki Sekiguchi[1,2], Seok-hwan Jeong[1], Yu Tanaka[1,2], Ken Morito[1,2]; [1]*PETRA, Japan;* [2]*Fujitsu Laboratories Ltd., Japan.* We designed high PI and SI for receiver with the high-density bridge structure and successfully verified simultaneous error-free operations of 12 ch x 25 Gb/s with a small crosstalk penalty of 1.2 dB.

W1A.3 • 08:45
Demonstration of a Packaged Photonic Integrated Network on Chip controlled by an FPGA-based scheduler, Yule Xiong[1], Nicola Andriolli[2], Stefano Faralli[2], Fabrizio Gambini[2], Paolo Pintus[3], Marco Chiesa[2], Ruben Ortuño[4], Odile Liboiron-Ladouceur[1], Isabella Cerutti[2]; [1]*McGill Univ., Canada;* [2]*Scuola Superiore Sant'Anna, Italy;* [3]*Univ. of California, Santa Barbara, USA;* [4]*Universidad Politécnica de Valencia, Spain.* The dynamic performance of a packaged photonic network-on-chip (NoC) based on multi-microrings is experimentally demonstrated. Controlled by a scheduler implemented in an FPGA, the packaged photonic NoC exhibits a BER penalty of approximately 0.5 dB.

Room 403A

W1B • SDM Multiplexers and 3D Waveguides—Continued

W1B.3 • 08:30 Invited
Capacity Limits for Spatially Multiplexed Free-space Communication, Joseph M. Kahn[1], Guifang Li[2], Xiaoying Li[3], Ningbo Zhao[3]; [1]*Stanford Univ., USA;* [2]*CREOL, Univ. of Central Florida, USA;* [3]*Tianjin Univ., China.* We show that OAM multiplexing does not realize the capacity limits of free-space channels, and is outperformed by multiplexing in parallel Gaussian beams or any complete modal basis.

Room 403B

W1C • Novel Fronthauling Techniques—Continued

W1C.3 • 08:30
Real-time Measurements of an Optical Reconfigurable Radio Access Unit for 5G Wireless Access Networks, Sebastian Rodriguez[1], Alvaro Morales[1], Simon Rommel[1], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1,2]; [1]*Technical Univ. of Denmark, Denmark;* [2]*ITMO Univ., Russia.* A reconfigurable radio access unit able to switch wavelength, RF carrier frequency and optical path is experimentally demonstrated. The system is able to do the switching processes correctly, while achieving BER values below FEC limit.

W1C.4 • 08:45
Simultaneous Transmission of Multi-RATs and Mobile Fronthaul in the MMW Bands over an IFoF System, Pham Tien Dat[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]; [1]*NICT, Japan;* [2]*Waseda Univ., Japan.* We propose and demonstrate a simultaneous transmission of LTE-A, 25-GHz OFDM/FBMC radio access, and 96-GHz filtered-OFDM mobile fronthaul signals over a simple and low cost intermediate-frequency-over-fiber system. We confirm the successful transmission for all signals.

Room 404AB

W1D • Control Architecture and Network Modeling II—Continued

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

Room 406AB

W1E • Tunable Lasers and Transmitters—Continued

W1E.3 • 08:30 Invited
Silicon Photonic Wavelength Tunable Lasers for High-capacity Optical Communication System, Tomohiro Kita[1], Hiroyuki Yamazaki[2], Naokatsu Yamamoto[3], Hirohito Yamada[1]; [1]*Tohoku Univ., Japan;* [2]*NEC Corporation, Japan;* [3]*NICT, Japan.* Silicon photonic wavelength-tunable laser diodes consist of a wavelength-tunable filter with silicon ring resonators and a semiconductor optical amplifier. Narrow spectral linewidth lasers for coherent optical communication systems and quantum dot heterogeneous laser were demonstrated.

Room 407

W1F • Advanced Fiber Lasers—Continued

W1F.3 • 08:30
Ultra-Broadband Tunable Fiber Laser, Vladislav Dvoyrin[1], Nikita Tarasov[1], Sergei K. Turitsyn[1]; [1]*Aston Univ., UK.* We demonstrate the ultra-broadband gain medium exploiting cascaded Raman amplification. Pumping the 5-km long linear cavity fiber laser at 1349 nm we show the tunability of the laser operation from 1400 to 1622 nm.

W1F.4 • 08:45
A New Ultrafast and High Peak Power Fiber Laser Operating at 1.5 µm using InN as Saturable Absorber, Marco Jiménez-Rodríguez[1], Laura Monteagudo-Lerma[1], Eva Monroy[2,3], Fernando Naranjo[1], Miguel González-Herráez[1]; [1]*Electronics, Univ. of Alcala, Spain;* [2]*INAC, CEA-Grenoble, France;* [3]*Univ. Grenoble-Alpes, France.* This work describes a novel ultrafast (<250 fs) fiber laser operating at 1.5 µm and based on InN as saturable absorber (SA). This SA accommodates much higher fluencies than comparable semiconductor or graphene-based SAs.

Room 408A

W1G • Nonlinearity Mitigation and Monitoring—Continued

W1G.3 • 08:30
Toward Blind Nonlinearity Estimation in Back-propagation Algorithm for Coherent Optical Transmission Systems, Lin Jiang[1], Lianshan Yan[1], Anlin Yi[1], Yan Pan[1], Jun Ge[1], Liangliang Dai[1], Wei Pan[1], Bin Luo[1]; [1]*Southwest Jiaotong Univ., China.* Blind estimation of nonlinear operator product in back-propagation algorithm is proposed. Significantly enhanced flexibility of nonlinear compensation is experimentally demonstrated in a 5x64-Gb/s WDM PDM-QPSK system over 1920-km SMF link with ~1.5-dB performance improvement.

W1G.4 • 08:45
Time-Domain Digital Back Propagation: Algorithm and Finite-Precision Implementation Aspects, Christoffer Fougstedt[1], Mikael Mazur[1], Lars Svensson[1], Henrik Eliasson[1], Magnus Karlsson[1], Per Larsson-Edefors[1]; [1]*Chalmers Univ. of Technology, Sweden.* We propose a nonlinear mitigation algorithm designed from an ASIC perspective, and analyze implementation aspects. Given 9 signal and 11 coefficient bits, reach is increased by 105% compared to linear compensation in single-channel 16-QAM transmission.

Room 408B

W1H • SDN Architecture for Packet and Physical Layer Optical—Continued

W1H.2 • 08:30 Invited
Control Plane Architectures for Flexi-Grid Networks, Oscar Gonzalez de Dios[1]; [1]*Telefonica, Spain.* Elastic optical networks are based on a flexible allocation of the spectrum and configurable transponders. The control architecture is key to unlock their potential. This paper presents the architectural choices, including GMPLS, SDN and TAPI.

Room 409AB

W1I • Elastic Optical Networks—Continued

W1I.3 • 08:30 Invited
How Much Transport Grooming is Needed in the Age of Flexible Clients?, António Eira[2,1], João Pedro[2,1]; [1]*Instituto Superior Técnico, Av. Rovisco Pais, 1, Instituto de Telecomunicações, Portugal;* [2]*Coriant, Portugal.* We analyze the impact of flexible client interfaces in the client- and line-side requirements of optical transport scenarios. The simulation results identify the network conditions where transport grooming fabrics are a necessary complement to flexibility on the client-side.

Room 410

W1J • Forward Error Correction and Coding—Continued

W1J.1 • 08:30
Nonbinary Staircase Codes for Spectrally and Energy Efficient Fiber-optic Systems, Alireza Sheikh[1], Alexandre Graell i Amat[1], Magnus Karlsson[1]; [1]*Chalmers Tekniska Hogskola, Sweden.* We consider the design of nonbinary staircase codes with higher order modulation for spectrally and energy efficient fiber-optic systems. We optimize the code parameters based on density evolution.

W1J.2 • 08:45
Distributed Rate-adaptive Staircase Codes for Connectionless Optical Metro Network, Laurent Schmalen[1], Lei M. Zhang[2], Ulrich Gebhard[1]; [1]*Bell Labs, Nokia, USA;* [2]*ECE, Univ. of Toronto, Canada.* We demonstrate a multipoint-to-point network architecture for optical metro networks with distributed FEC encoding based on modified staircase codes. We present a simple rate-adaptation scheme and demonstrate throughput maximization on the network.

Room 411

W1K • OFDM for Access Networks—Continued

W1K.2 • 08:30
Simplified 27.15 Gbits/s Spread-OFDM PON using DFT/IDFT-free Receiver with 1/16 Sub-Nyquist Sampling Rate, Chi-Hsiang Lin[1], Chun-Ting Lin[1], Chia-Chien Wei[2], Sien Chi[1], Ruie Fang[1]; [1]*National Chiao Tung Univ., Taiwan;* [2]*National Sun Yat-sen Univ., Taiwan.* This paper presents 27.15-Gbits/s spread-OFMD PON sub-Nyquist receiver via 1-GSample/s ADC for each 32-ONU to demodulate signals, which greatly reduces complexity. Moreover, DC algorithm is proposed to eliminate DC-located distortion caused by sub-Nyquist ADC.

W1K.3 • 08:45
A High Loss Budget 400-Gbps WDM-OFDM Long-Reach PON over 60 km Transmission by 10G-class EAM and PIN without In-line or Pre-amplifier, C. Y. Chuang[1], Chia-Chien Wei[2], Jun-Jie Liu[1], Hsin-Yu Wu[1], Hong-Minh Nguyen[1], Chun-Wei Wang[1], Shao-Yu Lu[1], Young-Kai Chen[3], Jyehong Chen[1]; [1]*Department of Photonics, National Chiao Tung Univ., Taiwan;* [2]*Department of Photonics, National Sun Yat-sen Univ., Taiwan;* [3]*Communication Science Research Department, Bell Laboratories, Alcatel-Lucent at Murray Hill, USA.* A 400-Gbps WDM-OFDM LR-PON over 60-km SMF is demonstrated with a 10G-class EAM and PIN. 25-dB loss budget is realized without in-line or pre-amplifier to economically support 128 ONUs with 3.1-Gbps/ONU capacity.

Show Floor Programming

Room 402AB

W1A • Photonic/ Electronic Integration and Packaging—Continued

W1A.4 • 09:00 Invited

>1-Tb/s On-board Optical Engine for High-Density Optical Interconnects, Hideyuki Nasu[1], Kazuya Nagashima[1], Toshinori Uemura[1], Atsushi Izawa[1], Yozo Ishikawa[1]; [1]*Furukawa Electric Co., Ltd., Japan.* We demonstrate a >1-Tb/s VCSEL-based on-board optical engine for high-density optical interconnects. The optical engine exhibits a good signal quality in an air-cooling environment with an ambient temperature of 40 °C.

Room 403A

W1B • SDM Multiplexers and 3D Waveguides—Continued

W1B.4 • 09:00

Compact Multimode 3dB Coupler for On-chip Mode Division Multiplexing, Kaixuan Chen[1,2], Jianhao Zhang[1], Zhichao Nong[3], Xinlun Cai[3], Sailing He[1,2], Liu Liu[2]; [1]*SCNU-ZJU Joint Research Center of Photonics, Centre for Optical and Electromagnetic Research, Zhejiang Univ., China;* [2]*SCNU-ZJU Joint Research Center of Photonics, Centre for Optical and Electromagnetic Research, South China Academy of Advanced Optoelectronics, South China Normal Univ., China;* [3]*State Key Laboratory of Optoelectronic Materials and Technologies, School of electronics and information technology, Sun Yat-sen Univ., China.* An on-chip 2*2 3dB coupler designed for multimode waveguide is demonstrated. The two modes from the input multimode waveguide can be simultaneously split in half to the two output multimode waveguides with a 21.8μm long coupling region.

W1B.5 • 09:15

90° Optical Hybrid Front-end Circuit Fabricated by 3D Direct Laser Inscription, Paul Mitchell[1]; [1]*Optoscribe Ltd., UK.* We show the fabrication of a 90° optical hybrid front-end circuit by direct laser inscription. Excess loss of 1.4 dB with maximum phase error of 3.6 degrees were achieved using MMI-based devices and a novel 3-dimensional layout.

Room 403B

W1C • Novel Fronthauling Techniques—Continued

W1C.5 • 09:00 Top Scored

Demonstration of IFoF based 5G Mobile Fronthaul in 28 GHz Millimeter Wave Testbed Supporting Giga-bit Mobile Services, Minkyu Sung[1], Seung-Hyun Cho[1], Kwang Seon Kim[1], Heon-Kook Kwon[1], Byung-Su Kang[1], Don Sung Oh[1], Deuk-Su Lyu[1], Hoon Lee[1], Sun Me Kim[1], Jong Hyun Lee[1], Hwan Seok Chung[1]; [1]*ETRI, Korea.* We report the successful demonstration of IFoF based mobile fronthaul link with 5G mobile communication system prototype supporting giga-bit mobile service. The data-rate per each user achieves 1.5 Gb/s, which satisfies vision of IMT-2020.

W1C.6 • 09:15

Investigation of F-OFDM in 5G Fronthaul Networks for Seamless Carrier-aggregation and Asynchronous Transmission, Meihua Bi[1,2], Weikang Jia[1], Longsheng Li[1], Xin Miao[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*College of Communication Engineering, Hangzhou Dianzi Univ., China.* We propose a asynchronous seamless carrier-aggregation scheme for supporting IFoF MFH system in 5G network based on F-OFDM. We successfully demonstrate gapless 5×200-MHz signals for downlink and asynchronous uplink with corresponding to 40.55 Gb/s CPRI-equivalent data rate over 6-GHz wireless and 20-km fiber channel.

Room 404AB

W1D • Control Architecture and Network Modeling II—Continued

W1D.2 • 09:00

Configuring Monitoring Entities through NETCONF and YANG in Control and Hierarchical Management Planes, Pietro Giardina[2], Nicola Sambo[1], Matteo Dallaglio[1], Giacomo Bernini[2], Gino Carrozzo[2], Filippo Cugini[1], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*NEXTWORKS, Italy.* This paper proposes a novel control and management scheme for elastic optical networks. YANG model for device configuration is presented and the scheme is demonstrated in a control plane testbed including hierarchical management plane.

W1D.3 • 09:15

Pre-programming Resilience Schemes upon Failure through NETCONF and YANG, Matteo Dallaglio[1], Nicola Sambo[1], Filippo Cugini[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* We propose and successfully implement a method to program resilience schemes (e.g., code adaptation) in a transponder controller. YANG models are proposed and demonstrated to configure actions and finite state machine in the transponder controller.

Room 406AB

W1E • Tunable Lasers and Transmitters—Continued

W1E.4 • 09:00

Flip-Chip-Integrated III-V/Si Hybrid External-cavity Laser using a Photonic Crystal Reflector, Shiyun Lin[1], Jin Yao[1], Stevan S. Djordjevic[1], Ying Luo[1], Jin-Hyoung Lee[1], Ivan Shubin[1], Jock Bovington[1], Daniel Y. Lee[1], Hiren D. Thacker[1], Chaoqi Zhang[1], Kannan Raj[1], John E. Cunningham[1], Ashok V. Krishnamoorthy[1], Xuezhe Zheng[1]; [1]*Oracle Corporation, USA.* We demonstrate an efficient surface-normal-coupled tunable external-cavity hybrid laser using a novel photonic crystal reflector. The ultra-compact reflector enables a single wavelength reflection and a short laser cavity to improve lasing stability.

W1E.5 • 09:15

High Power Tunable Light Source for Coherent Communication with Distributed Reflector Laser Array Combined by AWG Coupler, Yusuke Inaba[1], Maiko Ariga[1], Kazuaki Kiyota[1], Toshihito Suzuki[1], Kazuki Yamaoka[1], Shunsuke Okuyama[1], Masayoshi Nishita[1], Hajime Mori[1], Tatsuro Kurobe[1]; [1]*Furukawa Electric co., Ltd., Japan.* We fabricated TLS module with AWG-DR-LD array for digital coherent application. Separating SOA from LD chip enables us to maximize the performance. We achieved 80mW fiber output power and 80-120 kHz linewidth.

Room 407

W1F • Advanced Fiber Lasers—Continued

W1F.5 • 09:00 Tutorial

High Power Fiber Lasers, Jens Limpert[1]; [1]*Friedrich-Schiller-Univ., Jena, Germany.* Fiber lasers enjoy an excellent reputation as power-scalable diode-pumped solid-state laser concept. Their immunity against thermo-optical issues is combined with high efficiency and performance. The properties, challenges and perspectives of fiber lasers will be discussed.

Jens Limpert received his M.S in 1999 and Ph.D. in Physics from the Friedrich Schiller University of Jena in 2003. His research interests include high power lasers in the pulsed and continuous-wave regime. Jens Limpert is currently leading the Laser Development Group (including fiber- and waveguide lasers) at the Institute of Applied Physics. He is author or co-author of more than 270 peer-reviewed journal papers in the field of laser physics. His research activities have been awarded with the WLT-Award in 2006, an ERC starting grant in 2009 and an ERC consolidator grant in 2013. Jens Limpert is founder of the Active Fiber Systems GmbH a spin-off from the University Jena and the Fraunhofer-IOF Jena.

Room 408A

W1G • Nonlinearity Mitigation and Monitoring—Continued

W1G.5 • 09:00 Invited

Digital Nonlinear Compensation Technologies in Coherent Optical Communication Systems, Hisao Nakashima[1], Tomofumi Oyama[2], Chihiro Ohshima[2], Yuichi Akiyama[1], Takeshi Hoshida[1], Zhenning Tao[3]; [1]*Fujitsu Limited, Japan;* [2]*Fujitsu Laboratories Ltd., Japan;* [3]*Fujitsu R&D Center, China.* A perturbation-based digital nonlinear compensation and effective means of using it in an optical network were reviewed, and a real-time transmission by a 100 Gbit/s transceiver with the implemented digital nonlinear compensator was demonstrated.

Presentations selected for recording are designated with a ▶. Visit www.ofcconference.org and select the View Presentations link.

Room 408B

W1H • SDN Architecture for Packet and Physical Layer Optical—Continued

W1H.3 • 09:00 Invited

Optical Physical Layer SDN, Enabling Physical Layer Programmability through Open Control Systems, Daniel C. Kilper[1], Yao Li[1]; [1]*Univ. of Arizona, USA.* Software defined networking in the optical physical layer is complicated by transmission control used to both optimize performance and stabilize optical signals across multiple nodes. Different approaches are emerging to address these problems.

Room 409AB

W1I • Elastic Optical Networks—Continued

W1I.4 • 09:00

Do Elastic Transponders with Granularity Finer Than 50 Gb/S Make Gradual Fit of Modulation to Ageing More Profitable?, Jelena Pesic[2], Thierry Zami[1], Nicola Rossi[2], Sébastien Bigo[2]; [1]*Nokia , France;* [2]*Nokia, Bell Labs, France.* We evaluate the potential benefits of finer granularity rate adaptive transponders to better progressively fit ageing of the margin in WDM networks. The underlying technology and cost savings are presented for two network core topologies.

W1I.5 • 09:15

Impact of WSS Passband Narrowing Effect on the Capacity of the Flexible-spectrum Networks, Haining Yang[2], Rui Wang[1], Paul Wright[3], Abhijit Mitra[4], Brian Robertson[2], Peter Wilkinson[2], Subrat Kar[3], Andrew Lord[3], Daping Chu[1,2]; [1]*Univ. of Cambridge, UK;* [2]*Roadmap Systems Ltd, UK;* [3]*British Telecom Laboratories, UK;* [4]*Indian Inst. of Technology Delhi, India.* We show that the WSS passband shape needs to be optimized to the 3.6th and 3.2th Super-Gaussian orders in BT-UK and PAN-Europe networks, respectively, for realizing the 30% capacity increase promised by the flexible-spectrum standard.

Room 410

W1J • Forward Error Correction and Coding—Continued

W1J.3 • 09:00 Top Scored

Single-Carrier 400G PM-256QAM Generation at 34 GBaud Trading off Bandwidth Constraints and Coding Overheads, Hung-Chang Chien[1], Junwen Zhang[1], Jianjun Yu[1], Yi Cai[1]; [1]*ZTE TX Inc., USA.* For the first time, single-carrier 400G generation using PM-256QAM at record 34 GBaud is experimentally demonstrated, reaching 1.6-dBQ BTB system margin to the SD pre-FEC limit enabled by both higher coding gain and nonlinearity compensation.

W1J.4 • 09:15

Lattice Precoding for IM/DD POF Interconnects, Toshiaki Koike-Akino[1], Kieran Parsons[1], David Millar[1], Keisuke Kojima[1]; [1]*Mitsubishi Electric Research Labs, USA.* We introduce lattice precoding (LP) as an improved version of Tomlinson-Harashima precoding (THP) for direct intensity modulation & direct detection (IM/DD) communications over plastic optical fiber (POF). We show that LP offers a significant gain greater than 5 dB over conventional methods for short-range IM/DD SI-POF systems.

Room 411

W1K • OFDM for Access Networks—Continued

W1K.4 • 09:00 Invited

100G OFDM-PON for Converged 5G Networks: From Concept to Real-time Prototype, Kai Habel[1], Matthias Koepp[1], Stefan Weide[1], Luz Fernandez del Rosal[1], Christoph Kottke[1], Volker Jungnickel[1]; [1]*Fraunhofer HHI, Germany.* We propose a concept for implementation of a 100G OFDM-PON for a converged 5G network. A real-time OLT prototype and the DSP functions for an ONU are characterized.

Show Floor Programming

Room 402AB

W1A • Photonic/Electronic Integration and Packaging—Continued

W1A.5 • 09:30
60-micrometer Pitch Polymer Waveguide Array Attached Active Optical Flex, Hidetoshi Numata[1], M. Tokunari[1], J.B. Heroux[1]; [1]*International Business Machines Corp, Japan.* We present a 60-micrometer pitch polymer waveguide array attached active optical flexible module which is useful for compact and high-channel count optical interconnect. We fabricated this module and realized 20-Gbps optical signal transmission.

Room 403A

W1B • SDM Multiplexers and 3D Waveguides—Continued

W1B.6 • 09:30 Invited
Laser Fabrications of Multi-layer Waveguide Arrays in Multi-core Fibers and Glass Panels for Optical Interconnect, Kevin P. Chen[1], Ming-Jun Li[2]; [1]*Univ. of Pittsburgh, USA;* [2]*Corning Inc., USA.* This paper discuss ultrafast laser fabrication of 3D lightwave circuits in optical fibers and glass substrates for optical interconnects. The interaction between embedded waveguides and surface optical structures produced by semiconductor microfabrication will be discussed.

Room 403B

W1C • Novel Fronthauling Techniques—Continued

W1C.7 • 09:30 Invited
RAN Revolution with NGFI (xHaul) for 5G, Chih-Lin I[1]; [1]*China Mobile, China.* From "Rethinking Ring and Young" in 2011 to proposing NGFI (xHaul) in 2014, the RAN revolutionary path to meet ambitious 5G demands has been charted out. Traditional TDM based fronthaul solutions, e.g., CPRI, fell short both in required BW and architecture flexibility. Next generation fronthaul interface (NGFI, aka xHaul) proposed by China Mobile targeting a packet-based, traffic-dependent, and antenna scale-independent interface will be central to the 5G RAN revolution. The concept has been widely accepted in the industry and both IEEE and 3GPP, among others, are taking this approach towards 5G. This presentation will bring forth the latest progress within China Mobile and in the global industry. Specifically, a two-level NGFI architecture will be highlighted, and the function split options with associated requirements in, e.g. latency, bandwidth and synchronization will be presented. In addition, the opportunity of SDAI integration and challenge of SDN application will be discussed.

Room 404AB

W1D • Control Architecture and Network Modeling II—Continued

W1D.4 • 09:30
Field Trial of Data Analysis-based Autonomic Bandwidth Adjustment in Software Defined Multi-Vendor OTN Networks, Yajie Li[1], Yongli Zhao[1], Xiaosong Yu[1]; [1]*Beijing Univ. of Posts and Telecommunications, China.* To achieve cost-effective bandwidth provisioning, this paper proposes an autonomic bandwidth adjustment scheme based on data analysis of traffic load. The scheme is verified in field trial networks with commercial OTN equipment from three vendors.

W1D.5 • 09:45
Demonstration of Fast Cooperative Operations in Disaggregated Optical Node Systems, Kiyo Ishii[1], Satoshi Suda[1], Shigeyuki Yanagimachi[2], Hitoshi Takeshita[2], Dai Suzuki[3], Takafumi Terahara[3], Shu Namiki[1]; [1]*AIST, Japan;* [2]*IoT Device Labs., NEC Corporation, Japan;* [3]*Network Products Business Unit, Fujitsu Ltd., Japan.* A node controller is addressed to ease operations such as alarm monitoring and path provisioning for the centralized controller. It is actually implemented on off-the-shelf servers to successfully perform fast protections in disaggregated optical nodes.

Room 406AB

W1E • Tunable Lasers and Transmitters—Continued

W1E.6 • 09:30
A Mode-hop-free III-V/Si Hybrid External-cavity Laser, Jin Hyoung Lee[1], Ivan Shubin[1], Jock Bovington[1], Ying Luo[1], Daniel Y. Lee[1], Stevan S. Djordjevic[1], Shiyun Lin[1], Jin Yao[1], Hiren D. Thacker[1], John E. Cunningham[1], Kannan Raj[1], Ashok V. Krishnamoorthy[1], Xuezhe Zheng[1]; [1]*Oracle, USA.* We propose a novel approach of passive stabilization for on-chip III-V/Si hybrid laser over temperature variation by thermo-optic compensation. By engineering the effective thermal-optic coefficient of the cavity, we demonstrated mode-hop-free operation of an on-chip hybrid laser over 35°C temperature change without any active controls.

W1E.7 • 09:45
Small Form Factor Hybrid III-V/Si Wavelength-tunable Push-pull Microring based Transmitter, Chia-Ming Chang[1], Guilhem de Valicourt[1], Jeffrey Lee[1], KW Kim[1], Michael Eggleston[1], Po Dong[1], Anaelle Maho[2], Romain Brenot[2], Young-Kai Chen[1]; [1]*Nokia Bell Labs, USA;* [2]*III-V labs, France.* We demonstrate a compact low-chirp and energy-efficient integrated hybrid III-V/Si transmitter based on a Vernier tunable laser that covers the entire C-band, and a low drive voltage push-pull ring modulator that provides large extension ratio and low chirp.

Room 407

W1F • Advanced Fiber Lasers—Continued

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall G-K* (coffee service 10:00–10:30)

10:00-17:00 OFC Career Zone Live, *South Lobby*

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

Show Floor Programming

W1G • Nonlinearity Mitigation and Monitoring—Continued

W1G.6 • 09:30
Modified Digital Backpropagation Accounting for Polarization-Mode Dispersion, Cristian B. Czegledi[1], Gabriele Liga[2], Domanic Lavery[2], Magnus Karlsson[1], Erik Agrell[1], Seb J. Savory[3], Polina Bayvel[2]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Univ. College London, UK;* [3]*Univ. of Cambridge, UK.* We propose a modified DBP algorithm accounting for PMD. The accumulated PMD at the receiver is factorized into several PMD sections, and inserted into the DBP routine to distributively compensate for PMD, outperforming the conventional approach by 1.1 dB in SNR.

W1G.7 • 09:45
Experimental Study of Nonlinearity Tolerant Modulation Formats Based on LDPC Coded Non-uniform Signaling, Zhen Qu[1], Changyu Lin[1], Tao Liu[1], Ivan B. Djordjevic[1]; [1]*Univ. of Arizona, USA.* Nonlinearity tolerant 5-QAM and 9-QAM are experimentally studied for long-haul WDM transmission. Compared to QPSK and 8-QAM, the transmission reach is extended for 12% and 222% by using LDPC-coded non-uniform 5-QAM and 9-QAM, respectively.

W1H • SDN Architecture for Packet and Physical Layer Optical—Continued

W1H.4 • 09:30
TDM based Optical Bypass for Intra-rack Elephant Flow with a DPDK Based Online Timeslot Allocator, Bingli Guo[1], Shutong Li[1], Shan Yin[1], Shanguo Huang[1]; [1]*Beijing Univ. of Post and Telecomm., China.* An optical TDM system is experimentally demonstrated with sFlow based elephant flow detection and a DPDK based online timeslot allocator. With proposed timeslot allocation algorithm, allocator could have 383 Gbps throughput and continuous timeslots allocation.

W1H.5 • 09:45
Load and Nonlinearity Aware Resource Allocation in Elastic Optical Networks, Rui Wang[1], Sarvesh Bidkar[1], Reza Nejabati[1], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK.* We propose a novel routing and spectrum allocation solution for elastic all-optical networks based on load-aware nonlinear impairment estimation that significantly improves service acceptance ratio and spectrum utilization compared to nonlinearity assignment based on fixed-margins.

W1I • Elastic Optical Networks—Continued

W1I.6 • 09:30 Invited
Bandwidth Variable Transmitter for Software Defined Networks, Arnaud Dupas[1], Patricia Layec[1], Dominique Verchere[1], Sébastien Bigo[1]; [1]*Nokia Bell-Labs France, France.* We review the architecture of Bandwidth Variable Transmitter designed for Software Defined Networks. We focus on 10-100Gbit/s elastic coherent transmission performances and high speed switching time enabling SDN controlled zero packet loss operation.

W1J • Forward Error Correction and Coding—Continued

W1J.5 • 09:30
FPGA Demonstration of Stretched Continuously Interleaved BCH Code with Low Error Floor for Short-Range Optical Transmission, Fan Yu[1], Mo Li[1], Nebojsa Stojanovic[1], Changsong Xie[1], Zhiyu Xiao[1], Liangchuan Li[1]; [1]*Huawei Technologies Co. Ltd, China.* A novel SCI-BCH code and an error pattern breaking decoding algorithm are proposed. Compared with the CI-BCH code, the error floor is lowered from BER of 1e-9 to 1e-16 at small latency and storage cost.

W1J.6 • 09:45
Bit-interleaved Polar-coded Modulation for Low-latency Short-block Transmission, Toshiaki Koike-Akino[1], Ye Wang[1], Stark C. Draper[2], Kenya Sugihara[3], Wataru Matsumoto[3], David Millar[1], Kieran Parsons[1], Keisuke Kojima[1]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*Univ. of Toronto, Canada;* [3]*MELCO, Japan.* We show that polar codes with list+CRC decoding can outperform state-of-the-art LDPC codes in short block lengths. In addition, we introduce an efficient interleaver for polar-coded high-order modulations, achieving greater than 0.5dB gain for 256QAM.

W1K • OFDM for Access Networks—Continued

W1K.5 • 09:30
Digital OFDM-PON Employing Binary Intensity Modulation and Direct Detection Channels, Rong Hu[1], Cai Li[1], Li Haibo[1], Qi Yang[1], Ming Luo[1], Shaohua Yu[1], William Sheih[2]; [1]*WRI, China;* [2]*Uni. of Melbourne, Australia.* In this paper, a delta-sigma modulation is proposed to enable transmission of OFDM signals by cost-effective binary IM-DD channels. Compared to traditional OFDM-PON, around 4-dB improvement in receiver sensitivity is achieved with the 20% average EVM.

W1K.6 • 09:45
Real-time VLLC-OFDM HD-SDI Video Transmission System with TS-based SFO Estimation Real-time VLLC-OFDM HD-SDI Video Transmission System with TS-based SFO Estimation, Rui Deng[1], J He[1], Ming Chen[2], Yiran Wei[1], Jin Shi[1], Lin Chen[1]; [1]*Hunan Univ., China;* [2]*Hunan Normal Univ., China.* An SFO estimation method based on simple training symbols is proposed in real-time OFDM system. By using the SFO estimation scheme, we implement an asynchronous software configurable real-time VLLC-OFDM system, and experimentally demonstrate an HD-SDI Video transmission over the system.

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall G-K* (coffee service 10:00–10:30)

10:00-17:00 OFC Career Zone Live, *South Lobby*

10:00–12:00
W2A • Poster Session I

W2A.1
Tunable Mode-locked Laser Photonic Integrated Circuit using Intracavity Phase Modulators, Mu-Chieh Lo[1], Robinson Guzmán[1], Carlos Gordón[1], Guillermo Carpintero[1]; [1]*Universidad Carlos III de Madrid, Spain.* A 30 GHz mode-locked laser in PIC is presented using InP-based active-passive integration technology. The 2.8 mm long cavity contains phase modulators enabling sub-nm fine tuning of the lasing spectrum which is experimentally demonstrated.

W2A.2
Fiber Random Grating Feedback Induced Chaos in Semiconductor Laser with Highly Suppressed Time-Delay Signature, Yanping Xu[1], Liang Zhang[1], Mingjiang Zhang[1,2], Ping Lu[3], Stephen Mihailov[3], Xiaoyi Bao[1]; [1]*Univ. of Ottawa, Canada;* [2]*Inst. of Optoelectronic Engineering, Department of Physics and Optoelectronics, Taiyuan Univ. of Technology, China;* [3]*National Research Council Canada, Canada.* A semiconductor laser with distributed feedbacks from a novel fiber random grating is perturbed to emit chaotically. The time delay signature of the chaotic output is suppressed with the largest extent to date.

W2A.3
Athermal Operation of a Multi-section Laser for Optical Communications, Michael Wallace[1,2], Rudi O'Reilly[3], Ryan Enright[3], Frank Bello[4,5], John Donegan[1,4]; [1]*School of Physics, Trinity College Dublin, Ireland;* [2]*Future Networks and Communications (CONNECT), Trinity College Dublin, Ireland;* [3]*Efficient Energy Transfer Department, Bell Labs, Nokia, Ireland;* [4]*Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN), Trinity College Dublin, Ireland;* [5]*Advanced Materials and BioEngineering Centre (AMBER), Trinity College Dublin, Ireland.* Two distinct athermal bias current control procedures are demonstrated for a low-cost, monolithic, three section slotted single mode laser, achieving wavelength stability of ±0.01 nm over a temperature range of 10-85 C. An analytical model has been developed to provide further insight into the athermal operation of these devices.

W2A.4
Hybrid Integration of Modified Uni-traveling Carrier Photodiodes on a Multi-layer Silicon Nitride Platform Using Total Internal Reflection Mirrors, Shaoqi Feng[1], Yang Shen[2], Xiao-Jun Xie[2], Jizhao Zang[2], Siwei Li[1], Tiehui Su[1], Kuanping Shang[1], Weicheng Lai[1], Guangyao Liu[1], Joe C. Campbell[2], S. J. Ben Yoo[1]; [1]*Department of Electrical and Computer Engineering, Univ. of California, Davis, USA;* [2]*Department of Electrical and Computer Engineering, Univ. of Virginia, USA.* We demonstrate hybrid integration of modified uni-traveling carrier photodiodes on a multi-layer silicon nitride platform using total internal reflection mirrors. Low-loss high-efficiency coupling of InGaAs detector on a silicon substrate has been realized.

W2A.5
A Passive Optical Alignment Technique for Single-mode Fibers and Light-source Arrays, Koichiro Adachi[1], Akira Nakanishi[1], Takanori Suzuki[1], Hiroki Irie[1], Hiroyasu Sasaki[1], Tetsuya Aoki[1], Masato Shishikura[1], Kazuhiko Naoe[1], Shigehisa Tanaka[1]; [1]*Oclaro Japan, Inc., Japan.* A passive optical alignment based on a lens-integrated surface-emitting laser array and a single-mode fiber array was demonstrated. The proposed alignment technique enables better coupling efficiency than that of conventional DFB laser with active alignment.

W2A.6
Frequency Noise of a Normal Dispersion Microresonator-based Frequency Comb, Attila Fulop[1], Mikael Mazur[1], Abel Lorences-Riesgo[1], Pei-Hsun Wang[2], Yi Xuan[2,3], Dan E. Leaird[2], Minghao Qi[2,3], Peter A. Andrekson[1], Andrew Weiner[2,3], Victor Torres-Company[1]; [1]*Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers Univ. of Technology, Sweden;* [2]*School of Electrical and Computer Engineering, Purdue Univ., USA;* [3]*Birck Nanotechnology Center, Purdue Univ., USA.* Using delayed self-heterodyne coherent detection, we characterized the FM noise across the C-band of a widely spaced microresonator-based frequency comb. The resulting linewidth depends on both the pump laser and the comb line position.

W2A.7
Optimal Design of Ge-dot photo-MOSFETs for Highly-integrated Monolithic Si Photonics, Ming-Hao Kuo[1], Meng Chun Lee[2], Che-Wei Tien[2], Wei-Ting Lai[2], Pei-Wen Li[2]; [1]*National Central Univ., Taiwan;* [2]*National Chiao Tung Univ., Taiwan.* Ge-dot/SiO_2/SiGe-channel photoMOSFETs are demonstrated on Si substrate. A decrease in the dot size and gate oxide thickness significantly enhances the photoresponsivity (9000A/W) with 6nW under 850nm illumination, and improves response time (0.48ns) and power consumption.

W2A.8
Evanescent Field-assisted Mode-locked Laser Based On Short Single-wall Carbon Nanotubes And Photonic Crystal Fiber, Lei Gao[1], Tao Zhu[1]; [1]*Chongqing Univ., China.* We report a passively mode-locked fiber laser based on a saturable absorber via short single-wall carbon nanotubes interact with evanescent wave in cladding holes of grapefruit-type photonic crystal fiber.

W2A.9
Compact 4×5 Gb/s Silicon-on-Insulator OFDM Transmitter, Yiwei Xie[1], Leimeng Zhuang[1], Ronald Broeke[2], Qibing Wang[1], Binhuang Song[1], Zihan Geng[1], Arthur Lowery[1]; [1]*Monash Univ., Australia;* [2]*Bright Photonics B.V., Netherlands.* We characterize an integrated silicon 4×5 Gb/s OFDM transmitter PIC (2.1×4.8 mm^2) with four modulators and an optical Fourier transform. This PIC features a channel spacing of 5 GHz and an 80-GHz free spectral range.

W2A.10
C-C Bond Enriched SiC Add-drop Micro-ring Based All-Optical Logic Gate, Shih-Chang Syu[1], Yu-Chieh Chi[1], Chih-Hsien Cheng[1], Huai-Yung Wang[1], Gong-Ru Lin[1]; [1]*Graduate Inst. of Photonics and Optoelectronics, and Department of Electrical Engineering, National Taiwan Univ., Taiwan.* An all-optical AND gate made by PECVD grown C-C bond enriched SiC film based add-drop micro-ring with nonlinear refractive index up to 2.4×10^{-12} cm^2/W and 8.7-dB TE/TM polarization discriminated throughput is demonstrated.

W2A.11
Novel Broadband Gain-spectrum Measurement Technique for Raman and Parametric Amplifiers, Vladimir Gordienko[1], Marc F. Stephens[1], Atalla El-Taher[1], Nick J. Doran[1]; [1]*Aston Univ., UK.* We report a quick and accurate gain-spectrum measurement technique for broadband (>10THz) Raman and parametric optical amplifiers. Using a depolarized broadband source we predict WDM signal gain experimentally for both single and diverse polarization schemes.

