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This program contains the latest information up to 21 January 2020.

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 and access individual papers.

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

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OFC thanks the following corporate sponsors for their generous support:

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- ACACIA
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- Cisco
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OFC thanks the following media partners:
Make Our Community Your Community!

Join Now and Save 50% on Membership Dues!

The IEEE Communications Society (IEEE ComSoc) is a global network of 25,000+ engineers, practitioners and academics working together to advance communications technology for the betterment of humanity.

Benefits of a ComSoc Membership:
- Networking with Communications Technology Professionals Around the World
- Generous Conference Discounts
- Free Subscriptions to High-quality Technology Publications
- Top-notch Training and Continuing Education Resources
- Exciting Volunteer Opportunities

IEEE COMSOC TRAINING OPTIONS

We offer high-quality communications technology training by world-class industry experts. Courses are taught live, online and cover a wider range of topics from optical to 5G. Members receive discounts on all courses.

Discounts are also available for group purchases of 8 or more course seats. Plus, you can arrange for customized training to match the unique needs of your team. Contact Tara Gallus at t.gallus@comsoc.org to learn more.

Visit www.comsoc.org/training to view the full course schedule and join our email list to receive alerts for upcoming courses.

Stop by the ComSoc Booth #2839 and visit www.comsoc.org/membership for more information or to join.
Welcome to the 2020 Optical Fiber Communication Conference and Exhibition

On behalf of the many individuals, including countless volunteers who have organized OFC 2020, 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 visionary speakers will present new insights into current innovations and future challenges in optical communications and networking as well as frontier scientific research. Qi Bi, president of China Telecom Technology Innovation Center and CTO of China Telecom Beijing Research Institute will talk about the development and future of 5G; Karsten Danzmann, director of the Max Planck Institute for Gravitational Physics, Germany, will explore the recent merging of traditional astrophysics with the detection of gravitational waves; and, Sir David Payne, director of the Optoelectronics Research Centre, Zepler Institute for Photonics and Nanoelectronics at the University of Southampton, U.K., will share his views on the future of silica as an optical material.

The 2020 conference provides an exceptionally strong technical program consisting of a portfolio of 59 short courses, 515 contributed and 100+ invited papers, 24 tutorial presentations, 9 workshops, and 8 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 Computecom.

The OFC Short Course program taught on Sunday and Monday 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.

The main emphasis of the OFC program is research and development that addresses longer-term issues in optical communications and networking. Monday’s technical sessions includes 19 live demonstrations and prototypes of collaborative research projects, pre-commercial products and proof-of-concept implementations presented in the OFC Demo Zone. The technical offerings include four symposia. On Monday the symposia presented includes Quantum Information Science and Technology (QIST) in the context of Optical Communications and ends with The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks. Tuesday’s symposia includes Emerging Network Architectures for 5G Edge Cloud. Wednesday’s symposia starts with the first session of Future Photonics Devices 100 Gbit Optical Networks Enabled by Emerging Optical Technologies which concludes on Thursday. On Tuesday evening organizers Chris Cole, Luminous Computing, USA; Dan Kuchta, IBM Research, USA facilitate the Rump Session, When Will Co-packaged Optics Replace Pluggable Modules in the Datacenter? Poster sessions will be held on Wednesday and Thursday, providing the opportunity for in-depth discussion with presenters.

Hot topics this year include 5G, IoT; 100G; 400G; data center networks; photonic, electronic integration; digital signal processing, advanced modulation; disaggregation, open platforms, SDN, NFV; ethernet; network automation, artificial intelligence, machine learning; optical interconnects; quantum technologies; sensor devices and systems; silicon, integrated photonics; and wireless, visible light communications.

The OFC 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 Chih-Lin I, China Mobile and the Data Center Summit includes a keynote address by Jeffrey Cox, Microsoft Corporation, USA. Be sure to check out the other programs on the show floor addressing business solutions and emerging technologies. This year many industry groups will present, including Huawei USA, OIF, Telecom Infra Project (TIP), AIM Photonics, POFTO and others.

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, Shinji Matsuo, David Plant and Jun Shan Wey, 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.

Robert Doverspike
Network Evolution Strategies, LLC, USA

Dan Kuchta
IBM TJ Watson Research Center, USA

William Shieh
University of Melbourne, Australia

OFC 2020 • 8–12 March 2020
General Information

Customer Service and Conference Information

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

- Parking
- Coat and Baggage Check
- Restaurant information
- Show your Badge promotions
- General conference information
- Lost and Found (for after-hours Lost and Found, please go to the OFC Security Office located in Show Office D (look for security sign)).

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

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<th>Day</th>
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<td>Monday, 9 March</td>
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<td>Tuesday, 10 March</td>
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<td>Thursday, 12 March</td>
<td>08:00–17:00</td>
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Emergencies - Contact Security Command Center on house phone at ext. 5911 or call +1.619.525.5911.

Media Center

Rooms 4, 5A and 5B

The OFC 2020 Media Center consists of a Media Room and semi-private interview space for one-on-one interviews and/or briefings with media and analysts. The media room is restricted to registered media/analysts holding a Media badge.

Media Center Hours

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<tr>
<td>Thursday, 12 March</td>
<td>07:30–16:00</td>
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OFC Conference App

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

Schedule

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

Exhibit Hall

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

Access Technical Digest Papers

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

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

Download the OFC Conference App!

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

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

The OFC 2020 Guide will be listed under the “download guides” section of the application.

OFC Conference App Help Desk

Need assistance? Find an App Coach at the OFC Solution Desk near registration or contact our OFC Conference App support team, available 24 hours a day Monday through Friday, and from 09:00 to 21:00 EDT on weekends, at +1 888.889.3069, option 1.
General Information

Registration

Lobby D

**Hours:**

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Join the Conversation!

Get the latest updates from OFC via Twitter at @OFCConference. Use the hashtag #OFC20 and join in the conversation today!

Speaker Ready Room

Room 11

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

**Speaker Ready Room Hours***

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*All Exhibit Hall speakers (including Market Watch and Network Operator Summit) should go directly to the theater in which they are presenting. All theaters are located in the Exhibit Hall.

Wireless Internet Access

OFC is pleased to provide free wireless Internet service throughout 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: OFC2020

Conference Materials

OFC Technical Digest on a USB Slap Band

The OFC 2020 Technical Digest, composed of the 3-page summaries of invited and accepted contributed papers, as well as tutorial presentations notes will be on the USB Slap Band. The Technical Digest USB is included with a technical conference registration. These summaries will also be published in OSA Publishing’s Digital Library and submitted to the IEEE Xplore Digital Library, providing the author attends and presents their paper at the OFC 2020 conference.

Online Access to Technical Digest

Technical attendees have EARLY (at least one week prior to the meeting) and FREE continuous online access to the OFC 2020 Technical Digest. These 3-page summaries of tutorial, invited, and accepted contributed papers can be downloaded individually or by downloading daily .zip files. (.zip files are available for 60 days after the conference).

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

Postdeadline Paper Digest

The Postdeadline Paper Digest includes the 3-page summaries of accepted Postdeadline Papers. Papers will also be available to download online on Tuesday, 10 March. The digests will be available to all technical conference registrants beginning Thursday, 12 March, starting at 10:00 at Registration in Lobby D or outside Ballroom 6A. The papers will be presented Thursday, 12 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 2020 attendee as part of registration.

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.
Captured Session Content
We are delighted to announce that approximately 40 percent of the sessions at OFC 2020 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 2020 program including symposia, oral presentations, and the Postdeadline Papers sessions. All captured session content will be live for viewing within 24 hours of being recorded. Just look for the symbol ▶️ in the Agenda of Sessions and abstracts to easily identify the presentations being captured.

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

Event Policies and Terms/Code of Conduct
All OFC 2020 guests, attendees, and exhibitors are subject to the Event Policies and Terms, including the Code of Conduct. The full text is available at ofcconference.org/eventpolicies.
Join the Technology Communities Around the World at IEEE Conferences!

Are you interested in learning the latest technologies and meeting global communications experts? Annually IEEE Communications Society (ComSoc) holds over 40 conferences around the world that provide technical communities many opportunities to hear world-class expert insights, technology trends and advancements, and network with leaders of various fields of expertise. Conferences presentations cover topics including 5G, AI, ML, wireless communications, sensor and space technologies, IoT and more.

Check out the following conferences and join today!

**IEEE ISPLC 2020**
IEEE International Symposium on Power Line Communications and its Applications
31 March-3 April 2020 // Malaga, Spain
https://isplc2020.ieee-isplc.org/

**IEEE WCNC 2020**
IEEE Wireless Communications and Networking Conference
6-9 April 2020 // Seoul, South Korea
https://wcnc2020.ieee-wcnc.org/

**IEEE ISPLC 2020**
IEEE International Symposium on Power Line Communications and its Applications
31 March-3 April 2020 // Malaga, Spain
https://isplc2020.ieee-isplc.org/

**IEEE INFocom 2020**
IEEE International Conference on Computer Communications
27-30 April 2020 // Beijing, China
https://infocom2020.ieee-infocom.org/

**IEEE PIMRC 2020**
IEEE International Symposium on Personal, Indoor and Mobile Radio Communications
31 August-3 September 2020 // London, UK
https://pimrc2020.ieee-pimrc.org/

**IEEE CNS 2020**
IEEE Conference on Communications and Network Security
29 June-1 July 2020 // Avignon, France
https://cns2020.ieee-cns.org/

**IEEE ICBC 2020**
IEEE International Conference on Blockchain and Cryptocurrency
3-6 May 2020 // Toronto, Canada
https://icbc2020.ieee-icbc.org/

**IEEE GLOBECOM 2020**
IEEE Global Communications Conference
7-11 December 2020 // Taipei City, Taiwan
https://globecom2020.ieee-globecom.org/

**IEEE 6th World Forum on Internet of Things**
5-9 April 2020 // New Orleans, Louisiana, USA

**IEEE CQR 2020**
IEEEComSoc International Communications Quality and Reliability Workshop
11-14 May 2020 // Stevenson, Washington, USA
https://cqr2020.ieee-cqr.org/

**IEEE GLOBECOM 2020**
IEEE Global Communications Conference
7-11 December 2020 // Taipei City, Taiwan
https://globecom2020.ieee-globecom.org/

**IEEE NOMS 2020**
IEEE/IFIP Network Operations and Management Symposium
20-24 April 2020 // Budapest, Hungary
https://noms2020.ieee-noms.org/

**IEEE ICC 2020**
IEEE International Conference on Communications
7-11 June 2020 // Dublin, Ireland

Visit us at booth #2839
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Celebrating 50 Years of Light-speed Connections

In 1970, two significant technical achievements led to the development of practical fiber optical communications: the demonstration of low-loss fibers (16db/km) and the first CW room-temperature semiconductor lasers. Since then, numerous other breakthroughs have resulted in increasing the bandwidth and reach of fiber links, enabling the World Wide Web, video streaming, trans-oceanic high capacity links, high-capacity wireless communications and many other data services.

At the 2020 OFC Conference and Exhibition, come celebrate the successes of the OFC community that have facilitated light-speed connections between individuals and businesses across geographic and oceanic boundaries.

Special Keynote
Tuesday, 10 March, 18:15–19:00
Ballroom 20BCD

David F. Welch, Founder and Chief Innovation Officer, Infinera, USA

This multi-media presentation from David Welch looks back at 50 years of discovery and its impact on society. The talk will conclude with a brief glimpse into the near-term future.

In his role, Welch drives deep business and technology innovation through forward-looking strategies, including breakthrough technologies and technology partnerships, in addition to innovative business and market directions. Welch is currently a member of Infinera’s Board of Directors, where he has served the company since 2010. Prior to co-founding Infinera, he served as CTO, Transmission Division at JDS Uniphase, and in various executive roles, including CTO and Vice President of Corporate Development, at Spectra Diode Labs (SDL).

Welch also serves on the Board of Directors at several start-up companies. He holds over 130 patents, and over 300 technical publications, and has been awarded The Optical Society’s (OSA) Adolph Lomb Medal, Joseph Fraunhofer Award and John Tyndall Award, as well as the Institute of Engineering Technology’s J J Thompson Medal for Electronics. He is a Fellow of OSA and the Institute of Electrical and Electronics Engineers, and is a member of the National Academy of Engineering.

Welch holds a Bachelor of Science in electrical engineering from the University of Delaware and a PhD in electrical engineering from Cornell University.

The Timeline of Innovation
Exhibit Hall B, Booth 5801
As we look back at the discoveries of years past and speculate about what is yet to come, OFC unveils a unique show-floor exhibit that surveys 50 years of optical fiber innovations — from the first demonstration of low-loss fiber in 1970 to efficient 400GbE transport at any distance today. Browse the timeline of milestones, and see the progression of invention through artifacts and imagery.

John Tyndall Award Exhibit
Lobby E

The Tyndall Award, established in 1987 and jointly presented by IEEE Photonics Society and The Optical Society (OSA), has been bestowed upon 33 visionaries who have made outstanding contributions in the areas of optical-fiber technology. The interactive exhibit introduces visitors to the recipients, their inventions and innovations and the impact of their work.
Special Events and Programming

OIDA Workshop on Embedded Photonic Manufacturing for Data Centers
Sunday, 8 March, 07:30–18:30
Hilton San Diego Bayfront. Separate registration required.

Join your colleagues as leading experts take the stage to discuss new business and technology trends for manufacturing embedded photonic devices for data centers. Four immersive panel discussions—all led by subject matter experts—will help you gain a better understanding of the issues that could impact your company. Hear from leading decision makers with responsibility for the development of next generation data centers, who will share their key technology and cost requirements. The workshop will also have speakers from leading photonic companies and service providers who are developing innovative products and advanced manufacturing services to meet these emerging requirements. This event is colocated with OFC but requires a separate registration. osa.org/oidaworkshop

OFC Workshops

Sunday, 8 March, 13:00–15:30

S1A: Application and Technology Drivers for Short-reach Coherent Links at 800G and Beyond
Room: 6C
Organizers: Fotini Karinou, Microsoft Research Ltd, UK; Clint Schow, University of California Santa Barbara, USA; Joe Kahn, Stanford University, USA; Takahito Tamimura; Fujitsu Laboratories Ltd., Japan; Zhensheng Jia; CableLabs, USA; Timo Pfau, Acacia Communications Inc., USA

The year 2020 marks the tenth anniversary of the official deployment of coherent interfaces in long-haul networks. Advances in photonic integration, digital signal processing and mixed-signal circuitry are driving continual reductions in coherent interface cost, power consumption and size.

Everyone seems to agree that coherent detection will eventually replace direct detection in short-reach applications—including access networks, data-center interconnects and even inside data centers—but there is no widespread consensus on when, why and how this will occur. This workshop explores the applications and enabling technologies that will drive the transition from direct detection to coherent detection in these short-reach systems.

The workshop will be divided into two parts.

In Part I, data center operators, telecom network providers and system vendors will discuss the applications and use cases for coherent interfaces and the requirements they pose on reach, receiver sensitivity, power consumption and size.

In Part II, system and component vendors, as well as academic and industrial researchers, will present enabling technologies and novel link architectures for coherent interfaces that may address future requirements, and will highlight key technological challenges.

Speakers:
Xiang Zhou; Google, USA
Mark Filer; Microsoft, USA
Alberto Campos; CableLabs, USA
WinstonWay; NeoPhotonics, USA
Maxim Kuchnerov; Huawei Technologies Duesseldorf GmbH, Germany
Rob Stone; Broadcom Corp., USA
Robert Blum; Intel Corp., USA
Xiang Zhou; Google, USA
Albert Rafel; BT Technology, UK
Chongjin Xie; Alibaba, USA
Tomoo Takahara; Fujitsu Laboratories Ltd., Japan
Frank Chang; Source Photonics, USA
Matthew Sysak; Ayar Labs, USA

Chris Cole; Luminous Computing, USA
Kenneth Jackson; Sumitomo Electric Device Innovations, USA
Vlad Koslov; Lightcounting, USA
Ian Dedic; Acacia Communications Inc., UK
Katharine Schmidtke; Facebook, USA
Hacene Chaouch; Arista, USA

S1B: Optical Components for fJ/bit Exascale Computing: How and When?
Room: 6D
Organizers: Frank Peters, University College Cork, Ireland; Yasuhiro Matsui, Finisar, USA; Hideyuki Nasu, Furukawa Electric, Japan

System power is the primary constraint for the Exascale systems with a target of 20-40 MW for a 1 exaflop machine. This workshop will discuss the different optical interconnect technologies available and which are the most energy efficient, including both hybrid and fully integrated solutions. This workshop will focus on the photonic transceiver components that will be required to drive these Exascale systems.

There are currently many photonic device options to achieve a single-lane modulation speed beyond 100 Gbps: Si photonics, InP, LN, organic, graphene, etc. Which modulator technology will prove to be best? Is silicon photonics the way forward for these applications, and if so, how should the fJ/bit be calculated given that an off-chip laser may be required? Will isolators be required? If so, how will these be made cost effective. Alternatively, will quantum dot lasers be sufficient as isolator-free laser sources?

Speakers:
Richard Pitwon; Resolute Photonics, UK
Shiyoshi Yokoyama; Kyushu University, Japan
Frank Flens; II-VI, USA
Shigeru Kanazawa; NTT, Japan
Joris Van Campenhout; IMEC, Belgium
Juerg Leuthold; ETH, Switzerland
This workshop will specifically discuss the following aspects:

1. Do we really need contentionless for a ROADM?
2. Would an MxN WSS eventually replace the Multicast Switching (MCS) module for contentionless and when?
3. How high nodal degree would be for the future high-degree ROADM? What is the size of the M*N WSS required for the future high-degree ROADM?
4. What is the most promising architecture for a mini-ROADM in the 5G access? Should it be with filter or filterless? At which level should a mini-ROADM permeate an xHaul and a metro network?
5. How will future ROADMs interface with SDM line systems?
6. Will ROADMs ever become truly dynamic and reconfigurable in optical networks? Is dynamicity useful?
7. Will ROADMs ever have a part to play in data-center interconnect (DCI) networks?
8. What will be the optimal technological solutions for transponders in order to fully take advantage of the capability of ROADMs?
9. How open should a ROADM be?

This workshop is expected to attract a strong industry audience as currently ROADM deployment is increasing rapidly in optical networks around the world. Which ROADM architecture is the best is still under debate as we are seeing different carriers adopting different architectures. This workshop will also attract much interest from academia as the workshop will cover recent hot topics such as OPEN ROADM and ROADMs supporting SDM technology.

**Speakers:**

Kentaro Nakamura; Fujitsu Network Communications, USA

Optimizing Open Networks with Innovations in Modular Optical Architectures

Liangjia Zong; Huawei Technology, China

Green OXC Technologies for Intelligent Optical Networks

Antonio D’Errico; Ericsson, Italy

What’s Cooking in Silicon Photonics on ROADM/OXC for 5G Networks

Lynn Nelson; AT&T, USA

Title to be Announced.

Craig Cameron; Finisar, Australia

Moving beyond Performance: Does LCoS Have a Place on the Network Edge?

Thierry Zami; Nokia, France

Impact of the OXC Technologies on the WDM Network Performance

Dan Kilper; University of Arizona, USA

Optical Amplifiers in the 5G Era

Christos Gkantsidis; Microsoft, UK

Is DCI the Right Space for Optical Switching

Dan Marom, Hebrew University of Jerusalem, Israel

Title to be Announced.

Daping Chu, University of Cambridge, UK

Monolithic Integration of Stacked LCOS WSSs for Cost-effective Dynamic and Reconfigurable Optical Networks

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**S1D: Optics for Neuromorphic Computing and Machine Learning: Status, Prospects and Challenges**

**Room: 6F**

**Organizers:** Paraskevas Bakopoulos, Mellanox Technologies, Greece; Bhavin Shastri, Queen’s University, Canada; Chigo Okonkwo, TU Eindhoven, Netherlands

The recent rise in artificial intelligence and neuromorphic computing has demonstrated super-human performance in tasks such as image recognition, language translation, cancer detection, healthcare, self-driving cars, etc. This rise can be attributed to algorithmic innovations, access to big data, and new hardware (GPUs, Google’s tensor processing unit). With more computing applications, new demands are being placed on hardware that are faster and energy
efficient. Recently, there has been a resurging interest in using light to build processors to meet these demands and potentially enable new applications in high-performance computing, solving optimization problems, accelerating deep learning, etc. Photonic technologies offer high-speed optical communication and massive parallelism with optical signals, coupled with the advances in photonic integration technology and a large-scale silicon industrial ecosystem.

Through a collection of talks and panel discussions, this workshop will cover topics on the current status of the field in using light for machine learning and neuromorphic computing. The applications domains that may drive the demand for photonic and optoelectronic solutions, and the challenges associated with commercializing this technology will be addressed. The topics will range from devices, systems, architectures, algorithms, and applications for: photonic reservoir computing with delay-based systems; multiwavelength and coherent optical neural networks with integrated photonics; optical spiking neural networks with excitable lasers and phase-change materials; free-space diffractive optics; and coherent Ising machines.

Speakers:
Volker Sorger; George Washington University, USA
Title to be Announced
Bahram Jalali; University of California Los Angeles, USA
How to Use Physics to Accelerate AI
Jonathan Dong; Centre National de la Recherche Scientifique, France
Multiple Light Scattering for Large-scale Optical Reservoir Computing and Chaotic Systems Prediction
Shanhui Fan; Stanford University, USA
Title to be Announced
Nikos Pleros; Aristotle University of Thessaloniki, Greece
Title to be Announced
Patty Stabile; Eindhoven University of Technology, Netherlands
Title to be Announced
Antonio Hurtado; University of Strathclyde, UK
Title to be Announced
Harish Bhaskaran; University of Oxford, UK
Phase Change Photonics for In-memory Computing
Kathy Lüdge; Technische Universität Berlin, Germany
Reservoir Computing with Laser Networks - Modelling Aspects and Optimization
Alexander Tait; National Institute of Standards and Technology, USA
Title to be Announced
Bruno Romeira; International Iberian Nanotechnology Laboratory, Portugal
On-chip Nano-light-emitting Sources for Energy-efficient Neuromorphic Computing
Bert Offrein; IBM Zurich, Switzerland
Title to be Announced
S1E: Converged 5G and Heterogeneous Services Access Networks: How to Achieve Ultra-low Latency and High Reliability?
Room: 7
Organizers: Thomas Pfeiffer, Nokia Bella Labs, Germany; Junichi Kani, NTT Access Service Systems, Japan; Elaine Wong, University of Melbourne, Australia
Ultra-low latency transmission is increasingly gaining importance in access networks, be it for low layer split fronthaul in 5G wireless networks, or for latency-sensitive and mission-critical applications over wireless or fixed connections. Emerging cMTC, mMTC, human-to-X services in the industrial and private environment, or public IoT applications such as V2X communication, are calling for deterministic and reliable low-latency communication. With data transmitted over complex networks, passing through multiple nodes and crossing different network segments based on diverse transmission technologies (fiber, copper, wireless) and architectures (ptp, ptp on fiber or via mmWave, etc.), the latency, reliability and timing requirements imposed by the applications will be hard to meet. The workshop shall provide insight into the related challenges, and point out how and to which extent they can be addressed by system technologies (TDM-PON, WDM-PON, switched and meshed Ethernet, ptp fibers) as well as across network segments employing different technologies such as fixed-wireless.

Key questions this workshop intends to explore include:

- Where do hard constraints such as 1 ms latency, 6 nines reliability and 5 or 10 ns timing accuracy come from, and how necessary is it to adhere to these constraints?
- What are the new access architecture and protocol design for strict latency and high reliability guarantees?
- Do we need new network node architectures in support of edge and fog computing and how invasive (i.e. how close to the end user) should these computing resources be?
- How far can an orchestration layer help timely coordinate scheduling across segments, and when is hardware coordination needed?
- Can/should mission-critical applications co-exist with other less latency-intensive types of applications?

Speakers:
Martin Maier; INRS Montreal, Canada
HwanSeok Chung; ETRI, Korea
Marco Ruffini; TCD, Ireland
Akihiro Nakao; Tokyo University, Japan
Pascal Dom; Nokia, Belgium
Yuanqiu Luo; Futurewei, USA
Philippe Chanclou; Orange Labs, France
Nihel Benzaoui; Nokia Bell Labs, France

Sunday, 8 March, 16:00–18:30

S2B: Are Radical Photonic Devices and Architectures Needed for Future Data Centers?
Room: 6D
Organizers: Maura Raburn, Google, USA; Kenya Suzuki, NTT Device Innovation Center, Japan; Yikai Su, Shanghai Jiao Tong University, China
What is in store for future datacenters?

(When) will optical circuit and packet switching dominate? Or will more traditional architectures and
devices meet future speed, cost, scale-ability, and latency requirements?

Experts with opposing perspectives will debate our future.

Speakers:
Architectures
Ken-Ichi Sato; Nagoya University, Japan
George Porter; University of California San Diego, USA
Lena Wosinska; Kungliga Tekniska Hogskolan, Sweden

DC Operator
Chongjin Xie; Alibaba Group, USA
Francesca Parmigiani; Microsoft Research Ltd, UK

Devices
Shifu Yuan; Calient Technologies Inc., USA
Salah Ibrahim; NTT Photonics Laboratories, Japan
Mohan Kalkunte; Broadcom Ltd., USA

S2C: Trends and Perspectives in Space-division Multiplexed Transmission and Related Devices
Room: 6E

Organizers: Roland Ryf, Nokia Bell Labs, USA; Sergio Leon-Saval, University of Sydney, Australia; Cristian Antonelli, University of L’Aquila, Italy

Almost a decade has passed since the advent of a capacity crunch in fiber-optic transport networks was envisaged, and for as long increasingly encouraging results on Space-division Multiplexed (SDM) transmission over multi-mode and multi-core fibers have been reported from around the globe. These fibers have the potential of scaling the capacity of fiber-optic links while reducing the cost per bit and constitute a space-effective alternative to the use of parallel single-mode fibers. Nonetheless, the evolution of SDM is somehow controversial. In fact, on one hand, a clear case for SDM fibers has not yet been made, for reasons that seem to go well beyond the technological gaps that still have to be filled. On the other hand, a major internet company has recently announced that its latest submarine cable systems implement SDM technologies, while the Italian University of L’Aquila has deployed the first testbed based on SDM fibers. This workshop aims to stimulate an open discussion on future opportunities for massive parallel transmission systems based either on multiple single-mode fibers or on multi-core and multi-mode fibers between key players in the fiber-optic industry, including fiber manufacturers, systems, sub-systems, and components producers, as well as other possible uses of SDM technologies and devices for related optical fields. The workshop is organized in three sections, two addressing specific aspects and challenges in SDM transmission and devices, and the last section highlighting opportunities for SDM technologies in other areas.

S1. SDM Deployments
One of the key questions addressed in this section is what is preventing the transition from single-mode fibers to new fiber types. Is there room for the deployment of SDM fibers in the next-decade road map of optical communications? How important is it to deploy SDM testbeds to bring SDM transmission technology out of lab research?

S1 Speakers
Pierre Sillard; Prysmian Group, France
Tetsuya Hayashi; Sumitomo Electric, Japan
Ruben Soares Luis; NICT, Japan
Sergejs Makovejs; Coming, USA

S2. Integration for SDM
Independently of the fiber used for transmission, scaling the capacity of a transmission system will require the availability of cost effective devices that can support large number of parallel channels. In this section we will hear from industry experts about current and future efforts on transceivers, optical amplifiers and optical switches to support massive parallel optical channels.

S2 Speakers
Guilhem de Valicourt; IPG Photonics, USA
Hitoshi Takeshita; NEC, Japan
David Neilson; Nokia Bell Labs, USA

S3. Applications of SDM Transmission Devices beyond Fiber-optic Communications
The improvement and development of multi-core fibers and mode multiplexing devices driven by research on SDM transmission systems have prompted their use on different areas of science. This section will showcase three non SDM communications intensive areas of research in which SDM devices are making a significant difference.

S3 Speakers
Sarah Tedder; NASA Glenn Research Center, USA
Photonic Lanterns for Laser Satellite Communications
Nemanja Jovanovic, Caltech Optical Observatories, USA
Astronomical Applications of Multi-core Fiber Technology
Ivana Gasulla; Universidad Politécnica de Valencia, Spain
Multicore and Few-mode Fibres for Microwave Photonics

S2D: Network Analytics in the Age of Machine Learning: How to Share Data and Maximize Synergies Among Transport Systems and Network Operators
Room: 6F

Organizers: Antonio Napoli, Infinera Corp., Germany; Takayuki Mizuno, NTT Network Innovation Laboratories, Japan; Mark Filer, Microsoft, USA

Artificial Intelligence (AI)-based network planning and operation will play an important role in the next generation optical fiber communications. In future optical networks, every player will produce an enormous amount of data, and anyone might have access to those data. For the entire system to work properly, access to data is mandatory, but on the other hand, access to some data must be regulated.

This opens up important questions to be discussed:

• AI does not work with a partial set of data.
• How do we get all the required data worldwide?
• Who owns the required data?
• Can these data be shared? If yes, how and under which conditions / regulations will we share the data?
• How do we assure trust and anonymity of the data?
• Which organization will regulate the “data market” and which institution will standardize it?

In this workshop, we will discuss the above issues, and seek an agreement among global operators, ICPs and vendors with the help of academia.

Speakers:
Operator
Juan Pedro Palacios-Fernandez Gimenez; Telefonica, Spain
Jack Pugaczewski; Century Link, USA
Giuseppe Rizzelli; Facebook Inc., USA
Kaname Nishizuka; NTT Communications Corp., Japan
Yawei Yin; Microsoft, USA
Vendor
Joao Pedro; Infinera, Portugal
Patricia Layec; Nokia Bell Labs, France
Shoichiro Oda; Fujitsu Limited, Japan
Academia
Akira Hirano; TDU, Japan
Manya Ghobadi; MIT CSAIL, USA

S2E: Does Disaggregation Support Data Center Evolution?
Room: 7

Organizers: Michela Svaluto Moreolo, Centre Tecnològic De Telecomunicacions De Catalunya, Spain; Madeleine Glück, Columbia University, USA; Ken-ichi Kitayama, The Graduate School For The Creation Of New Photonics Industries, Japan

The concept of disaggregation is increasingly popular in both Datacom and Telecom, driven by the ever increasing capacity demand at reduced cost, as a promising candidate towards a more efficient resource utilization, improved flexibility, scalability and programmability. This workshop aims at exploring opportunities and enablers answering questions related to the disaggregation paradigm for supporting data center (DC) evolution from different perspectives, involving its impact on architectural, networking and management aspects as well as technological ones. Could this new paradigm achieve/provide the promised opportunities? Which are the enabling technologies? Are they mature enough? Which are the most promising for an actual increase of efficiency, cost/power saving, flexibility? What are the underlying challenges? What are the drawbacks? Could disaggregation be the enabler for converged inter/intra data center optical networks?

Specifically, the workshop will explore if an appropriate network architecture could be a key enabler of DC disaggregation. How is the inevitable additional latency of the disaggregated network compensated/mitigated/alleviated? How is the bandwidth requirement addressed?

What are the architectural, control and management ramifications of disaggregation? How can these be addressed? Is there resistance from the user (data center, telecom operators) community? Which is/are the best architectural choice(s) in support of DC disaggregation?

How can scalability be efficiently addressed? Where is the bottleneck? Are the solutions being proposed scalable or a temporary stop gap? What are the ramifications of disaggregation with respect to energy efficiency? Is it an energy cost or an energy saver? Is disaggregation viable now and if not, what is the block? Is it just not yet?

The technology implications at the system, subsystem and infrastructure level represent another key point towards the data center evolution in the framework of disaggregation paradigm. What is the role of the switching infrastructure? How should it be designed to support and ease disaggregation and what are the challenges? Are new hardware and specialized components needed? What is the role of photonics? What is the vendor perspective? Are there alternative non disaggregated solutions that meet cost/performance targets? Are there critical applications that would suffer performance degradation with disaggregation?

Speakers:
Victor Lopez; Telefonica, Spain
Enabling an Open Network Ecosystem: SDN and Whiteboxes
Hitesh Ballani; Microsoft, USA
Title to be Announced
Ling Liao; Intel Corporation, USA
SiPh Based Co-package Optics for Data Center Disaggregation

Shu Namiki; National Institute of Advanced Industrial Science and Technology (AIST), Japan
Disaggregation and Automation of Optical Layer Switching for Converged Compute and Network
Georgios Zervas; University College London (UCL), UK
MONet: Memory over Optical Network at Cluster Scale - From Physical Layer to Application Performance
John Shalf; Lawrence Berkeley National Laboratory, USA
Diverse Accelerators Are Coming: What Are the Alternatives for Integrating them into the Datacenter?
Nicola Calabretta; Eindhoven University of Technology (TUE), Netherlands
Title to be Announced

Lab Automation Hackathon
Sunday, 8 March, 20:00–22:00
Room: 17

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

Lab work is most efficient when data can be acquired in an automated way. 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. The hackathon format will consist of interactive demos and challenges in addition to a short introduction. 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 web browser or GUI. We will learn from companies 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 exercises. Students will show how they are developing new tools to complete their PhD. There will also be plenty
of time for mingling and discussion. Light food and drinks will be served.

OIDA Executive Forum
Monday, 9 March, 07:30–19:00
Hilton San Diego Bayfront. Separate registration required.

Join leaders from top companies on 9 March at OIDA Executive Forum as they discuss critical technology advancements and business opportunities that will shape the network and your company. In just one day you can connect with all the key industry experts in one place. Learn about future trends key to your business, your competitors and your industry. There will be four panel presentations this year and a Keynote Presentation by Elizabeth Rivera Hartling, Subsea Optical Network Architect, Facebook. A special Fireside Chat will feature a panel of executives from across the optical network supply chain providing their unique perspectives on a broad range of industry issues. Keep current on the service provider landscape, network automation, how 5G and other trends will drive fiber optic expansion and edge computing, the next big things like AI, cloud gaming and AR/VR—and more! This event is co-located with OFC.

OSA Roundtable with Seasoned Entrepreneurs in Optical Fiber Communications
Monday, 9 March, 12:30–14:00
Room: 1A&B
The advent of 5G, IoT and autonomous vehicles provides significant opportunities for new businesses in optical fiber communications to solve the challenges posed by these operations. In this OSA Technical Group event, seasoned entrepreneurs will share their insights and experiences in the optical communications market – from how they conceived the initial idea and curated it into a feasible business case to securing investment. Professionals who want to learn about the highly specialized market of optical communications as well as those looking to gauge the feasibility of their business ideas will have the opportunity to hear from our invited speakers and then interact with them directly to learn about this highly specialized market. The OSA Fiber Optics Technology and Applications Technical Group, the OSA Optical Communications Technical Group and the OSA Optics in Digital Systems Technical Group are jointly hosting this event; please RSVP at bit.ly/TGatOFC2020 to let us know you will be attending.

Hosted by OSA Technical Groups

OFC Panels
Eight panels are scheduled for OFC 2020. Please refer to the abstract section for full descriptions.

Is It Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity?
Monday, 9 March, 14:00–16:00
Room: 2
Organizers: Derek Nesset, Huawei Technologies R&D, Germany; Liang Du, Google, USA; Junwen Zhang, Cablelabs, USA

Automotive Communications and Technologies for 10G and Beyond
Monday, 9 March, 16:30–18:30
Room: 1B
Organizers: Dan Sadot, Ben Gurion Univ. of the Negev, Israel; Yuqing Jiao, Technische Universiteit Eindhoven, Netherlands; Yi Cai, ZTE Optics Lab, USA

As We Approach Shannon Limit, How do We Precisely Assess the Performance of Coherent Transponders for Field Deployment?
Tuesday, 10 March, 14:00–16:00
Room 6E
Organizers: Steve Grubb, Facebook Inc., USA; Georg Mohs, TE SubCom, USA; Priyanth Mehta, Ciena, Canada

How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?
Tuesday, 10 March, 14:00-16:00
Room 6D
Organizer: Rene Schmogrow, Google, USA
Pros and Cons of Low-margin Optical Networks
Wednesday, 11 March, 08:00–10:00
Room:  7
Organizers: Yvan Pointurier, Nokia Corp., France; Sorin Tibuleac, ADVA Optical Networking AG, USA; Martin Birk, AT&T Labs, USA

Will SDM Truly Revolutionize the Submarine Communication Industry?
Wednesday, 11 March, 14:00–16:00
Room 2
Organizers: Pascal Pecci, ASN, France; Valerie Kamalov, Google, USA; Mei Du, Tata Communications, USA

Devices and Systems at 130 Gbaud and Above: What is the Outlook?
Thursday, 12 March, 08:00–10:00
Room:  8
Organizers: Kenneth Jackson, Sumitomo Electric Device Innovations, USA; Arghisti Nellikyan, Nokia Bell Labs, USA; Hongbin Zhang, Acacia Communications, USA

Pluggable Coherent Optics for Short-Haul/Edge Applications and Beyond
Thursday, 12 March, 14:00–16:00
Room: 6E
Organizers: Xiaoxia Wu, SpaceX, USA; Rene Marcel Schmogrow, Google, USA; Xi (Vivian) Chen, Nokia Bell Labs, USA

OFC Demo Zone
Monday, 9 March, 14:00–16:15
Room:  Room 6A
Organizers: Xiaoxia Wu, SpaceX, USA; Xi (Vivian) Chen, Google, USA; Valey Kamalov, Google, USA; Mei Du, Tata Communications, USA

Open Networking Summit: Optical Metro/Aggregation Networks to Support Future Services over 5G
Monday, 9 March, 16:30–19:00
Room: 6E
Organizers: Albert Rafel, BT Technology, UK; Joerg-Peter Elbers, ADVA Optical Networking, Germany; Emilio Riccardi, Telecom Italia Mobile, Italy

5G promises to revolutionize society and industry by enabling a wide range of services, like enhanced Mobile Broad-Band (eMBB), Ultra-Reliable Low Latency Communications (URLLC), and Machine-Type Communications (mMTC), with very different and stringent requirements. 5G Transport will require large amounts of fiber deployments, but while a lot of focus is being given to fiber access networks, the optical metro/aggregation network has not yet received much attention.

Transport optical networks are traditionally considered a collection of big pipes, seen as an existing commodity, on top of which to add higher layer network resources and intelligence supporting the services. Considerable effort is devoted by both the research community and industry to the design and deployment of more efficient, more cost-effective, greener and more sustainable, and autonomic metro/aggregation networks, which are expected to complement 5G mobile networks supporting vertical services.

Furthermore, the expected widespread use of Edge Computing and Cell Site Gate-Way Nodes will blur the traditional strong separation between mobile, access, and metro/aggregation networks, which opens the possibility for beneficial technology cooperation. However, how these technological advancements in all network layers of the access/metro/aggregation domains, as well as in the control plane, can be pieced together to give a clear and unified vision of the 5G ecosystem, is still largely a subject of debate. This session will address the issue of whether and how the massive deployment of vertical services over 5G will change the traditional approach to building optical network infrastructures.

In particular, the session will open a discussion on the following questions:

1. What are the network requirements emerging from 5G services?
2. What does a future-proof access/metro/aggregation network architecture look like?
3. How can such architecture be implemented?

The session will be divided into two parts. In the first part, invited speakers will present their views on network (re)revolution. In the second part, different strategies leading to more efficient, more cost-effective, and more sustainable networks will be debated in a panel discussion.

