

Table of Contents

Conference Schedule	2	Connected OFCity Challenge 2018: Lighting Up the Emerging World	15
Corporate Sponsors	3	Photonics Society of Chinese-Americans Workshop & Social Networking Event	15
Chairs' Welcome Letter	4	Postdeadline Paper Presentations	15
General Information		Plenary Session	16
Customer Service and Conference Services	5	Awards and Honors	17
E-Center Kiosks	5	Short Course Schedule	18
First Aid Station	5	What's Happening on the Show Floor?	
Media Center	5	Exhibition	20
OFC Career Zone	5	Programming and Activities	21
OFC Conference App	5	The Suzanne R. Nagel Lounge	21
Registration	6	Market Watch	21
Speaker Ready Room	6	Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center	21
Sponsoring Society Exhibits	6	Network Operator Summit	22
Conference Materials	7	Expo Theater Programming	22
Special Events and Programming		Product Showcases	23
Workshops	8	Technical Program and Steering Committees	24
Lab Automation Hackathon	12	Explanation of Session Codes	28
Data Science Career Opportunities	13	Agenda of Sessions	29
Symposia	13	OFC Technical Program	
Panels	13	Abstracts	38
Data Center Summit - Data Center Optical Interconnect - Technologies and Markets	13	Key to Authors and Presiders	132
OIDA VIP Industry Leaders Speed Meetings Event	13		
Open Platform Summit	14		
Exhibitor Happy Hour and Conference Reception	14		
Rump Session – When Will Coherent Replace Direct Detection in the Data Center?	14		

This program contains the latest information up to 29 January 2018.

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 OFC Conference App for the latest changes.

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

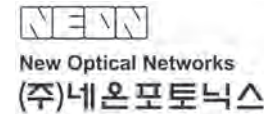
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Conference Schedule

All times reflect Pacific Time Zone	Sunday 11 March	Monday 12 March	Tuesday 13 March	Wednesday 14 March	Thursday 15 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 Kiosks	08:00–19:30	07:30–18:00	07:00–19:00	07:30–17:00	07:30–17:00
OFC Career Zone Live			10:00–17:00	10:00–17:00	10:00–16:00
Programming					
Short Courses	09:00–20:00	08:30–17:30			
Workshops	12:30–18:30				
Technical Sessions		08:00–18:30	14:00–18:30	08:00–18:30	08:00–16:00
Symposium: Challenges 5G Brings to Optical Fiber Communications Systems?		14:00–18:30			
Symposium: Future Photonic Devices and Materials for Optical Communications		14:00–18:30			
Symposium: Network Management Evolution to Streaming An			16:30–18:30		
Open Platform Summit: SDN & NFV Demo Zone			14:00–18:30		
Rump Session: When will Coherent Replace Direct Detection in the Data Center?			19:30–21:30		
Connected OFCity Challenge 2018: Lighting Up the Emerging World				14:00–16:00	
Poster Sessions				10:30–12:30	10:30–12:30
Postdeadline Papers					16:30–18:30
Exhibition and Show Floor Activities					
Exhibition and Show Floor (Unopposed Exhibit-Only Time)			10:00–17:00 (10:00–14:00)	10:00–17:00 (12:30–14:00)	10:00–16:00 (12:30–14:00)
The Suzanne R. Nagel Lounge			10:00–17:00	10:00–17:00	10:00–16:00
Product Showcases			10:15–10:45	10:15–13:30	10:15–10:45
Expo Theaters II and III Programs			10:15–17:00	10:15–17:00	10:15–14:15
Market Watch - Expo Theater I			10:30–16:00	15:30–17:00	10:30–14:00
Network Operator Summit - Expo Theater I				10:30–15:00	
Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center			16:15–17:00		
Exhibitor Happy Hour			17:15–18:45		
Special Events					
Lab Automation Hackathon	20:00–22:00				
Plenary Session			08:00–10:00		
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		
Conference Reception			18:30–20:00		



OFC thanks the following corporate sponsors for their generous support:



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Welcome to the 2018 Optical Fiber Communication Conference and Exhibition

On behalf of the many individuals, including countless volunteers that are organizing OFC 2018, it is our sincere pleasure to welcome you to San Diego, California. OFC is the foremost meeting in optical communications and networking, and this year's conference continues the tradition of providing an excellent program that captures advances in research, development and engineering.

In the plenary session on Tuesday morning, three dynamic speakers will address recent developments and future challenges in optical communications and networking. John Doyle, Jean-Lou Chameau Professor of Control and Dynamical Systems, Electrical Engineer, and BioEngineering at Caltech, USA will detail the universal laws and architectures in complex networks; Marcus Weldon, Chief Technology Officer, Nokia Bell Labs, USA will provide insight into the future of optical communications; Chengliang Zhang, Vice President, China Telecom Beijing Research Institute, China will explain optical networking in the cloud and 5G era.

The 2018 conference provides an exceptionally strong technical program consisting of a portfolio of 54 short courses, 560+ contributed and 105 invited papers, 22 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 three symposia: *Network Management Evolution to Streaming Analytics and Cognitive Systems*, *Challenges 5G Brings to Optical Fiber Communications Systems and Future Photonic Devices and Materials for Optical Communications*. Tuesday features a 2-part Open Platform 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 *When Will Coherent Replace Direct Detection in the Data Center?* organized by Chris Cole, Finisar Corp. 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; new network architectures and applications enabled by SDN and NFV; openConfig/open platforms for network management and cloud/Fog computing; optical wireless and visible light communications; silicon and integrated photonics for datacom and telecom; streaming analytics and cognitive systems.

The OFC Exhibit hosts more than 700 exhibitors from all over the world representing every facet of the optical communications market: communication and network equipment, data center

interconnects, electronic components and subsystems, fiber cables and assemblies, integrated photonics, test equipment, lasers, optical components, optical fibers, transmitters and receivers, sensors and much more. In addition to meeting with vendors and seeing new products, the Market Watch program and the Network Operator Summit form the core of the business-related programming of the meeting. Market Watch is a three-day series of panel discussions that engages the latest application topics and business issues in the field of optical communications. Presentations and panel sessions feature esteemed speakers from top carriers, system vendors, market analyst firms and component companies. The Network Operator Summit includes a keynote address by Najam Ahmad, Vice President, Network Engineering, Facebook on view of open approach for switching, routing and transport and two panels on the role of "open transport" in the new metro and inter-data-center architectures and what's next to get to 100G PON. 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 and OpenFog Consortium, ON2020, Open19 Foundation, OIF, ONF, and OpenConfig.

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, Robert Doverspike, Daniel Kuchta, and William Shieh, 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.



Martin Birk
AT&T Labs, USA



Xiang Liu
Futurewei Technologies, Inc., USA



David Richardson
Univ. of Southampton, UK

General Information

Conferences Services

Customer Service and Conference Information

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

- Coat and Baggage Check
- General Conference Information
- Lost and Found (for After Hours Lost and Found, please go to the OFC Security Office located in Show Office D (look for security sign).
- Parking
- Restaurant Information
- Show your Badge Promotions

E-Center Kiosks

Registration, Exhibit Hall E

The E-Center provides access to webmail services. Multiple stations allow attendees to check email. The E-Center Kiosks will be open during OFC 2018 registration hours.

First Aid Station

Box Office E

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

First Aid Station Hours

Sunday, 11 March	08:00–17:00
Monday, 12 March	08:00–17:00
Tuesday, 13 March	08:00–17:00
Wednesday, 14 March	08:00–17:00
Thursday, 15 March	08:00–17:00

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

Join the Conversation!

Get the latest updates from OFC via Twitter at @OFCConference. Use the hashtag #OFC18 and join in the conversation today!

Media Center

Rooms 4, 5A and 5B

The OFC 2018 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, 11 March	12:00–16:00
Monday, 12 March	07:30–18:00
Tuesday, 13 March	07:30–18:00
Wednesday, 14 March	07:30–18:00
Thursday, 15 March	07:30–18:00

OFC Career Zone

Exhibit Hall C

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

Job Seekers

Meet Participating Companies

Tuesday, 13 March	10:00–17:00
Wednesday, 14 March	10:00–17:00
Thursday, 15 March	10:00–16:00

Register Online at ofcconference.org/careerzone or Visit the Kiosks in Registration 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? It's not too late.

Participate Online at ofcconference.org/careerzone:

- 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.

OFC Conference App

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

Schedule

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

Exhibit Hall

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

Access Technical Digest Papers

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

IMPORTANT: 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 App!

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

1. Search for ‘OFC Conference’ in the app store.
2. Go to ofconference.org/app
3. Scan the QR code

The OFC 2018 Guide will be listed under the “download guides” section of the application



Conference App Help Desk

Need assistance? 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.

Registration

Exhibit Hall E

Hours:

Sunday, 11 March	08:00–19:30
Monday, 12 March	07:30–18:00
Tuesday, 13 March	07:00–19:00
Wednesday, 14 March	07:30–17:00
Thursday, 15 March	07:30–17:00

Sponsored by:



Speaker Ready Room

Room 11

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

Speaker Ready Room Hours*

Sunday, 11 March	13:00–17:00
Monday, 12 March	07:00–18:00
Tuesday, 13 March	10:00–18:00
Wednesday, 14 March	07:00–18:00
Thursday, 15 March	07:00–16:00

*Market Watch and Network Operator Summit speakers should go directly to Expo Theater I (#1940) in Exhibit Hall G to upload their presentations.

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

Sponsoring Society Exhibits

Exhibit Hall

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



Wireless Internet Access

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

SSID: OFC
Password: OFC2018



Conference Materials

OFC Technical Digest on a USB Slap Band

The OFC 2018 Technical Digest, composed of the 3-page summaries of invited and accepted contributed papers, as well as, tutorial presentations notes will be on a USB Slap Band. The Technical Digests USB is included with a technical conference registration. These summaries will also be published in OSA Publishing's Digital Library and submitted to the IEEE Xplore Digital Library, providing the author attends and presents their paper at the OFC 2018 Conference.

Sponsored by:



Online Access to Technical Digest

Technical attendees have EARLY (at least one week prior to the meeting) and FREE continuous online access to the OFC2018 Technical Digest. These 3 page summaries of tutorial, invited, and accepted contributed papers can be downloaded individually or by downloading daily .zip files. (.zip files are available for 60 days after the conference).

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

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

Postdeadline Paper Digest

The Postdeadline Paper Digest includes the 3-page summaries of accepted postdeadline papers. The Postdeadline Paper Digest includes the 3-page summaries of accepted postdeadline papers. Papers will also be available for download online on Tuesday, 13 March. The digests will be available to all technical conference registrants beginning Thursday, 15 March, by 10:00 at Registration (Exhibit Hall E). The papers will be presented Thursday, 15 March, 16:30–18:30.


Short Course Notes

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

Buyers' Guide

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

Captured Session Content

We are delighted to announce that approximately 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 18 June 2018. All captured session content will be live for viewing within twenty four hours of being recorded. Just look for the symbol  in the Agenda of Sessions and abstracts to easily identify the presentations being captured.

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

Code of Conduct

All Conference guests, attendees, and exhibitors are subject to the Code of Conduct policy, the full text of which is available at <http://www.ofcconference.org/en-us/home/about/code-of-conduct/>. Conference management reserves the right to take any and all appropriate actions to enforce the Code of Conduct, up to and including ejecting from the Conference individuals who fail to comply with the policy.





Special Events and Programming

Workshops

Sunday, 11 March, 12:30–15:30

S1A. DSP for Short Reach and Client Optics – What Makes Sense?

Room 2

Organizers: Benn Thomsen, *Microsoft, UK*; Andre Richter, *VPIphotonics, Germany*; Rene Schmogrow, *Google, USA*

This workshop aims to provide a platform for discussion on the right balance of cost- and power-efficient optical interface and channel equipment, and electronics-based transmitter- and receiver-side DSP techniques that go along with it as we head towards 400Gb/s and 1Tb/s interfaces in the sub 200km transmission range.

Invited contributions will address the following questions:

- **Service Provider requirements:** What would you expect from flexible DSP as a cloud or network provider? What are the requirements from a power, management and cost point of view? How do these requirements and the replacement cycle differ across the network space that you operate in i.e. LAN vs MAN vs WAN? Does it make sense to invest in a flexible Tx/Rx configuration when equipment is replaced every ~5years anyway?
- **Coherent modulation:** What can you have if coherent technology is deployed in the sub 200km space? What type of efforts in DSP is economically reasonable? What are the implications for power consumption and heat dissipation? Is there a one size fits all DSP approach that can span from inside the data center to metro applications and exploit the deployment volumes in this space? Can we simply reuse the existing long haul DSP ASICs?
- **Direct Detection:** Will direct detection augmented with (or without) DSP be more

compelling from a power and cost point of view? Do DSP intensive IM-DD systems have a future? What can technologies such as DMT, Stokes Vector, Kramers Kronig, etc. bring in terms of flexibility and channel impairment mitigation?

- **Error correction and coding:** Is flexible FEC an effective way of spanning the sub 200km application space whilst addressing the power and cost issues? Does constellation shaping have a role to play in short reach systems?
- **Photonic Integration:** Parallel optics vs. DSP and higher order modulation – what will be the preferred option? Will a rapid progress in photonic integration make the utilization of digital coherent techniques even more attractive for Short reach and Client optics?

This workshop will bring together experts from service providers, systems vendors and device manufacturers debating viewpoints on requirements, challenges and solution options among each other and with other workshop participants. The following speakers confirmed their contribution:

Speakers:

Nicklas Eiselt, *ADVA Optical Networking, Germany*
Mark Filer, *Microsoft, USA*
Tad Hofmeister, *Google, USA*
Ilya Lyubomirsky, *Inphi, USA*
Eric Maniloff, *Ciena, Canada*
Mohamed Osman, *McGill University, Canada*
Laurent Schmalen, *Nokia Bell Labs, Germany*
Mehrdad Ziari, *Infinera, USA*

S1B. Will Optical Switching Drive Data Center Design in 2028?

Room 6C

Organizers: Haoshou Chen, *Nokia Bell Labs, USA*; Pierro Gambini, *STMicroelectronics, Italy*; Richard Jensen, *Polatis, USA*; Hiroyuki Tsuda, *Keio University, Japan*

After a 10-year exponential traffic growth to 2028, increased server numbers and required single link

capacity will pose challenges for both hardware and software in intra- and inter- data center applications.

New architectures based on advanced optical switching technologies can potentially lower energy consumption and support the enhanced capacity.

Starting from a visionary overview, the workshop will focus on:

- How will capacity per link, switching performance and power consumption drive the architecture evolution?
- Which dimension: space, wavelength or time (packet) will be more cost- and energy- efficient for optical switching? How can photonic integration be used to lower the cost of optical switching and improve the performance?
- How will other building blocks, such as new optical fiber and transceivers, influence the choice of optical switching technology?

It will be a team competition workshop including four teams with their proposed data center infrastructures optimized for a 5 and 10 year time span.

Team A

Shu Namiki, *AIST, Japan, Team Leader*
Chris Cole, *Finisar, USA*
Christian Koos, *KIT, Germany*
Tomohiro Kudoh, *University of Tokyo, Japan*

Team B

Georgios Zervas, *University College London, UK, Team Leader*
Hitesh Ballani, *Microsoft Research Cambridge, UK*
Nikos Pleros, *Aristotle University of Thessaloniki, Greece*

Team C

David Neilson, *Nokia Bell Labs, USA, Team Leader*
George Papen, *UCSD, USA*
Ming Wu, *UC Berkeley, USA*

Team D

Oded Raz, *Tu/e, The Netherlands, Team Leader*
Cyriel Minckenberg, *Rockley Photonics, USA*
Nick Parsons, *Polatis, USA*



Panel of Experts:

Gilad Goldfarb, *Facebook, USA*
Joseph M. Kah, *Stanford University, USA*
Yikai Su, *Shanghai Jiao Tong University, China*
Joris Van Campenhout, *IMEC, Belgium*
Dirk van den Borne, *Juniper, USA*
Vijay Vusirikala, *Google, USA*

S1C. Ultimate Capacity Limits for TDM/TDMA PON

Room 6D

Organizers: Derek Nasset, *Huawei, UK*; Naoki Suzuki, *Mitsubishi Electric, Japan*; Lilin Yi, *Shanghai Jiao Ton University, China*

This workshop will pose the question as to whether there is an ultimate limit to conventional TDM/TDMA PON capacity. Already, the ITU-T has moved to the wavelength domain with the multi-channel NG-PON2 system and the IEEE is developing specifications for a 100G EPON system using four wavelengths at 25Gb/s. However, multiple wavelengths add some technical and operational complexity to the PON system and the question naturally arises as to what could be achieved with a single wavelength channel per direction?

This workshop will address this tough question from a number of perspectives to drive a debate as to the real limiting factors. Expert speakers will be invited to deliver concise but opinionated presentations on a sub-set of the following issues:

- What transmission techniques could be used to compensate for dispersion, device bandwidth limitations... etc?
- Can deployed ODNs with up to ~30dB loss be re-used?
- How far can the launch power be increased?
- Will optical amplifiers be necessary? Can they be practical and low-cost?
- What are the limits for receiver sensitivity? What about the burst mode issues?
- What receiver types could be used e.g. coherent or direct detection?

- When does it just become much more cost efficient to add wavelength channels?
- Are new PON protocols needed? For example to limit the power burden of continuous downstream frame processing or to support new services?
- How much more can be gained from electronics e.g. DSP, FEC...?
- How can low cost optical devices be realized for high-bandwidth PON implementation?
- What optical modules could be used? Is power consumption a killer? What about TO-cans?
- Is there a role for silicon photonics?
- Does co-existence with legacy PON limit what ultimate capacity could be achieved?
- What are the applications driving to higher capacity?
- Do network operators see advantages for multiple-channels or would single channel be just as good or, even, preferred?

Speakers:

Erik Agrell, *Chalmers University, Sweden*
Johan Bauwelinck, *IMEC, Belgium*
Vincent Houtsma, *Nokia, USA*
Dominiç Lavery, *University College London, UK*
Xiang Liu, *Huawei, USA*
Chao Lu, *PolyU, Kowloon, Hong Kong*
Seb Savory, *Cambridge University, UK*
Katsuhiro Shimizu, *Mitsubishi Electric, Japan*
Daisuke Umeda, *Sumitomo Electric Industries, Japan*
Naoto Yoshimoto, *Chitose Institute of Science and Technology, Japan*

S1D. Can Undersea System Designs be Truly "Open" and Independent from Initial Terminal Equipment Selections?

Room 6E

Organizers: Herve Fevrier, *Facebook, USA*; Dmitri Foursa, *TE Subcom, USA*; Lara Garrett, *TE Subcom, USA*

As the industry moves towards the adoption of ITU standards, it is important to understand the system

characterization parameters and capacity expectations. Simple back-to-back transponder characterization and system OSNR measurements are not sufficient for accurate system performance evaluation.

- Is there a set of system and transponder parameters that will allow accurate prediction of system capacity?
- Is it even possible to accurately predict the system performance with the evolution in transponder nonlinearity compensation capabilities?
- How do we commission "open cable" system?

The workshop will discuss characterization metrics for "open cable" system application and existing experience with system commissioning. B2B performance and nonlinearity compensation capabilities of different transponders will be discussed, as well as necessary system parameters required for 'Black Box' system characterization.

Speakers:

Elizabeth Rivera Hartling, *Ciena, USA*
Valey Kamalov, *Google, USA*
Howard Kidorf, *Pioneer Consulting, USA*
Dmitry Kovsh, *TE SubCom, USA*
Eduardo Mateo, *NEC, Japan*
Pascal Pecci, *ASN, France*
Niall Robinson, *ADVA Optical Networking, USA*

S1E. Optical Integration Beyond Silicon Photonics: Why, What and How?

Room 6F

Organizers: Daniel Blumenthal, *University of California, Santa Barbara, USA*; Benjamin Eggleton, *University of Sydney, Australia*; Leif Oxenløwe, *DTU, Denmark*

New integration technologies are on the horizon for communications, signal processing and sensing applications, opening up new possibilities for functions and systems on-chip with lower energy, higher performance and increased density. Silicon photonics in tandem with other legacy technologies is quickly becoming the de facto-standard for a large portion of research and commercialization. However, limitations of silicon photonics raise the issue if it is a ubiquitous



solution, and what other new photonics and device integration technologies can offer for future applications and capabilities.

The workshop will discuss the requirements of future applications and subsystems, how they can be met by traditional silicon photonics, what the limits are with this solution, and what new photonic technologies emerging on the horizon can meet these future requirements:

- What are the integration and performance requirements of tomorrow's high capacity and low power, low cost communications and sensor subsystems?
- What is the end-user perspective on silicon photonics and adoption of new technology solutions?
- How are subsystem and user requirements helped and hampered by the performance, scalability, and functional and physical limitations of silicon photonics?
- What are the opportunities for improvements in power dissipation, power handling capabilities, embedded gain, footprint, performance and functionality?
- What are the emerging applications?
- What are the next generation photonic technologies being developed that can address this space?
 - Examples include photonic molecules, photon-phonon and optomechanic based devices, quantum photonic integrated circuits, strong broadband non-linear optics, topological photonics, chiral photonics, and nanophotonics.
- What new applications can be enabled by these technologies?
 - Examples include dispersion engineering, chip scale RF processors, optical acoustic signal processing, nonlinear optical functions, unidirectional lasers, quantum communications and computing on chip, ultra-fast and large-scale optical logic, ultra-low energy optical switches, frequency comb devices, magnet-free optical isolation, ultra-low

energy devices for large-scale integration, ultra-fast chips to handle terabit communications in small form factors, sensors for position and navigation, optical signal processing functions for digital and RF communications.

Speakers:

Part I: End User Perspective

Opportunities for Next Generation Photonics and Functions in DCIs, Hitesh Balani, *Microsoft Research, USA*

Opportunities for Next Generation Integrated Photonics, Katharine Schmidtke, *Facebook, USA*

Special Purpose High Performance Computational Chips, Thomas Van-Vaerenbergh, *HPE, Belgium*

The Current State of Silicon Photonics and What are the Limits, Daoxin Dai, *Zhejiang University, China*

Panel Discussion: New Applications and Impact on Existing Applications

Part II: Next Generation Device Physics

Brillouin Scattering and Photon-phonon Signal Processing in Silicon, Peter Rakich, *Yale University, USA*

Silicon Rich Nitrides, Dawn Tan, *Singapore Design University of Technology, Singapore*

Flexible Silicon Solutions, Anna Peacock, *University of Southampton, UK*

Plasmonic Optics, Juerg Leuthold, *ETH Zurich, Switzerland*

Panel Discussion: What Does it Take for Next Generation Physics to Make its Way into Practical Devices and Functional Photonics?

Part III: Next Generation Devices and Functions

Integrated Photonics Beyond Silicon, Gunther Roelkens, *Ghent University, Belgium*

Integrated Photonics for Positional Navigation and Sensing (Optical Gyros), Matthew Puckett, *Honeywell, USA*

Integrated Photonics for Microwave Photonics, David Marpaung, *University of Twente, The Netherlands*

Functions for Photonic Molecules and Quantum Annealing, Guha Saikat, *University of Arizona, USA*

Panel Discussion: Prospects for Impact on Subsystems and Applications and Adoption by End Users

Sunday, 11 March, 16:00–18.30

S2A: Field Trials: Is it Make or Break for Innovative Technologies?

Room 2

Organizers: S. Chandrasekhar, *Nokia Bell Labs, USA*; Robert Killely, *University College London, UK*

Today several systems have been deployed worldwide with advanced modulation formats that exploit the full electric field of light for encoding, using coherent technology aided by electronic digital signal processing. In addition, there have been several field trials conducted based on both currently available technologies as well as potential next generation technologies. Field trials have covered metro, terrestrial, and submarine networks.

Nevertheless, the performance of systems in the field are significantly below those demonstrated in laboratory experiments. The metrics include reach, spectral efficiency, impairment mitigation, and paucity of formats. Does this imply that field performance is a "make or break" scenario for novel technologies? This workshop will try to address the shortcomings and challenges encountered in the process of taking a value proposition from the laboratory to a deployable field solution. It is expected that there will be participation from both researchers as well as industry technocrats, addressing the range of topics below:

Reach: Do lab demonstrations exaggerate potential reach without any considerations to margins? Or did the industry demand too much safety buffer for "always-on best-in-class service" slogans? Can we use the "software-defined" transponders with clever DSP to adapt to changing field environments? Is there a path to recover lost reach yet claim the slogans?





Spectral Efficiency / Formats: The best SE that is known to have been deployed is around 5-b/s/Hz (200G on 37.5-GHz using 16QAM). Researchers have shown well over 11-b/s/Hz in the lab. More recently, in field trials, numbers in the 7-9 b/s/Hz have been demonstrated with innovative technologies such as probabilistic shaping. It appears either research was way ahead of being practical or a lot got dumped along the way of implementation. Are some concepts too complex to implement in a piece of Silicon? Challenges in transferring algorithms from MatLab to Silicon? Is the return of investment poor? Is probabilistic shaping easy to implement?

Impairment Mitigation: Are lab transmitters and receivers too perfect, that we cannot replicate their performances in the line card? (e.g., ADC BW of real time scope vs BW of CMOS) Do our researchers splurge on infinite DSP resources that ASIC designers don't have the luxury, resulting is less than optimal performance? (e.g., using RRC roll-off factors of 0.001 with more than 100 tap equalizers). Is lab hardware (fibers, amplifiers, DSO, ...) too good that they do not reflect the realities of the field? Can resource-efficient clever DSP absorb some of the shortcomings in the line card performances or even transmission related impairments? Will we see the dawn of "self-correcting" line systems or even "self-healing" transponders?

Speakers:

Steve Grubb, *Facebook, USA*
Lynn Nelson, *AT&T, USA*
Maurice O'Sullivan, *Ciena, USA*
Christian Rasmussen, *Acacia, USA*
Tiejun J. Xia, *Verizon, USA*
Szilard Zsigmond, *Nokia, USA*

S2B: AI-assisted Automated Network Operation: Getting Matured or Not?

Room 6C

Organizers: Reza Nejabati, *University of Bristol, UK*;
Luis Velasco, *Universitat Politècnica de Catalunya, Spain*; Qunbi Zhuge, *Ciena, USA*

The Artificial Intelligence (AI) and Machine Learning (ML) have attracted much attention recently, and using such technologies for operating and optimizing networks is increasingly seen as a viable strategy

for large and complex environments, including the concept of AI-assisted automated network operation. This trend is expected to facilitate innovation in aspects such as physical layer monitoring and configuration or the control and management of future optical infrastructure. This confluence produces a degree of intelligence that may ultimately provide a large measure of network autonomy.

In the physical layer, such autonomous (ultimately "self-driving") networks are expected to extract physical layer information, optimize operation status, configure transceiver parameters and more. What kind of physical layer intelligence do we provide to aid autonomous optical transport network and how much benefit do we expect with an autonomous network aided by physical layer intelligence? Are today's software-defined network (SDN) techniques ready to leverage physical layer intelligence in order to realize an autonomous network? How do we define interfaces between hardware, firmware and software? Are machine learning algorithms key building blocks to enable physical layer intelligence?

At the network control and management level, the introduction of AI is expected to help automate and manage the ever growing network complexity, optimize resource usage and ultimately drive down costs, introducing proactive solutions. Are the network operators ready to introduce AI technology for efficient network operation? If "Yes", what are the main drivers? If the answer is "No", what are the show-stoppers? Do we need more technical advances and standardization to make AI technology more attractive and reliable? What kind of concrete AI-based techniques are readily applicable?

Speakers:

Vinayak Dangui, *Facebook, USA*
Juan Pedro Fernández-Palacios, *Telefónica, Spain*
Yuti Higuchi, *ONF, USA*
Joseph Kahn, *Stanford University, USA*
Alan Pak Tao Lau, *Hong Kong Polytechnic University, Hong Kong*
Patricia Layec, *Nokia Bell Labs, USA*
Dave Meyer, *Huawei, USA*
Loukas Paraschis, *Infinera, USA*
Danish Rafique, *ADVA, Germany*
Takahito Tanimura, *Fujitsu Labs, Japan*

S2C. Electro-optical Integration in a Package. What Technologies and Business Models can Make it Happen?

Room 6D

Organizers: Chris Cole, *Finisar, USA*; Marco Fiorentino, *Hewlett Packard Labs, USA*; Bert Offrein, *IBM Research GmbH, Switzerland*; Samuel Palermo, *Texas A&M University, USA*

Integration of optics with switch silicon in a package has been identified as an architectural solution to the problem of rising SerDes power to drive PCB copper channel to pluggable or on-board optics. The integration also promises to reduce packaging assembly overhead and cost. However a multitude of technical and business challenges have kept package level integration from widespread commercial use.

Some of the technical challenges are:

- ASIC I/O architecture
- Electrical and optical modulation type and rate
- Laser type and location
- Parallel and WDM optics partitioning
- Optics material systems
- Package and substrate material systems
- Thermal management
- Fiber assembly and routing
- Assembly yield and FIT

Some of the business challenges are:

- Who does the design
- Who does the manufacture and assembly
- Role of traditional transceiver companies
- Liability for and servicing of the final assembly
- Scalability with deployment
- Design and modeling tools

The workshop will be divided into two panels with broad range of speakers presenting their views on the challenges and solutions. Each presentation will be followed by audience Q&A.



**Systems and Integration Panelists:**

Alan Benner, *IBM, USA*
 Ashok Krishnamoorthy, *Axalume, USA*
 Nick Kucharewski, *Rockley Photonics, USA*
 Brian Taylor, *Facebook, USA*

Devices and Technology Panelists:

Ramakanath Alapati, *Amkor, USA*
 Ted Letavic, *GlobalFoundries, USA*
 Mike Li, *Intel, USA*
 Rada Nagarajan, *InPhi, USA*

S2D. When Will We Need to Scale the Fiber Capacity? What is the Most Realistic Approach?

Room 6E

Organizers: Cristian Antonelli, *Università dell' Aquila, Italy*; Takemi Hasegawa, *Sumitomo, Japan*; Ming-Jun Lin, *Corning, USA*; Antonio Napoli, *Coriant, Germany*

The demand for data traffic is increasing at a speed that by far exceeds the growth rates of aggregate WDM capacities, as well as that of router interfaces. In addition, the expected implementation of bandwidth-hungry transmission technologies, such as for example wireless 5G, will soon produce an unprecedented boost in traffic demand, to the extent that the need of new high-capacity networks will be more urgent than ever. Aim of this workshop is to debate on when and how the telecommunication industry will need to face the approaching capacity crunch, as well as to identify effective approaches to overcome the ultimate limitations imposed by the fiber-optical channel.

Three teams will propose distinct end-to-end optical system solutions, based on different transmission strategies. The first strategy relies on the use of advanced fibers, such as multi-core and multi-mode fibers. The second targets the utilization of the entire single-mode fiber bandwidth beyond C and L bands. The last one stems from the multi-fiber-based implementation of space-division multiplexing (SDM) which turned out to be the most attractive solution at OFC 2017 workshop "Making the Case for SDM in 2027."

Each team will propose a solution based on one of the aforementioned strategies, targeting specific application scenarios and identifying well-defined timelines for deployment. The three proposals will be evaluated by a jury, after a debate with the audience.

The winning solution will be selected based on the following criteria:

- Does the proposed solution represent a valid business case?
- Are the value propositions attractive?
- Are the solution and the proposed time-frame realistic?
- Will the required technology be ready on time?
- What is the risk of the investment?

Team Leaders:

Nicolas Fontaine, *Nokia Bell Labs, USA*
 Juan Pedro F-P. Gimenez, *Telefonica, Spain*
 Glenn Wellbrock, *Verizon, USA*

S2E: Will Cloud-Optical Boxes Change the Way Today's Networks are Deployed?

Room 6F

Organizers: Andrew Lord, *British Telecom, UK*; Harald Bock, *Coriant, USA*

To meet high capacity and low latency requirements driven by IoT and 5G mobile together with the delivery of video content, it is essential to combine optical transport, packet switching, NFV and cloud capabilities into a seamless and efficient end-to-end network. Various emerging industry consortia are seeking to drive aspects of the open interoperability required in such an environment, e.g. TIP, openROADM, MEC and fog computing.

A new generation of optical nodes tailored for this cloud environment is now emerging, extending the paradigm of packet-optical nodes to 'cloud-optical boxes' which may include packet and/or optical functions.

How is this going to change the way today's networks are designed and operated? On the one hand, cloud data centers strongly rely on disaggregation of HW and SW functions, which requires open traffic interfaces and open control APIs, whilst on the other hand, the split between functions needs to be defined and may differ depending on use-cases. This is resulting in different market requirements: e.g. while a large part of the industry uses open compute project

switches and DWDM DC-I equipment separately, the TIP initiative defines an integrated switch with DWDM interfaces.

This workshop will bring together experts from optical equipment vendors, cloud providers and network operators to express their opinions on 'cloud-optical boxes' and the appropriate function split required.

Speakers:

Marc De Leenheer, *ONF, USA*
 Scott Mountford, *AT&T, USA*
 Hans-Jürgen Schmidtke, *Facebook, USA*

Lab Automation Hackathon

Sunday, 11 March, 20:00–22:00
 Room 29D

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

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





Data Science Career Opportunities

Monday, 12 March, 09:00–16:30

Room 29D

Separate registration required

Sponsored by the OSA Foundation and Milton and Rosalind Chang, this short course provides an introduction to careers in data science. It incorporates interactive lectures and group exercises. Attendees will learn how their technical skills can transition into the data science field and what a career in data science is like. By the end of this short course, attendees will understand what the field of data science and the roles, necessary skills, and types of problems data scientists work on. Attendees will understand the data science project lifecycle and outputs.

Symposia

Three symposia are scheduled for 2018. Please refer to the abstract section for full descriptions:

Challenges 5G Brings to Optical Fiber Communications Systems, 12 March, 14:00–18:30, page 54.

Future Photonic Devices and Materials for Optical Communications, 12 March, 14:00–18:30, page 55.

Network Management Evolution to Streaming Analytics and Cognitive Systems, 13 March, 16:30–18:30, page 81.

Panels

There are 6 panels scheduled for OFC 2018. Please refer to the abstract section for full descriptions.

Machine Learning and SDN: Towards Intelligent Data Centers, 12 March, 14:00–16:00, page 55.

Flexible Grid Deployments, 13 March, 16:30–18:30, page 81.

2020 Network Vision 5G and Optical Networking, 14 March, 16:30–18:30, page 107.

Near Term, Large Scale Fiber Deployments for Evolving Networks, 15 March, 08:00–10:00, page 115.

400G Optics for Hyperscale Data Centers, 12 March, 10:30–12:30, page 47.

Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?, 14 March, 08:00–10:00, page 91.

Data Center Summit: Data Center Optical Interconnect - Technologies and Markets

Tuesday, 13 March, 10:15–12:15

Expo Theater II, Hall E

Session organized by OFC'18 N5 Program: Frank Chang, Inphi Corporation, USA

To many in the optical networking industry, data center means these massive buildings with servers, storage and switching that run cloud infrastructures for the likes of Amazon, Facebook, Google, Microsoft and others. In reality, the market connecting data centers poses a different opportunity for network operators. The needs for this market are quite diverse from the traditional optical networking ones and depend on what type of data center is involved. The various types of data center operators, their needs and how they are being addressed will be discussed in details.

Panelists will be invited from industry experts and debate the following with specific focus on technology, applications, deployment scenarios for data centers:

- What are the different types of data centers and how do they connect to each other?
- How is the cloud data center driving new generations of optical interconnects?
- What are the current technologies and equipment being used to address this market
 - Layer 2 – Ethernet over DWDM
 - Open Optical Line Systems (OOLS)
 - Packet Optical
 - Carrier Ethernet
 - Pluggables – 100G for DCI
 - Coherent - CFP-DCO, CFP2-ACO and CFP2-DCO

- What are the new technologies being developed for higher data rates?
- 400G and beyond – will the equipment be the same, just upgraded to 400G or do we need a new ecosystem?
- CDFP, CFP8, OSFP, QSFP-DD – will all have markets and if so, where?
- 400G ZR challenges and roadmap
- What are the potential architecture and roadmap after 400G?

Moderator

Frank Chang, Inphi Corporation, USA

Keynote

Terran Huang, Tencent, China

Panelists

David Chen, Applied Optoelectronics, USA

Stu Elby, Infinera, USA

Benny Koren, Mellanox, Israel

Rao G. Lingampalli, Equinix, USA

Sam Liu, Nokia, USA

Sanjai Parthasarathi, II-VI Photonics, USA

OIDA VIP Industry Leaders Speed Meetings Event

Tuesday, 13 March, 12:00–13:30

Room 33B

Separate 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: 

If you have questions about this event or are a Student or Recent Graduate and interested in attending, please email vipevents@osa.org.





Open Platform Summit: SDN/NFV Demonstration Zone

Open Platforms for Optical Innovation

Tuesday, 13 March, 14:00–16:00
Room 7AB

Organizers: Ramon Casellas, *CTTC, Spain*; Ilya Baldin, *RENCI/UNC Chapel Hill, USA*; Loukas Paraschis, *Infinera, USA*; Noboru Yoshikane, *KDDI Research, Japan*

In the first session of the Open Platform Summit, invited speakers will provide an overview of key frameworks, architectures and projects within the trend of using open hardware and software platforms for designing, deploying and operating large-scale networks and complex commercial environments, showcasing the benefits behind the concepts of Software Defined Networking (SDN) and Network Functions Virtualization (NFV).

The session presentations will be technology oriented, and will include both the point of view of the *operator/user* of the platform and that of the *system vendor / integrator*. For the former, focus will be on key benefits such as reduction of operational expenses and automation of network control or service provisioning. For the latter, the target is to provide an overview of key projects, including relevant architectural elements and main drivers and innovation opportunities.

Speakers

Hans-Juergen Schmidtke, *Facebook, USA*
The Telecom Infra Project (TIP)

Martin Birk, *AT&T, USA*
Open ROADM MSA Introduction and Progress

Gert Grammel, *Juniper, USA*
Anders Linders, *Telia, Sweden*
Stefan Melin, *Telia, Sweden*

TIP-PSE: Planning Open Optical Line Systems

Diego López, *Telefónica, Spain*
The OSM Way Towards Open NFV Orchestration

SDN/NFV Demonstration Zone

Tuesday, 13 March, 16:30–18:30
Room 6A

The OFC Open Platform Summit (OPS) Session II, “SDN & NFV Demonstration 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.

Live demonstrations are an opportunity to see technical achievements in greater detail and will facilitate vivid discussions with attendees. Presenters will be available for the duration of the session to answer questions and to perform the demonstration upon request. Demonstrations can be carried out multiple times during the session.

Exhibitor Happy Hour

Tuesday, 13 March, 17:15–18:45
Center Terrace, San Diego Convention Center

OFC 2018 exhibitors are invited to celebrate the opening of the show. Join your colleagues, customers, and friends for drinks and light appetizers before heading into the Conference Reception. Exhibitor badge required for entry.

Conference Reception

Tuesday, 13 March, 18:30–20:00
Sails Pavilion, San Diego Convention Center

Enjoy food and drinks with your friends and colleagues during the conference. Tickets for this event are included with all full conference registrations. Additional tickets may be purchased at Registration for US \$85.

Rump Session: When Will Coherent Replace Direct Detection in the Data Center?

Tuesday, 13 March, 19:30–21:30
Room 6F

Organizer: Chris Cole, *Finisar Corporation, USA*

Provocateurs: Sudeep Bhoja; *InPhi Corporation, USA*; Peter De Dobbelaere; *Luxtera Inc., USA*; Chris Doerr; *Acacia Inc., USA*; Fotini Karinou; *Huawei Technologies Co. Ltd., Germany*; George Papan; *UCSD, USA*; Bardia Pezeshki; *Kaiam Corporation, USA*; Martin Schell; *Fraunhofer HHI, Germany*; Haoli Qian; *Credo Semiconductor Inc., USA*; Chongjin Xie; *Alibaba Group Holding Ltd., China*

Description:

Over time, optics has replaced copper cables starting with long reach transmission, followed by regional, metro, inter-facility, and finally all links inside the data center except for server interconnect. Even server I/O is under challenge by active optical cables. Replacement of IMDD (Intensity Modulated Direct Detection) optics by Coherent optics appears to be following the same trend, but on a delayed time line. Coherent has now replaced IMDD in long reach transmission, regional, and metro applications. Coherent vs. IMDD for 20km, 40km and 80km links at 100G and 400G is the subject of intense industry debate including in standards bodies and tough competition in the market place. Will the trend continue, and when if ever will Coherent replace IMDD for 500m, 1km and 2km data center links?

Questions for Discussion:

- Coherent has superior sensitivity to IMDD. Does that matter for data center loss budgets of 3dB to 7dB?
- Coherent has superior impairment mitigation (CD, PMD) to IMDD. Does that matter for 500m to 2km reaches?
- Power is becoming the dominant performance metric in the data center. Which is inherently lower power – Coherent or IMDD?





- Analog techniques have traditionally led to the lowest power. Is analog easier for Coherent or IMDD? Which can more easily eliminate DSP?
- Coherent requires IQ modulation which imposes physical dimension requirements on modulator implementations. Does that lead to a cost disadvantage for transmitter implementations?
- Low latency links are becoming increasingly important for applications requiring large data base searches and machine learning. Which has inherently lower latency – Coherent or IMDD?
- Optical switching and hybrid electrical/optical topologies are becoming increasingly important for managing cost and power in the data center. Which has inherently faster locking speed – Coherent or IMDD?
- Does IMDD enable use of weak or no FEC for lowest latency links?

Format:

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

Connected OFCity Challenge 2018: Lighting Up the Emerging World

Wednesday, 14 March, 14:00–16:00

Room: 6C

Organizers: Marco Ruffini, *Trinity College Dublin, Ireland*; Inder Monga, *ESNet, USA*; Jun Shan Wey, *ZTE, USA*

Building on the success of its first two editions, the Connected OFCity Challenge returns in 2018 with a renewed format.

Alibaba and Google will collaboratively take on the challenge to develop communications infrastructure and services based on requirements defined by CSquared and NSRC, to address the pressing needs for two cities in a fast developing area in East Africa.

More information located on page 102.

**Photonic Society of Chinese-Americans Workshop & Social Networking Event
The Emerging Technology Enablers for Next Generation Networks**

Wednesday, 14 March

Room 14A, San Diego Convention Center

17:00–17:30, Registration and Social Networking

17:30–19:30, Panel Discussions, Q&A

Registration Contact:

Genzao Zhang: Genzao_Zhang@emcore.com, +1.626-710-8788

David Li: dli@archcomtech.com, +1. 630-308-3362

Workshop Registration Fee: Free

To serve our mission of bringing together photonics professionals, enhancing the communication and collaboration in the optical industry, PSC-SC has been organizing technical and social events during OFC in the past 10 years. In OFC2018, 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 / China International Optoelectronic Expo (CIOE)



Postdeadline Paper Presentations

Thursday, 15 March, 16:30–18:30

Rooms 6C, 6D, 6E, 6F

Discover the best and most cutting-edge research in optical communications. The OFC 2018 Technical Program Committee has accepted a limited number of postdeadline papers for oral presentation. The purpose of postdeadline papers is to give participants the opportunity to hear new and significant material in rapidly advancing areas. Only those papers judged to be truly excellent and compelling in their timeliness were accepted.

Lists of accepted papers with their presentation times will be posted throughout the convention center on Tuesday, 13 March. Please visit www.ofcconference.org and click the “Download Digest Papers” button to access these papers.



Plenary Session

OFC Plenary Session

Tuesday, 13 March, 08:00–10:00
Ballroom 20BCD



Universal Laws and Architectures in Complex Networks

John C. Doyle, *California Institute of Technology (Caltech), USA*

Effective layered architectures such as the brain seamlessly integrate high level goal and decision making and planning with fast lower level sensing, reflex, and

action and facilitate learning, adaptation, augmentation (tools), and teamwork, while maintaining internal homeostasis despite the severe demands such actions can put on the whole body's physiology, and despite being implemented in highly energy efficient hardware that has distributed, sparse, quantized, noisy, delayed, and saturating sensing, communications, computing, and actuation. Similar layering extends downward into the cellular level, and many aspects of this convergent evolution will increasingly dominate our most advanced technologies. Live demos using audience's brains highlight universal laws and architectures and their relevance to future network technologies. We'll briefly give pointers to a new unified mathematical framework that we hope will facilitate reverse engineering cells, brains, and societies and forward engineering future network architectures.

John Doyle is the Jean-Lou Chameau Professor of Control and Dynamical Systems, Electrical Engineer, and BioEngineering at Caltech, and received the BS&MS in EE, MIT (1977), and PhD in Math, UC Berkeley (1984). He was a consultant at Honeywell Systems and Research Center from 1976 to 1990.

Research is on mathematical foundations for complex networks with applications in biology, technology, medicine, ecology, neuroscience and multiscale physics that integrates theory from control, computation, communication, optimization and statistics (e.g., Machine Learning). An emphasis on universal laws and architectures, robustness/efficiency and speed/accuracy tradeoffs, adaptability and evolvability and

large scale systems with sparse, saturating, delayed, quantized, uncertain sensing, communications, computing and actuation. Early work was on robustness of feedback control systems with applications to aerospace and process control. His students and research group developed software packages like the Matlab Robust Control Toolbox and the Systems Biology Markup Language (SBML).



The Future of Optical Communications

Marcus Weldon, *Nokia Bell Labs, USA*

Abstract not available at time of print. Please refer to the website or the OFC App for the latest update.

Marcus Weldon is considered one of the luminaries in the industry in terms of the clarity, depth and breadth of his vision for the future of networks. He has championed many technological disruptions in telecommunications networks, from the evolution and convergence of networks to "all IP," the evolution of copper-based Access networks to support sophisticated interference cancellation (so-called vectoring), the evolution of wireless networks to highly-distributed networks of small cells and the emergence of virtualization and Software Defined Networking as profound industry changing forces that will drive a new integrated and federated network architecture and economics.

Marcus holds a BS in chemistry and computer science from King's College, London, and a PhD in physical chemistry from Harvard University. In 1995 he joined the Physics Division at AT&T Bell Labs as a post-doctoral researcher, before becoming a Member of Technical Staff in the Optical Materials Division. He won a series of scientific and engineering society awards for his work on electronic and optical materials, and holds numerous patents related to that work. In 2005 he moved from research to hold a variety of CTO roles in different business divisions, before becoming the Corporate CTO with responsibility for defining the future direction of the industry and the

associated evolution of the Alcatel-Lucent portfolio. He became the thirteenth President of Bell Labs in December 2013.



Optical Networking in the Cloud and 5G Era

Chengliang Zhang, *China Telecom Beijing Research Institute, China*

In this plenary talk, we will present recent optical network evolution of China Telecom and other major Chinese network operators, which is enabled by modern technologies

such as coherent 100G/200G, ROADM/WSS, transport SDN, and data center connectivity. With the intensification of cloud-based services and 5G wireless developments, we will also discuss how optical transport network (OTN) need to be transformed to better address future demands such as higher capacity, lower latency, and service-specific network slicing.

Chengliang Zhang has worked extensively in the optical networks, SDN/NFV and network evolution. From 1995 to 2002, he worked as an engineer and a director of Transmission and Access Research Department at China Information and Communication Research Institute where he engaged in research on optical networks. From 2002 to 2014, he was a deputy Chief Engineer at China Telecom Corporation Limited Beijing Research Institute (CTBRI), conducting research on optical networks and broadband networks. He is currently the Vice President of the China Telecom Beijing Research Institute and the Vice President of Optical committee, China Institute of Communications.

OFC and Sponsor Awards and Honors

Awards Ceremony and Luncheon

Tuesday, 13 March, 12:00–14:00
Ballroom 20A

Supported by:

CORNING

The conference sponsors – IEEE Communications Society, IEEE Photonics Society, and The Optical Society – will present awards and honors in a special luncheon on Tuesday, 13 March. 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.

The following awards will be presented at the luncheon:

2018 John Tyndall Award

IEEE Communications Society 2018 Fellows

IEEE Photonics Society 2018 Fellows

The Optical Society 2018 Fellows

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

The Corning Outstanding Paper Competition, OSAP

The Tingye Li Innovation Prize, OSAP



From left to right: Kent Choquette, Claudio Mazzali, Evgeny Dianov, 2017 John Tyndall Award Winner, Alan Willner

Short Course Schedule

Sunday, 11 March 2018

09:00–12:00

SC177: High-Speed Semiconductor Lasers and Modulators

John Bowers; *University of California at Santa Barbara, USA*

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

Stephen Trowbridge; *Nokia, USA*

SC444: Optical Communication Technologies for 5G Wireless

Xiang Liu; *Futurewei Technologies, Huawei R&D, USA*

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

Andrew Lord; *BT Labs, BT, UK*

SC461: High-capacity Data Center Interconnects NEW

Dirk van den Borne¹, Sander L. Jansen²; ¹*Juniper Networks, Germany*, ²*ADVA Optical Networking, Germany*

SC463: Optical Transport SDN: Architectures, Applications, and Actual Implementations NEW

Achim Autenrieth, Jörg-Peter Elbers; *ADVA Optical Networking SE, Germany*

09:00–13:00

SC105: Modulation Formats and Receiver Concepts for Optical Transmission Systems

Peter Winzer, Xi Chen; *Nokia Bell Labs, USA*

SC384: Background Concepts of Optical Communication Systems

Alan Willner; *University of Southern California, USA*

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

Harald Rohde, Robert Palmer; *Elenion, Germany*

SC454: Hands-on: Introduction to Silicon Photonics Circuit Design

Wim Bogaerts; *University of Gent, Belgium*

13:00–16:00

SC216: An Introduction to Optical Network Design and Planning

Jane M. Simmons; *Monarch Network Architects, USA*

SC429: Introduction to Flexible Photonic Networks

David Boertjes; *Ciena, Canada*

SC433: Introduction to Photodetectors for Optical Communications

Joe C. Campbell; *University of Virginia, USA*

SC462: Introduction to Pluggable Optics NEW

Sharon Hall¹, Robert Blum²; ¹*Oclaro, USA*, ²*Intel Corp., USA*

13:00–17:00

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

Martin Birk¹, Benny Mikkelsen²; ¹*AT&T Labs, USA*, ²*Acacia Communications, USA*

SC325: Highly Integrated Monolithic Photonic Integrated Circuits

Chris Doerr; *Acacia Communications, USA*

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

Bernd Nebendahl, Michael Koenigsmann; *Keysight, Germany*

13:30–17:30

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

Lionel Kimerling; *MIT, USA*

SC327: Modeling and Design of Fiber-Optic Communication Systems

Rene-Jean Essiambre; *Nokia Bell Labs, USA*

SC393: Digital Signal Processing for Coherent Optical Systems

Chris Fludger; *Cisco Optical GmbH, Germany*

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

Sylwester Latkowski¹, Arne Leinse², Twan Korthorst³, Peter O'Brien⁴; ¹*Eindhoven University of Technology, Netherlands*; ²*LioniX International, Netherlands, Netherlands*, ³*PhoeniX Software, Netherlands*, ⁴*Tyndall National Institute*

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*

SC408: SDM Based Fiber-optic Transmission Systems

Roland Ryf; *Nokia Bell Labs, USA*

SC451: Optical Fiber Sensors

Zuyuan He¹, William Shroyer²; ¹*Shanghai Jiao Tong University, China*, ²*SageRider, Inc., USA*

Monday, 12 March 2018

08:30–12:30

SC102: WDM in Long-Haul Transmission Systems

Neal S. Bergano; *TE Subcom, USA*

SC114: Passive Optical Networks (PONs) Technologies

Yuanqui Luo; *Huawei, USA*

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

Greg D. LeCheminant; *Keysight Technologies, USA*

SC443: Optical Amplifiers: From Fundamental Principles to Technology Trends

Michael Vasilyev¹, Shu Namiki²; ¹University of Texas at Arlington, USA ; ²National Institute of Advanced Industrial Science and Technology (AIST), Japan

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

Harald Rohde and Robert Palmer; *Elenion, Germany*

SC452: FPGA Programming for Optical Subsystem Prototyping

Noriaki Kaneda¹, Laurent Schmalen²; ¹Nokia Bell Labs, USA, ²Nokia Bell Labs, Germany

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

Chris Heisler¹, Steve Lane², Julien Maille², Steve Baldo³, Keith Foord⁴; ¹OptoTest Corporation, USA; ²Data-Pixel, France; ³Seikoh Giken Company, USA; ⁴Greenlee Communications, USA

SC460: Digital Coherent Optical System Performance Basics: Transceiver Technology and Performance NEW

Maurice O'Sullivan¹, John Cartledge²; ¹Ciena, Canada; ²Queen's University, Kingston, Canada

09:00–12:00

SC176: Metro Network Evolution

Loudon Blair, David Krauss; *Ciena Corp., USA*

SC359: Datacenter Networking 101

Hong Liu; *Google, USA*

SC390: Introduction to Forward Error Correction

Frank Kschischang; *University of Toronto, Canada*

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

Ori A. Gerstel; *Sedona Systems, Israel*

SC428: Link Design for Short Reach Optical Interconnects

Petar Pepeljugoski; *IBM Research, USA*

SC442: Free Space Switching Systems: PXC and WSS

David Neilson; *Nokia Bell Labs, USA*

SC448: Software Defined Networking for Optical Networks: a Practical Introduction

Ramon Casellas; *CTTC, Spain*

SC459: Space Division Multiplexing Components and Devices NEW

Nicolas Fontaine; *Nokia Bell Labs, USA*

SC465: Transmission Fiber and Cables NEW

Christopher Towery, Mike Ellwanger; *Corning Optical Communications, USA*

13:30–16:30

SC208: Optical Fiber Design for Telecommunications and Specialty Applications

David J. DiGiovanni; *OFS Labs, USA*

SC261: ROADM Technologies and Network Applications

Thomas Strasser; *Nistica Inc., USA*

SC385: Optical Interconnects for Extreme-scale Computing

John Shalf¹, Keren Bergman²; ¹Lawrence Berkeley National Laboratory, USA, ²Columbia University, USA

SC431: Photonic Technologies in the Data Center

Clint Schow; *University of California, USA*

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

Harald Haas; *LiFi Research and Development Centre, The University of Edinburgh, UK*

SC464: SDN Inside and in between Data Centers NEW

David Maltz; *Microsoft, USA*

13:30–17:30

SC160: Microwave Photonics

Vince Urlick; *DARPA, USA*

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

Sander L. Jansen¹, Dirk van den Borne²; ¹ADVA Optical Networking, Germany, ²Juniper Networks, Germany

SC347: Reliability and Qualification of Fiber-Optic Components

David Maack; *Corning, USA*

SC432: Hands on: Silicon Photonics Component Design & Fabrication

Lukas Chrostowski; *University of British Columbia, Canada*

SC449 : Hands-on: An Introduction to Writing Transport SDN Applications

Ricard Vilalta¹, Karthik Sethuraman²; ¹CTTC, Spain, ²NEC Corporation of America, USA

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

Chris Heisler¹, Steve Lane², Julien Maille², Steve Baldo³, Keith Foord⁴; ¹OptoTest Corporation, USA; ²Data-Pixel, France; ³Seikoh Giken Company, USA; ⁴Greenlee Communications, USA

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. 700+ 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 700+ exhibits, three exhibit hall theaters feature presentations by experts from major global brands and key industry organizations. Get high-level perspectives on hot topics like Cloud Services, SDN and FTTx. 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 A-H

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

Exhibit Hall Regulations

- All bags are subject to search.
- Neither photography nor videotaping is permitted in the exhibit hall without 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, 13 March	10:00–17:00	10:00–10:30, 16:00–16:30
Wednesday, 14 March	10:00–17:00	10:00–10:30, 16:00–16:30
Thursday, 15 March	10:00–16:00	10:00–10:30

Market Watch, Exhibit Hall G, Expo Theater I

Get an insider's look at today's most important industry developments.

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 speakers from top carriers, system vendors, market analyst firms and component companies. See page 21 for schedule.

Network Operator Summit, Exhibit Hall G, Expo Theater I

Get the inside perspective from network operators.

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.

Poster Presentation, Exhibit Hall B

Poster presentations are an integral part of the technical program and offer an opportunity for lively discussion between the poster presenters and attendees. OFC has expanded its presentation modes to include a select number of interactive demonstrations. These featured displays can range from live software demonstrations to the showcasing of research prototypes (subsystems or devices) that form the core of the related research paper. Beverages and light snacks are served during poster sessions. See pages 98 and 122 for full description.

Product Showcases, Exhibit Hall B, Expo Theater III

Exhibitors highlight their newest developments, products and services in 30-minute presentations on the show floor. Refer to page 23 or the OFC Conference App for presentation schedule.

Please refer to your OFC Buyers' Guide and Addendum for more details on the exhibition and other activities on the show floor, including participating company information, a map of the Exhibit Hall and specific presentation schedules for many of the programs. Check the OFC Conference App for regular updates to show floor programming (see page 6 for details on the app).

Show Floor Programming and Activities

The Suzanne R. Nagel Lounge

New for 2018 – Dedicated, inclusive space for attendees to better create connections, spark conversations and generate awareness of diversity and gender inclusion within the OFC community. The lounge will be open during exhibit hall hours and will provide professional development resources, i.e. career coaching, professional headshots, resume review and mentorship for women attendees at OFC.

Come relax or use the office center and connect with others who are working to ensure gender equity and inclusion within the field!

Sponsored by:



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.

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

N5 Network Operators Summit and Market Watch Sub-Committee Chair: Frank Chang; Inphi Corporation, USA

Sponsored by: HUAWEI

Schedule-at-a-Glance

Tuesday, 13 March	
10:30–12:00	Panel I: State of the Industry - Analyst Panel
12:30–14:00	Panel II: Optical Bearer Technologies for 5G Networks
14:30–16:00	Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics
Wednesday, 14 March	
15:30–17:00	Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality
Thursday, 15 March	
10:30–12:00	Panel V: Software Innovations in the Next-generation Optical Transport
12:30–14:00	Panel VI: IP and Optical Integration: Physical or Control Management Plane?

Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center

Tuesday, 13 March, 16:15–17:00
Expo Theater I, Exhibit Hall G

Session organized by San Diego Convention Center

A panel of the parties responsible for the recent fiber-based DAS (Distributed Antenna System) installation

at San Diego Convention Center speak to the drivers, challenges, strategy and technology considerations behind the project. This comprehensive case study conversation will cover the multi-dimensional perspective of all stakeholders – including the venue (SDCC), network owner, solutions integrator, technology vendor and the City of San Diego—as they address various topics surrounding the system deployment. Plus, the audience will learn project life-cycle best practices and glean the impact upon guest satisfaction and future convention bookings.

Topics to be discussed:

- Problem-solution story – the customer perspective
- Selection process for business and technology partners
- Technology and infrastructure rationale
- Fiber system deployment best practices and lessons learned
- Results and impact on the SDCC and City of San Diego

A private tour of the San Diego Convention Center DAS will be available to the first 60 guests to register (Three tours - limit of 20 guests each). Secure your spot by registering at <https://sdcc-das-tour-ofc.eventbrite.com>

Moderator

Mike Collado, *Corning, USA*

Panelists

Karen Totaro, *San Diego Convention Center, USA*
David Langford, *Smart City Networks, USA*
Bryce Bregen, *Connectivity Wireless Solutions, USA*
Bill Cune, *Corning, USA*
Chris Ward, *City of San Diego, USA*

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Network Operator Summit

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


N5 Network Operator Summit and Market

Watch Sub-Committee Chair: Frank Chang; *Inphi Corporation, USA*

Sponsored by:



Schedule-at-a-Glance

Wednesday, 14 March	
10:30–11:00	Network Operators Summit Keynote:  Najam Ahmad, Vice-President, Network Engineering, Facebook, USA
11:00–12:30	Panel I: The Role of “Open Transport” in the New Metro and Inter-Data-Center Architectures
12:30–13:30	NOS Networking Lunch
13:30–15:00	Panel II: On the Road to 100G PON (Beyond 10G PON)

Expo Theater Programming

Expo Theaters II and III include educational programs available to all OFC registrants. Topics range from business solutions to emerging technologies in the marketplace. This year many industry groups will present: AIM Photonics, COBO, Ethernet Alliance, IEEE, OpenFog Consortium, ON2020, Open19 Foundation, OIF, OpenConfig and POFTO.

Expo Theater II Programming, Exhibit Hall E

Sponsored by:



Schedule-at-a-Glance

Tuesday, 13 March	
10:15–12:15	Data Center Summit: Data Center Optical Interconnect – Technologies and Markets
12:45–13:45	Ethernet Alliance: Ethernet Roadmaps Update
14:00–17:00	Disaggregating the Transport Layer: What it Means to the Bottom Line <i>Session Sponsored by Juniper Networks</i>
Wednesday, 14 March	
10:15–11:45	COBO: COBO Specification Overview and Next Steps
12:00–13:00	Open19 Foundation: Server Fibreless Optical Networking
13:15–15:15	ON2020: Industry Visions for a Converged Optical Networking Roadmap
15:30–17:00	Machine Learning: Developing Efficiency in Customer Networks
Thursday, 15 March	
10:15–11:15	OIF: 400G Coherent: What does it Mean to You?
11:30–12:30	IEEE: Preparing for the GDPR: The EU’s Sweeping Data Privacy Reform Initiative
12:45–13:45	Standardization in ITU-T Study Group 15 – Networks, Technologies and Infrastructures for Transport, Access and Home

Expo Theater III Programming, Exhibit Hall B

Sponsored by:



Schedule-at-a-Glance

Tuesday, 13 March	
10:15–10:45	Product Showcase, Huawei USA
11:00–12:30	OpenConfig: Open Management and Monitoring of Multilayer Webscale and Carrier Networks
12:45–14:15	IEEE and OpenFog Consortium: Fog Computing and Optical Networking – What’s Next?
14:30–15:30	OIF: Enabling the Key Applications for Transport SDN
15:45–16:45	AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions
Wednesday, 14 March	
10:15–10:45	Product Showcase, Huawei USA
11:00–11:30	Product Showcase, Xilinx
11:30–12:00	Product Showcase, Xilinx
12:00–12:30	Product Showcase, Hengtong Optic-Electric Co., Ltd.
12:30–13:00	Product Showcase, Colorchip
13:00–13:30	Product Showcase, ATOP
13:30–14:30	Next Generation Coherent: Architectures and Technologies <i>Session Sponsored by Acacia Communications</i>
15:45–17:00	400G Standards, MSAs and Related Technologies: What is on the Horizon?
Thursday, 15 March	
10:15–10:45	Product Showcase, Huawei USA
11:00–13:00	POFTO: POF Symposium
13:15–14:15	Understanding Optical Signal-to-Noise Ratio

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Product Showcases

5G and Low Latency Network

Tuesday, 13 March, 10:15–10:45

Dr. Sean Long, Director, PLM for Transmission Network, *Huawei Technologies USA, USA*

5G mobility networks promise to deliver much higher speed and capacity while also providing greatly reduced latency. Though the best use cases for monetization of 5G will likely not emerge until network capabilities are enabled, 5G presents a unique set of opportunities and challenges for network transformation. Here we present Huawei's E2E, low latency network solution to better support 5G and future proof network transformation.

OXC and All-optical Intelligence Lead to WDM Transport Network (WTN)

Wednesday, 14 March, 10:15–10:45

Ning Deng, Principal Engineer, *Huawei Technologies Co., Ltd., China*

We will introduce latest solutions and technologies on Optical Cross Connect (OXC) and All-optical Intelligence. These technologies together lead to more agile and powerful end-to-end networking on WDM layer.

Next Generation Fronthaul Network Slicing for 5G

Wednesday, 14 March, 11:00–11:30

Faisal Dada, Wired Solutions Architect, *Xilinx, USA*
Harpinder Matharu, Director Communications Strategic & Technical Marketing, *Xilinx, USA*

Looking at the evolution of 5G network requirements for front, mid and backhaul. Discussing various technologies to address these requirements with a special focus on what key technologies from cloud networking can be reused and targeted for 5G.

The Next Generation 5G Optical Network

Wednesday, 14 March, 11:30–12:00

Faisal Dada, Wired Solutions Architect, *Xilinx, USA*
Harpinder Matharu, Director Communications Strategic & Technical Marketing, *Xilinx, USA*

Looking at the evolution of 5G network requirements for and impact on optical infrastructure. Discussing various technologies to address these requirements & changes with a special focus on what key technologies from cloud networking can be reused and targeted for 5G.

High Reliability Submarine Optical Fiber and its International Sea Trial

Wednesday, 14 March, 12:00–12:30

HengTong, *Optic-Electric, China*

In this presentation, we will show the self-developed submarine optical fiber, which has excellent transmission performance and high environmental reliability. The reliability has been proved by the international sea trial and has been successfully applied in engineering, it is the best choice for large capacity ocean communication system.

Industry First Datacenter Solutions with 200G QSFP56 FR4 and 100G Serial PAM4 Laser for 400G

Wednesday, 14 March, 12:30–13:00

Yigal Ezra, CEO, *Colorchip, USA*

The presentation will review ColorChip recent technological breakthroughs, expanding its patented SystemOnGlass™ photonic integrated circuit platform with 200G QSFP56 FR4 and 100G Serial PAM4 Laser, toward Datacenter Solutions for 400G and beyond.

The 200-800GE Optics for Datacenter Market

Wednesday, 14 March, 13:00–13:30

Ruizhi Zheng Ph.D, CEO of TCphotonics, *ATOP, USA*

In this presentation, we will demonstrate our solution to reduce the OSA (made by bulk optics) to meet the QSFP-DD, and even uQSFP-DD requirements. This makes it possible to package the 8x25/50G OSA in uQSFP transceiver, and 16x25/50G OSA in OSFP transceiver for datacenter market.

ACTN, Driver for Network Slicing for 5G Transport

Thursday, 15 March, 10:15–10:45

Dr. Young Lee, Technical Director, Network Architecture of SDN, *Huawei Technologies USA Inc., USA*

This presentation gives an overview of ACTN (Abstraction and Control of TE Networks) as an enabler for network slicing for 5G transport. ACTN is an IETF standard that enables SDN hierarchical control using network abstraction and dynamic creation of virtual network service with telemetry support for real-time KPI monitoring. Huawei is the leader for ACTN standards and product implementations in its TSDN product family.

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Technical Program and Steering Committees

General Chairs

Martin Birk, *AT&T Labs, USA*
Xiang Liu, *FutureWei Technologies, Inc., USA*
David J. Richardson, *University of Southampton, UK*

Program Chairs

Robert D. Doverspike, *Network Evolution Strategies LLC, USA*
Daniel Kuchta, *IBM TJ Watson Research Center, USA*
William Shieh, *University of Melbourne, Australia*

Subcommittees

Track D: Optical Components, Devices and Fiber

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

Rich Baca, *Microsoft Corporation, USA, Subcommittee Chair*
Alan F. Evans, *Corning Research & Development Corporation, USA*
Lara D. Garrett, *TE SubCom, USA*
Nitin K. Goel, *Facebook Inc., USA*
Kenneth Jackson, *Sumitomo, USA*
Chen Ji, *Institute of Semiconductor, Chinese Academy of Sciences, China*
Ashok V. Krishnamoorthy, *Axaluma, Inc., USA*
Jing Li, *Yangtze Optical Fibre and Cable, China*
Alan McCurdy, *OFS, Fiber Design & Simulation Group, USA*
Yusuke Nasu, *NTT Photonics Laboratories, Japan*
Daniel L. Peterson, *Verizon Communications, Inc., USA*
Xiaoxia Wu, *Juniper, USA*
Yongpeng Zhao, *Luster Lightech Corporation, China*

OFC D2: Passive Optical Devices for Switching and Filtering

Mark D. Feuer, *CUNY College of Staten Island, USA, Subcommittee Chair*
Joel Carpenter, *The University of Queensland, Australia*
Haoshuo Chen, *Nokia Bell Labs, USA*
Nicolas Dupuis, *IBM T.J. Watson Research Center, USA*
Piero Gambini, *STMicroelectronics, Italy*
Richard A. Jensen, *Polatis, Inc., USA*
Guo-Qiang Lo, *Institute of Microelectronics, Singapore*

Christi K. Madsen, *Texas A&M University, USA*
Sylvie Menezo, *CEA-LETI, France*
Joyce K S Poon, *University of Toronto, Canada*
Hiroyuki Tsuda, *Keio University, Japan*

OFC D3: Active Optical Devices and Photonic Integrated Circuits

Michael Larson, *Lumentum, USA, Subcommittee Chair*
Guang-Hua Duan, *3SP Technologies, France*
Dazeng Feng, *MellanoX, USA*
Kazuhiko Kurata, *PETRA, Japan*
Anders Larsson, *Chalmers Tekniska Hogskola, Sweden*
Yasuhiro Matsui, *Finisar Corporation, USA*
Kouji Nakahara, *Oclaro Japan, Inc., Japan*
Dong Pan, *SiFotonics Technologies Co., Ltd., USA*
Maura Raburn, *Google, USA*
Thomas Schrans, *Rockley Photonics, USA*
Zhiping Zhou, *Peking University, China*

OFC D4: Fiber and Propagation Physics

Oleg V. Sinkin, *TE SubCom, USA, Subcommittee Chair*
Kazuhiko Aikawa, *Fujikura Ltd., Japan*
John Ballato, *Clemson University, USA*
Marianne Bigot, *Prysmian Group, France*
Wladek Forsysak, *Aston University, UK*
Tetsuya Hayashi, *Sumitomo Electric Industries, Ltd., Japan*
Ming-Jun Li, *Corning Research & Development Corporation, USA*
Bishnu P. Pal, *Bennett University, Greater Noida, India*
Bera Palsdottir, *OFS Fitel Denmark I/S, Denmark*
Francesco Poletti, *University of Southampton, UK*
Axel Schulzgen, *University of Central Florida, USA*

OFC D5: Fiber-Optic and Waveguide Devices and Sensors

Rogério Nogueira, *Instituto De Telecomunicacoes, Portugal, Subcommittee Chair*
Rodrigo Amezcua Correa, *University of Central Florida, CREOL, USA*
Maxim A. Bolshtyansky, *TE SubCom, USA*
Nicolas K. Fontaine, *Nokia Corporation, USA*
Miguel Gonzalez Herraiz, *Universidad de Alcala, Spain*
Takemi Hasegawa, *Sumitomo Electric Industries Ltd, Japan*
Efstratios Kehayas, *Gooch & Housego, UK*
Yasutake Ohishi, *Toyota Technological Institute, Japan*
Francesca Parmigiani, *University of Southampton, UK*
Karsten K. Rottwitz, *Danmarks Tekniske Universitet, Denmark*

Track S: Photonic Systems and Subsystems

OFC S1: Advances in Deployable Subsystems and Systems

Chris Cole, *Finisar Corporation, USA, Subcommittee Chair*
Marc Bohn, *Coriant, Germany*
Fred Buchali, *Nokia Bell Labs, Germany*
Liang Dou, *ZTE Beijing, China*
Jonas Geyer, *Acacia Communications, Inc., USA*
Fotini Karinou, *Huawei Technologies Duesseldorf GmbH, Germany*
Georg Mohs, *TE SubCom, USA*
Gary Nicholl, *Cisco Systems, Inc., Canada*
Katharine E. Schmidtke, *Facebook Inc., USA*
Sorin Tibuleac, *ADVA Optical Networking, USA*

OFC S2: Optical, Photonic and Microwave Photonic Subsystems

Michael Vasilyev, *University of Texas at Arlington, USA, Subcommittee Chair*
Youichi Akasaka, *Fujitsu Laboratories of America Inc, USA*
Jose Azana, *INRS-Energie Materiaux et Telecom, Canada*
Daniel J. Blumenthal, *University of California Santa Barbara, USA*
Robert Elschner, *Fraunhofer Heinrich Hertz Institute, Germany*
Mable P. Fok, *University of Georgia, USA*
Toshihiko Hirooka, *Tohoku University, Japan*
Ju Han Lee, *University of Seoul, South Korea*
Colin J. McKinstrie, *Huawei Technologies, USA*
Hiroshi Murata, *Osaka University, Japan*
Leif Oxenlowe, *DTU Fotonik, Denmark*
Erwan Pincemin, *Orange Labs, France*

OFC S3: Radio-over-Fiber, Free Space Optics and Sensing Systems

Tetsuya Kawanishi, *Waseda University, Japan, Subcommittee Chair*
Edward I. Ackerman, *Photonics Systems, Inc., USA*
Gee-Kung Chang, *Georgia Institute of Technology, USA*
Hwan Seok Chung, *ETRI, South Korea*
Richard DeSalvo, *Harris Corporation, USA*
Nathan Gomes, *University of Kent at Canterbury, UK*
A. Koonen, *Technische Universiteit Eindhoven, Netherlands*
Christina Lim, *University of Melbourne, Australia*
Jason McKinney, *US Naval Research Laboratory, USA*



Dominic O'Brien, *University of Oxford, UK*
 Idelfonso Tafur Monroy, *Technical University of Denmark, Denmark*
 Rod Waterhouse, *Pharad LLC, USA*

OFC S4: Digital and Electronic Subsystems

Sebastian Randel, *Karlsruhe Institute of Technology, Germany, Subcommittee Chair*
 Alex Alvarado, *Eindhoven University of Technology, Netherlands*
 Yi Cai, *ZTE (TX) Inc., USA*
 Xi Chen, *Nokia Bell Labs, USA*
 Neil Gonzalez, *National University of Colombia, Colombia*
 Takayuki Kobayashi, *NTT Access Service Systems Laboratories, Japan*
 Alan Pak Tao Lau, *Hong Kong Polytechnic University, Hong Kong*
 Andre Richter, *VPIphotonics, Germany*
 Rene Schmogrow, *Google, USA*
 Benn Thomsen, *Microsoft, UK*
 Qunbi Zhuge, *Ciena Corporation, Canada*

OFC S5: Digital Transmission Systems

Robert Killley, *University College London, UK, Subcommittee Chair*
 Cristian Antonelli, *Universita degli Studi dell'Aquila, Italy*
 Andrea Carena, *Politecnico di Torino, Italy*
 Sethumadhavan Chandrasekhar, *Nokia Bell Labs, USA*
 Dmitri Foursa, *TE SubCom, USA*
 Magnus Karlsson, *Chalmers Tekniska Hogskola, Sweden*
 Takayuki Mizuno, *NTT Network Innovation Laboratories, Japan*
 Antonio Napoli, *Coriant, Germany*
 Colja Schubert, *Fraunhofer Institute Nachricht Heinrich-Hertz, Germany*
 Qi Yang, *State Key Laboratory of Optical Comm., China*
 Zhuhong Zhang, *Huawei Technologies Co Ltd, Canada*

Track N: Networks, Applications and Access

OFC N1: Advances in Deployable Networks and their Applications

Patrick Iannone, *Nokia Bell Labs, USA, Subcommittee Chair*
 Jean-Luc Auge, *Orange Labs, France*
 Fred Bartholf, *Comcast Corporation, USA*
 David Boertjes, *Ciena Corporation, Canada*
 Bruce Cortez, *AT&T, USA*
 Mei Du, *Tata Communications, USA*
 Herve Fevrier, *Facebook Inc., USA*
 Douglas Freimuth, *IBM Almaden Research Center, USA*

Weisheng Hu, *Shanghai Jiao Tong University, China*
 Werner Weiershausen, *Deutsche Telekom Technik GmbH, Germany*

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 Ilya Baldin, *RENCI/UNC Chapel Hill, USA, USA*
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 Giada Landi, *Nextworks, Italy*
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OFC N3: Network Architectures and Techno-Economics

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OFC N4: Optical Access Networks for Fixed and Mobile Services

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 Naoki Suzuki, *Mitsubishi Electric Corporation, Japan*
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OFC N5: Market Watch, Network Operator & Data Center Summit

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 Lisa A. Huff, *Discerning Analytics, USA*
 Osamu Ishida, *NTT Electronics Corporation, Japan*
 Julie Kunstler, *Ovum RHK Inc., USA*
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 Ting Wang, *NEC Laboratories America Inc., USA*

Track DSN: Devices, Systems and Networks

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

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 Adel A.M. Saleh, *University of California Santa Barbara, USA, Subcommittee Chair*
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 Dominic Goodwill, *Huawei Technologies R&D, Canada*
 Ken-ichi Kitayama, *Graduate School for the Creation of New, Japan*
 Bert Offrein, *IBM Research GmbH, Switzerland*
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Expo Theater II & III Programming

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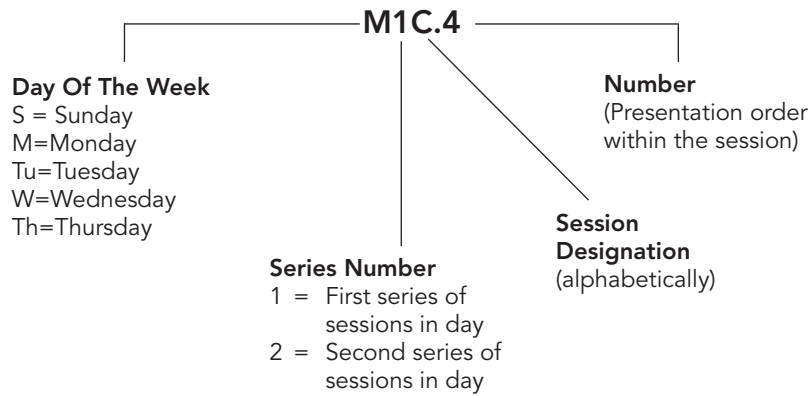
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Explanation of Session Codes



The first letter of the code denotes the day of the week (Sunday=Sunday, Monday=M, Tuesday=Tu, Wednesday=W, Th=Thursday). The 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 Presentation
-  Tutorial Presentation
-  Record Presentation
-  Top Scored Papers













Agenda of Sessions — Sunday, 11 March

	Room 2	Room 6C	Room 6D	Room 6E	Room 6F
09:00–12:00	SC177, SC328, SC444, SC447, SC461, SC463 (additional fee required)				
09:00–13:00	SC105, SC384, SC395, SC454 (additional fee required)				
	Workshops				
12:30–15:30	S1A • DSP for Short Reach and Client Optics - What Makes Sense?	S1B • Will Optical Switching Drive Data Center Design in 2028?	S1C • Ultimate Capacity Limits for TDM/TDMA PON	S1D • Can Undersea System Designs be Truly "Open" and Independent from Initial Terminal Equipment Selections?	S1E • Optical Integration Beyond Silicon Photonics: Why, What, and How?
13:00–16:00	SC216, SC429, SC433, SC462 (additional fee required)				
13:00–17:00	SC203, SC325, SC369 (additional fee required)				
13:30–17:30	SC267, SC327, SC393, SC450 (additional fee required)				
15:30–16:00	Coffee Break, Upper Level Corridors				
16:00–18:30	S2A • Field Trials: Is it Make or Break for Innovative Technologies?	S2B • AI-assisted Automated Network Operation: Getting Matured or Not?	S2C • Electro-optical Integration in a Package. What Technologies and Business Models Can Make it Happen?	S2D • When Will we Need to Scale the Fiber Capacity? What is the Most Realistic Approach?	S2E • Will Cloud-optical Boxes Change the Way Today's Networks are Deployed?
17:00–20:00	SC205, SC217, SC408, SC451 (additional fee required)				
20:00–22:00	Lab Automation Hackathon, Room 29D				

Key to Shading

 Short Courses

Agenda of Sessions — Monday, 12 March

	Room 1A	Room 1B	Room 2	Room 6C 	Room 6D 
08:30–12:30	SC102, SC114, SC178, SC443, SC446, SC452, SC453A, SC460 (additional fee required)				
08:00–10:00	M1A • Network Techno-economics	M1B • Beyond 10G PON Evolution I	M1C • DSP Techniques for High-order QAM (begins at 08:15)	M1D • Subsea and Open Systems  (begins at 08:30)	M1E • Open Systems and Modules  (begins at 08:15)
09:00–12:00	SC176, SC359, SC390, SC411, SC428, SC442, SC448, SC459, SC465 (additional fee required)				
09:00–16:30	Data Center Career Opportunities (additional fee required)				
10:00–10:30	Coffee Break, Upper Level Corridors				
10:30–12:30	M2A • 5G and Network Slicing	M2B • Beyond 10G and PON Evolution II	M2C • Transmission Systems	M2D • Energy Efficient Optical Links 	M2E • Open and Dynamic Networking 
12:00–13:30	Lunch Break (on own)				
13:30–16:30	SC208, SC261, SC385, SC431, SC445, SC464 (additional fee required)				
13:30–17:30	SC160, SC341, SC347, SC432, SC449, SC453B (additional fee required)				
14:00–16:00	M3A • Telemetry and Survivability	M3B • Coherent and DSP Technologies for PON	M3C • Probabilistic Shaping I	M3D • Symposium: Challenges 5G Brings to Optical Fiber Communications I 	M3E • Parametric Amplification Subsystems 
16:00–16:30	Coffee Break, Upper Level Corridors				
16:30–18:30	M4A • Modelling, Disaggregation, & Networking Automation		M4B • Practical Aspects in Fiber Transmission	M4C • Symposium: Challenges 5G Brings to Optical Fiber Communications II 	M4D • Mode Multiplexors and Components for Space-division Multiplexed Systems  (ends at 18:00)

Key to Shading



Short Courses















Recorded Session



Room 6E	Room 6F	Room 7AB	Room 8	Room 9	Room 10
SC102, SC114, SC178, SC443, SC446, SC452, SC453A, SC460 (additional fee required)					
M1F • Optical Wireless - Systems	M1G • Advanced Modulation Formats	M1H • Microwave Photonic Signal Processing I (begins at 08:30)		M1I • Lasers for Data Center Interconnects (begins at 08:15)	
SC176, SC359, SC390, SC411, SC428, SC442, SC448, SC459, SC465 (additional fee required)					
Data Center Career Opportunities (additional fee required)					
Coffee Break, Upper Level Corridors					
M2F • Machine Learning and Performance Monitoring	M2G • Microwave Photonic Signal Processing II (ends at 12:00)	M2H • Panel: 400G Optics for Hyperscale Data Centers	M2I • Emerging Devices and Materials	M2J • Fiber Lasers	M2K • Optical Wireless - Signal Processing
Lunch Break (on own)					
SC208, SC261, SC385, SC431, SC445, SC464 (additional fee required)					
SC160, SC341, SC347, SC432, SC449, SC453B (additional fee required)					
M3F • Data Center and Integration	M3G • Symposium: Future Photonic Devices and Materials for Optical Communications I	M3H • Panel: Machine Learning and SDN: Towards Intelligent Data Centers	M3I • Photonic Integration I	M3J • SDM/WDM Networking	M3K • Optical Wireless - Technologies
Coffee Break, Upper Level Corridors					
M4E • Probabilistic Shaping II	M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II	M4G • Optical Coherence Control (ends at 18:15)	M4H • Photonic Integration II	M4I • Deployments of Optical Access and Front Haul	M4J • MMW & THz Systems



Agenda of Sessions — Tuesday, 13 March

	Room 1A	Room 1B	Room 2	Room 6C 	Room 6D 	Room 6E 	Room 6F 
07:30–08:00	Coffee Break, Ballroom 20 Foyer						
08:00–10:00	Tu1A • Plenary Session, Ballroom 20BCD						
10:00–14:00	Unopposed Exhibit-only Time, Exhibit Hall (concessions available)						
10:00–10:30	Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C						
12:00–13:30	OIDA VIP Industry Leaders Speed Meetings Event, Room 33B (separate registration required)						
12:00–14:00	Awards Ceremony and Luncheon, Ballroom 20A						
14:00–16:00	Tu2A • Coupling and Packaging	Tu2B • Data Center & PON Transponder Technology	Tu2C • Short Reach I	Tu2D • Kramers-Kronig Transmissions 	Tu2E • Coherent and Tunable Devices 	Tu2F • Capacity Planning 	Tu2G • Content Distribution and Edge Computing 
16:00–16:30	Coffee Break, Upper Level Corridors; Exhibit Hall						
16:30–18:30	Tu3A • Planar Waveguide Platforms (ends at 18:15)	Tu3B • SDM Fibers	Tu3C • Coding and Modulation	Tu3E • Transport Network Design 	Tu3F • Silicon Photonic Interconnection Networks 	Tu3G • Nonlinearity Compensation and Encrypted Communication (ends at 18:15) 	Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems 
16:30–18:30	Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, Room 6A (extended coffee break)						
17:15–18:45	Exhibitor Happy Hour, Center Terrace						
18:30–20:00	Conference Reception, Sails Pavilion						
19:30–21:30	Rump Session, Room 6F						

Key to Shading

■ Market Watch/Data Center Summit

















 Recorded Session



Room 7AB	Room 8	Room 9	Room 10	Exhibit Hall G, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall B, Expo Theater III
Coffee Break, Ballroom 20 Foyer				Exhibit Hall Opens 10:00		
Tu1A • Plenary Session, Ballroom 20BCD				<p>■ MW Panel I: State of the Industry - Analyst Panel 10:30–12:00</p> <p>■ MW Panel II: Optical Bearer Technologies for 5G Networks 12:30–14:00</p> <p>■ MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics 14:30–16:00</p> <p>Talk & Tour: SDCC Wifi Session 16:00–17:00</p>	<p>■ Data Center Summit: Data Center Optical Interconnect - Technologies and Markets 10:15–12:15</p> <p>Ethernet Roadmaps Update <i>Ethernet Alliance</i> 12:45–13:45</p> <p>Disaggregating the Transport Layer: What It Means to The Bottom Line <i>Session Sponsored by Juniper Networks</i> 14:00–17:00</p>	<p>Product Showcase <i>Huawei</i> 10:15–10:45</p> <p>Open Management and Monitoring of Multilayer Webscale and Carrier Networks <i>OpenConfig</i> 11:00–12:30</p> <p>Fog Computing and Optical Networking - What's Next? <i>IEEE and OpenFog Consortium</i> 12:45–14:15</p> <p>Enabling the Key Applications for Transport SDN <i>OIF</i> 14:30–15:30</p> <p>AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions <i>AIM Photonics</i> 15:45–16:45</p>
Unopposed Exhibit-only Time, Exhibit Hall (concessions available)						
Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C						
OIDA VIP Industry Leaders Speed Meetings Event, Room 33B (separate registration required)						
Awards Ceremony and Luncheon, Ballroom 20A						
Tu2H • Open Platform Summit: Open Platforms for Optical Innovations	Tu2I • Underwater Free Space Optics Systems	Tu2J • Fiber Optic and Wavelength Devices	Tu2K • Low Latency Services and xHaul over PON			
Coffee Break, Upper Level Corridors; Exhibit Hall						
Tu3I • Panel: Flexible Grid Deployments	Tu3J • 5G Photonic Systems	Tu3K • Heterogeneous Integration	Tu3L • Software - Defined Access			
Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, Room 6A (extended coffee break)						
Exhibitor Happy Hour, Center Terrace						
Conference Reception, Sails Pavilion						
Rump Session, Room 6F				Exhibit Hall Closes 17:00		



Agenda of Sessions — Wednesday, 14 March

	Room 1A	Room 1B	Room 2	Room 6C 	Room 6D 	Room 6E 	Room 6F 
07:30–08:00	Coffee Break, Upper Level Corridors						
08:00–10:00	W1A • Connector - Something Old, Something New	W1B • High Capacity Transmission Systems	W1C • Optical Switching in Data Centers	W1D • Machine Learning and Network Availability 	W1E • Devices for Mode Multiplexing 	W1F • Radio-over-fiber I 	W1G • Performance Monitoring and Nonlinear Transmission  (begins at 8:15)
10:00–17:00	Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C						
10:30–12:30	W2A • Joint Poster Session I, Exhibit Hall B						
12:30–14:00	Unopposed Exhibit-only Time, Exhibit Hall (concessions available)						
14:00–16:00			W3A • Nonlinearity Compensation	W3B • Connected OFCity Challenge 2018: Lighting Up the Emerging World 	W3C • Multimode Fibers for Datacenters 	W3D • Fiber Amplifiers 	W3E • All-optical Impairment Mitigation 
16:00–16:30	Coffee Break, Upper Level Corridors; Exhibit Hall						
16:30–18:30	W4A • Deployable Transport Networks	W4B • Radio-over-fiber II	W4C • Space Division Multiplexed Transmission (ends at 17:45)	W4D • High Speed Devices for Data Centers  (ends at 18:15)	W4E • Kramers-Kronig Receivers 	W4F • Machine Learning for Network Control and Management 	W4G • Advanced Technologies for High Speed PON 
17:00–19:30	Photonic Society of Chinese-Americans Workshop & Social Networking Event, Room 14A						

Key to Shading

■ Market Watch/Network Operator Summit













 Recorded Session



Room 7AB	Room 8	Room 9	Room 10	Exhibit Hall G, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall B, Expo Theater III
Coffee Break, Upper Level Corridors				Exhibit Hall Opens at 10:00		
W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?	W1I • Devices for Interconnects	W1J • Short Reach II	W1K • Optical Fiber Sensors	■ Network Operator Summit Keynote: 10:30–11:00 Panel I: The Role of “Open Transport” in the New Metro and Inter-Data-Center Architectures 11:00–12:30 Panel II: On the Road to 100G PON (Beyond 10G PON) 13:30–15:00 ■ MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality 15:30–17:00	COBO Specification Overview and Next Steps <i>COBO</i> 10:15–11:45 Server Fibreless Optical Networking <i>Open19 Foundation</i> 12:00–13:00 Industry Visions for a Converged Optical Networking Roadmap <i>ON2020</i> 13:15–15:15 Machine Learning: Developing Efficiency in Customer Networks 15:30–17:00	Product Showcase <i>Huawei</i> 10:15–10:45 Product Showcase <i>Xilinx</i> 11:00–11:30 Product Showcase <i>Xilinx</i> 11:30–12:00 Product Showcase <i>Colorchip</i> 12:30–1:00 Product Showcase <i>ATOP</i> 13:00–13:30 Next Generation Coherent: Architectures and Technologies <i>Session Sponsored by Acacia Communications</i> 13:30–14:30 400G Standards, MSAs and Related Technologies: What is on the Horizon? 15:45–17:00
Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C						
W2A • Joint Poster Session I, Exhibit Hall B						
Unopposed Exhibit-only Time, Exhibit Hall (concessions available)						
	W3F • Nanophotonic Devices (ends at 15:45)					
Coffee Break, Upper Level Corridors; Exhibit Hall						
W4H • Panel: 2020 Network Vision 5G and Optical Networking	W4I • Data Center Traffic Management	W4J • Imaging, Spectroscopy & Transmission (ends at 18:00)	W4K • Novel Fiber Concepts			
Photonic Society of Chinese-Americans Workshop & Social Networking Event, Room 14A				Exhibit Hall Closes at 17:00		



Agenda of Sessions — Thursday, 15 March

	Room 1A	Room 1B	Room 2	Room 6C 	Room 6D 	Room 6E 	Room 6F 
07:30–08:00	Coffee Break, Upper Level Corridors						
08:00–10:00	Th1A • Advances in Coherent Design and Measurement	Th1B • 5G Transport (begins at 08:30)	Th1C • Wideband Transmission (begins at 09:00)	Th1D • Application Awareness and Online Optimization 	Th1E • Components for Future PON 	Th1F • High Capacity Subsystems 	Th1G • Photonic Networks for Data Centers  (begins at 08:15)
10:00–16:00	Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C						
10:30–12:30	Th2A • Joint Poster Session II, Exhibit Hall B						
12:30–14:00	Unopposed Exhibit-only Time, Exhibit Hall (concessions available)						
14:00–16:00	Th3A • Current Topics in Long Haul/Metro Transmission (ends at 15:00)			Th3B • Directly Modulated Lasers 	Th3C • Optical Switching II 	Th3D • Nonlinear Fiber Effects 	Th3E • Advanced Transmission Technology  (ends at 15:45)
16:00–16:30	Beverage and Coffee Break, Upper Level Corridors						
16:30–18:30	Postdeadline Sessions, Rooms 6C, 6D, 6E, 6F						

Key to Shading

■ Market Watch/Network Operator Summit

 Recorded Session



Room 7AB	Room 8	Room 9	Room 10	Exhibit Hall G, Expo Theater I	Exhibit Hall E, Expo Theater II	Exhibit Hall B, Expo Theater III
<i>Coffee Break, Upper Level Corridors</i>				Exhibit Hall Opens at 10:00		
Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Network	Th1I • Comb Lasers (begins at 08:15)	Th1J • Optical Switching I (begins at 08:15)	Th1K • SDM Amplifiers & Components (begins at 08:30)	■ MW Panel V: Software Innovations in the Next-generation Optical Transport 10:30–12:00 ■ MW Panel VI: IP and Optical Integration: Physical or Control/Management Plane? 12:30–14:00	400G Coherent: What Does it Mean to You? <i>OIF</i> 10:15–11:15	Product Showcase <i>Huawei</i> 10:15–10:45 POF Symposium <i>POFTO</i> 11:00–13:00
<i>Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C</i>					Understanding Optical Signal-to-Noise Ratio 13:15–14:15	
Th2A • Joint Poster Session II, Exhibit Hall B						
<i>Unopposed Exhibit-only Time, Exhibit Hall (concessions available)</i>						
Th3F • Data Center Interconnect Deployments (ends at 15:00)	Th3G • Hybrid Access Networks for Wireless Delivery		Th3H • Optical Switching Sub-systems (ends at 15:45)		Preparing for the GDPR: The EU's Sweeping Data Privacy Reform Initiative <i>IEEE</i> 11:30–12:30	
<i>Beverage and Coffee Break, Upper Level Corridors</i>				Exhibit Hall Closes at 16:00		
<i>Postdeadline Sessions, Rooms 6C, 6D, 6E, 6F</i>						





Room 1A

08:00–10:00

M1A • Network Techno-economics

Presider: Victor Lopez; Telefonica I+D, Spain

M1A.1 • 08:00 **Top Scored**

Techno-economic Evaluations of 400G Optical Interconnect Implementations for Datacenter Networks, Theodoros Rokkas^{2,1}, Ioannis Neokosmidis¹, Behnam Shariati³, Ioannis Tomkos²; ¹inCITES Consulting, Luxembourg; ²Athens Information Technology, Greece; ³Universitat Politècnica de Catalunya (UPC), Spain. The cost evolution and power consumption of different 400G transceivers are modeled and the benefits of constructing and scaling the Facebook's datacenter Fabric utilizing different technologies is presented through comparative cost and power consumption analysis

M1A.2 • 08:15

Fiber Type Dependent Benefits when Deploying Up-to-300Gb/s Elastic Transponders Adapting to Ageing of Margins, Jelena Pestic³, Nicola Rossi², Thierry Zami¹; ¹Nokia Corporation, France; ²Nokia Bell Labs, France; ³Nokia Bell Labs, France. We compare cost savings when planning a WDM French backbone network based on SSMF or LEAF, with 32 GBaud elastic optical transponders adapting their capacity from 100 to 300 Gb/s to the actual ageing margins.