W2A.12
Periodically Poled $LiNbO_3$ Ridge Waveguide with 21.9 dB Phase-Sensitive Gain by Optical Parametric Amplification, Tadashi Kishimoto[1,2], Koji Inafune[1], Yoh Ogawa[2], Norihiko Sekine[2], Hitoshi Murai[1], Hironori Sasaki[1]; [1]*Oki Electric Industry Co., Ltd., Japan;* [2]*National Inst. of Information and Communications Technology, Japan.* We develop a periodically poled $LiNbO_3$ (PPLN) ridge waveguide device and experimentally demonstrate a phase-sensitive amplification based on a cascaded SHG and OPA process. We successfully obtain the high phase-sensitive parametric gain of 21.9 dB.

W2A.13
Three-stage Quasi-phase-matched Fiber Optical Parametric Amplifier with Flat 30-dB Gain with 31-nm Bandwidth, Shigehiro Takasaka[1], Ryuichi Sugizaki[1]; [1]*Furukawa Electric Co., Ltd., Japan.* We demonstrate a PM-FOPA using three dispersion stable PM-HNLFs alternately concatenated with PM pump phase shifters for quasi-phase-matching. We achieve gain as high as 30 dB with 31 nm bandwidth.

W2A.14
Femtosecond Laser Inscribed Axial Long-period Fiber Gratings in Two-mode fiber for Efficient Optical Angular Momentum Generation, Yunhe Zhao[1,2], Yunqi Liu[1], Chengbo Mou[1], Neil Gordon[2], Kaiming Zhou[2], Lin Zhang[2], Tingyun Wang[1]; [1]*Shanghai Univ., China;* [2]*Aston Univ., UK.* We demonstrate a novel all-fiber mode converter based on an axial long-period fiber grating which was inscribed in two-mode fiber using a femtosecond laser. The OAM±1,1 modes can be effectively generated using this mode converter.

W2A.15
High-efficiency Light Injection and Extraction Using Fiber Bending, Takui Uematsu[1], Takanori Kiyokura[1], Hidenobu Hirota[1], Tomohiro Kawano[1], Tetsuya Manabe[1]; [1]*NTT Corporation, Japan.* We achieve a temporary optical coupler that injects/extracts light into/from a fiber with high efficiency by using fiber bending. We demonstrate experimentally that extraction efficiency is improved by using a double-clad fiber.

W2A.16
Simple Geometric Approach for Optimization of Phase-sensitive Fibre Optic Parametric Amplifiers, Alexey Redyuk[1,2], Anastasia Bednyakova[1,2], Sergey Medvedev[2], Mikhail Fedoruk[1,2], Sergei K. Turitsyn[1,3]; [1]*Novosibirsk State Univ., Russia;* [2]*Inst. of Computational Technologies SB RAS, Russia;* [3]*Aston Inst. of Photonic Technologies, UK.* We demonstrate application of a simple design method - geometric approach for optimisation of the performance of phase-sensitive fiber optical parametric amplifier.

W2A • Poster Session I—Continued

W2A.17
Broadband Mode Multiplexer/Demultiplexer Based on Tapered Multi-Core Fiber, Shanyong Cai[1], Song Yu[1], Mingying Lan[2], Li Gao[2], Wanyi Gu[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China;* [2]*School of Digital Media and Design Arts, Beijing Univ. of Posts and Telecommunications, China.* A broadband mode multiplexer/demultiplexer based on two mutually spliced tapered multi-core fiber is proposed in this paper. The bandwidth is larger than 800nm for mode coupling from LP_{01} mode to LP_{11} mode and is equivalent to 400nm for mode coupling from LP_{01} mode to LP_{21} mode.

W2A.18
Black Phosphorus-coated Tilted Fiber Bragg Grating for Ultrasensitive Ion Sensing, Chen Liu[1], Zhengbo Sun[2], Liang Zhang[2], Jiancheng Lv[2], Xue-Feng Yu[2], Xianfeng Chen[1]; [1]*Bangor Univ., UK;* [2]*Shenzhen Inst.s of Advanced Technology, Chinese Academy of Sciences, China.* We propose an ultrasensitive ion sensor based on black phosphorus coated 81°-tilted fiber grating for Pb^{2+} ion detection, demonstrating significant performance of ultrahigh sensitivity (8.6×10^{-5}dB/ppb), lower detection limit (0.4ppb) and wider concentration range (0.1ppb ~1.5×10^{7}ppb).

W2A.19
Wideband Fully-Distributed Vibration Sensing by using UWFBG Based Coherent OTDR, Fan Ai[1,2], Qizhen Sun[1,2], Wei Zhang[1,2], Tao Liu[1,2], Zhijun Yan[1,2], Deming Liu[1,2]; [1]*Huazhong Univ of Science and Technology, China;* [2]*National Engineering Laboratory for Next Generation Internet Access System, China.* A scheme combining coherent OTDR with UWFBG to realize wideband and high sensitive distributed vibration sensing is proposed. Frequency response from 2Hz to 5kHz and 4-m spatial resolution are experimentally demonstrated along 1.3km fiber.

W2A.20
Design of Elliptical-core Few-mode Fibers for Optical Parametric Amplification, Cheng Guo[1], Zhenzhen Zhang[1], Ningbo Zhao[1], Lin Zhang[1], Xiaoying Li[1], Guifang Li[2]; [1]*The College of Precision Instruments and Optoelectronic Engineering, Tianjin Univ., China;* [2]*The College of Optics & Photonics, Univ. of Central Florida, USA.* We present a dispersion-optimized elliptical-core few-mode fiber for broadband parametric amplification in the C-band. The asymmetric structure is beneficial to eliminate crosstalk in transmission system and degradation to parametric gain.

W2A.21
Demonstration of Orbital Angular Momentum (OAM) Fiber Amplifier in Data-Carrying OAM-Division Multiplexing and Wavelength-Division Multiplexing (WDM) System, Jun Liu[1], Hongya Wang[1], Shi Chen[1], Shuang Zheng[1], Long Zhu[1], Andong Wang[1], Nan Zhou[1], Shuhui Li[1], Li Shen[1], Cheng Du[2], Qi Mo[1,2], Jian Wang[1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Fiberhome Telecommunication Technologies Co. Ltd, China.* We demonstrate an orbital angular momentum (OAM) fiber amplifier and evaluate its performance in an OAM and wavelength multiplexing system. The small signal gain is up to 19 dB from 1530 nm to 1565 nm. The OSNR penalties at a BER of 2e-3 are less than 1.8 dB for all channels.

W2A.22
Broadband Optical Amplifier for a Wavelength Region of 1515 – 1775 nm, Sergei V. Firstov[1], Konstantin Riumkin[1], Sergey Alyshev[1], Mikhail Melkumov[1], Evgeny M. Dianov[1]; [1]*Fiber Optics Research Center RAS, Russia.* We report the first demonstration of optical amplifier based on bismuth- and erbium-codoped germanosilicate fibers. The 15-dB small-signal gain window covers a 260-nm band by using a single-wavelength pumping at 1460 nm.

W2A.23
Novel Ultra Low Loss & Large Effective Area G.654.E Fibre in Terrestrial Application, Zhang Lei[2,1], Jihong Zhu[2,1], Jing Li[2,1], Honghai Wang[2,1], Ruichun Wang[2,1], Raadj Matai[2,1], Jie Luo[2,1]; [1]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, China;* [2]*Key Laboratory of Optical Fiber and Cable Manufacture Technology, China.* The paper introduced latest ITU-T G.654.E sepecification and typical G.654.E profile design. Our ULL-G.654.E fiber's performances in the 1st G.654.E terrestrial cable and longest long haul link in China were also review and discussed.

W2A.24
168 Gb/s Line Rate Real-Time PAM Receiver Enabled by Timing Recovery with 8/7 Oversampling in a Single FPGA, Arne Josten[1], Benedikt Baeuerle[1], Marco Eppenberger[1], Edwin Dornbierer[1], David Hillerkuss[1], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland.* Demonstration of a real-time receiver working with 28GBd at 32GSa/s. The signal processing is done on a single FPGA. The resource-saving non-integer oversampling of 8/7 is enabled by a timing synchronization in the frequency domain.

W2A.25
Enabling 64Gbaud Coherent Optical Transceivers, Danish Rafique[1], Helmut Griesser[1], Joerg-Peter Elbers[1]; [1]*ADVA Optical Networking, Germany.* We establish bandwidth requirements for 64Gbaud coherent transceivers, and show comparisons with commercial device models. Compared to theory, our results suggest OSNR penalties as low as 2.2dB for DP-64QAM and DP-16QAM, and 1.1dB for DP-4QAM.

W2A.26
Extra Penalty When Fitting the Filtering Bandwidth of Successive Traversed WSS's to a Lower Channel Symbol Rate, Thierry Zami[1], Bruno Lavigne[1], Benoit Faure[1]; [1]*Nokia Corporation, France.* We investigate with a real time Baud rate agile transponder, the OSNR penalty on a signal traversing several WSS's the filtering bandwidths of which are set proportionally to the symbol rate for optimal spectral utilization.

W2A.27
Full C-band Tunable MEMS-VCSEL for Next Generation G.metro Mobile Front- and Backhauling, Christoph Wagner[1,2], Jim Zou[2], Markus Ortsiefer[3], Christoph Greus[3], Christian Neumeyr[3], Klaus Grobe[4], Michael H. Eiselt[2], Sujoy Paul[5], Julijan Cesar[5], Franko Küppers[5], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Advanced Technology, ADVA Optical Networking SE, Germany;* [3]*Vertilas GmbH, Germany;* [4]*ADVA Optical Networking SE, Germany;* [5]*Inst. for Microwave Engineering and Photonics, Technical Univ. Darmstadt, Germany.* We report full C-band tunable, 10 Gbit/s capability, directly modulated MEMS-VCSEL for next generation converged mobile fronthaul and backhaul applications. Bit error rates below 10^{-9} were achieved over up to 40 km SSMF.

W2A.28
Design of Softwarized EPON OLT and its Transmission Jitter Suppression Techniques over MPCP, Masashi Tadokoro[1], Keita Nishimoto[1], Takeaki Mochida[1], Toshikiyo Tanaka[1], Takashi Yamada[1], Akiyuki Takeda[1], Takashi Inoue[1]; [1]*NTT, Japan.* Softwarized-OLT is expect to realize flexible and cost-effective PON systems but the large transmission jitter of gate messages caused by computing process is critical for MPCP. Thus, we propose and evaluate jitter suppression DBA techniques.

W2A.29
First Demonstration of Distributed Time Synchronization System over Transport Network towards 5G Requirements, Liuyan Han[1], Xintian Hu[1], Han Li[1], Lei Wang[1], Nan Hua[2]; [1]*China Mobile Research Inst., China;* [2]*Electronic Engineering, Tsinghua Univ., China.* We demonstrate the distributed time synchronization system for the first time based on commercial modules. Experimental results show its convergence and high accuracy without network time error accumulation to meet the 5G requirements.

W2A.30
Experimental Assessment of Degradation-triggered Reconfiguration in Optically Interconnected Cloud-RAN, Lluis Gifre[1], Marc Ruiz[1], Alberto Castro[2], Roberto Proietti[2], S. J. Ben Yoo[2], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Department of Electrical and Computer Engineering, Univ. of California (UCDavis), USA.* C-RAN control architecture is proposed and experimentally assessed. A local controller in each location receives latency, jitter, and BER monitoring data from local BBUs and detects a CPRI degradation, which triggers a mobile network reconfiguration.

W2A.31
Demonstration of Effective OAM for Alien Wavelength and Transport Network, Francesco Paolucci[1], Nicola Sambo[1], Filippo Cugini[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* We propose and experimentally demonstrate cooperation between alien and transport network controllers. Such cooperation guarantees proper alien transmission performance as well as the correct functionalities of Operations, Administration and Maintenance (OAM) in the transport domain.

Show Floor Programming

On-board Optics — Challenges, Discoveries and the Path Forward
COBO
10:15–11:45
For more details, see page 44

Product Showcase
Huawei
10:15–10:45
For more details, see page 47

■ Network Operator Summit

Keynote
10:30–11:00
For more details, see page 43

Product Showcase
PhoeniX Software
11:00–11:30
For more details, see page 47

■ Network Operator Summit

Panel I: Next-Generation Access and Metro – Where is the Money?
11:00–12:30
For more details, see page 43

Product Showcase
Jabil AOC Technologies
11:30–12:00
For more details, see page 47

W2A • Poster Session I—Continued

W2A.32

Experimenting with Multi-controller Collaboration for Large-scale Intra-data Center Networks, Yinqiu Jia[1,2], Nan Hua[1,2], Yufang Yu[1,2], Yanhe Li[1,2], Xiaoping Zheng[1,2]; [1]*Tsinghua National Laboratory for Information Science and Technology (TNList), China;* [2]*Department of Electronic Engineering, Tsinghua Univ., China.* We propose a novel multi-controller collaboration scheme for large-scale OTSS based data center networks. A multi-controller collaboration scheme is provided to avoid collisions. We evaluate optical experiment and dynamic network emulations to verify network performance.

W2A.33

Highly Linear Analog Photonic Link Based on Composite Optical Phase-locked Loop, Xiaoyi Tian[1], Weilin Xie[1,2], Xiaocheng Wang[1], Jie Qin[1], Nan Deng[1], Yi Dong[1], Weisheng Hu[1]; [1]*State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China;* [2]*Laboratoire Aime Cotton, CNRS-Universite Paris Sud 11-ENS Cachan-Université Paris-Saclay, France.* Highly linear analog photonic link based on optical phase-locked loop techniques is proposed. A 5 km long transmission of RF signals with a shot-noise-limited spur-free dynamic range of 126.4dBHz$^{2/3}$ is demonstrated.

W2A.34

A Broadband Beam-steered Fiber Mm-Wave Link with High Energy-spectral-spatial Efficiency for 5G Coverage, Zizheng Cao[1], Xinran Zhao[1], A. Koonen[1]; [1]*Technische Universiteit Eindhoven, USA.* Utilizing an integrated optical-tunable-delay-line, reversely-modulated single sideband modulation, and Nyquist subcarrier modulation, we demonstrate an 8 Gbps mm-wave beam steered link with a spatial-spectral efficiency of 16 bits/s/Hz.

W2A.35

SINR-based Equalization for Multiband LTE-A and Gbps 4-PAM Transmission over 50m Thick-core POF and Wireless Link, Federico Forni[1,2], Yan Shi[2], Henrie v. Boom[1], Eduward Tangdiongga[1], A. Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Genexis, Netherlands.* A signal-to-interference-plus-noise-ratio-based (SINR-based) equalization scheme is proposed and tested for co-transmission of 8 bands 64-QAM LTE-A signal and a 1.8Gb/s 4-PAM signal over 50m of 1mm core diameter GI-POF and 3.5m wireless for in-home networks.

W2A.36

Optimal Synchronization Based on Anchor Phase Linear Regression for Self-interference Cancellation in Software-Defined-Radio Fiber-wireless Systems, Lin Cheng[1,2], Boris Shih[3], Anthony Ng'Oma[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Science and Technology Division, Corning Incorporated, USA;* [3]*Corning Research Center Taiwan, Corning Incorporated, Taiwan.* We propose and experimentally demonstrate a synchronization method based on the linear regression of phase response over an anchor downlink band to provide optimal suppression for self-interference cancellation in centralized software-defined-radio fiber-wireless systems.

W2A.37

A 56-Gbps PAM4 LiFi Transmission System Based on VCSEL with Two-stage Injection-locked Technique, Xin-Yao Lin[1], Zih-Yi Yang[1], Hai-Han Lu[1], Chang-Kai Lu[2], Chun-Ming Ho[1], Ming-Te Cheng[1], Sheng-Jhe Huang[1], De-Yu Chen[1]; [1]*National Taipei Univ. of Technology, Taiwan;* [2]*Jinwen Univ. of Science and Technology, Taiwan.* A 56-Gbps PAM4 LiFi transmission based on a 680-nm/5.2-GHz VCSEL with two-stage injection-locked technique is proposed and experimentally demonstrated. Good BER performance and three independent clear eye diagrams are obtained over a 20-m free-space link.

W2A.38

Improving Performance of Mobile Fronthaul by High-order Delta-sigma Modulation based on PAM-4 IM-DD Channels, Rong Hu[1], Li Haibo[1], Qi Yang[1], Ming Luo[1], Lilin Yi[2], Shaohua Yu[1]; [1]*WRI, China;* [2]*Shanghai Jiaotong Uni., China.* A transmission of 32 aggregated 4G-LTE signals is demonstrated in mobile fronthaul using high-order delta-sigma modulation and PAM-4 based IM-DD channels, achieving 68% improvement in average EVM compared to the 1st-order modulation of 1-bit resolution.

W2A.39

6.36 Gbit/s RGB LED-based WDM MIMO Visible Light Communication System Employing OFDM Modulation, I-Cheng Lu[2], Chih-Han Lai[1], Chien-Hung Yeh[3], Jyehong Chen[1]; [1]*Department of Photonics, National Chiao Tung Univ., Taiwan;* [2]*Information and Communications Research Labs, Industrial Technology Research Inst., Taiwan;* [3]*Department of Photonics, Feng Chia Univ., Taiwan.* An aggregate data rate of 6.36 Gbit/s of RGB 2×2 MIMO VLC system is demonstrated for the proof-of-concept. Moreover, the corresponding VLC rates under the free-space transmissions of 1 to 3 m are also analyzed.

W2A.40

A Novel Memoryless Power Series Based Adaptive Nonlinear Pre-distortion Scheme in High Speed Visible Light Communication, Yingjun Zhou[1], Zhang Junwen[1], Can Wang[1], Jiaqi Zhao[1], Mengjie Zhang[1], Mudong Zeng[1], Nan Chi[1]; [1]*Fudan Univ., China.* We proposed and experimentally demonstrated a novel memoryless power series based adaptive nonlinear pre-distortion scheme to mitigate nonlinear impairments for high-speed VLC system. Performance improvements with pre-distortion has been verified through 1.6Gbit/s 16QAM-OFDM VLC transmission.

W2A.41

Non-orthogonal Multiple Access Based on SCMA and OFDM/OQAM Techniques in Bidirectional RoF System, Chang Liu[1], Lei Deng[1], Jiale He[1], Di Li[1], Songnian Fu[1], Ming Tang[1], Mengfan Cheng[1], Deming Liu[1]; [1]*Huazhong Univ. of Sci. &Techn, China.* Bidirectional RoF system based on SCMA-OFDM/OQAM is proposed to increase spectral efficiency (SE) and support massive users. 1.932Gbps SCMA-OFDM/OQAM signal is transmitted over 24.5km SSMF and 0.3m air distance, resulting in 1.89 times SE increase.

W2A.42

4.05-Gb/s RGB LED-based VLC System Utilizing PS-Manchester Coded Nyquist PAM-8 Modulation and Hybrid Time-frequency Domain Equalization, Mengjie Zhang[1], Meng Shi[1], Fumin Wang[1], Jiaqi Zhao[1], Yingjun Zhou[1], Zhixin Wang[1], Nan Chi[1]; [1]*Fudan Univ., China.* A novel PS-Manchester coded Nyquist PAM-8 modulation with hybrid time-frequency domain equalization scheme is proposed and experimentally demonstrated in a RGB LED-based VLC system. An aggregate data rate of 4.05-Gb/s is successfully achieved.

W2A.43

Reconfigurable Radio-over-multicore Optical Fronthaul for Seamless 2G, UMTS and LTE-A MIMO Wireless Provision, Maria Morant[1], Roberto Llorente[1]; [1]*Nanophotonics Technology Center, Universitat Politecnica de Valencia, Spain.* A flexible and reconfigurable radio-over-multicore fiber fronthaul capable of providing simultaneous 2G, 3G and 4G cellular wireless services in the same frequency band with the advantage of antenna equipment reusability is proposed and evaluated experimentally.

W2A.44

Faster-than-Nyquist Signal Generation of Single Carrier 483-Gb/s (120.75-GBaud) PDM-QPSK with 92-GSa/s DAC, Yanzhao Lu[1], Yi Yu[1], Ling Liu[1], Yuanda Huang[1], Xie Wang[1], Liangchuan Li[1]; [1]*Huawei Technologies Co. Ltd., China.* We propose a method of combining multi-tap pre-coding and faster-than-Nyquist filter for generating sub-symbol-rate sampling signal. Single carrier of 483-Gb/s (120.75-GBaud) PDM-QPSK modulation is demonstrated by using 92-GSa/s DAC with sampling rate of 0.76-sample/symbol.

W2A.45

Modified Constant Modulus Algorithm Based on Minimization of Mutual Information for Mode-division Multiplexed Transmission, Xiang Li[1], Ming Luo[1], Rong Hu[1], Cai Li[1], Ying Qiu[1], Qi Yang[1]; [1]*Wuhan Research Inst. of Posts and Telecommunications, China.* We propose a modified CMA based on minimization of mutual information for mode-division multiplexing. In comparison with conventional CMA, the modified algorithm can improve the convergence speed by more than 50% after few-mode fiber transmission.

W2A.46

Kalman-MLSE Equalization of Nonlinear Noise, Ori Golani[1], Meir Feder[1], Mark Shtaif[1]; [1]*Tel Aviv Univ., Israel.* We investigate the potential of adaptive equalization techniques to mitigate intra-channel nonlinear interference noise (NLIN). We develop an equalizer tailored for NLIN reduction, based on Kalman filtering and maximum likelihood sequence estimation (MLSE).

W2A.47

Correlation-Based Polarization Demultiplexing for Clock Recovery in Coherent Optical Receivers, Valery N. Rozental[1], Bill Corcoran[1], Arthur Lowery[1]; [1]*Dept. of Electrical & Computer Systems Engineering, Monash Univ., Australia.* We propose and experimentally validate a novel method for polarization demultiplexing, based on intensity sample cross-correlation of polarization-multiplexed signals. The method allows to avoid PMD-induced failure conditions in digital clock recovery with limited computational complexity.

W2A.48

Experimental Analysis of Pilot-based Equalization for Probabilistically Shaped WDM Systems with 256QAM/1024QAM, Metodi P. Yankov[1], Edson P. da Silva[1], Francesco Da Ros[1], Darko Zibar[1]; [1]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark.* Pilot based equalization is studied in a 5x10 GBaud WDM transmission experiment. The equalization is independent of the modulation format and is demonstrated for 256/1024QAM with uniform and probabilistically optimized distribution using an optimized pilot insertion rate of 2-5%.

W2A.49

Symbol Flipping Decoding Algorithm Based on Prediction for Non-binary LDPC Codes, Shuai Wang[1], Zulin Wang[1,3], Lei Jing[2], Qin Huang[1]; [1]*Beihang Univ., China;* [2]*Huawei Technology Co., Ltd., China;* [3]*Collaborative Innovation Center of Geospatial Technology, China.* This paper proposes a symbol flipping decoding algorithm based on prediction for non-binary LDPC codes, considering not only soft reliability, but also hard reliability. It provides 2.6 dB improvement compared with the weighted Algorithm B.

W2A • Poster Session I—Continued

W2A.50
Performance Evaluation of Clock Recovery for Coherent Mode Division Multiplexed Systems, Júlio C. Diniz[1], Molly Piels[1], Darko Zibar[1]; [1]*DTU Fotonik, Denmark.* The impact of mode mixing and group delay spread on clock tone quality of a 6-mode 32 GBd NRZ-QPSK MDM system is investigated. Even for low group delay spread, strong coupling causes clock tone disappearance.

W2A.51
Experimental Estimation of Optical Nonlinear Memory Channel Conditional Distribution using Deep Neural Networks, Rafael Rios-Müller[1], José Manuel Estaran[1], Jeremie Renaudier[1]; [1]*Nokia Bell Labs, France.* We demonstrate that neural networks can approximate the conditional distribution of non-linear channels with memory. This distribution then feeds the BCJR algorithm to detect transmitted data in experimental IM/DD 3.2-km transmission of 64 GBd PAM4.

W2A.52
112-Gb/s C-band Transmission using 4-Level/7-Level Coding PAM with Chromatic-Dispersion Pre-compensation under 25-GHz Bandwidth-Limitation, Akira Masuda[1], Shuto Yamamoto[1], Yoshiaki Sone[1], Shingo Kawai[1], Mitsunori Fukutoku[1]; [1]*NTT Network Innovation Laboratories, Japan.* We experimentally demonstrate 112-Gb/s 4-level/7-level coding PAM C-band transmission using pre-compensation under 25-GHz bandwidth limitation in a conventional direct-detection system. We confirm the scheme has higher residual -CD tolerance and requires fewer receiver-side FFE taps.

W2A.53
High Performance and Low Complexity Carrier Phase Recovery Schemes for 64-QAM Coherent Optical Systems, Jaime Rodrigo Navarro[4,1], Aditya Kakkar[1], Richard Schatz[1], Xiaodan Pang[4], Oskars Ozolins[4], Fredrik Nordwall[2], Hadrien Louchet[3], Sergei Popov[1], Gunnar Jacobsen[4]; [1]*Optics and Photonics Division, KTH Royal Inst. of Technology, Sweden;* [2]*Tektronix AB, Sweden;* [3]*VPIphotonics GmbH, Sweden;* [4]*Network and Transmission Laboratory, Acreo Swedish ICT, Sweden.* We experimentally validate two novel CPR schemes outperforming existing CPRs in complexity and performance. A complexity reduction of at least a factor of 4 is reported compared to the BPS algorithm for a 64QAM system.

W2A.54
Low Complexity Timing Recovery Algorithm for PAM-8 in High Speed Direct Detection Short Range Links, Aditya Kakkar[1,2], Jaime Rodrigo Navarro[2,1], Xiaodan Pang[2], Oskars Ozolins[2], Richard Schatz[1], Urban Westergren[1], Gunnar Jacobsen[2], Sergei Popov[1]; [1]*Optics and Photonics Division, Royal Inst. of Technology (KTH), Sweden;* [2]*Network and Transmission Laboratory, Acreo Swedish ICT, Sweden.* We propose a low complexity timing algorithm for high order PAM. Experimental results demonstrate higher performance and lower complexity than conventional algorithms in a 32 Gbaud PAM-8 transmission over 4 km SMF links.

W2A.55
Calibration of In-Phase/Quadrature Amplitude and Phase Response Imbalance for Coherent Receiver, Cheng Ju[1], Zhenning Tao[1], Yangyang Fan[1], Ying Zhao[1], Hao Chen[1], Xiaofei Su[1], Takeshi Hoshida[2]; [1]*Fujitsu Research and Development Center, China;* [2]*Fujitsu Laboratories Ltd., Japan.* We propose an In-phase/Quadrature imbalance calibration method which only uses the transceiver itself for coherent receiver. Experiment shows that IQ skew calibration accuracy reaches 0.2 ps and the method is robust to many practical imperfections.

W2A.56
Fully-Parallel Soft-decision Cycle Slip Recovery, Toshiaki Koike-Akino[1], Tsuyoshi Yoshida[2], Kieran Parsons[1], David Millar[1], Keisuke Kojima[1], Milutin Pajovic[1]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*MELCO, Japan.* We propose a parallel cycle slip recovery method employing soft-decision slip-state estimation at pilots. Through mutual information analysis, we show that the proposed method achieves 0.6dB gain in the presence of frequent cycle slips and strong phase noise.

W2A.57
Maximization of the Achievable Mutual Information using Probabilistically Shaped Squared-QAM Constellations, Dario Pilori[1], Fabrizio Forghieri[2], Gabriella Bosco[1]; [1]*Politecnico di Torino, DET, Italy;* [2]*Cisco Photonics Italy srl, Italy.* Probabilistically-shaped QAM constellations are compared to uniformly distributed ones in terms of maximum values of achievable mutual information, showing that the potential gain depends on both target transmission rate and reference constellation cardinality.

W2A.58
Joint Estimation of Time-frequency Impairments for Single Carrier Coherent Transmission System with FrFT Tailored Training Symbol, Huibin Zhou[1], Ming Tang[1], Zhenhua Feng[1], Xi Chen[1], Lin Gan[1], Songnian Fu[1], Deming Liu[1]; [1]*Huazhong Univ of Science and Technology, China.* A training symbol exploiting time-frequency properties of FrFT is proposed and experimentally demonstrated to simultaneously achieve high performance frame timing synchronization, frequency offset and chromatic dispersion estimation for single carrier 28Gbaud DP-QPSK coherent transmission system.

W2A.59
Super-resolution Spectral Reconstruction for DWDM Channel Monitoring, Molly Piels[1], Darko Zibar[1]; [1]*Technical Univ. of Denmark, Denmark.* We demonstrate a super-resolution algorithm to estimate channel power and spacing. We show minimal loss in power accuracy and frequency accuracy 1000× below the spectrometer resolution.

W2A.60
Low-Complexity Embedded BICM-ID Structure for Multi-Dimensional Coded Modulation, Zhiyu Xiao[1], Mo Li[1], Fan Yu[1], Nebojsa Stojanovic[1], Changsong Xie[1], Liangchuan Li[1]; [1]*Huawei Technologies Co., Ltd., China.* A low-complexity BICM-ID structure which embeds demappers inside the iterative FEC decoder is proposed and demonstrated. 0.47-dB SNR gain over BICM can be obtained for the 8-dimentional modulation format with 8.5-million extra ASIC gates at 100-Gb/s throughput.

12:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall G-K* (concessions available)

Show Floor Programming

On-board Optics — Challenges, Discoveries and the Path Forward
COBO
10:15–11:45
For more details, see page 44

Product Showcase
Huawei
10:15–10:45
For more details, see page 47

■ Network Operator Summit

Keynote
10:30–11:00
For more details, see page 43

Product Showcase
PhoeniX Software
11:00–11:30
For more details, see page 47

■ Network Operator Summit

Panel I: Next-Generation Access and Metro – Where is the Money?
11:00–12:30
For more details, see page 43

Product Showcase
Jabil AOC Technologies
11:30–12:00
For more details, see page 47

Room 402AB

13:00–15:00
W3A • Panel: Are Electronic and Optical Components Ready to Support Higher Symbol Rates and Denser Constellations?
Moderators: Rich Baca; Microsoft, USA; Gary Nicholl; Cisco, Canada

The optical interconnect industry is embracing higher speeds and higher order modulation formats to meet the continuing growth in bandwidth demand. Does the industry have a technology roadmap consistent with these market needs? Are there bottlenecks in the electronics: drivers, TIAs, ADCs, DSPs or the optics: lasers, modulators, detectors? This panel discussion will address these questions with industry experts sharing their view of optimal solutions with constraints such as cost and power consumption, and insight into future innovations that may be needed. Come be a part of the discussion and gain an understanding of what the industry is doing and where it is headed.

Panelists:

Beck Mason, *Oclaro, USA*

Torben Nielsen, *Acadia, USA*

Vasudevan Parthasarathy, *Broadcom, USA*

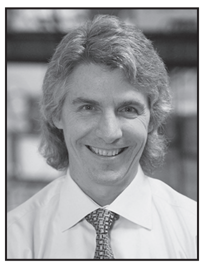
Kim Roberts, Ciena, Canada

Room 403A

13:00–15:00
W3B • Direct-Detection Transceivers
Presider: Takayuki Kobayashi; NTT Access Service Systems Laboratories, Japan

W3B.1 • 13:00 Tutorial

Optical Communications Systems for Data Center Networking, David Plant[1]; [1]*McGill Univ., Canada.* We present high-order modulation formats and digital signal processing techniques enabling intensity modulate/direct detection in short reach optical transmission systems ranging from 10 meters to 300 km. Techniques for increasing the capacity will be reviewed.



David V. Plant received the Ph.D. degree from Brown University in 1989. He was a Research Engineer at UCLA 1989 to 1993, and has been a Professor at McGill University, Montreal, QC, Canada, since 1993, where he holds a James McGill Professorship. He has received five teaching awards and other awards including the IEEE Photonics Society Distinguished Lectureship, the IEEE Microwave Theory and Techniques Society Microwave Prize, the IEEE Photonics Society Distinguished Service Award, and a Killam Research Fellowship. He is a Fellow of the Royal Society of Canada, IEEE OSA, CAE, and EIC.

Room 403B

13:00–15:00
W3C • Symposium: What is Driving 5G, and How Can Optics Help I
Presiders: Gee-Kung Chang; Georgia Institute of Technology, USA; Björn Skubic; Ericsson Research, Broadband Technol., Sweden

The vision of 5G is commonly presented as part of the network vision for 2020 and beyond, which in turn embodies a number of services for the future information society in which everything that can connect to this society will do so. The typical services identified span across areas such as enhanced mobile broadband services, media distribution, Smart Cities, and the internet of things (IoT), with massive as well as ultra-reliable and low latency (critical) machine-type communications to support both end-user and operational purposes. Besides new services and applications, 5G will also need to support a wide range of business ecosystems and cooperation models supporting digitalization of industry and trends of business horizontalization. 5G goes far beyond the definition of new radio interfaces. 5G is about a new end-to-end network vision, in which softwarization and virtualization allow a common network infrastructure to be flexibly used for a variety of diverse applications.

The symposium will consist of two sessions. The first session will focus on "What is driving 5G?" with speakers from the 5G community as well as vertical industries that can be benefited adopting the 5G vision. This session will give an overview of the services, applications and ecosystems that are driving 5G and provide some insight on how these can create a new and substantial business opportunity for optical networking and its most advanced technologies. The second session will focus on the role of optics and will include speakers from the

continued on page 112

Room 404AB

13:00–14:45
W3D • Inter/Intra Data Center Networks
Presider: Josue Kuri; Facebook, Inc., USA

W3D.1 • 13:00 Invited

Leveraging FlexGrid and Advanced Modulations in a Multi-layer Interdatacenter Network, Alexander I. Nikolaidis[1]; [1]*Facebook, USA.* The inter-DC network is unique due to a small number of locations, significant capacity, dynamic traffic and topology, and a large, shared pool of client capacity. FlexGrid increases spectrum per channel, while advanced modulations increase capacity per spectrum. The technologies combine to maximize transponder capacity and spectral efficiency.

Room 406AB

13:00–15:00
W3E • III-V / Silicon Integrated Devices
Presider: Takuo Tanemura; The Univ. of Tokyo, Japan

W3E.1 • 13:00

Heterogeneously Integrated InP/Si Metal-oxide-semiconductor Capacitor Mach-Zehnder Modulator, Tatsurou Hiraki[1,2], Takuma Aihara[1], Koichi Hasebe[1], Takuro Fujii[1,2], Koji Takeda[1,2], Tai Tsuchizawa[1,2], Takaaki Kakitsuka[1,2], Hiroshi Fukuda[1,2], Shinji Matsuo[1,2]; [1]*NTT Device Technology Labs., Japan;* [2]*NTT Nanophotonics Center, Japan.* We have developed a Mach-Zehnder modulator using a 700-μm-long heterogeneously integrated InP/Si metal-oxide-semiconductor capacitor. It exhibits $V_\pi L$ and insertion loss of 0.41 Vcm and 1.0 dB, respectively. We also demonstrate 25-Gbit/s NRZ signal modulation.

W3E.2 • 13:15

High-efficiency O-band Mach-Zehnder Modulator based on InGaAsP/Si Hybrid MOS capacitor, Jaehoon Han[1,2], Shinichi Takagi[1,2], Mitsuru Takenaka[1,2]; [1]*Department of Electrical Engineering and Information Systems, The Univ. of Tokyo, Japan;* [2]*JST-CREST, Japan.* We demonstrated O-band InGaAsP/Si hybrid MOS optical modulators using direct wafer bonding with a thin Al_2O_3 bonding interface. Owing to the large electron-induced refractive index change in InGaAsP, we successfully achieved $V_\pi L$ of 0.094 Vcm.

Room 407

13:00–14:45
W3F • Low Cost Systems for Wireless and Non-telecom Applications
Presider: Tetsuya Kawanishi; National Inst of Information & Comm Tech, Japan

W3F.1 • 13:00 Invited

Applications for Optical Components in THz Systems, Andreas Stohr[1]; [1]*Univ. Duisburg-Essen, Germany.* This discuss the generic advantages of using photonics for THz applications especially for highly spectral efficient THz communications and sensitive THz spectroscopy systems.

Room 408A

13:00–15:00
W3G • Data Center Interconnect Technologies
Presider: Bert Offrein; IBM Research GmbH, Switzerland

W3G.1 • 13:00 Invited

Datacenter Interconnect and Networking: From Evolution to Holistic Revolution, Ryohei Urata[1], Hong Liu[1], Xiang Zhou[1], Amin Vahdat[1]; [1]*Google, USA*. In this presentation, we will review the evolution of Google's intra-datacenter interconnects and networking over the past decade, then outline future technology directions which, along with a more holistic design approach, will be needed to keep pace with the requirements and growth of the datacenter.

Room 408B

13:00–14:45
W3H • Multicore and Multimode Fiber Devices
Presider: Victor Kopp; Chiral Photonics Inc, USA

W3H.1 • 13:00

Independent Core Attenuation Control in Multicore Fibers by Direct Femtosecond Laser Inscription, Martynas Beresna[1], Yongmin Jung[1], Yun Wang[1], John Hayes[1], Shaif-ul Alam[1], Gilberto Brambilla[1], David J. Richardson[1]; [1]*Univ. of Southampton, UK*. We report the fabrication of a multicore fiber attenuator in which the attenuation of each core is independently set using fs-laser inscription. An exemplar 4-core device with ~1 dB loss-variation between adjacent cores is demonstrated.

W3H.2 • 13:15

All-fiber Optical Interconnection for Dissimilar Multicore Fibers with Low Insertion Loss, Yong-min Jung[1], John Hayes[1], Yusuke Sasaki[2], Kazuhiko Aikawa[2], Shaif-ul Alam[1], David J. Richardson[1]; [1]*Optoelectronics Research Centre (ORC), UK;* [2]*Fujikura, Japan*. We present a novel approach for providing low-loss optical-interconnection between multicore-fibers having dissimilar core-pitch. Using simple image formation by a graded-index-fiber-lens a significant core-pitch difference (36mm and 29mm) is compensated with low coupling loss (~1.5dB).

Room 409AB

Room 410

13:00–15:00
W3I • Control of Multi-layer Networks
Presider: Ilya Baldin; RENCI, Univ. of North Carolina at Chapel Hill, USA

W3I.1 • 13:00

End-to-End SDN/NFV Orchestration of Video Analytics Using Edge and Cloud Computing over Programmable Optical Networks, Ricard Vilalta[1], Ion Popescu[2], Arturo Mayoral[1], Xiaoyuan Cao[2], Ramon Casellas[1], Noboru Yoshikane[2], Ricardo Martinez[1], Takehiro Tsuritani[2], Itsuro Morita[2], Raul Muñoz[1]; [1]*CTTC, Spain;* [2]*KDDI Research Inc., Japan*. This paper proposes the introduction of SDN-enabled containers to support the deployment of SDN/NFV applications located at the network edge, which are able to trigger on-demand connectivity services. A video analytics use case is demonstrated.