Speakers
Glenn Wellbrock; Verizon Transport Networks, USA
Jun Terada; NTT Access Networks Labs, Japan
Andrew Lord; BT Labs, UK
Jan Söderström; Ericsson, USA
Attilio Zani; Telecom Infra Project, UK

OIDA/OSAF Professional Development & Networking Lunch and Learn
Tuesday, 10 March, 12:00–13:30
Room:  15
Invite-Only Event
This event will allow industry executives to share their business experience with early career professionals, recent graduates and students. Past discussion topics
have included how you started your career, using your degree in an executive position, etc. Additionally, we may pair experts from academia at each table, with the goal of diversifying the representation of both academia and industry career paths. Students will rotate to most tables as time allows with an informal networking lunch to follow the networking portion.

Sponsored by GoFoton

The Art of Writing the Perfect OFC Paper
Tuesday, 10 March, 16:00–18:00
Room 14B
Join OFC committee members, journal editors, and distinguished researchers for an interactive workshop on how to write a highly scored OFC paper. We will discuss the qualities of great OFC submissions and the common reasons why papers are rejected from OFC. The workshop will kick off with a few short talks followed by smaller breakout/brainstorming sessions and end with some time for networking.

OIDA Roadmap on Quantum Photonics
Tuesday, 10 March, 16:15–17:00
Exhibit Hall, Theater I
OSA Industry Development Associates (OIDA) will discuss findings from its roadmap on quantum photonics. The roadmap identifies challenges and opportunities for photonic technologies for three groups of applications: quantum communication, quantum computing, and quantum sensing. The session will focus in particular on quantum communication.

Hosted by OSA Industry Development Associates

Rump Session: When Will Co-packaged Optics Replace Pluggable Modules in the Datacenter?
Tuesday, 10 March, 19:30–21:30
Room: 6F
Organizers: Chris Cole, Luminous Computing, USA; Dan Kuchta, IBM Research, USA
Provocateurs:
Joris Van Campenhout; IMEC, Belgium
Peter De Dobbeleere; Cisco/Luxtera, USA
Jane Gu; University of California Davis, USA
Shu Namiki; AIST, Japan
Zuowei Shen; Google, USA
James Stewart; Facebook, USA
Rob Stone; Broadcom, USA
Greg Walz; Molex, USA
Zhiping Yao; Alibaba, China
Description:
A major limitation of today’s switch cards is the PCB electrical connection between the ASIC and front panel pluggable optics. As Baud rate increases the PCB link SerDes power increases to overcome frequency dependent copper trace and connector losses. Further, ASIC bandwidth is constrained by physical limitations of the MCM ball grid array and pluggable module electrical connector I/O count. Co-packaging the ASIC and optics on a common MCM promises to remove this limitation. Over the past decade, industry has been working to make this approach real, with the pluggable paradigm holding firm. With each new generation of switch ASICs, the demise of pluggable is predicted, only to be pushed out to a future generation. The Rump Session will discuss if, and when, the pluggable paradigm will run out of steam, and if it’s replacement will be co-packaging.

Format:
• Short introductory presentations by session organizers.
• One content slide plus one punch line slide each from a panel of industry provocateurs, adding up to 50% of session time.

Questions for Discussion:

• At which switch node will pluggable no longer be a viable paradigm: 25.6T, 51.2T, 102.4T, 204.8T?

• How important are traditional pluggable advantages of partitioning, testability, field installation and replacement, and upgradability?

• Does an interposer between co-packaged optics and MCM preserve some of the traditional pluggable advantages?

• What is the optimum modulation format for co-packaged optics? Is it the same or different than for pluggable?

• Is optical link interoperability between co-packaged and pluggable optics a requirement? What if this limits co-packaged approaches?

• It is generally assumed that co-packaging enables replacing VSR with XSR SerDes. This may result in at most 50% SerDes power savings, which translates to 20-30% host card power savings. Does this justify an entirely new paradigm? Or is at least 50% power savings required?

• Does co-packaging enable new network paradigms, like higher radix?

• Do advanced copper I/O techniques like fly-over cables and high-density connectors extend the pluggable paradigm?

• An intermediate step is on-board optics. A shared limitation is that the PCB routing of on-board modules requires VSR SerDes and therefore does not reduce power. Are there on-board optics approaches that would remove this limitation and postpone the need for co-packaging?

• Are there security advantages associated with co-packaging?

• Which is the preferred fiber attach; vertical or edge coupled? Should it be pig-tailed or connectorized at the MCM?

• Is MCF (multi-core fiber) required to overcome the spatial density limitations of routing out fibers from an MCM?
• Vigorous audience participation after each provocateur presentation, with organizers facilitating wide ranging discussion, adding up to the other 50% of session time.

• Attendees come prepared with tough questions, insightful comments, and different perspectives to challenge the provocateurs and broaden the discussion.

OFC Rise and Shine Morning Run/Walk
Wednesday, 11 March, 06:00–07:00
Bottom of San Diego Convention Center Stairs (front entrance)
Pack your running shoes and meet up for an early morning, 3 mile run or walk with fellow OFC colleagues. Please see Registration for details on how to sign up.

Special Chairs’ Session: Vision 2030: Taking Optical Communications through the Next Decade
Wednesday, 11 March, 14:00–18:30
Room: 6F
Organizers: Shinji Matsuo, NTT Device Technology Labs, NTT Corp., Japan; David Plant, McGill University, Canada; Jun Shan Wey, ZTE TX, USA
Reflecting upon the 2010-2019 decade, OFC has led the optical communications industry and research communities to achieve significant and groundbreaking milestones. Looking forward to the next decade, we seek to answer a key question: what are the emerging hot topics and groundbreaking innovations to be anticipated? This session gathers together eight visionary speakers who will discuss past successes alongside forthcoming innovations in the next decade.

Speakers
John Bowers; University of California Santa Barbara, USA
Philippe Chanclou, Orange Labs, France
Chris Doerr; Acacia Communications Inc., USA
Chih-Lin I; China Mobile Communications Group, China
Michal Lipson; Columbia University, USA
Hong Liu, Google, USA
Kim Roberts; Ciena, Canada
Alexei Pilipetskii; SubCom, USA
Meint Smit and Kevin Williams; Technical University Eindhoven, Netherlands
Hiroyuki Takesue; NTT Basic Research Labs, Japan
Peter Vetter; Nokia Bell Labs, USA
Peter Winzer; Independent Consultant, USA

Photonic Society of Chinese-Americans Workshop and Social Networking Event
Wednesday, March 11, 17:00–19:30
Room 17B
Organizers: The Optical Society (OSA), OSA China Office, China International Optoelectronic Expo (CIOE)

What’s the “Light” at the End of the Tunnel?
To serve our mission of bringing together photonics professionals, enhancing the communication and collaboration in the optical industry, PSC has been organizing technical and social events during OFC in the past 12 years. In OFC 2020, we’ll get updates from experts, industry leaders once again. The optics markets are becoming more turbulent and highly competitive than ever. The demands and prices add more pressure to the whole supply chain. The gross margin retains a similar level year to year but net margin continues to decline with less visibility into the orders. On the other hand, 5G deployment, 10G PON, Data Center upgrades offer unprecedented opportunities for the optics industry. So what is the “light” at the end of the tunnel that can help us navigate the business through today’s turbulent markets? Is it the answer new business model, e.g. more market consolidation with more vertical integration? Or is it the new applications like LiDAR, quantum computing? Or is it a new way of manufacturing? ...

The panel of the PSC annual event consists of well-respected experts from carriers, service operators, and leaders in the optical industry, who will share their views on technology trends, market opportunities and challenges along with the business strategies amongst the US, China and the rest of the world.

Postdeadline Paper Presentations
Thursday, 12 March, 16:30–18:30
Rooms: 6C, 6D, 6E, 6F
Discover the best and most cutting-edge research in optical communications. The OFC 2020 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, 10 March. Please visit ofcconference.org and click the “Download Digest Papers” button to access these papers.
REGISTER NOW
ADVANCE REGISTRATION DEADLINE:
18 MAY 2020

OSA Quantum 2.0 Conference
15 – 18 June 2020
Hyatt Regency Reston
Reston, Virginia, USA
osa.org/QuantumConference

A new conference focusing on advances in quantum science and the technical innovations needed to introduce practical quantum technologies and ultimately commercializable products.

CALL FOR PAPERS
ABSTRACT AND SUMMARY SUBMISSION DEADLINE:
24 MARCH 2020

OSA Advanced Photonics Congress
13 – 16 July 2020
Hotel Bonaventure Montréal
Montréal, Québec, Canada
osa.org/PhotonicsOPC

The congress, comprised of nine topical meetings, addresses the many aspects of photonic device research and development and their use in networks.
5G Evolution: Challenges and Opportunities
Qi Bi, President, China Telecom Technology Innovation Center, China

As large deployments ramp up in many parts of the world, 5G has been one of the hot topics in the media and has stimulated expectations in many industries. Based on extensive field experience and careful analysis, his talk will break out much of the media hype and provide a candid synopsis on what 5G has actually achieved so far, what are the challenges that 5G still faces and in what directions 5G may further evolve in the future. Through a comprehensive examination of the established technology trends of the cellular industry, he will map the current 5G technology into historical and evolutional trajectories and provide technical insights into many of the 5G features that have been designed for industrial verticals and IoT industries in addition to the consumer broadband communications. His talk will also touch upon the impact of the 5G ecosystem on the cellular industry.

Qi Bi is the President of China Telecom Technology Innovation Center and the CTO of China Telecom Beijing Research Institute, managing R&D organizations with responsibilities in wireless communications. His current focus is on 5G innovations responsible for technologies, standards and trials in China Telecom.

Previously, Bi worked at Bell Labs for 20+ years and was awarded the prestigious Bell Labs Fellow in 2002. Other awards included Bell Labs President’s Gold Awards in 2000 & 2002, the Bell Labs Innovation Team Award in 2003, and Asian American Engineer of the Year in 2005. He is an IEEE Fellow, and currently serves as a member of the IEEE evaluation committee member for the communication society of IEEE.

Bi received his M.S. from Shanghai Jiao Tong University and Ph.D. from Pennsylvania State University. He holds 47 US patents, 63 European patents and 64 Chinese patents. While in China Telecom, one of his 4G innovation project resulted in successfully deployment in 75% of China Telecom’s markets, and won the GTB Innovation Award at London in 2014.

The Challenge and Impact of Detecting Ripples in Spacetime
Benno Willke, Research Group Leader, Max Planck Institute for Gravitational Physics, Germany

In 2015, the twin LIGO instruments made the first confirmed detection of gravitational waves by measuring the changes in the distance laser light traveled on the order of a one thousandth the width of a proton. In 2017, LIGO and Virgo together used gravitational waves to detect colliding neutron stars, allowing for the first multi-wavelength and multi-messenger astrophysical observations. Scientists and engineers at the Max Planck Institute for Gravitational Physics played a key role in these detections and are now working on laser systems for an even more sensitive third generation of gravitational-wave detector, which will be used in future multi-messenger observations to answer outstanding astrophysical questions about the early formation of the Universe and its ongoing evolution.

Benno Willke received his doctorate in 1992 from the University of Hannover (Germany) in the field of plasma physics. He then worked on the design and installation of the GEO600 gravitational-wave detector and the laser system of the LIGO gravitational-wave interferometers. From 1998 to 2009 he chaired the lasers working group of the LIGO scientific collaboration (LSC) and led the development, fabrication and installation of the Advanced LIGO laser subsystem. During this time he spent one year at Stanford University (USA) as a Humboldt fellow. In 2014, he was appointed adjunct professor at the Leibniz Universität Hannover.

Wilke’s current research interests are lasers for 3rd generation gravitational-wave detectors, novel laser stabilization methods and the search for new particles using light-shining-through-wall experiments.

Is There a Future for Silica as an Optical Material?
Sir David Payne, Director, Optoelectronics Research Centre, Zepler Institute for Photonics and Nanoelectronics, University of Southampton, UK

Sir David Payne will discuss how photonics has changed our lives by powering the optical fiber internet, as well as an entire generation of high-power lasers. Optical fibers carry terabits of data per second in a vast information network that brings untold human connectivity. But capacity demand continues to grow at a startling rate. Will the “wonder material” silica remain a pillar of telecommunications as demand continues to grow? Or will alternative fiber designs be the solution? And what of the fiber laser? Will it too prove infinitely scalable? And what of storing all these bytes?

Sir David Neil Payne CBE FRS FREng is a leading Professor at the University of Southampton and Director of the Optoelectronics Research Centre. A world class pioneer of technology, his work has had a great impact on telecommunications and laser technology over the last forty years. The vast transmission capacity of today’s internet results directly from the erbium-doped fiber amplifier (EDFA) invented by Payne and his team in the 1980s. His pioneering work in fiber fabrication in the 70s resulted in almost all of the special fibers in use today including fiber lasers which are currently undergoing rapid growth for application in manufacturing and defense.
Payne has made numerous leading contributions to many diverse fields of photonics and is widely acknowledged as an inventor of key components. With US funding, he led the team that broke the kilowatt barrier for fiber laser output to international acclaim and now holds many other fiber laser performance records. An original member of the Highly Cited Researchers (USA) he is honored as one of the most referenced, influential researchers in the world. He has published over 650 Conference and Journal papers.

As an entrepreneur Payne’s activities have led to a cluster of 11 photonics spin out companies in and around Southampton - helping to boost the local economy. He founded SPI Lasers PLC, which has been purchased by the Trumpf Corporation of Germany for $40M. He is an Emeritus Chairman of the Marconi Society and a foreign member of the Russian Academy of Sciences. Payne is a fellow of the Royal Society, The Optical Society and the Royal Academy of Engineering.

In addition he has been awarded the top American, European and Japanese prizes in photonics. Awards include the John Tyndall Award in 1991, the Marconi Prize in 2008 and the 2007 IEE Photonics Award the first to be awarded to a person outside the USA. In 2010, Payne received the AILU (Association of Laser Users) Award for his pioneering work with fiber lasers. In 2018, he was elected as a Foreign Fellow of the Indian National Science Academy. He became a Commander of the British Empire in 2007 and knighted in the 2013 New Years Honors list.
OFC and Co-Sponsor Awards and Honors

Awards Ceremony and Luncheon
Tuesday, 10 March, 12:00–14:00
Upper Level, Ballroom 20A
Supported by CORNING

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

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

2020 John Tyndall Award
First presented in 1987, this award recognizes outstanding contributions, in any area of optical-fiber technology, that have met the test of time and been of proven benefit to science, technology, or society. It is jointly presented by OSA and IEEE Photonics Society and is funded by Corning, Incorporated.

IEEE Communications Society 2020 Fellows
Recognizes the extraordinary contributions and accomplishments of IEEE members. Fellows are honored for their outstanding technical, educational, and leadership achievements.

IEEE Photonics Society 2020 Fellows
A distinction reserved for select IEEE members who have achieved extraordinary accomplishments. Fellows have contributed to the advancement or application of engineering, science and technology, bringing the realization of significant value to society.

The Optical Society 2020 Fellows
Recognizes OSA members who have served with distinction in the advancement of optics and photonics through distinguished contributions to education, research, engineering, business leadership and society.

2020 IEEE Photonics Award
Established in 2002, this award recognizes outstanding achievements in photonics. It is presented by the IEEE Photonics Society.

IEEE/OSA Journal of Lightwave Technology Best Paper Award
Recognizes the top cited original papers published in the Journal in 2017, as determined by a variety of citation metrics and databases. It is presented by the Journal’s Coordinating and Steering Committees. Copies of the winning papers will be available throughout OFC and will be made open access in the IEEE Xplore Digital Library.

IEEE Communications Society Charles Kao Award for Best Optical Communications & Networking Paper
Recognizes published papers that open new lines of research, envision bold approaches to optical communication and networking, formulate new problems to solve and essentially enlarge the field of optical communications and networking. Papers published in the prior three calendar years of the Journal of Optical Networking are eligible.

Corning Outstanding Student Paper Competition
Endowed through the OSA Foundation by Corning Incorporated, the paper competition recognizes innovation, research excellence and presentation abilities in optical communications. All students submitting their papers during the regular “call for papers” process for OFC are eligible for the competition. Finalists present their work to the General Chairs in a private session at the conference.

Corning Women in Optical Communications Scholarship
Endowed through the OSA Foundation by Corning Incorporated, these scholarships recognize three outstanding women graduate students studying optical communications and networking to support their participation in OFC.

Tingye Li Innovation Prize
Presented to an early career professional who has demonstrated innovative research, the prize honors the global impact Dr. Li made to the field of optics and photonics. It is administered by the OSA Foundation, and endowed by Alliance Fiber Optic Products, Inc., AT&T, The Optical Society, IEEE Photonics Society, IEEE Communications Society, Thorlabs, Inc, The Li Family and supporters of the Tingye Li Memorial Fund.
WOMEN IN OPTICAL COMMUNICATIONS

SCHOLARSHIP WINNERS

Shaimaa Azzam
Purdue University
USA

Ann Margareth Rosa Brusin
Politecnico di Torino
Italy

Fatemeh Ghaedi Vanani
CREOL
USA

TRAVEL GRANTS WINNERS

Hannah Watson, University of Cambridge, United Kingdom
Svenja Mauth, Eidgenössische Technische Hochschule, Switzerland
Monette Khadr, SUNY Albany, United States
Yan Fu, Shanghai Jiao Tong University, China
Riti Gour, University of Texas at Dallas, United States
Yating Wan, University of California Santa Barbara, United States
Erin Knutson, Tulane University, United States
Ligia Moreira Zorello, Politecnico di Milano, Italy
Uliara de Moura, Technical University of Denmark, Denmark
Mai Banawan, Universite Laval, Canada

Learn More: osa.org/corningscholarship
Corning Incorporated Booth #3727 | The Optical Society Booth #2639
# Short Course Schedule

**Sunday, 8 March, 2020**

**09:00–12:00**

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

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

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

SC470: Secure Optical Communications  
Andrew Shields; Toshiba Research Labs, UK  
Helmut Grießer; ADVA Optical Networking, Germany

SC485: Advanced Fiber Access Networks NEW  
Cedric F. Lam; Google, USA  
Shuang Yin; Google, USA

**09:00–13:00**

SC105: Modulation Formats and Receiver Concepts for Optical Transmission Systems  
Peter Winzer; Independent Consultant, USA  
Xi (Vivian) Chen; Bell Labs, Alcatel-Lucent, USA

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

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

SC395: Modeling and Simulation of Optical Transmitter and Receiver Components  
Harald Rohde; Elenion, Germany  
Howard Wang; Elenion, Germany

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

SC461: High-capacity Data Center Interconnects  
Dirk van den Borne; Juniper Networks, Germany  
Sander L. Jansen; ADVA Optical Networking, Germany  
Mark Filer; Microsoft, USA

SC469: Hands-on: Laboratory Automation and Control Using Python (Beginner)  
Jochen Schröder; Chalmers University of Technology, Sweden  
Binbin Guan; Acacia Communications, USA  
Roland Ryf; Nokia Bell Labs, USA

**13:00–16:00**

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

SC217: Applications of Radio-over-fiber Technologies Including Future 5G Networks  
Dalma Novak; Pharad, LLC., USA

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

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

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

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

**13:30–17:30**

SC443: Optical Amplifiers: From Fundamental Principles to Technology Trends  
Michael Vasilyev; University of Texas at Arlington, USA  
Lu Li; SubCom, USA

SC452: FPGA Programming for Optical Subsystem Prototyping  
Noriaki Kaneda, Nokia Bell Labs, USA  
Robert Elschner, Fraunhofer HHI, Germany

**17:00–20:00**

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

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

SC484: Transport Evolution Due to Cloud Services and Network Resiliency NEW  
Loukas Paraschis, Infinera, USA

**Monday, 9 March, 2020**

**08:30–12:30**

SC102: WDM in Long-haul Transmission Systems  
Neal S. Bergano; Retired, USA
SC160: Microwave Photonics  
Vince Urick; DARPA, USA

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

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

SC446: Hands-on: Characterization of Coherent Opto-electronic Subsystems  
Harald Rohde; Elenion, Germany  
Howard Wang; Elenion, Germany

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

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

SC468: Advanced FEC Techniques for Optical Communications  
Laurent Schmalen; Karlsruhe Institute of Technology (KIT), Germany

SC473: Photonic Switching Systems  
Benjamin Lee; IBM, USA  
David Neilson; Nokia Bell Labs, USA

SC483: Hands-on: Machine Learning in Optical Networks NEW  
Massimo Tornatore; Politecnico di Milano, Italy  
Darko Zibar; DTU FOTONIK, Denmark

SC487: Hands-On: Laboratory Automation and Control using Python (Advanced) NEW  
Nicolas Fontaine, Nokia Bell Labs USA  
Binbin Guan, Acacia Communications USA  
Jochen Schröder, Chalmers University of Technology Sweden

09:00–12:00

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

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

SC359: Datacenter Networking 101  
Hong Liu; Google, USA  
Ryohei Urata; Google, USA

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

SC450: Design, Manufacturing, and Packaging of Opto-electronic Modules  
Peter O’Brien; Tyndall National Institute, Ireland  
Yoichi Taira; IBM, Japan

SC465: Transmission Fiber and Cables  
Michael Ellwanger; Corning Optical Communications, USA  
Chris Towery; Corning Optical Communications, USA and

SC486: Optoelectronic Devices for LIDAR and High-BW or 3D Sensing NEW  
Martin Ziringibl; Finisar, USA  
Krzysztof Szczerba; Finisar, USA  
Anna Tatarczak; Finisar, USA

13:30–16:30

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

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

SC447: The Life Cycle of an Optical Network: From Planning to Decommissioning  
Andrew Lord, BT Labs, UK

SC459: Multimode Photonic Devices, Components, and Characterization  
Nicolas Fontaine; Nokia Bell Labs, USA

SC462: Introduction to Pluggable Optics  
Robert Blum; Intel Corp., USA  
Sharon Hall; Oclaro, USA

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

13:30–17:30

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

SC327: Modeling and Design of Long-haul Fiber-optic Communication Systems  
Rene-Jean Essiambre; Bell Labs, Alcatel-Lucent, USA

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

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

SC393: Digital Signal Processing for Coherent Optical Transceivers  
Chris Fludger; Infinera, Germany

SC451: Optical Fiber Sensors  
Alexis Mendez; MCH Engineering, USA  
William Shroyer; SageRider, Inc., USA

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

SC454: Hands-on: Introduction to Silicon Photonics Circuit Design  
Wim Boegarts; University of Ghent, Belgium

SC472: Hands-on: Controlling and Monitoring Optical Network Equipment  
Ricard Vilalta; CTTC, Spain  
Noboru Yoshikane; KDDI Research, Japan
Your Home for Optical Communications Research

Visit OSA Publishing’s Digital Library for top-cited content in optics and photonics at osapublishing.org.
Activities on the Show Floor

The OFC 2020 Exhibition is the perfect place to build and maintain professional contacts and to broaden your knowledge about the companies that lead our industry in product development and technological advances. 700+ exhibits showcase the entire continuum of the supply chain – from communications systems and equipment to network design and integration tools to components and devices. In addition, three exhibit hall theaters feature presentations by experts from major global brands and key industry organizations. Get high-level perspectives on hot topics like 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

Halls B-H

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

Exhibition Hours

| Tuesday, 10 March | 10:00–17:00 | 10:00–14:00 |
| Wednesday, 11 March | 10:00–17:00 | 12:30–14:00 |
| Thursday, 12 March | 10:00–16:00 | 12:30–14:00 |

Exhibit Hall Regulations

- All bags are subject to search.
- 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.
- Neither photography nor videotaping is permitted in the exhibit hall without written consent of OFC Show Management, and in the event of video captured of any exhibitor’s booth, products or technologies, that company’s written consent as well. Non-compliance may result in the surrendering of film/drive, removal from the hall, forfeiture of badge and/or ineligibility to attend in the future.
- Distribution of literature is limited to exhibitors and must be done from within the confines of their booths.
- Smoking is not permitted inside the San Diego Convention Center. You are welcome to step outside the Convention Center to smoke in designated smoking areas only, but please be considerate of others when you do.
- 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:

| Hall D Interactive Coffee Break Sponsored by Infinera |
| Exhibit Hours | Coffee Breaks |
| Tuesday, 10 March | 10:00–17:00 | 10:00–10:30, 16:00–16:30 |
| Wednesday, 11 March | 10:00–17:00 | 10:00–10:30, 16:00–16:30 |
| Thursday, 12 March | 10:00–16:00 | 10:00–10:30 |

Interoperability Demonstrations

This year there are five multivendor interoperability demonstrations on the show floor. Stop by to see what is new and talk to representatives about specifics.

- 400G Open ZR+ Coherent Transceiver Demos, Booth #6049
- Consortium For On-Board Optics (COBO) Demos, Booth #5818
- The Ethernet Alliance Live Interoperability Ethernet Demos, Booth #4943
- OpenROADM MSA SDN Demo, Booth #6149
- Optical Internetworking Forum (OIF) Demos, Booth #6221

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.
OFC Career Zone Live

*Exhibit Hall B2*

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 Live and be prepared to discuss your future with representatives from the industry’s leading companies.

**Job Seekers**

**Meet Participating Companies**

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Register Online at ofcconference.org/careerzone to:
- Search job postings freely
- Post your résumés online confidentially
- Network and schedule interviews with employers/recruiters

**Employers**

Didn’t sign up for the on-site OFC Career Zone? It’s not too late.

**Participate online at ofcconference.org/careerzone to:**
- Post jobs online
- Review résumés before, during or after the conference
- Create alerts to inform you of newly submitted résumés and openings

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**Poster Presentations**

*Tuesday and Wednesday, 10-11 March, 10:30–12:00*  
*Exhibit Hall B1*

Poster presentations are an integral part of the technical program and offer an opportunity for lively discussion between the poster presenters and attendees. Beverages and light snacks are served during poster sessions. Refer to the abstract section for a full description.

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**Sponsoring Society Booths**

*Exhibit Hall F*

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

**The Optical Society (OSA) Member Lounge**

*Exhibit Hall F, Booth 2639*

OSA members are invited to take a brief respite from the conference at the OSA Member Lounge. Whether it’s to plan your schedule, meet up with other members or take a moment for yourself. Attendees can also participate in a series of informal 30-minute technical sessions at the OSA Member Lounge, along with light refreshments. In addition, take advantage of renewing your membership at 50% discount for one-year, three-year and five-year individual memberships.

This special rate is available whether you’re joining for the first time or renewing for another year.

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**Expo Theater I Programming, Exhibit Hall B2, #5337**

**NS Market Watch and Network Operator Summit Sub-Committee Chair:** Karen I. Matthews, Technology and Market Development Manager, Corning Research & Development Corp., USA

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**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 the industry, research and investment community.

The program will be located in Exhibit Hall B2, Booth #5337. Attendees can easily attend the sessions and tour the exhibit hall. Audience members are encouraged to participate in the question and answer segments that follow the presentations.

Sponsored by **HUAWEI**

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**Market Watch Schedule-at-a-Glance**

**Tuesday, 10 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Panel I: State of the Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:30–12:00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Panel II: 5G and Re-thinking Access Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:30–14:00</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Panel III: Optical Interconnect and Computing for Scaling Machine Learning Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:30–16:00</td>
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</tr>
</tbody>
</table>

**Wednesday, 11 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Panel IV: What Is Next for Data Center Interconnects?</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:30–17:00</td>
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</tr>
</tbody>
</table>

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.
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### Expo Theater II Programming, Exhibit Hall E, #3139

**Theater II Sponsored by**

**juniper networks**

#### Schedule at-a-Glance

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15–11:15</td>
<td><strong>Ethernet Alliance</strong>: Ethernet Interoperability and Deployments – New and Legacy Solutions Work Together</td>
</tr>
<tr>
<td>11:30–12:15</td>
<td>Data Center Summit Keynote&lt;br&gt;Jeffrey L. Cox, Partner Director Network Architecture, Microsoft Corporation, USA</td>
</tr>
<tr>
<td>12:15–13:45</td>
<td>Data Center Summit Panel: Data Center 2020 – Less Hyper-scale and More Co-location and Compute at the Edge?</td>
</tr>
<tr>
<td>13:50–14:50</td>
<td>Preparing the Transport Network for 5G&lt;br&gt;<strong>Session sponsored by Juniper Networks</strong></td>
</tr>
<tr>
<td>15:00–17:00</td>
<td>Embedded Optics and How They Should Be Done to Support the OEM Eco-system - Panel Debate</td>
</tr>
</tbody>
</table>

**Tuesday, 10 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15–11:15</td>
<td><strong>Design Consideration of Next Generation Ethernet Switches With Higher Speed Optics</strong></td>
</tr>
<tr>
<td>11:30–12:30</td>
<td><strong>COBO</strong>: System Evaluation of On-board Optics</td>
</tr>
<tr>
<td>12:45–13:45</td>
<td>Transforming Network Operations Through Automation&lt;br&gt;<strong>Session sponsored by Juniper Networks</strong></td>
</tr>
<tr>
<td>14:00–15:00</td>
<td>Introduction to OpenROADM MSA, Latest Update, and Show Floor Demo Overview</td>
</tr>
<tr>
<td>15:05–16:00</td>
<td>The World’s First Intercontinental Connections… Contrasting Early Terrestrial-Subsea Networks with the Present</td>
</tr>
</tbody>
</table>

See Buyer’s Guide and the OFC Conference App for program descriptions.

**Wednesday, 11 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15–11:15</td>
<td>Revolutionizing the Economics of Pluggable Optics with Silicon Photonics&lt;br&gt;<strong>Session sponsored by Juniper Networks</strong></td>
</tr>
<tr>
<td>11:30–13:00</td>
<td><strong>TIP</strong>: The Disaggregated Transport Network</td>
</tr>
</tbody>
</table>

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### Expo Theater III Programming, Exhibit Hall G, #2239

**Theater III Sponsored by**

**Acacia Communications**

#### Schedule at-a-Glance

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:15–14:45</td>
<td><strong>IEEE Future Directions</strong>: Cloud Network Evolution Bandwidth Drivers</td>
</tr>
<tr>
<td>15:00–16:00</td>
<td><strong>Open Eye MSA Group</strong>: New Optical Module Implementations Make High-bandwidth DCI Interfaces Cost Effective and Easy to Deploy for Hyperscale Data Center Providers</td>
</tr>
<tr>
<td>16:15–17:00</td>
<td><strong>OIF</strong>: 112 Gbps Electrical Interfaces – An OIF Update on CEI-112G</td>
</tr>
</tbody>
</table>

**Tuesday, 10 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15–10:45</td>
<td>Product Showcase - Bringing the Single Fiber Capacity to the Next Level, Huawei Technologies</td>
</tr>
<tr>
<td>11:00–12:00</td>
<td><strong>AIM Photonics</strong>: AIM Photonics Member Successes and Updates</td>
</tr>
<tr>
<td>12:15 – 13:15</td>
<td><strong>5G Architectures and Service Considerations</strong></td>
</tr>
<tr>
<td>13:30 – 14:30</td>
<td><strong>OIF</strong>: 400ZR Specification Update</td>
</tr>
<tr>
<td>14:45 – 15:45</td>
<td><strong>ITU-T SG15</strong>: Standards Update on 5G Transport, Higher Speed PON, Latest OTN Technologies and Interoperable Optical Coherent Interfaces</td>
</tr>
<tr>
<td>16:00 – 17:00</td>
<td>Accelerating ROI on the Road to SDN</td>
</tr>
</tbody>
</table>

**Wednesday, 11 March**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15–10:45</td>
<td>Product Showcase - The Next-Generation OTN Technology for Enterprise Market&lt;br&gt;<strong>Presenter, Huawei Technologies</strong></td>
</tr>
<tr>
<td>11:00–11:30</td>
<td>Product Showcase - Versal™ ACAPs: for Creators of the Highest Bandwidth, Most Secure Networks. Xilinx, Inc.</td>
</tr>
<tr>
<td>13:00–13:30</td>
<td>Product Showcase, XR Optics: Game-changing Multipoint Coherent Optical Solutions, Cisco</td>
</tr>
<tr>
<td>13:30–14:30</td>
<td>Unleashing the Full Potential of Silicon Photonics&lt;br&gt;<strong>Session Sponsored by Acacia Communications</strong></td>
</tr>
</tbody>
</table>

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Product Showcases

Exhibit Hall, Expo Theater III, #2239

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

Bringing the Single Fiber Capacity to the Next Level

Tuesday, 10 March, 10:15–10:45
Dr. Maxim Kuschnarov, Senior R&D Manager, Transmission & Access Product Line, Huawei Technologies

Fiber is the most valuable resource for all users. Here we demonstrate the latest development on our commercial platform aiming to improve single fiber capacity and maximizing the value of fiber by using the latest coherent technology and wide-spectrum line system.

Cisco Next Generation Silicon Photonics for Single-Lambda 100G Pluggable Optics

Wednesday, 11 March, 13:00–13:30
Patrick Chou, PhD, Product Manager, Cisco Systems

Cisco productized 100G silicon photonics in 2013. The second generation has now come to fruition in the form of single-lambda 100G pluggable optics in a QSFP28 form factor.

XR Optics: Game-changing Multipoint Coherent Optical Solutions

Wednesday, 11 March, 14:30–15:30
Dr. David Welch, Founder and Chief Innovation Officer, Infinera

This session will discuss how intelligent multipoint coherent optical technology, XR optics, can transform access and aggregation networks. XR optics provides a dramatically more efficient and economically disruptive network solution ideal for supporting challenging new high-bandwidth services such as 5G, DAA, next-generation PON, and cloud-based business services.

Approaches to Achieve an Open and Intelligent Optical Network

Thursday, 10 March, 10:15–10:45
Dr. Christopher Janz, Technical Vice President & Director, Optical Systems Competency Centre, Huawei Technologies

Intelligence, synthesized in software, is the key to improved optical network operational outcomes and to process automation. Here we demonstrate the latest development to achieve open and intelligent optical networks.

Versal™ ACAPs: for Creators of the Highest Bandwidth, Most Secure Networks

Wednesday, 11 March, 11:00–11:30
Mike Thompson, Sr. Product Line Manager, Xilinx, Inc.