Room 1B

08:00–10:00

M1B • Beyond 10G PON Evolution I

Presider: Elaine Wong; Univ. of Melbourne, Australia

M1B.1 • 08:00

Real-time Downstream 25Gbit/s PAM4 for High Speed TDM-PONs with both 25 and 12.5Gbit/s ONUs, Sylvain Barthomeuf^{1,2}, Fabienne Saliou¹, Luiz Anet Neto¹, Bertrand Le Guyader¹, Philippe Chanclou¹, Didier Erasme²; ¹Orange Labs, France; ²LTCI, Télécom ParisTech, France. We experimentally achieved 40km, Real-time, N1 ODN class (29dB) compliant PAM4 transmission with PAM4/NRZ receptions on the same PON. The emitted PAM4 is interpreted either as PAM4 or NRZ to allow full or half line-rates.

M1B.2 • 08:15

Burst-mode Actively-filtered Receiver for TDM-PON Enabling Extended Reach and Improved Sensitivity, Robert Borkowski¹, Wolfgang Poehlmann¹, Rene Bonk¹, Thomas Pfeiffer¹; ¹Nokia Bell Labs, Germany. We experimentally demonstrate an actively-filtered receiver for TDM-PON. Bias-current tuning of a DFB-based-filter enables tracking the wavelength-drift of DML under burst-mode operation. We measure >70% reach increase, >5dB sensitivity improvement, and 4.8dB higher extinction ratio.

Room 2

08:15–10:00

M1C • DSP Techniques for High-order QAM

Presider: Takayuki Kobayashi; NTT Network Innovation Laboratories, Japan

M1C.1 • 08:15 **Top Scored**

Single-carrier 48 GBaud PDM 256QAM Transmission over Unrepeated 100km Single-mode-fiber using Commercially Available μ TTLA and LN IQ Modulator, Asuka Matsushita¹, Masanori Nakamura¹, Fukutaro Hamaoka¹, Yoshiaki Kisaka¹; ¹NTT Corporation, Japan. Record symbol-rate PDM-256QAM single-carrier transmission of 100km is achieved using commercially available laser and modulator with only applying compensation for linear frequency response of transceiver and receiver; device nonlinear-ity compensation is not used.

Room 6C

08:30–10:00

M1D • Subsea and Open Systems **Invited**

Presider: Mei Du; Coriant, USA

Room 6D

08:15–10:00

M1E • Open Systems and Modules **Invited**

Presider: Katharine Schmidtke; Facebook Inc., USA

M1E.1 • 08:15 **Invited**

Opening Up the Transport Infrastructure, Luis Martin Garcia¹; ¹Facebook, USA. This talk will cover how Optical and IP transport networks are being disrupted by initiatives like the Telecom Infra Project to make networks more open, disaggregated and free of vendor lock-ins.

Room 6E

08:00–10:00

M1F • Optical Wireless Systems **Invited**

Presider: Ton Koonen; Technische Universiteit Eindhoven, Netherlands

M1F.1 • 08:00 **Invited**

A 84 Gb/s VSB-PAM8 VCSEL-based Fiber-FSO Convergence, Yun-Chieh Wang¹, Pei-Hsien Chew¹, Yu-Bo Jheng¹, Chung-Yi Li¹, Hai-Han Lu¹, Xu-Hong Huang², Wen-Shing Tsai³; ¹National Taipei Univ. of Technology, Taiwan; ²School of Information Science and Engineering, Fujian Univ. of Technology, China; ³Department of Electrical Engineering, Ming Chi Univ. of Technology, Taiwan. A 84 Gb/s VSB-PAM8 VCSEL-based fiber-FSO convergence with injection locking scheme and linear equalizer is demonstrated. Such proposed VSB-PAM8 VCSEL-based fiber-FSO convergence is a notable option with good transmission performances for providing high transmission rate.

M1F.2 • 08:15 **Top Scored**

Experimental Demonstration of a 12.5 Gb/s Indoor Optical Wireless Communication System with Silicon Integrated Photonic Circuit, Ke Wang^{1,2}, Ampalavanapillai Nirmalathas³, Christina Lim³, Elaine Wong³, Kamal Alameh⁴, Hongtao Li², Efstratios Skafidas³; ¹Royal Melbourne Inst. of Technology, Australia; ²Nanjing Univ. of Science and Technology, China; ³The Univ. of Melbourne, Australia; ⁴Edith Cowan Univ., Australia. A high-speed indoor infrared optical wireless communication system using silicon photonics integrated beam steering circuit is experimentally demonstrated. Results show that up to 12.5 Gb/s error-free operation is achieved through over 140 cm free-space distance.





Room 1A

M1A • Network Techno-economics—Continued

M1A.3 • 08:30

A Statistical Assessment of Networking Merit of 2MxN WSS, Mattia Cantono¹, Stefano Piciaccia², Alberto Tanzi², Gabriele Maria Galimberti², Brian Smith³, Marcello Bianchi³, Vittorio Curri¹; ¹Politecnico di Torino, Italy; ²Cisco Photonics, Italy; ³Lumentum, Canada. We assess the networking impact in terms of blocking probability and device counts of a novel low-contention probability network node. We show no significant penalties with respect to full-CDC solutions in a metro network scenario

M1A.4 • 08:45 **Top Scored**
Network Design Framework to Spectral- and Cost-efficiently Exploit Next-generation Line Interfaces, Daniela A. Moniz^{1,2}, João Pedro^{1,2}, João Pires²; ¹Coriant Portugal, Portugal; ²Instituto de Telecomunicações, Portugal. This paper proposes a network design framework for phased service provisioning with current- and next-generation high symbol rate line interfaces. Network simulations show that both cost- and spectral-savings can be attained over the network lifecycle.

Room 1B

M1B • Beyond 10G PON Evolution I—Continued

M1B.3 • 08:30 **Top Scored**
Investigation of 100G (4x25G) NG-PON2 Upgrade using a Burst Mode Laser based on a Multi-electrode Laser to Enable 100 GHz Wavelength Grid, Vincent Houtsmas¹, Dora van Veen¹, Stefano Porto², Nagesh Basavanahally¹, Cris Bolle¹, Harald Schmuck¹; ¹Nokia Bell Labs, USA; ²Tyndall, Ireland. Investigation of NG PON2 upgrade to 25 Gb/s line-rate on a 100 GHz grid using a burst-mode transmitter based on a multi-electrode DFB. Compliance with NG PON2 MSE requirements is shown.

M1B.4 • 08:45
Symmetrical 50-gb/s/λ PAM-4 TDM-PON in O-band with DSP and Semiconductor Optical Amplifier Supporting PR-30 Link Loss Budget, Junwen Zhang¹, Jun Shan Wey¹, Jianjun Yu¹; ¹ZTE TX Inc, USA. We experimentally investigate the symmetrical 50-gb/s/λ PAM-4 TDM-PON solutions in the O-band to support the PR-30 link loss budget, with the using of DSP and SOA. The performances of DSP and SOA setup are studied.

Room 2

M1C • DSP Techniques for High-order QAM—Continued

M1C.2 • 08:30
Improving Achievable Information Rates of 64-GBd PDM-64QAM by Nonlinear Transmitter Predistortion, Robert Elschner¹, Robert Emmerich¹, Carsten Schmidt-langhorst¹, Felix Frey^{1,2}, Pablo Wilke Berenguer¹, Johannes K. Fischer¹, Helmut Griesser³, Danish Rafique³, Joerg-peter Elbers³, Colja Schubert¹; ¹Fraunhofer HHI, Germany; ²Inst. of Communications Engineering, Ulm Univ., Germany; ³ADVA Optical Networking SE, Germany. We assess the gains in achievable information rate for 64-GBd PDM-64QAM signal transmission with Volterra-based digital predistortion of nonlinear transmitter components and show an improvement of up to 0.6 bit/4D-symbol over conventional linear predistortion.

M1C.3 • 08:45 **Invited**
Advanced DSP Technologies with Symbol-rate over 100-GBaud for High-capacity Optical Transport Network, Masanori Nakamura¹, Fukutaro Hamaoka¹, Asuka Matsushita¹, Hiroshi Yamazaki^{2,1}, Munehiko Nagatani^{2,1}, Takayuki Kobayashi¹, Yoshiaki Kisaka¹, Yutaka Miyamoto¹; ¹NTT Network Innovation Laboratories, Japan; ²NTT Device Technology Laboratories, Japan. 100-GBaud-class systems are promising candidates for over 400-gbps serial long-haul transport without increasing the number of transponders. We review DSP technologies, e.g. signal generation, calibration, post compensation and advanced modulation for realizing 100-GBaud-class transceivers.

Room 6C

M1D • Subsea and Open Systems—Continued

M1D.1 • 08:30 **Invited**
Submarine Cables: Deployment: Evolution and Perspectives, Stephen Grubb¹; ¹Facebook Inc., USA. We are experiencing a tremendous resurgence in the deployment of new submarine cables worldwide. The drivers and sustainability of this unprecedented increase in bandwidth will be examined. The technology drivers will be detailed that have increased the submarine capacity per fiber 20X while the cost of unit bandwidth has decreased 200X.

Room 6D

M1E • Open Systems and Modules—Continued

M1E.2 • 08:45 **Invited**
Margin Requirement Of Disaggregating The DWDM Transport System And Its Consequence On Application Economics, Michel Belanger¹, Maurice O'Sullivan¹, Paul Littlewood¹; ¹Ciena, Canada. Disaggregation is proposed to reduce network costs and accelerate feature development. This paper evaluates the costs in regional and metro networks associated with the primary disaggregation models, and describes the system design implications of each.

Room 6E

M1F • Optical Wireless Systems—Continued

M1F.3 • 08:30 **Invited**
Use Cases for Optical Wireless Communication, Dominic Schulz¹, Pablo Wilke Berenguer¹, Jonas Hilt¹, Peter Hellwig¹, Anagnostis Paraskevopoulos¹, Ronald Freund¹, Volker Jungnickel¹; ¹Fraunhofer Heinrich Hertz Inst., Germany. We present results from trials in three promising uses cases for optical wireless communication (OWC): Mobile backhaul, industrial wireless, and indoor Li-Fi. We point out specific requirements and illustrate performance through measurements in typical scenarios.





Room 1A

M1A • Network Techno-economics—Continued

M1A.5 • 09:00 **Invited**
Agile Optical Networking: Beyond Filtered Solutions, Christine Tremblay¹, Émile Archambault¹, Michel Belanger², Paul Littlewood², William Clelland², Marija Furdek³, Lena Wosinska³; ¹Ecole de Technologie Supérieure, Canada; ²Ciena Corp., Canada; ³KTH Royal Inst. of Technology, Sweden. Filterless optical networks based on broadcast-and-select nodes and coherent transceivers are attractive cost-effective and flexible solutions in core networks. In this talk, we explore the suitability of filterless architectures in metropolitan core and aggregation networks.

Room 1B

M1B • Beyond 10G PON Evolution I—Continued

M1B.5 • 09:00
Demonstration of 50Gb/s/λ Symmetric PAM4 TDM-PON with 10G-class Optics and DSP-free ONUs in the O-band, Kuo Zhang^{1,2}, Qunbi Zhuge², Haiyun Xin¹, Zhenping Xing², Meng Xiang², Sujie Fan², Lili Yi¹, Weisheng Hu¹, David V. Plant²; ¹Shanghai Jiao Tong Univ., China; ²McGill Univ., Canada. We demonstrate a 50Gb/s/λ PAM4 TDM-PON based on 10G-class DMLs and PDs in O-band with downlink pre-compensation and uplink post-equalization. Results show that, without any DSP in the ONU, 29dB optical power budget is achieved.

Room 2

M1C • DSP Techniques for High-order QAM—Continued

M1C.4 • 09:15
Experimental Validation of a Channel Estimation Algorithm for Transmitter-side Digital Pre-compensation Filters, Sjoerd P. van der Heide¹, Ton Koonen¹, Chigo Okonkwo¹; ¹Inst. for Photonic Integration (IPI), Eindhoven Univ. of Technology, Netherlands. A channel estimation algorithm is introduced and experimentally validated with a 112-gbit/s PAM-4 transmission system. The algorithm is shown to estimate overall system bandwidth and demonstrates pre-compensation gains ranging from 0.8 to 1.5 dB.

Room 6C

M1D • Subsea and Open Systems—Continued

M1D.2 • 09:00 **Top Scored**
Modelling the Impact of SRS on NLI Generation in Commercial Equipment: an Experimental Investigation, Mattia Cantono¹, Jean-Luc Auge², Vittorio Curri¹; ¹Politecnico di Torino, Italy; ²Orange Labs, France. We experimentally demonstrate using commercial equipment how performance predictions based on the GN-model may fail on side channels because of SRS, and demonstrate the effectiveness of the GGN-model including distributed SRS effects in NLI estimation.

M1D.3 • 09:15 **▶**
Physical Simulation Environment of the Telecommunications Infrastructure Project (TIP), Gert Grammel¹, Vittorio Curri², Jean-Luc Auge³; ¹Juniper, Germany; ²DET, Politecnico di Torino, Italy; ³Orange Labs, France. The TIP PSE working group aims at validating the GN-model in large scale testbeds, provided by facebook, Microsoft, Orange, Telefonica and UTD to use it as foundation for a vendor-independent open-source planning and engineering tool.

Room 6D

M1E • Open Systems and Modules—Continued

M1E.3 • 09:15 **▶**
Demonstration of 53.125 Gb/s, CWDM, PAM-4, Directly Modulated Laser Transmission over 20 km SMF, Prashant P. Baveja¹, Mingshan Li¹, YuJing Chen¹, Ding Wang¹, Huanlin Zhang¹, Yi Wang¹, Qin Li¹, Chong Wang¹, Hsiu-Che Wang¹, I-Lung Ho¹, Jun Zheng¹; ¹Applied Optoelectronics Inc, USA. 20 km, 53.125 Gb/s, CWDM, O-band, PAM-4 DML transmission is demonstrated. -11 dBm outer OMA at KP-4 FEC threshold up to 70 °C TOSA case temperature is measured using a TO ROSA packaged using 26 GHz PIN PD, linear TIA and self-adaptive DSP.

Room 6E

M1F • Optical Wireless Systems—Continued

M1F.4 • 09:00 **▶**
1 Gb/s All-LED Visible Light Communication System, Bernhard Schrenk¹, Christoph Pacher¹; ¹AIT Austrian Inst. of Technology, Austria. We evaluate the use of LEDs intended for illumination as low-cost filtered optical detectors. An optical wireless system that is exclusively based on commercial off-the-shelf 5-mm R/G/B LEDs is experimentally demonstrated for Gb/s close-proximity transmission.

M1F.5 • 09:15 **▶**
230 Mbit/s Real-time Optical Wireless Transmission in Non-directed Line-of-sight Configuration, Giulio Cossu¹, Alessandro Messa¹, Wajahat Ali¹, Alessandro Sturmiolo¹, Ernesto Ciaramella¹; ¹Scuola Superiore Sant Anna di Pisa, Italy. We experimentally realized a Real-time optical wireless transmission in Non-directed Line-of-sight (i.e. without lens), by a low-cost infrared LED and FPGA-based DMT processing. We achieve from 230 to 100 Mbit/s over a 3 m² area.






Room 6F

M1G • Advanced Modulation Formats—Continued


M1G.2 • 09:00  **Top Scored**
11.5bits/s/Hz PM-256QAM Comb-based Superchannel Transmission by Combining Optical and Digital Pilots, Mikael Mazur¹, Jochen Schröder¹, Abel Lorences-Riesgo^{1,2}, Tsuyoshi Yoshida^{1,3}, Magnus Karlsson¹, Peter A. Andrekson¹; ¹Chalmers Univ. of Technology, Sweden; ²IT-instituto de Telecomunicações, Portugal; ³Mitsubishi Electric Corporation, Japan. We demonstrate 44Tb/s transmission using three 50x24GBaud PM-256QAM comb-based superchannels. Each superchannel combines a single optical pilot tone with individual digital pilot symbols to minimize the total overhead, enabling record spectral-efficiency over the full C-band.

M1G.3 • 09:15 
Flex-rate Transmission using Hybrid Probabilistic and Geometric Shaped 32QAM, Shaoliang Zhang¹, Zhen Qu^{1,3}, Fatih Yaman¹, Eduardo Mateo², Takanori Inoue², Kohei Nakamura², Yoshihisa Inada², Ivan Djordjevic³; ¹NEC Laboratories America Inc, USA; ²Submarine Network Division, NEC Corporation, Japan; ³ECE, Univ. of Arizona, USA. A novel algorithm to design geometric shaped 32QAM to work with probabilistic shaping is proposed to approach the Shannon limit within ~0.2 dB in SNR. The experimental results show ~0.2 dB SNR advantage over 64GBaud PAS-64QAM, and flex-rate transmission demonstrates > 50% km reach improvement over 32QAM.

Room 7AB

M1H • Microwave Photonic Signal Processing I—Continued

M1H.3 • 09:00  **Invited**
Silicon-based Brillouin Photonics and Signal Processing, Peter T. Rakich¹, Eric Kittlaus¹, Nils Otterstrom¹, Ryan Behunin^{1,2}, Zheng Wang³; ¹Yale Univ., USA; ²Physics, Northern Arizona Univ., USA; ³Electrical and Computer Engineering, Univ. of Texas at Austin, USA. We use a new class of optomechanical waveguides to we create strong stimulated Brillouin scattering in silicon waveguides. Harnessing these interactions, we create Brillouin-based narrow-band RF-photonics filters, optical amplifiers, and lasers in silicon photonics.

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Room 9

M1I • Lasers for Data Center Interconnects—Continued

M1I.4 • 09:00
7x100 Gbps PAM-4 Transmission over 1-km and 10-km Single Mode 7-core Fiber using 1.5- μ m SM-vCSEL, Xiaodan Pang^{1,3}, Joris Van Kerrebrouck², Oskars Ozolins³, Rui Lin^{1,4}, Aleksejs Udalcovs³, Lu Zhang¹, Silvia Spiga⁵, Markus C. Amann⁵, Geert Van Steenberge⁶, Lin Gan⁴, Ming Tang⁴, Songnian Fu⁴, Richard J. Schatz¹, Gunnar Jacobsen², Sergei Popov¹, Deming Liu⁴, Weijun Tong⁷, Guy Torfs², Johan Bauwelink², Xin Yin², Jiajia Chen¹; ¹KTH Royal Inst. of Technology, Sweden; ²IDLab, INTEC, Ghent Univ. – imec, Belgium; ³Networking and Transmission Laboratory, Rise Acreo AB, Sweden; ⁴Huazhong Univ. of Science and Technology, China; ⁵Walter Schottky Institut, Technische Universität München, Germany; ⁶CMST, Ghent Univ. – IMEC, Belgium; ⁷Yangtze Optical Fiber and Cable Joint Stock Limited Company, China. 100 Gbps/ N -core PAM-4 transmission is successfully demonstrated over 1-km and 10-km single mode 7-core fiber links, enabled by directly modulated 1.5- μ m single mode VCSEL of 23 GHz modulation bandwidth with pre- and post- digital equalizations.

M1I.5 • 09:15
Net 100 Gbit/s Eight-dimensional Formats Loaded Discrete Multitone Transmission Using 850 nm Multimode VCSEL, Xiaofeng Lu¹, Darko Zibar¹, Idelfonso Tafur Monroy²; ¹Department of Photonics Engineering, Technical Univ. of Denmark, Denmark; ²Department of Electrical Engineering, Technical Univ. of Eindhoven, Netherlands. We demonstrate a discrete multi-tone transmission loaded with eight-dimensional formats with 0.25-bit granularity, enabling a net 100-gbit/s transmission over 100 m MMF, with and without power loading, and investigate its benefits on the reach, power, and thermal tolerance.

NOTES

Monday, 12 March





Room 1A

M1A • Network Techno-economics—Continued

M1A.6 • 09:30

Minimizing the Cost and Augmenting the Resilience of Vulnerable Optical Transport Networks, Bodhisattwa Gangopadhyay¹, João Pedro², Stefan Spälter²; ¹Global Technical Support, Coriant, Portugal; ²Coriant, Portugal. This paper proposes an architecture combining high density muxponders, universal OTN switching, flexi-rate line interfaces and a cost-optimized node clustering scheme to enhance network resiliency without compromising the total cost of ownership (TCO).

M1A.7 • 09:45

Modular SDN-enabled S-BVT Adopting Widely Tunable MEMS VCSEL for Flexible/Elastic Optical Metro Networks, Michela Svaluto Moreolo¹, Laia Nadal¹, Josep M. Fabrega¹, Javier Vilchez¹, Ramon Casellas¹, Raul Muñoz¹, Christian Neumeyr², Alberto Gatto³, Paola Parolari³, Pierpaolo Boffi³; ¹CTr Tecnològic de Telecom de Catalunya, Spain; ²Vertilas GmbH, Germany; ³Politecnico di Milano, Italy. We propose an SDN-enabled S-BVT adopting directly-modulated tunable VCSEL with direct-detection for optical metro networks and spectrum defragmentation. We experimentally assess it over different network paths up to 185km and in presence of adjacent slices.

Room 1B

M1B • Beyond 10G PON Evolution I—Continued

M1B.7 • 09:30

Real-time FPGA Demonstration of PAM-4 Burst-mode All-digital Clock and Data Recovery for Single Wavelength 50G PON Application, Junwen Zhang¹, Xin Xiao¹, Jianjun Yu¹, Jun Shan Wey¹; ¹ZTE TX Inc, USA. We demonstrate the burst-mode all-digital clock and data recovery for 26.20546-GBaud PAM-4 signal with Real-time FPGA processing. With a free-running ADC, clock recovery is achieved within 32 symbols based on the squaring timing recovery algorithm.

M1B.8 • 09:45

Adaptive Equalization Enabled 25Gb/s NRZ Modulation Based on 10-g Class Optics for Upstream Burst-mode Transmission, Jian Chen¹, Acai Tan¹, Zhengxuan Li¹, Yong Guo², Yongjia Yin², Qianwu Zhang¹, Yingxiong Song¹, Yingchun Li¹, Min Wang¹; ¹Shanghai Univ., China; ²ZTE Corporation, China. We demonstrate 10G-class optics based 25-gb/s upstream burst-mode transmission using adaptive equalization for ISI compensation. -23 dBm sensitivity at FEC limit of 1×10⁻³ is achieved, where tap adaption can be realized within 400 training bits.

Room 2

M1C • DSP Techniques for High-order QAM—Continued

M1C.5 • 09:30

Reception of Burst Mode High-order QAM Signals with Pilot-aided Digital Signal Processing, Chen Zhu¹, Noriaki Kaneda¹, Jeffrey Lee¹; ¹Bell Laboratories, Nokia, USA. We present pilot-assisted burst mode DSP design for high-order QAM signals. Short preambles are used for frame, frequency synchronization and channel estimation. The proposed scheme is experimentally demonstrated to detect 16G-baud PDM 128/256/512-QAM bursts.

M1C.6 • 09:45

Digitally Enhanced DAC: Low-resolution Digital Pre-compensation for High Speed Optical Links, Yaron Yoffe¹, Eyal Wohlgemuth¹, Dan Sadot¹; ¹Ben Gurion Univ. of the Negev, Israel. A novel algorithm is proposed to overcome bandwidth limitation using low resolution DACs. We demonstrate electrical back-to-back 32GBaud QAM-64 over 11GHz and optical 32GBaud QAM-4 over 5GHz using 4 bits and 2.6 bits DACs respectively

Room 6C

M1D • Subsea and Open Systems—Continued

M1D.4 • 09:30

Design of Submarine “Open” Cables, Pascal Pecci¹, Vincent LETELLIER¹, Olivier Gautheron¹, Alice Shelton¹, Olivier Courtois¹, Matteo Gumier¹, Vincent Chevalier¹, Paul Gabla¹; ¹ASN, France. Digital coherent receiver and GN model moved submarine transmission systems into the “open” cables era. This new paradigm leads to consider new parameters to design and characterize open submarine systems independently of the terminal equipment.

Room 6D

M1E • Open Systems and Modules—Continued

M1E.4 • 09:30

Demonstration of Real-time 400G Single-carrier Ultra-efficient 1.2Tb/s Superchannel over Large A_{eff} Ultra-low Loss Terrestrial Fiber of 150km Single Span and 250km (2×125km Spans) using Only EDFA Amplification, Yu Rong Zhou¹, Kevin Smith¹, Mike Gilson¹, Jingxin Chen², Weiwei Pan², Youhui Chang², Shuangyuan Wu², Shipeng Wu², Derek Nesses², Ian Davis³; ¹BT, UK; ²Huawei Technologies, UK; ³Corning Limited, UK. We successfully demonstrated Real-time 400G (64GBaud DP-16QAM) single-carrier ultra-efficient 1.2Tb/s superchannel (6.25bit/s/Hz) over new ultra-low loss large A_{eff} terrestrial fiber with long term error-free performance over 150km single-span and 250km (2 spans) using only EDFAs.

M1E.5 • 09:45

Silicon Photonic Multi-rate DCO-CFP2 Interface for DCI, Metro, and Long-haul Optical Communications, Erwan Pincemin¹, Yann Loussouarn¹, Mike Pan², Glen Miller², Alan Gibbemeyer², Benny Mikkelsen²; ¹Orange Labs, France; ²Acacia Inc, USA. For the first time, a 100/200-gbps DP-QPSK/8QAM/16QAM silicon photonic DCO-CFP2 interface using various FECs and consuming less than 19 Watts is presented and evaluated. Performances make the transceiver compliant with DCI, metro/regional, LH, and ULH applications.

Room 6E

M1F • Optical Wireless Systems—Continued

M1F.6 • 09:30

Towards Dynamic Ultrahigh Capacity Symmetric Bidirectional Indoor Optical-wireless Communication, Ketemaw Addis Mekonnen¹, Zizheng Cao¹, Eduward Tangdiongga¹, Ton Koonen¹; ¹Eindhoven Univ. of Technology, Netherlands. By implementing optical carrier reuse concept, we demonstrate a novel full-duplex optical-wireless communication system using a reflective-modulator chip at the user terminal, equipped with localization/tracking functionalities, with unshared symmetric capacity of up to 40Gb/s.

M1F.7 • 09:45

LCoS-based Access Node for Bidirectional Optical Wireless Communications, Hsi-Hsir Chou¹, Jen-Hao Hsiao¹; ¹National Taiwan Univ. of Science & Tech, Taiwan. An LCoS-based access node using optical fibers as the transmitter and receiver to extend the high-speed data transmission from NG-PON 2 to indoor home area network through optical wireless communications without O/E/O conversions is reported.

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



Room 6F

M1G • Advanced Modulation Formats—Continued

M1G.4 • 09:30

Novel Low-complexity Fully-blind Density-centroid –tracking Equalizer for 64-QAM Coherent Optical Communication Systems, Junfeng J. Zhang¹, Chen Wei¹, Mingyi Gao¹, Bo W. Chen¹, Gangxiang Shen¹; ¹*Soochow Univ., China*. We proposed a low-complexity non-data-aided density-centroid-tracking equalizer to improve the performance of 64-QAM coherent optical communication system. We experimentally demonstrated it over 80-km single mode fiber transmission and observed approximately 2-dB power penalty improvement.

M1G.5 • 09:45

Nonlinearity-tolerant 8D Modulation Formats By Set-partitioning PDM-QPSK, Djalal Falih Bendimerad¹, Hartmut Hafermann¹, Huijian Zhang¹; ¹*Huawei Technologies France, France*. We present two new nonlinearity tolerant modulation formats at spectral efficiencies lower than 4bits/4D-symbol, obtained using a simplified bit-to-symbol mapping approach to set-partition PDM-QPSK in 8 dimensions.

Room 7AB

M1H • Microwave Photonic Signal Processing I—Continued

M1H.4 • 09:30

SBS-based OEO with High Tuning Resolution and Wide Tuning Range by Selecting Different-order Phase Modulation Sideband as Pump, Mengyue Shi¹, Lilin Yi¹, Weisheng Hu¹; ¹*Shanghai Jiao Tong Univ., China*. Optoelectronic oscillator with tuning resolution of 10MHz and tuning range up to 40GHz is realized based on stimulated Brillouin scattering. The sideband mode suppression ratio is 50dB and the SSB phase noise is -120dBc/Hz@100kHz.

M1H.5 • 09:45

Integrated Frequency-tunable Microwave Photonic Bandpass Filter on a Silicon Photonic Chip, Weifeng Zhang¹, Jianping Yao¹; ¹*Univ. of Ottawa, Canada*. A photonic integrated frequency-tunable microwave photonic bandpass filter consisting of a high-speed phase modulator, a thermally-tunable high-q microdisk resonator, and a high-speed photodetector, fully integrated on a silicon platform, is designed, fabricated and characterized.

Room 9

M1I • Lasers for Data Center Interconnects—Continued

M1I.6 • 09:30

Parameter Extraction through Joint Optimization of Modulation Response and RIN Spectra, Alirio Melgar¹, Varghese A. Thomas¹, Justin Lavrencik¹, Stephen E. Ralph¹; ¹*Georgia Inst. of Technology, USA*. Extraction of VCSEL rate equation model parameters through joint optimization of modulation response and RIN spectra is presented. It accurately accounts for both ISI and noise, and employs drive-dependent parasitics found in VCSELs.

M1I.7 • 09:45

A 14 Gb/s Directly Modulated Hybrid Microring Laser Transmitter, Ashkan Roshan Zamir¹, Kunzhi Yu¹, Di Liang², Chong Zhang², Cheng Li², Gaofeng Fan¹, Binhao Wang², Marco Fiorentino², Raymond Beausoleil², Samuel Palermo¹; ¹*Texas A&M Univ., USA*; ²*Hewlett Packard Labs, USA*. The first demonstration of a hybrid-integrated directly modulated microring laser transmitter operating up to 14 Gb/s operation is reported. A CMOS driver with an asymmetric 2-tap feed-forward compensates for the microring laser non-linear dynamics.

NOTES

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

Monday, 12 March





Room 1A

10:30–12:30

M2A • 5G and Network Slicing

Presider: Reza Mirzaei Nejad; Universite Laval, Canada

M2A.1 • 10:30

Multi-tenant Hybrid Slicing with Cross-layer Heterogeneous Resource Coordination in 5G Transport Network, Qize Guo^{1,2}, Rentao Gu^{1,2}, Mingyu Cen¹, Xueyu Kang¹, Tianyi Zhao¹, Lin Bai³, Yuefeng Ji^{1,2}; ¹Beijing Laboratory of Advanced Information Network, Beijing Univ. of Posts and Telecommunications, China; ²Beijing Advanced Innovation Center for Future Internet Technology, Beijing Univ. of Technology, China; ³Beijing Univ. of Posts and Telecommunications, China. We proposed a multi-tenant slicing scheme with multi-domain, multi-layer and multivendor (M²) features. The experimental demonstration shows the slicing created and modified around in 353ms and 150ms, with the hybrid resource isolation has offered.

M2A.2 • 10:45

On the Scalability of Connectivity Services in a Multi-operator Orchestrator Sandbox, Ajmal Muhammad¹, Andrea Sgambelluri², Olivier Dugeon³, Jorge M. Pérez⁴, Francesco Paolucci², Oscar Gonzalez de Dios⁵, Fabio Ubaldi⁶, Teresa Pepe⁶, Carlos J. Cano⁴, Paolo Monti¹; ¹KTH Royal Inst. of Technology, Sweden; ²Scuola Superiore Sant'Anna, via Moruzzi 1, Italy; ³Orange Lab, France; ⁴Universidad Carlos III de Madrid, Spain; ⁵TID Telefonica, Spain; ⁶Ericsson Research, Via Moruzzi 1, Spain. The paper investigates the performance of a multi-domain orchestrator (MdO) deployed in a real multi-domain European testbed. Results show how the MdO prototype scales well with the number of domains advertised and connectivity services provisioned.

Room 1B

10:30–12:30

M2B • Beyond 10G PON Evolution II

Presider: Derek Nettet; BT, Germany

M2B.1 • 10:30 **Invited**

What Applications Are Driving Higher Capacity In Access?, Phil Miguez¹; ¹Comcast, USA. The growth of consumer high speed data has continued to expand at a rate of nearly 50% year over year. This paper explores the key drivers of this exceptional growth and the network changes being implemented to meet current and future capacity requirements.

Room 2

10:30–12:30

M2C • Transmission Systems

Presider: Dmitri Foursa; TE SubCom, USA

M2C.1 • 10:30 **Invited**

ADC & DAC - Technology Trends and Steps to Overcome Current Limitations, Tomislav Drenski¹, Jens C. Rasmussen¹; ¹Socionext, UK. ADC & DAC technology trends addressing Ultra Long Haul (ULH) to Very Short Reach (VSR) transmissions are presented. The challenges are reviewed and possible solutions to overcome current limitations for the different applications are discussed.

Room 6C

10:30–12:30

M2D • Energy Efficient Optical Links

Presider: Samuel Palermo; Texas A&M Univ., USA

M2D.1 • 10:30

A 34GBaud Linear Transimpedance Amplifier with Automatic Gain Control for 200Gb/s DP-16QAM Optical Coherent Receivers, Mostafa G. Ahmed¹, Tam N. Huynh¹, Christopher Williams¹, Yong Wang¹, Rahul Shringarpure¹, Reza Yousefi¹, Jose Roman¹, Noam Ophir¹, Alexander Rylyakov¹; ¹Elenion Technologies, LLC, USA. A 34GBaud TIA achieves 1.5% THD at 1mAppd input, 20pA/sqrt(Hz) input referred noise density, output amplitude of up to 1Vppd and maintains 27GHz bandwidth over 43dB of transimpedance gain dynamic range, enabling a 200Gb/s dual-polarization 16QAM coherent receiver operation.

M2D.2 • 10:45

A 137-mW, 4 ch x 25-gbps Low-power Compact Transmitter Flip-chip-bonded 1.3-um LD-array-on-si, Toshiki Kishi¹, Munehiko Nagatani¹, Shigeru Kanazawa², Shinsuke Nakano², Hiroaki Katsuragi², Takuro Fujii¹, Hidetaka Nishi¹, Takaaki Kakitsuka¹, Koichi Hasebe¹, Kota Shikama¹, Yuko Kawajiri¹, Atsushi Aratake¹, Hideyuki Nosaka¹, Hiroshi Fukuda¹, Shinji Matsuo¹; ¹NTT Device Technology Laboratories, Japan; ²NTT Device Innovation Center, Japan. A low-power compact 4-channel transmitter consisting of a 65-nm CMOS cascode shunt LD driver and flip-chip-bonded 1.3-um LD-array-on-si achieves 25-gbps 2-km-long SSMF error-free operation for each channel, with power consumption of 1.37 mW/Gbps.

Room 6D

10:30–12:30

M2E • Open and Dynamic Networking

Presider: Noboru Yoshikane; KDDI Research, USA

M2E.1 • 10:30 **Invited**

Progress toward an Open, SDN Controlled Photonic Network, Kathleen Tse¹; ¹AT&T Corp, USA. AT&T is moving to a photonic layer that is fully software controlled and open. This allows us to deliver bandwidth when and where it is needed and optimize the network as it grows and changes.

Room 6E

10:30–12:30

M2F • Machine Learning and Performance Monitoring

Presider: Alan Pak Tao Lau; Hong Kong Polytechnic Univ., Hong Kong

M2F.1 • 10:30

Integration of Multivariate Gaussian Mixture Model for Enhanced PAM-4 Decoding Employing Basis Expansion, Feng Lu¹, Peng-Chun Peng², Siming Liu¹, Mu Xu¹, Shuyi Shen¹, Geek-Kung Chang¹; ¹School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA; ²Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan. For the first time, we introduced Gaussian-mixture-model (GMM) and basis expansion in the PAM-4 decoder after equalization to estimate and eliminate residual linear/nonlinear impairments. With 100-gbps testbed, we experimentally demonstrated 1 to 1.5-dB sensitivity improvement.

M2F.2 • 10:45

Transmission of 4x50-Gb/s PAM-4 Signal over 80-km Single Mode Fiber using Neural Network, Ming Luo¹, Gao Fan², Xiang Li¹, Zhixue He¹, Songnian Fu²; ¹WRI, China; ²HUST, China. We apply neural network algorithms with two kinds of input features as the nonlinear DSP method, and realize 4x50-gb/s PAM-4 IM/DD transmission for 80-km fiber with ~2 dB power sensitivity improvement over conventional nonlinear algorithms.





Room 6F

10:30–12:00

M2G • Microwave Photonic Signal Processing II

Presider: Jose Azana; INRS-energie Matériaux et Telecom, Canada

M2G.1 • 10:30

Intelligent Remote Sensing Systems Based on Microwave Photonic Technologies, Antonella Bogoni^{1,2}; ¹CNIT, Italy; ²TeCIP, Sant'Anna School of Advanced Studies, Italy. This paper presents some recent evolutions of the concept of photonics-based radar. In particular, it reports on the coherent MIMO radar network and on the wideband RF scanning receiver, discussing their potentials.

Room 7AB

10:30–12:30

M2H • Panel: 400G Optics for Hyperscale Data Centers

Organizers: Xiaoxia Wu, Juniper, USA; Kenneth Jackson, Sumitomo Electric, USA

Hyperscale data center operators are demanding ever higher data throughputs at an accelerated pace. With 10Gb/s and 40Gb/s server-to-switch and switch-to-switch connections deployed just a few short years ago, 25Gb/s, 50Gb/s and 100Gb/s are now the norm. These higher rates are creating an urgent need for even higher bandwidth interconnects and many operators believe 400G will enable improvements in network scale, efficiency and cost. This panel will examine the various architectures that drive this need as well as specific requirements of the ecosystem and deployment time-table to support these high performance networks.

Panelists:

Rich Baca, Microsoft, USA

Andy Bechtolsheim, Arista Networks, USA

Chris Cole, Finisar, USA

Philip Gadd, Intel, USA

Benny Mikkelsen, Acacia Communications, USA

Osa Mok, Innolight, USA

Kohichi Tamura, Oclaro, USA

Xiang Zhou, Google, USA

Room 8

10:30–12:30

M2I • Emerging Devices and Materials

Presider: Dong Pan; Sifotonics, USA

M2I.1 • 10:30

Driver-less Sub-1 Vpp-operation of a Plasmonic-organic Hybrid Modulator at 100 GBd NRZ, Benedikt Baeuerle¹, Claudia Hoessbacher¹, Wolfgang Heni¹, Yuriy Fedoryshyn¹, Arne Josten¹, Christian Haffner¹, Tatsuhiko Watanabe¹, Delwin L. Elder², Larry R. Dalton², Juerg Leuthold¹; ¹ETH Zurich, Switzerland; ²Department of Chemistry, Univ. of Washington, USA. We demonstrate driver-less 100 GBd operation of a plasmonic intensity modulator. Drive voltages below 1V lead to low power consumption of 2.84 fJ/bit for 100 Gbit/s with a direct detected BER below the HD-FEC limit.

M2I.2 • 10:45

High Speed Modulator Based on Electro-optic Polymer Infiltrated Subwavelength Grating Waveguide Ring Resonator, Zeyu Pan¹, Xiaochuan Xu², Chi-Jui Chung¹, Hamed Dalir², Hai Yan¹, Ke Chen¹, Yaguo Wang¹, Ray Chen^{1,2}; ¹Univ. of Texas at Austin, USA; ²Omega Optics, Inc., USA. We present a high-speed modulator based on electro-optic polymer infiltrated subwavelength grating waveguide ring resonator. A 3-dB small signal modulation bandwidth of 41.36 GHz has been demonstrated.

Room 9

10:30–12:30

M2J • Fiber Lasers

Presider: Efstratios Kehayas; Gooch & Housego, UK

M2J.1 • 10:30

Ultra-large Mode Area Fibers for High Power Lasers, Cesar Jauregui¹, Jens Limpert^{1,2}, Andreas Tünnermann^{1,2}; ¹Friedrich-Schiller-Universität Jena, Germany; ²Fraunhofer Inst. for Applied Optics and Precision Engineering, Germany. The most recent advances on ultra-large mode area fibers for high-power operation will be presented. Moreover, an approach to synthesize ultra-large mode area fibers that circumvents technical limitations by using multi-core fibers will be discussed.

Room 10

10:30–12:30

M2K • Optical Wireless - Signal Processing

Presider: Tetsuya Kawanishi; Waseda Univ., Japan

M2K.1 • 10:30

Non-linear Compensation of Multi-CAP VLC System Employing Pre-distortion Base on Clustering of Machine Learning, Xingyu Lu¹, Mingming Zhao¹, Liang Qiao¹, Nan Chi¹; ¹Fudan Univ., China. We proposed and experimentally demonstrated a pre-distortion scheme based on clustering algorithm of machine learning to mitigate nonlinear impairments for VLC system. BER degraded at least 50% over 5-band CAP16 transmission with pre-distortion.

M2K.2 • 10:45

Accurate Indoor Visible Light Positioning System utilizing Machine Learning Technique with Height Tolerance, Chin-wei Hsu^{2,1}, Siming Liu¹, Feng Lu¹, Chi-Wei Chow², Chien-Hung Yeh³, Gee-Kung Chang¹; ¹School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA; ²Department of Photonics, College of Electrical and Computer Engineering, National Chiao Tung Univ., Taiwan; ³Department of Photonics, Feng Chia Univ., Taiwan. An accurate, low-cost indoor visible light positioning system utilizing machine learning technique is proposed and experimentally demonstrated. The average position resolution of the system can achieve 3.65 cm with height tolerance range of 15 cm.



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Monday, 12 March





Room 1A

M2A • 5G and Network Slicing—Continued

M2A.3 • 11:00  **Invited**
Converged Access/Metro Infrastructures for 5G services, Anna Tzanakaki^{1,2}, Markos Anastasopoulos², Dimitra E. Simeonidou²; ¹Univ. of Athens, Greece; ²Univ. of Bristol, UK. This paper focuses on Converged Access/Metro Infrastructures for 5G services proposing the novel “Disaggregated RAN” architecture adopting “disaggregation” of hardware and software components across wireless, optical and compute/storage domains. The proposed approach is theoretically evaluated.

Room 1B


M2B • Beyond 10G PON Evolution II—Continued

M2B.2 • 11:00
56 Gbps IM/DD PON based on 10G-class Optical Devices with 29 dB Loss Budget Enabled by Machine Learning, Peixuan Li¹, Lilin Yi¹, Lei Xue¹, Weisheng Hu¹; ¹Shanghai Jiao Tong Univ., China. We demonstrate 56Gbps PAM4 PON transmission over 25km SSMF using 10G-class DML and APD with 6 GHz 3-dB bandwidth. 29 dB loss budget is achieved by a novel equalization technique based on convolutional neural network.

M2B.3 • 11:15
Experimental Demonstration of Unequally Spaced PAM-4 Signal to Improve Receiver Sensitivity for 50-gbps PON with Power-dependent Noise Distribution, Junwen Zhang¹, Jun Shan Wey¹, Jianjun Yu¹; ¹ZTE TX Inc, USA. For APD or SOA pre-amplified receivers with power-dependent non-uniform noise distributions, we demonstrate an enhanced PAM-4 modulation and detection scheme with unequally spaced signal levels, achieving improved receiver sensitivity for 50-b/s/λ PON.

Room 2

M2C • Transmission Systems—Continued


M2C.2 • 11:00  **Top Scored**
Record 560 Gb/s Single-carrier and 850 Gb/s Dual-carrier Transmission over Transoceanic Distances, Ivan Fernandez de Jauregui Ruiz^{1,2}, Amirhossein Ghazisaeidi¹, Patrick Brindell¹, Rafael Rios-Muller¹, Aymeric Arnould¹, Haik Mardoyan¹, Omar Ait Sab³, Jeremie Renaudier¹, Gabriel Charlet¹; ¹Nokia Bell Labs, France; ²Telecom SudParis, France; ³ASN, France. We demonstrate record single-carrier 560-gb/s over 6,600 km and 430-gb/s transmission over 13,200 km, as well as dual-carrier 850-gb/s over 6,600km, and 1-tb/s over 3,960km, leveraging advanced DACs, wideband receiver, probabilistic shaping and nonlinear mitigation.

M2C.3 • 11:15
8x506-Gb/s 16QAM WDM Signal Coherent Transmission over 6000-km Enabled by PS and HB-cDM, Jianjun Yu¹, Junwen Zhang¹, Kaihui Wang², Benyuan Zhu³, Steve Dzioba⁴, Hungchang Chien¹, Xinying Li^{1,2}, Yi Cai¹, Xin Xiao¹, Jianyang Shi², Yufei Chen⁵, Yan Xia⁵, sheping shi⁵; ¹ZTE TX Inc, USA; ²Fudan Uni., China; ³OFS USA, USA; ⁴NeoPhotonics Corp, USA; ⁵ZTE, China. We experimentally demonstrate 506-gb/s/channel (66.125-GBaud/channel) eight-channel WDM probabilistically-shaped 16QAM signal coherent transmission over 6000-km fiber with BER under 4.2x10⁻². 150% transmission-distance improvement, and 0.216-bit/symbol achievable-information-rate improvement can be attained after probabilistic shaping.

Room 6C


M2D • Energy Efficient Optical Links—Continued

M2D.3 • 11:00 
4x40 Gb/s 2 pJ/bit Optical RX with 8ns Power-on and CDR-lock Time in 14nm CMOS, Alessandro Cevrero¹, Ilter Ozkaya^{1,7}, Thomas Morf¹, Thomas Toifl¹, Yusuf Leblebici⁷, Marc Seifried¹, Frank Ellinger², Mahdi Khafaji², Jan Pliva², Ronny Henker², Nikolay Ledentsov³, Joerg Kropp³, Vitaly Shchulin³, Martin Zoldak⁴, Leos Halmo⁴, Ian Eddie⁵, Jarek Turkiewicz²; ¹IBM research, Switzerland; ²TU Dresden, Germany; ³VI system, Germany; ⁴Argotech, Czechia; ⁵CST Global Ltd, UK; ⁶Warsaw technical Univ., Poland; ⁷EPFL, Switzerland. We report a low-power 4-channel NRZ optical RX including a digital burst-mode CDR measured up to 40Gb/s/lane in 14nm CMOS. The RX, designed for 850nm VCSEL based optical links, can wake-up and achieve phase-lock in 8ns at BER<2*10⁻¹².

M2D.4 • 11:15  **Top Scored**
FEC-free 60-Gb/s Silicon Photonic Link Using SiGe-driver ICs Hybrid-integrated with Photonics-enabled CMOS, Benjamin G. Lee¹, Nicolas Dupuis¹, Jason Orcutt¹, Javier Ayala², Karen Nummy², Herschel Ainspan¹, Jonathan E. Proesel¹, Christian Baks¹, Douglas M. Gill¹, Mounir Meghelli¹, William M. Green¹; ¹IBM TJ Watson Research Center, USA; ²Globalfoundries, USA. We report an error-free 60-gb/s link driven by SiGe ICs using a segmented-electrode Mach Zehnder modulator with optical-domain feed-forward equalization and a high-bandwidth Ge photodetector, both integrated in a commercial photonics-enabled CMOS process.

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.2 • 11:00 
Estimating Network Throughput with an Adaptive Routing and Wavelength Assignment Algorithm, Robert J. Vincent¹, David J. Ives¹, Seb J. Savory¹; ¹Univ. of Cambridge, UK. We propose an adaptive sequential loading algorithm that approaches the ILP throughput. Of 2,000 network realizations tested, shortest path routing achieves >90 % of the maximum throughput in 341 cases c.f. 1,904 with the proposed algorithm.

M2E.3 • 11:15 
Joint Jobs Scheduling and Routing for Metro-scaled Micro Datacenters over Elastic Optical Networks, Zhen Liu^{1,2}, Jiawei Zhang^{1,2}, Lin Bai¹, Yuefeng Ji^{1,2}; ¹State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications (BUPT), China; ²Beijing Advanced Innovation Centre for Future Internet Technology, Beijing Univ. of Technology (BJUT), China. A joint jobs scheduling and routing algorithm is proposed for geographically-distributed micro datacenters over EON. Simulation results show that the algorithm can reduce the jobs' average completion time and bandwidth consumption.

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.3 • 11:00  **Invited**
Optical Performance Monitoring in Fiber-optic Networks Enabled by Machine Learning Techniques, Faisal N. Khan¹, Chao Lu¹, Alan Pak Tao Lau¹; ¹The Hong Kong Polytechnic Univ., Hong Kong. We review applications of machine learning (ML) in various aspects of optical communications including optical performance monitoring, fiber nonlinearity compensation, and software-defined networking. The future role of ML in optical communications is also discussed.





Room 6F

M2G • Microwave Photonic Signal Processing II—Continued

M2G.2 • 11:00

Frequency-agile and Filter-free Wireless Communication Transceiver based on Photonics, Filippo Scotti¹, Daniel Onori², Antonella Bogoni¹, Paolo Ghelfi¹; ¹CNIT, Italy; ²TECIP, Scuola Superiore Sant'Anna, Italy. A photonics-based tunable RF transceiver able to generate and receive signals, without any RF or optical filter, is proposed. Experimental results with WiFi traffic show flat and good performance over the whole 2-18GHz frequency range.

M2G.3 • 11:15

Photonic Sampling of Broadband QAM Microwave Signals Exploiting Interleaved Optical Nyquist Pulses, Valeria Vercesi¹, Daniel Onori², John Davies³, Alwyn Seeds¹, Chin-Pang Liu¹; ¹Univ. College London, UK; ²Scuola Superiore Sant'Anna, Italy; ³Thales UK, UK. We performed photonic sampling of 6 GBaud 16-QAM signals at 20 GHz sampling frequency by interleaving and time-aligning two 10 GHz Nyquist optical sampling pulse trains using a SMF as the dispersive medium

Room 7AB

M2H • Panel: 400G Optics for Hyperscale Data Centers—Continued

Room 8

M2I • Emerging Devices and Materials—Continued

M2I.3 • 11:00

Highly Efficient Silicon Photonics Phase Modulator using Graphene, Marco Romagnoli¹; ¹CNIT Photonic Networks and Technologies National Laboratory, Italy. Compact graphene-silicon phase-shifter with 0.28Vcm modulation efficiency at 1550nm is reported. The 2V MZ modulator has been tested over 50km SMF link at 10Gb/s and the chirped EA modulator over 100km SMF fiber link.

Room 9

M2J • Fiber Lasers—Continued

M2J.2 • 11:00

Dual Repetition-rate Laser Based On In-cavity Fractional Temporal Self-imaging for Low-noise RF Signal Generation, Mohamed Seghilani¹, Xiao-Zhou Li¹, Luis Romero Cortés¹, Reza Maram¹, Jose Azana¹; ¹INRS-EMT, Canada. We demonstrate a dual repetition-rate laser based on fractional temporal self-imaging. Experimental noise evaluation confirms that the environmental noise is nearly canceled when the laser's outputs are heterodyned, making the laser ideal for low-noise RF-generation.

M2J.3 • 11:15

Experimental Demonstration of Mid-IR Octave Spanning Supercontinuum Generation in Low Loss Silicon-germanium Waveguide, Milan Sinobad^{1,2}, Pan Ma³, Barry Luther-Davies³, Stephen Madden³, David J. Moss⁴, Regis Orobtschouk², Salim Boutami⁵, Jean-Michel Hartmann⁵, Jean-Marc Fedeli⁵, Christelle Monat², Christian Grillet²; ¹MIT Univ., Australia; ²Lyon Inst. of Nanotechnology, France; ³Australian National Univ., Australia; ⁴Centre for Microphotonics, Swinburne Univ. of Technology, Australia; ⁵CEA-leti, France. We report supercontinuum extending from 3 to 6µm generated in Si_{10.6}Ge_{0.4}/Si waveguide pumping with ~200fs pulses at 4.15µm. Experimentally measured low propagation loss (0.4dB/cm in range 3.8-5.0µm) and dispersion engineering waveguide allowed us achieving ~5mW useful average power.

Room 10

M2K • Optical Wireless - Signal Processing—Continued

M2K.3 • 11:00

Experimental Demonstration of OQAM-OFDM based MIMO-NOMA over Visible Light Communications, Jin Shi¹, Yang Hong², J He¹, Deng Rui¹, Lian-Kuan Chen²; ¹Hunan Univ., China; ²The Chinese Univ. of Hong Kong, China. We propose and experimentally demonstrate the first OQAM-OFDM based MIMO-nOMA for multi-user VLC. With the optimized power ratio, our scheme significantly outperforms conventional MIMO scheme, and an aggregate capacity of 3.2 Gbit/s can be achieved.

M2K.4 • 11:15

SNR-threshold based Adaptive Loading for PAM-fast-OFDM over Optical Wireless Communications, Yang Hong¹, Shuang Gao¹, Lian-Kuan Chen¹, Jian Zhao^{2,3}; ¹The Chinese Univ. of Hong Kong, Hong Kong; ²Tyndall National Inst., Ireland; ³Univ. College Cork, Ireland. We propose and experimentally demonstrate the first adaptively-loaded PAM-fast-OFDM over OWC using a simple yet effective SNR-threshold based loading algorithm. Results show >4-dB sensitivity improvement, and a 5.2-gbit/s transmission with ~44% capacity enhancement is achieved.

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Room 1A

M2A • 5G and Network Slicing—Continued

M2A.4 • 11:30 **Invited**

Optical Networks Virtualization and Slicing in the 5G Era, Ricard Vilalta¹, Arturo Mayoral López-de-Lerma², Raul Muñoz¹, Ricardo Martínez¹, Ramon Casellas¹; ¹CTTC, Spain; ²Wipro, Spain. We provide an overview of operationalization and deployment of the different data plane and control plane technologies used for Optical Network Virtualization and Network Slicing, which are two key enablers of future 5G networks.

Room 1B

M2B • Beyond 10G PON Evolution II—Continued

M2B.4 • 11:30

50-gb/s TDM-PON Based on 10G-class Devices by Optics-simplified DSP, Lei Xue¹, Lilin Yi¹, Peixuan Li¹, Weisheng Hu¹; ¹Shanghai Jiao Tong Univ., China. We demonstrate a 50-gb/s PAM-4 TDM-PON over 25-km SSMF based on DML and APD with 6-gHz 3-dB bandwidth in O-band. Dispersion-supported optical equalization is used to reduce the complexity of FFE and Volterra algorithms.

M2B.5 • 11:45

Spectrum-efficient 50-gbps Long-range Optical Access over 85-km SSMF via DML using Windowed OFDM Supporting Quasi-gapless Asynchronous Multiband Transmission, Shuyi Shen¹, Thavamaran Kanesan², Feng Lu¹, Mu Xu¹, Peng-Chun Peng¹, Siming Liu¹, Chin-Wei Hsu¹, Qi Zhou¹, Yahya M. Alfidhli¹, Hyung Joon Cho¹, Sufian M. Mitani², Jeff Finkelstein³, Gee-Kung Chang¹; ¹ECE, Georgia Inst. of Technology, USA; ²TM Research & Development, Malaysia; ³Cox Communications, USA. This paper demonstrates a long-range optical access network using windowed OFDM, providing 50.22-gbps data rate over 85-km SSMF transmission via DML. In multiband transmission, windowed OFDM has achieved 153% bandwidth gain with suppressed out-of-band leakage.

Room 2

M2C • Transmission Systems—Continued

M2C.4 • 11:30

Comparison of Nonlinearity Tolerance of Modulation Formats For Sub-carrier Modulation, Keisuke Kojima¹, Tsuyoshi Yoshida^{2,3}, Kieran Parsons¹, Toshiaki Koike-Akino¹, David Millar¹, Keisuke Matsuda⁴; ¹Mitsubishi Electric Research Labs, USA; ²Mitsubishi Electric Corp., Japan; ³Chalmers Univ. of Technology, Sweden. We investigate the use of 4D constant modulus modulation format combined with subcarrier modulation. Compared to the star-8QAM format, the proposed format has an improved performance gain from reducing the baud rate down to 1 GBd.

M2C.5 • 11:45

56-gb/s Optical SSB PAM-4 Transmission over 800-km SSMF using DDMZM Transmitter and Simplified Direct Detection Kramers-Kronig Receiver, Mingyue Zhu¹, Jing Zhang¹, Hao Ying¹, Xiang Li², Ming Luo², Yingxiong Song³, Fan Li⁴, Xiatao Huang¹, Xingwen Yi¹, Kun Qiu¹; ¹Univ. of Electronics Science & Tech, China; ²State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts and Telecommunications, China; ³Shanghai Inst. for Advanced Communication and Data Science, Shanghai Univ., China; ⁴School of Electronics and Information Technology, Sun Yat-sen Univ., China. We propose and experimentally demonstrate a simplified direct detection Kramer-Kronig (DD-KK) receiver followed by a Volterra filter to mitigate the SSB and fiber nonlinearity in a 56-gb/s optical SSB PAM-4 transmission over 800-km SSMF.

Room 6C

M2D • Energy Efficient Optical Links—Continued

M2D.5 • 11:30 **Invited**

Energy-efficient 120-gbps DMT Transmission using a 1.3- μ m Membrane Laser on Si, Nikolaos Pantelimon Diamantopoulos¹, Takuro Fujii¹, Hidetaka Nishi¹, Koji Takeda¹, Takaaki Kakitsuka¹, Shinji Matsuo¹; ¹NTT Device Technology Labs, Japan. We report DMT transmissions of 120-gbps over 10-km SSMF (for SD-FEC) and 100-gbps over 2-km (for HD-FEC), by directly modulating a single-mode membrane laser grown on an InP/SiO₂/Si substrate, requiring only 28.2 mW for driving.

M2D.6 • 11:45 **Invited**

Analog Optical Signaling for Large Scale Radio Telescopes in Harsh Environments, Jonas Weiss¹, Peter Maat², Folkert Horst¹, Bert J. Offrein¹; ¹IBM, Zurich, Switzerland; ²Astron, Netherlands. We present optical analog signaling technologies, developed specifically for the Square Kilometre Array (SKA). SKA will be the world's largest radio telescope when finished, combining thousands of antennas installed in remote and harsh environments.

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.4 • 11:30 **Invited**

"OPEN" and its Impact on Engineering, Design, Operations and Profitability in the Communication Network, Kirsten Rundberget¹; ¹Fujitsu Network Communications Inc, USA. The advent of "Open" is causing a radical shift in the way communications networks are designed, deployed and operated. This paper explores the impact of "Open" across communications networks of today and tomorrow.

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.4 • 11:30 **Invited**

Joint Estimation of Linear and Non-linear Signal-to-noise Ratio based on Neural Networks, Francisco Javier Vaquero Caballero¹, David J. Ives¹, Qunbi Zhuge², Maurice O'Sullivan², Seb J. Savory¹; ¹Electrical Engineering, Univ. of Cambridge, UK; ²Ciena, Canada. A novel technique estimating ASE and non-linear SNR is presented. Our method is evaluated by simulations obtaining a std error of 0.23 dB for both ASE and non-linear SNR.

M2F.5 • 11:45 **Invited**

Blind and Fast Modulation Format Identification by Frequency-offset Loading for Hitless Flexible Transceiver, Lu Jianing^{1,2}, Songnian Fu¹, Lei Deng¹, Ming Tang¹, Zhouyi Hu², Deming Liu¹, Calvin Chan²; ¹School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China; ²Department of Information Engineering, The Chinese Univ. of Hong Kong, Hong Kong. We propose a blind and fast modulation format identification enabled by frequency-offset loading technique for hitless flexible transceiver. Arbitrary format switching among 28-GBaud DP-4/8/16/64QAM, hybrid-4/16QAM, and SP-128QAM can be accurately identified with only 2048 symbols.

Room 6F

M2G • Microwave Photonic Signal Processing II—Continued

M2G.4 • 11:30

Fast and Linear Photonic Integrated Microwave Phase-shifter for 5G Beam-steering Applications, Fabio Falconi², Claudio Porzi¹, Sergio Pinna¹, Vito Sorianello², Giovanni Serafino¹, Marzio Puleri³, Antonio D'Errico³, Marco Romagnoli², Antonella Bogoni^{1,2}, Paolo Ghelfi²; ¹TeCIP - Scuola Superiore Sant'Anna, Italy; ²CNIT-national Photonics Labs, Italy; ³Ericsson Telecomunicazioni SpA, Italy. An integrated SOI photonic microwave phase-shifter employing optical deinterleaver and reverse-biased p-n junction waveguide for precise, continuous linear phase shift in excess of 360° with fast reconfiguration time below 1 ns for beam-steering applications is demonstrated.

M2G.5 • 11:45

Integrated Photonic True-time Delay Beamformer for a Ka-band Phased Array Antenna Receiver, Vanessa C. Duarte^{1,2}, João G. Prata¹, Carlos Ribeiro¹, Rogerio N. Nogueira^{1,3}, Georg Winzer², Lars Zimmermann², Rob Walker⁴, Stephen Clements⁴, Marta Filipowicz⁵, Marek Napierala⁵, Tomasz Nasilowski⁵, Jonathan Crabb⁶, Leontios Stampoulidis⁶, Javad Anzalchi⁷, Miguel V. Drummond¹; ¹Instituto de Telecomunicações, Portugal; ²IHP - Innovations for High Performance Microelectronics, Germany; ³Watgrid, Lda, Portugal; ⁴aXenic Ltd, UK; ⁵InPhoTech Sp. z o.o., Poland; ⁶Gooch & Housego, UK; ⁷Airbus Defence and Space, UK. We demonstrate a silicon photonic 4x1 TTD beamformer operated in Real-time. Beamforming of a 1 Gb/s QPSK signal carried at 28 GHz was validated by a fourfold improvement in output amplitude and EVM.

Room 7AB

M2H • Panel: 400G Optics for Hyperscale Data Centers—Continued

Room 8

M2I • Emerging Devices and Materials—Continued

M2I.4 • 11:30

Record High Bandwidth Integrated Graphene Photodetectors for Communication Beyond 180 Gb/s, Daniel Schall¹, Emiliano Pallecchi², Guillaume Ducournau², Vanessa Avramovic², Martin Otto¹, Daniel Neumaier¹; ¹AMO GmbH, Germany; ²Institut d'Electronique de Microélectronique et de Nanotechnologie (IEMN), France. We report on the fastest silicon waveguide integrated photodetectors with a bandwidth larger than 128 GHz for ultrafast optical communication. The photodetectors are based on CVD graphene that is compatible to wafer scale production methods.

M2I.5 • 11:45

Single-sideband Thin Film Lithium Niobate (TFLN™) Electro-optic Modulators for RF over Fiber, Vincent Stenger¹, James Toney¹, Dean Brown², Steven McKeown², Benjamin Griffin³, Robert Nelson³, Sriram Sriram¹; ¹SRICO, Inc., USA; ²UES, Inc., USA; ³US Air Force Research Laboratory, USA. A high speed thin film lithium niobate modulator device is integrated with a Bragg grating for *in situ* sideband filtering. The configuration has potential for high efficiency linear intensity modulation at bandwidths exceeding 70 GHz.

Room 9

M2J • Fiber Lasers—Continued

M2J.4 • 11:30

Ultra-short Wavelength Operation of a Thulium Doped Fiber Laser in the 1620-1660nm Wavelength Band, Shaoxiang Chen^{1,2}, Yongmin Jung¹, S.U Alam¹, Saurabh Jain¹, Morten Ibsen¹, R. Sidharthan², Daryl Ho², Seongwoo Yoo², David J. Richardson¹; ¹Univ. of Southampton, UK; ²Nanyang Technological Univ., Singapore. We present a tunable thulium-doped fiber laser (TDFL) incorporating a Tm/Ge co-doped fiber capable of accessing the U-band wavelength region (1620-1660nm). These results represents by far the shortest laser wavelengths so far for a TDFL.

M2J.5 • 11:45

Tunable Multi-wavelength EDF Laser Based on Sagnac Interferometer with Weakly-coupled FMF Delay Line, Muqing Zhou¹, Fang Ren², Juhao Li¹, Dawei Ge¹, Yichi Zhang³, Zhangyuan Chen¹, Yongqi He¹; ¹Peking Univ., China; ²Univ. of Science and Technology Beijing, China; ³Wuhan Research Inst. of Posts and Telecommunications, China. We propose an EDF laser based on Sagnac interferometer with weakly-coupled FMF delay line. We experimentally demonstrate that it has high stability, an OSNR higher than 30-dB and a tuning range over 30-nm.

Room 10

M2K • Optical Wireless - Signal Processing—Continued

M2K.5 • 11:30

Demonstration of Reduced Complexity Multi-band CAP Modulation using Xia-pulses in Visible Light Communications, Paul A. Haigh¹, Izzat Darwazeh¹; ¹Univ. College London, UK. This work proposes and demonstrates, for the first time, a new method for CAP modulation in VLC based on full-Nyquist Xia pulses. By receiver modification, we demonstrate a signification reduction in computational complexity by >90%.

M2K.6 • 11:45

80 Gb/s Free-space Reconfigurable Optical Interconnects with Carrierless-amplitude-phase Modulation and Space-time Block Code, Ke Wang^{1,2}, Ampalavanapillai Nirmalathas³, Christina Lim³, Elaine Wong³, Kamal Alameh⁴, Hongtao Li², Efstratios Skafidas⁵; ¹Royal Melbourne Inst. of Technology, Australia; ²Nanjing Univ. of Science and Technology, China; ³The Univ. of Melbourne, Australia; ⁴Edith Cowan Univ., Australia. Carrierless-amplitude-phase modulated and space-time coded free-space reconfigurable optical interconnects with extended range and reduced inter-channel crosstalk are experimentally demonstrated. Results show that 80 Gb/s interconnect is achieved and the error-free distance is improved by about 65%.



Room 1A

M2A • 5G and Network Slicing—Continued

M2A.5 • 12:00

SDN-enabled Sliceable Multi-dimensional (Spectral and Spatial) Transceiver Controlled with YANG/NETCONF, Raul Muñoz¹, Noboru Yoshikane², Ramon Casellas¹, Josep Fabrega¹, Ricard Vilalta¹, Michela Svaluto Moreolo¹, Laia Nadal¹, Daiki Soma², Yuta Wakayama², Shohei Bep-pu², Seiya Sumita², Takehiro Tsuritani², Itsuro Morita²; ¹CTTC, Spain; ²KDDI Research, Japan. We demonstrate the first SDN-enabled sliceable SDM-wDM transceiver providing multiple spectral-spatial super-channels spanning different cores and modes over a 11-km 6-mode 19-core fiber. We define an open API based on YANG/NETCONF for disaggregated optical networks.

M2A.6 • 12:15

Experimental Demonstration of DDOS Mitigation over a Quantum Key Distribution (QKD) Network using Software Defined Networking (SDN), Emilio Hugues Salas¹, Foteini Ntavou¹, Yanni Ou¹, Jake Kennard¹, Catherine White², Dimitrios Gkounis¹, Konstantinos Nikolovgenis¹, George T. Kanellos¹, Chris Erven¹, Andrew Lord², Reza Nejabati¹, Dimitra E. Simeonidou¹; ¹Univ. of Bristol, UK; ²British Telecom (BT) Research and Innovation, UK. We experimentally demonstrate, for the first time, DDOS mitigation of QKD-based networks utilizing a software defined network application. Successful quantum-secured link allocation is achieved after a DDOS attack based on Real-time monitoring of quantum parameters.

Room 1B

M2B • Beyond 10G PON Evolution II—Continued

M2B.6 • 12:00

Demonstration of Simultaneous Multiple ONUs Activation in WDM-PON System for 5G Fronthaul, Kyosuke Sone¹, Goji Nakagawa¹, Yoshio Hirose¹, Takeshi Hoshida¹; ¹Fujitsu Limited, Japan. We successfully demonstrate simultaneous activation of multiple ONUs by the random waiting time function in upstream transmission of registration request and random function of sweep start wavelength of tunable filter at ONU in WDM-PON system.

M2B.7 • 12:15

Optimized Differential Detection-based Optical Carrier Recovery for Intradyme PSK Receivers in udWDM-PON, Saeed Ghasemi¹, Jeison Tabares¹, Victor Polo¹, Josep Prat¹; ¹Universitat Politècnica de Catalunya (UPC), Spain. We present an optical carrier recovery based on differential detection that reduces required DSP hardware resources. Results show -55dBm sensitivity for BER=10⁻³ and high tolerance against fast LO frequency dithering, with DPSK data at 1.25Gbps.

Room 2

M2C • Transmission Systems—Continued

M2C.6 • 12:00

Transmitter-side Volterra Filtering for Increased Dispersion Tolerance in 56 GBaud PAM-4 Systems, Jignesh D. Jokhakar^{1,2}, Tobias Eriksson², Mathieu Chagnon^{2,3}, Bill Corcoran¹, Arthur Lowery¹, Fred Buchali², Henning Bülow²; ¹Monash Univ., Australia; ²Nokia Bell Labs, Germany; ³Univ. of Stuttgart, Germany. We experimentally demonstrate that a transmitter-side Volterra-based pre-distortion for 56 GBaud, PAM4 signal with receiver FFE outperforms receiver-side Volterra filtering and allows for 70% higher tolerance to chromatic-dispersion. Transmitter coefficients are computed without receiver feedback

M2C.7 • 12:15

100Gb/s 16-QAM Transmission over 80 km SSMF Using a Silicon Photonic Modulator Enabled VSB-IM/DD System, Zhenping Xing¹, David Patel¹, Thang M. Hoang¹, Meng Qiu¹, Rui Li¹, Eslam El-Fiky¹, Meng Xiang¹, David V. Plant¹; ¹McGill Univ., Canada. We demonstrate a VSB-IM/DD system using silicon photonic modulator. 25 GBaud 16 QAM over 80 km at a BER below 3.8x10⁻³ is achieved with either KK detection or our nonlinear equalization based SSBI mitigation method.

Room 6C

M2D • Energy Efficient Optical Links—Continued

M2D.7 • 12:15

93% Complexity Reduction of Volterra Nonlinear Equalizer by L₁-regularization for 112-gbps PAM-4 850-nm VCSEL Optical Interconnect, Wan-Jou Huang¹, Wei-Fan Chang², Chia-Chien Wei³, Jun-Jie Liu², Yi-Ching Chen², Kai-Lun Chi⁴, Chih-Lin Wang¹, Jin-Wei Shi⁴, Jyehong Chen²; ¹Integrated Photonics, Industrial Technology Research Inst., Taiwan; ²Department of Photonics, National Chiao Tung Univ., Taiwan; ³Department of Photonics, National Sun Yatsen Univ., Taiwan; ⁴Department of Electrical Engineering, National Central Univ., Taiwan. We successfully transmit a 112-gbps PAM-4 signal over 200-m OM4 fiber using 850-nm VCSEL and Volterra filter. Adopting L₁-regularization can reduce 93% of computation complexity of the Volterra filter at KP4 FEC limit.

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.5 • 12:00

Throughput Scaling for MMF-enabled Optical Datacenter Networks by Time-slicing-based Crosstalk Mitigation, Zhizhen Zhong¹, Nan Hua¹, Yufang Yu¹, Zhongying Wu², Juhao Li², Haozhe Yan¹, Shangyuan Li¹, Ruijie Luo¹, Jialong Li¹, Yanhe Li¹, Xiaoping Zheng¹; ¹Tsinghua Univ., China; ²Peking Univ., China. Modal crosstalk is the main bottleneck in MMF-enabled optical datacenter networks with direct detection. A novel time-slicing-based crosstalk-mitigated MDM scheme is first proposed, then theoretically analyzed and experimentally demonstrated.

M2E.6 • 12:15

A High-reliability Sub-nanosecond Network Time Synchronization Method Enabled by Double-frequency Distributed Time Synchronization, Ruijie Luo¹, Nan Hua¹, Xiaoping Zheng¹, Bingkun Zhou¹; ¹Tsinghua Univ., China. We propose a low-cost high-reliability sub-nanosecond network time synchronization method using double-frequency distributed time synchronization technology for future mobile communications and positioning systems, and achieve 0.17-ns sync accuracy in a prototype 4-node sync network.

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.6 • 12:00

An Accurate and Robust PDL Monitor by Digital Signal Processing in Coherent Receiver, Huihui Li², Guoxiu Huang¹, Zhenning Tao², Hao Chen², Shoichiro Oda¹, Yuichi Akiyama¹, Tomohiro Yamauchi¹, Takeshi Hoshida¹; ¹Fujitsu Laboratories Ltd., Japan; ²Fujitsu R&D center, China. An accurate and robust PDL monitor based on receiver side DSP is proposed and experimentally verified. The standard deviation of monitor error is 0.1 dB and the method tolerates various imperfections, such as unsynchronized clock.

M2F.7 • 12:15

An Accurate Algorithm to Quantitatively Identify the Performance Degradation Caused by Linear Crosstalk, Xiaofei Su¹, Yangyang Fan¹, Ke Zhang¹, Hao Chen¹, Zhenning Tao¹, Shoichiro Oda², Takeshi Hoshida²; ¹Fujitsu R&D center, China; ²Fujitsu Laboratories Ltd., Japan. A new algorithm to estimate the signal impairment by linear crosstalk is proposed. Experiments demonstrate the linear relationship between the Q penalty and crosstalk indicator with R²=0.98 under various transmission distances and conditions.

12:00–13:30 Lunch Break (on own)



Room 6F

M2G • Microwave Photonic Signal Processing II—Continued

Room 7AB

M2H • Panel: 400G Optics for Hyperscale Data Centers—Continued

Room 8

M2I • Emerging Devices and Materials—Continued

M2I.6 • 12:00 **Invited** Integrated Ferroelectric BaTiO₃/Si Plasmonic Modulator for 100 Gbit/s and Beyond, Andreas Messner¹, Felix Eltes², Ping Ma¹, Stefan Abel², Benedikt Baeuerle¹, Arne Josten¹, Wolfgang Heni¹, Daniele Caimi², Jean Fompeyrine², Juerg Leuthold¹; ¹ETH Zurich, Switzerland; ²IBM Research - Zurich, Switzerland. We present an integrated ferroelectric BaTiO₃/Si plasmonic modulator and test its performance at 116 Gbit/s. The modulator has been tested to withstand temperatures up to 250°C.

Room 9

M2J • Fiber Lasers—Continued

M2J.6 • 12:00 Multi-wavelength Fiber Laser using a Single Multicore Erbium Doped Fiber, Yong-Min Jung¹, J. R. Hayes¹, S.U Alam¹, David J. Richardson¹; ¹Optoelectronics Research Centre (ORC), UK. We propose and demonstrate a simple multi-wavelength fiber laser based on a single multicore erbium doped fiber. An exemplary 7-wavelengths fiber laser was realized in a linear cavity by using 7-core EDF and an arrayed-waveguide-grating.

Room 10

M2K • Optical Wireless - Signal Processing—Continued

M2K.7 • 12:00 **Top Scored** Multichannel Analog and Digital Signal Transmission with Watt-class Electrical Power Delivery by Means of Power-over-fiber using a Double-clad Fiber, Daisuke Kamiyama¹, Akira Yoneyama¹, Motoharu Matsuura¹; ¹Univ. of Electro-communications, Japan. We have successfully achieved high transmission performance of multichannel analog and digital signals with over 7-watt electrical power delivery by means of power-over-fiber using a double-clad fiber, for the first time.

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

M2J.7 • 12:15 Revolver Hollow-core Fibers and Raman Fiber Lasers, Alexey Gladyshev¹, Alexey F. Kosolapov¹, Maxim S. Astapovich¹, Anton N. Kolyadin¹, Andrey D. Pryamikov¹, Maxim M. Khudyakov¹, Mikhail E. Likhachev¹, Igor A. Bufetov¹; ¹FORC RAS, Russia. Hollow-core silica fiber with optical losses of ~1 dB/m at the wavelength of 4.4 μm is demonstrated. Based on this revolver fiber 4.4-μm fiber Raman laser is realized with output average power of 250 mW and quantum conversion efficiency as high as 36 %.

M2K.8 • 12:15 Dynamic Tuning of Contention Window for Optical Wireless Networks, Sampath S. Edirisinghe¹, Christina Lim¹, Ampalavanapillai Nirmalathas^{1,2}, Elaine Wong¹, Ke Wang³, Kamal Alameh⁴; ¹Department of Electrical and Electronic Engineering, The Univ. of Melbourne, Australia; ²Networked Society Inst., The Univ. of Melbourne, Australia; ³School of Engineering, RMIT Univ., Australia; ⁴Electron Science Research Inst., Edith Cowan Univ., Australia. We propose a novel contention window tuning algorithm for multi-gigabit optical wireless networks based on IEEE 802.11 standard that improves the enhanced distributed coordination function and meets the stringent requirements of optical wireless

12:00–13:30 Lunch Break (on own)

Monday, 12 March





Room 1A

14:00–16:00

M3A • Telemetry and Survivability

Presider: Ramon Casellas; Centre Tecnològic Telecomunicacions Catalunya, Spain

M3A.1 • 14:00

Experimental Demonstration of Active and Passive Optical Networks Telemetry, Luis Gifre², Jose Luis Izquierdo-Zaragoza¹, Behnam Shariati¹, Luis Velasco¹; ¹Universitat Politècnica de Catalunya, Spain; ²Universidad Autónoma de Madrid (UAM), Spain. A distributed architecture enabling active and passive optical network telemetry is presented; a YANG data model is used for remotely configuring monitoring devices for telemetry purposes. Experimental demonstration is carried out for failure localization.

M3A.2 • 14:15

Field Trial of Monitoring On-demand at Intermediate-nodes Through Bayesian Optimization, Fanchao Meng¹, Alex Mavromatis¹, Yu Bi¹, Shuangyi Yan¹, Rui Wang¹, Yanni Ou¹, Konstantinos Nikolovgenis¹, Reza Nejabati¹, Dimitra E. Simeonidou¹; ¹Univ. of Bristol, UK. We demonstrate an intelligent monitoring on-demand switching strategy at network nodes using Bayesian optimization. It is shown our proposed method achieves identical monitoring capability as complete system exploration while saving a lot of data.

Room 1B

14:00–16:00

M3B • Coherent and DSP Technologies for PON

Presider: Naoki Suzuki; Mitsubishi Electric Corporation, Japan

M3B.1 • 14:00 **Invited**

Recent Progress and Outlook for Coherent PON, Domaniç Lavery¹, M. Sezer Erkilinc¹, Polina Bayvel¹, Robert Killely¹; ¹Univ. College London, UK. Coherent receivers offer high data rates and reach for optical access but, due to their complexity, have proved resistant to implementation. Here, recent research in low-complexity coherent PON is reviewed, and promising future research directions are identified.

Room 2

14:00–16:00

M3C • Probabilistic Shaping I

Presider: Qi Yang; State Key Laboratory of Optical Comm., China

M3C.1 • 14:00 **Invited**

Probabilistic Constellation Shaping: Challenges and Opportunities for Forward Error Correction, Laurent Schmalen¹; ¹Nokia Bell Labs, Germany. We discuss the impact of probabilistic amplitude shaping on the forward error correction stage in future optical transceivers and highlight some potential pitfalls, as well as challenges and opportunities for future research that may arise.

Room 6C

14:00–16:00

M3D • Symposium: Challenges 5G brings to Optical Fiber Communications Systems I

Organizers: Phillipe Chanclou, Orange Labs, France; Gee-Kung Chang, Georgia Inst. of Technology, USA; Theodore Sizer, Nokia Bell Labs, USA

The challenges and opportunities of 5G demand new solutions which will have impact in all sectors of telecommunication industry. Going far beyond the definition of a new radio interfaces, 5G creates a new vision of end-to-end interconnected network through seamlessly integrated optical, copper, and wireless access networks as well as the metro and core networks which interconnect them. 5G will usher in a common network infrastructure for a variety of diverse applications spanning across enhanced mobile broadband services and the internet of things, supporting massive Internet of Things (IoT) and mission critical ultra-reliable and low latency machine-type communications. New applications which demand low latency will drive a significant change in the architecture of our telecommunication networks, bringing new distributed cloud entities to no more than 40km from every user – this radical change in the overall architecture will especially drive the performance of the optical network which connects the access points and the myriad new connected cloud. The symposium is aimed to inform and challenge the OFC community on key 5G drivers and system requirements that will create market opportunities for optical fiber communications and photonic networking systems. There are two technical sessions in this symposium. The first session will focus on an overview of the requirements of various applications and ecosystems

Room 6D

14:00–16:00

M3E • Parametric Amplification Subsystems

Presider: Youichi Akasaka; Fujitsu Laboratories of America Inc, USA

M3E.1 • 14:00 **Tutorial**

Fundamentals and Applications of Optical Parametric Amplifiers, Peter A. Andrekson¹; ¹Chalmers Tekniska Hogskola, Sweden. Advances of fiber-optic parametric amplifiers and their use in optical communication will be reviewed. Both phase-insensitive and phase-sensitive implementations will be discussed, the latter being capable of noiseless amplification as well as mitigation of transmission-induced nonlinearities.



After receiving his PhD degree from Chalmers (1988), he spent three years with Bell Laboratories, and then returned to Chalmers where he is a full professor. Andrekson is a Fellow of the OSA and the IEEE, and a member of the Royal Swedish Academy of Engineering Sciences. He has authored five hundred publications, including several tutorials at OFC. He served on the Board of Governors for the IEEE Photonics Society and has served on several program committees, most recently as program chair of ECOC2017. He also served as expert evaluator of Nobel prizes in physics and held an ERC advanced grant (2012-2017) on phase-sensitive optical amplifiers.

Room 6E

14:00–16:00

M3F • Data Center and Integration

Presider: Chen Ji; CAS Inst. of Semiconductors, China

M3F.1 • 14:00 **Top Scored**

AIM Process Design Kit (AIMP-DKv2.0): Silicon Photonics Passive and Active Component Libraries on a 300mm Wafer, Erman Timurdogan¹, Zhan Su¹, Christopher Poulton¹, Matt J. Byrd¹, Simon Xin¹, Ren-Jye Shiue¹, Benjamin R. Moss¹, Ehsan S. Hosseini¹, Michael R. Watts¹; ¹Analog Photonics, USA. A new process design kit (AIMPDKv2.0) is introduced that offers a verified silicon photonics component library on 300mm silicon-on-insulator wafers. The library includes multi-layer waveguides, polarization manipulation, switches, filters, and high-speed digital/analog detectors and modulators.

M3F.2 • 14:15

Wafer-scale High-density Edge Coupling for High Throughput Testing of Silicon Photonics, Robert Polster¹, Liang Y. Dai¹, Oscar Jimenez¹, Qixiang Cheng¹, Michal Lipson¹, Keren Bergman¹; ¹Columbia Univ., USA. High-throughput functional testing of silicon photonics is a key challenge for scalable manufacturing. We present a technique for wafer-scale testing using high-density edge couplers that add excess loss of 2.2dB without requiring additional footprint.





Room 6F

14:00–16:00

M3G • Symposium: Future Photonic Devices and Materials for Optical Communications I

Organizers: Steven Koester, Univ. of Minnesota, USA; Gunther Roelkens, Ghent Univ., Belgium; Yoichi Taira, Keio Univ., Japan

This special symposium will focus on emerging photonic devices and materials for the next generation of optical communications. Topics will include 2D-, magneto-optic-, and meta-materials, Photonic Nuerons, QKD, Topological Photonics, Entanglement, Plasmonics, and optomechanical resonators.

M3G.1 • 14:00

Brillouin Scattering and Photon-phonon Signal Processing in Silicon, Peter T. Rakich¹; ¹Yale University, USA. We explore emerging chip-scale technologies based on Brillouin interactions and their potential impact for optical communications. In particular, we examine the benefits of new chip-scale ultra-narrow linewidth laser sources and new Brillouin-based filtering technologies.

Room 7AB

14:00–16:00

M3H • Panel: Machine Learning and SDN: Towards Intelligent Data Centers

Organizer: Payman Samadi, Cornell Univ., USA

Machine learning based applications for data analytics are forcing drastic changes in data center architecture. On the other side, machine learning itself along with SDN can be leveraged to improve data center operation. In this panel, we discuss the opportunities and challenges that machine learning introduces in all layers of data centers. We specifically focus on emerging opportunities of machine learning for network infrastructure and service management, scheduling and resource allocation, physical layer reconfiguration, and energy consumption.

Panelists:

Omar Baldonado, Facebook, USA

Kevin Deierling, Mellanox, USA

Jamie Gaudette, Microsoft, USA

Uri Elzur, Intel, USA

Kathy Meier-Hellstern, AT&T Labs Research, USA

Danish Rafique, ADVA Optical Networking, Germany

Room 8

14:00–16:00

M3I • Photonic Integration I

President: Piero Gambini; STMicroelectronics, Italy

M3I.1 • 14:00

Low-loss Silicon Photonic Switch Module Technology and its use for Transponder Aggregators in Optical Network Nodes, Shigeru Nakamura¹, Shigeyuki Yanagimachi¹, Hitoshi Takeshita¹, Akio Tajima¹; ¹NEC Corporation, Japan. Silicon photonic switches are attractive for extensible optical switch systems required for optical networks in telecom areas and data-centers. We show our low-loss silicon photonic switch modules and their application to CDC-rOADMs using multiple modules.

Room 9

14:00–16:00

M3J • SDM/WDM Networking

President: Rui Morais; Instituto De Telecomunicacoes, USA

M3J.1 • 14:00

Impact of Fractionally Spatial Super-channel Time-slotted Switch Architecture Design, Yusuke Hirota¹, Jose Manuel Delgado Mendinueta¹, Satoshi Shinada¹, Ruben S. Luis¹, Hideaki Furukawa¹, Hiroaki Harai¹, Naoya Wada¹; ¹NICT, Japan. We compare fractionally and whole spatial super-channel time-slotted switch architecture designs in terms of network-wide performance of its switching granularity and experimentally demonstrate collision avoidance functionality of SDM based transmission.