W3I.2 • 13:15

An Application-aware Multi-Layer Service Provisioning Algorithm based on Auxiliary Graphs, Marco Savi[1], Federico Pederzolli[1], Domenico Siracusa[1]; [1]*CREATE-NET, Italy.* A novel application-aware multi-layer resource allocation algorithm is proposed. We demonstrate that it prevents the violation of application requirements (bandwidth, latency, availability, encryption), while keeping blocking probability lower than an existing algorithm.

Room 411

13:00–14:00
W3J • Subcarrier Multiplexing and Nonlinear Tolerant Transmission
Presider: Andrea Carena; Politecnico di Torino, Italy

W3J.1 • 13:00

Demonstration of 64x0.5Gbaud Nonlinear Frequency Division Multiplexed Transmission with 32QAM, Son T. Le[1], Henning Buelow[1], Vahid Aref[1]; [1]*Nokia Bell Labs, Stuttgart, Germany.* Record data rate of 32Gb/s for NFDM transmissions is experimentally demonstrated using 64 overlapping orthogonal 0.5Gbaud channels with 32QAM format, showing a record performance gain of 1.3dB in comparison with conventional system over 1464km.

W3J.2 • 13:15

Nonlinear Inter-subcarrier Intermixing Reduction in Coherent Optical OFDM using Fast Machine Learning Equalization, Elias Giacoumidis[1], Jinlong Wei[2], Sofien Mhatli[3], Marc F. Stephens[4], Nick J. Doran[4], Andrew Ellis[4], Benjamin Eggleton[1]; [1]*CUDOS, Univ. of Sydney, Australia;* [2]*Huawei Duesseldorf GmbH, Germany;* [3]*EPT Université de Carthage, Tunisia;* [4]*AIPT, Aston Univ., UK*. We experimentally demonstrate a Newton support vector machine (N-SVM)-based nonlinear equalizer (NLE) of reduced classifier complexity for 40-Gb/s 16-QAM CO-OFDM. At 2000-km N-SVM extends the launched optical power by 2-dB compared to Volterra-based NLE.

Show Floor Programming

Product Showcase
EXFO, Canada
13:00–13:30
For more details, see page 47

Product Showcase
Xilinx, Inc.
13:30–14:30
For more details, see page 47

■ Network Operator Summit

Panel II: Optical Mobile Network Access
13:30–15:00
For more details, see page 43

Network Analytics in the Next-Generation Optical Transport
IEEE Big Data Initiative
13:45–15:15
For more details, see page 45

Product Showcase
ColorChip
14:30–15:00
For more details, see page 48

Room 402AB

W3A • Panel: Are Electronic and Optical Components Ready to Support Higher Symbol Rates and Denser Constellations?—Continued

Room 403A

W3B • Direct-Detection Transceivers—Continued

Room 403B

W3C • Symposium: What is Driving 5G, and How Can Optics Help I—Continued

optical networking/communications community. This session will give an overview of how optics can play a key role for realizing 5G networks and will cover topics such as evolved x-haul, radio over fiber, distributed cloud connect (including edge/fog computing) and support for tactile (low latency) Internet applications.

Speakers:

Chih-Lin I, *China Mobile Research Inst., China*

Theodore Sizer, *Nokia Bell Labs, USA*

Takehiro Nakamura, *NTT Docomo, Inc., Japan*

Tao Zhang, *Cisco Systems, Inc, USA*

Room 404AB

W3D • Inter/Intra Data Center Networks—Continued

W3D.2 • 13:30

Self-Adaptive, Multi-rate Optical Network for Geographically Distributed Metro Data Centers, Payman Samadi[1], Matteo Fiorani[2], Yiwen Shen[1], Lena Wosinska[2], Keren Bergman[1]; [1]*Columbia Univ. , USA;* [2]*kth, Sweden.* We propose a self-adaptive, multi-rate converged architecture and control-plane for metro-scale inter-data-center networks, enabling live autonomous bandwidth steering. Experimental and numerical evaluations demonstrate up to 5x and 25% improvements in transmission times and spectrum usage.

W3D.3 • 13:45

Evaluating the Impact of Data Center Locations and Distance-adaptive Transmission on the Wavelength Resources for Serving Cloud Traffic, Kyle Guan[1]; [1]*Nokia Bell Labs, USA.* In this work, we evaluate the impact of distance-adaptive transmission and the locations of data centers (DCs) on the required bandwidth resources for serving DC-to-user and DC-to-DC cloud traffic.

Room 406AB

W3E • III-V / Silicon Integrated Devices—Continued

W3E.3 • 13:30 Invited

Hybrid III-V/Silicon Integration: Enabling the Next Generation of Advanced Photonic Transmitters, Guilhem de Valicourt[1]; [1]*Nokia Bell Labs, France.* We review recent advances on hybrid III-V/Silicon devices using edge coupling. Design of external silicon cavities enables the realization of a broad range of on-chip functionalities as well as advanced hybrid transmitters.

Room 407

W3F • Low Cost Systems for Wireless and Non-telecom Applications—Continued

W3F.2 • 13:30

3 Gb/s OOK VLC Link Using Bandwidth-Enhanced CMOS Avalanche Photodiode, Bassem Fahs[1], Mona M. Hella[1]; [1]*ECSE - LESA, Rensselaer Polytechnic Inst., USA.* This paper presents a 3-Gb/s OOK VLC link over 1.5-m distance with BER <10−6. The setup uses a custom CMOS Avalanche photodiode with a 3×3 subsections design for bandwidth enhancement and a 680-nm laser diode.

W3F.3 • 13:45

Microwave Photonic Link Based on Coherent Detection Using Low-cost Free-Running Laser Sources Incorporating Optical Independent Sideband and Optical Orthogonal Modulation for 4×4 MIMO, Xiang Chen[1], Jianping Yao[1]; [1]*Univ. of Ottawa, Canada.* A microwave photonic link based on coherent detection using low-cost free-running laser sources incorporating optical independent sideband and optical orthogonal modulation with improved spectral efficiency for 4×4 MIMO is proposed and experimentally demonstrated.

Room 408A

W3G • Data Center Interconnect Technologies—Continued

W3G.2 • 13:30
Impact of Damping on 50 Gbps 4-PAM Modulation of 25G Class VCSELs, Tamás Lengyel[1], Emanuel P. Haglund[1], Johan Gustavsson[1], Krzysztof Szczerba[2], Anders G. Larsson[1], Magnus Karlsson[1], Peter A. Andrekson[1]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Finisar Corp., USA.* We investigate the effects of photon lifetime and damping of the modulation response on the quality of 50 Gbps 4-PAM signal generation with directly modulated 25G class VCSELs and identify the appropriate values for the K-factor.

W3G.3 • 13:45 Top Scored
Eye Skew Modeling, Measurements and Mitigation Methods for VCSEL PAM-4 Channels at Data Rates over 66 Gb/s, Jose M. Castro[1], Rick Pimpinella[1], Bulent Kose[1], Paul Huang[1], Asher Novick[1], Brett Lane[1]; [1]*Panduit Corp., USA.* Investigation of eye skew and techniques for reducing its impact on system performance at data rates from 64 Gb/s to 70 Gb/s using PAM-4 directly modulated VCSELs over 100 m MMF is presented.

Room 408B

W3H • Multicore and Multimode Fiber Devices—Continued

W3H.3 • 13:30 Invited
Application of Multicore Optical Fibers in Astronomy, Nemanja Jovanovic[1,2], Olivier Guyon[1], Hajime Kawahara[3], Takayuki Kotani[4]; [1]*Subaru Telescope, USA;* [2]*Physics and Astronomy, Macquarie Univ., Australia;* [3]*Department of Earth and Planetary Science, The Univ. of Tokyo, Japan;* [4]*National Astronomical Observatory of Japan, Japan.* Multicore fibers are desirable for astronomy as they offer superior fill factors and can transport light in many channels with the overhead of only a single fiber. We provide an overview of several astronomical applications.

Room 409AB

Room 410

W3I • Control of Multi-layer Networks—Continued

W3I.3 • 13:30 Invited
High Performance SDN Hardware Architectures and Their Uses in the Evolving Transport Network, Yatish Kumar[1]; [1]*Corsa Technologies, Canada.* L2/L3 forwarding requirements determine what Programmable (SDN) Networking means for transport networks. The end of Moore's law (16-7 nm silicon) and optical channel capacity (Shannon-Nyquist limits) pose constraints on hardware architectures. We look at how programmable L2/L3 SDN maps to technology contrained physical architectures.

Room 411

W3J • Subcarrier Multiplexing and Nonlinear Tolerant Transmission—Continued

W3J.3 • 13:30
Effectiveness of Symbol-rate Optimization with PM-16QAM Subcarriers in WDM Transmission, Fernando Guiomar[1], Andrea Carena[1], Gabriella Bosco[1], Antonello Nespola[2], Luca Bertignono[1], Pierluigi Poggiolini[1]; [1]*Politecnico di Torino, Italy;* [2]*Istituto Superiore Mario Boella, Italy.* We demonstrate up to 9% reach gain provided by symbol-rate optimization over PM-16QAM subcarriers in WDM transmission. Applying an ideal CPE, we also discuss on the potentially achievable SRO gains enabled by enhanced phase noise compensation.

W3J.4 • 13:45
Electronically Subcarrier Multiplexed PM-32QAM with Optimized FEC Overheads, Tobias A. Eriksson[1], Fred Buchali[1], Wilfried Idler[1], Laurent Schmalen[1], Gabriel CHARLET[2]; [1]*Nokia Bell Labs, Germany;* [2]*Nokia Bell Labs, France.* We experimentally investigate PM-32QAM with up to 16 subcarriers per wavelength and demonstrate that at a net bitrate of 350 Gbit/s, the distance can be increased by 300 km in WDM transmission using variable rate FEC.

Show Floor Programming

Product Showcase
Xilinx, Inc.
13:30–14:30
For more details, see page 47

■ Network Operator Summit

Panel II: Optical Mobile Network Access
13:30–15:00
For more details, see page 43

Network Analytics in the Next-Generation Optical Transport
IEEE Big Data Initiative
13:45–15:15
For more details, see page 45

Product Showcase
ColorChip
14:30–15:00
For more details, see page 48

Room 402AB

W3A • Panel: Are Electronic and Optical Components Ready to Support Higher Symbol Rates and Denser Constellations?—Continued

Room 403A

W3B • Direct-Detection Transceivers—Continued

W3B.2 • 14:00 Top Scored
504 and 462 Gb/s Direct Detect Transceiver for Single Carrier Short-reach Data Center Applications, Mathieu Chagnon[1], David Plant[1]; [1]*McGill Univ., Canada.* We demonstrate a single carrier direct detect transceiver operating at 84 Gsymbols/s providing 5.5 and 6 bits per symbol delivering 462 and 504 Gb/s employing a novel modulation format and DSP for 400+ GbE PMD.

W3B.3 • 14:15
Experimental Demonstration of Novel Simple Blind Polarization-demultiplexing Algorithm for Stokes Vector Direct Detection Receivers, Shota Ishimura[1], Kosuke Nishimura[1]; [1]*KDDI Research, Inc., Japan.* We propose a novel blind polarization-demultiplexing algorithm for SV-DD receivers which significantly reduces computational complexity. We numerically confirmed that the algorithm is robust against SOP fluctuations and experimentally demonstrated its effectiveness by 20-km transmission.

Room 403B

W3C • Symposium: What is Driving 5G, and How Can Optics Help I—Continued

Room 404AB

W3D • Inter/Intra Data Center Networks—Continued

W3D.4 • 14:00 Invited
Disaggregated Compute, Memory and Network Systems: A New Era for Optical Data Centre Architectures, Georgios S. Zervas[1], Fangsheng Jiang[2], Qianqiao Chen[1,2], Vaibhawa Mishra[1], Hui Yuan[1], Kostas Katrinis[3], Dimitris Syrivelis[4], Andrea Reale[3], Dionysios Pnevmatikatos[5], Michael Enrico[6], Nick Parsons[6]; [1]*Univ. College London, UK;* [2]*Univ. of Bristol, UK;* [3]*IBM Research, Ireland;* [4]*UTH, Greece;* [5]*FORTH, Greece;* [6]*Huber-Suhner Polatis, UK.* The disaggregated dRedBox Data Centre architecture is proposed that enables dynamic allocation of pooled compute and memory resources. An orchestration platform is described and algorithms are simulated that demonstrate the efficient utilization of IT infrastructure.

Room 406AB

W3E • III-V / Silicon Integrated Devices—Continued

W3E.4 • 14:00
Monolithic Integration of InGaAsP MZI Modulator and InGaAs Driver MOSFET using III-V CMOS Photonics, Jin-Kwon Park[1,2], Shinichi Takagi[1,2], Mitsuru Takenaka[1,2]; [1]*Univ. of Tokyo, Japan;* [2]*JST-CREST, Japan.* We monolithically integrated carrier-injection InGaAsP optical modulator and InGaAs MOSFET on III-V-on-insulator wafer. InGaAsP modulator was successfully driven directly by InGaAs driver MOSFET, exhibiting a proof-of-concept of electronic-photonic integration capability of III-V CMOS photonics platform.

W3E.5 • 14:15
Three Modes Multiplexed Photonic Integrated Circuit for Large Capacity Optical Interconnection, Guanyu Chen[1], Yu Yu[1], De Zhou[1], Wenhao Wu[1], Xi Xiao[2], Songnian Fu[1], Xinliang Zhang[1]; [1]*Wuhan National Lab for Optoelectronics, China;* [2]*State Key Laboratory of Optical Communication Technologies and Networks,, Wuhan Research Inst. of Posts Telecommunications, China.* We demonstrated a three modes multiplexed photonic integrated circuit suitable for chip-scale large capacity optical interconnection. The 30 Gb/s link including modulation, multiplexer/demultiplexer and detection is experimentally demonstrated with superior performance.

Room 407

W3F • Low Cost Systems for Wireless and Non-telecom Applications—Continued

W3F.4 • 14:00 Invited
Mm- Wave Based Bio-Sensing and Data Communications Using Low-cost CMOS Circuits, Hua Wang[1]; [1]*Georgia Tech, USA.* Abstract not available.

Room 408A

W3G • Data Center Interconnect Technologies—Continued

W3G.4 • 14:00 Invited

Scalable and Low Cost Data Center Architecture for Cloud Services, Edward Crabbe[1]; [1]*Oracle, USA*. Abstract not available.

Room 408B

W3H • Multicore and Multimode Fiber Devices—Continued

W3H.4 • 14:00

Four-fiber Fan-out for MCF with Square Lattice Structure, Kohei Kawasaki[1], Takeshi Sugimori[2], Kengo Watanabe[1], Ryuichi Sugizaki[1], Tsunetoshi Saito[1]; [1]*Furukawa Electric, Japan;* [2]*FITEC Corp., Japan*. Fiber bundle Fan-out for MCF with square lattice structure is investigated. Core position error from ideal position is simulated using Brownian movement theory. Insertion loss with MCF < 0.4 dB is achieved.

W3H.5 • 14:15

Distributed and Discriminative Brillouin Optical Fiber Sensing based on Heterogeneous Multicore Fiber, Ming Tang[1], Zhiyong Zhao[1], Songnian Fu[1], Weijun Tong[2], Deming Liu[1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*YOFC, China*. We characterized Brillouin scattering in heterogeneous multicore fiber (H-MCF), and unveil new perspective for distributed sensing using H-MCF based spatial-division multiplexing, in which discriminative measurement is achieved and bending induced uncertainty has been eliminated.

Room 409AB

Room 410

W3I • Control of Multi-layer Networks—Continued

W3I.4 • 14:00

A Framework for Dynamic Multi-layer Resource Allocation in Application-centric Networking, Ciril Rozic[2], Marco Savi[1], Chris Matrakidis[2], Dimitrios Klonidis[2], Domenico Siracusa[1], Ioannis Tomkos[2]; [1]*CREATE-NET, Italy;* [2]*Athens Information Technology, Greece*. In an SDN-based network, connection requests are accommodated so that the network application requirements are met. We devise an approach where optical network resources can be allocated and released dynamically through an SDN orchestrator.

W3I.5 • 14:15

Cost-Efficient Multi-layer Restoration to Address IP Router Outages in IP-over-EONs, Siqi Liu[1], Wei Lu[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China*. We study how to address the IP router outages in an IP-over-EON with multi-layer restoration (MLR), and propose an auxiliary-graph (AG) based scheme that can minimize the additional OPEX of MLR with the help of the spectrum expansion capability of sliceable bandwidth-variable transponders (SBV-Ts).

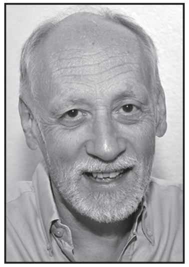
Room 411

14:00–15:00
W3K • Perspectives in Quantum Communication

Presider: Cristian Antonelli; Universita degli Studi dell'Aquila, Italy

W3K.1 • 14:00 Tutorial

Advances in Quantum Cryptography and Further Applications in Quantum Communication, Nicolas Gisin[1]; [1]*Universite de Geneve, Switzerland*. There is no secure communication without good sources of randomness. Compact, reliable and easy to use quantum random number generators exist. Quantum physics also offers cryptographic key distribution systems that fit in standard telecom boxes.



Nicolas Gisin was born in Geneva, Switzerland, in 1952. He received his Ph.D. degree in theoretical physics from the University of Geneva in 1981. After a post-doc at the University of Rochester, NY, and four years in industry, he joined the Group of Applied Physics at the University of Geneva where he has led the optics section since 1988. His activities range from the foundations of quantum physics to applications in quantum communications. He received two consecutive ERC Advanced Grants. In 2009 he was the first awardee of the John Steward Bell prize and in 2014 the Swiss Science prize delivered by the Marcel Benoist Foundation.

Show Floor Programming

Product Showcase
Xilinx, Inc.
13:30–14:30
For more details, see page 47

■ **Network Operator Summit**

Panel II: Optical Mobile Network Access
13:30–15:00
For more details, see page 43

Network Analytics in the Next-Generation Optical Transport
IEEE Big Data Initiative
13:45–15:15
For more details, see page 45

Product Showcase
ColorChip
14:30–15:00
For more details, see page 48

Room 402AB

W3A • Panel: Are Electronic and Optical Components Ready to Support Higher Symbol Rates and Denser Constellations?—Continued

Room 403A

W3B • Direct-Detection Transceivers—Continued

W3B.4 • 14:30 Top Scored
280-Gb/s 320-km Transmission of Polarization-division Multiplexed QAM-PAM with Stokes Vector Receiver, Thang M. Hoang[1], Mohammed Sowailem[1], Mohammed Osman[1], Carl Paquet[2], Stephane Paquet[2], Ian Woods[2], Qunbi Zhuge[2], David Plant[1]; [1]*McGill Univ., Canada;* [2]*Ciena, Canada.* We propose a novel three-dimensional modulation scheme on Stokes space for metro and regional optical transmissions. Based on this scheme, 320-km transmission of 280-Gb/s 16QAM-PAM2 signals using a Stokes vector receiver is experimentally demonstrated.

W3B.5 • 14:45
H-V Plane Projection Based Polarization Recovery and Probabilistic Shaping for Stokes Vector Direct Detection, An Li[1], Wei-Ren Peng[1], Clarence Kan[1], Yanjun Zhu[1], Zhihong Li[1], Samina Chowdhury[1], Yan Cui[1], Yusheng Bai[1]; [1]*Futurewei Technologies, Inc., USA.* We propose a novel polarization recovery method and probabilistically shaped 64QAM-OFDM for Stokes-vector direct detection enabling high Baud rate and cost-effective short reach application. A single-λ 176-Gb/s signal was successfully received after 20km SMF transmission.

Room 403B

W3C • Symposium: What is Driving 5G, and How Can Optics Help I—Continued

Room 404AB

W3D • Inter/Intra Data Center Networks—Continued

W3D.5 • 14:30
Network Performance Trade-off in Optical Spatial Division Multiplexing Data Centers, Li Yan[1], Matteo Fiorani[2], Ajmal Muhammad[2], Massimo Tornatore[3], Erik Agrell[1], Lena Wosinska[2]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Optical Network Lab, Royal Inst. of Technology, Sweden;* [3]*Politecnico di Milano, Italy.* We propose close-to-optimal network resource allocation algorithms modular data centers using optical spatial-division multiplexing. A trade-off between the number of established connections and throughput is identified and quantified.

Room 406AB

W3E • III-V / Silicon Integrated Devices—Continued

W3E.6 • 14:30 Invited
850 nm Hybrid Vertical Cavity Laser Integration for On-chip Silicon Photonics Light Sources, Gunther Roelkens[1], Emanuel P. Haglund[2], Sulakshna Kumasi[1], Erik Haglund[2], Johan Gustavsson[2], Roel Baets[1], Anders G. Larsson[2]; [1]*Ghent Univ. - imec, Belgium;* [2]*Chalmers Univ. of Technology, Sweden.* The realization of 850 nm hybrid III-V/dielectric VCSELs is reported in order to realize low power consumption integrated light sources for SiN waveguide circuits, which find applications both in short-reach optical communication and optical sensors.

Room 407

W3F • Low Cost Systems for Wireless and Non-telecom Applications—Continued

W3F.5 • 14:30
Low-cost Visible Light Communication System based on Off-the-shelf LED for up to 4.3 Gb/s/λ Transmission, Bernhard Schrenk[1], Markus Hofer[1], Fabian Laudenbach[1], Hannes Hübel[1], Thomas Zemen[1]; [1]*AIT Austrian Inst. of Technology, Austria.* Multi-Gb/s/λ visible light communication is demonstrated using a commodity LED rated for 150 Mb/s and OFDM/Nyquist-FDM with 256-QAM sub-carrier modulation. 1Gb/s/λ throughput and real-time video streaming is achieved over 10dB optical budget and PIN receiver.

13:30–15:00 IEEE Women in Photonics/WICE Luncheon, *515A* (separate registration required)

15:00–15:30 Coffee Break, *400 Foyer; Exhibit Hall*

17:00–19:30 Photonic Society of Chinese-Americans Workshop and Social Networking Event, *Room 518*

Room 408A

W3G • Data Center Interconnect Technologies—Continued

W3G.5 • 14:30
High Bit-Rate Distance Product of 128 Gbps•km 4-PAM Transmission over 2-km OM4 fiber Using an 850-nm VCSEL and a Volterra Nonlinear Equalizer, Jun-Jie Liu[1], Kai-Lun Chi[2], Chia-Chien Wei[3], Tien-Chien Lin[1], C. Y. Chuang[1], Xin-Nan Chen[2], Jin-Wei Shi[2], Jyehong Chen[1]; [1]*Department of Photonics, National Chiao Tung Univ., Taiwan;* [2]*Department of Electrical Engineering, National Central Univ., Taiwan;* [3]*Department of Photonics, National Sun Yat-sen Univ., Taiwan.* We successfully demonstrate a 64-Gbps 4-PAM transmission over 2-km OM4 fiber incorporating a Volterra equalizer with BER of 6.5×10^{-5}. Record high bit-rate distance product of 128 Gbps•km is confirmed for optical-interconnect applications.

W3G.6 • 14:45
Experimentally Benchmarked Fiber Propagation Model for 50Gbps PAM-4 MMF Links Employing Multimode VCSELs, Alirio Melgar[1], Varghese A. Thomas[1], Justin Lavrencik[1], Siddharth Varughese[1], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA.* MMF propagation of multi-mode VCSEL signals with preferential coupling of VCSEL modes into fiber modes and colored noise is modeled and benchmarked using 50Gbps PAM-4 and 25Gbps PAM-2 experimental results at 850nm and 940nm.

Room 408B

W3H • Multicore and Multimode Fiber Devices—Continued

W3H.6 • 14:30
Simultaneous Measurement of Temperature and Strain Based on a Polarization-Maintaining Few-Mode Fiber, Liyao Yu[1], Jian Zhao[1], Qi Mo[2], Lin Zhang[1], Guifang Li[3,1]; [1]*Key Laboratory of Opto-electronic Information Technical Science of Ministry of Education, School of Precision Instruments and Opto-electronics Engineering, Tianjin Univ., China;* [2]*Fiberhome & Fujikura Optics Co,. Ltd, China;* [3]*CREOL, The College of Optics & Photonics, Univ. of Central Florida,, USA.* An optical sensor based on a polarization-maintaining few-mode fiber (PM-FMF) for simultaneous sensing of temperature and strain is demonstrated, for the first time. The sensor has a temperature sensitivity of about 175 pm/°C and a strain sensitivity of about 5 pm/με with an accuracy of 0.1°C and 10 με.

Room 409AB

Room 410

W3I • Control of Multi-layer Networks—Continued

W3I.6 • 14:30 Invited
Packet-Optical Integration and Trend Towards White Boxes, Hans-Juergen Schmidtke[1], Ilya Lyubomirsky[1], Brian Taylor[1]; [1]*Facebook Inc., USA.* Many implementations have been developed to integrate Packet (mostly IP) networks with underlying transport networks. The paper describes the benefits of packet-optical integration and an opportunity how to use the white box approach to realize the integration. Voyager as an example is described.

Room 411

W3K • Perspectives in Quantum Communication—Continued

Show Floor Programming

■ **Network Operator Summit**

Panel II: Optical Mobile Network Access
13:30–15:00
For more details, see page 43

Network Analytics in the Next-Generation Optical Transport
IEEE Big Data Initiative
13:45–15:15
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Product Showcase
ColorChip
14:30–15:00
For more details, see page 48

13:30–15:00 IEEE Women in Photonics/WICE Luncheon, *515A* (separate registration required)

15:00–15:30 Coffee Break, *400 Foyer; Exhibit Hall*

17:00–19:30 Photonic Society of Chinese-Americans Workshop and Social Networking Event, *Room 518*

Room 402AB

15:30–17:30
W4A • Coded Modulation
Presider: Sebastian Randel; Karlsruher Institut für Technologie, Germany

W4A.1 • 15:30 Invited

Advances in Coded Modulation for Optical Communications, Gerhard Kramer[1]; [1]*Electrical and Computer Engineering, Technical Univ. of Munich, Germany.* The talk reviews a higher-order modulation method that approaches Shannon capacity extremely closely. The design, called Probabilistic Amplitude Shaping (PAS), is layered, rate adaptive, systematic, and can substantially improve communication over fiber and wireless links.

Room 403A

15:30–17:30
W4B • Microwave Photonic Subsystems
Presider: Paul Matthews; Northrop Grumman Corp, USA

W4B.1 • 15:30 Invited

Signal Processing Subsystems for RF Photonics, Keith J. Williams[1]; [1]*US Naval Research Laboratory, USA.* An overview of analog microwave photonics will be presented as it relates to RF front ends. Special emphasis will be placed on techniques to achieve discrete-device-based link performance in higher density integrated photonic circuits.

Room 403B

15:30–17:30
W4C • Symposium: What is Driving 5G, and How Can Optics Help II
Presiders: Jun Terada; NTT, Japan; Anna Tzanakaki; University of Athens, Greece

The vision of 5G is commonly presented as part of the network vision for 2020 and beyond, which in turn embodies a number of services for the future information society in which everything that can connect to this society will do so. The typical services identified span across areas such as enhanced mobile broadband services, media distribution, Smart Cities, and the internet of things (IoT), with massive as well as ultra-reliable and low latency (critical) machine-type communications to support both end-user and operational purposes. Besides new services and applications, 5G will also need to support a wide range of business ecosystems and cooperation models supporting digitalization of industry and trends of business horizontalization. 5G goes far beyond the definition of new radio interfaces. 5G is about a new end-to-end network vision, in which softwarization and virtualization allow a common network infrastructure to be flexibly used for a variety of diverse applications.

The symposium will consist of two sessions. The first session will focus on “What is driving 5G?” with speakers from the 5G community as well as vertical industries that can be benefited adopting the 5G vision. This session will give an overview of the services, applications and ecosystems that are driving 5G and provide some insight on how these can create a new and substantial business opportunity for optical networking and its most advanced technologies. The second session will focus on the role of optics and will include speakers from the optical networking/communications community. This session will give an overview of how optics can play a key role for realizing 5G networks and will

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Room 404AB

15:30–17:30
W4D • PAM-4 Inter-data Center Transmission
Presider: Marc Bohn; Coriant, Germany

W4D.1 • 15:30

TDECQ (Transmitter Dispersion Eye Closure Quaternary) Replaces Historic Eye-mask and TDP Test for 400 Gb/s PAM4 Optical Transmitters, Jonathan King[2], David Leyba[1], Greg LeCheminant[1]; [1]*Keysight Technologies, USA;* [2]*Finisar Corporation, USA.* For PAM4 transmission in 400 Gb/s Datacom networks, use of equalization and FEC, and a need to reduce cost, force a replacement of historic eye-mask and TDP tests. We describe that replacement: TDECQ.

W4D.2 • 15:45

56Gb/s Chirp-managed Symbol Transmission with Low-cost, 10-G Class LD for 400G Intra-data Center Interconnection, Jianjun Yu[2], Junwen Zhang[2,1], Hung_Chang Chien[2], Xinying Li[2,3], Yuming Xu[1,3], Gee-Kung Chang[3], Xiaolong Pan[4], Fu Wang[4], Zhipei Li[4], Bo Liu[4], Lijia Zhang[4], Xiangjun Xin[4]; [1]*Fudan Univ., China;* [2]*ZTE (TX) Inc, USA;* [3]*Georgia Inst. of Technology, USA;* [4]*Beijing Univ. of Posts and Telecommunications, China.* We have demonstrated up to 56-Gb/s cost-efficient transmission for data center interconnection over 10-km SMF-28 with negative power penalty. This 56-Gb/s transmitter comprises a low-cost 10-G-class directly-modulated distributed-feedback laser without requiring any expensive DAC, ADC and power-consumptive DSP.

Room 406AB

15:30–17:30
W4E • Photonic and Planar Switches
Presider: Benjamin Lee; IBM TJ Watson Research Center, USA

W4E.1 • 15:30 Invited

Large-scale Silicon Photonic Switches Using Electro-optic MZIs, Linjie Zhou[1], Liangjun Lu[1], Shuoyi Zhao[1], Zhanzhi Guo[1], Dong Li[1], Jianping Chen[1]; [1]*Shanghai Jiao Tong Univ., China.* We review our recent progress on silicon photonic switches based on electro-optic MZI and dual-ring assisted MZI switch elements. Phase error corrections are performed using thermal tuning to set the initial switching state.

Room 407

15:30–17:30
W4F • WDM and SDM Networking
Presider: Masahiko Jinno; Kagawa Univ., Japan

W4F.1 • 15:30 Top Scored

Actual Margins Algorithm for Multi-period Planning, Polizois Soumplis[1,4], Konstantinos Christodoulopoulos[3,4], Marco Quagliotti [2], Annachiara Pagano[2], Emmanouel Varvarigos[3,4]; [1]*Computer Engineering and Informatics Department, Univ. of Patras, Greece;* [2]*Telecom Italia, Italy;* [3]*School of Electrical and Computer Engineering, National Technical Univ. of Athens, Greece;* [4]*CTI, Greece.* We present an algorithm that provisions lightpaths considering the actual physical performance and use it in a multi-period planning scenario to postpone equipment deployment. This, yields savings compared to current provisioning practice with End-Of-Life margins.

W4F.2 • 15:45

Fast Parallel Lightpath Re-optimization for Crosstalk Reduction in Multi-core Fiber Networks, Ruijie Luo[1,2], Nan Hua[1,2], Yao Li[2,3], Xiaoping Zheng[1,2], Bingkun Zhou[1,2]; [1]*Tsinghua National Laboratory for Information Science and Technology, China;* [2]*Electronic Engineering, Tsinghua Univ., China;* [3]*College of Optical Sciences, Univ. of Arizona, USA.* We propose a novel SDN-based parallel lightpath re-optimization mechanism enabled by high-precision time synchronization for crosstalk reduction in multi-core fiber networks. Experimental and simulation results show that the proposed mechanism can significantly reduce re-optimization time.

Room 408A

15:30–17:30
W4G • Indium Phosphide Photonic Integration
Presider: Michael Larson; Lumentum, USA

W4G.1 • 15:30 Tutorial

InP Photonic Integrated Circuits, Larry A. Coldren[1]; [1]*Univ. of California Santa Barbara, USA.* InP Photonic IC (PIC) materials, integration technology and platforms will be reviewed. Motivations for integration, particulary with active elements, will be summarized. Examples of early PICs and their evolution to today's state-of-the-art will be given. Applications, primarily related to optical fiber communications, will be indicated. Some comparisons with other integration technologies, e.g., Si-photonics, will be given.

Larry A. Coldren is the Fred Kavli Professor of Optoelectronics and Sensors at the University of California, Santa Barbara, CA. He received his Ph.D. in EE from Stanford Univ. and spent 13 years in research at Bell Labs before joining UCSB in 1984, where he holds appointments in the ECE and Materials Departments. He acted as Dean of Engineering at UCSB from 2009-2011. In 1991 he co-founded Optical Concepts, acquired as Gore Photonics, to develop novel Vertical-Cavity Surface-Emitting Laser (VCSEL) modules; and later in 1998, Agility Communications, acquired by JDS-Uniphase (now Lumentum), to develop widely-tunable integrated optical transmitters. He has authored

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Room 408B

15:30–17:30
W4H • Evolution of Optical Networks
Presider: David Boertjes; Ciena Corporation, Canada

W4H.1 • 15:30

Interoperation of Layer-2/3 Modular Switches with 8QAM/16QAM Integrated Coherent Optics over 2000 km Open Line System, Mark M. Filer[1], Hacene Chaouch[3], Xiaoxia Wu[2], Jamie Gaudette[1], Jeffrey L. Cox[1]; [1]*Microsoft Corp., USA;* [2]*Juniper Networks, USA;* [3]*Arista Networks, USA.* Arista, Cisco, and Juniper's layer-2/3 modular switches with integrated coherent optics are interoperated over 2000 km at 150G 8QAM and 1000 km at 200G 16QAM on Microsoft's open line system.

W4H.2 • 15:45 Top Scored

Field Trial Transmission of 1.5 Tb/s Superchannel over 875 km, with 250 Gb/s Real-Time Transponders and EDFA Amplification, Jean-Luc Auge[1], Bruno Lavigne[2], Marek Dabrowski[3], Florian Pulka[2], Mael Le Monnier[2], Arkadiusz Klimas[2], Thierry Zami[2], Zbigniew Jakubowski[3], Slawomir Dabrowski[3], Witold Konopka[3], Ibrahim Houmed[1]; [1]*Orange Labs, USA;* [2]*Nokia, France;* [3]*Orange Polska, Poland.* This field trial transmits 1.5Tb/s superchannel with 5b/s/Hz spectral efficiency over 875km of EDFA-amplified SMF, using six 250Gb/s real time elastic transponders featuring 1dB minimum Q margin over 48 hours. Channels are 50GHz spaced.

Room 409AB

15:30–17:30
W4I • High-speed Interconnects
Presider: Chongjin Xie; Alibaba Group, USA

W4I.1 • 15:30 Invited

Optical Interconnects: Design and Analysis, Azita Emami[1]; [1]*California Inst. of Technology , USA.* This paper focuses on design challenges and solutions for realization of low-power high-speed electronics for optical interconnects. Design methodologies for high sensitivity receivers and optimized driver circuitries at the transmitter side are presented.

Room 410

15:30–17:30
W4J • SDN/NFV and Service Function Chaining
Presider: Ramon Casellas; Ctr Tecnològic de Telecom de Catalunya, Spain

W4J.1 • 15:30 Invited

SDN/NFV Futures at Verizon, Bryan C. Larish[1]; [1]*Verizon, USA.* We provide a brief overview of Verizon's initial SDN/NFV deployments and then describe future directions being evaluated and implemented to expand the SDN/NFV infrastructure's usefullness. We will discuss ideas for implementing performance-sensitive VNFs, to include optical network elements, and using SDN/NFV to improve infrastructure security.

Room 411

15:30–17:30
W4K • Panel: Quantum Communication Programs Around the World
Moderators: Andrew Lord; BT Labs, UK; Masahide Sasaki; National Inst of Information & Comm Tech, Japan

In a future where quantum computers will break much current cryptography, quantum communications offers the potential for unbreakable security, through untappable distribution of secret keys over optical fibres and free space, including satellite communications. This panel will take stock of the huge, current world-wide interest in and funding of quantum communications programs including developments in the US, China, Japan and Europe.

What will be the killer applications of quantum communications –will it be for bespoke point to point short-haul secure systems or can it form the basis of unprecedented long-lived security solutions even enabling data storage? Will it extend to core and access networks? Will quantum satellites create secure international communications or will classical, quantum-safe cryptography render quantum communications obsolete before it even starts?

Panelists:

Johannes Buchmann, *Technische Universitat Darmstadt, Germany*

Lijun Ma, *NIST, USA*

Gregoire Ribordy, *ID Quantique, Switzerland*

Qiang Zhang, *University Science and Technology, China*

Show Floor Programming

■ Market Watch
Panel IV: Pluggable Optics - How is the Ecosystem and Value Chain Changing
15:30–17:00
For more details, see page 41

How will Fog Reshape Computing and Networking
IEEE Cloud Computing
15:30–17:00
For more details, see page 45

Wednesday, 22 March

Room 402AB

W4A • Coded Modulation—Continued

W4A.2 • 16:00
A Novel Post-Probabilistically-shaped PAM Signaling as a Channel Coding for Efficient Optical Communications, Tsuyoshi Yoshida[1], Naoki Suzuki[1], Takashi Sugihara[1]; [1]*Mitsubishi Electric Corporation, Japan.* We propose a novel post-probabilistically-shaped PAM as a simple channel coding being applicable to optical communication systems with SD-FEC. It directly controls the distribution and achieves 0.52 dB required SNR reduction with 4% incremental overhead.

W4A.3 • 16:15 Top Scored
120-GBaud Coded 8 Dimensional 16QAM WDM Transmission using Low-complexity Iterative Decoding Based on Bit-wise Log Likelihood Ratio, Masanori Nakamura[1], Fukutaro Hamaoka[1], Asuka Matsushita[1], Hiroshi Yamazaki[1,2], Munehiko Nagatani[1,2], Akihide Sano[1], Akira Hirano[1], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, NTT Corp, Japan;* [2]*NTT Device Technology Labs, NTT Corp, Japan.* We propose a low-complexity decoding scheme that is 8.68e-4 times that of conventional optimal decoding for 8D-16QAM. Experiments confirm that the proposed scheme allows 9-WDM 600-Gbps/ch transmission over 3,500km without penalty.

Room 403A

W4B • Microwave Photonic Subsystems—Continued

W4B.2 • 16:00 Top Scored
100 GHz Optical-to-radio Converter Module and its Application in Radio and Power Over Fiber Transmission Through Multi-core Fiber, Toshimasa Umezawa[1], Pham T. Dat[1], Eiichi Hase[2], Kenichi Kashima[2], Atsushi Kanno[1], Kouichi Akahane[1], Atsushi Matsumoto[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[3,1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Hitachi Kokusai Electric Ltd., Japan;* [3]*Waseda Univ., Japan.* We developed a 100 GHz optical-to-radio converter module integrated with a 100 GHz amplifier, which was applied in radio (12-Gbps, OFDM, 16-QAM, IF = 92-GHz) and power over fiber transmission through a multi-core fiber.