For those developing next generation highest speed, secure networks targeting emerging technologies and protocols, we will present an overview of integrated technologies in Versal ACAP devices including 112G PAM4 transceivers, off-the-shelf Ethernet and OTN connectivity, encryption, PCIe Gen5, and large FPGA fabric that together minimize power consumption and time to market.
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David Plant, McGill University, Canada
Jun Shan Wey, ZTE TX, USA

Subcommittees

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D1: Advances in prototypes and product developments of components and subsystems for data centers and optical networks
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Patrick Chiang, Fudan University, China
Friedel Gerfers, Technische Universität Berlin, Germany
Marika Immonen, TTM Technologies, Finland
Kenneth Jackson, Sumitomo Electric, USA
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Hidemuki Nasu, Furukawa Electric, Japan
Yu Chen, NTT Photonics Laboratories, Japan
Zuowei Shen, Google, USA
Haxing Shi, Consultant, USA

D2: Passive optical devices for switching and filtering
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Joel Anthony Carpenter, University of Queensland, Australia
Giampiero Contestabile, Scuola Superiore Sant Anna di Pisa, Italy
Nicolás Dupuis, IBM TJ Watson Research Center, USA
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Yuqing Jiao, Eindhoven University of Technology, Netherlands

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Hui Cao, Yale University, USA
Kehayas Elstratiotes, Gooch & Housego, USA
Clemence Jollivet, Coherent Inc., USA
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Chigo Okonkwo, Technische Universiteit Eindhoven, Netherlands
Francesca Parmigiani, Microsoft Research, USA

Hidehisa Tazawa, Sumitomo Electric Industries Ltd, Japan
Joel Villatoro, University of the Basque Country, Spain
Yining Wang, Beijing University of Technology, China

Track S: Systems and Subsystems

S1: Digital subsystems and systems for data centers
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Fred Buchali, Nokia Bell Labs, USA
Sai Chen, Alibaba Group, China
Madeleine Glick, Columbia University, USA
Yue-Kai Huang, NEC Laboratories America Inc., USA
Hoon Kim, Korea Advanced Institute of Science and Technology, Korea
Reza Motaghian, Amazon Web Services, USA
Xiaodan Pang, Infinera, Sweden
Stephen Ralph, Georgia Institute of Technology, USA
Sorin Tübleac, ADV Optical Networking AG, USA
Hongbin Zhang, Acacia Communications, USA

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Daniel Blumenthal, University of California Santa Barbara, USA
Maurizio Burla, ETH Zurich, Switzerland
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Lu Li, SubCom, USA
Ana Pejkic, University of California San Diego, USA
Ewan Pincemin, Orange Labs, France
Ben Putnam, NICt Japan, Japan
Siva Yegnanarayanan, Massachusetts Institute of Technology, USA

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Sang Yeup Kim, NTT Access Network, Japan  
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Xiaoxia Wu, SpaceX, USA  
Fan Zhang, Peking University, China  
Liang Zhang, Huawei Technologies Duesseldorf GmbH, Germany  

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Jianjun Yu, Fudan University, China

Track N: Networks, Applications and Access

N1: Advances in system, network and service developments and field trials in commercial data centers and networks  
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Bruce Cortez, AT&T, USA  
Steve Grubb, Facebook, USA  
Praveen Kumar, Bharti Airtel Ltd, India  
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Albert Rafael, British Telecommunications, UK  
Sheldon Walkin, Nokia, Canada  
Shuto Yamamoto, NTT, Japan  
Xiang Zhou, Google, USA

N2: Optical networking for data center and computing applications  
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Hideaki Funakawa, National Inst. of Information and Communications Technology, Japan  
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Yawei Yin, Microsoft Corp., USA  
Georgios Zervas, University College London, UK

N3: Architectures and software-defined control for metro and core networks  
Qiong Zhang, Fujitsu Labs America, USA, Subcommittee Chair  
Achim Autenrieth, ADVA Optical Networking SE, Germany  
Maite Brandt-Pearce, University of Virginia, USA  
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N4: Optical access networks for fixed and mobile services  
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Marco Ruffini, Trinity College Dublin, Ireland  
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N5: Market Watch, Network Operator Summit & Data Center Summit (Invited Program)  
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Ed Harstead, Nokia, USA  
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The first letter of the code denotes the day of the week (Sunday=Sunday, Monday=M, Tuesday=T, Wednesday=W, Th=Thursday). The second element indicates the session series in that day (for instance, 1 would denote the first parallel sessions in that day). Each day begins with the letter A in the third element and continues alphabetically through a series of parallel sessions. The lettering then restarts with each new series. The number on the end of the code (separated from the session code with a period) signals the position of the talk within the session (first, second, third, etc.). For example, a presentation coded M1C.4 indicates that this paper is being presented on Monday (M) in the first series of sessions (1), and is the third parallel session (C) in that series and the fourth paper (4) presented in that session.
## Agenda of Sessions — Sunday, 8 March

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<th>Room 6D</th>
<th>Room 6E</th>
<th>Room 6F</th>
<th>Room 7</th>
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</thead>
<tbody>
<tr>
<td>09:00–12:00</td>
<td>SC177, SC208, SC444, SC470, SC485 (additional fee required)</td>
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<tr>
<td>09:00–13:00</td>
<td>SC105, SC328, SC384, SC395, SC432, SC461, SC469 (additional fee required)</td>
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</tr>
<tr>
<td>12:00–13:00</td>
<td>Lunch Break (on own)</td>
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</tr>
<tr>
<td>13:00–15:30</td>
<td>S1A • Application and Technology Drivers for Short-reach Coherent Links at 800G and Beyond (Session 1)</td>
<td>S1B • Optical Components for f/J/bit Exascale Computing: How and When?</td>
<td>S1C • What ROADM/OXC Technologies will Cost-effectively Enable Dynamic and Reconfigurable Optical Networks in 5G Era?</td>
<td>S1D • Optics for Neuromorphic Computing and Machine Learning: Status, Prospects and Challenges</td>
<td>S1E • Converged 5G and Heterogeneous Services Access Networks: How to Achieve Ultra-low Latency and High Reliability?</td>
</tr>
<tr>
<td>13:00–16:00</td>
<td></td>
<td>SC216, SC217, SC433, SC460 (additional fee required)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>13:00–17:00</td>
<td></td>
<td>SC203, SC267, SC369, SC390, SC463 (additional fee required)</td>
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<td>13:30–17:30</td>
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<td>SC443, SC452 (additional fee required)</td>
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<td>15:30–16:00</td>
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<tr>
<td>16:00–18:30</td>
<td>S2A • Application and Technology Drivers for Short-reach Coherent Links at 800G and Beyond (Session 2)</td>
<td>S2B • Are Radical Photonic Devices and Architectures Needed for Future Data Centers?</td>
<td>S2C • Trends and Perspectives in Space-division Multiplexed Transmission and Related Devices</td>
<td>S2D • Network Analytics in the Age of Machine Learning: How to Share Data and Maximize Synergies Among Transport Systems and Network Operators</td>
<td>S2E • Does Disaggregation Support Data Center Evolution?</td>
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<td>17:00–20:00</td>
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<td>20:00–22:00</td>
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### Key to Shading
- Short Courses

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OFC 2020 • 8–12 March 2020
### Agenda of Sessions — Monday, 9 March

<table>
<thead>
<tr>
<th>Time</th>
<th>Room 1A</th>
<th>Room 1B</th>
<th>Room 2</th>
<th>Room 3</th>
<th>Room 6C</th>
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</thead>
<tbody>
<tr>
<td>08:00–10:00</td>
<td>M1A • Edge Computing</td>
<td>M1B • Cognitive Optical Networks</td>
<td>M1C • Photonic Sensors</td>
<td>M1D • Novel Active Devices</td>
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<td></td>
<td>Symposium: Quantum Information Science and Technology (QIST) in the Context of Optical Communications (Session 1)</td>
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<tr>
<td>08:30–12:30</td>
<td>SC102, SC160, SC178, SC341, SC446, SC448, SC453A, SC468, SC473, SC483, SC487 (additional fee required)</td>
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<tr>
<td>09:00–12:00</td>
<td>SC114, SC261, SC359, SC408, SC450, SC465, SC486 (additional fee required)</td>
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<tr>
<td>10:00–10:30</td>
<td>Coffee Break, Upper Level Corridors</td>
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<tr>
<td>10:30–12:30</td>
<td>M2A • Advanced Active Components</td>
<td>M2B • High-speed Integrated Modulators</td>
<td>M2C • SDM Imaging and Sensing</td>
<td>M2D • Optimizing Network Capacity and Performance</td>
<td>M2E</td>
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<td></td>
<td>Symposium: Quantum Information Science and Technology (QIST) in the Context of Optical Communications (Session 2)</td>
</tr>
<tr>
<td>12:30–14:00</td>
<td>Lunch Break (on own)</td>
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<tr>
<td>13:30–16:30</td>
<td>SC429, SC431, SC447, SC459, SC462, SC464 (additional fee required)</td>
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<tr>
<td>13:30–17:30</td>
<td>SC325, SC327, SC347, SC357, SC393, SC451, SC453B, SC454, SC472 (additional fee required)</td>
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<tr>
<td>14:00–16:00</td>
<td>M3A • New Photonic Materials</td>
<td>M3B • Propagation Effects in SMF and SDM Fibers</td>
<td>M3C • Panel: Is it Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity?</td>
<td>M3D • VCSELS and Surface Normal Devices</td>
<td>M3E</td>
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<td>Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 1)</td>
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<tr>
<td>14:00–16:15</td>
<td>M3Z • OFC Demo Zone, Room 6A</td>
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<tr>
<td>16:00–16:30</td>
<td>Coffee Break, Upper Level Corridors</td>
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<tr>
<td>16:30–18:30</td>
<td>M4A • Quantum Security Subsystems</td>
<td>M4B • Panel: Automotive Communications and Technologies for 10G and Beyond</td>
<td>M4C • MCF Amplifiers and Cable</td>
<td>M4D • Network Design and Switching Architecture</td>
<td>M4E</td>
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<td></td>
<td>Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 2)</td>
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**Key to Shading**
- Short Courses
- Recorded Session
<table>
<thead>
<tr>
<th>Room 6D</th>
<th>Room 6E</th>
<th>Room 6F</th>
<th>Room 7</th>
<th>Room 8</th>
<th>Room 9</th>
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</thead>
<tbody>
<tr>
<td>M1F • Next Generation TOSA/ROSA Components</td>
<td>M1G • Machine Learning and its Applications</td>
<td>M1H • Chip-to-chip Optical Interconnects</td>
<td>M1I • Optical Signal Processing</td>
<td>M1J • Positioning Beam-steering for Advanced Wireless Communications</td>
<td>M1K • Dis-aggregated Access Networks</td>
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<tr>
<td>SC102, SC160, SC178, SC341, SC446, SC448, SC453A, SC468, SC473, SC483, SC487 (additional fee required)</td>
<td>SC114, SC261, SC359, SC408, SC450, SC465, SC486 (additional fee required)</td>
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<tr>
<td>M2F • Digital Signal Processing and Radio-over-fiber Systems for 5G</td>
<td>M2G • Multiband and SDN for Capacity Scaling</td>
<td>M2H • Access Networks for Mobile and Multi-access Edge Computing</td>
<td>M2I • Photonic Integrated Subsystems</td>
<td>M2J • Data Analytic-based Monitoring</td>
<td>M2K • Neuromorphic I: Device-oriented</td>
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<tr>
<td>Lunch Break (on own)</td>
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<tr>
<td>M3F • Wavelength Selective Devices</td>
<td>M3G • Submarine Transmission</td>
<td>M3H • Microwave Photonic Filters</td>
<td>M3I • Optical Wireless: Technology and Applications</td>
<td>M3J • Short-reach Systems I</td>
<td>M3K • Open Network Control and Orchestration</td>
</tr>
<tr>
<td>M3Z • OFC Demo Zone, Room 6A</td>
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<td>Coffee Break, Upper Level Corridors</td>
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<tr>
<td>M4F • High Order Direct Detect Formats (Ends at 18:15)</td>
<td>M4G • Open Networking Summit: Optical Metro/Aggregation Networks to Support Future Services over 5G (Ends at 19:00)</td>
<td>M4H • Silicon Photonics and High Density Integration</td>
<td>M4I • Advanced Radio-over-fiber Technology</td>
<td>M4J • Digital Signal Processing I</td>
<td>M4K • High-speed Long-haul Transmission (Ends at 18:15)</td>
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</tbody>
</table>
## Agenda of Sessions — Tuesday, 10 March

<table>
<thead>
<tr>
<th>Time</th>
<th>Room 1A</th>
<th>Room 1B</th>
<th>Room 2</th>
<th>Room 3</th>
<th>Room 6C</th>
<th>Room 6D</th>
<th>Room 6E</th>
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<tbody>
<tr>
<td>07:30–08:00</td>
<td>Plenary Session Coffee Break, <em>Upper Level, Ballroom 20 Lobby</em></td>
<td>Plenary Session, <em>Ballroom 20BCD</em></td>
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<tr>
<td>08:00- 10:00</td>
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<tr>
<td>10:00–14:00</td>
<td>Unopposed Exhibit-only Time, <em>Exhibit Hall (coffee service 10:00–10:30)</em></td>
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<tr>
<td>10:00–17:00</td>
<td>Exhibition and Show Floor, <em>Exhibit Hall (concessions available)</em></td>
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<td>12:00–14:00</td>
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<tr>
<td>14:00–16:00</td>
<td>T3A • Linear and Nonlinear Space Division Multiplexing</td>
<td>T3B • Novel Materials</td>
<td>T3C • Lasers for Communications and Sensing</td>
<td>T3D • Quantum and Secure Communications</td>
<td>T3E • Symposium: Emerging Network Architectures for 5G Edge Cloud (Session 1)</td>
<td>T3F • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?</td>
<td>T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?</td>
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<td>16:00–16:30</td>
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<tr>
<td>16:30–18:00</td>
<td>T4A • Radio-over-fiber Technologies for 5G</td>
<td>T4B • Machine Learning for Fiber Amplifier and Sensors</td>
<td>T4C • Neuromorphic II: Entire Aspect</td>
<td>T4D • AI Assisted Access Networks</td>
<td>T4E • Symposium: Emerging Network Architectures for 5G Edge Cloud (Session 2)</td>
<td>T4F • Quantum Networking and Artificial Intelligence</td>
<td>T4G • Optical Transmitter Subsystems</td>
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<tr>
<td>17:15–18:15</td>
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<tr>
<td>18:15–19:00</td>
<td>Celebrating 50 Years of Light-speed Connections, <em>Keynote Presentation</em>, <em>Ballroom 20BCD</em></td>
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<tr>
<td>19:00–20:30</td>
<td>Celebrating 50 Years of Light-speed Connections, <em>Conference Reception</em>, <em>Sails Pavilion</em></td>
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<td>19:30–21:30</td>
<td>Rump Session: When Will Co-packaged Optics Replace Pluggable Modules in the Datacenter?</td>
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### Key to Shading
- Market Watch/Data Center Summit
- Recorded Session

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**OFC 2020 • 8–12 March 2020**
<table>
<thead>
<tr>
<th>Room 6F</th>
<th>Room 7</th>
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<tbody>
<tr>
<td>Plenary Session Coffee Break, Upper Level, Ballroom 20 Lobby</td>
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<tr>
<td>Plenary Session, Ballroom 20BCD</td>
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<td>Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30)</td>
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<td>Exhibition and Show Floor, Exhibit Hall (concessions available)</td>
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<tr>
<td>OFC Career Zone Live, Exhibit Hall B2</td>
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<tr>
<td>OFC and Co-Sponsors Awards and Honors Ceremony and Luncheon, Upper Level, Ballroom 20A</td>
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<tr>
<td>T3H • Silicon Photonics Applications</td>
<td>T3I • Short-reach Systems II</td>
<td>T3J • Orchestration and Control</td>
<td>T3K • Intra Data Center Networks I</td>
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<tr>
<td>Coffee Break, Exhibit Hall</td>
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<tr>
<td>T4H • Quantum Dots and Novel III-V Devices</td>
<td>T4I • Long-haul Systems and Nonlinear Mitigation</td>
<td>T4J • Multi-core Fibers</td>
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<tr>
<td>Exhibitor Happy Hour, Center Terrace</td>
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<tr>
<td>Celebrating 50 Years of Light-speed Connections, Keynote Presentation, Ballroom 20BCD</td>
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<tr>
<td>Celebrating 50 Years of Light-speed Connections, Conference Reception, Sails Pavilion</td>
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<tr>
<td>Rump Session: When Will Co-packaged Optics Replace Pluggable Modules in the Datacenter? Room 6F</td>
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</table>

Exhibit Hall Theater I
- MW Panel I: State of the Industry
  10:30–12:00
- MW Panel II: 5G and Re-thinking Access Networks
  12:30–14:00
- MW Panel III: Optical Interconnect and Computing for Scaling Machine Learning (ML) Systems
  14:30–16:00
- OIDA Roadmap on Quantum Photonics
  16:15–17:00

Exhibit Hall Theater II
- Ethernet Interoperability and Deployments – New and Legacy Solutions
  Work Together
  10:15–11:15
- Data Center Summit: Keynote and Panel
  Session sponsored by InnoLight
  11:30–13:45
- Preparing the Transport Network for 5G
  Session sponsored by Juniper Networks
  13:50–14:50
- Embedded Optics and How They Should Be Done to Support the OEM Eco-system – Panel Debate
  15:00–17:00

Exhibit Hall Theater III
- Product Showcase - Huawei Technologies Canada Co., Ltd.
  10:15–10:45
- AIM Photonics Member Successes and Updates
  11:00–12:00
- 5G Architectures and Service Considerations
  12:15–13:15
- 400ZR Specification Update
  13:30–14:30
- Standards Update on 5G Transport (and more)
  ITU-T SG15
  14:45–15:45
- Accelerating ROI on the Road to SDN
  SDN
  16:00–17:00

Exhibit Hall Opens 10:00
Exhibit Hall Closes 17:00

Agenda of Sessions
OFC 2020 • 8–12 March 2020
<table>
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<tr>
<td>07:30–08:00</td>
<td>Morning Coffee, Upper Level Corridors</td>
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<tr>
<td>08:00–10:00</td>
<td>W1A • Optical Input/Output and Filters</td>
<td>W1B • Multi-mode Fiber Technology</td>
<td>W1C • Novel Doped Fiber Amplifier</td>
<td>W1D • Short-reach Interconnects</td>
<td>W1E • Advances in Coherent PON</td>
<td>W1F • Intra Data Center Networks II</td>
<td>W1G • Trends in Free Space Optics Communications</td>
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<tr>
<td>10:00–14:00</td>
<td>Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30)</td>
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<td>10:00–17:00</td>
<td>Exhibition and Show Floor, Exhibit Hall</td>
<td>OFC Career Zone Live, Exhibit Hall B2</td>
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<td>10:30–12:30</td>
<td>W2A • Poster Session I, Exhibit Hall B1</td>
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<td>Lunch Break (on own; concessions available in Exhibit Hall)</td>
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<tr>
<td>14:00–16:00</td>
<td>Replay recorded tutorial, Machine Learning and its Applications in Optical Communication Systems</td>
<td>W3A • Neuromorphic III: System-oriented</td>
<td>W3B • Panel: Will SDM Truly Revolutionize the Submarine Communication Industry?</td>
<td>W3C • Open Network Architecture (Ends at 15:45)</td>
<td>W3D • High-speed Transmission</td>
<td>W3E • Ultra-wideband Transmission</td>
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<tr>
<td>16:00–16:30</td>
<td>Coffee Break, Upper Level Corridors and Exhibit Hall</td>
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<tr>
<td>16:30–18:30</td>
<td>W4A • Digital Signal Processing II</td>
<td>W4B • Nonlinear Devices and Amplifiers</td>
<td>W4C • Novel Passive Devices</td>
<td>W4D • Speciality Fibers</td>
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Key to Shading:
- Market Watch/Network Operator Summit
- Recorded Session
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<tr>
<td><strong>Morning Coffee, Upper Level Corridors</strong></td>
<td>W1H • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)</td>
<td>W1I • Panel: Pros and Cons of Low-margin Optical Networks</td>
<td>W1J • Advanced Transmission Path Metrics</td>
</tr>
<tr>
<td><strong>Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30)</strong></td>
<td>W1K • Machine Learning for Optical Communication Systems (Begins at 08:45)</td>
<td><strong>Lunch Break (on own; concessions available in Exhibit Hall)</strong></td>
<td><strong>Exhibit Hall Theater I</strong></td>
</tr>
<tr>
<td><strong>Exhibition and Show Floor, Exhibit Hall</strong></td>
<td><strong>OFC Career Zone Live, Exhibit Hall B2</strong></td>
<td><strong>W2A • Poster Session I, Exhibit Hall B1</strong></td>
<td>NOS Keynote 10:30–11:15</td>
</tr>
<tr>
<td><strong>W3A • Exhibit Hall</strong></td>
<td>W3B • Panel: What is Next for Data Center Interconnects (DCIs)? 15:30–17:00</td>
<td><strong>W2B • Poster Session II, Exhibit Hall B3</strong></td>
<td>NOS Panel II: Transport on a Plug 13:30–15:00</td>
</tr>
<tr>
<td>W3C • Open Amplifiers</td>
<td><strong>W3D • High-speed II</strong></td>
<td><strong>W3E • Open Fiber Technology</strong></td>
<td>NOS Panel III: Is Next for Data Center Interconnects (DCIs)? 15:30–17:00</td>
</tr>
<tr>
<td><strong>W3F • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 1)</strong></td>
<td>W3G • Datacentre Infrastructure and Metrology</td>
<td><strong>W3H • Open Metrology</strong></td>
<td>Cloud Network Evolution Bandwidth Drivers 11:30–13:45</td>
</tr>
<tr>
<td><strong>Coffee Beak, Upper Level Corridors and Exhibit Hall</strong></td>
<td><strong>W3I • Open receivers</strong></td>
<td><strong>W3J • Open Receivers</strong></td>
<td>IEEE Future Directions 13:15–14:45</td>
</tr>
<tr>
<td>W4A • Symposium: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</td>
<td>W4B • Reliability and Test</td>
<td>W4C • Photodetectors and Receivers</td>
<td>New Optical Module Implementations (and more) 11:30–13:45</td>
</tr>
<tr>
<td><strong>W4D • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</strong></td>
<td>W4E • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</td>
<td><strong>W4F • Open Receivers</strong></td>
<td>New High-bandwidth, Non-DSP Interface for Data Center and Campus Interconnects 15:00–16:00</td>
</tr>
<tr>
<td><strong>Exhibit Hall Theater II</strong></td>
<td><strong>W4G • Photodetectors and Receivers</strong></td>
<td><strong>W4H • Open Receivers</strong></td>
<td>112 Gbps Electrical Interfaces OIF 16:15–17:00</td>
</tr>
<tr>
<td><strong>Exhibit Hall Theater III</strong></td>
<td><strong>W4I • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</strong></td>
<td><strong>W4J • Open Receivers</strong></td>
<td><strong>Product Showcase</strong> Huawei Tech. Co. 10:15–10:45</td>
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<tr>
<td><strong>Exhibit Hall Opens 10:00</strong></td>
<td><strong>W4K • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</strong></td>
<td><strong>W4L • Open Receivers</strong></td>
<td><strong>Product Showcase</strong> Xilinx 11:00–11:30</td>
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<td><strong>Product Showcase</strong> Unleashing the Full Potential of Silicon Photonics Session Sponsored by Acacia Communications 13:30–14:30</td>
<td><strong>W4M • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</strong></td>
<td><strong>W4N • Open Receivers</strong></td>
<td><strong>Open, Multi-vendor Networks - Design, Management and Operations</strong> OpenConfig 15:30–17:00</td>
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<tr>
<td><strong>Exhibit Hall Closes 17:00</strong></td>
<td><strong>W4O • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)</strong></td>
<td><strong>W4P • Open Receivers</strong></td>
<td><strong>Check the OFC Conference App for the latest updates.</strong></td>
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**OFC 2020 •  8–12 March 2020**

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## Agenda of Sessions — Thursday, 12 March

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<th>Time</th>
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<th>Room 6C</th>
<th>Room 6D</th>
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<tr>
<td>07:30–08:00</td>
<td>Morning Coffee, Upper Level Corridors</td>
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<tr>
<td>08:00–10:00</td>
<td>Th1A • Advanced Design for Passive Devices</td>
<td>Th1B • High Speed PON</td>
<td>Th1C • Microwave Photonics</td>
<td>Th1D • Pushing the Bit-rate in Practical Networks</td>
<td>Th1E • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)</td>
<td>Th1F • Al for Reliable Networking</td>
<td>Th1G • Modulation and Coding</td>
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<td>10:00–14:00</td>
<td>Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30)</td>
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<td>10:00–16:00</td>
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<td>Exhibition and Show Floor, Exhibit Hall</td>
<td>OFC Career Zone Live, Exhibit Hall B2</td>
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<td>10:30–12:30</td>
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<td>Lunch Break (on own; concessions available in Exhibit Hall)</td>
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<tr>
<td>14:00–16:00</td>
<td>Th3A • Disaggregation, Open Platform, SDN, NFV</td>
<td>Th3B • Optical Switching</td>
<td>Th3C • High-speed and Multi-wavelength Devices</td>
<td>Th3D • Machine Learning for Optical Network Performance</td>
<td>Th3E • Optimizing Coherent Transponders</td>
<td>Th3F • Novel Fiber Optic Sensors</td>
<td>Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond</td>
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<td>16:00–16:30</td>
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<td>Coffee Break, Upper Level Corridors</td>
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<td>16:30–18:30</td>
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<td>Postdeadline Papers, Room 6C, 6D, 6E, 6F</td>
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**Key to Shading**
- Market Watch/Network Operator Summit
- Recorded Session
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<tr>
<th>Room 6F</th>
<th>Room 7</th>
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<th>Exhibit Hall Theater I</th>
<th>Exhibit Hall Theater II</th>
<th>Exhibit Hall Theater III</th>
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<tr>
<td>Morning Coffee, Upper Level Corridors</td>
<td>Th1H • Characterization of SDM Fibers</td>
<td>Th1I • Digital Signal Processing Techniques and Management</td>
<td>Th1J • Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?</td>
<td>Th1K • Optical Wireless Sensing Systems for 5G</td>
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<td>Th2A • Poster Session II, Exhibit Hall B1</td>
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<tr>
<td>Th3H • SDM Transmission (Ends at 15:30)</td>
<td>Th3I • Optical and Thermal Connectivity</td>
<td>Th3J • Direct Detection Systems and Subsystems (Ends at 15:30)</td>
<td>Th3K • Future and Emerging Access Network Technologies</td>
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**Exhibit Hall Opens 10:00**
- Market Watch Panel V: Inside the Data Center 10:30–12:00
  - System Evaluation of On-board Optics 10:15–11:15
  - Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics 10:15–10:45
  - Transforming Network Operations through Automation 10:30–12:30
- Market Watch Panel VI: Advanced Packaging and Photonic Integration 12:30–14:00
  - System Evaluation of On-board Optics 11:30–12:30
  - Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics 10:15–10:45
- Market Watch Panel VII: IP+WDM Architecture Evolution 14:30–16:00
  - Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics 10:15–10:45

**Exhibit Hall Closes 16:00**
- Beyond 400ZR.... What Comes Next? Session Sponsored by Acacia Communications 11:00–12:00
  - 3D-sensing Use in Consumer and Automotive Markets Intel 12:15–13:30
- POF Symposium POFTE 13:45–14:45
  - Fibre Types and Amplifiers: Choices and Trade-offs 15:00–16:00
- Product Showcase Huawei Technologies USA 10:15–10:45
  - The World's First Intercontinental Connections.... Contrasting Early Terrestrial-subsea Networks with the Present 15:05–16:00

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M1A.1 • 08:00
Telemetry-driven Optical 5G Serverless Architecture for Latency-sensitive Edge Computing, Istvan Pelle1, Francesco Paolucci1, Balazs Sorkoly1, Filippo Cugini1, 1MTA-BME Network Softwarization Research Group, Hungary; 2CNIT, Italy; 3Scuola Superiore Sant’Anna, Italy. Latency-sensitive serverless subfunctions are optimally deployed at edge and cloud according to telemetry-retrieved data from the 5G transport infrastructure. Once deployed, serverless functions provided extremely fast invocation time of less than 450 ms.

M1A.2 • 08:15
Flexible Optical Network Enabled Hybrid Recovery for Edge Network with Reinforcement Learning, Meng Lian1, Rentao Gu1, Yongyao Gu1, Zhihao Wang1, Yufeng Ji1; 1Beijing Laboratoire of Advanced Information Network, Beijing Univ. of Posts and Telecommunications, China. The proposed hybrid recovery utilizes flexible optical network with reinforcement learning to recover IP fault for edge network. The testbed experiments indicate, the recovery time is 20% of rerouting-based strategy for a heavy-loaded network.

M1B.1 • 08:00
Tutorial Machine Learning in Multi-layer Optical Networks: Why and How, Rui M. Morais1, 1Infinera, Portugal. This tutorial addresses the questions of why and how machine learning (ML) can be useful in multi-layer optical networks. Some key concepts are illustrated by realistic use-cases highlighting the challenges and requisites of adopting ML.

M1C.1 • 08:00
Tutorial Mid-infrared Gas Spectroscopy Using Fiber Laser Driven Supercontinuum, Camille-Sophie Bréz1, Davide Grassani1, Eirini Tagkoudi1, 1École Polytechnique Federale de Lausanne, Switzerland. Middle-infrared (mid-IR) gas spectroscopy based on turn-key fiber lasers offers simplicity and robustness. Here we review recent work on fiber-laser driven mid-IR spectroscopy leveraging efficient dispersive-wave generation in silicon nitride waveguide covering 3-5 micron region.

M1D.1 • 08:00
Tutorial Graphene and Related Materials for Photonics and Optoelectronics, Andrea C. Ferrari1; 1Univ. of Cambridge, UK. Graphene is an ideal material for optoelectronics. I will show that graphene-based integrated photonics could enable ultrahigh spatial bandwidth density, low power consumption for next generation datacom and telecom. Heterostructures based on layers of atomic crystals can also be exploited in novel optical devices, such as single photon emitters, and tuneable light emitting diodes.

M1E.1 • 08:00
Tutorial The Enabling Role of Optics and Photonics in the National Quantum Initiative, Michael G. Raymer1, 1OMI, Univ. of Oregon, USA. Optics and photonics play key roles in integrating Univ., industry and government research to move quantum information science and technology from theory into practice, including the central areas of quantum sensors, communication systems and computers.

M1F.1 • 08:00
Invited A Single Channel 112 Gb/s PAM4 Optical Transceiver Link Based on Silicon Photonics and CMOS Electronics, Haisheng Rong1; 1Intel Corporation, USA. Abstract not available.

Room 1A
08:00–10:00
M1A • Edge Computing
Presider: Yawei Yin; Microsoft Corp, USA

Room 1B
08:00–10:00
M1B • Cognitive Optical Networks
Presider: Josue Kuri; Google LLC, USA

Room 2
08:00–10:00
M1C • Photonic Sensors
Presider: Joel Villatoro; Univ. of the Basque Country UPV/ EHU, Spain

Room 3
08:00–10:00
M1D • Novel Active Devices
Presider: Mitsuri Takenaka; Univ. of Tokyo, Japan

Room 6C
08:00–10:00
M1E • Symposium: Quantum Information Science and Technology (QIST) in the Context of Optical Communications (Session 1)

Room 6D
08:00–10:00
M1F • Next Generation TOSA/ROSA Components
Presider: Yusuke Nasu; NTT Photonics Laboratories, Japan
Room 6E

08:00–10:00
M1G • Machine Learning and its Applications
Presider: Hussam Batshon; NEC Laboratories America Inc, USA

M1G.1 • 08:00
Neural Network Assisted Geometric Shaping for 800Gbit/s and 1Tbit/s Optical Transmission, Maximilian Schaedler¹,², Stefano Calabò¹, Fabio Pittalà¹, Georg Böcherer³, Maxim Kuschnerov¹, Christian Bluemml¹, Stephan Pachnicke¹, Huawei Munich Research Center, Germany; Chair of Communications, Kiel Univ. (CAU), Germany; Huawei Technologies France SASU, France. End-to-end learning for amplified and unamplified links including binary-mapping is proposed to improve the performance of optical coherent systems. 1.0dB and 1.2dB gains are demonstrated on coherent 92Gbaud DP-32QAM 800Gb/s and 82Gbaud DP-128QAM 1Tb/s measurements, respectively.

M1G.2 • 08:15
Deep Learning Based Digital Back Propagation with Polarization State Rotation & Phase Noise Invariance, Bertold Ian Bitachon¹, Amirhossein Ghazisaeidi¹, Benedict Baeuerle¹, Marco Eppenberger¹, Jung Leuthold¹, ETH Zurich, Switzerland; Polariton AG, Switzerland; Nokia Bell Labs, France. A new deep learning training method for digital back propagation (DBP) is introduced. It is invariant to polarization state rotation and phase noise. Applying the method one gains more than 1 dB over standard DBP.

Room 6F

08:00–10:00
M1H • Chip-to-chip Optical Interconnects
Presider: Madeleine Glick; Columbia Univ., USA

M1H.1 • 08:00
Invited
Co-packaged TeraPHY Optical I/O Enables Next Generation of Data Center Applications, Vladimir Stojanovic¹, Vladimir Drnovšek², Daniele de Fabritiis¹, Ayar Labs, USA. Abstract not available.

Room 7

08:00–10:00
M1I • Optical Signal Processing
Presider: Youichi Akasaka; Fujitsu Laboratories of America Inc, USA

M1I.1 • 08:00
Invited
Narrowband and Low-noise Brillouin Amplification for Coherent Communications, Mark D. Pelusi¹, Takashi Inoue¹, Shu Namiki¹, National Inst. of Advanced Industrial Science and Technology (AIST), Japan. Advantages of Brillouin amplification for phase noise sensitive 64-QAM coherent communications are described. The limits of narrowband gain enhancing the carrier-to-noise ratio of noisy pilot tones for high performance optical signal carrier recovery are shown.

Room 8

08:00–10:00
M1J • Positioning Beam-steering for Advanced Wireless Communications
Presider: Nan Chi; Fudan Univ., China

M1J.1 • 08:00
Invited
Optically Controlled Beam-steering Wireless Systems, Ton Koonen¹, Ketema Mekeonen¹, Zuheng Cao¹, Frans Huijskens¹, Ngoc-Quan Pham¹, Eduard Tangdiongga¹, Technische Universiteit Eindhoven, Netherlands. Wavelength-controlled 2D steering of mm-wave beams and infrared beams provides high communication capacity, privacy and energy efficiency. Using diffractive elements and accurate user localization, delivery of multiple 10GbE video streams by infrared beams is demonstrated.

Room 9

08:00–10:00
M1K • Dis-aggregated Access Networks
Presider: Michael Freiberger; Verizon Communications Inc, USA

M1K.1 • 08:00
Tutorial
The Telco Cloudification, from OpenCORD to SDN-enabled Broadband Access (SEBA), Saurav Das¹, Open Networking Foundation, USA. Abstract not available.
M1A.3 • 08:30 • Invited
Multi-layer Network Slicing for Accelerating Business Velocity for Edge Computing, Akihito Nakao¹, Institute Initiative in Information Studies, The Univ. of Tokyo, Japan. Abstract not available.

M1C.2 • 08:30
Proposal of Brillouin Optical Time Domain Collider for Dynamic Strain Measurement, Yinfu Zhang¹, Wei Pan¹; Southwest Jiaotong Univ., China. The dynamic strain sampling rate of Brillouin-based distributed sensors is limited by fiber length. For breaking this limit, a Brillouin optical time domain collider is proposed. A 10-times enhancement on sampling rate is experimentally demonstrated.

M1C.3 • 08:45
Silicon-based Integrated Broadband Wavelength-meter with Low Temperature Sensitivity, Long Chen¹, Chris Doerr¹, Shenghua Liu¹, Li Chen¹, Michelle Xu¹, Acacia Communications, Inc., USA. We demonstrated an integrated broadband wavelength-meter with three optical 90-degree mixers, differential photodiodes, and delays of thin TM waveguides, allowing unambiguous wavelength determination over 4 THz with high accuracy and relaxed requirement on temperature control.

M1F.2 • 08:30 • Top-Scored
High Output Power and Compact LAN-WDM EADFB Laser TOSA for 4 × 100-Gbit/s/λ 40-km Fiber-Amplifier Less Transmission, Shigeru Kanazawa¹, Takahiro Shindo¹, Mingchen Chen¹, Naoki Fujiwara¹, Masahiro Nada¹, Toshihide Yoshimatsu¹, Atsushi Kanda¹, Yushiko Nakashima¹, Fumito Nakajima¹, Kimikazu Sano¹, Yozo Ishikawa², Kazuyoshi Mizuma², Hideaki Matsuzaki³, NTT Device Innovation Center, Japan; NTT Device Technology Labs., Japan; Furukawa Electric Co. Ltd, Japan. We achieved the world’s first demonstration of 4 × 100-Gbit/s/λ 4-PAM signals 40-km fiber-amplifier-less transmission featuring a power budget over 18 dB using a 4-channel high output power LAN-WDM EADFB laser TOSA and APD ROSA.

M1F.3 • 08:45
A Hybrid-integrated 400G TROSA Module Using Chip-to-chip Optical Butt-coupling, Young-Tak Han¹, Seokjun Han¹, Seokjung Han¹, Hyun-Do Jung¹, Seok-Tae Kim¹, Sang-Ho Park¹, Seo-Young Lee¹, Yongsoo Baek¹; Electronics and Telecom Research Inst, Korea (the Republic of). Using an optical butt-coupling method, we have developed a low-cost hybrid-integrated 4×100G TROSA module, showing clear Tx optical eye patterns and Rx sensitivities within -7.0 ~ -6.4 dBm at 106-Gbps PAM4 signals for all channels.
16-QAM Probabilistic Constellation Shaping by Learning the Distribution of Transmitted Symbols from the Training Sequence, Ahmad Fallahpour¹, Fatemeh Alishahi¹, Amir Minooofari¹, Kaiheng Zou¹, Ahmed Almamari¹, Peicheng Liao¹, Hui Min Zhou¹, Moshe Tur¹, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²Tel Aviv Univ., Israel. A technique for probabilistic constellation shaping based on distribution learning from a training sequence is investigated. In this approach, the probability distribution is optimized such that it can maximize the mutual information. We provide evidence that it can maximize the mutual information.

Experimental Demonstration of an Optical Second-order Volterra Nonlinear Filter using Wave Mixing and Delays to Equalize a 20-Gbaud 4-APSK Channel, Kahieng Zou¹, Peicheng Liao¹, Hui Min Zhou¹, Ahmad Fallahpour¹, Amir Minooofari¹, Ahmed Almamari¹; Fatemeh Alishahi¹, Moshe Tur¹, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²Tel Aviv Univ., Israel. We demonstrate an optical second-order Volterra filter using wave mixing and delays. We measure the frequency response and perform the compensation of a nonlinearly distorted 20-Gbaud 4-APSK signal with BER reduction from 8.2×10⁻³ to 3.2×10⁻³.

Assisted Adaptively Partitioned Entropy Loading for FBMC/OQAM System, Xi Chen¹,², Shuangyi Yan¹, Bing Tang¹, Songnian Fu¹, Deming Liu¹, Dimtra Simeonidou², Huazhong Univ of Science and Technology, China; ²High Performance Networks Group, Department of Electrical and Electronic Engineering, Univ. of Bristol, UK. We adopted k-means clustering to efficiently partition the subcarriers to reduce the complexity of PS-QAM on FBMC/OQAM system using KK receiver. The net data rate of 100 Gb/s is achieved after 125 km transmission.

Experimental Demonstration of PAM-4 Transmission through Microring Silicon Photonic Clos Switch Fabric, Liang Yuan¹,², Yu-Han Hung¹, Qixiang Cheng¹, Keren Bergman¹; ¹Lightwave Research Laboratory, USA. We present the first experimental demonstration of a 25 Gbps optical PAM4 signal transmission through a microring-based Clos topology under realistic operating conditions. We observe a 1.1-dBm penalty at the bit error rate of 1.03×10⁻⁷.

Gain Ripple and Passband Narrowing due to Residual Chromatic Dispersion in Non-degenerate Phase-Sensitive Amplifiers, Shimppei Shimizu¹, Takushi Kazama¹, Takayuki Kobayashi¹, Takeshi Umeki¹, Koji Enbutsu¹, Ryoichi Kasahara¹, Yutaka Miyamoto¹; ¹NTT Network Innovation Laboratories, NTT Corporation, Japan. We theoretically show dispersion dependence of gain spectrum in non-degenerate PSA under phase locking, and experimentally demonstrate WDM amplification of PS-64QAM signal using PPLN-based PSA with gain-flattened spectrum by estimation and compensation of chromatic dispersion.
Monday, 9 March

Room 1A

M1A • Edge Computing—Continued

M1A.4 • 09:00
Deep Reinforced Energy Efficient Traffic Grooming in Fog-cloud Elastic Optical Networks, Ruijie Zhu1, Shihua Li1, Peisen Wang1, Lulu Li1, Ar erot Samuel1; Yongli Zhao2, 2Zhengzhou Univ., China; 3Beijing Univ. of Posts and Telecommunications, China. We propose a novel energy efficient traffic grooming algorithm based on deep reinforcement learning in fog-cloud elastic optical networks. Simulation results show that it can achieve much lower energy consumption than the state-of-art algorithm.

Room 1B

M1B • Cognitive Optical Networks—Continued

M1B.2 • 09:00
Hybrid Learning Assisted Abstraction for Service Performance Assessment Over Multi-domain Optical Networks, Rui Wang1, Xi Chen1,2, Zhengguang Gao1, Shuangyi Yan1, Reza Nejabati1, Dimitra Simeoni-dou1; Univ. of Bristol, UK; 2School of Electronic and Optical Information, Huazhong Univ. of Science and Technology, China; 3State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. This paper demonstrates the field-trial validation for a novel machine learning-assisted lightpath abstraction strategy in multi-domain optical network scenarios. The proposed abstraction framework shows high accuracy for dynamic optical networks with 0.44 dB estimation error.

M1B.3 • 09:15
Multi-stage Aggregation and Lightpath Provisioning of Geo-distributed Data over EON Assisted by MEC, Zhen Lu1, Jiawei Zhang1, Zicheng Guo1, Yuefeng Ji1; Beijing Univ. of Posts and Telecommunications, China. A multi-stage aggregation and lightpath provisioning algorithm is proposed for geo-distributed data in EON assisted by MEC. Simulation results show the algorithm can reduce the job completion time and bandwidth consumption.

M1C • Photonic Sensors—Continued

M1C.4 • 09:00
Single-shot Detection Time-stretched Interferometer with Attosecond Precision, Tianhao Xian1, Li Zhan1; 1Shanghai Jiao Tong Univ., China. A single-shot time-stretched interferometer for femtosecond and picosecond time detection is proposed and demonstrated. The time precision is ~40 attosecond. This technique succeeds in characterizing the motion of delay-line and in fabricating vibrating sensor.

M1C.5 • 09:15
Phase-shifted Bragg Grating-based Mach-Zehnder interferometric device to support real-time sensing monitoring using an intensity interrogation scheme, Enxiao Luan1, Han Yun1, Stephen Lin1, Karen Cheung1, Lukas Chrostowski1, Nicolas Jaeger1; University of California, Davis, USA. We experimentally demonstrated the suitability of the phase-shifted Mach-Zehnder interferometric device to support real-time sensing monitoring using an intensity interrogation scheme. The proposed sensor presents a sensitivity of ~810 dB/RIU with a broadband light source.

M1D • Novel Active Devices—Continued

M1D.2 • 09:00
128 Gbps NRZ and 224 Gbps PAM-4 Signals Reception in Graphene Plasmonic PDM Receiver, Yiun Wang1,2, Ying Zhang1,2, Zhibin Jiang1,2, Wentao Deng1,2, Xinyu Huang1,2, Qizhi Yan1, Liao Chen1,2, Xiang Li1,2, Lei Ye1,2; Xinliang Zhang1; Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; 2State Key Laboratory of Optical Science and Technology, Huazhong Univ. of Science and Technology, China. We report high data rate reception of polarization division multiplexing signals using graphene-on-plasmonic slot waveguide photodetectors with bandwidth exceeding 70 GHz. 128 Gbps NRZ and 224 Gbps PAM-4 signals reception are experimentally demonstrated at 1550 nm with high quality.

M1D.3 • 09:15
High-speed Plasmonic Modulator for Simultaneous C- and O-band Data Modulation with Simplified Fabrication, Andreas Messner1, Pascal A. Jud1, Joel Winiger1, Wolfgang Heni1,2, Benedikt Baueerle2, Marco Eppenberger2, Koch Ueli3, Christian Haffner1,4, Huajun Xu4, Delwin L. Elder1, Larry R. Dalton3, Ping Ma3, Juerg Leuthold1; ETH Zurich, Switzerland, 2Polaron Technologies AG, Switzerland, 3Department of Chemistry, Univ. of Washington, USA, 4National Inst. of Standards and Technology, USA. A plasmonic modulator spanning both C- and O-band for dual-band data modulation up to 100 Gbit/s in one single device is presented. Fiber-to-fiber insertion loss can be as low as 11 dB.
In this presentation, we will discuss the fundamentals of basic Machine Learning (ML) techniques. We will then provide an overview of current ML applications in optical communications and networks and highlight upcoming trends and challenges.