M3J.2 • 14:15

Modulation Format, Spectrum and Core Assignment in a Multicore Flexi-grid Optical Link, Cristina Rottondi², Paolo Martelli¹, Pierpaolo Boffi¹, Luca Barletta¹, Massimo Tornatore¹; ¹Politecnico di Milano, Italy; ²Dalle Molle Inst. for Artificial Intelligence, Switzerland. We model and solve the core and spectrum assignment problem in a multicore flexi-grid link, considering distance-adaptive reaches for different modulation formats and crosstalk impairments. Problem complexity and exemplifying numerical results on 19-core fibers are discussed.

Room 10

14:00–16:00

M3K • Optical Wireless - Technologies

President: Atsushi Kanno; NICT, Japan

M3K.1 • 14:00

Power-efficient Noise-tolerant Techniques for Achieving High-sensitivity Optical Communications, David O. Caplan¹, Jeffrey H. Shapiro^{1,2}; ¹MIT Lincoln Lab, USA; ²Massachusetts Inst. of Technology, USA. We present efficient techniques for generating high-fidelity waveforms and robust methods of achieving nearly-ideal transmitter and receiver implementations. Compatibility with multiple modulation formats provides versatile and sensitive performance options suitable for fiber and free-space applications.

Monday, 12 March





Room 1A

M3A • Telemetry and Survivability—Continued

M3A.3 • 14:30
Cognitive Tool for Estimating the QoT of New Lightpaths, Sandra Aladin¹, Christine Tremblay¹; ¹*École de Technologie Supérieure, Canada*. We propose a cognitive tool which takes into account linear and nonlinear impairments for QoT estimation and we perform a comparative analysis of three machine-learning techniques for lightpath classification using synthetic BER data.

M3A.4 • 14:45 **Invited**
Softwarized, Elastic and Agile Optical Networks for Dynamic Environmental Change and Failure Recovery, Hiroaki Harai¹; ¹*National Inst of Information & Comm Tech, Japan*. We present elasticity and agility in softwarized optical network construction and service continuation, where existing services are kept transient quality against sudden traffic changes and failures. We show proper optical power management in network protection.

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

M3B.2 • 14:30
Fast, Low-complexity Widely-linear Compensation for IQ Imbalance in Burst-mode 100-gb/s/λ Coherent TDM-PON, Ryosuke Matsumoto¹, Keisuke Matsuda¹, Naoki Suzuki¹; ¹*Mitsubishi Electric, Japan*. We propose fast, low-complexity widely-linear compensation for IQ imbalance in 100-gb/s/λ coherent TDM-PON. The proposed method reduces the power penalty to 0.3 dB, achieving 32.4-dB loss budget for 100-gb/s DP-QPSK bursts with an 826-ns overhead.

M3B.3 • 14:45 **Top Scored**
Demonstration of 10-Gb/s, 5-GHz Spaced Coherent UDWDM-PON with Digital Signal Processing in Real-time, Ming Luo¹, Tao Zeng¹, Lilin Yi², Jie Li¹, Xiang Li¹, Qi Yang¹, Lei Xue²; ¹*State Key Laboratory of Optical Comm. Technologies and Networks, Wuhan Research Inst. of Posts and Telecommunications, China*; ²*State Key Lab of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China*. This paper experimentally demonstrate the Real-time field trial of 40×10-gb/s coherent UDWDM-PON at 5-gHz spacing over 40-km field-installed fiber. The system stability is demonstrated by 8-hour Real-time BER measurement with power budget of 29 dB.

Room 2

M3C • Probabilistic Shaping I—Continued

M3C.2 • 14:30 **Invited**
Balancing Probabilistic Shaping and Forward Error Correction for Optimal System Performance, Junho Cho¹; ¹*Nokia Bell Labs, USA*. We review probabilistic shaping (PS) and forward error correction (FEC) and study the interplay between the two to jointly maximize the overall information rate.

Room 6C

M3D • Symposium: Challenges 5G brings to Optical Fiber Communications Systems I—Continued

in 5G new radio era and the challenges that they place on the optical network solutions. The second session will illustrate key optical technologies that can be developed to meet the 5G vision and goals, covering topics such as flexible x-haul, radio over fiber, distributed cloud and edge computing architecture and support for low latency Internet communications.

M3D.1 • 14:00 **Invited**
Next-Generation Optical Fronthaul in the iCirrus Project, Joerg-Peter Elbers¹; ¹*ADVA Optical Networking SE, Germany*. We discuss next-generation fronthaul solutions for 5G and legacy radio access networks. Architectures, findings and experimental results from recent lab and field trial activities will be reported.

M3D.2 • 14:30 **Invited**
Innovative FlexE Solution to Meet the Critical 5G Transport Requirements, Kai Cong¹; ¹*ZTE, China*. 5G introduce diverse demanding requirements on transport in bandwidth, reliability, latency, etc. FlexE meets them well with its basic and extension features, and have a cost advantages with reuse of the massive industry chain of traditional Ethernet.

Room 6D

M3E • Parametric Amplification Subsystems—Continued

Room 6E

M3F • Data Center and Integration—Continued

M3F.3 • 14:30 **Invited** 
High Performance InP PIC Technology Development based on a Generic Photonic Integration Foundry, Francisco M. Soares¹; ¹*Fraunhofer Inst Nachricht Henrich-Hertz, Germany*. We have achieved monolithic integration of photodetectors, DFB- and DBR lasers, SOAs, spot-size converters, polarization-rotators and splitters, EAMs, and passive-waveguide devices on InP technology. This generic foundry process provides endless possibilities for PIC designers.

Room 6F**M3G • Symposium:
Future Photonic Devices
and Materials for Optical
Communications I—Continued**

M3G.2 • 14:30 **Invited** 
Plasmonics for Communications, Juerg Leuthold¹; ¹*ETH Zurich, Switzerland*. Plasmonics has the potential to complement photonics and microwave photonics with ultrafast, energy efficient and most compact components. As a result, novel plasmonic modulators, detectors and microwave components emerge offering bandwidths beyond 100 GHz.

Room 7AB**M3H • Panel: Machine
Learning and SDN:
Towards Intelligent Data
Centers—Continued****Room 8****M3I • Photonic Integration I—
Continued**

M3I.2 • 14:30
Broadband and Fabrication Tolerant Silicon Polarization Beam Splitters with Ultra-high Extinction Ratio of 40 dB, Thomas Y. Ang¹, Jun Rong Ong¹, Ezgi Sahin^{2,1}, Bryan Pawlina^{3,1}, George Chen², Dawn T. Tan², Soon Thor Lim^{1,4}, Ching Eng Png^{1,4}; ¹*Inst. of High Performance Computing, Singapore*; ²*Singapore Univ. of Technology and Design, Singapore*; ³*Department of Engineering Physics, Univ. of British Columbia, Canada*; ⁴*OPTIC2connect Pte Ltd, Singapore*. High-performance silicon polarization beam splitters were experimentally demonstrated for both the C and L bands. Extinction ratio is ≥ -40 dB for the entire measured bandwidth of 90 nm, with insertion losses of ~ 1 dB.

M3I.3 • 14:45
TE Mode Input Operation of Waveguide Optical Isolator with Tapered Mode Converter and Magneto-optical Phase Shifter, Ryusuke Yamaguchi¹, Yuya Shoji¹, Tetsuya Mizumoto¹; ¹*Tokyo Inst. of Technology, Japan*. A novel waveguide optical isolator operating for TE mode input is proposed with tapered mode converters and a magneto-optical phase shifter. A maximum isolation ratio of 6.4 dB is demonstrated at a wavelength of 1557 nm.

Room 9**M3J • SDM/WDM
Networking—Continued**


M3J.3 • 14:30
Assigning Counter-propagating Cores in Multi-core Fiber Optical Networks to Suppress Inter-core Crosstalk and Inefficiency due to Bi-directional Traffic Asymmetry, Fengxian Tang¹, Longfei Li¹, Sanjay K. Bose², Gangxiang Shen¹; ¹*Soochow Univ., China*; ²*Department of Electrical and Electronic Engineering, Indian institution of technology, India*. We propose the assignment of Multi-core Fiber (MCF) cores in a counter-propagating way to design an MCF optical network, which suppresses MCF inter-core crosstalk and reduces the capacity inefficiency caused by increasing asymmetry of bi-directional traffic. Simulation results demonstrate the effectiveness of our proposed approaches.

M3J.4 • 14:45
Comparison of SDM-WDM based Data Center Networks with Equal/unequal Core Pitch Multi-core Fibers, Hui Yuan¹, Arsalan Saljoghei¹, Adaranijo Peters², Georgios Zervas¹; ¹*Univ. College London, UK*; ²*Univ. of Bristol, UK*. A wavelength-dependent crosstalk calculation formula for bi-directional MCF with unequal core pitches is derived. SDM-wDM based DCN simulations indicate that MCF core density and layout play a significant role on optimizing various scales of DCNs.

Room 10**M3K • Optical Wireless -
Technologies—Continued**

M3K.2 • 14:30
20 Gbit/s Tricolor R/G/B Laser Diode based Bi-directional Signal Remodulation Visible Light Communication System, Liang-Yu Wei¹, C. W. Hsu¹, Yung Hsu¹, Chi-Wai Chow¹, Chien-Hung Yeh²; ¹*Department of Photonics and Inst. of Electro-optical Engineering, National Chiao Tung Univ., Taiwan*; ²*Department of Photonics, Feng Chia Univ., Taiwan*. We demonstrate a bi-directional signal-remodulated visible-light-communication (VLC) system using tricolor R/G/B laser diodes to produce a 20.231-gbit/s orthogonal-frequency-division-multiplexed (OFDM) downstream signal and 2-mbit/s remodulated on-off-keying (OOK) upstream signal.

M3K.3 • 14:45
10.72Gb/s Visible Light Communication System Based on Single Packaged RGBYC LED Utilizing QAM-DMT Modulation With Hardware Pre-equalization, Xin Zhu², Fumin Wang¹, Meng Shi¹, Nan Chi¹, Junlin Liu², Fengyi Jiang²; ¹*Fudan Univ., China*; ²*National Inst. of LED on Silicon Substrate, Nanchang Univ., Nanchang 330096, People's Republic of China, China*. In this paper, we experimentally demonstrated a 10.72Gb/s wavelengths multiplexing visible light communication system over 1-m indoor free space transmission using a single packaged RGBYC LED with hardware pre-equalization and post equalizer

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Room 1A

M3A • Telemetry and Survivability—Continued

M3A.5 • 15:15
Machine-learning-based Soft-failure Detection and Identification in Optical Networks, Shahin Shakhkarami¹, Francesco Musumeci¹, Filippo Cugini², Massimo Tornatore¹; ¹Politecnico di Milano, Italy; ²CNIT, Italy. We develop and test several machine-learning methods to perform detection and identification of equipment failures in optical networks. Results, obtained over real BER traces, show above 98% accuracy in most cases with reasonable algorithm complexity.

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

M3B.4 • 15:00
Simultaneous DPSK-ASK Modulated Dual-eML Transmitter for Coherent UDWDM-PON, Juan Camilo Velásquez Micolta¹, Marc Domingo¹, Victor Polo¹, Josep Prat¹; ¹Universitat Politècnica de Catalunya, Spain. An integrated dual-eML is modulated to obtain a simultaneous DPSK/ASK signal. Rx sensitivity of -40 dBm at BER=10⁻³ was achieved at 5Gb/s with simple heterodyne detection.

M3B.5 • 15:15
Wide Range Carrier Frequency Offset Estimation Method using Training Symbols with Asymmetric Constellations for Burst-mode Coherent Reception, Ryo Koma¹, Masamichi Fujiwara¹, Ryo Igarashi¹, Takuya Kanai¹, Jun-ichi Kani¹, Akihiro Otaka¹; ¹NTT Access Network Service Systems Labor, Japan. We propose a simple feed-forward carrier frequency offset estimation method robust against timing errors in the detection of training symbols. A wide compensation range of ±0.5 times the signal baud-rate is numerically and experimentally confirmed.

Room 2

M3C • Probabilistic Shaping I—Continued

M3C.3 • 15:00
Combining Probabilistic Shaping and Nonlinear Mitigation: Potential Gains and Challenges, Fernando P. Guiomar², Luca Bertignono², Antonello Nespola³, Pierluigi Poggiolini², Fabrizio Forghieri¹, Andrea Carena²; ¹Cisco Photonics Srl, Italy; ²Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Italy; ³Istituto Superiore Mario Boella, Italy. We experimentally compare different options for transmission at 200G net bit-rate and demonstrate that the benefits of probabilistic shaping and nonlinear mitigation via SRO and/or DBP can be effectively combined to enable propagation reach enhancement of >40%.

M3C.4 • 15:15
A Simple Nonlinearity-tailored Probabilistic Shaping Distribution for Square QAM, Eric Sillekens¹, Daniel Semrau¹, Gabriele Liga¹, Nikita Shevchenko¹, Zhe Li¹, Alex Alvarado², Polina Bayvel¹, Robert Killely¹, Domeniçlavory¹; ¹Univ. College London, UK; ²Eindhoven Univ. of Technology (TU/e), Netherlands. A new probabilistic shaping distribution that outperforms Maxwell-boltzmann is studied for the nonlinear fiber channel. Additional gains of 0.1 bit/symbol MI or 0.2 dB SNR for both DP-256QAM and DP-1024QAM are reported after 200 km nonlinear fiber transmission.

Room 6C

M3D • Symposium: Challenges 5G brings to Optical Fiber Communications Systems I—Continued

M3D.3 • 15:00 **Invited**
5G Bearer Network, Michel Tong¹; ¹Huawei, UK. 5G deployment in capacity, reliability, cloudification, multi-connectivity, interference and coordination determines the transport network architecture. Technologies in bearer network are evolving with 5G requirements in High-bandwidth, Low-latency, High-precision clock, Automation and Network slicing.

Room 6D

M3E • Parametric Amplification Subsystems—Continued

M3E.2 • 15:00 **Invited**
Towards Practical Implementation of Optical Parametric Amplifiers based on PPLN Waveguides, Takeshi Umeki^{1,2}, Takushi Kazama², Takayuki Kobayashi¹, Koji Enbutsu², Tadanaga Osamu², Hirokazu Takenouchi^{1,2}, Ryoichi Kasahara², Yutaka Miyamoto¹; ¹NTT Network Innovation Labs, Japan; ²NTT Device Technology Labs, Japan. We review the capabilities of optical parametric amplifiers based on periodically poled LiNbO₃ (PPLN) waveguides. Specifically, we discuss the applicability of PSA for WDM, QAM, and PDM signals and simultaneous nonlinearity mitigation using CSI-oPC.

Room 6E

M3F • Data Center and Integration—Continued

M3F.4 • 15:00
Silicon Photonics Platform for 400G Data Center Applications, Tuo Shi¹, Tzung-I Su¹, Ning Zhang¹, Ching-Yin Hong¹, Dong Pan¹; ¹SiFotonics Technologies, Co., Ltd, USA. We demonstrate a silicon photonic platform for 400G data center 500m to 120km applications. The silicon platform has successfully integrated a variety of C-band and O-band passive and active optical components, and has successfully demonstrated PSM4, 64GBaud ICR, 64GBaud ICR PIC capable of 400G applications.

M3F.5 • 15:15
100G SWDM Transmission over 250m OM5 and OM4+ Multimode Fibers, Earl Parsons¹, Michael Lanier¹, Randall Patterson¹, Gary Irwin¹; ¹CommScope, USA. We demonstrate 100G SWDM4 transmission over 250m OM5 and OM4+ multimode fibers. Error-free performance was achieved with the OM5 fibers. The OM4+ fibers did not support error-free performance due to low bandwidth at longer wavelengths.





Room 6F

M3G • Symposium: Future Photonic Devices and Materials for Optical Communications I—Continued

M3G.3 • 15:00 **Invited** 
Magneto-optical Devices, Mo Li¹; ¹Univ. of Minnesota, USA. We present two types of opto-spintronic devices. In the first device, single optical pulses can directly switch the free layer in a magnetic tunnel junction (MTJ) on a sub-picosecond time scale. In the second device, the TM optical mode of a waveguide generates a directional, spin-polarized surface current in a topological insulator.

Room 7AB

M3H • Panel: Machine Learning and SDN: Towards Intelligent Data Centers—Continued

Room 8

M3I • Photonic Integration I— Continued

M3I.4 • 15:00
Genetic Algorithm and Polynomial Chaos Modelling for Performance Optimization of Photonic Circuits under Manufacturing Variability, Daniele Melati¹, Abi Waqas^{2,3}, Dan-Xia Xu¹, Andrea Melloni²; ¹National Research Council, Canada; ²Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy; ³Department of Telecommunication, Mehran Univ. of Engineering and Technology, Pakistan. We propose an efficient technique based on polynomial chaos expansion and genetic algorithms to enable constrained optimization of photonic integrated circuits subject to fabrication tolerances. Simulations on a realistic SOI design confirm its effectiveness.

M3I.5 • 15:15
On-chip Continuously Tunable Optical Delay Line based on Cascaded Mach-Zehnder Interferometers, Daniele Melati¹, Andrea Melloni²; ¹National Research Council, Canada; ²Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy. We propose a novel integrated optical delay line based on cascaded Mach-Zehnder interferometers. It allows a continuous delay tuning, can achieve wideband operation and is experimentally demonstrated with a delay up to 125 ps.

Room 9

M3J • SDM/WDM Networking—Continued

M3J.5 • 15:00
Reduction of the Power Consumption in a WDM/SDM Network by using Cladding Pump Scheme MC-EDFA with Impairment Aware Least Wavelength Bandwidth Routing, Hitoshi Takeshita¹, Keiichi Matsumoto¹, Emmanuel L. de Gabory¹; ¹NEC Corporation, Japan. We show 39 % reduction of amplification power consumption with cladding pump MC-EDFA using 16-core spectral superchannels over SDM NSFNET16 topology. Impairment aware least wavelength bandwidth routing algorithm further reduces the power consumption by 45%.

M3J.6 • 15:15
Fragmentation-minimized Transponder Upgrading Employing Channel Bandwidth Aligned Slot Allocation in Flexible Grid Optical Networks, Hiroshi Hasegawa¹, Takuma Yasuda¹, Yojiro Mori¹, Ken-Ichi Sato¹; ¹Nagoya Univ., Japan. Efficient implementation strategy of new generation channel-speeds is presented where frequency fragmentation is minimized. Substantial improvement in frequency utilization or reduction in fiber number (~15%) is verified for various network conditions and different channel-bandwidth allocations.

Room 10

M3K • Optical Wireless - Technologies—Continued

M3K.4 • 15:00
Demonstration of Inter-dimensional Adaptive Diversity Combining and Repetition Coding in Converged MMW/FSO Links for 5G and beyond Mobile Fronthaul, Feng Lu¹, Mu Xu¹, Shuyi Shen¹, Yahya M. Alfidhli¹, Hyung Joon Cho¹, Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA. We firstly introduce inter-dimensional adaptive-diversity-combining-technique in fiber-wireless fronthaul. By adaptively combining symbols from millimeter-wave and free-space-optics links in time/frequency domain and applying repetition coding, we experimentally attained better tunability in power margins with improved reliability.

M3K.5 • 15:15
On CSI-free Linear Equalization for Optical Fast-OFDM over Visible Light Communications, Yingjie Shao¹, Yang Hong¹, Lian-Kuan Chen¹; ¹The Chinese Univ. of Hong Kong, Hong Kong. Real-valued OCT precoding to achieve CSI-free linear equalization is proposed for fast-OFDM VLC. We show SNRs over subcarriers can be equalized to approximately the harmonic mean of original SNRs, and >35% capacity improvement is achieved.





Room 1A

M3A • Telemetry and Survivability—Continued

M3A.6 • 15:30

Experimental Validation of Transport SDN Restoration of Signal-degraded Connections in Flexi-grid Networks, Ricardo Martínez¹, Ramon Casellas¹, Josep M. Fabrega¹, Ricard Vilalta¹, Raul Muñoz¹, Laia Nadal¹, Michela Svaluto Moreolo¹, Asier Villafranca², Pascual Sevillano²; ¹*Ctr Tecnologic de Telecoms de Catalunya, Spain*; ²*Aragon Photonics Lab, Spain*. We validate experimentally the integration of a PCE-based T-SDN controller with an OAM Handler to restore signal-degraded flexi-grid connections. A distributed monitoring system is adopted where a RSMA algorithm exploits benefits of elastic optical networks.

M3A.7 • 15:45

Observe-decide-act: Experimental Demonstration of a Self-healing Network, Konstantinos Christodoulopoulos², Nicola Sambo³, Nikos Argyris¹, Pietro Giardina⁴, Gianni Kanakis¹, Aristotelis Kretsis², Francesco Fresi³, Andrea Sgambelluri³, Giacomo Bernini⁴, Camille Delezoide⁵, Filippo Cugini³, Hercules Avramopoulos¹, Emmanouel Varvarigos^{2,1}; ¹*National Technical Univ. of Athens, Greece*; ²*Computer Technology Inst. and Press, Greece*; ³*Scuola Superiore Sant'Anna, Italy*; ⁴*Nextworks, Italy*; ⁵*Nokia Bell Labs, France*. We experimentally demonstrate a self-healing network, following the observe-decide-act paradigm: monitoring reveals degradation, decision is taken, network is reconfigured to restore service. We also demonstrate, for the first time, pre-programmed resilience in integrated data/control testbed.

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

M3B.6 • 15:30 **Invited**

DSP for High-speed Fiber-wireless Convergence, Huaiyu Zeng¹, Xiang Liu¹, Sharief Megeed¹, Frank Effenberger¹; ¹*Futurewei Technologies, USA*. We review recent advances in the common public radio interfaces (CPRI/eCPRI) between remote radio units and baseband units via optical fiber, and discuss how DSP may be used to support both CPRI and eCPRI to achieve high bandwidth efficiency and low processing latency.

Room 2

M3C • Probabilistic Shaping I—Continued

M3C.5 • 15:30

Experimental and Numerical Comparison of Probabilistically-shaped 4096 QAM and Uniformly-shaped 1024 QAM in All-raman Amplified 160 km Transmission, Seiji Okamoto^{2,1}, Masaki Terayama², Masato Yoshida², Keisuke Kasai², Toshihiko Hirooka², Masataka Nakazawa²; ¹*Nippon Telegraph & Telephone Corp, Japan*; ²*Tohoku Univ., Japan*. We experimentally and numerically compared probabilistically-shaped 4096 QAM with uniformly-shaped 1024 QAM with a spectral efficiency of 15.3 bit/s/Hz after an all-raman 160 km transmission. The 1.4-dB power margin was improved by constellation shaping.

M3C.6 • 15:45

Residual Non-linear Phase Noise in Probabilistically Shaped 64-QAM Optical Links, Dario Piloni¹, Fabrizio Forghieri², Gabriella Bosco¹; ¹*Politecnico di Torino, Italy*; ²*Cisco Photonics Italy, Italy*. We show that the performance penalty for probabilistically-shaped constellations induced by residual non-linear phase noise after standard CPE is significantly higher in low-symbol rate systems, canceling the potential gain achievable through symbol rate optimization.

Room 6C

M3D • Symposium: Challenges 5G brings to Optical Fiber Communications Systems I—Continued

15:30 Panel Discussion

Room 6D

M3E • Parametric Amplification Subsystems—Continued

M3E.3 • 15:30 **Invited**

Fiber-optic Frequency Shifting of THz-range WDM Signal using Orthogonal Pump-signal Polarization Configuration, Tomoyuki Kato¹, Shigeki Watanabe¹, Takahito Tanimura¹, Robert Elschner², Carsten Schmidt-Langhorst², Colja Schubert², Takeshi Hoshida¹; ¹*Fujitsu Laboratories Ltd., Japan*; ²*Fraunhofer HHI, Germany*. We propose a nonlinear fiber-based optical frequency shifter using two CW pumps orthogonally polarized to signals and demonstrate THz-range error-free frequency shifting of 1.6-tb/s DP-16QAM WDM signal without guard-band midway through 160 km transmission.

M3E.4 • 15:45 **Top-scored**

Polarization-diversity In-line Phase Sensitive Amplifier for Simultaneous Amplification of Fiber-transmitted WDM PDM-16QAM Signals, Takeshi Umeke^{1,2}, Takushi Kazama², Takayuki Kobayashi¹, Shigehiro Takasaka³, Yasuhiro Okamura⁴, Koji Enbutsu², Tadanaga Osamu², Hirokazu Takenouchi^{1,2}, Ryuichi Sugizaki³, Atsushi Takada⁴, Ryoichi Kasahara², Yutaka Miyamoto¹; ¹*NTT Network Innovation Labs, Japan*; ²*NTT Device Technology Labs, Japan*; ³*Furukawa Electric Co., Ltd, Japan*; ⁴*Faculty of Engineering, Tokushima Univ., Japan*. We developed in-line PSA for the simultaneous amplification of wavelength-multiplexed and polarization-multiplexed QAM signals. We achieved >20-dB gain and a 12-nm bandwidth for 16-channel PDM-16QAM signals with an inherent PSA characteristic of a 5.1-dB SNR advantage.

Room 6E

M3F • Data Center and Integration—Continued

M3F.6 • 15:30 **Invited**

VCSEL-based Optical Transceivers for Future Data Center Applications, Jim Tatum¹, Gary Landry¹, Deepa Gazula¹, Jerome K. Wade¹, Petter Westbergh¹; ¹*Finisar Corporation, USA*. Progress on VCSELS and Photodiodes for 56Gbps/channel data links is reported for both PAM4 and NRZ modulation formats.

Monday, 12 March

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





Room 6F

M3G • Symposium: Future Photonic Devices and Materials for Optical Communications I—Continued

M3G.4 • 15:30 **Invited**
Superconducting Nanowire Single-Photon Detectors for Future Optical Communications, H Terai¹, Shigehito Miki¹, Taro Yamashita¹, Shigeyuki Miyajima¹, Masahiro Yakuno¹; ¹*NICT, Japan*. Superconducting nanowire single-photon detector enable photon detection with >80% detection efficiency, low noise and precise timing, all these features are attractive for future optical communications such as quantum information technologies and deep space communications.

Room 7AB

M3H • Panel: Machine Learning and SDN: Towards Intelligent Data Centers—Continued

Room 8

M3I • Photonic Integration I—Continued

M3I.6 • 15:30
Flexible Silicon Optical Splitters based on High Order Modes, Daigao Chen¹, Xi Xiao¹, Lei Wang¹, Yuguang Zhang¹, Xiao Hu¹; ¹*State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts Telecommunications, China*. Based on the natural splitting in the intensity distribution of high order modes, and using three mode order converters, we demonstrate 0.5/0.5, 0.667/0.333 and 0.75/0.25 Y junction power splitters with high fabrication tolerance.

M3I.7 • 15:45
Ultra-broadband and Ultra-compact Optical 90° Hybrid Based on 2x4 MMI Coupler with Subwavelength Gratings on Silicon-on-insulator, Luhua Xu¹, Yun Wang¹, David Patel¹, Mohamed Morsy-Osman¹, Rui Li¹, Michael Hui¹, Mahdi Parvizi², Naim Ben-Hamida², David V. Plant¹; ¹*McGill Univ., Canada*; ²*Ciena Corporation, Canada*. We propose an ultra-broadband and ultra-compact optical 90° hybrid based on a subwavelength gratings dispersion-engineered 2x4 MMI coupler on silicon-on-insulator. Our device is only 41.3 μm in length, with an operating bandwidth over 150 nm.

Room 9

M3J • SDM/WDM Networking—Continued

M3J.7 • 15:30 **Top Scored**
Network Architecture in the Era of Integrated Optics, Nick Kucharewski¹, Cyriel Minkenbergh¹, German Rodriguez¹; ¹*Rockley Photonics, Switzerland*. Disparities in reach and cost between electrical and optical ports have important implications for network architecture. We quantify network cost, capturing the tradeoffs of pizzabox versus chassis switches and the potential impact of integrated optics.

M3J.8 • 15:45
Spectrally Efficient and Highly Resilient Grouped Routing Network Enhanced with Optical Performance Monitoring, Keisuke Kayano¹, Hiroshi Saito¹, Yojiro Mori¹, Hiroshi Hasegawa¹, Ken-Ichi Sato¹, Shoichiro Oda², Setsuo Yoshida², Takeshi Hoshida²; ¹*Nagoya Univ., Japan*; ²*Fujitsu Limited, Japan*. We demonstrate a spectrally efficient and highly resilient grouped-routing optical network, whose Q-factor margin is precisely controlled with optical performance monitoring. Its effectiveness is confirmed via network analysis and transmission experiments on 200-gbps DP-16QAM signals.

Room 10

M3K • Optical Wireless - Technologies—Continued

M3K.6 • 15:30
Robust and Secure Indoor Optical Wireless Communications Supporting Multiple Users, Tian Liang¹, Ke Wang², Christina Lim¹, Elaine Wong¹, Tingting Song¹, Ampalavanapillai Nirmalathas¹; ¹*The Univ. of Melbourne, Australia*; ²*MIT Univ., Australia*. We experimentally demonstrate a robust and secure multiple-access mechanism for indoor optical wireless communications using time-slot-coding and chaotic phase. Results show that it is secure against eavesdropper's exhaustive searching accuracy as high as 1e-10 and is robust against 67% (4-QAM) and 23% (16-QAM) code misalignment.

M3K.7 • 15:45 **Top Scored**
High-speed Two-dimensional Photodetector Array for 4-WDM 25-GBaud FSO Communication, Toshimasa Umezawa¹, Takahide Sakamoto^{1,3}, Atsushi Kanno¹, Kouichi Akahane¹, Atsushi Matsumoto¹, Naokatsu Yamamoto¹, Tetsuya Kawanishi^{1,2}; ¹*National Inst of Information & Comm Tech, Japan*; ²*Waseda Univ., Japan*; ³*Japan Science and Technology Agency, Japan*. We present a newly developed 32-pixel high-speed 2D photodetector array operated at up to 39 GBaud, and its application for WDM FSO communications. 4-WDM 25-GBaud FSO parallel beams could be directly detected by the 2D-PDA.

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



Room 1A

16:30–18:30
M4A • Modelling, Disaggregation & Networking Automation
Presider: Achim Autenrieth; ADVA Optical Networking SE, Germany

M4A.1 • 16:30 **Invited**
Software Defined Optical Network from the Perspective of a Software Developer, Lihua Yuan¹; ¹Microsoft Corp, USA. Azure invests heavily in software automation to help the network evolving towards the desired scalability and reliability. This talk shares our learnings through this evolution and discuss the impact to optical infrastructure.

Room 1B

16:30–18:30
M4B • Practical Aspects in Fiber Transmission
Presider: Oleg Sinkin; TE SubCom, USA

M4B.1 • 16:30 **Invited**
Ultra-low Loss Silica Core Fiber, Yoshiaki Tamura¹; ¹Sumitomo Electric Industry, Japan. We review recent advances in optical fiber technologies that realize ultra-low losses as low as 0.142 dB/km including pure-silica core and reduction of microscopic density fluctuation.

Room 2**Room 6C**

16:30–18:30
M4C • Symposium: Challenges 5G brings to Optical Fiber Communications Systems II **▶**
Organizers: Phillipe Chanclou, Orange Labs, France; Gee-Kung Chang, Georgia Inst. of Technology, USA; Theodore Sizer, Nokia Bell Labs, USA

M4C.1 • 16:30 **Invited**
Bandwidth Efficient and Flexible Fronthaul, Philippe Sehier¹; ¹Nokia, Finland. This paper provides an overview of the numerous fronthaul interfaces definitions initiatives launched in several fora and SDO, and describes the main requirement on transport. Focus is given on Low layer interfaces, and massive MIMO.

Room 6D

16:30–18:00
M4D • Mode Multiplexors and Components for Space-Division Multiplexed Systems **▶**
Presider: Takemi Hasegawa; Sumitomo Electric Industries Ltd, Japan

M4D.1 • 16:30 **▶**
Demonstration of Weakly-coupled MDM-WDM Amplification and Transmission over 15-km FMF Employing IM/DD, Jinglong Zhu¹, Juhao Li¹, Dawei Ge¹, Zhongying Wu¹, Fang Ren², Zhenzhen Zhang³, Xiaoying Li³, Yichi Zhang⁴, Zhengbin Li¹, Zhangyuan Chen¹, Yongqi He¹; ¹Peking Univ., China; ²Univ. of Science and Technology Beijing, China; ³Tianjin Univ., China; ⁴Wuhan Research Inst. of Posts and Telecommunications, China. We propose an all-fiber few-mode EDFA employing low-modal-crosstalk mode-selective couplers, based on which we experimentally demonstrate weakly-coupled MDM-wDM amplification and transmission over 2-mode 15-km FMF without MIMO processing.

M4D.2 • 16:45 **▶**
16-QAM-carrying Orbital Angular Momentum (OAM) Mode-division Multiplexing Transmission using All-fiber Fused Mode Selective Coupler, Yan Luo¹, Wei Zhou¹, Lulu Wang¹, Andong Wang¹, Jian Wang¹; ¹Huazhong Univ. of Scien & Technol, China. We demonstrate mode-division multiplexing (MDM) transmission exploiting orbital angular momentum (OAM) modes with low loss and negligible mode crosstalk. An all-fiber fused mode selective coupler is fabricated and employed as an efficient OAM mode multiplexer/demultiplexer.

Room 6E

16:30–18:30
M4E • Probabilistic Shaping II **▶**
Presider: Yi Cai; ZTE USA, Inc., USA

M4E.1 • 16:30 **Tutorial** **▶**
On Joint Design of Probabilistic Shaping and Forward Error Correction for Optical Systems, Georg Böcherer¹; ¹Mathematical and Algorithmic Sciences Lab, Huawei Technologies, France. Probabilistic shaping for rate/reach increase and flexibility in optical systems is treated. Practical design tools are developed for distribution matching algorithms, demapping strategies, and FEC codes, accounting for the performance-complexity trade-off.



Georg Böcherer was born in Freiburg, Germany. He obtained his M.Sc. degree in EE and IT from the ETH Zürich, Switzerland, in 2007, and his Ph.D. degree from the RWTH Aachen University, Germany, in 2012. From 2012 to 2017, he was with the Institute for Communications Engineering, Technical University of Munich. In December 2017, he joined the Mathematical and Algorithmic Sciences Lab at Huawei Technologies France. His research interests are information theory and coded modulation. He received the E-plus award for his Ph.D. thesis and a 2015 Bell Labs Prize for his work on probabilistic shaping.



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Monday, 12 March



Room 6F

16:30–18:30
M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II

M4F.1 • 16:30 **Invited**
Optical Nanofiber Technologies for Single Photon Generation, Kohzo Hakuta¹; ¹*University of Electro-Communications, Japan*. Optical nanofiber technologies are discussed for both bare nanofibers and cavity created nanofibers. Emphasis is on the single-photon channeling into the fiber guided modes with a hybrid system of an optical-nanofiber and a single quantum-emitter.

Room 7AB

16:30–18:15
M4G • Optical Coherence Control
President: Colin McKinstrie; Huawei Technologies, USA

M4G.1 • 16:30 **Invited**
Injection-locked Homodyne Detection for Higher-order QAM Transmission, Keisuke Kasai¹, Yixin Wang¹, Masato Yoshida¹, Toshihiko Hirooka¹, Masataka Nakazawa¹; ¹*Research Inst. of Electrical Communication, Tohoku Univ., Japan*. We present recent advances on an injection-locked homodyne detection system and its application to higher-order QAM transmission. A simple injection locking circuit enables precise optical carrier-phase synchronization. We describe a 216 Gbit/s, 512QAM-160 km transmission.

Room 8

16:30–18:30
M4H • Photonic Integration II
President: Mark Feuer; CUNY College of Staten Island, USA

M4H.1 • 16:30 **Invited**
Photonic Integration for Quantum Communications, Shayan Mookherjee¹; ¹*Univ. of California San Diego, USA*. Integrated photonics shows promise as a cost-effective, yet high performance, device platform for generating, manipulating and detecting single or entangled photons, with potential applications in secure communications, precision sensors and quantum interconnects.

Room 9

16:30–18:30
M4I • Deployments of Optical Access and Front Haul
President: Patrick Iannone; Nokia Bell Labs, USA

M4I.1 • 16:30 **Tutorial**
Edge Compute and AT&T's PON Deployment Vision, Edward A. Walter¹; ¹*AT&T, USA*. This tutorial talk will review the Open Mobile Edge Cloud (OMEC) as a unified design that encompass aspects of various initiatives' already undertaken in academia/industry and Passive Optical Networks (PON) in support of consumer, business, and infrastructure deployments.



Ed Walter has been engaged in Access ideation and development since 2006 when he joined the AT&T Lightspeed project to deploy Broadband/IPTV across xDSL and PON technologies. He is active with the architecture and Standards Organizations (e.g. ITU & IEEE) that support XGS, NGPON2, and future 25/50/100G PON technologies.

Room 10

16:30–18:30
M4J • MMW & THz Systems
President: Idelfonso Tafur Monroy; Danmarks Tekniske Universitet, Denmark

M4J.1 • 16:30 **Top Scored**
600-GHz-wave Beam Steering by Terahertz-wave Combiner, Yang Zhou¹, Goki Sakano¹, Yusuke Yamanaka¹, Hiroshi Ito², Tadao Ishibashi³, Kazutoshi Kato¹; ¹*Kyushu Univ., Japan*; ²*Kitasato Univ., Japan*; ³*NTT Electronics Techno Corporation, Japan*. We achieved 600-GHz-wave power combination with directional gain by optically phase tuning of arrayed photomixers. Using this phase control technique for phase shift, we also demonstrated the beam steering within an angle of 35 degrees.

M4J.2 • 16:45
Optical Beamformer for K-band Smart Antenna Systems, Ailee Trinidad¹, Netsanet Tessema¹, Zizheng Cao¹, Johan van Zantvoort¹, Aleksei Dubok², Ali N.H. Al-Rawi², Eduward Tangdiongga¹, Bart Smolders², Ton Koonen¹; ¹*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands*; ²*Centre for Wireless Technology, Eindhoven Univ. of Technology, Netherlands*. Beam forming using a 4x1 phased array with an optical feed network for K-band smart antenna systems is presented. Up to 45 degree steering angles are achieved. Wireless transmission throughputs of up to 3 Gbit/s using 32-OFDM subcarriers are achieved for the attained steering angles.

Monday, 12 March



Room 1A**M4A • Modelling, Disaggregation & Networking Automation—Continued****M4A.2 • 17:00**

Node Internal Modeling for Network Recovery with Emergency Optical Systems, Sugang Xu¹, Noboru Yoshikane², Masaki Shiraiwa¹, Takehiro Tsuritani², Hiroaki Harai¹, Yoshinari Awaji¹, Naoya Wada¹; ¹*NICT, Japan*; ²*KDDI Research, Japan*. We propose a ROADM internal model and demonstrate network recovery with the control of a lightweight emergency optical system, which has a highly customizable internal structure to meet the different requirements in disaster recovery.

M4A.3 • 17:15

Experimental Demonstration of Fully Disaggregated White Box including Different Types of Transponders and Monitors, Controlled by NETCONF and YANG, Nicola Sambo¹, Kostas Christodoulopoulos², Nikos Argyris³, Pietro Giardina⁴, Camille Delezoides⁵, Andrea Sgambelluri¹, Aristotelis Kretsis², Giannis Kanakis³, Francesco Fresi¹, Giacomo Bernini⁴, Hercules Avramopoulos³, Emmanouel Varvarigos², Piero Castoldi¹; ¹*Sant'Anna di Pisa, Italy*; ²*CTI, Greece*; ³*NTUA, Greece*; ⁴*Nextworks, Italy*; ⁵*Nokia Bell Labs, France*. We experimentally demonstrated a fully disaggregated white box composed of two different types of transponders, monitors (including filtering effect parameters), add-drop multiplexers, and switches. NETCONF and YANG control the hardware.

Room 1B**Room 2****M4B • Practical Aspects in Fiber Transmission—Continued****M4B.2 • 17:00**

Observation of Guided Acoustic-wave Brillouin Scattering and its Digital Compensation in Coherent QAM Transmission, Masataka Nakazawa¹, Masaki Terayama¹, Seiji Okamoto¹, Masato Yoshida¹, Keisuke Kasai¹, Toshihiko Hirooka¹; ¹*Tohoku Univ., Japan*. Guided acoustic-wave Brillouin scattering (GAWBS) noise was observed in a digital coherent QAM transmission, which deteriorated the transmission performance. A new digital signal processing method is presented that compensates for the GAWBS noise.

M4B.3 • 17:15 **Top Scored**

Impact of Spontaneous Guided Acoustic-wave Brillouin Scattering on Long-haul Transmission, Maxim A. Bolshtyansky¹, Jin-Xing Cai¹, Carl Davidson¹, Matt Mazurczyk¹, Ding Wang¹, Milen Paskov¹, Oleg V. Sinkin¹, Dmitri Foursa¹, Alexei Pilipetskii¹; ¹*TE SubCom, USA*. We measure forward optical scattering coefficient of thermally excited acoustic modes of modern submarine transmission fiber to be -32 dB/Mm. We estimate 0.6 dB of Q-factor penalty in our testbed due to this effect.

Room 6C**M4C • Symposium: Challenges 5G brings to Optical Fiber Communications Systems II—Continued****M4C.2 • 17:00** **Invited**

Evolved Cable Access Networks to Support 5G Services, Zhensheng Jia¹, Luis Alberto Campos¹, Jing Wang¹, Lin Cheng¹, Curtis Knittle¹; ¹*Cable Labs, USA*. We review HFC network evolution towards distributed architecture and Fiber Deep strategy, and explore the advantages of this evolved network with regard to backhaul capability, site and power availability, and resilient architecture for future 5G services.

Room 6D**M4D • Mode Multiplexors and Components for Space-division Multiplexed Systems—Continued****M4D.3 • 17:00** **Invited**

Enabling Component Technologies for Space Division Multiplexing, Yong-Min Jung¹, S.U. Alam¹, David J. Richardson¹; ¹*Optoelectronics Research Centre (ORC), UK*. We present an overview of recent progress on SDM components. In particular, we will discuss in detail various recently developed SDM fiber isolators, pump couplers and mode field diameter adaptors.

Room 6E**M4E • Probabilistic Shaping II—Continued****Monday, 12 March**

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



Room 6F

M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II—Continued

M4F.2 • 17:00 **Invited**
Frequency Comb, Tobias Kippenberg¹; ¹Ecole Polytechnique Federale de Lausanne, Switzerland. Abstract not available.

Room 7AB

M4G • Optical Coherence Control—Continued

M4G.2 • 17:00
Phase Noise Characteristics of Injection-locked Lasers Operated at Low Injection Powers, Ravikiran Kakarla¹, Kovendhan Vijayan¹, Jochen Schröder¹, Peter A. Andrekson¹; ¹Chalmers Univ. of Technology, Sweden. Optical injection locking at -65 dBm input power is demonstrated by using an electrical phase-locked loop and an EDFA pre-amplifier. A slave laser output phase noise below 6 degrees (rms) was confirmed.

M4G.3 • 17:15
Simultaneous 40-channel DWDM-DPSK Signal Monitoring System Realized by Using Single-channel Linear Optical Sampling Technique, Bingxin Xu¹, Xinyu Fan¹, Shuai Wang¹, Zuyuan He¹; ¹Shanghai Jiao Tong Univ., China. We propose a novel DWDM signal monitoring system based on linear optical sampling technique with only a single channel. A system with 40-channel 20 Gb/s DWDM-dPSK signals is successfully monitored experimentally.

Room 8

M4H • Photonic Integration II—Continued

M4H.2 • 17:00
Fast Frequency Tuning of Silicon-photonic Thermo-optic MZI Filters using "Turbo Pulse" Method, Hiroyuki Matsuura¹, Keijiro Suzuki¹, Satoshi Suda¹, Kazuhiro Ikeda¹, Hitoshi Kawashima¹, Shu Namiki¹; ¹AIST, Japan. We discuss and demonstrate the application of Turbo Pulse method to the silicon-photonic MZI based tunable filter. The tuning time was shortened to no longer than 7.0 μs from 36 μs without the method.

M4H.3 • 17:15
Mach-Zehnder-based 1x16 Multiplexer in SOI and Analysis of Phase Noise Properties, Massimo Valerio Preite^{1,2}, Philippe Velha^{1,2}, Olivier Lemonnier³, Christophe Kopp³, Fabrizio Di Pasquale^{1,2}, Claudio Oton^{1,2}; ¹Scuola Sant'Anna, Italy; ²Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy; ³CEA LETI, France. A Silicon Photonic 1x16 Mach-Zehnder-based demultiplexer is presented. The device shows insertion loss below 1.5dB and channel isolation of ~20dB. An analysis shows the different statistics of intra-die and inter-die phase noise fluctuations.

Room 9

M4I • Deployments of Optical Access and Front Haul—Continued

Room 10

M4J • MMW & THz Systems—Continued

M4J.3 • 17:00
mmWave Beamforming using Photonic Signal Processing for Future 5G Mobile Systems, Hongbo Lu¹, Gengchen Liu¹, Roberto Proietti¹, Vincent Squitieri¹, Kaiqi Zhang¹, Alberto Castro¹, Q. Jane Gu¹, Zhi Ding¹, S. J. Ben Yoo¹; ¹UC Davis, USA. We propose a photonic signal processing technique enabling reconfigurable multiple mmWave-beam forming for 5G cellular systems. We demonstrate the beamforming capability with a 4-by-4 patch array antenna, achieving 15-dBi antenna gain and 8-gbps throughput.

M4J.4 • 17:15 **Top Scored**
120Gb/s Wireless Terahertz-wave Signal Delivery by 375GHz-500GHz Multi-carrier in a 2x2 MIMO System, Xinying Li^{2,1}, Jianjun Yu^{2,3}, Kaihui Wang², Miao Kong², Wen Zhou², Zihang Zhu², Can Wang², Mingming Zhao², Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA; ²Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China; ³ZTE (TX) Inc., USA. We experimentally demonstrate 6x20-gb/s six-channel PDM-QPSK THz-wave signal delivery over 10-km SMF-28 and 142-cm wireless 2x2 MIMO link with a BER under 3.8x10⁻³, which realizes the first 2x2 MIMO wireless transmission of multi-channel THz-wave signal.

Wireless Internet Access
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Monday, 12 March





Room 1A

M4A • Modelling, Disaggregation & Networking Automation—Continued

M4A.4 • 17:30 **Invited**
OpenROADM over ONOS, Marc De Leenheer¹, Yuta Higuchi², Guru Parulkar³¹; ¹Open Networking Foundation, USA; ²NEC America, USA; ³Stanford Univ., USA. We discuss the integration of OpenROADM data models into ONOS, the network OS built for high performance, scale and high availability. We review experimental data, deployment considerations, lessons learned, and next steps.

M4A.5 • 18:00
P4-based Multi-layer Traffic Engineering Encompassing Cyber Security, Francesco Paolucci¹, Filippo Cugini², Piero Castoldi¹; ¹Scuola Superiore Sant'Anna, Italy; ²CNIT, Italy. The design and experimental validation of effective P4-based solutions for dynamic optical bypass, traffic offload and cyber security without involving SDN controller are proposed. P4 switch latency scalability versus installed flow entry size is demonstrated.

Room 1B

M4B • Practical Aspects in Fiber Transmission—Continued

M4B.4 • 17:30
Proactive Detection of Optical Cable Failure Caused by Water Freezing Using 1- μ m-band Mode-detection OTDR, Atsushi Nakamura¹; ¹NTT Corporation, Japan. An experiment shows that information allowing the prediction of optical loss increases due to icing in cable conduits can be extracted by using OTDR measurements in the 2-IP mode region of the fibers under test.

M4B.5 • 17:45
Laboratory Measurements of SOP Transients due to Lightning Strikes on OPGW Cables, Fabio Pittalà¹, Christopher Stone², David Clark², Maxim Kuschnerov¹, Changsong Xie¹, A Manu Haddad²; ¹Huawei Technologies Duesseldorf GmbH, Germany; ²Advanced High Voltage Engineering Research Centre, School of Engineering, Cardiff Univ., UK. We report laboratory experiments in which lightning current impulses of magnitudes up to and above 150kA were applied to OPGW cables of length up to 18m. Unprecedentedly, fast SOP speeds exceeding 8Mrad/s were measured.

M4B.6 • 18:00 **Invited**
Requirements for Simulation-aided Design of SDM Systems, Igor Koltchanov¹, Stefanos Dris¹, Alexander Uvarov², Andre Richter¹; ¹VPI Photonics, Germany; ²VPI Development Center, Belarus. We discuss general requirements and implementation options for an efficient simulation framework supporting the design of SDM systems, as well as aspects regarding the analysis, comparison and optimization of underlying technology and component options.

Room 6C

M4C • Symposium: Challenges 5G brings to Optical Fiber Communications Systems II—Continued

M4C.3 • 17:30 **Invited**
FTTA/PTTA Connectivity Solutions - On the Way to 5G, Josef Gramsamer¹; ¹Rosenberger, Germany. To support multiple applications and achieve seamless integration, 5G networks and related services require different end-to-end network design.

18:00 Panel Discussion

Room 6D

M4D • Mode Multiplexors and Components for Space-division Multiplexed Systems—Continued

M4D.4 • 17:30 **Invited**
A Novel Fabrication Method for Photonic Lanterns, Neethu M. Mathew¹, Lars Grüner-Nielsen², Mario A. Usuga¹, Karsten K. Rottwitt¹; ¹Technical Univ. of Denmark, Denmark; ²Danish Optical Fiber Innovation, Denmark. A new fabrication method for photonic lanterns using a low index UV curable polymer is presented. The insertion loss is predicted, and measurements show a loss lower than 3 dB.

M4D.5 • 17:45 **Invited**
Mode Selective Photonic Lantern with Graded Index Core, Juan Carlos Alvarado Zacarias^{1,2}, Nicolas K. Fontaine², Jose Enrique Antonio-Lopez¹, Zeinab Sanjabi Eznaveh¹, Md Selim Habib¹, Haoshuo Chen², Roland Ryf², Pierre Sillard³, Adrian Amezcua-Correa³, Sergio G. Leon-Saval⁴, Dennis Van Ras³, Cedric Gonnet³, Rodrigo Amezcua-Correa¹; ¹CREOL, The College of Optics & Photonics, USA; ²Nokia Bell Labs, USA; ³Prysmian Group, France; ⁴Univ. of Sidney, Australia. We demonstrate a mode selective photonic lantern with a graded index core, which modes are a better match when splicing to graded index transmission fiber compare to those from a photonic lantern with step index core.

Room 6E

M4E • Probabilistic Shaping II—Continued

M4E.2 • 17:30 **Invited**
Low-complexity Variable-length Output Distribution Matching with Periodical Distribution Uniformization, Tsuyoshi Yoshida^{2,1}, Magnus Karlsson², Erik Agrell²; ¹Mitsubishi Electric Corporation, Japan; ²Chalmers Univ. of Technology, Sweden. Run-length code based distribution matching (DM) for probabilistic shaping is combined with a uniformizer to realize low-complexity fixed-length DM. The proposed method is 0.4 dB better than previous low-complexity DM methods.

M4E.3 • 17:45 **Invited**
Experimental Verification of Rate Flexibility and Probabilistic Shaping by 4D Signaling, Fabian Steiner¹, Francesco Da Ros², Metodi P. Yankov², Georg Böcherer¹, Patrick Schulte¹, Søren Forchhammer², Gerhard Kramer¹; ¹Technical Univ. of Munich, Germany; ²DTU Fotonik, Technical Univ. of Denmark, Denmark. The rate flexibility and probabilistic shaping gain of 4-dimensional signaling is experimentally tested for short-reach, unrepeatable transmission. A rate granularity of 0.5 bits/QAM symbol is achieved with a distribution matcher based on a simple look-up table.

M4E.4 • 18:00 **Invited**
Universal Hybrid Probabilistic-geometric Shaping Based on Two-dimensional Distribution Matchers, Zhen Qu^{1,2}, Shaoliang Zhang¹, Ivan Djordjevic²; ¹NEC Laboratories America, USA; ²Univ. of Arizona, USA. We propose universal distribution matchers applicable to any two-dimensional signal constellation. We experimentally demonstrate that the performance of 32-ary QAM, based on hybrid probabilistic-geometric shaping, is superior to probabilistically shaped 32QAM and regular 32QAM.



Room 6F

M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II—Continued

M4F.3 • 17:30 **Invited** **Three Dimensional Silicon Optical Waveguide Structure Bent by Ion Implantation for Surface Coupling**, Youichi Sakakibara¹; ¹Natl Inst of Adv Industrial Sci & Tech, Japan. Titled vertically bent structure with several-micrometers curving radii and a spot size conversion function enables efficient coupling between optical fibers and silicon photonic chips from the surface side with broad spectrum bandwidth and assembly tolerance.

M4F.4 • 18:00 **Invited** **Photonic Reservoir Computing: a Brain-inspired Approach for Information Processing**, Peter Bienstman¹; ¹Ghent University, Belgium. We present our results on silicon photonics neuromorphic information processing based on techniques like reservoir computing. We will discuss scalability, novel architectures for enhanced power efficiency, as well as all-optical readout. Additionally, we will touch upon new machine learning techniques to operate these integrated readouts.

Room 7AB

M4G • Optical Coherence Control—Continued

M4G.4 • 17:30 **Invited** **On-chip Quantum Optical Frequency Comb Sources**, Christian Reimer¹, Michael Kues¹, Piotr Roztock¹, Stefania Sciarra¹, Luis Romero Cortés¹, Benjamin Wetzels¹, Yanbing Zhang¹, Alfonso Cino², Sai Chu³, Brent Little⁴, David J. Moss⁵, Lucia Caspani⁶, Jose . Azana¹, Roberto Morandotti¹; ¹INRS-eMT, Canada; ²Univ. of Palermo, Italy; ³City Univ. of Hong Kong, China; ⁴Xi'an Inst. of Optics and Precision Mechanics, China; ⁵Swinburne Univ. of Technology, Australia; ⁶Univ. of Strathclyde, UK. Integrated optical frequency comb sources, based on nonlinear microring resonators, can be used to generate complex quantum states. In particular, we achieved multi-photon and high-dimensional entangled quantum states, as well as their coherent control.

M4G.5 • 18:00 **Optical Crosstalk Reduction using Amplified Spontaneous Emission (ASE)**, Haoshuo Chen¹, Nicolas K. Fontaine¹, Roland Ryf¹, Juan Carlos Alvarado², John van Weerdenburg³, Rodrigo Amezcua-Correa², Chigo Okonkwo³, Ton Koonen³; ¹Nokia Bell Labs, USA; ²CREOL, Univ. of Central Florida, USA; ³Inst. for Photonic Integration, Univ. of Technology, Netherlands. We employ spectrally filtered amplified spontaneous emission as the signal carrier and matched local oscillator to mitigate optical crosstalk. We demonstrate polarization crosstalk reduction in single-mode fiber transmission and modal crosstalk reduction over multimode fiber.

Room 8

M4H • Photonic Integration II—Continued

M4H.4 • 17:30 **An Integrated Silicon Bragg Grating Filter without Circulator**, Rulei Xiao¹, Yuechun Shi¹, Yong Zhao¹, Xiangfei Chen¹; ¹Nanjing Univ., China. We demonstrated an integrated silicon Bragg grating filter with an equivalent circulator. The reflected power by the Bragg grating will not be reflected to the launched port, but be dropped at a third port.

M4H.5 • 17:45 **Bandwidth Tunable Filter with Large Bandwidth and Wavelength Tuning Range**, Tingge Dai¹, Gencheng Wang¹, Jianfei Jiang¹, Yuehai Wang¹, Yubo Li¹, Hui Yu¹, Xiaoqing Jiang¹, Jianyi Yang¹; ¹Zhejiang Univ., China. We demonstrate a silicon-multiple-microring-based Vernier optical filter with both large bandwidth and wavelength tuning range. The bandwidth can be tuned from 0.3 nm to 1.2 nm. The wavelength tuning range can cover C-band.

M4H.6 • 18:00 **Top Scored** **Fully Flexible Filtering Element on SOI with 7-80 GHz Bandwidth Tunability and Full FSR Tuning**, Giannis Pouloupoulos¹, Giannis Giannoulis¹, Nikos Iliadis¹, Wahlbrink Thorsten³, Anna Lena Giesecke³, Dimitrios Kalavrouziotis², Dimitrios Apostolopoulos¹, Hercules Avramopoulos¹; ¹NTUA, Greece; ²Mellanox Technologies Ltd, Israel; ³AMOGmbH, Germany. We demonstrate a fully tunable Silicon-on-insulator filtering element, relying on a 2nd order micro ring resonator equipped with three variable optical couplers. Experimental results revealed bandwidth tunability between 7-80 GHz and full FSR tuning.

Room 9

M4I • Deployments of Optical Access and Front Haul—Continued

M4I.2 • 17:30 **Experimental Demonstration of 100 Gb/s Optical Network Transport and Aggregation for Ethernet Fronthaul with Low and Bounded Delay**, Raimena Veislari¹, Steinar Bjornstad^{1,2}, Jan P. Braute¹; ¹TransPacket, Norway; ²ITEM, NTNU, Norway. 3-node integrated packet/circuit network experiment demonstrates 100Gb/s transport and aggregation of five 10Gb/s links with low and bounded delay. 3.4μs maximum end-to-end delay is achieved, even when combining with less delay-sensitive traffic, reaching 98% utilization.

M4I.3 • 17:45 **Coordinating Multi-access Edge Computing with Mobile Fronthaul for Optimizing 5G End-to-end Latency**, Wei Wang^{1,2}, Yongli Zhao¹, Massimo Tornatore^{2,3}, Han Li⁴, Jie Zhang¹, Biswanath Mukherjee²; ¹Beijing Univ. of Posts and Telecomm., China; ²Department of Computer Science, Univ. of California, Davis, USA; ³Politecnico, di Milano, Italy; ⁴China Mobile Communications Corporation, China. In 5G, latency-sensitive traffic might be processed directly at central-offices by Multi-access Edge Computing (MEC) right after being transported through Mobile Fronthaul (MFH). We investigate how to optimize end-to-end latency by coordinating MEC with MFH.

M4I.4 • 18:00 **Invited** **Scenarios and Economic Analysis of Fronthaul**, Andrea Di Giglio¹; ¹Telecom Italia Lab, Italy. This work presents a comparison between C-RAN and emerging DA-RAN approaches for 5G networks. Main results show that DA-RAN and splitting alternative to CPRI bring economical and architectural advantages.

Room 10

M4J • MMW & THz Systems—Continued

M4J.5 • 17:30 **Invited** **Radio-over-fiber-based Seamless Fiber-wireless Convergence for Small Cell and Linear Cell Networks**, Pham Tien Dat¹, Atsushi Kanno¹, Naokatsu Yamamoto¹, Tetsuya Kawanishi²; ¹National Inst. of Information and Communication Technology, Japan; ²Waseda Univ., Japan. We present radio-over-fiber technologies for fiber and wireless convergence for small cell and linear cell networks, including a flexible and low-latency mobile fronthaul for ultra-dense small cells, and high-speed wireless backhaul system for high-speed trains.

M4J.6 • 18:00 **Four-channel RoF Transmission over Polarization Maintaining Elliptical Ring Core Fiber**, Reza Mirzaei Nejad¹, Farzan Tavakoli¹, Lixian Wang¹, Xun Guan¹, Sophie LaRochelle¹, Leslie A. Rusch¹; ¹Universite Laval, Canada. Transmission of four RoF streams over polarization maintaining elliptical ring core fiber is demonstrated. RoF streams are recovered without MIMO processing; signals on two polarizations of a mode could be recovered even under severe bending.





Room 1A

M4A • Modelling, Disaggregation & Networking Automation—Continued

M4A.6 • 18:15
Fast and Accurate Lightpath Validation for SDN Controllers, Rui M. Morais1,2, João Pedro1,2, 1Coriant Portugal, Portugal; 2Instituto De Telecomunicacoes, Portugal. We present a method to quickly and accurately evaluate the feasibility of an optical path in online routing scenarios. The method is based on performance metrics that compress the set of all feasible paths.

Room 1B

Room 2

M4B • Practical Aspects in Fiber Transmission—Continued

Room 6C

M4C • Symposium: Challenges 5G brings to Optical Fiber Communications Systems II—Continued

Room 6D

M4D • Mode Multiplexors and Components for Space-division Multiplexed Systems—Continued

Room 6E

M4E • Probabilistic Shaping II—Continued

M4E.5 • 18:15
Efficient Offline Evaluation of FEC Codes Based on Captured Data with Probabilistic Shaping, Tsuyoshi Yoshida2,1, Magnus Karlsson2, Erik Agrell2, 1Mitsubishi Electric Corporation, Japan; 2Chalmers Univ. of Technology, Sweden. We propose a tool for reusing experimental or simulation data of probabilistically shaped signals with different FEC codes. A single recorded histogram of log-likelihood ratios is sufficient to examine arbitrary coding at low BERs.

NOTES

Large empty rectangular area with horizontal lines for taking notes.

Monday, 12 March





Room 6F

M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II—Continued

Room 7AB

M4G • Optical Coherence Control—Continued

Room 8

M4H • Photonic Integration II—Continued

Room 9

M4I • Deployments of Optical Access and Front Haul—Continued

Room 10

M4J • MMW & THz Systems—Continued

M4H.7 • 18:15

Integrated Optical Ultra-broadband Add-drop Filter in Silicon-on-insulator Platform, Sumi R¹, Ramesh K¹, Nandita DasGupta¹, Bijoy K. Das¹; ¹Indian Inst. of Technology Madras, India. A sub-wavelength grating waveguide is designed and integrated in two arms of a 2 x 2 Mach-Zehnder interferometer in silicon-on-insulator which is capable of dropping(adding) ultra-broad wavelength bands centering at λ~1550nm with band-edge extinction exceeding 35-dB.

M4J.7 • 18:15

Probabilistically Shaped 16QAM Signal Transmission in a Photonics-aided Wireless Terahertz-wave System, Kaihui Wang¹, Xinying Li², Miao Kong¹, Pengqi Gou¹, Wen Zhou¹, Jianjun Yu^{1,2}; ¹Fudan Univ., China; ²ZTE TX inc, USA. The 16QAM signal adopting probabilistic shaping (PS) technology is transmitted in a photonics-aided wireless Terahertz-wave system. The experimental results show an improvement of BER performance compared to the uniform distribution.

NOTES

Large empty rectangular area with horizontal lines for taking notes.

Monday, 12 March



Room 1A

Room 1B

Room 2

Room 6C

Room 6D

Room 6E

07:30–08:00 Coffee Break, Ballroom 20 Foyer

08:00–10:00 Tu1A • Plenary Session, Ballroom 20BCD

10:00–14:00 Unopposed Exhibit-only Time, Exhibit Hall (concessions available)

10:00–10:30 Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C

12:00–13:30 OIDA VIP Industry Leaders Speed Meetings Event, Room 33B (separate registration required)

12:00–14:00 Awards Ceremony and Luncheon, Ballroom 20A

14:00–16:00

Tu2A • Coupling and Packaging

Presider: Hiroyuki Tsuda; Keio Univ., Japan

14:00–16:00

Tu2B • Data Center & PON Transponder Technology

Presider: Yongpeng Zhao; Luster Lightech Corp., China

14:00–16:00

Tu2C • Short Reach I

Presider: Xi Chen; Nokia Bell Labs, USA

14:00–16:00

Tu2D • Kramers-Kronig Transmissions

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

14:00–16:00

Tu2E • Coherent and Tunable Devices

Presider: Michael Larson; Lumentum, USA

14:00–16:00

Tu2F • Capacity Planning

Presider: João Pedro; Coriant, Portugal

Tu2A.1 • 14:00

Expanded-beam Through-substrate Coupling Interface for Alignment Tolerant Packaging of Silicon Photonics, Nivesh Mangal^{1,2}, Jeroen Missette², Gunther Roelkens³, Joris Van Campenhout¹, Geert Van Steenberge², Brad Snyder¹; ¹imec, Belgium; ²Centre for Microsystems Technology, Ghent Univ., Belgium; ³Photonics Research Group, Ghent Univ.-imec, Belgium. We demonstrate an alignment tolerant through-substrate coupling interface by combining an optimized downward-directionality grating on a silicon photonic chip with a hybrid integrated polymer lens, generating a collimated beam at $\lambda=1310\text{nm}$ for more than $600\mu\text{m}$.

Tu2B.1 • 14:00 **Invited**

Revolutionizing the Data Centers and HPCs - Optical Interconnects, Tolga Tekin¹; ¹Fraunhofer IZM, Germany. Abstract not available.

Tu2C.1 • 14:00 **Invited**

DSP-free Coherent Receivers for Data Center Links, Jose Paulo Krause Perin¹, Anujit Shastri¹, Joseph M. Kahn¹; ¹Stanford Univ., USA. We review low-power DSP-free coherent receiver architectures for DP-QPSK that exhibit performance comparable to their DSP-based counterparts, while consuming an estimated $\sim 4\text{ W}$ for 200 Gbit/s DP-QPSK in 90-nm CMOS.

Tu2D.1 • 14:00 **Invited**

The Kramers-Kronig Receiver, Antonio Mecozzi¹, Cristian Antonelli¹, Mark Shtaiif², Xi Chen³, Sethumadhavan Chandrasekhar³, Peter J. Winzer³; ¹Physical and Chemical Sciences, Univ. of L'Aquila, Italy; ²Department of Physical Electronics, Tel Aviv Univ., Israel; ³Nokia Bell Labs, USA. This presentation reviews the operation principles and various implementations of the Kramers-Kronig (KK) receiver. Some of the recently published experimental demonstrations are reviewed.

Tu2E.1 • 14:00

Compact Silicon Microring Modulator with Tunable Extinction Ratio and Wide FSR, Hossam A. Shoman¹, Hasitha Jayatilleka¹, Anthony Park¹, Nicolas Jaeger¹, Sudip Shekhar¹, Lukas Chrostowski¹; ¹Electrical and Computer Engineering, Univ. of British Columbia, Canada. A tunable two-point coupling scheme for a microring modulator on a silicon-on-insulator platform, that achieves a $>30\text{ dB}$ extinction ratio while maintaining a large (19.23 nm) free spectral range, is presented.

Tu2F.1 • 14:00 **Tutorial**

The Software-defined Flexible Optical Network, António Eira^{1,2}; ¹Coriant, Portugal; ²Instituto de Telecomunicações, Portugal. This tutorial discusses how hardware and software flexibility affect the design of optical networks. It covers the interworking between multi-rate/flow interfaces, universal OTN switching, FlexE enabled clients, and how SDN controllers can leverage this flexibility effectively.

continued on page 72



Room 6F

Room 7AB

Room 8

Room 9

Room 10

07:30–08:00 Coffee Break, Ballroom 20 Foyer

08:00–10:00 Tu1A • Plenary Session, Ballroom 20BCD

10:00–14:00 Unopposed Exhibit-only Time, Exhibit Hall (concessions available)

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12:00–14:00 Awards Ceremony and Luncheon, Ballroom 20A

14:00–16:00
Tu2G • Content Distribution and Edge Computing
President: Werner Weiershausen; Deutsche Telekom Technik GmbH, Germany

14:00–16:00
Tu2H • Open Platform Summit: Open Platforms for Optical Innovation

14:00–16:00
Tu2I • Underwater Free Space Optics Systems
President: Richard DeSalvo; Harris Corporation, USA

14:00–16:00
Tu2J • Fiber Optic and Wavelength Devices
President: Nicolas Fontaine; Nokia Bell Labs, USA

14:00–16:00
Tu2K • Low Latency Services & XHaul over PON
President: Thomas Pfeiffer; Nokia Bell Labs, Germany

Tu2G.1 • 14:00 **Tutorial**
Content Distribution Networks and their Impact on Optical Networks, Jeffrey D. Bower¹; ¹Product Architecture, Akamai Technology, Inc., USA. Low latency optical network design often focuses on reducing the route distance between points A and B. The introduction of Content Distribution Networking into this design can change the focus to moving as much content as possible close to the content consumer.

continued on page 73

In the first session of the Open Platform Summit, invited speakers will provide an overview of key frameworks, architectures and projects within the trend of using open hardware and software platforms for designing, deploying and operating large-scale networks and complex commercial environments, showcasing the benefits behind the concepts of Software Defined Networking (SDN) and Network Functions Virtualization (NFV).

The session presentations will be technology oriented, and will include both the point of view of the operator/user of the platform and that of the system vendor / integrator. For the former, focus will be on key benefits such as reduction of operational expenses and automation of network control or service provisioning. For the latter, the target is to provide an overview of key projects, including relevant architec-

continued on page 73

Tu2I.1 • 14:00
Seawater Communication with Blue Laser Carried 16-QAM OFDM at 3.7 GBaud, Huai-Yung Wang¹, Yu-Fang Huang¹, Wei-Chun Wang¹, Cheng-Ting Tsai¹, Chih-Hsien Cheng¹, Yu-Chieh Chi¹, Gong-Ru Lin¹; ¹Graduate Inst. of Photonics and Optoelectronics, Department of Electrical Engineering, National Taiwan Univ., Taiwan. Point-to-point seawater communication based on directly 16-QAM OFDM encoded 450-nm blue laser is performed to carry the data with 2.7 GBaud (10.8 Gbps) and 3.7 GBaud (14.8-gbps) for transmission over 10.2 m and 1.7 m

Tu2J.1 • 14:00 **Top Scored**
Demonstration of Multiple Kerr-frequency-comb Generation using Different Lines from Another Kerr Comb Located up to a 50 km Distance, Peicheng Liao¹, Changjing Bao¹, Ahmed Almaiman¹, Arne Kordts², Maxim Karpov², Martin Hubert Peter Pfeiffer², Lin Zhang³, Fatemeh Alishahi¹, Yinwen Cao¹, Amirhossein Mohajerin Ariaei¹, Kaiheng Zou¹, Ahmad Fallahpour¹, Moshe Tur⁴, Youichi Akasaka⁵, Tobias Kippenberg², Alan E. Willner¹; ¹Univ. of Southern California, USA; ²Ecole Polytechnique Federale de Lausanne, Switzerland; ³Tianjin Univ., China; ⁴Tel Aviv Univ., Israel; ⁵Fujitsu Laboratories of America, USA. We experimentally demonstrate multiple Kerr-frequency-comb generation using different lines from another Kerr comb located up to a 50 km distance. The master and generated slave combs are mutually coherent and have a small variance of frequency error.

Tu2K.1 • 14:00 **Tutorial**
Mobile XHaul Evolution: Enabling Tools for a Flexible 5G XHaul Network, Yuki Yoshida¹; ¹NICT, Japan. Optical platform needs to be more flexible, time-critical, yet reliable to accommodate 5G+ RAN. In this talk, major developments on mobile XHaul in both wireless and optical fields in 2017 will be summarized, and key enabling technologies for the XHaul in 5G Phase II will be discussed.

continued on page 73

Show Floor Programming

Data Center Optical Interconnect - Technologies and Markets

10:15–12:15

For more details, see page 13

Product Showcase

Huawei

10:15–10:45

For more details, see page 23

■ MW Panel I: State of the Industry - Analyst Panel

10:30–12:00

Open Management and Monitoring of Multilayer Webscale and Carrier Networks

OpenConfig

11:00–12:30

■ MW Panel II: Optical Bearer Technologies for 5G Networks

12:30–14:00

Ethernet Roadmaps Update

Ethernet Alliance

12:45–13:45

Fog Computing and Optical Networking - What's Next?

IEEE and OpenFog Consortium

12:45–14:15

Disaggregating the Transport Layer: What It Means to The Bottom Line

Session Sponsored by Juniper Networks

14:00–17:00

Enabling the Key Applications for Transport SDN

OIF

14:30–15:30

■ MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics

14:30–16:00

Tuesday, 13 March



Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.2 • 14:15
Characterization of Coupling Properties of Vertically Curved Si Surface Optical Coupler Designed for Coupling with 5- μ m-MFD SMF, Yuki Atsumi¹, Tomoya Yoshida¹, Emiko Omoda¹, Youichi Sakakibara¹; ¹AIST, Japan. A 5- μ m-spot-size surface optical coupler based on vertically-curved Si waveguide showed 150nm/0.5dB spectrum bandwidth, ~5dB coupling loss for TE polarization, and incident angle and alignment tolerance of 6 degrees and $\pm 1.5\mu$ m in 5- μ m-spot SMF coupling.

Tu2A.3 • 14:30 **Invited**
Packaging and Assembly Challenges for 50G Silicon Photonics Interposers, Brad Snyder¹, Nivesh Mangal¹, Guy Lepage¹, Sadhishkumar Balakrishnan¹, Xiao Sun¹, Nicolas Pantano¹, Michal Rakowski¹, Lieve Bogaerts¹, Peter De Heyn¹, Peter Verheyen¹, Andy Miller¹, Marianna Pantouvaki¹, Philippe Absil¹, Joris Van Campenhout¹; ¹imec, Belgium. We address the challenges in realizing low-loss, broadband optical interfaces for high-density fiber or polymer waveguides along with through-silicon via interconnects in a 50 GHz silicon photonics interposer platform suitable for 2.5D/3D packaging with advanced CMOS logic.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

Tu2B.2 • 14:30 **Top Scored**
A Compact 212.5-Gbit/s Transmitter Optical Sub-assembly with DMLs and Quad Linear Driver, Naoki Itabashi¹, Yoshiyuki Sugimoto¹, Yasushi Fujimura¹, Keiji Tanaka¹, Shoichi Ogita¹; ¹Transmission Devices Laboratory, Sumitomo Electric Industries, Ltd., Japan. We present a compact 212.5-gbit/s transmitter optical sub-assembly equipped with directly modulated lasers and quad 53.125-gbit/s linear driver. We demonstrate high-quality and high-output-power operation with low-power consumption (1.01 W), which is desirable for 200GBASE-IR4 application.

Room 2

Tu2C • Short Reach I—Continued

Tu2C.2 • 14:30
Investigation on the Dispersion Tolerance in Dual-drive MZM-based DAC-less Optical PAM4 Transmission, Kuo Zhang^{1,2}, Qunbi Zhuge^{2,3}, Haiyun Xin¹, Zhenping Xing², Rui Li², Meng Xiang², Sujie Fan², Lilin Yi¹, Weisheng Hu¹, David V. Plant²; ¹Shanghai Jiao Tong Univ., China; ²McGill Univ., Canada; ³Ciena, Canada. We investigate the chirp characteristics of the two PAM4 generation methods based on dual-drive MZM. Prominent difference in transmission performance between the two methods is experimentally shown for 112Gb/s PAM4 signals when chromatic dispersion exists.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.2 • 14:30 **▶**
16x112Gb/s Single-sideband PAM4 WDM Transmission over 80km SSMF with Kramers-Kronig Receiver, Yixiao Zhu¹, Mingxuan Jiang¹, Xiaoke Ruan¹, Chenjia Li¹, Fan Zhang¹; ¹Peking Univ., China. Based on Kramers-Kronig receiver and phase alignment operation, we demonstrate 56GBaud single-sideband PAM4 16-channel WDM transmission over 80km SSMF. Single channel 80km transmission of 80GBaud SSB-PAM4 signal is also demonstrated.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

Tu2E.2 • 14:15 **▶**
Bandwidth-aware Figure of Merit for Silicon-photonics Depletion Mode Modulators, Hassan Sepehrian¹, Amin Yekani¹, Leslie A. Rusch¹, Wei Shi¹; ¹ECE, Laval Univ., Canada. A new figure of merit is presented that includes not only the optical-loss and $V\pi$ of SiP electro-optic modulators but also their E-o bandwidth limitation. It translates system-level requirements into device-level design parameters.

Tu2E.3 • 14:30 **▶**
Active Bragg Reflector Waveguide Demultiplexer Array with Over 100 Wavelength Channels and Optical Gain for Large Port-count WSS, Xiaodong Gu¹, Masanori Nakahama¹, Fumio Koyama¹; ¹Tokyo Inst. of Technology, Japan. We demonstrated a compact wavelength demultiplexer array based on an active Bragg reflector waveguide beam scanner with large-angular-dispersion. The device provides no-insertion-loss operation with a number of wavelength channels over 100.

Room 6E

Tu2F • Capacity Planning—Continued



António Eira received his MSc degree in 2010 from Instituto Superior Técnico. He joined Coriant (then NSN) in 2011, where he has since worked on network optimization topics for optical networks. His roles include the development of novel algorithms supporting elastic networking concepts in Coriant's planning tool portfolio, as well as customized sales support. Also in the scope of flexible transport networks, he was actively involved in the EU project IDEALIST. He is currently part of Coriant's multi-layer performance optimization group, where he pursues innovative applications of networking algorithms to multi-layer network design, spectrum management and interoperable systems.



Join the conversation.
 Follow @OFCConference on Twitter.
 Use hashtag #OFC18.

Room 6F**Tu2G • Content Distribution and Edge Computing—Continued**

With 20 years of experience in the telecommunications industry, Jeff Bower has experience across all 7 OSI layers. He started with layer 2 in the ATM NOC at AT&T, moved to L1 and L2 with Lucent, Internet Photonics, and Ciena, then expanded up to L3-7 as a Senior Product Architect at Akamai with special focus on layer 3 and 4 solutions.

Room 7AB**Tu2H • Open Platform Summit: Open Platforms for Optical Innovation—Continued**

tural elements and main drivers and innovation opportunities.

Speakers:

Hans-Juergen Schmidtke, *Facebook, USA*

Martin Birk, *AT&T, USA*

Gert Grammel, *Juniper, USA*

Diego López, *Telefónica, Spain*

Room 8**Tu2I • Underwater Free Space Optics Systems—Continued****Tu2I.2 • 14:15**

Sea-trial of an Ethernet-based Underwater VLC Communication System, Giulio Cossu¹, Alessandro Sturmiolo¹, Alessandro Messa¹, Simone Grechi², David Scaradozzi³, Andrea Caiti², Ernesto Ciaramella¹; ¹Scuola Superiore Sant Anna di Pisa, Italy; ²Univ. of Pisa, Italy; ³Università Politecnica delle Marche, Italy. We experimentally demonstrate at NATO site in Spezia a bi-directional underwater optical wireless transmission compliant with 10Base-t Ethernet. Zero packet loss was achieved up to 10 m distance in a real harbour, with shallow murky waters and daylight.

Tu2I.3 • 14:30 Invited

Optical based Underwater Communications, Jen-Chieh Chang¹, Yun-Chieh Wang¹, De-Yu Chen¹, Chung-Yi Li¹, Hai-Han Lu¹, Xu-Hong Huang², Wen-Shing Tsai³; ¹National Taipei Univ. of Technology, Taiwan; ²School of Information Science and Engineering, Fujian Univ. of Technology, China; ³Department of Electrical Engineering, Ming Chi Univ. of Technology, Taiwan. A high-speed 24 Gb/s PAM4 optical-based underwater communication (OBUC) with afocal scheme for reducing/expanding collimated beam diameter is demonstrated. Such proposed OBUC link is better than existing OBUC given its practicability for high-speed underwater link.

Room 9**Tu2J • Fiber Optic and Wavelength Devices—Continued****Tu2J.2 • 14:15**

Linearly Polarized Multi-wavelength Comb via Rayleigh Scattering induced Brillouin Random Lasing Resonance, Liang Zhang¹, Yuan Wang^{1,2}, Yanping Xu¹, Liang Chen¹, Xiaoyi Bao¹; ¹Univ. of Ottawa, Canada; ²Inst. of Optoelectronic Technology, China Jiliang Univ., China. A linearly polarized kHz-linewidth multi-wavelength comb in the telecom spectral window with over-40-dB optical signal-to-noise ratio was experimentally demonstrated by randomly distributed Rayleigh scattering induced Brillouin lasing oscillation in polarization maintaining fibers.

Tu2J.3 • 14:30

A Fiberized Metamaterial Device for Ultrafast Control of Coherent Optical Signals, Iosif Demirtzioglou¹, Angelos Xomalis¹, Eric Plum¹, Yong-Min Jung¹, Cosimo Lacava¹, Kevin F. MacDonald¹, Periklis Petropoulos¹, David J. Richardson¹, Nikolay I. Zheludev¹; ¹ORC, UK. We demonstrate selective transmission and absorption of 1-ps pulses, pulse shaping and 1-ps dark pulse generation in a fiber-optic device based on a plasmonic metamaterial, providing an example of all-optical signal processing with THz bandwidth.

Room 10**Tu2K • Low Latency Services & XHaul over PON—Continued**

Yuki Yoshida received B.S., M.S., and Ph.D. degrees in Informatics from Kyoto University in 2004, 2006, and 2009, respectively. From 2009 to 2016, he was an assistant professor in Osaka University. Since 2016, he has been a senior researcher in Network System Research Institute, National Institute of Information and Communications Technology (NICT), Japan. He is also a visiting associate professor in Graduate School for the Creation of New Photonics Industries (GPI), Japan. His research interests include digital signal processing for optical/wireless communications, optical/wireless access, and optical-wireless convergence. He is a member of the IEEE and the Institute of Electronics, Information, and Communications Engineers (IEICE), Japan.

Show Floor Programming**Disaggregating the Transport Layer: What It Means to The Bottom Line**

Session Sponsored by Juniper Networks
14:00–17:00

Enabling the Key Applications for Transport SDN

OIF
14:30–15:30

MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics

14:30–16:00

AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions

AIM Photonics
15:45–16:45

Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center

16:15–17:00

For more details, see page 21

Tuesday, 13 March

Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.4 • 15:00 Invited
In-line Optical Amplification for Silicon Photonics Platform by Flip-chip Bonded InP-SOAs, Takeshi Matsumoto¹, Teruo Kurahashi¹, Ryotaro Konoike², Ken Tanizawa², Keihiro Suzuki², Ayahito Uetake¹, Kazumasa Takabayashi¹, Kazuhiro Ikeda², Hitoshi Kawashima², Suguru Akiyama¹, Shigeaki Sekiguchi¹; ¹Fujitsu Laboratories Ltd., Japan; ²National Inst. of Advanced Industrial Science and Technology (AIST), Japan. We reviewed hybrid-integration of InP semiconductor optical amplifier on silicon photonics chip, and our in-line integration using precise flip-chip bonding technology. We demonstrated loss-less operation of 4x4 switches with 4ch-SOA array.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

Tu2B.3 • 14:45
Low-cost Hybrid-integrated Micro-intradyne Coherent Receiver using FPCB Wirings, Seo Young Lee¹, Young-Tak Han¹, Jong-Hoi kim¹, Young-Ho Ko¹, Hyun-Do Jung¹, Joong-Seon Choe¹, Chun Ju Youn¹, Won-Seok Han¹, Seok-Tae Kim¹, Yongsoo Baek¹; ¹ETRI, Korea. We report on a low-cost hybrid-integrated Micro-iCR based on a silica DP-oH and InP WG-pDs. RF and DC FPCB wirings provide low-cost and good RF performance. A 3-dB bandwidth is measured to be ~36 GHz.

Tu2B.4 • 15:00 Invited
SOA for Future PONs, Rene Bonk¹; ¹Nokia, Bell Labs, Germany. SOA applicability to provide up to 35 dB power budget for high-rate T(W) DM-PON is analyzed. Booster and pre-amplifier in PON-applications will have utmost importance in 50 Gbit/s/λ IM-dD and could also be applied in coherent access solutions.

Room 2

Tu2C • Short Reach I—Continued

Tu2C.3 • 14:45
Dispersion-uncompensated Transmission of NRZ and PAM-4 Single-sideband Signals using D-EML, Mohamed Essghair Chaibi¹, Laurent Bramerie¹, Didier Erasme², Christophe Peucheret¹; ¹FOTON Laboratory, France; ²LTCL, Telecom ParisTech, Paris-Saclay Univ., France. The generation of optical SSB signals using a D-EML is demonstrated for NRZ and PAM-4 modulations. Transmission at 10.7Gb/s of NRZ signals over 100-km SSMF and at 21.4Gb/s of PAM-4 signals over 50km is reported.

Tu2C.4 • 15:00
A 50Gb/s-PAM4 CDR with On-chip Eye Opening Monitor for Reference-level and Clock-sampling Adaptation, Liu Chang¹, Bozhi Yin¹, Tingyu Yao¹, Nan Qi², Dan Li³, Jingbo Shi¹, Juncheng Wang¹, Shang Hu¹, Rui Bai⁴, Xuefeng Chen⁴, Nan Chi⁵, Jiangbing Du⁶, Patrick Y. Chiang¹; ¹School of Microelectronics, Fudan Univ., China; ²Inst. of Semiconductors, CAS, China; ³Xian Jiaotong Univ., China; ⁴PhotonIC Technologies, China; ⁵Department of Communication Science and Engineering, Fudan Univ., China; ⁶Shanghai Jiaotong Univ., China. A 50Gb/s-PAM4 Clock/Data Recovery (CDR) transceiver is designed in a 40nm-cMOS process. An on-chip Eye Opening Monitor (EOM) is introduced that enables adaptive reference level and timing sampling placement for non-uniform and distorted PAM4-inputs.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.3 • 14:45 ▶
Transmission in 125-km SMF with 3.9 bit/s/Hz Spectral Efficiency using a Single-drive Mzm and a Direct-detection Kramers-Kronig Receiver without Optical CD Compensation, Marco Presi¹, Giulio Cossu¹, Giampiero Contestabile¹, Ernesto Ciaramella¹, Cristian Antonelli², Antonio Mecozzi², Mark Shtaiif³; ¹TeCIP Inst., Scuola Superiore Sant'Anna Univ., Italy; ²Physical and Chemical Sciences, Univ. of l'Aquila, Italy; ³School of Electrical Engineering, Tel Aviv Univ., Israel. We demonstrate single channel transmission in 125-km SMF of 59 Gbit/s in a 15 GHz optical bandwidth (3.9 bit/s/Hz gross spectral efficiency) using a single-drive Mach-Zehnder modulator and Kramers-Kronig detection without optical chromatic dispersion compensation.

Tu2D.4 • 15:00 ▶
Performance of Digital Back-propagation in Kramers-Kronig Direct-detection Receivers, Zhe Li¹, Lidia Galdino¹, Tianhua Xu², M. Sezer Erkilinc¹, Kai Shi^{3,1}, Eric Sillekens¹, Benn C. Thomsen^{3,1}, Polina Bayvel¹, Robert Killely¹; ¹Univ. College London, UK; ²Univ. of Warwick, UK; ³Microsoft Research Ltd, UK. We report the first investigation of fiber nonlinearity compensation by digital back-propagation in Kramers-Kronig direct-detection receivers. Improvements in performance of 112 Gb/s/λ WDM transmission over single-span SSMF links of up to 160 km are demonstrated.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

Tu2E.4 • 14:45 ▶
CMOS-compatible Silicon Photonic IQ Modulator for 84 GBaud 16QAM and 70 GBaud 32QAM, Jiachuan Lin¹, Hassan Sepehrian¹, Leslie A. Rusch¹, Wei Shi¹; ¹Université Laval, Canada. Using an all-silicon modulator, we demonstrate single-polarization 336 Gb/s (84 GBaud) 16QAM and 350 Gb/s (70 GBaud) 32QAM at BER well below 20% FEC-threshold. We achieved a net rate of 291 Gb/s on a single polarization.

Tu2E.5 • 15:00 Tutorial
Coherent Optics in SI Photonics, Christopher R. Doerr¹; ¹Acacia Communications, Inc., USA. Silicon photonics is ideally suited for coherent; it can integrate many functions with high yield and performance and employ low-cost consumer electronics packaging. We discuss the basics, the state of the art, and future directions.



Christopher R. Doerr earned a B.S. in aeronautical engineering and a B.S., M.S., and Ph.D. in electrical engineering from the Massachusetts Institute of Technology. He was an Air Force pilot

continued on page 76

Room 6E

Tu2F • Capacity Planning—Continued

Tu2F.2 • 15:00 ▶
Predeployment of Transceivers for Dynamic Lightpath Provisioning in Translucent Flexgrid Optical Networks, Krzysztof Walkowiak¹, Miroslaw Klinkowski²; ¹Systems and Computer Networks, Wroclaw Univ. of Science and Technology, Poland; ²National Inst. of Telecommunications, Poland. We focus on translucent flexgrid optical networks with flexible back-to-back regeneration and analyze the impact of the number of available transceivers on network performance for several proposed transceiver location methods and dynamic routing algorithms.



Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

Tu2G.2 • 15:00

Demonstration of SDN Application for Multilayer Video Contribution Network Service, Konstantinos Antoniou¹, Paul Wright², Kristan Farrow², Andrew Lord², Reza Nejabati¹, Dimitra E. Simeonidou¹; ¹Univ. of Bristol, UK; ²BT, UK. This paper describes a demonstration of an end-to-end, SDN-controlled Video Contribution Network providing dynamic service set-up, using optical switching to enable flexible provisioning of resources. We show seamless operation of legacy and future technologies.

Room 7AB

Tu2H • Open Platform Summit: Open Platforms for Optical Innovation—Continued

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.4 • 15:00

Effect of Limited Aperture Size on a Retro-reflected Communication Link between a Ground Station and a UAV using Multiplexing of Orbital-angular-momentum Beams, Long Li¹, Runzhou Zhang¹, Peicheng Liao¹, Hao Song¹, Kaiheng Zou¹, Guodong Xie¹, Zhe Zhao¹, Cong Liu¹, Haoqian Song¹, Kai Pang¹, Guillaume Labroille², Pu Jian², Dmitry Starodubov¹, Brittany Lynn³, Robert Bock⁴, Moshe Tur⁵, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²CAILabs, France; ³Space & Naval Warfare Systems Center, USA; ⁴R-dEX System, USA; ⁵School of Electrical Engineering, Tel Aviv Univ., Israel. We experimentally demonstrate and investigate the effect of limited aperture size on a 200-gbit/s retro-reflected free-space optical link between a ground station and a UAV up to ~100-m roundtrip distance by multiplexing 2 OAM beams.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Tu2J.4 • 14:45

Dynamic Multiwavelength Optical Reflection Filter Induced in a Suspended-core Fiber Bragg Grating by Amplitude Modulated Acoustic Waves, Ricardo E. Da Silva^{1,2}, Martin Becker¹, Manfred Rothhardt¹, Hartmut Bartelt¹, Alexandre A. Pohl²; ¹Leibniz Inst. of Photonic Technology, Germany; ²Federal Univ. of Technology-paraná (UTFPR), Brazil. A new technique to generate a multiwavelength reflection spectrum by modulating a 1cm long fiber Bragg grating with an amplitude modulated acoustic wave is reported. Up to 15 wavelength peaks with ~5pm bandwidth are achieved.