W4B.3 • 16:15
A Silicon Integrated Microwave-photonic Transceiver, Minghua Chen[1]; [1]*Tsinghua Univ., China.* A fully integrated photonic-assisted tunable RF transceiver based on SOI technology has been proposed and experimentally demonstrated, which contains the signal processing units of the up/down-conversion, phase shifting and filtering as well as the frequency multiplier of the local oscillator.

Room 403B

W4C • Symposium: What is Driving 5G, and How Can Optics Help II—Continued

cover topics such as evolved x-haul, radio over fiber, distributed cloud connect (including edge/fog computing) and support for tactile (low latency) Internet applications.

Speakers (in speaking order)

Dimitra Simeonidou, *University of Bristol, UK*

Jim Zou, *ADVA Optical, Germany*

Anthony Ng'Oma, *Corning, Inc., USA*

Xiang Liu, *Huawei, USA*

Room 404AB

W4D • PAM-4 Inter-data Center Transmission—Continued

W4D.3 • 16:00
Real-Time 200 Gb/s (4x56.25 Gb/s) PAM-4 Transmission over 80 km SSMF using Quantum-dot Laser and Silicon Ring-modulator, Nicklas Eiselt[2,1], Helmut Griesser[2], Michael H. Eiselt[2], Wilfried Kaiser[3], Saeid Aramideh[3], Juan José Vegas Olmos[1], Idelfonso Tafur Monroy[1], Joerg-Peter Elbers[2]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Advanced Technology, ADVA Optical Networking SE, Germany;* [3]*Ranovus, Canada.* We report real-time 4x56.26-Gb/s DWDM PAM-4 transmission over 80-km SSMF with novel optical transmitter sub-assembly comprising multi-wavelength quantum-dot laser and silicon ring modulators. Pre-FEC BERs below 1E-4 are achieved after 80-km, allowing error-free operation with HD-FEC.

W4D.4 • 16:15
Demonstration and Performance Analysis of 4 Tb/s DWDM Metro-DCI System with 100G PAM4 QSFP28 Modules, Mark M. Filer[1], Steven Searcy[2], Yang Fu[3], Radhakrishnan Nagarajan[3], Sorin Tibuleac[2]; [1]*Microsoft Corp., USA;* [2]*ADVA Optical Networking, USA;* [3]*Inphi Corp, USA.* We demonstrate a 4-Tb/s metro-DCI system with commercial QSFP28 modules (40x100G dual-wavelength 56-Gb/s PAM4). We detail system performance over 80km and quantify tolerance to chromatic dispersion and nonlinearity over a wide range of fiber types.

Room 406AB

W4E • Photonic and Planar Switches—Continued

W4E.2 • 16:00
Silicon 1 × 2 Mode- and Polarization-selective Switch, Yong Zhang[1], Qingming Zhu[1], Yu He[1], Ciyuan Qiu[1], Yikai Su[1], Richard Soref[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Univ. of Massachusetts at Boston, USA.* We experimentally demonstrate an on-chip silicon 1×2 switch that routes 8 data channels on 4 modes and 2 polarizations. The insertion losses are < 8dB, and the crosstalk values are below -15dB. The 8 channels are tested with a 72-Gb/s signal.

W4E.3 • 16:15
Accelerating Switching Speed of Thermo-optic MZI Silicon-photonic Switches with "Turbo Pulse" in PWM Control, Hiroyuki Matsuura[1], Satoshi Suda[1], Ken Tanizawa[1], Keijiro Suzuki[1], Kazuhiro Ikeda[1], Hitoshi Kawashima[1], Shu Namiki[1]; [1]*AIST, Japan.* We implemented a novel heater control scheme with high-energy header pulses applied to silicon Mach-Zehnder switches. Four to five times faster switching time (5.8 μs and 4.4 μs) was achieved for heating-up and cooling-down operations.

Room 407

W4F • WDM and SDM Networking—Continued

W4F.3 • 16:00
Early Pre-FEC BER Degradation Detection to Meet Committed QoS, Alba P. Vela[1], Marc Ruiz[1], Francesco Fresi[2], Nicola Sambo[2], Filippo Cugini[3], Luis Velasco[1], Piero Castoldi[2]; [1]*Universitat Politècnca de Catalunya, Spain;* [2]*Scuola Superiore Sant'Anna, Italy;* [3]*CNIT, Italy.* Early optical layer BER degradation detection is proposed to trigger affected demands re-routing, targeting at reducing SLA violation. Results show that the proposed detection and re-routing algorithms noticeably reduce bandwidth and number of demands affected.

W4F.4 • 16:15
QoT Aware Adaptive Elastic Optical Networks, Ippokratis Sartzetakis[1,2], Kostas Christodoulopoulos[1,2], Emmanouel Varvarigos[1,2]; [1]*CTI, Greece;* [2]*School of Electrical and Computer Engineering, NTUA, Greece.* Operating Elastic Optical Networks with low margins increases their efficiency but suffers from soft-failures, rendering the QoT of lightpaths unacceptable. We present a toolkit that leverages the flexibility dimensions to survive against QoT problems.

Room 408A

W4G • Indium Phosphide Photonic Integration—Continued

or co-authored over a thousand journal and conference papers, including numerous plenary, tutorial and invited presentations. He has co-authored 8 book chapters and two textbooks. He has been issued 61 patents and is a recipient of several awards, including the John Tyndall, Aron Kressel, David Sarnoff and IPRM Awards. He is a Life Fellow of the IEEE, and a Fellow of the OSA and IEE as well as a member of the National Academy of Engineering.

Room 408B

W4H • Evolution of Optical Networks—Continued

W4H.3 • 16:00

Migrating Elastic Optical Networks from Standard Single-Mode Fibers to Ultra-low Loss Fibers: Strategies and Benefits, Yanxin Guan[1], Haomin Jiang[1], Mingyi Gao[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*IIT Guwahati, India.* We consider replacing standard single-mode fibers with ultra-low loss fibers in an elastic optical network. Replacement strategies are compared based on bandwidth blocking performance. Simulations show that the OSNR-blocking-based strategy is efficient and saturation exists between the fiber attenuation factor and blocking performance improvement.

W4H.4 • 16:15

Evolution of Core Traffic for Growing CDNs: Is the Growth Rate of Core Network Traffic Overestimated?, Pablo Pavon-Marino[1], Francisco-Javier Moreno-Muro[1], Nina Skorin-Kapov[2]; [1]*Politechnical Univ. of Cartagena, Spain;* [2]*Univ. Center of Defense, Spain.* The dramatic growth of user traffic will precipitate CDN expansion, both in capacity and new datacenter locations, the latter bringing content closer to the user. We investigate how this may partially alleviate core traffic growth

Room 409AB

W4I • High-speed Interconnects—Continued

W4I.2 • 16:00

Single Wavelength 100G Real-Time Transmission for High-Speed Data Center Communications, Andrea Chiuchiarelli[1], Rohan Gandhi[2], Sandro Rossi[1], Luís H. Carvalho[3], Francesco Caggioni[2], Júlio C. Oliveira[3], Jacklyn Reis[1]; [1]*CPqD, Brazil;* [2]*Applied Micro, USA;* [3]*BrPHOTONICS, Brazil.* The first demonstration of real-time 53.125-GBd PAM-4 optical transmission over 2-km SSMF enabled by 16-nm DSP-ASIC and small-size, high-bandwidth optoelectronics is reported. Pre-FEC BER <KP4 threshold is demonstrated for future high-speed data center connectivity.

W4I.3 • 16:15

Intra-Datacenter Links Exploiting PCI Express Generation 4 Interconnections, Alberto Gatto[1], Paola Parolari[1], Marco Brunero[1], Francesco Corapi[1], Viscardo Costa[2], Claudio Meani[2], Pierpaolo Boffi[1]; [1]*Politecnico di Milano, Italy;* [2]*ITALTEL S.p.A., Italy.* We demonstrate few-km reaches for PCIe-based optical fiber interconnections according to latency limitations, characterizing 16-Gb/s per lane Generation4 up to 10 km and confirming the Generation3 compliance of 2-km links employing suitable PCIe cards.

Room 410

W4J • SDN/NFV and Service Function Chaining—Continued

W4J.2 • 16:00 Invited

Efficient and Verifiable Service Function Chaining in NFV: Current Solutions and Emerging Challenges, Ying Zhang[2], Sujata Banerjee[1]; [2]*Hewlett Packard Labs, USA.* The ability to deploy Service Function Chains (SFC) efficiently and correctly is important in Network Functions Virtualization (NFV) infrastructures. This talk discusses the challenges and emerging solutions for scalable instantiation and verification of SFCs.

Room 411

W4K • Panel: Quantum Communication Programs Around the World—Continued

Show Floor Programming

■ **Market Watch**
Panel IV: Pluggable Optics - How is the Ecosystem and Value Chain Changing
15:30–17:00
For more details, see page 41

How will Fog Reshape Computing and Networking
IEEE Cloud Computing
15:30–17:00
For more details, see page 45

Room 402AB

W4A • Coded Modulation—Continued

W4A.4 • 16:30
Achievable Rates of Multidimensional Multisphere Distributions, Rene-Jean J. Essiambre[1], Johnny Karout[2], Erik Agrell[2], Antonia Tulino[1]; *[1]Nokia Corporation, USA; [2]Chalmers Univ. of Technology, Sweden.* The mutual information (MI) of multidimensional multisphere distributions in arbitrary dimensions in the presence of additive white Gaussian noise is derived. We show for instance that 2-D distributions have higher MI than 4-D ones in a range of signal-to-noise ratios.

W4A.5 • 16:45
Nonlinearity-tolerant Time Domain Hybrid Modulation for 4-8 bits/symbol based on 2A8PSK, Keisuke Kojima[1], Tsuyoshi Yoshida[2], Kieran Parsons[1], Toshiaki Koike-Akino[1], David Millar[1], Keisuke Matsuda[2]; *[1]Mitsubishi Electric Research Labs, USA; [2]Mitsubishi Electric Corp., Japan.* We propose time domain hybrid modulation to cover 4-8 bits/symbol range, based on 5, 6, and 7 bits/symbol 4D-2A8PSK. Simulation results indicate that they have up to 1.6 dB higher span loss budget than the hybrid modulation based on conventional modulation formats in nonlinear channels.

Room 403A

W4B • Microwave Photonic Subsystems—Continued

W4B.4 • 16:30 Invited
Semiconductor-based Terahertz Photonics for Industrial Applications, Kyung Hyun Park[1], Eui Su Lee[1], Il-MIn Lee[1], Kiwon Moon[1], Hyun-Soo Kim[1], Jeomg-Woo Park[1], Dong-Woo Park[1], Dong Hun Lee[1], Sang-Pil Han[1]; *[1]Electronics and Telecom Research Inst, Korea.* With a vision of easily-accessible terahertz industrial applications, we are in pursuit of small and cost-effective terahertz technologies. Our various approaches for the enhanced performances, including arrayed devices and nano-based devices will be presented.

Room 403B

W4C • Symposium: What is Driving 5G, and How Can Optics Help II—Continued

Room 404AB

W4D • PAM-4 Inter-data Center Transmission—Continued

W4D.5 • 16:30 Tutorial
PAM4 Signaling for Intra-data Center and Data Center to Data Center Connectivity (DCI), Sudeep Bhoja[1]; *[1]Inphi, USA.* We review challenges in digital signal processing techniques for PAM4 intra-data center and data center interconnect applications. DSP & FEC techniques for PAM4 direct-detection transceiver IC that achieves 100Gbps in 28nm CMOS process for 80km DWDM Data Center Interconnect (DCI) in a QSFP28 form factor will be discussed.

Sudeep Bhoja has served as Inphi's Chief Technology Officer, Networking Interconnect since March 2012. At Inphi, he leads the DSP system architecture team responsible for the development of Pulse Amplitude Modulation (PAM4) DSP transceiver chips. Prior to Inphi, he was Technical Director in the Infrastructure and Networking Group at Broadcom and played an instrumental role in developing 10-Gigabit Ethernet optical and copper transceivers. Prior to Broadcom, he was Chief Architect at Big Bear Networks, a maker of 10Gb/s and 40Gb/s optical transceivers and developed the industry leading 10G Electronic Dispersion Compensation (EDC) products. He also held R&D positions at Lucent Technologies and Texas Instruments. He is the named inventor of over 30 pending and approved patents. He received an M.S.E.E. from Purdue University, West Lafayette, IN, USA.

Room 406AB

W4E • Photonic and Planar Switches—Continued

W4E.4 • 16:30 Top Scored
Silicon Photonic Switch Subsystem with 900 Monolithically Integrated Calibration Photodiodes and 64-Fiber Package, Patrick Dumais[1], Dominic Goodwill[1], Mohammad Kiaei[1], Dritan Celo[1], Jia Jiang[1], Chunshu Zhang[1], Fei Zhao[2], Xin Tu[2], Chunhui Zhang[2], Shengyong Yan[2], Jifang He[2], Ming Li[2], Wanyuan Liu[2], Yuming Wei[2], Dongyu Geng[2], Hamid Mehrvar[1], Eric Bernier[1]; *[1]Huawei Technologies Canada, Canada; [2]Huawei Technologies, China.* Monolithic germanium photodiodes on every cell calibrate a 32x32 silicon photonic switch of 448 Mach-Zehnders in 10 minutes. 64 fibers permanently attached through a waveguide concentrator in a wire-bonded BGA achieve 2.9dB C-band TE fiber-to-die.

W4E.5 • 16:45
Fully Integrated Non-Duplicate Polarization-diversity 8 × 8 Si-Wire PILOSS Switch, Ken Tanizawa[1], Keijiro Suzuki[1], Kazuhiro Ikeda[1], Shu Namiki[1], Hitoshi Kawashima[1]; *[1]Natl Inst of Adv Industrial Sci & Tech, Japan.* We demonstrate a polarization-diversity 8×8 thermo-optic Si-wire switch that uses only a single PILOSS switch matrix integrated with polarization splitter-rotators. A PDL of 2 dB and DGD of 1.5 ps are achieved in C-band.

Room 407

W4F • WDM and SDM Networking—Continued

W4F.5 • 16:30 Top Scored
Multi-core Fibers in Submarine Networks for High-capacity Undersea Transmission Systems, Md. Nooruzzaman[1], Toshio Morioka[1]; *[1]Technical Univ. of Denmark, Denmark.* Application of multi-core fibers in undersea networks for high-capacity submarine transmission systems is studied. It is demonstrated how different architectures of submerged branching unit affect network component counts in long-haul undersea transmission systems.

W4F.6 • 16:45 Top Scored
Learning Process for Reducing Uncertainties on Network Parameters and Design Margins, Emmanuel Seve, Jelena Pesic[1], Camille Delezoide[1], Yvan Pointurier[1]; *[1]Nokia Bell Labs France, France.* Using monitored physical parameters in a learning process, we decrease design margins by reducing uncertainties on the input parameters of a Quality of Transmission (QoT) tool, improving the accuracy of the signal-to-noise ratio prediction.

Room 408A

W4G • Indium Phosphide Photonic Integration—Continued

W4G.2 • 16:30

Multi-channel Interference (MCI) Widely Tunable Laser Integrated with Semiconductor Optical Amplifier, Quanan Chen[1,2], Xiang Ma[1,2], Wei Sun[1,2], Ye Liu[1,2], Gonghai Liu[1,2], Gongyuan Zhao[1,2], Qiaoyin Lu[1,2], Weihua Guo[1,2]; [1]*Huazhong Univ. of science and technology, China;* [2]*Wuhan National Laboratory for Optoelectronics, China.* We demonstrate the MCI laser integrated with SOA through a two-port multi-mode interference reflector. A tuning range of more than 45 nm with SMSRs up to 47 dB is achieved.

W4G.3 • 16:45

A Chip-Scale Heterodyne Optical Phase-locked Loop with Low-power Consumption, Arda Simsek[1], Shamsul Arafin[1], Seong-Kyun Kim[1], Gordon Morrison[2], Leif Johansson[2], Milan Mashanovitch[2], Larry A. Coldren[1], Mark Rodwell[1]; [1]*UCSB, USA;* [2]*Freedom Photonics LLC, USA.* A chip-scale heterodyne optical phase-locked loop, consuming only 1.3 W of electrical power, with a maximum offset locking frequency of 17.4 GHz is demonstrated. The InP-based photonic integrated receiver circuit consumes only 166 mW.

Room 408B

W4H • Evolution of Optical Networks—Continued

W4H.5 • 16:30 Invited

MONET: An Early Demonstrator of National and Metro Reconfigurable, Wavelength Routed Optical Networks- A Historical Perspective, Rod C. Alferness[1]; [1]*Univ. of California Santa Barbara, USA.* We provide a historical perspective of Multiple Wavelength Optical Networking (MONET) including its impact on commercially deployed WDM networks and offer a perspective to the future.

Room 409AB

W4I • High-speed Interconnects—Continued

W4I.4 • 16:30

EML-based IM/DD 400G (4x112.5-Gbit/s) PAM-4 over 80 km SSMF Based on Linear Pre-Equalization and Nonlinear LUT Pre-distortion for Inter-DCI Applications, Junwen Zhang[1], Jianjun Yu[1], Hung Chang Chien[1]; [1]*ZTE Tx Inc, USA.* We experimentally demonstrated EML-based IM/DD 4x112.5-Gbit/s PAM-4 transmission over 80km SSMF for inter-DCI applications. Thanks to the transmitter-side DSP based on linear pre-equalization and nonlinear look-up-table pre-distortion, the performances are significantly improved.

W4I.5 • 16:45

100 Gbit/s Serial Transmission Using a Silicon-Organic Hybrid (SOH) Modulator and a Duobinary Driver IC, Heiner Zwickel[4], Timothy De Keulenaer[1], Stefan Wolf[4], Clemens Kieninger[4], Yasar Kutuvantavida[4], Matthias Lauermann[2], Michiel Verplaetse[1], Ramses Pierco[1], Renato Vaernewyck[1], Arno Vyncke[1], Xin Yin[1], Guy Torfs[1], Wolfgang Freude[4], Elad Mentovich[3], Johan Bauwelinck[1], Christian Koos[4]; [1]*Ghent Univ., Belgium;* [2]*Infinera Corporation, USA;* [3]*Mellanox Technologies Ltd., Israel;* [4]*Karlsruhe Inst. of Technology, Germany.* 100 Gbit/s three-level (50 Gbit/s OOK) signals are generated using a silicon-organic hybrid modulator and a BiCMOS duobinary driver IC at a BER of 8.5×10^{-5} ($<10^{-12}$). We demonstrate dispersion-compensated transmission over 5 km.

Room 410

W4J • SDN/NFV and Service Function Chaining—Continued

W4J.3 • 16:30

Service Chaining in Multi-Layer Networks using Segment Routing and Extended BGP FlowSpec, Francesco Paolucci[1], Alessio Giorgetti[1], Filippo Cugini[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* Effective service chaining enforcement along TE paths is proposed using Segment Routing and extended BGP Flowspec for micro-flows mapping. The proposed solution is experimentally evaluated with a deep packet inspection service supporting dynamic flow enforcement.

W4J.4 • 16:45

Optical Network as a Service for Service Function Chaining across Datacenters, Victor Mehmeri[1,2], Xi Wang[2], Qiong Zhang[2], Paparao Palacharla[2], Tadashi Ikeuchi[2], Idelfonso Tafur Monroy[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Fujitsu Laboratories of America, Inc., USA.* We present the SPN OS, a Network-as-a-Service orchestration platform for NFV/SDN integrated service provisioning across multiple datacenters over packet/optical networks. Our prototype showcases template-driven service function chaining and high-level network programming-based optical networking.

Room 411

W4K • Panel: Quantum Communication Programs Around the World—Continued

Show Floor Programming

■ **Market Watch Panel IV: Pluggable Optics - How is the Ecosystem and Value Chain Changing**
15:30–17:00
For more details, see page 41

How will Fog Reshape Computing and Networking
IEEE Cloud Computing
15:30–17:00
For more details, see page 45

Room 402AB

W4A • Coded Modulation—Continued

W4A.6 • 17:00
A Generalized Pairwise Optimization for Designing Multi-dimensional Modulation Formats, Shaoliang Zhang[1], Fatih Yaman[1], Eduardo Mateo[2], Takanori Inoue[2], Kohei Nakamura[2], Yoshihisa Inada[2]; [1]*NEC Laboratories America Inc, USA;* [2]*NEC Corporation, Japan.* A modified pairwise optimization algorithm has been proposed to optimize N-dimensional constellation. The resulting optimized 2- and 4-dimensional 8QAM formats outperform star-8QAM by >0.4 dB at the SNR above the FEC limit in both simulation and experiments.

W4A.7 • 17:15
Filtering Tolerant Digital Subcarrier Multiplexing System with Flexible Bit and Power Loading, Xiang Meng[2,3], Qunbi Zhuge[4,3], Xingyu Zhou[3], Meng Qiu[3], Fangyuan Zhang[3], Thang M. Hoang[3], Mohammed Sowailem[3], Ming Tang[2], Deming Liu[2], Songnian Fu[2,1], David Plant[3]; [1]*WNLO, China;* [2]*Next generation Internet Access National Engineering Lab (NGIA), Huazhong Univ. of Sci&Tech (HUST), China;* [3]*Department of Electrical and Computer Engineering, McGill Univ., Canada;* [4]*Ciena Corporation, Canada.* We propose to use adaptive bit and power loading in digital subcarrier-multiplexing (SCM) systems based on time-domain hybrid QAM to increase optical filtering tolerance. 17.5% capacity improvement is achieved in experimental demonstrations.

Room 403A

W4B • Microwave Photonic Subsystems—Continued

W4B.5 • 17:00
Fast Dynamic In-band RF Self-Interference Cancellation for Enabling Efficient Spectral Usage, Qi Zhou[1], Jia Ge[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* A photonic system capable of cancelling fast changing co-channel wideband RF self-interference is designed and demonstrated, providing a potential solution to RF spectral scarcity and full-duplex transmission in wideband emerging wireless systems.

W4B.6 • 17:15
Selective Grating Inscription in Multicore Fibers for Radiofrequency Signal Processing, Ivana Gasulla Mestre[1], David Barrera[1], Javier Hervas[1], Salvador Sales[1]; [1]*Universitat Politecnica de Valencia, Spain.* We present and experimentally demonstrate the implementation of true time delay lines for microwave photonics signal processing based on the selective inscription of Fiber Bragg gratings along the individual cores of a multicores fiber.

Room 403B

W4C • Symposium: What is Driving 5G, and How Can Optics Help II—Continued

Room 404AB

W4D • PAM-4 Inter-data Center Transmission—Continued

Room 406AB

W4E • Photonic and Planar Switches—Continued

W4E.6 • 17:00 Invited
Switching Devices and Systems Enabled by Advanced Planar Lightwave Circuits, Masanori Takahashi[1], Shintaro Yamasaki[1], Junichi Hasegawa[1]; [1]*Furukawa Electric Co., Ltd., Japan.* We review our recent achievements on the development of a multicast switch (MCS) based on a high-Δ planar lightwave circuit (PLC). We present compact and low-loss MCS which consists of ZrO_2-SiO_2 PLC.

Room 407

W4F • WDM and SDM Networking—Continued

W4F.7 • 17:00
Networking Benefit of Hybrid Fiber Amplification for Lightpath Regenerators Saving, Mattia Cantono[1], Alessio Ferrari[1], Uzma Waheed [2], Arsalan Ahmad[2], S. M. Hassan Zaidi[2], Andrea Bianco[1], Vittorio Curri[1]; [1]*Politecnico di Torino, Italy;* [2]*National Univ. of Sciences and Technology, Pakistan.* We consider the networking benefit of selectively upgrading line optical amplifiers to Hybrid Erbium/Raman solution to reduce the number of optical-electrical-optical regenerators. We consider two different network topologies and eleven different hybrid amplification solutions.

W4F.8 • 17:15
Effective Capacity Quantification of Joint-switching-enabled Flex-Grid/SDM Optical Backbone Networks, Ruben D. Rumipamba[1], Jordi Perelló[1], Joan M. Gené[1], Salvatore Spadaro[1]; [1]*UPC, Spain.* We quantify the network capacity scaling from 7 to 30 spatial channels. While multi-fiber provides a 5x capacity increase, MCF limits it to 4x and 2x in national and continental backbone networks, respectively.

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

Show Floor Programming

W4G • Indium Phosphide Photonic Integration—Continued

W4G.4 • 17:00 Invited

DAC-free Generation of M-QAM Signals with InP Segmented Mach-Zehnder Modulators, Martin Schell[1], Gerrit Fiol[1], Alessandro Aimone[1]; [1]*Fraunhofer Institut, Germany.* The concept of DAC-less generation of multi-level optical signals is discussed together with its latest InP-based results. A flexible transmitter sub-assembly enabling 32 GBd M-QAM operation up to 256-QAM is shown.

W4H • Evolution of Optical Networks—Continued

W4H.6 • 17:00 Invited

Multinational Submarine Networks, Lara D. Garrett[1]; [1]*TE SubCom, TE Connectivity, USA.* We discuss system design issues introduced by different ownership models in undersea OADM cables, including the selection of OADM node architectures and the level of OADM reconfigurability.

W4I • High-speed Interconnects—Continued

W4I.6 • 17:00

Broadband Plasmonic Modulator Enabling Single Carrier Operation Beyond 100 Gbit/s, Claudia Hoessbacher[1], Arne Josten[1], Benedikt Baeuerle[1], Yuriy Fedoryshyn[1], Horst Hettrich[2], Yannick Salamin[1], Wolfgang Heni[1], Christian Haffner[1], Rolf Schmid[2], Delwin Elder[3], David Hillerkuss[1], Michael Moeller[2], Larry Dalton[3], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland;* [2]*Micram Microelectronic GmbH, Germany;* [3]*Univ. of Washington, USA.* We demonstrate a plasmonic Mach-Zehnder modulator with a flat frequency response exceeding 170 GHz. Modulation of the device is shown at 100 GBd NRZ and 60 GBd PAM-4.

W4I.7 • 17:15 Top Scored

High Speed 160 Gb/s DMT VCSEL Transmission Using Pre-equalization, Christoph Kottke[2,1], Christoph Caspar[2], Volker Jungnickel[2], Ronald Freund[2], Mikel Agustin[3], Nikolay Ledentsov[3]; [1]*Technische Universität Berlin, Germany;* [2]*Fraunhofer Heinrich Hertz Inst., Germany;* [3]*VI Systems, Germany.* High speed single channel DMT operation of a directly modulated 850 nm VCSEL with 26 GHz bandwidth is presented. Successful transmission of 161, 152, 135 Gb/s over 10, 300, 550 m of OM4 MMF is demonstrated at the SD-FEC BER limit.

W4J • SDN/NFV and Service Function Chaining—Continued

W4J.5 • 17:00

On Efficient Incentive-Driven VNF Service Chain Provisioning with Mixed-strategy Gaming in Broker-based EO-IDCNs, Xiaoliang Chen[1], Lu Sun[2], Zuqing Zhu[2], Hongbo Lu[1], S. J. Ben Yoo[1]; [1]*Univ. of California, Davis, USA;* [2]*Univ. Scien. Techn. China, China.* We propose to realize incentive-driven virtual network function service chain provisioning in broker-based elastic optical inter-datacenter networks with mixed-strategy gaming and design a heuristic to find the near-equilibrium solutions. Simulation results verify both the effectiveness and stability of the proposed approach.

W4J.6 • 17:15

Exploiting Time-synchronized Operations in Software-defined Elastic Optical Networks, Abubakar Siddique Muqaddas[1], Miquel Garrich A.[1], Paolo Giaccone[1], Andrea Bianco[1]; [1]*Politecnico di Torino, Italy.* We propose and discuss NETCONF / OpenFlow implementations of timesynchronized operations, recently standardized in SDN, to minimize disruption time during lightpath reassignment in Elastic Optical Networks. 75% disruption time reduction is reported in our test scenario.

W4K • Panel: Quantum Communication Programs Around the World—Continued

07:30-08:00 Coffee Break, *400 Foyer*

Room 402AB

08:00–10:00
Th1A • Detectors/ Receivers
Presider: Andreas Steffan; Finisar Corporation, Germany

Th1A.1 • 08:00 Invited

Low Power Consumption and High-Speed Ge Receivers, Laurent Vivien[1], L. Virot[1], D Benedikovic[1], B Szelag[2], C Alonso-Ramos[1], JM Hartmann[2], Paul Crozat[1], E Cassan[1], Delphine Marris-Morini[1], Charles Baudot[3], Frederic Boeuf[3], JM Fedeli[2], C Kopp[2]; [1]*Universite de Paris-Sud XI, France;* [2]*Univ. Grenoble Alpes and CEA, France;* [3]*STMicroelectronics, France.* A new Si/Ge/Si heterojunction based waveguide photodetector has been demonstrated in order to reduce the fabrication cost, increase the responsivity, and improve process robustness. State of the art characteristics in terms of dark current, responsivity and bandwidth have been obtained.

Room 403A

08:00–10:00
Th1B • Silicon Photonics
Presider: Ken Morito; Fujitsu Laboratories Ltd., Japan

Th1B.1 • 08:00

Driver-integrated 56-Gb/s Segmented Electrode Silicon Mach Zehnder Modulator using Optical-domain Equalization, Benjamin G. Lee[1], Nicolas Dupuis[1], Renato Rimolo-Donadío[1], Tam Huynh[1], Christian W. Baks[1], Douglas M. Gill[1], William M. Green[1]; [1]*IBM TJ Watson Research Center, USA.* We report an IC-driven silicon photonic segmented electrode Mach Zehnder modulator exploiting optical domain feed-forward equalization resulting in 56-Gb/s NRZ operation with BER<10^{-12}. The result could enable FEC-free links for latency sensitive datacenter applications.

Th1B.2 • 08:15

56 Gb/s Single-Carrier 16-QAM and 32-QAM Subcarrier Modulation using a Silicon Micro-ring Resonator, Yuliang Gao[1], Zhao Wang[2], John C. Cartledge[1], Scott Yam[1], Andy Knights[2]; [1]*Queen's Univ. at Kingston, Canada;* [2]*McMaster Univ., Canada.* Single-carrier, single-polarization subcarrier modulation systems are demonstrated at a bit rate of 56 Gb/s using a silicon micro-ring resonator modulator. Transmission over 10 km SMF is achieved for 16-QAM and 32-QAM by compensating for nonlinear signal distortion.

Room 403B

08:30–10:00
Th1C • SDM Transmission II
Presider: Takayuki Mizuno; NTT Network Innovation Laboratories, Japan

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Room 404AB

08:00–09:45
Th1D • Advances in Coherent Subsystems
Presider: Han Henry Sun; Infinera Corporation, Canada

Th1D.1 • 08:00 Invited

Design Considerations for a Digital Subcarrier Coherent Optical Modem, David Krause[1], Ahmed Awadalla[1], Abdullah Karar[1], Han Henry Sun[1], Kuang-Tsan Wu[1]; [1]*Infinera Canada Inc, Canada.* Subcarrier modulation is shown to provide a number of system benefits including complexity savings in dispersion compensation, Kerr nonlinearity mitigation and flexibility in spectral efficiency. Design considerations are discussed.

Room 406AB

08:00–09:45
Th1E • Visible Light Communications
Presider: Christina Lim; University of Melbourne, Australia

Th1E.1 • 08:00

Phosphor-based LED Visible Light Communication System Bandwidth Enhancement Employing MC-CDMA, De-Hua Chen[2], Ya-Jou Cheng[1], You-Wei Chen[3,2], Jhih-Heng Yan[1], Kai-Ming Feng[1,2]; [1]*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan;* [2]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan;* [3]*Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan.* We experimentally apply MC-CDMA based on OFDM to a 2-meter transmission phosphor-based LED VLC system. MC-CDMA provides highly uniform per-user performances and thus enhances the available communication bandwidth.

Th1E.2 • 08:15

Experimental Demonstration of Performance-enhanced MIMO-OFDM Visible Light Communications, Yang Hong[1], Lian-Kuan Chen[1], Jian Zhao[2,3]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*Tyndall National Inst., Ireland;* [3]*Univ. College Cork, Ireland.* We experimentally demonstrate individual OCT precoding and SVD-based adaptive loading to boost the capacity of MIMO-OFDM VLC systems. For 1.5-Gbit/s 1-m transmission, the average BER can be reduced from 1.7×10^{-2} to 4.1×10^{-3} and 4.7×10^{-4}, respectively.

Room 407

08:00–09:45
Th1F • Applications of Parametric Nonlinear Processors
Presider: Robert Elschner; Fraunhofer Heinrich Hertz Inst., Germany

Th1F.1 • 08:00 Top Scored

Experimental Demonstration of Tunable Optical Channel Slicing and Stitching to Enable Dynamic Bandwidth Allocation, Yinwen Cao[1], Ahmed Almaiman[1], Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Changjing Bao[1], Peicheng Liao[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Youichi Akasaka[2], Carsten Langrock[3], Martin Fejer[3], Joseph Touch[1,4], Moshe Tur[5], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Fujitsu Laboratories of America, USA;* [3]*Stanford Univ., USA;* [4]*Information Sciences Inst., USA;* [5]*Tel Aviv Univ., Israel.* A tunable optical channel slicing and stitching scheme is experimentally demonstrated in QPSK/16QAM systems. Its application to dynamic bandwidth allocation in WDM channels brings >6dB OSNR improvement at 1e-3 BER comparing to direct channel insertion.

Th1F.2 • 08:15 Top Scored

Continuously Tunable Optical Frequency Shift of 1.6-Tb/s Superchannel up to THz-Range by Polarization Switched Frequency Conversion, Tomoyuki Kato[1], Shigeki Watanabe[1], Takahito Tanimura[1], Thomas Richter[2], Robert Elschner[2], Carsten Schmidt-Langhorst[2], Colja Schubert[2], Takeshi Hoshida[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fraunhofer Heinrich Hertz Inst., Germany.* We present a continuously tunable optical frequency shifter which allows to choose any shift-frequency including fractions of the original signal bandwidth. A 1.6-Tb/s PDM-16QAM superchannel is arbitrarily frequency-shifted within THz-range during a 200-km error-free transmission.

07:30-08:00 Coffee Break, *400 Foyer*

Show Floor Programming

Room 408A

08:00–10:00
Th1G • Gratings and Filters
Presider: Hiroyuki Tsuda; Keio Univ., Japan

Th1G.1 • 08:00
Broadband Wavelength Filter Device using a Sidewall Grating in Multimode SOI Rib Waveguide, Parimal Sah[1], Bijoy K. Das[1]; [1]*IIT Madras, India.* A filter device with a flat-top passband of $\Delta\lambda_{pb}$ > 40 nm is demonstrated using multi-mode SOI waveguide with a side-wall grating. The passband is bounded by highly extinguished sidebands of $\Delta\lambda_{sb}$ > 10 nm.

Th1G.2 • 08:15
Mode-evolution-based, Broadband 1x2 Port High-Pass/Low-pass Filter for Silicon Photonics, Emir S. Magden[1], Cristopher Poulton[1], Nanxi Li[1], Diedrik Vermeulen[1], Alfonso Ruocco[1], Neetesh Singh[1], Gerald Leake[2], Douglas Coolbaugh[2], Leslie Kolodziejski[1], Michael Watts[1]; [1]*Massachusetts Inst. of Technology, USA;* [2]*College of Nanoscale Science and Engineering, USA.* We demonstrate integrated, mode-evolution-based, 1x2 port high-pass/low-pass filters in a silicon photonics platform that can simultaneously achieve broadband operation, single cutoff wavelength, and a record high filter roll-off of 2.5 dB/nm for the first time.

Room 408B

08:00–10:00
Th1H • Advances in Multicore Fiber Technology
Presider: Kazuhide Nakajima; Nippon Telegraph & Telephone Corp, Japan

Th1H.1 • 08:00 Top Scored
Randomly-coupled Single-mode 12-core Fiber with Highest Core Density, Taiji Sakamoto[1], Shinichi Aozasa[1], Takayoshi Mori[1], Masaki Wada[1], Takashi Yamamoto[1], Saki Nozoe[1], Yuto Sagae[1], Kyozo Tsujikawa[1], Kazuhide Nakajima[1]; [1]*NTT access network service systems lab., Japan.* 125-µm cladding randomly-coupled 12-core fiber is realized with the highest core density of any single-mode multi-core fiber. A spatial mode dispersion coefficient of 8.4 ps/√km is achieved by controlling the twisting rate along the fiber.

Th1H.2 • 08:15 Top Scored
Single-Mode 37-Core Fiber with a Cladding Diameter of 248 µm, Yusuke Sasaki[1], Katsuhiro Takenaga[1], Kazuhiko Aikawa[1], Yutaka Miyamoto[2], Toshio Morioka[3]; [1]*Advanced Technology Laboratory, Fujikura Ltd., Japan;* [2]*NTT Network Innovation Laboratories, NTT Corporation, Japan;* [3]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark.* A heterogeneous single-mode 37-core fiber with a cladding diameter of 248 µm is designed and fabricated. The fiber provides the highest core count and low total-crosstalk less than -20 dB/1000 km in C+L band.

Room 409AB

08:00–10:00
Th1I • Network Architecture Evolution
Presider: Chris Bowers; Juniper, USA

Th1I.1 • 08:00 Tutorial
Beyond 100G OTN Interface Standardization, Steve Gorshe[1]; [1]*Microsemi Corporation, USA.* This tutorial covers the recently developed ITU-T next generation Optical Transport Network (OTN) standards for rates beyond 100Gbit/s, including the "FlexO" OTN PHY. The new modular approaches provide greater implementation and client signal transport flexibility.

Steven Scott Gorshe received his B.S.E.E. from the University of Idaho (1979) and M.S.E.E. (1982) and Ph.D. (2002) from Oregon State University. His work includes a variety of hardware design, system architecture, and applied research for GTE, NEC America, PMC-Sierra, and Microsemi where he is a Distinguished Engineer. He is ITU-T Q11/15 Associate Rapporteur. His standards activity there and in other bodies includes >400 contributions, and multiple technical editorships. He is an IEEE Fellow, has 38 patents granted/pending, is co-author of two books, three chapters and many papers. His IEEE ComSoc activities include <i>Communications Magazine</i> EiC and Board-of-Governors MAL.

Room 410

08:00–10:00
Th1J • Data Analytics and Machine Learning
Presider: Mazen Khaddam; Cox Communications, Inc., USA

Th1J.1 • 08:00
QoT Estimation for Unestablished Lighpaths using Machine Learning, Luca Barletta[1], Alessandro Giusti[2], Cristina Rottondi[2], Massimo Tornatore[1]; [1]*Politecnico di Milano, Italy;* [2]*Dalle Molle Inst. for Artificial Intelligence, Switzerland.* We investigate a machine-learning technique that predicts whether the bit-error-rate of unestablished lightpaths meets the required threshold based on traffic volume, desired route and modulation format. The system is trained and tested on synthetic data.