M1H.4 • 09:00 Tutorial Energy-efficient Multi-wavelength, Chip-to-chip, Switched Optical Interconnects, Ashok Krishnamoorthy1,2; 1Axalume, Inc., USA. We discuss optical chip-to-chip electrical and optical interconnects, reviewing optical component technologies and their application to energy-efficient optically-interconnected systems with enhanced performance metrics. Examples will be provided to highlight system-level successes and to motivate an evolution of next generation optically-interconnected platforms from electrically switched, to optical wavelength-switched and broadband optically-switched systems.

M1I.4 • 09:00 Top-Scored Generation and Coherent Detection of 2-μm-band WDM-QPSK Signals by On-chip Spectral Translation, Deming Kong1, Yong Liu1, Zhengqi Ren1, Yangmin Jung2, Minhao Pu3, Kresten Yuind1, Michael Galili1, LiF Oxenløwe1, David Richardson1, Hao Hu1, 2Technical Univ. of Denmark, Denmark; 3Optoelectronics Research Centre, Univ. of Southampton, UK. We have proposed and demonstrated the generation and coherent detection of 2-μm-band I/Q modulated signals for the first time using on-chip spectral translation. 6×32 Gbaud WDM-QPSK signals exhibit BERs below the 7% HD-FEC threshold.

M1J.4 • 09:00 Beyond 100-kbit/s Transmission over Rolling Shutter Camera-based VLC Enabled by Color and Spatial Multiplexing, Lijiong Liu1, Rui Deng1, Jin Shi2, Jing He2, Luan-Kuan Chen1, 2Department of Information Engineering, The Chinese Univ. of Hong Kong, Hong Kong; 2College of Computer Science and Electronic Engineering, Hunan Univ., China. The camera-based VLC (CVLC) is a promising technique for various application scenarios. For the first time, we demonstrate a rolling shutter based CVLC system with beyond 100-kbit/s data rate by employing color and spatial multiplexing.

M1K.2 • 09:00 Two-stage Abstraction for Disaggregated Modular OLT Architecture Supporting OpenFlow Control, Keita Nishimoto1, Kota Asaka1, Jun-ichi Kani1, Jun Terada1; 1NTT Access Network Service Systems Laboratories, Japan. We implement our abstraction method for provisioning and controlling, via OpenFlow, the disaggregated PON-OLT that features separation of hardware module and softwareized OLT functions, and demonstrate its operation by utilizing open source controllers ONOS / VOLTHA.

Monday, 9 March

M1G.5 • 09:00 Tutorial Machine Learning and its Applications in Optical Communication Systems, Faisal N. Khan1, Qirui Fan1, Jianing Lu1, Gai Zhou1, Chao Lu1, Alan Pak Tao Lau1; 1Photonics Research Center, Department of Electrical Engineering, Hong Kong Polytechnic Univ., China; 2Photonics Research Center, Department of Electrical and Information Engineering, The Hong Kong Polytechnic Univ., China. In this presentation, we will discuss the fundamentals of basic Machine Learning (ML) techniques. We will then provide an overview of current ML applications in optical communications and networks and highlight upcoming trends and challenges.

M1L.5 • 09:15 Compensation of SOA Nonlinear Distortions by Mid-stage Optical Phase Conjugation, Aneesh Sobhanan1, Mark Pelusi2, Takashi Inoue1, Deepa Venkitesh1, Shu Namiki3, 1Indian Inst. of Technology Madras, India; 2National Inst. of Advanced Industrial Science and Technology, Japan. We investigate optical phase conjugation for compensating nonlinear distortions due to carrier dynamics in semiconductor optical amplifiers. Experiments with WDM-3X12Gb/s 16-QAM signals show the ability to outperform a single device by 2dB average Q2-factor improvement.

M1L.5 • 09:15 Non-orthogonal Matrix Precoding based Faster-than-nyquist Signaling over Optical Wireless Communications, Zhaoyu Hu1, Chun-Kit Chan1; 1Technical Univ. of Hong Kong, Hong Kong. We first investigate a novel non-orthogonal matrix precoding underlying frame-level allocation over multi-tenant, Multi-service PONs for Low-latency Fronthaul Applications Based on Cooperative-DBA, Arsalan Ahmad1,2, Sanwal Zeb1, Abdul Wahab2, Rana Azhar Khan3, Marco Ruffini1, Univ. of Dublin Trinity College, Ireland; 3National Univ. of Sciences and Technology, Pakistan. We propose and compare algorithms to allocate upstream PON capacity, where multiple virtual operators generate independent frame-level allocation over shared infrastructure. Our fragmentation-based approach shows the ability to limit latency increase to a few microseconds.
M1A • Edge Computing—Continued

M1A.6 • 09:30
Remote Human-to-Machine Distance Emulation through AI-Enhanced Servers for Tactile Internet Applications, Sourav Mondal1, Lihua Ruan1, Elaine Wong1; ‘Univ. of Melbourne, Australia. We alleviate the master-slave distance limitation of human-to-machine applications by forecasting and pre-empting haptic feedback transmission. Results show 99% accuracy in detecting touch events and 96% accuracy in forecasting feedback from different slave materials.

M1B • Cognitive Optical Networks—Continued

M1B.4 • 09:30
Dynamically Controlled Flexible-Grid Networks Based on Semi-Flexible Spectrum Assignment and Network-state-value Evaluation, Ryuta Shiraki1, Yojiro Mori1, Hiroshi Hasegawa1, Ken-ichi Sato1; ‘Information and Communication Engineering, Nagoya Univ., Japan; 2The National Inst. of Advanced Industrial Science and Technology, Japan. We propose a novel RSA algorithm for dynamically-changing flexible-grid networks. The proposed scheme can suppress spectral fragmentation and adapt to traffic-distribution change. Extensive simulations show that the fiber-utilization efficiency is increased by 1% to 57%.

M1C • Photonic Sensors—Continued

M1C.6 • 09:30
Real-time Structured-light Depth Sensing Based on Ultra-compact, Non-mechanical VCSEL Beam Scanner, Ruixiao Li1, Masashi Takanoshita1, Shaining Hu1, Xiaodong Gu1, Fumio Koyama1; ‘Tokyo Inst. of Technology. Japan. We realized real-time scanning structured-light depth sensing with accuracy of less than 270mm for distance of 35cm using ultra-compact (<0.5mm3) non-mechanical beam scanner. The peak output power can be as low as 1mW.

M1D • Novel Active Devices—Continued

M1D.4 • 09:30
50 Gbit/s Silicon Modulator Operated at 1950 nm, Wenxiang Liu1, Miaoqiong Li2, Hongpu Giang3, Yuguang Zhang2, Hucheng Xie1, Xi Xiao2, Ke Xu1; ‘Harbin Inst. of Technology, China; 3National Information Optoelectronics Innovation Center, China; 4Wuhan Research Inst. of Posts & Telecommunications, China. We have experimentally demonstrated an integrated silicon Mach-Zehnder modulator which operates at 1950 nm wavelength range. 50 Gbit/s intensity modulation is achieved with bit error rate below 3.8×10-3.

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

M1E • Symposium: Quantum Information Science and Technology (QIST) in the context of Optical Communications (Session 1)—Continued

M1F • Next Generation TOSA/ROSA Components—Continued

M1F.5 • 09:30
25.78-Gbit/s Burst-mode Receiver for 50G-EPON OLT, Naruto Tanaka1, Danuake Umeda1, Yoshiyuki Sugimoto2, Tomyokey Funda1, Keiji Tanaka1, Shoichi Ogita1, ‘Transmission Devices Laboratory, Sumitomo Electric Industries, LTD, Japan; 2Information Network R&D Center, Sumitomo Electric Industries, LTD, Japan. We report the world’s first receiver optical sub-assembly equipped with 25G burst-mode TIA which is applicable for 50G-EPON OLT transceiver. We demonstrate its 25G/10G dual-rate burst-mode receiver characteristics.

M1F.6 • 09:45
PAM-X™: A 25Gb/s-PAM4 Optical Transceiver Chipset for 5G Optical Front-Haul, Lei Zhao1, Xin Wang1, Xiaoyan Bai2, Juncheng Wang2, Tao Xia1, Yi Peng1, Yuansi Zhang1, Lei Wang1, Liugui Song1, Shenglong Zha1, Xuefeng Chen1, Patrick V. Zhang1; ‘Fudan University, Shanghai, China, 2PhotonIC Technologies, Shanghai, China. A complete 25Gb/s-PAM4 optical transceiver chipset using commercial 10G-lasers for 10km single-mode fiber is presented. Measurement results demonstrate <12dBm sensitivity across all temperatures and <30ps/√bit power efficiency.
**M1I.6 • 09:30**  
**Invited**  
Phase Reconstruction Scheme Using Dispersive Media in Direct Detection, Masayuki Matsumoto¹; Wakayama Univ., Japan. A non-iterative reconstruction scheme of phase-modulated signals using dispersive media in direct detection is described. The phase retrieval is performed by solving the temporal transport-of-intensity equation. Required carrier-to-signal power ratio and allowable carrier location in frequency are numerically studied.

**M1J.6 • 09:30**  
Ultrahigh-capacity Optical-wireless Communication Using 2D Gratings for Steering and Decoding of DPSK Signals, Ketema Addis Mekonnen¹, Eduward Tangdiongga¹, Ton Koanen¹; Eindhoven Univ. of Technology, Netherlands. We demonstrate the use of a 2D-gratings beam-steering device also as a demodulator for multiple differentially-encoded optical-wireless signals. Using this novel concept, ~2bits/sec/Hz spectral efficiency was achieved without any change in the system compared to on-off-keying.

**M1K.4 • 09:30**  
**Invited**  
Softwarized and Open OLT Architecture for Flexible Optical Access Network, Keita Nishimoto¹, Takahiro Suzuki¹, Kota Asaka¹, Junichi Kani¹, Jun Terada¹; NTT Access Network Service Systems Laboratories, Japan. Recently, many telecom carriers are promoting the re-architecture of access networks and COs by utilizing SDN/NFV and OSS. We present our research relevant to the software PON-OLT architecture that we proposed for further flexibility.

**M1J.7 • 09:45**  
Multi-user Localization and Upstream Signaling for Indoor OWC System using a Camera Technology, Ngoc Quan Pham¹, Ketema Mekonnen¹, Eduward Tangdiongga¹, Ali Mefleh², Ton Koanen¹; Eindhoven Univ. of Technology, Netherlands; KPN, Netherlands. We present upstream signaling and localization for an indoor beam-steered OWC system using vision-based technology. We demonstrate a 1.2kbps upstream signaling and localization system which enables to identify a large number of users with <0.05° error.

10:00–10:30  
Coffee Break, Upper Level Corridors
M2A.1 • 10:30
Broadband 145GHz Photodetector Module Targeting 200Gbaud Applications, Patrick Runge1, Felix Ganzer1, Jonas Gläsel1, Sebastian Wünsch1, Sven Mutschall1, Martin Schell1; 1Fraunhofer Institut, Germany.

We demonstrate a photodetector module with a 0.8-mm RF connector and an estimated 3dB-bandwidth of 145GHz. The bandwidth of the module exceeds all other state of the art photodetector modules. The intended application of the module is for test and measurement equipment of next generation optical networks with 200Gbaud.

M2A.2 • 10:45
Superior Temperature Performance of Si-Ge Waveguide Avalanche Photodiodes at 64Gbps PAM4 Operation, Yuan Yuan1,2, Zhihong Huang1, Binhao Wang1, Wayne Sim1, Di Liang1, Joe C. Campbell2, Raymon Beausoleil2; 1Hewlett Packard Labs, 2Nokia Bell Labs, USA.

We demonstrate a low voltage Si-Ge waveguide avalanche photodiode with extremely high temperature performance. It exhibits high temperature stability from 30 °C to 90 °C, and achieves excellent operation with 64 Gb/s PAM4 modulation.

M2B.1 • 10:30
Ultra-miniaturized Endoscopes with Multicore Fibers, Espen R. Andreassen1, Siddharth Sivankutty2, Viktor Tsvirkun2, Karen Baudelle1, Olivier Vanvincq1, Goëry Rigneault1; 1Université de Strasbourg, France; 2Aix Marseille Univ., France.

We present a 50 Gb/s O-band reflective electroabsorption modulator operating in both non-return-to-zero (NRZ) and PAM-4 modulation formats without equalization. We obtained >9 dB NRZ dynamic extinction ratio for a peak-to-peak voltage of 2.4 V.

M2B.2 • 10:45
In-Phase/Quadrature Modulation by Directly Reflectivity Modulated laser, Po Dong1, Arghisi Melikyan1, Kwangwoong Kim1, Nonaki Kaneda1, Brian Stem1, Yves Baeyens1; 1Nokia Bell Labs, USA.

We report a directly reflectivity modulated laser that generates a 50-Gbaud QPSK signal with a BER of 2.2x10^-5. We believe this is the first demonstration of a coherent transmitter made from a directly driven laser.
10:30–12:30
M2G • Multiband and SDN for Capacity Scaling
Presider: Mark Filer; Microsoft Corp., USA

10:30–12:30
M2H • Access Networks for Mobile and Multi-access Edge Computing
Presider: Marco Ruffini; Univ. of Dublin Trinity College, Ireland

10:30–12:30
M2I • Photonic Integrated Subsystems
Presider: Lu Li; SubCom, USA

10:30–12:30
M2J • Data Analytic-based Monitoring
Presider: Takahito Tanimura; Fujitsu Limited, Japan

10:30–12:30
M2K • Neuromorphic I: Device-oriented
Presider: Ken-ichi Kitayama; Grad Sch Creation of New Photonics Ind, Japan

M2G.1 • 10:30 Invited
Spatial Channel Network (SCN): Introducing Spatial Bypass Toward the SDM Era, Masahiko Jinno 1, Takahiro Kodama 1; Kagawa Univ., Japan. We review the spatial-channel network technology toward the spatial-division-multiplexing era from the viewpoints of network and node architectures, physical performance, network-resource utilization efficiency, and novel optical switches for modular and low-loss spatial cross-connects.

M2H.1 • 10:30 Invited
Real-time Assessment of PtP/PtMP Fixed Access Serving RAN with MEC Capabilities, Anas El Anikouri 1, Santiago Ruano Rincón 1, Gael Simon 1, Luiz Anet Neto 1, Annie Gravey 1, Philippe Chancou 1, ‘Orange Labs, France; ‘IMT Atlantique, France. In this paper we propose the introduction of an intelligent access network equipment capable of hosting Mobile Edge Computing capabilities in a convergence scenario of PtP and PtMP topologies.

M2I.1 • 10:30 Tutorial
Silicon Photonic Waveguide Bragg Gratings, Lukas Chrostowski 1; Univ. of British Columbia, Canada. Abstract not available.

M2J.1 • 10:30 Invited
DSP-aided Telemetry in Monitoring Linear and Nonlinear Optical Transmission Impairments, Qunbi Zhuge 1, Xiaomin Liu 1, Huazhi Lun 1, Mengfan Fu 1, Lilin Yi 1, Weisheng Hu 1; Shanghai Jiao Tong Univ., China. DSP-aided telemetry within coherent receivers provide unprecedented capabilities to monitor linear and nonlinear optical transmission impairments. The recent progress of it is reviewed and discussed in the context of advanced network applications.

M2K.1 • 10:30
Temporal Resolution Enhancement in Quantum-dot Laser Neurons due to Ground State Quenching Effects, George Sarantoglou 1, Menelaos Skontranis 1, Adonis Bogris 1, Charis Mesaritakis 1; Univ. of the Aegean, Greece; ‘Informatics and Computer Engineering, Univ. of West Attica, Greece. We present experimental results for an all-optical quantum-dot neuron, biased to a ground-state quenching regime alongside emission from the excited state. This regime, allows reduction of the temporal width of spikes down to 500 ps and enhanced firing rate.

M2H.2 • 10:45 Invited
Cohesion between 5G Mobile Wireless and Fixed Optical Based Wireline Networks, Mark Watts 1, Verizon Communications Inc, USA. Interworking between 5G Mobility and Fixed Optical Access Application is rapidly increasing in importance for users and network operators. Use cases are converging, with overlapping network features and functionality and in some cases, duplicative.

M2K.2 • 10:45
A DFB-LD-based Photonic Neuromorphic Network for Spatiotemporal Pattern Recognition, Bowen Ma 1, Jiaping Chen 1, Wewen Zou 1; Shanghai Jiao Tong Univ., China. We present a photonic neuromorphic network using DFB-LDs for spatiotemporal pattern recognition. Complete input patterns are investigated theoretically and experimentally. The output peak powers decrease with the difference between the target pattern and other patterns.
Monday, 9 March

M2A  Advanced Active Components—Continued

M2A.3  11:00  Invited
Development of VCSELs and VCSEL-based Links for Data Communication beyond 50Gb/s, Nikolay Ledentsov Jr.1, Lukasz Chorchos2, Vitaly A. Shchukin1, Vladimir P. Kalosh1, Jaroslaw P. Turkiewicz1, Nikolay Ledentsov1; 1VI Systems GmbH, Germany; 2Inst. of Telecommunications, Warsaw Univ. of Technology, Poland. Recent advances in VCSELs and VCSEL-based links are reviewed. The impact of the VCSEL bandwidth extension to 28GHz on the performance of energy-efficient link capable of operating above 71Gbit/s in NRZ modulation is studied.

M2B  High-speed Integrated Modulators—Continued

M2B.3  11:00
Uncooled Operation of 53-Gbaud PAM4 EA-DFB Lasers in the Wavelength Range of 1510±1570 nm for 800-GbE Applications, Yoshihiro Nakai1, Shigenori Hayakawa1, Syunya Yamauchi1, Yoroshiy Isamu2,1, Tetsuya Takamure1, Hideaki Asakura1, Ryosuke Nakajima1, Shigetaka Hamasada1, Kazuhiko Naoe1, Lumentum Japan, Inc., Japan. 53-Gbaud EA-DFB lasers—with four wavelengths in the 1500-nm region—for 800-GbE applications were developed. They demonstrated uncooled 53-Gbaud PAM4 operation with a TDECQ of lower than 2.5 dB over a wide temperature from 20 to 85°C.

M2B.4  11:15
25 Gbit/s Silicon Based Modulators for the 2 μm Wavelength Band, Wei Cao1, Milos Nedeljkovic2, Shenghao Liu1, Callum G. Littlejohns1, David Thomson1, Frederic Gardes1, Zhengqi Ren1, Ke Li1, Graham T. Reed1, Goran Mashanovich1; 1Univ. of Southampton, UK; 2Chiral Photonics Inc, USA. We demonstrate high-speed silicon modulators optimized for operating at the wavelength of 2 μm. The Mach-Zehnder interferometer carrier-depletion modulator has a modulation efficiency VπLπ of 2.89 V/cm at 4 V reverse bias. It operates at a data rate of 25 Gbit/s with an extinction ratio of 6.25 dB.

M2C  SDM Imaging and Sensing—Continued

M2C.2  11:00  Top-Scored
Single-pixel Imaging Through Multimode Fiber Using Silicon Optical Phased Array Chip, Taichiro Fukui1, Yusuke Kohno1, Rui Tang1, Yoshiaki Nakano1, Takuo Tanemura1; 1School of Engineering, The Univ. of Tokyo, Japan. We experimentally demonstrate single-pixel imaging using a multimode fiber attached with optical phased-array chip. By driving 128 integrated phase shifters, speckle patterns are generated from the fiber to realize clear imaging with 490 resolvable points.

M2C.3  11:15  Top-Scored
Low Return Loss Multicore Fiber-Fanout Assembly for SDM and Sensing Applications, Victor I. Kopp1,3, Jingchun Park1, Jan Singer1, Dan Neugrosch1,3, Andy Gillooly1,3, Chiral Photonics Inc, USA; 2Fibercore House, Fibercore, UK; 3SDM using uncoupled or coupled core multicore fibers promises to increase the bandwidth density in optical links. In addition, these fibers form a platform for various sensing systems, including 3D shape sensing. Both applications will be advanced by the low return loss fanout-multicore fiber assembly demonstrated here.

M2D  Optimizing Network Capacity and Performance—Continued

M2D.2  11:00  Invited
Pushing the Count-rate and Efficiency Limits of Single-photon Avalanche Diodes with RF Interferometry, Joshua Bienfang1,2,1NIST, USA. Abstract not available.

M2D.3  11:15
Field and Laboratory Demonstration of 48nm Optical Transport with Real-Time 32T (80×400G) over G.652 Fiber Distances up to 640km, Praveen Kumar1, Deepak Sanghi2,3, G.652 link in laboratory and 42km Error-free transmission of 32Tb/s (80×4000Gb/s) is achieved over 640km G.652 link in laboratory and 42km G.652 link in field.
M2G • Multiband and SDN for Capacity Scaling—Continued

M2G.2 • 11:00 Evaluation of the Flexibility of Switching Node Architectures for Spaced Division Multiplexed Elastic Optical Network, Sincang Ding1, Shan Yin1, Zhan Zhang1, Shanguo Huang1; State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We present a flexibility model for quantitatively evaluating switching node architectures in terms of switching strategies, function and required components in SDM-EON, revealing designs with the most switching flexibility.

M2G.3 • 11:15 Design Strategies Exploiting C+L-band in Networks with Geographically-dependent Fiber Upgrade Expenditures, Daniela A. Moniz2,1, Victor Lopez2, João Pedro2; Instituto de Telecomunicações, Portugal; 2Infinera, Portugal; 3Telefónica, Spain. This paper proposes a framework leveraging next-generation interfaces and C+L-band to design transport networks where fiber-based capacity upgrade is geographically-dependent. Simulation results highlight the effectiveness of the proposal and the possible trade-offs between number of interfaces and fibers.

M2H • Access Networks for Mobile and Multi-access Edge Computing—Continued

M2H.3 • 11:15 Top-Scored PON Virtualisation with EAST-WEST Communications for Low-latency Converged Multi-access Edge Computing (MEC), Sandip Das1, Marco Ruffini1; Computer Science, Trinity College Dublin, Ireland. We propose a virtual-PON based Mobile Front-haul (MFH) architecture that allows direct communications between edge points (enabling EAST-WEST communication). Dynamic slicing improves service multiplexing while supporting ultra-low latency under 100µs between cells and MEC nodes.

M2I • Photonic Integrated Subsystems—Continued

M2I.2 • 11:00 Experimental Comparisons between Machine Learning and Analytical Models for QoT Estimations in WDM Systems, Qirui Fan1, Jianing Lu1, Gai Zhou1, Changjian Guo1, Linyue Lu1, Jianjiang Li1, Chongjin Xie1, Chao Li1, Faisal N. Khan1, Alan Pak Tao Lau1; The Hong Kong Polytechnic Univ., Hong Kong; 1Alibaba Group, USA. We experimentally compare QoT estimations for WDM systems using Machine Learning (ML) and GN-based analytical models. ML estimates the side channels with better accuracy but is temporally less stable and less generalizable to different link configurations.

M2J • Data Analytic-based Monitoring—Continued

M2J.2 • 11:00 Fast BER Distribution and Neural Networks for Joint Monitoring of Linear and Nonlinear Noise-to-Signal Ratios, Ali Salehiomran1, Zhiping Jiang1; Optical Systems Competency Center, Huawei Technologies Canada, Canada. Experimentally observed long-tail fast BER (10ns-1µs) histogram (FBH) in presence of NLLN is explained through simulation. Features from FBHs are applied to train an ANN to estimate linear and nonlinear NSRs with <5% error.

M2J.3 • 11:15 Invited Fast BER Distribution and Neural Networks for Joint Monitoring of Linear and Nonlinear Noise-to-Signal Ratios, Ali Salehiomran1, Zhiping Jiang1; Optical Systems Competency Center, Huawei Technologies Canada, Canada. Experimentally observed long-tail fast BER (10ns-1µs) histogram (FBH) in presence of NLLN is explained through simulation. Features from FBHs are applied to train an ANN to estimate linear and nonlinear NSRs with <5% error.

M2K • Neuromorphic I: Device-oriented—Continued

M2K.3 • 11:00 Scalable Photonic Integration of Neural Networks, Johnny Moughames2, Javier Porte2, Maxime Jacquet3, Laurent Larget2, Muamer Kadic1, Daniel Brunner1; CNRS, France; 2FEMTO-ST, Univ. Franche-Comte, France. Photonic neural networks are promising candidates for next generation computing. Using a novel integration technology we demonstrate photonic neural networks for which the number of neurons scales linear with the substrate’s footprint. It is the first time such advantageous scaling is reported for large scale photonic neural network integration.
Room 1A
M2A • Advanced Active Components—Continued

M2A.4 • 11:30
4x112 Gbps/fiber CWDM VCSEL Arrays for Co-packaged Interconnects, Binhao Wang1, Wayne Sorrin1, Paul Rosenberg1, Lennie Kiyama1, Saga Mathai1, Michael R. Tan1, Hewlett Packard Enterprise, USA. We demonstrate a 4x112 Gbps/fiber VCSEL link using a co-packaged coarse wavelength division multiplexing (CWDM) optical module. A complete co-packaged CWDM module can achieve a 2.668 Tb/s aggregated bandwidth by assembling four 1x6 VCSEL arrays.

M2A.5 • 11:45
Electrical and Optical Reliability Analysis of GeSi Electro-absorption Modulators, Artemisa Taiera1, Srinivasan Ashwyn Srinivasan1, Sadhishkumar Balakrishnan1, Mananna Pantouvaki2, Philippe Absil1, Joris Van Campenhout1, Kristof Croezen1, imec, Belgium. Reliability analysis on Electro-absorption Modulators reveals two degradation parts, trap generation and filling of pre-existing defects on Ge/Si and Ge/Ox interface. After stress, electro-optical extracted parameters indicate no impact of temperature, bias or stress time.

Room 1B
M2B • High-speed Integrated Modulators—Continued

M2B.5 • 11:30
Mach-Zehnder Modulator using Membrane InGaAsP Phase Shifters and SOAs inside Interferometer Arms on Si Photonics Platform, Takuma Aihara1, Tatsuruhiro Hiraki1, Takuro Fujii1, Koji Takeda1, Takaaki Kakituka1, Tsai Tsuchizawa1, Shinji Matsuo1, NTT, Japan. A Mach-Zehnder modulator having III-V waveguide phase shifters and semiconductor optical amplifiers inside interferometer arms is heterogeneously integrated with Si waveguides. The device exhibits 6-88 Mbit/s output power and 40-Gbit/s NRZ modulations with clear eye-openings.

Room 2
M2C • SDM Imaging and Sensing—Continued

M2C.4 • 11:30
Digital Holographic Endo-microscopes Based on Multimode Fibres, Tomas Cizmar1,2, Leibniz-Institut für Photonische Technologie, Germany; ‘Microphotonics, Inst. of Scientific Instruments of the CAS, Czechia. Here I review the recent progress of endomicroscopes based on holographic control of light transport through multimode fibres. I discuss the fundamental and technological bases as well as recent applications of the new imaging tool.

Room 3
M2D • Optimizing Network Capacity and Performance—Continued

M2D.4 • 11:30
Metro-haul Project Vertical Service Demo: Video Surveillance Real-time Low-latency Object Tracking, Anna Dachhan1, Johannes Fischer2, Bodo Lent1, Achim Autenrieth1, Behnam Shariati1, Pablo Wilke Berenguer1, Jörg-Peter Elbers1, ADVA Optical Networking, Germany; ‘Gogny GmbH, Germany; ‘Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany. We report on the EU H2020 project METRO-HAUL use-case demonstration, including flexible allocation of storage and computing resources in different network locations and deployment of a network slice instance through a programmable multi-layer optical network.

Room 6C
M2E • Symposium: Quantum Information Science and Technology (QIST) in the Context of Optical Communications (Session 2)—Continued

M2E.3 • 11:30

M2F • Digital Signal Processing and Radio-over-fiber Systems for 5G—Continued

M2F.4 • 11:30
A MMW Coordinate Multi-Point Transmission System for 5G Mobile Fronthaul Networks based on a Polarization-Tracking-free PDM-RoF Mechanism, ‘Hiih-Heng Yan1,2, Jian-Kai Huang1, Yu-Yang Lin1, Jin-Wei Hsu1, Kai-Ming Feng1,2, Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; ‘Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan. A PDM-RoF mechanism is firstly experimentally demonstrated for MMW coordinate multi-point transmission system with a polarization-tracking-free RAU design. Without additional latency for PDM demultiplexing, we evaluate various coordinate multi-point joint transmission scenarios.

Room 6D
M2F.5 • 11:45
Wide FoV Autonomous Beamformer Supporting Multiple Beams and Multi-band Operation for 5G Mobile Fronthaul, Min-Yu Huang1, You-Wei Chen1, Run-Kai Shiu1,2, Hua Wang1, Gee-Kung Chang1,2, Georgia Inst. of Technology, USA; ‘National Taipei Univ. of Technology, Taiwan. An autonomous beamformer covering 24-37 GHz for fiber-wireless network demonstrates multi-beam and multi-band signal transmission with wide-FoV (110°-180°) self-steering beam-tracking/forming over a 10-km fiber and 56-cm wireless link for future dynamic 5G-NR fronthaul applications.
We investigate on network capacity enabled by C+L line systems (OLS) vs. fiber doubling showing that at optimal power, C+L OLS doubles the traffic of C-only with very-low penalty with respect to fiber doubling.
M2A.6 • 12:00
Compact Tunable DFB/Ring Laser Module Integrated with Extremely-high-μm-PLC Wavelength Lockers, Masayoishi Nishita1, Yasutaka Higa1, Nori-taka Matsubara1, Junichi Hasegawa1, Kazuki Yamazaki1, Maiko Ariga1, Yasuke Inaba1, Masayoshi Kimura1, Masaki Wakaba1, Masahiko Yoshida1, Kazuomi Maruyama1, Shunsuke Okuyama1, Toshihito Suzuki1, Hiroyuki Ishii1, Vitaly Mikhailov1, Richard Sefel1, Yasunaga Kaneko1, Ken'ichi Uchida2, Kenji Ishikawa2, Takashi Ohno2, Shinya Masuda2, and Masanori Saitoh2.

M2B.7 • 12:00
120 Gb/s Hybrid Silicon and Lithium Niobate Modulators with On-chip Termination Resistor, Shih-hao Sun1, Mingbo He1, Mengyue Yin2, Xian Zhang3, Zilliang Ruan4, Liu Liu5, Xinjun Cai5, 1Sun Yat-Sen Univ., China; 2South China Normal Univ., China. We demonstrated hybrid silicon and lithium niobate Mach-Zehnder modulators with on-chip termination resistor. The device shows high electro-optic bandwidth up to 60 GHz, low Vth of 2.25 V and low insertion loss of 2 dB.

M2C.5 • 12:00
Characterization of Multi-core Fiber Group Delay with Correlation OTDR and Modulation Phase Shift Methods, Florian Azendorf1,2, Annika Dochhan1,2, Patrik Urban1, Bernhard Schmauss1, Josep Fabrega3, Michael Eiselt1, Krzysztof Wilczyński4, Lukasz Szostkiewicz5, Laia Nadal1, F. Javier Vilchez1, Michela S. Moreolo5, 1ADVA Optical Networking, Germany; 2HTFT, Germany; 3InPhoTech, Poland; 4CTTC, Spain. Using a Correlation-OTDR and a modulation phase shift method we characterized four multi-core fibers. The results show that the differential delay depends on the position of the core in the fiber and varies with temperature.

M2E.4 • 12:00
Optimized Quantum Photonics, Jelena Vuckovic, Stanford University, USA. Abstract not available.

M2F.5 • 12:00
Low Power All-digital Radio-over-Fiber Transmission for 28-GHz Band Using Parallel Electro-absorption Modulators, Hao Lin1,2, Joris Van Kerrebrouck3, Hannes Ramon3, Laurens Bogarten1, Josi Lambrecht3, Chia-Yi Wu1, Laurens Breyne4, Jakob Declercq1, Johann Bauwelinck1, Xin Yin1, Peter Osseur1, Piet DeMesters1, Guy Torfs1, 1Univ. Ghent-imec, Belgium. We present a low-power all-digital radio-over-fiber transmitter for beyond 28-GHz using sigma-delta modulation, a 140mW NRZ driver and parallel electro-absorption modulators. 5.25Gb/s (2.625Gb/s) 64-QAM is transported over 10-km SSMF at 1560 nm with 7.6% (5.2%) EVM.

M2F.7 • 12:15
<500ns Latency Overhead Analog-to-digital-compression Radio-over-fiber (ADX-RoF) Transport of 16-channel MIMO, 1024QAM Signals with 5G NR Bandwidth, Paukun Zhu1, Yo-ki Yoshida2, Ken-ichi Kitayama3, 1The Graduate School for the Creation of New Photonics Industries, Japan; 2National Inst. of Information and Communications Technology, Japan. Real-time analog-to-digital-compression radio-over-fiber (ADX-RoF) transport with <500ns processing latency overhead is demonstrated by using a single-chip programmable radio platform. 16-channel 6.14MHz 1024QAM-OFDM signals of 5G NR-class is delivered with ~4-Gb/s optical OOK interface, maintaining EVM=1.4%.

12:30–14:00 Lunch Break (on own)
M2G.6 • 12:00 † Invited

TransLambda: A Multi-band Transmission System and its Realization, Practical Applications and Use Cases in Optical Networks, Muhammad S. Sarwar1, Takeshi Sakamato1, Takeshi Hoshida2, Tomoyuki Kato1; Fujitsu Network Communications Inc, USA; Fujitsu Ltd., Japan. We focus on the introduction and practical use of TransLambda™, a multiband transmission system based on all optical wavelength conversion in optical transport network architectures, and detail its system-level considerations, network applications, and use cases.

M2H.6 • 12:15

Hybrid W-band/Baseband Transmission for Fixed-mobile Convergence Supported by Heterodyne Detection with Data-Carrying Local Oscillator, Shuyi Shen1, Qi Zhou1, You-Wei Chen1, Shuang Yao1, Rui Zhang1, Yehya M. Alfadhli1, Shang-Jen Su1, Jeffrey Finkelstein1, Gee-Kung Chang1; Georgia Inst. of Technology, USA; Cox Communications, USA. A novel architecture with data-carrying local oscillator was proposed and demonstrated, supporting co-transmission of 35.39-Gbps W-band OFDM at 85-GHz and 10.9-Gbps OOK signals. Sensitivity penalty induced by interference as low as 0.5 dB was experimentally validated.

M2I.4 • 12:00 Invited

Novel Electro-optic Components for Integrated Photonic Neural Networks, Pascal Stark1, Jacqueline Geler-Kremer1,2, Felix Eltes1, Daniele Caimi1, Jean Fompeyrine1, Bert J Offen1, Stefan Abel1; IBM Research GmbH, Switzerland; Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland. We demonstrate PIC-based non-volatile optical synaptic elements, an essential building block in large non-von Neumann circuits realized in integrated photonics. The impact of non-idealities on the performance of a photonic recurrent neural networks is evaluated.

M2J.6 • 12:00 Invited

Machine Learning Based Fiber Nonlinear Noise Monitoring for Subcarrier-multiplexing Systems, Xiaomin Liu1, Huazhi Lun1, Mengfan Fu1, Lilin Yi1, Weisheng Hu1, Qunbi Zhuge1; Shanghai-Jiao Tong Univ, China. We propose a set of correlation features for machine learning based fiber nonlinear noise monitoring in subcarrier-multiplexing systems. Improved accuracy is demonstrated by adding correlations between subcarriers and data fusion processing across subcarriers.

M2K.6 • 12:00 Invited

Microresonator-enhanced, Waveguide-coupled Emission from Silicon Defect Centers for Superconducting Optoelectronic Networks, Alexander Tait1, Sonia Buckley1, Adam McCaughan1, Jeffrey Chiles1, Sae Woo Nam1, Richard Min1, Jeffrey Shainline1; National Inst of Standards & Technology, USA. Superconducting optoelectronic networks could achieve scales unmatched in hardware-based neuromorphic computing. After summarizing recent progress in this area, we report new results in cryogenic silicon photonic light sources, components central to these architectures.

M2J.7 • 12:15

The Real Time Implementation of a Simplified 2-section Equalizer with Supernal SOP Tracking Capability, Tao Zeng1, Zhixue He1, Lingheng Meng1, Jie Li1, Xiang Li1, Shaohua Yu1; State Key Laboratory of Optical Communication Technologies and Networks, China information and communication technology Group Corporation, China. We propose a 2-section equalizer architecture, two adaptive multi-tap 1×1 equalizer updated by proposed joint-CMA, followed by a feedforward 1-tap 2×2 MIMO. We implement it in 10G coherent transceiver and achieve 20Mrad/s SOP tracking speed.
Monday, 9 March

**Room 1A**

14:00–16:00

**M3A • New Photonic Materials**

Presider: Hideyuki Nasu; Furukawa Electric, Japan

M3A.1 • 14:00

*Invited*

**Indium Phosphide Membrane Photonic Integrated Circuits on Silicon**, Kevin A. Williams 1; 1Technische Universiteit Eindhoven, Netherlands. The intimate integration of photonics and electronics in transceivers facilitates energy-efficiency, bandwidth acceleration and a route to radical miniaturization. We present and implement a wafer-to-wafer integration method which combines electronic and photonic foundry technologies.

**Room 1B**

14:00–16:00

**M3B • Propagation Effects in SMF and SDM Fibers**

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

M3B.1 • 14:00

*Invited*

**Nonlinear Impairment Scaling in Multi Mode Fibers for Mode Division Multiplexing**, Peter M. Krummrich 1, Marius Brehler1, Georg Rademacher2, Klaus Petermann2; 1Technische Universitaet Dortmund, Germany; 2NICT, Japan; 3Technische Universitaet Berlin, Germany. The scaling of nonlinear effects in multi mode transmission fibers with mode count has been investigated. Results indicate that transmission reaches comparable to standard single mode fibers are achievable for at least 100 modes.

**Room 2**

14:00–16:00

**M3C • Panel: Is it Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity**

M3C.1 • 14:00

**Invited**

Delivering more bandwidth/capacity has been the top research focus in optical networks, access or otherwise. However, new services like 5G mobile X haul, edge computing, AR/VR, and UHD video distribution, are placing additional requirements on access networks. Characteristics like low latency, flexibility, reliability and scalability will be increasingly important for future access networks.

As we move to the next-generation of access networks, what new features are needed? What are the research priorities beyond more capacity? For instance, ultra-low latency transmission is increasingly gaining importance in access networks for emerging time critical services. More deterministic and reliable access networks architectures, and even new ODNs, are being demanded. Network virtualization, and more intelligent operation and resilience in access networks, also attract more and more interest.

This panel will provide a forum for a wide range of speakers to share their ideas on what is important in next-generation access networks. Speakers will discuss what key innovations are needed, beyond additional capacity, and the drivers behind those needs.

**Room 3**

14:00–16:00

**M3D • VCSELs & Surface Normal Devices**

Presider: Michael Tan; Hewlett Packard Enterprise, USA

M3D.1 • 14:00

*Invited*

**Optical Interconnects Using Single Mode and Multi Mode VCSEL and Multi Mode Fiber**, Nikolay Le-dentsov 1; 1VI Systems GmbH, Germany. Single mode (SM) VCSELs, produced in industrial 4» technology, are suitable for 100Gb/s PAM2 and >160Gb/s PAM4 data transmission. >107Gb/s transmission over 1km of multimode (MM) fiber at 850nm and 910nm is realized.

**Room 6C**

14:00–16:00

**M3E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 1)**

M3E.1 • 14:00

*Invited*

**Deep Learning for Inverse Design of Optical Device**, Keisuke Kojima 1; 1Mitsubishi Electric Research Labs, USA. We review the recent progress of the design and optimization of optical devices using machine learning. The emphasis is on the regression and the generative deep learning models for nanophotonic devices.