Tu2J.5 • 15:00

Silicon-graphene Hybrid Slot Waveguide with Enhanced Four-wave Mixing Efficiency, Yuxing Yang¹, Jiang Xinhong¹, Zhenzhen Xu¹, Yong Zhang¹, Ciyuan Qiu¹, Xuhan Guo¹, Yikai Su¹; ¹Shanghai Jiao Tong Univ., China. An enhanced four-wave mixing in a silicon-graphene hybrid slot waveguide is proposed and experimentally demonstrated. The conversion efficiency is -48.8 dB, showing 3.2-dB and 0.5-dB improvements relative to silicon slot waveguide and strip waveguide, respectively.

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

Tu2K.2 • 15:00

A Novel Data-compression Technology for Digital Mobile Fronthaul with Lloyd Algorithm and Differential Coding, Mu Xu^{1,2}, Zhensheng Jia², Jing Wang², L. Alberto Campos², Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA; ²CableLabs, USA. A data-compression technology with differential-coded Lloyd algorithm is envisioned to improve bandwidth efficiencies in digital-mobile-fronthaul networks. We experimentally demonstrated transmissions of 180 Gbps over 80-km fronthaul links encapsulating 64x100-mHz 1024-QAM 5G-nR carriers with lower-than-0.5% EVM.

Show Floor Programming

Disaggregating the Transport Layer: What It Means to The Bottom Line

Session Sponsored by Juniper Networks
14:00–17:00

Enabling the Key Applications for Transport SDN

OIF
14:30–15:30

■ **MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics**

14:30–16:00

AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions

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15:45–16:45

Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center

16:15–17:00
For more details, see page 21

Tuesday, 13 March



Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.5 • 15:30
Optimization Design of Efficient Broadband Bi-layer Grating Couplers for a Silicon Nitride-on-silicon Foundry Platform, Jason Mak¹, Quentin Wilmart², Segolene Olivier², Sylvie Menezes², Joyce K. Poon¹; ¹Univ. of Toronto, Canada; ²CEA-IETI, France. We propose and validate an optimization-based design procedure for bi-layer grating couplers in a silicon nitride-on-silicon photonic platform. Peak fiber-to-chip coupling efficiency of -2.1dB and a 1-dB bandwidth of 72nm were achieved in the O-band.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

Tu2B.5 • 15:30 **Invited**
25G Based PON Technology, Ed Harstead¹; ¹Nokia, USA. Commercial PONs have traditionally leveraged mature components from transport systems. Starting with 25G PON, the data center ecosystem will be leveraged. A strategy to accommodate higher loss budgets at lower cost is presented.

Room 2

Tu2C • Short Reach I—Continued

Tu2C.5 • 15:15
Single-λ 112Gbit/s 80-km Transmission of PAM4 Signal with Optical Signal-to-signal Beat Noise Cancellation, An Li¹, Wei-Ren Peng¹, Yan Cui¹, Yusheng Bai¹; ¹Futurewei Technologies, Inc., USA. We present a novel scheme of PAM4 with optical signal-to-signal beat noise cancellation for short reach applications. The required OSNR at FEC threshold is only 27.3 dB for a single-λ 112-gb/s signal after 80km transmission.

Tu2C.6 • 15:30
Real-time Demonstration of Polarization-multiplexed PAM using Compact Silicon Photonics Device, Antonello Nespola², Sean Anderson³, Paolo Savio², Dario Pilori², Luca Bertignono¹, Matt Traverso³, Mark Webster³, Fabrizio Forghieri⁴, Roberto Gaudino⁵; ¹Dipartimento di Elettrotelecomunicazioni (DET), Politecnico di Torino, Italy; ²ISMB, Istituto Superiore Mario Boella, Italy; ³Cisco Systems, USA; ⁴Cisco Photonics Italy srl, Italy; ⁵Dipartimento di Elettrotelecomunicazioni (DET), Politecnico di Torino, Italy. We experimentally demonstrate doubling capacity per wavelength using polarization-multiplexed PAM and direct-detection polarization recovery using a compact silicon photonic integrated device. Moreover, we present fundamental theoretical curves for PM-PAM performance.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.5 • 15:15 **Top Scored**
1.6Tbps WDM Direct Detection Transmission with Virtual-carrier over 1200km, Son T. Le¹, Karsten Schuh¹, Fred Buchali¹, Mathieu Chagnon¹, Henning Bülow¹; ¹Nokia Bell Labs, Germany. We demonstrate a 1.6Tbps 8-channel WDM direct detection transmission with virtual carriers over a record distance of 1200km with Corning® TXF™ fiber by using either Kramers-Kronig receiver or a two-stage interference cancellation scheme

Tu2D.6 • 15:30
Single-lane 100Gb/s 4-PAM Transmission over 80km SSMF Based on K-K scheme and Integrated 10G TOSA, Tianjian Zuo¹, Sen Zhang¹, Lei Liu¹, Weiqiang Cheng², Xiaofei Xu¹; ¹Huawei Technologies Co., Ltd., China; ²China Mobile Research Inst., China. We experimentally demonstrated a 10G tunable InP TOSA based 100G 4-PAM transmission over 80 km SSMF employing Kramers-Kronig receiving technologies, nonlinear compensation algorithm and partial response signaling. The required OSNR of 32.5 dB at the 7% overhead FEC limit (BER=4. x10⁻³) was achieved.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

1990-1991. Since joining Bell Labs in 1995, Doerr's research has focused on integrated devices for optical communication. He received the OSA Engineering Excellence Award in 2002. He is a Fellow of IEEE and OSA. He was Editor-in-Chief of IEEE Photonics Technology Letters from 2006-2008. He was an Associate Editor for the Journal of Lightwave Technology from 2008-2011. He was awarded the IEEE William Streifer Scientific Achievement Award in 2009. He became a Bell Labs Fellow in 2011. He joined Acacia Communications in 2011.

Room 6E

Tu2F • Capacity Planning—Continued

Tu2F.3 • 15:15
Benefit of Progressive Deployment of Regenerators along with Traffic Growth in WDM Elastic Networks, Thierry Zami¹, Annalisa Morea¹, Jelena Pasic²; ¹Nokia Corporation, France; ²Nokia Bell Labs, France. We present a new strategy of regenerator placement along with traffic growth in the elastic WDM networks, by introducing additional regenerators on the already allocated connections only from when needed to accommodate extra demand of capacity

Tu2F.4 • 15:30 **Invited**
Long-term Capacity Planning in Facebook Network, Yuri Smirnov¹, Alex Gilgur¹; ¹Facebook Inc., USA. This paper discusses future traffic prediction and design of resilient communication networks as part of long-term capacity planning initiatives at Facebook.



Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

Tu2G.3 • 15:15 **Real-time Investigation of Transmission Latency of Standard 4K and Virtual-reality Videos over a Commercial PON Testbed**, Jun Shan Wey³, Junwen Zhang³, Xiaohuan Lu¹, Zhuang Ma², Biduo Chen², ¹ZTE Corp - Nanjing, China; ²ZTE Corp - Shanghai, China; ³ZTE TX - NJ, USA. Video applications are key drivers for future PON systems; however, it is unclear how network latency impacts video performance. This paper reports experimental results and show that G-PON can support IPTV/OTT services for standard and virtual-reality 4K videos.

Tu2G.4 • 15:30 **How Far Can Optical Access Networks Support in Multi-access Edge Computing for Low Delay?**, Junli Xue¹, Guochu Shou¹, ¹Beijing Univ. of Posts and Telecommunications, China. This paper proposes an optical access network scheme to support multi-access edge computing. Experiments in the testbed demonstrate that the round-trip time of optical access networks with 60km fiber and 5hops is below 1ms.

Room 7AB

Tu2H • Open Platform Summit: Open Platforms for Optical Innovation—Continued

Tu2H.3 • 15:15 **Experimental Effect of Scattering on an 80-Gbit/s QPSK Wireless Link using 4 Orbital-angular-momentum Beams**, Runzhou Zhang¹, Long Li¹, Zhe Zhao¹, Guodong Xie¹, Peicheng Liao¹, Hao Song¹, Cong Liu¹, Haoqian Song¹, Kai Pang¹, Robert Bock³, Moshe Tur², Alan E. Willner¹, ¹Univ. of Southern California, USA; ²School of Electrical Engineering, Tel Aviv Univ., Israel; ³R-dEX system, USA. We experimentally investigate the effect of multiple scattering on the performance of an 80-gbit/s orbital angular momentum (OAM) multiplexed optical wireless link regarding both power loss and channel crosstalk.

Tu2H.4 • 15:30 **An IF-free TDM Fronthaul Aggregating Two 128-MIMO Signals with Enhanced Spectral Efficiency Using Baseband Sample Interleaved Gathering**, Longsheng Li¹, Meihua Bi^{1,2}, Yunhao Zhang¹, Kuo Zhang¹, Xin Miao¹, Weisheng Hu¹, ¹Shanghai Jiao Tong Univ., China; ²College of Communication Engineering, Hangzhou Dianzi Univ., China. We demonstrate a novel signal-sample-interleaved-gathering scheme in the TDM-based analog fronthaul, where signal aggregation is completely realized by simple DSP without intermediate-frequency (IF)-conversion. Experiment aggregating two 128-MIMO signals verifies that ~25% signal bandwidth is reduced.

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.5 • 15:15 **Multi-material and Multi-functional Optical Fibers**, Fabien Sorin¹, ¹Ecole Polytechnique Fédérale de Lausanne, Switzerland. We will present the material science behind thermal drawing that enables us to impart optical fibers with novel architectures and advanced optoelectronic functionalities, as well as propose a new avenue for soft optical devices.

Tu2I.6 • 15:15 **Invited** **First Demonstration of an Ultra-low-latency Fronthaul Transport Over a Commercial TDM-PON Platform**, Sarvesh S. Bidkar¹, Joseph Galaro², Thomas Pfeiffer¹, ¹Access Research, Nokia Bell Labs, Germany; ²Access Research, Nokia Bell Labs, USA. We demonstrate for the first time, feasibility of latency-critical mobile fronthaul (CPRI) transport over a 6 km PON infrastructure with co-existing residential broadband traffic using a standards-compliant commercial TDM-PON platform with a sub-200 µs round trip delay.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Tu2J.6 • 15:15 **Invited** **Low Latency Networks: Future Service Level Use Cases and Requirements**, Michael Freiberger¹, Mark T. Watts¹, ¹Verizon Communications Inc, USA. The Tactile Internet with mobile and machine-to-machine (M2M) applications, along with long-standing financial and storage applications, are driving optical services to provide higher bandwidth, higher availability, and increasingly lower latency.

Tu2J.7 • 15:30 **Invited** **Enabling the Key Applications for Transport SDN**, OIF. We demonstrate for the first time, feasibility of latency-critical mobile fronthaul (CPRI) transport over a 6 km PON infrastructure with co-existing residential broadband traffic using a standards-compliant commercial TDM-PON platform with a sub-200 µs round trip delay.

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

Tu2K.3 • 15:15 **Invited** **Enabling the Key Applications for Transport SDN**, OIF. We demonstrate for the first time, feasibility of latency-critical mobile fronthaul (CPRI) transport over a 6 km PON infrastructure with co-existing residential broadband traffic using a standards-compliant commercial TDM-PON platform with a sub-200 µs round trip delay.

Tu2K.4 • 15:30 **Invited** **Enabling the Key Applications for Transport SDN**, OIF. We demonstrate for the first time, feasibility of latency-critical mobile fronthaul (CPRI) transport over a 6 km PON infrastructure with co-existing residential broadband traffic using a standards-compliant commercial TDM-PON platform with a sub-200 µs round trip delay.

Show Floor Programming

Disaggregating the Transport Layer: What It Means to The Bottom Line

Session Sponsored by Juniper Networks
14:00–17:00

Enabling the Key Applications for Transport SDN

OIF
14:30–15:30

MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics

14:30–16:00

AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions

AIM Photonics
15:45–16:45

Talk and Tour: Case Installation of Fiber-based Distributed Antenna System at the San Diego Convention Center

16:15–17:00

For more details, see page 21

Tuesday, 13 March



Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.6 • 15:45
Sub-wavelength Spacing Optical Phase Array Nanoantenna Emitter with Vertical Silicon Photonic Vias, Yu Zhang¹, Chuan Qin¹, Kuanping Shang¹, Gengchen Liu¹, Guangyao Liu¹, S. J. Ben Yoo¹; ¹ECE, Univ. of California, Davis, USA. We propose and demonstrate an ultra-compact single-side emission nanoantenna array with sub-wavelength spacing utilizing silicon photonic vertical vias with 45° reflectors. A 24-channel optical phase array with thermal tuners demonstrates a proof-of-concept emission pattern.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

Room 2

Tu2C • Short Reach I—Continued

Tu2C.7 • 15:45 **Top Scored**
Single-channel 480-gb/s Direct Detection of POL-MUX IQ Signal using Single-sideband Stokes Vector Receiver, Di Che¹, Chuanbowen Sun¹, William Shieh¹; ¹Univ. of Melbourne, Australia. We propose the single-sideband Stokes vector receiver to demultiplex a 4-d signal that fundamentally solves the carrier fading of POL-MUX direct detection, verified by a POL-MUX 60-GBaud 16-QAM transmission over 80-km SSMF with digital dispersion post-compensation.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.7 • 15:45 **Top Scored**
The Enhanced Kramers-Kronig Receiver, Lior Blech¹, Yonina Eldar², Cristian Antonelli³, Antonio Mecozzi³, Mark Shtaif¹; ¹Tel-Aviv Univ., Israel; ²Technion, Israel; ³Univ. of L'Aquila, Italy. We present a new receiver scheme that recovers complex-valued QAM modulated data while using two separate branches of direct detection. Its power efficiency is far better than in other receiver schemes of comparable characteristics.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

Room 6E

Tu2F • Capacity Planning—Continued

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

NOTES



Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

Tu2G.5 • 15:45
Dynamic Routing of Y-00 Quantum Stream Cipher in Field-deployed Dynamic Optical Path Network, Fumio Futami¹, Takayuki Kurosu², Ken Tanizawa¹, Kentaro Kato¹, Satoshi Suda², Shu Namiki²; ¹Tamagawa Univ., Japan; ²National Inst. of Advanced Industrial Science and Technology (AIST), Japan. Secure GbE communication by Y-00 protocol using noise masking for inter-datacenter connections is demonstrated in a dynamic optical path network testbed in Tokyo. We achieve dynamic path change with key re-synchronization between Y-00 cipher transceivers.

Room 7AB

Tu2H • Open Platform Summit: Open Platforms for Optical Innovation—Continued

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.7 • 15:45
Free Space Intra-datacenter Interconnection Utilizing 2D Optical Beam Steering, Behnam Shariati¹, Adonis Bogris^{2,3}, Paul V. Dijk⁴, Chris G. H. Roeloffzen⁴, Ioannis Tomkos⁵, Dimitris Syvridis³; ¹Universitat Politècnica de Catalunya, Spain; ²Technological Educational Inst. of Athens (TEI), Greece; ³National and Kapodistrian Univ. of Athens (UOA), Greece; ⁴LioniX International, Netherlands; ⁵Athens Information Technology (AIT), Greece. We evaluate the performance and benefits of novel integrated Free-space-optics (FSO) transceivers, supporting optical beam steering at low power consumption with ns steering speed. A proper intra-datacenter network architecture is also presented.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

Show Floor Programming

Disaggregating the Transport Layer: What It Means to The Bottom Line
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For more details, see page 21

Tuesday, 13 March

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

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Room 1A

16:30–18:15
Tu3A • Planar Waveguide Platforms
Presider: Haoshuo Chen; Nokia Bell Labs, USA

Tu3A.1 • 16:30
Ultra-compact Silicon Multi-mode Waveguide Bend based on Sub-wavelength Asymmetric Y-junction, Weijie Chang¹, Lulu Lu¹, Deming Liu¹, Minming Zhang¹; ¹Huazhong Univ. of Science and Tech, China. An ultra-compact multi-mode bend composed of a pair of asymmetric Y junction based on inverse-designed subwavelength structures is proposed and experimentally demonstrated with inter-mode crosstalk < -24 dB, a footprint of 3.6 × 3.6 μm².

Tu3A.2 • 16:45
Ultra-low Loss Silicon Oxynitride (SiO_xN_y) Quantum Photonic Platform, Soon Thor Lim¹, Alagappan Gandhi¹, Jun Rong Ong¹, Thomas Ang¹, Ching Eng, Jason Png^{1,2}; ¹Photonics and Plasmonics, Inst. of High Performance Computing, Singapore; ²OPTIC2connect, Singapore. SiO_xN_y shows promises for bright emitters of single photons. We successfully fabricated ultra-low-loss SiO_xN_y waveguide and AWG with low insertion loss <1dB and <3dB total loss (<2dB on-chip loss and <1dB coupling loss) at 1310nm.

Room 1B

16:30–18:30
Tu3B • SDM Fibers
Presider: Tetsuya Hayashi; Sumitomo Electric Industries Ltd, Japan

Tu3B.1 • 16:30 Invited
Recent Progress and Outlook on Multicore Fiber for Practical Use, Tomohiro Gonda¹, Katsunori Imamura¹, Kohei Kawasaki¹, Ryuichi Sugizaki¹, Shinichi Arai¹, Masayoshi Tsukamoto¹, Masato Shiino¹; ¹Furukawa Electric, Japan. We review our recent achievement on uncoupled MCF for practical use. We introduce 4core-MCF with 125μm cladding which has upgradability from standard SMF system to MCF system, connecting technology and ultra-high density MCF-cable.

Room 2

16:30–18:15
Tu3C • Coding and Modulation
Presider: Alex Alvarado; Eindhoven Univ. of Technology, Netherlands

Tu3C.1 • 16:30
Rate-adaptive LDPC Convolutional Coding with Joint Layered Scheduling and Shortening Design, Toshiaki Koike-Akino¹, David Millar¹, Kieran Parsons¹, Keisuke Kojima¹; ¹Mitsubishi Electric Research Labs, USA. We propose a joint design method of layered scheduling, shortening and puncturing for LDPC convolutional codes to be scalable across a variety of overhead ranges. Our method achieves greater than 0.4 dB gain over conventional methods.

Tu3C.2 • 16:45 Top Scored
Multilevel Coding with Spatially-coupled Codes for beyond 400Gbps Optical Transmission, Yohei Koganei¹, Tomofumi Oyama¹, Kiichi Sugitani², Hisao Nakashima¹, Takeshi Hoshida¹; ¹Fujitsu Laboratories Ltd., Japan; ²Fujitsu Kyushu Network Technologies Ltd., Japan. We propose a multilevel coding technique inheriting the performance of spatially-coupled codes. Net coding gains of 12.5, 13.2 and 13.7dB are expected for 16, 64 and 256QAM with low implementation complexity.

Room 6C

16:30–18:30
Tu3E • Transport Network Design ▶
Presider: António Eira; Coriant, Portugal

Tu3E.1 • 16:30 ▶
Networking Benefit of Multi-subcarrier Transceivers, Mattia Cantono¹, Fernando Guiomar¹, Andrea Carena¹, Vittorio Curri¹; ¹Politecnico di Torino, Italy. We analyze the benefit of multi-subcarrier transceivers on two network topologies. We describe nonlinearities modeling challenges and demonstrate the existence of an optimal subcarrier symbol rate at network-level yielding average OSNR increase up to 0.7dB.

Tu3E.2 • 16:45 ▶
Remote Abstraction of an Installed Dark Fiber Network using Noise to Signal Ratio, David J. Ives¹, Francisco Javier Vaquero Caballero¹, Seb J. Savory¹; ¹Univ. of Cambridge, UK. A dark fiber network was partially abstracted utilizing network monitors, prior information and a single probe channel. Validation employed 13x200Gb/s DWDM signals transmitted at the optimum launch power, with measured performance 0.2dB better than abstracted.

Room 6D

16:30–18:30
Tu3F • Silicon Photonic Interconnection Networks ▶
Presider: Adel Saleh; Univ. of California Santa Barbara, USA

Tu3F.1 • 16:30 Tutorial ▶
Silicon Photonics for High Performance Interconnection Networks, Keren Bergman¹; ¹Electrical Engineering, Columbia Univ., USA. The growth in data analytics applications is driving the need for intense datacenter interconnect performance. The tutorial will explore silicon-photonics networks that leverage dynamic bandwidth steering for delivering required bandwidths at reduced system-wide energy consumption.



Keren Bergman is the Charles Batchelor Professor of Electrical Engineering at Columbia University where she serves as the Scientific Director of the Columbia Nano Initiative. Prof. Bergman received the B.S. from Bucknell University in 1988, and the M.S. in 1991 and Ph.D. in 1994 from M.I.T. all in Electrical Engineering. At Columbia, Bergman leads the Lightwave Research Laboratory encompassing multiple cross-disciplinary programs at the intersection of computing and photonics. Bergman serves on the Leadership Council of AIM Photonics leading projects that support the institute's silicon photonics manufacturing capabilities and Datacom applications. She is a Fellow of the OSA and IEEE.

Room 6E

16:30–18:15
Tu3G • Nonlinearity Compensation and Encrypted Communication ▶
Presider: Fotini Karinou; Huawei Technologies Duesseldorf GmbH, Germany

Tu3G.1 • 16:30 Tutorial ▶
Enabling Technologies for Fiber Nonlinearity Mitigation in High Capacity Transmission Systems, Olga Vassilieva¹; ¹Fujitsu Laboratories of America Inc, USA. We review the latest technologies for fiber nonlinearity mitigation to extend reach of high capacity transmission systems. This tutorial discusses their basic principles, practical implementations and future challenges.



Olga Vassilieva, Ph.D., is a senior member of the research staff for Fujitsu Laboratories of America, Inc., specializing in research and development of high bit-rate coherent optical transmission systems, advanced optical modulation formats, and transmission impairment mitigation techniques. She has worked at Fujitsu since August, 2000. Dr. Vassilieva is a member of the IEEE Photonics Society, the author and co-author of numerous scientific papers, and holds more than 40 patents.



Room 6F

16:30–18:30
Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems 
Organizers: Loukas Paraschis, Infinera, USA; Vijay Vusirikala, Google, USA

New network analytics frameworks, extensively based on innovations in streaming telemetry methodologies, and lately even combined with the potential of cognitive systems, have been increasingly considered an important evolution of network management and mediation for wireline transport. More specifically, new innovative wireline transport automation and abstraction frameworks have been developed mainly by network operators; like Openconfig, Open-ROADM, and more recently TIP. These frameworks identify network analytics as a very important use-case. For example, OpenConfig, in particular, has identified streaming telemetry as a top priority, and explicitly aims to replace “data-pull” monitoring to address limitations of the current network monitoring technologies (notably SNMP). It has already enjoyed significant evidence of success by achieving initial “all-you-can-eat” streaming telemetry implementations from the major routing, and more recently also transport vendors.

The underlying motivation for this evolution in network management is to a great extent related to the pervasive “scale-out” of automation use-cases successfully employed initially by hyper-scale compute inside the Weboperators’ massively scalable DCs. These innovations have been extended to networking with the exciting end-goal of a fully autonomic, policy-driven network operations paradigm with little (if any) human intervention. However, extending the automation achievements of compute to WAN transport may raise some interesting new challenges. Notably,

continued on page 83

Room 7AB

16:30–18:30
Tu3I • Panel: Flexible Grid Deployments
Organizers: Dave Boertjes, Ciena Corp., Canada, Mei Du, Tata Communications, USA

The Flexible Grid has created a lot of excitement in the industry. It promises a large degree of freedom over the usage of optical spectrum, and as a result the bulk of new ROADM deployments today are Flexible Grid capable, if not enabled. It's a sort of insurance policy which enables the photonic network to be future proof for any spectral width of transceiver which may be developed. But with the vast possibilities of flexibility come challenges in deployment complexity which must be balanced against the actual benefit in terms of things like spectral efficiency and overall cost of ownership. This panel considers optical network deployments based on flex-grid technologies including the impacts on software models, the relationship to flexible rate transceivers and challenges of network control and management.

Panelists:

- Brandon Collings, *Lumentum, USA*
- Lara Garrett, *TE Subcom, USA*
- David Miedema, *Ciena, USA*
- Rene Schmogrow, *Google, USA*
- Thomas Strasser, *Nistica, USA*
- Glenn Wellbrock, *Verizon, USA*

Room 8

16:30–18:30
Tu3J • 5G Photonic Systems
President: Christina Lim; Univ. of Melbourne, Australia

Tu3J.1 • 16:30  Invited
RoF-based Optical Fronthaul Technology for 5G and Beyond, Hoon Kim¹; ¹KAIST, Korea. We explore the possibility of using directly modulated laser for the implementation of mobile fronthaul networks based on the RoF technology. The deleterious effects arising from laser's chirp are investigated together with their compensation techniques.

Room 9

16:30–18:15
Tu3K • Heterogeneous Integration
President: Thomas Schrans; Rockley Photonics, USA

Tu3K.1 • 16:30  Invited
Optical Transceivers using Heterogeneous Integration on Silicon, Gregory Fish¹; ¹Juniper Networks Inc., USA. The heterogeneous integration of InP into a silicon photonics platform enables the inclusion of all photonic elements in a cost-effective manufacturing process that fundamentally changes how photonic transceivers can be packaged and integrated into systems.

Room 10

16:30–18:30
Tu3L • Software - Defined Access
President: Ken-Ichi Suzuki; NTT Access Network Service Systems Labs., Japan

Tu3L.1 • 16:30
Remotely Controlled XG-PON DBA with Linear Prediction for Flexible Access System Architecture, Naoki Hanaya¹, Yu Nakayama², Manabu Yoshino², Ken-Ichi Suzuki², Ryogo Kubo¹; ¹Keio Univ., Japan; ²NTT, Japan. We propose a dynamic bandwidth allocation (DBA) algorithm with linear prediction in a remotely controlled 10-gigabit-capable passive optical network (XG-PON). Simulation results show that the proposed DBA provides low-latency upstream communication compared to non-predictive DBA.

Tu3L.2 • 16:45  Top Scored
Coherent Receiver DSP Implemented on a General-purpose Server for Full Software-defined Optical Access, Sangyeup Kim¹, Takahiro Suzuki¹, Jun-Ichi Kani¹, Akihiro Otaka¹, Toshihiro Hanawa²; ¹NTT Corporation, Japan; ²The Univ. of Tokyo, Japan. We propose a novel software-defined access scheme combined with DSP-enabled (de)modulation approaches and demonstrate a Real-time coherent detection of 5-gbit/s QPSK signals on a general-purpose server for a full software-defined platform for the first time.

Show Floor Programming

Disaggregating the Transport Layer: What It Means to The Bottom Line
Session Sponsored by Juniper Networks
 14:00–17:00

AIM Photonics: Meeting Challenges of the Marketplace and Providing Innovative Solutions
AIM Photonics
 15:45–16:45

Talk and Tour: Case Installation of Fiber-based Distribution Antenna System at the San Diego Convention Center
 16:15–17:00
 For more details, see page 21

Tuesday, 13 March

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Room 1A

Tu3A • Planar Waveguide Platforms—Continued

Tu3A.3 • 17:00

A Compact Thin-film Lithium Niobate Platform with Arrayed Waveguide Gratings and MMIs, Mathias Prost¹, Guangyao Liu¹, S. J. Ben Yoo¹; ¹*Department of Electrical and Computer Engineering, Univ. of California, Davis, USA*. We design and demonstrate a thin-film z-cut Lithium Niobate photonic platform. We report experimental transmission measurement of different passive photonic building blocks at 1.55 μm central wavelength including AWG and MMI splitter.

Tu3A.4 • 17:15

32-port 5.5%- Δ Silica-based Connecting Device for Low-loss Coupling between SMFs and Silicon Waveguides, Junichi Hasegawa¹, Kazuhiro Ikeda², Keijiro Suzuki², Shintaro Yamasaki¹, Go Kobayashi¹, Masanori Takahashi¹, Hitoshi Kawashima²; ¹*Furukawa Electric Co., Ltd., Japan*; ²*National Inst. of Advanced Industrial Science and Technology, Japan*. We report a low-loss connecting technique between silicon waveguides and standard single-mode fibers using a unique extremely-high- Δ silica-based PLC. 32-port coupling with coupling losses of 1.4-1.6 dB/facet and pitch conversion has been demonstrated.

Room 1B

Tu3B • SDM Fibers—Continued

Tu3B.2 • 17:00 **Invited**

Few-mode and Multicore Amplifiers for SDM Transmissions, Laurent Bigot¹, Jean-Baptiste Trinel¹, Géraud Bouwmans¹, Esben Ravn Andresen¹, Yves Quiquempois¹; ¹*CNRS - Université Lille 1, PhLAM, France*. The optical performances of few-mode and multicore fiber amplifiers will strongly influence the future of SDM for long-haul transmission. We review this topic with a special focus on a new generation of few-mode erbium-doped fiber.

Room 2

Tu3C • Coding and Modulation—Continued

Tu3C.3 • 17:00 **Invited**

Coded Modulation for Next-generation Optical Communications, David Millar¹, Tobias Fehenberger¹, Toshiaki Koike-Akino¹, Keisuke Kojima¹, Kieran Parsons¹; ¹*Mitsubishi Electric Research Labs, USA*. We review coded modulation for next-generation coherent optical communications systems. Geometric constellation shaping is discussed in detail, along with strategies to maintain complexity at levels comparable to a conventional square quadrature amplitude modulation (QAM) with bit-interleaved coded modulation (BICM) architecture.

Room 6C

Tu3E • Transport Network Design—Continued

Tu3E.3 • 17:00 **Invited**

Data Analytics based Optical Performance Monitoring Technique for Optical Transport Networks, Takahito Tanimura^{1,2}, Takeshi Hoshida¹, Tomoyuki Kato¹, Shigeki Watanabe¹, Hiroyuki Morikawa²; ¹*Fujitsu Laboratories Ltd., Japan*; ²*The Univ. of Tokyo, Japan*. We experimentally demonstrate that a convolutional neural network (CNN) can acquire an accurate OSNR estimation functionality from asynchronously sampled data right after intradyne coherent detection, while the feature selection before the CNN can be omitted.

Room 6D

Tu3F • Silicon Photonic Interconnection Networks—Continued

Room 6E

Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued





Room 6F

Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems—Continued

WANs are characterized by significant heterogeneity in technology (both hardware and software), in failure modes (with typically more stringent availability requirements, e.g. up to 5 9s), and in performance metrics (e.g. latency variation in the WAN can be 3 to 9 orders of magnitude more than in compute).

In this symposium, senior architects of network operations, engineering, and development teams have been invited to debate the most important characteristics, and true value of network analytics, telemetry, and cognitive systems in next generation network management and mediation. Such software innovations have become increasingly important for next-generation transport networks, both packet and optical. Among the many interesting topics, the symposium will particularly aim to explore:

- What are the key enabling technology and system innovations, and remaining limitations towards this new generation of Network Management and Mediation for wireline transport based on streaming Telemetry and Network Analytics? What is the current reality, and true future potential of Cognitive Systems?
- What are the key similarities and differences in network analytics and cognitive systems between routing and optical transport?

continued on page 85

Room 7AB

Tu3I • Panel: Flexible Grid Deployments—Continued

Room 8

Tu3J • 5G Photonic Systems—Continued

Tu3J.2 • 17:00
Asynchronous Transmission using Universal Filtered Multicarrier for Multiservice Applications in 5G Fiber-wireless Integrated Mobile Fronthaul, Hyung Joon Cho¹, Hyunwoo Cho¹, Mu Xu¹, Feng Lu¹, Shuyi Shen¹, Xiaoli Ma¹, Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA. We propose a fiber-wireless-access system capable of asynchronous transmission with diverse applications in 5G communication through UFMC modulation. Experimental results validate stable asynchronous data transmission with three different services while reducing number of sub-band filters.

Tu3J.3 • 17:15
Experimental Demonstration of Bandwidth-efficient Indoor Distributed Antenna System based on IFoF Technology supporting 4G LTE-A and 5G Mobile Services, Minkyu Sung¹, Joonyoung Kim¹, Seung-Hyun Cho¹, Hwan Seok Chung¹, Joonki Lee¹, Jong Hyun Lee¹; ¹Optical Network Research Group, Electronics and Telecommunications Research Inst. (ETRI), Korea. We report the demonstration of IFoF based indoor distributed-antenna-system supporting 4G-LTE-a and 5G services. We confirm the feasibility of technology that simultaneous clock, C&M and data transmission over modulated IF carriers for cost-effective Indoor DAS

Room 9

Tu3K • Heterogeneous Integration—Continued

Tu3K.2 • 17:00 **Invited**
Heterogeneously Integrated III-V Lasers Fabricated Using Epitaxial Growth on an InP/SiO₂/Si Substrate, Takuro Fujii^{1,2}, Koji Takeda^{1,2}, Hidetaka Nishi^{1,2}, Shinji Matsuo^{1,2}; ¹NTT Device Technology Laboratories, Japan; ²NTT Nanophotonics Center, Japan. We present a III-V/Si integration technology that employs epitaxially-grown active layers on an InP/SiO₂/Si substrate for low-cost fabrication of PICs. Based on it, a directly-modulated membrane-laser array exhibiting a low, VCSEL-like operating energy is reported.

Room 10

Tu3L • Software - Defined Access—Continued

Tu3L.3 • 17:00
Experimental Demonstration for over Mbps Baseband-over-modulation AMCC Implementation in PtP WDM-PON, Zhongwei Tan¹, Chuanchuan Yang¹, Zhaopeng Xu¹, Lei Chen², Xingang Huang², Haipeng Guo¹, Ziyuan Zheng¹, Fan Zhang¹, Ziyu Wang¹; ¹Peking Univ., China; ²ZTE Corporation, China. Up to 10 Mbps transmission of nonlinear baseband-over-modulation AMCC implementation in different modulation index over 10 Gbps PtP WDM-PON is experimentally demonstrated. The results confirm lower power penalty for PON signal in AMCC superimposition.

Tu3L.4 • 17:15
Wavelength Adjustment of Upstream Signal using AMCC with Power Monitoring for WDM-PON in 5G Mobile Era, Kazuaki Honda¹, Hirotaka Nakamura¹, Kazutaka Hara¹, Kyosuke Sone², Goji Nakagawa², Yoshio Hirose², Takeshi Hoshida², Jun Terada¹, Akihiro Otaka¹; ¹NTT Access Network Service Systems Laboratories, NTT, Japan; ²Fujitsu Limited, Japan. We propose the wavelength adjustment method of the upstream signal using the AMCC complied with G.989.3 against the wavelength drift in WDM-PON and demonstrate it in the evaluation platform implementing the AMCC processor.

Show Floor Programming

Tuesday, 13 March



Room 1A

Tu3A • Planar Waveguide Platforms—Continued

Tu3A.5 • 17:30 **Invited**
3µm Silicon Photonics, Timo T. Aalto¹, Matteo Cherchi¹, Mikko Harjanne¹, Fei Sun¹, Markku Kapulainen¹; ¹VTT Technical Research Centre of Finland, Finland. This paper presents the latest progress in the development of compact and low-loss photonic integrated circuits on 3-micron silicon-on-insulator platform that covers both near and mid-infrared applications.

Room 1B

Tu3B • SDM Fibers—Continued

Tu3B.3 • 17:30
Inter-core Skew Measurements in Temperature Controlled Multi-core Fiber, Benjamin J. Puttnam¹, Georg Rademacher¹, Ruben S. Luis¹, Jun Sakaguchi¹, Yoshinari Awaji¹, Naoya Wada¹; ¹National Inst Info & Comm Tech (NICT), Japan. We investigate propagation delay (skew) between cores of an MCF and 2 spans of SMF in a temperature controlled environment. Temperature variations increase measured skew-fluctuations with skew-variation in SMF orders of magnitude larger than between MCF cores.

Tu3B.4 • 17:45
Experimental and Analytical Characterization of Time Variation of ICXT in MCFs with Multiple Interfering Cores, Tiago F. Alves¹, Adolfo Cartaxo¹; ¹Instituto de Telecomunicações, Portugal. A stochastic model for the time-variation of crosstalk in multicore-fibers with multiple interfering cores is proposed and validated experimentally. This model enables the system design using the properties of crosstalk generated by single interfering cores.

Room 2

Tu3C • Coding and Modulation—Continued

Tu3C.4 • 17:30
An Iterative Soft Interference Cancellation for Pilot-assisted Optical-OFDM with LDPC Code Optimized by EXIT Chart, Noboru Osawa¹, Shinsuke Ibi¹, Koji Igarashi¹, Seiichi Sampei¹; ¹Osaka Univ, Japan. This paper proposes an iterative soft interference canceller with the assistance of LDPC code for mitigating beat interference in a pilot-assisted optical-OFDM. The LDPC code is analytically optimized by EXIT chart based on Turbo principle.

Tu3C.5 • 17:45
Irregular Polar Turbo Product Coding for High-throughput Optical Interface, Toshiaki Koike-Akino¹, Congzhe Cao², Ye Wang¹, Keisuke Kojima¹, David Millar¹, Kieran Parsons¹; ¹Mitsubishi Electric Research Labs, USA; ²Electrical & Computer Engineering, Univ. of Alberta, Canada. We propose polar turbo product code (TPC) to enable parallel/pipeline decoding, for high-throughput transmission. With irregular polar codes, the computational complexity and latency can be significantly reduced, yet outperforming BCH-constituent TPC by 0.5dB.

Room 6C

Tu3E • Transport Network Design—Continued

Tu3E.4 • 17:30 **▶**
Towards a Route Planning Tool for Open Optical Networks in the Telecom Infrastructure Project, Brian Taylor¹, Gilad Goldfarb¹, Saamil Bandyopadhyay¹, Vittorio Curri², Hans-Juergen Schmidke¹; ¹Facebook, USA; ²Politecnico di Torino, Italy. We explore the validity of the Gaussian-noise (GN) model as the basis for an open-source optical network planning tool. Comparison of experimental results and TIP-PSE GN-model based predictions suggest the GN model a feasible choice.

Tu3E.5 • 17:45
Demonstrating Network-scale Gain Transient Impact of Multiple Series EDFAs in Link Failure Cases, Yusuke Hirota¹, Masaki Shiraiwa¹, Hideaki Furukawa¹, Hiroaki Harai¹, Naoya Wada¹; ¹NICT, Japan. This paper identifies that a link failure causes temporal QoT degradation propagation of 40.2% existing paths in a whole network by conventional EDFA and experimentally demonstrates this transient degradation can be suppressed by burst-mode EDFA.

Room 6D

Tu3F • Silicon Photonic Interconnection Networks—Continued

Tu3F.2 • 17:30 **▶**
Autonomous Dynamic Bandwidth Steering with Silicon Photonic-based Wavelength and Spatial Switching for Datacom Networks, Yiwon Shen¹, Alexander Gazman¹, Ziyi Zhu¹, Min Yee Teh¹, Maarten Hattink¹, Sebastien Rumley¹, Payman Samadi¹, Keren Bergman¹; ¹Columbia Univ., USA. We present an autonomous SDN network architecture that leverages the spatial and wavelength switching capabilities of silicon photonics microring-based circuits for self-adaptive bandwidth steering. These functionalities are seamlessly integrated and demonstrated in a datacom testbed.

Tu3F.3 • 17:45 **▶**
Reconfigurable Silicon Photonic Platform for Memory Scalability and Disaggregation, Erik F. Anderson¹, Alexander Gazman¹, Ziyi Zhu¹, Maarten Hattink¹, Keren Bergman¹; ¹Columbia Univ., USA. We demonstrate a bi-directional optically-connected memory architecture based on a silicon photonic platform. Optical multicast and sub-microsecond spatial switching is demonstrated to minimize reconfiguration times of 10Gbps data-streams between a CPU and two memory nodes.

Room 6E


Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued

Tu3G.2 • 17:30 **Invited** **▶**
Deployed Systems for Quantum Communications, Qiang Zhang¹; ¹Univ. of Science and Technology of China, China. Quantum cryptography can provide information theoretical secure communication. I shall review the deployed quantum communication systems in China, including metropolitan, backbone and satellite based international network, the technology challenging, the performance and an outlook.



Room 6F

Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems—Continued

Tu3H.1 • 16:30 **Invited** 
Multi-vendor Streaming Telemetry, Anees Shaikh¹; ¹Google, USA. Network control and management is increasingly being performed by software systems that are able to rapidly and automatically reconfigure the network in response to changes in traffic or health based on the availability of accurate, real-time state from the network. However, traditional monitoring technologies, both in routing and transport, are ill-equipped to support these requirements due to limitations such as long polling loops, excessive resource consumption on devices, and archaic transport protocols and data formats. To address these challenges, we have defined and implemented a new approach to telemetry for network devices, working with the broader industry. Streaming telemetry provides significant improvements in data coverage and data frequency, and a modern architecture that is well suited to automation and software-defined control. In this talk, we will discuss our experience with introducing streaming telemetry for both optical transport and routing platforms, and the benefits of a model-based approach to simplify monitoring in a complex, multi-vendor environment.

Tu3H.2 • 16:54 **Invited**
Real-Time Traffic Management in AT&T's SDN-Enabled Core IP/Optical Network, Simon Tse¹; ¹AT&T, USA. AT&T deployed an SDN controller that co-manages real-time traffic routing using a highly efficient optimization engine for its core IP network. This paper highlights some key learnings from the implementation and potential future work.

Room 7AB

Tu3I • Panel: Flexible Grid Deployments— Continued

Room 8

Tu3J • 5G Photonic Systems—Continued

Tu3J.4 • 17:30
Demonstration of Non-orthogonal Multiple Access Scheme using Multilevel Coding without Successive Interference Cancellation with 60 GHz Radio-over-fiber Fronthaul, Yu Tian¹, Ka-Lun Lee¹, Christina Lim¹, Ampalavanapillai Nirmalathas¹; ¹Department of Electrical and Electronic Engineering, Univ. of Melbourne, Australia. We propose a multilevel coding based non-orthogonal multiple access scheme for 60 GHz RoF fronthaul link and verify through experiments with error-free transmission over 3-km fiber and 2.5-m wireless link, serving two users at cell edge and center.

Tu3J.5 • 17:45
Power-fading-free IF-over-fiber Transmission with DEMZM using Simple Chirp Control for High-capacity Mobile Fronthaul Links, Shota Ishimura¹, Abdelmoula Bekkali¹, Kazuki Tanaka¹, Kosuke Nishimura¹, Masatoshi Suzuki¹; ¹KDDI Research, Inc., Japan. We propose a simple power-fading-free IF-over-fiber transmission scheme with DEMZM. We successfully transmitted signals over 20-km SMF with 589.7-gb/s CPRI-equivalent data rate and achieved better performance than the parallel IM/PM transmission system.

Room 9

Tu3K • Heterogeneous Integration—Continued

Tu3K.3 • 17:30 **Invited**
High-efficiency, Low-loss Optical Phase Modulator based on III-V/Si Hybrid MOS Capacitor, Mitsuru Takenaka¹, Jae-Hoon Han¹, Jin-Kwon Park¹, Frederic Boeuf¹, Junichi Fujikata², Shigeki Takahashi², Shinichi Takagi¹; ¹Univ. of Tokyo, Japan; ²Photonics Electronics Technology Research Association, Japan. We present efficient, low-loss phase modulation using III-V/Si hybrid MOS capacitor on Si photonics platform, which will be an essential building-block for universal photonic integrated circuits monolithically integrated with driver circuits based on InGaAs MOSFETs.

Room 10

Tu3L • Software - Defined Access— Continued

Tu3L.5 • 17:30
Multi-vendor Interoperation of SFP+ Transceivers for CPRI Signal Transmission with Superimposed AMCC for Mobile Fronthaul, Goji Nakagawa², Kyosuke Sone², Setsuo Yoshida¹, Shoichiro Oda¹, Yoshio Hirose², Takeshi Hoshida²; ¹Fujitsu Laboratories Limited, Japan; ²Fujitsu Limited, Japan. We have experimentally investigated electrical superimposition and detection characteristics of AMCC signal employing three different vendor of SFP+ transceivers and clarified the characteristics of multi-vendor interoperation, as well as the receiver sensitivity characteristics of AMCC signal.

Tu3L.6 • 17:45
10-gbps Real-time Burst-frame Synchronization Using Dual-stage Detection for Full-software Optical Access Systems, Takahiro Suzuki¹, Sangyeup Kim¹, Jun-Ichi Kani¹, Akihiro Otaka¹, Toshihiro Hanawa²; ¹NTT, Japan; ²The Univ. of Tokyo, Japan. For realizing full-software optical access systems, we propose a novel burst-frame synchronization algorithm with reduced computation complexity using dual-stage detection and, for the first time, demonstrate its 10-gbps Real-time implementation on a GPU.

Show Floor Programming

Tuesday, 13 March



Room 1A Room 1B Room 2 Room 6C Room 6D Room 6E

Tu3A • Planar Waveguide Platforms—Continued


Tu3A.6 • 18:00
Demonstration of 2 μm On-chip Two-mode Division Multiplexing using Tapered Directional Coupler-based Mode (De)Multiplexer, Meng Huang¹, Shuang Zheng¹, Yun Long¹, Lulu Wang¹, Zhengsen Ruan¹, Jian Wang¹, Li Shen¹, Shuhui Li¹; ¹Wuhan National Lab for Optoelectronics, China. We experimentally demonstrate two-mode division multiplexing with directly modulated 5-gbit/s signals on an SOI platform at the 2 μm wavelength region. The on-chip device exhibits low mode crosstalk and wide bandwidth over the wave band.

Tu3B • SDM Fibers—Continued

Tu3B.5 • 18:00
Low Loss Splicing between Coupled Multi-core Fibers with Thermally Expanded Cores, Masato Suzuki¹, Hitoshi Yoshii¹, Teruhiro Ito¹, Yoshinori Yamamoto¹, Tetsuya Hayashi¹, Takemi Hasegawa¹; ¹Sumitomo Electric Industries, Ltd., Japan. We demonstrate that the tolerance to core offsets for a low splice loss between coupled multi-core fibers can be increased to 1.6 times using thermally expanded core technique without suffering impairment by increased crosstalk.

Tu3B.6 • 18:15
Realistic Model for Frequency-dependent Crosstalk in Weakly-coupled Multicore Fiber, Lin Gan¹, Ming Tang¹, Li Shen¹, Chen Xing¹, Changjian Ke¹, Chen Yang², Weijun Tong², Songnian Fu¹, Deming Liu¹; ¹Next Generation Internet Access National, USA; ²Yangtze Optical Fiber and Cable Joint Stock Limited Company, China. We established a realistic channel model that describes frequency-dependent crosstalk precisely for weakly-coupled multicore fibers. The crosstalk variations induced by relative time delay, polarization mode dispersion and calculation step size have been discussed.

Tu3C • Coding and Modulation—Continued

Tu3C.6 • 18:00 
Energy-efficient High-throughput Staircase Decoders, Christoffer Fougstedt¹, Per Larsson-Edefors¹; ¹Chalmers Univ. of Technology, Sweden. We introduce staircase decoder implementations achieving up to 1-tb/s throughput with energy dissipation of 1.2 pJ/information bit. The implementations are estimated to achieve >10.5 dB of net coding gain depending on the configuration.


Room 6C
Tu3E • Transport Network Design—Continued

Tu3E.6 • 18:00 
Design and Deployment of Optical White Box, Niall A. Robinson¹; ¹ADVA Optical Networking AG, USA. White box solutions have been deployed inside data centers for many years. Like SDN this technological approach is spilling into the transmission world. Let's review current industry status and explore the future of this exciting space.

Room 6D
Tu3F • Silicon Photonic Interconnection Networks—Continued

Tu3F.4 • 18:00 
Silicon Photonics and Plasmonics towards Network-on-chip Functionalities for Disaggregated Computing, Nikos Pleros¹; ¹Dept of Informatics, Aristotle Univ. of Thessaloniki, Greece. The main challenges in today's landscape of chip-scale computational settings are overviewed, discussing about the potential of silicon photonics and plasmonics to yield Network-on-chip technologies and architectures capable of overcoming the limitations of current infrastructures.

Room 6E
Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued

Tu3G.3 • 18:00 
Chaotic Laser based Online Physical Random Bit Streaming System and its Application to High-throughput Encryption, Kenichi Arai¹, Susumu Shinohara², Peter Davis³, Satoshi Sunada⁴, Takahisa Harayama²; ¹NTT Corporation, Japan; ²Waseda Univ., Japan; ³Telecognix Corporation, Japan; ⁴Kanazawa Univ., Japan. We developed a high-speed entropy source using a compact chaotic laser module for streaming unpredictable random bits. It achieved 4 Gbps streaming of random bits to an encryption application via a general-purpose API.

16:30–18:30 Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, Room 6A (extended coffee break)

17:15–18:45 Exhibitor Happy Hour, Center Terrace

18:30–20:00 Conference Reception, Sails Pavilion

19:30–21:30 Rump Session: When Will Coherence Replace Direct Detection in the Data Center?, Room 6F



Room 6F

Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems—Continued

Tu3H.3 • 17:18 **Invited**
Key Enablers of Automated Optical Networks, Vinayak Dangui¹; ¹Facebook, USA. For an automated optical network, the following are key elements: (1) streamlined API to network elements, (2) optimized telemetry parameters, and (3) predictive maintenance framework. We present how these components enable automation in Facebook's network.

Tu3H.4 • 17:42 **Invited**
Network Monitoring for Cloud, Martin Machacek¹; ¹Oracle, USA. The goal of the talk is to analyze monitoring system requirements specific to cloud infrastructure networks and identify device functions allowing to address them. I'll summarize typical properties of cloud data networks, identify requirements for monitoring systems and outline key paradigms and technologies suitable for supporting them.

Tu3H.5 • 18:06 **Invited**
Intent Based Networking, David Erickson¹; ¹Forward Networks, USA. In this talk David will describe the goals and promises of Intent Based Networking, where it is at today, and example use cases driving operational value in production today.

Room 7AB

Tu3I • Panel: Flexible Grid Deployments—Continued

Room 8

Tu3J • 5G Photonic Systems—Continued

Tu3J.6 • 18:00
Blind Compensation of Nonlinear Waveform Distortions in Radio-over-fiber System, Byung Gon Kim¹, Sung Hyun Bae¹, Hoon Kim¹, Yun Chur Chung²; ¹KAIST, Korea. We propose a DSP-based nonlinearity compensation technique for RoF links which does not require any prior knowledge about the links. By using this technique, we successfully transport twelve 198-mHz-bandwidth 64-QAM f-OFDM signals over 20 km of SSF.

Tu3J.7 • 18:15
A PDM based Spectral Aggregation and Cell Densification for 5G Point-to-multipoint Mobile Fronthaul with a Polarization-tracking-free RAU Design, Jih-Heng Yan¹, Mu Xu², Hsu-Hung Huang³, Mengzhe Liao¹, Kai Ming Feng^{1,3}, Gee-Kung Chang²; ¹Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; ²School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA; ³Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan. A point-to-multipoint PDM spectral aggregation and cell densification in 5G mobile fronthaul is proposed without requiring laborious polarization tracking in RAUs. A 25-km SMF transmission experiment shows less-than-1-dB power sensitivity differences between two polarization signals.

Room 9

Tu3K • Heterogeneous Integration—Continued

Tu3K.4 • 18:00
High-speed Heterogeneous InP-on-Si Capacitive Phase Modulators, Sylvie Menezo¹, Torrey Thiessen², Philippe Grosse¹, Joyce K. Poon², Christophe Jany¹, Jérémy Da Fonseca¹, Bertrand Szlag¹, Benoit Charbonnier¹, Georgio El Zammari¹, Olivier Lemonnier¹, Patricia Bilondeau¹, Stéphane Malhouitre¹, Brigitte Montmayeul¹, Loïc Sanchez¹; ¹CEA-IETI, France; ²Univ. of Toronto, Canada. We present O-band InP-on-si phase modulators with 0.5dB IL, 1V.cm V_πL and >25GHz bandwidth for 250μm long sections. 25 Gbps operation without optical amplifiers or pre-emphasis is demonstrated with an MZM integrating such phase modulators.

Room 10

Tu3L • Software - Defined Access—Continued

Tu3L.7 • 18:00 **Invited**
Flexible Access System Architecture (FASA), Kota Asaka¹, Hirotaka Ujikawa¹, Jun-Ichi Kani¹, Akihiro Otaka¹; ¹NTT Access Network Service Systems Laboratories, Japan. To quickly meet diverse requirements given by emerging new services, we recently proposed a new concept of Flexible Access System Architecture (FASA). The paper reviews our activities on FASA along with disaggregation of time-critical functions.

Show Floor Programming

Tuesday, 13 March

16:30–18:30 Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, Room 6A (extended coffee break)

17:15–18:45 Exhibitor Happy Hour, Center Terrace

18:30–20:00 Conference Reception, Sails Pavilion

19:30–21:30 Rump Session: When Will Coherence Replace Direct Detection in the Data Center?, Room 6F



Tu3D.1

Integrated Optical-wireless Resource Slicing Management for 5G Service-based Architecture and Multi-level RAN, Rentao Gu^{1,2}, Mingyu Cen¹, Luhan Wang¹, Qize Guo^{1,2}, Yuanjiong Diao³, Han Li⁴, Chen Aimin³, Lin Bai¹, Yuefeng Ji^{1,2}; ¹Beijing Univ. of Posts and Telecommunications, China; ²Beijing Advanced Innovation Center for Future Internet Technology, Beijing Univ. of Technology, China; ³ZTE Corporation, China; ⁴China Mobile Research Inst., China. This demo provides an integrated end-to-end optical-wireless slicing cross latest SBA based core network, backhaul network and two-level fronthaul networks, presenting consistent heterogeneous coordination capabilities on different multi-vendor transport equipment and computing resources.

Tu3D.2

Demonstration of Routing and Spectrum Assignment Automation in a Transport SDN Framework, Srivatsan Balasubramanian¹, Satyajeeet Ahuja¹, Marco Rizzi¹, Gaya Nagarajan¹; ¹Facebook Inc, USA. We demonstrate a use case of transport SDN which can help with automation of routing and spectrum assignment thereby removing an error and delay prone manual planning phase.

Tu3D.3

High Performance Streaming Telemetry in Optical Transport Networks, Abhinava Sadasivarao¹, Sachin Jain¹, Sharfuddin Syed¹, Khuzema Pitheawan¹, Pravin Kantak¹, Biao Lu¹, Loukas Paraschis¹; ¹Infinera Corporation, USA. We demonstrate streaming telemetry capabilities for optical networks implemented as modular software service. The telemetry system is capable of user-defined configurable streaming to an external collector at very high frequencies of all critical optical performance metrics.

Tu3D.4

Demonstration of Real Time VNF Implementation of OLT with Virtual DBA for Sliceable Multi-tenant PONs, Frank Slyne¹, Amr Elrasad¹, Christian Bluemm¹, Marco Ruffini¹; ¹CONNECT Centre, Trinity College Dublin, Ireland. We demonstrate the VNF implementation of a sliceable PON architecture enabling true multi-tenancy, giving Virtual Network Operators full control over capacity scheduling. We analyze resource sharing efficiency and latency performance for different NFV co-location scenarios.

Tu3D.5

CASTOR: An Architecture to Bring Cognition to Transport Networks, Luis Velasco¹, Luis Gifre², Jose Luis Izquierdo-Zaragoza¹, Guillermo Julián³, Jorge Lopez de Vergara³; ¹Universitat Politècnica de Catalunya, Spain; ²Universidad Autónoma de Madrid (UAM), Spain; ³Naudit, Spain. CASTOR architecture to enable cognitive networking is demonstrated. Extended nodes make local decisions, whilst a centralized system beside the network controller makes network-wide decisions. Interaction with ONOS, Net2Plan, and passive monitoring devices is exhibited.

Tu3D.6

Flow/Application Triggered SDN control in Hybrid Data-center Network "HOLST", Yukihiro Imakiire¹, Masayuki Hirono¹, Masaki Murakami¹, Satoru Okamoto¹, Naoaki Yamanaka¹; ¹Keio Univ., Japan. We have proposed a new data-center network architecture "HOLST" with dynamic and adaptive network configuration for reducing power consumption. This demonstration shows the method of detecting and assigning flows from traffic and application trigger.

Tu3D.7

Topology Description Generation and Path Computation Framework for Dynamic Optical Path Network with Heterogeneous Switches, Kiyo Ishii¹, Atsuko Takefusa², Shu Namiki¹, Tomohiro Kudoh^{3,1}; ¹AIST, Japan; ²National Inst. of Informatics, Japan; ³The Univ. of Tokyo, Japan. A topology description scheme, a topology generation system, and a path computation system for dynamic optical path networks which support dynamic generation of wide area performance-guaranteed network slices will be demonstrated.

Tu3D.8

Towards IP & Transport Network Transformation Using Standardized Transport NorthBound Interfaces, Ricard Vilalta¹, Victor Lopez², Young Lee³, Haomian Zheng⁴, Lin Yi⁴, Ramon Casellas¹, Oscar Gonzalez de Dios², Ricardo Martínez¹, Raul Muñoz¹; ¹CTTC, Spain; ²Telefónica, Spain; ³Huawei, USA; ⁴Huawei, China. This demo proposes the usage of standardized YANG data models for multi-vendor and multi-layer optical control interoperability. L2/L3 network service establishment will be demonstrated as part of the network transformation devices for SDN/NFV.

Tu3D.9

Automated Management and Control of a Multi-vendor Disaggregated Network at the L0 Layer, Omer F. Yilmaz¹, Stephane St-Laurent¹, Matthew Mitchell¹; ¹Infinera Corporation, USA. We propose to demonstrate automated service management and automated optical power controls over Infinera and Lumentum Open Optical Line Systems using an Infinera Layer-0 SDN controller.

Tu3D.10

Joint Optimal Service Chain Allocation, VNF instantiation and Metro Network Resource Management Demonstration, Francisco-Javier Moreno-Muro¹, Cesar San-Nicolas-Martinez¹, Elena Martin-Seoane¹, Miquel Garrich^{1,3}, Pablo Pavon-Marin¹, Oscar Gonzalez de Dios², Victor Lopez²; ¹Politecnica Univ. of Cartagena, Spain; ²Telefonica GCTO, Spain; ³Optical Technologies Division, CPqD, Brazil. In a metro network with VIMS orchestrated by an ETSI-oSM instance, and an optical transport controller, we demonstrate optimized service chain provisioning using the open-source Net2Plan tool with interfaces to OSM (new) and transport controller

Tu3D.11

Network Slicing Resource Allocation and Monitoring over Multiple Clouds and Networks, Ricardo Martínez¹, Ricard Vilalta¹, Ramon Casellas¹, Raul Muñoz¹, Li Fei², Pengcheng Tang², Victor Lopez²; ¹Ctr Tecnologic de Telecoms de Catalunya, Spain; ²Huawei, China; ³Telefonica Global CTO, Spain. This demo presents an in-operation network slice resource allocator, which is able to consider networking and cloud infrastructure. Monitoring cloud and network resources allows enhancing the (re-)allocation of network slices, while accommodating novel slice requests.

Tu3D.12 •

Fully Disaggregated ROADM White Box with NETCONF/YANG Control, Telemetry, and Machine Learning-based Monitoring, Andrea Sgambelluri², Jose Luis Izquierdo-Zaragoza³, Alessio Giorgetti², Luis Gifre⁴, Luis Velasco³, Francesco Paolucci², Nicola Sambo², Francesco Fresi², Piero Castoldi², Anna Chiado Piat⁵, Roberto Morro⁵, Emilio Riccardi⁵, Antonio D'Errico⁶, Filippo Cugini¹; ¹CNIT, Italy; ²Scuola Superiore Sant'Anna, Italy; ³Optical Communications Group (GCO), Universitat Politècnica de Catalunya (UPC), Spain; ⁴Universidad Autónoma de Madrid (UAM), Spain; ⁵TIM, Italy; ⁶Ericsson, Italy. A first demonstration of ROADM White Box augmented with machine learning capabilities is demonstrated. The white box includes various level of disaggregation, NETCONF/YANG control, telemetry and spectrum-based advanced monitoring functionalities.

Tu3D.13

O2CMF: Experiment-as-a-service for Agile Fed4Fire Deployment of Programmable NFV, Isabella D. Ceravolo¹, Diego G. Cardoso¹, Cristina K. Dominici¹, Rodolfo D. Villaça¹, Moises R. Ribeiro¹, Magnus Martinello^{1,2}, Reza Nejabati², Dimitra E. Simeonidou²; ¹Software Defined Networks Research Group, Federal Univ. of Espirito Santo (UFES), Brazil; ²High Performance Networks Group, Univ. of Bristol, UK. An open platform over OpenStack for control and management of experiments (O2CMF) for merging and adapting wireless and optical federated testbeds with proper cloud infrastructure is presented. TO-SCA-enabled orchestration provides programmability for NFV experiments.

Tu3D.14

Demonstration of NFV for Mobile Edge Computing on an Optically Disaggregated Datacentre in a Box, Michael P. Enrico¹, Vaibhawa Mishra², Arsalan Saljoghei², Maciej Bielski³, Evert Pap⁴, Ilias Syrigos⁵, Oscar Gonzalez de Dios⁶, Dimitris Theodoropoulos⁷, Dionisios Pnevmatikatos⁷, Andrea Reale⁸, Dimitris Syrivelis⁹, Georgios Zervas⁸, Nick J. Parsons¹, Kostas Katrinis⁸; ¹HUBER+SUHNER Polatis Ltd, UK; ²Univ. College London, UK; ³Virtual Open Systems SAS, France; ⁴Sintecs BV, Netherlands; ⁵Univ. of Thessaly, Greece; ⁶Telefonica I+D, Spain; ⁷FORTH, Greece; ⁸IBM Research - Ireland, Ireland. This demonstrator showcases the hardware and software integration achieved by the dReDBox project [1] towards realization of a novel architecture using dynamically-reconfigurable optical interconnects to create a flexible, scalable and efficient disaggregated datacentre infrastructure.

Tu3D.15

Network Orchestration for Dynamic Network Slicing for Fixed and Mobile Vertical Services, Rodolfo Alvizu², Sebastian Troia¹, Van Minh Nguyen², Guido Alberto Maier², Achille Pattavina²; ¹Politecnico di Milano, Italy; ²SWAN networks, Italy. We demonstrate how a hybrid and hierarchical transport-SDN control plane based on a network orchestrator and an SDN controller can provide dynamic network slicing for enterprise-networking services and mobile metro-core networks.

07:30–08:00 Coffee Break, Upper Level Corridors

08:00–10:00

W1A • Connector - Something Old, Something New
 Presenter: Alan Evans; Corning Research & Development Corp, USA

W1A.1 • 08:00

20-year Reliability Test Results For SC Connector Installed on Outside Plant, Yoshiteru Abe¹, Kota Shikama², Shuichiro Asakawa³, Shuichi Yanagi¹; ¹NTT Access Network Service Systems Laboratories, NTT Corporation, Japan; ²NTT Device Technology Laboratories, NTT Corporation, Japan; ³NTT Device Innovation Center, NTT Corporation, Japan. Since 1997 we have tested the reliability of SC connectors installed outdoors in hot and humid environments. SC connectors with optimized ferrule end dimensions have maintained good optical performance for 20 years.

W1A.2 • 08:15

Novel Image Processing Methods for IL Estimation of Field Terminated Connectors, Jose Castro¹, Yu Huang¹, Rick Pimpinella¹, Bulent Kose¹, Alex Berian¹, Asher Novick¹, Brett Lane¹; ¹Panduit, USA. Investigation of novel methods to estimate insertion loss (IL) in field terminated connector based on radiation pattern variations as a function of the loss

08:00–10:00

W1B • High Capacity Transmission Systems
 Presenter: Fred Buchali; Nokia Bell Labs, Germany

W1B.1 • 08:00 **Invited**

Advances in 400 GbE Field Trials, Lynn E. Nelson¹; ¹AT&T Labs, USA. We review two recent 400G field trials in AT&T's network. We demonstrated 400Gb/s Ethernet end-to-end circuits, with CFP8 client interfaces and dual-wavelength 16QAM or single-wavelength 32QAM lineside, and SDN-controlled creation, deletion, and re-routing of 400G services.

08:15–10:00

W1C • Optical Switching in Data Centers
 Presenter: Payman Samadi; Cornell Univ., USA

W1C.1 • 08:15

dReDBox: Demonstrating Disaggregated Memory in an Optical Data Centre, Arsalan Saljoghei¹, Michael P. Enrico², Dimitris Syryvelis³, Kostas Katrinis³, Andrea Reale³, Maciej Bielski⁴, Ilias Syriogis⁵, Dionisios Pnevmatikatos⁵, Dimitris Theodoropoulos⁵, Nick J. Parsons², Georgios Zervas¹, Vaibhawa Mishra¹; ¹Univ. College London, UK; ²Huber+Suhner Polatis, UK; ³IBM-research Ireland, Ireland; ⁴Virtual Open Systems, France; ⁵Foundation of Research and Technology Hellas, Greece; ⁶Univ. of Thessaly, Greece. This paper showcases the first experimental demonstration of disaggregated memory using the dReDBox optical Data Centre architecture. Experimental results demonstrate the 4-tier network scalability and performance of the system at the physical and application layer.

08:00–10:00

W1D • Machine Learning and Network Availability **▶**
 Presenter: Qiong Zhang; Fujitsu Laboratories of America Inc, USA

W1D.1 • 08:00 **▶**

Guaranteed-availability Network Function Virtualization in Interdatacenter Networks, Jian Kong¹, Inwoong Kim², Xi Wang², Qiong Zhang², Weisheng Xie³, Hakki C. Cankaya³, Nannan Wang², Tadashi Ikeuchi², Jason P. Jue¹; ¹The Univ. of Texas, Dallas, USA; ²Fujitsu Laboratories of America, USA; ³Fujitsu Network Communications, USA. Considering the availability of the datacenter's network elements, we propose a coordinated protection mechanism that adopts both backup path protection and SFC replicas distributed among datacenters to support high availability while reducing total cost.

W1D.2 • 08:15 **Tutorial** **▶**

Data Analytics and Machine Learning Applied to Transport Layer, Massimo Tornatore^{1,2}; ¹Politecnico di Milano, Italy; ²Computer Science, Univ. of California, Davis, USA. After a generic introduction to machine-learning concepts and tools, some applications of machine learning in optical networks are introduced and discussed, with a focus on QoT estimation, failure detection and failure identification.

continued on page 92

08:00–10:00

W1E • Devices for Mode Multiplexing **▶**
 Presenter: Joel Carpenter; Univ. of Queensland, Australia

W1E.1 • 08:00 **Tutorial** **▶**

Optical Channel Switching in the Wavelength and Space Dimensions for SDM and WDM Networks, Dan M. Marom¹; ¹Hebrew Univ. of Jerusalem, Israel. This tutorial surveys the modifications of ROADM architecture and its underlying hardware elements, in support of increased capacity transmission schemes: for WDM-based networks, improved bandwidth utilization, elasticity, and increased transmission window beyond the C-band; in SDM networks, introduction of additional SMF fibers, cores, or spatial modes.



Dan M. Marom is a Full Professor in the Applied Physics Department at Hebrew University, Israel, heading the Photonic Devices Group and currently serving as the Department Chair. He received the B.Sc. Degree in Mechanical Engineering and the M.Sc. Degree in Electrical Engineering, both from Tel-Aviv University, Israel, in 1989 and 1995, respectively, and was awarded a Ph.D. in Electrical Engineering from the University of California, San Diego

continued on page 92

08:00–10:00

W1F • Radio-over-fiber I **▶**
 Presenter: Rod Waterhouse; Pharad, LLC, USA

W1F.1 • 08:00 **▶**

10 Gb/s Radio-over-fiber at 28 GHz Carrier Frequency Link based on 1550 nm VCSEL Chirp Enhanced Intensity Modulation after 2 km Fiber, Joris Van Kerrebrouck¹, Haolin Li¹, Silvia Spiga², Markus C. Amann², Xin Yin¹, Johan Bauwelinck¹, Piet Demeester¹, Guy Torfs¹; ¹IDLab, IN-TEC - imec, UGent, Belgium; ²Walter Schottky Institut, Germany. 10Gb/s, 28GHz radio-over-fiber transmission using a directly-modulated single-mode C-band VCSEL is demonstrated over 2km. The chirp of the VCSEL is translated into intensity modulation to extend the fiber-reaches and increase the power budget with 10dB.

W1F.2 • 08:15 **▶**

Full-duplex and Scalable MIMO Fiber-Wireless Seamless System in W-band for Future Mobile Networks, Pham Tien Dat¹, Atsushi Kanno¹, Naokatsu Yamamoto¹, Tetsuya Kawamishi²; ¹Network System Research Inst., National Inst. of Information and Communication Technology, Japan; ²Waseda Univ., Japan. We present a scalable fiber-wireless system in W-band for the simultaneous transmission of MIMO signals in both downlink and uplink directions. Satisfactory performance is confirmed for 2 × 2 MIMO OFDM and LTE-a signals.



Room 6F

Room 7AB

Room 8

Room 9

Room 10

Show Floor Programming

07:30–08:00 Coffee Break, Upper Level Corridors

08:15–10:00
W1G • Performance Monitoring and Nonlinear Transmission

President: Sethumadhavan Chandrasekhar; Nokia Bell Labs, USA

W1G.1 • 08:15 **Invited**
Learning from the Optical Spectrum: Soft-failure Identification and Localization

Luis Velasco¹, Behnam Shariati¹, Alba P. Vela¹, Jaime Comellas¹, Marc Ruiz¹; ¹Universitat Politècnica de Catalunya, Spain. The availability of coarse-resolution cost-effective Optical Spectrum Analyzers (OSA) allows its widespread deployment in operators' networks. In this paper, several machine learning approaches for failure identification and localization that take advantage of OSAs are presented.

08:00–10:00
W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?

Organizers: Thomas Pfeiffer, Nokia Bell Labs, Germany; Volker Jungnickel, Fraunhofer HHI, Germany

Optical access networks today are typically deployed as single path, single channel connections from the metro domain towards the end users. This architecture, however, will not be appropriate for accommodating business critical services, and particularly x-haul services in wireless and copper networks. Redundant, flexible and manageable access links will increasingly be required. Likewise, network designs will be needed allowing for reliably handling different kinds of traffic patterns with varying needs for capacity and latency, such as sustained capacity per node, sporadic traffic or aggregate peak rates even exceeding the capacity that the network was designed for.

The panel shall identify shortcomings of current access network architectures and provide proposals how to improve their resilience both on the physical and MAC layer as well as on the traffic engineering level. Which operational benefits can be gained from monitoring means and SDN-type of resource management? How can increased requirements on network management and maintenance be met also in access? What is the acceptable ratio of equipment and software efforts vs. improved quality and availability of services?

08:00–10:00
W1I • Devices for Interconnects

President: Kouji Nakahara; Oclaro Japan, Inc., Japan

W1I.1 • 08:00 **Invited**
Silicon Photonics for 56G NRZ Optical Interconnects

Joris Van Campenhout¹, Yoojin Ban¹, Peter De Heyn¹, Ashwyn Srinivasan¹, Jeroen De Coster¹, Sebastien Lardenois¹, Brad Snyder¹, Sadhishkumar Balakrishnan¹, Guy Lepage¹, Negin Golshani¹, Sofie Janssen¹, Alicja Lesniewska¹, Kristof Croes¹, Andy Miller¹, Peter Verheyen¹, Marianna Pantouvaki¹, Philippe Absil¹; ¹imec, Belgium. We discuss recent progress in the performance of modulators and photodetectors co-integrated in a silicon photonics platform, and capable of operation in the O-band or C-band at 56Gb/s single-lane NRZ data rates and beyond.

08:00–10:00
W1J • Short Reach II

President: Qunbi Zhuge; Ciena Corporation, Canada

W1J.1 • 08:00

112Gb/s Self-heterodyne Stokes Vector Detection with Compact Receiver for Short Reach Optical Communications, An Li¹, Samina Chowdhury¹, Yangjing Wen¹, Wei-Ren Peng¹, Yan Cui¹, Yusheng Bai¹; ¹Futurewei Technologies, Inc., USA. We propose a novel self-heterodyne Stokes vector detection (SH-sVD) system with only two balanced photodiodes and two analog-to-digital converters at receiver. A single-λ 112-gb/s 16QAM signal was successfully received after 80km transmission.

W1J.2 • 08:15
Application of Tomlinson-Harashima Precoding (THP) for Short-reach Band-limited Nyquist PAM and Faster-than-Nyquist PAM Signaling, Nobuhiko Kikuchi¹, Riu Hirai¹, Takayoshi Fukui²; ¹Hitachi Ltd, Japan; ²Oclaro Japan, Inc., Japan. We experimentally prove the effectiveness of Tomlinson-Harashima Precoding for IM/DD Nyquist PAM signals with severe transmitter-side bandwidth limitation despite the increase of optical signal levels, and its application to 50-GBaud Faster-than-Nyquist PAM4 is also demonstrated.

08:00–10:00
W1K • Optical Fiber Sensors

President: Rogerio Nogueira; Instituto De Telecomunicacoes, Portugal

W1K.1 • 08:00 **Invited**

Improving Distributed Sensing with Continuous Gratings in Single and Multi-core Fibers, Paul Westbrook¹, Tristan Kremp¹, Kenneth Feder¹, Wing Ko¹, Eric Monberg¹, Hongchao Wu¹, Debra Simoff², Roy Ortiz¹; ¹OFS Laboratories, USA; ²OFS Fitel, USA. We review advances in single and multicore continuous fiber grating array sensor technology. Grating enhanced backscattering offers order of magnitude signal improvements for distributed sensing of shape, temperature and strain over lengths up to 1km.

Wednesday, 14 March



Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.3 • 08:30

Small Footprint Air-gap Multi Fiber Connector with Low Loss and Low Mating Force, Hajime Arao¹, Sho Yakabe¹, Fumiya Uehara¹, Dai Sasaki¹, Takayuki Shimazu¹; ¹Sumitomo Electric Industries, Ltd., Japan. Multi-fiber connector with low mating force (3N) has been developed by applying gap between fibers. The proposed multi-mode/single-mode connector has achieved an average loss of 0.49dB/0.67dB and more than 38dB/60dB return loss without anti-reflection coating.

W1A.4 • 08:45

Edge Coupling Integrated Optics Packaging Concept using Liquid Crystal Element, Alex Paquet¹, Daniel B. Landry¹, Yan Desroches¹, Christine Alain¹; ¹INO, Canada. Many packaging approaches for integrated optics cannot meet the industry demand. We propose a post-assembly correction concept, using a liquid crystal element compatible with small form-factor pluggable modules, which may significantly reduce costs.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.2 • 08:30

Comparison of WDM Bandwidth Loading Using Individual Transponders, Shaped, and Flat ASE Noise, Thomas Richter¹, Jie Pan¹, Sorin Tibuleac¹; ¹ADVA Optical Networking North America Inc., USA. Channel emulation is compared for 100-gb/s PDM-QPSK from commercial transponders with channel-like spectrally carved noise and flat noise bands. The performance is evaluated in experiments and simulations on standard SMF and TW-rS DWDM transmission links.

W1B.3 • 08:45

DSP-enabled Frequency Locking for Near-Nyquist Spectral Efficiency Superchannels utilizing Integrated Photonics, Jefferey Rahn¹, Lee Dardis¹, David Krause², Mark Rice¹, Chris Berry¹, Aleš Kumpera², Alan Nilsson¹, Xian Xu¹, Parmijit Samra¹, Kenneth Weidner¹, Zufikar Morbi¹, Scott Demars¹, Charles Chen¹, Paul Freeman¹; ¹Infinera Corporation, USA; ²Infinera Canada, Canada. Digitally synthesized near-Nyquist subcarriers and photonic integration are shown to improve spectral efficiency. Spectral utilization 3.3% over baud rate is enabled by 1% Root-raised-cosine shaping and precision adjacent-channel wavelocking $\sigma < 100$ MHz.

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.2 • 08:30

Disaggregated Optical Data Center in a Box Network using Parallel OCS Topologies, Hui Yuan¹, Arsalan Saljoghei¹, Adaranijo Peters², Georgios Zervas¹; ¹Univ. College London, UK; ²Univ. of Bristol, UK. Two parallel OCS topologies are proposed that deliver 95 nsec round-trip latency on disaggregated optical data center in a box system. They offer 40% cost and 68% power consumption efficiency at maximum IT resource utilization.

W1C.3 • 08:45 **Invited**

Bridging the Last Mile for Optical Switching in Data Centers, Hitesh Ballani¹, Paolo Costa¹, Istvan Haller¹, Krzysztof Jozwik¹, Kai Shi¹, Benn C. Thomsen¹, Hugh Williams¹; ¹Microsoft Research, UK. Optical switches promise to revolutionize data centers by providing high bandwidth and low latency at low cost. This paper discusses some of the remaining challenges that need to be solved to make this technology successfully deployed in production.

Room 6C

W1D • Machine Learning and Network Availability—Continued



Massimo Tornatore is an Associate Professor with the Department of Electronics, Information, and Bioengineering, at Politecnico di Milano. He also holds an appointment as Adjunct Full Professor in the Department of Computer Science, University of California, Davis. His research interests include performance evaluation, optimization and design of communication and cloud networks (with an emphasis on the application of optical-networking technologies). He currently serves as an Editor for Photonic Network Communications, Optical Switching and Networking and IEEE Communication Surveys and Tutorials. He is a co-author of more than 250 scientific publications and was the co-recipient of ten best-paper awards.

Room 6D

W1E • Devices for Mode Multiplexing—Continued

(UCSD), in 2000. Prof. Marom is a Fellow of the Optical Society of America and a Senior Member of the IEEE Photonics Society. He was awarded the IEEE Photonics Society Distinguished Lecturer Award for 2014 and 2015, and is currently serving on the Society's Board of Governors. From 1996 through 2000, he was a Fannie and John Hertz Foundation Graduate Fellow at UCSD, and was a Peter Brojde Scholar in 2006-2007.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.3 • 08:30

Full-duplex Coherent Radio-over-fiber Transmission over 1:128 Split PON using an EML as Bidirectional RRH Optics, Bernhard Schrenk¹; ¹AIT Austrian Inst. of Technology, Austria. A lean coherent optical transceiver interface is presented. Simultaneous analogue 64QAM-OFDM down-/uplink transmission is experimentally demonstrated exploiting a single EML as coherent receiver and transmitter. No optical DSP is required in either signal chain.

W1F.4 • 08:45

Transmitter-embedded AMCC, LTE-A and OTDR signal for Direct Modulation Analog Radio over Fiber Systems, Luis Ernesto Ynoquio Herrera¹, Felipe Calliari¹, Diego Rodrigo Villafani Caballero¹, Gustavo C. do Amaral¹, Patryk Urban², Jean P. von der Weid¹; ¹Puc-rio, Brazil; ²Ericsson Research, Sweden. AMCC, LTE-a and OTDR signals are embedded in a single transmitter. Experiments show little impact on data transmission under in-service monitoring. Fault localization capability is verified with 10 dB dynamic range and 10 m resolution.



Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.2 • 08:45

White Gaussian Noise Based Capacity Estimate and Characterization of Fiber-optic Links, Roland Ryf¹, John van Weerdenburg², Roberto A. Alvarez-Aguirre^{1,3}, Nicolas K. Fontaine¹, René-Jean Essiambre¹, Haoshuo Chen¹, Juan Carlos Alvarado Zacarias^{1,3}, Rodrigo Amezcua Correa³, Ton Koonen², Chigo Okonkwo²; ¹Nokia Bell Labs, USA; ²Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands; ³CREOL, The Univ. of Central Florida, USA. We use white Gaussian noise as a test signal for single-mode and multimode transmission links and estimate the link capacity based on a calculation of mutual information. We also extract the complex amplitude channel estimations and mode-dependent loss with high accuracy.

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.2 • 08:30

Error-free Loopback of a Compact 25 Gb/s x 4 ch WDM Transceiver Assembly Incorporating Silicon (De)Multiplexers with Automated Phase-error Correction, Tomoyuki Akiyama^{1,2}, Tsuyoshi Aoki^{1,2}, Takasi Simoyama¹, Akio Sugama^{1,2}, Shigeaki Sekiguchi^{1,2}, Yohei Sobu¹, Shinsuke Tanaka^{1,2}, Yu Tanaka^{1,2}, Seok-Hwan Jeong^{1,2}, Motoyuki Nishizawa¹, Nobuaki Hatori¹, Akinori Hayakawa^{1,2}, Toshihiko Mori^{1,2}; ¹PETRA, Japan; ²Fujitsu Laboratories Ltd., Japan. We propose (de)multiplexers based on tunable cascaded asymmetric Mach-Zehnder interferometers to exclude necessity of highly-scaled expensive Si process by fully-automated fabrication error correction, and demonstrate an error-free loopback with a 12x12 mm transceiver assembly.

W1I.3 • 08:45

A Single-laser Flexible-grid WDM Silicon Photonic Transmitter using Microring Modulators, Yelong Xu¹, Jiachuan Lin¹, Raphaël Dubé-Demers¹, Sophie LaRochelle¹, Leslie A. Rusch¹, Wei Shi¹; ¹Université Laval, Canada. We report a flexible-grid WDM silicon photonic transmitter by monolithic integration of a microring modulator based comb generator with multi-channel modulators. It shows simultaneous multi-channel data transmission at different channel spacings without significant signal degradation

Room 9

W1J • Short Reach II—Continued

W1J.3 • 08:30

Performance Enhanced IM/DD 112 Gb/s/λ Transmission using Constellation Switching PAM4, Meng Xiang¹, Qunbi Zhuge^{2,1}, Zhenping Xing¹, Kuo Zhang¹, Thang M. Hoang¹, Fangyuan Zhang¹, David V. Plant¹; ¹ECE, McGill Univ., Canada; ²Ciena Corporation, Canada. We experimentally demonstrate a single wavelength 112 Gb/s IM/DD transmission system using constellation switching PAM4. Significant improvement is observed with respect to the conventional PAM4 system at the KP4 FEC threshold.

W1J.4 • 08:45

Single Photodiode-per-polarization Receiver for 400G Systems, Bill P. Corcoran^{1,2}, Benjamin Foo^{1,3}, Arthur Lowery^{1,2}; ¹Monash Univ., Australia; ²Centre for Ultrahigh-bandwidth Devices for Optical Systems, Australia; ³Microtechnology and Nanoscience (MC2), Chalmers Univ. of Technology, Sweden. We present a simplified heterodyne receiver using one single ended photodiode per polarization for polarization multiplexed coherent signals. We demonstrate this receiver for the reception of PM-16QAM over field-installed metro-area fibers at distances up to 306-km.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.2 • 08:30

> 10 dB SNR Enhancement in Distributed Acoustic Sensors through First Order Phase Noise Cancellation, María R. Fernández-Ruiz¹, Juan Pastor-Graells¹, Hugo F. Martins², Andres Garcia-Ruiz¹, Sonia Martin-Lopez¹, Miguel Gonzalez Herraes¹; ¹Universidad de Alcalá (UAH), Spain; ²FOCUS S.L, Spain. The performance of Rayleigh-based distributed acoustic sensors (DAS) is strongly dependent on the coherence of the laser source. We present a simple methodology to reduce the impact of the laser phase noise in chirped-pulse DAS.

W1K.3 • 08:45

Long-range, Power-efficient Distributed Flow Measurements Using Chirped-pulse Phase-sensitive Reflectometry, Andres Garcia-Ruiz¹, Alejandro Dominguez-Lopez¹, Juan Pastor-Graells¹, Hugo F. Martins², Sonia Martin-Lopez¹, Miguel Gonzalez Herraes¹; ¹Universidad de Alcalá, Spain; ²R&D, FOCUS S.L., Spain. We demonstrate a technique allowing to perform distributed wind speed measurements over >17 km with <0.6 km/h uncertainty at only 60 mW/m of power dissipation. Applications in dynamic line rating and catenary monitoring are envisaged.

Show Floor Programming

Wednesday, 14 March



Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.5 • 09:00 **Invited**
Ultra-high-density MCF Connector Technology, Tetsu Morishima¹, Osamu Shimakawa¹, Jun Ito¹, Takayuki Shimazu¹, Hajime Arai¹, Toshihisa Yokochi¹, Fumiya Uehara¹, Masaki Ohmura¹, Tetsuya Nakanishi¹, Tomomi Sano¹, Tetsuya Hayashi¹; ¹Sumitomo Electric Industries, Ltd., Japan. This talk will present our single-/multi-fiber multi-core fiber (MCF) connectors with the insertion loss of less than 1 dB and physical contact achieved by rotational fiber alignment mechanism and MCF-optimized end face polishing method, respectively.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.4 • 09:00
The Trade-off between Tranceiver Capacity and Symbol Rate, Lidia Galdino¹, Domanic Lavery¹, Zhixin Liu¹, Katarzyna Balakier¹, Eric Sillekens¹, Daniel Elson¹, Gabriel Saavedra¹, Robert Killey¹, Polina Bayvel¹; ¹Univ. College London, UK. The achievable throughput using high symbol rate, high order QAM is investigated for a CMOS-based DAC/ADC. The optimum symbol rate and modulation format is found to be 80GBd DP-256QAM, with a 800Gb/s net data rate.

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.4 • 09:15
Decision Tree Classification based Mix-flows scheduling in Optical Switched DCNs, Cen Wang^{1,2}, Hong Cao¹, Shenzhen Yang¹, Junyuan Guo¹, Hongxiang Guo¹, Jian Wu¹; ¹BUPT, China; ²Optical transmission and network, KDDI Research Lab, Japan. We propose a novel mix-flows scheduling strategy assisted with decision tree based flow classification for optical switched DCNs. Experimental results show it can effectively lower the completion time of small interactive flows and Coflows.

Room 6C

W1D • Machine Learning and Network Availability—Continued

W1D.3 • 09:15 **Top Scored**
Q-availability based Virtual Optical Network Provisioning, Inwoong Kim¹, Xi Wang¹, Martin Bouda¹, Olga Vassilieva¹, Qiong Zhang¹, Paparao Palacharla¹, Tadashi Ikeuchi¹; ¹Fujitsu Laboratories of America, USA. We show significant gain in Virtual Optical Network (VON) capacity by provisioning based on Q-availabilities of optical channels instead of fixed Q-margin. The Q-availability is calculated using stochastic simulations based on GN model.

Room 6D

W1E • Devices for Mode Multiplexing—Continued

W1E.2 • 09:00 **Top Scored**
Over-100-spatial-channel Programmable Spectral Processor for SDM Signal Monitoring, Mitsumasa Nakajima¹, Kenya Suzuki^{1,2}, Kazuno Seno^{1,2}, Takashi Goh¹, Ryoichi Kasahara¹, Mitsunori Fukutoku², Yutaka Miyamoto², Toshikazu Hashimoto¹; ¹NTT Device Technology Labs., Japan; ²NTT Network Innovation Labs, Japan. We propose a densely integrated programmable spectral processor array that handles over 100ch optical signals. Using the device, we achieved the optical performance monitoring for 100 spatial channels over C-band.

W1E.3 • 09:15 **Top Scored**
Reconfigurable 3-channel All-optical MIMO Circuit on Silicon Based on Multi-plane Light Conversion, Rui Tang¹; ¹The Univ. of Tokyo, Japan. We demonstrate reconfigurable all-optical MIMO demultiplexing on a compact silicon chip. 3-mode demultiplexing is realized experimentally with wavelength-dependent loss less than 3 dB and modal crosstalk less than -13 dB over 26-nm optical bandwidth.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.5 • 09:00 **Invited**
Research to Field Trial, A RoF Journey, Thavamaran Kanesan¹; ¹TM Research & Development, Malaysia. Abstract not available.



Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.3 • 09:00

Non-linearity Modeling at Ultra-high Symbol Rates, Pierluigi Poggolini¹, Gabriella Bosco¹, Andrea Carena¹, Fernando P. Guiomar¹, Mahdi Ranjbar Zefreh¹, Fabrizio Forghieri², Stefano Piciaccia²; ¹Politecnico di Torino, Italy; ²CISCO Photonics, Italy. We investigate the accuracy of several versions of the GN and EGN models for symbol rates up to 426 GBaud, over about 2THz of optical bandwidth, considering PM-32/64/128/256 QAM and addressing non-linear phase-noise mitigation.

W1G.4 • 09:15

Observing the Interaction of PMD with Generation of NLI in Uncompensated Amplified Optical Links, Mattia Cantono¹, Dario Piloni¹, Alessio Ferrari¹, Andrea Carena¹, Vittorio Curri¹; ¹Politecnico di Torino, Italy. We present simulative analyses displaying how PMD has negligible interaction with the generation of nonlinear interference, and show that the GN-model is accurate yet conservative in estimating the generalized SNR also in wide-bandwidth transmission.

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.4 • 09:00

Monolithic Optical Transceivers in 65-nm Bulk CMOS, Amir H. Atabaki¹, Sajjad Moazeni², Fabio Pavanello³, Hayk Gevorgyan⁴, Jelena Notaros³, Luca Alloatti¹, Mark Wade³, Chen Sun², Seth Kruger⁵, Kenais Alqubaisi⁴, Imbert Wang⁴, Bohan Zhang¹, Anatol Khilo⁴, Christopher Baiocco⁵, Milos Popovic⁴, Vladimir Stojanovic², Rajeev Ram¹; ¹Massachusetts Inst. of Technology, USA; ²Univ. of California, Berkeley, USA; ³Univ. of Colorado, Boulder, USA; ⁴Boston Univ., USA; ⁵Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Inst., USA. We present the integration of optical passive and active components next to millions of nano-scale bulk silicon transistors through a single deposited layer of polysilicon on silicon oxide islands. We demonstrate 10 Gb/s monolithic O-band optical transceivers on this platform.