Th1J.2 • 08:15 Top Scored
Dynamic Power Pre-adjustments with Machine Learning that Mitigate EDFA Excursions during Defragmentation, Yishen Huang[1], Patricia B. Cho[1], Payman Samadi[1], Keren Bergman[1]; [1]*Columbia Univ., USA.* We examine EDFA power excursions during three defragmentation methods of flexgrid super-channels. Using a machine learning approach, we demonstrate automatic and dynamic adjustments of pre-EDFA power levels, and show the mitigation of post-EDFA power discrepancy among channels by over 62%.

Room 411

08:30–10:00
Th1K • Coherent Technologies for Access
Presider: Domanic Lavery; Univ. College London, UK

Room 402AB

Th1A • Detectors/ Receivers—Continued

Th1A.2 • 08:30
64 GBaud High-bandwidth Micro Intradyne Coherent Receiver using High-efficiency and High-speed InP-based Photodetector Integrated with 90° Hybrid, Masaru Takechi[2], Yoshihiro Tateiwa[2], Munetaka Kurokawa[2], Yasushi Fujimura[2], Hideki Yagi[2], Yoshihiro Yoneda[1]; [1]*Sumitomo Electric Device Innovations, Inc., Japan;* [2]*Transmission Devices Laboratories, Sumitomo Electric Industries, Ltd., Japan.* 64 GBaud high-bandwidth micro intradyne coherent receiver using InP-based 90° hybrid integrated with photodiodes is demonstrated. A 3 dB bandwidth of 40 GHz with differential transimpedance of 4500 ohm and high average responsivity more than 70 mA/W within the C-band are achieved.

Th1A.3 • 08:45
Schottky Diodes in 40nm Bulk CMOS for 1310nm High-speed Optical Receivers, Wouter Diels[1], Michiel Steyaert[1], Filip Tavernier[1]; [1]*Katholieke Universiteit Leuven, Belgium.* Schottky diodes in CMOS as 1310 photodetectors are proposed. N-well and p-well Schottky diodes have been fabricated and characterized in 40nm bulk CMOS. To the authors' knowledge, this is the first 1310nm CMOS photodetector reported.

Room 403A

Th1B • Silicon Photonics—Continued

Th1B.3 • 08:30 Invited
Complexity Scaling in Silicon Photonics, Amit Khanna[1], Yaojia Chen[1], Ari Novack[1], Yang Liu[1], Ran Ding[1], Tom Baehr-Jones[1], Michael Hochberg[1]; [1]*Elenion Technologies, USA.* Silicon photonics provides an excellent platform for scaling photonic system-on-chip complexity and bandwidth. We continue to see chip complexity doubling every 12-18 months.

Room 403B

Th1C • SDM Transmission II—Continued

Th1C.1 • 08:30
Transmission of 256Gb/s PM-16QAM Signal through Hybrid Cladding and Core Pumping Scheme MC-EDFA Controlled for Reduced Power Consumption, Emmanuel Le Taillandier de Gabory[1], Keiichi Matsumoto[1], Sadao Fujita[1], Shigeru Nakamura[1], Shigeyuki Yanagimachi[1], Jun'ichi Abe[1]; [1]*NEC Corporation, Japan.* We transmit 256Gb/s signal through 404km, passing 8 times a hybrid pumping scheme MC-EDFA controlled depending on monitored temperature. Received Q value variations are within ±0.15dB while power consumption is reduced by up to 38.0%.

Th1C.2 • 08:45
200 Gbit/s 16QAM WDM Transmission over a Fully Integrated Cladding Pumped 7-Core MCF System, Carlos Castro[1,2], Saurabh Jain[3], Yongmin Jung[3], Erik De Man[2], Stefano Calabrò[2], Klaus Pulverer[2], Marc Bohn[2], John Hayes[3], Shaif-ul Alam[3], David J. Richardson[3], Katsuhiro Takenaga[4], Takayuki Mizuno[5], Yutaka Miyamoto[5], Toshio Morioka[6], Werner Rosenkranz[1]; [1]*Univ. of Kiel, Germany;* [2]*Coriant R&D GmbH, Germany;* [3]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [4]*Fujikura Ltd., Japan;* [5]*NTT Network Innovation Laboratories, Japan;* [6]*Technical Univ. of Denmark, Denmark.* A complete, realistic integrated system is investigated, consisting of directly spliced 7-core MCF, cladding-pumped 7-core amplifiers, isolators, and couplers. The system is demonstrated in a 16QAM C-band WDM scenario over 720 km.

Room 404AB

Th1D • Advances in Coherent Subsystems—Continued

Th1D.2 • 08:30
Transmission Performance of Layer-2/3 Modular Switch with mQAM Coherent ASIC and CFP2-ACOs over Flex-grid OLS with 104 Channels Spaced 37.5 GHz, Mark M. Filer[1], Hacene Chaouch[2]; [1]*Microsoft Corp., USA;* [2]*Arista Networks, USA.* 150G 8QAM and 200G 16QAM signals, residing on a layer-2/3 modular switch card with integrated coherent optics, are sent over a fully-loaded, flexible-grid open line system with 104 co-propagating 37.5 GHz channels.

Th1D.3 • 08:45
Low Cost Transmitter Self-calibration of Time Delay and Frequency Response for High Baud-rate QAM Transceivers, Chris R. Fludger[1], Thomas Duthel[1], Peter Hermann[1], Theodor Kupfer[1]; [1]*Cisco Optical GmbH, Germany.* We present a low-cost transmitter based self-calibration for IQ time delay and frequency response using only low-bandwidth components. Sub-ps timing correction and frequency response correction enable transmission of 400GE, 66Gbaud DP-16QAM and 44Gbaud DP-64QAM.

Room 406AB

Th1E • Visible Light Communications—Continued

Th1E.3 • 08:30 Invited
Enabling Technologies for High Speed Visible Light Communication, Nan Chi[1], Yingjun Zhou[1], Jian-Yang Shi[1], Yiguang Wang[1], Xingxing Huang[1]; [1]*Fudan Univ., China.* We summarized the latest progress on enabling technologies for high speed VLC system beyond Gigabit/s including advanced modulation formats, software and hardware pre-equalization, advanced coding and nonlinear compensation.

Room 407

Th1F • Applications of Parametric Nonlinear Processors—Continued

Th1F.3 • 08:30
Design and Demonstration of 30-nm Tunable Guard-band-less All-optical Wavelength Converter for WDM Signals, Takashi Inoue[1], Shigehiro Takasaka[2], Kazuya Ota[3], Shu Namiki[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan;* [2]*Furukawa Electric Co., Ltd., Japan;* [3]*Trimatiz Ltd., Japan.* We design an all-optical wavelength converter enabling guard-band-less tunable operation over 30-nm bandwidth for WDM signals. Arbitrary conversion operations in 1530-1560nm range for 8-channel 32-Gbaud DP-QPSK signals with the bandwidth of 1THz are successfully demonstrated.

Th1F.4 • 08:45
C- to L- band Wavelength Conversion Enabled by Parametric Processes in a Few Mode Fiber, Francesca Parmigiani[1], Yongmin Jung[1], Peter Horak[1], Lars Grüner-Nielsen[2], Tommy Geisler[2], Periklis Petropoulos[1], David J. Richardson[1]; [1]*Univ. of Southampton, UK;* [2]*OFS, Denmark.* We propose and experimentally demonstrate the potential for all-optical wavelength conversion within and between the C- and L-bands using inter-modal four-wave-mixing processes among different phase-matched and dispersion-tailored spatial modes in a single elliptical-core few mode fiber.

Room 408A

Th1G • Gratings and Filters—Continued

Th1G.3 • 08:30 Invited

Silicon Photonic Bragg Grating Devices, Sophie LaRochelle[1], Alexandre D. Simard[1,2]; [1]*Universite Laval, Canada;* [2]*Ciena, Canada.* Integrated Bragg grating filters in silicon-on-insulator waveguides are evolving from simple broadband reflectors to filters with complex spectral responses and high-speed modulators. We review recent progress and applications of these devices.

Room 408B

Th1H • Advances in Multicore Fiber Technology—Continued

Th1H.3 • 08:30

Time-dependent Crosstalk from Multiple Cores in a Homogeneous Multi-core Fiber, Georg Rademacher[1], Benjamin J. Puttnam[1], Ruben S. Luis[1], Y. Awaji[1], Naoya Wada[1]; [1]*National Inst of Information & Comm Tech, Japan.* We investigate the time-dependence of crosstalk in homogeneous multi-core fibers originating from multiple interfering cores. We observe that increasing the number of interacting cores increases the frequency of crosstalk fluctuations by an order of magnitude.

Th1H.4 • 08:45

Bending Radius Dependence of Spatial Mode Dispersion in Randomly Coupled Multi-Core Fiber, Shinichi Aozasa[1], Taiji Sakamoto[1], Saki Nozoe[1], Yuto Sagae[1], Masaki Wada[1], Takayoshi Mori[1], Kyozo Tsujikawa[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan.* Randomly coupled multi-core fiber (MCF) with a uniform twist realized lower spatial mode dispersion (SMD) and bending-radius dependence. The SMD-macrobending relationship was examined numerically and experimentally using MCFs fabricated with a preform rotation mechanism.

Room 409AB

Th1I • Network Architecture Evolution—Continued

Room 410

Th1J • Data Analytics and Machine Learning—Continued

Th1J.3 • 08:30

Experimental Assessment of Node and Control Architectures to Support the Observe-Analyze-Act Loop, Lluis Gifre[1], Alba P. Vela[1], Marc Ruiz[1], Jorge Lopez de Vergara[2], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Department of Electronics and Communication Technologies, Universidad Autónoma de Madrid (UAM), Spain.* An architecture supporting the OAA loop is proposed. It consists on extending nodes and the domain controller with analytics capabilities for local and network-wide operation automation. The architecture is experimentally assessed through a use case.

Th1J.4 • 08:45 Top Scored

Accurate Prediction of Quality of Transmission with Dynamically Configurable Optical Impairment Model, Martin Bouda[1], Shoichiro Oda[2], Olga Vassilieva[1], Masatake Miyabe[2], Setsuo Yoshida[2], Toru Katagiri[2], Yasuhiko Aoki[3], Takeshi Hoshida[2], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America Inc, USA;* [2]*Fujitsu Laboratories Ltd., Japan;* [3]*Fujitsu Limited, Japan.* We propose a dynamically configurable optical impairment model for a physical layer abstraction enabling physical parameters learning in multi-vendor networks. We experimentally demonstrate quality of transmission prediction in mesh networks with 0.6 dB Q-factor accuracy.

Room 411

Th1K • Coherent Technologies for Access—Continued

Th1K.1 • 08:30 Top Scored

Optical Coherent Transmission of 20x192-MHz DOCSIS 3.1 Channels with 16384QAM based on Delta-Sigma Digitization, Jing Wang[1], Zhensheng Jia[2], L. Alberto Campos[2], Curtis Knittle[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Cable Television Laboratories (CableLabs), Inc., USA.* We demonstrated delta-sigma digitization and 80-km coherent transmission of 20x192-MHz DOCSIS 3.1 channels via a low-cost single-wavelength DP-16QAM system. Modulation-error-ratio higher than 48 dB was achieved supporting 16384QAM on all 20 DOCSIS channels.

Th1K.2 • 08:45

Large-Capacity Optical Access Network Utilizing Multicore Fiber and Self-Homodyne Coherent Detection, Zhenhua Feng[1], Liang Xu[1], Qiong Wu[1], Ming Tang[1], Songnian Fu[1], Weijun Tong[2], Deming Liu[1]; [1]*School of Optical and Electronic Information, Huazhong Univ of Science & Technology, China;* [2]*State Key Laboratory of Optical Fiber and Cable Manufacture Technology, angtze Optical Fiber and Cable Joint Stock Limited Company (YOFC), China.* We proposed a cost-efficient large-capacity WDM-SDM optical access network employing MCF and self-homodyne detection. 4×6×200-Gb/s PDM-16QAM-OFDM downstream transmission was realized over 37-km 7-core fiber with simplified DSP enabling use of low-cost 10MHz linewidth DFB lasers.

Show Floor Programming

Room 402AB

Th1A • Detectors/ Receivers—Continued

Th1A.4 • 09:00

$Ge_{0.9}Sn_{0.1}$ Multiple-quantum-well p-i-n Photodiodes for Optical Communications at 2 μm, Yuan Dong[1], Wei Wang[1], Shengqiang Xu[1], Dian Lei[1], Xiao Gong[1], Shuh Ying Lee[2], Wan Khai Loke[2], Soon Fatt Yoon[2], Gengchiau Liang[1], Yee Chia Yeo[1]; [1]*National Univ. of Singapore, Singapore;* [2]*Nanyang Technological Univ., Singapore.* We demonstrate a $Ge_{0.9}Sn_{0.1}$ multiple-quantum-well p-i-n photodiode on Si substrate with a cutoff wavelength beyond 2 μm. A record-low dark current density of 31 mA/cm^2 at V_{bias} = −1 V is achieved.

Th1A.5 • 09:15

High-gain Phase Modulated Analog Photonic Link Using High-power Balanced Photodiodes, Zhanyu Yang[1], Andreas Beling[1], Qianhuan Yu[1], Peng Yao[2], Xiaojun Xie[1], Christopher Schuetz[2], Joe C. Campbell[1]; [1]*Univ. of Virginia, USA;* [2]*phase sensitive innovation, USA.* A phase modulated analog photonic link with interferometric detection is experimentally demonstrated. A link gain of 15 dB at 100 mA photocurrent and 10 GHz modulation frequency is achieved.

Room 403A

Th1B • Silicon Photonics—Continued

Th1B.4 • 09:00

Integrated 5-channel WDM hybrid III-V/Si transmitter enabling 100Gb/s and beyond, Guilhem de Valicourt[2], Chia-Ming Chang[2], Sethumadhavan Chandrasekhar[2], Young-Kai Chen[2], Anaelle Maho[1], Romain Brenot[1], Po Dong[2]; [1]*III-V Lab, France;* [2]*Nokia Bell Labs, USA.* We report the demonstration of an ultra-compact 5-channel hybrid integrated III-V/Si transmitter. We successfully achieved modulation up to 40 Gbit/s/channel providing a total aggregated capacity of 200 Gbit/s and transmission over 10 km at 21.4 Gbit/s/channel for 100Gbit/s.

Th1B.5 • 09:15

69 Gb/s DMT Direct Modulation of a Heterogeneously Integrated InP-on-Si DFB Laser, Abdul Rahim[1], Amin Abbasi[1], Nuno Andre[2], Andrew Katumba[1], Hadrien Louchet[2], Kasper van Gasse[1], Roel Baets[1], Geert Morthier[1], Gunther Roelkens[1]; [1]*Ghent Univ., Belgium;* [2]*VPI Photonics, Germany.* A heterogeneously integrated InP-on-Si DFB laser, with direct modulation bandwidth of 21GHz has been used for the generation of a 69Gb/s discrete multi-tone signal. Transmission at 56Gb/s over 5 km SSMF is demonstrated as well.

Room 403B

Th1C • SDM Transmission II—Continued

Th1C.3 • 09:00 Tutorial

High-Capacity Transmission Using High-density Multicore Fiber, Toshio Morioka[1]; [1]*DTU Fotonik, Denmark.* Recent progress in large-capacity transmission technologies based on multicore fibers is reviewed with future perspectives towards well beyond Pbit/s.

Toshio Morioka joined NTT Labs., in Yokosuka, Japan in 1985 and moved to Technical University of Denmark in 2011. Since 1985, he has been engaged in pioneering research on ultrafast and large-capacity transmission technologies, demonstrating all-optical TDM demultiplexing in 1987, proposing supercontinuum WDM sources in 1993 and organizing EXAT (EXtremely Advanced optical Transmission) Initiative in 2008 to initiate SDM research in Japan. He is a fellow of OSA and IEICE (Institute of Electronics, Information and Communication Engineers of Japan). He received the MS degree from the University of Arizona, and the MS degree and PhD degree from Waseda University, Japan.

Room 404AB

Th1D • Advances in Coherent Subsystems—Continued

Th1D.4 • 09:00 Invited

Lessons Learned from CFP2-ACO System Integrations, Interoperability Testing and Deployments, Hacene Chaouch[1], Mark M. Filer[2], Andreas Bechtolsheim[1]; [1]*Arista Networks, Inc., USA;* [2]*Microsoft, USA.* We discuss the key metrics of analog coherent interfaces for today's 200G 16QAM and future 400-600G 64QAM pluggable systems. A cloud service provider perspective on next generation DCI requirements is also discussed.

Room 406AB

Th1E • Visible Light Communications—Continued

Th1E.4 • 09:00

Adaptive Physical-layer Network Coding over Visible Light Communications, Yang Hong[1], Lian-Kuan Chen[1], Xun Guan[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong.* We propose and experimentally demonstrate the adaptive physical-layer network coding to boost throughput of VLC-based two-way relay networks. Experimental results show that the network capacity can be improved by 100% with ~2.5-dB SNR penalty.

Th1E.5 • 09:15

Software Defined Adaptive MIMO Visible Light Communications after an Obstruction, Peng Deng[1], Mohsen Kaverhad[1]; [1]*The Pennsylvania State Univ., USA.* We experimentally demonstrate a software-defined 2x2 MIMO VLC system employing link adaptation of spatial multiplexing and diversity. The average error-free spectral efficiency of 12 b/s/Hz is achieved over 2 meters indoor transmission after an obstruction.

Room 407

Th1F • Applications of Parametric Nonlinear Processors—Continued

Th1F.5 • 09:00 Invited

Ultra-Broadband Optical Signal Processing using AlGaAs-OI Devices, Michael Galili[1], Francesco Da Ros[1], Hao Hu[1], Minhao Pu[1], Kresten Yvind[1], Leif K. Oxenlowe[1]; [1]*Danmarks Tekniske Universitet, Denmark.* Aluminum Gallium Arsenide on insulator (AlGaAs-OI) has recently been developed into a very attractive platform for optical signal processing. This paper reviews key results of broadband optical signal processing using this platform.

Room 408A

Th1G • Gratings and Filters—Continued

Th1G.4 • 09:00 Top Scored

Automatic Tuning and Temperature Stabilization of High-order Silicon Vernier Microring Filters, Hasitha Jayatilleka[1], Robert Boeck[1], Mohammed Altaha[1], Jonas Flueckiger[1], Nicolas Jaeger[1], Sudip Shekhar[1], Lukas Chrostowski[1]; [1]*Univ. of British Columbia, Canada.* Using in-resonator photoconductive heaters to monitor and tune the light intensity inside the resonators, a four-ring Vernier filter is automatically tuned across the entire C-band and stabilized over a 40 °C temperature range.

Th1G.5 • 09:15

Widely Tunable Guided-mode Resonance Filter Using 90° Twisted Liquid Crystal Cladding, Chun-Ta Wang[1], Hao-Hsiang Hou[1], Ping-Chien Chang[1], Keng H. Lin[1], Cheng-Chang Li[1], Hung-Chang Jau[1], Yung-Jr Hung[1], Tsung-Hsien Lin[1]; [1]*National Sun Yat Sen Univ. LCDlab, Taiwan.* This work proposes a tunable reflective guided-mode resonant (GMR) filter that incorporates a 90° twisted nematic liquid crystal (TNLC). The GMR grating acts as an optical resonator that reflects strongly at the resonance wavelength. The TNLC functions as an achromic polarization rotator that alters the polarization of incident light.

Room 408B

Th1H • Advances in Multicore Fiber Technology—Continued

Th1H.5 • 09:00

Fabrication of Multi Core Fiber by Using Slurry Casting Method, Jun Yamamoto[1], Tamotsu Yajima[1], Yusuke Kinoshita[1], Futoshi Ishii[1], Masato Yoshida[2], Toshihiko Hirooka[2], Masataka Nakazawa[2]; [1]*Kohoku Kogyo Co. Ltd., Japan;* [2]*Tohoku Univ., Japan.* We fabricated a 7-core fiber using a slurry casting method with highly pure SiO_2 powder as a starting material. The minimum loss was 0.25 dB/km and the crosstalk was -33.4 dB/100 km.

Th1H.6 • 09:15

Low Crosstalk 125 µm-Cladding Multi-Core Fiber with Limited Air-Holes Fabricated by Over-Cladding Bundled Rods Technique, Saki Nozoe[1], Ryohei Fukumoto[2], Taiji Sakamoto[1], Takashi Matsui[1], Yoshimichi Amma[2], Katsuhiro Takenaga[2], Kyozo Tsujikawa[1], Shinichi Aozasa[1], Kazuhiko Aikawa[2], Kazuhide Nakajima[1]; [1]*NTT Corporation, Japan;* [2]*Fujikura, Japan.* We realize a 125 µm-cladding four-core fiber with four air-holes using novel fabrication technique without any drilling process. Core-to-core crosstalk is reduced to -63 dB/km at 1550 nm by intentionally remaining the air-holes during the fabrication.

Room 409AB

Th1I • Network Architecture Evolution—Continued

Th1I.2 • 09:00

Optimizing Multi-layer IP over WDM Networks: A Real Experience in a Tier 1 Telco, Javier Jimenez[1], Jim Mosquera[1], Juan Pablo Agredo[1], Cristyan Manta[1], Maximiliano Tapia[1]; [1]*Wipro Technologies, Chile.* We describe a real-world multi-layer IPoWDM network optimization program that has significantly reduced transport costs of a leading service provider. We present six strategies for making architectural and policy adjustments that result in a ~25% CAPEX reduction.

Th1I.3 • 09:15

Extending Segment Routing into Optical Networks, Madhukar Anand[1], Ramesh Subrahmaniam[1], Soumya Roy[1], Radhakrishna Valiveti[1]; [1]*Infinera Corporation, USA.* : New extensions to Segment Routing are introduced here that allow for an end-to-end path to include optical transport network segments that steer packets across optical networks for maximal performance with minimal operational changes.

Room 410

Th1J • Data Analytics and Machine Learning—Continued

Th1J.5 • 09:00

Investigation of Optical Impacts on Virtualization using SDN-enabled Transceiver and Optical Monitoring, Yanni Ou[1], Fanchao Meng[1], Prince M. Anandarajah[2], Shuangyi Yan[1], Alejandro Aguado[1], Maria Pascual[2,3], Reza Nejabati[1], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK;* [2]*Dublin City Univ., Ireland;* [3]*Pilot Photonics, Ireland.* We propose a scheme to introduce real-time optical layer monitoring into optical network virtualization enabled by software defined networking. The optical layer factors that impact the virtualization are characterised and investigated using this scheme experimentally.

Th1J.6 • 09:15

T-SDN Control Strategy for Expedited Connection Services using Physical Layer Impairment-aware RSA, Hamid Mehrvar[1], Mohammad Rad[1], Christopher Janz[1], Eric Bernier[1]; [1]*Huawei Technology, Canada.* Impairment-aware RSA requires extensive computations of physical layer non-linearities. We propose strategies that either avoid or minimize these extensive computations with minimal trade-offs on blocking performance. It enables T-SDN services with fast connection set-up time.

Room 411

Th1K • Coherent Technologies for Access—Continued

Th1K.3 • 09:00

Polarization-Independent Heterodyne DPSK Receiver Based on 3x3 Coupler for Cost-Effective udWDM-PON, Jeison A. Tabares[1], Victor Polo[1], Josep Prat[1]; [1]*Universitat Politècnica de Catalunya, USA.* A polarization-independent heterodyne DPSK receiver with simple architecture based on 3x3 coupler is proposed for cost-effective PON. Results show -49dBm sensitivity for BER=10-3 at 1.25Gbps, <1dB penalty for random polarization tests, and high tolerance to interfering power.

Th1K.4 • 09:15

1.25-2.5Gbps Cost-Effective Transceiver Based on Directly Phase Modulated VCSEL for Flexible Access Networks, Jose A. Altabas[1], David Izquierdo[1,2], Jose A. Lazaro[3], Ignacio Garces[1]; [1]*Universidad de Zaragoza, Spain;* [2]*Centro Universitario de la Defensa, Spain;* [3]*Universitat Politècnica de Catalunya, Spain.* A 1.25-2.5Gbps cost-effective transceiver based on DPSK directly phase modulated VCSEL and a heterodyne receiver with a VCSEL as LO is proposed. The proposed transmitter sensitivity is -43.5dBm for 1.25Gbps and -40.5dBm for 2.5Gbps.

Show Floor Programming

Room 402AB

Th1A • Detectors/ Receivers—Continued

Th1A.6 • 09:30 Top Scored

Simple Direct-detection-based Stokes Vector Receiver Circuit on InP, Samir Ghosh[1], Takuo Tanemura[1], Yuto Kawabata[1], Kazuhiro Katoh[1], Kazuro Kikuchi[1], Yoshiaki Nakano[1]; [1]*The Univ. of Tokyo, Japan*. Compact and robust photonic-integrated circuit for low-cost direct-detection-based Stokes vector (SV) receiver is presented. A proof-of-concept device is fabricated on InP to demonstrate successful decoding of multilevel SV-modulated signal at 1 Gbaud.

Th1A.7 • 09:45

Spectral-temporal Imaging Techniques for Real Time Characterization of High Speed VCSEL Mode Interaction, Jose M. Castro[1], Rick Pimpinella[1], Asher Novick[1], Bulent Kose[1], Paul Huang[1], Brett Lane[1]; [1]*Panduit Corp., USA.* We demonstrate real-time spectral-temporal imaging methods for real-time characterization of VCSEL noise and mode interaction. OCIS codes: (060.2340) Fiber optics components (060.2360) Fiber optics.

Room 403A

Th1B • Silicon Photonics—Continued

Th1B.6 • 09:30

Optical Circuit Switching/Multicasting of Burst Mode PAM-4 using a Programmable Silicon Photonic Chip, Colm Browning[1], Alexander Gazman[2], Vidak Vujicic[1], Aravind P. Anthur[1], Ziyi Zhu[2], Keren Bergman[2], Liam Barry[1]; [1]*Dublin City Univ., Ireland;* [2]*Columbia Univ., USA.* Aiming to facilitate increased intra-datacenter throughput and reconfigurability, the use of a programmable silicon photonic chip to achieve optical circuit switching and multicasting of 12.5GBaud burst mode PAM-4 is experimentally demonstrated for the first time.

Th1B.7 • 09:45 Top Scored

Ultra-Dense 16x56Gb/s NRZ GeSi EAM-PD Arrays Coupled to Multicore Fiber for Short-Reach 896Gb/s Optical Links, Peter De Heyn[1], Victor I. Kopp[2], Ashwyn Srinivasan[1], Peter Verheyen[1], J Park[2], M.S. Wlodawski[2], J Singer[2], Dan Neugroschl[2], Brad Snyder[1], Sadhish Balakrishnan[1], Guy Lepage[1], Marianna Pantouvaki[1], Philippe Absil[1], Joris Van Campenhout[1]; [1]*imec, Belgium;* [2]*Chiral Photonics, USA.* A 16-channel spatial-division multiplexed transceiver is demonstrated using a multicore fiber coupled to a dense array of co-integrated 56Gb/s GeSi electro-absorption modulators and photodetectors, realizing 896Gb/s aggregate bi-directional bandwidth in 1.47mm^2 silicon footprint.

Room 403B

Th1C • SDM Transmission II—Continued

Room 404AB

Th1D • Advances in Coherent Subsystems—Continued

Th1D.5 • 09:30

Multi-Vendor 100G DP-QPSK Line-side Interoperability Field Trial over 1030 km, Nestor Garrafa[1], Omar Salome[1], Thomas Mueller[2], Oscar P. Carcelen[2], Gianluca Calabretta[3], Nacho Carretero[3], Gabriele M. Galimberti[3], Steven Keck[2], Victor Lopez[4], Dirk Van Den Borne[2]; [1]*Telxius, USA;* [2]*Juniper Networks, USA;* [3]*Cisco Systems Inc., Italy;* [4]*Telefónica Global CTO, Spain.* We discuss a multi-vendor line-side interoperability field trial using Juniper and Cisco 100G coherent DWDM routers interfaces. The field trial demonstrates 100G DP-QPSK transmission over a 1030-km link from Boca Raton to Jacksonville uses the HG-FEC line-side interoperability mode for 100G coherent DWDM transceivers.

Room 406AB

Th1E • Visible Light Communications—Continued

Th1E.6 • 09:30

Bi-directional 35-Gbit/s 2D Beam Steered Optical Wireless Downlink and 5-Gbit/s Localized 60-GHz Communication Uplink for Hybrid Indoor Wireless Systems, Amir Masood Khalid[1], Peter Baltus[1], Rainier van Dommele[1], Ketemaw Addis Mekonnen[1], Zizheng Cao[1], Chin Wan Oh[1], Marion Matters[1], A. Koonen[1]; [1]*Technical Univ. of Eindhoven, Netherlands.* We present a full-duplex dynamic indoor optical wireless system using 2D passive optical beam steering for downlink and 60-GHz communication for upstream transmission. We demonstrate 35-Gb/s NRZ-OOK downstream multicasting and 5-Gb/s NRZ-ASK upstream communication.

Room 407

Th1F • Applications of Parametric Nonlinear Processors—Continued

Th1F.6 • 09:30

Optical Quantization Based on Intensity to Frequency Conversion Using Frequency Chirp in a QD-SOA, Norihiko Ninomiya[1], Hiroki Hoshino[1], Motoharu Matsuura[1]; [1]*Univ. of Electro-Communications, Japan.* We present a novel optical quantization technique based on intensity-to-frequency conversion using frequency chirp in a quantum-dot semiconductor optical amplifier. A four-level signal at 10-GSamples/s is successfully achieved for photonic analog-to-digital conversions.

10:00–16:00 Exhibition and Show Floor, *Exhibit Hall G-K* (coffee service from 10:00–10:30)

10:00–16:00 OFC Career Zone Live, *South Lobby*

Room 408A

Th1G • Gratings and Filters—Continued

Th1G.6 • 09:30

Silicon Polarization Splitter and Rotator using a Subwavelength Grating based Directional Coupler, Yu He[1], Yong Zhang[1], Xiaodong Wang[1], Boyu Liu[1], Xinhong Jiang[1], Ciyuan Qiu[1], Yikai Su[1], Richard Soref[2]; [1]*Shanghai Jiao Tong Univ., USA;* [2]*Engineering Department, Univ. of Massachusetts, USA.* A compact polarization splitter-rotator is experimentally demonstrated by using a subwavelength grating waveguide based directional coupler. Over 13 dB extinction ratios for both polarizations are achieved. Large tolerance (50 nm) to waveguide-width variation is also verified.

Th1G.7 • 09:45 Top Scored

Ultra-broadband Fabrication-tolerant Polarization Splitter and Rotator, Kang Tan[1,2], Ying Huang[1], Guo-Qiang Lo[1], Changyuan Yu[2,3], Chengkuo Lee[2]; [1]*Inst. of Microelectronics, A*STAR, Singapore;* [2]*Department of Electrical & Computer Engineering, National Univ. of Singapore, Singapore;* [3]*National Univ. of Singapore (Suzhou) Research Inst., China.* A polarization splitter and rotator that supports simultaneous O-, C-, and L-band operation is first experimentally demonstrated, with record 1-dB bandwidth over 360 nm, high fabrication tolerance, and high TE-TM conversion efficiency of -0.33 dB.

Room 408B

Th1H • Advances in Multicore Fiber Technology—Continued

Th1H.7 • 09:30 Invited

Coupled Single-mode Multi-core Fiber Design for Long-haul MIMO Transmission System, Taiji Sakamoto[1], Takayoshi Mori[1], Masaki Wada[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*NTT access network service systems lab., Japan.* We review recent progress on coupled single-mode multi-core fiber (MCF) for space-division multiplexed transmission with low modal dispersion. We introduce a super-mode-based group delay design and report the transmission characteristics of fabricated coupled MCF.

Room 409AB

Th1I • Network Architecture Evolution—Continued

Th1I.4 • 09:30 Invited

Energy Efficiency Measures for Future Core Networks, Jaafar Elmirghani[1], Leonard Nonde[1], Ahmed Lawey[1], Taisir Elgorashi[1], Mohamed Musa[1], Xiaowen Dong[2], Kerry Hinton[3], Thierry Klein[4]; [1]*Univ. of Leeds, UK;* [2]*Huawei Shannon Lab, China;* [3]*Univ. of Melbourne, Australia;* [4]*Bell Labs, USA.* We summarize the various techniques developed by the GreenTouch consortium over the past 5 years to minimize core network power consumption. Adopting GreenTouch techniques can potentially improve the energy efficiency by 316x in a 2020 reference network compared to the state of the art in 2010.

Room 410

Th1J • Data Analytics and Machine Learning—Continued

Th1J.7 • 09:30

A Bayesian-based Approach for Virtual Network Reconfiguration in Elastic Optical Path Networks, Toshihiko Ohba[1], Shin'ichi Arakawa[1], Masayuki Murata[1]; [1]*Graduate School of Information Science and Technology, Osaka Univ., Japan.* We investigate a Bayesian approach for VN reconfiguration in elastic optical networks. The approach identifies traffic condition from simple observations and selects VN suitable to the condition. Results show a fast converge of VN reconfiguration.

Th1J.8 • 09:45

Field Trial of a Novel SDN Enabled Network Restoration Utilizing In-depth Optical Performance Monitoring Assisted Re-planning, Fanchao Meng[1], Yanni Ou[1], Shuangyi Yan[1], Reza Nejabati[1], Dimitra Simeonidou[1]; [1]*Univ. of Bristol, UK.* We experimentally demonstrate a monitoring scheme utilizing both intermediate node and receiver monitoring for network re-planning. Either modulation format switching or light-path re-routing is adopted for restoration. The recovered signal performs better compared with static planning.

Room 411

Th1K • Coherent Technologies for Access—Continued

Th1K.5 • 09:30

Performance Evaluation of CPFSK Transmitters for TDM-based Digital Coherent PON Upstream, Masamichi Fujiwara[1], Ryo Koma[1], Jun-ichi Kani[1], Ken-Ichi Suzuki[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Labor, Japan.* Two burst-mode CPFSK transmitters using directly-modulated DFB-LDs are proposed and high receiver sensitivities of -44.0 dBm and -45.0 dBm are measured in experiments, both of which are record values for 10-Gb/s CPFSK signals.

Th1K.6 • 09:45

Adaptive Stokes Space Based Polarization Demultiplexing for Flexible UDWDM Metro-Access Networks, Somayeh Ziaie[1,3], Nelson J. Muga[3,1], Ricardo Ferreira[1,3], Fernando Guiomar[2], Ali Shahpari[1,3], António L. Teixeira[1,3], Armando Pinto[1,3]; [1]*Univ. of Aveiro, Portugal;* [2]*Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Italy;* [3]*Instituto de Telecomunicações, Portugal.* We experimentally demonstrate a flexible coherent UDWDM system with support to optical-wireless links and adaptive DP-QPSK/DP-16QAM modulation, enabled by Stokes-based polarization-demultiplexing. The system is shown to be resilient to dynamic power ranges of >12 dB.

Show Floor Programming

10:00–16:00 Exhibition and Show Floor, *Exhibit Hall G-K* (coffee service from 10:00–10:30)

10:00–16:00 OFC Career Zone Live, *South Lobby*

10:00–12:00
Th2A • Poster Session II

Th2A.1

Double Slot Fiber-to-chip Coupler using Direct Strip-slot Mode Coupling, Kyunghun Han[1], Min Teng[1], Ben Niu[1], Yunjo Lee[1], Sangsik Kim[1], Minghao Qi[1]; [1]*Purdue Univ., USA.* We present a fiber-to-chip coupler using asymmetric double slot waveguide and direct strip-slot mode coupling to shorten a transition while maintaining high coupling efficiency. Experimental result shows 1.8 dB insertion loss with a broad bandwidth.

Th2A.2

Polymer Waveguide Based Spot-size Converter For Low-loss Coupling Between Si Photonics Chips And Single-mode Fibers, Kazuki Yasuhara[1], Feng Yu[2], Takaaki Ishigure[3]; [1]*Graduate School of Science and Technology, Keio Univ., Japan;* [2]*Japan research center, Huawei technologies Japan K.K., Japan;* [3]*Faculty of Science and Technology, Keio Univ., Japan.* By applying the Mosquito method, we fabricate tapered polymer waveguides for spot size converters (SSCs) enabling low-loss coupling between Si waveguides and standard single mode fibers. The fabricated SSC exhibits remarkably low insertion loss as 2.77 dB.

Th2A.3

Stochastic Simulation and Sensitivity Analysis of Photonic Circuit through Morris and Sobol Method, Abi Waqas[1], Daniele Melati[1], Andrea Melloni[1]; [1]*Politecnico Di Milano, Italy.* Two different sensitivity analysis methods are applied to the coupled ring resonator filter to assess how the fabrication processes variation of some geometrical parameters can influence the performance of the photonics devices.

Th2A.4

A Polymer Waveguide Material Optimized for On-Board Optical Links and Si Photonic Interfaces, Shotaro Takenobu[1], Tymon. Barwicz[2], Nobuhiko Imajyo[1], Kenta Kobayashi[1], Takashi Sayama[1], Seiki Ohara[1], Paul Fortier[3], Yoichi Taira[2]; [1]*Asahi Glass Co. Ltd., Japan;* [2]*IBM TJ Watson Research Center, USA;* [3]*IBM Bromont, Canada.* We report on a polymer optical waveguide material with 0.29 dB/cm loss at 1550nm, wide spectral window of transparency, environmental stability, and solder-reflow compatibility. Flexible ribbons are sufficiently robust for standard high-throughput microelectronics assembly.

Th2A.5

Low-loss and Polarization-insensitive Photonic Integrated Circuit Based on Micron-scale SOI Platform for High Density TDM PONs, Qiang Zhang[1]; [1]*Huawei, China.* We present a photonic integrated circuit of four-channel bidirectional-optical-subassembly on micron-scale silicon. Experiment results with loss less than 1.5dB, PDL<0.5dB, and near 30dB isolation, allow for realization of Class C+ QSFP TDM-PON OLT module.

Th2A.6

MEMS Tunable Hybrid Plasmonic-Si Waveguide, Xu Sun[1], Lars Thylén[1], Lech Wosinski[1]; [1]*KTH, Sweden.* A MEMS tunable hybrid plasmonic-Si (HP) waveguide is investigated, showing very large changes of both effective refractive index and propagation loss when applying bias voltage. Preliminary experimental results show that: with 15μm MEMS structure in Si waveguide platform, the extinction ratio can be over 20dB between "on" and "off" states.

Th2A.7

Broadband, Mode-selective 15-Mode Multiplexer Based on Multi-plane Light Conversion, Nicolas Barré[1], Bertrand Denolle[1], Pu Jian[1], Jean-François Morizur[1], Guillaume Labroille[1]; [1]*CAILabs, France.* We report a 15 spatial mode multiplexer based on Multi-Plane Light Conversion, with high mode selectivity across the full C+L band. The multiplexer shows average 4.4 dB insertion loss and 23 dB mode selectivity.