**Room 6D**

14:00–16:00

**M3F • Wavelength Selective Devices**

Presider: Kenya Suzuki; NTT Device Innovation Center, Japan

M3F.1 • 14:00

*Invited*

**Recent Progress on Wavelength Selective Switch**, Yiran Ma 1, Ian Clarke 1, Luke Stewart 1; 1II-VI Incorporated, Australia. WSS application scenarios have been illustrated from network core to edge. WSS in core network is focused on higher port count and outstanding performance, while cost is the key factor for WSS in edge network.

**Room 1A**

14:00–16:00

**M3A • New Photonic Materials**

Presider: Hideyuki Nasu; Furukawa Electric, Japan

M3A.1 • 14:00

*Invited*

**Indium Phosphide Membrane Photonic Integrated Circuits on Silicon**, Kevin A. Williams 1; 1Technische Universiteit Eindhoven, Netherlands. The intimate integration of photonics and electronics in transceivers facilitates energy-efficiency, bandwidth acceleration and a route to radical miniaturization. We present and implement a wafer-to-wafer integration method which combines electronic and photonic foundry technologies.
14:00–16:00
M3G • Submarine Transmission 📤
Presider: Oleg Sinkin; TE SubCom, USA

14:00–16:00
M3H • Microwave Photonic Filters 🌠
Presider: Daniel Blumenthal, USA

14:00–16:00
M3I • Optical Wireless: Technology and Applications 🌟
Presider: Mona Hella; Rensselaer Polytechnic Inst., USA

14:00–16:00
M3J • Short-reach Systems I 🌟
Presider: Xi Chen; Nokia Bell Labs, USA

14:00–16:00
M3K • Open Network Control & Orchestration 🌟
Presider: Achim Autenrieth; ADVA Optical Networking SE, Germany

M3G.1 • 14:00 🌟 Top-Scored
Record 300 Gb/s per Channel 99 GBd PDM-QPSK Full C-Band Transmission over 20570 km Using CMOS DACs, Aymeric Arnould1, Amrithosein Ghazisaeidi1, Dylan Le Gac1, Maria Ionescu1, Patrick Bindel1, Jeremie Renaudier1; 1 Nokia Bell Labs France, France. We demonstrate a record 300 Gb/s per-channel bitrate over 20570 km across the full C-band. The measured 41 channels are modulated with 99 Gbd PDM-QPSK using CMOS DACs and optical pre-emphasis, avoiding nonlinear compensation.

M3G.2 • 14:15
Transmission Performance of Hybrid-shaped 56APSK Modulation Formats from 34.7 to 74.7 Gbd Over Transoceanic Distance, Jin-Xing Cai1, Matt Mazurczyk1, William Patterson1, Carl Davidson1, Yue Hu1, Oleg V. Sinkin1, Maxim Bolshtyansky1, Dmitri G. Foursa1, Alexei N. Pilipetskoi1; 1 SubCom, USA. We experimentally study the impact of symbol rate on transmission performance. From 34.7 to 74.77Gbd SNR decreases by ~1.5dB; hardware and nonlinear transmission effects cause 0.7dB and 0.8dB respectively. NLC benefit decreases at higher rates.

M3H.1 • 14:00 🌟 Invited
High-resolution Microwave Photonics Using Strong On-chip Brillouin Scattering, Amol Choudhary1; 1 Department of Electrical Engineering, Indian Inst. of Technology (IIT) Delhi, India. Processing of microwave signals with resolution as low as 10 MHz is enabled by integrated Brillouin scattering with gain >50dB. We discuss reconfigurable filters, delay lines and phase shifters and also focus on system performance.

M3I.1 • 14:00 🌟 Invited
Li-Fi for Industrial Wireless Applications, Vok- mer Jungnickel1, Pablo Wilke Benenguer1, Sreela Maravanchery Mana1, Maite Hinnichi1, Sepideh Mohammadi Koohi1, Kai Lennert Bober1, Christoph Kottke1; 1 Fraunhofer Inst Nachrichten-Herrnisch-Hertz, Germany. We propose a new system concept for LiFi in industrial wireless applications. A distributed MU-MIMO architecture is used, enabling seamless mobility, reliable low-latency communications, and integration with positioning and 5G.

M3J.1 • 14:00
Recovery of DC Component in Kramers-Kronig Receiver Utilizing AC-coupled Photodetector, Tianwai Bo1, Hoon Kim1; 1 Korea Advanced Inst of Science & Tech, Korea (the Republic of). We propose and demonstrate a simple DSP method for recovering the DC component in Kramers-Kronig receiver implemented by using AC-coupled photodetector, without cumbersome DC sweeping nor bit-error-ratio calculation.

M3J.2 • 14:15
Signal-signal Beat Noise Mitigation by Square Root Processing of the Detected Photocurrent, Qilin Zhang1, Chester Shu1; 1 Chinese Univ. of Hong Kong, Hong Kong. The signal-signal beat noise mitigation performances of the original received signal, the square root processed signal, and the Kramers-Kronig processed signal are experimentally compared in a 110 Gbit/s probabilistically-shaped 64 QAM direct detection system.

M3K.1 • 14:00 🌟 Tutorial
Open Optical Transport, Martin Birk1; 1 AT&T Labs, USA. This tutorial will cover open optical transport for coherent fiber optic transmission systems, starting with the data plane, describing different open projects and efforts. The second section will address the control plane, identifying industry efforts and models used. Following that will be a view of Orchestrator and Controller projects. The last part will describe life cycle efforts (designing, planning, operating) of open optical transport networks. Martin Birk received his master’s and doctorate degrees from Germany’s University of Ulm in 1994 and 1999, respectively. Since 1999, he has been with AT&T Labs in New Jersey, working on high-speed optical transmission at data rates of 400Gbit/s, 100Gbit/s and above. In 2016, he received the AT&T Fellow award.
M3A.2 • 14:30
1.6Tbps Coherent 2-channel Transceiver Using a Monolithic Ti/Rx InP PIC and Single SiGe ASIC, Vikrant Lal1, Pavel Studenkov1, Thomas Frost2, Huan-Shang Tsai1, Babak Behnia1, John Osenbach1, Stefan Wolf1, Robert Gaing3, Stefano Porta1, Robert Maher2, Hossein Hodaie1, Jiaming Zhang1, Carlo Di Giovanni1, Koichi Hoshino1, Thomas Vallaitis2, Bryan Ellis1, Jeanne Yan1, King Fong3, Ehsan Soudi1, Matthias Kuntz1, Sanketh Buggaveeti1, Don Pavinski1, Steve Sanders1, Zhenxing Wang1, Gloria Höfler1, Peter Vetter3, Glenn Wellbrock3, Jun Terada1, NTT Corp., Japan; 2ADVA Optical Networking, Germany; 3Comcast, USA

M3A.3 • 14:45
Data-mining-assisted Resonance Labeling in Ring-Based DWDM Transceivers, Peng Sun1, Jared Hulme1, Ashkan Seyedi2, Marco Fiorentino3, Raymond Beausoleil4, Hewlett Packard Lab, USA. An algorithm using hierarchical clustering is proposed to label resonances in ring-based DWDM transceivers. By identifying missing resonances and split-peaks due to reflection, the algorithm enables binning of individual ring resonators by passive optical tests.

M3B.2 • 14:30
106 Gb/s Normal-incidence Ge/Si Avalanche Photodiode with High Sensitivity, Bin Shen1, Fan Qi1, Penglei Cai1, Xueping Chen1, Zengwen He1, Yanhu Duan1, Guanghui Hou1, Tzungui Su1, Su Li1, Wang Chen1, Chingyin Hong1, Rong-Chen Yu1, Dong Pan1, Si-Fotonics Technologies, USA. 106 Gb/s (33GBaud PAM4) normal-incidence Ge/Si APDs were demonstrated with sensitivities of -16.8 dBm. To our knowledge, this is the best sensitivity reported for 100G APD.

M3C.3 • 14:45
Ultra-thin III-V Photodetectors Epi-taxially Integrated on Si with Bandwidth Exceeding 25 GHz, Svenja Mauch1, Yanick Baumgartner1, Saurabh Sant1, Gian Ding1, Marlyne Sousa1, Lukas Czornomaz1, Andreas Schenk1, Kirsten Moselund1, IBM Research - Zurich, Switzerland; 2Department of Information Technology and Electrical Engineering, ETH Zurich, Switzerland. We demonstrate the first local monolithic integration of high-speed III-V p-i-n photodetectors on Si by in-plane epitaxy. Ultra-low capacitance permits data reception at 32Gbps. The approach allows close integration to electronics enabling future receiverless communication.

M3C.2 • 14:30
106 Gb/s Normal-incidence Ge/Si Avalanche Photodiode with High Sensitivity, Bin Shen1, Fan Qi1, Penglei Cai1, Xueping Chen1, Zengwen He1, Yanhu Duan1, Guanghui Hou1, Tzungui Su1, Su Li1, Wang Chen1, Chingyin Hong1, Rong-Chen Yu1, Dong Pan1, Si-Fotonics Technologies, USA. 106 Gb/s (33GBaud PAM4) normal-incidence Ge/Si APDs were demonstrated with sensitivities of -16.8 dBm. To our knowledge, this is the best sensitivity reported for 100G APD.

M3D.2 • 14:30
Advances in Deep Learning for Digital Signal Processing in Coherent Optical Modems, Maximilian Schaedler1, Maximilian Schaedler1, Christian Bluemmi1, Stefano Calabro1, Huawei, Germany. We analyze the advances of deep learning in optical coherent modems on the physical layer with respect to modulation design, equalization and signal detection and give an outlook on a combined control and physical layer optimization using neural networks.

M3E.2 • 14:30
Normal-incidence Ge/Si Avalanche Photodiode with High Sensitivity, Bin Shen1, Fan Qi1, Penglei Cai1, Xueping Chen1, Zengwen He1, Yanhu Duan1, Guanghui Hou1, Tzungui Su1, Su Li1, Wang Chen1, Chingyin Hong1, Rong-Chen Yu1, Dong Pan1, Si-Fotonics Technologies, USA. 106 Gb/s (33GBaud PAM4) normal-incidence Ge/Si APDs were demonstrated with sensitivities of -16.8 dBm. To our knowledge, this is the best sensitivity reported for 100G APD.

M3F.3 • 14:45
Five-core 1×6 Core Selective Switch and Its Application to Spatial Channel Networking, Masahiko Jinno1, Takahiro Kodama1, Tsubasa Ishikawa1, Kaga- ka Univ., Japan. We design and prototype a 5-core 1×6 core selective switch (CSS) with an integrated input and output multi-core fiber collimator and spatial multiplexer/demultiplexer array. Spatial bypassing and spectral grooming using a CSS-based hierarchical cross-connect are demonstrated.
M3G.4 • 14:45
System Performance and Pre-emphasis Strategies for Submarine Links with Imperfect Gain Equalization, Yue Hu1, Carl Davidson1, Lee J. Richardson3, Maxim Bolshinsky3, Dmitri G. Foursa1, Alexei N. Pilipetskii1; 1Subcom, USA. We studied C-band system performance penalties due to gain tilt. Several transmission pre-emphasis strategies for penalty compensation were considered. The overall penalties were small and minor differences between strategies were observed for investigated tilt range.

M3G.3 • 14:30
Experimental Demonstration of Widely Tunable Rate/Reach Adaptation From 80 km to 12,000 km Using Probabilistic Constellation Shaping, Jianqiu Liu1,2, Tobias J. Kippenberg1,2, Xi Chen3, Junho Cho3, Chandrasekhar Sethumadhavan3, Jr, Peter Winzer2, 1Universitat Politècnica de Catalunya, Spain; 2Nokia Bell Labs, USA. We experimentally demonstrate the rate/reach adaptability of probabilistically constellation-shaped quadrature amplitude modulation across from 80 km to 12,000 km using the same 32-Gbaud transponder hardware and highlight the roles of template and shaping distribution.

M3H.2 • 14:30
Reconfigurable Radiofrequency Photonic Filters Based on Soliton Microcombs, Jianqiu Liu1,2, Tobias J. Kippenberg1,2, Xi Chen3, Junho Cho3, Chandrasekhar Sethumadhavan3, Jr, Peter Winzer2, 1Universitat Politècnica de Catalunya, Spain; 2Nokia Bell Labs, USA. We demonstrate soliton based radiofrequency filters using a 104 GHz Si3N4 microresonator. The filter passband frequencies are widely reconfigured via inherent soliton states of perfect soliton crystals and two-soliton microcombs, without any external pulse shaping.

M3H.3 • 14:45
A Single-passband Microwave Photonic Filter with kHz Bandwidth, Huashun Wen1,2, Ning Hua Zhu1,2, 1State Key Laboratory on Integrated Optoelectronics, Inst. of Semiconductors, Chinese Academy of Sciences, China; 2School of Electronic, Electrical and Communication Engineering, Univ. of Chinese Academy of Sciences, China. A single-passband microwave photonic filter with 3 dB bandwidth of 12 ± 2.5 kHz over spectral range of 2-40 GHz is experimentally demonstrated by optical-injection of a single-frequency Brillouin fiber laser.

M3J.3 • 14:30
Transmission of 36-Gbaud PAM-8 Signal in IM/DD System Using Pairwise-distributed Probabilistic Amplitude Shaping, Daeho Kim1, Zonglong He1, Tianwei Bo1, Yukui Yu1, Hoon Kim1, 1Korea Advanced Inst of Science & Tech, Korea (the Republic of); 2Chalmers Univ. of Technology, Sweden. We experimentally demonstrate the transmission of 36-Gbaud probabilistically-shaped PAM-8 signal over 10-km link. The performance measured after FEC decoding and IDM shows that the receiver sensitivity is improved by >1 dB compared to uniform-distributed signal.

M3H.4 • 14:45
Miniature R/G/V-LDs+Y-LED Mixed White-lighting Module with High-Lux and High-CRI for 20-Gbps Li-Fi, Yi-Chien Wu1,2, Chia-Yu Su1,2, Huan-Tung Wang1,2, Chih-Hsien Cheng1,2, Gong-Ru Lin1,2, 1Graduate Inst. of Photonics and Optoelectronics, and Department of Electrical Engineering, National Taiwan Univ., Taiwan; 2NTU-Tektronix Joint Research Center, National Taiwan Univ., Taiwan. Miniature white-lighting beam mixed by R/G/V-LDs+Y-LED module with high illuminance of 12000 lux, high color-rendering-index of >60 is demonstrated for vehicle light fidelity or distant optical wireless lighting transmission at data rate beyond 20 Gbps.
M3A • New Photonic Materials—Continued

M3A.4 • 15:00
On-chip Mode-division Multiplexing with Modal Crosstalk Mitigation, Yatian Huang1, Ruinhuan Zhang2, Haoshuo Chen1, Hanzi Huang1, Qingming Zhu2, Yu He1, Yingxiong Song1, Nicolas K. Fontaine1, Roland Ryf3, Yong Zhang1, Yikai Su1, Min Wang1; Shanghai Univ., China; 2Shanghai Jiao Tong Univ., China; 3Nokia Bell Labs, USA. We experimentally demonstrate modal crosstalk mitigation over an on-chip mode-division multiplexing link employing low-coherence matched detection. 20-Gbaud QPSK and 8-PSK mode-multiplexed signals are successfully transmitted with a maximum modal crosstalk of -6.5 dB.

M3A.5 • 15:15
Analysis and Demonstration of Ultra-broadband Mach-Zehnder Hybrid Polymer/Sol-Gel Waveguide Modulators, Yasufumi Enami1,2; 1Head-quarters for Innovative Society-Academia Cooperation, Univ. of Fukui, Japan; 2Lightwave Logic, USA. A bandwidth of the hybrid modulators is calculated numerically and analytically based on experimentally obtained device parameters, which is >130 GHz. The electro-optic response is reduced by < 2 dB at 67 GHz. The electrical transmission S21 is reduced by 5 dB at 110 GHz (upper limit) of a vector network analyzer, which also assured the bandwidth.

M3B • Propagation Effects in SMF and SDM Fibers—Continued

M3B.4 • 15:00
On-chip Mode-division Multiplexing With Modal Crosstalk Mitigation, Yatian Huang1, Ruinhuan Zhang2, Haoshuo Chen1, Hanzi Huang1, Qingming Zhu2, Yu He1, Yingxiong Song1, Nicolas K. Fontaine1, Roland Ryf3, Yong Zhang1, Yikai Su1, Min Wang1; Shanghai Univ., China; 2Shanghai Jiao Tong Univ., China; 3Nokia Bell Labs, USA. We experimentally demonstrate modal crosstalk mitigation over an on-chip mode-division multiplexing link employing low-coherence matched detection. 20-Gbaud QPSK and 8-PSK mode-multiplexed signals are successfully transmitted with a maximum modal crosstalk of -6.5 dB.

M3C • Panel: Is it Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity—Continued

M3D • VCSELS & Surface Normal Devices—Continued

M3D.4 • 15:00
Large Optical Aperture Top-illuminated 50-Gbaud PIN-PD with High 3-dB Bandwidth at a low bias of 1.5 V, Takashi Toyonaka1, Hiroshi Hamada1, Shigehisa Tanaka1, Masatoshi Arasawa1, Ryu Washino1, Yasushi Sakuma1, Kazuhiko Naoe1; 1Device Development Center, Lumentum Japan, Inc., Japan. High 3-dB bandwidth of 28 GHz at 1.5 V was demonstrated by introducing a capacitance-control layer into a high-responsivity top-illuminated PIN-PD with large optical-aperture diameter of 20 µm for 50-Gbaud PAM4 operation.

M3E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 1)—Continued

M3F • Wavelength Selective Devices—Continued

M3F.4 • 15:00
Low-loss Silicon 2 × 4A Multiplexers Composed of On-chip Polarization-splitter-rotator and 2 × 2 and 2 × 1 Mach-Zehnder Filters for 400GbE, Junya Takano1, Takeshi Fujisawa1, Yusuke Sawada1, Kunimasa Saitoh1; 1Hokkaido Univ., Japan. 2 × 4A Si-photonics multiplexers for 400GbE composed of Mach-Zehnder filters and a polarization-splitter-rotator are proposed and experimentally demonstrated for the first time. Relative spectral position of two filters is locked by using 2×2 and 2×1 configurations.
Alexei Pilipetskii received his PhD in 1990 in nonlinear fiber optics. Later his interests shifted to the fiber optic data transmission. Alexei currently leads Forward Looking Team at SubCom. He is an author and co-author of more than 200 publications and 25 patent applications. He is an IEEE Photonics Society Fellow.
M3A.6 • 15:45 ★ Top-Scored
Chip-scale, Optical-frequency-stabilized PLL for DSP-Free, Low-Power Coherent QAM in the DCI, Grant M. Brodnik1, Mark W. Harrington1, Debapam Bose1, Andrew M. Natherton1, Wei Zhang1, Liron Stern2, Paul A. Morton1, John E. Bowers1, Scott B. Papp4, Daniel J. Blumenthal1; 1Univ. of California Santa Barbara, USA; 2Time and Frequency Division 688, National Inst. of Standards and Technology, USA; 3Morton Photonics, USA; 4Department of Physics, Univ. of Colorado, USA. We demonstrate a DSP-free 16-QAM/500Gb/s link based on independent transmit and LO frequency-stabilized ultra-narrow-linewidth SBS lasers, with ~40Hz integral linewidths and 7x10⁻⁴ fractional frequency stability. The low-BW optical-frequency-stabilized PLL with 3x10⁻⁴ rad² phase error operates within 1% of DSP and self-homodyne.

M3D.6 • 15:45
Scalable Arrays of 107 Gbit/s Surface-normal Electroabsorption Modulators, Stefano Grillanda1, Ting-Chen Hu1, David Neilson3, Nagesh Basavanahally1, Yee Loui1, Hugo Satar1, Mark Cappuzzo1, Rose Kopf1, Al Tate1, Gregory Rayborrn2, Andrew Adamiecki3, Nicolas K. Fontaine1, Mark Earnshaw1; 1Nokia Bell Labs, USA; 2Nokia Bell Labs, USA. We demonstrate arrays of surface-normal electroabsorption modulators with ultrawide bandwidth (>45 GHz), polarization insensitive response and ultralow total coupling loss to single-mode-fibers (0.7 dB). We show modulation up to 107 Gbit/s and packaging with arrayed-waveguide-gratings.

M3F.6 • 15:30
Ultra-low loss and fabrication tolerant silicon nitride (Si3N4) (de-)muxes for 1-μm CWDM optical interconnects, Stanley Cheung1, Michael R. Tan1, Hewlett Packard Labs, USA. We demonstrate 990 – 1065nm bottom-emitting VCSELs. Channel separation of 25 nm, XT < -35 dB and -20 dB are reported with temperature shift of 14.5 pm/°C.

M3F.7 • 15:45
Fabrication-insensitive CWDM (De)multiplexer based on Cascaded Mach-Zehnder Interferometers, Tzu-Hsiang Yen1, Yong-Jr Hung1; 1National Sun Yat-Sen Univ., Taiwan. We demonstrate a MZI-based (De)multiplexer that greatly reduces the spectral shift from 15.6±2.5 nm to 0.67±0.715 nm by employing narrow and wide waveguides in different arms of a MZI.
M3H.6 • 15:30 Invited Photonic Integration for RF Beamforming in Phased Array Systems, Paul A. Morton1, Jacob B. Khurgin2, Chao Yang2, Ming Luo2, Paul Photonics Inc., USA; John E. Bowers3, Morton Photonics Inc., USA; Johns Hopkins Univ., USA; UCSB, USA. A novel photonics based approach to RF Beamforming in a receive-mode electronically scanned array (Rx-ESA) is described, enabled by heterogeneous photonic integrated circuits (PICs), with future applications including 5G RF Beamforming (a.k.a. Massive MIMO).

M3H.6 • 15:30 Modulation Classification based on Deep Learning for DMT Subcarriers in VLC System, Wu Liu1, Xiang Li1, Chao Yang1, Ming Luo1, Wuhan Research Inst. of Post & Tele, China. We propose a deep learning(DL) enabled modulation classification scheme using only dozens of received symbols. For each DMT subcarrier in VLC system, experiments achieve 100% classification accuracy rate using 75 symbols received at BER threshold.

M3J.7 • 15:45 High-speed Visible Light Communication System Based on a Packaged Single Layer Quantum Dot Blue Micro-LED with 4-Gbps QAM-OFDM, Zixian Wei1, Li Zhang1, Lei Wang1, Chien-Ju Chen1, Alberto Pepe1, Xin Liu1, Kai-Chia Chen1, Yuhao Dong1, Meng-Chyi Wu1, Lai Wang1, Yi Luo1, H.Y. Fu1, Tsinghua-Berkeley Shenzhen Inst., China; Department of Electronic Engineering, Tsinghua Univ., China; Tsinghua-Shenzhen International Graduate School, Tsinghua Univ., China; Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan. We demonstrate a 3-meter 4-Gbps QAM-OFDM VLC system with 3.2×1012 bit-error-rate (BER) by implementation of our own fabricated and packaged single layer quantum dot (QD) blue micro-LED with a record high 1.06 GHz modulation bandwidth.

M3J.8 • 15:45 80-GBd Probabilistic Shaped 256QAM Transmission over 560-km SSMF Enabled by Dual-virtual-carrier Assisted Kramers-Kronig Detection, An Li1, Wei-Ren Peng1, Yan Cui1, Yushe Bao1, FutureWei Technologies, Inc., USA. We demonstrate transmission of 80-GBd probabilistic shaped 256QAM over 560-km SSMF, a record reach at 400-Gb/s line rate using single laser and direct detection, enabled by probabilistic constellation shaping and dual-virtual-carrier assisted Kramers-Kronig detection.

M3K.4 • 15:45 Collaborative Routing in Partially-trusted Relay based Quantum Key Distribution Optical Networks, Xingyu Zou1, Xiaosong Yu1, Yongli Zhao1, Avishek Nag2, Jie Zhang3, Beijing Univ of Posts & Telecom, China; School of Electrical and Electronic Engineering Univ College, Ireland. This paper proposes a collaborative routing scheme in partially-trusted relay based quantum key distribution optical networks. Simulation results show it achieves good performance in terms of quantum key distribution success rate.
M3Z.1 OpenConfig-extension for VLAN-based End-to-end Network Slicing Over Optical Networks, Abubakar Siddique Musaddads1, Alessio Giorgetti2, Rodrigo Stange Tessinari3, Thierno Diallo3, Andrea Sambellunio, Reza Nejatbibi, Dimitri Simeunovic1, 1Univ of Bristol, UK; 2Scuola Superiore Sant’Anna, Italy. We demonstrate end-to-end VLAN-based network slicing over optical networks using ONOS, based on extended OpenConfig model for hybrid packet-optical terminal devices. Validation is performed by end-to-end interconnected VNFs supporting video streaming use case.

M3Z.2 Demonstration of Precise Planning of Broadband Access Network based on Mining Traffic Trends and Demands from Hybrid Data Sources, Hui Li1, Xiang Guo2, Tienshan Zhan3, Wu Jia4, Yudan Su5, Guangsheng Yang6, Jingjie Sun7, Yan Shao8, Yuefeng Ji9, Guangquan Wang10; 1Yale University, USA; 2Mininet Project, USA; 3CONEXANT Systems, USA; 4NEC Corporation, China; 5level. We demonstrate a C-band optical cross-connect switch based on InP integrated photonic, butt-coupled to a silica PLC for facile optical alignment. The switch allows the development of low power, low latency and low-cost WDM-switches.

M3Z.4 Automatic Resource Mapping Using Functional Block Based Disaggregation Model for ROADAM Networks, Kyo Ishi1, Sugang Xu2, Noboru Yoshikane3, Atsuko Takefusa4, Shigeiyuki Yamaguchi5, Takeshi Hoshida6, Koji Kudoh7, Takehiro Tsurtani8, Yo-shina Ajwai9, Shu Nam1, 1AIST, Japan; 2NICT, Japan; 3NII, Japan; 4NEC Corporation, Japan; 5KDDI Research, Japan; 6NTT, Japan; 7NTT, Japan; 8NTT, Japan; 9NTT, Japan. We demonstrate construction of an Open Line System controller, reconciling device alarms from Open ONNF-based SDON Platform encompassing OpenROADM-controlled White Box enabling artificial intelligence and GPUs to make a robot rover slammer between ports.

M3Z.6 Demonstration of Alarm Correlation in Partially Disaggregated Optical Networks, Quan Pham9, Victor López-Arévalo1,2, Arámbula-López1,2, Des-Lerma1,2, Konrad Mrówka3, Rafael Mrob4, Sebastian Auer5, Hui-Trung Thieu5, Guang-Huy Tran1,2, Dominique G. Vercelere1, Gary Atkinson1, Achim Aristienkoff1, Stephan Neidlinger1, Lubo Tancsics2, ENSA Lab, Nokia Bell Labs, France; 2E-lighthouse Services GmbH, Germany. We demonstrate a C-band optical cross-connect switch based on InP integrated photonic, butt-coupled to a silica PLC for facile optical alignment. The switch allows the development of low power, low latency and low-cost WDM-switches.

M3Z.8 Packaged Graphene Photodetectors with 50 GHz RF bandwidth operating at 1550 nm and 2 mm wavelength, Galip Hepgüler1, Ab-bas Madani2, Stefan Wagner2, Dan-iel Schau1,2, 1AMO GmbH, Germany; 2Black Semiconductor, Germany. We demonstrate practical graphene photodetectors operating with a bandwidth of 50 GHz. We are presenting the first graphene photonic device prototypes approaching TRL 5 level.

M3Z.9 Demonstration of Software-defined Packet-optical Network Emulation with Mininet-optical and ONOS, Bob Lantz1,2, Alan A. Diaz Montiel1, Ji-akai Yu1, Christian D. Ross1, Marco Rufini2, Daniel C. Kilper3, 1College of Optical Sciences, Univ. of Arizona, USA; 2Mininet Project, USA; 3CON-NECT Centre, Trinity College, Ire-land. We demonstrate practical software emulation of a software-defined, packet-optical network. Our emulator, Mininet-Optical, models the physical, data plane and control plane behavior, under control of the ONOS SDN controller.

M3Z.10 Remote Control of a Robot Rover Combining 5G, AI, and GPU Image Processing at the Edge, Francesco Gian-none1, Koteswararao Kondepulu2, Piero Castoldi3,4, Luca Valcarceghi5, Andrea Bragaglini6, Fabrizio Gatti6, Antonia Napoli-poni7, Justine Cres Bero-moe8, 1Scuola Superiore Sant Anna di Pisa, Italy; 2Ericsson, Italy; 3CNIT, Italy. A fully packed photonic integrated switch matrix including 1398 circuit elements interconnected in a 3-D stack is controlled through OpenROADM NETCONF/YANG Agent and experimentally validated in an ONOS-based SDN testbed encompassing OpenConfig-driven 100G pol-mux transponders.

M3Z.11 Experimental Demonstration of multiple Disaggregated OLs running Virtualised Multi-tenant DBA, over a Xeon Processor, Frank Slyne1,2, Marco Rufini1, Robin Giller1, Da-vid Coyle3, Jasvinder Singh4, Rory Lantz1,2, 1Scuola Superiore Sant Anna di Pisa, Italy; 2TIM, Italy; 3Department of Excellence in Robotics and A.I., Italy; 4Scuola Superiore Sant Anna, Italy. The demo shows the effectiveness of a low latency remote control based on 5G and image processing at the edge exploiting artificial intelligence and GPUs to make a robot rover slammer between ports.

M3Z.12 Demonstration of Alarm Knowledge Graph Construction for Fault Localization on ONOS-based SDN Platform, Zhoutong Liu1, Yongli Zhao2, Yajie Li2, Sabidur Rahman3, Ying Wang4, Xiaoxiong Yu5, Luohang Zhang5, Guo Li6, 1University of California, USA; 2State Grid Information & Telecommunication Company, China; 3State Grid Ningxia Electric Power Research Institute, China. We demonstrate construction of alarm knowledge graphs, which is helpful for fault localization in software defined optical networks (SDON). The demonstration shows the method of constructing alarm knowledge graphs on ONOS-based platform using knowledge extraction.

M3Z.13 OpenROADM-controlled White Box enabling Silicon Photonics Integrated Reconfigurable Switch Matrix, Andrea Sambellun1, Philippe Velha1, Claudio Jose Otieno2, Alessio Giorgetti3, Antonio D’Emrico1, Stefano Stracca1, Filippo Cugini2, 1Scuola Superiore Sant Anna di Pisa, Italy; 2Ericsson, Italy; 3CNIT, Italy. A fully packed photonic integrated switch matrix including 1398 circuit elements interconnected in a 3-D stack is controlled through OpenROADM NETCONF/YANG Agent and experimentally validated in an ONOS-based SDN testbed encompassing OpenConfig-driven 100G pol-mux transponders.
M3Z.15 Disaggregated, Sliceable and Load-aware Optical Metro Access Network for 5G Applications and Service Distribution in Edge Computing, Bitao Pan, Xuwei Xue, Fu Wang, Eduardo Magalhães, Roberto Moro, Emilio Ricardi, Nicola Calabretta; Eindhoven Univ. of Technology, Netherlands; TIM, Italy. A disaggregated, sliceable metro-access ring with SDN control is demonstrated with the use case of service distribution in the edge computing nodes. Successful SDN controlled dynamic network slicing generation, load-aware bandwidth resources assignment is implemented.

M3Z.17 Physical-layer Awareness: GNPy and ONOS for End-to-end Circuits in Disaggregated Networks, Jan Kundrát, Andrea Campanela, Esther Lerouzic, Alessio Ferrari, Ondrej Havlís, Michal Hazlinsky, Gert Grammel, Gabriele Galimberti; Cesnet, Czechia; Telecom Infra Project, USA; Orange Labs, France; Open Networking Foundation, USA; Politecnico di Torino, Italy; CESNET, Czechia; Telecom Infra Project, USA; Orange Labs, France; Open Networking Foundation, USA; Politecnico di Torino, Italy. This demo shows the automatic end-to-end path provisioning over a multi-vendor fully disaggregated Open Line System by Czech Light using the GNPy QoT estimator and Cassini transceiver by the Telecom Infra Project integrated with ONOS.

M3Z.16 Withdrawn

M3Z.18 Flexible Optical Network Enabled Proactive Cross-layer Restructuring for 5G/BSG Backhaul Network with Machine Learning Engine, Rentao Gu, Yongyao Qu, Meng Lian, Hongbiao Li, Zhaow Wang, Yinan Zhu, Qize Guo, Jianjun Yang, Dajiang Wang, Yuefeng Ji; Beijing Univ. of Posts and Telecomms, China; ZTE Corporation, China; China United Network Communications Co. Ltd., China. It demonstrates a flexible optical network enabled “Network Restructuring as Traffic Changes” for 5G/BSG backhaul network, which realizes proactive cross-layer network generation and mitigation based network recovery, powered by cognitive enhancement and decision deduction.

M3Z.19 Demonstration of Monitoring and Data Analytics-triggered Reconfiguration in Partially Disaggregated Optical Networks, Lluis Gifre Renom, Fabien Boitier, Camille Delezoide, Marta Buffa, Annalisa Morea, Ramon Casellas, Luis Velasco; Nokia Bell Labs, France; Universitat Politècnica de Catalunya, Spain; Nokia, Italy; Centre Tecnològic Telecomunicacions Catalunya (CTTC), Spain. We demonstrate a novel agent for optical disaggregated optical networks. When the Monitoring and Data Analytics detects a degradation, it recommends the SDN controller to trigger a network reconfiguration computed by a novel planning tool.

NOTES

16:00–16:30 Coffee Break, Upper Level Corridors
A revolution in the automotive industry is upon us, the self-driving cars. The autonomous car systems require ever-increasing bandwidth for delivering information from the various high resolution sensors to the processing units and have to be extremely reliable. The currently and near future developed automotive sensors include high-resolution cameras, Lidars, SWIRs, and radars, each generating Multi-Gigabit/sec of payload data that should be delivered to the main processing unit with very low latency and BER.

These autonomous vehicles impose a paradigm shift in the car communication systems, essentially turning it to a small “data center on wheels”. Consequently, new technologies should be developed and/or adopted for this application, including plastic optical fibers (POF), VCSELs, photonic integrated circuits (PICs), or upgraded “traditional copper”. Furthermore, new network architectures should be adopted, including rings, stars, multiple point-to-point, resilient networks, and others.

The autonomous driving also demands unprecedented coordination among the traffic. This requires efficient inter-vehicle and road-side communications, where microwave photonics and optical wireless communications become important candidate technologies.

Takemi Hasegawa is Group Leader in Optical Communications Laboratory, Sumitomo Electric Industries Ltd. Japan. Ultra-low loss multicore fibers will enable to scale the capacity of middle to long-distance transmission by overcoming spatial limitation. This tutorial will cover progresses in fibers, amplifiers and components, and challenges for practical applications.
5G promises to revolutionize society and industry by enabling a wide range of services, like enhanced Mobile Broad-Band (eMBB), Ultra-Reliable Low Latency Communications (URLLC) and massive Machine-Type Communications (mMTC), with very different and stringent requirements. 5G Transport will require large amounts of fiber deployments, but while a lot of focus is being given to fiber access networks, the optical metro/aggregation network has not yet received much attention.

Transport optical networks are traditionally considered a collection of big pipes, seen as an existing commodity, on top of which to add higher layer network resources and intelligence supporting the services. Considerable effort is devoted by both the research community and industry to the design and deployment of more efficient, more cost-effective, greener and more sustainable, and autonomic metro/aggregation networks, which are expected to complement 5G mobile networks supporting vertical services.

Furthermore, the expected widespread use of Edge Computing and Cell Site Gate-Way Nodes will blur the traditional strong separation between mobile, access, and metro/aggregation networks, which opens the possibility for beneficial technology cooperation. However, how these technological advancements in all network layers of the access/metro/aggregation domains, as well as in the control plane, can be pieced together to give a clear and unified vision of the 5G ecosystem, is still largely a subject of debate. This session will address the issue of whether and how the massive deployment of vertical services over 5G will change the traditional approach to building optical network infrastructures.

**M4H.1 • 16:30** Invited

*Si PIC Based on Photonic Crystal for Lidar Application*, Toshikiko Baba¹, Hiroaki Ito¹, Hiroshi Abe¹, Takehisa Shima², Yoosuke Hinokura¹, Ryo Tetsuya¹, Jun Maeda¹, Mikya Kamata¹, Ryo Kurahashi¹, Ryo Shiratori¹, ‘Yokohama National Univ., Japan. Wide-range nonmechanical beam steering is available by an array of Si photonic crystal slow-light waveguides and their switching without complicated control. FMCW LiDAR action is obtained with this beam steering on a Si photonics chip.

**M4J.1 • 16:30** Invited

*Radio-over-fiber Technology: Present and Future*, Christina Lim¹, ‘Univ. of Melbourne, Australia. This paper reviews the recent research in the area of radio-over-fiber technology focusing on physical layer investigations and demonstrations, and also provides a brief discussion on the future outlook.

**M4J.1 • 16:30** Tutorial

*Few-mode Fiber Transmission*, Guifang Li¹, ‘Univ. of Central Florida, USA. This tutorial will describe different types of few-mode fibers and their unique properties, followed by fiber-optic transmission systems that they potentially enable, and the prospects of these transmission systems making realistic impacts in the commercial world.

**M4K.1 • 16:30** Invited

*Long-haul WDM Transmission with Over-1-Tb/s Channels Using Electromagnetically-synthesized High-symbol-rate Signals*, Taka-yuki Kobayashi¹, Masanori Nakanuma¹, Fuku-taro Hamazaki¹, Munehiko Nagatani¹, Hiroshi Yamazaki¹, Hideyuki Nosaka², Yutaka Miyamoto¹, ‘NTT Network Innovation Laboratories, Japan; ¹NTT Device Technology Laboratories, Japan. Recent technical progress on 1-Tb/s-class transmission systems based-on high-speed electronics are reviewed. And this paper discusses key technologies and issues of the beyond-1-Tb/s WDM transmission systems with over-100-Gbaud symbol-rate for achieving long-haul transport.

Guifang Li is currently Professor of Optics & Photonics at the University of Central Florida and Editor-in-Chief of Advances in Optics & Photonics (OSA). His research interests include optical communications and networking, RF photonics, optical signal processing. He is a recipient of the NSF CAREER award, the Office of Naval Research Young Investigator award. He is a fellow of IEEE, SPIE, the Optical Society and the National Academy of Inventors. He previously served as a Deputy Editor for Optics Express, and an associate editor for Chinese Optics Letters, IEEE Photonics Technology Letters, IEEE Photonics Journal and Optica.
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**M4A.2 • 17:00**
Two-level Optical Encryption for Secure Optical Communication, Ye-tian Huang, Haoshuo Chen, Hanzi Huang, Qianwu Zhang, Zhengquan Li, Nicolas K. Fontaine, Roland Ryf, Min Wang, Shanghai Univ., China; Nokia Bell Labs, USA. We demonstrate 60 Gbit/s transmission over 43-km SMF using low-coherence matched detection combined with spectral phase coding as two-layer optical encryption. Encrypted signal and carrier are multiplexed through polarization diversity and demultiplexed using polarization tracking.

**Speakers:**
Daniel Adler; Valens, Israel
Ken Tanizawa; Tamagawa Univ., Japan
Shilong Pan; Nanjing University of Aeronautics and Astronautic, China

**M4A.3 • 17:15**
Photonic Generation of Quantum Noise Assisted Cipher at Microwave Frequencies for Secure Wireless Links, Ken Tanizawa, Fumio Futa-mi, Tamagawa Univ., Japan. We propose novel wireless physical layer encryption utilizing signal masking by truly random quantum noise. 12-Gbit/s cipher with sufficient masking is generated in 30-GHz band by optical heterodyne, and secure microwave wireless transmission is achieved.