W1I.5 • 09:15

Zn-diffusion/Oxide-relief 940 nm VCSELs with Excellent High-temperature Performance for 50 Gbit/sec Transmission, Jin-Wei Shi¹, Kai-Lun Chi¹, Zheng-Ting Xie¹, Mikel Agustin², Jörg Kropp², Nikolay Ledentsov², Kuo-Feng Tseng³, Ling-Gang Yang³; ¹National Central Univ., Taiwan; ²VI Systems, Germany; ³Hon Hai Precision Ind. Co. LTD., Taiwan. 940nm VCSELs with small resistances (35Ω) and ultra-wide E-o bandwidths from room-temperature (31GHz) to 85°C (29GHz) operations are demonstrated. It achieves 50Gbps error-free transmission over 50m OM5 fiber without using equalization and pre-emphasis techniques.

Room 9

W1J • Short Reach II—Continued

W1J.5 • 09:00

112 Gb/s/λ CAP Signals Transmission over 480 km in IM-DB System, Jianyang Shi^{1,2}, Junwen Zhang², Xinying Li^{2,3}, Nan Chi¹, Gee-Kung Chang¹, Jianjun Yu²; ¹Fudan, China; ²ZTE, USA; ³Georgia Inst. of Technology, USA. We demonstrate a 112 Gbit/s/λ CAP over 480 km of SSMF with low-cost direct detection. A joint processing algorithm is employed to improve system performance. To the best of our knowledge, this is the first time that single-wavelength 100G signal transmission is experimentally achieved over 480 km of SSMF with CAP-16 and direct detection.

W1J.6 • 09:15

448-Gb/s PAM4 Transmission Over 300-km SMF-28 Without Dispersion Compensation Fiber, Zhixin Liu¹, Tianhua Xu^{1,2}, Gabriel S. Mondaca¹, Polina Bayvel¹; ¹Univ. College London, UK; ²Univ. of Warwick, UK. We report on 4×112Gb/s direct-detection PAM4 transmission over 300-km standard single mode fiber. Chromatic dispersion is digitally compensated at the transmitter side.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.4 • 09:00

From Spider Webs to a Biomimetic Optical Fibre Sensor, Kenny Hey Tow¹, Desmond Chow¹, Fritz Vollrath², Isabelle Dicaire⁴, Tom Gheysens³, Luc Thévenaz¹; ¹Ecole Polytechnique Fédérale de Lausanne, Switzerland; ²Univ. of Oxford, UK; ³Univ. of Ghent, Belgium; ⁴CCCT Optech, Canada. Can we use spider silk threads as natural, biological optical fibre sensors? In this communication, we will see how we can harness the optical properties of spider dragline silk and use it for sensing.

Show Floor Programming

Wednesday, 14 March



Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.6 • 09:30

Physical-contact 256-core MPO Connector with Flat Polished Multi-core Fibers, Yuki Saito¹, Tetsu Morishima¹, Ken Manabe¹, Tetsuya Nakanishi¹, Tomomi Sano¹, Tetsuya Hayashi¹; ¹Sumitomo Electric Industries, Ltd., Japan. Physical contact of all the cores of ultra-high-density 256-core MPO connectors with 32 strands of 8-core fibers was achieved with a 22-n mating force by polishing method realizing flat fiber facets and small fiber-protrusion difference.

W1A.7 • 09:45

Multicore-fiber LC Receptacle with Compact Fan-in/Fan-out for Short-reach Transceivers, Kota Shikama¹, Yoshiteru Abe¹, Toshiki Kishi¹, Koji Takeda¹, Takuro Fujii¹, Hidetaka Nishi¹, Takashi Matsui¹, Atsushi Aratake¹, Kazuhide Nakajima¹, Shinji Matsuo¹; ¹Nippon telegraph and telephone, Japan. We describe a multicore-fiber LC receptacle with a compact fan-in/fan-out as a new transceiver interface for connecting LDs and PDs. We achieve low-loss coupling with the receptacle between a 4-core MCF and a laser array.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.6 • 09:30 **Invited**

High-capacity SDM Transmission over Transoceanic Distances, Alexey V. Turukhin¹, Oleg V. Sinkin¹, Hussam Batshon¹, Matt Mazurczyk¹, Maxim A. Bolshtyansky¹, Dmitri Foursa¹, Alexei Pilipetskii¹; ¹TE SubCom, USA. We review recent experimental and theoretical works that discuss capacity and power efficiency improvements achievable in transoceanic transmission with SDM. We outline challenges and potential solutions for increasing the capacity of future SDM undersea transmission.

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.5 • 09:30 **Invited**

An Overview of the Open Compute Project and Next-generation Data Centers, Omar Baldonado¹; ¹Facebook Inc., USA. This talk covers the Open Compute Project (OCP), a collaborative community focused on redesigning hardware technology to efficiently support the growing demands on compute infrastructure. This is especially relevant for optics in next-generation data centers.

Room 6C

W1D • Machine Learning and Network Availability—Continued

W1D.4 • 09:30

Real-time Spectrum Surveillance in Filterless Optical Networks, Behnam Shariati¹, Marc Ruiz¹, Andrea Sgambelluri², Filippo Cugini³, Luis Velasco³; ¹Universitat Politecnica de Catalunya, Spain; ²Scuola Superiore Sant'Anna, Italy; ³CNIT, Italy. A monitoring system exploiting data analytics and cost-effective optical spectrum analyzers with under 1.2GHz resolution is proposed. Its performance is demonstrated in a filterless network experimental test-bed. The system enables prompt action before lightpath disruption.

W1D.5 • 09:45

Applying Data Visualization for Failure Localization, Alba P. Vela¹, Marc Ruiz¹, Luis Velasco¹; ¹Universitat Politecnica de Catalunya, Spain. Data visualization is applied to BER measures in a bigdata repository. Bubble charts are produced to identify lightpaths with increasing BER and spectrum color maps are then used to identify the most likely degraded link.

Room 6D

W1E • Devices for Mode Multiplexing—Continued

W1E.4 • 09:30 **Top Scored**

Silicon Chip-to-chip Mode-division Multiplexing, Jan M. Baumann¹, Edson Porto da Silva¹, Yunhong Ding¹, Valerija Kamchevska¹, Michael Galili¹, Kjeld Dalgaard¹, Lars Frandsen¹, Leif K. Oxenlowe¹, Toshio Morioka¹; ¹DTU Fotonik, Denmark. A chip-to-chip mode-division multiplexing connection is demonstrated using a pair of multiplexers/demultiplexers fabricated on the silicon-on-insulator platform. Successful mode multiplexing and demultiplexing is experimentally demonstrated, using the LP₀₁, LP_{11a} and LP_{11b} modes.

W1E.5 • 09:45

Symmetric Lithium-niobate Waveguide Fabricated by Bonding for Mode-division-multiplexing Applications, Mengruo Zhang², Kaixin Chen², Wei Jin¹, Kin S. Chiang^{1,2}; ¹City Univ. of Hong Kong, Hong Kong; ²Univ. of Electronic Science and Technology of China, China. We fabricate a symmetric lithium-niobate waveguide that supports six fiber-compatible spatial modes by a bonding process and demonstrate the feasibility of forming vertical directional couplers with such a waveguide for fiber-based mode-division-multiplexing applications.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.6 • 09:30

W-band Radio-over-fiber Link Based on Self-oscillating Optical Frequency Comb Generator, G.K.M. Hasanuzzaman¹, Atsushi Kanno², Pham Tien Dat², Stavros Iezekiel¹; ¹Univ. of Cyprus, Cyprus; ²NICT, Japan. A 94.8 GHz radio-over-fiber link was implemented with a self-oscillating frequency comb. An LTE Advanced OFDM FDD 64-QAM signal of 20 MHz bandwidth was transmitted over 1.3 m wireless distance with an EVM of 2.23%.

W1F.7 • 09:45

Physical Layer 1 Gb/s Secret Wireless Data Transmission at W-band using a Photonic Duffing System, Rafael Puerta¹, Alvaro Morales², Simon Rommel¹, Inwoong Kim³, Olga Vasiliieva³, Tadashi Ikeuchi³, Idelfonso Tafur Monroy²; ¹Technical Univ. of Denmark, Denmark; ²Electrical Engineering, Eindhoven Univ. of Technology, Netherlands; ³Fujitsu Laboratories of America, USA. First demonstration of photonic-enabled 1 Gb/s secret wireless data transmission at W-band based on Duffing chaotic systems. The presented results validate a new methodology to increase security by exploiting chaos for gigabit data transmissions.

Wednesday, 14 March

10:00–17:00 Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C





Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.5 • 09:30

A Novel Detection Strategy for Nonlinear Frequency-division Multiplexing, Stella Civelli^{1,2}, Enrico Forestieri^{1,2}, Marco Secondini^{1,2}; ¹Tecip, Scuola Superiore Sant'Anna, Italy; ²Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy. A novel decision feedback detection strategy exploiting a causality property of the nonlinear Fourier transform is introduced. The novel strategy achieves a considerable performance improvement compared to previously adopted strategies in terms of Q-factor.

W1G.6 • 09:45

100 Gbps b-modulated Nonlinear Frequency Division Multiplexed Transmission, Son T. Le¹, Karsten Schuh¹, Fred Buchali¹, Henning Bülow¹; ¹Nokia Bell Labs, Germany. We demonstrate that the performance of 100 Gb/s NFDN system employing the continuous nonlinear spectrum is significantly enhanced by modulating only the b-coefficient, providing a gain up to 1.5 dB over the conventional OFDM system

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.6 • 09:30

85°C Operation of 850 nm VCSELs Deliver a 42 Gb/s Error-free Data Transmission for 100 meter MMF Link, Hsiao-Lun Wang¹, Junyi Qiu¹, Xin Yu¹, Milton Feng¹, Nick Holonyak¹; ¹Micro and Nanotechnology Laboratory, USA. 850nm VCSELs record performance of 46Gb/s (RT), 43Gb/s (75°C) and 42Gb/s (85°C) error-free transmission for a 100 meter MMF link are reported without the use of equalizer or forward error correction.

W1I.7 • 09:45

High-speed High-efficiency Broadband Silicon Photodiodes for Short-reach Optical Interconnects in Data Centers, Soroush Ghandiparsi¹, Aly F. Elrefaie², Hilal Consizoglu¹, Yang Gao¹, Cesar Bartolo-Perez¹, Hasina H. Mamtaz¹, Ahmed Mayet¹, Toshishige Yamada², Ekaterina Ponzovskaya Devine², Shih-Yuan Wang², M. Saif Islam¹; ¹Electrical and Computer Engineering, Univ. of California, Davis, USA; ²W&WSens Devices, Inc., USA. We demonstrate a silicon-based surface-illuminated CMOS-compatible broadband photodiode with ≤ 30 ps FWHM and above 55% EQE at 850nm for up to 50Gb/s by using photon-trapping micro/nano-structures. This is the fastest reported response for a Silicon photodiode.

Room 9

W1J • Short Reach II—Continued

W1J.7 • 09:30

4x100G PAM-4 Transmission in Faster-than-Nyquist Systems Incorporating Eigenvalue-space Precoding, Mu Xu^{1,2}, Zhensheng Jia², Peng-Chun Peng¹, Siming Liu¹, Feng Lu¹, Curtis Knittle², Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA; ²CableLabs, USA. An eigenvalue-space precoding is proposed to combat narrow-filtering effect in optical PAM-4 systems. Transmissions at 24, 60, and 120Gbps/wavelength with 6-dB bandwidths of 4, 7.5, and 17.5 GHz are experimentally demonstrated over up-to-30-km SSMF.

W1J.8 • 09:45

Low Complexity Frequency-domain Nonlinear Equalization for 40-Gb/s/wavelength Long-reach PON, Junwei Zhang¹, Changjian Guo², Jie Liu¹, Xiong Wu¹, Alan Pak Tao Lau³, Chao Lu², Siyuan Yu^{1,4}; ¹School of Electronics and Information Technology, Sun Yat-sen Univ., China; ²Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., China; ³Department of Electrical Engineering, The Hong Kong Polytechnic Univ., China; ⁴Merchant Venturers School of Engineering, Univ. of Bristol, UK. We propose to use a frequency-domain nonlinear equalization (FD-nE) for long-reach PONs. Compared with time-domain NE, similar performance with 63% complexity reduction is achieved utilizing FD-nE in a 40.08-gbit/s OFDM-iM-dD transmission system over 60-km SSMF.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.5 • 09:30

Stretchable Multi-function Fiber Sensor for Tension, Bending and Torsion Sensing, Li Xu¹, Ning Liu¹, Jia Ge¹, Xianqiao Wang¹, Mable P. Fok¹; ¹Univ. of Georgia, USA. We demonstrate a stretchable fiber-optic sensor by embedding a sinusoidal-structured fiber Bragg grating in a silicone sheet at an off-center position, which uniquely enables 30% of elongation and facilitates tension, torsion direction, and bending measurement.

W1K.6 • 09:45

Stable Torsion Sensor with Tunable Sensitivity and Rotation Direction Discrimination Based on a tapered Trench-assisted Multi Core Fiber, Fengze Tan¹, Zhengyong Liu¹, Jiajing Tu¹, Changyuan Yu¹, Chao Lu¹, Hwa-Yaw Tam¹; ¹Hong Kong Polytechnic Univ., Hong Kong. A tapered Trench-assisted Multi Core Fiber (TA-MCF) is firstly proposed and experimentally demonstrated for torsion sensing. The rotation direction can be discriminated and the torsion sensitivity is tunable up to 1.1 nm/°.

Show Floor Programming

Wednesday, 14 March

10:00–17:00 Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C



W2A.1

Highly Accurate and Efficient Maintenance Technology for Optical Cables and Utility Poles, Takashi Goto¹, Masaki Waki¹, Kazunori Katayama¹; ¹NTT Access Network Service Systems Laboratories, NTT Corporation, Japan. We propose a highly efficient and accurate maintenance method for outdoor facilities that employs a point cloud to measure the angle and bend in utility poles and the vertical clearance for communication cables.

W2A.2

8.74kW Pump-gain Integrated Functional Laser Fiber, Huan Zhan¹, Yuying Wang¹, Kun Peng¹, Shuang Liu¹, Yuwei Li¹, Li Ni¹, Xiaolong Wang¹, Cong Gao¹, Shihao Sun¹, Lihua Zhang¹, Juan Yu¹, Jianjun Wang¹, Feng Jing¹, Aoxiang Lin¹; ¹China Academy of Engineering Physics, China. We fabricated a (8+1)-type pump-gain integrated functional laser fiber with 8 passive pump-fibers and 1 signal-gain fiber. 8.74 kW laser output with optical-to-optical efficiency of 81% was achieved in counter-pump MOPA setup.

W2A.3

Modal Dispersion Compensation Module for 100G SWDM Transmission Using OM4 Multimode Fiber, Xin Chen¹, Jason E. Hurlley¹, Dong Gui¹, Jeff Stone¹, Ming-Jun Li¹; ¹Corning Research & Development Corp, USA. A low insertion loss modal dispersion compensation module for SWDM applications including a two-band MUX/DEMUX and modal dispersion compensating fiber was fabricated. Extended transmission distance over OM4 MMF in 100G SWDM transmission experiment is demonstrated.

W2A.4

Novel In-service OSNR Monitoring Method for Reconfigurable Coherent Networks, Daniel Garipey¹, Steven Searcy², Michel Leclerc¹, Pascal Gosselin-Badaroudine¹, Gang He¹, Sorin Tibuleac²; ¹EXFO, Canada; ²ADVA Optical Networking, USA. A novel in-service OSNR monitoring technique is experimentally validated on tightly filtered polarization-multiplexed signals for a range of network operating conditions and reconfigurations. The results demonstrate sufficient accuracy and robustness for measurements in practical networks.

W2A.5

Multimode EDFA Designs with Reduced MDG by Considering Spatially Dependent Saturation Effects, Steffen Jeurink¹, Peter M. Krummrich¹; ¹Chair for High Frequency Technology, TU Dortmund, Germany. We propose a spatial gain equalization strategy for multimode EDFAs which considers transversally non-uniform saturation. Characteristic minima of the MDG are observed along the fiber. The fiber length is adjusted to achieve low MDG.

W2A.6

Nonlinear Absorption in Single-photon Detector and Ultrafast Mode-locked Laser Pulse Characterization, Zhengyong Li¹, XK Zhan¹, HY Wang¹, SC Wang¹, BC Wang¹; ¹Beijing Jiaotong Univ., China. We observe novel nonlinear absorption in a bi-alkali-cathode single-photon detector, and propose mutual-correlation scheme to fabricate. Extended transmission distance over OM4 MMF in 100G SWDM transmission experiment is demonstrated.

W2A.7

Enabling Simultaneous DAS and DTS Measurement Through Multicore Fiber Based Space-division Multiplexing, Zhiyong Zhao², Ming Tang³, Liang Wang¹, Songnian Fu³, Weijun Tong⁴, Chao Lu²; ¹The Chinese Univ. of Hong Kong, Hong Kong; ²The Hong Kong Polytechnic Univ., Hong Kong; ³Huazhong Univ. of Science and Technology, China; ⁴Yangtze Optical Fiber and Cable Joint Stock Limited Company, China. Through space-division multiplexing using multicore fiber, simultaneous measurements of DAS and DTS have been achieved based on Φ -OTDR and ROTDR, respectively. Wavelet transform denoising has been employed to improve the temperature uncertainty to 0.5 °C.

W2A.8

100km Quasi-lossless Fiber-optic Transmission with a Novel Cascaded Random Raman Fiber Laser, Han Wu¹, Bing Han¹, Zinan Wang¹, Yunjiang Rao¹; ¹UESTC, China. Ultra-long distance (100km) quasi-lossless fiber-optic transmission is experimentally performed by using the 3rd-order Raman amplification pumped by a novel 1280nm cascaded random Raman fiber laser, which is the longest quasi-lossless transmission system reported to date.

W2A.9

Programmable and Fast-switchable Passively Harmonic Mode-locking Fiber Laser, Guoqing Pu¹, Lilin Yi¹, Li Zhang¹, Weisheng Hu¹; ¹Shanghai Jiao Tong Univ., China. Programmable harmonic mode-locking are achieved in graphene-based mode-locking fiber laser enabled by mode-locking discrimination algorithm and fast polarization tuning. Fundamental, second-order and third-order harmonic mode-locking states can be switched in microsecond level.

W2A.10

Silica Capillary based Whispering Gallery Mode Resonators and Functional Fiber Devices, Xiaobei Zhang¹, Jiawei Wang¹, Ming Yan¹, Hai Xiao², Tingyun Wang¹; ¹Shanghai Univ., China; ²Clemson Univ., USA. A novel and compact silica capillary based Whispering Gallery Mode resonators and functional fiber devices are demonstrated with Fano resonances observed, while the temperature, refractive index and strain sensing are also investigated.

W2A.11

Polarization-insensitive and Bandwidth-adjustable Anisotropic Dynamic Gratings based on Synthesis of Optical Coherence Function Method, Pan Xu¹, Peng Gan¹, Jun Wang¹, Zhengliang Hu¹, Yongming Hu¹; ¹National Univ of Defense Technology, China. We demonstrated a linear type polarization-insensitive and bandwidth-adjustable anisotropic dynamic grating in a piece of non-birefringent erbium-doped fiber (EDF) by utilizing phase modulation method.

W2A.12

Simultaneous Distributed Temperature and Vibration Measurement with UWFBG based Coherent OTDR, Fan Ai¹, Hao Li¹, Tao He¹, Zhijun Yan¹, Deming Liu¹, Qizhen Sun¹; ¹Huazhong Univ. of Science and Technology, China. An UWFBG based coherent OTDR is proposed to realize distributed temperature and vibration sensing simultaneously. Ultra-high temperature accuracy of 0.05K and ultra-high response frequency of up to 100kHz is demonstrated.

W2A.13

Highly Sensitive Temperature Sensor Based on Hybrid Photonic Crystal Fiber, Zhilin Xu¹, Juan Juan Hu², Slawomir Ertman⁴, Tomasz Wolinski⁴, Weijun Tong³, Ping Shum¹; ¹Nanyang Technological Univ., Singapore; ²Smart Energy & Environment Cluster, Infrastructure Department Inst. for Infocomm Research, AStar, Singapore; ³Yangtze Optical Fibre and Cable JointStock Co. Ltd., China; ⁴Warsaw Univ. of Technology, Poland. A hybrid guiding mechanism in photonic crystal fiber (PCF) is realized by selectively infiltrating liquid crystal 5CB into a twin-core PCF. Due to the introduction of PBG guiding mechanism into the index-guiding twin-core PCF, the hybrid PCF shows strong temperature responsiveness and thus possesses good potential for sensing applications.

W2A.14

Highly Mode Selective 3-mode Photonic Lantern through Geometric Optimization, Li Shen¹, Lin Gan¹, Chen Yang², Weijun Tong², Songnian Fu¹, Deming Liu¹, Ming Tang¹; ¹Huazhong Univ. of Sci. and Tech., China; ²YOFC, China. We demonstrated that core geometry has a great impact on mode selectivity of photonic lanterns and designed an optimized 3-mode photonic lantern with >20 dB mode selectivity and >95% coupling efficiency for all modes.

W2A.15

Performance Comparison and Analysis of Non-local Means and Wavelet Denoising for BOTDA Sensor, Huan Wu¹, Liang Wang¹, Zhiyong Zhao², Chester Shu¹, Chao Lu²; ¹The Chinese Univ. of Hong Kong, Hong Kong; ²The Hong Kong Polytechnic Univ., Hong Kong. We experimentally compare and analyse the performance (i.e. measurement accuracy/spatial resolution) of NLM and WD for denoising BOTDA signals under different SNR improvement and sampling point number.

W2A.16

112 Gb/s PAM4 Transmission over 2 km SMF using a C-band GeSi Electro-absorption Modulator, Eslam Elfiky¹, Peter De Heyn², Mohamed Morsy-Osman¹, Ashwyn Srinivasan², Alireza Samani¹, Marianna Pantouvaki², Mohammed Sowailam¹, Joris Van Campenhout², David V. Plant¹; ¹McGill Univ., Canada; ²Imec, Belgium. We demonstrate 112 Gb/s 4-level pulse amplitude modulation over 2 km of SMF using a C-band GeSi electro-absorption modulator for data-center interconnects. Also, we present first results towards 400 Gb/s wavelength division multiplexed transmission.

W2A.17

In-service Crosstalk Monitoring and Tracing for Short-reach Space-division Multiplexing (SDM) Optical Networks, Ruijie Luo¹, Nan Hua¹, Yufang Yu¹, Zhizhen Zhong¹, Zhongyong Wu², Juhao Li², Xiaoping Zheng¹, Bingkun Zhou¹; ¹Tsinghua Univ., China; ²Peking Univ., China. We propose an in-service crosstalk monitoring and tracing method using fine-grained monitoring optical time slices for SDM-enabled intra-datacenter and HPC systems. Modal crosstalk below -36.01dB was successfully monitored and traced in an MMF transmission system.

W2A.18

OCBridge: An Efficient Topology Reconfiguration Strategy in Optical Data Center Network, YiNan Tang¹, Hongxiang Guo¹, Jian Wu¹; ¹Beijing Univ. of Posts and Telecommunications, China. We proposed an algorithm named OCBridge to effectively reconfigure the topology of optical data center network. Simulation results show it can reduce hotspots and achieve better throughput in data center networks compared with relative proposals.

Exhibit Hall B

W2A • Joint Poster Session I—Continued

W2A.19

Real-time 100 Gbps/λ/core NRZ and EDB IM/DD Transmission over 10 km Multicore Fiber, Rui Lin^{2,1}, Xiaodan Pang^{1,3}, Joris Van Kerrebrouck⁴, Michiel Verplaetse⁴, Oskars Ozolins³, Aleksejs Udalcovs³, Lu Zhang¹, Lin Gan², Ming Tang², Songnian Fu², Richard J. Schatz¹, Urban Westergren¹, Sergej Popov¹, Deming Liu², Weijun Tong³, Timothy D. Keulenaer⁴, Guy Torfs⁴, Johan Bauwelink⁴, Xin Yin⁴, Jiajia Chen¹; ¹The Royal Inst. of Technology (KTH), Sweden; ²School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China; ³Networking and Transmission Laboratory, RISE Acreo AB, Sweden; ⁴Department of Information Technology(INTEC)-iDLab, Univ. of Ghent-imec, Belgium; ⁵Yangtze Optical Fiber and Cable Joint Stock Limited Company (YOFC), China; ⁶BiFAST spin-off of IDLab, Ghent Univ.-imec, Belgium. A BiCMOS chip-based Real-time IM/DD spatial division multiplexing system is experimentally demonstrated for short-reach communications. 100 Gbps/λ/core NRZ and EDB transmission is achieved below 7%-overhead HD-FEC limit after 10km 7-core fiber with optical dispersion compensation.

W2A.20

Wavelength Reuse for Scalable Multicasting: A Cross-layer Perspective, Houman Rastegarfar¹, Kamran Keykhosravi², Erik Agrell², Nasser Peyghambarian¹; ¹Univ. of Arizona, USA; ²Chalmers Univ. of Technology, Sweden. We examine the feasibility of ultrahigh-scale datacenter multicasting by simultaneously taking into account the choice of architecture, modulation, and coding. Our Monte Carlo simulations indicate the dominant impact of in-band crosstalk on the throughput performance.

W2A.21

SDN-based Application Driven In-band Adaptive Coding in Data Centers, Mingwei Yang¹, Houman Rastegarfar¹, Ivan Djordjevic¹; ¹Univ. of Arizona, USA. A software-defined adaptive coding scheme is experimentally implemented and evaluated for 50 Gbps 4-PAM optical switching in wavelength-routing DCs. Up to 1 dB reduction in transmission power is achieved with switching latencies of hundreds of milliseconds.

W2A.22

Demonstration of 30Gbit/s QPSK-to-PAM4 Data-format and Wavelength Conversion to Enable All-optical Gateway from Long-haul to Datacenter, Ahmad Fallahpour¹, Amirhossein Mohajerin Ariaei¹, Ahmed Almainan¹, Yinwen Cao¹, Fatemeh Alishahi¹, Changjing Bao¹, Peicheng Liao¹, Bishara Shamee¹, Morteza Ziyadi¹, Dmitry Starodubov¹, Moshe Tur², Carsten Langrock³, Martin Fejer³, Joseph Touch⁴, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²Tel Aviv Univ., Israel; ³Stanford Univ., USA; ⁴Information Sciences Inst., USA. A tunable optical QPSK to PAM4 converter is experimentally demonstrated. The proposed method maps four symbols of QPSK signal to four different amplitude levels which can be directly detected in photo-diode. Open eyes are obtained for the detected PAM4 signal.

W2A.23

A Novel Scalable and Low Latency Hybrid Data Center Network Architecture based on Flow Controlled Fast Optical Switches, Fu L. Yan¹, Gonzalo Guelbenzu¹, Nicola Calabretta¹; ¹TU/e, Netherlands. We present a novel hybrid DCN based on flow-controlled fast optical switches. Results show packet loss <1.4E-5 and latency <2.4μs for 100,000 servers (0.3 load). Costs and power consumptions are also compared with current technologies.

W2A.24

All-fiber Full-duplex Bidirectional Data Transmission for Data Center Networks (DCNs) over 2-km Orbital Angular Momentum (OAM) Fiber using Commercial SFP+ Transceivers and Mode Selective Couplers, Yifan Zhao¹, Yize Liang¹, Xinzhou Su¹, Wei Zhou¹, Yan Luo¹, Zongyuan Huang¹, Shuhui Li¹, Jian Wang¹; ¹Huazhong Univ. of Science and Technology, China. We demonstrate an all-fiber full-duplex bidirectional data transmission link for data center networks (DCNs) using orbital angular momentum (OAM) multiplexing over 2-km OAM fiber. Commercial SFP+ transceivers and mode selective couplers are employed to excite OAM₁ and OAM₁ modes carrying 10Gbase-t signals, achieving less than -15.11 dB crosstalk.

W2A.25

BlockONet: Blockchain-based Trusted Cloud Radio over Optical Fiber Network for 5G Fronthaul, Hui Yang¹, Yizhen Wu², Jie Zhang¹, Haowei Zheng¹, Yuefeng Ji¹, Young Lee²; ¹Beijing Univ. of Posts & Telecom, China; ²Huawei Technologies Co., Ltd, China. We first present a blockchain-based trusted cloud radio over optical fiber network architecture (BlockONet) with anonymous access identification for future 5G fronthaul. The feasibility and efficiency of the architecture are experimentally verified on our testbed.

W2A.26

Demonstration of Triple-mode Controller Recovery with Multiple Integrated Services in SDN, Muhammad Irfan¹, Muhammad Faizan¹, Syed Waleed¹, Maheen Iqbal²; ¹FEST, Iqra Univ., Pakistan; ²Designing, Cybernet, Pakistan. We present the first completely orchestrated and automatic failure recovery scheme employed various services utilizing the intelligence of SDN. Our proposed three step mechanism can safeguard controllers from failures with a recovery time of 11ms.

W2A.27

Scheduling Algorithm for All-optical Switch under Non-uniform Traffic Condition, Jongtae Song¹, Kyeong-Eun Han¹, Dae-Ub Kim¹, Chansung Park¹, Kwangjoon Kim¹; ¹ETRI, Korea. We introduce a scheduling algorithm for all-optical data center switch supporting high throughput and low delay for non-uniform traffic condition. Simulation result shows that our system achieves 100% throughput and shorter delay than existing methods.

W2A.28

Maximizing Availability-weighted Slice Capacity for Sliceable Wireless-optical Broadband Access Networks, Ke Chen¹, Chao Guo¹, Longfei Li¹, Sanjay K. Bose², Gangxiang Shen¹; ¹Soochow Univ., China; ²Department of Electrical and Electronic Engineering, Indian institution of technology, India. We consider a sliceable wireless-optical broadband access network (WOBAN) to maximize its availability-weighted capacity. For this, Integer Linear Programming (ILP) models and corresponding heuristic algorithms are developed. Simulation results show the proposed approaches are efficient to maximize slices' availability-weighted capacity.

W2A.29

Demonstration of XHaul Architecture for 5G over Converged SDN Fiber Network, Jim (Shihuan) Zou¹, Anthony Magee², Michael Eiselt¹, Andrew Straw², Ardel Iddin², Tim Edwards², Paul Wright³, Andrew Lord³; ¹ADVA Optical Networking SE, Germany; ²ADVA Optical Networking Ltd., UK; ³British Telecommunications, UK. We proposed and showcased an XHaul architecture converging front-end and backhaul for 5G networks. The solution leveraged agile functional placement and hosting for cell sites and agile optical transmission based on the wavelength-agnostic WDM technology.

W2A.30

Extended Reach 40km Transmission of C-band Real-time 53.125 Gbps PAM-4 Enabled with a Photonic Integrated Tunable Lattice Filter Dispersion Compensator, Grant M. Brodnick¹, Catia Pinho², Frank Chang³, Daniel J. Blumenthal¹; ¹Univ. of California Santa Barbara, USA; ²Instituto de Telecomunicações (IT), Univ. of Aveiro, Portugal; ³Inphi Corp., USA. Reach-extended C-band transmission of Real-time 53.125Gbps PAM-4 data over 40km SSMF is enabled using a dispersion compensating photonic-integrated programmable lattice filter. Transmission of 100GHz spaced channels error-free below the FEC threshold is demonstrated.

W2A.31

100Gb/s PolMux-NRZ Transmission at 1550nm over 30km Single Mode Fiber Enabled by a Silicon Photonics Optical Dispersion Compensator, Vito Soriano¹, Gabriele De Angelis¹, Francesco Fresi², Fabio Cavaliere⁴, Luca Poti¹, Michele Midrio³, Marco Romagnoli¹; ¹CNIT - National Laboratory of Photonic Networks, Italy; ²Scuola Superiore Sant'Anna, TeCIP Inst., Italy; ³CNIT - Università degli Studi di Udine, Italy; ⁴Ericsson, Italy. We demonstrate 100Gb/s PolMux-nRZ transmission at 1550nm over 30km SM-fiber with a power penalty of 2.5dB by means of a silicon photonics integrated circuit including optical dispersion compensators and an integrated polarization active controller.

W2A.32

Single-wire DAC/ADC Control and Feedback of Silicon Photonic Ring Resonator Circuits for Wavelength Switching, Ziyi Zhu¹, Alexander Gazman¹, David Gidony¹, Yiwon Shen¹, Kenneth Shepard¹, Keren Bergman¹; ¹Columbia Univ., USA. We develop a robust and scalable solution for control and feedback of silicon photonic circuits used for optical unicast and multicast. A single-wire DAC and ADC feedback architecture is evaluated with 20Gb/s PAM-4 data streams.

Show Floor Programming

COBO Specification Overview and Next Steps

COBO
10:15-11:45

Product Showcase

Huawei
10:15-10:45
For more details, see page 23

Network Operator Summit

Keynote:
10:30-11:00

Panel I: The Role of "Open Transport" in the New Metro and Inter-data-center Architectures
11:00-12:30

Product Showcase Xilinx

11:00-11:30
For more details, see page 23

Product Showcase Xilinx

11:30-12:00
For more details, see page 23

Server Fibreless Optical Networking

Open19 Foundation
12:00-13:00

Product Showcase

Hengtong Optic-Electric Co., Ltd.
12:00-12:30
For more details, see page 23

Product Showcase

Colorchip
12:30-13:00
For more details, see page 23

Product Showcase

ATOP
13:00-13:30
For more details, see page 23

Industry Visions for a Converged Optical Networking Roadmap

ON2020
13:15-15:15

Next Generation Coherent: Architectures and Technologies

Session Sponsored by Acacia Communications
13:30-14:30

Network Operator Summit

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30-15:00

Wednesday, 14 March

W2A • Joint Poster Session I—Continued

W2A.33

Experimental Demonstration of Real-time Add/Drop Operations in DSP-enabled Flexible ROADMs for Converging Fixed and Mobile Networks, Roger P. Giddings¹, Ehab Al-Rawachy^{1,2}, Jianming Tang¹; ¹Bangor Univ., UK; ²College of Electronics Engineering, Ninevah Univ., Iraq. Low-cost and versatile DSP-enabled ROADMs with excellent transparency are vital for seamlessly converging fixed and mobile networks, we demonstrate, for the first time, Real-time add/drop operations providing switching at sub-wavelength and spectrally-overlapped sub-band levels.

W2A.34

Coarse and Fine Continuously Tunable Optical Delay Using the Time of Flight in Fiber Bragg Gratings and Wavelength Conversion, Ahmed Almaiman¹, Yinwen Cao¹, Amirhossein Mohajerin-Ariae¹, Fatemeh Alishahi¹, Ahmad Fallahpour¹, Dmitry Starodubov¹, Peicheng Liao¹, Changjing Bao¹, Shlomo Zach², Nadav Cohen², Moshe Tur², Alan E. Willner¹; ¹Univ. of Southern California, USA; ²School of Electrical Engineering, Tel Aviv Univ., Israel. We use the time-of-flight in arrayed, channelized and chirped fiber Bragg gratings along with wavelength conversion in PPLN waveguides to build continuously coarse- and fine-tunable delay line. More than 20 ns continues tuning range is achieved with less-than-0.6dB OSNR penalty for a 10 GBaud QPSK signal.

W2A.35

Doubly Differential Two-level 8PSK for Enabling Optical Packet Switching in Coherent Systems, Fan Liu^{1,2}, Yi Lin², Anthony J. Walsh², Yonglin Yu¹, Liam Barry²; ¹Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; ²School of Electronic Engineering, Dublin City Univ., Ireland. We demonstrate that a doubly differential two-level 8 phase shift keying (PSK) modulation format can be used to reduce the waiting time in packet switched spectrally efficient coherent systems due to high frequency offset tolerance

W2A.36

A Novel OFDM Training Sequence Strategy Based on a Sliding Window for Optical Burst Traffic, Bing Han¹, Paulette Gavignet¹, Erwan Pincemin¹; ¹Orange Labs, France. In order to mitigate the transients occurring in the coherent receivers facing an absence of burst, a novel channel estimator, using a sliding window, is proposed here for optical DP-16QAM-OFDM burst traffic. Our experimental results show a significant performance gain of this new estimator resulting in an error threshold cancellation.

W2A.37

Photonic Generation of Pseudo Random Microwave Waveform based on a Random Fiber Grating, Hong Deng¹, Ping Lu², Stephen Mihailov², Jianping Yao¹; ¹Univ. of Ottawa, Canada; ²National Research Council Canada, Canada. A photonic approach to pseudo-random waveform generation based on a random fiber grating is proposed and demonstrated. A pseudo-random waveform with a temporal duration of 10 ns and a time-bandwidth product of 322.4 is demonstrated.

W2A.38

Reconfigurable Inter-core Switching within Multicore Fiber, Ruoxu Wang¹, Qiong Wu¹, Ming Tang¹, Songnian Fu¹, Deming Liu¹; ¹Huazhong Univ. of Sci. & Tech., China. We achieved a reconfigurable inter-core signal switching using directional bending of long period grating in multicore fibers. Wavelength selective switching of 6×224 Gb/s OFDM signals in 3 cores is experimentally demonstrated.

W2A.39

A 10Gb/s All-optical Match-line for Optical Content Addressable Memory (CAM) Rows, George Mourgiyas-Alexandris¹, Chris Vagionas¹, Apostolos Tsakyridis¹, Pavlos Maniotis¹, Nikos Pleros¹; ¹Department of Informatics, Aristotle Univ. of Thessaloniki, Greece. We experimentally demonstrate the first all-optical match-line for a two Optical CAM-cell-based address look-up row, using wavelength encoding and an AWG-multiplexer. Error-free 2-bit search memory operation at 10Gb/s is experimentally demonstrated.

W2A.40

Optical Signal Processing in the Discrete Nonlinear Frequency Domain, Shi Li¹, Jonas Koch¹, Stephan Pachnicke¹; ¹Christian-Albrechts Univ. zu Kiel, Germany. We investigate the possibility of optical signal processing (OSP) for the nonlinear discrete spectrum. OSP is used to generate and separate a fifth-order soliton optically by a novel transmitter and receiver setup with highly-nonlinear fiber.

W2A.41

Automatic Tuning of Microring-based Hitless Reconfigurable Add-drop Filters, Douglas O. Aguiar¹, Maziyar Milanizadeh¹, Emanuele Guglielmi¹, Francesco Zanetto¹, Marco Sampietro¹, Francesco Morichetti¹, Andrea Melloni¹; ¹Politecnico di Milano, Italy. Exploiting a novel channel labeling scheme, we demonstrate automated tuning and locking of a hitless silicon microring-resonator filter. Hitless tuning with more than 30 dB isolation is achieved, enabling application in add-drop reconfigurable architectures.

W2A.42

Gray-encoded Set-partition 8QAM for Per-wavelength 200-Gb/s Application, Wei-Ren Peng¹, Yanjun Zhu¹, An Li¹, Yan Cui¹, Yusheng Bai¹; ¹High-speed Optical Lab, Futurewei Technologies Inc., USA. A simple Gray-encoding scheme, using a pair of small-sized tables, to reduce the non-gray penalty for set-partition 8QAM is demonstrated. The experimental results show that a 42.3-GBd PDM-sP-8QAM signal, for 200-gb/s per channel use, can exhibit ~0.5-dB OSNR benefit with this encoding method

W2A.43

Convolutional Neural Network based Nonlinear Classifier for 112-Gbps High Speed Optical Link, C. Y. Chuang¹, Li-Chun Liu¹, Chia-Chien Wei², Jun-Jie Liu¹, Lindor Henrickson⁴, Wan-Jou Huang³, Chih-Lin Wang³, Young-Kai Chen⁵, Jyehong Chen¹; ¹National Chiao Tung Univ., Taiwan; ²Department of Photonics, National Sun Yat-Sen Univ., Taiwan; ³Integrated Photonics Department, Industrial Technology Research Inst., Taiwan; ⁴Department of Electrical Engineering, National Chung Hsing Univ., Taiwan; ⁵Nokia Bell Labs, USA. We have designed a novel convolutional neural network based nonlinear classifier that outperforms traditional Volterra nonlinear equalizers. A BER of 3.5×10⁻⁶ is obtained for a 112-gbps PAM4 EML-based optical link over 40-km SMF transmission.

W2A.44

Probabilistically Shaped 1024-QAM OFDM Transmission in an IM-DD System, Jianyang Shi^{1,2}, Junwen Zhang², Nan Chi¹, Yi Cai², Xinying Li^{2,1}, Yun Zhang², Qi Zhang³, Jianjun Yu²; ¹Fudan, China; ²ZTE, USA; ³Beijing Univ. of Posts and Telecommunication, China. We experimentally demonstrate a 28.95 Gbit/s/λ PS-1024-QAM DFT-s OFDM over 40 km of SSMF in a low-cost IM-DD system. A 1.85 Gbit/s capacity increment is achieved using PS-1024-QAM format. To the best of our knowledge, this is the first time to employ high order PS-QAM format in OFDM modulation.

W2A.45

First Demonstration of FPGA-based Hitless Flexible Receiver with Blind Modulation Format Identification, Gengchen Liu¹, Kaiqi Zhang¹, Roberto Proietti¹, Hongbo Lu¹, Zhi Ding¹, S. J. Ben Yoo¹; ¹Univ. of California Davis, USA. We present a FPGA-based flexible receiver with Real-time DSP at 10 GBd that adapts to the modulation format of the incoming signal automatically. Hitless switching between 1.024-μs long QPSK and 16-QAM frames has been experimentally demonstrated.

W2A.46

100Gbps IM/DD Transmission over 25km SSMF using 20G-class DML and PIN Enabled by Machine Learning, Peixuan Li¹, Lilin Yi¹, Lei Xue¹, Weisheng Hu¹; ¹Shanghai Jiao Tong Univ., China. We experimentally demonstrate 100Gb/s/λ IM/DD transmission over 25km SSMF using 20G-class DML and PIN enabled by convolutional neural network based equalization technique. Transmission performance in C-band and O-band using PAM-8 and PAM-16 are compared.

W2A.47

Single-wavelength, Single-photodiode per Polarization 276 Gb/s PDM 8-QAM over 100 km of SSMF, Rafael Puerta^{1,2}, Tomohiro Yamauchi², Takahito Tanimura², Yuichi Akiyama², Tomoo Takahara², Idelfonso Tafur Monroy³, Takeshi Hoshida²; ¹Technical Univ. of Denmark, Denmark; ²Fujitsu Laboratories Ltd, Japan; ³Eindhoven Univ. of Technology, Netherlands. We demonstrate heterodyne detection of 46 GBaud polarization-multiplexed QAM signaling using a transmitter based on a conventional dual-polarization I/Q modulator and a receiver consisting of two single-photodiodes without a local oscillator.

W2A.48

Exploring the Stokes Space by Non-orthogonal Polarization Modulation for a Smooth Upgrade of Optical Link Capacity, Bernhard Schrenk¹, Hannes Hübel¹; ¹AIT Austrian Inst. of Technology, Austria. We experimentally demonstrate transmission at 4 bits/symbol through 2-dimensional Stokes vector modulation while retaining a direct detection receiver. Robustness against channel-induced state transform is confirmed through measurements over 40 km of field-deployed fiber.

W2A.49

Real-time Carrier Phase Recovery for 16-QAM Utilizing the Nonlinear Least Squares Algorithm, Ioannis-Vatistas Kostalampros¹, Christos Spatharakis¹, Konstantinos Maragos¹, Georgios Lentaris¹, Nikos Argyris¹, Stefanos Dris², Andre Richter², Hercules Avramopoulos¹, Dimitrios Soudris¹; ¹National Technical Univ. of Athens, Greece; ²VPI Photonics GmbH, Germany. NLS carrier phase recovery for 16-QAM is implemented Real-time on a Virtex-7 FPGA and demonstrated at 36 GBd, operating on simulated and experimental data; 64 GBd operation is shown to be feasible in larger FPGAs.

W2A.50

Single-IFFT Real-time Layered/Enhanced ACO-OFDM Transmitter, Qibing Wang¹, Binhuang Song¹, Bill Corcoran¹, Arthur Lowery¹; ¹Monash Univ., Australia. Using only a single middle-out Fourier transform, we are able to generate all layers of a 16-QAM-encoded layered/enhanced ACO-OFDM transmitter. We transmit over 10-km of standard single-mode fiber without error propagation in the receiver.

Exhibit Hall B

W2A • Joint Poster Session I—Continued

W2A.51

Laser Phase Noise Tolerance of Probabilistically-shaped Constellations, Seiji Okamoto¹, Fukutaro Hamaoka¹, Masanori Nakamura¹, Yoshiaki Kisaka¹; ¹*Nippon Telegraph & Telephone Corp, Japan*. We numerically confirmed that required-oSNR gain was obtained by probabilistically-shaped 64/256 QAM compared with uniformly-shaped 16/64 QAM in not only arbitrary white Gaussian noise condition but also in phase noise condition.

W2A.52

System Performance Enhancement using Asymmetric Multi-dimensional PAM for Short-reach Optical Transmission, Shuto Yamamoto¹, Akira Masuda¹, Hiroki Taniguchi¹, Mitsunori Fukutoku¹; ¹*NTT Network Innovation Laboratories, NTT Corporation, Japan*. We propose an asymmetric multi-dimensional modulation that enhances the total performance in multi-lane IM-dD transmissions. Simulation results show the improvement of system tolerance to chromatic dispersion and experimental results show the applicability to 120-gb/s signals.

W2A.53

A PMD-adaptive DBP Receiver based on SNR Optimization, Gabriele Liga¹, Cristian B. Czegledi², Polina Bayvel¹; ¹*UCL, UK*; ²*Electrical Engineering, Chalmers Univ. of Technology, Sweden*. We propose a novel adaptive digital backpropagation (DBP) scheme that tracks the fiber polarization-mode dispersion via the optimization of the signal-to-noise ratio. Gains of up to 1.4 dB over conventional DBP are achieved.

W2A.54

Flexible Transmission Enabled by Novel M²-QAM Formats with Record Distance - Spectral Efficiency Tuneability, Fred Buchali¹, Qian Hu¹, Mathieu Chagnon¹, Karsten Schuh¹, Sergejs Makovejs²; ¹*Nokia Bell Labs, Germany*; ²*Corning, UK*. We propose a variable M²-QAM format and coding scheme and demonstrate record distance - spectral efficiency tuneability by 6.4 bit/s/Hz and $\Delta L \approx 18x$, respectively, at 400 and 600 Gb/s per carrier and report record terrestrial reach for high spectral efficient up to 256QAM.

W2A.55

Kramers-Kronig Detection of Polarization Multiplexing Signals by a Single-ended Photodiode, Qiulin Zhang¹, Chester Shu¹; ¹*CUHK, Hong Kong*. We demonstrate that polarization multiplexing signals can be detected by a single-ended photodiode after beating with a pair of orthogonal and staggered carriers. The feasibility of proposed scheme is verified by 8GBaud PDM-QPSK signals.

W2A.56

Weighted Filter Penalty Prediction for QoT Estimation, Camille Delozeide¹, Petros Ramantanis¹, Patricia Layec¹; ¹*Nokia Bell Labs, France*. We experimentally show that noise distribution with regards to filters impacts the QoT by several dB. We thus propose a new QoT prediction method achieving up to 1.7dB margin reduction for links with high hop counts.

W2A.57

Numerical Estimation of Nonlinear Impairments in a 62.5 μ m MMF for MDM Transmission, Marius Brehler¹, Peter M. Krummrich¹; ¹*Chair for High Frequency Technology, TU Dortmund, Germany*. The nonlinear propagation in a multimode fiber using 78 spatial modes is investigated numerically. We show that nonlinear impairments are no obstacle for using fibers with such a high mode count for mode-division multiplexing.

W2A.58

Digital Nonlinearity Compensation Considering Signal Spectral Broadening Effects in Dispersion-managed Systems, Boris P. Karanov¹, Tianhua Xu², Nikita A. Shevchenko¹, Domaniç Lavery¹, Gabriele Liga¹, Robert Kiley¹, Polina Bayvel¹; ¹*Univ. College London, UK*; ²*Univ. of Warwick, UK*. The impact of spectral broadening on the performance of nonlinear compensation applied to legacy submarine dispersion-managed links is studied. An additional 2.2 dB SNR improvement at optimum launch power is achieved by optimizing the compensated bandwidth.

W2A.59

Noise Robust Receiver for Eigenvalue Communication Systems, Rasmus T. Jones¹, Simone Gaiarin¹, Metodij P. Yankov¹, Darko Zibar¹; ¹*Technical Univ. of Denmark, Denmark*. It is demonstrated that in the presence of losses and noise a receiver based on the direct NFT is not optimal. A neural network based receiver is proposed that enables transmission of up to 2000km.

W2A.60

Challenges and Advances of Direct Detection Systems for DCI and Metro Networks, Jinlong Wei¹, Qiang Zhang¹, Liang Zhang¹, Nebojša Stojanović¹, Cristian Prodaniuc¹, Fotini Karinou¹, Changsong Xie¹; ¹*Huawei Technologies Duesseldorf GmbH, Germany*. A 56-gb/s NRZ direct detection system is demonstrated with record 15.5-dB (16.2-dB) OSNR sensitivity over 320-km (640-km) SMF. Furthermore, the challenges and recent advances of direct detection systems for DCIs and metro networks are reviewed.

W2A.61

Successive Four-dimensional Stokes-space Direct Detection, Amir Tasbihi¹, Frank R. Kschischang¹; ¹*Electrical and Computer Engineering Department, Univ. of Toronto, Canada*. We present a successive detection scheme for the fourth dimension in a four-dimensional Stokes space direct detection receiver. At the expense of a small number of electrical-domain computations, the additional information rate can be substantial.

W2A.62

An Efficient Nonlinear Equalizer for 40-Gb/s PAM4-PON Systems, Xizi Tang¹, Ji Zhou¹, Mengqi Guo¹, Jia Qi¹, Tiantian Zhang¹, Zhenshan Zhang¹, Yueming Lu¹, Yaojun Qiao¹; ¹*Beijing Univ Posts & Telecommunications, China*. We firstly propose a decision feedback equalizer (DFE) based on a novel nonlinear filter structure for 40-gb/s PAM4-PON systems. The proposed equalizer achieves similar performance with Volterra DFE at only 21.7% tap numbers.

W2A.63

Noise Prediction and Cancellation Algorithm for the Bandwidth Limited PAM-4 System in the Presence of Intra-channel Homodyne Crosstalk, Tianjian Zuo¹, Tianyu Song¹, Sen Zhang¹, Lei Liu¹, Weiqiang Cheng², Xiaofei Xu¹; ¹*Huawei Technologies Co., Ltd., China*; ²*China Mobile Research Inst., China*. As a low-complexity solution, this paper proposes the use of noise prediction and cancellation (NPC) algorithm in a PAM-4 system, which achieves similar performance as the MLSE based PAM-4 receiver and increases tolerance towards intra-channel homodyne crosstalk.

W2A.64

Improving the Performance of Coherent Quantum Communications with Bayesian Inference, Sebastian Kleis¹, Christian G. Schaeffer¹; ¹*Helmut Schmidt Univ, Univ of FAF Hamburg, Germany*. Laser phase noise limits reach in coherent quantum communications. We experimentally investigate the usefulness of Bayesian inference methods to reduce the impact. An excess noise improvement of 15% is shown, resulting in improved reach and key rate.

Show Floor Programming

COBO Specification Overview and Next Steps

COBO
10:15-11:45

Product Showcase

Huawei
10:15-10:45
For more details, see page 23

■ Network Operator Summit

Keynote:
10:30-11:00

Panel I: The Role of "Open Transport" in the New Metro and Inter-data-center Architectures
11:00-12:30

Product Showcase *Xilinx*

11:00-11:30
For more details, see page 23

Product Showcase *Xilinx*

11:30-12:00
For more details, see page 23

Server Fibreless Optical Networking

Open19 Foundation
12:00-13:00

Product Showcase

Hengtong Optic-Electric Co., Ltd.
12:00-12:30
For more details, see page 23

Product Showcase

Colorchip
12:30-13:00
For more details, see page 23

Product Showcase

ATOP
13:00-13:30
For more details, see page 23

Industry Visions for a Converged

Optical Networking Roadmap ON2020
13:15-15:15

Next Generation Coherent:

Architectures and Technologies Session Sponsored by Acacia Communications
13:30-14:30

■ Network Operator Summit

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30-15:00

Wednesday, 14 March

12:30-14:00 Unopposed Exhibit-only Time, Exhibit Hall (concessions available)



Room 2

14:00–16:00

W3A • Nonlinearity Compensation

Presider: *Andrea Carena; Politecnico di Torino, Italy*

W3A.1 • 14:00 **Tutorial**

Equalization for Combating the Effects of Nonlinear Noise in Long-haul Transmission: Limits And Prospects, Mark Shtaif¹; ¹*Tel-aviv Univ., Israel*. The tutorial will review the relevant mechanisms of nonlinear interference in modern coherent fiber communications systems, and discuss various methods for mitigating their effect. The prospects of nonlinearity mitigation will be considered.



Mark Shtaif is a Professor of EE at the School of EE at Tel-Aviv University, and currently he is functioning as the head of this school. His research interests include nonlinear-propagation, optical nonlinearities, polarization phenomena, communication theory, and signal processing. Prof. Shtaif is a fellow of the IEEE and OSA.

Room 6C

14:00–16:00

W3B • Connected OFCity Challenge 2018: Lighting Up the Emerging World

Organizers: *Marco Ruffini, Trinity College Dublin, Ireland; Inder Monga, ESNNet, USA; Jun Shan Wey, ZTE, USA*

Building on the success of its first two editions, the Connected OFCity Challenge returns in 2018 with a renewed format.

Alibaba and Google will collaboratively take on the challenge to develop communications infrastructure and services based on requirements defined by CSquared and Network Startup Resource Center (NSRC), to address the pressing needs for two cities in a fast developing area in East Africa.

The scenarios will provide a realistic insight into the major issues faced by the communications industry in the region, which include network reliability, environmental restrictions, limited funds, regulatory issues, and more.

We will discuss the development of a cost-effective broadband infrastructure to foster pervasive education, health care and future services, using technologies such as interactive AR/VR. Audience members will gain awareness of optimal design solutions for broadband development and important services in emerging regions. In this updated edition, the audience will play an active role in the challenge, not only to provide feedback and questions, but also have a chance to show their knowledge on this emerging area.

Requirement Task Group:

CSquared

Based in Nairobi, Kenya, CSquared is a large whole sale broadband infrastructure supplier of metro fiber and WiFi networks to mobile operators and ISPs in Ghana, Uganda, and soon in Liberia.

Network Startup Resource Center (NSRC)

NSRC is a non-profit group that develops Internet infrastructure and network engineering expertise throughout Africa, Asia-Pacific, Latin America/Caribbean, and the Middle East. NSRC collaborates with network operators, universities, and government agencies in the regions to improve Internet access and services.

Design Task Groups:

Alibaba

AIS (Alibaba Infrastructure Service) is to develop innovative technologies and build efficient infrastructure to support Alibaba online platforms and Alibaba cloud services.

Google

Room 6D

14:00–16:00

W3C • Multimode Fibers for Datacenters

Presider: *Ming-Jun Li; Corning Research & Development Corp, USA*

W3C.1 • 14:00 **Invited**

Recent Advances on MMFs for WDM and MDM, Denis Molin¹, Marianne Bigot¹, Adrian Amezcuza-Correa¹, Pierre Sillard¹; ¹*PRYSMIANGROUP, USA*. We show how multimode fibers, that have always been flexible transmission media, can be adapted to wavelength division multiplexing in data communications and mode division multiplexing in telecommunications to keep up with capacity increase.

W3C.2 • 14:30 **Invited**

Universal Fibers for Both Single-mode and Multimode Transmissions in Data Centers, Xin Chen², Jason E. Hurley², Jeff Stone², Aramais Zakharian², Bruce Chow³, Doug Coleman¹, Ming-Jun Li²; ¹*Corning Optical Communications LLC, USA*; ²*1. Corning Research and Development Corporation, USA*; ³*2. Corning Optical Fiber and Cable, Corning Incorporated, USA*. Universal fiber is a single medium that can support both multimode and single-mode transmission. We present the fiber properties and system performance at 100G and discuss the benefit of using it in data center.

Room 6E

14:00–16:00

W3D • Fiber Amplifiers

Presider: *Francesca Parmigiani; Univ. of Southampton, UK*

W3D.1 • 14:00 **Tutorial**

Optical Amplification in Extended Wavelength Windows, Mikhail Melkumov¹; ¹*Fiber Lasers and Amplifiers Lab., FORC RAS, Russia*. Latest results in the field of bismuth-doped fiber amplifiers for extended wavelength windows are presented. Fundamental and technical challenges toward the development of efficient amplifiers on bismuth fibers are discussed.



Mikhail Melkumov received M.S. in 2001 from Lomonosov Moscow State University, Russia. In 2006 he received his PhD degree from the Prokhorov General Physics Institute of the Russian Academy of Sciences. Currently he is a head of Fiber lasers and amplifiers laboratory in the Fiber optics research center (FORC RAS), Moscow, Russia. His research interests include: Raman and Rear-earth-doped fiber lasers, Bi-doped fiber lasers and amplifiers, spectroscopy of active centers in silica-based glasses and fibers.



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Use hashtag #OFC18.





Room 6F

14:00–16:00

W3E • All-optical Impairment Mitigation

Presider: Robert Elschner; Fraunhofer Inst Nachricht Henrich-Hertz, Germany

W3E.1 • 14:00 **Top Scored**

Optical Mitigation of Inter-channel Crosstalk for Multiple Spectrally Overlapped 40-Gbit/s QPSK WDM Channels using Nonlinear Wave Mixing, Amirhossein Mohajerin Ariaei¹, Fatemeh Alishahi¹, Ahmad Fallahpour¹, Yinwen Cao¹, Ahmed Almaman¹, Changjing Bao¹, Peicheng Liao¹, Bishara Shamee¹, Joseph Touch², Moshe Tur³, Carsten Langrock⁴, Martin Fejer⁴, Alan E. Willner¹; ¹Univ. of Southern California (USC), USA; ²Information Sciences Inst., USA; ³Tel Aviv Univ., Israel; ⁴Stanford Univ., USA. Using an all-optical method and without multi-channel detection, the inter-channel interferences of overlapped WDM data channels are mitigated simultaneously. We experimentally demonstrate performance improvement for 20-GBaud QPSK overlapped channels under different channel spacing.

W3E.2 • 14:15

Optical Phase Conjugation in Installed Optical Networks, Gabriel Saavedra¹, Yujia Sun², Kyle Bottrill², Lidia Galdino¹, Zhixin Liu¹, Francesca Parmigiani², David J. Richardson², Periklis Petropoulos², Robert Killey¹, Polina Bayvel¹; ¹Univ. College London, UK; ²Univ. of Southampton, UK. We demonstrate a record throughput of 5.7 Tbit/s employing an optical phase conjugator to jointly compensate chromatic dispersion and increase the nonlinear threshold in an installed optical network using commercially available lumped amplifiers.

W3E.3 • 14:30

Link-placement Characterization of Optical Phase Conjugation for Nonlinearity Compensation, Francesco Da Ros¹, Metodi P. Yankov¹, Edson P. da Silva¹, Mads Lilliehölm¹, Søren Forchhammer¹, Michael Galili¹, Leif K. Oxenlowe¹; ¹Technical Univ. of Denmark, Denmark. The impact of the OPC offset on the nonlinearity compensation is experimentally investigated, achieving gains up to 0.6-dB SNR and 0.17-bit/symbol mutual information with optimal mid-link OPC for dispersion-compensated transmission up to 966 km.

W3E.4 • 14:45

Silicon Waveguide with Lateral p-i-n Diode for Nonlinearity Compensation by On-chip Optical Phase Conjugation, Andrzej Gajda¹, Francesco Da Ros², Edson P. da Silva², Anna M. Peczek³, Erik Liebig⁴, Andreas Mai¹, Michael Galili², Leif K. Oxenlowe², Klaus Petermann⁴, Lars Zimmermann¹; ¹IHP, Germany; ²DTU Fotonik, Technical Univ. of Denmark, Denmark; ³IHP Solutions GmbH, Germany; ⁴Institut für Hochfrequenz- und Halbleiter-systemtechnologien, TU Berlin, Germany. A 1-dB Q-factor improvement through optical phase conjugation in a silicon waveguide with a lateral p-i-n diode enables BER<HD-FEC after 644-km dispersion-compensated transmission for all channels of a 5xWDM 16-QAM single-polarization signal.

Room 9

14:00–15:45

W3F • Nanophotonic Devices

Presider: Maura Raburn; Google, USA

W3F.1 • 14:00 **Invited**

Nanophotonic Technology for Chip-based Quantum Light Sources, Marcelo I. Davanco¹; ¹National Inst of Standards & Technology, USA. Nanophotonics is enabling for photonic quantum technologies, providing means to effectively control light-matter interactions on chip. This talk will discuss the use of nanophotonic geometries for creation of efficient and versatile chip-based quantum light sources.

W3F.2 • 14:30

Low Threshold Current 1.3 μ m Fabry-Perot III-V Quantum Dot Lasers on (001) Si with Superior Reliability, Daehwan Jung¹, Justin Norman¹, Mj Kennedy¹, Robert Herrick², Chen Shang¹, Catherine Jan¹, Art Gossard¹, John Bowers¹; ¹UCSB, USA; ²Intel Corp., USA. We report 1.3 μ m quantum dot lasers monolithically integrated on Si substrate. A threshold current of 6.2 mA, output power of 185 mW, and excellent device lifetimes of more than a million hours were achieved

W3F.3 • 14:45

High Performance 1550 nm Quantum Dot Semiconductor Optical Amplifiers Operating at 25-100 °C, Ori Eyal^{1,4}, Amnon Willinger^{1,2}, Vissarion B. Mikhelashvili¹, Saddam Banyoudeh³, Florian Schnabel³, Vitalii Sichkovsky³, Johann P. Reithmaier³, Gad Eisenstein^{1,4}; ¹Electrical Engineering, Technion-Israeli Inst. of Technology, Israel; ²Spectra Physics Tel Aviv, Israel; ³Technological Physics, Inst. of Nano-structure Technologies and Analytics, Univ. of Kassel, Germany; ⁴Russel Berrier Nanotechnology Inst., Israel. We report static and dynamic properties of 1550 nm quantum dot semiconductor optical amplifiers operating at 25-100 °C. Amplification of a single and two 28 Gbit/s channels separated by 2 nm were demonstrated over the entire temperature range.

Show Floor Programming

Industry Visions for a Converged Optical Networking Roadmap

ON2020
13:15–15:15

Next Generation Coherent: Architectures and Technologies

Session Sponsored by Acacia Communications
13:30–14:30

■ Network Operator Summit

Panel II: On the Road to 100G PON (Beyond 10G PON)

13:30–15:00

■ MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality

15:30–17:00

Machine Learning: Developing Efficiency in Customer Networks

15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?

15:45–17:00

Wednesday, 14 March





Room 2

W3A • Nonlinearity Compensation—Continued

W3A.2 • 15:00

Multi-dimensional Pulse-shaping FIR Filter for Nonlinear Interference Alignment, Toshiaki Koike-Akino¹, David Mil- lar¹, Kieran Parsons¹, Keisuke Kojima¹; ¹Mitsubishi Electric Research Labs, USA. We design an irregular pulse-shaping filter to mitigate nonlinear distortion in optical fiber transmission. Our optimized four-dimensional filter allowing nonphysical rotations achieves up to 0.55dB gain over standard root-raised-cosine (RRC) Nyquist shaping.

W3A.3 • 15:15

FEC-assisted Perturbation-based Nonlinear Compensation for WDM Systems, Edson Porto da Silva¹, Metodi P. Yankov¹, Toshio Morioka¹, Leif K. Oxenlowe¹; ¹DTU Fotonik, Denmark. A FEC-assisted iterative perturbation-based nonlinear post-compensation scheme is proposed and experimentally investigated. Improved compensation performance is observed for a 5xWDM-dP 32-GBd dispersion-uncompensated transmission over 3500 and 840 km for 16QAM and 64QAM, respectively.

W3A.4 • 15:30

Nonlinear Interference Mitigation via Deep Neural Networks, Christian Häger^{1,2}, Henry D. Pfister²; ¹Department of Electrical Engineering, Chalmers Univ. of Technology, Sweden; ²Department of Electrical and Computer Engineering, Duke Univ., USA. A neural-network-based approach is presented to efficiently implement digital backpropagation (DBP). For a 32x100km fiber-optic link, the resulting "learned" DBP significantly reduces the complexity compared to conventional DBP implementations.

W3A.5 • 15:45

Efficient Time-domain DBP using Random Step-size and Multi-band Quantization, Celestino Sanches Martins¹, Luca Bertignono², Antonello Nespola³, Andrea Carena², Fernando Guiomar², Armando Pinto¹; ¹Universidade de Aveiro, Portugal; ²Politecnico di Torino, Italy; ³Istituto Superiore Mario Boella, Italy. Employing step-size randomization and multi-band quantization, we propose a reduced complexity time-domain (TD) digital backpropagation (DBP) and experimentally demonstrate penalty-free operation at an average number of ~ 4 bits per FIR coefficient.

Room 6C

W3B • Connected OFCity Challenge 2018: Lighting Up the Emerging World—Continued

Room 6D

W3C • Multimode Fibers for Datacenters—Continued

W3C.3 • 15:00

Study of Dispersion Compensating Multimode Fiber for Future VCSEL PAM-4 Channels at Data Rates over 100 Gb/s, Asher S. Novick¹, Jose Castro¹, Bulent Kose¹, Yu Huang¹, Rick Pimpinella¹, Brett Lane¹; ¹CRD, Panduit, USA. We study the effects of dispersion compensating multimode fiber for data rates exceeding 100 GB/s using 4-level pulse amplitude modulation (PAM-4). Performances of different data rates, fibers, and VCSEL bias currents are compared.

W3C.4 • 15:15

Spectral Dependence of Multimode Fiber Modal Bandwidth, Jose Castro¹, Rick Pimpinella¹, Bulent Kose¹, Yu Huang¹, Asher S. Novick¹, Brett Lane¹; ¹Panduit, USA. We theoretically and experimentally investigate the modal bandwidth spectral dependence behavior of OM3 and OM4 fibers in support of the development of future multi-wavelength transceivers.

W3C.5 • 15:30

Graded-index Seven-core Fiber Optimized for High Density and Ultra-Wideband Parallel Transmission Application, Yingping Liu¹, Lin Ma¹, Chen Yang², Weijun Tong², Zuyuan He¹; ¹Shanghai Jiao Tong Univ., China; ²State Key Laboratory of Optical Fiber and Cable Manufacture Technology, China. We propose graded-index seven-core fiber optimized for high density and ultra-wideband parallel transmission application. We demonstrated both 1 km-propagation at 850 nm and 12.4 km-propagation at 1310 nm simultaneously at a data rate of 7×10-gb/s.

W3C.6 • 15:45

Reference-less Method for Computing the Transmission Matrix of a Multimode Fiber, Moussa N'Gom¹, Theodore B. Norris¹, Eric Michielssen¹, Raj Nadakuditi¹; ¹Univ. of Michigan - Ann Arbor, USA. A simple imaging system together with complex semidefinite programming is used to generate the transmission matrix of a multimode fiber. The optical design does not contain a reference arm and no interferometric measurements are required. The input signal is modulated in phase to induce strong mode interference at the fiber output.

Room 6E

W3D • Fiber Amplifiers—Continued

W3D.2 • 15:00

C + L Band Distributed Few-mode Raman Amplification with Flattened Gain for Mode-Division-multiplexed Optical Transmission Over 75-km Few-mode Fiber, Jiaxiang Li¹, Lulu Wang², Jiangbing Du¹, Zuyuan He¹, Chengkun Cai², Long Zhu², Andong Wang², Jian Wang²; ¹Shanghai Jiao Tong Univ., China; ²Huazhong Univ. of Science and Technology, China. We first experimentally demonstrate a C + L band few-mode Raman amplifier with 4-dB flat on-off gain. In the 1530-1605 nm range, the wavelength dependent gain for both LP01 and LP11 modes is less than 0.6-dB. The amplifier was successfully employed in MDM transmission.

W3D.3 • 15:15

Low Penalty, Dual Stage, Broadband Discrete Raman Amplifier for High Capacity WDM Metro Networks, Lukasz Krzczanowicz¹, Md. Asif Iqbal¹, Ian Phillips¹, Mingming Tan¹, Pavel Skvortcov¹, Paul Harper¹, Wladek Forsysiak¹; ¹Aston Univ., UK. We present a broadband (>70nm), dual stage, discrete Raman amplifier built with small and standard core fibre with ~19.5dB net gain. We transmit 120Gb/s DP-QPSK signals over 3040km with 38 amplifications for a preFEC BER<3.8x10⁻³.

W3D.4 • 15:30

Reduced Crosstalk, Polarization Insensitive Fiber Optical Parametric Amplifier (PI FOPA) for WDM Applications, Marc F. Stephens¹, Vladimir Gordienko¹, Nick Doran¹; ¹Aston Univ., UK. We demonstrate a novel PI FOPA architecture with up to 11.5dB reduction of WDM crosstalk over a conventional scheme when amplifying 22 channels at 10dB to 20dB net gain. Noise figure is increased by ≤1.5dB.

W3D.5 • 15:45

Optical Add-drop Filter based on Raman-assisted Phase-sensitive Amplifiers, Bofang Zheng¹, Qijie Xie¹, Chester Shu¹; ¹Chinese Univ. of Hong Kong, Hong Kong. We demonstrate an optical add-drop filter based on Raman-assisted phase-sensitive amplifiers. Bit error rate measurements with multi-channel signals in QPSK and 16-QAM formats reveal its enhanced selectivity over conventional phase-sensitive amplifiers.

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



Room 6F

W3E • All-optical Impairment Mitigation—Continued

W3E.5 • 15:00 **Tutorial**

All-optical Signal Processing Techniques for Flexible Networks, Alan E. Willner¹; ¹*Univ. of Southern California, USA*. This tutorial will highlight challenges in achieving efficient flexible optical networks. Various optical approaches that enable key functions will be discussed, including: dynamic bandwidth allocation, format conversion, increasing spectral efficiency, and phase-sensitive operations.



Alan Willner (Ph.D., Columbia) worked at AT&T Bell Labs and Bellcore, and is the Sample Chaired Professor of Engineering at USC. He received the following: Member US National Academy of Eng., Int'l Fellow U.K. Royal Society of Eng., IEEE Eric Sumner Award, NSF Presidential Faculty Fellows Award from White House, IET JJ Thomson Medal, Packard Foundation Fellowship, OSA Forman Eng. Excellence Award, IEEE Photonics Society Eng. Achievement Award, SPIE President's Award, Fellow National Academy of Inventors, Globecom Best Paper Award, and Eddy Best Technical Paper Award from Pennwell. He is a AAAS, IEEE, OSA, and SPIE Fellow. He was co-chair of National Academies' Committee on Optics and Photonics, president OSA, president IEEE Photonics Society, Optics Letters editor-in-chief, Journal of Lightwave Technology editor-in-chief, IEEE JSTQE editor-in-chief, CLEO general co-chair, and OFC steering/program committee member.

Room 9

W3F • Nanophotonic Devices—Continued

W3F.4 • 15:00

Lateral Current Injection Membrane Buried Heterostructure Lasers Integrated on 200-nm-thick Si Waveguide, Takuma Aihara¹, Tatsuhiro Hiraki¹, Koji Takeda¹, Koichi Hasebe¹, Takuro Fujii¹, Tai Tsuchizawa¹, Takaaki Kakitsuka¹, Shinji Matsuo¹; ¹*NTT, Japan*. Heterogeneous integration of lasers and 200-nm-thick Si waveguides is the key to realizing high-performance transmitters. A 500- μ m-long DFB laser on Si waveguide exhibits 4.6-mW fiber coupled output power at 25°C and lasing up to 130°C.

W3F.5 • 15:15 **Invited**

Nanoscale Optical Modulators: Application Drivers and Recent Developments, Gordon A. Keeler¹; ¹*DARPA, USA*. Tiny active components will enable a new generation of integrated photonics for communications and sensing. This paper discusses highlights from ongoing programs that seek to reduce the footprint of optical modulators using strong light-matter interaction.

Show Floor Programming

Industry Visions for a Converged Optical Networking Roadmap

ON2020
13:15–15:15

Next Generation Coherent: Architectures and Technologies

Session Sponsored by Acacia Communications
13:30–14:30

■ Network Operator Summit

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30–15:00

■ MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality
15:30–17:00

Machine Learning: Developing Efficiency in Customer Networks
15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?
15:45–17:00

Wednesday, 14 March

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





Room 1A

16:30–18:30
W4A • Deployable Transport Networks
Presider: Jean-luc Auge; Orange Labs, France

W4A.1 • 16:30 **Invited**
Benefits of Performance Awareness in Coherent Dynamic Optical Networks, Juraj Slovak¹, Wolfgang Schairer¹, Maximilian Herrmann¹, Klaus Pulverer¹, Enrico Torrenzo², ¹Coriant R&D, Germany; ²Coriant R&D, Portugal. Awareness of optical network performance and its accurate prediction enables squeezing of margins allocated for stable operation. We discuss potential of online performance assessment by leveraging functionalities of bandwidth variable transponders in flexible optical networks.

Room 1B

16:30–18:30
W4B • Radio-over-fiber II
Presider: Gee-Kung Chang; Georgia Inst. of Technology, USA

W4B.1 • 16:30 **Tutorial**
Microwave Photonic Systems for Sensing Applications, Dalma Novak¹, Rod Waterhouse¹; ¹Pharad, LLC, USA. Microwave photonic (MWP) technology provides many opportunities to extend the capabilities of a range of systems. This tutorial discusses recent advances in MWP technologies for application in remote sensing systems.



Dalma Novak is VP of Engineering at Pharad, LLC; a high technology company located in MD developing advanced RF-over-fiber and antenna products. She is a Fellow of the IEEE and has over 25 years of experience working in the fields of optical and wireless telecommunications. She has published more than 280 papers in these technical areas, including seven book chapters. Prior to Pharad she held positions at The University of Melbourne, Dorsal Networks, and Corvis Corporation. She received her PhD in Electrical Engineering in 1992. Dalma was the President of the IEEE Photonics Society for 2014-2015.

Room 2

16:30–17:45
W4C • Space Division Multiplexed Transmission
Presider: Takayuki Mizuno; NTT Network Innovation Laboratories, Japan

W4C.1 • 16:30 **Top Scored**
266.1-Tbit/s Repeated Transmission over 90.4-km 6-mode Fiber Using Dual C+L-band 6-mode EDFA, Yuta Wakayama¹, Daiki Soma¹, Shohei Beppu¹, Seiya Sumita¹, Koji Igarashi^{1,2}, Takehiro Tsuritani¹; ¹KDDI Research, Inc., Japan; ²Osaka Univ., Japan. We demonstrate 6-mode and 580-wave-length multiplexed transmission with an in-line dual C+L-band cladding-pumped few-mode EDFA. A total capacity of 266.1 Tbit/s is achieved over a 90.4-km transmission line at a spectral efficiency of 36.7 bit/s/Hz.

W4C.2 • 16:45 **Top Scored**
Mode-multiplexed 16-QAM Transmission over 2400-km Large-effective-area Depressed-cladding 3-mode Fiber, John van Weerdenburg^{1,2}, Roland Ryf¹, Roberto A. Alvarez-Aguirre^{1,3}, Nicolas K. Fontaine¹, René-Jean Essiambre¹, Haoshuo Chen¹, Juan Carlos Alvarado Zacarias^{1,3}, Rodrigo Amezcua Correa³, Simon Gross⁴, Nicolas Riesen⁵, Michael Withford⁴, David Peckham⁶, Alan McCurdy⁶, Robert Lingle⁶, Ton Koonen², Chigo Okonkwo²; ¹Nokia Bell Labs, USA; ²Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands; ³CREOL, the Univ. of Central Florida, USA; ⁴MQ Photonics Research Centre, Macquarie Univ., Australia; ⁵Univ. of South Australia, Australia; ⁶OFS, USA. We demonstrate 2400 km mode-multiplexed 16-QAM transmission over a low DMGD (27.1 ps/km) and low MDL (1.75 dB) 3-mode fiber link. The large effective-area 3-mode fiber is shown to outperform a standard single-mode fiber for distances up to 4500km

Room 6C

16:30–18:15
W4D • High Speed Devices for Data Centers **►**
Presider: Kazuhiko Kurata; PETRA, Japan

W4D.1 • 16:30 **►**
56 Gb/s DAC-less and DSP-free PAM-4 Using A Silicon Photonic Dual-drive Michelson Interferometric Modulator, Rui Li¹, David Patel¹, Eslam El-Fiky¹, Alireza Samani¹, Zhenping Xing¹, Yun Wang¹, David V. Plant¹; ¹McGill Univ., Canada. We present a silicon photonic dual-drive Michelson interferometric modulator for DAC-less and DSP-free PAM-4 signal generation. 56 Gb/s PAM-4 transmission over 2 km of SSMF is successfully achieved, with a BER below HD FEC threshold.

W4D.2 • 16:45 **►**
106-Gbit/s PAM4 40-km Transmission using an Avalanche Photodiode with 42-gHz Bandwidth, Masahiro Nada¹, Toshihide Yoshimatsu², Yoshifumi Muramoto², Tetsuhiro Ohno², Nakajima Fumito¹, Hideaki Matsuzaki¹; ¹NTT Device Technology Laboratories, NTT, Japan; ²NTT Device Innovation Center, Japan. 106-gbit/s PAM4 transmission over 40-km single-mode fiber is demonstrated using an avalanche photodiode (APD) with a gap-grading layer for high-speed operation. The APD shows maximum bandwidth of 42GHz with 0.5-a/W responsivity at unity gain.

Room 6D

16:30–18:30
W4E • Kramers-Kronig Receivers **►**
Presider: Andre Richter; VPIphotonics, Germany

W4E.1 • 16:30 **Invited** **►**
A Comparative Study of Technology Options for Next Generation Intra- and Inter-datacenter Interconnects, Mohamed Morsy-Osman¹, David V. Plant¹; ¹McGill Univ., Canada. We review signaling schemes, whose receiver relies on signal self-beating or signal beating with accompanying CW tone, and compare their transceiver architectures, spectral efficiencies, receiver bandwidths and enabling digital signal processing.

Room 6E

16:30–18:30
W4F • Machine Learning for Network Control and Management **►**
Presider: Mazen Khaddam; Cox Communications, Inc., USA

W4F.1 • 16:30 **►**
Realizing AI-assisted Multi-layer Restoration in a Software-defined IP-over-EON with Deep Learning: An Experimental Study, Siqi Liu¹, Baojia Li¹, Zuqing Zhu¹; ¹Univ of Science and Technology of China, China. By using deep learning, we experimentally demonstrate AI-assisted multi-layer restoration in an IP-over-EON, which recovers affected traffic timely with congestion-avoidance rerouting.

W4F.2 • 16:45 **►**
Deep-RMSA: A Deep-reinforcement-learning Routing, Modulation and Spectrum Assignment Agent for Elastic Optical Networks, Xiaoliang Chen¹, Jiannan Guo², Zuqing Zhu², Roberto Proietti¹, Alberto Castro¹, S. J. Ben Yoo¹; ¹Univ. of California Davis, USA; ²Univ. of Science and Technology of China, China. This paper demonstrates Deep-RMSA, a deep reinforcement learning based self-learning RMSA agent that can learn successful policies from dynamic network operations while realizing cognitive and autonomous RMSA in EONs.



Room 6F

16:30–18:30

W4G • Advanced Technologies for High Speed PON

Presider: Volker Jungnickel; Fraunhofer HHI, Germany

W4G.1 • 16:30

High-order Polarization Overlay for Future Optical Access, Bernhard Schrenk¹, Fabian Laudenbach¹, Hannes Hübel¹; ¹AIT Austrian Inst. of Technology, Austria. We demonstrate non-orthogonal Stokes vector modulation at 4 bits/symbol while retaining direct photodetection. 20Gb/s transmission is obtained over a loss budget of 22dB. Pilot-assisted receiver training mitigates the polarization transform along 40km of field-deployed fiber.

W4G.2 • 16:45

Bandwidth Enhancement for an Optical Access Link by using a Frequency Interleaved DAC, Christian Schmidt^{1,2}, Christoph Kottke^{1,2}, Ronald Freund^{1,2}, Volker Jungnickel¹; ¹Fraunhofer HHI, Germany; ²Technical Univ. of Berlin, Germany. We present the experimental realization of the frequency interleaved DAC concept for an IM/DD based access link. The first open 80 GBd PAM-4 electrical eye diagram of the frequency-interleaved DAC without using post-equalization is presented.

Room 7AB

16:30–18:30

W4H • Panel: 2020 Network Vision 5G and Optical Networking

Organizers: Douglas Freimuth, IBM TJ Watson Research Center, USA; Gee-Kung Chang, Georgia Inst. of Technology, USA; Christina Lim, Univ. of Melbourne, Australia; Rod Waterhouse, Pharad, LLC, USA

The network vision of 2020 includes 5G and the multitude of services and applications it enables. 5G and these associated services and applications will have a potential impact on the backhaul, fronthaul, metro and access networks. Carriers and optical equipment providers are working together to define product roadmaps to handle the increased bandwidth and potential architectural changes 5G will bring to the optical infrastructure. This panel will discuss the potential changes 5G will bring to the optical network. We will discuss business drivers, progress in standards and prototypes and services/applications including IoT, media distribution and mobile broadband services. We will further discuss bandwidth requirements in the backhaul and fronthaul optical networks and potential architectural changes when new applications and services are enabled on 5G.

Panelists:

Philippe Chanclou, Orange Labs, France Telecom, France
Paul Littlewood, Ciena, USA
Jun Shan Wey, ZTE, USA
Tod Sizer, Nokia, USA

Room 8

16:30–18:30

W4I • Data Center Traffic Management

Presider: Ken-ichi Kitayama; Graduate School for the Creation of New, Japan

W4I.1 • 16:30 **Invited**

Network Traffic Characteristics of Data Centers in the Wild Revisited, Theophilus Benson¹; ¹Brown Univ., USA. Although there is tremendous interest in designing improved networks for data centers, very little is known about the network-level traffic characteristics of current data centers. In this paper, we conduct an empirical study of the network traffic in 10 data centers belonging to three different types of organizations, including university, enterprise, and cloud data centers. Our definition of cloud data centers includes not only data centers employed by large online service providers offering Internet-facing applications, but also data centers used to host data-intensive (MapReduce style) applications. We collect and analyze SNMP statistics, topology, and packet-level traces. We examine the range of applications deployed in these data centers and their placement, the flow-level and packet-level transmission properties of these applications, and their impact on network utilization, link utilization, congestion, and packet drops. We describe the implications of the observed traffic patterns for data center internal traffic engineering as well as for recently proposed architectures for data center networks.

Room 9

16:30–18:00

W4J • Imaging, Spectroscopy, and Transmission

Presider: Maxim Bolshtyansky; TE SubCom, USA

W4J.1 • 16:30 **Invited**

Image Transmission through Multimode Fibers, Demetri Psaltis¹; ¹Ecole Polytechnique Federale de Lausanne, Switzerland. Multimode fibers can support more than a hundred thousand modes. We will show how to transmit images with the same number of pixels as the number of modes.



Room 10

16:30–18:30

W4K • Novel Fiber Concepts

Presider: Francesco Poletti; Univ. of Southampton, UK

W4K.1 • 16:30 **Invited**

Orbital Angular Momentum (OAM) of Light in Fiber, Siddharth Ramachandran¹; ¹Boston Univ., USA. Light carries spin (polarization) and orbital angular momentum (OAM). We review recent work on the stable propagation and nonlinear properties of such states in fibers, which have spawned applications ranging from telecommunications to biomedical imaging.

Show Floor Programming

■ MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality
15:30–17:00

Machine Learning: Developing Efficiency in Customer Networks
15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?
15:45–17:00

Wednesday, 14 March



Room 1A

W4A • Deployable Transport Networks—Continued

W4A.2 • 17:00 **Invited**

Extension of SDN Networks to the Satellite Domain; Integration of a SDN Enabled WAN Network, with Terrestrial and Submarine Elements, with Command and Control of Multiple Satellite Constellations, Robert Kimball¹, Richard Williams², John Connelly¹, Nathen McNeal¹, Charles Cynamon², Robert Hughes², Kurt Richardson²; ¹Ciena Corporation, USA; ²LinQuest Corporation, USA. Dynamic software controlled terrestrial fiber networks combined with an agile satellite communications (SATCOM) service management system increases system resiliency; bringing resources into the operational environment. This includes failover of critical communications paths over different technologies.

Room 1B

W4B • Radio-over-fiber II—Continued

Room 2

W4C • Space Division Multiplexed Transmission—Continued

W4C.3 • 17:00

93.34 Tbit/s/mode (280 Tbit/s) Transmission in a 3-mode Graded-index Few-mode Fiber, Georg Rademacher¹, Ruben S. Luis¹, Benjamin J. Puttnam¹, Roland Ryf², Hideaki Furukawa¹, Ryo Maruyama³, Kazuhiko Aikawa³, Akihiro Maruta⁴, Yoshinari Awaji¹, Naoya Wada¹; ¹National Inst of Information & Comm Tech, Japan; ²Nokia Bell Labs, USA; ³Fujikura Ltd, Japan; ⁴Osaka Univ., Japan. We transmit 381x24.5 GBaud PDM-64-QAM modulated channels per mode of a 30 km graded-index three-mode fiber, resulting in a record per-mode data-rate of 93.34 Tbit/s and an aggregated net-data-rate of 280 Tbit/s.

W4C.4 • 17:15

First Demonstration of Orbital Angular Momentum (OAM) Distributed Raman Amplifier over 18-km OAM Fiber with Data-carrying OAM Multiplexing and Wavelength-division Multiplexing, Long Zhu¹, Jiaxiong Li², Guoxuan Zhu³, Lulu Wang¹, Chengkun Cai¹, Andong Wang¹, Shuhui Li¹, Ming Tang¹, Zuyuan He², Siyuan Yu^{3,4}, Cheng Du⁵, Wenyong Luo⁵, Jie Liu³, Jiangbing Du², Jian Wang¹; ¹Wuhan National Lab for Optoelectronics, China; ²Shanghai Jiao Tong Univ., China; ³Sun Yat-sen Univ., China; ⁴Univ. of Bristol, UK; ⁵Fiberhome Telecommunication Technologies Co. Ltd, China. We propose and demonstrate orbital angular momentum (OAM) distributed Raman amplifier over 18-km OAM fiber with 2 OAM modes multiplexing and 16 wavelength-division multiplexing. The on-off gain of the two OAM modes are about 3 dB from 1530 nm to 1565 nm.

Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.3 • 17:00 **Top Scored**

Monolithic Dual-polarization Silicon Modulator for 180 Gb/s DMT Signal Transmission, Xinru Wu^{1,2}, Yang Hong¹, Yeyu Tong¹, Lin Chang², Wen Zhou¹, Lian-Kuan Chen¹, John Bowers², Hon Ki Tsang¹; ¹The Chinese Univ. of Hong Kong, Hong Kong; ²Univ. of California, Santa Barbara, USA. We present a monolithic dual-polarization modulator based on two silicon Mach-Zehnder modulators and a two-dimensional grating coupler as the dual-polarization output coupler. Data transmission at 180 Gb/s using discrete multi-tone modulation is demonstrated.

W4D.4 • 17:15 **Invited**

100 Gb/s DAC-less and DSP-free Transmitters using GeSi EAMs for Short-reach Optical Interconnects, Jochem Verbist^{1,2}, Michiel Verplaetse¹, Joris Lambrecht¹, Ashwyn Srinivasan³, Joris Van Kerrebrouck¹, Peter De Heyn³, Timothy De Keulenaer⁴, Ramses Pierco⁴, Renato Vaernewyck⁴, Arno Vyncke⁴, Philippe Absil³, Guy Torfs¹, Xin Yin¹, Joris Van Campenhout³, Gunther Roelkens², Johan Bauwelinck¹; ¹IDLab, Ghent Univ. - IMEC, Belgium; ²Photonics Research Group, Ghent Univ. - imec, Belgium; ³imec, Belgium; ⁴BiFast, Belgium. We present single-lane 100-gb/s NRZ, electrical duobinary and PAM-4 transmitters using silicon photonics GeSi electro-absorption modulators. No DSP, DAC or traveling-wave structures are required, enabling compact and low-power transceivers for data center interconnects.

Room 6D

W4E • Kramers-Kronig Receivers—Continued

W4E.2 • 17:00 **Top Scored**

Kramers-Kronig Receiver without Digital Upsampling, Tianwai Bo¹, Hoon Kim¹; ¹School of Electrical Engineering, KAIST, Korea. We propose a new Kramers-Kronig receiver which does not require digital upsampling. The experimental demonstration performed in 80-km transmission of 112-gb/s SSB-OFDM signal shows that our proposed receiver exhibits similar performance to the conventional one.

W4E.3 • 17:15 **Top Scored**

Transmission of 80-GBd 16-QAM over 300 km and Kramers-Kronig Reception using a Low-complexity FIR Hilbert Filter Approximation, Christoph Füllner¹, Stefan Wolf¹, Juned Kemal¹, Joachim Lutz², Lars Altenhain², Rolf Schmid², Wolfgang Freude¹, Christian Koo¹, Sebastian Randel¹; ¹Karlsruhe Inst. of Technology, Germany; ²Micram Microelectronic GmbH, Germany. We demonstrate Kramers-Kronig reception at a net rate of 267 Gb/s using a single high-bandwidth photodiode. We propose a low complexity DSP implementation, analyze back-to-back performance, and show transmission over up to 300 km.