Th2A.8

Large Mode-field-diameter Surface Optical Coupler Based on SiO_2-capsuled Vertically Curved Si Waveguide, Yuki Atsumi[1], Tomoya Yoshida[1], Emiko Omoda[1], Youichi Sakakibara[1]; [1]*AIST, Japan.* We design surface optical couplers based on vertically-curved Si waveguide for 5-μm-MFD SMFs. The device shows high-efficient coupling of < 1 dB loss in wavelength range of 330 nm with high device-size and fiber-alignment robustness.

Th2A.9

Design and Characterization of an Optical Chip for Data Compression based on Haar Wavelet Transform, Catia Pinho[2,1], Ana Tavares[2,1], Guilherme Cabral[2], Tiago Morgado[2], Ali Shahpari[2,1], Mário Lima[2,1], António L. Teixeira[2,1]; [1]*Department of Electronics, Telecommunications and Informatics (DETI), Univ. of Aveiro, Portugal;* [2]*Instituto de Telecomunicações, Univ. of Aveiro, Portugal.* A new optical chip for data compression based on Haar Transform (HT) was designed and tested. Asymmetric couplers and multimode interferometers (1x2 and 2x2) are implemented in the chip to perform all-optical HT operations.

Th2A.10

Rectangular Versus Circular Fiber Core Designs: New Opportunities for Mode Division Multiplexing?, Lior Rechtman[1], Dan M. Marom[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* The properties of rectangular core fiber are investigated for mode division multiplexing. Polarization degenerate mode groups, favorable mode profiles for device coupling, modal area uniformity, and good splice performance suggest it's a good candidate.

Th2A.11

Comparison of Multimode Fiber Modal Bandwidth Metrics, Petr Sterlingov[1]; [1]*Corning SNG Ltd., Russia.* We describe a multimode fiber bandwidth metric significantly more strongly correlated to link inter-symbol interference (ISI) penalties than conventional metrics. The improvement is demonstrated in plots of ISI vs. bandwidth for various link lengths.

Th2A.12

Mode-Dependent Gain Characterization of Erbium-doped Multimode Fiber Using C^2 Imaging, Haoshuo Chen[1], Bin Huang[1,2], Nicolas K. Fontaine[1], Roland Ryf[1], Jose Antonio-Lopez[2], Li Guifang[2], Rodrigo Amezcua Correa[2], Pierre Sillard[3], Cedric Gonnet[3], Juan Carlos Alvarado Zacarias[2], Zeinab Sanjabi Eznaveh[2], Axel Schulzgen[2]; [1]*Nokia Bell Labs, USA;* [2]*Univ. of Central Florida, USA;* [3]*Prysmian Group, France.* We characterize an erbium-doped step-index multimode fiber using C^2 imaging based on a swept-wavelength interferometer. Modal contents, delays and mode-dependent gains are fully characterized using space-to-time mapping.

Th2A.13

Performance Analysis of Flexible Regeneration and Modulation Conversion in Elastic Optical Networks, Miroslaw Klinkowski[2], Krzysztof Walkowiak[1]; [1]*Wroclaw Univ. of Science and Technology, Poland;* [2]*National Inst. of Telecommunications, Poland.* We study potential performance gains resulting from deliberate use of signal regeneration along with modulation conversion in translucent elastic optical networks (EONs) realizing super-channel transmission.

Th2A.14

Energy Saving in SBPP-Based IP over WDM Networks with Protection Router Card Sleeping, Lin Zhu[1], Haomin Jiang[1], Yongcheng Li[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*IIT Guwahati, India.* We develop an energy-saving scheme for the shared backup path protected (SBPP) IP over WDM network through sleeping protection router cards. Results show that the scheme is efficient and reduces energy consumption significantly compared to other conventional schemes.

Th2A.15

A Capacity Analysis for Space Division Multiplexing Optical Networks with MIMO Equalization, Yao Li[1,3], Nan Hua[1,2], Xiaoping Zheng[1,2]; [1]*Tsinghua National Laboratory for Information Science and Technology (TNList), China;* [2]*Department of Electronic Engineering, Tsinghua Univ., China;* [3]*College of Optical Sciences, Univ. of Arizona, USA.* We analyze the capacity of SDM networks under limited DSP complexities. Results show that DSP complexity limitations can severely restrict the network capacity enhancement brought by adding spatial channels, especially for large-scale networks.

Th2A.16

Benefits of Higher Modulation in Flexible Grid Networks using Optical WDM and Digital OTN Switching, Onur Turkcu[1], Abishek Gopalan[1], Biao Lu[1], Steve Sanders[1], Parthiban Kandappan[1]; [1]*Infinera, USA.* We study the effects of higher modulation formats on the design of optical network architectures using Flexible Grid and Sliceable Bandwidth Variable Transponders. We show architectures with digital switching getting more benefit from higher modulation.

Th2A.17

Holding-Time Information (HTI): When to Use it?, Sandeep Kumar Singh[1], Admela Jukan[1]; [1]*TU Braunschweig, Germany.* The known technique of HTI-aware routing can be used for connection admission, or spectrum defragmentation. We show that HTI used for defragmentation is the most beneficial in reducing blocking in space-division multiplexed elastic optical networks.

Th2A.18

On the Power Consumption of MIMO Processing and its Impact on the Performance of SDM Networks, Nikolaos Panteleimon Diamantopoulos[1], Behnam Shariati[1,2], Ioannis Tomkos[1]; [1]*Athens Information Technology (AIT), Greece;* [2]*Universitat Politecnica de Catalunya (UPC), Spain.* The power consumption of MIMO-DSP for SDM networks is investigated, assuming emerging sub-20-nm CMOS technology. Significant limitations on the network performance are revealed when scaling to large MIMO multiplicity (i.e. 12×12).

Th2A • Poster Session II—Continued

Th2A.19
An Impairment-aware Resource Allocation Scheme for Dynamic Elastic Optical Networks, Madushanka N. Dharmaweera[1], Li Yan[2], Magnus Karlsson[1], Erik Agrell[2]; [1]*Microtechnology and Nanoscience, Chalmers Univ. of Technology, Sweden;* [2]*Signals and Systems, Chalmers Univ. of Technology, Sweden.* By using impairment-driven variable guardbands, our proposed dynamic resource allocation scheme accommodates 50% more traffic in comparison to existing fixed transmission-reach- and guardband-based algorithms.

Th2A.20
Distributed Sub-Light-tree Construction Scheme for Multicast Services in Elastic Optical Datacenter Networks, Xin Li[1], Shanguo Huang[1], Bingli Guo[1], Yongli Zhao[1]; [1]*Beijing Univ of Posts & Telecom, China.* We propose a distributed sub-light-tree construction (DSLTC) scheme which uses multiple distributed sub-light-trees with different source datacenters to jointly serve one multicast request. DSLTC scheme achieves higher spectrum efficiency than the conventional subtree scheme.

Th2A.21
Hardware Programmable SDM/WDM ROADM, Yanlong Li[1,2], Shuangyi Yan[3], Nan Hua[1,2], Yanni Ou[3], Fengchen Qian[3], Reza Nejabati[3], Dimitra Simeonidou[3], Xiaoping Zheng[1,2]; [1]*Tsinghua National Laboratory for Information Science and Technology(TNList), China;* [2]*Department of Electronic Engineering, Tsinghua Univ., China;* [3]*Department of Electrical & Electronic Engineering, Univ. of Bristol, UK.* A novel hardware-programmable and scalable SDM/WDM ROADM architecture is proposed with a heuristic hardware-planning algorithm for multi-dimensional networks. Availability and performance of the proposed architecture and algorithm are evaluated by simulation and experiment.

Th2A.22
Demonstration of Data-rate and Power-budget Adaptive 100 Gb/s/λ-based Coherent PON Downlink Transmission, Takahiro Kodama[1], Ryosuke Matsumoto[1], Naoki Suzuki[1]; [1]*Optical Communication Technology Department, Mitsubishi Electric Corporation, Japan.* A data-rate and power-budget controlled 100 Gb/s/λ-based coherent PON downlink using 16-dimensional optical resource mapping and I/Q-imbalanced modulation has been demonstrated. We show 0.9 dB power-budget improvement for 25 Gb/s/ONU 80-km transmission.

Th2A.23
Novel Rank-based Low-latency Scheduling for Maximum Fronthaul Accommodation in Bridged Network, Yu Nakayama[1], Daisuke Hisano[1], Takahiro Kubo[1], Tatsuya Shimizu[1], Hirotaka Nakamura[1], Jun Terada[1], Akihiro Otaka[1]; [1]*Access Network Service Systems Laboratories, NTT, Japan.* This paper proposes a novel rank-based queue scheduling method for achieving low latency in a fronthaul bridged network. We confirmed with computer simulations the proposed scheme increased the number of accommodated fronthaul streams by 40%.

Th2A.24
Equalization Strategies for 25G PON, Andrew Stark[1], Thomas Detwiler[1]; [1]*Adtran, USA.* We explore performance limits of equalization strategies on bandwidth-constrained NRZ transmission. Without de-emphasis FFE/DFE equalizers achieve excellent link performance at normalized bandwidths 0.45 to 0.65. Signal de-emphasis with FFE/DFE enables link operation at bandwidth 0.25.

Th2A.25
Investigation of the Performance of GFDMA and OFDMA for Spectrally Efficient Broadband PONs, Arsalan Saljoghei[1], Arman Farhang[2], Colm Browning[1], Nicola Marchetti[2], Linda Doyle[2], Liam Barry[1]; [1]*School of Electronic Engineering, Dublin City Univ., Ireland;* [2]*CONNECT, Trinity College Dublin, Ireland.* The performance of GFDMA for upstream transmission in broadband passive optical networks is analysed. Results show that GFDMA offers superior performance against multiple access interference compared to OFDM in intensity modulated PONs.

Th2A.26
Channel Bonding Design for 100 Gb/s PON Based on FEC Codeword Alignment, Liang Zhang[1,3], Yuanqiu Luo[1], Bo Gao[2], Xiang Liu[1], Frank Effenberger[1], Nirwan Ansari[3]; [1]*Fixed Access Network, Futurewei (Huawei) Technologies, USA;* [2]*Fixed Access Network, Huawei Technologies Wuhan Research Center, China;* [3]*Department of Electrical and Computer Engineering, New Jersey Inst. of Technology, USA.* We propose a channel bonding system structure and algorithms for 100 Gb/s PON. The algorithms schedule FEC codeword transmission among four 25 Gb/s wavelength channels, and they are demonstrated with high efficiency and low latency.

Th2A.27
Real-Time Demonstration of 28 Gbit/s Electrical Duobinary TDM-PON Extension Using Remote Nodes, Rene Bonk[1], Robert Borkowski[1], Wolfgang Poehlmann[1], Joris Van Kerrebrouck[2], Chris Chase[3], Robert Lucas[3], Timothy De Keulenaer[2], Johan Bauwelinck[2], Doutje Van Veen[4], Vincent Houtsma[4], Xin Yin[2], Thomas Pfeiffer[1]; [1]*Nokia, Bell Labs, Germany;* [2]*IDLab, Dep. INTEC, Ghent Univ. – imec, Belgium;* [3]*Bandwidth 10, USA;* [4]*Nokia, Bell Labs, USA.* An experimental real-time reach and split extension of a 28 Gbit/s electrical duobinary TDM-PON is demonstrated. 50 dB budget is achieved using either remote nodes based on SOA or based on a distributed OLT concept.

Th2A.28
Forward Error Correction Analysis for 10Gb/s Burst-mode Transmission in TDM-DWDM PONs, Nicola Brandonisio[1], Stefano Porto[1], Daniel Carey[1], Peter Ossieur[1], Giuseppe Talli[1], Nick Parsons[2], Paul D. Townsend[1]; [1]*Tyndall National Inst., Ireland;* [2]*Polatis Ltd., UK.* The performance limits of 10Gb/s forward error correction for a PON upstream channel are analyzed experimentally by measuring true burst-mode pre- and post-error correction BER, frame loss rate and error location within the burst frame.

Th2A.29
Experimented Phase Noise Limitations in Directly-detected Single Side-Band Optical OFDM Systems, Alberto Gatto[1], Silvio Mandelli[2], Jacopo Morosi[1], Maurizio Magarini[1], Paolo Martelli[1], Pierpaolo Boffi[1]; [1]*Politecnico di Milano - DEIB, Italy;* [2]*Nokia Bell Labs, Germany.* We experimentally evaluate the impact of realistic phase noise on single side-band optical OFDM systems, directly detected after uncompensated propagation. Measures obtained with sources typical of short-medium reach applications are compared to a semi-analytical model.

Th2A.30
Semi-passive Power/Wavelength Splitting Node with Integrated Spectrum Monitoring for Reconfigurable PON, Bernhard Schrenk[1], Markus Hofer[1], Michael Hentschel[1], Thomas Zemen[1]; [1]*AIT Austrian Inst. of Technology, Austria.* A reconfigurable splitter for O- to L-band operation is demonstrated for analogue 64QAM-OFDM radio-over-fiber transmission. 10-ms burst switching and coarse spectral monitoring of lighted channels is facilitated through optical energy transmission at a -10dBm feed.

Th2A.31
Real-time Demonstration of Fairness-aware Dynamic Subcarrier Allocation for Adaptive Modulation in Elastic Lambda Aggregation Network, Yumiko Senoo[2], Kota Asaka[2], Takuya Kanai[2], Jun Sugawa[1], Koji Wakayama[1], Ken-Ichi Suzuki[2], Akihiro Otaka[2]; [1]*Research&Development Group, Hitachi, Ltd., Japan;* [2]*Access Network Service Systems Laboratories, NTT, Japan.* We propose a dynamic subcarrier allocation algorithm based on transmission parameters and traffic conditions. Real-time demonstration confirms that our algorithm can greatly improve fairness of frame loss rate among ONUs compared to fixed subcarrier allocation.

Th2A.32
Direct Beat Phase Modulated DFB for flexible 1.25-5 Gb/s Coherent UDWDM-PONs, Juan Camilo Velásquez Micolta[1], Iván N. Cano[1], Victor Polo[1], Josep Prat[1]; [1]*Universitat Politécnica de Catalunya , Spain.* We experimentally demonstrate a flexible direct phase modulated DFB laser through a beat signal for UDWDM PON. Rx sensitivity of -45 dBm at BER=10^{-3} and channel spacing of 7.5 GHz is achieved for 5 Gb/s.

Th2A.33
Latency in a 2D Torus Burst Optical Slot Switching Data Center, Nihel D. Benzaoui[1], Yvan Pointurier[1], Sébastien Bigo[1]; [1]*Nokia Bell Labs, USA.* We evaluate the latency of a BOSS-datacenter based on the 2D-topology. We show that the 2D-torus BOSS-datacenter is a scalable, homogeneous, load-independent and microsecond scale latency network even for high loads, typically 85%.

Show Floor Programming

Product Showcase
Huawei
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Panel V: Photonic Integration Business Case – Reality Check
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Th2A • Poster Session II—Continued

Th2A.34

VCSELs to Multicore Fiber Reconfigurable Optical Switch Based on Diffractive MEMS Mirrors, Mahmoud Gadalla[1], Véronique François[1], Bora Ung[1]; [1]*École de technologie supérieure (ÉTS), Canada.* VCSELs light was coupled to any selected core(s) in a multicore fiber with average max crosstalk of -10.4 dB using diffractive MEMS. This is a step toward agile multicore fiber interconnects and ROADM.

Th2A.35

Hardware Programmable Network Function Service Chain on Optical Rack-Scale Data Centers, Qianqiao Chen[1], Vaibhawa Mishra[1], Nick Parsons[2], Georgios S. Zervas[1]; [1]*Univ. of Bristol, UK;* [2]*Huber-Suhner Polatis, UK.* A datacenter network that supports programmable optical and multi-layer service chaining by adopting miniaturized reconfigurable optical backplanes and FPGAs is demonstrated. The end-to-end testbed delivers hitless on-chip service chain switch-over, 9.8G throughput and sub-microsecond latency.

Th2A.36

Network Synthesis of a Topology Reconfigurable Disaggregated Rack Scale Datacentre for Multi-Tenancy, Adaranijo Peters[1], Georgios S. Zervas[1]; [1]*Univ. of Bristol, UK.* A performance analysis of a hybrid reconfigurable disaggregated datacentre is presented. It offers substantial benefits in terms of network blocking, power consumption and cost when compared to pure circuit switched and statistical hybrid architectures.

Th2A.37

Co-design of a Low-latency Centralized Controller for Silicon Photonic Multistage MZI-based Switches, Yule Xiong[1], Felipe Gohring de Magalhães[2,3], Gabriela Nicolescu[3], Fabiano Hessel[2], Odile Liboiron-Ladouceur[1]; [1]*McGill Univ., Canada;* [2]*PPGCC/PUCRS, Brazil;* [3]*Ecole Polytechnique de Montreal, Canada.* An FPGA-based centralized controller architecture for silicon photonics switches is experimentally demonstrated achieving scheduling decision in one clock cycle. The FPGA simultaneously operates as the controller, and the traffic payload generator with error detection.

Th2A.38

Few-Mode 850-nm VCSEL Chip with Direct 16-QAM OFDM Encoding at 80-Gbit/s for 100-m OM4 MMF Link, Hsuan-Yun Kao[1], Cheng-Ting Tsai[1], Chun-Yen Peng[1], Shan-Fong Liang[1], Zu-Kai Weng[1], Yu-Chieh Chi[1], Hao-Chung Kuo[4], Jian Jang Huang[1], Tai-Cheng Lee[1], Tien-Tsorng Shih[2], Jau-Ji Jou[2], Wood-Hi Cheng[3], Chao-Hsin Wu[1], Gong-Ru Lin[1]; [1]*National Taiwan Univ., Taiwan;* [2]*National Kaohsiung Univ. of Applied Sciences, Taiwan;* [3]*National Chung Hsing Univ., Taiwan;* [4]*National Chiao Tung Univ., Taiwan.* Chip-level direct 16-QAM OFDM encoding of a few-transverse-mode 850-nm Zn-diffused VCSEL is employed to transmit 80-Gbit/s data covering 20-GHz analog bandwidth over 100-m-long OM4 MMF with corresponding BER of 3.3×10^{-3}.

Th2A.39

A Silicon Metamaterial Chip-to-Chip Coupler for Photonic Flip-Chip Applications, Tymon Barwicz[1], Swetha Kamlapurkar[1], Yves Martin[1], Robert L. Bruce[1], Sebastian Engelmann[1]; [1]*IBM TJ Watson Research Center, USA.* We demonstrate a metamaterial converter with a highly elongated coupler mode optimized for direct optical chip-to-chip connections. We show a highly broadband converter response with <0.35dB penalty over the 120nm spectrum measured.

Th2A.40

4-mode MDM Transmission over MMF with Direct Detection Enabled by Cascaded Mode-selective Couplers, Zhongying Wu[1], Juhao Li[1], Yu Tian[1], Dawei Ge[1], Jinglong Zhu[1], Qi Mo[3], Fang Ren[2], Jinyi Yu[1], Zhengbin Li[1], Zhangyuan Chen[1], Yongqi He[1]; [1]*Peking Univ., China;* [2]*Univ. of Science and Technology Beijing, China;* [3]*Wuhan Research Inst. of Posts and Telecommunications, China.* We propose and fabricate low modal-crosstalk mode multiplexer/demultiplexer consisting of cascaded mode-selective couplers (MSCs) for MMF transmission, based on which 4-mode MDM transmission with OOK modulation and direct detection over 500-m MMF is experimentally demonstrated.

Th2A.41

Bio-Inspired Optical Microwave Phase Lock Loop based on Nonlinear Effects in Semiconductor Optical Amplifier, Ruizhe Lin[1], Luis A. Perea[1], The Phiet T. Do[1], Jia Ge[1], Li Xu[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* Optical microwave phase lock loop using semiconductor optical amplifiers is experimentally demonstrated. Bio-inspired by Eigenmannia and implemented with photonics, the proposed scheme is compact, has a simple architecture, and has a wide operating frequency range.

Th2A.42

Measurement of Optical Signal-to-noise-ratio in Coherent Systems using Polarization Multiplexed Transmission, Wolfgang Moench[1], Eberhard Loecklin[1]; [1]*Viavi, Germany.* A new method for measuring Optical Signal-to-Noise-Ratio (OSNR) in systems using polarization multiplexed transmission was investigated. The OSNR can be calculated from the correlation between spectral components in the optical spectrum of a transmission signal.

Th2A.43

Mode-Group Multiplexed Transmission using OAM Modes over 1 km Ring-Core Fiber without MIMO Processing, Feng Feng[1], Xianqing Jin[2], Dominic O'Brien[3], Frank Payne[3], Timothy Wilkinson[1]; [1]*Univ. of Cambridge, UK;* [2]*Univ. of Science and Technology of China, China;* [3]*Univ. of Oxford, UK.* We demonstrate mode-group multiplexed transmission over 1km ring-core fiber to transmit 2×10Gbit/s using OOK modulation and direct detection. SLM based spatial (de)multiplexers perform all-optical multiplexing and demultiplexing in an OAM mode basis.

Th2A.44

Dual Laser Switching for Dynamic Wavelength Operation in Amplified Optical Transmission, Shengxiang Zhu[1], Weiyang Mo[1], Daniel C. Kilper[1], Aravind P. Anthur[2], Liam Barry[2]; [1]*Univ. of Arizona, USA;* [2]*Dublin City Univ., Ireland.* Fast switching of a dual laser PM-QPSK transceiver is used to mitigate channel-power excursions in amplified optical transmission under wavelength reconfiguration.

Th2A.45

Comparison of CD(C) ROADM Architectures for Space Division Multiplexed Networks, José Manuel Rivas-Moscoso[2], Behnam Shariati[2,1], Dan M. Marom[3], Dimitrios Klonidis[2], Ioannis Tomkos[2]; [1]*Universitat Politécnica de Catalunya , Spain;* [2]*Athens Information Technology (AIT), Greece;* [3]*The Hebrew Univ. of Jerusalem, Israel.* We compare different architectures of CD and CDC ROADMs supporting spatial superchannel routing in terms of required components, revealing the most cost-effective designs.

Th2A.46

Fast Reconfigurable SOA-based All-optical Wavelength Conversion of QPSK Data Employing Switching Tunable Pump Lasers, Yi Lin[1], Aravind P. Anthur[1], Sean O'Duill[1], Sepideh T. Naimi[1], Yonglin Yu[2], Liam Barry[1]; [1]*Dublin City Univ., Ireland;* [2]*Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China.* We demonstrate a dynamically reconfigurable SOA-based all-optical wavelength convertor for QPSK data at 12.5 GBuad using a fast switching tunable laser as one of the pump sources. The experimental results indicate that it is feasible to build fast reconfigurable wavelength convertors with <30 ns switching time.

Th2A.47

Adiabatic Chirp Impact on the OSNR Sensitivity of Complex Direct Modulation: An Experiment Investigation, Di Che[1], Feng Yuan[1], William Sheih[1]; [1]*Univ. of Melbourne, Australia.* We study the adiabatic chirp impact on the complex direct modulation using polarization-multiplexed PAM-4 system by varying signal baud-rate with data-rate up to 120 Gb/s. Experiment shows insufficient chirp at 30-Gbaud degrades >4 dB OSNR sensitivity compared with 10-Gbaud.

Th2A.48 • 10:00

Simultaneous Measurement of Chromatic and Modal Dispersion in FMFs Using Microwave Photonic Techniques, Ruilong Mi[1], Ningbo Zhao[1], Zhiqun Yang[1], Lin Zhang[1], Guifang Li[2,1]; [1]*Tianjin Univ., China;* [2]*CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA.* A microwave-photonic technique for measuring dispersion characteristics of few-mode fibers is proposed and experimentally demonstrated. This technique allows simultaneous high-precision measurement of chromatic dispersion and differential modal group delay, for the first time.

Th2A.49

Reproducible Broadband Optical Noise Generation Based on Phase Modulation to Intensity Modulation Conversion and a Nonlinear Transformation, Xingxing Jiang[1], Mengfan Cheng[1], Fengguang Luo[1], Lei Deng[1], Changjian Ke[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1], Minming Zhang[1], Ping Shum[2]; [1]*HuaZhong Univ. of Sci. & Tech., China;* [2]*Nanyang Technological Univ., Singapore.* We experimentally demonstrate a reproducible broadband optical noise generation scheme. A flat spectrum and a symmetrical distribution can be obtained. The complexity of the analogue noise can be determined by the input binary sequence.

Th2A.50

Capacity Limits of Space-Division Multiplexed Submarine Links Subject to Nonlinearities and Power Feed Constraints, Omar Domingues[1], Darli Mello[1], Reginaldo Silva[3], Sercan O. Arik[2], Joseph M. Kahn[2]; [1]*School of Electrical and Computer Engineering, Univ. of Campinas, Brazil;* [2]*Department of Electrical Engineering, Stanford Univ., USA;* [3]*Padtec S/A, Brazil.* We compute the capacity limits of space-division multiplexed submarine links. We demonstrate that limitations due to nonlinearities become negligible compared to power-feed limitations as the propagation distance and the total number of spatial channels increase.

Th2A.51

1.6Tb/s (4x400G) Unrepeatered Transmission over 205-km SSMF using 65-GBaud PDM-16QAM with Joint LUT Pre-Distortion and Post DBP Nonlinearity Compensation, Junwen Zhang[1], Jianjun Yu[1], Hung Chang Chien[1]; [1]*ZTE Tx Inc, USA.* With joint LUT-based pre-distortion and DBP-based post-compensation to mitigate the opto-electronic components and fiber nonlinearity impairments, we demonstrate the unrepeatered transmission of 1.6Tb/s based on 4-lane 400G single-carrier PDM-16QAM over 205-km SSMF without distributed amplifier.

Th2A • Poster Session II—Continued

Th2A.52
Single-Channel 3.84 Tbit/s, 64 QAM Coherent Nyquist Pulse Transmission over 150 km with Frequency-Stabilized and Mode-Locked Laser, Masato Yoshida[1], Junpei Nitta[1], Kosuke Kimura[1], Keisuke Kasai[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We report a polarization-multiplexed 320 Gbaud, 64 QAM coherent optical Nyquist pulse transmission with a frequency-stabilized mode-locked laser. Single-channel 3.84 Tbit/s data were successfully transmitted over 150 km with a spectral efficiency of 10.6 bit/s/Hz.

Th2A.53
Nonlinear Transmission Performance in Delay-managed Few-mode Fiber Links with Intermediate Coupling, Filipe Ferreira[1], Christian Sanchez[1], Naoise Suibhne[1], Stylianos Sygletos[1], Andrew Ellis[1]; [1]*Aston Univ., UK.* Linear equalization performance for delay-managed few-mode links in the nonlinear regime with intermediate linear coupling is studied for the first time. Existing fibers can allow similar performance per mode to that of uncoupled single-mode propagation.

Th2A.54
Spectral Efficiency Estimation in Periodic Nonlinear Fourier Transform Based Communication Systems, Morteza Kamalian Kopae[1], Jaroslaw E. Prilepsky[1], Son T. Le[2], Sergei K. Turitsyn[1]; [1]*Aston Univ., UK;* [2]*Nokia, Bell labs, Germany.* We evaluate, for the first time, the achievable spectral efficiency of periodic nonlinear Fourier transform based communication systems with hard decision FEC and modulated perturbed plane waves with high order QAM formats, e.g 32QAM-512QAM.

Th2A.55
Influence of Lasers with Non-White Frequency Noise on the Design of Coherent Optical Links, Aditya Kakkar[1,2], Jaime R. Navarro[2,1], Richard Schatz[1], Xiaodan Pang[2], Oskars Ozolins[2], Fredrik Nordwall[3], Darko Zibar[4], Gunnar Jacobsen[2], Sergei Popov[2]; [1]*Optics and Photonics Division, Royal Inst. of Technology(KTH), Sweden;* [2]*Network and Transmission Laboratory, Acreo Swedish ICT, Sweden;* [3]*Tektronics AB, Sweden;* [4]*DTU Fotonik, Denmark Technical Univ., Denmark.* We experimentally demonstrate for a 28 Gbaud 64-QAM metro link that the LO frequency noise causes timing impairment. Results show the existence of LO frequency noise spectrum regimes where different design criteria apply.

Th2A.56
Low-Complexity Chromatic Dispersion Equalizer for 400G Transmission Systems, Celestino Sanches Martins[1,2], Sofia Amado[1,2], Sandro Rossi[3], Andrea Chiuchiarelli[3], Jacklyn D. Reis[3], Andrea Carena[4], Fernando Guiomar[4], Armando Pinto[1,2]; [1]*Universidade de Aveiro, Portugal;* [2]*Instituto de Telecomunicações, Portugal;* [3]*CPqD, Division of Optical Technologies, Brazil;* [4]*DET, Politecnico di Torino, Corso Duca degli Abruzzi, Italy.* We experimentally demonstrate a reduced complexity time-domain CD equalizer in a dual-carrier 400G PM-16QAM system, yielding hardware savings of over 99% in terms of multipliers, and a latency reduction of ~80% over standard frequency-domain CD equalization.

Th2A.57
Spatial Pulse Position Modulation for Multi-mode Transmission Systems, John van Weerdenburg[1], Alex Alvarado[1,2], Juan Carlos Alvarado Zacarias[3], Jose Antonio-Lopez[3], Jochem Bonarius[1], Denis Molin[4], Marianne Bigot[4], A. Koonen[1], Adrian Amezcua-Correa[4], Pierre Sillard[4], Rodrigo Amezcua Correa[3], C M. Okonkwo[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Optical Networks Group, Univ. College London (UCL), UK;* [3]*CREOL, Univ. of Central Florida, USA;* [4]*Prysmian group, France.* A spatial pulse position modulation is proposed and experimentally validated for a 12 spatial channel transmission over 53km multi-mode fiber. Improved data rates up to 30% are demonstrated with respect to conventional QPSK.

Th2A.58
4 bits/symbol Phase and Amplitude Modulation on a Single Discrete Eigenvalue for Nonlinear Fourier Transform based Transmissions, Tao Gui[1], Shun Ka Lo[1], Xian Zhou[1,2], Chao Lu[1], Alan Pak Tao Lau[1], Ping-Kong Alexander Wai[1]; [1]*The Hongkong Polytechnic Univ., Hong Kong;* [2]*Univ. of Science & Technology Beijing, China.* We experimentally demonstrated and compared various 4 bits/symbol phase and amplitude modulation formats on a single discrete eigenvalue. 4Gbaud with a total bit rate of 16 Gb/s transmission over 750 km is achieved.

12:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall G-K*
(concessions available)

Th2A.59
Real-Time 8×200-Gb/s 16-QAM Unrepeatered Transmission Over 458.8 km Using Concatenated Receiver-side ROPAs, Yue-Kai Huang[1], Ezra Ip[1], Yoshiaki Aono[2], Tsutomu Tajima[2], Shaoliang Zhang[1], Fatih Yaman[1], Yoshihisa Inada[3], John Downie[4], William Wood[4], Aramais Zakharian[4], Jason Hurley[4], Snigdharaj Mishra[5]; [1]*NEC Laboratories America Inc, USA;* [2]*Converged Network Division,, NEC Corporation, Japan;* [3]*Submarine Network Division,, NEC Corporation, Japan;* [4]*Corning Inc., USA;* [5]*Corning Optical Communications, Corning Incorporated, USA.* We demonstrate real-time 8×200-Gb/s DP-16QAM transmission over a 458.8 km link assisted by one Tx-ROPA and two concatenated Rx-ROPAs. Compared with using only one Rx-ROPA, a 5 dB increase in total link loss was achieved.

Th2A.60
Reach Extension with 32- and 64 GBaud Single Carrier vs. Multi-Carrier Signals, Olga Vassilieva[1], Inwoong Kim[1], Tomofumi Oyama[2], Schoichiro Oda[2], Hisao Nakashima[2], Takeshi Hoshida[2], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America Inc, USA;* [2]*Fujitsu Laboratories Limited, Japan.* We show that 32 GBaud single- and multi-carrier DP-QPSK can deliver longer reach for the same capacity as 64 GBaud DP-QPSK. However, 64 GBaud multi-carrier DP-QPSK signal can provide 12% longer reach than single-carrier 32 GBaud DP-QPSK.

Th2A.61
Nonlinear Mitigation using Probabilistically Shaped Real-Valued Modulation Formats, Tobias A. Eriksson[1], Fred Buchali[1], Laurent Schmalen[1]; [1]*Nokia Bell Labs, Germany.* We experimentally demonstrate probabilistically-shaped modulation formats with increased spectral efficiency and nonlinear mitigation capabilities compared to phase-conjugated twin-waves QPSK at 54.2Gbaud, yielding 21% increased reach.

Th2A.62
Intra and Inter-channel Nonlinearity compensation in WDM Coherent Optical OFDM using Artificial Neural Network Based Nonlinear Equalization, Elias Giacoumidis[1], Sofien Mhatli[2], Jinlong Wei[3], Son T. Le[4], Ivan Aldaya[5], Marc F. Stephens[4], Mary McCarthy[4], Andrew Ellis[4], Nick J. Doran[4], benjamin eggleton[1]; [1]*CUDOS, Univ. of Sydney, Australia;* [2]*EPT Université de Carthage, Tunisia;* [3]*Huawei Duesseldorf GmbH, Germany;* [4]*AIPT, Aston Univ., UK;* [5]*State Univ. of Campinas , Brazil.* Nonlinear effects are experimentally tackled, for the first time, in WDM-CO-OFDM by an artificial neural network (ANN)-based equalizer at 3200 km. For the middle 20-Gb/s channel ANN outperforms to Volterra-based equalization by ~2-dB in Q-factor.

Th2A.63
Impact of WDM Channel Count on Nonlinear Effects in MDM Transmission Systems, Marius Brehler[1], Peter M. Krummrich[1]; [1]*TU Dortmund, Germany.* We vary the number of WDM channels and investigate the impact on the nonlinear effects in mode-division multiplexed transmissions. The OSNR requirements for 15 spatial modes and up to 80 WDM channels are evaluated.

Th2A.64
Frequency-domain Hybrid N x 100 Gb/s Regular QAMs for Simple, Scalable, and Transparent Software-defined Optical Transport, Masashi Binkai[3], Takahiro Kodama[3], Tsuyoshi Yoshida[3,1], Yuita Noguchi[3], Naoki Suzuki[3], Kuniaki Motoshima[2]; [1]*Department of Microtechnology and Nanoscience, Chalmers Univ. of Technology Phtonics Laboratory, Sweden;* [2]*Communication Systems Group, Mitsubishi Electric Corporation, Japan;* [3]*Information Technology R&D Center, Mitsubishi Electric Corporation, Japan.* Frequency-domain hybrid modulation with N x 100 Gb/s/subcarrier regular QAMs is proposed. Superchannel spectral manipulation achieved 1.5 dB Q-margin increase for a 300 Gb/s superchannel with DP-QPSK and DP-16QAM for 900 km real-time transmission.

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Room 402AB

13:00–15:00
Th3A • Optical Technologies for Radio Access Network I
Presider: Volker Jungnickel; Fraunhofer HHI, Germany

Th3A.1 • 13:00 Tutorial
Architecture and Technologies for the Current and Future Radio Access Network, Erik Dahlman[1]; [1]*Ericsson AB, Sweden.* This tutorial will provide an overview of the current status of 5G mobile communication including - The main 5G use cases with corresponding requirements and service characteristics - Key technologies pursued to address these use cases - Standardization activities and corresponding time line to reach the target of first 5G specifications targeting to be available in 2018.

Erik Dahlman is currently Senior Expert in Radio Access Technologies within Ericsson Research. He was deeply involved in the development and standardization of 3G radio access technologies (WCDMA and HSPA), first in Japan and later within the global 3GPP standardization body. Later on he was involved in the standardization/development of the 3GPP Long Term Evolution (LTE) and its continued evolution. His currently focuses on research and development of future 5G wireless access technologies.

Erik Dahlman is the co-author of the books 3G Evolution – HSPA and LTE for Mobile Broadband, 4G – LTE and LTE-Advanced for mobile broad-

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Room 403A

13:00–15:00
Th3B • Practical Solutions to Tranceiver Integration
Presider: Chen Ji; Chinese Acad Sci Inst of Semiconductor, China

Th3B.3 • 13:00 Invited
Cost-effective 25G APD TO-Can/ROSA for 100G Applications, Mengyuan Huang[1], Pengfei Cai[1], Su Li[1], Tzung-I Su[1], Liangbo Wang[1], Wang Chen[1], Chingyin Hong[1], Dong Pan[1]; [1]*SiFotonics Technologies Co., Ltd., USA.* Owing to the breakthrough of Ge/Si avalanche photodiode, we developed a cost effective 25G APD TO-can solution for various 100G applications including 100G-PON, 5G wireless, and data center applications with PAM4 and DMT modulations.

Room 403B

13:00–14:45
Th3C • Optical Wireless Systems
Presider: A. Koonen; Technische Universiteit Eindhoven, Netherlands

Th3C.1 • 13:00 Invited
UAV Aerial Network and Free Space Communication, Hamid Hemmati[1]; [1]*Facebook Inc., USA.* Nearly half the world population, greater than three billion in total, has either no access or fairly poor access to the Internet. Facebook, through its Internet.org partnership intends to provide Internet access to the developing countries of the world. The required data-rate to provide Internet service to those online simultaneously in these countries is estimated at well over 100 Tbps; a staggering data-rate. Cost effective means are required to make the service possible and that requires significant advancements of the state-of-the-art in technology at a variety of communications bands and for all telecomm scenarios from terrestrial inks to satellite links.

Room 404AB

13:00–15:00
Th3D • DSP for Direct-Detection Systems
Presider: Neil Guerrero Gonzalez; Universidad Nacional de Colombia, Colombia

Th3D.1 • 13:00
Up to 190-Gb/s OOK Signal Generation using a Coding and Cutting Technique with a 92 GSa/s DAC, Qiang Zhang[1], Nebojsa Stojanovic[1], Liang Zhang[2], Tianjian Zuo[2], changsong xie[1], Enbo Zhou[2]; [1]*Huawei Technologies Duesseldorf GmbH, Germany;* [2]*Huawei Technologies Co. LTD, China.* On-off keying (OOK) signals up to 190 Gb/s are generated in a bandwidth limited system using a 92 GSa/s DAC and a simple coding and cutting technique. The coding method is cascaded duo-binary coding, and the performance at different baud-rates is investigated.

Th3D.2 • 13:15
Performance Improvement of Electronic Dispersion Post-compensation in Direct Detection Systems Using DSP-based Receiver Linearization, Zhe Li[1], Mustafa S. Erkilinc[1], Kai Shi[1], Eric Sillekens[1], Lidia Galdino[1], Benn C. Thomsen[1], Polina Bayvel[1], Robert Killey[1]; [1]*Univ. College London, UK.* Significant improvements in the performance of electronic dispersion post-compensation enabled by beating interference compensation were experimentally demonstrated in a 112 Gb/s/λ WDM Nyquist-subcarrier modulation direct-detection system in transmission over distances up to 240 km.