This panel will discuss the evolving needs, the technology candidates, and the main associated debates in this automotive revolution era.

**Speakers:**
Kasia Bakalier; AIRBUS Satellite and Defense, UK
Ton Koonen; Eindhoven University of Technology, Netherlands
Michael A. Reimer; Eui Young Park, Michael Hubbard; Qunbi Zhuge; 1Ciena, Canada; 2Cambridge Univ., UK.

**M4D.2 • 17:00**
Colorless, Partially Directional, and Contentionless Architecture for High Degree ROADMs, Yangcheng Li, Liangjia Zong, Mingyi Gao, Biswanath Mukherjee, Gangxiang Shen, Soochow Univ., China; Transmission Technology Research Department, Huawei, China. We design a Colorless, partially Directional, and Contentionless (CpDC) architecture for high-degree ROADMs, in which a fixed interconnection pattern is developed to connect different nodal degrees and add/drop modules. Simulation results show the advantages of the proposed architecture.

**M4D.3 • 17:15**
Reliable Slicing with Isolation in Optical Metro-aggregation Networks, Andrea Marotta, Dajana Cassioli, Massimo Tornatore, Yusuke Hirota, Yoshinari Awaji, Biswanath Mukherjee, Univ. of L’Aquila, Italy; Politecnico di Milano, Italy; Univ. of California, USA; National Inst. of Information and Communications Technology, Japan. We discuss how different degrees of slice isolation influence resource allocation in protected optical metro-aggregation networks. The case of slice reliability with dedicated protection at lightpath is modelled and numerically evaluated.

**M4E • Symposium:**
The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 2)—Continued

**M4F • High Order Direct Detect Formats—Continued**

**M4F.2 • 17:00**
Neural Network Training for OSNR Estimation - from Prototype to Product, Andrew Shiner, Moham mad E. Mousa-Pasandi, Meng Qiu, Michael A. Reimer, Eui Young Park, Michael Hubbard; Qunbi Zhuge; Francisco J. Vaquero Caballero; Maurice O’Sullivan; Ciena, Canada; Cambridge Univ., UK. A method for in-service OSNR measurement with a coherent transceiver is presented and experimentally verified. A neural network is employed to identify and remove the nonlinear noise contribution to the estimated OSNR.

**M4F.3 • 17:00**
Novel Optical Field Reconstruction for IM/DD with Receiver Bandwidth Well Below Full Optical Signal Bandwidth, Gian Hu, Robert Borkowski, Mathieu Chagnon, Karsten Schuh, Fred Buchali, Henning Bi l ow, Nokia Bell Labs, Germany. We propose a novel signal reception scheme for IM/DD enabling optical field reconstruction. We experimentally demonstrate 60-GBd PAM-4 transmission over 80-km without active and passive optical managements, with 33-GHz electrical bandwidth at transmitter and receiver.

**M4F.4 • 17:15**
Demonstration of 214Gbps per lane IM/DD PAM-4 Transmission using O-band 35GHz-class EML with Advanced MLSE and KP4-FEC, Wei Wu, Zhilei Huang, Biwei Pan, Huanlu Li, Guangpeng Li, Jian Tang, Yuchun Lu, Huawei Technologies Co. Ltd., China. A single-wavelength single-polarization 35GHz-class (112Gbps-class) commercial EML-based IM/DD transmission is experimentally demonstrated. By using advanced MLSE with low complexity and power consumption, the BER is below standard KP4-FEC requirement of 2×10^-4.
In particular, the session will open a discussion on the following questions:

What are the network requirements emerging from 5G services?

What does a future-proof access/metro/aggregation network architecture look like?

How can such architecture be implemented?

The session will be divided into two parts. In the first part, invited speakers will present their views on network (re)volution. In the second part, different strategies leading to more efficient, more cost-effective, and more sustainable networks will be debated in a panel discussion.

Speakers:

Glenn Wellbrock; Verizon Transport Networks, USA

Jun Terada; NTT Access Networks Labs, Japan

Andrew Lord; BT Labs, UK

Jan Söderström; Ericsson, USA

Attilio Zani; Telecom Infra Project, UK

M4H.1 • 17:00 A 400 Gb/s O-band WDM (8×50 Gb/s) Silicon Photonic Ring Modulator-based Transceiver, Stelios Pitsis1, Miladis Moralis-Pegios1, Theoni Alexoudi1, Konstantinos Fotiadis1, Yoon Gi Bar1, Peter De Heyn1, Joris Van Campenhout1, Nikos Pleros1, 1Department of Informatics, Center for Interdisciplinary Research & Innovation, Aristotle Univ. of Thessaloniki, Greece; imec, Belgium. We present a 400 Gb/s-capable RM-based Si-photonic WDM O-band TxRx with 1.17nm channel spacing for high-speed optical interconnects and demonstrate successful 50Gb/s-NRZ TxRx operation achieving a -4.5dB Tx extinction ratio under 2.15Vpp drive.

M4H.2 • 17:00 Polarization-diverse Silicon Photonics WDM Receiver with a Reduced Number of OADMs and Balanced Group Delays, Jovana Nojic1, Max Planck Inst. of Microstructure Physics, Germany; 2Inst. of Integrated Photonics, RWTH Aachen Univ., Germany. We experimentally validate a 10-channel polarization diverse WDM receiver with only one ring based add-drop multiplexer per channel and on-chip optical delay lines balancing the two polarization paths for speeds up to 28 Gb/s.

M4J.1 • 17:00 100 Gb/s Real-Time Transmission over a THz Wireless Fiber Extender Using a Digital-coherent Optical Modem, Carlos Castro1, Robert Elschner1, Thomas Merkeli, Colja Schuberti, Ronald Frendii, 1Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany; 2Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Germany. We demonstrate the real-time transmission of a 34-Gb/s PDM-QPSK signal over two fiber-optic links interconnected by a THz wireless fiber extender at 300 GHz carrier frequency, with joint impairment compensation by a single-carrier DSP.

M4J.2 • 17:00 49.2-Tbit/s WDM Transmission over 2x93-km Field-Deployed Fiber, Karsten Schult1, Fred Buchal1, Roman Dischler1, Mathieu Chagnon1, Vahid Aref1, Henning Bülow1, Qian Hu1, Florian Pulkar1, Massimo Frascolla1, 1Énergie, Matériaux et Télécommunications (EMT), Institut National de la Recherche Scientifique (INRS), Canada. We apply joint impairment compensation by a single-carrier DSP.

M4J.3 • 17:15 Entropy and Symbol-rate Optimized 120 Gbaud PS-36QAM Signal Transmission over 2400 km at Net-rate of 800 Gbps/A, Masaori Nakamura1, Takayuki Kobayashi1, Hiroshi Yamazaki1,2, Fukutaro Hamaoka1, Munehiko Nagatani1,2, Hitoshi Wakita1, Hideyuki Nosaka1,2, Yutaka Miyamoto1, 1NTT Network Innovation Laboratories, Japan; 2NTT Device Technology Laboratories, Japan. We apply symbol-rate and entropy optimization to over-100-Gbaud PS-36QAM signal generation. It enables 800-Gbps/A signal transmission over 2400 km in 1250GHz-spaced WDM system by maximization of SNR margin from the required SNR at FEC limit.
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M4A • Quantum Security Subsystems—Continued

M4B • Panel: Automotive Communications and Technologies for 10G and Beyond—Continued

M4C • MCF Amplifiers and Cable—Continued

M4D • Network Design and Switching Architecture—Continued

M4E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 2)—Continued

M4F • High Order Direct Detect Formats—Continued

M4A.4 • 17:30
Compact Differential Phase-shift Quantum Receiver Assisted by a SOI / BiCMOS Micro-ring Resonator, Ne-manja Vakic1, Dinka Milovancev1, Winfried Baxlertner1, Hannes Hübel1, Bernhard Schrenk1; 1AIT Austrian Inst of Technology, Austria. We demonstrate a phase-selective and colorless quantum receiver assisted by a silicon-on-insulator microcavity, enabling a low 1.3% QBER at 5.3kb/s secure-key rate. No penalty incurs compared to a delay interferometer. BiCMOS 3D-integration is proven feasible.

M4A.5 • 17:45 • Invited
Progress on Quantum Key Distribution Using Ultralow Loss Fiber, Alberto Boaro1, Davide Rusca1, Gianluca Bosà1, Raphael Houlmann1, Cédric Vulliez1, Misael Caloz1, Matthieu Boso1, Raphael Houlmann1, Cédric to Boaron1, Davide Rusca1, Gianluca Vokic1, Dinka Milovancev1, 1Univ. of Geneva, Switzerland; 2Corning Incorporated, USA.

M4C.2 • 17:30
Power Efficient All-fiberized 12-core Erbium/ytterbium Doped Optical Amplifier, Gilles Melin1, Romain Kerampani1, Achille Montevedde1, Sylvain Bondas1, Thierry Robin1, David Landais1, Aurelien Lebretan1, Yves Jaouen1, Thierry Taunay1, iXblue, France; iLumibird, France; iPhotonics Bretagne, France; iTECOM Paris, France. 20dB gain in C-band with only 3.5W of pump is achieved with an all-fiberized 12-core Er/Yb doped fiber amplifier. This result is a first step towards SDM transmission including power efficient amplifiers and ROADM subsystems—Continued

M4C.3 • 17:45
Full C-band and Power Efficient Coupled-multi-core Fiber Amplifier, Masaki Wada1, Taiji Sakamoto1, Shinichiro Aozasa1, Ryota Imada1, Takashi Yamamoto1, Kazuhide Nakajima1, iNT access network service systems lab., Japan. A coupled 12-core fiber amplifier with the highest optical power conversion efficiency of 10.2% is achieved among the reported C-band cladding-pumped amplifiers. Potential as full C-band inline amplifier is confirmed using full coupled-core SDM link.

M4C.4 • 17:30
Is There a Most Appropriate Channel Spacing in WDM Networks When Individually Routing 67 GbAud Carriers?, Thierry Zami1, Bruno Lavigne1, 1Nokia Corporation, France. As elastic optical transponders faster than 60 Gbaud emerge in meshed terrestrial WDM networks, we investigate whether 75 GHz spectral channel spacing outperforms 87.5 GHz spacing when routing individual optical carriers transparently through optical nodes.

M4C.5 • 17:45
Experimental Assessment of a Programmable VCSEL-based Photonic System Architecture over a Multi-hop Path with 19-Core MCF for Future Agile Tb/s Metro Networks, Michela Svaluto Moreolo1, Josep M. Fabregas1, Laia Nadal1, Ricardo Martinez1, Ramon Casellas1, F. Javier Vilchez1, Raul Muñoz1, Ricard Vilalta1, Alberto Gatto2, Paola Parolari2, Pierpaolo Boffi3, Christian Neumeyer1, 1Peking Univ., China; 2ZTE, China. We experimentally demonstrate optical interconnects of 160Gb/s generated by a compact silicon based GeSi electro-absorption modulator using artificial neural network based nonlinear equalization.

M4C.6 • 17:45
Why Data Science and Machine Learning Need Silicon Photonics, Benjamin Klenk1, Larry Dennison1, 1NVIDIA Corporation, USA. Training deep neural networks demands vast amounts of computation, provided by large distributed systems. The increasing demand for bandwidth will exceed the limits of electrical and non-integrated optical signaling and will require integrated
M4H • Silicon Photonics and High Density Integration—Continued

M4H.4 • 17:30 Invited
Uncovering Reflection Insensitive Semiconductor Lasers for Silicon Photonic Integration, Frederic Grillot1,2; 1Institut Polytechnique de Paris, France; 2The Univ. of New Mexico, USA. We report on two recent high performance semiconductor lasers made with the silicon photonic platform. Both structures display a quasi complete reflection insensitivity, resulting in a key attribute for the development of isolator-free integrated technologies.

M4J • Digital Signal Processing I—Continued

M4J.4 • 17:30
Multi-channel Equalization for Comb-based Systems, Mikael Mazur1, Jochen Schröder1, Magnus Karlsson1, Peter Andrekson1; 1Chalmers Tekniska Hogskola, Sweden. We propose and demonstrate a frequency comb-enabled joint DSP. With joint processing, the required guard-bands decreases and the optimal roll-off factor increases, reducing penalties from non-ideal transceiver electronics while simultaneously increasing the spectral efficiency.

M4K • High-speed Long-haul Transmission—Continued

M4K.4 • 17:45
Spectrally Efficient DP-1024QAM 640 Gb/s Long Haul Transmission using a Frequency Comb, Frederik Klejs1, Edson Porto da Silva2, Mads Lillieholm1, Metodi P. Yankov1, Toshiaki Matsumura1, Leif Oxenløwe1, Michael Gali1; 1DTU, Denmark; 2Federal Univ. of Campina Grande, Brazil. We experimentally investigate the long haul transmission of an 8 Gbd DP-1024QAM over fully Raman amplified fiber spans using an optical frequency comb. We reach a potential spectral efficiency of 8.7 bit/s/Hz at 3000 km transmission and a potential data rate of 640 Gb/s.
### Monday, 9 March

**Room 1A**

- **M4A** • Quantum Security Subsystems—Continued

**Room 1B**

- **M4B** • Panel: Automotive Communications and Technologies for 10G and Beyond—Continued

**Room 2**

- **M4C** • MCF Amplifiers and Cable—Continued

**Room 3**

- **M4D** • Network Design and Switching Architecture—Continued

**Room 6C**

- **M4E** • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 2)—Continued

**Room 6D**

- **M4F** • High Order Direct Detect Formats—Continued

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**M4C.4 • 18:00**  
**M4C.5 • 18:15**

- **Top-Scored**  
  Spatial Mode Dispersion Control in a Coupled MCF using High Density Cabling Parameters, Yusuke Yamada¹, Taiji Sakamoto¹, Yuto Sagae¹, Masaki Wada¹, Saki Nozoe¹, Yoko Yamashita¹, Hisashi Izumita¹, Kazuhide Nakajima¹, Hiroki Tanioka¹; ¹NTT, Japan. Spatial-mode dispersion (SMD) of a coupled multi-core fiber is controlled with cabling parameters for the first time. An SMD coefficient of 1.5 ps/√km is achieved by optimizing the bundle pitch and tension in the cable.

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**M4D.6 • 18:00**

Network Design Framework Exploiting Low-margin Provisioning of Optical Shared Restoration Resources, Daniela A. Moniz¹,², João Pedro¹,², João Pires²; ¹Infinera Corporation, Portugal; ²Instituto de Telecomunicações, Portugal. This paper proposes a network design framework tailored to support optical restoration with low-margins by exploiting real-time performance monitoring. Simulation results highlight that it enables resource savings without additional risks of traffic disruption.

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**M4E.4 • 18:00**  
**Invited** Machine Learning for Optical Network Security Management, Marija Furdek, Chalmers University of Technology, Sweden. We discuss the role of supervised, unsupervised and semi-supervised learning techniques in identification of optical network security breaches. The applicability, performance and challenges related to practical deployment of these techniques are examined.

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**M4A.4 • 18:00**  
Real-time Optical Gain Monitoring for Coupled Core Multi-Core EDFA with Strong Inter-Core Crosstalk, Hi-toshi Takeshita¹, Keiichi Matsumoto¹, Hidemi Noguchi¹, Emmanuel Le Taillandier de Gabory¹; ¹NEC Corporation, Japan. We have successfully confirmed the feasibility of real-time optical gain spectrum monitoring of CC-MC-EDFA with the standard deviation within 0.65 dB even if the optical power per core fluctuates due to the inter-core crosstalk.
M4H.5 • 18:00 Grating Coupled Laser (GCL) for Si Photonics, Shiyun Lin1, Ding Wang1, Ferdous Khan1, Jeannie Chen1, Alexander Nickel1, Brian Kim1, Yasuhiro Matsui1, Bruce Young1, Martin Kvaernaak1, Glen Carey1, Tsunugi Sudo1; 1II-VI Incorporated, USA. We report a laser with an integrated grating coupler that emits a large ~30 μm mode through its substrate. The GCL allows coupling to a corresponding grating in the Si PIC and insertion of an optical isolator without lenses.

M4H.6 • 18:15 Top-Scored InP/Silicon Hybrid External-cavity Lasers (ECL) Using Photonic Wirebonds as Coupling Elements, Yilin Xu1,2, Pascal Mauer1,2, Matthias Blaicher1, Philipp-Immanuel Dietrich1, Pablo Marin-Palomo1, Wladislaw Hartmann1, Muhammad R. Billah1,2, Ute Troppenz1, Martin Moehrle1, Sebastian Randel1, Wolfgang Freude1; 1Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology (KIT), Germany; 2Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany. We demonstrate an InP/Silicon integrated ECL using a photonic wirebond as intra-cavity coupling element. In our proof-of-concept experiments, we demonstrate 50 nm tuning range, SMSR above 40 dB, and linewidths of 750 kHz.

M4J.4 • 18:00 Clock Recovery Limitations in Probabilistically Shaped Transmission, Fabio A. Barbosa1, Sandro M. Rossi2, Darli A. Mello1; 1School of Electrical and Computer Engineering, Univ. of Campinas, Brazil; 2Division of Optical Technologies, CPqD, Brazil. We assess the performance of the modified Gardner timing error detector under probabilistic shaping. The results indicate severe limitations in specific combinations of shaping and roll-off factors. The results are validated by simulations and experiments.

M4J.5 • 18:15 Baud-rate Timing Phase Detector for Systems with Severe Bandwidth Limitations, Nebojsa Stojanovic1, Talha Rahman1, Stefano Calabro1, Jinlong Wei1, Changsong Xie1; 1Huawei Technologies Co., Ltd., Germany. A novel timing phase detector using one sample per symbol is developed. The phase detector is especially suitable for systems suffering from serious bandwidth limitations. Its superior performance is demonstrated in simulations and experiments.

M4K.6 • 18:00 Experimental Study of Closed-Form GN Model Using Real-time m-QAM Transceivers with Symbol Rate up to 69 GBd, Sergey Burtsev1, Steven Searcy1, Sorin Tibuleac1; 1ADVA, USA. Real-time transceivers were used to evaluate the accuracy of the closed-form GN model for SSMF and NZDSF C-band terrestrial applications with symbol rates from 34 to 69 GBd and modulation formats from QPSK to 64QAM.
Tuesday, 10 March

07:30–08:00  Plenary Session Coffee Break, Upper Level Corridors, Ballroom 20 Lobby

08:00–10:00  Plenary Session, Room Ballroom 20BCD

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

10:00–17:00  Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall)

OFC Career Zone Live, Exhibit Hall B2

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

14:00–16:00  T3A • Linear and Nonlinear Space Division Multiplexing

Presider: Sophie LaRochelle; Universite Laval, Canada

14:00–16:00  T3B • Novel Materials

Presider: Yikai Su; Shanghai Jiao Tong Univ., China

14:00–16:00  T3C • Lasers for Communications and Sensing

Presider: Yasuhiro Matsui; Finisar Corporation, USA

14:00–16:00  T3D • Quantum and Secure Communications

Presider: Andrew Shields; Toshiba Research Europe Ltd, UK

14:00–16:00  T3E • Symposium: Emerging Network Architectures for 5G Edge Cloud (Session 1)

14:00–16:00  T3F • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?

T3A.1 • 14:00  Tutorial

SDM Optical Communications, Nicolas K. Fontaine; ‘Nokia Bell Labs, USA. Abstract not available.

T3B.1 • 14:00  Invited

On-chip Optical Isolators, Tetsuya Mizumoto1, Huya Shoji2, Tokyo Inst. of Technology, Japan. Magneto-optical phase shift is effective to realize on-chip optical isolators. Optical isolators are fabricated on SOI platforms with isolation ratios of 30 and 16 dB for TM and TE mode input, respectively.

T3C.1 • 14:00  Invited

50-GHz Gain Switching and Period Doubling Using an Optical Injection Locked Cavity-enhanced DFB Laser, Zhixin Liu1, Yasuhiro Matsui2, Richard Schatz2, Ferdous Khan2, Martin Kwakernaak1, Tsurugi Sudo1; 1Univ. College London, UK; 2Finisar Corporation, USA. We demonstrate gain-switched pulse generation at a record-high repetition rate of 50GHz by injection locking a cavity-enhanced DFB laser. More than 50GHz carrier-photon resonance is achieved by using the detuned-loading and photon-photon resonance effects.

T3D.1 • 14:00  Invited

Entanglement-based Fiber Optic and Satellite QKD Systems, Rupert Ursin1; Austrian Academy of Sciences, Austria. Abstract not available.

T3E.1 • 14:00  Invited

Title to be Announced, Andrew Wilkinson1; Ericsson, Sweden. Abstract not available.

With the advent of powerful compute infrastructure, machine learning has become hugely popular, including but not limited to the field of optical communication and networking. Machine learning in this context may be applied to enhance network monitoring and troubleshooting as well as optimization and anomaly detection.

In this session we ask network operators as well as network equipment manufacturers about the potential and value of ML in optical networking and beyond.

Speakers:

Yoshiaki Aono; NEC Corp., Japan
Zahra Bakhtiari; Microsoft, USA
Biondo Biondi; Stanford University, USA
Mattia Cantono; Google, USA
Petar Djkic; Ciena, Canada
Knocking on Shannons' Door

Pierre Mertz; Infinera, USA

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

10:00–17:00 Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall) OFC Career Zone Live, Exhibit Hall B2

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

14:00–16:00 T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?

How close will we be able to approach Shannon limit in the field?

How do we precisely assess the performance?

Field trial vs. lab testing

Accuracy of Simulation vs. experimental results

Offline testing vs. real time testing

What is an acceptable error between lab results and field trials?

How do we close the gap between technology design and field deployment?

Speakers:

Colin Meakim, Ciena, Canada

Approaching the Shannon Limit of Subsea Networks

Pierre Mertz, Infinera, USA

Knocking on Shannons’ Door

14:00–16:00 T3H • Silicon Photonics Applications

Presider: Dominic Goodwill; Huawei Technologies R&D, Canada

T3H.1 • 14:00 ★ Top-Scored 1.6Tbps Silicon Photonics Integrated Circuit for Co-packaged Optical-IO Switch Applications, Saeed Fatholoumi1, Kimchau Nguyen1, Hari Mahalingam1, Meer N. Sabki1, Zhi Li1, Christopher S. Seibert1, Mohammad Montazeri1, Jian Chen1, Jonathan K. Doyle1, Hasitha Jayatilleka1, Catherine Jan1, John Heck1, Ranju Venables1, Harel Frish1, Reece A. Defrees1, Randal S. Appleton1, Summer Hollingsworth1, Sean P. McCargar1, Richard Jones1, Daniel Zhu1, Yuliya Akulova1, Ling Liu1, SPPD, Intel Corporation, USA. We demonstrate a 1.6Tbps Silicon Photonics Integrated Circuit (SiPIC) meeting co-packaged optics requirements for network switch applications. It has sixteen 10Gbps PAM4 optical channels, including lasers, modulators and V-grooves. Post-FEC error-free operation over temperature is demonstrated.

T3I.1 • 14:00 102 Gbaud PAM-4 Transmission Over 2 km Using a Pulse Shaping Filter with Asymmetric ISI and Tomlinson-Harashima Precoding, Xueyang Li1, Zhenping Xing1, Samul Alam1, Maxime Jacques1, David Plant1, ’McGill Univ., Canada. We introduce the asymmetric-ISI pulse shaping filter with Tomlinson-Harashima precoding to increase the receiver RF swing, and demonstrate 102 Gbaud PAM-4 transmission over 2 km with a BER below 3.8×10⁻³ using linear equalizer at receiver.

T3J.1 • 14:00 Blockchain-anchored Failure Responsibility Management in Disaggregated Optical Networks, Silvia Fichera1, Andrea Scagbrelli1, Alessio Giorgietti1, Filippo Cugini1, Francesco Paolucci1, Scuola Superiore Sant’Anna, Italy, “CNIT, Italy. A novel framework based on blockchain is proposed to provide trusted SLA accounting. Extensions to SDN ONOS controller successfully assess controversial SLA degradations responsibilities upon failure events in a multi-vendor OpenROADM-based white box scenario.

T3K.1 • 14:00 ★ Top-Scored Demonstrating Optically Interconnected Remote Serial and Parallel Memory in Disaggregated Data Centers, Vaibhawa Mishra1, Joshua L. Benjamin1, Georgios S. Zervas1, ’Univ. College London, UK. Remote serial and parallel memory using memory-over-network bridge and optical switched interconnect is demonstrated. Remote memory bandwidth of 93% (HMC) and 66% (DDR4) of the local 3.2 and 3.7 GB/s bandwidth is showcased.

Tuesday, 10 March
Nicolas Fontaine obtained his PhD in 2010 at the University of California Davis in the Next Generation Network Systems Laboratory in Electrical Engineering. In his dissertation he studied how to generate and measure the amplitude and phase of broadband optical waveforms in many narrowband spectral slices. Since June 2011, he has been a member of the technical staff at Bell Laboratories at Crawford Hill, NJ in the advanced photonics division. At Bell Labs, he develops devices for space-division multiplexing in multi-core and few mode fibers, builds wavelength crossconnects and filtering devices, and investigates spectral slice coherent receivers for THz bandwidth waveform measurement. In his free time he enjoys learning jazz piano.

**Room 1A**

T3A • Linear and Nonlinear Space Division Multiplexing—Continued

**Room 1B**

T3B • Novel Materials—Continued

**Room 2**

T3C • Lasers for Communications and Sensing—Continued

**Room 3**

T3D • Quantum and Secure Communications—Continued

**Room 6C**

T3E • Emerging Network Architectures for 5G Edge Cloud (Session 1)—Continued

**Room 6D**

T3F • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?—Continued

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**T3C.2 • 14:15**

Analysis of TDECQ Dependence on Skew and Extinction Ratio with 106-Gb/s PAM-4 modulation of Directly Modulated Submicron Ridge Localized Buried Heterostructure Lasers, Kazuki Suga1, Kouji Nakahara2, Kaoru Okamoto1, Shigenori Hayakawa1, Masatoshi Arasaki1, Tetsuya Nishida1, Ryu Washino1, Takashi Kitatani1, Masatoshi Mitaki1, Hironori Sakamoto1, Yasushi Sakuma1, Shige-hisa Tanaka1; (Lumentum Japan, Inc., Japan). The importance of high relaxation oscillation frequency to obtain superior 106-Gb/s PAM-4 waveforms was revealed for SR-LBH lasers. In addition, clear 56-Gb/s NRZ eye openings were first demonstrated up to 85°C using SR-LBH laser.

**T3B.2 • 14:30**

Integrable Magnetless Thin Film Waveguide Optical Isolator based on Bismuth Iron Garnet Material, Vincent Stenger1, Dolendra Karki1, Andrea Pollick1, Miguel Levy1; SRIIC, Inc., USA; (Michigan Technological Univ., USA). A passive magnetless integrated optic Faraday isolator has been demonstrated that features ~3 dB total insertion loss and 25 dB isolation. The compact 500 μm long ridge waveguide isolator is integrable with silicon photonic platforms.

**T3C.3 • 14:30**

10-Gbit/s Sky-blue Distributed Feedback Laser Diode-based Visible Light Communication, Meiwei Kong1, Jorge A. Holguin Lerma1, Omar Alkhazragi1, Xiaobin Sun1, Tien Khee Ng1, Boon S. Ooi1; (Photonics Laboratory, King Abdullah Univ. of Science and Technology (KAUST), Saudi Arabia). A novel sky-blue (~480 nm) InGaN-based distributed feedback laser diode is developed for high-speed visible light communication. With a 3-dB system bandwidth of ~1.5 GHz, 10 Gbit/s is achieved by using orthogonal frequency-division multiplexing technology.

**T3D.2 • 14:30**

10 Tbit/s QAM Quantum Noise Stream Cipher Coherent Transmission over 160 km, Masato Yoshida1, Takashi Kan1, Keisuke Kasai1, Toshihiko Hirooka1, Masataka Nakazawa1; (Tohoku Univ., Japan). We present the first 10 Tbit/s secure physical layer transmission over 160 km with a spectral efficiency of 6 bits/Hz by using digital coherent QAM quantum noise stream cipher (QNCS) and injection-locked WDM techniques.

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Nicolas Fontaine obtained his PhD in 2010 at the University of California Davis in the Next Generation Network Systems Laboratory in Electrical Engineering. In his dissertation he studied how to generate and measure the amplitude and phase of broadband optical waveforms in many narrowband spectral slices. Since June 2011, he has been a member of the technical staff at Bell Laboratories at Crawford Hill, NJ in the advanced photonics division. At Bell Labs, he develops devices for space-division multiplexing in multi-core and few mode fibers, builds wavelength crossconnects and filtering devices, and investigates spectral slice coherent receivers for THz bandwidth waveform measurement. In his free time he enjoys learning jazz piano.
**T3H.2 • 14:15** Star-Scored

400G/800G Silicon Photonics Integrated Circuit Transceiver Chips for CPO, OBO, and Pluggable Modules, Erman Timurdogan¹, Zhan Su¹, Ren-Jye Shiu², Matthew Byrd³, Christopher Poulton¹, Kenneth Jabon³, Christopher DeRose⁴, Benjamin Moss⁴, Ehsan Hosseini⁵, Ivan Duzevski⁶, Michael Whitt⁷, Ronald Millman⁷, Dogen Atla⁷, Michael Watts¹, ‘Analog Photonics, USA. 400G/FR4 silicon photonics transmit-receive chips, compatible with co-packaged-optics, on-board-optics, and pluggable form factors, were demonstrated with a combined bandwidth density of 940Gbaud/mm, energy efficiency of <10pJ/bit, and -5.4dBm OMA sensitivity at the KP4 pre-FEC-BER=2.4e-4.

**T3H.3 • 14:30** Star-Scored

45nm CMOS - Silicon Photonics Monolithic Technology (45SCL) for Next-generation, Low Power and High Speed Optical Interconnects, Michal Rakowski¹, Colleen Meagher¹, Karen Nummy², Abdel Salam Aboketaf¹, Javier Ayala¹, Yusheng Bian¹, Brendan Harris², Kate Mclean², Kevin Mcstay³, Asli Sahin², Thomas Houghton³, Crystal Hedges¹, Ken Giewont¹, Ajej Jacobs¹, Ted Letavic¹, Dave Riggs¹, Anthony Yu¹, John Pellerin¹, ‘Photonics Technology Solutions, GlobalFoundries, USA; ²GlobalFoundries, USA; ³GlobalFoundries, USA. GlobalFoundries monolithic 45nm CMOS-Silicon Photonics 300mm high-volume manufacturing platform based on 45nm RF technology node, and optimized for high performance and low power short-reach optical interconnects for on-chip and chip-to-chip applications will be discussed.
T3A.2 • 15:00  
Novel Fuseless Optical Fiber Side-coupler based on Half-taper for Cladding Pumped EDFAs, Charles Matte-Breton1, Ruohui Wang1, Younes Messaddeq2, Sophie Lafortchelle1, 1Université Laval, Canada. We present a novel method for optical fiber side-coupler fabrication that does not require to heat the fibers. More than 94% of average coupling efficiency is demonstrated for input pump power ranging from 1.4 W to 20.7 W.

T3B.3 • 14:45  
Heterogeneous Co-integration of BTO/Si and III-V technology on a Silicon Photonics Platform, Pascal Stark1, Felix Eites1, Yannick Baumgartner1, Daniele Caimi1, Youn Popoff2, Norbert Meier1, Lukas Czernornaz1, Jean Flopypeyrine1, Bert J Offrein1, Stefan Abel1, IBM Research – Zurich, Switzerland; 1Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland. We demonstrate for the first time the heterogeneous co-integration of Si photonics, BTO/ Si for high-speed modulation and III-V materials for photodetection and emission. We show light coupling with losses <0.5 dB between the different functional layers.

T3C.4 • 14:45  
High Performance BH InAs/InP QD and InGaAsP/InP QW Mode-locked Lasers as Comb and Pulse Sources, Marlene Zander1, Wolfgang Riehbein1, Martin Moehrle1, Kevin Kolpatzcek2, Jan Balzer1, Stefan Breuer1, Dieter Franke1, Martin Schell1; Fraunhofer Heinrich-Hertz Inst., Germany. We explore and compare buried heterostructure (BH) quantum dot (QD) and quantum well (QW) lasers with more than 33 channels in the DWDM 50 GHz grid, thus enabling > 1 Tb/s optical transmission. In addition, the mode-locked devices can be applied as pulse sources with < 500 fs pulses by using a simple SMF.

T3D.3 • 14:45  
Experimental Demonstration of High Key Rate and Low Complexity CV-QKD System with Local Local Oscillator, Shengjun Ren1, Shuai Yang1, Adrian Wonfor1, Richard Penty1, Ian White1; 1Univ. of Cambridge, UK. We experimentally demonstrate a 250MHz repetition rate Gaussian-modulated coherent-state CV-QKD with local local oscillator implementation which is capable of realizing record 14.2 Mbps key generation in the asymptotic regime over 15km of optical fiber.

T3E.3 • 15:00  
Invited  
Title to be Announced, Eric Heaton1; 1Intel, USA. Abstract not available.

T3F.4 • 15:00  
Spectrally-shaped Continuous-Variable QKD Operating at 500 MHz Over an Optical Pipe Lit by 11 DWDM Channels, Dinka Milovancev1, Nemanja Vokic1, Fabian Laudenbach1, Christoph Pacher1, Hannes Hübel1, Bernhard Schrenk1; 1AIT Austrian Inst. of Technology, Austria. We demonstrate high-rate CV-QKD supporting a secure-key rate of 22Mb/s through spectral tailoring and optimal use of quantum receiver bandwidth. Co-existence with 11 adjacent carrier-grade C-band channels spaced by only 20nm is accomplished at >10Mb/s.
**Room 6F**

**T3H • Silicon Photonics**

Applications—Continued

**Room 7**

**T3I • Short-reach Systems II—Continued**

**Room 8**

**T3J • Orchestration and Control—Continued**

**Room 9**

**T3K • Intra Data Center Networks I—Continued**

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**Show Floor Programming**

**Continued**

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**Preparing the Transport Network for 5G**  
13:50–14:50, Theater II

- MW Panel III: Optical Interconnect and Computing for Scaling Machine Learning (ML) Systems  
14:30–16:00, Theater I

- Standards Update on 5G Transport (and more)  
ITU-T SG15  
14:45–15:45, Theater III

- Embedded Optics and How They Should Be Done to Support the OEM Eco–system – Panel Debate  
15:00–17:00, Theater II

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**T3H.4 • 14:45**  
Invited  
Silicon Photonics for 100 Gbaud, Ji-anying Zhou₁, Jian Wang₁, Qun Zhang₁, 'NEOPhotonics Corp, USA; 'Minnesota State Univ, USA. We reviewed recent breakthroughs on silicon photonics for 100Gbaud operation. We experimentally demonstrated 120Gbaud QPSK and 100Gbaud 32QAM operations using a high performance all-silicon IQ modulator with extinction ratio of >25dB and 6dB-bandwidth of 50GHz.

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**T3I.4 • 14:45**  
Single lane 176Gb/s Single Side-band PAM-4 Transmission over 400km with a Silicon Photonic Dual-drive Mach-Zehnder Modulator, Lei Zhang₁, Fan Yang₁, Xiaoke Ruan₁, Yanping Li₁, Fan Zhang₁; 'Peking Univ., China. We experimentally demonstrate ultra-high speed metro-scale optical transmission of SSB PAM-4 signal with a record single lane bit rate of 176Gb/s over 400km SSMF based on conventional silicon photonic dual-drive modulator with Mach-Zehnder structure.

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**T3J.3 • 14:45**  
Dual Use SDN Controller for Management and Experimentation in a Field Deployed Testbed, Jiakai Yu₁, Craig Gutierrez₂, Artur Minakhmetov³, Michael Sherman³, Tingjun Chen³, Shengxiang Zhu³, Gil Zusman³, Ivan Seskar⁴, Daniel C. Kilper¹; 'College of Optical Sciences, Univ. of Arizona, USA; 'Electrical Engineering, Columbia Univ., USA; 'LTCI, Télécom Paris, Institut Polytechnique de Paris, France; 'Electrical and Computer Engineering, Rutgers Univ., USA. An SDN controller is developed for both testbed management and experimentation for the optical x-haul network in the COSMOS testbed providing a service-on-demand and reconfigurable platform for 5G wireless experiments coupled with edge cloud services.

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**T3K.4 • 15:00**  
Real-time Node Local Control for Ultra-dynamic and Deterministic All-optical Intra Data Center Networks, Mijail Szczerban₁, José Estarán Tolosa₁, Nihel D. Benzouia₁, Haik Mardoyan¹, Yvan Pointurier¹; 'Nokia Bell Labs, France. We enable ultra-dynamic features in scheduled optical data centers through a novel control mechanism local to each node. We experimentally show sub-μs resource allocation, at least halving distributed computing application completion time.

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**T3J.4 • 15:00**  
uABNO: A Cloud-native Architecture for Optical SDN Controllers, Ricard Vilalta¹, Juan Luis de la Cruz¹, Arturo Mayoral López-de-Lerma³, Victor López³, Ricardo Martínez³, Ramon Casellas³, Raul Muñoz³; 'CTTC, Spain; 'Telefónica gCTIO/I+D, Spain. We present a cloud-native architecture for Optical SDN Controllers based on ABNO architecture and gRPC interfaces, which is demonstrated and evaluated. Autoscaling mechanisms for high request loads and auto-healing support are evaluated.

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**T3J.5 • 15:00**  
Computationally Efficient 120 Gbs/ PWL Equalized 2D-TCM-PAM8 in Dispersion Unmanaged DML-DD System, Yan Fu¹, Deming Kong¹, Haiyun Xin¹, Meihua Bi³, Shi Jia¹, Kuo Zhang¹, Weisheng Hu¹, Hao Hu¹; 'Shanghai Jiao Tong Univ., China; 'Fotonik, Technical Univ. of Denmark, Denmark; 'Hangzhou Dianzi Univ., China. We proposed a PWL equalizer in 120 Gbs/2D-TCM-PAM8 based DML-DD system to correct eye skew. Computationally efficient 120 Gbs/8-state 2D-TCM-PAM8 over 2 km C-band transmission is demonstrated below HD-FEC(3.8e-3).
**T3A.3 • 15:15**  
Low-loss Low-MDL Core Multiplexer for 3-Core Coupled-core Multi-core Fiber, Sjoerd P. van der Heide1, Juan Carlos Alvarado Zacarías2, Nicolas K. Fontaine3, Roland Ryf4, Haoshuo Chen5, Rodrigo Amezcua Correa6, Ton Koonen7, Chigo M. Okonkwo8; 1Eindhoven Univ. of Technology, Netherlands; 2Nokia Bell Labs, USA; 3CREOL, Univ. of Central Florida, USA.  
A fiber-based core multiplexer is designed, fabricated and evaluated. Insertion losses vary between 0.74 dB and 0.91 dB. Digital holography reveals mode-dependent loss fluctuates between 0.3 dB and 0.9 dB across C- and L-band.