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.3 • 17:00 **Invited**

ANN-based Transfer Learning for QoT Prediction in Real-time Mixed Line-rate Systems, Weiyang Mo^{1,2}, Yuekai Huang², Shaoliang Zhang², Ezra Ip², Daniel Kilper¹, Yoshiaki Aono³, Tsutomu Tajima³; ¹The Univ. of Arizona, USA; ²NEC Laboratories America, USA; ³Converged Network Division, NEC Corporation, Japan. Quality of transmission prediction for Real-time mixed line-rate systems is realized using artificial neural network based transfer learning with SDN orchestrating. 0.42 dB accuracy is achieved with a 1000 to 20 reduction in training samples.

W4F.4 • 17:15 **Invited**

Machine Learning-assisted Management of a Virtualized Network, Michiaki Hayashi¹; ¹KDDI Research Inc., Japan. Toward proactive network management, machine learning is expected especially from enhancing fault management and sustaining automated system itself. This paper describes the motives for using machine learning, and provides some proof-of-concept demonstrations.

Wednesday, 14 March

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Room 6F

W4G • Advanced Technologies for High Speed PON—Continued

W4G.3 • 17:00  **Invited** 
Bandwidth Extension Techniques for High-speed Access Networks, Christoph Kottke^{2,1}, Christian Schmidt^{2,1}, Ronald Freund^{2,1}, Volker Jungnickel²; ¹*Technische Universität Berlin, Germany*; ²*Fraunhofer Heinrich Hertz Inst., Germany*. Recent advances in bandwidth extension techniques for high-speed access environments are presented together with own transmission experiments. Current issues and critical aspects are highlighted.

Room 7AB

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

Room 8

W4I • Data Center Traffic Management—Continued

W4I.2 • 17:00
Leveraging Deep Learning to Achieve Efficient Resource Allocation with Traffic Evaluation in Data-center Optical Networks, Ao Yu¹, Hui Yang¹, Wei Bai¹, Linkuan He¹, Hongyun Xiao², Jie Zhang¹; ¹*BUPT, China*; ²*ZTE, China*. This paper first presents a deep learning-based resource allocation strategy supported by global evaluate factor in intra-datacenter optical networks. Numerical results show the proposed strategy improves traffic prediction accuracy and has superior performance.

W4I.3 • 17:15
A Novel Buffering Design and Performance Evaluation of Optical Flow Switch with Smart Scheduling Algorithms, Yuh-Jiuh Cheng¹, Yhi Shiau¹, Bor-Tauo Chen¹; ¹*Broadband Networks Laboratory, TL, Chunghwa Telecom Co., Ltd., Taiwan*. In this paper, buffering design and performance evaluation of OFS with smart scheduling algorithms are proposed. The buffer scheduling methods are used for a hybrid switching module or all-optical switching module on the data center.

Room 9

W4J • Imaging, Spectroscopy, and Transmission—Continued

W4J.2 • 17:00
Demonstration of Stable 3x10 Gb/s Mode Group-multiplexed Transmission over a 20 km Few-mode Fiber, Huiyuan Liu¹, He Wen^{1,3}, Juan Carlos Alvarado Zacarias¹, Jose Enrique Antonio-Lopez¹, Ning Wang¹, Pierre Sillard², Rodrigo Amezcua Correa¹, Guifang Li^{1,3}; ¹*Univ. of Central Florida, USA*; ²*Prysmian Group, France*; ³*Tianjin Univ., China*. We experimentally demonstrate stable 3x10 Gb/s mode group-multiplexed transmission over a 20 km few-mode fiber using OOK modulation and direct detection. Stability in transmission was achieved by combining all degenerate modes at the receiver.

W4J.3 • 17:15
3x4x10-gb/s MDM-WDM Transmission over 21-km OM3 MMF with OOK Modulation and Direct Detection, Zhongying Wu¹, Juhao Li¹, Yu Tian¹, Dawei Ge¹, Jinglong Zhu¹, Yichi Zhang², Jinyi Yu¹, Zhengbin Li¹, Zhangyuan Chen¹, Yongqi He¹; ¹*Peking Univ., China*; ²*Fiberhome, China*. 3x4x10-gb/s IM-dD MDM-WDM transmission over OM3 MMF is experimentally demonstrated. 3 modes with large Δn_{eff} are selectively excited as independent-spatial-channels. Enabled by cascaded low-modal-crosstalk MSCs and wavelength-interleaved scheme, a record distance of 21-km is achieved.


Room 10

W4K • Novel Fiber Concepts—Continued

W4K.2 • 17:00
Phase Purity Measurement of Ultra-broadband Orbital Angular Momentum Mode Excited by Meta-facet Few-mode Fiber, Yifan Zhao¹, Jinrun Zhang¹, Jian Wang¹; ¹*Huazhong Univ of Science and Technology, China*. We design and fabricate metasurface on the facet of few-mode fiber (FMF). Ultra-broadband orbital angular momentum modes (OAM_{1,1} and OAM_{1,-1}) are excited in the fiber and the phase purity from 1480-1640 nm is measured through one interferogram image.

W4K.3 • 17:15
Design of a Weakly-coupled Ring-core FMF and Demonstration of 6-mode 10-km IM/DD Transmission, Dawei Ge¹, Juhao Li¹, Jinglong Zhu¹, Lei Shen², Yuyang Gao¹, Jinyi Yu¹, Zhongying Wu¹, Zhengbin Li¹, Zhangyuan Chen¹, Yongqi He¹; ¹*Peking Univ., China*; ²*Yangtze Optical Fibre and Cable Joint Stock Limited Company, China*. We design and fabricate a weakly-coupled ring-core 6-mode fiber with a minimum Δn_{eff} of 1.49×10^{-3} , based on which 6-mode 10-km MDM transmission with OOK modulation and direct detection is experimentally demonstrated.

Show Floor Programming


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Wednesday, 14 March



Room 1A

W4A • Deployable Transport Networks—Continued

W4A.3 • 17:30  **Capacity Enhancement in Optical Networks using Margin Extraction**, Mohammad Sheikh Zefreh¹; ¹*Ciena, Canada*. In this paper, the value of margin extraction in optical networks is investigated. Simulation results for a sample network show that up to 64% of multi-rate transponders can run with higher rates using extracted margins.

W4A.4 • 17:45 **Demonstration of Automatic Connection Pair Discovery and Path Setting in Filter-less Point-to-point WDM Systems**, Yutaka Takita¹, Masatake Miyabe¹, Kazuyuki Tajima¹, Hiroshi Tomonaga¹, Takeshi Hoshida¹; ¹*Fujitsu Labs. Ltd., Japan*. We propose the filter-less point-to-point WDM system with IP-layer driven automatic optical connection pair discovery and path setting function. We confirmed its basic operation in a 100km span 32-lambdas WDM system with enhanced transponders.

Room 1B

W4B • Radio-over-fiber II—Continued

W4B.2 • 17:30 **Experimental Study of Distributed Massive MIMO (DM-MIMO) in In-building Fiber-wireless Networks**, Solomon T. Abraha¹, Dave Castellana¹, Xiaojun Liang¹, Anthony Ng'oma¹, Andrey Kobaykov¹; ¹*Corning Research & Development Corp, USA*. We experimentally demonstrate up to 10x greater system capacity using Distributed M-MIMO compared to Collocated M-MIMO in an indoor environment. We further show that user-distribution-driven antenna placement enables significant infrastructure savings up to 25%.

W4B.3 • 17:45 **Mitigation of Multi-user Access Impairments in 5G A-RoF-based Mobile Fronthaul utilizing Machine Learning for an Artificial Neural Network Nonlinear Equalizer**, Siming Liu^{1,2}, Yahya M. Alfadhli², Shuyi Shen², Huiying Tian¹, Gee-Kung Chang²; ¹*School of Information and Communication Engineering, Beijing Univ. of Posts and Telecom, China*; ²*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA*. We propose a complex-valued multi-level artificial neural network nonlinear equalizer (ANN-nLE) in bandwidth-efficient radio-over-fiber mobile fronthaul systems. The proposed ANN-nLE is experimentally demonstrated to mitigate intra/inter-band interferences caused by nonlinear impairments in multi-user environments.

Room 2

W4C • Space Division Multiplexed Transmission—Continued

W4C.5 • 17:30 **Maximum Submarine Cable Capacity Analysis with C-band, C+L-band, and Multicore Fiber C-band**, John D. Downie¹; ¹*Corning Research & Development Corp, USA*. The maximum capacity of fixed voltage submarine cables is analyzed using single-core fibers with C- and C+L-band systems, and multi-core fibers (MCFs) with C-band transmission. Extra losses for C+L and MCFs limit their relative capacity.


Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.5 • 17:45  **Assessment of Integrated Ge Franz-Keldysh Modulator for Discrete Multi-tone Modulation**, Yeyu Tong¹, Xinru Wu¹, Jie Liu¹, Chester Shu¹, Hon Ki Tsang¹; ¹*The Chinese Univ. of Hong Kong, Hong Kong*. We measure the second order and third order spurious-free dynamic range (SFDR) of an integrated germanium Franz-Keldysh modulator and assess the performance of the modulator for discrete multi-tone (DMT) modulation without any pre-equalization.

Room 6D


W4E • Kramers-Kronig Receivers—Continued

W4E.4 • 17:30  **Comparison of Chromatic Dispersion Sensitivity between Kramers-Kronig and SSBI Iterative Cancellation Receiver**, Chuanbowen Sun¹, Di Che¹, William Shieh¹; ¹*Univ. of Melbourne, Australia*. We compare the chromatic dispersion (CD) sensitivity between Kramers-Kronig (KK) and SSBI iterative cancellation (IC) receiver. It is shown that KK receiver is sensitive to CD while IC receiver is insensitive.

W4E.5 • 17:45  **264 Gb/s Twin-SSB-KK Direct Detection Transmission Enabled by MIMO Processing**, Sujie Fan^{1,2}, Qunbi Zhuge^{3,2}, Zhenping Xing², Kuo Zhang², Thang M. Hoang², Mohamed Morsy-Osman², Mohammed Sowaim², Yan Li¹, Jian Wu¹, David V. Plant²; ¹*Beijing Univ. of Posts & Telecommunications, China*; ²*McGill Univ., Canada*; ³*Ciena Corporation, Canada*. We experimentally demonstrate the transmission of 264 Gb/s twin-SSB-KK single carrier signals over 80 km SSMF, enabled by a novel MIMO processing scheme to remove the crosstalk between sideband signals caused by non-ideal optical filters.

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.5 • 17:45  **Field Trial of Gaussian Process Learning of Function-agnostic Channel Performance Under Uncertainty**, Fanchao Meng¹, Shuangyi Yan¹, Konstantinos Nikolovgenis¹, Yanni Ou¹, Rui Wang¹, Yu Bi¹, Emilio H. Salas¹, Reza Nejabati¹, Dimitra E. Simeonidou¹; ¹*Univ. of Bristol, UK*. We successfully demonstrated a novel performance learning method using monitoring and Gaussian process. After 436km dark fiber transmission the model captures most of the test data with 0.7dB mean error and enables robust QoT predictor.



Room 6F

W4G • Advanced Technologies for High Speed PON—Continued

W4G.4 • 17:30

60-km Transmission of 28-Gb/s QPSK Upstream Signal in RSOA-based WDM PON Using SBS Suppression Technique, Daeho Kim¹, Byung Gon Kim¹, Hoon Kim¹; ¹KAIST, Korea. We experimentally demonstrate the 60-km transmission of 28-gb/s QPSK signal in RSOA-based coherent WDM-PON. The frequency dithering of seed laser and fast carrier-phase estimator are employed to suppress SBS and track the laser's phase, respectively.

W4G.5 • 17:45

Novel DDM-OFDM-PON with Hybrid Sub-Nyquist Sampling Rates Featuring Heterogeneous ONUs with Different Capacities, Jhih-Hao Hsu¹, Min Yu¹, Chia Chien Wei¹, Chi-Hsiang Lin², Chun-Ting Lin², Fumin Liu³, Lei Zhou³, LiMing Fang³; ¹National Sun Yat-Sen Univ., Taiwan; ²National Chiao Tung Univ., Taiwan; ³Huawei Technologies, China. We propose a delay-division-multiplexing-OFDM-PON (DDM-OFDM-PON) with hybrid sub-Nyquist sampling rates, wherein heterogeneous ONUs can request different capacities. 26-dB loss budget in 25-km 25-gbps DDM-OFDM-PON was achieved using hybrid sampling at (1/32, 1/16, 1/8) or (1/32, 1/8, 1/2) Nyquist rates.

Room 7AB

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

Room 8

W4I • Data Center Traffic Management—Continued

W4I.4 • 17:30

Optical Networks Throughput Enhancement via TCP Stop-and-wait on Hybrid Switches, Artur Minakhmetov¹, Cédric Ware¹, Luigi Iannone¹; ¹Telecom ParisTech, France. We report on possible 50% throughput increase in Optical Packet Switching (OPS) data-center networks by replacing all-optical switches with optical switches with shared electronic buffers further enhanced with TCP Stop-and-wait algorithms.

W4I.5 • 17:45

Novel Circuit Switching Enabled Reconfigurable HPC Network for Traffic Pattern, Yu Shang¹, Bingli Guo¹, Wenzhe Li¹, Yu Zhou¹, Xin Li¹, Yunquan Zhang^{2,3}, Shanguo Huang¹; ¹BUPT, China; ²National Supercomputer Center, China; ³State Key Laboratory of Computer Architecture, Inst. of Computing Technology, Chinese Academy of Sciences, China. We propose a reconfigurable hybrid network architecture using optical circuit switches for HPC systems, and evaluate the performance of different topologies according to different traffic patterns through high throughput and low latency.

Room 9

W4J • Imaging, Spectroscopy, and Transmission—Continued

W4J.4 • 17:30

Applications of Multimode Fibers for Spectroscopy and Polarization Control, Hui Cao¹; ¹Yale Univ., USA. A multimode fiber spectrometer is developed with ultrahigh resolution and extreme broad bandwidth. Shaping the input wavefront enables an effective control of output polarization states of a multimode fiber with random polarization and mode coupling.

Room 10

W4K • Novel Fiber Concepts—Continued

W4K.4 • 17:30

PANDA-type Elliptical-core Multimode Fiber with Fully Lifted Eigenmodes for Low-crosstalk Direct Fiber Vector Eigenmode Space-division Multiplexing, Shi Chen¹, Jian Wang¹; ¹Wuhan National Lab for Optoelectronics, China. We propose a PANDA-type elliptical-core MMF featuring an elliptical core and two symmetrical circular stress-applying parts. With proper fiber geometric dimension and doping concentration, the designed fiber is able to support 24 fully lifted eigenmodes with minimum Δn_{eff} between adjacent modes larger than 1.30×10^{-4} over the whole C+L band.

W4K.5 • 17:45

Outlook on In-fiber Silicon Photonics, Anna C. Peacock¹; ¹Univ. of Southampton, UK. This paper reviews the recent advancements in the fabrication and application of silicon optical fibers. Particular focus is placed on novel materials and device designs for use in optical signal processing systems.

Show Floor Programming

Wednesday, 14 March





Room 1A

W4A • Deployable Transport Networks—Continued

W4A.5 • 18:00

How Much is CD ROADM Contention Blocking?, Guangzhi Li¹, Kerong Yan², Li Huang², Bin Xia², Fanhua Kong², Yang Li²; ¹Futurewei Technology Inc., USA; ²Huawei Technologies, China. This paper models CD ROADM network contention blocking and shows that the contention blocking impact is marginal when CD ROADM add/drop port usage is less than 75%. Numerical results verify the effectiveness.

W4A.6 • 18:15

Influence of the Maturity of Technology on the Benefit of 75 Ghz-Spaced 64 GBaud Channels in WDM Elastic Networks, Thierry Zami¹, Bruno Lavigne¹, Marco Bertolini¹; ¹Nokia Corporation, France. We quantify how the benefit of 75 GHz-spaced 64 GBaud channels in WDM core networks depends on both the associated elastic modulation set and the maturity of transponder implementation correlated to the WDM transmission reaches

Room 1B

W4B • Radio-over-fiber II—Continued

W4B.4 • 18:00

Experimental Demonstration of Analog IFoF-based Seamless Fiber-wireless Interface for 5G Indoor DAS Supporting 8 FA and 2x2 MIMO configuration, Joonyoung Kim¹, Minkyu Sung¹, Eon-Sang Kim¹, Seung-Hyun Cho¹, Jong Hyun Lee¹; ¹ETRI, Korea. We demonstrate analog IFoF-based seamless fiber-wireless interface for 5G indoor DAS that provides down-to 2-% EVM for ambient temperature from -20 to 60 °C with up-to 17 dB power budget, allowing >40 power split-ratio.

W4B.5 • 18:15

Experimental Demonstration of Analog Transmission using Mode Division Multiplexing, Cheng Xu¹, Guanjun Gao¹, Pengyue Deng¹, Ruihuan Wu¹, Tianwei Jiang¹, Yifan Shen¹, Jie Zhang¹; ¹Beijing Univ. of Posts & Telecom, China. We demonstrate MDM-based analog fiber-optic link to further increase link gain and reduce nonlinearity. Compared with using LP11 mode only in FMF, MDM-based link increases the SFDR by 4.6dB.

Room 2

W4C • Space Division Multiplexed Transmission—Continued

Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.6 • 18:00  **Top Scored**

56GHz Waveguide Ge/Si Avalanche Photodiode, Mengyuan Huang¹, Pengfei Cai¹, Su Li¹, Guanghui Hou¹, Naichuan Zhang¹, Tzung-I Su¹, Chingyin Hong¹, Dong Pan¹; ¹SiFotonics Technologies, USA. We report a waveguide Ge/Si APD with ultra-high 3dB-bandwidths: 56GHz with a 1310nm responsivity of 1.08A/W and 36GHz with a 1310nm responsivity of 6A/W, which, to our knowledge, are the best performance among all reported APD devices.

Room 6D

W4E • Kramers-Kronig Receivers—Continued

W4E.6 • 18:00 

Frequency-resolved Measurements of Signal, Noise, and Signal-signal Beat Interference in Self-coherent Direct-detection Receivers, Xi Chen¹, Sethumadhavan Chandrasekhar¹, Peter J. Winzer¹; ¹Nokia Bell Labs, USA. We demonstrate a novel measurement technique that uniquely identifies the power spectral densities of signal, signal-signal-beat interference, and noise in direct-detection receivers.

W4E.7 • 18:15 

Single Wavelength 480 Gb/s Direct Detection Transmission Over 80 km SSMF Enabled by Stokes Vector Receiver and Reduced-complexity SSBI Cancellation, Thang M. Hoang¹, Qunbi Zhuge^{2,1}, Zhenping Xing¹, Mohammed Sowailam¹, Mohamed Morsy-Osman¹, David V. Plant¹; ¹McGill Univ., Canada; ²Ciena Corporation, Canada. We experimentally demonstrate a 4-dimensional modulation direct detection system based on Stokes vector receiver and a novel reduced-complexity SSBI cancellation algorithm for signal linearization. A 480 Gb/s data rate over 80 km SSMF is achieved

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.6 • 18:00 

Analytics-driven Fault Discovery and Diagnosis for Cognitive Root Cause Analysis, Danish Rafique¹, Thomas Szyrkowiec¹, Achim Autenrieth¹, Joerg-Peter Elbers¹; ¹ADVA Optical Networking, Germany. We propose an SDN-integrated framework for distributed cognitive fault discovery and diagnosis across end-to-end network infrastructure. The approach is evaluated on a real-world use-case and proactively identifies root cause of autonomously-detected optical power level anomalies.

W4F.7 • 18:15  **Top Scored**

Experimental Demonstration of Cognitive Provisioning and Alien Wavelength Monitoring in Multi-domain EON, Roberto Proietti¹, Xiaoliang Chen¹, Alberto Castro¹, Gengchen Liu¹, Hongbo Lu¹, Kaiqi Zhang¹, Jiannan Guo², Zuqing Zhu², Luis Velasco³, S. J. Ben Yoo³; ¹Univ. of California Davis, USA; ²Univ. of Science and Technology of China, China; ³Universitat Politècnica de Catalunya, Spain. This paper proposes a cognitive multi-domain EON architecture with machine-learning aided RMSA and alien wavelength monitoring. Testbed experiments show modulation format recognition, QoT monitoring and cognitive routing for a 160 Gbd alien multi-wavelength lightpath.

Wednesday, 14 March

17:00–19:30 Photonic Society of Chinese-Americans Workshop & Social Networking Event, Room 14A



Room 6F

W4G • Advanced Technologies for High Speed PON—Continued

W4G.6 • 18:00 Improved Performance of High-order QAM OFDM based on Probabilistically Shaping in the Datacom, Jianyang Shi^{1,2}, Junwen Zhang², Xinying Li², Nan Chi¹, Yun Zhang², Qi Zhang³, Jianjun Yu²; ¹Fudan, China; ²ZTE, USA; ³Beijing Univ. of Posts and Telecommunication, China. We experimentally demonstrated a PS-256-QAM OFDM fiber transmission in a low-cost IM-dD system. Compared with uniform 128-QAM, the proposed PS-256-QAM obtains the same entropy of 7 bits/QAM symbol, but higher achievable-information-rate performance and stronger nonlinearity robustness.

W4G.7 • 18:15 Realization of Tunable Frequency Response in Polarization Modulation and Direct Detection Scheme for High-speed Optical Access System, Siming Liu^{1,3}, Peng-Chun Peng^{2,3}, Chin-Wei Hsu³, Huiping Tian¹, Ge-Kung Chang³; ¹School of Information and Communication Engineering, Beijing Univ. of Posts and Telecom, China; ²Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan; ³School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA. We are the first to transmit 80-gbps 16QAM signals through a single mode fiber in a polarization-modulation-direct-detection (PolM-dD) system. The PolM-dD system has a tunable frequency response and can overcome the chromatic-induced power fading effect.

Room 7AB

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

Room 8

W4I • Data Center Traffic Management—Continued

W4I.6 • 18:00 Invited Role of Standards in Web-scale Data-centers, Mark M. Filer¹; ¹Microsoft Corp., USA. Standards play an increasingly important role for cloud providers considering the dramatic growth that cloud services are experiencing. Distinctions are made between open consortia, multi-source agreements, and standards, and case studies with lessons learned are presented.

Room 9

W4J • Imaging, Spectroscopy, and Transmission—Continued

Room 10

W4K • Novel Fiber Concepts—Continued

W4K.6 • 18:15 Interfacing Telecom Fibers and Silicon Core Fibers with Nano-spikes for In-fiber Silicon Devices, Ozan Aktas¹, Haonan Ren¹, Antoine F. Runge¹, Anna C. Peacock¹, Thomas Hawkins^{2,3}, John Ballato^{2,3}, Ursula J. Gibson^{4,5}; ¹Univ. of Southampton, UK; ²Center for Optical Materials Science and Engineering Technologies (COMSET), Clemson Univ., USA; ³Department of Materials Science and Engineering, Clemson Univ., USA; ⁴Department of Physics, Norwegian Univ. of Science and Technology, Norway; ⁵Applied Physics Department, KTH Royal Inst. of Technology, Sweden. We report fabrication of tapered silicon core fibers with nano-spikes enabling efficient optical coupling into the core, as well as their seamless integration with single mode fibers. A proof-of-concept integrated in-fiber silicon device is demonstrated.

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

Show Floor Programming

Wednesday, 14 March

17:00–19:30 Photonic Society of Chinese-Americans Workshop & Social Networking Event, Room 14A



Room 1A

Room 1B

Room 2

Room 6C

Room 6D

Room 6E

07:30–08:00 Coffee Break, Upper Level Corridors

08:00–10:00

Th1A • Advances in Coherent Design and Measurement

Presider: Sorin Tibuleac; ADVA Optical Networking, USA

08:30–10:00

Th1B • 5G Transport

Presider: Jiajia Chen; Kungliga Tekniska Hogskolan, Sweden

09:00–10:00

Th1C • Wideband Transmission

Presider: Robert Killey; Univ. College London, UK

08:00–10:00

Th1D • Application Awareness and Online Optimization

Presider: Ramon Casellas; Centre Tecnològic Telecomunicacions Catalunya, Spain

08:00–10:00

Th1E • Components for Future PON

Presider: Lilin Yi; Shanghai Jiao Tong Univ., China

08:00–10:00

Th1F • High Capacity Subsystems

Presider: Sebastian Randel; Karlsruhe Inst. of Technology, Germany

Th1A.1 • 08:00 **Invited**

Novel OSNR Measurement Techniques for Coherent-detection Systems, Daniel Gariépy¹, Steven Searcy², Gang He¹, Sorin Tibuleac²; ¹EXFO, Canada; ²ADVA Optical Networking, USA. We discuss in-service OSNR measurement options independent of coherent receiver metrics. We review a spectral analysis technique for discriminating ASE when fiber nonlinearities contribute “Gaussian-like” noise and evaluate its performance in practical network scenarios.

Th1D.1 • 08:00 **Tutorial**

The Role of Open-source Network Optimization Software in the SDN/NFV World, Pablo Pavon-Marino^{1,2}, Miquel Garrich^{3,1}, Francisco-Javier Moreno-Muro¹; ¹Universidad Politécnica de Cartagena, Spain; ²E-lighthouse Network Solutions, Spain; ³Optical Technologies Division, CPqD, Brazil. SDN/NFV means an unprecedented network control, for an unprecedented resource dynamics. Manual optimization is unmanageable. This tutorial covers open source optimization software initiatives for offline planning and online provisioning and orchestration of SDN/NFV networks.

Th1E.1 • 08:00 **Invited**

Components for High Speed 5G Access, Helene Debregeas¹, Robert Borkowski², Rene Bonk², Thomas Pfeiffer², Francois Lelarge³, Mohand Achouche¹; ¹Ill-V Lab, France; ²Nokia Bell Labs, France; ³Almae-technologies, France. Emerging access networks require specific components. We present a counter-heating method for wavelength stabilization in NG-PON2 TWDM-PON systems, and a +6dBm-high-power externally modulated laser at 10Gb/s and 28Gb/s for XGS-PON or 25G-ePON systems.

Th1F.1 • 08:00 **Invited**

Entropy Loading for Band-limited Meshed-optical-networks: The Multicarrier Advantage, Di Che¹, William Shieh¹; ¹Univ. of Melbourne, Australia. Modern meshed optical networks deploy plentiful cascaded-rOADMs to enhance the network flexibility, which induce severe filter narrowing effect. We reveal the linear advantage of multicarrier by the optimum power allocation and capacity-approaching modulation.

Thursday, 15 March

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Pablo Pavón Mariño is Full Professor in the Technical University of Cartagena (Spain), leader of the Net2Plan open-source network planning software initiative (www.net2plan.com) and co-founder of E-lighthouse Network Solutions spin-off (www.e-lighthouse.com). His research interests include optimization and planning of multi-layer optical networks and SDN/NFV infrastructures.





Room 6F

Room 7AB

Room 8

Room 9

Room 10

Show Floor Programming

07:30–08:00 Coffee Break, Upper Level Corridors

08:15–10:00

Th1G • Photonic Networks for Data Centers

President: Dominic Goodwill; Huawei Technologies R&D, Canada

08:00–10:00

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks

Organizers: Danny Peterson, Verizon, USA; Alan McCurdy, OFS, Fiber Design & Simulation Group, USA; Jing Li, Yangtze Optical Fibre and Cable, China

08:15–10:00

Th1I • Comb Lasers

President: Zhiping Zhou; Peking Univ., China

08:15–10:00

Th1J • Optical Switching I

President: Nicolas Dupuis; IBM TJ Watson Research Center, USA

08:30–10:00

Th1K • SDM Amplifiers & Components

President: Karsten Rottwitt; Danmarks Teknishe Universitet, Denmark

In the last year there has been an ever-increasing flurry of announcements of optical network expansions to support applications in the evolving data and telecommunications markets. Standards organizations, governments and businesses are anticipating enormous growth in connectivity over the next 5 years with the advent of 5G wireless, enhanced cloud services, the Internet of Things, smart cities etc. Analysts have projected a required spend of \$130 – 150B in the US alone in the next 5-7 years to meet the needs. To support this future demand, plans are being made now for an expansion of fiber-based networks to provide the required high capacity communication links via small cells, enhanced edge network capability, better data center interconnects, metro backhaul and more. The burden of this expansion has been placed on carriers, ICPs, MSOs, municipalities as well as various private enterprises. In this Panel, experts from these organizations will discuss their view of the upcoming transport demand and their plans for near term network expansions to address these needs. Questions to be addressed include: What applications are driving this expansion? Who are the relevant customers? What are the preferred fiber and cable types? How will the expanded architecture address the current demand and evolve in the future?

Th1G.1 • 08:15 **Top Scored**
Microsecond Optical Switching Network of Processor SoCs with Optical I/O, Sajjad Moazeni¹, Johannes Henriksson¹, Tae Joon Seok^{2,1}, Mark Wade³, Chen Sun³, Ming Wu¹, Vladimir Stojanovic¹; ¹UC Berkeley, USA; ²Gwangju Inst. of Science and Technology, Korea; ³Ayar Labs, Inc., USA. We demonstrate an OCS network with microsecond switching time between processors featuring monolithic ring-resonator-based WDM-compatible optical I/Os. This solution can solve EPS scalability challenge and enable novel architectures for emerging disaggregated and heterogeneous data-centers and HPC.

Th1I.1 • 08:15
Monolithic Mode Locked Laser-based Optical Frequency Comb for OFDM Integrated on InP Generic Technology Platform, Mu-Chieh Lo¹, Robinson Cruzoe Guzmán Martínez¹, Guillermo Carpintero¹; ¹Universidad Carlos III de Madrid, Spain. We report on-chip optical frequency comb structures based on mode-locked lasers, fabricated on generic platform, enabling on-chip integration with optical multiplexers/demultiplexers and modulators. The comb structures feature wide spectral bandwidth and mode spacing selectability.

Th1J.1 • 08:15 **Invited**
Large-scale Silicon Photonic Switch, Eric Bernier¹, Dominic Goodwill¹, Patrick Dumais¹, Hamid Mehrvar¹, Dritan Celso¹, Jia Jiang¹, Chunhui Zhang¹, Fei Zhao², Xin Tu², Chunhui Zhang², Shengyong Yan², Jifang He², Ming Li², Wanyuan Liu², Yuming Wei², Dongyu Geng²; ¹Huawei Technologies Canada Co., Ltd., Canada; ²Huawei Technologies Co., Ltd., China. A packaged and fully operational 32x32 silicon photonic switch chip having 448 switch cells and 1856 crossings is demonstrated. Development of low loss optical components is essential to the operation of complex Mach-Zehnder switch fabrics.

continued on page 117

Thursday, 15 March





Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.2 • 08:30

OSNR Measurement Comparison in Systems with ROADM Filtering for Flexible Grid Networks, Jie Pan¹, Thomas Richter¹, Sorin Tibuleac¹; ¹ADVA Optical Networking, USA. OSNR measurement methods are compared for a ROADM-enabled flexible grid system with different noise loading scenarios using both experiment and simulation. The impact of the noise loading location on the filtering penalty is also investigated.

Th1A.3 • 08:45

Real-time 10Gbps Polarization Independent Quasicoherent Receiver for NG-PON2 Access Networks, Jose A. Altabas¹, Guillermo Silva Valdecasa², Morten Didriksen², Jose Antonio Lazaro³, Ignacio Garces¹, Idelfonso Tafur Monroy⁴, Jesper B. Jensen²; ¹Universidad de Zaragoza, Spain; ²Bifrost Communications, Denmark; ³Universitat Politècnica de Catalunya, Spain; ⁴Inst. for Photonics Integration, Eindhoven Univ. of Technology, Netherlands. A Real-time 10Gbps polarization independent quasicoherent receiver for NG-PON2 access networks is proposed and experimentally validated. The sensitivity of this receiver is -33dBm and making feasible a 35dB power budget (required for E2 class).

Room 1B

Th1B • 5G Transport—Continued

Th1B.1 • 08:30

Access Network Economics: A Total-cost-of-ownership Perspective, Christoph Lange¹, Dirk Kosiankowski¹, Sandro Krauß¹, Andreas Gladisch¹; ¹Deutsche Telekom, Germany. Several fiber-based access solutions are compared regarding TCO and NPV using an analytic framework and real service area data. Fiber-copper and fixed-wireless solutions show improved TCO and NPV efficiency short-term, FTTH in longer-term constellations.

Th1B.2 • 08:45

Software Defined 5G Converged Access as a Viable Techno-economic Solution, Andrea Marotta¹, Koteswararao Kondepu², Dajana Cassioli¹, Cristian Antonelli¹, Luis M. Correia³, Luca Valcarengi²; ¹Univ. of L'Aquila, Italy; ²Scuola Superiore Sant'Anna, Italy; ³INESC-ID/INOV, Instituto Superior Técnico - Univ. of Lisbon, Portugal. Software Defined Converged Access represents a feasible solution to effectively address 5G traffic demands. This paper proposes an integrated mobile-optical control for wavelength and bandwidth allocation. Evaluations of bandwidth utilization and techno-economic viability are provided.

Room 2

Th1C • Wideband Transmission—Continued

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Room 6D

Th1E • Components for Future PON—Continued

Th1E.2 • 08:30

Beyond 25 Gb/s Directly-modulated Widely Tunable VCSEL for Next Generation Access Network, Alberto Gatto¹, Paola Parolari¹, Christian Neumeyr², Pierpaolo Boffi¹; ¹Politecnico di Milano - DEIB, Italy; ²Vertilas GmbH, Germany. We demonstrate capacities beyond 25Gb/s up to 40 km in the whole C-band range without any dispersion compensation by DMT direct modulation and direct detection exploiting widely tuneable MEMS-VCSELS for future low-cost high-capacity access networks.

Th1E.3 • 08:45

10Gb/s Low-cost Directly Modulated Multi-electrode Laser with Suppressed Thermal Wavelength Drift for Burst-mode Upstream Transmission in TWDM-PONs, Stefano Porto^{1,2}, Dora van Veen¹, Vincent Houtsuma¹, Nagesh Basavanahally¹, Cris Bolle¹, Harald Schmuck³, Paul D. Townsend², Mark Earnshaw¹, Thomas Pfeiffer³; ¹Bell Labs, Nokia, USA; ²Tyndall National Inst., Univ. College Cork, Ireland; ³Bell Labs, Nokia, Germany. We report on a novel 10Gb/s low-cost multi-electrode DML employed as a very wavelength stable burst-mode source for upstream TWDM-PONs. 10X wavelength drift reduction is achieved compared to conventional DMLs enabling transmission on 100GHz grid.

Room 6E

Th1F • High Capacity Subsystems—Continued

Th1F.2 • 08:30

4096 QAM (72 Gbit/s) Single-carrier Coherent Optical Transmission with a Potential SE of 15.8 bit/s/Hz in All-Raman Amplified 160 km Fiber Link, Masaki Terayama¹, Seiji Okamoto¹, Keisuke Kasai¹, Masato Yoshida¹, Masataka Nakazawa¹; ¹Tohoku Univ., Japan. We have successfully achieved a 4096 QAM (72 Gbit/s) - 160 km transmission with a potential spectral efficiency of 15.8 bit/s/Hz by employing precise digital polarization demultiplexing and an all-Raman amplified 160 km fiber link.

Th1F.3 • 08:45

Achievement of 90-GBaud PAM-4 with MLSE based on 2nd Order Volterra Filter and 2.88-Tb/s O-band Transmission using 4-λ LAN-wDM and 4-core Fiber SDM, Akira Masuda¹, Shuto Yamamoto¹, Hiroki Taniguchi¹, Mitsunori Fukutoku¹; ¹NTT, Japan. We achieve 180-gb/s PAM-4 transmission under 32-gHz bandwidth limitation applying MLSE based on 3-memory T-spaced 2nd order Volterra filter. We experimentally demonstrate 2.88-tb/s O-band transmission using 4-λ LAN-wDM and SDM over 2-km 4-core fiber.





Room 6F

Th1G • Photonic Networks for Data Centers—Continued

Th1G.2 • 08:30

Automated Calibration of Balanced Control to Optimize Performance of Silicon Photonic Switch Fabrics, Yishen Huang¹, Qixiang Cheng¹, Keren Bergman¹; ¹*Columbia Univ., USA*. Highly-efficient, fabric-wide calibration of balanced control for optical switch fabrics without built-in power-detectors is first realized with fully-automated implementation. This technique co-optimizes thermo-optic and electro-optic phase elements, correcting phase-error and power-imbalance simultaneously for optimized performance.

Th1G.3 • 08:45

The ARPA-E ENLITENED Program - Integrated Photonic Technology for Energy-efficient Data Center Networks, Michael W. Haney¹; ¹*Advanced Research Projects Agency-Energy, USA*. The recently launched ARPA-e ENLITENED program aims to exploit integrated photonic interconnect and switching technologies to provide transformative energy efficiency improvements in future data centers. The program's motivation, goals, and progress are reviewed.

Room 7AB

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Panelists:

Christina (Colasanto) Bassett, *Verizon, USA*

Robert Howald, *Comcast, USA*

Trevor Smith, *Commscope, USA*

Danny Thornton, *Microsoft, USA*

Room 8

Th1I • Comb Lasers—Continued

Th1I.2 • 08:30

A Heterogeneously Integrated III-V/Si Colliding Pulse Mode-locked Laser with On-chip Feedback, Songtao Liu¹, Komljenovic Tin¹, Srinivasan Sudharsanan², Norberg Erik², Gregory Fish², John Bowers¹; ¹*Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA*; ²*Juniper Networks, USA*. We demonstrate a heterogeneously integrated O-band III-V/Si colliding pulse mode-locked laser with tunable on-chip external feedback for pulse stabilization. The 3-dB RF linewidth is 13.8 kHz, a reduction by a factor of 2.9x with the adjustment of external feedback.

Th1I.3 • 08:45

Temporal Soliton Locked in a Micro-resonator Pumped by a Diode Laser without an Amplifier, Nicolas Volet¹, Xu Yi², Qi-Fan Yang², Eric Stanton¹, Paul A. Morton³, Ki Youl Yang², Kerry J. Vahala², John Bowers¹; ¹*Univ. of California Santa Barbara, USA*; ²*California Inst. of Technology, USA*; ³*Morton Photonics, USA*. A single-soliton state is generated in a micro-resonator using a customized low-noise diode laser. This demonstration greatly simplifies the soliton generation setup and represents a significant step forward to a fully integrated soliton comb system.

Room 9

Th1J • Optical Switching I—Continued

Th1J.2 • 08:45

Crosstalk Spectrum Optimisation for Stacked Wavelength Selective Switches Based on 2D Beam Steering, Haining Yang², Philip Dolan², Brian Robertson², Peter Wilkinson^{2,1}, Daping Chu^{2,1}; ¹*Univ. of Cambridge, UK*; ²*Roadmap Systems Ltd, UK*. We report a 4(1×8) WSS prototype using 2D beam steering with minimum insertion loss of 4.7dB and uniform pass-band step of 1GHz. The worst-case crosstalk was suppressed to <-30dB with optimised spectrum profile for improved OSNR.

Room 10

Th1K • SDM Amplifiers & Components—Continued

Th1K.1 • 08:30

Pump Mode Characterization of Annular Cladding Erbium-doped Fibers Using Low-coherence Interferometry, Huiyuan Liu^{4,1}, Haoshuo Chen⁴, Nicolas K. Fontaine⁴, Roland Ryf⁴, Jian Chen³, Qianwu Zhang³, Yingchun Li³, Cang Jin², Sophie LaRochelle², Guifang Li¹; ¹*Univ. of Central Florida, USA*; ²*COPL, Université Laval, Canada*; ³*Shanghai Univ., China*; ⁴*Nokia Bell Labs, USA*. We characterize core and cladding pump modes of annular cladding 6-core 3-mode erbium-doped fibers using low-coherence interferometry (LCI). Efficient mode conversion at pump wavelength for modal gain equalization is also demonstrated and characterized by LCI.

Th1K.2 • 08:45

EDF Length Dependence of Amplification Characteristics of Cladding Pumped 19-core EDFA, Shigehiro Takasaka¹, Koichi Maeda¹, Kohei Kawasaki¹, Kazuaki Yoshioka¹, Hajime Oshio¹, Ryuichi Sugizaki¹, Hidenori Takahashi², Takehiro Tsuritani², Masato Shiino¹; ¹*Furukawa Electric Co., Ltd., Japan*; ²*KDDI Research Inc., Japan*. We demonstrate a C-band cladding pumped 19-core EDFA. Optimum EDF length and output power of the EDFA agree with those of a cladding pumped 7-core EDFA. High output power is brought by sufficiently long EDF.

Show Floor Programming

Thursday, 15 March





Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.4 • 09:00

World's First TO-can Coherent Transceiver, Bernhard Schrenk¹, Fotini Karinou²; ¹*AIT Austrian Inst. of Technology, Austria*; ²*Huawei Technologies, Germany*. We fit both, coherent homodyne receiver and transmitter, in a transistor-outline package with single fiber/RF port. Full-duplex 2.5Gb/s transmission over 27.5km reach, 28dB loss budget and coherent Ethernet connectivity are demonstrated without optical-layer DSP functions.

Th1A.5 • 09:15

Coherent Analog Low Power, Small Size 400/200/100Gb/s Receiver Based on Bipolar SiGe Technology, Edem Ibragimov¹, Hong Jiang¹, Pushui Xu¹, Xiangtao Li¹; ¹*Greensand Networks, USA*. We demonstrate first to our knowledge analog coherent engine (ACE). Simulations show power consumption under 2W for 400Gb/s ACE. Combination of ACE with CMOS direct detection unit is good candidate for short reach communications.

Room 1B

Th1B • 5G Transport—Continued

Th1B.3 • 09:00

DBA Capacity Auctions to Enhance Resource Sharing across Virtual Network Operators in Multi-tenant PONs, Nima Afrazi¹, Amr Elrasad¹, Marco Ruffini¹; ¹*CONNECT Center, Trinity College Dublin, Ireland*. We propose an economic-robust auction mechanism for multi-tenant PON's capacity sharing that operates within the DBA process. We demonstrate that our mechanism improves PON utilization by providing economic sharing incentives across VNOs and infrastructure providers.

Th1B.4 • 09:15

Deep Neural Network Based Dynamic Resource Reallocation of BBU Pools in 5G C-RAN ROADM Networks, Weiyang Mo¹, Craig Guterman², Yao Li¹, Gil Zussman², Daniel Kilper¹; ¹*The Univ. of Arizona, USA*; ²*Electrical Engineering, Columbia Univ., USA*. An LSTM network is developed to predict BBU pool traffic in 5G C-RAN ROADM networks. 5G throughput improvement and resource savings are observed with resource reallocation by reconfiguring the optical network 30 minutes in advance.

Room 2

Th1C • Wideband Transmission—Continued

Th1C.1 • 09:00


On the Effects of Transmitter Induced Channel Correlation in Broadband WDM Transmission, Jin-Xing Cai¹, Yue Hu¹, Alexey V. Turukhin¹, Matt Mazurczyk¹, Milen Paskov¹, Husam Batshon¹, Carl Davidson¹, Maxim A. Bolshtyansky¹, Dmitri Foursa¹; ¹*TE SubCom, USA*. We investigate how transmitter-induced correlations impact channel performance in experiments and simulations. We observe performance impacts ranging from ~0.7 dB after 600 km to be negligible beyond 4,000 km over 9.74 THz bandwidth. Correlation impact on NLC is discussed.

Th1C.2 • 09:15


Transmission Performance Improvement using Broadband Incoherent Counter-pumped Distributed Raman Amplification, Md A. Iqbal¹, Paul Harper¹, Mingming Tan¹; ¹*Aston Univ., UK*. We propose a novel dual-order counter-pumped distributed Raman amplification technique using broadband incoherent 1st-order pump to suppress RIN transfer and improve Q-factor and transmission reach by 0.3dB and 833km respectively compared with conventional narrowband pumping.

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Th1D.2 • 09:00 

Hysteresis-based Margin Allocation for Adaptive Coding in SDN-enabled Optical Networks, Yao Li¹, Mingwei Yang², Weiyang Mo¹, Shengxiang Zhu², Zhen Qu², Ivan Djordjevic², Daniel Kilper¹; ¹*College of Optical Sciences, The Univ. of Arizona, USA*; ²*Department of Electrical and Computer Engineering, The Univ. of Arizona, USA*. Hysteresis-based margin-allocation for adaptive coding is experimentally investigated against PDL-induced OSNR fluctuations in a SDN-enabled multi-domain optical network. Up to 90% network outage reduction can be observed under different margins.

Th1D.3 • 09:15 

An Automated Service-downgrade Negotiation Scheme for Application-centric Networks, Antonio Marsico¹, Marco Savi¹, Domenico Siracusa¹, Elio Salvadori¹; ¹*FBK CREATE-NET, Italy*. We propose a novel negotiation scheme for an application-driven relaxation of different requirements in multi-layer networks. Simulative results show that it improves service acceptance while keeping requirements' degradation much lower than applications' worst-case acceptable values.

Room 6D

Th1E • Components for Future PON—Continued

Th1E.4 • 09:00 

Photonic Integrated Circuits for NGPON2 Tunable ONUs, John O'Carroll¹; ¹*Eblana Photonics, Ltd., Ireland*. In comparison to current single wavelength standards tunable NGPON2 transceivers will be more complex. This tutorial reviews photonic integration technologies that could meet this challenge and the potential to leverage technologies developed for other applications.



John O'Carroll joined Eblana Photonics in 2004 and is the director of technical development in the company's optical communications business unit where he worked on developing the product road map, business strategy and applications engineering activities. He received the B.Eng and M.Eng degrees from the University of Limerick and a Ph.D. from Dublin City University. His research interests include the development of high speed laser diodes and photonic integrated circuits for use in next generation optical networks with a particular focus on PON and Datacom networks.

Room 6E

Th1F • High Capacity Subsystems—Continued

Th1F.4 • 09:00 

Scaling Optical Networking Technologies for Next Generation SDM Systems, Peter J. Winzer¹; ¹*Nokia Bell Labs, USA*. Based on the need to scale optical networks beyond WDM, we discuss the techno-economics of parallel spatial paths (SDM) and highlight integration options across all network elements to continue historic cost/bit and energy/bit reductions.



Peter Winzer has contributed to many aspects of optical communications and networking, high-speed coherent transmission, and spatial multiplexing. He has amply published and patented and is actively involved within the IEEE and the OSA. He is a Highly Cited Researcher, a Fellow of Bell Labs, IEEE, and OSA, and a Member of the National Academy of Engineering.





Room 6F

Th1G • Photonic Networks for Data Centers—Continued

Th1G.4 • 09:15

System-level Demonstration of a Dynamically Reconfigured Burst-mode Link using a Nanosecond Si-photonics Switch, Alex Forencich^{1,2}, Valerija Kamchevska^{1,3}, Nicolas Dupuis¹, Christian Baks¹, Benjamin G. Lee¹, George Papen², Laurent Schares¹; ¹IBM T.J. Watson Research Center, USA; ²Univ. of California at San Diego, USA; ³Technical Univ. of Denmark, Denmark. Using a novel FPGA-based network emulator, microsecond-scale packets with 12.5-20-gb/s data are generated, routed through a nanosecond Si-photonics switch, and received in a fast-locking burst-mode receiver. Error-free links with <382-ns system-level switching are demonstrated.

Room 7AB

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Room 8

Th1I • Comb Lasers—Continued

Th1I.4 • 09:00

An InAs/InP Quantum dot C-band Coherent Comb Laser, Zhenguo Lu¹, Jiaren Liu¹, Chunying Song¹, John Webber¹, Yuexin Mao¹, Shoude Chang¹, Heping Ding¹, Philip Poole¹, Pedro Barrios¹, Daniel Poitras¹, Siegfried Janz¹, Maurice O'Sullivan²; ¹National Research Council Canada, Advanced Electronics and Photonics Research Centre, Canada; ²Ciena, Canada. We have developed InAs/InP quantum-dot 34.462-gHz C-band coherent comb laser modules with low relative intensity and phase noises over its filtered 45 channels, which can be used for data center and coherent communication systems.

Th1I.5 • 09:15

Ultra-narrow Linewidth Quantum Dot Coherent Comb Lasers, Zhenguo Lu¹, Jiaren Liu¹, Philip Poole¹, Chunying Song¹, Shoude Chang¹; ¹National Research Council Canada, Advanced Electronics and Photonics Research Centre, Canada. We have developed a secondary-cavity self-injection feedback locking system to simultaneously reduce the linewidths of over 39 individual channels of an InAs/InP quantum-dot coherent comb laser from a few MHz to less than 200 kHz.

Room 9

Th1J • Optical Switching I—Continued

Th1J.3 • 09:00

Integrated Wavelength Selective Switch Array for Space Division Multiplexed Network with Ultra-low Inter-spatial Channel Crosstalk, Keita Yamaguchi¹, Kenya Suzuki¹, Kazuno Seno¹, Hiroki Kawahara¹, Mitsunori Fukutoku¹, Toshikazu Hashimoto¹, Yutaka Miyamoto¹; ¹NTT Corporation, Japan. We propose a novel optics for integrated wavelength selective switch (WSS) array that suppresses inter-sub WSS crosstalk for space-division multiplexed network. A crosstalk level of as low as -50 dB has been achieved.

Th1J.4 • 09:15

Fast, High-radix Silicon Photonic Switches, Tao Chu¹, Lei Qiao², Weijie Tang¹, Defeng Guo², Weike Wu¹; ¹College of Information Science and Electronic Engineering, Zhejiang Univ., China; ²Inst. of Semiconductors, Chinese Academy of Sciences, China. With a limited number of built-in power monitors to detect the optimum operating points of all switch units, we demonstrated a 32 x 32 MZI-based silicon electro-optical switch operating with nanosecond speeds.

Room 10

Th1K • SDM Amplifiers & Components—Continued

Th1K.3 • 09:00

Low-loss and Low-crosstalk All-fiber-based Six-mode Multiplexer and Demultiplexer for Mode-multiplexed QAM Signals in C-band, Koji Igarashi^{2,1}, Yuta Wakayama², Daiki Soma², Takehiro Tsuritani², Itsuro Morita², Kyung Park³, Byoung Kim⁴; ¹Osaka Univ., Japan; ²KDDI Research Inc., Japan; ³KS Photonics, Korea; ⁴KAIST, Korea. We show all-fiber-based six-mode multiplexer and demultiplexer. The OSNR penalty due to six-mode multiplexing is suppressed to be 2 dB in DP-16QAM with 12x12MIMO and 3 dB in DP-QPSK even with 4x4/2x2MIMO over C-band.

Th1K.4 • 09:15

Tilted Fiber Bragg Gratings for Selective Coupling in a Multicore Optical Fiber, David Barrera¹, Javier Madrigal¹, Salvador Sales¹; ¹Photonics Research Labs, ITEAM, Universitat Politècnica de Valencia, Spain. We have produced a device for the selective light coupling among the seven cores of a multicore optical fiber. We have used a tilted fiber Bragg grating for increasing 40dB the crosstalk between the cores.

Show Floor Programming

Thursday, 15 March



Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.6 • 09:30 **Invited**
Power Efficient DSP and Optical Integration, Timo Pfau¹, Ricardo Aroca¹, Chris Doerr¹, Jonas Geyer¹, Hongbin Zhang¹, Christian Rasmussen¹; ¹Acacia Communications, Inc., USA. We review the technical innovations in ASIC technology, DSP, and photonic integration over the past years that enabled to reduce the footprint and power/Gbit/s of coherent modules by a factor of 10.

Room 1B

Th1B • 5G Transport—Continued

Th1B.5 • 09:30
Joint Optimization of BBU Pool Allocation and Selection for C-RAN Networks, Yao Li¹, Mariya Bhopalwala¹, Sandip Das², Jiakai Yu³, Weiyang Mo¹, Marco Ruffini², Daniel Kilper¹; ¹College of Optical Sciences, The Univ. of Arizona, USA; ²CONNECT Research Centre, Univ. of Dublin, Trinity College, Ireland; ³Department of Electrical and Computer Engineering, The Univ. of Arizona, USA. BBU pool allocation and selection are jointly optimized for maximizing wireless traffic capacity while minimizing wavelength resource occupation in optical networks. Numerical results show optimal BBU pool locations under different traffic patterns and network capacities.

Th1B.6 • 09:45
MixCo: Optimal Cooperative Caching for Mobile Edge Computing in Fiber-wireless Access Networks, Ning Wang¹, Weidong Shao¹, Sanjay K. Bose², Gangxiang Shen¹; ¹Soochow Univ., China; ²Department of Electrical and Electronic Engineering, Indian institution of technology, India. We consider the optimal content caching problem among Mobile Edge Computing (MEC) servers in a Fiber-wireless (FIWi) access network, to minimize the average content delivery latency subject to limited storage and computing capacity of each server. An MILP model and a Mix-cooperative (MixCo) caching strategy are developed for efficient performance.

Room 2

Th1C • Wideband Transmission—Continued

Th1C.3 • 09:30
Inter-channel Stimulated Raman Scattering and its Impact in Wideband Transmission Systems, Gabriel Saavedra¹, Daniel Semrau¹, Mingming Tan², Md. Asif Iqbal², Daniel Elson¹, Lidia Galdino¹, Paul Harper², Robert Killely¹, Polina Bayvel¹; ¹Univ. College London, UK; ²Aston Inst. of Photonic Technologies, UK. The impact of inter-channel stimulated Raman scattering (ISRS) in wideband optical transmission systems is studied. ISRS cross-talk due to channel modulation was found to be negligible and a good agreement was found with theoretical results.

Th1C.4 • 09:45
Experiments on Stimulated Raman Scattering in S- and L-bands 16-QAM Signals for Ultra-wideband Coherent WDM Systems, Kyo Minoguchi¹, Seiji Okamoto¹, Fukutaro Hamaoka¹, Asuka Matsushita¹, Masanori Nakamura¹, Etsushi Yamazaki¹, Yoshiaki Kisaka¹; ¹NTT Network Innovation Laboratories, Japan. We experimentally evaluated stimulated Raman scattering (SRS) effect between S- and L-bands over 210-km SSMF 16-QAM transmission. SRS mainly induced power transition from S- to L-band, and was not the cause of nonlinear crosstalk penalty.

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Th1D.4 • 09:30 **Invited**
Application Aware Multilayer Control and Optimization of Elastic WDM Switched Optical Networks, Ioannis Tomkos¹, Ciril Rozic¹, Marco Savi², Pontus Sköldström³, Victor Lopez⁴, Mohit Chamania⁵, Domenico Siracusa², Chris Matrakidis¹, Dimitrios Klonidis¹, Ori Gerstel⁶; ¹Athens Information Technology Center, Greece; ²FBK, Italy; ³RISE Acreo AB, Sweden; ⁴Telefonica I+D/GCTO, Spain; ⁵ADVA Optical Networking, Germany; ⁶Sedona Systems, Israel. In dynamic networks with diverse application requirements, Software Defined Networking (SDN) principles enable application-aware in-operation planning. EU project ACINO built a network orchestrator as the connecting component between network applications and the underlying network infrastructure.

Room 6D

Th1E • Components for Future PON—Continued

Room 6E

Th1F • High Capacity Subsystems—Continued

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10:00–16:00 Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C





Show Floor Programming

Room 6F

Th1G • Photonic Networks for Data Centers—Continued

Th1G.5 • 09:30

O-band Energy-efficient Broadcast-friendly Interconnection Scheme with SiPho Mach-Zehnder Modulator (MZM) & Arrayed Waveguide Grating Router (AWGR), Stelios Pitris^{1,2}, Charoula Mitsolidou^{1,2}, Theoni Alexoudi^{1,2}, Diego Pérez-Galacho³, Laurent Vivien³, Charles Baudot⁴, Peter De Heyn⁵, Joris Van Campenhout⁵, Delphine Marris-Morini³, Nikos Pleros^{1,2}; ¹Department of Informatics, Aristotle Univ. of Thessaloniki, Greece; ²Center for Interdisciplinary Research and Innovation, Aristotle Univ. of Thessaloniki, Greece; ³Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Université Paris-sud, Université Paris-saclay, France; ⁴ST Microelectronics, France; ⁵imec, Belgium. We present an O-band energy-efficient broadcast-friendly optical architecture relying on a silicon photonics broadband MZM and an 8x8 AWGR. Experimental validation is demonstrated at 10Gb/s followed by an energy-saving analysis for the proposed broadcast scheme.

Th1G.6 • 09:45

Integrated, Scalable and Reconfigurable Silicon Photonics based Optical Switch for Colorless, Directionless and Contentionless Operation, Stefano Tondini¹, Astghik Chalyan¹, Giorgio Fontana¹, Lorenzo Pavesi¹, Nikola Zečević³, Michael Hofbauer³, Horst Zimmermann³, Stefano Stracca⁴, Alberto Bianchi⁴, Costanza Manganello², Philippe Velha², Paolo Pintus², Fabrizio Di Pasquale², Claudio Oton², Christophe Kopp⁵, Guido Chiaretti⁶, Aina Serrano⁷, Jose Ayucar⁷, Giovan B. Preve², Jong Lee⁸, Francesco Testa⁴; ¹Univ. of Trento, Italy; ²Scuola S. Anna, Italy; ³TU Wien, Austria; ⁴Ericsson, Italy; ⁵Cea Leti, France; ⁶STMicroelectronics, Italy; ⁷Universitat Politècnica de València, Spain; ⁸ETRI, Korea. We demonstrate a BCD8sP electronic-photonics integrated device for low cost, low power, mass-manufacturable optical switching. Our network on-chip has 1000 photonic components driven by dedicated electronic controls. Total insertion loss is -22dB, including input and output coupling, and channel isolation is better than 35dB, in a chip area of 1 cm².

Room 7AB

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Room 8

Th1I • Comb Lasers—Continued

Th1I.6 • 09:30

InP Photonic Integrated Comb Generator made by a cascade of Optical Modulators, Tommaso Cassese¹, Nicola Andriolli¹, Marco Chiesa¹, Ángel Rubén Criado Serrano², Giampiero Contestabile^{1,3}; ¹Scuola Superiore Sant'Anna, Italy; ²Luz wavelabs, Spain; ³CNIT, Italy. We report the first InP photonic integrated comb generator made by cascading a DBR laser, one Mach-Zehnder intensity modulator and two phase modulators. The photonic circuit also includes a booster SOA at the output.

Th1I.7 • 09:45

Wide, Continuously Swept VCSEL Using a Novel Air-cavity-dominant Design, Pengfei Qiao¹, Kevin T. Cook¹, Jipeng Qi¹, Larry A. Coldren², Connie J. Chang-Hasnain¹; ¹EECS Dept. and Tsinghua-Berkeley Shenzhen Inst., Univ. of California, Berkeley, USA; ²Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA. We report electrically-pumped MEMS-VCSELS with a record 70 nm continuous wavelength sweep at 1057-nm with 600 kHz rate using a novel air-cavity-dominant design. Such devices are promising for swept-source OCT and 3D sensing applications.

Room 9

Th1J • Optical Switching I—Continued

Th1J.5 • 09:45

Dual 8x16 MCS using Hybrid-integrated Silica PLC and Polymer TIR Switch Array, Jang-Uk Shin¹, Sangho Park¹, Young-Tak Han¹, Yongsoo Baek¹, Byeong Kwon Choi², Joonoh Park², Chulhee Park²; ¹Electronics & Telecomm Res. Inst, Korea; ²ChemOptics, Korea; ³Woorio Co., Ltd., Korea. We firstly report the design and fabrication of silica-polymer hybrid-integrated (chip-to-chip bonded) dual 8x16 multicast switch for contentionless ROADM. We used silica PLCs for passive waveguide devices and polymer TIR switch as switching devices.

Room 10

Th1K • SDM Amplifiers & Components—Continued

Th1K.5 • 09:30

Non-circularly-symmetric Mode-group Demultiplexer Based on Fused-type FMF Coupler for MGM Transmission, Yuyang Gao¹, Juhao Li¹, Chuanyan Du¹, Cen Xia², Yan Liu^{2,3}, Zhengbin Li¹, Yongqi He¹, Zhangyuan Chen¹, Guifang Li²; ¹Peking Univ., China; ²Univ. of Central Florida, USA; ³Beijing Jiaotong Univ., China. A mode-group demultiplexer (MG-dEMUX) based on fused-type FMF coupler is proposed and fabricated for the LP₁₁ mode group, based on which 2x5-gb/s weakly-coupled MGM transmission over 10-km TMF is experimentally demonstrated with simple direct detection.

Th1K.6 • 09:45

Mode-selective Polished Fiber Couplers based on Fiber Gratings, Sebastian Schlangen¹, Kort Bremer¹, Andreas Isaak², Marc C. Wurz², Gabriel Pelegrina Bonilla², Jörg Neumann², Bernhard Roth¹, Ludger Overmeyer¹; ¹HOT - Leibniz Universitaet Hannover, Germany; ²Laser Zentrum Hannover e.V., Germany; ³IMPT-Leibniz Universität Hannover, Germany. A key challenge for using multimode fibers for optical data transmission lies in the development of efficient mode-selective fiber couplers. Here, we present a novel and easy-to-implement process for their realization and first experimental results.

10:00–16:00 Exhibition and Show Floor Programs, Coffee Break, Exhibit Hall and OFC Career Zone Live, Exhibit Hall C

Thursday, 15 March



Th2A.1

O-band Silicon Photonics 8×8 Arrayed Waveguide Grating Router (AWGR) for 1.6 Tb/s On-chip Routing, Stelios Pitris^{1,2}, George Dabos^{1,2}, Charoula Mitsolidou^{1,2}, Theoni Alexoudi^{1,2}, Peter De Heyn³, Joris Van Campenhout³, Ronald Broeke⁴, George T. Kanellos⁵, Nikos Pleros^{1,2}; ¹Department of Informatics, Aristotle Univ. of Thessaloniki, Greece; ²Center for Interdisciplinary Research and Innovation, Aristotle Univ. of Thessaloniki, Greece; ³imec, Belgium; ⁴Bright Photonics BV, Netherlands; ⁵High Performance Networks Group, Univ. of Bristol, UK. We present an 8×8 silicon photonics AWGR with 10 nm channel spacing for O-band cyclic-routing operation. Successful transmission at 25 Gb/s is demonstrated for all 8×8 AWGR channel combinations with a maximum power penalty of 0.82 dB.

Th2A.2

Poly-crystalline Silicon Waveguide Devices on Hollow Deep Trench Isolation in Standard Foundry Bulk Silicon Process, Sungwon Chung¹, Makoto Nakai¹, Edward Preisler², Hossein Hashemi¹; ¹Univ. of Southern California, USA; ²TowerJazz, USA. We first demonstrate poly-crystalline silicon waveguide devices on deep-trench isolation in a commercial bulk 180nm SiGe BiCMOS process without any process modifications or post-processing. At 1550nm, the measured loss for the poly-crystalline silicon waveguide and an MMI compatible with the waveguide are around 3.0 dB/mm and 0.38 dB, respectively.

Th2A.3

Integrated InP Polarization Rotator Using the Plasmonic Effect, Shinmo An¹, O-Kyun Kwon¹; ¹ETRI, Korea. An InP based polarization rotator is demonstrated using the plasmonic effect. It operates as a half-wave retarder. Simple device structure ensures large fabrication tolerance. The device exhibits polarization extinction ratio of 20 dB over C-band.

Th2A.4

Thermo-optical Phase Shifter with Integrated Diodes for Multiplexed Control, Antonio R. Alves^{1,2}, Wim Bogaerts^{1,2}; ¹Ghent Univ. - IMEC, Photonics Research Group, Belgium; ²Center for Nano and Biophotonics (NB-photonics), UGent, Belgium. We present a thermo-optic silicon phase shifter with diodes for multiplexed control and demonstrate that such heaters can be driven using digital signals to increase the linearity of the phase shift response of the device.

Th2A.5

Integrated Polarization Beam Splitter Module for Polarization-encoded Free-space BB84 QKD, Joong-Seon Choe¹, Heasin Ko¹, Byung-Seok Choi¹, Kap-Joong Kim¹, Chun Ju Youn¹; ¹ETRI, Korea. We present an integrated polarization beam splitter module for free-space BB84 quantum key distribution. The module is based on silica PLC birefringent Mach-Zehnder interferometer chip, and replaces successfully the bulk-optic-based polarization splitting subsystem of BB84 quantum key distribution test-bed operating at 780 nm.

Th2A.6

Compact Grating Coupler for Higher-order Mode Coupling, Yaxiao Lai¹, Yu Yu¹, Songnian Fu¹, Jing Xu¹, Perry Ping Shum², Xinliang Zhang¹; ¹Wuhan National Lab for Optoelectronics, China; ²School of Electrical and Electronics Engineering, Nanyang Technological Univ., Singapore. An on-chip LP₁₁-TE₁ mode grating coupler is experimentally demonstrated by utilizing double-grating structure and a Y-junction. A 0.6 dB improvement of coupling efficiency with a quarter taper length is achieved comparing with conventional grating coupler.

Th2A.7

Compact and Power Efficient 2 × 2 Thermo-optical Switch based on Dual-nanobeam MZI, Jiang Xinhong¹, Hongxia Zhang¹, Ciyuan Qiu¹, Yong Zhang¹, Yikai Su¹, Richard A. Soref²; ¹Shanghai Jiao Tong Univ., China; ²Univ. of Massachusetts, USA. A compact 2×2 thermo-optical switch based on a dual-nanobeam MZI is experimentally demonstrated. The footprint is 38 μm×84 μm. The heating powers for the cross and bar states are ~2.66 mW and ~2.36 mW, respectively.

Th2A.8

Broadband SOI Mode Order Converter based on Topology Optimization, Min Teng^{1,2}, Keisuke Kojima¹, Toshiaki Koike-Akino¹, Bingnan Wang¹, Chungwei Lin¹, Kieran Parsons¹; ¹Mitsubishi Electric Research Labs, USA; ²Purdue Univ., USA. Topology optimized SOI mode order converters are proposed to allow mutual conversion between TE₀, TE₁, and TE₂. Broadband conversion efficiency around 85% can be realized on an ultra-compact (~4 μm) footprint.

Th2A.9

Design, Fabrication and Demonstration of Ultra-broadband Orbital Angular Momentum (OAM) Modes Emitter and Synthesizer on Silicon Platform, Zhou Nan¹, Shuang Zheng¹, Xiaoping Cao¹, Shengqian Gao², Shimao Li², Mingbo He², Jian Wang¹, XinLun Cai²; ¹Wuhan National Laboratory for Optoelectr, China; ²State Key Laboratory of Optoelectronic Materials and Technologies and School of Physics and Engineering, Sun Yat-sen Univ., China. We design, fabricate and demonstrate chip-scale ultra-broadband orbital angular momentum (OAM) emitter and synthesizer on a silicon platform. The maximum purity of OAM_{1,1} and synthesized OAM_{1,1} and OAM₁ are 0.93 and 0.9 in telecommunication band.

Th2A.10

Ultra-compact Silicon Polarization Beam Splitter with a Short Coupling Length of 0.768 μm, Yong Zhang¹, Xiaodong Wang¹, Xuhan Guo¹, Ciyuan Qiu¹, Xiulan Cheng¹, Yikai Su¹, Richard A. Soref²; ¹Shanghai Jiao Tong Univ., China; ²Univ. of Massachusetts, USA. We demonstrate an ultra-compact silicon polarization beam splitter with a coupling length of 0.768 μm. Lower than 2-dB insertion losses and over 10-dB extinction ratios are achieved over a wavelength range of 60 nm.

Th2A.11

Inter-die Fabrication Uniformity of Silicon Photonic Fiber-to-waveguide Edge Couplers, Junrong Ong¹, Thomas Ang¹, Xin Guo², Ezgi Sahin³, Soon Thor Lim¹, Dawn Tan³, Wang Hong³, Ching Eng, Jason Png¹; ¹Inst. of High Performance Computing, Singapore; ²Nanyang Technological Univ., Singapore; ³Singapore Univ. of Technology and Design, Singapore. Silicon-on-insulator fiber-to-waveguide inverse taper edge couplers of different tip widths of 120nm to 200nm are fabricated using a multi-project wafer service. The coupling efficiencies and the inter-die fabrication uniformity of the edge couplers are compared.

Th2A.12

A Simple, Robust Two-tone Method to Measure the Dynamic Nonlinear Characteristics of Phase Shifter in Silicon Mach-Zehnder Modulator, Tong Ye¹, Yanhui Qi¹, Hao Chen¹, Zhenning Tao¹, Tomofumi Oyama², Hisao Nakashima², Takeshi Hoshida², Haowen Shu³, Xingjun Wang³; ¹Fujitsu R&D Center, China; ²Fujitsu Laboratories Ltd, Japan; ³Peking Univ., China. A simple and robust method is proposed to measure high-frequency nonlinear phase-voltage relationship of phase shifter in silicon Mach-Zehnder modulator. Experiments show that static and dynamic characteristics are different, and nonlinearity decreases along with frequency.

Th2A.13

A Large-signal Equivalent Circuit for Depletion-type Silicon Ring Modulators, Minkyu Kim¹, Myungjin Shin¹, Min-Hyeong Kim¹, Byung-Min Yu¹, Christian Mai², Stefan Lischke², Lars Zimmermann², Woo-Young Choi¹; ¹Yonsei Univ., Korea; ²IHP, Germany. We demonstrate an accurate and easy-to-use large-signal equivalent circuit for depletion-type Si ring modulators. Design optimization of a 25-gbps Si photonic transmitter including the driver and the modulator is carried out entirely with SPICE simulation.

Th2A.14

Narrow Linewidth Hybrid InP-triPLeX Photonic Integrated Tunable Laser based on Silicon Nitride Micro-ring Resonators, Yi Lin¹, Colm Browning¹, Roelof Bernardus Timens², Douwe H. Geuzebroek², Chris G. H. Roeloffzen², Dimitri Geskus², Ruid M. Oldenbeuving², René G. Heideman², Youwen Fan^{3,2}, Klaus J. Boller³, Jialin Zhao⁴, Liam Barry¹; ¹Dublin City Univ., Ireland; ²LioniX International, Netherlands; ³Univ. of Twente, Netherlands; ⁴Huawei Technologies Co., China. Detailed characterization of a hybrid integrated tunable laser based on micro-ring resonators shows a tuning range of 50 nm with ~40 kHz linewidth. The device demonstrates performance comparable with commercial external cavity lasers in 16QAM coherent system.

Th2A.15

High Performance Self-injection Locked 524 nm Green Laser Diode for High Bitrate Visible Light Communications, Md. Hosne Mobarok Shamim¹, Mohamed Shemis¹, Chao Shen², Hassan Oubei², Tien K. Ng², Boon Ooi², Mohammed Z. Khan¹; ¹Electrical Engineering, King Fahd Univ. of Petroleum & Minerals, Saudi Arabia; ²King Abdullah Univ. of Science and Technology, Saudi Arabia. First demonstration of self-injection locking on 524 nm visible laser diode is presented. Enhancement by ~440 MHz (~30%) in modulation bandwidth, ~7 times reduction in lasing linewidth, and ~10 dB improvement in SMSR is achieved.

Th2A.16

High Throughput Bandwidth Characterization of Silicon Photonic Modulators using Offset Frequency Combs, Nathan Abrams¹, Robert Polster¹, Liang Y. Dai¹, Keren Bergman¹; ¹Columbia Univ., USA. We develop a low complexity, high-throughput testing technique for concurrently characterizing the bandwidths of multiple in-series modulators with independent frequency combs. The approach is demonstrated on two serial modulators at 9.2 GHz and 15.5 GHz.

Th2A.17

Phase Noise Characterization of a Mode-locked Quantum-dot Coherent Optical Frequency Comb Source Laser, Kristian Zanette¹, John C. Cartledge¹, Rongqing Hui², Maurice O'Sullivan²; ¹Queen's Univ. at Kingston, Canada; ²Ciena, Canada; ³Univ. of Kansas, USA. The amplitude fluctuations and correlation times of the two contributions to the phase noise of a quantum-dot optical frequency comb source laser are characterized using simultaneously recovered phase noise trajectories for pairs of comb lines.

Th2A.18

A 520-nm Green GaN LED with High Bandwidth and Low Current Density for Gigabits OFDM Data Communication, Chien Ju Chen¹, Jih-Heng Yan², De-Hua Chen³, Kai-Hsiang Lin², Kai Ming Feng³, Meng Chyi Wu^{1,3}; ¹Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan; ²Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; ³Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan. We develop 520-nm green GaN LEDs with a 340-mHz E-o bandwidth. For the first time, an OFDM signal modulates the green LED, which data rate achieves 2.16 Gb/s at a low current density 679 A/cm².

Th2A • Joint Poster Session II—Continued

Th2A.19

Modeling and Design Aspects of a Monolithically Integrated Optoelectronic Chip enabling 64GBaud Operation, Danish Rafique¹, Benjamin Wohlfeil¹, Gilda Mehrpoor¹, Helmut Griesser¹, Despoina Petousi², Pedro Rito², Iria Lopez², Lars Zimmermann², Michael Eiselt¹, Joerg-Peter Elbers¹; ¹ADVA Optical Networking, Germany; ²IHP GmbH, Germany. We report on the modeling of silicon photonic IQ-modulators with monolithically co-integrated BiCMOS segmented drivers. The structure is evaluated for coherent inter-dCI applications with symbol rates up to 64GBd and modulation formats up to DP-64QAM.

Th2A.20

Silicon Photonic Modulator based on Coupled Bragg Grating Resonators used as Phase Shifters, Omid Jafari¹, Hassan Sepehrian¹, Wei Shi¹, Sophie LaRochelle¹; ¹Electrical Engineering, Laval Univ., Canada. Bragg gratings with phase-shifts are inserted in a Mach-Zehnder modulator to enhance phase modulation, reduce device length and improve efficiency ($V_{\pi}xL=0.28$ Vcm). Simulations show 3 nm optical bandwidth corresponding to 50 K operating temperature range.

Th2A.21

Block-wise Time Domain Large Signal Model of Carrier-depletion Mach-Zehnder Silicon Photonic Modulators, Qun Zhang^{1,2}, Jianying Zhou², Jin Hong²; ¹Minnesota State Univ. Mankato, USA; ²NeoPhotonics Corporation, USA. Time domain large signal model operating in block signal mode is proposed for traveling-wave silicon photonic (SiPh) modulators based on carrier depletion. The underlying theory, implantation algorithm details, and waveform level simulation results are summarized.

Th2A.22

Demonstration of a Rectangularly-arranged Strongly-coupled Multi-core Fiber, Shota Saitoh¹, Katsuhiro Takenaga¹, Kazuhiko Aikawa¹; ¹Fujikura Ltd, Japan. We present a novel design of strongly-coupled multi-core fibers for MIMO-less transmission. The modal crosstalk between two propagating modes (LP_{01} -like and LP_{11} -like) of a fabricated fiber is less than -23 dB/km over the C+L band.

Th2A.23

Cladding-rods-assisted Depressed-core 9-IP-mode Fiber with Improved Modal Spacing, Jiawei Han¹, Jie Zhang², Guanjun Gao², Yongli Zhao², Shanglin Hou³; ¹Tianjin Normal University, China; ²Beijing Univ. of Posts and Telecommunications, China; ³Lanzhou Univ. of Technology, China. We report the design of a cladding-rods-assisted depressed-core 9-IP-mode fiber featuring more equally spaced modal effective indices, suitable for high-spatial-density uncoupled mode-division-multiplexing systems. It exhibits improved modal spacing ($\geq 1.0 \times 10^{-3}$) and large modal effective areas ($\geq 127 \mu m^2$).

Th2A.24

Design, Fabrication, Measurement and MDM Transmission of a Novel Weakly-coupled Ultra Low Loss FMF, Lei Shen^{1,2}, Su Chen^{1,2}, Xueting Sun^{1,2}, Yaping Liu^{1,2}, Lei Zhang^{1,2}, Tao Hu³, Juhao Li³; ¹Key Laboratory of Optical Fiber and Cable Manufacture Technology, China; ²Yangtze Optical Fiber and Cable Joint Stock Limited Company, China; ³Peking Univ., China. A novel weakly-coupled ultra low loss FMF is designed and fabricated, and we demonstrate 4-mode MDM transmission over 20-km ultra low loss FMF with 10-gb/s OOK modulation and direct detection.

Th2A.25

Numerical Analysis of Power Coupling in Few-mode Step Index Fibers, Gianluca Guerra¹, Andrea Gallarossa¹, Luca Palmieri¹; ¹Department of Information Engineering, Università degli Studi di Padova, Italy. Power coupling in few-mode step index fibers is studied for different kinds of perturbation. The analysis shows that coupling may change depending on perturbation even in the asymptotic regime.

Th2A.26

Observation of Fiber Fuse Propagation Speed Oscillation Due to Inter-mode Interference in Two-mode Fibers, Shoulin Jiang¹, Lin Ma¹, Xinyu Fan¹, Shuai Wang¹, Zuyuan He¹; ¹Shanghai Jiao Tong Univ., China. We investigated fiber fuse propagation speed oscillation in two-mode fibers by combining heterodyne detection and time-frequency analysis. We confirmed that the propagation speed oscillation was caused by the inter-mode interference between LP_{01} and LP_{11} modes.

Th2A.27

Solid Type Low-latency Single-mode Fiber with Large Effective Area and Low Loss, Yuto Sagae¹, Takashi Matsui¹, Kyozo Tsujikawa¹, Kazuhide Nakajima¹; ¹NTT, Japan. A novel solid type low-latency single-mode fiber (SMF) is proposed. Proposed small core dual-cladding structure successfully achieves a 0.3% latency reduction from a silica-core fiber while maintaining a 121.4 μm^2 effective-area and 0.194 dB/km loss.

Th2A.28

Toward Multilayer Disaggregated Node Telemetry and Local Decision Making, Luis Velasco¹, Luis Gifre², Jose Luis Izquierdo-Zaragoza¹; ¹Universitat Politècnica de Catalunya, Spain; ²Universidad Autónoma de Madrid (UAM), Spain. A generic node agent supporting disaggregated node telemetry is presented. Data collection close to devices enable making local decisions, leveraging SDN controllers for network-wide operations. The agent is demonstrated in a BER-triggered transponder reconfiguration scenario.

Th2A.29

First Experimental Demonstration of Disaggregated Emergency Optical System for Quick Disaster Recovery, Masaki Shiraiwa¹, Noboru Yoshikane², Sugang Xu¹, Takehiro Tsuritani², Naoki Miyata³, Tatsuo Mori³, Masatake Miyabe⁴, Toru Katagiri⁴, Sota Yoshida⁵, Masaki Tanaka⁵, Tomofumi Hayashi⁶, Hidetsugu Sugiyama⁶, Ikuo Satou⁷, Mashito Mikuni⁸, Satoru Okamoto⁸, Yoshinari Awaji¹, Naoya Wada¹; ¹National Inst Information & Comm Tech, Japan; ²KDDI Research, Inc., Japan; ³NTT Communications Corporation, Japan; ⁴Fujitsu Limited, Japan; ⁵Mitsubishi Electric Corporation, Japan; ⁶Red Hat K. K, Japan; ⁷OA Laboratory Corporation, Japan; ⁸Keio Univ., Japan. We demonstrated the effectiveness of a portable emergency optical system in disaster recovery. The system replaces functional units of damaged optical network and recovers a control-plane network by taking the advantage of surviving wireless access.

Th2A.30

Orchestrating Lightpath Adaptation and Flexible Functional Split to Recover Virtualized RAN Connectivity, Koteswararao Kondepudi¹, Nicola Sambo¹, Francesco Giannone¹, Piero Castoldi¹, Luca Valcarengi¹; ¹Scuola Superiore Sant'Anna, Italy. This study shows that a two-step recovery scheme orchestrating lightpath transmission adaptation and evolved NodeB (eNB) functional split reconfiguration preserves the Virtualized RAN fronthaul connectivity even when network capacity is scarce.

Th2A.31

Cross-layer Aware Packet-optical Link Management in Software-defined Network Operating System, Young-Jin Kim¹, Jesse E. Samsarian¹, Nakjung Choi¹, Nishok Mohanasamy¹, Marina Thottan¹; ¹Nokia Bell-labs, USA. Software-defined network management systems presently lack joint link-status awareness on both packet and optical layers. Using a NOS with cross-layer link awareness, we demonstrate faster service restoration of packet links over failed optical links.

Th2A.32

VPN Service Provisioning via Virtual Router Deployment and Quantum Key Distribution, Alejandro Aguado¹, Victor Lopez², Jesus Martinez-Mateo¹, Diego R. Lopez², Momtchil Peev³, Vicente Martin¹; ¹Center for Computational Simulation, Universidad Politécnica de Madrid, Spain; ²Telefonica I+D, Spain; ³Quantum Communication and Computing Laboratory, Huawei Technologies Dusseldorf GmbH, Germany. Here we demonstrate, for the first time, VPN services integrated within a virtual router using QKD to perform encryption and authentication. Any management operation is also secured using QKD, providing a whole quantum-safe ecosystem.

Th2A.33

On the Benefits of Programmable Optics for Post-failure VM Migrations in Data-centers, Ashwin Gumaste¹, Kushwaha Aniruddha¹, Admela Jukan²; ¹Indian Inst. of Technology, Bombay, India; ²ECE, Technische Universität Braunschweig, Germany. The role of programmable optics in data-center edges is investigated as a method for achieving high VNF availability in post-failure scenarios, while making the VM migrations simple and cost-effective.

Th2A.34

Joint Intra- and Inter-datacenter Network Optimization and Orchestration, Giada Landi², Marco Capitani², Aristotelis Kretsis¹, Panagiotis Kokkinos¹, Kostas Christodoulopoulos¹, Emmanouel Varvarigos^{1,3}; ¹Univ. of Patras, Greece; ²Nextworks, Italy; ³National Technical Univ. of Athens, Greece. We present a hierarchical orchestration platform for inter-domain datacenter networks that includes hybrid optical-electrical intra-datacenter networking and inter-datacenter networking utilizing elastic technologies. We demonstrate dynamic and joint allocation of capacity in an emulated testbed.

Show Floor Programming

400G Coherent: What Does it Mean to You?

OIF
10:15–11:15

Product Showcase

Huawei
10:15–10:45
For more details, see page 23

■ MW Panel V: Software Innovations in the Next-generation Optical Transport
10:30–12:00

POF Symposium

POFTO
11:00–13:00

Preparing for the GDPR: The EU's Sweeping Data Privacy Reform Initiative
IEEE
11:30–12:30

■ MW Panel VI: IP and Optical Integration: Physical or Control/Management Plane?
12:30–14:00

Standardization in ITU-T Study Group 15 – Networks, Technologies and Infrastructures for Transport, Access and Home ITU
12:45–13:45

Understanding Optical Signal-to-Noise Ratio
13:15–14:15

Th2A • Joint Poster Session II—Continued

Th2A.35

Disaggregating Optical Nodes in a Multi-layer SDN Orchestrator for the Integration of an In-operation Planning Tool, Federico Pederzoli¹, Mohit Chamania², Michele Santuari¹, Thomas Szyrkowiec³, Chris Matrakidis⁴, Ciril Rozić⁴, Dimitrios Klonidis⁵, Victor Lopez⁵, Domenico Siracusa¹; ¹FBK CREATE-NET, Italy; ²ADVA Optical Networking, Germany; ³ADVA Optical Networking, Germany; ⁴AIT, Greece; ⁵Telefonica I+D, Spain. Optical disaggregation can provide the intermediate models required by In-operation planning to compute feasible configurations in IP/Optical networks. We demonstrate disaggregation on a real SDN-orchestrated testbed, and quantify its benefits and costs.

Th2A.36

CAPEX Optimization with Joint Allocation of Hybrid RF/FSO and Optical Fibre Resources in 5G Backhaul, Da Feng¹, Weiqiang Sun¹, Weisheng Hu¹; ¹SJTU, China. We optimize CAPEX of a 5G backhaul with hybrid RF/FSO links and storage by exploiting matching between source nodes and destination nodes for allocation of links to minimize total required resources.

Th2A.37

A Shared Segment Protection Approach for Distributed Sub-tree Based Optical Multicasting Scheme in Elastic Optical Datacenter Networks, Tao Gao¹, Xin Li¹, Bingli Guo¹, Shan Yin¹, Shanguo Huang¹; ¹Beijing Univ of Posts & Telecom, China. We design a shared segment protection approach for multicast requests provisioned by distributed sub-trees in elastic optical datacenter networks. It outperforms conventional protection schemes in terms of spectrum efficiency, blocking probability, and notification time.

Th2A.38

Joint Optimization of Unicast, Anycast, Multicast and Multicast Traffic in Elastic Optical Networks, Xiao Luo¹, Chen Shi², Xue Chen¹, Liqian Wang¹; ¹Beijing Univ of Posts & Telecom, China; ²Iowa State Univ., USA. We estimate a hybrid communication scheme with unicast, anycast, multicast and multicast traffic in elastic optical networks. A request classification gene encoding based approach is proposed which optimizes hybrid traffic jointly to improve network efficiency.

Th2A.39

On Multi-layer Restoration in Optical Networks with Encryption Solution Deployment, Xin Jin¹, Wei Lu¹, Siqi Liu¹, Zuqing Zhu¹; ¹Univ of Science and Technology of China, China. We consider the scenario in which an optical network with encryption solution deployment can be affected by electrical layer failures, and propose an algorithm to improve the cost-effectiveness of multi-layer restoration in it.

Th2A.40

Reliability Gains of Infrastructure Programmability in an Optical C-RAN, Houman Rastegarfar¹, Tommy Svensson², Nasser Peyghambarian¹; ¹Univ. of Arizona, USA; ²Chalmers Univ. of Technology, Sweden. We study the interplay of optical, wireless, and control domains in a software-defined C-RAN architecture in terms of survivability. Our analysis indicates the significant advantage of optical network programmability under a negligible fronthaul latency penalty.

Th2A.41

Techno Economic Assessment of Immersive Video Services in 5G Converged Optical/Wireless Networks, Ioannis Neokosmidis¹, Theodoros Rokkas¹, Pietro Paglierani², Claudio Meani², Karim M. Nasr³, Klaus Moessner³, Muhammad Shuaib Siddiqui⁴, Pouriya Sayyad Khodashenas⁴; ¹inCITES Consulting SARL, Luxembourg; ²Italtel SpA, Italy; ³Inst. for Communication Systems, 5G IC, Univ. of Surrey, UK; ⁴i2CAT Foundation, Spain. The economic feasibility of a 5G media service in converged optical/wireless networks for crowded events in venues shows a ~6.5 years payback period. Sensitivity analysis highlights the impact of tariffs and CAPEX on net present value.

Th2A.42

Towards Secure Optical Networks: A Framework to Aid Localization of Harmful Connections, Federico Pederzoli¹, Marija Furdek², Domenico Siracusa¹, Lena Wosinska²; ¹FBK CREATE-NET, Italy; ²KTH Royal Inst. of Technology, Sweden. We model the scope of optical signal insertion attacks by defining attack syndromes for each connection, and present a cost-efficient routing heuristic that aids localization of harmful connections by reducing syndrome ambiguity in the network.

Th2A.43

Impact of WSS Filtering Penalty on the Capacity of Elastic WDM Ring Optical Networks, Haining Yang², Paul Wright³, Brian Robertson², Peter Wilkinson², Philip Dolan², Andrew Lord², Daping Chu²; ¹Univ. of Cambridge, UK; ²Roadmap Systems Ltd, UK; ³British Telecom Laboratories, UK. Our network model shows that the 3dB width of the Gaussian spectrum intensity profile in WSSs needs to be <6GHz for realising the ~30% capacity increase in a WDM ring network as promised by the flexible-spectrum standard.

Th2A.44

Multiplane Orbital Angular Momentum and Wavelength Switch based on Integrated Tunable Vortex Emitters, Mirco Scaffardi¹, Nicola Andrioli², Muhammad N. Malik^{2,1}, Ning Zhang³, Emma Lazzeri², Charalambos Klitis³, Martin Lavery³, Marc Sorel³, Antonella Bogoni^{1,2}; ¹CNIT - Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy; ²Sant' Anna di Pisa, Italy; ³Univ. of Glasgow, UK. A multiplane switch architecture exploiting OAM and wavelength domains is characterized in terms of BER, scheduling/reconfiguration latency, and power consumption. Doubling the exploited OAM modes reduces the latency by 42% and the power by 17%.

Th2A.45

When CORD Meets Hub, Qingya She¹, Kirsten Rundberget¹, Weisheng Xie¹; ¹Fujitsu Networks Communications Inc., USA. Architectures of CORD at the nodal level and Hub at the metro network level are studied. Ways in which they can cooperate, as well as the impact on network operations and economics, are also analyzed.

Th2A.46

Ultra-fast Hitless 100Gbit/s Real-time Bandwidth Variable Transmitter with SDN Optical Control, Arnaud Dupas¹, Patricia Layec¹, Dominique Verchere¹, Quan Pham Van¹, Sébastien Bigo¹; ¹Nokia Corporation, France. We designed an ultra-fast real-time bandwidth-variable transmitter achieving zero-packet loss with ~10μs switching time, ~40x faster than previous record. We use a new coding scheme to generate baud rates and measure reconfiguration through SDN control.

Th2A.47

Regenerator Allocation in Nonlinear Elastic Optical Networks WITH Random Data Rates, Li Yan¹, Yuxin Xu², Maite Brandt-Pearce², Nishan Dharmaweera¹, Erik Agrell¹; ¹Chalmers Univ. of Technology, Sweden; ²Univ. of Virginia, USA. We optimize the regenerator allocation in nonlinear elastic networks whose traffic demands have random data rates. Compared with previous regenerator allocation algorithm, our method achieves the same blocking probability with 11% less regenerator sites.

Th2A.48

Real-time Demonstration of Adaptive Functional Split in 5G Flexible Mobile Fronthaul Networks, Yahya M. Alfadhli¹, Mu Xu¹, Siming Liu¹, Peng-Chun Peng^{1,2}, Gee-Kung Chang¹; ¹Georgia Inst. of Technology, USA; ²Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan. We experimentally demonstrate a flexible and reconfigurable Fronthaul-i with analog RoF integration that aims to optimally serve different 5G applications. RoF integration can reduce the latency by more than %15 to support URLLC applications.