Room 406AB

13:00–15:00
Th3E • Waveguide Devices
Presider: Mark Feuer; CUNY College of Staten Island, USA

Th3E.1 • 13:00
Silicon Nitride Tri-layer 1×3 Couplers with Arbitrary Splitting Ratio for 3D Photonic Integrated Circuits, Kuanping Shang[1], Shaoqi Feng[1], Guangyao Liu[1], Siwei Li[1], S. J. Ben Yoo[1]; [1]*Univ. of California, Davis, USA.* We design tri-layer Si3N4 1×3 couplers with arbitrary power splitting ratio and small reflection for 3D photonic integrated circuits. We demonstrate the power splitting ratio from 1:1:4 to 1:22:27 with 0.185dB excess loss.

Th3E.2 • 13:15
Ultimately Low-loss and Compact Si Wire 90° Waveguide Bend Composed of Clothoid and Normal Curves for Dense Optical Interconnect PICs, Shuntaro Makino[1], Masahiro Suga[1], Takanori Sato[1], Takeshi Fujisawa[1], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan.* Ultimately low-loss 90° waveguide bend composed of clothoid and normal curves is proposed for dense optical interconnect PICs. 90 % reduction of the bending loss is experimentally demonstrated with excellent agreement between theory and experiment.

Room 407

13:00–14:45
Th3F • Transmission Experiments and Modeling

Th3F.1 • 13:00
Digital Subcarrier Multiplexing in Optically Routed Networks, Ronen Dar[1], Peter Winzer[1]; [1]*Nokia Bell Labs, USA.* We examine the benefit of digital subcarrier multiplexing in optically routed networks. We show that optimizing the number of subcarriers not only improves system tolerance to nonlinearities, but also induces smaller performance variations in various network scenarios.

Th3F.2 • 13:15
Temporal Stochastic Channel Model for Absolute Polarization State and Polarization-Mode Dispersion, Cristian B. Czegledi[1], Magnus Karlsson[1], Pontus Johannisson[2], Erik Agrell[1]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Sensor Systems, Sweden.* We propose and validate a discrete-time channel model for the temporal drift of the absolute polarization state and polarization-mode dispersion for coherent fiber optic systems. The model can be used in simulations to test and develop DSP for coherent receivers.

Room 408A

13:00–15:00
Th3G • Power Efficient Optics
Presider: Christopher Cole; Finisar Corporation, USA

Th3G.1 • 13:00 Invited
Power and Reach Trade-offs Increasing the Optical Channel Rate through Higher Baud Rate and Modulation Order, Christian Rasmussen[1]; [1]*Acacia Communications, Inc., USA.* This paper discusses trade-offs of important parameters such as transmission reach and transceiver power when the bit rate of an optical channel is increased through the symbol rate and the numbers of bits per symbol.

Presentations selected for recording are designated with a ▶. Visit www.ofcconference.org and select the View Presentations link.

Room 408B

13:00–15:00
Th3H • Sensors for Telecom and Biomedical Applications
Presider: Rogrio Nogueira; Instituto De Telecomunicacoes, Portugal

Th3H.1 • 13:00 Invited
Multicore Fiber Sensors, Joel Villatoro[1], Oskar Arrizabalaga[1], J. E Antonio-Lopez[2], Joseba Zubia[1], Idurre Saez de Ocáriz[3]; [1]*ETSI- Communications Engineering, UPV/EHU, Spain;* [2]*Microstructured Fibers and Devices, CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA;* [3]*NA, CTA -Fundación Centro de Tecnologías Aeronáuticas, Spain.* We report on precision interferometric sensors based on strongly-coupled core multicore fibers (MCF). Our devices were validated in a high-fidelity aerospace test laboratory and in real-world environments. The high potential of MCF sensors is discussed.

Room 409AB

13:00–15:00
Th3I • Novel Photonic Devices
Presider: Dazeng Feng; Mellanox, USA

Th3I.1 • 13:00
Multi-Gigabit Operation of a Compact, Broadband Modulator Based on ENZ Confinement in Indium Oxide, Gordon A. Keeler[1], Kent M. Geib[1], Darwin K. Serkland[1], S. Parameswaran[1], Ting S. Luk[2], Alejandro J. Griñe[1], Jon Ihlefeld[1], Salvatore Campione[1], Joel R. Wendt[1]; [1]*Sandia National Laboratories, USA;* [2]*Center for Integrated Nanotechnologies, Sandia National Laboratories, USA.* We report the first high-speed demonstration of a compact electroabsorption modulator based on epsilon-near-zero confinement in conducting oxide films. The non-resonant, 4µm-long device operates simultaneously over the entire C band through field-effect carrier density tuning.

Th3I.2 • 13:15
Photonic Integrated Circuit Using Lanthanum-modified Lead Zirconate Titanate Thin Films, Shunsuke Abe[1], Shin Masuda[1], Koichiro Uekusa[1], Hideo Hara[1], Masao Shimizu[1]; [1]*Advantest Laboratories, Ltd., Japan.* We fabricated a novel photonic integrated circuit using a lanthanum-modified lead zirconate titanate thin film. An optical modulator operating up to 50 Gb/s and a variable attenuator were successfully integrated on the PLZT thin film.

Room 410

13:00–14:30
Th3J • Nonlinear Mitigation Techniques
Presider: Toshihiko Hirooka; Tohoku Univ., Japan

Th3J.1 • 13:00
Novel Wavelength-shift-free Optical Phase Conjugator used for Fiber Nonlinearity Mitigation in 200-Gb/s PDM-16QAM Transmission, Isaac Sackey[1,2], Robert Elschner[1], Carsten Schmidt-Langhorst[1], Tomoyuki Kato[3], Takahito Tanimura[3], Shigeki Watanabe[3], Takeshi Hoshida[3], Colja Schubert[1]; [1]*Fraunhofer Heinrich Hertz Inst., Germany;* [2]*Technische Universität Berlin, Germany;* [3]*Fujitsu Laboratories Ltd., Japan.* We experimentally realize a wavelength-shift free optical phase conjugator exploiting inherent suppression of the original signal in a polarization-diversity loop. We achieve 0.5-dB Q^2-factor improvement in 200 Gb/s PDM-16QAM transmission over 800 km.

Th3J.2 • 13:15
Optical Nonlinearity Mitigation of 6×10GBd Polarization-division Multiplexing 16-QAM Signals in a Field-installed Transmission Link, Yujia Sun[1], Abel Lorences-Riesgo[2], Francesca Parmigiani[1], Kyle Bottrill[1], Satoshi Yoshima[3], Graham Hesketh[1], Magnus Karlsson[2], Peter A. Andrekson[2], David J. Richardson[1], Periklis Petropoulos[1]; [1]*Optoelectronics Research Center, Univ. of Southampton, UK;* [2]*Chalmers Univ. of Technology, Sweden;* [3]*Mitsubishi Electric Corporation, Japan.* We report nonlinear impairment mitigation of PDM 16-QAM WDM signals through mid-link optical phase conjugation in a 834km-long installed fiber link. Efficient reuse of signal bandwidth and Q-factor improvements of up to 3dB are demonstrated.

Room 411

13:00–14:45
Th3K • Network Survivability
Presider: Massimo Tornatore; Politecnico di Milano, Italy

Th3K.1 • 13:00
Enhanced Survivability of Translucent Elastic Optical Network Employing Shared Protection with Fallback, Masahiko Jinno[1], Tomohiko Takagi[1], Yuto Uemura[1]; [1]*Kagawa Univ., Japan.* We propose a novel shared-protection scheme for elastic optical networks employing virtualized elastic regenerators that provides almost the same high degree of survivability as dedicated protection even when double-link failures occur while saving backup resources.

Th3K.2 • 13:15
Ultra-fast Ring-protection Demonstration of Fixed Latency Sub-wavelength Granularity Ethernet Packet Paths, Raimena Veisllari[1], Steinar Bjornstad[1,2], Jan P. Braute[1]; [1]*Transpacket, Norway;* [2]*Telematics, NTNU, Norway.* A novel ultra-fast and scalable ring-protection switching scheme is proposed and demonstrated for fixed latency Ethernet paths of sub-wavelength granularity. Protection in a seven node ring network is achieved within 712 µs.

Show Floor Programming

ONF: The Path Forward
ONF
12:00–13:30
For more details, see page 45

■ Market Watch Panel VI: SDN & Optics- What is the Business Case?
12:30–14:00
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Technological Evolution of Next Generation Connect
Huawei
13:30–14:30
For more details, see page 48

Transport SDN: Commercial Applications, Solutions & Innovation Areas
Huawei
15:00–16:00
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Room 402AB

Th3A • Optical Technologies for Radio Access Network I—Continued

band and, most recently, 4G – LTE-Advanced Pro and The Road to5G. He is a frequent invited speaker at different international conferences and holds more than 100 patents within the area of mobile communication. In 2009, Erik Dahlman received the Major Technical Award, an award handed out by the Swedish Government, for his contributions to the technical and commercial success of the 3G HSPA radio-access technology. In 2010, he was part of the Ericsson team receiving the LTE Award for "Best Contribution to LTE Standards", handed out at the LTE World Summit. In 2014 he was nominated for the European Inventor Award, the most prestigious inventor award in Europe, for contributions to the development of 4G LTE.

Room 403A

Th3B • Practical Solutions to Tranceiver Integration—Continued

Th3B.2 • 13:30
Compact 8 Lane Integrated ROSA with Low Optical Loss 1:8 Optical De-multiplexer for 400GbE Application, Hiroshi Hara[1], Masanobu Kawamura[1], Fumihiro Nakajima[1], Hiroyasu Oomori[1]; [1]*Sumitomo Electric Industries, Ltd., Japan.* A compact 8 lane Integrated ROSA with low optical loss 1:8 Optical de-multiplexer is developed. The package size is 22.3 mm × 12.0 mm × 5.3 mm. The total optical insertion loss is estimated to be 1.0dB.

Th3B.1 • 13:45
Multi-wavelength 100Gb/s Silicon Photonics Based Transceiver with Silica mux/demux and MEMS-coupled InP Lasers, Lucas B. Soldano[1], Jay Kubicky[1], Dinh Ton[1]; [1]*Kaiam Corporation, Italy.* A QSFP-packaged 100Gb/s CWDM4 transceiver is demonstrated by a hybrid assembly of a commercial silicon photonics chip containing modulators and electronics, a silica based mux/demux PLC, and a MEMS carrier with four InP lasers.

Room 403B

Th3C • Optical Wireless Systems—Continued

Th3C.2 • 13:30
Free Space to Few-mode Fiber Coupling Efficiency Improvement with Adaptive Optics under Atmospheric Turbulence, Donghao Zheng[1], Yan Li[1], Beibei Li[1], Wei Li[1], Erhu Chen[2], Jian Wu[1]; [1]*Beijing Univ. of Posts & Telecom, China;* [2]*Beijing Insitute of Tracking & Telecom Technology, China.* Coupling efficiency between free-space-optical beam and few-mode-fibers with adaptive optics is investigated. The experimental results show that coupling efficiency of single-mode-fiber and few-mode-fiber is improved by over 10dB with adaptive optics under moderate turbulence.

Th3C.3 • 13:45
A 10m/10Gbps Underwater Wireless Laser Transmission System, Chun-Ming Ho[1], Chang-Kai Lu[2], Hai-Han Lu[1], Sheng-Jhe Huang[1], Ming-Te Cheng[1], Zih-Yi Yang[1], Xin-Yao Lin[1]; [1]*National Taipei Univ. of Technology, Taiwan;* [2]*Jinwen Univ. of Science and Technology, Taiwan.* A 10Gbps/5GHz 16-QAM-OFDM underwater wireless laser transmission system based on light injection and optoelectronic feedback techniques is proposed and demonstrated. Good bit error rate performance and constellation map are achieved over a 10-m underwater link.

Room 404AB

Th3D • DSP for Direct-Detection Systems—Continued

Th3D.3 • 13:30
1.55-µm EML-based DMT Transmission with Nonlinearity-aware Time Domain Super-Nyquist Image Induced Aliasing, Xuezhi Hong[1,3], Oskars Ozolins[2], Changjian Guo[3], Xiaodan Pang[2], Junwei Zhang[3], Jaime R. Navarro[2], Aditya Kakkar[1], Richard Schatz[1], Urban Westergren[1], Gunnar Jacobsen[2], Sergei Popov[1], Jiajia Chen[1,3]; [1]*School of ICT, KTH Royal Inst. of Technology, Sweden;* [2]*Networking and Transmission Laboratory, Acreo Swedish ICT AB, Sweden;* [3]*South China Academy of Advanced Optoelectronics, South China Normal Univ., China.* We experimentally demonstrate a DMT transmission system with 1.55-µm EML using nonlinearity-aware time domain super-Nyquist image induced aliasing. Compared with linear equalization, the capacity is improved by ~16.8%(33.1%) with proposed method for 4(40) km transmission.

Th3D.4 • 13:45
High-Spectral Efficiency DWDM transmission of 100-Gbit/s/lambda IM/DD Single Sideband-baseband-Nyquist-PAM8 Signals, Riu Hirai[1], Nobuhiko Kikuchi[1], Takayoshi Fukui[2]; [1]*Hitachi Ltd, Japan;* [2]*Oclaro Japan, Japan.* 107.52-Gbit/s SSB-Nyquist-PAM8 signaling is realized for the first time, achieving high-spectral efficiency of 4.30 bit/s/Hz (net SE 3.58), with intensity-modulation and polarization-independent conventional direct-detection and the longest 80-km SSMF transmission of PAM8 signals.

Room 406AB

Th3E • Waveguide Devices—Continued

Th3E.3 • 13:30
Inverse-designed Ultra-compact Star-crossings Based on PhC-like Subwavelength Structures, Luluzi Lu[1], Minming Zhang[1], Dongyu Li[1], Feiya Zhou[1], Weijie Chang[1], Jiang Tang[1], Deming Liu[1]; [1]*Huazhong Univ. of Sci. & Tech., China.* Inverse-designed star-crossings with 8 and 10 ports are proposed, with ultra-short coupling lengths of 5.28µm and 5.4µm respectively. Their measured ILs are less than 1.6dB and 2.4dB respectively over 60nm bandwidth centered 1550nm wavelength.

Th3E.4 • 13:45
Novel a-Si on Garnet Nonreciprocal Phase Shift Optical Isolator with TE Mode Operation, Eiichi Ishida[1], Kengo Miura[1], Yuya Shoji[2,1], Hideki Yokoi[3], Tetsuya Mizumoto[1,2], Nobuhiko Nishiyama[1,2], Shigehisa Arai[2,1]; [1]*Department of Electrical and Electronic Engineering, Tokyo Inst. of Technology, Japan;* [2]*Laboratory for Future Interdisciplinary Research of Science and Technology, Tokyo Inst. of Technology, Japan;* [3]*Department of Electronic Engineering, Shibaura Inst. of Technology, Japan.* A waveguide optical isolator operating in TE mode was demonstrated with an isolation of 17.9 dB. Amorphous silicon core along lateral walls of magneto-optical garnet was fabricated to induce nonreciprocal phase shift in TE mode.

Room 407

Th3F • Transmission Experiments and Modeling—Continued

Th3F.3 • 13:30 Invited
Information Rates and Post-FEC BER Prediction in Optical Fiber Communications, Alex Alvarado[1]; [1]*Department of Electrical Engineering, Eindhoven Univ. of Technology, Netherlands.* Information-theoretic metrics to predict the error probability of optical fiber communications systems with forward error correction (FEC) are reviewed. Soft-decision, hard-decision, binary and nonbinary FEC systems are considered. The numerical evaluation of these metrics in both simulations and experiments is also discussed. Ready-to-use closed-form approximations are presented.

Room 408A

Th3G • Power Efficient Optics—Continued

Th3G.2 • 13:30 Invited

Optimizing Power Consumption of a Coherent DSP for Metro and Data Center Interconnects, Theodor Kupfer[1], Andreas Bisplinghof[1], Thomas Duthel[1], Chris R. Fludger[1], Stefan Langenbach[1]; [1]*Cisco Optical GmbH, Germany.* We discuss several options for reducing power consumption of DSP used for coherent interfaces. These options are put in perspective with the needs of metro and data center interconnects for an overall optimized solution.

Room 408B

Th3H • Sensors for Telecom and Biomedical Applications—Continued

Th3H.2 • 13:30

3-Dimensional Soft Shape Sensor based on Dual-layer Orthogonal Fiber Bragg Grating Mesh, Li Xu[1], Jia Ge[1], Jay H. Patel[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* We present a soft silicone shape sensor for 3D surface shape measurement. The sensor is based on dual-layer fiber Bragg grating arrays with orthogonal mesh structure, which enable 3D bi-directional shape sensing.

Th3H.3 • 13:45

Colloidal Quantum Dots Based Integrated Fiber-optic Detector, Ao Yang[1], Xin Tian[1], Kecheng Yang[1], Junyu Li[1], Xiaochao Tan[1], Huan Liu[1], Haisheng Song[1], Jiang Tang[1], Fei Yi[1]; [1]*Huazhong Univ. of Science and Technology, China.* We report an integrated fiber-optic power meter by dip coating PbS colloidal quantum dots onto a pretreated specialty fiber. We measured the readout current at 1550nm as a function of the optical power, the bias voltage and the distance between the contact electrodes.

Room 409AB

Th3I • Novel Photonic Devices—Continued

Th3I.3 • 13:30

Thin-film Lithium Niobate on Silicon Mach-Zehnder Electrooptic Modulators up to 50 GHz, Ashutosh Rao[1], Aniket Patil[2], Payam Rabiei[2], Amirmahdi Honardoost[1], Richard DeSalvo[3], Arthur Paolella[3], Sasan Fathpour[1]; [1]*CREOL, Univ Central Florida, USA;* [2]*Partow Technologies LLC, USA;* [3]*Harris Corporation, USA.* Compact electrooptical modulators are demonstrated on thin-film lithium niobate on silicon with half-wave voltage-length product of 3.1 to 6.5 V.cm (from DC up to 50 GHz), 18 dB extinction ratio, and 33-GHz 3-dB electrical bandwidth.

Th3I.4 • 13:45

Power-efficient Electro-optical Single-tone Optical-frequency Shifter Using X-cut Y-Propagating Lithium Tantalate Waveguide Emulating a Rotating Half-wave-plate, Chuan Qin[1], Hongbo Lu[1], Andrea Pollick[2], Sri Sriram[2], S. J. Ben Yoo[1]; [1]*Univ. of California Davis, USA;* [2]*Srico Inc., USA.* We demonstrate a single-tone electro-optical frequency shifter based on an X-cut, Y-propagating Zn-diffused lithium tantalate waveguide emulating a rotating half-wave plate achieving 10 dB reduction in power consumption compared to Z-propagating LiNbO3 counterparts.

Room 410

Th3J • Nonlinear Mitigation Techniques—Continued

Th3J.3 • 13:30 Invited

Solitons and Nonlinear Fourier Transformation, Akihiro Maruta[1]; [1]*Osaka Univ., Japan.* The eigenvalue of the associated equation of the nonlinear Schrödinger equation which describes lightwave propagation in a nonlinear dispersive fiber, is invariable. This property can be applied to a nonlinearity-resilient modulation scheme and analysis of soliton collision induced rogue wave generation.

Room 411

Th3K • Network Survivability—Continued

Th3K.3 • 13:30 Invited

Network Fault Protection Performance Enhancement by using Elastic Optical Path, Hitoshi Takeshita[1], Takefumi Oguma[1], Shinsuke Fujisawa[1], Yuta Suzuki[1], Baku Yatabe[1], Akio Tajima[1]; [1]*NEC, Japan.* The challenges of enhancing protection performance by improving the spectral efficiency of elastic optical networks are studied. Novel optical filter configuration, signal equalization, and spectral bandwidth assignment technologies are shown to reduce the guard band.

Show Floor Programming

ONF: The Path Forward
ONF
12:00–13:30
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■ Market Watch Panel VI: SDN & Optics-What is the Business Case?
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Room 402AB

Th3A • Optical Technologies for Radio Access Network I—Continued

Th3A.2 • 14:00
Real Time Demonstration of the Transport of Ethernet Fronthaul Based on vRAN in Optical Access Networks, Zakaria Tayq[1,2], Luiz Anet Neto[1], Bertrand le guyader[1], Arnaud De Lannoy[1], Maha Chouaref[1], Christelle Aupetit-Berthelemot[2], Mahesh Nelamangala Anjanappa [3], Si Nguyen [3], Kuntal Chowdhury[3], Philippe Chanclou[1]; [1]*Orange, France;* [2]*Xlim, France;* [3]*Altiostar, USA.* A real time transmission of the new functional split fronthaul interface over PtP and PtMP optical access networks is experimentally demonstrated. The data traffic evolution is investigated as well as the impact of latency and packet loss.

Th3A.3 • 14:15
Mobile-PON: A High-efficiency Low-latency Mobile Fronthaul Based on Functional Split and TDM-PON with a Unified Scheduler, Siyu Zhou[1,2], Xiang Liu[2], Frank Effenberger[2], Jonathan Chao[1]; [1]*New York Univ., USA;* [2]*Futurewei Technologies, Huawei R&D, USA.* We propose and numerically demonstrate a novel mobile fronthaul architecture based on functional-split and TDM-PON with a unified mobile-PON scheduler, eliminating the need for PON scheduling and increasing the bandwidth efficiency by ~10× over CPRI.

Room 403A

Th3B • Practical Solutions to Tranceiver Integration—Continued

Th3B.4 • 14:00 Invited
Emerging Integrated Devices for Coherent Transmission - Digitally Assisted Analog Optics, Takashi Saida[1]; [1]*NTT Device Innovation Center, NTT Corporation, Japan.* Digital signal processing has been widening our choice of material systems for optical integration platforms. We review recent work on digital coherent optics, and show our results for high-speed InP modulators and ultra-compact Si-based coherent-optical-subassemblies.

Room 403B

Th3C • Optical Wireless Systems—Continued

Th3C.4 • 14:00 Invited
Trends and Progress in Optical Wireless Communications, Steve Hranilovic[1]; [1]*Electrical & Computer Engineering, McMaster Univ., Canada.* Free-space optical communications has been of interest for many years, however, there remain theoretical and algorithmic challenges in its implementation. In this paper, I describe recent trends and results from our research in advancing the modelling and information theory for free-space optical channels in space and in scattering environments.

Room 404AB

Th3D • DSP for Direct-Detection Systems—Continued

Th3D.5 • 14:00 Invited
IM/DD Transmission Techniques for Emerging 5G Fronthaul, DCI and Metro Applications, Gordon N. Liu[1], Liang Zhang[1], Tianjian Zuo[1], Qiang Zhang[1], Jie Zhou[1], Enbo Zhou[1]; [1]*Huawei Technologies Co Ltd, China.* Our IM/DD techniques investigations are reviewed. Poly-binary is low complexity and good for the 5G fronthaul and DCI scenarios while DMT is suitable for metro transmission due to better bandwidth utilization and higher dispersion tolerance.

Room 406AB

Th3E • Waveguide Devices—Continued

Th3E.5 • 14:00 Tutorial
Passive Waveguide Device Technologies - Building Block of Functionality and Integration, Yasuo Kokubun[1]; [1]*Yokohama National Univ., Japan.* Passive waveguide devices and related fabrication technologies are reviewed from the view point of functionality which is related to material and operating principle, and the possible scheme of integration.

Yasuo Kokubun received his Dr. Eng. degree from Tokyo Institute of Technology, Japan, in 1980. After he worked as a research associate from 1980 to 1983, he joined the Yokohama National University as an associate professor in 1983, and is now a professor. From 1984 to 1985 he was with AT&T Bell Laboratories, NJ. He served as the Dean of the Faculty of Engineering from 2006 to 2009 and as the Vice-President from 2009 to 2015. Professor Kokubun is a Fellow of IEEE, the Japan Society of Applied Physics, the Institute of Electrical, Information and Communication Engineers, and a member of OSA.

Room 407

Th3F • Transmission Experiments and Modeling—Continued

Th3F.4 • 14:00
10 Tb/s Self-Homodyne 64-QAM Superchannel Transmission with 4% Spectral Overhead, Mikael Mazur[1], Abel Lorences-Riesgo[1], Magnus Karlsson[1], Peter A. Andrekson[1]; [1]*Chalmers Univ. of Technology, Sweden.* We use a 10nm frequency comb to transmit a 10Tb/s 50x20GBaud PM-64QAM superchannel over 80km SMF. Using two unmodulated carriers we regenerate a phase locked receiver comb, enabling self-homodyne detection with record-low spectral overhead.

Th3F.5 • 14:15
42.3-Tbit/s, 18-Gbaud 64QAM WDM Coherent Transmission of 160 km over Full C-band using an Injection Locking Technique with a Spectral Efficiency of 9 bit/s/Hz, Takashi Kan[1], Keisuke Kasai[1], Masato Yoshida[1], Masataka Nakazawa[1]; [1]*Research Inst. of Electrical Communication, Tohoku Univ., Japan.* We demonstrate a 235-channel WDM 18-Gbaud 64QAM coherent transmission of 160 km over the full C-band with a new homodyne detection technique using injection locking. 42.3-Tbit/s data were successfully transmitted with a 9-bit/s/Hz spectral efficiency.

Room 408A

Th3G • Power Efficient Optics—Continued

Th3G.3 • 14:00
Ultra-low Power SiGe Driver-IC for high-speed Electroabsorption Modulated DFB Lasers, Jung Han Choi[1], Marko Gruner[1], Heinz-Gunter Bach[1], Michael Theurer[1], Ute Troppenz[1], Martin Möhrle[1], Martin Schell[1]; [1]*Fraunhofer-Heinrich-Hertz Inst., Germany.* A small footprint electroabsorption modulated DFB laser TOSA with an ultra-low power SiGe driver with a power efficiency of 3.59 pJ/bit is demonstrated. Good optical eye openings up to 56 GBd NRZ and 64 Gb/s PAM-4 were obtained. The novel SiGe EML driver consumes 84 mW only.

Th3G.4 • 14:15
A 40-Gb/s 1.5-μm VCSEL Link with a Low-power SiGe VCSEL Driver and TIA Operated at 2.5 V, Wouter C. Soenen[1], Bart Moeneclaey[1], Xin Yin[1], Silvia Spiga[2], Markus-Christian Amann[2], Christian Neumeyr[3], Markus Ortsiefer[3], Elad Mentovich[4], Dimitris Apostolopoulos[5], Paraskevas Bakopoulos[5], Johan Bauwelinck[1]; [1]*IDlab Dep. INTEC, Ghent Univ.-imec, Belgium;* [2]*Walter Schottky Inst., Technische Universität München, Germany;* [3]*Vertilas GmbH, Germany;* [4]*Mellanox Technologies, Israel;* [5]*Dep. Electrical & Computer Engineering, NTUA, Greece.* VCSEL links typically require multiple supply voltages for high-speed and low-power operation. We report a 40-Gb/s 1.5-μm VCSEL link achieving 8.7 pJ/bit of energy efficiency with a 0.13-μm SiGe VCSEL driver and TIA operated at 2.5 V.

Room 408B

Th3H • Sensors for Telecom and Biomedical Applications—Continued

Th3H.4 • 14:00
Ghost Imaging using Integrated Optical Phased Array, Kento Komatsu[1], Yasuyuki Ozeki[1], Yoshiaki Nakano[1], Takuo Tanemura[1]; [1]*The Univerisity of Tokyo, Japan.* We propose inherently robust and low-cost imaging scheme based on integrated optical-phased array (OPA) driven by random control patterns. A proof-of-concept monolithic InP-based OPA is fabricated to demonstrate high-speed one-dimensional scanning without need for time-consuming calibration.

Th3H.5 • 14:15
Compact Spectrometer Based on a Silicon Multimode Waveguide, Molly Piels[1], Darko Zibar[1]; [1]*Technical Univ. of Denmark, Denmark.* A multimode waveguide spectrometer with 4 GHz resolution, 250 GHz usable range, and a 1.6 mm x 2.1 mm footprint is demonstrated. The operating range is greatly extended by including distinct mode-exciting elements on chip.

Room 409AB

Th3I • Novel Photonic Devices—Continued

Th3I.5 • 14:00
Optical OFDM Transmission using Low-Noise Kerr Frequency Comb Generated in On-Chip Microresonator, Heng Zhou[1], Zengjie Zhang[1], Jing Zhang[1], Xingwen Yi[1], Shu-Wei Huang[2], Hao Liu[2], Mingbin Yu[3], D. L. Kwong[3], Kun Qiu[1], Chee Wei Wong[2]; [1]*UESTC, China;* [2]*UCLA, USA;* [3]*IME, Singapore.* We demonstrate high-bitrate coherent optical OFDM transmission utilizing low-noise Kerr frequency comb as multi-channel laser source. 4QAM-OFDM data with total bitrate of 136.0 Gb/s are successfully transmitted over a 100 km fiber link.

Th3I.6 • 14:15
Correlation Properties of the Phase Noise Between Pairs of Lines in a Quantum-Dot Optical Frequency Comb Source, Kristian Zanette[1], John C. Cartledge[1], Maurice O'Sullivan[2]; [1]*Queen's Univ. at Kingston, Canada;* [2]*Ciena Corp., Canada.* The correlation properties of the phase noise between pairs of comb lines are determined for a quantum-dot frequency comb source laser through simultaneous measurements of the in-phase and quadrature components for each of the comb lines.

Room 410

Th3J • Nonlinear Mitigation Techniques—Continued

Th3J.4 • 14:00
Experimental Investigation of Nonlinearity Mitigation Properties of a Hybrid Distributed Raman/Phase-sensitive Amplifier Link, Henrik Eliasson[1], Samuel L. Olsson[1], Magnus Karlsson[1], Peter A. Andrekson[1]; [1]*Chalmers Univ. of Technology, Sweden.* The first experimental demonstration of a long-haul transmission system utilizing both phase-sensitive amplifiers and distributed Raman amplification is presented. The impact of the span power map in a nonlinear transmission regime is investigated.

Th3J.5 • 14:15
Demonstration of Tunable Mitigation of Interchannel Interference of Spectrally Overlapped 16-QAM/QPSK Data Channels using Wave Mixing of Delayed Copies, Amirhossein Mohajerin Ariaei[1], Morteza Ziyadi[1], Yinwen Cao[1], Ahmed Almaiman[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Changjing Bao[1], Peicheng Liao[1], Bishara Shamee[1], Joseph Touch[2], Moshe Tur[3], Carsten Langrock[4], Martin Fejer[4], Alan Willner[1]; [1]*Univ. of Southern California (USC), USA;* [2]*Information Sciences Inst., USA;* [3]*Tel Aviv Univ., Israel;* [4]*Stanford Univ., USA.* A tunable all-optical inter-channel interference mitigation method is proposed for an overlapped channel system that avoids the need for multi-channel detection. We experimentally demonstrate the system performance improvement for 16QAM and QPSK overlapped channels for both 20/25 Gbaud data and under different channel spacing conditions.

Room 411

Th3K • Network Survivability—Continued

Th3K.4 • 14:00
QoS-Aware Protection in Flexgrid Optical Networks, Patricia Layec[1], Arnaud Dupas[1], Arnaud Bisson[2], Sébastien Bigo[1]; [1]*Nokia Bell Labs France, France;* [2]*Nokia, France.* We propose a protection scenario for flexgrid networks whereby premium traffic survives cuts with just-enough bandwidth. We demonstrate a novel two-wavelength Baudrate-switchable optical transmitter reconfiguring in <2.8ms. We compute typical spectral usage boosted by 80%.

Th3K.5 • 14:15
Highly Reliable Large-scale Optical Cross-connect Architecture Utilizing MxM Wavelength-selective Switches, Shuhei Yamakami[1], Masaki Niwa[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; [1]*Nagoya Univ., Japan.* We propose a highly reliable and large-scale OXC architecture that consists of MxM WSSs. The proposed scheme can drastically reduce the annual down-time of optical paths stemming from WSS failures while retaining excellent cost-effectiveness.

Show Floor Programming

Technological Evolution of Next Generation Connect
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Transport SDN: Commercial Applications, Solutions & Innovation Areas
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Room 402AB

Th3A • Optical Technologies for Radio Access Network I—Continued

Th3A.4 • 14:30
Efficient Mobile Fronthaul Serving Massive MIMO New Radio Services Using Single-IF with Sample-wise TDM for Reduced RRH Complexity and Ultra-low Latency, Feng Lu[1], Mu Xu[1], Lin Cheng[1], Jing Wang[1], Shuyi Shen[1], Charles Su[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Optical Communications & Networking, JABIL, USA.* We firstly propose an efficient-mobile-fronthaul with single-intermediate-frequency and sample-wise TDM for new-radio massive MIMO applications. It is simple in architecture/DSP, spectral-efficient, and has low-latency/high-performance. Bi-directional new-radio/LTE-A mobile-fronthaul with 32×32 MIMO and 2-RRHs are experimentally demonstrated.

Th3A.5 • 14:45
Demonstration of Bandwidth Efficient and Low-complexity Mobile Fronthaul Architecture via CDM-Based Digital Channel Aggregation, Li Haibo[2,1], Qi Yang[1], Ming Luo[1,2], Rong Hu[1], Peng Jiang[3], Yongpiao Liu[3], Xiang Li[1], Shaohua Yu[2,1]; [1]*Lab Optical Comm. Tech & Networks, China;* [2]*Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China;* [3]*Wuhan Hongxin Telecommunication Technologies Co., LTD, China.* We experimentally demonstrate a bandwidth-efficient and low-complexity mobile fronthaul architecture, in which 48 20-MHz LTE signals are aggregated via CDM in single IM-DD channel with an average EVM of ~3.6% after 5-km transmission over SSMF.

Room 403A

Th3B • Practical Solutions to Tranceiver Integration—Continued

Th3B.5 • 14:30 Invited
Multi-Tb/s Extended C-Band Tunable Optical Engines Utilizing InP Coherent Photonic Integrated Circuits Operating at 44Gbaud, 16-QAM, Vikrant Lal[1]; [1]*Infinera Corporation, USA.* We report on the development of optical engines based upon multi-channel Extended C-Band tunable InP PICs operating up to 44Gbaud, 16-QAM for a total capacity of 4.9 Tb/s.

Room 403B

Th3C • Optical Wireless Systems—Continued

Th3C.5 • 14:30
A Dual-infrared-transmitter Optical Wireless Based Indoor User Localization System with High Accuracy, Ke Wang[1], Tingting Song[2,3], Tian Liang[2], Ampalavanapillai Nirmalathas[2], Christina Lim[2], Kamal Alameh[4], Efstratios Skafidas[2,5]; [1]*School of Engineering, RMIT Univ., Australia;* [2]*Department of Electrical and Electronic Engineering, The Univ. of Melbourne, Australia;* [3]*National Key Laboratory of Tunable Laser Technology, Harbin Inst. of Technology, China;* [4]*Electron Science Research Inst. (ESRI), Edith Cowan Univ., Australia;* [5]*Centre for Neural Engineering (CfNE), The Univ. of Melbourne, Australia.* A dual-infrared-transmitter optical wireless based indoor localization system with background light power estimation capability is proposed and experimentally demonstrated. Results show that the proposed system can attain an average localization accuracy of around 3.2 cm.

Room 404AB

Th3D • DSP for Direct-Detection Systems—Continued

Th3D.6 • 14:30
300-km Transmission of Dispersion Pre-compensated PAM4 Using Direct Modulation and Direct Detection, Zhixin Liu[1,2], Graham Hesketh[1], Brian Kelly[3], John O'Caroll[3], Richard Phelan[3], David J. Richardson[1], Radan Slavík[1]; [1]*Opoelectronics Research Centre, Univ. of Southampton, UK;* [2]*Optical Networks Group, Electronic & Electrical Engineering, Univ. College London, UK;* [3]*Eblana Photonics, Ireland.* 20-Gbit/s PAM4 signal was generated by directly modulating two injection-locked Fabry-Perot lasers. Our transmitter can control the full field of the optical signal and achieved error-free transmission over 300-km SMF-28.

Th3D.7 • 14:45
On the Impact of Tomlinson-Harashima Precoding in Optical PAM Transmissions for Intra-DCN Communication, Kengo Matsumoto[1]; [1]*Graduate School of Engineering, Osaka Un, Japan.* Anti-chromatic dispersion capability of the Tomlinson-Harashima precoding in optical PAM transmissions is investigated analytically and experimentally. The use of THP enables nearly two orders of magnitude BER performance improvement in a 30-Gbaud PAM-4 transmission over a 20-km SSMF.

Room 406AB

Th3E • Waveguide Devices—Continued

Room 407

Th3F • Transmission Experiments and Modeling—Continued

Th3F.6 • 14:30
WDM Transmission using Quantum-dash Mode-locked Laser Diodes as Multi-wavelength Source and Local Oscillator, Juned Kemal[1], Pablo Marin-Palomo[1], Vivek Panapakkam[3], Philipp Trocha[1], Stefan Wolf[1], Kamel Merghem[3], Francois Lelarge[4], Abderrahim Ramdane[3], Sebastian Randel[1], Wolfgang Freude[1,2], Christian Koos[1,2]; [1]*Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology (KIT), Germany;* [2]*Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany;* [3]*Laboratoire de Photonique et Nanostructures, CNRS UPR20, France;* [4]*III-V Lab, France.* We demonstrate coherent WDM transmission using a pair of quantum-dash modelocked laser-diodes – one to generate a multitude of optical carriers, and another to generate a multitude of LO tones. We transmit a line rate of 4 Tbit/s (23×45 GBd PDM-QPSK) over 75 km.

15:00–15:30 Coffee Break, *400 Foyer; Exhibit Hall*

Room 408A	Room 408B	Room 409AB	Room 410	Room 411

Room 408A

Th3G • Power Efficient Optics—Continued

Th3G.5 • 14:30 Invited

Use of Embedded Optics to Decrease Power Consumption in IO Dense Systems, Rob Stone[1]; [1]*Broadcom Corporation, USA.* Use of embedded optical modules in highly IO dense systems such as network switches or routers has the potential to deliver solutions with overall lower power consumption. We consider this from a historical perspective and consider implications of these new architectures, with SerDes power savings of 50% possible by moving to embedded modules.

Room 408B

Th3H • Sensors for Telecom and Biomedical Applications—Continued

Th3H.6 • 14:30 Invited

Applying Fiber Optic and Telecom Technologies for Multiphoton Biomedical Imaging, Chris Xu[1]; [1]*Cornell Univ., USA.* The main characteristics of the pulsed excitation source, such as wavelength, pulse energy, and repetition rate, for multiphoton biomedical imaging are discussed. Recent advances in these sources using fiber optic and telecom techniques are presented.