**T3C.6 • 15:30**  
850 nm Single-mode Surface-emitting DFB Lasers with Surface Grating and Large-area Oxidized-aperture, Can Liu1, Qiaoqin Lu2, Weihua Guo3, Pengfei Zhang4, MinWen Xiang5, Chun Liu6, Quan Chen7, Bao Tang8; 1Huazhong Univ. of Science and Technology, China; 2Nokia Bell Labs, USA; 3CREOL, Univ. of Central Florida, USA; 4National Inst of Information & Comm Tech (NICT), Japan; 5Royal Inst. of Technology (KTH), Sweden; 6Eindhoven Univ. of Technology, Netherlands.  
We introduce a hybrid quantum-classical variational algorithms to realize quasi-ML decision of high-dimensional modulation (HDM) in fiber-optic communications, motivated by the recent advancement of quantum processors. Our Ising Hamiltonian model for demodulation is demonstrated on a real quantum processor.
T3H.5 • 15:15
Real-time Demonstration of Silicon Photonics-based QSFP-DD 400GBASE-DR4 Transceivers for Datacenter Applications, Chongjin Xie1, Peter Magill2, David Li1, Yinxi Zhang3, Long Zheng1, Anbin Wang1, Yun Bao1, Chunchun Sui1, Matthew Streshinsky1, Jianwei Mu1, Sigeng Yang2, Wanju Sun3; ‘Alibaba Group, USA; ‘Elmenon Technologies, USA; ‘Hsiene Broadband, China. We demonstrate a real-time silicon photonics-based 400GBASE-DR4 transceiver packaged in a QSFP-DD form factor. The performance of the transmitter including TDECQ, extinction ratio and OMA and receiver sensitivity are measured, all satisfying IEEE 400GBASE-DR4 specifications.

T3H.6 • 15:30
400Gbps Fully Integrated DR4 Silicon Photonics Transmitter for Data Center Applications, Haijiang Yu1, Pierre Doussiere1, David Patel1, Wenhua Lin1, Kadhair Al-hemyari1, Jung Park1, Catherine Jan1, Robert Herrick1, Isako Hashino1, Lincoln Busselle1, Michael Bresnahan1, Adam Bowles1, George Ghircan1, Harel Frish1, Shane Yerkes1, Ranju Venables1, Pegah Sedighian1, Xavier Serey1, Kimchau Nguyen1, Animesh Banerjee1, Siamak Amiralizadeh1, Jing Li1, Sushant Gupta1, Avi Fuerst1, Avars Dahal1, Jian Chen1, Yann Malinge1, Han Mahalingam1, Mike Kwon1, Gupta Sanjeev1, Agrawal Ankur1, Raghuram Narayan1, Daniel Zhu1, Yuliya Akulova1; ‘Intel Corporation, USA. A 400Gbps PAM-4 fully integrated DR4 silicon photonics transmitter with four heterogeneously integrated DFB lasers has been demonstrated for data center applications over a temperature range of 0–70°C and a reach of up to 2km.

T3I.7 • 15:30
Dual-SSB Modified Duobinary PAM4 Signal Transmission in a Direct Detection System without using Guard Band, Jingchi Li1, Shaohua An1, Xingfeng Li1, Yikai Su1; ‘Shanghai Jiao Tong Univ, China. We experimentally demonstrate a single-carrier dual-SSB signal generation without guardband based on a low-cost DDMZM. A 112-Gb/s dual-SSB modified duobinary PAM4 signal is transmitted over 80-km SMF by using a MIMO linear equalizer.

T3I.8 • 15:30
Data Analytics Practice for Reliability Management of Optical Transceivers in Hyperscale Data Centers, Jianqiang Li1, Zhicheng Wang1, Chunjin Xie1; ‘Alibaba Group, USA; ‘Alibaba Group, China; ‘Huzhong Univ of Science and Technology, China; ‘Alibaba Group, USA. There are limitations when directly interpreting reliability information of optical transceivers from manufacturers to end users. Data analytics in a large optical transceivers’ population is studied for data center operators with a case study.
T3A • Linear and Nonlinear Space Division Multiplexing—Continued

T3B • Novel Materials—Continued

T3C • Lasers for Communications and Sensing—Continued

T3D • Quantum and Secure Communications—Continued

T3E • Emerging Network Architectures for 5G Edge Cloud (Session 1)—Continued

T3F • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?—Continued

T3C.7 • 15:45
Micro-transfer-printed III-V-on-silicon Distributed Feedback Lasers, Bhawal Haq 1,2, Sulakshna Kumari 1,2, Jing Zhang 1,2, Agnieszka Gocalinska, Emanuele Pelucchi, Brian Corbett, Gunther Roekens 1,2. 1INTEC, Ghent Univ.; imec, Belgium; 2Center of Nanophotonics, Belgium. We report on III-V-on-silicon DFB lasers realized by micro-transfer-printing pre-fabricated III-V semiconductor optical amplifiers on a silicon waveguide circuit comprising a first-order quarter wave shifted grating. Single mode operation at 1530 nm is demonstrated.

T3D.7 • 15:45
Simple and Robust QKD System with Qubit4Sync Temporal Synchronization and the POGNAC Polarization Encoder, Costantino Agnesi 1, Luca Calderaro 1, Marco Avesani 1, Andrea Stano 1, Giulio Foletto, Mujtaba Zahidy, Alessia Scriminich, Francesco Vedovato 1, Giuseppe Vallone 1, Paolo Villoresi 1. Dip. Ingegneria dell’Informazione, Università degli Studi di Padova, Italy. Here we present a simple and robust polarization encoded QKD system that performs synchronization, polarization compensation and QKD with the same optical setup without requiring any changes or any additional hardware.

16:00–16:30 Coffee Break, Upper Level Corridors and Exhibit Hall
T3H.7 • 15:45
A Fully Integrated 25 Gb/s Si Ring Modulator Transmitter with a Temperature Controller, Min-kyu Kim1, Min-Hyong Kim1, Youngkwan Jo1, Hyun-Kyu Kim1, Stefan Liesche2, Christian Mai3, Lars Zimmermann3, Woo-Young Choi1; 1Department of Electrical and Electronics Engineering, Yonsei Univ., Korea (the Republic of); 2IHP, Germany; 3Technische Universitaet Berlin, Germany. We realized a fully integrated 25 Gb/s Si ring modulator transmitter containing a temperature controller that guarantees the optimal ring modulator temperature against any temperature perturbation. The transmitter is implemented with a 0.25-μm photonic BiCMOS technology.

T3J.6 • 15:45
Intent Defined Optical Network: Toward Artificial Intelligence-based Optical Network Automation, Kai-xuan Zhan1, Hui Yang1, Qiuyan Yao1, Xudong Zhao1, Ao Yu1, Jie Zhang1, Young Lee2; 1State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China; 2Huawei Technologies Co., Ltd, China. Toward AI-based optical network automated operation, we propose an intent defined optical network (IDON) architecture with self-adapted generation and optimization (SAGO) policy. The feasibility and efficiency are verified on the enhanced SDN testbed.

T3K.7 • 15:45
Scaling HPC Networks with Co-packaged Optics, Pavlos Maniotis1, Laurent Schares1, Benjamin Lee1, Marc Taubenblatt1, Daniel Kuchta1; 1IBM TJ Watson Research Center, USA. We propose an HPC network architecture with co-packaged optics enabling 128-port 51.2-Tb/s switches. Simulations for a >34,000-accelerator system show up to 11.2x throughput improvement over the Summit supercomputer, opening the way to direct-network-attached GPUs.
Tuesday, 10 March

T4A.1 • 16:30  
Invited  
5G mmWave Commercial Trial for Vertical Applications, Jongsik Lee¹; ‘KT, Korea (the Republic of). This presentation gives you the brief introduction of 28GHz mmWave 5G trial in South Korea. Especially, the trial network configuration and the test result of 5G use cases such as autonomous vehicle and smart factory/office is presented.

T4B.1 • 16:30  
Intelligent Gain Flattening of FMF Raman Amplification by Machine Learning Based Inverse Design, Yufeng Chen¹, Jiangbing Du¹, Yuting Huang¹, Ke Xu¹, Zuyuan He¹; ‘Shanghai Jiao Tong Univ., China; ‘Harbin Inst of Technology (Shenzhen), China. We report an intelligent gain flattening method for rapid, precise and objective driven FMF Raman amplifier design, by using machine learning based inverse design method to optimize the pump wavelengths, powers and mode contents.

T4D.1 • 16:30  
Combining Efficient Probabilistic Shaping and Deep Neural Network to Mitigate Capacity Crunch in 5G Fronthaul, Qi Zhou¹, Rui Zhang¹, Youwei Chen¹, Shuyi Shen¹, Shang-Jen Su¹, Jeffrey Finkelstein¹, Gee-Kung Chang¹; ‘Georgia Inst. of Technology, USA; ‘Cox Communications, Georgia. We experimentally demonstrate a capacity-approaching transmission in 5G fronthaul utilizing PS-PAM8 and DNN. An 80-Gb/s over 20-km SSMF transmission performance is realized with a beyond 7.3-dB gross gain over uniform PAM modulations with linear post-equalization.

T4C.1 • 16:30  
VCSELs for Fast Neurounomorphic Photonic Systems Operating at GHz Rates, Matěj Hejda¹, Joshua Robertson¹, Juliàn Bueno¹, Antonio Hurtado¹; ‘Inst. of Photonics, Dept. of Physics, Univ. of Strathclyde, UK. We report experimentally on VCSEL-based artificial optical spiking neurons with ultrafast spiking refractory period, hence allowing operation at GHz rates. This feature is used to demonstrate all-optical digital-to-spiking information format conversion at 1.0 Gb/s.

T4C.2 • 16:45  
Top-Scored  
Micro-ring-resonator Based Passive Photonic Spike-time-dependent-Plasticity Scheme for Unsupervised Learning in Optical Neural Networks, Charis Mesantakis¹, Menelaos Skontarlis¹, George Sarantoglu¹, Adonis Bagra²; ‘Univ. of the Aegean, Greece; ‘Informatics and Computer Engineering, Univ. of West Attica, Greece. In this work, a photonic spike-time-dependent-plasticity scheme based on high-order passive ring resonators is demonstrated. Numerical simulations confirmed the validity of the approach assuming post and presynaptic quantum dot laser neurons.

T4D.2 • 16:45  
FPGA Implementation of Deep Neural Network Based Equalizers for High-Speed PON, Noniaki Kaneda¹, Ziyi Zhu¹, Chun-Yen Chuang¹, Amitkumar Mahadevan¹, Bob Farah¹, Keren Bergman¹, Dora van Veen¹, Vincent Houtsma¹; ‘Nokia Bell Labs, USA; ‘Columbia Univ., USA. A fixed-point deep neural network-based equalizer is implemented in FPGA and is shown to outperform MLSE in receiver sensitivity for 50 Gb/s PON downstream link. Embedded parallelization is proposed and verified to reduce hardware resources.
Nakamura2, Takashi Goh 3, Toshikazu Hashimoto1, Yutaka Miyamoto2; Takahiro Kodama 1,2, Akihiro sion, for Optical Short-r...
T4A • Radio-over-fiber Technologies for 5G—Continued

**T4A.2 • 17:00**
Silicon Photonics to Add 5G RoF Services to PONs Employing Carrier Reuse, Leslie Rusch1, Mingyang Lyu1, Wei Shi1; 1EEC Dept. / COPL, Univ. Laval, Canada. We experimentally validate silicon photonics for passive optical networks enabling radio over fiber on wavelength slots. We detect an 8-GHz OFDM signal and five 125-MHz RF signals, and remodulate RoF onto a clean carrier.

T4B • Machine Learning for Fiber Amplifier and Sensors—Continued

**T4B.3 • 17:00**
Load Aware Raman Gain Profile Prediction in Dynamic Multi-band Optical Networks, Ann Margareth Rosa Brusin1, Uliara C. de Moura2, Andrea D’Amico1, Vittorio Cumi1, Darko Zibar1, Andrea Carena1; 1Politecnico di Torino, Italy; 2Technical Univ. of Denmark, Denmark. We introduce a load aware machine learning method for prediction of Raman gain profiles. It enables future network controllers to manage seamless upgrades toward multi-band optical line systems with dynamic loads.

T4C • Neuromorphic Photonics II: Entire Aspect—Continued

**T4C.3 • 17:00**
Tutorial Neuromorphic Photonics, Paul R. Prucnal1; 1Princeton Univ., USA. Abstract not available.

T4D • AI Assisted Access Networks—Continued

**T4D.3 • 17:00**
Invited Neural Network-based Equalization in high-speed PONs, Lilin Yi1, Tao Liao1, Lei Xue1, Weisheng Hu1; Shanghai Jiao Tong Univ., China. We introduce neural network (NN)-based equalization in high-speed passive optical networks. Data feature engineering is proposed to improve performance of NN-based equalization. Besides, an unsupervised learning scheme for NN-based equalizer is proposed to train the model without known symbols of received signal.

T4E • Symposium: Emerging Network Architectures for 5G Edge Cloud (Session 2)—Continued

**T4E.2 • 17:00**
Invited Title to be Announced, Rafael Francis1; 1Ciena, USA. Abstract not available.

T4F • Quantum Networking and Artificial Intelligence—Continued

**T4F.2 • 17:30**
Invited Artificial Intelligence in Optical Networks, Shirshendu Bhattacharya1, 1Google Zürich, Switzerland. Artificial Intelligence may provide solutions to problems previously not solvable using conventional techniques. In this paper, we discuss potential AI applications related to challenges in optical networks.

T4A.3 • 17:15
Design of Flexible Fronthaul Featuring Per-UE Granularity and RU-level Puncturing for URLLC Applications, Yahya M. Alfadhli1, Shuang Yao2, Muhammad Shameer Omar2, Shang-Jen Su1, Shuyi Shen1, Rui Zhang1, You-Wei Chen1, Peng-Chun Peng2, Gee-Kung Chang1; 1Georgia Inst. of Technology, USA; 2Department of Electro-Optical Engineering, National Taipei Univ. of Technology, Taiwan. We propose and experimentally verify a fine-grained, Per-UE, flexible fronthaul where different applications are transported over different function splits (i.e., URLLC over A-RoF-based fronthaul, Option-9, and other traffic over Option-7), exploiting two RU-level puncturing methods.

**T4A.4 • 17:15**
Hybrid Machine Learning EDFA Model, Shengxiang Zhu1, Craig Guterman1, Alan D. Manteii1, Jiakai Yu1, Marco Ruffini1, Gil Zussman1, Daniel C. Kilper1; 1Univ. of Arizona, USA; 2Columbia Univ., USA; 3Trinity College Dublin, Ireland. A hybrid machine learning (HML) model combining a-priori and a-posteriori knowledge is implemented and tested, which is shown to reduce the prediction error and training complexity, compared to an analytical or neural network learning model.
Simultaneous bi-directional optical process is demonstrated. Based on a single off-the-shelf 32-channel WDM transmitter and a time lens, Mads Lilleholm1, Xiaoyu Xu1, Peter D. Eknes1, Michael Galil1, Led Oxenløwe1, Pengyu Guan1;1CableLabs, USA. We demonstrate simultaneous WDM signal generation using an optical time lens and off-the-shelf components. 32 WDM-channels with 50-GHz spacing are generated from a single SFP+ transceiver source and received using another SFP+ after 50-km unamplified transmission.

Monolithic Polarization Controller on Regrowth-free InGaAsP/InP Platform with Strained MQW Layer, Maiko Ito1, Kosuke Okawa1, Takahiro Suganuma1, Takuo Tanemura1, Yoshiaki Nakano1;1School of Engineering, The Univ. of Tokyo, Japan. Carrier-injection-based polarization controller with strained MQW layer is demonstrated. Based on novel design concept, both polarization-rotating and phase-shifting sections are integrated monolithically on regrowth-free InGaAsP/InP platform to achieve efficient conversion over the entire Poincare sphere.

Regrowth-free InGaAsP/InP platform. 1Technical Univ. of Denmark, Denmark. We demonstrate simultaneous WDM-signal generation, 50-GHz spacing are generated from a single SFP+ transceiver source and received using another SFP+ after 50-km unamplified transmission.
T4A.4 • 17:30
Experimental Demonstration of A-RoF SDN for Radio Access Sharing Applications, Luiz Anet Neto1, Wang Ming1, Gaël Simon1, Feaheun Lehaneur1, Anas El Ankouri1, Guillaume Lopere1, Dylan Chevalier1, Philippe Chanclou1, ‘Orange Labs, France. We experimentally assess a radio access A-RoF mobile interface with carrier-aggregated data-plane and IF-transposed Ethernet control-plane. We also demonstrate software-based management of two classes of services associated to different PHY layer parameters.

T4B.5 • 17:30
Robust Convolutional Neural Network Model for Wavelength Detection in Overlapping Fiber Bragg Grating Sensor Network, Baochen Li1,2, Zhi-Wei Tan1, Perry Ping Shum1,2, Dora Juan Juan Hu3, Chenlu Wang1,2, Yu Zheng1,2, Shuhui Liu4, ‘Nanyang Technological Univ., Singapore; ’CINTRA CNRS/NTU/Thales, Singapore; ’Inst. for Infocomm Research, Agency for Science, Technology and Research, Singapore; ’Hubei Key Laboratory of Optical Information and Pattern Recognition, China. We have designed a CNN model to detect Bragg wavelengths in overlapping spectra. The mean RMS error of 0.123pm and mean testing time of 12.4ms are achieved, which outperforms most of the existing techniques.

T4A.5 • 17:45
Top-Scored
Flexible 360° 5G mmWave Small Cell Coverage through WDM 4x1 Gb/s Fiber Wireless Fronthaul and a Si3N4 OADM-assisted Massive MIMO Phased Array Antenna, Eugenia Ruggieri1, Apostolos Takyridis1, Christos Vagionas1, George Kalfas1, Ruud M. Oldenbeuving2, Paul W. Dijkstra3, Chris G. Roelloffzen4, Yigal Leiba1, Nikos Pleros1, Amalia Miliou1, ‘Aristotle Univ. of Thessaloniki, Greece; ’LIONIX International B.V, Netherlands; ’Siklu Communication Ltd., Israel. Four Wavelength Division Multiplexed 1Gb/s QAM16 streams are transmitted through 10km fiber, an Optical Add/Drop Multiplexer and a V-band beamsteering antenna with 90° steering, demonstrating the first 5G Fiber-Wireless A-RoF architecture with 360° coverage.

T4D.4 • 17:30
Transfer Learning Aided Neural Networks for Nonlinear Equalization in Short-reach Direct Detection Systems, Zhaoqiong Xu1, Chuanbowen Sun1, Tonghui Ji1,2, Honglin Ji1, William Shieh1, ‘Univ. of Melbourne, Australia; ’Univ of Science and Technology Beijing, China. Transfer learning-aided NNs are proposed for nonlinear equalization in a 50-Gb/s 20-km PAM4 link. About 90% reduction in epochs and 56% in training symbols are achieved with NNs transferred from the most similar source system.
T4G • Optical Transmitter Sub-systems—Continued

T4G.5 • 17:30 Invited
Overcoming Low-power Limitations on Optical Frequency Combs Using a Micro-ring Resonator, Bill P. Conzalan1, Chawphon Prayoonpong2, Andreas Boes1, Xingyan Xu1, Mengxi Tan1, Sai T. Chu1, Brent E. Little1, Roberto Marandotti3, Aman Mitchell4, David J. Moss2; 1Electrical and Computer Systems Engineering, Monash Univ., Australia; 2School of Engineering, RMIT Univ., Australia; 3Centre for Micro-Photonics, Swinburne Univ., Australia; 4Dept. Physics and Material Science, City Univ. of Hong Kong, China; 5Xi’an Inst. of Optics and Precision Mechanics, Chinese Academy of Sciences, China; 6EMT, INRS, Canada; 7ITMO University, Russian Federation. We show that filtering of an optical frequency comb with a high quality-factor ring resonator enables the use of amplified low power combs as a multi-wavelength source. This approach improves effective source OSNR by 10 dB.

T4G.6 • 17:45
Kerr Soliton Microcomb Pumped by an Integrated SBS Laser for Ultra-Low Linewidth WDM Sources, Mark W Harrington1, Grant M. Brodnik1, Travis C. Briles2, Jordan R. Stone2, Richelle H. Streeter2, Scott B. Papp2, Daniel J. Blumenthal1; 1Univ. of California at Santa Barbara, USA; 2Time and Frequency Division 688, National Inst. of Standards and Technology, USA; 3Univ. of Colorado, Boulder, USA. An ultra-low linewidth WDM comb is realized using an integrated SiN SBS laser to pump a 128 GHz channel spacing SiN Kerr soliton microcavity laser. We measure the frequency noise of each of 25 C-band individual comb lines yielding ultra-low ~10Hz fundamental and ~4.0kHz integral linewidths for high-capacity coherent WDM.

T4H • Quantum Dots and Novel III-V Devices—Continued

T4H.5 • 17:30 Invited
III-V Micro- and Nano-lasers Grown on Silicon Emitting in the Telecom Band, Kei May Lau1, Ya Han1, Si Zhu1, Wei Luo1, Ying Xue1; ‘Hong Kong Univ of Science and Technology, Hong Kong. We present our recent effort on the integration of 1.5 μm III-V micro-cavity lasers on (001) Si wafers, and bufferless nano-lasers on (001) silicon-on-insulators (SOI) via direct hetero-epitaxy by metal organic chemical vapor deposition.

T4H.6 • 17:45
Demonstration of 3,010 km WDM Transmission in 3.83 THz Bandwidth Using SOAs, Matt Mazurczyk1, Jin-Xing Cai1, Milen Paskov1, William Patterson1, Oleg V. Sinkin1, Yue Hu1, Carl Davidson1, Patrick Corbett1, Timothy Hammond1, Maxim Bolshyansky1, Dmitri G. Foursa1, Alexei N. Pilipetskii1; SubCom, USA. We transmit 5.53Tb/s over 3,010km using SOAs, ultralow-loss fibers (0.145dB/km) and a new coded modulation format with SE=1.5 b/s/Hz. C-band transmission capacity in a ~602km circulating loop testbed with 3.83THz bandwidth is confirmed with FEC.

T4I • Long-haul Systems and Non-linear Mitigation—Continued

T4I.4 • 17:30
Cost-effective Solution for High-Capacity Unrepeatered Transmission, Tiago Sutili1, Pedro P. Neto2, Fabio D. Simões1; 1CPQD, Brazil; 2Padtec S.A., Brazil. A cost-effective 310-km SSMF unrepeatered optical link employing off-the-shelf EDFAs, 1st-order DRAs, and a ROPA is experimentally demonstrated. An iterative optimization process enabled a 12.8-Tbps net transmission (37.5-GHz spaced 128 channels x 100 Gbps).

T4I.5 • 17:45
Demonstration of 3,010 km WDM Transmission in 3.83 THz Bandwidth Using SOAs, Matt Mazurczyk1, Jin-Xing Cai1, Milen Paskov1, William Patterson1, Oleg V. Sinkin1, Yue Hu1, Carl Davidson1, Patrick Corbett1, Timothy Hammond1, Maxim Bolshyansky1, Dmitri G. Foursa1, Alexei N. Pilipetskii1; SubCom, USA. We transmit 5.53Tb/s over 3,010km using SOAs, ultralow-loss fibers (0.145dB/km) and a new coded modulation format with SE=1.5 b/s/Hz. C-band transmission capacity in a ~602km circulating loop testbed with 3.83THz bandwidth is confirmed with FEC.

T4J • Multi-core Fibers—Continued

17:15–18:15 Exhibitor Happy Hour, Center Terrace
18:15–19:00 Celebrating 50 Years of Light-speed Connections - Keynote Presentation, Ballroom 20BCD
19:00–20:30 Celebrating 50 Years of Light-speed Connections, Conference Reception, Sails Pavilion
19:30–21:30 Rump Session: When Will Copackaged Optics Replace Pluggable Modules in the Datacenter?, Room 6D
Room 1A  Room 1B  Room 2  Room 3  Room 6C  Room 6D

08:00–10:00 W1A • Optical Input/Output and Filters
Presider: Giampiero Contestabile

08:00–10:00 W1B • Multi-mode Fiber Technology
Presider: Xin Chen; Corning Inc, USA

08:00–10:00 W1C • Novel Doped Fiber Amplifier
Presider: Efstratios Kehayas; G&H, UK

08:00–10:00 W1D • Short-reach Interconnects
Presider: Fred Buchali; Nokia Bell Labs, Germany

08:00–10:00 W1E • Advances in Coherent PON
Presider: Derek Nesset; Nokia Bell Labs, France

08:00–10:00 W1F • Intra Data Center Networks II
Presider: Yvan Pointurier; Nokia Bell Labs, France

W1A.1 • 08:00 Invited
Ultrafast Laser-written Sub-components for Space Division Multiplexing, Simon Gross1, Andrew Ross-Adams1, Nicolas Riesen1, Sergio G. Leonsavali, Michael J. Withford1; Macquarie Univ., Australia; 2Univ. of South Australia, Australia; 3The Univ. of Sydney, Australia. The increase in Internet data demand has resulted in the development of novel optical fibers. Ultrafast laser inscription is a powerful tool to create 3D waveguide circuits that can interface with these new fiber types.

W1B.1 • 08:00 Invited
Deep Learning Imaging through Specialty Multi-mode Fibers, Jian Zhao1, Shengli Fan2, Jose Enrique Antonio-Lopez1, Axel Schülzgen1; Univ. of Central Florida, USA; 3Photonics Center, Boston Univ., USA. We demonstrate a cost-effective, highly accurate, and fast-speed cell sensing system enabled by the combination of the disordered optical fiber and the deep-learning classifier. It is compatible with both coherent and incoherent illumination.

W1C.1 • 08:00
Improved Nd Doped Silica Fiber for E-band Amplification, Leil S. Kiani1, Paul Pax1, Derek R. Drachenberg1, Jay Dawson1, Charles Boyle1, Cody Mart1, Victor Khitra1, Charles Yu2, Robert Crist1, Matthew Cook2; Simon Gross1, Andrew Ross-Adams1, Michael Runkel1, Michael Messersli1; Lawrence Livermore National Lab, USA. Building on previous work, we have designed a Nd doped fiber for E-band amplification. Modeling results indicate a fiber design that is applicable to telecom amplifiers.

W1C.2 • 08:15
An Extended L-band EDFA Using C-band Pump Wavelength, Chengmin Lei1, Hanlin Feng1, Luxan Wang1, Younès Messaddeq1, Sophie LaRochelle1; Center for Optics, Photonics and Lasers, Université Laval, Canada; 2Huawei Technologies Canada, Canada. We investigate an extended L-band EDFA pumped by C-band wavelengths. A two-stage scheme with 1480 nm/1545.5 nm pumping is demonstrated with 20-dB gain over 1570-1620 nm and NF lower than 5.7 dB.

W1D.1 • 08:00
High-performance Preamble Design and Upstream Burst-mode Detection in 100-Gb/s/TDM Coherent-PON, Junwen Zhang1, Mu Xu1, Haipeng Wang1,1, Eiji Honda1, Yojiro Mori1, Hiroshi Hasegawa1, Ken-ichi Sato2, Nagoya Univ., Japan; 1The National Inst. of Advanced Industrial Science and Technology (AIST), Japan. We propose robust, high-efficient preamble design and signal processing for upstream burst-mode detection in 100-Gb/s/TDM Coherent-PON. Using a 71.68 ns preamble, we achieve 36-dB power budget after 50-km SMF and 20-db dynamic range.

W1E.1 • 08:00
FOSphere: A Scalable and Modular Low Radix Fast Optical Switch Based Data Center Network, Pulong Yan1, Elham Kahan1, Xiaotao Guo1, Fu Wang1, Bi Tao Pan1, Xuwei Xue1, Shaohuan Zhang1, Nicola Calabretta1,1; ‘Technology Univ. of Eindhoven, Netherlands. We propose a novel scalable and modular low-radix fast optical switch based DCN with sphere topology (FOSphere). Numerical analyses on 10880-server indicates that FOSphere achieves 4.1 μs server-to-server latency and 2.6E-3 packet loss at load 0.4.

W1F.1 • 08:15
High-throughput Optical Circuit Switch for Intra-datacenter Networks Based on Spatial Super-channels, Eiji Honda1, Yojiro Mori1, Hiroshi Hasegawa1, Ken-ichi Sato2, Nagoya Univ., Japan; 1The National Inst. of Advanced Industrial Science and Technology (AIST), Japan. We propose a novel optical circuit switch architecture based on spatial super-channels. We construct part of a 1.53×1.536 optical switch and its performance is experimentally confirmed. The total throughput of the switch reaches 2.1 Tbps.
W1G • Trends in Free Space Optics Communications
Presider: Mohamed-Slim Alouini; King Abdullah Univ of Sci & Technology, Saudi Arabia

W1G.1 • 08:00 Tutorial
Recent Trends of Free-space Laser Communications for Satellites Communications and Future Prospects, Morio Toyoshima1; ‘National Inst of Information & Comm Tech, Japan. Space laser communications have been verified in orbit recently by micro-satellites, which will revolutionize space systems architecture. Many satellite mega-constellations plan to use space laser communications. The trends and future prospects will be presented.

Morio Toyoshima received his PhD from the University of Tokyo, Japan, in 2003 in electronics engineering. He joined NICT, Japan, in 1994 and has conducted several world first space laser communication and basic quantum communication missions. He is now the Director of Space Communications Laboratory in NICT since 2011.

W1H • Symposium: Future Photonic Devices f/J/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)

W1H.1 • 08:00 Invited
Electronic and Photonic Co-optimization for f/J/bit Optical Links, Clint Schow1; ‘Univ. of California Santa Barbara, USA. Abstract not available.

W1I • Panel: Pros and Cons of Low-margin Optical Networks

Traditional optical networks are over-engineered due to conservative assumptions used in the planning process with regards to module characteristics, system performance, and network fiber infrastructure, and due to the requirement to sustain many years of error/failure-free operation with limited reconfigurations (if any). As a result, typical optical networks operate with high performance margins and underutilized capacity.

However, modern optical networks with flexible ROADM, highly-configurable transponders and (typically SDN-based) software control may have a shorter circuit life time than traditional fixed optical networks.

Furthermore, the ability to pull performance data on many parameters in a ROADM or transponder every second or even faster enables unprecedented visibility into the optical layer behavior.

As we approach the practical limits of spectral efficiency, one avenue to further increase capacity is to more accurately determine the actual performance of the optical network and operate it at higher capacity with lower margin.

This panel will investigate the new trend for lower margin optical networks. We will start with Network Operator views and then have experts from industry and academia discuss their challenges and solution proposals.

W1J • Advanced Transmission Path Metrics
Presider: Georg Mohs; TE SubCom, USA

08:00–10:00
W1J.1 • 08:00
Leveraging Long-term QoT Awareness for Capacity Boost of Pan-European Network, Juraj Slovak1, Wolfgang Scharer1, Donato Sperti2, Pedro Capela1, Silvestre Martins3, Uffe Andersen1, Anders Lindgren1, Joakim Tjäder4, Stefan Melin1, Infinera Corporation, Germany; Infinera Portugal, Portugal; Telia Carrier, Denmark; Telia Company, Sweden. Online quality of transmission (QoT) monitoring and validation enables conversion of unused margins into higher network capacities. We quantify the benefit of long-term performance awareness in a Pan-European optical network of a Tier-1 operator.

W1J.2 • 08:15
Exploring Channel Probing to Determine Coherent Optical Transponder Configurations in a Long-haul Network, Kaida Kaeval1, Danish Rafique1, Kamil Blawat1, Klaus Grobe1, Helmut Griesser1, Jørg-Peter Elbers1, Piotr Rydlichowski2, Artur Binczewski2, Marko Tikas3; ‘ADVA Optical, Germany; Poznan Supercomputing and Networking Center, Poland; ‘Telia2 Estonia, Estonia. We use channel probing to determine the best transponder configurations for spectral services in a long-haul production network. An estimation accuracy better than ±0.7dB in GSNR margin is obtained for lightpaths up to 5738km.

Continued on page 99
W1A.2 • 08:30
Tapered Self-written Waveguide between Silicon Photonics Chip and Standard Single-mode Fiber, Yohei Sato1, Kota Shikama1, Tai Tsuchiawa2, Hidetaka Nishi1, Atsushi Aratake1, Norio Sato1; 1NT Device Technology Laboratories, Japan. The first self-written waveguide applied to silicon photonics with a spot-size converter using a SiON waveguide achieves low coupling loss and high alignment tolerance between a standard single-mode fiber and silicon photonics chip.

W1A.3 • 08:45
Vertical Optical Fiber Assembly on Silicon Photonic Chips Using 3D-curved Silicon Waveguide Couplers, Yusuke Sakakibara1, Tomaoki Kiriya1, Tomoya Yoshida1, Yuki Atsumi1, Emiko Omoda1, Katsuhiro Iwasaki1, Takashi Kato1; 1NT Device Technology Laboratories, Japan. Using UV adhesive mixed with glass spacer beads, vertical surface connection of optical fibers to silicon photonic chips via elephant couplers was realized with wavelength and polarization insensitiveness at temperatures from -18.5°C to 90°C.

W1B.2 • 08:30
Modeling the Breakdown in Degeneracy for High-index-contrast Ring Core Fiber, Mai Banawan1, Liyan Wang2, Sophie LaRochelle1, Leslie Rusch1; 1Department of Electrical and Computer Engineering, COPL, Universite Laval, Canada; 2Hewlett Technologies Canada Co., Ltd., Canada. Our numerical model of elliptical deformation of ring cores uncovers distinctly different behaviors of lower and higher order OAM modes. Degeneracy of modes, across topological charge and polarization are laid bare in simulations.

W1B.3 • 08:45
Ultra-low Inter-mode-group Crosstalk Ring-Core Fiber Optimized Using Neural Networks and Genetic Algorithm, Chunmin Shi1, Lei Shen1, Junwei Zhang1, Junyi Liu1, Lei Zhang1, Jie Luo2, Jie Liu1, Siyuan Yu1; 1Sun Yat-Sen Univ., China; 2OFC, China. We design and fabricate a ring-core fiber whose refractive-index profile is optimized using neural networks and genetic algorithm under fabrication constraints. Experimental results confirm ultra-low inter-mode-group crosstalk of <55 dB/km.

W1C.3 • 08:30
Invited
Recent Advances on Radiation-hardened Optical Fiber Technologies, Sylvain Girard1, Thierry Robin2, Adriana Morana1, Gilles Melin1, Alexandre Barmin1, Aziz Boukenter1, Berot Cadier1, Emmanuel Mann1, Laurent Lablond1, Arnaud Laurent2, Youcef Ouendane1; 1Universite Jean Monnet, France; 2XBlue, France. Optical fibers possess key advantages for integration in radiation-rich environments as parts of communication systems, lasers sources, optical amplifiers, sensors. We reviewed how the understanding of the basic mechanisms of radiation effects can be exploited to optimize their tolerance to the most challenging environments.

W1D.2 • 08:30
Distortion-aware 2D Soft Decision for VCSEL-MMF Optical PAM Interconnection, Lin Sun1,2, Jiangbing Du1, Wenjia Zhang1, Nan Chi1, Chao Lu1, Zuyuan He1; 1Shanghai Jiao Tong Univ., China; 2Hong Kong Polytechnic Univ., Hong Kong; 2Fudan Univ., China. A distortion-aware 2D soft decision method of PAM signals have been proposed for VCSEL-MMF interconnection system. Improvements and application potential have been experimentally investigated on a 112-Gbps optical PAM-4/8 system using a multimode VCSEL.

W1D.3 • 08:45
168Gbps PAM-4 Multimode Fiber Transmission through 50m using 28GHz 850nm Multimode VCSELs, Justin Lavenock1, Siddhant Varughese1, Nikolay Ledentsov Jr1,2, Lukasz Chorchos1, Nikolay Ledentsov1, Stephen E. Ralph1; 1Georgia Inst. of Technology, USA; 2VI Systems GmbH, Germany; 2Warsaw Univ. of Technology, Poland. We experimentally demonstrate PAM-4 data rates beyond 160Gbps over 50m OMS using unpackaged 850nm VCSELs. Power penalties of PAM-4 are examined demonstrating maximum data rates, with and without FEC, over 50m and 100m of fiber.

W1E.3 • 08:30
Invited
Transceiver Technologies for Next-generation PON Networks, Dora van Veen1, Vincent Houtsma1; 1Nokia Bell Labs, USA. We will review the specific requirements for upgrading passive optical networks and present recent research on high speed optical transmission for Next-Generation TDM-, TDWM- and WDM-PONs based on low cost optical and DSP technologies.
### W1G • Trends in Free Space Optics Communications—Continued

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<th>Speakers:</th>
<th>David Boertjes, Ciena Corp., Canada</th>
<th>Camille Delezoide, Nokia Bell Labs, France</th>
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<td>Juraj Slovak, Infinera, Germany</td>
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### W1H • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)—Continued

#### W1H.2 • 08:30 Invited Femto-farad Nanophotonic Devices for fJ/bit Signal Conversion, Kengo Nozaki1, Shinji Matsuo1, Takuro Fujii2, Koji Takeda3, Eiichi Kuramoto1, Akiko Shinya1, Masaya Notomo1; 1NTT Basic Research Laboratories, Japan; 2NTT Nanophotonics Center, Japan; 3NTT Device Technology Laboratories, Japan. We use a photonic-crystal platform to demonstrate opto-electronic devices and integrated functions with a femto-farad capacitance. This allows us to realize amplifier-free photo-receiver, electro-optic modulator, and O-E-O signal converter operating in a fJ/bit energy consumption.

#### W1J • Advanced Transmission Path Metrics—Continued

#### W1J.3 • 08:30 Invited Standardizing Performance Metrics for Submarine Transmission Paths, Priyanth Mehta 1; 1Ciena Canada, Canada. This paper describes the progress and obstacles towards defining a universal performance metric for ultralong haul submarine transmission paths. Sources of error and quantitative assessment of capacity prediction is also addressed.

### W1K • Machine Learning for Optical Communication Systems—Continued

#### W1K.1 • 08:45 Invited Advancing Classical and Quantum Communication Systems with Machine Learning, Darko Zibar1, Uiera C.de Moura1, Hou Man Chin1, Ann Margareth Rosa Brusin1, Nitin Jain1, Francesco Da Ros1, Sebastian Kleis2, Christian Schaeffer2, Tobias Gehring2, Urik I. Andersen1, Andrea Carena3; 1Technical Univ. of Denmark, Denmark; 2Politecnico Di Torino, Italy; 3Helmuth Schmidt Univ., Germany. A perspective on how machine learning can aid the next-generation of classical and quantum optical communication systems is given. We focus on the design of Raman amplifiers and phase tracking at the quantum limit.
Advances in Few-mode Fiber Design and Manufacturing, Pierre Sillard. This tutorial will show how recent advances in design and manufacturing have improved the performance of few-mode fibers, and what are the challenges to turn them into implementable solutions.

Bismuth-doped Fiber Amplifier Operating in the Spectrally Adjacent to EDFA Range of 1425-1500 nm, Vladimir Khopin, Elena Starosta, Valery Mashkov, and others. This paper presents a Bi-doped fiber amplifier from 1287 to 1354 nm. The wider bandwidth was achieved using inhomogeneous broadening of bismuth active centers (BAC-P). Blue shifted BAC-P were pumped at 1178 nm and generated laser radiation at 1276 nm which serves as a pump source for red shifted BAC-P.

1.12 Tbit/s Fiber Vector Eigenmode Multiplexing Transmission Over 5-km FMF with Kramer's-Kronig Receiver, Linyue Lu, Jianping Li, Chao Lu, and others. This paper presents a 1.12 Tbit/s fiber vector eigenmode multiplexing transmission over 5-km few-mode fiber using HE11 and EH11 fiber modes, achieving 25-mWatts per channel.

Performance Comparison of Coherent and Direct Detection Schemes for 50G PON, Xiampa Zhu, Bo Yang, and others. This paper compares the performance of coherent and direct detection schemes for 50G PON, showing the advantages and disadvantages of each approach.