Th2A.49

Experimental Demonstration of SDN-controlled Variable-rate Fronthaul for Converged LTE-over-PON, Pedro Alvarez¹, Frank Slyne¹, Christian Blumm¹, Johann Marquez-Barja², Luiz DaSilva¹, Marco Ruffini¹; ¹Univ. of Dublin Trinity College, Ireland; ²Univ. of Antwerp - IMEC, Belgium. We introduce the concept of variable-rate fronthaul and provide experimental validation over PONs. Our SDN controller dynamically modifies the wireless cell bandwidth depending on load, thus varying the fronthaul rate with sub-second end-to-end reconfiguration times.

Th2A.50

A Flexible Low-latency Metro-access Converged Network Approach based on Time-synchronized TWDM-PON, Jialong Li¹, Nan Hua¹, Yufang Yu¹, Zhizhen Zhong¹, Xiaoping Zheng¹, Bingkun Zhou¹; ¹Tsinghua Univ, China. A flexible time-synchronized TWDM-PON (TS-TWDM-PON) architecture is proposed and implemented for low-latency metro-access communication. Results show that a two-order-of-magnitude reduction in end-to-end delay can be achieved with the new TS-TWDM-PON architecture.

Th2A.51

K-means Clustering based Multi-dimensional Quantization Scheme for Digital Mobile Fronthaul, Lu Zhang^{1,2}, Xiaodan Pang², Oskars Ozolins³, Aleksejs Udalcovs³, Sergei Popov², Shilin Xiao¹, Jiajia Chen²; ¹Shanghai Jiao Tong Univ., China; ²School of ICT, KTH, Royal Inst. of Technology, Sweden; ³RISE Acreo Swedish ICT AB, Sweden. We propose to group highly-correlated neighboring samples into multi-dimensional vectors and adopt k-means clustering for quantization in mobile fronthaul. 30-gbit/s transmissions have been experimentally demonstrated for up to 40 100MHz LTE channels over 20km fiber.

Th2A.52

Improved Link Budget (35 dB) of 2x25 Gb/s WDM/TDM-PON by using LTE-over-PON, Han Hyub Lee¹, Kyeong-Hwan Doo¹, Kwangok Kim¹, Sil-Gu Mun¹, Seung Hwan Kim¹, Hwan Seok Chung¹; ¹Electronics & Telecomm Res. Inst, Korea. We demonstrated a link budget improved 2x25 Gb/s WDM/TDM-PON by using O-band SOA with an assist light and FEC. When the assist light is used to the SOA, gain-saturation induced crosstalk of SOA was successfully mitigated. 50G-ethernet PON traffic was transmitted over 20-km reach and 256-split.

Th2A.53

High Optical Budget PtP DWDM System in Overlay with CWDM for Mobile XHaul with Remote Wavelength Tuning and Monitoring in Tunable SFPs, Sylvain Barthelemy¹, Fabienne Saliou¹, Naveena Genay¹, Luiz Anet Neto¹, Philippe Chanclou¹, Erik Pennings², Jin Hyung Ahn², Sun Keun Yu², Sung Eun Hong²; ¹Orange Labs, France; ²SOLiD, Korea. We experimentally achieved 33dB optical budget with real time monitoring and wavelength tuning within a DWDM system in a fronthaul architecture. Compatibility with commercial RAT and remote control of the Tunable-SFPs are demonstrated.

Th2A.54

Highly Flexible WDM PON System with a Single TDM Time Lens Source Enabling Record 150 km Downstream Reach, Pengyu Guan¹, Francesco Da Ros¹, Mads Lillieholm¹, Kjeld Dalggaard¹, Michael Galili¹, Palle Jeppesen¹, Toshio Morioka¹, Leif K. Oxenlowe¹; ¹Technical Univ. of Denmark, Denmark. We propose a new OLT transmitter for WDM-PON based on optical Fourier transformation of a single-source TDM-PON signal to WDM-PON signals. We demonstrate flexible bit rates (10x1-to-64x2Gb/s) and 40x1Gb/s WDM-PON record unamplified downstream transmission reach of 150 km.

Exhibit Hall B

Th2A • Joint Poster Session II—Continued

Th2A.55

Using Raman Gain to Offset Excess Losses of an Intelligent Optical Distribution Network in a TWDM PON, Michael Straub¹, Patrick Iannone¹; ¹Nokia Bell Labs, USA. We use bi-directional distributed Raman amplification to offset the excess losses of an intelligent splitter module. We demonstrate this technique in a 42-km, 1:32 split, TWDM PON.

Th2A.56

Redundancy for Long-reach TWDM PON, Liang B. Du¹, Shuang Yin¹, Xiangjun Zhao¹, Tao Zhang¹, Adam Barratt¹, Joy Jiang¹, Daoyi Wang¹, Cedric F. Lam¹; ¹Google, USA. A redundancy design for long-reach TWDM PON without backup OLTs is proposed, protecting the truck fiber and optionally the CO. Network modeling shows availability of redundant long-reach PONs is better than traditional PONs.

Th2A.57

Simultaneous Multiband WSN, WLAN, LTE-a, and Gb/s 4-PAM Signals Transmission over 50 m 1 mm Core Diameter POF for Home Area Network, Federico Fornì^{1,2}, N.C. Tran², H.P.A. v. Boom¹, Eduward Tangdionga¹, Ton Koonen¹; ¹Eindhoven Univ. of Technology, Netherlands; ²Genexis, Netherlands. Four wireless-sensors-network channels were transmitted over 50m GI-pOF and 12m wireless together with a WLAN signal, 9 64-QAM LTE-a bands with reduced PAPR, and 1.66Gb/s 4-PAM baseband signal for multi-standard wired-wireless smart-home and in-home networks.

Th2A.58

Linearized Photonic Down-conversion Using Second-harmonic Generation, Gregory S. Kanter¹, Paul Moraw¹, Daniel Reilly¹; ¹NuCrypt, USA. We demonstrate that second harmonic generation effectively doubles the modulation index of a phase modulator, and simulate a photonic down-conversion system that exploits the enhanced modulation index to improve linearity without substantially reducing gain.

Th2A.59

Achievable Information Rate Enhancement of Visible Light Communication Using Probabilistically Shaped OFDM Modulation, Zhixue He¹, Wu Liu¹, Chenhui Xie², Songnian Fu², Xiang Li¹, Chao Yang¹, Qi Yang¹; ¹State Key Laboratory of Optical Comm. Technologies and Networks, China; ²School of Optics and Electronic Information, Huazhong Univ. of Science and Technology, China. We experimentally demonstrate a visible light communication (VLC) system based on the probabilistically shaped (PS) OFDM modulation. The overall achievable information rate (AIR) can be improved by 13.6% in comparison with conventional bit-loading scheme.

Th2A.60

PAM-4 Wireless Transmission based on Look-up-table Pre-distortion and CMMA Equalization at V-band, Wen Zhou¹, Pengqi Gou¹, Kaihui Wang¹, Miao Kong¹, Xinying Li^{1,2}, Li Zhao¹, Zihang Zhu¹, Jianjun Yu^{1,2}; ¹Shanghai Inst. for Advanced Communication and Data Science, Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China; ²ZTE (TX) Inc., USA. We introduce new DSP including look-up-table pre-distortion at transmitter-side and cascaded multi-modulus-algorithm equalization at receiver-side to improve the ROF transmission performance. We experimentally achieved 6.5GBaud PAM-4 wireless transmission with 9m free space distance at V-band.

Th2A.61

Spectrally Efficient SSB signals for W-band Links Enabled by Kramers-Kronig Receiver, Luis Gonzalez-guerrero¹, Haymen Shams¹, Irshaad Fatadin², Martyn Fice¹, Mira Naftaly², Alwyn Seeds¹, Cyril Renaud¹; ¹Univ. College London, UK; ²National Physical Laboratory, UK. We demonstrate a radio-over-fiber link based on the Kramers-Kronig receiver for the first time. Using this technique, we recover an 11 GBd single sideband signal with a net spectral efficiency of 3.4 (bit/s)/Hz at W-band.

Th2A.62

Modal Dispersion and Feed Light Crosstalk Mitigations by using Center- and Offset-launching for Optically-powered Radio-over-multimode Fiber Systems, Hayao Kuboki¹, Motoharu Matsuura¹; ¹Univ. of Electro-communications, Japan. We have successfully achieved high RoF transmission performance with around 10-watt feed power-over-fiber using a conventional multimode fiber. The modal dispersion and feed light crosstalk are effectively mitigated by the combination of center- and offset-launching.

Th2A.63

Multipath Interference Free Multi-LED Visible Light Communications with Gold Sequence Multiplexing, Jihui-Heng Yan¹, Ya-Jou Cheng¹, Kai-Hsiang Lin¹, De-Hua Chen², Chien Ju Chen³, Kai Ming Feng^{1,2}; ¹Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; ²Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan; ³Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan. We experimentally demonstrate a multi-LED VLC system with low complexity Gold sequence multiplexed OFDM signals. Without time synchronization or uplink feedback mechanism, the received signal qualities are uniform and ubiquitously isolated from wireless multipath interferences.

Th2A.64

MISO Visible Light Communication System Utilizing MCMMA Aided Pre-convergence of STBC Decoding, Liang Qiao¹, Xingyu Lu¹, Shangyu Liang¹, Nan Chi¹; ¹Fudan Univ., China. We experimentally apply the MCMMA algorithm to reduce BER in VLC-mISO system. Experiments demonstrate the performance with MCMMA algorithm can achieve higher Baud Rate than the scheme of STBC without MCMMA.

Th2A.65

Enhanced Emission and Modulation Properties of Localized Surface Plasma Coupled GaN-based Green Light-emitting Diodes, Jiehui Li¹, Pengqi Gou¹, Nan Chi¹, Haiyan Ou²; ¹Fudan Univ., China; ²Technical Univ. of Denmark, Denmark. A localized surface plasma coupled LED with modulation bandwidth of 152MHz which was enhanced by 1.65 times relative to grid LED was fabricated for high-speed VLC system, while the light power increased by 1.67 times.

Th2A.66

Simultaneous Temperature and Strain Measurement using Deep Neural Networks for BOTDA Sensing System, Biwei Wang², Liang Wang¹, Changyuan Yu², Chao Lu²; ¹The Chinese Univ. of Hong Kong, Hong Kong; ²The Hong Kong Polytechnic Univ., Hong Kong. DNN is used for the first time in simultaneous measurement of temperature and strain along a large-effective-area fiber (LEAF) in a BOTDA system with short processing time.

Th2A.67

Linearized Phase Modulation Microwave Photonics Link via Optimizing Processing of Optical Sidebands, Ruihuan Wu¹, Tianwei Jiang¹, Song Yu¹, Jianming Shang¹, Chenxia Liu¹, Wanyi Gu¹; ¹Beijing Univ. of Posts & Telecomm., China. A multi-order nonlinear distortions suppression in phase modulation microwave photonics link via optimizing processing of optical sidebands is presented. Experimental results show the SFDR increases by 21.1 dB compared to that without nonlinear compensation.

Th2A.68

Photonic Design Parameters for AWG-based RF Channelized Receivers, Kyle S. Davis¹, Andrew Stark¹, Benjamin Yang¹, Anthony Lentine², Christopher DeRose², Michael Gehl²; ¹Georgia Tech Research Inst., USA; ²Sandia National Laboratory, USA. An 11-channel 1-gHz bandwidth silicon photonic AWG was fabricated and measured in the lab. Two photonic architectures are presented: (1) RF-envelope detector, and (2) RF down-converter for digital systems. The RF-envelope detector was modeled based on the demonstrated AWG characteristics to determine estimated system-level RF receiver performance.

Th2A.69

Digital Radio over Fiber Distribution using Millimetre Wave Bridging, Haymen Shams¹, Tongyun Li², Cyril Renaud¹, Alwyn Seeds¹, Richard V. Penty², Martyn Fice¹, Ian White²; ¹Univ. College London, UK; ²Centre for Photonic Systems, Electrical Division, Department of Engineering, Univ. of Cambridge, UK. This paper demonstrates a novel digital radio-over-fiber system using a millimeter-wave bridge giving access where fiber cannot. The system can transport multiple digitised LTE-compatible signals with high spectral efficiency, low latency, and wide dynamic range.

Show Floor Programming

400G Coherent: What Does it Mean to You?

OIF
10:15–11:15

Product Showcase

Huawei
10:15–10:45
For more details, see page 23

■ **MW Panel V: Software Innovations in the Next-generation Optical Transport**
10:30–12:00

POF Symposium

POFTO
11:00–13:00

■ **Preparing for the GDPR: The EU's Sweeping Data Privacy Reform Initiative**
IEEE
11:30–12:30

■ **MW Panel VI: IP and Optical Integration: Physical or Control/Management Plane?**
12:30–14:00

■ **Standardization in ITU-T Study Group 15 – Networks, Technologies and Infrastructures for Transport, Access and Home ITU**
12:45–13:45

■ **Understanding Optical Signal-to-Noise Ratio**
13:15–14:15

Thursday, 15 March

12:30–14:00 Unopposed Exhibit-only Time, Exhibit Hall (concessions available)



Room 1A

14:00–15:00

Th3A • Current Topics in Long Haul/Metro Transmission

Presider: Nitin Goel; Facebook Inc., USA

Th3A.1 • 14:00 **Invited**

Traffic Engineering and Topology Programming, Monia Ghobadi¹; ¹Microsoft, USA. With the adoption of ROADMs in long-haul networks, providers have the ability to change the physical layer of networks. We propose a graph abstraction for the practical adoption of programmable topologies into traffic engineering schemes.

Th3A.2 • 14:30 **Invited**

Pizzabox Transponders Deployment in the Field and Related Issues, Giuseppe Rizzelli², Andrew Sutters¹, Nitin K. Goel¹; ¹Facebook, USA; ²Facebook, UK. Pizzabox transponders deployment in metro and backbone networks allows us to achieve large power and space savings. However, to reduce time to market, many basic software features are left out, thus making operations more complex.

Room 6C

14:00–16:00

Th3B • Directly Modulated Lasers

Presider: Yasuhiro Matsui; Finisar Corporation, USA

Th3B.1 • 14:00 **Tutorial**

Ultra-high-speed Optical-cavity-enhanced DMLs, Richard J. Schatz¹; ¹Applied Physics, Royal Inst. of Technology (KTH), Sweden. The modulation bandwidth of directly modulated lasers for Datacom can be enhanced by utilizing the wavelength selectivity of the laser cavity. Three effects will be discussed; detuned loading, photon-photon resonance and chirp to intensity conversion. A review of the field will be presented, including recent theoretical and experimental results.



Richard Schatz (Ph.D. 1995, Docent 2014) has since 1987 conducted research at Royal Institute of Technology (KTH), Stockholm, on the modeling, design and characterization of fiber-optical transmitters (edge emitter lasers, VCSELs and modulators) and links, both for on-off keying and multilevel modulation formats. He is the developer of the software LaserMatrix, used by industry for interactive design of high-speed and low noise semiconductor lasers.

Room 6D

14:00–16:00

Th3C • Optical Switching II

Presider: Richard Jensen; Polatis, Inc., USA

Th3C.1 • 14:00

Wide-range Automated Wavelength Calibration over a Full FSR in a Dual-ring based Silicon Photonic Switch, Qingming Zhu¹, Hongxia Zhang¹, Ruiyuan Cao¹, Ning Zhao¹, Jiang Xinhong¹, Danping Li², Yanbo Li², Xiaolu Song², Xuhan Guo¹, Yong Zhang¹, Ciyuan Qiu¹; ¹Shanghai Jiao Tong Univ., China; ²Huawei Technologies Co., Ltd., China. We demonstrate an automated wavelength calibration scheme for a dual-ring based silicon electro-optic switch. By using an improved saddle point searching algorithm, the calibration over a full free spectral range of 6 nm is achieved.

Th3C.2 • 14:15

Self-holding Operation of Magneto-optical Switch using Thin-film Magnet, Ken Okazeri¹, Kenji Muraoka¹, Yuya Shoji¹, Shigeki Nakagawa¹, Nobuhiko Nishiyama¹, Shigehisa Arai¹, Tetsuya Mizumoto¹; ¹Tokyo Inst. of Technology, Japan. A novel self-holding switch is demonstrated by a magneto-optical waveguide switch. The switching state is flipped by a pulsed current and maintained without any power supply by virtue of the non-volatility of thin-film magnet.

Th3C.3 • 14:30 **Tutorial**

Photonic Switch Fabrics in Computer Communications Systems, Benjamin G. Lee¹; ¹IBM TJ Watson Research Center, USA. Dense, efficient, and potentially low-cost photonic switches show promise for transforming Computercom networks. This talk will cover the fundamentals of photonic switching technologies, as well as the architectures and packaging features that can enable scaling.

Room 6E

14:00–16:00

Th3D • Nonlinear Fiber Effects

Presider: Wladek Forysiak, UK

Th3D.1 • 14:00 **Tutorial**

Nonlinearity of Optical Fibers, Govind P. Agrawal¹; ¹Univ. of Rochester, USA. Fiber nonlinearities are regarded as being harmful for optical communication systems, although they are useful for applications such as Raman amplification and supercontinuum generation. In this tutorial I review them and discuss their practical implications.



Govind Agrawal is James Wyant Professor of Optics at University of Rochester. He is an author of about 450 research papers and eight books. His books on Nonlinear Fiber Optics and Fiber-Optic Communication Systems are used worldwide. Prof. Agrawal is a Fellow of IEEE and OSA. He received IEEE Quantum Electronics Award in 2012 and was awarded OSA's Esther Hoffman Beller Medal in 2015. Since 2014, he is serving as Editor-in-Chief of Advances in Optics and Photonics.

continued on page 128



Room 6F

14:00–15:45

Th3E • Advanced Transmission Technology

Presider: Antonio Napoli; Coriant, Germany

Th3E.1 • 14:00 **Invited**

Digital Pre-compensation Techniques Enabling Cost-efficient High-order Modulation Formats Transmission, Dan Sadot^{1,2}, Yaron Yoffe¹, Hananel Feig¹, Gil Paryanti¹; ¹Electrical and Computer Engineering, Ben Gurion Univ. of the Negev, Israel; ²MultiPhy, Israel. Digital precompensation complementary to post equalization increases the DSP compensation envelope. Implementable parallel least square of nonlinear bandlimited channel, asymmetric imbalance predistortion of MZM impairments, and quantization noise preshaping minimizing DAC resolution requirement are presented

Th3E.2 • 14:30 **Invited**

Secure Transmission using QAM Quantum Noise Stream Cipher with Continuous Variable QKD, Masataka Nakazawa¹, Masato Yoshida¹, Takuya Hirano²; ¹Tohoku Univ., Japan; ²Gakusyuin Univ., Japan. We describe a Real-time 70 Gbit/s, 128 QAM quantum noise stream cipher transmission system with a continuous variable quantum key distribution system, which enables encrypted data to be transmitted over 100 km.

Room 7AB

14:00–15:00

Th3F • Data Center Interconnect Deployments

Presider: Bruce Cortez; AT&T, USA

Th3F.1 • 14:00 **Invited**

Present and Future Optical Technology Deployments in Facebook's Terrestrial Networks, Gaya Nagarajan¹; ¹Facebook, USA. We discuss the current state and future evolution of Facebook terrestrial networks, for long-haul and metro. We highlight the underlying architectural principles, for both hardware blocks and software APIs, that result in scalable, efficient, automated networks.

Th3F.2 • 14:30

Leveraging Predictive Analytics to Achieve Knowledge-defined Orchestration in a Hybrid Optical/Electrical DC Network: Collaborative Forecasting and Decision Making, Wei Lu¹, Lipei Liang¹, Bingxin Kong¹, Baojia Li¹, Zuqing Zhu¹; ¹Univ of Science and Technology of China, China. We design and experimentally demonstrate a hybrid optical/electrical DC network that achieves knowledge-defined orchestration with two collaborative machine learning modules.

Th3F.3 • 14:45

Service Function-oriented Topology Aggregation in Multi-domain Inter-dc Elastic Optical Networks, Boyuan Yan¹, Yongli Zhao¹, Xiaosong Yu¹, Wei Wang¹, Jie Zhang¹; ¹Beijing Univ. of Posts and Telecom, China. A service function-oriented topology aggregation is proposed, based on which a routing and resource assignment algorithm is designed for service function chain construction in multi-domain optical networks. Simulation results show it can achieve high efficiency.

Room 8

14:00–16:00

Th3G • Hybrid Access Networks for Wireless Delivery

Presider: Hwan Seok Chung; ETRI, Korea

Th3G.1 • 14:00 **Invited**

Ultrafast Beam Steering Enabled by Photonics & Plasmonics, Juerg Leuthold¹, Romain Bonjour¹, Yannick Salamin¹, Claudia Hoessbacher¹, Wolfgang Heni¹, Christian Haffner¹, Arne Josten¹, Benedikt Baeuerle¹, Masafumi Ayata¹, Andreas Messner¹, Ueli Koch¹, Tatsuhiko Watanabe¹, Yuriy Fedoryshyn¹, Ping Ma¹, Maurizio Burla¹; ¹ETH Zurich, Switzerland. Photonics and plasmonics offer unique opportunities to realize ultrafast millimeter wave beam steering concepts relying on phased array antennas. We discuss recent advances and experiments demonstrating settling times in the order of 10s of ps.

Th3G.2 • 14:30

Wireless Extension for 2.5 Gbit/s GPON, Rattana Cheunchom¹; ¹Univ. of Duisburg Essen, Germany. We report on a coherent RoF architecture for connecting multiple ONUs in a GPON network via a 71-76 GHz E-band wireless link to the OLT. Novel coherent photonic mixer (CPX) modules providing up to +17 dBm RF output power in the E-band are used for direct optic-to-rF conversion.

Th3G.3 • 14:45

Enabling 5G Services in PON with a Novel Smart Edge Based on SiP MRM, Xun Guan¹, Yelong Xu¹, Jiachuan Lin¹, Mingyang Lyu¹, Raphaël Dubé-Demers¹, Sophie LaRochelle¹, Wei Shi¹, Leslie A. Rusch¹; ¹Department of electronic and computer engineering, Centre for optics, photonics and lasers, Canada. We propose a novel passive optical network (PON) smart edge supporting 5G services by exploiting silicon photonic (SiP) microring modulators (MRM) with advantages of compactness, low-cost, low power and colorless operation. We validate the proposal experimentally.

Room 9

14:00–15:45

Th3H • Optical Switching Sub-systems

Presider: Leif Oxenlowe; DTU Fotonik, Denmark

Th3H.1 • 14:00

4 OAM x 4 WDM Optical Switching Based on an Innovative Integrated Tunable OAM Multiplexer, Ning Zhang¹, Mirco Scaffardi², Muhammad N. Malik^{2,3}, Veronica Toccafondo², Charalambos Klitis¹, Martin Lavery¹, Gianluca Meloni², Francesco Fresi³, Emma Lazzeri³, Diego Marini¹, Jiangbo Zhu⁴, Xinlun Xinlun⁵, Siyuan Yu⁴, Luca Poti², Giovan B. Preve², Antonella Bogoni^{2,3}, Marc Sorell¹; ¹Univ. of Glasgow, UK; ²CNIT - Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy; ³Sant' Anna di Pisa, Italy; ⁴Univ. of Bristol, UK; ⁵State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-sen Univ., China. A 4OAMx4WDM switching experiment has been carried out combining an innovative integrated tunable OAM multiplexer based on 4-concentric omega-shaped silicon waveguides and a refractive element-based OAM demultiplexer; operation is demonstrated up to 120Gb/s.

Th3H.2 • 14:15 **Top Scored**

83.33 Tb/s Coherent PDM-8PSK SDM-TDM Spatial Super-channel and High-speed Core-joint Switching System, Jose Manuel Delgado Mendinueta¹, Satoshi Shinada¹, Yusuke Hirota¹, Ruben S. Luis¹, Hideaki Furukawa¹, Naoya Wada¹; ¹NICT, Japan. We experimentally demonstrate a record 83.33 Tb/s switching capacity on a time-division spatial super-channel 2x2 switching node making use of core-joint, ns switching-speed and transparent electro-absorption optical switches.

Th3H.3 • 14:30 **Invited**

Large-scale Optical Circuit Switch Architecture for Intra-datacenter Networking, Yojiro Mori¹, Ken-Ichi Sato¹; ¹Nagoya Univ., Japan. This paper reviews recently developed large-scale optical-circuit-switch architectures suitable for intra-datacenter networking that synergistically combine space switches and wavelength-routing switches. Tunable laser and tunable filter based wavelength-routing schemes are compared in terms of hardware requirements.





Room 1A


Th3A • Current Topics in Long Haul/Metro Transmission—Continued

Room 6C

Th3B • Directly Modulated Lasers—Continued

Th3B.2 • 15:00  **Top Scored**
Monolithic Integration of an 8-channel Directly Modulated Membrane-laser Array and a SiN AWG Filter on Si, Hidetaka Nishi¹, Takuro Fujii¹, Nikolaos Panteleimon Diamantopoulos¹, Koji Takeda¹, Erina Kanno¹, Takaaki Kakitsuka¹, Tai Tsuchizawa¹, Hiroshi Fukuda¹, Shinji Matsuo¹; ¹NTT, Japan. Eight-channel 56-gbit/s PAM-4 direct modulations are demonstrated using a 1.3- μ m WDM transmitter, consisting of membrane lasers and a SiN AWG filter. Direct bonding, epitaxial regrowth, and low-temperature SiN deposition are employed for integration on Si.

Th3B.3 • 15:15 
Superior BER Transmission of 106-Gb/s/lane Skewless PAM4 over 10 km by Utilizing 1.3- μ m Directly Modulated InGaAlAs-mQW BH Lasers and Incoherent Multiplexing of Two NRZ Signals, Kouji Nakahara¹, Riu Hirai², Takeshi Kitatani¹, Nobuhiko Kikuchi², Takayoshi Fukui¹, Kaoru Okamoto¹, Yasushi Sakuma¹, Kohichi Tamura¹, Shigehisa Tanaka¹; ¹Oclaro Japan, Inc., Japan; ²Center for Technology Innovation, Hitachi, Japan. We firstly demonstrate incoherent multiplexing of two NRZ signals utilizing directly modulated lasers transmits 106-gb/s/lane PAM-4 signals over 10 km without non-linear compensation. Skewless eye diagram of this method attained lower BERs than conventional method.


Th3B.4 • 15:30 
Mode Selective Active Multimode Interferometer Laser Diode with over 40 GHz Direct Modulation Bandwidth, Bingzhou Hong¹, Tomotaka Mori¹, Haisong Jiang¹, Kiichi Hamamoto¹; ¹Kyushu Univ., Japan. Mode selective active multimode interferometer laser diode demonstrated high speed modulation capacity. Over 40 GHz direct modulation bandwidth was confirmed for the both 0th and 1st order modes.

Room 6D

Th3C • Optical Switching II—Continued




Benjamin G. Lee received the B.S. degree from Oklahoma State University in 2004, and the M.S. and Ph.D. degrees from Columbia University in 2006 and 2009, respectively, all in electrical engineering. He subsequently became a Postdoctoral Researcher at IBM Thomas J. Watson Research Center, where he is currently a Research Staff Member. His research interests include silicon photonic devices, integrated optical switches and networks for high-performance computing systems and datacenters, and highly parallel multimode transceivers. He is a Member of the Optical Society and the IEEE Photonics Society. He currently serves on the Board of Governors for the Photonics Society.


Th3C.4 • 15:30 
Demonstration of On-chip 640-Gbit/s Throughput, Granularity-flexible Programmable Optical Filtering and Reconfigurable Optical Add/drop Multiplexing on Silicon Platform, Shuang Zheng¹, Yun Long¹, Dingshan Gao¹, Yan Luo¹, Lulu Wang¹, Jinrun Zhang¹, Andong Wang¹, Long Zhu¹, Zhou Nan¹, Meng Huang¹, Zhengsen Ruan¹, Li Shen¹, Jian Wang¹; ¹Wuhan National Laboratory for Optoelectr, China. By integrating cascaded arrayed-waveguide gratings with array switches on silicon platform, we design and fabricate an on-chip multi-functional photonic signal processor. 640-gbit/s throughput, granularity-flexible programmable optical filtering and reconfigurable optical add/drop multiplexing are demonstrated experimentally.

Room 6E

Th3D • Nonlinear Fiber Effects—Continued

Th3D.2 • 15:00  **Top Scored**
Blue-enhanced Supercontinuum Generation in a Graded-index Fluorine-doped Multimode Fiber, Zeinab Sanjabi Eznaveh¹, Mohammad Amin Eftekhari¹, Jose Enrique Antonio-Lopez¹, Miroslav Kolesik², Helena Lopez-Aviles¹, Frank W. Wise³, Demetrios Christodoulides¹, Rodrigo Amezcua Correa¹; ¹CREOL, Univ. of Central Florida, USA; ²College of Optical Sciences | The Univ. of Arizona, USA; ³Applied and Engineering Physics, Cornell, USA. We demonstrate blue-enhanced white-light supercontinuum generation in a fluorine-doped parabolic-index multimode fiber. The spectrum expands from 450–2,400nm with excellent spectral flatness and a beam quality factor of M²~1.7 at 1064nm.

Th3D.3 • 15:15 
Nonlinear Propagation Equations for Arbitrary Levels of Random Linear Coupling between Modes, Shaival Buch^{1,2}, Sami Mumtaz^{1,2}, Rene-Jean Essiambre², Antonia M. Tulino², Govind P. Agrawal¹; ¹Univ. of Rochester, USA; ²Nokia Bell Laboratories, USA. We derive expressions that enable the study of the impact of arbitrary levels of linear coupling between spatial modes on nonlinear propagation in space-division multiplexed transmission systems, valid for both multimode and coupled-core fibers.

Th3D.4 • 15:30 
Stable Measurement of Effective Area in Coupled Multi-core Fiber, Elaine S. Chou^{1,2}, Tetsuya Hayashi¹, Takuji Nagashima¹, Joseph M. Kahn², Tetsuya Nakanishi¹; ¹Optical Communications Laboratory, Sumitomo Electric Industries, Ltd., Japan; ²Edward L. Ginzton Laboratory, Stanford Univ., USA. We achieved stable near-field and far-field patterns measurements and effective area evaluation of randomly coupled multi-core fibers by using a wide-bandwidth light source to average intensity over wavelength and eliminate time-varying intensity fluctuations.



Room 6F

Th3E • Advanced Transmission Technology—Continued

Th3E.3 • 15:00

Single-laser Differential Phase Shift Transmitter for Small Form-factor Quantum Key Distribution Optics, Bernhard Schrenk¹, Michael Hentschel¹, Hannes Hübel¹; ¹*AIT Austrian Inst. of Technology, Austria*. A cost-effective QKD transmitter based on a phase-modulated laser with integrated pulse carving is experimentally demonstrated. A raw key rate of 4.5kb/s at 2.65% quantum bit error ratio is obtained after 27 km fiber transmission.

Th3E.4 • 15:15

96-GBaud PDM-8QAM Single Channel Transmission over 9,600 km by Nonlinear Tolerance Enhancement using PPLN-based Optical Phase Conjugation, Takayuki Kobayashi¹, Takeshi Umeki², Ryoichi Kasahara², Hiroshi Yamazaki², Munehiko Nagatani², Hltoshi wakita², Hirokazu Takenouchi², Yutaka Miyamoto¹; ¹*NTT Network Innovation Laboratories, Japan*; ²*NTT Device Technology Laboratories, Japan*. 96-GBaud PDM-8QAM single carrier long-haul transmission is demonstrated employing polarization-diverse PPLN-based optical phase conjugator which increased the optimal fiber input power by 4dB and extends the transmission distance from 7,040 km to 9,600km.

Th3E.5 • 15:30

Compensation of Mode Coupling in MDM Transmission System using Digital Optical Phase Conjugation, Sung Hyun Bae¹, Youngho Jung¹, Byoung Gon Kim¹, Jun Ho Chang¹, Hoon Kim¹, Yun Chur Chung¹; ¹*School of electrical engineering, KAIST, Korea*. We propose and demonstrate the compensation of mode coupling in MDM systems by using digital optical phase conjugation. We achieve BERs better than 0.0001 without electrical MIMO processing in FMF link having large mode coupling.

Room 7AB

Th3F • Data Center Interconnect Deployments—Continued

Room 8

Th3G • Hybrid Access Networks for Wireless Delivery—Continued

Th3G.4 • 15:00

First Demonstration of Doppler Compensation Technique using Period-one Nonlinear Semiconductor Laser Dynamics for OFDM-RoF Coherent Detection, Yu-Han Hung¹, Jih-Heng Yan², Hsu-Hung Huang³, Chin-Hao Tseng¹, Kai Ming Feng^{2,3}, Sheng-Kwang Hwang^{1,4}; ¹*Department of Photonics, National Cheng Kung Univ., Taiwan*; ²*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan*; ³*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan*; ⁴*National Cheng Kung Univ., Advanced Optoelectronic Technology Center, Taiwan*. A Doppler compensation technique is proposed and demonstrated for OFDM-RoF coherent detection through frequency synchronization based on period-one nonlinear dynamics of semiconductor lasers. A 28-GHz chirped microwave with +/-100 kHz variation is frequency-synchronized in Real-time.

Th3G.5 • 15:15

Demonstration of Ultra-high-resolution Photonics-based Ka-band Inverse Synthetic Aperture Radar Imaging, Yao Yao¹, Fangzheng Zhang¹, Ying Zhang¹, Xingwei Ye¹, Daiyin Zhu¹, Shilong Pan¹; ¹*NUAA, China*. We demonstrate a photonics-based Ka-band radar system with 12 GHz bandwidth by optical signal generation and de-chirp processing. Inverse synthetic aperture radar imaging with a range resolution as high as ~1.3 cm high-resolution is achieved.

Th3G.6 • 15:30

Extremely Wide Bandwidth Microwave Photonic Phase Shifter for W-band Chirped Monopulse Radar, Bohao Liu¹, Jih-Min Wun², Nathan O'Malley¹, Daniel Leaird¹, Nan-Wei Chen³, Jin-Wei Shi², Andrew Weiner¹; ¹*Purdue Univ., USA*; ²*National Central Univ., Taiwan*; ³*Yuan Ze Univ., Taiwan*. Phase-shifting of extremely wide-band chirped pulses (80-95 GHz) is realized using optically shaped pulses and dual photonic transmitters. Sum/difference radiation patterns with ~15 dB extinction ratio are demonstrated, offering prospects for W-band monopulse radar.

Room 9

Th3H • Optical Switching Sub-systems—Continued

Th3H.4 • 15:00

T/O-band Wavelength Routing System using Quantum Dot Semiconductor Devices and 1081-channel AWG Router, Ryogo Kubo¹, Takuto Fujimoto¹, Takahiro Shobudani¹, Yudai Okuno¹, Masaki Suzuki¹, Hiroyuki Tsuda¹, Makoto Sudo², Tadashi Hajikano², Yasunori Tomomatsu³, Katsumi Yoshizawa⁴; ¹*Keio Univ., Japan*; ²*Optoquest Co., Ltd., Japan*; ³*Koshin Kogaku Co., Ltd., Japan*; ⁴*Pioneer Micro Technology Corporation, Japan*. We demonstrate a wavelength routing system that covers a broad wavelength range of 1000-1360 nm, i.e., T/O-band. The system includes our developed T/O-band-specific quantum dot semiconductor devices and 1081-channel arrayed waveguide grating (AWG) router.

Th3H.5 • 15:15

Next-generation ROADMs Employing Bandwidth-adaptive Silicon-photonics Filters for Flexible Drop Operation, Yojiro Mori¹, Koh Ueda¹, Keijiro Suzuki², Hiroyuki Matsuura², Ken Tanizawa², Kazuhiro Ikeda², Shu Namiki², Hitoshi Kawashima², Ken-Ichi Sato^{1,2}; ¹*Nagoya Univ., Japan*; ²*National Inst. of Advanced Industrial Science and Technology (AIST), Japan*. As one step in realizing next-generation flexible ROADMs, we demonstrate the effectiveness of a bandwidth-adaptable silicon-photonics filter, through transmission experiments on 10-gbps OOK, 40-gbps DQPSK, 100-gbps DP-QPSK, 400-gbps 2-subchannel DP-16QAM, and 1-tbps 5-subchannel DP-16QAM signals.

Th3H.6 • 15:30

Experimental Utilization of Repeated Spatial-mode Shifting for Achieving Discrete Delays in a Free-space Recirculating Loop, Ahmed Almainan¹, Amirhossein Mohajerin-Ariae¹, Guodong Xie¹, Zhe Zhao¹, Fatemeh Alishahi¹, Yinwen Cao¹, Peicheng Liao¹, Changjing Bao¹, Ahmad Fallahpour¹, Bishara Shamee¹, Youichi Akasaka², Shlomo Zach³, Nadav Cohen³, Moshe Tur³, Alan E. Willner¹; ¹*Univ. of Southern California, USA*; ²*Fujitsu Laboratories of America, USA*; ³*School of Electrical Engineering, Tel Aviv Univ., Israel*. We demonstrate an all-optical free-space recirculating delay loop by shifting the spatial mode order using the orbital-angular momentum (OAM) basis. The orthogonality of the OAM modes is used to easily select the desirable delay at the loop output.





Room 1A

Th3A • Current Topics in Long Haul/Metro Transmission—Continued

Room 6C

Th3B • Directly Modulated Lasers—Continued

Th3B.5 • 15:45 ▶ A Fully-integrated Multi-λ Hybrid DML Transmitter, Di Liang¹, Chong Zhang¹, Ashkan Roshan-Zamir², Kunzhi Yu², Cheng Li¹, Geza Kurczveil¹, Yingtao Hu¹, Wenqing Shen³, Marco Fiorentino¹, Satish Kumar³, Samuel Palermo², Raymond Beausoleil¹; ¹Hewlett Packard Labs, USA; ²Department of Electrical and Computer Engineering, Texas A&M Univ., USA; ³School of Mechanical Engineering, Georgia Inst. of Technology, USA. A multi-wavelength, hybrid directly-modulated laser (DML) transmitter with integrated thermal shunt, MOS capacitor and CMOS driver circuit is fabricated. 14 Gb/s operation from conventional direct current modulation and a novel MOS-type laser modulation are demonstrated.

Room 6D

Th3C • Optical Switching II—Continued

Th3C.5 • 15:45 ▶ Low-crosstalk, Low-power Mach-Zehnder Interferometer Optical Switch based on III-V/Si Hybrid MOS Phase Shifter, Qiang Li¹, Jae-Hoon Han^{1,2}, Chong Pei Ho^{1,3}, Shinichi Takagi¹, Mitsuru Takenaka¹; ¹The Univ. of Tokyo, Japan; ²Korea Inst. of Science and Technology, Korea; ³Japan Society for Promotion of Sciences Fellowship, Japan. An optical switch with InGaAsP/Si hybrid metal-oxide-semiconductor phase shifter is demonstrated with low crosstalk (-28.6 dB) and low power consumption (1.3 nW) due to the large electron-induced refractive index change and small absorption in InGaAsP.

Room 6E

Th3D • Nonlinear Fiber Effects—Continued

Th3D.5 • 15:45 ▶ Non-invasive Distributed Characterization in Phase and Intensity of the Nonlinear Stage of Modulation Instability, Corentin Naveau¹, Pascal Szriftgiser¹, François Copie¹, Alexandre Kudlinski¹, Matteo Conforti¹, Stefano Trillo², Arnaud Mussot¹; ¹Univ. Lille, CNRS, UMR 8523-phLAM – Physique des Lasers Atomes et Molécules, France; ²Department of Engineering, Univ. of Ferrara, Italy. We report a novel experimental setup to perform distributed characterization in intensity and phase of the nonlinear stage of modulation instability by means of a non-invasive experimental setup: a heterodyne time domain reflectometer.

16:00–16:30 Beverage and Coffee Break, Upper Level Corridors

16:30–18:30 Postdeadline Sessions, Rooms 6C, 6D, 6E, 6F

NOTES

Large rectangular area with horizontal lines for taking notes.

Thursday, 15 March





Room 6F

Th3E • Advanced Transmission Technology—Continued

Room 7AB

Th3F • Data Center Interconnect Deployments—Continued

Room 8

Th3G • Hybrid Access Networks for Wireless Delivery—Continued

Th3G.7 • 15:45
Efficient Mobile Fronthaul using Windowed OFDM Exhibiting High CFO Tolerance and Strong OOB-leakage Suppression with Low DSP Complexity, Shuyi Shen¹, Thavamaran Kanesan², Feng Lu¹, Mu Xu¹, Lin Cheng¹, Jing Wang¹, Yahya M. Alfadhli¹, Hyung Joon Cho¹, Sufian M. Mitani², Gee-Kung Chang¹; ¹*ECE, Georgia Inst. of Technology, USA*; ²*TM Research & Development, Malaysia*. A novel windowed-OFDM transmission scheme is demonstrated to achieve 2.2-dB improvement of carrier-frequency-offset tolerance and 20-dB out-of-band-leakage suppression for MMW-RoF mobile fronthaul, with low computational complexity and no additional overhead owing to effective time-domain windowing.

Room 9

Th3H • Optical Switching Subsystems—Continued

16:00–16:30 Beverage and Coffee Break, Upper Level Corridors

16:30–18:30 Postdeadline Sessions, Rooms 6C, 6D, 6E, 6F

NOTES

Thursday, 15 March





Key to Authors and Presiders

A

Abe, Yoshiteru - W1A.1, W1A.7
 Abel, Stefan - M2I.6
 Abraha, Solomon T. - W4B.2
 Abrams, Nathan - Th2A.16
 Absil, Philippe - Tu2A.3, W1I.1, W4D.4
 Achouche, Mohand - Th1E.1
 Afraz, Nima - Th1B.3
 Agrawal, Govind P. - Th3D.1, Th3D.3
 Agrell, Erik - M4E.2, M4E.5, Th2A.47, W2A.20
 Aguado, Alejandro - Th2A.32
 Aguiar, Douglas O. - W2A.41
 Agustin, Mikel - W1I.5
 Ahmed, Mostafa G. - M2D.1
 Ahn, Jin Hyung - Th2A.53
 Ahuja, Satyajeet - Tu3D.2
 Ai, Fan - W2A.12
 Aihara, Takuma - W3F.4
 Aikawa, Kazuhiko - Th2A.22, W4C.3
 Aimin, Chen - Tu3D.1
 Ainspan, Herschel - M2D.4
 Ait Sab, Omar - M2C.2
 Akahane, Kouichi - M3K.7
 Akasaka, Youichi - M3E, Th3H.6, Tu2J.1
 Akiyama, Suguru - Tu2A.4
 Akiyama, Tomoyuki - W1I.2
 Akiyama, Yuichi - M2F.6, W2A.47
 Aktas, Ozan - W4K.6
 Aladin, Sandra - M3A.3
 Alain, Christine - W1A.4
 Alam, S.U. - M2J.4, M2J.6, M4D.3
 Alameh, Kamal - M1F.2, M2K.6, M2K.8
 Alexoudi, Theoni - Th1G.5, Th2A.1
 Alfadhli, Yahya M. - M2B.5, M3K.4, Th2A.48, Th3G.7, W4B.3
 Ali, Wajahat - M1F.5
 Alishahi, Fatemeh - Th3H.6, Tu2J.1, W2A.22, W2A.34, W3E.1
 Alloatti, Luca - W1I.4
 Almainan, Ahmed - Th3H.6, Tu2J.1, W2A.22, W2A.34, W3E.1
 Alqubaisi, Kenaish - W1I.4
 Al-Rawachy, Ehab - W2A.33

Al-Rawi, Ali N.H. - M4J.2
 Altabas, Jose A. - Th1A.3
 Altenhain, Lars - W4E.3
 Alvarado Zacarias, Juan Carlos - M4D.5, W1G.2, W4C.2, W4J.2
 Alvarado, Alex - M3C.4, Tu3C
 Alvarado, Juan Carlos - M4G.5
 Alvarez, Pedro - Th2A.49
 Alvarez-Aguirre, Roberto A. - W1G.2, W4C.2
 Alves, Antonio R. - Th2A.4
 Alves, Tiago F. - Tu3B.4
 Alvizu, Rodolfo - Tu3D.15
 Amann, Markus C. - M1I.2, M1I.4, W1F.1
 Amezcua-Correa, Adrian - M4D.5, W3C.1
 Amezcua-Correa, Rodrigo - M4D.5, M4G.5, Th3D.2, W1G.2, W4C.2, W4J.2
 An, Shinmo - Th2A.3
 Anastasopoulos, Markos - M2A.3
 Anderson, Erik F. - Tu3F.3
 Anderson, Sean - Tu2C.6
 Andrekson, Peter A. - M1G.2, M3E.1, M4G.2
 Andresen, Esben Ravn - Tu3B.2
 Andriolli, Nicola - Th1I.6, Th2A.44
 Anet Neto, Luiz - M1B.1, Th2A.53
 Ang, Thomas Y. - M3I.2, Th2A.11, Tu3A.2
 Aniruddha, Kushwaha - Th2A.33
 Antonelli, Cristian - Th1B.2, Tu2D, Tu2D.1, Tu2D.3, Tu2D.7
 Antonio-Lopez, Jose Enrique - M4D.5, Th3D.2, W4J.2
 Antoniou, Konstantinos - Tu2G.2
 Anzalchi, Javad - M2G.5
 Aoki, Tsuyoshi - W1I.2
 Aono, Yoshiaki - W4F.3
 Apostolopoulos, Dimitrios - M4H.6
 Arai, Kenichi - Tu3G.3
 Arai, Shigehisa - Th3C.2
 Arai, Shinichi - Tu3B.1
 Arao, Hajime - W1A.3, W1A.5
 Aratake, Atsushi - M2D.2, W1A.7
 Archambault, Émile - M1A.5

Argyris, Nikos - M3A.7, M4A.3, W2A.49
 Arnould, Aymeric - M2C.2
 Aroca, Ricardo - Th1A.6
 Asaka, Kota - Tu3L.7
 Asakawa, Shuichiro - W1A.1
 Astapovich, Maxim S. - M2J.7
 Atabaki, Amir H. - W1I.4
 Atsumi, Yuki - M4F.3, Tu2A.2
 Auge, Jean-Luc - M1D.2, M1D.3, W4A
 Autenrieth, Achim - M4A, W4F.6
 Avramopoulos, Hercules - M3A.7, M4A.3, M4H.6, W2A.49
 Avramovic, Vanessa - M2I.4
 Awaji, Yoshinari - M4A.2, Th2A.29, Tu3B.3, W4C.3
 Ayala, Javier - M2D.4
 Ayata, Masafumi - M3G.2, Th3G.1
 Ayucar, Jose - Th1G.6
 Azana, Jose - M2G, M2J.2, M4G.4

B

Bae, Sung Hyun - Th3E.5, Tu3J.6
 Baek, Yongsoon - Th1J.5, Tu2B.3
 Baeuerle, Benedikt - M2I.1, M2I.6, M3G.2, Th3G.1
 Bai, Lin - M2A.1, M2E.3, Tu3D.1
 Bai, Rui - Tu2C.4
 Bai, Wei - W4I.2
 Bai, Yusheng - Tu2C.5, W1J.1, W2A.42
 Baiocco, Christopher - W1I.4
 Baks, Christian - M2D.4, Th1G.4
 Balakier, Katarzyna - W1B.4
 Balakrishnan, Sadhishkumar - Tu2A.3, W1I.1
 Balasubramanian, Srivatsan - Tu3D.2
 Baldonado, Omar - W1C.5
 Ballani, Hitesh - W1C.3
 Ballato, John - W4K.6
 Ban, Yoojin - W1I.1
 Bandyopadhyay, Saamil - Tu3E.4
 Banyoudeh, Saddam - W3F.3
 Bao, Changjing - Th3H.6, Tu2J.1, W2A.22, W2A.34, W3E.1
 Bao, Xiaoyi - Tu2J.2

Barletta, Luca - M3J.2
 Barratt, Adam - Th2A.56
 Barrera, David - Th1K.4
 Barrios, Pedro - Th1I.4
 Barry, Liam - Th2A.14, W2A.35
 Bartelt, Hartmut - Tu2J.4
 Barthomeuf, Sylvain - M1B.1, Th2A.53
 Bartolo-Perez, Cesar - W1I.7
 Basavanahally, Nagesh - M1B.3, Th1E.3
 Batshon, Hussam - Th1C.1, W1B.6
 Baudot, Charles - Th1G.5
 Baumann, Jan M. - W1E.4
 Bauwelinck, Johan - M1I.2, M1I.4, W1F.1, W2A.19, W4D.4
 Baveja, Prashant P. - M1E.3
 Bayvel, Polina - M3B.1, M3C.4, Th1C.3, Tu2D.4, W1B.4, W1J.6, W2A.53, W2A.58, W3E.2
 Beausoleil, Raymond - M1I.7, Th3B.5
 Becker, Martin - Tu2J.4
 Behunin, Ryan - M1H.3
 Bekkali, Abdelmoula - Tu3J.5
 Belanger, Michel - M1A.5, M1E.2
 Bendimerad, Djalal Falih - M1G.5
 Ben-Hamida, Naim - M3I.7
 Benson, Theophilus - W4I.1
 Beppu, Shohei - M2A.5, W4C.1
 Bergman, Keren - M3F.2, Th1G.2, Th2A.16, Tu3F.1, Tu3F.2, Tu3F.3, W2A.32
 Berian, Alex - W1A.2
 Bernier, Eric - Th1J.1
 Bernini, Giacomo - M3A.7, M4A.3
 Berry, Chris - W1B.3
 Bertignono, Luca - M3C.3, Tu2C.6, W3A.5
 Bertolini, Marco - W4A.6
 Bertran Pardo, Oriol - W1B.5
 Bhopalwala, Mariya - Th1B.5
 Bi, Meihua - Tu2I.6
 Bi, Yu - M3A.2, W4F.5
 Bianchi, Alberto - Th1G.6
 Bianchi, Marcello - M1A.3
 Bidkar, Sarvesh S. - Tu2K.3
 Bielski, Maciej - Tu3D.14, W1C.1
 Bienstman, Peter - M4F.4
 Bigo, Sébastien - Th2A.46

Bigot, Laurent - Tu3B.2
 Bigot, Marianne - W3C.1
 Bilondeau, Patricia - Tu3K.4
 Bjornstad, Steinar - M4I.2
 Blech, Lior - Tu2D.7
 Bluemm, Christian - Tu3D.4
 Blumenthal, Daniel J. - M1H, W2A.30
 Blumm, Christian - Th2A.49
 Bo, Tianwai - W4E.2
 Böcherer, Georg - M4E.1, M4E.3
 Bock, Robert - Tu2I.4, Tu2I.5
 Boeuf, Frederic - Tu3K.3
 Boffi, Pierpaolo - M1A.7, M3J.2, Th1E.2
 Bogaerts, Lieve - Tu2A.3
 Bogaerts, Wim - Th2A.4
 Bogoni, Antonella - M2G.1, M2G.2, M2G.4, Th2A.44, Th3H.1
 Bogris, Adonis - Tu2I.7
 Bolle, Cris - M1B.3, Th1E.3
 Boller, Klaus J. - Th2A.14
 Bolshtyansky, Maxim A. - M4B.3, Th1C.1, W1B.6, W4J
 Bonjour, Romain - M3G.2, Th3G.1
 Bonk, Rene - M1B.2, Th1E.1, Tu2B.4
 Boom, H.P.A. V. - Th2A.57
 Borkowski, Robert - M1B.2, Th1E.1
 Bosco, Gabriella - M1G.1, M3C.6, W1G.3
 Bose, Sanjay K. - M3J.3, Th1B.6, W2A.28
 Bottrill, Kyle - W3E.2
 Bouda, Martin - W1D.3
 Boutami, Salim - M2J.3
 Bouwmans, Géraud - Tu3B.2
 Bower, Jeffrey D. - Tu2G.1
 Bowers, John - Th1I.2, Th1I.3, W3F.2, W4D.3
 Bramerie, Laurent - Tu2C.3
 Brandt-Pearce, Maite - Th2A.47
 Braute, Jan P. - M4I.2
 Brehler, Marius - W2A.57
 Bremer, Kort - Th1K.6
 Brindel, Patrick - M2C.2
 Brodnick, Grant M. - W2A.30
 Broeke, Ronald - Th2A.1
 Brown, Dean - M2I.5





Browning, Colm - Th2A.14
 Buch, Shaival - Th3D.3
 Buchali, Fred - M2C.6, Tu2D.5, W1B,
 W1G.6, W2A.54
 Bufetov, Igor A. - M2J.7
 Bülow, Henning - M2C.6, Tu2D.5,
 W1G.6
 Burla, Maurizio - M3G.2, Th3G.1
 Byrd, Matt J. - M3F.1

C

Cai, Chengkun - W3D.2, W4C.4
 Cai, Jin-Xing - M4B.3, Th1C.1
 Cai, Pengfei - W4D.6
 Cai, Xinlun - Th2A.9
 Cai, Yi - M2C.3, M4E, W2A.44
 Caimi, Daniele - M2I.6
 Caiti, Andrea - Tu2I.2
 Calabretta, Nicola - W2A.23
 Calliari, Felipe - W1F.4
 Campos, Luis Alberto - M4C.2,
 Tu2K.2
 Cankaya, Hakki C. - W1D.1
 Cano, Carlos J. - M2A.2
 Cantono, Mattia - M1A.3, M1D.2,
 Tu3E.1, W1G.4
 Cao, Congzhe - Tu3C.5
 Cao, Hong - W1C.4
 Cao, Hui - W4J.4
 Cao, Ruiyuan - Th3C.1
 Cao, Xiaoping - Th2A.9
 Cao, Yinwen - Th3H.6, Tu2J.1,
 W2A.22, W2A.34, W3E.1
 Cao, Zizheng - M1F.6, M4J.2
 Capitani, Marco - Th2A.34
 Caplan, David O. - M3K.1
 Cardoso, Diego G. - Tu3D.13
 Carena, Andrea - M3C.3, Tu3E.1,
 W1G.3, W1G.4, W3A, W3A.5
 Carpenter, Joel - W1E
 Carpintero, Guillermo - Th1I.1
 Cartaxo, Adolfo - Tu3B.4
 Cartledge, John C. - Th2A.17
 Casellas, Ramon - M1A.7, M2A.4,
 M2A.5, M3A, M3A.6, Th1D,
 Tu3D.11, Tu3D.8
 Caspani, Lucia - M4G.4
 Cassese, Tommaso - Th1I.6
 Cassioli, Dajana - Th1B.2
 Castellana, Dave - W4B.2

Castoldi, Piero - M4A.3, M4A.5,
 Th2A.30, Tu3D.12
 Castro, Alberto - M4J.3, W4F.2,
 W4F.7
 Castro, Jose - W1A.2, W3C.3, W3C.4
 Cavaliere, Fabio - W2A.31
 Celso, Dritan - Th1J.1
 Cen, Mingyu - M2A.1, Tu3D.1
 Ceravolo, Isabella D. - Tu3D.13
 Cevrero, Alessandro - M2D.3
 Chagnon, Mathieu - M2C.6, Tu2D.5,
 W2A.54
 Chaibi, Mohamed Essghair - Tu2C.3
 Chalyan, Astghik - Th1G.6
 Chamania, Mohit - Th1D.4, Th2A.35
 Chan, Calvin - M2F.5
 Chanclou, Philippe - M1B.1, M3D,
 M4C, Th2A.53
 Chandrasekhar, Sethumadhavan -
 Tu2D.1, W1G, W4E.6
 Chang, Frank - W2A.30
 Chang, Gee-Kung - M2B.5, M2F.1,
 M2K.2, M3D, M3K.4, M4C, M4J.4,
 Th2A.48, Th3G.7, Tu2K.2, Tu3J.2,
 Tu3J.7, W1J.5, W1J.7, W4B,
 W4B.3, W4G.7
 Chang, Jen-Chieh - Tu2I.3
 Chang, Jun Ho - Th3E.5
 Chang, Lin - W4D.3
 Chang, Liu - Tu2C.4
 Chang, Shoude - Th1I.4, Th1I.5
 Chang, Wei-Fan - M2D.7
 Chang, Weijie - Tu3A.1
 Chang, Youhui - M1E.4
 Chang-Hasnain, Connie J. - Th1I.7
 Charbonnier, Benoit - Tu3K.4
 Charlet, Gabriel - M2C.2
 Che, Di - Th1F.1, Tu2C.7, W4E.4
 Chen, Biduo - Tu2G.3
 Chen, Bo W. - M1G.4
 Chen, Bor-Tauo - W4I.3
 Chen, Charles - W1B.3
 Chen, Chien Ju - Th2A.18, Th2A.63
 Chen, Daigao - M3I.6
 Chen, De-Hua - Th2A.18, Th2A.63
 Chen, De-Yu - Tu2I.3
 Chen, George - M3I.2
 Chen, Hao - M1I.3, M2F.6, M2F.7,
 Th2A.12
 Chen, Haoshuo - M4D.5, M4G.5,
 Th1K.1, Tu3A, W1G.2, W4C.2

Chen, Jiajia - M1I.2, M1I.4, Th1B,
 Th2A.51, W2A.19
 Chen, Jian - M1B.8, Th1K.1
 Chen, Jingxin - M1E.4
 Chen, Junyang - M3G.3
 Chen, Jyehong - M2D.7, W2A.43
 Chen, Kaixin - W1E.5
 Chen, Ke - M2I.2, W2A.28
 Chen, Lei - Tu3L.3
 Chen, Liang - Tu2J.2
 Chen, Lian-Kuan - M2K.3, M2K.4,
 M3K.5, W4D.3
 Chen, Nan-Wei - Th3G.6
 Chen, Ray - M2I.2
 Chen, Shaoxiang - M2J.4
 Chen, Shi - W4K.4
 Chen, Su - Th2A.24
 Chen, Xi - Tu2C, Tu2D.1, W4E.6
 Chen, Xiangfei - M4H.4
 Chen, Xiaoliang - W4F.2, W4F.7
 Chen, Xin - W2A.3, W3C.2
 Chen, Xue - Th2A.38
 Chen, Xuefeng - Tu2C.4
 Chen, Yi-Ching - M2D.7
 Chen, Young-Kai - W2A.43
 Chen, Yufei - M2C.3
 Chen, Yujing - M1E.3
 Chen, Zhangyuan - M2J.5, M4D.1,
 Th1K.5, W4J.3, W4K.3
 Cheng, Chih-Hsien - Tu2I.1
 Cheng, Lin - M4C.2, Th3G.7
 Cheng, Qixiang - M3F.2, Th1G.2
 Cheng, Weiqiang - Tu2D.6, W2A.63
 Cheng, Xiulan - Th2A.10
 Cheng, Ya-Jou - Th2A.63
 Cheng, Yuh-Jiuh - W4I.3
 Cherchi, Matteo - Tu3A.5
 Cheunhom, Rattana - Th3G.2
 Chevalier, Vincent - M1D.4
 Chew, Pei-Hsien - M1F.1
 Chi, Kai-Lun - M2D.7, W1I.5
 Chi, Nan - M2K.1, M3K.3, Th2A.64,
 Th2A.65, Tu2C.4, W1J.5, W2A.44,
 W4G.6
 Chi, Yu-Chieh - Tu2I.1
 Chiado Piat, Anna - Tu3D.12
 Chiang, Kin S. - W1E.5
 Chiang, Patrick Y. - Tu2C.4
 Chiaretti, Guido - Th1G.6
 Chien, Hungchang - M2C.3
 Chiesa, Marco - Th1I.6

Cho, Hyung Joon - M2B.5, M3K.4,
 Th3G.7, Tu3J.2
 Cho, Hyunwoo - Tu3J.2
 Cho, Junho - M3C.2
 Cho, Seung-Hyun - Tu3J.3, W4B.4
 Choe, Joong-Seon - Th2A.5, Tu2B.3
 Choi, Byeongkwon - Th1J.5
 Choi, Byung-Seok - Th2A.5
 Choi, Nakjung - Th2A.31
 Choi, Woo-Young - Th2A.13
 Chou, Elaine S. - Th3D.4
 Chou, Hsi-Hsir - M1F.7
 Choudhury, Gagan - Tu3H.2
 Chow, Bruce - W3C.2
 Chow, Chi-Wai - M2K.2, M3K.2
 Chow, Desmond - W1K.4
 Chowdhury, Samina - W1J.1
 Christodoulides, Demetrios - Th3D.2
 Christodouloupoulos, Konstantinos -
 M3A.7, M4A.3, Th2A.34
 Chrostowski, Lukas - Tu2E.1
 Chu, Daping - Th1J.2, Th2A.43
 Chu, Sai - M4G.4
 Chu, Tao - Th1J.4
 Chuang, C. Y. - W2A.43
 Chung, Chi-Jui - M2I.2
 Chung, Hwan Seok - Th2A.52, Th3G,
 Tu3J.3
 Chung, Sungwon - Th2A.2
 Chung, Yun Chur - Th3E.5, Tu3J.6
 Ciaramella, Ernesto - M1B.6, M1F.5,
 Tu2D.3, Tu2I.2
 Cino, Alfonso - M4G.4
 Civelli, Stella - W1G.5
 Clark, David - M4B.5
 Clelland, William - M1A.5
 Clements, Stephen - M2G.5
 Cohen, Nadav - Th3H.6, W2A.34
 Coldren, Larry A. - Th1I.7
 Coleman, Doug - W3C.2
 Comellas, Jaume - W1G.1
 Conforti, Matteo - Th3D.5
 Connelly, John - W4A.2
 Consizoglu, Hilal - W1I.7
 Contestabile, Giampiero - Th1I.6,
 Tu2D.3
 Cook, Kevin T. - Th1I.7
 Copie, François - Th3D.5
 Corcoran, Bill P. - M2C.6, W1J.4,
 W2A.50
 Correia, Luis M. - Th1B.2

Cortez, Bruce - Th3F
 Cossu, Giulio - M1F.5, Tu2D.3, Tu2I.2
 Costa, Paolo - W1C.3
 Courtois, Olivier - M1D.4
 Crabb, Jonathan - M2G.5
 Criado Serrano, Ángel Rubén - Th1I.6
 Croes, Kristof - W1I.1
 Cugini, Filippo - M3A.5, M3A.7,
 M4A.5, Tu3D.12, W1D.4
 Cui, Yan - Tu2C.5, W1J.1, W2A.42
 Curri, Vittorio - M1A.3, M1D.2,
 M1D.3, Tu3E.1, Tu3E.4, W1G.4
 Cynamon, Charles - W4A.2
 Czeglédi, Cristian B. - W2A.53

D

Da Fonseca, Jérémy - Tu3K.4
 Da Ros, Francesco - M4E.3, Th2A.54,
 W3E.3, W3E.4
 Da Silva, Edson P. - W3E.3, W3E.4
 Da Silva, Ricardo E. - Tu2J.4
 Dabos, George - Th2A.1
 Dai, Liang Y. - M3F.2, Th2A.16
 Dai, Tingge - M4H.5
 Dalgaard, Kjeld - Th2A.54, W1E.4
 Dalir, Hamed - M2I.2
 Dalton, Larry R. - M2I.1, M3G.2
 Dangui, Vinayak - Th3F.1, Tu3H.3
 Dardis, Lee - W1B.3
 Darwazeh, Izzat - M2K.5
 Das, Bijoy K. - M4H.7
 Das, Sandip - Th1B.5
 Dasgupta, Nandita - M4H.7
 Dasilva, Luiz - Th2A.49
 Davanco, Marcelo I. - W3F.1
 David, Julien - W1B.5
 Davidson, Carl - M4B.3, Th1C.1
 Davies, John - M2G.3
 Davis, Ian - M1E.4
 Davis, Kyle S. - Th2A.68
 Davis, Peter - Tu3G.3
 De Angelis, Gabriele - W2A.31
 De Coster, Jeroen - W1I.1
 De Gabory, Emmanuel L. - M3J.5
 De Heyn, Peter - Th1G.5, Th2A.1,
 Tu2A.3, W1I.1, W2A.16, W4D.4
 De Keulenaer, Timothy - W4D.4
 De Leenheer, Marc - M4A.4
 Debregeas, Helene - Th1E.1
 Delezoide, Camille - M3A.7, M4A.3,
 W2A.56





Delgado Mendinueta, Jose Manuel - M3J.1, Th3H.2
 Demars, Scott - W1B.3
 Demeester, Piet - W1F.1
 Demirtzioglou, Iosif - Tu2J.3
 Deng, Hong - W2A.37
 Deng, Lei - M2F.5
 Deng, Pengyue - W4B.5
 Derose, Christopher - Th2A.68
 D'Errico, Antonio - M2G.4, Tu3D.12
 Desalvo, Richard - Tu2I
 Desroches, Yan - W1A.4
 Dharmaweera, Nishan - Th2A.47
 Di Giglio, Andrea - M4I.4
 Di Pasquale, Fabrizio - M4H.3, Th1G.6
 Diamantopoulos, Nikolaos
 Panteleimon - M2D.5, Th3B.2
 Diao, Yuanjiong - Tu3D.1
 Dicaire, Isabelle - W1K.4
 Didriksen, Morten - Th1A.3
 Dijk, Paul V. - Tu2I.7
 Ding, Heping - Th1I.4
 Ding, Yunhong - W1E.4
 Ding, Zhi - M4J.3, W2A.45
 Djordjevic, Ivan - M1G.3, M4E.4,
 Th1D.2, W2A.21
 Do Amaral, Gustavo C. - W1F.4
 Doerr, Christopher R. - Tu2E.5, Th1A.6
 Dolan, Philip - Th1J.2, Th2A.43
 Domingo, Marc - M3B.4
 Dominguez-Lopez, Alejandro - W1K.3
 Dominicini, Cristina K. - Tu3D.13
 Doo, Kyeong-Hwan - Th2A.52
 Doran, Nick - W3D.4
 Downie, John D. - W4C.5
 Drenski, Tomislav - M2C.1
 Dris, Stefanos - M4B.6, W2A.49
 Drummond, Miguel V. - M2G.5
 Du, Cheng - W4C.4
 Du, Chuanyan - Th1K.5
 Du, Jiangbing - Tu2C.4, W3D.2,
 W4C.4
 Du, Liang B. - Th2A.56
 Du, Mei - M1D
 Duarte, Vanessa C. - M2G.5
 Dubé-Demers, Raphaël - Th3G.3,
 W1I.3
 Dubok, Aleksei - M4J.2
 Ducournau, Guillaume - M2I.4
 Dugeon, Olivier - M2A.2
 Dumais, Patrick - Th1J.1

Dupas, Arnaud - Th2A.46
 Dupuis, Nicolas - M2D.4, Th1G.4,
 Th1J
 Dzioba, Steve - M2C.3

E

Earnshaw, Mark - Th1E.3
 Eddie, Ian - M2D.3
 Edirisinghe, Sampath S. - M2K.8
 Edwards, Tim - W2A.29
 Effenberger, Frank - M3B.6
 Eftekhari, Mohammad Amin - Th3D.2
 Eira, António - Tu2F.1, Tu3E
 Eiselt, Michael - Th2A.19, W2A.29
 Eisenstein, Gad - W3F.3
 El Zammam, Georgio - Tu3K.4
 Elbers, Joerg-Peter - M1C.2, M3D.1,
 Th2A.19, W4F.6
 Eldar, Yonina - Tu2D.7
 Elder, Delwin L. - M2I.1, M3G.2
 Elfiky, Eslam - W2A.16
 El-Fiky, Eslam - M2C.7, W4D.1
 Ellinger, Frank - M2D.3
 Elrasad, Amr - Th1B.3, Tu3D.4
 Elrefaie, Aly F. - W1I.7
 Elschner, Robert - M1C.2, M3E.3,
 W3E
 Elson, Daniel - Th1C.3, W1B.4
 Eltes, Felix - M2I.6
 Emmerich, Robert - M1C.2
 Enbutsu, Koji - M3E.2, M3E.4
 Enrico, Michael P. - Tu3D.14, W1C.1
 Erasme, Didier - M1B.1, Tu2C.3
 Erickson, David - Tu3H.5
 Erik, Norberg - Th1I.2
 Eriksson, Tobias - M2C.6
 Erkilinc, M.Sezer - M3B.1, Tu2D.4
 Ertman, Slawomir - W2A.13
 Erven, Chris - M2A.6
 Essiambre, René-Jean - W1G.2,
 W4C.2, Th3D.3
 Evans, Alan - W1A
 Eyal, Ori - W3F.3

F

Fabrega, Josep M. - M1A.7, M2A.5,
 M3A.6
 Faizan, Muhammad - W2A.26
 Falconi, Fabio - M2G.4
 Fallahpour, Ahmad - Th3H.6, Tu2J.1,
 W2A.22, W2A.34, W3E.1

Fan, Gao - M2F.2
 Fan, Gaofeng - M1I.7
 Fan, Sujie - M1B.5, Tu2C.2, W4E.5
 Fan, Xinyu - M4G.3, Th2A.26
 Fan, Yangyang - M2F.7
 Fan, Youwen - Th2A.14
 Fang, Liming - W4G.5
 Farrow, Kristan - Tu2G.2
 Fatadin, Irshaad - Th2A.61
 Faure, Jean Paul - W1B.5
 Fedeli, Jean-Marc - M2J.3
 Feder, Kenneth - W1K.1
 Fedoryshyn, Yuriy - M2I.1, M3G.2,
 Th3G.1
 Fehenberger, Tobias - Tu3C.3
 Fei, Li - Tu3D.11
 Feig, Hananel - Th3E.1
 Fejer, Martin - W2A.22, W3E.1
 Feng, Da - Th2A.36
 Feng, Kai Ming - Th2A.18, Th2A.63,
 Th3G.4, Tu3J.7
 Feng, Milton - W1I.6
 Fernandez De Jauregui Ruiz, Ivan -
 M2C.2
 Fernández-Ruiz, María R. - W1K.2
 Ferrari, Alessio - W1G.4
 Feuer, Mark - M4H
 Fice, Martyn - Th2A.61, Th2A.69
 Filer, Mark M. - W4I.6
 Filipowicz, Marta - M2G.5
 Finkelstein, Jeff - M2B.5
 Fiorentino, Marco - M1I.7, Th3B.5
 Fischer, Johannes K. - M1C.2
 Fish, Gregory - Th1I.2, Tu3K.1
 Fok, Mable P. - W1K.5
 Fompeyrine, Jean - M2I.6
 Fontaine, Nicolas K. - M4D.5, M4G.5,
 Tu2J, Th1K.1, W1G.2, W4C.2
 Fontana, Giorgio - Th1G.6
 Foo, Benjamin - W1J.4
 Forchhammer, Søren - M4E.3, W3E.3
 Forencich, Alex - Th1G.4
 Forestieri, Enrico - W1G.5
 Forghieri, Fabrizio - M3C.3, M3C.6,
 Tu2C.6, W1G.3
 Forni, Federico - Th2A.57
 Forsyia, Wlodek - Th3D, W3D.3
 Fougstedt, Christoffer - Tu3C.6
 Foursa, Dmitri - M2C, M4B.3, Th1C.1,
 W1B.6
 Frandsen, Lars - W1E.4

Freeman, Paul - W1B.3
 Freiberger, Michael - Tu2K.4
 Fresi, Francesco - M3A.7, M4A.3,
 Th3H.1, Tu3D.12, W2A.31
 Freude, Wolfgang - W4E.3
 Freund, Ronald - M1F.3, W4G.2,
 W4G.3
 Frey, Felix - M1C.2
 Fu, Songnian - M1I.2, M1I.4, M2F.2,
 M2F.5, Th2A.59, Th2A.6, Tu3B.6,
 W2A.14, W2A.19, W2A.38, W2A.7
 Fujii, Takuro - M2D.2, M2D.5, Th3B.2,
 Tu3K.2, W1A.7, W3F.4
 Fujikata, Junichi - Tu3K.3
 Fujimoto, Takuto - Th3H.4
 Fujimura, Yasushi - Tu2B.2
 Fujiwara, Masamichi - M3B.5
 Fukuda, Hiroshi - M2D.2, Th3B.2
 Fukui, Takayoshi - Th3B.3, W1J.2
 Fukutoku, Mitsunori - Th1F.3, Th1J.3,
 W1E.2, W2A.52
 Füllner, Christoph - W4E.3
 Fumito, Nakajima - W4D.2
 Furdek, Marija - M1A.5, Th2A.42
 Furukawa, Hideaki - M3J.1, Th3H.2,
 Tu3E.5, W4C.3
 Futami, Fumio - Tu2G.5

G

Gabla, Paul - M1D.4
 Gaierin, Simone - W2A.59
 Gajda, Andrzej - W3E.4
 Galaro, Joseph - Tu2K.3
 Galdino, Lidia - Th1C.3, Tu2D.4,
 W1B.4, W3E.2
 Galili, Michael - Th2A.54, W1E.4,
 W3E.3, W3E.4
 Galimberti, Gabriele Maria - M1A.3
 Galtarossa, Andrea - Th2A.25
 Gambini, Piero - M3I
 Gan, Lin - M1I.2, M1I.4, Tu3B.6,
 W2A.14, W2A.19
 Gan, Peng - W2A.11
 Gandhi, Alagappan - Tu3A.2
 Gangopadhyay, Bodhisattwa - M1A.6
 Gao, Cong - W2A.2
 Gao, Dingshan - Th3C.4
 Gao, Guanjun - Th2A.23, W4B.5
 Gao, Mingyi - M1G.4
 Gao, Shengqian - Th2A.9
 Gao, Shuang - M2K.4

Gao, Tao - Th2A.37
 Gao, Yang - W1I.7
 Gao, Yuyang - Th1K.5, W4K.3
 Garces, Ignacio - Th1A.3
 Garcia-Ruiz, Andres - W1K.2, W1K.3
 Garipey, Daniel - Th1A.1, W2A.4
 Garrich, Miquel - Th1D.1, Tu3D.10
 Gatto, Alberto - M1A.7, Th1E.2
 Gaudino, Roberto - Tu2C.6
 Gautheron, Olivier - M1D.4
 Gavignet, Paulette - W2A.36
 Gazman, Alexander - Tu3F.2, Tu3F.3,
 W2A.32
 Gazula, Deepa - M3F.6
 Ge, Dawei - M2J.5, M4D.1, W4J.3,
 W4K.3
 Ge, Jia - W1K.5
 Gehl, Michael - Th2A.68
 Genay, Naveena - Th2A.53
 Geng, Dongyu - Th1J.1
 Gerstel, Ori - Th1D.4
 Geskus, Dimitri - Th2A.14
 Geuzebroek, Douwe H. - Th2A.14
 Gevorgyan, Hayk - W1I.4
 Geyer, Jonas - Th1A.6
 Ghandiparsi, Soroush - W1I.7
 Ghasemi, Saeed - M2B.7
 Ghazisaeidi, Amirhossein - M2C.2
 Ghelfi, Paolo - M2G.2, M2G.4
 Gheysens, Tom - W1K.4
 Ghobadi, Monica - Th3A.1
 Giannone, Francesco - Th2A.30
 Giannoulis, Giannis - M4H.6
 Giardina, Pietro - M3A.7, M4A.3
 Gibbemeyer, Alan - M1E.5
 Gibson, Ursula J. - W4K.6
 Giddings, Roger P. - W2A.33
 Gidony, David - W2A.32
 Giesecke, Anna Lena - M4H.6
 Gifre, Lluís - M3A.1, Th2A.28,
 Tu3D.12, Tu3D.5
 Gilgur, Alex - Tu2F.4
 Gill, Douglas M. - M2D.4
 Gilson, Mike - M1E.4
 Giorgetti, Alessio - Tu3D.12
 Gkounis, Dimitrios - M2A.6
 Gladisch, Andreas - Th1B.1
 Gladyshev, Alexey - M2J.7
 Goel, Nitin K. - Th3A, Th3A.2
 Goh, Takashi - W1E.2
 Goldfarb, Gilad - Tu3E.4





Golshani, Negin - W11.1
 Gonda, Tomohiro - Tu3B.1
 Gonnet, Cedric - M4D.5
 Gonzalez De Dios, Oscar - M2A.2,
 Tu3D.10, Tu3D.14, Tu3D.8
 Gonzalez Herraes, Miguel - W1K.2,
 W1K.3
 Gonzalez-Guerrero, Luis - Th2A.61
 Goodwill, Dominic - Th1G, Th1J.1
 Gordienko, Vladimir - W3D.4
 Gossard, Art - W3F.2
 Gosselin-Badaroudine, Pascal - W2A.4
 Goto, Takashi - W2A.1
 Gou, Pengqi - M4J.7, Th2A.60,
 Th2A.65
 Grammel, Gert - M1D.3
 Gramsamer, Josef - M4C.3
 Grechi, Simone - Tu2I.2
 Green, William M. - M2D.4
 Griesser, Helmut - M1C.2, Th2A.19
 Griffin, Benjamin - M2I.5
 Grillet, Christian - M2J.3
 Gross, Simon - W4C.2
 Grosse, Philippe - Tu3K.4
 Grubb, Stephen - M1D.1
 Grüner-Nielsen, Lars - M4D.4
 Gu, Q. Jane - M4J.3
 Gu, Rentao - M2A.1, Tu3D.1
 Gu, Wanyi - Th2A.67
 Gu, Xiaodong - Tu2E.3
 Guan, Pengyu - Th2A.54
 Guan, Xun - M4J.6, Th3G.3
 Guelbenzu, Gonzalo - W2A.23
 Guerra, Gianluca - Th2A.25
 Guglielmi, Emanuele - W2A.41
 Gui, Dong - W2A.3
 Guiomar, Fernando P. - M3C.3,
 Tu3E.1, W1G.3, W3A.5
 Gumaste, Ashwin - Th2A.33
 Gumier, Matteo - M1D.4
 Guo, Bingli - Th2A.37, W4I.5
 Guo, Changjian - W1J.8
 Guo, Chao - W2A.28
 Guo, Defeng - Th1J.4
 Guo, Haipeng - Tu3L.3
 Guo, Hongxiang - W1C.4, W2A.18
 Guo, Jiannan - W4F.2, W4F.7
 Guo, Junyuan - W1C.4
 Guo, Mengqi - W2A.62
 Guo, Qize - M2A.1, Tu3D.1
 Guo, Xin - Th2A.11

Guo, Xuhan - Th2A.10, Th3C.1,
 Tu2J.5
 Guo, Yong - M1B.8
 Gustavsson, Johan S. - M11.1
 Gutterman, Craig - Th1B.4
 Guzmán Martínez, Robinson Cruzoe
 - Th1I.1

H

Habib, Md Selim - M4D.5
 Haddad, A Manu - M4B.5
 Hafermann, Hartmut - M1G.5
 Haffner, Christian - M2I.1, M3G.2,
 Th3G.1
 Häger, Christian - W3A.4
 Haglund, Erik - M1I.1
 Haigh, Paul A. - M2K.5
 Hajikano, Tadashi - Th3H.4
 Hakuta, Kohzo - M4F.1
 Haller, Istvan - W1C.3
 Halmó, Leos - M2D.3
 Hamamoto, Kiichi - Th3B.4
 Hamaoka, Fukutaro - M1C.1, M1C.3,
 Th1C.4, W2A.51
 Han, Bing - W2A.36, W2A.8
 Han, Jae-Hoon - Th3C.5, Tu3K.3
 Han, Jiawei - Th2A.23
 Han, Kyeong-Eun - W2A.27
 Han, Won-Seok - Tu2B.3
 Han, Young-Tak - Th1J.5, Tu2B.3
 Hanawa, Toshihiro - Tu3L.2, Tu3L.6
 Hanaya, Naoki - Tu3L.1
 Haney, Michael W. - Th1G.3
 Hara, Kazutaka - Tu3L.4
 Harai, Hiroaki - M3A.4, M3J.1, M4A.2,
 Tu3E.5
 Harayama, Takahisa - Tu3G.3
 Harjanne, Mikko - Tu3A.5
 Harper, Paul - Th1C.2, Th1C.3, W3D.3
 Harstead, Ed - Tu2B.5
 Hartmann, Jean-Michel - M2J.3
 Hasanuzzaman, G.K.M. - W1F.6
 Hasebe, Koichi - M2D.2, W3F.4
 Hasegawa, Hiroshi - M3J.6, M3J.8
 Hasegawa, Junichi - Tu3A.4
 Hasegawa, Takemi - M4D, Tu3B.5
 Hashemi, Hossein - Th2A.2
 Hashimoto, Toshikazu - Th1J.3, W1E.2
 Hatori, Nobuaki - W1I.2
 Hattink, Maarten - Tu3F.2, Tu3F.3
 Hawkins, Thomas - W4K.6

Hayakawa, Akinori - W1I.2
 Hayashi, Michiaki - W4F.4
 Hayashi, Tetsuya - Th3D.4, Tu3B,
 Tu3B.5, W1A.5, W1A.6
 Hayashi, Tomofumi - Th2A.29
 Hayes, J. R. - M2J.6
 He, Gang - Th1A.1, W2A.4
 He, J - M2K.3
 He, Jifang - Th1J.1
 He, Li - M3G.3
 He, Linkuan - W4I.2
 He, Mingbo - Th2A.9
 He, Tao - W2A.12
 He, Yongqi - M2J.5, M4D.1, Th1K.5,
 W4J.3, W4K.3
 He, Zhixue - M2F.2, Th2A.59
 He, Zuyuan - M4G.3, Th2A.26,
 W3C.5, W3D.2, W4C.4
 Heideman, René G. - Th2A.14
 Hellwig, Peter - M1F.3
 Heni, Wolfgang - M2I.1, M2I.6,
 M3G.2, Th3G.1
 Henker, Ronny - M2D.3
 Henriksson, Lindor - W2A.43
 Henriksson, Johannes - Th1G.1
 Hentschel, Michael - Th3E.3
 Herrick, Robert - W3F.2
 Herrmann, Maximilian - W4A.1
 Hey Tow, Kenny - W1K.4
 Higuchi, Yuta - M4A.4
 Hilt, Jonas - M1F.3
 Hirai, Riu - Th3B.3, W1J.2
 Hiraki, Tatsuro - W3F.4
 Hirano, Takuya - Th3E.2
 Hirono, Masayuki - Tu3D.6
 Hirooka, Toshihiko - M3C.5, M4B.2,
 M4G.1
 Hirose, Yoshio - M2B.6, Tu3L.4, Tu3L.5
 Hirota, Yusuke - M3J.1, Th3H.2,
 Tu3E.5
 Ho, Chongpei - Th3C.5
 Ho, Daryl - M2J.4
 Ho, I-Lung - M1E.3
 Hoang, Thang M. - M2C.7, W1J.3,
 W4E.5, W4E.7
 Hoessbacher, Claudia - M2I.1, M3G.2,
 Th3G.1
 Hofbauer, Michael - Th1G.6
 Holonyak, Nick - W1I.6
 Honda, Kazuaki - Tu3L.4
 Hong, Bingzhou - Th3B.4

Hong, Ching-Yin - M3F.4, W4D.6
 Hong, Jin - Th2A.21
 Hong, Sung Eun - Th2A.53
 Hong, Wang - Th2A.11
 Hong, Yang - M2K.3, M2K.4, M3K.5,
 W4D.3
 Hoshida, Takeshi - M2B.6, M2F.6,
 M2F.7, M3E.3, M3J.8, Th2A.12,
 Tu3C.2, Tu3E.3, Tu3L.4, Tu3L.5,
 W2A.47, W4A.4
 Hosseini, Ehsan S. - M3F.1
 Hou, Guanghui - W4D.6
 Hou, Shanglin - Th2A.23
 Houtsma, Vincent - M1B.3, Th1E.3
 Hsiao, Jen-Hao - M1F.7
 Hsu, Chin-Wei - M2B.5, M2K.2,
 M3K.2, W4G.7
 Hsu, Jih-Hao - W4G.5
 Hsu, Yung - M3K.2
 Hu, Juan Juan - W2A.13
 Hu, Qian - W2A.54
 Hu, Shang - Tu2C.4
 Hu, Tao - Th2A.24
 Hu, Weisheng - M1B.5, M1H.4,
 M2B.4, M2B.4, Th2A.36, Tu2C.2,
 Tu2I.6, W2A.46, W2A.9
 Hu, Xiao - M3I.6
 Hu, Yingtao - Th3B.5
 Hu, Yongming - W2A.11
 Hu, Yue - Th1C.1
 Hu, Zhenglai - W2A.11
 Hu, Zhouyi - M2F.5
 Hua, Nan - M2E.5, M2E.6, Th2A.50,
 W2A.17
 Huang, Guoxiu - M2F.6
 Huang, Hsu-Hung - Th3G.4, Tu3J.7
 Huang, Li - W4A.5
 Huang, Meng - Th3C.4, Tu3A.6
 Huang, Mengyuan - W4D.6
 Huang, Shanguo - Th2A.37, W4I.5
 Huang, Wan-Jou - M2D.7, W2A.43
 Huang, Xiatao - M2C.5
 Huang, Xingang - Tu3L.3
 Huang, Xu-Hong - M1F.1, Tu2I.3
 Huang, Yishen - Th1G.2
 Huang, Yu - W1A.2, W3C.3, W3C.4
 Huang, Yuekai - W4F.3
 Huang, Yu-Fang - Tu2I.1
 Huang, Zongyuan - W2A.24
 Hübel, Hannes - Th3E.3, W2A.48,
 W4G.1

Hughes, Robert - W4A.2
 Hugues Salas, Emilio - M2A.6
 Hui, Michael - M3I.7
 Hui, Rongqing - Th2A.17
 Hung, Yu-Han - Th3G.4
 Hurley, Jason E. - W2A.3, W3C.2
 Huynh, Tam N. - M2D.1
 Hwang, Sheng-Kwang - Th3G.4

I

Iannone, Luigi - W4I.4
 Iannone, Patrick - M4I, Th2A.55
 Ibi, Shinsuke - Tu3C.4
 Ibragimov, Edem - Th1A.5
 Ibsen, Morten - M2J.4
 Iddin, Ardel - W2A.29
 Iezekiel, Stavros - W1F.6
 Igarashi, Koji - Th1K.3, Tu3C.4, W4C.1
 Igarashi, Ryo - M3B.5
 Ikeda, Kazuhiro - M4H.2, Th3H.5,
 Tu2A.4, Tu3A.4
 Ikeuchi, Tadashi - W1D.1, W1D.3,
 W1F.7
 Iliadis, Nikos - M4H.6
 Imakiiri, Yukihiko - Tu3D.6
 Imamura, Katsunori - Tu3B.1
 Inada, Yoshihisa - M1G.3
 Inoue, Takanori - M1G.3
 Ip, Ezra - W4F.3
 Iqbal, Maheen - W2A.26
 Iqbal, Md. Asif - Th1C.2, Th1C.3,
 W3D.3
 Irfan, Muhammad - W2A.26
 Irwin, Gary - M3F.5
 Isaak, Andreas - Th1K.6
 Ishibashi, Tadao - M4J.1
 Ishii, Kiyu - Tu3D.7
 Ishimura, Shota - Tu3J.5
 Islam, M. Saif - W1I.7
 Itabashi, Naoki - Tu2B.2
 Ito, Hiroshi - M4J.1
 Ito, Jun - W1A.5
 Ito, Teruhiro - Tu3B.5
 Ives, David J. - M2E.2, M2F.4, Tu3E.2
 Izquierdo-Zaragoza, Jose Luis -
 M3A.1, Th2A.28, Tu3D.12, Tu3D.5

J

Jabulka, Vladimir B. - M1H.2
 Jacobsen, Gunnar - M1I.4
 Jaeger, Nicolas - Tu2E.1



Jafari, Omid - Th2A.20
 Jain, Sachin - Tu3D.3
 Jain, Saurabh - M2J.4
 Jan, Catherine - W3F.2
 Janssen, Sofie - W11.1
 Jany, Christophe - Tu3K.4
 Janz, Siegfried - Th11.4
 Jauregui, Cesar - M2J.1
 Jayatilaka, Hasitha - Tu2E.1
 Jensen, Jesper B. - Th1A.3
 Jensen, Richard - Th3C
 Jeong, Seok-Hwan - W11.2
 Jeppesen, Palle - Th2A.54
 Jeurink, Steffen - W2A.5
 Jheng, Yu-Bo - M1F.1
 Ji, Chen - M3F
 Ji, Yuefeng - M2A.1, M2E.3, Tu3D.1, W2A.25
 Jia, Zhensheng - M4C.2, Tu2K.2, W1J.7
 Jian, Pu - Tu2I.4
 Jiang, Fengyi - M3K.3
 Jiang, Haisong - Th3B.4
 Jiang, Hong - Th1A.5
 Jiang, Jia - Th1J.1
 Jiang, Jianfei - M4H.5
 Jiang, Joy - Th2A.56
 Jiang, Mingxuan - Tu2D.2
 Jiang, Shoulin - Th2A.26
 Jiang, Tianwei - Th2A.67, W4B.5
 Jiang, Xiaoqing - M4H.5
 Jianing, Lu - M2F.5
 Jimenez, Oscar - M3F.2
 Jin, Cang - Th1K.1
 Jin, Wei - W1E.5
 Jin, Xin - Th2A.39
 Jing, Feng - W2A.2
 Jokhakar, Jignesh D. - M2C.6
 Jones, Rasmus T. - W2A.59
 Josten, Arne - M2I.1, M2I.6, M3G.2, Th3G.1
 Jozwik, Krzysztof - W1C.3
 Jue, Jason P. - W1D.1
 Jukan, Admela - Th2A.33
 Julián, Guillermo - Tu3D.5
 Jung, Daehwan - W3F.2
 Jung, Hyun-Do - Tu2B.3
 Jung, Yong-Min - M2J.4, M2J.6, M4D.3, Tu2J.3
 Jung, Youngho - Th3E.5