Room 409AB

Th3I • Novel Photonic Devices—Continued

Th3I.7 • 14:30

Quantum Dot Lasers Grown on (001) Si Substrate for Integration with Amorphous Si Waveguides, Yating Wan[1], Qiang Li[1], Alan Y. Liu[2], Yu Geng[1], Justin Norman[2], Weng Chow[3], Arthur C. Gossard[2], John E. Bowers[2], Evelyn Hu[4], Kei M. Lau[1]; [1]*HKUST, Hong Kong;* [2]*UCSB, USA;* [3]*Sandia National Laboratories, USA;* [4]*Harvard Univ., USA.* Heteroepitaxially grown InAs quantum dot lasers were demonstrated on (001) Si under continuous-wave optical pumping with low thresholds (down to 35 μW). The feasibility of integrating active and passive devices through electrical injection was analyzed.

Th3I.8 • 14:45 Top Scored

Single-λ 312 Gb/s Discrete Multitone Interconnect of Mode-division Multiplexed Network with a Multicore Fiber, Xinru Wu[1], Chaoran Huang[1], Ke Xu[2], Wen Zhou[1], Chester Shu[1], Hon Ki Tsang[1]; [1]*The Chinese Univ. of Hong Kong, USA;* [2]*Harbin Inst. of Technology, Shenzhen Graduate School, China.* We demonstrate a single wavelength discrete multi-tone interconnect with on-chip mode-division multiplexing and off-chip multicore fiber. A gross data rate of 312 Gb/s is achieved under HD-FEC limit of 3.8×10^{-3}.

Room 410

Room 411

Th3K • Network Survivability—Continued

Th3K.6 • 14:30

Correlated-failure-aware VON mapping, Jian Kong[1], Nannan Wang[1], Jason P. Jue[1], Inwoong Kim[2], Xi Wang[2], Qiong Zhang[2], Hakki C. Cankaya[3], Weisheng Xie[3], Tadashi Ikeuchi[2]; [1]*The Univ. of Texas, Dallas, USA;* [2]*Fujitsu Laboratories of America, USA;* [3]*Fujitsu Network Communications, USA.* We analyze the availability of virtual optical networks (VONs) mapped over a physical optical network with correlated failures, and we propose a correlated-failure-aware VON mapping algorithm to support high availability while reducing the penalty cost and total link cost.

Thank you for attending OFC. Look for your post-conference survey via email and let us know your thoughts on the program.

15:00–15:30 Coffee Break, *400 Foyer; Exhibit Hall*

Show Floor Programming

Transport SDN: Commercial Applications, Solutions & Innovation Areas
Huawei
15:00–16:00
For more details, see page 45

Room 402AB

15:30–17:15
Th4A • Optical Amplifiers
Presider: Maxim Bolshtyansky; TE SubCom, USA

Th4A.1 • 15:30
20dB Net-Gain Fiber Optical Parametric Amplification of 18x120Gb/s Polarization-Multiplexed Signals, Marc F. Stephens[1], Vladimir Gordienko[1], Nick J. Doran[1]; [1]*Aston Univ., UK.* We report the amplification and characterization of 18x120Gb/s (2.16Tb/s) polarization-division multiplexed WDM signals using a polarization-insensitive single-pump FOPA, whilst achieving fiber-to-fiber net signal gains of 10-20dB over >2THz gain bandwidth.

Th4A.2 • 15:45
Experimental Demonstration of Raman-Assisted Phase Sensitive Amplifier with Reduced ASE Noise Level and More than 25dB Net Gain, Yinwen Cao[1], Ahmed Almaiman[1], Youichi Akasaka[2], Fatemeh Alishahi[1], Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Changjing Bao[1], Peicheng Liao[1], Ahmad Fallahpour[1], Bishara Shamee[1], Tadashi Ikeuchi[2], Shigehiro Takasaka[3], ryuichi Sugizaki[3], Joseph Touch[1,5], Moshe Tur[4], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Fujitsu Laboratories of America,, USA;* [3]*Furukawa Electric Co. LTD, Japan;* [4]*Tel Aviv Univ., Israel;* [5]*Information Sciences Inst., USA.* The performance of a black-box Raman-assisted PSA amplifier is experimentally evaluated. In a 20-Gbaud QPSK system, more than 25dB net gain is demonstrated. Comparing to a 4dB-noise-figure EDFA, ~1.5dB ASE noise level reduction is observed.

Room 403A

15:30–17:30
Th4B • Optical Technologies for Radio Access Network II
Presider: Björn Skubic; Ericsson, Sweden

Th4B.1 • 15:30 Invited
Mobile Fronthaul Architecture and Technologies: a RAN Equipment Assessment, Philippe Chanclou[1], Luiz Anet Neto[1], Kamil Grzybowski[1], Zakaria tayq[1], Fabienne Saliou[1], Naveena Genay[1]; [1]*Orange Labs, France.* Optical fiber is the required technology for Radio Access Network (RAN) backhaul and fronthaul. We report the evolution of RAN equipment including the advent of virtualization and an investigation of the required architecture and optical access technologies.

Room 403B

15:30–17:30
Th4C • DSP for Coherent Systems
Presider: David Millar; Mitsubishi Electric Research Laboratories, USA

Th4C.1 • 15:30
Discrete Cosine Transform Based Pilot-aided Phase Noise Estimation for High-order QAM Coherent Optical Systems, Chen Zhu[1], Noriaki Kaneda[1]; [1]*Bell Laboratories, Nokia, USA.* We present a low-complexity, feed-forward pilot-aided phase noise estimation based on discrete cosine transform low pass filter model for high-order QAM signals. The proposed scheme is experimentally demonstrated in 11-Gbaud PDM-128-QAM and PDM-256-QAM systems.

Th4C.2 • 15:45
Improved Linewidth Tolerant Carrier Phase Recovery Based on Polar MAP Metric Estimate, Marti Sales Llopis[1], Md Saifuddin Faruk[1], Seb J. Savory[1]; [1]*Univ. of Cambridge, UK.* A new metric that analytically approximates the maximum a posteriori (MAP) solution is presented. Used with a decision-directed carrier phase estimation algorithm, the linewidth tolerance exceeds the limits achieved when using the conventional Euclidean distance.

Room 404AB

15:30–17:15
Th4D • Submarine Transmission Systems
Presider: Dmitri Foursa; TE SubCom, USA

Th4D.1 • 15:30
Unrepeatered WDM Transmission of Single-carrier 400G (66-GBd PDM-16QAM) over 403 km, João Januario[1,2], Sandro Rossi[1], José H. Junior[1], Andrea Chiuchiarelli[1], André Souza[1], Alexandre Felipe[1], Aldário Bordonalli[2], Sergejs Makovejs[3], Juliano Oliveira[1], Jacklyn Reis[1]; [1]*Division of Optical Technologies, CPqD, Brazil;* [2]*School of Electrical and Computer Engineering, State Univ. of Campinas, Brazil;* [3]*Corning Incorporated, USA.* This paper demonstrates a record single-carrier 400 Gb/s unrepeatered WDM transmission over 403 km with 64.7-dB span loss. Using optimized amplification map with 1st-order Raman amplifiers, ROPAs, and 112/150-um2 Aeff fibers, error-free transmission is demonstrated for 16 x 66 GBd-16QAM.

Th4D.2 • 15:45 Top Scored
24 Tb/s Unrepeatered C-Band Transmission of Real-Time Processed 200 Gb/s PDM-16-QAM over 349 km, Hans Bissessur[1], Christian Bastide[1], Sophie Etienne[1], Sebastien Dupont[1]; [1]*Alcatel-Lucent Submarine Networks, France.* We present a record unrepeatered experiment with 120 PDM-16-QAM channels at 200 Gb/s over 349.2 km, applying a high-power booster and a ROPA with third-order Raman pumping from the receiver end.

Room 407

15:30–17:30
Th4E • Novel Applications of Microwave Photonics
Presider: Richard DeSalvo; Harris Corporation, USA

Th4E.1 • 15:30 Invited
LIGO Experiments, Eric Gustafsson[1]; [1]*California Inst. of Technology, USA.* This talk will be about the first two detections of Gravitational Waves by the LIGO Observatory detectors and will include a brief description of several of the Advanced LIGO detector optical and laser subsystems

Room 408A

15:30–17:30
Th4F • Network Design
Presider: Qiong Zhang; Fujitsu Laboratories of America Inc, USA

Th4F.1 • 15:30 Invited

Techniques for Agile Network Re-Optimization Following Traffic Fluctuations, Tomohiro Hashiguchi[1], Kazuyuki Tajima[1], Yutaka Takita[1], Toru Katagiri[1]; [1]*Fujitsu Limited, Japan*. We study the cost effectiveness of network re-optimization for both short-term traffic variations and long-term traffic growth. The presented re-optimization operation is effective in reducing equipment cost while curbing the increase of operational cost.

Room 408B

15:30–17:30
Th4G • Laser Transmitters
Presider: Thomas Schrans; Rockley Photonics, USA

Th4G.1 • 15:30 Top Scored

4 x 56 Gb/s High Output Power Electroabsorption Modulated Laser Array, Michael A. Theurer[1], Martin Möhrle[1], Ute Troppenz[1], Heinz-Gunter Bach[1], Ariane Sigmund[1], Georges Przyrembel[1], Martin Schell[1]; [1]*Fraunhofer Heinrich Hertz Inst., Germany*. We demonstrate a high output power EML-array operating at 4 x 56 Gb/s NRZ. On chip RF transmission lines enable flexibility for packaging and driver integration. A common active layer structure allows for cost effective fabrication.

Th4G.2 • 15:45

56 Gb/s Electro-Absorption Modulation of a Heterogeneously Integrated InP-on-Si DFB Laser Diode, Amin Abbasi[2], Bart Moeneclaey[1], Jochem Verbist[1], Xin Yin[1], Johan Bauwelinck[1], Gunther Roelkens[2], Geert Morthier[2]; [1]*INTEC, Ghent Univ. - imec, IDLab, Belgium;* [2]*INTEC, Ghent Univ.-Imec, Belgium.* Electro-absorption modulation of a heterogeneously integrated InP/Si DFB laser is demonstrated by reverse biasing the InP tapers, used to couple the light between the InP and the Si waveguides. Modulation at 56 Gb/s is demonstrated.

Room 409AB

15:30–17:15
Th4H • Characterization of SDM Fibers
Presider: Axel Schulzgen; Univ. of Central Florida, USA

Th4H.1 • 15:30 Invited

Creation, Propagation and Detection of Vector Modes for Optical Communication, Andrew Forbes[1]; [1]*Univ. of Witwatersrand, South Africa*. Vector modes are the natural modes of many fibre systems and have the capacity to be used as a modal set for optical communication. Here we outline recent progress in the creation and detection of these modes, and use the tools to study their propagation in free space and fibre.

Room 410

15:30–17:15
Th4I • Coherent Optical Signal Processing
Presider: Michael Vasilyev; Univ. of Texas at Arlington, USA

Th4I.1 • 15:30

Bit-rate-transparent Optical RZ-to-NRZ Format Conversion Based on Linear Spectral Phase Filtering, Reza Maram[1], Francesco Da Ros[2], Pengyu Guan[2], Kasper M. Røge[2], Michael Galili[2], Leif K. Oxenlowe[2], Jose Azana[1]; [1]*INRS-Energie Materiaux et Telecom, Canada;* [2]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark*. We propose a novel and strikingly simple design for all-optical bit-rate-transparent RZ-to-NRZ conversion based on optical phase filtering. The proposed concept is experimentally validated through format conversion of a 640 Gbit/s coherent RZ signal to NRZ signal.

Th4I.2 • 15:45

Enhanced Self-coherent Optical OFDM using Stimulated Brillouin Scattering, Elias Giacoumidis[1], Eric Magi[1], Amol Choudary[1], David Marpaung[1], Bill Corcoran[2], Mark D. Pelusi[1], Benjamin Eggleton[1]; [1]*CUDOS, Univ. of Sydney, Australia;* [2]*Monash Univ., Australia*. We experimentally demonstrate the first self-coherent optical OFDM (SCO-OFDM) based on received optical carrier amplification by stimulated Brillouin scattering. Compared to the conventional CO-OFDM, SCO-OFDM has similar performance with 9.6-Gb/s (16-QAM) enhanced data rate.

Show Floor Programming

Transport SDN: Commercial Applications, Solutions & Innovation Areas
Huawei
15:00–16:00
For more details, see page 45

Room 402AB

Th4A • Optical Amplifiers—Continued

Th4A.3 • 16:00
Second-order Few-mode Distributed Raman Amplifier for Mode-division Multiplexing Transmission, Jiaxiong Li[1], Jiangbing Du[1], Lin Ma[1], Ming-Jun Li[2], Zuyuan He[1]; *[1]Shanghai Jiao Tong Univ., China; [2]Corning, USA.* We first experimentally demonstrate a second-order few-mode distributed Raman amplifier with 4 dB mode-equalized gain. The noise figure improvement of the LP_{01} and LP_{11} modes are respectively 1.1 dB and 0.9 dB compared with first-order Raman amplification scheme.

Th4A.4 • 16:15
Ultra-low DMG Multimode EDFA, Zeinab Sanjabi Eznaveh[1], Nicolas K. Fontaine[2], Haoshuo Chen[2], Jose Antonio-Lopez[1], Juan Carlos Alvarado Zacarias[1], Bin Huang[1], Adrian Amezcua-Correa[3], Cedric Gonent[3], Pierre Sillard[3], Li Guifang[1], Axel Schulzgen[1], Roland Ryf[2], Rodrigo Amezcua Correa[1]; *[1]CREOL, Univ. of Central Florida, USA; [2]Nokia Bell Labs, USA; [3]PRYSMIAN, Italy.* We demonstrate amplification in a multimode cladding-pumped fiber amplifier supporting 14 spatial modes. Using a large core EDF, we obtain <0.5dB differential modal gain, 16dB gain, and 25dBm output power across the C-band.

Th4A.5 • 16:30
Optical Amplifier Based on a 7-core Fiber for Telecommunication Satellite Purposes, Marta Filipowicz[1], Marek Napierala[1], Michal Murawski[2], Lukasz Ostrowski[2], Lukasz Szostkiewicz[2], Pawel Mergo[3], M. Kechagias[4], J. Farzana[4], Leo Stampoulidis[4], E. Kehayas[4], Tomasz Nasilowski[1]; *[1]InPhoTech Sp. z o.o., Poland; [2]Polish Centre For Photonics and Fiber Optics, Poland; [3]Faculty of Chemistry, Laboratory of Optical Fiber Technology, Maria Curie-Sklodowska Univ., Poland; [4]Gooch & Housego, UK.* We present a 7-core radiation hardened optical fiber amplifier for application in telecommunication satellites. The amplifier is part of a solution that aims to overcome bottleneck problems associated with saltellites, such as size and weight reduction together with information capacity growth.

Room 403A

Th4B • Optical Technologies for Radio Access Network II—Continued

Th4B.2 • 16:00
Demonstration of a FPGA-Based CPRI-over-Ethernet Real-Time System Achieving 120 Gb/s Throughput over a 10-km SSMF Link with 16 Bi-Directional 10GE Connections, Sharief Megeed[1], Xiang Liu[1], Huaiyu Zeng[1], Frank Effenberger[1]; *[1]Futurewei Technologies, USA.* We experimentally demonstrate a real-time CPRI-over-Ethernet system for mobile fronthaul using four Xilinx Virtex-7 FPGAs. Error-free transmission over a 10-km SSMF link has been achieved with a total throughput of 120 Gb/s and a round-trip processing latency of <20 µs.

Th4B.3 • 16:15
Novel Scheme of PTP Packets Distribution over TDM-PON for Time Synchronization among Mobile Base Stations, Kazuki Tanaka[1], Naoya Nishi[1], Ryo Inohara[1], Kosuke Nishimura[1]; *[1]KDDI Research, Inc., Japan.* We propose a precise time synchronization technique for mobile base stations by a novel PTP packets distribution scheme over TDM-PON and experimentally demonstrate the effectiveness achieving the time accuracy within 13 ns for 72 hours.

Th4B.4 • 16:30 Invited
Technologies for Convergence of Fixed and Mobile Access: An Operator's Perspective, Carsten Behrens[1], Erik Weis[1], Dirk Breuer[1]; *[1]Deutsche Telekom AG Laboratories, Germany.* Carriers face the challenge to integrate their fixed and mobile infrastructures. In this paper we show results of techno-economic assessment relating to structural convergence and discuss FMC-architectures with respect to functional convergence.

Room 403B

Th4C • DSP for Coherent Systems—Continued

Th4C.3 • 16:00
Extended Kalman Filter for Carrier Phase Recovery in Optical Filter Bank Multicarrier Offset QAM Systems, Trung-Hien Nguyen[1], Francois Rottenberg[2], Simon-Pierre Gorza[1], Jerome Louveaux[2], Francois Horlin[1]; *[1]OPERA department, Universite Libre de Bruxelles, Belgium; [2]ICTEAM Inst., Universite catholique de Louvain, Belgium.* We investigate the carrier phase recovery using extended Kalman filter in optical filter bank multicarrier offset-QAM systems. The proposed method is of low complexity and its performance is comparable to the state-of-the-art BPS method.

Th4C.4 • 16:15
Achievable Information Rates of Square MQAM Modulation Formats after Carrier Phase Estimation, Milen Paskov[1], Domanic Lavery[1], Alex Alvarado[1], Polina Bayvel[1]; *[1]Univ. College London, UK.* The performance of a pragmatic carrier phase estimation algorithm is evaluated over a range of SNRs. The optimal SNR regions for MQAM are compared to an AWGN channel observing gains of up to 40% in throughput.

Th4C.5 • 16:30 Invited
Signal Processing for Spectrally Efficient Systems, Gabriel Charlet[1], Amirhossein Ghazisaeidi[1], Rafael Rios-Müller[1], Jeremie Renaudier[1], Laurent Schmalen[1]; *[1]Nokia Bell Labs, France.* Signal processing for spectrally efficient coherent systems will be presented, including phase estimation, timing estimation, forward error correction coding and nonlinear mitigation techniques which are particularly challenging for high order constellations.

Room 404AB

Th4D • Submarine Transmission Systems—Continued

Th4D.3 • 16:00 Invited
Advanced Technologies for High Capacity Transoceanic Distance Transmission Systems, Jin-Xing Cai[1]; *[1]TE SubCom, USA.* We discuss possible techniques for realizing higher capacity transoceanic transmission systems and outline the important role of wide bandwidth amplification using C+L EDFAs, nonlinear transmission optimization, space division multiplexing, advanced modulation formats, and variable spectral efficiency.

Th4D.4 • 16:30
400G Frequency-Hybrid Superchannel for the 62.5 GHz Slot, Sofia Amado[1,2], Fernando Guiomar[3], Nelson J. Muga[1,2], Antonello Nespola[4], Luca Bertignono[3], Andrea Carena[3], Armando Pinto[1,2]; *[1]Instituto de Telecomunicações, Portugal; [2]Departamento de Electrónica e Telecomunicações, Universidade de Aveiro, Portugal; [3]Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Italy; [4]Istituto Superiore Mario Boella, Italy.* We experimentally demonstrate a PM-16QAM/64QAM triple-carrier 400G superchannel compatible with the 62.5GHz grid. The optimum power ratio between carriers is analytically determined using the EGN model, enabling a maximum reach of 1700km.

Room 407

Th4E • Novel Applications of Microwave Photonics—Continued

Th4E.2 • 16:00
Microwave Photonic Chaos Based Device Fingerprinting, Philip Y. Ma[2,1], Yue-Kai Huang[2], Matthew P. Chang[1], Eric C. Blow[1], Shaoliang Zhang[2], Paul R. Prucnal[1]; *[1]Princeton Univ., USA; [2]NEC Laboratories America, USA.* We propose a microwave photonic system that can be challenged to generate dynamic chaotic response as the device fingerprint. Chaotic response consistency and variability are obtained to avoid false negatives and positives.

Th4E.3 • 16:15
Real-time Gigabit RS-coded OFDM Signal Transmission over WDM-based X-Band 2×2 MIMO RoF System, Ming Chen[2,1], Xin Xiao[2], Jianjun Yu[2], Xinying Li[2], Fan Li[2]; *[1]Hunan Normal Univ., China; [2]ZTE(TX) Inc., USA.* We experimentally demonstrate a real-time 2.3-Gb/s WDM-based 2×2 MIMO RS-coded OFDM-RoF system at X-band for future high-speed fiber-wireless access. The real-time measured BER after 2.24-km SMF-28 and 10-m wireless transmission is below 1×10^{-9}.

Th4E.4 • 16:30 Top Scored
Experimental Demonstration of LTE-A M×4×4 MIMO Radio-over-multicore Fiber Fronthaul, Maria Morant[1], Roberto Llorente[1]; *[1]Nanophotonics Technology Center, Universitat Politecnica de Valencia, Spain.* The carrier aggregation support in a 3GPP 2×4×4 MIMO LTE-Advanced optical MCF fronthaul is proposed and demonstrated experimentally. The optical power margin between cores transmitting MIMO is evaluated to be 5dB better than SISO configuration.

Room 408A

Th4F • Network Design—Continued

Th4F.2 • 16:00
Demonstration of Reconfigurable WDM Multicast Supporting Content Replication and Protection Switching for Content Delivery Optical Network, Ze Li[1], Min Zhang[1], Danshi Wang[1], Dequan Xie[2], Yue Cui[1], Qi Yang[2]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Wuhan Research Inst. of Posts and Telecommunications, China*. We propose a reconfigurable WDM multicast scheme supporting content replication and protection switching for CDON through SOA and our LCoS-based TB-WSS. One-to-six/seven/eight 25 Gb/s QPSK WDM multicasts also with protection switching function have been successfully demonstrated.

Th4F.3 • 16:15
Dynamic Control of Coarse/Fine Hybrid Granular Routing Optical Networks, Yusaku Ito[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; [1]*Nagoya Univ., Japan*. Dynamic control of coarse/fine granular routing optical networks is proposed. The routing scheme exploits virtual direct links, which enhances fiber frequency utilization and eliminates the need to control intermediate nodes. Its effectiveness is numerically verified.

Th4F.4 • 16:30 Invited
Routing and Regenerator Planning in a Carrier's Core ROADM Network, Balagangadhar Bathula[1], Angela Chiu[1], Rakesh Sinha[1], Sheryl L. Woodward[1]; [1]*AT&T, USA*. Optimizing routing and regenerator planning in a carrier's inter-city ROADM network provides significant savings. We describe how regenerator site planning and regenerator pre-deployment can be optimized for an inter-city IP over optical network.

Room 408B

Th4G • Laser Transmitters—Continued

Th4G.3 • 16:00 Invited
Ultra-broadband EA-DFB Laser Module for 200-Gbit/s PAM4 Transmitter, Hiroshi Yamazaki[1], Shigeru Kanazawa[2], Yasuhiko Nakanishi[2], Yuta Ueda[2], Wataru Kobayashi[1], Yoshifumi Muramoto[2], Hiroyuki Ishii[1], Hiroaki Sanjoh[2]; [1]*NTT Device Technology Laboratories, Japan;* [2]*NTT Device Innovation Center, Japan*. A lumped-electrode EA-DFB laser module with a modulation bandwidth of ~59 GHz was designed and fabricated based on a flip-chip interconnection technique. It enables 107-Gbaud PAM4 transmission.

Th4G.4 • 16:30
28-Gbit/s 80-km Transmission using SOA-assisted Extended-reach EADFB Laser (AXEL), Koichi Hasebe[1], Wataru Kobayashi[1], Naoki Fujiwara[2], Takahiko Shindo[1], Toshihide Yoshimatsu[2], Shigeru Kanazawa[2], Tetsuichiro Ohno[2], Hiroaki Sanjoh[2], Yoshitaka Ohiso[1], Hiroyuki Ishii[1], Yoshiaki Sone[3], Hideaki Matsuzaki[1]; [1]*NTT Device Technology Labs, Japan;* [2]*NTT Device Innovation Center, Japan;* [3]*NTT Network Innovation Labs, Japan.* We fabricated 1.3-mm AXELs to extend the transmission distance with 28-Gbit/s-NRZ signal. SOA-assisted gain is effective in increasing the average output power. We successfully demonstrated 80-km transmission with an APD-ROSA.

Room 409AB

Th4H • Characterization of SDM Fibers—Continued

Th4H.2 • 16:00
Nondestructive Characterization of Differential Mode Delay in Few-mode Fiber Link Using Rayleigh Backscattering Spectral Shifts, Shingo Ohno[1], Daisuke Iida[1], Toge Kunihiro[1], Tetsuya Manabe[1]; [1]*NTT Access Service Systems Laboratories, Japan*. We propose a nondestructive method for characterizing accumulated differential mode delay along a few-mode fiber link using Rayleigh backscattering spectral shifts caused by slight environmental disturbances, and achieve 20-ps accuracy and 40-m resolution.

Th4H.3 • 16:15
Distributed Measurement of Single-way Inter-modal Crosstalk in Spliced FMFs Based on BOTDA, Hiroshi Takahashi[1], Chihiro Kito[1], Kunihiro Toge[1], Tetsuya Manabe[1], Fumihiko Ito[2]; [1]*NTT, Japan;* [2]*Shimane Univ., Japan*. This paper focuses on the distributed measurement of inter-modal crosstalk for spliced FMFs, and reveals that single-way inter-modal crosstalk in spliced GI-FMFs, unlike round-trip crosstalk with reflectometric methods, can be characterized using a BOTDA-based method.

Th4H.4 • 16:30
Nearfield Complex Imaging, Yifei Wang[2,1], Jian Fang[1], An Li[1], Qi Yang[3], William Shieh[1]; [1]*The Univ. of Melbourne, Australia;* [2]*Victoria research laboratory, NICTA Ltd., Australia, Australia;* [3]*Wuhan Research Inst. of Post and Telecommunications, China*. Complex imaging via coherent detection is proposed for acquiring two-dimensional nearfield optical image recovering amplitude and phase simultaneously. We experimentally demonstrate the technique using few-mode-fiber (FMF) modes with high extinction-ratio, and characterize the FMF differential-group-delay.

Room 410

Th4I • Coherent Optical Signal Processing—Continued

Th4I.3 • 16:00 Invited
Optical Injection Locking for Carrier Phase Recovery and Regeneration, Radan Slavik[1], Zhixin Liu[1], David J. Richardson[1]; [1]*Univ. of Southampton, UK.* We review various scenarios for using optical injection locking for phase synchronization of signals to a local oscillator. We concentrate on the principle of operation and key properties needed.

Th4I.4 • 16:30
Polarization-independent Optical Injection Locking, Jignesh Jokhakar[1], Bill Corcoran[1], Arthur Lowery[1]; [1]*Monash Univ., Australia*. A pluggable system making optical injection locking independent of the incoming signal's polarization-state is proposed and experimentally verified to maintain stable locking for random polarizations without performance loss in carrier recovery for coherent optical communications.

Show Floor Programming

Room 402AB

Th4A • Optical Amplifiers—Continued

Th4A.6 • 16:45 Top Scored
Coupled 2-LP 6-core EDFA with 125 μm Cladding Diameter, Masaki Wada[1], Taiji Sakamoto[1], Shinichi Aozasa[1], Takayoshi Mori[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*NTT Corporation, USA*. We demonstrate a cladding-pumped 2-LP mode coupled 6-core EDFA with a 125-μm cladding diameter. A differential mode-core gain of less than 4-dB and a 6.5-dB average noise figure are successfully achieved in the C-band.

Th4A.7 • 17:00
Broadband Near Infrared (NIR) Luminescence Spectra of Bi/Er Co-doped Silicate Fiber (BEDF) under 830 and 980 nm Dual Pumping, Zhao Qiancheng[1], Yanhua Luo[1], Iain skinner[1], Gang-Ding Peng[1]; [1]*Univ. of New South Wales, Australia*. The luminescence characteristics for BEDF are investigated under 830 nm, 980 nm and dual pumping. Dual pumping scheme proves to flatten and broaden the emission spectrum in the range 950-1600 nm with multiple active centers.

Room 403A

Th4B • Optical Technologies for Radio Access Network II—Continued

Th4B.5 • 17:00
Optical Transport Network Architecture Enabling Ultra-Low Latency for Communications among Base Stations, Jun Li[1], Jiajia Chen[1]; [1]*KTH-Royal Inst. of Technology, Sweden*. We propose a novel transport network architecture for mobile backhauling along with its tailored communication protocol to offer ultra-low latency. Results show that less than 0.5 milliseconds packet delay can be achieved for inter-base-station communications.

Th4B.6 • 17:15
Flex-Frame Timing-Critical Passive Optical Networks for Delay Sensitive Mobile and Fixed Access Services, Mu Xu[1,2], Xiang Liu[2], Naresh Chand[2], Frank Effenberger[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Huawei R&D USA, Futurewei Technologies, USA*. We demonstrate a timing-critical TDM-PON compatible fiber-wireless access network with shorter frames and upstream bursts to support delay-sensitive wireless and fixed services. In comparison with conventional schemes, transmission latencies are reduced up to 70%.

Room 403B

Th4C • DSP for Coherent Systems—Continued

Th4C.6 • 17:00
Optical 16-QAM Signal Homodyne Detection by Extracting ±π/4 and ±3π/4-Phase Symbols, Akira Mizutori[1], Tomoyasu Abe[1], Takahisa Kodama[1], Masafumi Koga[1]; [1]*Oita Univ., Japan*. This paper demonstrates stable 16-Gbit/s 16-QAM signal homodyne detection. By extracting desired-phase symbols from optical signal, Costas loop for QPSK achieved LO light phase-locking to signal carrier. Homodyne phase-lock is confirmed in the experiment.

Th4C.7 • 17:15
Phase-Noise Compensation for Spatial-division Multiplexed Transmission, Arni F. Alfredsson[1], Erik Agrell[1], Henk Wymeersch[1], Magnus Karlsson[1]; [1]*Chalmers Univ. of Technology, Sweden*. The problem of correlated phase noise in spatial-division multiplexed transmission is studied. To compensate for the phase noise, an algorithm for joint-core phase-noise estimation and symbol detection is proposed, which outperforms conventional methods.

Room 404AB

Th4D • Submarine Transmission Systems—Continued

Th4D.5 • 16:45 Top Scored
50GBd 64APSK Coded Modulation Transmission over Long Haul Submarine Distance with Nonlinearity Compensation and Subcarrier Multiplexing, Matt Mazurczyk[1], Jin-Xing Cai[1], Hussam G. Batshon[1], Yu Sun[1], Oleg V. Sinkin[1], Maxim A. Bolshtyansky[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; [1]*TE SubCom, USA*. We achieve transoceanic distance transmission with 350-390 Gb/s 64APSK coded modulation channels and explore the benefit of nonlinearity compensation with subcarrier multiplexing. Estimated total capacity with variable spectral efficiency is 66.8 Tb/s.

Th4D.6 • 17:00
Performance Comparison of Advanced Modulation Formats for Transoceanic Coherent Systems, Ivan Fernandez de Jauregui Ruiz[1], Amirhossein Ghazisaeidi[1], Rafael Rios-Muller[1], Patrice Tran[1]; [1]*Nokia Bell Labs, France*. We experimentally compare the performance of probabilistically-shaped 64QAM (PS64QAM), 64APSK, 64QAM and 32QAM in terms of SNR and GMI in B2B and after 6600km transmission. We show that PS64QAM outperforms all formats by 0.4 bits/symbol.

Room 407

Th4E • Novel Applications of Microwave Photonics—Continued

Th4E.5 • 16:45
Orthogonal Chirp Division Multiplexing in Millimeter-wave Fiber-wireless Integrated Systems for Enhanced Mobile Broadband and Ultra-reliable Communications, Feng Lu[1], Lin Cheng[1], Mu Xu[1], Jing Wang[1], Shuyi Shen[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA*. We firstly propose to apply orthogonal-chirp-division-multiplexing in MMW fiber-wireless-integrated systems. It supports enhanced-mobile-broadband and ultra-reliable low-latency transmissions, and is more robust to system degradations and interferences, as experimentally demonstrated with up to 5-dB EVM improvement.

Th4E.6 • 17:00 Invited
High Bitrate Mm-Wave Links Using RoF Technologies and Its Non-telecom Application, Atsushi Kanno[1]; [1]*National Inst. of Information and Commnications Technology, Japan*. Millimeter-wave RoF technology is discussed for application to high bitrate wireless communication in fiber-wireless bridge configuration and railway communication systems. Non-telecommunication application such as a millimeter-wave radar system is also shown in the paper.

17:30–18:00 Beverage Break, *400 Foyer*

18:00–20:00 Postdeadline Papers, *403A, 403B, 408A and 408B*

Room 408A

Th4F • Network Design—Continued

Th4F.5 • 17:00
Cost-Effective Next-Generation Information Highways Leveraging Universal OTN Switching and Flexible-rate, Bodhisattwa Gangopadhyay[1], João Pedro[1], Stefan Spaelter[1]; [1]*Coriant, Portugal.* Current trend of data growth and revenue pattern make multi-layer network technology and architecture selection critical. This paper highlights how combining universal OTN switch and flexi-rate line interfaces can outperform traditional technologies in minimizing CAPEX.

Th4F.6 • 17:15
Network Utilization Improvement using Format-agnostic Multi-channel Wavelength Converters, Kiyo Ishii[1], Takashi Inoue[1], Inwoong Kim[2], Xi Wang[2], Hung Nguyen Tan[1,3], Qiong Zhang[2], Tadashi Ikeuchi[2], Shu Namiki[1]; [1]*AIST, Japan;* [2]*Fujitsu Laboratories of America, Inc., USA;* [3]*The Unversity of Danang-Univ. of Science and Technology, Viet Nam.* We demonstrate the effectiveness of multi-channel, format-agnostic, all-optical wavelength converters (AO-WCs) in improving network utilization. Simulations show doubled network utilization with significantly fewer AO-WCs and experiments confirm successful multi-channel conversions over full operating wavelength range.

Room 408B

Th4G • Laser Transmitters—Continued

Th4G.5 • 16:45
Record 6dBm Electroabsorption Modulated Laser For 10Gb/s and 25Gb/s High Power Budget Access Networks, Helene Debregeas[1], Francois Lelarge[2], Romain Brenot[1], Christophe Caillaud[1], jean-guy provost[1], frederic pommereau[1]; [1]*III-V Lab, France;* [2]*Almae Technologies, France.* We present an electro-absorption modulated laser with 6dBm modulated power leading to record power budget NRZ transmissions at 1.55µm: 37dB at 10Gb/s over 50km and 30dB at 28Gb/s over 10km with a pre-amplified photodiode.

Th4G.6 • 17:00
56 Gb/s PAM-4 Directly Modulated Laser for 200G/400G Data-center Optical Links, Prashant P. Baveja[1], Mingshan Li[1], Ding Wang[1], Chiuhui Hsieh[1], Huanlin Zhang[1], Ning Ma[1], Yi Wang[1], Justin Lii[1], Edward Liang[1], Chong Wang[1], Morris Ho[1], Jun Zheng[1]; [1]*Applied Opto-Electronics Inc., USA.* PAM-4 modulation up to 56 Gb/s of a 1.3-mm InGaAlAs-MQW, low-RIN (< -150 dB/Hz) DFB laser, based on a simple, high volume manufacturing capable, ridge waveguide (RWG) platform, operating upto 70 °C, is experimentally demonstrated.

Th4G.7 • 17:15
Low-cost E1-class 10-Gb/s Directly Modulation Laser in TO-can Package with Optical Filtering for XG-PON Application, Enyu Zhou[1], Ning Cheng[1], Sulin Yang[1], Liqiang Yu[1], Xiang Liu[1], Cong Chen[1], Lingjie Wang[1]; [1]*Huawei Technology Co. Ltd, China.* A low-cost E1-class 1577nm 10Gb/s directly modulation DFB laser in TO-can package is demonstrated with 7.3dBm output power and 8.9dB extinction ratio using optical filtering. 37.6dB power budget is achieved after 20km single-mode fiber transmission.

Room 409AB

Th4H • Characterization of SDM Fibers—Continued

Th4H.5 • 16:45
Flexible Scheme for Measuring Chromatic Dispersion Based on Interference of Frequency Tones, Kyle Bottrill[1], Mohamed A. Ettabib[1], James C. Gates[1], Cosimo Lacava[1], Francesca Parmigiani[1], David J. Richardson[1], Periklis Petropoulos[1]; [1]*Univ. of Southampton, UK.* We propose and demonstrate a flexible new scheme for measuring chromatic dispersion profiles of optical devices. This is achieved by measuring the phase difference between two mutually coherent tones that are mixed together through a modulator.

Th4H.6 • 17:00
Investigation of Inter-core Crosstalk and Raman Nonlinearity in Wideband MCF Transmission, Ruben S. Luis[1], Benjamin J. Puttnam[1], Georg Rademacher[1], Werner Klaus[1], Y. Awaji[1], Naoya Wada[1]; [1]*National Inst Information & Comm Tech, Japan.* We address the interplay between Raman nonlinearity and crosstalk on a multicore fiber transmitting a 80 nm WDM signal spanning across C+L bands. We show a 0.1 dB/THz increase of crosstalk tilt due to Raman fiber nonlinearity.

Room 410

Th4I • Coherent Optical Signal Processing—Continued

Th4I.5 • 16:45 Top Scored
Regeneration of Phase Unlocked Serial Multiplexed DPSK Signals in a Single Phase Sensitive Amplifier, Pengyu Guan[1], Francesco Da Ros[1], Niels-Kristian Kjøller[1], Hao Hu[1], Kasper M. Røge[1], Michael Galili[1], Toshio Morioka[1], Leif K. Oxenlowe[1]; [1]*Technical Univ. of Denmark, Denmark.* We demonstrate phase-regeneration of phase unlocked OTDM-DPSK serial signals in a single phase sensitive amplifier through optical cross-phase modulation. The BER of an 8×10 Gbit/s OTDM-DPSK signal is improved by 2 orders of magnitude.

Th4I.6 • 17:00
Experimental Demonstration of Tunable Optical De-aggregation of Each of Multiple Wavelength 16-QAM Channels into Two 4-PAM Channels, Ahmad Fallahpour[1], Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Yinwen Cao[1], Ahmed Almaiman[1], Fatemeh Alishahi[1], Changjing Bao[1], Peicheng Liao[1], Bishara Shamee[1], Loukas Paraschis[2], Moshe Tur[3], Carsten Langrock[4], Martin Fejer[4], Joseph Touch[5], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Infinera Corporation, USA;* [3]*Tel Aviv Univ., Israel;* [4]*Stanford Univ., USA;* [5]*Information Sciences Inst., USA.* We experimentally demonstrate tunable all-optical simultaneous de-aggregation of multiple wavelength 16-QAM channels into two 4-PAM channels using a single stage nonlinear element. Tunability of the proposed approach over modulation format and bitrate is shown by de-aggregation of multiple channels for 10/15-Gbaud QPSK signals into two BPSK signals.

Show Floor Programming

17:30–18:00 Beverage Break, *400 Foyer*

18:00–20:00 Postdeadline Papers, *403A, 403B, 408A and 408B*

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Key to Authors and Presiders

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