Jungnickel, Volker - M1F.3, W4G, W4G.2, W4G.3

K

K, Ramesh - M4H.7
 Kahn, Joseph M. - Th3D.4, Tu2C.1
 Kai, Cong - M3D.2
 Kakarla, Ravikiran - M4G.2
 Kakitsuka, Takaaki - M2D.2, M2D.5, Th3B.2, W3F.4
 Kalavrouziotis, Dimitrios - M4H.6
 Kamchevska, Valerija - Th1G.4, W1E.4
 Kamiyama, Daisuke - M2K.7
 Kanai, Takuya - M3B.5
 Kanakis, Giannis - M3A.7, M4A.3
 Kanazawa, Shigeru - M2D.2
 Kaneda, Noriaki - M1C.5
 Kanellos, George T. - M2A.6, Th2A.1
 Kanesan, Thavamaran - M2B.5, Th3G.7, W1F.5
 Kang, Xueyu - M2A.1
 Kani, Jun-Ichi - M3B.5, Tu3L.2, Tu3L.6, Tu3L.7
 Kanno, Atsushi - M3K, M3K.7, M4J.5, W1F.2, W1F.6
 Kanno, Erina - Th3B.2
 Kantak, Pravin - Tu3D.3
 Kanter, Gregory S. - Th2A.58
 Kapulainen, Markku - Tu3A.5
 Karanov, Boris P. - W2A.58
 Karinou, Fotini - Th1A.4, Tu3G, W2A.60
 Karlsson, Magnus - M1G, M1G.2, M4E.2, M4E.5
 Karpov, Maxim - Tu2J.1
 Kasahara, Ryoichi - M3E.2, M3E.4, Th3E.4, W1E.2
 Kasai, Keisuke - M3C.5, M4B.2, M4G.1, Th1F.2
 Katagiri, Toru - Th2A.29
 Katayama, Kazunori - W2A.1
 Kato, Kazutoshi - M4J.1
 Kato, Kentaro - Tu2G.5
 Kato, Tomoyuki - M3E.3, Tu3E.3
 Katrinis, Kostas - Tu3D.14, W1C.1
 Katsurai, Hiroaki - M2D.2
 Kawahara, Hiroki - Th1J.3
 Kawajiri, Yuko - M2D.2
 Kawanishi, Tetsuya - M2K, M3K.7, M4J.5, W1F.2
 Kawasaki, Kohei - Th1K.2, Tu3B.1

Kawashima, Hitoshi - M4H.2, Th3H.5, Tu2A.4, Tu3A.4
 Kayano, Keisuke - M3J.8
 Kazama, Takushi - M3E.2, M3E.4
 Ke, Changjian - Tu3B.6
 Keeler, Gordon A. - W3F.5
 Kehayas, Efstratios - M2J
 Kemal, Juned - W4E.3
 Kennard, Jake - M2A.6
 Kennedy, Mj - W3F.2
 Keulenaer, Timothy D. - W2A.19
 Keykhosravi, Kamran - W2A.20
 Khaddam, Mazen - W4F
 Khafaji, Mahdi - M2D.3
 Khan, Faisal N. - M2F.3
 Khan, Mohammed Z. - Th2A.15
 Khilo, Anatol - W11.4
 Khodashenas, Pouria Sayyad - Th2A.41
 Khudyakov, Maxim M. - M2J.7
 Kikuchi, Nobuhiko - Th3B.3, W1J.2
 Killey, Robert - M3B.1, M3C.4, Th1C, Th1C.3, Tu2D.4, W1B.4, W2A.58, W3E.2
 Kilper, Daniel - Th1B.4, Th1B.5, Th1D.2, W4F.3
 Kim, Byung Gon - Tu3J.6, Th1K.3, Th3E.5, W4G.4
 Kim, Daeho - W4G.4
 Kim, Dae-Ub - W2A.27
 Kim, Eon-Sang - W4B.4
 Kim, Hoon - Th3E.5, Tu3J.1, Tu3J.6, W4E.2, W4G.4
 Kim, Inwoong - W1D.1, W1D.3, W1F.7
 Kim, Jong-Hoi - Tu2B.3
 Kim, Joonyoung - Tu3J.3, W4B.4
 Kim, Kap-Joong - Th2A.5
 Kim, Kwangjoon - W2A.27
 Kim, Kwangok - Th2A.52
 Kim, Min-Hyeong - Th2A.13
 Kim, Minkyu - Th2A.13
 Kim, Sangyeup - Tu3L.2, Tu3L.6
 Kim, Seok-Tae - Tu2B.3
 Kim, Seung Hwan - Th2A.52
 Kim, Young-Jin - Th2A.31
 Kimball, Robert - W4A.2
 Kippenberg, Tobias - M4F.2, Tu2J.1
 Kisaka, Yoshiaki - M1C.1, M1C.3, Th1C.4, W2A.51
 Kishi, Toshiki - M2D.2, W1A.7

Kitatani, Takeshi - Th3B.3
 Kitayama, Ken-Ichi - W4I
 Kittlaus, Eric - M1H.3
 Kleis, Sebastian - W2A.64
 Klinkowski, Mirosław - Tu2F.2
 Klitis, Charalambos - Th2A.44, Th3H.1
 Klionidis, Dimitrios - Th1D.4, Th2A.35
 Knittle, Curtis - M4C.2, W1J.7
 Ko, Heasin - Th2A.5
 Ko, Wing - W1K.1
 Ko, Young-Ho - Tu2B.3
 Kobayashi, Go - Tu3A.4
 Kobayashi, Takayuki - M1C, M1C.3, M3E.2, M3E.4, Th3E.4
 Kobyakov, Andrey - W4B.2
 Koch, Jonas - W2A.40
 Koch, Ueli - M3G.2, Th3G.1
 Kocot, Chris - M11.3
 Koester, Steven - M3G, M4F
 Koganei, Yohei - Tu3C.2
 Koike-Akino, Toshiaki - M2C.4, Th2A.8, Tu3C.1, Tu3C.3, Tu3C.5, W3A.2
 Kojima, Keisuke - M2C.4, Th2A.8, Tu3C.1, Tu3C.3, Tu3C.5, W3A.2
 Kokinos, Panagiotis - Th2A.34
 Kolesik, Miroslav - Th3D.2
 Koltchanov, Igor - M4B.6
 Kolyadin, Anton N. - M2J.7
 Koma, Ryo - M3B.5
 Kondepu, Koteswararao - Th1B.2, Th2A.30
 Kong, Bingxin - Th3F.2
 Kong, Fanhua - W4A.5
 Kong, Jian - W1D.1
 Kong, Miao - M4J.4, M4J.7, Th2A.60
 Konoike, Ryotaro - Tu2A.4
 Koonen, Ton - M1C.4, M1F, M1F.6, M4G.5, M4J.2, Th2A.57, W1G.2, W4C.2
 Koos, Christian - W4E.3
 Kopp, Christophe - M4H.3, Th1G.6
 Kordts, Arne - Tu2J.1
 Kose, Bulent - W1A.2, W3C.3, W3C.4
 Kosiankowski, Dirk - Th1B.1
 Kosolapov, Alexey F. - M2J.7
 Kostalampros, Ioannis-Vatistas - W2A.49
 Kottke, Christoph - W4G.2, W4G.3
 Koyama, Fumio - Tu2E.3
 Kramer, Gerhard - M4E.3

Krause Perin, Jose Paulo - Tu2C.1
 Krause, David - W1B.3
 Krauß, Sandro - Th1B.1
 Kremp, Tristan - W1K.1
 Kretsis, Aristotelis - M3A.7, M4A.3, Th2A.34
 Kropp, Jörg - M2D.3, W11.5
 Kruger, Seth - W11.4
 Krummrich, Peter M. - W2A.5, W2A.57
 Krzaczanowicz, Lukasz - W3D.3
 Kschischang, Frank R. - W2A.61
 Kubo, Ryogo - Th3H.4, Tu3L.1
 Kuboki, Hayao - Th2A.62
 Kucharewski, Nick - M3J.7
 Kudlinski, Alexandre - Th3D.5
 Kudoh, Tomohiro - Tu3D.7
 Kues, Michael - M4G.4
 Kumar, Satish - Th3B.5
 Kumpera, Aleš - W1B.3
 Kurahashi, Teruo - Tu2A.4
 Kurata, Kazuhiko - W4D
 Kurczveil, Geza - Th3B.5
 Kurosu, Takayuki - Tu2G.5
 Kuschnerov, Maxim - M4B.5
 Kwon, O-Kyun - Th2A.3

L

Labroille, Guillaume - Tu2I.4
 Lacava, Cosimo - Tu2J.3
 Lai, Yaxiao - Th2A.6
 Lam, Cedric F. - Th2A.56
 Lambrecht, Joris - W4D.4
 Landi, Giada - Th2A.34
 Landry, Daniel B. - W1A.4
 Landry, Gary - M3F.6
 Lane, Brett - W1A.2, W3C.3, W3C.4
 Lange, Christoph - Th1B.1
 Langrock, Carsten - W2A.22, W3E.1
 Lanier, Michael - M3F.5
 Lardenois, Sebastien - W11.1
 Laroche, Sophie - M4J.6, Th1K.1, Th2A.20, Th3G.3, W11.3
 Larson, Michael - Tu2E
 Larsson, Anders G. - M11.1
 Larsson-Edefors, Per - Tu3C.6
 Lau, Alan Pak Tao - M2F, M2F.3, W1J.8
 Laudenschach, Fabian - W4G.1
 Lavery, Domaniç - M3B.1, W1B.4, W2A.58





Lavery, Martin - Th2A.44, Th3H.1
 Lavigne, Bruno - W1B.5, W4A.6
 Lavory, Domeniç - M3C.4
 Lavrencik, Justin - M11.1, M11.6
 Layec, Patricia - Th2A.46, W2A.56
 Lazaro, Jose Antonio - Th1A.3
 Lazzeri, Emma - Th2A.44, Th3H.1
 Le Guyader, Bertrand - M1B.1
 Le Monnier, Mael - W1B.5
 Le, Son T. - Tu2D.5, W1G.6
 Leaird, Daniel - Th3G.6
 Leblebici, Yusuf - M2D.3
 Leclerc, Michel - W2A.4
 Ledentsov, Nikolay - M2D.3, W11.5
 Lee, Benjamin G. - M2D.4, Th1G.4, Th3C.3
 Lee, Han Hyub - Th2A.52
 Lee, Jeffrey - M1C.5
 Lee, Jong - Th1G.6
 Lee, Jong Hyun - Tu3J.3, W4B.4
 Lee, Joonki - Tu3J.3
 Lee, Ka-Lun - Tu3J.4
 Lee, Seo Young - Tu2B.3
 Lee, Young - Tu3D.8, W2A.25
 Lelarge, Francois - Th1E.1
 Lemonnier, Olivier - M4H.3, Tu3K.4
 Lentaris, Georgios - W2A.49
 Lentine, Anthony - Th2A.68
 Leon-Saval, Sergio G. - M4D.5
 Lepage, Guy - Tu2A.3, W11.1
 Lesniewska, Alicja - W11.1
 Letellier, Vincent - M1D.4
 Leuthold, Juerg - M2I.1, M2I.6, M3G.2, Th3G.1
 Li, An - Tu2C.5, W1J.1, W2A.42
 Li, Baojia - Th3F.2, W4F.1
 Li, Cheng - M11.7, Th3B.5
 Li, Chenjia - Tu2D.2
 Li, Chung-Yi - M1F.1, Tu2I.3
 Li, Dan - Tu2C.4
 Li, Danping - Th3C.1
 Li, Fan - M2C.5
 Li, Guangzhi - W4A.5
 Li, Guifang - Th1K.1, Th1K.5, W4J.2
 Li, Han - M4I.3, Tu3D.1
 Li, Hao - W2A.12
 Li, Haolin - W1F.1
 Li, Hongtao - M1F.2, M2K.6
 Li, Huihui - M2F.6
 Li, Jialong - M2E.5, Th2A.50
 Li, Jiexiong - W3D.2, W4C.4

Li, Jie - M3B.3
 Li, Jiehui - Th2A.65
 Li, Juhao - M2E.5, M2J.5, M4D.1, Th1K.5, Th2A.24, W2A.17, W4J.3, W4K.3
 Li, Long - Tu2I.4, Tu2I.5
 Li, Longfei - M3J.3, W2A.28
 Li, Longsheng - Tu2I.6
 Li, Ming - Th1J.1
 Li, Ming-Jun - W2A.3, W3C, W3C.2
 Li, Mingshan - M1E.3
 Li, Mo - M3G.3
 Li, Peixuan - M2B.2, M2B.4, W2A.46
 Li, Qiang - Th3C.5
 Li, Qin - M1E.3
 Li, Rui - M2C.7, M3I.7, Tu2C.2, W4D.1
 Li, Shangyuan - M2E.5
 Li, Shi - W2A.40
 Li, Shimao - Th2A.9
 Li, Shuhui - Tu3A.6, W2A.24, W4C.4
 Li, Su - W4D.6
 Li, Tongyun - Th2A.69
 Li, Wenzhe - W4I.5
 Li, Xiang - M2C.5, M2F.2, M3B.3, Th2A.59
 Li, Xiangtao - Th1A.5
 Li, Xiaoying - M4D.1
 Li, Xiao-Zhou - M2J.2
 Li, Xin - Th2A.37, W4I.5
 Li, Xinying - M2C.3, M4J.4, M4J.7, Th2A.60, W1J.5, W2A.44, W4G.6
 Li, Yan - W4E.5
 Li, Yanbo - Th3C.1
 Li, Yang - W4A.5
 Li, Yanhe - M2E.5
 Li, Yao - Th1B.4, Th1B.5, Th1D.2
 Li, Yingchun - M1B.8, Th1K.1
 Li, Yubo - M4H.5
 Li, Yuwei - W2A.2
 Li, Zhe - M3C.4, Tu2D.4
 Li, Zhengbin - M4D.1, Th1K.5, W4J.3, W4K.3
 Li, Zhengxuan - M1B.8
 Li, Zhengyong - W2A.6
 Liang, Di - M11.7, Th3B.5
 Liang, Lipei - Th3F.2
 Liang, Shangyu - Th2A.64
 Liang, Tian - M3K.6
 Liang, Xiaojun - W4B.2
 Liang, Yize - W2A.24
 Liao, Mengzhe - Tu3J.7

Liao, Peicheng - Th3H.6, Tu2I.4, Tu2I.5, Tu2J.1, W2A.22, W2A.34, W3E.1
 Liebig, Erik - W3E.4
 Liga, Gabriele - M3C.4, W2A.53, W2A.58
 Likhachev, Mikhail E. - M2J.7
 Lillieholm, Mads - Th2A.54, W3E.3
 Lim, Christina - M1F.2, M2K.6, M2K.8, M3K.6, Tu3J, Tu3J.4
 Lim, Soon Thor - M3I.2, Th2A.11, Tu3A.2
 Limpert, Jens - M2J.1
 Lin, Aoxiang - W2A.2
 Lin, Chi-Hsiang - W4G.5
 Lin, Chungwei - Th2A.8
 Lin, Chun-Ting - W4G.5
 Lin, Gong-Ru - Tu2I.1
 Lin, Jiachuan - Th3G.3, Tu2E.4, W11.3
 Lin, Kai-Hsiang - Th2A.18, Th2A.63
 Lin, Rui - M11.2, M11.4, W2A.19
 Lin, Yi - Th2A.14, W2A.35
 Lingle, Robert - W4C.2
 Lipson, Michal - M3F.2
 Lischke, Stefan - Th2A.13
 Little, Brent - M4G.4
 Littlewood, Paul - M1A.5, M1E.2
 Liu, Bohao - Th3G.6
 Liu, Chenxia - Th2A.67
 Liu, Chin-Pang - M2G.3
 Liu, Cong - Tu2I.4, Tu2I.5
 Liu, Deming - M11.2, M11.4, M2F.5, Tu3A.1, Tu3B.6, W2A.12, W2A.14, W2A.19, W2A.38
 Liu, Fan - W2A.35
 Liu, Fumin - W4G.5
 Liu, Gengchen - M4J.3, Tu2A.6, W2A.45, W4F.7
 Liu, Guangyao - Tu2A.6, Tu3A.3
 Liu, Huiyuan - Th1K.1, W4J.2
 Liu, Jiaren - Th1I.4, Th1I.5
 Liu, Jie - W1J.8, W4C.4, W4D.5
 Liu, Jun-Jie - M2D.7, W2A.43
 Liu, Junlin - M3K.3
 Liu, Lei - Tu2D.6, W2A.63
 Liu, Li-Chun - W2A.43
 Liu, Ning - W1K.5
 Liu, Shuang - W2A.2
 Liu, Siming - M2B.5, M2F.1, M2K.2, Th2A.48, W1J.7, W4B.3, W4G.7
 Liu, Siqi - Th2A.39, W4F.1

Liu, Songtao - Th1I.2
 Liu, Wanyuan - Th1J.1
 Liu, Wu - Th2A.59
 Liu, Xiang - M3B.6
 Liu, Yan - Th1K.5
 Liu, Yaping - Th2A.24
 Liu, Yinping - W3C.5
 Liu, Zhen - M2E.3
 Liu, Zhengyong - W1K.6
 Liu, Zhixin - W1B.4, W1J.6, W3E.2
 Lo, Mu-Chieh - Th1I.1
 Long, Yun - Th3C.4, Tu3A.6
 Lopez De Vergara, Jorge - Tu3D.5
 Lopez, Diego R. - Th2A.32
 Lopez, Iria - Th2A.19
 Lopez, Victor - M1A, Th1D.4, Th2A.32, Th2A.35, Tu3D.10, Tu3D.11, Tu3D.8
 Lopez-Aviles, Helena - Th3D.2
 Lord, Andrew - M2A.6, Th2A.43, Tu2G.2, W2A.29
 Lorences-Riesgo, Abel - M1G.2
 Loussouarn, Yann - M1E.5
 Lowery, Arthur - M2C.6, W1J.4, W2A.50
 Lu, Biao - Tu3D.3
 Lu, Chao - M2F.3, Th2A.66, W1J.8, W1K.6, W2A.15, W2A.7
 Lu, Feng - M2B.5, M2F.1, M2K.2, M3K.4, Th3G.7, Tu3J.2, W1J.7
 Lu, Hai-Han - M1F.1, Tu2I.3
 Lu, Hongbo - M4J.3, W2A.45, W4F.7
 Lu, Luluzi - Tu3A.1
 Lu, Ping - W2A.37
 Lu, Wei - Th2A.39, Th3F.2
 Lu, Xiaofeng - M1I.5
 Lu, Xiaohuan - Tu2G.3
 Lu, Xingyu - M2K.1, Th2A.64
 Lu, Yueming - W2A.62
 Lu, Zhenguo - Th1I.4, Th1I.5
 Luis, Ruben S. - M3J.1, Th3H.2, Tu3B.3, W4C.3
 Luo, Ming - M2C.5, M2F.2, M3B.3
 Luo, Ruijie - M2E.5, M2E.6, W2A.17
 Luo, Wenyong - W4C.4
 Luo, Xiao - Th2A.38
 Luo, Yan - M4D.2, Th3C.4, W2A.24
 Luther-Davies, Barry - M2J.3
 Lutz, Joachim - W4E.3
 Lynn, Brittany - Tu2I.4
 Lyu, Mingyang - Th3G.3

M

Ma, Lin - Th2A.26, W3C.5
 Ma, Pan - M2J.3
 Ma, Ping - M2I.6, M3G.2, Th3G.1
 Ma, Xiaoli - Tu3J.2
 Ma, Zhuang - Tu2G.3
 Maat, Peter - M2D.6
 Macdonald, Kevin F. - Tu2J.3
 Machacek, Martin - Tu3H.4
 Madden, Stephen - M2J.3
 Madrigal, Javier - Th1K.4
 Maeda, Koichi - Th1K.2
 Magee, Anthony - W2A.29
 Mai, Andreas - W3E.4
 Mai, Christian - Th2A.13
 Maier, Guido Alberto - Tu3D.15
 Mak, Jason - Tu2A.5
 Makovejs, Sergejs - W2A.54
 Malhouitre, Stéphane - Tu3K.4
 Malik, Muhammad N. - Th2A.44, Th3H.1
 Mamtaz, Hasina H. - W1I.7
 Manabe, Ken - W1A.6
 Mangal, Nivesh - Tu2A.1, Tu2A.3
 Manganelli, Costanza - Th1G.6
 Maniotis, Pavlos - W2A.39
 Mao, Yuexin - Th1I.4
 Maragos, Konstantinos - W2A.49
 Maram, Reza - M2J.2
 Mardoyan, Haik - M2C.2
 Marini, Diego - Th3H.1
 Marom, Dan M. - W1E.1
 Marotta, Andrea - Th1B.2
 Marquez-Barja, Johann - Th2A.49
 Marris-Morini, Delphine - Th1G.5
 Marsico, Antonio - Th1D.3
 Martelli, Paolo - M3J.2
 Martin, Vicente - Th2A.32
 Martinello, Magnos - Tu3D.13
 Martínez, Ricardo - M2A.4, M3A.6, Tu3D.11, Tu3D.8
 Martinez-Mateo, Jesus - Th2A.32
 Martingarcia, Luis - M1E.1
 Martin-Lopez, Sonia - W1K.2, W1K.3
 Martin-Seoane, Elena - Tu3D.10
 Martins, Hugo F. - W1K.2, W1K.3
 Maruta, Akihiro - W4C.3
 Maruyama, Ryo - W4C.3
 Masuda, Akira - Th1F.3, W2A.52
 Mateo, Eduardo - M1G.3
 Mathew, Neethu M. - M4D.4





Matrakidis, Chris - Th1D.4, Th2A.35
 Matsuda, Keisuke - M2C.4, M3B.2
 Matsui, Takashi - Th2A.27, W1A.7
 Matsui, Yasuhiro - Th3B
 Matsumoto, Atsushi - M3K.7
 Matsumoto, Keiichi - M3J.5
 Matsumoto, Ryosuke - M3B.2
 Matsumoto, Takeshi - Tu2A.4
 Matsuo, Shinji - M2D.2, M2D.5,
 Th3B.2, Tu3K.2, W1A.7, W3F.4
 Matsushita, Asuka - M1C.1, M1C.3,
 Th1C.4
 Matsuura, Hiroyuki - M4H.2, Th3H.5
 Matsuura, Motoharu - M2K.7,
 Th2A.62
 Matsuzaki, Hideaki - W4D.2
 Mavromatis, Alex - M3A.2
 Mayet, Ahmed - W1I.7
 Mayoral López-De-Lerma, Arturo -
 M2A.4
 Mazur, Mikael - M1G.2
 Mazurczyk, Matt - M4B.3, Th1C.1,
 W1B.6
 Mccurdy, Alan - W4C.2
 Mckeown, Steven - M2I.5
 Mckinstrie, Colin - M4G
 Mcneal, Nathen - W4A.2
 Meani, Claudio - Th2A.41
 Mecozzi, Antonio - Tu2D.1, Tu2D.3,
 Tu2D.7
 Megeed, Sharief - M3B.6
 Meghelli, Mounir - M2D.4
 Mehrpoor, Gilda - Th2A.19
 Mehrvar, Hamid - Th1J.1
 Mekonnen, Ketemaw Addis - M1F.6
 Melati, Daniele - M3I.4, M3I.5
 Melgar, Alirio - M1I.6
 Melkumov, Mikhail - W3D.1
 Melloni, Andrea - M3I.4, M3I.5,
 W2A.41
 Meloni, Gianluca - Th3H.1
 Menezo, Sylvie - Tu2A.5, Tu3K.4
 Meng, Fanchao - M3A.2, W4F.5
 Messa, Alessandro - M1F.5, Tu2I.2
 Messner, Andreas - M2I.6, M3G.2,
 Th3G.1
 Miao, Xin - Tu2I.6
 Michielssen, Eric - W3C.6
 Midrio, Michele - W2A.31
 Miguelez, Phil - M2B.1
 Mihailov, Stephen - W2A.37

Mikhelashvili, Vissarion B. - W3F.3
 Miki, Shigehito - M3G.4
 Mikkelsen, Benny - M1E.5
 Mikuni, Mashito - Th2A.29
 Milanizadeh, Maziyar - W2A.41
 Millar, David - M2C.4, Tu3C.1, Tu3C.3,
 Tu3C.5, W3A.2
 Miller, Andy - Tu2A.3, W1I.1
 Miller, Glen - M1E.5
 Minakhmetov, Artur - W4I.4
 Minkenberg, Cyriel - M3J.7
 Minoguchi, Kyo - Th1C.4
 Mirzaei Nejad, Reza - M4J.6
 Mishra, Vaibhawa - Tu3D.14, W1C.1
 Missinne, Jeroen - Tu2A.1
 Mitani, Sufian M. - M2B.5, Th3G.7
 Mitchell, Matthew - Tu3D.9
 Mitsolidou, Charoula - Th1G.5,
 Th2A.1
 Miyabe, Masatake - Th2A.29, W4A.4
 Miyajima, Shigeyuki - M3G.4
 Miyamoto, Yutaka - M1C.3, M3E.2,
 M3E.4, Th1J.3, Th3E.4, W1E.2
 Miyata, Naoki - Th2A.29
 Mizumoto, Tetsuya - M3I.3, Th3C.2
 Mizuno, Takayuki - W4C
 Mo, Weiyang - Th1B.4, Th1B.5,
 Th1D.2, W4F.3
 Moazeni, Sajjad - Th1G.1, W1I.4
 Moessner, Klaus - Th2A.41
 Mohajerin Ariaei, Amirhossein -
 Tu2J.1, W2A.22, W3E.1
 Mohajerin-Ariaei, Amirhossein -
 Th3H.6, W2A.34
 Mohanasamy, Nishok - Th2A.31
 Molin, Denis - W3C.1
 Monat, Christelle - M2J.3
 Monberg, Eric - W1K.1
 Mondaca, Gabriel S. - W1J.6
 Moniz, Daniela A. - M1A.4
 Monroy, Idelfonso Tafur - M4J
 Monti, Paolo - M2A.2
 Montmayeul, Brigitte - Tu3K.4
 Mookherjea, Shayani - M4H.1
 Morais, Rui M. - M3J, M4A.6
 Morales, Alvaro - W1F.7
 Morandotti, Roberto - M4G.4
 Moraw, Paul - Th2A.58
 Morbi, Zulfikar - W1B.3
 Morea, Annalisa - Tu2F.3

Moreno-Muro, Francisco-Javier -
 Th1D.1, Tu3D.10
 Moreolo, Michela Svaluto - M1A.7,
 M2A.5, M3A.6
 Morf, Thomas - M2D.3
 Mori, Tatsuo - Th2A.29
 Mori, Tomotaka - Th3B.4
 Mori, Toshihiko - W1I.2
 Mori, Yojiro - M3J.6, M3J.8, Th3H.3,
 Th3H.5
 Morichetti, Francesco - W2A.41
 Morikawa, Hiroyuki - Tu3E.3
 Morioka, Toshio - Th2A.54, W1E.4,
 W3A.3
 Morishima, Tetsu - W1A.5, W1A.6
 Morita, Itsuro - M2A.5, Th1K.3
 Morro, Roberto - Tu3D.12
 Morsy-Osman, Mohamed - M3I.7,
 W2A.16, W4E.1, W4E.5, W4E.7
 Morton, Paul A. - Th1I.3
 Moss, Benjamin R. - M3F.1
 Moss, David J. - M2J.3, M4G.4
 Motaghian, Reza - M1I.3
 Mourgias-Alexandris, George -
 W2A.39
 Muhammad, Ajmal - M2A.2
 Mukherjee, Biswanath - M4I.3
 Mumtaz, Sami - Th3D.3
 Mun, Sil-Gu - Th2A.52
 Muñoz, Raul - M1A.7, M2A.4, M2A.5,
 M3A.6, Tu3D.11, Tu3D.8
 Murakami, Masaki - Tu3D.6
 Muramoto, Yoshifumi - W4D.2
 Muraoka, Kenji - Th3C.2
 Mussot, Arnaud - Th3D.5
 Musumeci, Francesco - M3A.5

N

Nada, Masahiro - W4D.2
 Nadakuditi, Raj - W3C.6
 Nadal, Laia - M1A.7, M2A.5, M3A.6
 Naftaly, Mira - Th2A.61
 Nagarajan, Gaya - Th3F.1, Tu3D.2
 Nagashima, Takuji - Th3D.4
 Nagatani, Munehiko - M1C.3, M2D.2,
 Th3E.4
 Nakagawa, Goji - M2B.6, Tu3L.4,
 Tu3L.5
 Nakagawa, Shigeki - Th3C.2
 Nakahama, Masanori - Tu2E.3
 Nakahara, Kouji - Th3B.3, W1I

Nakai, Makoto - Th2A.2
 Nakajima, Kazuhide - Th2A.27, W1A.7
 Nakajima, Mitsumasa - W1E.2
 Nakamura, Atsushi - M4B.4
 Nakamura, Hirotaka - Tu3L.4
 Nakamura, Kohei - M1G.3
 Nakamura, Masanori - M1C.1, M1C.3,
 Th1C.4, W2A.51
 Nakamura, Shigeru - M3I.1
 Nakanishi, Tetsuya - Th3D.4, W1A.5,
 W1A.6
 Nakano, Shinsuke - M2D.2
 Nakashima, Hisao - Th2A.12, Tu3C.2
 Nakayama, Yu - Tu3L.1
 Nakazawa, Masataka - M3C.5, M4B.2,
 M4G.1, Th1F.2, Th3E.2
 Namiki, Shu - M4H.2, Th3H.5, Tu2G.5,
 Tu3D.7
 Nan, Zhou - Th2A.9, Th3C.4
 Napierala, Marek - M2G.5
 Napoli, Antonio - Th3E
 Nasilowski, Tomasz - M2G.5
 Nasr, Karim M. - Th2A.41
 Naveau, Coentin - Th3D.5
 Nejabati, Reza - M2A, M2A.6, M3A.2,
 Tu2G.2, Tu3D.13, W4F.5
 Nelson, Lynn E. - W1B.1
 Nelson, Robert - M2I.5
 Neokosmidis, Ioannis - M1A.1,
 Th2A.41
 Nespola, Antonello - M3C.3, Tu2C.6,
 W3A.5
 Nettet, Derek - M1E.4, M2B
 Neumaier, Daniel - M2I.4
 Neumann, Jörg - Th1K.6
 Neumeyr, Christian - M1A.7, Th1E.2
 Ng, Tien K. - Th2A.15
 N'Gom, Moussa - W3C.6
 Ng'Oma, Anthony - W4B.2
 Nguyen, Van Minh - Tu3D.15
 Ni, Li - W2A.2
 Nikolovgenis, Konstantinos - M2A.6,
 M3A.2, W4F.5
 Nilsson, Alan - W1B.3
 Nirmalathas, Ampalavanapillai -
 M1F.2, M2K.6, M2K.8, M3K.6,
 Tu3J.4
 Nishi, Hidetaka - M2D.2, M2D.5,
 Th3B.2, Tu3K.2, W1A.7
 Nishimura, Kosuke - Tu3J.5
 Nishiyama, Nobuhiko - Th3C.2

Nishizawa, Motoyuki - W1I.2
 Nogueira, Rogerio N. - M2G.5, W1K
 Norman, Justin - W3F.2
 Norris, Theodore B. - W3C.6
 Nosaka, Hideyuki - M2D.2
 Notaros, Jelena - W1I.4
 Novak, Dalma - W4B.1
 Novick, Asher S. - W1A.2, W3C.3,
 W3C.4
 Ntavou, Foteini - M2A.6
 Nummy, Karen - M2D.4

O

O'Carroll, John - Th1E.4
 Oda, Shoichiro - M2F.6, M2F.7,
 M3J.8, Tu3L.5
 Ogita, Shoichi - Tu2B.2
 Ohmura, Masaki - W1A.5
 Ohno, Tetsuichiro - W4D.2
 Okamoto, Kaoru - Th3B.3
 Okamoto, Satoru - Th2A.29, Tu3D.6
 Okamoto, Seiji - M3C.5, M4B.2,
 Th1C.4, Th1F.2, W2A.51
 Okamura, Yasuhiro - M3E.4
 Okazeri, Ken - Th3C.2
 Okonkwo, Chigo - M1C.4, M4G.5,
 W1G.2, W4C.2
 Okuno, Yudai - Th3H.4
 Oldenbeuving, Ruud M. - Th2A.14
 Olivier, Segolene - Tu2A.5
 O'Malley, Nathan - Th3G.6
 Omoda, Emiko - Tu2A.2
 Ong, Jun Rong - M3I.2, Tu3A.2,
 Th2A.11
 Onori, Daniel - M2G.2, M2G.3
 Ooi, Boon - Th2A.15
 Ophir, Noam - M2D.1
 Orcutt, Jason - M2D.4
 Orobtcchouk, Regis - M2J.3
 Ortiz, Roy - W1K.1
 Osamu, Tadanaga - M3E.2, M3E.4
 Osawa, Noboru - Tu3C.4
 Oshio, Hajime - Th1K.2
 O'Sullivan, Maurice - M1E.2, M2F.4,
 Th1I.4, Th2A.17
 Otaka, Akihiro - M3B.5, Tu3L.2,
 Tu3L.4, Tu3L.6, Tu3L.7
 Oton, Claudio - M4H.3, Th1G.6
 Otterstrom, Nils - M1H.3
 Otto, Martin - M2I.4
 Ou, Haiyan - Th2A.65





Ou, Yanni - M2A.6, M3A.2, W4F.5
 Oubei, Hassan - Th2A.15
 Overmeyer, Ludger - Th1K.6
 Oxenlowe, Leif K. - Th2A.54, Th3H,
 W1E.4, W3A.3, W3E.3, W3E.4
 Oyama, Tomofumi - Th2A.12, Tu3C.2
 Ozkaya, Ilter - M2D.3
 Ozolins, Oskars - M11.2, M11.4,
 Th2A.51, W2A.19

P

Pacher, Christoph - M1F.4
 Pachnicke, Stephan - W2A.40
 Paglierani, Pietro - Th2A.41
 Palacharla, Paparao - W1D.3
 Palermo, Samuel - M11.7, M2D,
 Th3B.5
 Pallecchi, Emiliano - M2I.4
 Palmieri, Luca - Th2A.25
 Pan, Dong - M2I, M3F.4, W4D.6
 Pan, Jie - Th1A.2, W1B.2
 Pan, Mike - M1E.5
 Pan, Shilong - Th3G.5
 Pan, Weiwei - M1E.4
 Pan, Zeyu - M2I.2
 Pang, Kai - Tu2I.4, Tu2I.5
 Pang, Xiaodan - M11.2, M11.4,
 Th2A.51, W2A.19
 Pantano, Nicolas - Tu2A.3
 Pantouvaki, Marianna - Tu2A.3, W11.1,
 W2A.16
 Paolucci, Francesco - M2A.2, M4A.5,
 Tu3D.12
 Pap, Evert - Tu3D.14
 Papen, George - Th1G.4
 Paquet, Alex - W1A.4
 Paraschis, Loukas - Tu3D.3, Tu3H
 Paraskevopoulos, Anagnostis - M1F.3
 Park, Anthony - Tu2E.1
 Park, Chansung - W2A.27
 Park, Chulhee - Th1J.5
 Park, Jin-Kwon - Tu3K.3
 Park, Joonoh - Th1J.5
 Park, Kyung - Th1K.3
 Park, Sangho - Th1J.5
 Parmigiani, Francesca - W3D, W3E.2
 Parolari, Paola - M1A.7, Th1E.2
 Parsons, Earl - M3F.5
 Parsons, Kieran - M2C.4, Th2A.8,
 Tu3C.1, Tu3C.3, Tu3C.5, W3A.2
 Parsons, Nick J. - Tu3D.14, W1C.1

Parulkar, Guru - M4A.4
 Parvizi, Mahdi - M3I.7
 Paryanti, Gil - Th3E.1
 Paskov, Milen - M4B.3, Th1C.1
 Pastor-Graells, Juan - W1K.2, W1K.3
 Patel, David - M2C.7, M3I.7, W4D.1
 Pattavina, Achille - Tu3D.15
 Patterson, Randall - M3F.5
 Pavanello, Fabio - W1I.4
 Pavesi, Lorenzo - Th1G.6
 Pavon-Marino, Pablo - Th1D.1,
 Tu3D.10
 Pawlina, Bryan - M3I.2
 Peacock, Anna C. - W4K.5, W4K.6
 Pecci, Pascal - M1D.4
 Peckham, David - W4C.2
 Peczek, Anna M. - W3E.4
 Pederzoli, Federico - Th2A.35,
 Th2A.42
 Pedro, João - M1A.4, M1A.6, M4A.6,
 Tu2F
 Peev, Momtchil - Th2A.32
 Pelegrina Bonilla, Gabriel - Th1K.6
 Peng, Kun - W2A.2
 Peng, Peng-Chun - M2B.5, M2F.1,
 Th2A.48, W1J.7, W4G.7
 Peng, Wei-Ren - Tu2C.5, W1J.1,
 W2A.42
 Pennings, Erik - Th2A.53
 Penty, Richard V. - Th2A.69
 Pepe, Teresa - M2A.2
 Pérez, Jorge M. - M2A.2
 Pérez-Galacho, Diego - Th1G.5
 Pesic, Jelena - M1A.2, Tu2F.3
 Petermann, Klaus - W3E.4
 Peters, Adaranijo - M3J.4, W1C.2
 Petousi, Despoina - Th2A.19
 Petropoulos, Periklis - Tu2J.3, W3E.2
 Peucheret, Christophe - Tu2C.3
 Peyghambarian, Nasser - Th2A.40,
 W2A.20
 Pfau, Timo - Th1A.6
 Pfeiffer, Martin Hubert Peter - Tu2J.1
 Pfeiffer, Thomas - M1B.2, Th1E.1,
 Th1E.3, Tu2K, Tu2K.3
 Pfister, Henry D. - W3A.4
 Pham Van, Quan - Th2A.46
 Phillips, Ian - W3D.3
 Piciaccia, Stefano - M1A.3, W1G.3
 Pierco, Ramses - W4D.4
 Pilipetskii, Alexei - M4B.3, W1B.6

Pilori, Dario - M3C.6, Tu2C.6, W1G.4
 Pimpinella, Rick - W1A.2, W3C.3,
 W3C.4
 Pincemin, Erwan - M1E.5, W2A.36
 Pinho, Catia - W2A.30
 Pinna, Sergio - M2G.4
 Pinto, Armando - W3A.5
 Pintus, Paolo - Th1G.6
 Pires, João - M1A.4
 Pithewan, Khuzema - Tu3D.3
 Pitris, Stelios - Th1G.5, Th2A.1
 Pittalà, Fabio - M4B.5
 Plant, David V. - M1B.5, M2C.7,
 M3I.7, Tu2C.2, W1J.3, W2A.16,
 W4D.1, W4E.1, W4E.5, W4E.7
 Pleros, Nikos - Th1G.5, Th2A.1,
 Tu3F.4, W2A.39
 Pliva, Jan - M2D.3
 Plum, Eric - Tu2J.3
 Pneumatikos, Dionisios - Tu3D.14,
 W1C.1
 Png, Ching Eng - M3I.2, Th2A.11,
 Tu3A.2
 Poehlmann, Wolfgang - M1B.2
 Poggiolini, Pierluigi - M3C.3, W1G.3
 Pohl, Alexandre A. - Tu2J.4
 Poitras, Daniel - Th1I.4
 Poletti, Francesco - W4K
 Polo, Victor - M2B.7, M3B.4
 Polster, Robert - M3F.2, Th2A.16
 Ponizovskaya Devine, Ekaterina -
 W1I.7
 Poole, Philip - Th1I.4, Th1I.5
 Poon, Joyce K. - Tu2A.5, Tu3K.4
 Popov, Sergei - M11.2, M11.4,
 Th2A.51, W2A.19
 Popovic, Milos - W1I.4
 Porto Da Silva, Edson - W1E.4, W3A.3
 Porto, Stefano - M1B.3, Th1E.3
 Porzi, Claudio - M2G.4
 Potì, Luca - Th3H.1, W2A.31
 Pouloupoulos, Giannis - M4H.6
 Poulton, Christopher - M3F.1
 Prat, Josep - M2B.7, M3B.4
 Prata, João G. - M2G.5
 Preisler, Edward - Th2A.2
 Preite, Massimo Valerio - M4H.3
 Presi, Marco - M1B.6, Tu2D.3
 Preve, Giovan B. - Th1G.6, Th3H.1
 Prodaniuc, Cristian - W2A.60
 Proesel, Jonathan E. - M2D.4

Proietti, Roberto - M4J.3, W2A.45,
 W4F.2, W4F.7
 Prost, Mathias - Tu3A.3
 Pryamikov, Andrey D. - M2J.7
 Psaltis, Demetri - W4J.1
 Pu, Guoqing - W2A.9
 Puerta, Rafael - W1F.7, W2A.47
 Puleri, Marzio - M2G.4
 Pulverer, Klaus - W4A.1
 Puttnam, Benjamin J. - Tu3B.3, W4C.3

Q

Qi, Jia - W2A.62
 Qi, Jipeng - Th1I.7
 Qi, Nan - Tu2C.4
 Qi, Yanhui - Th2A.12
 Qiao, Lei - Th1J.4
 Qiao, Liang - M2K.1, Th2A.64
 Qiao, Pengfei - Th1I.7
 Qiao, Yaojun - W2A.62
 Qin, Chuan - Tu2A.6
 Qiu, Ciyuan - Th2A.10, Th2A.7,
 Th3C.1, Tu2J.5
 Qiu, Junyi - W1I.6
 Qiu, Kun - M2C.5
 Qiu, Meng - M2C.7
 Qu, Zhen - M1G.3, M4E.4, Th1D.2
 Quiquempois, Yves - Tu3B.2

R

R, Sumi - M4H.7
 Raburn, Maura - W3F
 Rademacher, Georg - Tu3B.3, W4C.3
 Rafique, Danish - M1C.2, Th2A.19,
 W4F.6
 Rahn, Jefferey - W1B.3
 Rakich, Peter T. - M1H.3, M3G.1
 Rakowski, Michal - Tu2A.3
 Ralph, Stephen E. - M1I.1, M1I.6
 Ram, Rajeev - W1I.4
 Ramachandran, Siddharth - W4K.1
 Ramantanis, Petros - W2A.56
 Randel, Sebastian - Th1F, W4E.3
 Ranjbar Zefreh, Mahdi - W1G.3
 Rannello, Mario - M1B.6
 Rao, Yunjiang - W2A.8
 Rasmussen, Christian - Th1A.6
 Rasmussen, Jens C. - M2C.1
 Rastegarfar, Houman - Th2A.40,
 W2A.20, W2A.21
 Reale, Andrea - Tu3D.14, W1C.1

Reilly, Daniel - Th2A.58
 Reimer, Christian - M4G.4
 Reithmaier, Johann P. - W3F.3
 Ren, Fang - M2J.5, M4D.1
 Ren, Haonan - W4K.6
 Renaud, Cyril - Th2A.61, Th2A.69
 Renaudier, Jeremie - M2C.2
 Ribeiro, Carlos - M2G.5
 Ribeiro, Moises R. - Tu3D.13
 Ribeiro, Ricardo M. - M1H.2
 Riccardi, Emilio - Tu3D.12
 Rice, Mark - W1B.3
 Richardson, David J. - M2J.4, M2J.6,
 M4D.3, Tu2J.3, W3E.2
 Richardson, Kurt - W4A.2
 Richter, Andre - M4B.6, W2A.49, W4E
 Richter, Thomas - Th1A.2, W1B.2
 Riesen, Nicolas - W4C.2
 Rios-Muller, Rafael - M2C.2
 Rito, Pedro - Th2A.19
 Rizzelli, Giuseppe - Th3A.2
 Rizzi, Marco - Tu3D.2
 Robertson, Brian - Th1J.2, Th2A.43
 Robinson, Niall A. - Tu3E.6
 Rodriguez, German - M3J.7
 Roelkens, Gunther - M3G, M4F,
 Tu2A.1, W4D.4
 Roeloffzen, Chris G. H. - Th2A.14,
 Tu2I.7
 Rokkas, Theodoros - M1A.1, Th2A.41
 Romagnoli, Marco - M2G.4, M2I.3,
 W2A.31
 Roman, Jose - M2D.1
 Romero Cortés, Luis - M2J.2, M4G.4
 Rommel, Simon - W1F.7
 Roshan-Zamir, Ashkan - M1I.7, Th3B.5
 Rossi, Nicola - M1A.2
 Roth, Bernhard - Th1K.6
 Rothhardt, Manfred - Tu2J.4
 Rottondi, Cristina - M3J.2
 Rottwitt, Karsten K. - M4D.4, Th1K
 Rozic, Ciril - Th1D.4, Th2A.35
 Roztocky, Piotr - M4G.4
 Ruan, Xiaoke - Tu2D.2
 Ruan, Zhengsen - Th3C.4, Tu3A.6
 Ruffini, Marco - Th1B.3, Th1B.5,
 Th2A.49, Tu3D.4
 Rui, Deng - M2K.3
 Ruiz, Marc - W1D.4, W1D.5, W1G.1
 Rumley, Sebastien - Tu3F.2
 Rundberget, Kirsten - M2E.4, Th2A.45





Runge, Antoine F. - W4K.6
 Rusch, Leslie A. - M4J.6, Th3G.3,
 Tu2E.2, Tu2E.4, W11.3
 Ryf, Roland - M4D.5, M4G.5, Th1K.1,
 W1G.2, W4C.2, W4C.3
 Rlylyakov, Alexander - M2D.1

S

Saavedra, Gabriel - Th1C.3, W1B.4,
 W3E.2
 Sadasivarao, Abhinava - Tu3D.3
 Sadot, Dan - M1C.6, Th3E.1
 Sagae, Yuto - Th2A.27
 Sahin, Ezgi - M3I.2, Th2A.11
 Saito, Hiroshi - M3J.8
 Saito, Yuki - W1A.6
 Saitoh, Shota - Th2A.22
 Sakaguchi, Jun - Tu3B.3
 Sakakibara, Youichi - M4F.3, Tu2A.2
 Sakamoto, Takahide - M3K.7
 Sakano, Goki - M4J.1
 Sakuma, Yasushi - Th3B.3
 Salamin, Yannick - M3G.2, Th3G.1
 Salas, Emilio H. - W4F.5
 Saleh, Adel - Tu3F
 Sales, Salvador - Th1K.4
 Saliou, Fabienne - M1B.1, Th2A.53
 Saljoghei, Arsalan - M3J.4, Tu3D.14,
 W1C.1, W1C.2
 Salvadori, Elio - Th1D.3
 Samadi, Payman - Tu3F.2, W1C
 Samani, Alireza - W2A.16, W4D.1
 Sambo, Nicola - M3A.7, M4A.3,
 Th2A.30, Tu3D.12
 Sampei, Seiichi - Tu3C.4
 Sampietro, Marco - W2A.41
 Samra, Parmijit - W1B.3
 Sanches Martins, Celestino - W3A.5
 Sanchez, Loic - Tu3K.4
 Sanjabi Eznaveh, Zeinab - M4D.5,
 Th3D.2
 San-Nicolas-Martinez, Cesar -
 Tu3D.10
 Sano, Tomomi - W1A.5, W1A.6
 Santuari, Michele - Th2A.35
 Sasaki, Dai - W1A.3
 Sato, Ken-Ichi - M3J.6, M3J.8,
 Th3H.3, Th3H.5
 Satou, Ikuo - Th2A.29
 Savi, Marco - Th1D.3, Th1D.4
 Savio, Paolo - Tu2C.6

Savory, Seb J. - M2E.2, M2F.4, Tu3E.2
 Scaffardi, Mirco - Th2A.44, Th3H.1
 Scaradozzi, David - Tu2I.2
 Schaeffer, Christian G. - W2A.64
 Schairer, Wolfgang - W4A.1
 Schall, Daniel - M2I.4
 Schares, Laurent - Th1G.4
 Schatz, Richard J. - M1I.2, M1I.4,
 Th3B.1, W2A.19
 Schlangen, Sebastian - Th1K.6
 Schmalen, Laurent - M3C.1
 Schmid, Rolf - W4E.3
 Schmidt, Christian - W4G.2, W4G.3
 Schmidtke, Hans-Juergen - Tu3E.4
 Schmidtke, Katharine - M1E
 Schmidt-Langhorst, Carsten - M1C.2,
 M3E.3
 Schmuck, Harald - M1B.3, Th1E.3
 Schnabel, Florian - W3F.3
 Schrans, Thomas - Tu3K
 Schrenk, Bernhard - M1F.4, Th1A.4,
 Th3E.3, W1F.3, W2A.48, W4G.1
 Schröder, Jochen - M1G.2, M4G.2
 Schubert, Colja - M1C.2, M3E.3
 Schuh, Karsten - Tu2D.5, W1G.6,
 W2A.54
 Schulte, Patrick - M4E.3
 Schulz, Dominic - M1F.3
 Sciarra, Stefania - M4G.4
 Scotti, Filippo - M2G.2
 Searcy, Steven - Th1A.1, W2A.4
 Seconдини, Marco - W1G.5
 Seeds, Alwyn - M2G.3, Th2A.61,
 Th2A.69
 Seghilani, Mohamed - M2J.2
 Sehier, Philippe - M4C.1
 Seifried, Marc - M2D.3
 Sekiguchi, Shigeaki - Tu2A.4, W1I.2
 Semrau, Daniel - M3C.4, Th1C.3
 Seno, Kazuno - Th1J.3, W1E.2
 Seok, Tae Joon - Th1G.1
 Sepehrian, Hassan - Th2A.20, Tu2E.2,
 Tu2E.4
 Serafino, Giovanni - M2G.4
 Serrano, Aina - Th1G.6
 Sevillano, Pascual - M3A.6
 Sgambelluri, Andrea - M2A.2, M3A.7,
 M4A.3, Tu3D.12, W1D.4
 Shahkarami, Shahin - M3A.5
 Shaikh, Anees - Tu3H.1

Shamee, Bishara - Th3H.6, W2A.22,
 W3E.1
 Shamim, Md. Hosne Mobarok -
 Th2A.15
 Shams, Haymen - Th2A.61, Th2A.69
 Shang, Chen - W3F.2
 Shang, Jianming - Th2A.67
 Shang, Kuanping - Tu2A.6
 Shang, Yu - W4I.5
 Shao, Weidong - Th1B.6
 Shao, Yingjie - M3K.5
 Shapiro, Jeffrey H. - M3K.1
 Shariati, Behnam - M1A.1, M3A.1,
 Tu2I.7, W1D.4, W1G.1
 Shastri, Anujit - Tu2C.1
 Shchulin, Vitaly - M2D.3
 She, Qingya - Th2A.45
 Sheikh Zefreh, Mohammad - W4A.3
 Shekhar, Sudip - Tu2E.1
 Shelton, Alice - M1D.4
 Shemis, Mohamed - Th2A.15
 Shen, Chao - Th2A.15
 Shen, Gangxiang - M1G.4, M3J.3,
 Th1B.6, W2A.28
 Shen, Lei - Th2A.24, W4K.3
 Shen, Li - Th3C.4, Tu3A.6, Tu3B.6,
 W2A.14
 Shen, Shuyi - M2B.5, M2F.1, M3K.4,
 Th3G.7, Tu3J.2, W4B.3
 Shen, Wenqing - Th3B.5
 Shen, Yifan - W4B.5
 Shen, Yiwen - Tu3F.2, W2A.32
 Shepard, Kenneth - W2A.32
 Shevchenko, Nikita - M3C.4
 Shevchenko, Nikita A. - W2A.58
 Shi, Chen - Th2A.38
 Shi, Jianyang - M2C.3, W1J.5,
 W2A.44, W4G.6
 Shi, Jin - M2K.3
 Shi, Jingbo - Tu2C.4
 Shi, Jin-Wei - M2D.7, Th3G.6, W1I.5
 Shi, Kai - Tu2D.4, W1C.3
 Shi, Meng - M3K.3
 Shi, Mengyue - M1H.4
 Shi, Sheping - M2C.3
 Shi, Tuo - M3F.4
 Shi, Wei - Th2A.20, Th3G.3, Tu2E.2,
 Tu2E.4, W1I.3
 Shi, Yuechun - M4H.4
 Shiao, Yhi - W4I.3

Shieh, William - Th1F.1, Tu2C.7,
 W4E.4
 Shiino, Masato - Th1K.2, Tu3B.1
 Shikama, Kota - M2D.2, W1A.1,
 W1A.7
 Shimakawa, Osamu - W1A.5
 Shimazu, Takayuki - W1A.3, W1A.5
 Shin, Jang-Uk - Th1J.5
 Shin, Myungjin - Th2A.13
 Shinada, Satoshi - M3J.1, Th3H.2
 Shinohara, Susumu - Tu3G.3
 Shiraiwa, Masaki - M4A.2, Th2A.29,
 Tu3E.5
 Shiue, Ren-Jye - M3F.1
 Shobudani, Takahiro - Th3H.4
 Shoji, Yuya - M3I.3, Th3C.2
 Shoman, Hossam A. - Tu2E.1
 Shou, Guochu - Tu2G.4
 Shringarpure, Rahul - M2D.1
 Shtaif, Mark - Tu2D.1, Tu2D.3, Tu2D.7,
 W3A.1
 Shu, Chester - W2A.15, W2A.55,
 W3D.5, W4D.5
 Shu, Haowen - Th2A.12
 Shum, Perry Ping - Th2A.6, W2A.13
 Sichkovsky, Vitalii - W3F.3
 Siddiqui, Muhammad Shuaib -
 Th2A.41
 Sidharthan, R. - M2J.4
 Sillard, Pierre - M4D.5, W3C.1, W4J.2
 Sillekens, Eric - M3C.4, Tu2D.4,
 W1B.4
 Silva Valdecasa, Guillermo - Th1A.3
 Simeonidou, Dimitra E. - M2A.3,
 M2A.6, M3A.2, M4I.4, Tu2G.2,
 Tu3D.13, W4F.5
 Simoff, Debra - W1K.1
 Simoyama, Takasi - W1I.2
 Simsarian, Jesse E. - Th2A.31
 Sinkin, Oleg V. - M4B, M4B.3, W1B.6
 Sinobad, Milan - M2J.3
 Siracusa, Domenico - Th1D.3, Th1D.4,
 Th2A.35, Th2A.42
 Sizer, Theodore - M3D, M4C
 Skafidas, Efstratios - M1F.2, M2K.6
 Sköldström, Pontus - Th1D.4
 Skvortcov, Pavel - W3D.3
 Slovak, Juraj - W4A.1
 Slyne, Frank - Th2A.49, Tu3D.4
 Smirnov, Yuri - Tu2F.4
 Smith, Brian - M1A.3

Smith, Kevin - M1E.4
 Smolders, Bart - M4J.2
 Snyder, Brad - Tu2A.1, Tu2A.3, W1I.1
 Soares, Francisco M. - M3F.3
 Sobu, Yohei - W1I.2
 Soma, Daiki - M2A.5, Th1K.3, W4C.1
 Sone, Kyosuke - M2B.6, Tu3L.4,
 Tu3L.5
 Song, Binhuang - W2A.50
 Song, Chunying - Th1I.4, Th1I.5
 Song, Hao - Tu2I.4, Tu2I.5
 Song, Haoqian - Tu2I.4, Tu2I.5
 Song, Jiongtae - W2A.27
 Song, Tianyu - W2A.63
 Song, Tingting - M3K.6
 Song, Xiaolu - Th3C.1
 Song, Yingxiong - M1B.8, M2C.5
 Soref, Richard A. - Th2A.10, Th2A.7
 Sorel, Marc - Th2A.44, Th3H.1
 Sorianello, Vito - M2G.4, W2A.31
 Sorin, Fabien - Tu2J.6
 Soudris, Dimitrios - W2A.49
 Sowalem, Mohammed - W2A.16,
 W4E.5, W4E.7
 Spälter, Stefan - M1A.6
 Spatharakis, Christos - W2A.49
 Spiga, Silvia - M1I.2, M1I.4, W1F.1
 Squitieri, Vincent - M4J.3
 Srinivasan, Ashwyn - W1I.1, W2A.16,
 W4D.4
 Sriram, Sriram - M2I.5
 Stampolidis, Leontios - M2G.5
 Stanton, Eric - Th1I.3
 Stark, Andrew - Th2A.68
 Starodubov, Dmitry - Tu2I.4, W2A.22,
 W2A.34
 Steiner, Fabian - M4E.3
 Stenger, Vincent - M2I.5
 Stephens, Marc F. - W3D.4
 St-Laurent, Stephane - Tu3D.9
 Stojanović, Nebojša - W2A.60
 Stojanovic, Vladimir - Th1G.1, W1I.4
 Stone, Christopher - M4B.5
 Stone, Jeff - W2A.3, W3C.2
 Stracca, Stefano - Th1G.6
 Straub, Michael - Th2A.55
 Straw, Andrew - W2A.29
 Sturniolo, Alessandro - M1F.5, Tu2I.2
 Su, Tzung-I - M3F.4, W4D.6
 Su, Xiaofei - M2F.7
 Su, Xinzhou - W2A.24





Su, Yikai - Th2A.10, Th2A.7, Tu2J.5
 Su, Zhan - M3F.1
 Suda, Satoshi - M4H.2, Tu2G.5
 Sudharsanan, Srinivasan - Th1I.2
 Sudo, Makoto - Th3H.4
 Sugama, Akio - W1I.2
 Sugimoto, Yoshiyuki - Tu2B.2
 Sugitani, Kiichi - Tu3C.2
 Sugiyama, Hidetsugu - Th2A.29
 Sugizaki, Ryuichi - M3E.4, Th1K.2, Tu3B.1
 Sumita, Seiya - M2A.5, W4C.1
 Sun, Chen - Th1G.1, W1I.4
 Sun, Chuanbown - Tu2C.7, W4E.4
 Sun, Fei - Tu3A.5
 Sun, Qizhen - W2A.12
 Sun, Shihao - W2A.2
 Sun, Weiqiang - Th2A.36
 Sun, Xiao - Tu2A.3
 Sun, Xueting - Th2A.24
 Sun, Yujia - W3E.2
 Sunada, Satoshi - Tu3G.3
 Sung, Minkyu - Tu3J.3, W4B.4
 Sutters, Andrew - Th3A.2
 Suzuki, Keijiro - M4H.2, Th3H.5, Tu2A.4, Tu3A.4
 Suzuki, Ken-Ichi - Tu3L, Tu3L.1
 Suzuki, Kenya - Th1J.3, W1E.2
 Suzuki, Masaki - Th3H.4
 Suzuki, Masato - Tu3B.5
 Suzuki, Masatoshi - Tu3J.5
 Suzuki, Naoki - M3B, M3B.2
 Suzuki, Takahiro - Tu3L.2, Tu3L.6
 Svensson, Tommy - Th2A.40
 Syed, Sharfuddin - Tu3D.3
 Syriogs, Ilias - Tu3D.14, W1C.1
 Syriovelis, Dimitris - Tu3D.14, W1C.1
 Syvridis, Dimitris - Tu2I.7
 Szelag, Bertrand - Tu3K.4
 Szriftgiser, Pascal - Th3D.5
 Szyrkowiec, Thomas - Th2A.35, W4F.6

T

Tabares, Jeison - M2B.7
 Tafur Monroy, Idelfonso - M1I.5, Th1A.3, W1F.7, W2A.47
 Taira, Yoichi - M3G, M4F
 Tajima, Akio - M3I.1
 Tajima, Kazuyuki - W4A.4
 Tajima, Tsutomu - W4F.3
 Takabayashi, Kazumasa - Tu2A.4

Takada, Atsushi - M3E.4
 Takagi, Shinichi - Th3C.5, Tu3K.3
 Takahara, Tomoo - W2A.47
 Takahashi, Hidenori - Th1K.2
 Takahashi, Masanori - Tu3A.4
 Takahashi, Shigeki - Tu3K.3
 Takasaka, Shigehiro - M3E.4, Th1K.2
 Takeda, Koji - M2D.5, Th3B.2, Tu3K.2, W1A.7, W3F.4
 Takefusa, Atsuko - Tu3D.7
 Takenaga, Katsuhiko - Th2A.22
 Takenaka, Mitsuru - Th3C.5, Tu3K.3
 Takenouchi, Hirokazu - M3E.2, M3E.4, Th3E.4
 Takeshita, Hitoshi - M3I.1, M3J.5
 Takita, Yutaka - W4A.4
 Tam, Hwa-Yaw - W1K.6
 Tamura, Kohichi - Th3B.3
 Tamura, Yoshiaki - M4B.1
 Tan, Acai - M1B.8
 Tan, Dawn T. - M3I.2, Th2A.11
 Tan, Fengze - W1K.6
 Tan, Mingming - Th1C.2, Th1C.3, W3D.3
 Tan, Zhongwei - Tu3L.3
 Tanaka, Kazuki - Tu3J.5
 Tanaka, Keiji - Tu2B.2
 Tanaka, Masaki - Th2A.29
 Tanaka, Shigehisa - Th3B.3
 Tanaka, Shinsuke - W1I.2
 Tanaka, Yu - W1I.2
 Tang, Fengxian - M3J.3
 Tang, Jianming - W2A.33
 Tang, Ming - M1I.2, M1I.4, M2F.5, Tu3B.6, W2A.14, W2A.19, W2A.38, W2A.7, W4C.4
 Tang, Pengcheng - Tu3D.11
 Tang, Rui - W1E.3
 Tang, Weijie - Th1J.4
 Tang, Xizi - W2A.62
 Tang, Yinan - W2A.18
 Tangdiongga, Eduward - M1F.6, M4J.2, Th2A.57
 Taniguchi, Hiroki - Th1F.3, W2A.52
 Tanimura, Takahito - M3E.3, Tu3E.3, W2A.47
 Tanizawa, Ken - Th3H.5, Tu2A.4, Tu2G.5
 Tanzi, Alberto - M1A.3
 Tao, Zhenning - M2F.6, M2F.7, Th2A.12

Tasbihi, Amir - W2A.61
 Tatarczak, Anna - M1I.3
 Tatum, Jim - M1I.3, M3F.6
 Tavakoli, Farzan - M4J.6
 Taylor, Brian - Tu3E.4
 Teh, Min Yee - Tu3F.2
 Tekin, Tolga - Tu2B.1
 Teng, Min - Th2A.8
 Terada, Jun - Tu3L.4
 Terai, H - M3G.4
 Terayama, Masaki - M3C.5, M4B.2, Th1F.2
 Tessema, Netsanet - M4J.2
 Testa, Francesco - Th1G.6
 Theodoropoulos, Dimitris - Tu3D.14, W1C.1
 Thévenaz, Luc - W1K.4
 Thiessen, Torrey - Tu3K.4
 Thomas, Varghese A. - M1I.6
 Thomsen, Benn C. - Tu2D.4, W1C.3
 Thorsten, Wahlbrink - M4H.6
 Thottan, Marina - Th2A.31
 Tian, Huiping - W4B.3, W4G.7
 Tian, Yu - Tu3J.4, W4J.3
 Tibuleac, Sorin - Th1A, Th1A.1, Th1A.2, W1B.2, W2A.4
 Tien Dat, Pham - M4J.5, W1F.2, W1F.6
 Timens, Roelof Bernardus - Th2A.14
 Timurdogan, Erman - M3F.1
 Tin, Komljenovic - Th1I.2
 Toccafondo, Veronica - Th3H.1
 Toifl, Thomas - M2D.3
 Tomkos, Ioannis - M1A.1, Th1D.4, Tu2I.7
 Tomomatsu, Yasunori - Th3H.4
 Tomonaga, Hiroshi - W4A.4
 Tondini, Stefano - Th1G.6
 Toney, James - M2I.5
 Tong, Michel - M3D.3
 Tong, Weijun - M1I.2, M1I.4, Tu3B.6, W2A.13, W2A.14, W2A.19, W2A.7, W3C.5
 Tong, Yeyu - W4D.3, W4D.5
 Torfs, Guy - M1I.2, M1I.4, W1F.1, W2A.19, W4D.4
 Tornatore, Massimo - M3A.5, M3J.2, M4I.3, W1D.2
 Torrenco, Enrico - W4A.1
 Touch, Joseph - W2A.22, W3E.1
 Townsend, Paul D. - Th1E.3

Tran, N.C. - Th2A.57
 Traverso, Matt - Tu2C.6
 Tremblay, Christine - M1A.5, M3A.3
 Trillo, Stefano - Th3D.5
 Trinel, Jean-Baptiste - Tu3B.2
 Trinidad, Ailee - M4J.2
 Troia, Sebastian - Tu3D.15
 Tsai, Cheng-Ting - Tu2I.1
 Tsai, Wen-Shing - M1F.1, Tu2I.3
 Tsakyridis, Apostolos - W2A.39
 Tsang, Hon Ki - W4D.3, W4D.5
 Tse, Kathleen - M2E.1
 Tse, Simon - Tu3H.2
 Tseng, Chin-Hao - Th3G.4
 Tseng, Kuo-Feng - W1I.5
 Tsuchizawa, Tai - Th3B.2, W3F.4
 Tsuda, Hiroyuki - Th3H.4, Tu2A
 Tsujikawa, Kyozo - Th2A.27
 Tsukamoto, Masayoshi - Tu3B.1
 Tsuritani, Takehiro - M2A.5, M4A.2, Th1K.2, Th1K.3, Th2A.29, W4C.1
 Tu, Jiajing - W1K.6
 Tu, Xin - Th1J.1
 Tulino, Antonia M. - Th3D.3
 Tünnermann, Andreas - M2J.1
 Tur, Moshe - Th3H.6, Tu2I.4, Tu2I.5, Tu2J.1, W2A.22, W2A.34, W3E.1
 Turkiewicz, Jarek - M2D.3
 Turukhin, Alexey V. - Th1C.1, W1B.6
 Tzanakaki, Anna - M2A.3, M4I.4

U

Ubaldi, Fabio - M2A.2
 Udalcovs, Aleksejs - M1I.2, M1I.4, Th2A.51, W2A.19
 Ueda, Koh - Th3H.5
 Uehara, Fumiya - W1A.3, W1A.5
 Uetake, Ayahito - Tu2A.4
 Ujikawa, Hirotaka - Tu3L.7
 Umeki, Takeshi - M3E.2, M3E.4, Th3E.4
 Umezawa, Toshimasa - M3K.7
 Urban, Patryk - W1F.4
 Usuga, Mario A. - M4D.4
 Uvarov, Alexander - M4B.6

V

Vaernewyck, Renato - W4D.4
 Vagionas, Chris - W2A.39
 Vahala, Kerry J. - Th1I.3

Valcarengi, Luca - Th1B.2, Th2A.30
 Van Campenhout, Joris - Th1G.5, Th2A.1, Tu2A.1, Tu2A.3, W1I.1, W2A.16, W4D.4
 Van Der Heide, Sjoerd P. - M1C.4
 Van Kerrebrouck, Joris - M1I.2, M1I.4, W1F.1, W2A.19, W4D.4
 Van Ras, Dennis - M4D.5
 Van Steenberge, Geert - M1I.2, M1I.4, Tu2A.1
 Van Veen, Dora - M1B.3, Th1E.3
 Van Weerdenburg, John - M4G.5, W1G.2, W4C.2
 Van Zantvoort, Johan - M4J.2
 Vaquero Caballero, Francisco Javier - M2F.4, Tu3E.2
 Varvarigos, Emmanouel - M3A.7, M4A.3, Th2A.34
 Vassilieva, Olga - Tu3G.1, W1D.3, W1F.7
 Veisllari, Raimena - M4I.2
 Vela, Alba P. - W1D.5, W1G.1
 Velasco, Luis - M3A.1, Th2A.28, Tu3D.12, Tu3D.5, W1D.4, W1D.5, W1G.1, W4F.7
 Velásquez Micolta, Juan Camilo - M3B.4
 Velha, Philippe - M4H.3, Th1G.6
 Verbist, Jochem - W4D.4
 Vercesi, Valeria - M2G.3
 Verchere, Dominique - Th2A.46
 Verheyen, Peter - Tu2A.3, W1I.1
 Verplaetse, Michiel - W2A.19, W4D.4
 Vijayan, Kovendhan - M4G.2
 Vilalta, Ricard - M2A.4, M2A.5, M3A.6, Tu3D.11, Tu3D.8
 Vilchez, Javier - M1A.7
 Villaça, Rodolfo D. - Tu3D.13
 Villafani Caballero, Diego Rodrigo - W1F.4
 Villafranca, Asier - M3A.6
 Vincent, Robert J. - M2E.2
 Vivien, Laurent - Th1G.5
 Volet, Nicolas - Th1I.3
 Vollrath, Fritz - W1K.4
 Von Der Weid, Jean P. - M1H.2, W1F.4
 Vyncke, Arno - W4D.4



W

Wada, Naoya - M3J.1, M4A.2, Th2A.29, Th3H.2, Tu3B.3, Tu3E.5, W4C.3
 Wade, Jerome K. - M3F.6
 Wade, Mark - Th1G.1, W1I.4
 Wakayama, Yuta - M2A.5, Th1K.3, W4C.1
 Waki, Masaki - W2A.1
 Wakita, Hitoshi - Th3E.4
 Waleed, Syed - W2A.26
 Walker, Rob - M2G.5
 Walkowiak, Krzysztof - Tu2F.2
 Walsh, Anthony J. - W2A.35
 Walter, Edward A. - M4I.1
 Wang, Andong - M4D.2, Th3C.4, W3D.2, W4C.4
 Wang, Bc - W2A.6
 Wang, Bingnan - Th2A.8
 Wang, Binhao - M1I.7
 Wang, Biwei - Th2A.66
 Wang, Can - M4J.4
 Wang, Cen - W1C.4
 Wang, Chih-Lin - M2D.7, W2A.43
 Wang, Chong - M1E.3
 Wang, Daoyi - Th2A.56
 Wang, Ding - M1E.3, M4B.3
 Wang, Fumin - M3K.3
 Wang, Gencheng - M4H.5
 Wang, Hsiao-Lun - W1I.6
 Wang, Hsiu-Che - M1E.3
 Wang, Huai-Yung - Tu2I.1
 Wang, Hy - W2A.6
 Wang, Imbert - W1I.4
 Wang, Jian - M4D.2, Th2A.9, Th3C.4, Tu3A.6, W2A.24, W3D.2, W4C.4, W4K.2, W4K.4
 Wang, Jianjun - W2A.2
 Wang, Jiawei - W2A.10
 Wang, Jing - M4C.2, Th3G.7, Tu2K.2
 Wang, Jun - W2A.11
 Wang, Juncheng - Tu2C.4
 Wang, Kaihui - M2C.3, M4J.4, M4J.7, Th2A.60
 Wang, Ke - M1F.2, M2K.6, M2K.8, M3K.6
 Wang, Lei - M3I.6
 Wang, Liang - Th2A.66, W2A.15, W2A.7
 Wang, Liqian - Th2A.38
 Wang, Lixian - M4J.6

Wang, Luhan - Tu3D.1
 Wang, Lulu - M4D.2, Th3C.4, Tu3A.6, W3D.2, W4C.4
 Wang, Min - M1B.8
 Wang, Nannan - W1D.1
 Wang, Ning - Th1B.6, W4J.2
 Wang, Qibing - W2A.50
 Wang, Rui - M3A.2, W4F.5
 Wang, Ruoxu - W2A.38
 Wang, Sc - W2A.6
 Wang, Shih-Yuan - W1I.7
 Wang, Shuai - M4G.3, Th2A.26
 Wang, Tingyun - W2A.10
 Wang, Wei - M4I.3, Th3F.3
 Wang, Wei-Chun - Tu2I.1
 Wang, Xi - W1D.1, W1D.3
 Wang, Xianqiao - W1K.5
 Wang, Xiaodong - Th2A.10
 Wang, Xiaolong - W2A.2
 Wang, Xingjun - Th2A.12
 Wang, Yaguo - M2I.2
 Wang, Ye - Tu3C.5
 Wang, Yi - M1E.3
 Wang, Yixin - M4G.1
 Wang, Yong - M2D.1
 Wang, Yuan - Tu2J.2
 Wang, Yuehai - M4H.5
 Wang, Yun - M3I.7, W4D.1
 Wang, Yun-Chieh - M1F.1, Tu2I.3
 Wang, Yuying - W2A.2
 Wang, Zheng - M1H.3
 Wang, Zinan - W2A.8
 Wang, Ziyu - Tu3L.3
 Waqas, Abi - M3I.4
 Ware, Cédric - W4I.4
 Watanabe, Shigeki - M3E.3, Tu3E.3
 Watanabe, Tatsuhiko - M2I.1, M3G.2, Th3G.1
 Waterhouse, Rod - W1F, W4B.1
 Watts, Mark T. - Tu2K.4
 Watts, Michael R. - M3F.1
 Webber, John - Th1I.4
 Webster, Mark - Tu2C.6
 Wei, Chen - M1G.4
 Wei, Chia-Chien - M2D.7, W2A.43, W4G.5
 Wei, Jinlong - W2A.60
 Wei, Liang-Yu - M3K.2
 Wei, Yuming - Th1J.1
 Weidner, Kenneth - W1B.3
 Weiershausen, Werner - Tu2G

Weiner, Andrew - Th3G.6
 Weiss, Jonas - M2D.6
 Weisser, Stefan - W1B.5
 Wen, He - W4J.2
 Wen, Yangjing - W1J.1
 Westbergh, Petter - M3F.6
 Westbrook, Paul - W1K.1
 Westergren, Urban - W2A.19
 Wetzell, Benjamin - M4G.4
 Wey, Jun Shan - M1B.4, M1B.7, M2B.3, Tu2G.3
 White, Catherine - M2A.6
 White, Ian - Th2A.69
 Wilke Berenguer, Pablo - M1C.2, M1F.3
 Wilkinson, Peter - Th1J.2, Th2A.43
 Williams, Christopher - M2D.1
 Williams, Hugh - W1C.3
 Williams, Richard - W4A.2
 Willinger, Amnon - W3F.3
 Willner, Alan E. - Th3H.6, Tu2I.4, Tu2I.5, Tu2J.1, W2A.22, W2A.34, W3E.1, W3E.5
 Wilmart, Quentin - Tu2A.5
 Winzer, Georg - M2G.5
 Winzer, Peter J. - Th1F.4, Tu2D.1, W4E.6
 Wise, Frank W. - Th3D.2
 Withford, Michael - W4C.2
 Wohlfeil, Benjamin - Th2A.19
 Wohlgemuth, Eyal - M1C.6
 Wolf, Stefan - W4E.3
 Wolinski, Tomasz - W2A.13
 Wong, Elaine - M1B, M1F.2, M2K.6, M2K.8, M3K.6
 Wosinska, Lena - M1A.5, Th2A.42
 Wright, Paul - Th2A.43, Tu2G.2, W2A.29
 Wu, Han - W2A.8
 Wu, Hongchao - W1K.1
 Wu, Huan - W2A.15
 Wu, Jian - W1C.4, W2A.18, W4E.5
 Wu, Meng Chyi - Th2A.18
 Wu, Ming - Th1G.1
 Wu, Qiong - W2A.38
 Wu, Ruihuan - Th2A.67, W4B.5
 Wu, Shipeng - M1E.4
 Wu, Shuangyuan - M1E.4
 Wu, Weike - Th1J.4
 Wu, Xinru - W4D.3, W4D.5
 Wu, Xiong - W1J.8

Wu, Yizhen - W2A.25
 Wu, Zhongying - M2E.5, M4D.1, W2A.17, W4J.3, W4K.3
 Wun, Jhih-Min - Th3G.6
 Wurz, Marc C. - Th1K.6

X

Xia, Bin - W4A.5
 Xia, Cen - Th1K.5
 Xia, Yan - M2C.3
 Xiang, Meng - M1B.5, M2C.7, Tu2C.2, W1J.3
 Xiao, Hai - W2A.10
 Xiao, Hongyun - W4I.2
 Xiao, Rulei - M4H.4
 Xiao, Shilin - M1I.2, Th2A.51
 Xiao, Xi - M3I.6
 Xiao, Xin - M1B.7, M2C.3
 Xie, Changsong - M4B.5, W2A.60
 Xie, Chenhui - Th2A.59
 Xie, Chongjin - M1I
 Xie, Guodong - Th3H.6, Tu2I.4, Tu2I.5
 Xie, Qijie - W3D.5
 Xie, Weisheng - Th2A.45, W1D.1
 Xie, Zheng-Ting - W1I.5
 Xin, Haiyun - M1B.5, Tu2C.2
 Xin, Simon - M3F.1
 Xing, Chen - Tu3B.6
 Xing, Zhenping - M1B.5, M2C.7, Tu2C.2, W1J.3, W4D.1, W4E.5, W4E.7
 Xinhong, Jiang - Th2A.7, Th3C.1, Tu2J.5
 Xinlun, Xinlun - Th3H.1
 Xomalis, Angelos - Tu2J.3
 Xu, Bingxin - M4G.3
 Xu, Cheng - W4B.5
 Xu, Dan-Xia - M3I.4
 Xu, Jing - Th2A.6
 Xu, Li - W1K.5
 Xu, Luhua - M3I.7
 Xu, Mu - M2B.5, M2F.1, M3K.4, Th2A.48, Th3G.7, Tu2K.2, Tu3J.2, Tu3J.7, W1J.7
 Xu, Pan - W2A.11
 Xu, Pushui - Th1A.5
 Xu, Sugang - M4A.2, Th2A.29
 Xu, Tianhua - Tu2D.4, W1J.6, W2A.58
 Xu, Xian - W1B.3
 Xu, Xiaochuan - M2I.2
 Xu, Xiaofei - Tu2D.6, W2A.63

Xu, Yanping - Tu2J.2
 Xu, Yelong - Th3G.3, W1I.3
 Xu, Yuxin - Th2A.47
 Xu, Zhaopeng - Tu3L.3
 Xu, Zhenzhen - Tu2J.5
 Xu, Zhilin - W2A.13
 Xue, Junli - Tu2G.4
 Xue, Lei - M2B.2, M2B.4, M3B.3, W2A.46

Y

Yakabe, Sho - W1A.3
 Yakuno, Masahiro - M3G.4
 Yamada, Toshishige - W1I.7
 Yamaguchi, Keita - Th1J.3
 Yamaguchi, Ryusuke - M3I.3
 Yamamoto, Naokatsu - M3K.7, M4J.5, W1F.2
 Yamamoto, Shuto - Th1F.3, W2A.52
 Yamamoto, Yoshinori - Tu3B.5
 Yaman, Fatih - M1G.3
 Yamanaka, Naoaki - Tu3D.6
 Yamanaka, Yusuke - M4J.1
 Yamasaki, Shintaro - Tu3A.4
 Yamashita, Taro - M3G.4
 Yamauchi, Tomohiro - M2F.6, W2A.47
 Yamazaki, Etsushi - Th1C.4
 Yamazaki, Hiroshi - M1C.3, Th3E.4
 Yan, Boyuan - Th3F.3
 Yan, Fu L. - W2A.23
 Yan, Hai - M2I.2
 Yan, Haozhe - M2E.5
 Yan, Jhih-Heng - Th2A.18, Th2A.63, Th3G.4, Tu3J.7
 Yan, Kerong - W4A.5
 Yan, Li - Th2A.47
 Yan, Ming - W2A.10
 Yan, Shengyong - Th1J.1
 Yan, Shuangyi - M3A.2, W4F.5
 Yan, Zhijun - W2A.12
 Yanagi, Shuichi - W1A.1
 Yanagimachi, Shigeyuki - M3I.1
 Yang, Benjamin - Th2A.68
 Yang, Chao - Th2A.59
 Yang, Chen - Tu3B.6, W2A.14, W3C.5
 Yang, Chuanchuan - Tu3L.3
 Yang, Haining - Th1J.2, Th2A.43
 Yang, Hui - W2A.25, W4I.2
 Yang, Jianyi - M4H.5
 Yang, Ki Youl - Th1I.3
 Yang, Ling-Gang - W1I.5



Yang, Mingwei - Th1D.2, W2A.21
 Yang, Qi - M3B.3, M3C, Th2A.59
 Yang, Qi-Fan - Th11.3
 Yang, Shenzhen - W1C.4
 Yang, Yuxing - Tu2J.5
 Yankov, Metodi P. - M4E.3, W2A.59, W3A.3, W3E.3
 Yao, Jianping - M1H.1, M1H.5, W2A.37
 Yao, Tingyu - Tu2C.4
 Yao, Yao - Th3G.5
 Yasuda, Takuma - M3J.6
 Ye, Tong - Th2A.12
 Ye, Xingwei - Th3G.5
 Yeh, Chien-Hung - M2K.2, M3K.2
 Yekani, Amin - Tu2E.2
 Yi, Lilin - M1B.5, M1H.4, M2B.2, M2B.4, M3B.3, Th1E, Tu2C.2, W2A.46, W2A.9
 Yi, Lin - Tu3D.8
 Yi, Xingwen - M2C.5
 Yi, Xu - Th11.3
 Yilmaz, Omer F. - Tu3D.9
 Yin, Bozhi - Tu2C.4
 Yin, Shan - Th2A.37
 Yin, Shuang - Th2A.56
 Yin, Xin - M11.2, M11.4, W1F.1, W2A.19, W4D.4
 Yin, Yongjia - M1B.8
 Ying, Hao - M2C.5
 Ynoquio Herrera, Luis Ernesto - M1H.2, W1F.4
 Yoffe, Yaron - M1C.6, Th3E.1
 Yokochi, Toshihisa - W1A.5
 Yoneyama, Akira - M2K.7
 Yoo, S. J. Ben - M4J.3, Tu2A.6, Tu3A.3, W2A.45, W4F.2, W4F.7
 Yoo, Seongwoo - M2J.4
 Yoshida, Masato - M3C.5, M4B.2, M4G.1, Th1F.2, Th3E.2
 Yoshida, Setsuo - M3J.8, Tu3L.5
 Yoshida, Sota - Th2A.29
 Yoshida, Tomoya - M4F.3, Tu2A.2
 Yoshida, Tsuyoshi - M1G.2, M2C.4, M4E.2, M4E.5
 Yoshida, Yuki - Tu2K.1
 Yoshii, Hitoshi - Tu3B.5
 Yoshikane, Noboru - M2A.5, M2E, M4A.2, Th2A.29
 Yoshimatsu, Toshihide - W4D.2
 Yoshino, Manabu - Tu3L.1

Yoshioka, Kazuaki - Th1K.2
 Yoshizawa, Katsumi - Th3H.4
 Youn, Chun Ju - Th2A.5, Tu2B.3
 Yousefi, Reza - M2D.1
 Yu, Ao - W4I.2
 Yu, Byung-Min - Th2A.13
 Yu, Changyuan - Th2A.66, W1K.6
 Yu, Hui - M4H.5
 Yu, Jiakai - Th1B.5
 Yu, Jianjun - M1B.4, M1B.7, M2B.3, M2C.3, M4J.4, M4J.7, Th2A.60, W1J.5, W2A.44, W4G.6
 Yu, Jinyi - W4J.3, W4K.3
 Yu, Juan - W2A.2
 Yu, Kunzhi - M11.7, Th3B.5
 Yu, Min - W4G.5
 Yu, Siyuan - Th3H.1, W1J.8, W4C.4
 Yu, Song - Th2A.67
 Yu, Sun Keun - Th2A.53
 Yu, Xiaosong - Th3F.3
 Yu, Xin - W11.6
 Yu, Yonglin - W2A.35
 Yu, Yu - Th2A.6
 Yu, Yufang - M2E.5, Th2A.50, W2A.17
 Yuan, Hui - M3J.4, W1C.2
 Yuan, Lihua - M4A.1

Z

Zach, Shlomo - Th3H.6, W2A.34
 Zakharian, Aramais - W3C.2
 Zami, Thierry - M1A.2, Tu2F.3, W1B.5, W4A.6
 Zanette, Kristian - Th2A.17
 Zanetto, Francesco - W2A.41
 Zečević, Nikola - Th1G.6
 Zeng, Huaiyu - M3B.6
 Zeng, Tao - M3B.3
 Zervas, Georgios - M3J.4, Tu3D.14, W1C.1, W1C.2
 Zhan, Huan - W2A.2
 Zhan, Xk - W2A.6
 Zhang, Bohan - W11.4
 Zhang, Chong - M11.7, Th3B.5
 Zhang, Chunhui - Th1J.1
 Zhang, Chunshu - Th1J.1
 Zhang, Fan - Tu2D.2, Tu3L.3
 Zhang, Fangyuan - W1J.3
 Zhang, Fangzheng - Th3G.5
 Zhang, Hongbin - Th1A.6
 Zhang, Hongxia - Th2A.7, Th3C.1
 Zhang, Huanlin - M1E.3

Zhang, Huijian - M1G.5
 Zhang, Jiawei - M2E.3
 Zhang, Jie - M4I.3, Th2A.23, Th3F.3, W2A.25, W4B.5, W4I.2
 Zhang, Jing - M2C.5
 Zhang, Jinrun - Th3C.4, W4K.2
 Zhang, Junfeng J. - M1G.4
 Zhang, Junwei - W1J.8
 Zhang, Junwen - M1B.4, M1B.7, M2B.3, M2C.3, Tu2G.3, W1J.5, W2A.44, W4G.6
 Zhang, Kaiqi - M4J.3, W2A.45, W4F.7
 Zhang, Ke - M2F.7
 Zhang, Kuo - M1B.5, Tu2C.2, Tu2I.6, W1J.3, W4E.5
 Zhang, Lei - Th2A.24
 Zhang, Li - W2A.9
 Zhang, Liang - Tu2J.2, W2A.60
 Zhang, Lihua - W2A.2
 Zhang, Lin - Tu2J.1
 Zhang, Lu - M11.2, M11.4, Th2A.51, W2A.19
 Zhang, Mengruo - W1E.5
 Zhang, Minming - Tu3A.1
 Zhang, Naichuan - W4D.6
 Zhang, Ning - M3F.4, Th2A.44, Th3H.1
 Zhang, Qi - W2A.44, W4G.6
 Zhang, Qiang - Tu3G.2, W2A.60
 Zhang, Qianwu - M1B.8, Th1K.1
 Zhang, Qiong - W1D, W1D.1, W1D.3
 Zhang, Qiulin - W2A.55
 Zhang, Qun - Th2A.21
 Zhang, Runzhou - Tu2I.4, Tu2I.5
 Zhang, Sen - Tu2D.6, W2A.63
 Zhang, Shaoliang - M1G.3, M4E.4, W4F.3
 Zhang, Tao - Th2A.56
 Zhang, Tiantian - W2A.62
 Zhang, Weifeng - M1H.1, M1H.5
 Zhang, Xiaobei - W2A.10
 Zhang, Xinliang - Th2A.6
 Zhang, Yanbing - M4G.4
 Zhang, Yichi - M2J.5, M4D.1, W4J.3
 Zhang, Ying - Th3G.5
 Zhang, Yong - Th2A.10, Th2A.7, Th3C.1, Tu2J.5
 Zhang, Yu - Tu2A.6
 Zhang, Yuguang - M3I.6
 Zhang, Yun - W2A.44, W4G.6
 Zhang, Yunhao - Tu2I.6

Zhang, Yunquan - W4I.5
 Zhang, Zhenshan - W2A.62
 Zhang, Zhenzhen - M4D.1
 Zhao, Fei - Th1J.1
 Zhao, Jialin - Th2A.14
 Zhao, Jian - M2K.4
 Zhao, Li - Th2A.60
 Zhao, Mingming - M2K.1, M4J.4
 Zhao, Ning - Th3C.1
 Zhao, Tianyi - M2A.1
 Zhao, Xiangjun - Th2A.56
 Zhao, Yifan - W2A.24, W4K.2
 Zhao, Yong - M4H.4
 Zhao, Yongli - M4I.3, Th2A.23, Th3F.3
 Zhao, Yongpeng - Tu2B
 Zhao, Zhe - Th3H.6, Tu2I.4, Tu2I.5
 Zhao, Zhiyong - W2A.15, W2A.7
 Zheludev, Nikolay I. - Tu2J.3
 Zheng, Bofang - W3D.5
 Zheng, Haomian - Tu3D.8
 Zheng, Haowei - W2A.25
 Zheng, Jun - M1E.3
 Zheng, Shuang - Th2A.9, Th3C.4, Tu3A.6
 Zheng, Xiaoping - M2E.5, M2E.6, Th2A.50, W2A.17
 Zheng, Ziyuan - Tu3L.3
 Zhong, Zhizhen - M2E.5, Th2A.50, W2A.17
 Zhou, Bingkun - M2E.6, Th2A.50, W2A.17
 Zhou, Ji - W2A.62
 Zhou, Jianying - Th2A.21
 Zhou, Lei - W4G.5
 Zhou, Muqing - M2J.5
 Zhou, Qi - M2B.5
 Zhou, Wei - M4D.2, W2A.24
 Zhou, Wen - M4J.4, M4J.7, Th2A.60, W4D.3
 Zhou, Yang - M4J.1
 Zhou, Yu - W4I.5
 Zhou, Yu Rong - M1E.4
 Zhou, Zhiping - Th1
 Zhu, Benyuan - M2C.3
 Zhu, Chen - M1C.5
 Zhu, Daiyin - Th3G.5
 Zhu, Guoxuan - W4C.4
 Zhu, Jiangbo - Th3H.1
 Zhu, Jinglong - M4D.1, W4J.3, W4K.3
 Zhu, Long - Th3C.4, W3D.2, W4C.4
 Zhu, Mingyue - M2C.5

Zhu, Qingming - Th3C.1
 Zhu, Shengxiang - Th1D.2
 Zhu, Xin - M3K.3
 Zhu, Yanjun - W2A.42
 Zhu, Yixiao - Tu2D.2
 Zhu, Zihang - M4J.4, Th2A.60
 Zhu, Ziyi - Tu3F.2, Tu3F.3, W2A.32
 Zhu, Zuqing - Th2A.39, Th3F.2, W4F.1, W4F.2, W4F.7
 Zhuge, Qunbi - M1B.5, M2F.4, Tu2C.2, W1J, W1J.3, W4E.5, W4E.7
 Zibar, Darko - M11.5, W2A.59
 Zimmermann, Horst - Th1G.6
 Zimmermann, Lars - M2G.5, Th2A.13, Th2A.19, W3E.4
 Ziyadi, Morteza - W2A.22
 Zoldak, Martin - M2D.3
 Zou, Jim (Shihuan) - W2A.29
 Zou, Kaiheng - Tu2I.4, Tu2J.1
 Zuo, Tianjian - Tu2D.6, W2A.63
 Zussman, Gil - Th1B.4