Experimental Assessments of a Flexible Optical Data Center Network Based on Integrated Wavelength Selective Switch, Shusui Xu, and others. This paper presents experimental assessments of a flexible optical data center network, showing the potential for increased efficiency and scalability.

A 25.6 Tbps capacity Hipaos optical packet switch architecture with 1024 in/out ports operating at 25Gbps, presenting successful contention resolution and error-free operation with a control plane latency of 97.28ns.

Pierre Sillard received the engineering diploma of Telecom ParisTech, in 1994, and the PhD degree in Optics from the University of Paris VI in 1998. He has been working in the field of optical fibers and optical networks since 1999, and he is now with Prysmian Group in France. He has published more than 250 papers and has been granted more than 100 patents. In 2004, he received the TR35 innovator award from MIT Technology Review. He is a member of the OSA and IEEE societies and he serves as a reviewer and committee member of several journals and conferences.
W1G • Trends in Free Space Optics Communications—Continued

W1G.2 • 09:00 Simultaneous Orthogonalizing and Shaping of Multiple LG Beams to Mitigate Crosstalk and Power Loss by Transmitting Each of Four Data Channels on Multiple Modes in a 400-Gbit/s Free-space Link, Kai Pang1, Haoqian Song1, Xinzhou Su1, Kasiheng Zou1, Zhe Zhao1, Hao Song1, Ahmed Almaiman1, Runzhou Zhang1, Cong Liu1, Nanhe Hu1, Shlomo Zach2, Nadav Cohen2, Brittany Lynn2, Andreas F. Molisch1, Robert W. Boyd1, Moshe Tur1, Alan E. Willner1; ‘Univ. of Southern California, USA; ‘Tel Aviv Univ., Israel; ‘Space & Naval Warfare Systems Center, Pacific, USA; ‘Univ. of Rochester, USA. We experimentally utilize orthogonal combinations of multiple Laguerre-Gaussian modes in a 400-Gbit/s free-space link with limited-size aperture or misalignment. Power loss and crosstalk could be reduced by up to ~15 dB and ~40 dB, respectively.

W1G.3 • 09:15 Simultaneous Turbulence Mitigation and Mode Demultiplexing using one MPLIC in a Two-Mode 200-Gbit/s Free-space OAM-multiplexed Link, Hao Song1, Xinzhou Su1, Haoqian Song1, Runzhou Zhang1, Zhe Zhao1, Kasiheng Zou1, Cong Liu1, Kai Pang1, Nanhe Hu1, Ahmed Almaiman1, Moshe Tur1, Alan E. Willner1, Shlomo Zach2, Nadav Cohen2, Andreas F. Molisch1, Robert W. Boyd1; ‘Univ. of Southern California, USA; ‘Tel Aviv Univ., Israel; ‘King Saudi Univ., Saudi Arabia; ‘Univ. of Ottawa, Canada; ‘Univ. of Rochester, USA. We experimentally utilize a multi-plane light convertor (MPLIC) for simultaneous orbital-angular-momentum (OAM) mode demultiplexing and turbulence-induced crosstalk mitigation. Results show up to 15-dB reduction of crosstalk in a two-mode 200-Gbit/s OAM-multiplexed link.

W1H • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)—Continued

W1H.3 • 09:00 Invited Simultaneous Turbulence Mitigation and Mode Demultiplexing using one MPLC in a Two-Mode 200-Gbit/s Free-space OAM-multiplexed Link, Hao Song1, Xinzhou Su1, Haoqian Song1, Runzhou Zhang1, Zhe Zhao1, Kasiheng Zou1, Cong Liu1, Kai Pang1, Nanhe Hu1, Ahmed Almaiman1, Moshe Tur1, Alan E. Willner1, Shlomo Zach2, Nadav Cohen2, Andreas F. Molisch1, Robert W. Boyd1; ‘Univ. of Southern California, USA; ‘Tel Aviv Univ., Israel; ‘King Saudi Univ., Saudi Arabia; ‘Univ. of Ottawa, Canada; ‘Univ. of Rochester, USA. We experimentally utilize a multi-plane light convertor (MPLIC) for simultaneous orbital-angular-momentum (OAM) mode demultiplexing and turbulence-induced crosstalk mitigation. Results show up to 15-dB reduction of crosstalk in a two-mode 200-Gbit/s OAM-multiplexed link.

W1I • Panel: Pros and Cons of Low-margin Optical Networks—Continued

W1I.3 • 09:00 Panel: Pros and Cons of Low-margin Optical Networks—Continued

W1J • Advanced Transmission Path Metrics—Continued

W1J.4 • 09:00 Tutorial From the Acceptance of Turnkey Systems to Open Networks with G-SNR, Elizabeth Rivera Hartling1, Stephen Grubb1, Tim Stuch1, Herve Fevrier1, ‘Facebook Inc., USA. This tutorial will discuss collaboratively formed industry recommendations for characterizing Open Subsea Cables, with the intent of assessment, maximization and understanding of capacity potential, utilizing methodologies to test key parameters such as G-SNR, among others.

W1K • Machine Learning for Optical Communication Systems—Continued

W1K.2 • 09:15 Maximizing Fiber Cable Capacity Under A Supply Power Constraint Using Deep Neural Networks, Junho Cho1, Chandrasekhar Sethumadhavan1, Erxhen Sula1, Samuel Olsson1, Ills- worth C. Burrows1, Gregory Raybon1, Roland Ryf1, Nicholas K. Fontaine1, Jean-christophe Antona1, Stephen Grubb1, Peter Winzer1, Andrew Chraplyvy1; ‘Nokia Bell Labs, USA; ‘Facebook, USA; ‘EPFL, Switzerland; ‘Nokia, USA; ‘ASN, France. We experimentally achieve a 19% capacity gain per Watt of electrical supply power in a 12-span link by eliminating gain flattening filters and optimizing launch powers using deep neural networks in a parallel fiber context.
W1C.6 • 09:30  
**Tetrahedral-Cr Enhancement Employing Dielectric Coating for Higher Gain of Broadband Cr-doped Fiber Amplifiers**, Chi-Ming Liu1, Jhuan-Wei Li1, Liu Chun-Nien2, Wei-Chih Cheng1, Charles Tu1, Tien-Tsorng Shih3, Sheng-Lung Huang2, Wood-Hi Cheng1.  
1Graduate Inst. of Optoelectronic Engineering, National Chung Hsing Univ., Taiwan; 2Department of Electronic Engineering, National Kaohsiung Univ. of Applied Sciences, Taiwan; 3Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan. 
We report gross gain of 8.4-dB for 300-nm broadband single-mode Cr-doped crystalline core fiber (SMCCDF) employing dielectric coating, thermal annealing, and polarization pumping techniques. This gross gain is the highest yet demonstrated of the SMCCDFs.

10:00–13:00  
**Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30)**
**Lunch Break (on own)**

10:00–17:00  
**Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall)**
**OFC Career Zone Live, Exhibit Hall B2**
W1G • Trends in Free Space Optics Communications—Continued

W1G.4 • 09:30 Beyond Terabit/s WDM Optical Wireless Transmission using Wave-length-transparent Beam Tracking and Steering, Yang Hong1, Feng Feng1, Kyle Bottrell2, Natsumu Taengnoi3, Ravinder Singh1, Grahame Faulkner1, Dominic O’Brien1, Penkilis Petropoulos1; ’Univ. of Southampton, UK; ’Univ. of Oxford, UK. We report up to 1.165-Tb/s optical wireless WDM transmission using a wavelength-transparent beam tracking and steering system. Over a 3.5-m perpendicular distance, beyond 1-Tb/s capacity was achieved across a lateral coverage up to 1.8 m.

W1G.5 • 09:45 C-band PS 4096QAM OFDM FSO Transmission with 6.98bit/s/Hz Net SE Based on Kramers-Kronig Detection, Yiran Wei1, Yingjun Zhou1, Cuiwei Liu1, Feng Wang1, Kashi Wang1, Juming Shi1, Nan Chi1, Jianjun Yu1; Fudan Univ., China. We experimentally demonstrate 10Gbaud PS 4096QAM OFDM with KK detection over 25m FSO transmission. As far as we know, this is the highest QAM delivery in a FSO communication system.

W1H • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)—Continued

W1H.4 • 09:30 Invited Ultra-efficient Optical Switching based on a Large Pockels Effect embedded in Silicon Photonics, Felix Eltes1, Jean Pompeyjine1, Stefan Abel1; IBM Research GmbH, Switzerland. We have combined BTO with conventional silicon photonic platforms to enhance the performance of silicon photonics by exploiting the Pockels effect. We have demonstrated modulators, switches, and tuning elements with excellent performance exceeding that of silicon-based devices.

W1I • Panel: Pros and Cons of Low-margin Optical Networks—Continued

W1J • Advanced Transmission Path Metrics—Continued

W1K • Machine Learning for Optical Communication Systems—Continued

W1K.3 • 09:30 Experimental Prediction and Design of Ultra-wideband Raman Amplifiers Using Neural Networks, Xiaoyan Ye1, Aymeric Arnould1, Amirhossein Ghazisaeidi1, Dylan Le Gac1, Jeremy Renaudier1; Nokia Bell Labs France, France. A machine learning method for Raman gain prediction and multipump broadband amplifier design is experimentally demonstrated over a 100 nm-wide optical bandwidth. We show high accuracy and ultra-fast prediction of arbitrary gain profile over a 100 km-long SSMF span.

W1K.4 • 09:45 Anomaly Localization in Optical Transmissions Based on Receiver DSP and Artificial Neural Network, Huashu Lun1, Xiaomin Liu2, Meng Cai1, Mengfan Fu1, Ywen Wu1, Lilin Yi1, Weisheng Hu1, Qunbi Zhuge1; ’Shanghai Jiao Tong Univ., China. We propose a receiver DSP based scheme to localize WSS anomaly in an optical link. Through extensive simulations, we show that the accuracy reaches up to 96.4% with a good generalization performance.

10:00–13:00 Unopposed Exhibit-only Time, Exhibit Hall (coffee service 10:00–10:30) Lunch Break (on own)

10:00–17:00 Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall) OFC Career Zone Live, Exhibit Hall B2
A Passive Mode-Locked Quantum Dot Laser with 10.8 Tbit/s Transmission Over 100-km SSMF, Guoqiang Liu 1, Zhenguo Lu 1, Jieren Liu 1, Youxin Mao 1, Martin Vachon 1, Chunying Song 1, Philip Poole 1, National Research Council Canada, Canada. We demonstrate 10.8 Tbit/s (16-QAM 400 Gbaud) data transmission over 100 km of standard single mode fiber using an InAs/InP quantum dot mode-locked laser with a channel spacing of 34.2 GHz.

2.3-dimensional Fiber Array with Re-flow Compatibility for High-density Optical Interconnection, Tsutani Kumagai 1, Hajime Arai 1, Hong Nguyen 1, Tetsuya Nakashima 1, Sumitomo Electric Industries, Ltd. Japan. We developed a 2-dimensional fiber array (2DA) as an optical interconnection device for co-packaged optics. The 2DA was capable of maintaining a low connection loss of < 1.0 dB after reflow process at 260°C.

Vertical-curved Si Surface Optical Coupler for Coupling with Standard Single-mode Optical Fibers, Yuki Atsumi 1, Tomoya Yoshida 1, Emiko Omoda 1, Youichi Sakakibara 1, Natl Inst of Adv Industrial Sci. & Tech, Japan. A vertically-curved-waveguide surface optical coupler for coupling with a 10-μm-MFD standard single-mode optical fiber was developed. The fabricated coupler showed 1-dB bandwidths of >160 nm and >120 nm and coupling losses of 3.9 dB and 4.0 dB for TE and TM polarization.

Dual-band Optical Filters Using Integrated Multimode Bragg Gratings, Jonathan Cauchon 1, Wei Shi 1, Universite Laval, Canada. We demonstrate a multimode integrated Bragg grating allowing dual-band filtering in the 1.5-1.6 μm region. Bandwidths of 4.4 and 7.5 nm and a band separation of 42 nm are achieved.

Ultra-Compact Silicon TM-pass Polarizer with a Photonic Crystal Nanobeam Structure, Yu He 1, Yong Zhang 1, Ruihuan Zhang 1, Sun Liu 1, Yikai Su 1, Shanghai Jiao Tong Univ., China. An ultra-compact TM-pass polarizer is experimentally demonstrated by using PhC nanobeam structure. The TE mode is reflected with an extinction ratio over 20.4 dB, while the TM mode propagates through with a 0.7-dB insertion loss.

Metal surface Beam Deflector Array on a 12-inch Glass Wafer, Nanxi Li 1, Yuan Hsing Fu 1, Yuanyong Ding 1, Chengxiu Xu 1, Ling Zhang 1, Yanyan Zhou 1, Keng Heng Lai 1, Vladimir Bliznetsov 1, Hui-Jung Lee 1, Wei Loong Loh 1, Shiying Zhu 1, Chunying Lin 1, Navab Singh 1, Inst. of Microelectronics, Agency for Science Technology and Research, Singapore. We have demonstrated a large-area metal surface beam deflector array patterned directly on a 12-inch glass wafer using immersion lithography. The captured random points at 940 nm wavelength show a good match with the design.

Performance Evaluation of a Comb-based Transmission System Employing Multi-functional Active Demultiplexers, Priyab Dobaballapur Lakshminarasimhan 1, Alekscandra Kozubowska-Anandarajah 1, Pascale Landais 1, Prince M. Anandaraja 1, School of Electronics Engineering, Dublin City Univ., Ireland; CONNNECT Research Centre, Trinity College Dublin, Ireland. A compact OFC-based transmitter for short-reach applications is demonstrated. A single device is employed to implement OFC demultiplexing, amplification and direct modulation. Using this method, error free data transmission over 3km of fiber is achieved.

A Single-loop PT-symmetric Sub-kHz Fiber Laser Based on an Integrated Microdisk Resonator, Jiaping Yao 1, Zhiqiang Fan 1, Dong Li 1, Yanyan Zhou 1, Keng Heng Lai 1, Vladimir Bliznetsov 1, Hongxiu Tan 1, Yating Xiang 1, Zhigang Fu 1, Ming Tang 1, Junqiu Liu 2, Anton Lukashchuk 2, Jason Hurley 1, Jeff Stone 1, Doug Coleman 1, Jie Liu 1, Qi Wu 1, Ming-Jun Li 1, ‘Coming Research & Development Corp., USA. We propose a simple and compact adapter using specially designed modal conditioning single-mode fiber for fundamental mode transmission through multimode fiber and demonstrate error-free fiber transmission over 1-km multimode fiber using a 100G CWDM4 transceiver.

Miniature Optical Connector with Magnetic Physical Contact, Kota Shikama 1, Norio Sato 1, Atsushi Arakaki 1, Satoshi Shigematsu 1, Takeshi Sakamoto 1, ’Nippon telegraph and telephone, Japan. We present a miniature physical-contact optical connector featuring a novel magnetic attraction structure. The magnetic optical connectors we designed and fabricated yield low insertion and high repeatability. The distance is comparable to that of a conventional connector.

Inverse Design of Few-mode Fiber by Neural Network for Weak-coupling Optimization, Zhiqin He 1, Changbing Du 1, Weihong Shen 1, Yuting An 1, Shanghai Jiao Tong Univ., China. We used a neural network to inversely design a four-ring few-mode fiber for weak-coupling optimization so as to support MIMO-less MM optical communication. This method provides high-accuracy, high-efficiency and low-complexity for complexed fiber design.

A Simple and Compact Fiber Modal Adapter for Upgrading 850 nm Multimode Fibers for Fundamental Mode Transmission at 1310 nm, Xin Chen 1, Kangmei Li 1, Aramais Zakharian 1, Jason Hurley 1, Jeff Stone 1, Doug Coleman 1, Jie Liu 1, Qi Wu 1, Ming-Jun Li 1, ‘Coming Research & Development Corp., USA. We propose a simple and compact adapter using specially designed modal conditioning single-mode fiber for fundamental mode transmission through multimode fiber and demonstrate error-free fiber transmission over 1-km multimode fiber using a 100G CWDM4 transceiver.

Compensating Model of Nonlocal Effects in a Brillouin Optical Time-domain Analysis System, Can Liu 1, Lianshan Yan 1, ‘Southwest Jiaotong Univ., China. A novel model for compensating the nonlocal effects is proposed in BOTDA. A basic experimental configuration is only required. Experimental results show that a hotspot at 39.1 km can be accurately measured under probe power from -14 dBm to +2 dBm, and a 13.5 MHz Brillouin frequency shift error is corrected.

Training-free Feature Extraction of BOTDA Based on Sparse Representation, Hongou Tan 1, Ting Tang 1, Hao Wu 1, Li Shen 1, Kangjie Li 1, Maqi Zhang 1, Can Zhao 1, Lin Gan 1, Songnian Fu 1, Ming Tang 1, Huazhong Univ. of Science and Technology, China. We propose a method based on sparse representation to extract amplitude, linewidth, and Brillouin frequency shift (BFS) in BOTDA using dictionary-learning algorithm without feedback and off-line training, which enables more accurate BFS measurements in real-time.
W2A.19 Rayleigh Speckle Observations from Single Mode Fiber for Wavelength Measurement, Yalonggang Fan1, Xin Yu Fan1, Shuai Wang1, Zhaopeng Zhang1, Zuyuan He1; Shanghai Jiao Tong Univ., China. We propose a novel wavelength metering using Rayleigh speckle obtained by optical time domain reflectometry. It is experimentally demonstrated that the system can resolve multi-wavelength signal with 6 fm wavelength resolution and 25 nm bandwidth.

W2A.20 Experimental Demonstration of Using Wet-mate Connector in Offshore Long-distance Raman Amplified Optical Links, Steinar Bjerntveit1, Rolf Bae1, Kris Sanapi1, W.R.L. Clements1, Bernard Shum-tim3, Luigi Carlonusto3, Soren Michaelsen1, NTNU, Norway; 1Tampnet, Norway, 2MPF communications, Canada, 3Ciena, Canada. Deploying fibre cables to offshore installations may desire a pluggable construction for sub-sea use. Sub-sea connection of fibre cables, carrying high power Raman pump power, using a wet-mate connector is demonstrated for the first time.

W2A.21 GOSNR Characterization by Optical Spectrum Analysis, Gang He1, Steven Searcy1, Daniel Garijpy1, Sorin Tibuleac1; EXFO Inc, Canada; 1ADV, USA. We introduce a GOSNR measurement based on optical spectrum analysis and experimentally validate the method using multiple coherent signal types (34 and 69 Gbd), QPSK and 16QAM over 8 and 12 spans LEAF transmission.

W2A.22 On the Workload Deployment, Resource Utilization and Operational Cost of Fast Optical Switch Based Rack-scale Disaggregated Data Center Network, Xiaotao Guo1, Fu-long Yan1, George Exarchakos1, Xuewei Xue1, Biao Pan1, Nicola Calabretta1; 1Eindhoven Univ. of Technology, Netherlands. We investigate operational performance of a novel rack-scale disaggregated network. Results show that the disaggregated network achieves 30.6% higher workloads acceptance rate, 12.9% higher resource utilization, and 33% more power saving compared with the server-centric.

W2A.23 Towards Zero-crosstalk-margin Operation of Spectrally-Spatially Flexible Optical Networks Using Heterogeneous Multicore Fibers, Anuj Agrawal1, Vimal Bhatia1, Shashi Prakash1; 1IIT Indore, India; 2Photons Laboratory, Devil Ahiya Univ., India. In spectrally-spatially flexible optical network (SS-FON), crosstalk (XT)-margin over-provisioning is unavoidable due to transmission reach granularity and modulation schemes. We show that heterogeneous multicore fibers of specific core designs can achieve zero-XT-margin. We also propose a core-type selection method to minimize XT-margin in SS-FONs.

W2A.24 Recurrent Neural Networks for Short-term Forecast of Lightpath Performance, Sandra Aladini1, Stefania Alliggi1, Anh Vu Stephan Tran1, Christine Tremblay1; 1Ecole de Technologie Superieure, Canada. We show how the Recurrent Neural Networks can be used for performance prediction of lightpaths using field bit error rate data. Moreover, we illustrate how the forecast horizon and observation windows affect the forecast accuracy.

W2A.25 Optimal Upstream Spectrum Resource Allocation on IP-over-EONs Access Links, Junyi Shao1, Weiqiang Sun1, Weisheng Hu1; 1Shanghai Jiao Tong Univ., China. We propose a resource allocation strategy on IP-over-EONs access links. It realizes the dynamic self-adaptive spectrum resource adjustment applying to traffic fluctuations and handles the performance requirements under the circuit-packet hybrid architecture.

W2A.26 SDN Controlled Edge Computing Metro Access Network with Network Slicing and Load-aware end-to-end Service Protection for 5G applications, Biao Pan1, Xuewei Xue1, Fulong Yan1, Fu Wang1, Eduardo Magalhaes1, Nicola Calabretta1; 1Eindhoven Univ. of Technology, Netherlands. We demonstrate SDN reconfigurable edge computing metro-access network based on low-cost ROADM nodes with edge-computing and programmable FPGA-based interfaces supporting classification and network slicing. Dynamic network operation and QoS protection is validated with live-streaming use case.

W2A.27 Reconfiguration of VNF Placement in an Optical Metro Network by a Modular Planning Tool, Guido Maier1, Leila Askari1, Sebastian Troia1, Ligia M. Moreira-Zorello1, Francesco Musumeci1, Massimo Tomatitore1; 1Politecnico di Milano, Italy. We demonstrate the recurrent reconfiguration of virtual network function placement and routing and wavelength assignment in optical metro networks supporting 5G services. Reconfiguration solutions are provided by a dedicated planning-tool module.

W2A.28 Low-latency Latency-based Resource Allocation in Converged Access Networks, Lihua Ruan1, Sourav Mondal1, Imai Dia1, Elaine Wang1; 1The Univ. of Melbourne, Australia. We propose a federated resource learning (FedRL) solution to innovate resource allocation in converged access networks. FedRL lowers network latency with reinforcement-learning-based bandwidth decision and achieves fast learning with federated learning efforts.

W2A.29 Demonstration of AI-assisted Energy-efficient Traffic Aggregation in 5G Access Network, Luyao Guan1, Min Zhang1, Dan Shi Wang1; 1Beijing Univ of Posts and Telecom, China. We propose an AI-assisted energy-efficient traffic aggregation scheme, which is demonstrated in software-defined optical network testbed. The experimental results show proposed scheme can efficiently reduce energy consumption by traffic aggregation according to traffic prediction.

W2A.30 Real-Time Demonstration of 2.4Tbps (2000Gbps/A) Bidirectional Coherent DWDM-PON Enabled by Coherent Nyquist Subcarriers, Amir Rashidinejad1, An Nguyen2, Magnus Olsen3, Steven Hand2, David Welch2; 1Infinera Corporation, USA; 2Infinera Canada, Canada; 3Infinera Canada, Canada. We propose and experimentally demonstrate an all-optical architecture for data center interconnect networks with reconfiguration times of a few seconds. Filtering and amplification transient effects have minimal impact on BER performance.

W2A.31 Nonlinear Pre-Distortion Based on Indirect Learning Architecture and Cross-Shad. Xen-enabled Behavioral Modeling for 120-Gbps Multi-mode Optical Interconnects, Chenyang Liang1, Wenjia Zhang1, Line Ge1, Jiangdong Du1, Zuyuan He1; 1Shanghai Jiao Tong Univ., China. In this paper, we present a novel nonlinear pre-distortion scheme enabled by indirect learning architecture and cross-correlation-based behavioral modeling. 120-Gbps PAM-4 error free transmission is demonstrated using 30-GHz class VCSEL.
W2A.34 Laser Diode Chirp Requirements in Wideband Analog Photonic Signal Processing, Farzad M. Koushanli, Mckay B. Bradford, Monireh Moayedi Pour Fard, Thienn-An Nguyen, Sri-ram Vishwanath; 1Univ. of Texas at Austin, USA. 2GenXCmm Inc. USA. Distortions added to a 150 MHz OFDM signal in a photonic link comprised of a 4-tap filter and a directly modulated laser is simulated to study the laser chirp impact on the link dynamic range.

W2A.35 Switchable Down- Up- and Dual-chirp Linearly Frequency Modulated Signal Generation Utilizing a Dual-polarization Dual-parallel Mach-Zehnder Modulator, Peng Li, Lianshan Yan, Jia Ye, Xihua Zou, Bin Luo, Wei Pan; School of Information Science and Technology, Southwest Jiaotong Univ., China. A photonic method to generate switchable down-, up- and dual-chirp linearly frequency-modulated (OFM) signals is presented. Such signals with a carrier frequency of 5 GHz and a chirp rate of 1 GHz/4s are experimentally demonstrated.

W2A.36 Scalable and Fast Optical Circuit Switch Created with Silicon-photonic Tunable Antennas, Tomoya Kitajima, Toshihisa Kato, Takahiro Ishii, Chiyuri Izumi, Kazuhiro Ikeda, 1, Shu Namiki, Ken-ichi Wei-Liang Li, 1, Tsung-Hung Tsai, 1, Zhen-Xiong Xie, 1, Bo-Jun Lin, 1, Xin-Yuan Ding, 1, Tsung-Hung Tsai, 1, Ping-Yao Huang, 1, Chia-Chien Chen, 1, National Chiao Tung Univ., Taiwan; 2National Sun Yat-sen Univ., Taiwan. We demonstrate 2×2 MIMO 60-GHz OFDM-RoF System employing In/Out Nonlinear Compensation Filtering Algorithm, Zhen-Xiong Xie, Bo-Jun Lin, Pin-Yuan Ding, Tsung-Hung Tsai, Ping-Yao Huang, Chia-Chien Chen, National Chiao Tung Univ., Taiwan; National Sun Yat-sen Univ., Taiwan. We demonstrate 2×2 MIMO 60-GHz RoF system with nonlinear compensation. The proposed In/Out Volterra nonlinear compensation not only improves data rate up to 81.37Gbps but also extends wireless distance to 42 meters with data rate of ~703Gbps.

W2A.37 High-speed Radio-on-free-space Optical Mobile Fronthaul System for Ultra-dense Radio Access Network, Pham Tien Dat, 1, Atsushi Kanno, 1, Keizo Inagaki, 2, François Rottenberg, 1, Naokatsu Yamamoto, 1, Tetsuya Takeyama, 1, National Inst. of Information and Communication Technology (NICT), Japan; 2ICTEAM Inst., Universite catholique de Louvain, Belgium; 3Waseda Univ., Japan. We present a transmission of radio signals over a seamless fiber-FSO system for ultra-dense RAN. We successfully transmitted 80-Gbps and 40-Gbps 2 × 2 MIMO FBMC-OQAM signal in the 90-GHz band over DL and UL direction.

W2A.38 81.37-Gbps 2×2 MIMO 60-GHz OFDM-RoF System Employing I/Q Nonlinear Compensation Filtering Algorithm, Zhen-Xiong Xie, Bo-Jun Lin, Pin-Yuan Ding, Tsung-Hung Tsai, Ping-Yao Huang, Chia-Chien Chen, 1National Chiao Tung Univ., Taiwan; 2National Sun Yat-sen Univ., Taiwan. We demonstrate 2×2 MIMO 60-GHz RoF system with nonlinear compensation. The proposed I/Q Volterra nonlinear compensation not only improves data rate up to 81.37Gbps but also extends wireless distance to 42 meters with data rate of ~703Gbps.

W2A.39 52.58-Gbps Fiber-wireless 60-GHz 2×2 MIMO System Integrating Optical Mode Division Multiplexing and Optical MIMO, Ping-Yao Huang, Wei-Liang Li, Tsung-Hung Tsai, Zhen-Xiong Xie, Ching-Chieh Lin, National Chiao Tung Univ., Taiwan. Optical LP01 and LP1 mode are utilized to carry 2×2 MIMO signals for 60-GHz wireless signals. The proposed system can achieve data rate of 52.58-Gbps for fiber-wireless system with 5-km FMM and 3-m air link.

W2A.40 Hybrid Fiber-optical/THz-wireless Link Transmission Using Low-cost IM/DD Optics, Francisco M. Rodrigo, 1, Ricardo Ferreira, 1, Carlos Castro, 2, Robert Eklund, 2, Thomas Merkle, 1, Colja Schubert, 1, Antonio Texeira, 1, 1IPAdvanced S.A., Portugal; 2Fraunhofer Heinrich Hertz Inst., Germany; 3Fraunhofer-Institut fuer Angewandte Festkorperephysik, Germany. A THz fiber-optical/wireless transmission of 16 GbD 16-QAM is demonstrated over 20 km of fiber. Transmission of 50-Gbps net rate is achieved using low-cost IM/DD optics and wireless front-ends operating at 306 GHz.

W2A.41 Quantum Dash Passively Mode Locked Laser for Optical Heterodyne Millimeter-wave-to-Optical Analog Radio-over-Fiber Fronthaul Systems, Amol Delmaide, 1, Theo Verelst, 2, Colm Browning, 1, Yi Lin, 1, Guy Aubin, 2, P. Lelangue, 1, Abraham Ramdane, 1, Liam Barry, 1, Dublin Digital fiber-optical/THz wireless transmission of 16 GbD 16-QAM is demonstrated over 20 km of fiber. Transmission of 50-Gbps net rate is achieved using low-cost IM/DD optics and wireless front-ends operating at 306 GHz.

W2A.42 Delivery of 138.88Gbps Signal in a RoF Network with Real-time Processing Based on Heterodyne Detection, Can Wang, 1, Xinying Li, 1, Mingmin Zhao, 1, Kaihui Wang, 1, Jiao Jiang, 1, Junwen Zhang, 1, Huaqiang Tang, 1, Yaoyun Gao, 1, Guo-Qing Zhang, 1, School of Information and Communication Engineering, Beijing Univ. of Posts and Telecommunications, China; 2School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA. We demonstrate C-band 112-Gb/s PAM4 over 20-km transmission with pre- and post-equalization. Pre-filter coarsely pre-compensates system bandwidth at transmitter while FFE-DFE with ease of transceiver nonlinearity joint post-compensates residual bandwidth limitation and dispersion-induced power fading at receiver.

W2A.43 Artificial Neural Network-Based Compensation for Transceiver Non-linearity in Probabilistic Shaping Systems, Tu T. Nguyen, 1, Tingting Zhang, 1, Mahmood Abu-Romoh, 1, Andrew Ellis, 1, Aston Univ., UK. Artificial neural network for transceiver nonlinearity compensation in dual-polarization probabilistically shaped 28 GBaud systems is experimentally investigated with achieved SNR performance gain up to 1 dB.

W2A.44 Cascade Recurrent Neuronal Network Enabled 100-Gb/s PAM4 Short-reach Optical Link Based on DML, Zhaopeng Xu, 1, Chuanbowen Sun, 1, Tonghui Ji, 1,2, Honglin Ji, 1, Wilard Qiao, 1, Gee-Kung Chang, 2, 1School of Information and Communication Engineering, Beijing University of Posts and Telecommunications, China; 2School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA. We demonstrate C-band 112-Gb/s PAM4 over 20-km transmission with pre- and post-equalization. Pre-filter coarsely pre-compensates system bandwidth at transmitter while FFE-DFE with ease of transceiver nonlinearity joint post-compensates residual bandwidth limitation and dispersion-induced power fading at receiver.

W2A.45鸭 Shaping-based Dual-band DMD and Gain Estimation in Coupled SDM Transmission, Ruby S. Bravo Opsina, 1, Chigo M. Okonkwo, 1, Dari A. Melho, 1, Eindhoven Univ. of Technology; 2Netherland Inst. of Campinas, Brazil. We model analytically the MDG/ML estimation process in coupled SDM transmission using hybrid equalizer coefficients of coherent receivers. We show that estimation errors can be partially compensated in moderate regimes of SNR and MLD/MDG.

W2A.46 Efficient Echo-cancellation Algorithms for Full Duplex Coherent Optical Systems, Xi Chen, 1, Zhensheng Zhang, 1, Junwen Zhang, 1, Huaqiang Tang, 1, Luis Alberto Campos, 2, David J. Ives, 1, Seb J. Savory, 1, University of Cambridge, UK. Power fluctuations accumulate in ROADM-free space-switched networks. Thousands of randomized nonlinear transmissions demonstrate that capacity with an inventory of [5,10,15,20]dB gain amplifiers is within 10% of optimal and triple that with [10,20]dB amplifiers over 1,000km.

W2A.47 Real Time Transmission Measurements from 200 Gbps to 600 Gbps over Links with Long 122 km Fiber Spans, John D. Downie, Jason Hurley, Xiaoqian Jiang, James Himmelreich, Sergeis Makovejev, Donald Govan, Giacomo Loris, 1Corning Research & Development Corp, USA; 2Corning Incorporated, UK; 3Lumentum, UK; 4Lumentum, Italy. We present results for real-time coherent transmission with data rates from 200 Gbps to 600 Gbps in 50 Gbps increments over a re-circulating loop with 122 km spans of ultra-low loss, large effective area fiber.

W2A.48 Long-haul and High-speed Key Distribution Based on One-way Non-dual Arbitrary Basis Transformation in Optical Fiber Link, Chao Le, 1, Jie Zhang, 1, Yajie Li, 1, Yongli Zhao, 2, Bo Wang, 2, Hang Gao, 1, Junja Li, 1, Mingrui Zhang, 2, Beijing Univ. of Posts and Telecommunications, China. We propose a long-haul and high-speed key distribution key based on one-way non-dual arbitrary basis transformation in optical fiber link. The key distribution rate of 277 kbits with free key error rate is demonstrated over 300km.
W2A.52  
A Method to Separate the Penalties Caused by Various Nonlinear Signal-pump Impairments in Raman Amplified System, Jingnan Li, Yangyang Fan, Zhenning Tao, Tong Ye, Hiroyuki Irie, Hisao Nakashima, Kou-suke Komaki, Takeshi Hoshida; Fujitsu R&D Center, China; Fujitsu Ltd., Japan. We separate various nonlinear impairments caused by pump laser RIN in Raman amplified system. Experiment shows that nonlinear polarization scattering has more impact than phase noise does, and the gain fluctuation has the least impact.

W2A.53  
On-chip Continuous-variable Quantum Key Distribution(CV-QKD) and Homodyne Detection, Yuan Shen, Lin Caof, Xuyang Wang, Jun Zou, Wei Lu, Yunxiang Wang, Hong Cai, Bin Dong, Xianhuo Luo, Weijun Fan, Leong Chuan Kwek, Aiqun Liu; Nanyang Technological Univ., Singapore; Institute of Microelectronics, Singapore; Advanced Micro Foundry, Singapore. An on-chip continuous-variable quantum key distribution(CV-QKD) system is integrated using silicon photonics fabrication process and demonstrates the capability of transceiving Gaussian-modulated coherent states and homodyne detection.

W2A.54  
Stochastic EXIT Design for Low-latency Short-block LDPC Codes, Toshiaki Koike-Akino, David S. Millar, Keisuke Kojima, Kieran Parsons; Chalmers Univ. of Technology, Sweden. We introduce a stochastic version of extrinsic information transfer (EXIT) chart which accounts for dispersion in finite-length LDPC decoding. The proposed approach can design short LDPC codes systematically, achieving about 1.2 dB gain over recently proposed scattered EXIT design.

W2A.55  
Improved Simulation Accuracy of the Split-step Fourier Method, Shen Li, Magnus Karlsson, Erik Agrell; Chalmers Univ. of Technology, Sweden. We investigate a modified split-step Fourier method (SSFM) by including low-pass filters in the linear steps. This method can simultaneously achieve a higher simulation accuracy and a slightly reduced complexity.

W2A.56  
Deployment Opportunities for DPS-QKD in the Co-existence Regime of Lit GPON / NG-PON2 Access Networks, Nemanja Vokic, Dinka Milovancev, Bernhard Schrenk, Michael Hentschel, Hannes Hübels; AIT Austrian Inst. of Technology, Austria. We demonstrate cost-effective QKD integration for GPON and NG-PON2. Operation at $5.1 \times 10^{-7}$ secure bits/pulse and a QBER of 3.28% is accomplished for a 13.5-km reach, 2:16-split PON, with 0.52% co-existence penalty for 19 classical channels.

Revolutionizing the Economics of Pluggable Optics with Silicon Photonics  
10:15–11:15, Theater II

Product Showcase  
Huawei Tech. Co.  
10:15–10:45, Theater III

NOS Keynote  
10:30–11:15, Theater I

Product Showcase  
Xilinx  
11:00–11:30, Theater III

NOS Panel I: Next Generation Access Network  
11:15–12:45, Theater I

TIP: The Disaggregated Transport Network  
11:30–13:00, Theater II

Product Showcases  
11:30–12:30, Theater III

Product Showcase  
13:00–13:30, Theater III

Cloud Network Evolution Bandwidth Drivers  
IEEE Future Directions  
13:15–14:45, Theater II

Unleashing the Full Potential of Silicon Photonics  
13:30–14:30, Theater III

NOS Panel II  
13:30–15:00, Theater I
Subsea cable capacity has been growing at a dramatic rate over the past years. Until early 2018, the main effort in meeting the demand for capacity growth is to increase the capacity per fiber pair (FP). The technology has advanced in each element of sub-marine cable building blocks: fiber design with large effective area (110, 130 and then 150 nm), high power repeater (20+ dBm) more spectral efficiency (5+ b/s/Hz) transponders broad transmission bandwidth (40nm, 72nm with C+L). However, the capacity per FP faces the Shannon limit and the power for submarine network is limited by the power feeding equipment (PFE).

Recently, the new paradigm—Spatial division multiplexing (SDM) cable has been introduced, where the number of FPs within one cable has been increased (12 FPs, 16 FPs...). The main effort shifted from maximizing the capacity per FP to maximizing the capacity per cable. During this workshop, experts will discuss the impact on each element of the submarine cable linked to the new SDM cable paradigm and will give their insight on the future of submarine communication.

**Topics to cover:**
- Definition and drivers for SDM cable in subsea cable
- SDM cable impacts on subsea cable components
  - Cable/fiber design: linear vs. non-linear regime
  - Repeater design: very high power (20+ dBm per Fiber Pair) to pumping (16-18dBm per FPs)
- Branching Unit: ROADM unit equipped with WSS vs. FPs switched BU
- SLTE: Approaching Shannon limit vs. low cost SLTE
- SDM cable impact to subsea network topology: point to point vs. mesh subsea network
- Open cable access: managed spectrum vs. managed FP as a granularity

**Speakers:**
- Tim Stronge, Telegeography, USA
- Massimiliano Salsi, Google, USA
- Priyant Mehta, Ciena, Canada
- Eduardo Mateo, NEC Corporation, Japan
- Olivier Courtois, ASN, France
- Masaaki Hirano, Sumitomo Electric Industries Ltd., Japan
- Stephen Grubb, Facebook Inc., USA
14:00–16:00
W3E • Ultra-wideband Transmission
Presider: Johannes Fischer; Fraunhofer Heinrich-Hertz-Institut, Germany

W3E.1 • 14:00
Tutorial
Ultra-wideband Transmission and High-symbol Rate Signal Handling Technologies, Fukutaro Hamaoka1; NTT Network Innovation Laboratories, Japan. This tutorial reviews the recent progress in ultra-wideband transmission techniques beyond the C and L bands and 100-200 GBaud-class high-symbol rate signal handling technologies with bandwidth multiplexers and ultra-broadband optical frontends.

Fukutaro Hamaoka received his PhD in electrical engineering from Keio University, Japan, in 2009. He is currently with NTT Network Innovation Laboratories where he is engaged in the research and development of high capacity optical transport systems with ultra-wideband wavelength division multiplexing and high-symbol rate techniques.

W3F • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 1)

W3F.1 • 14:00
Invited
Terabit Transmitters Using Heterogeneous III-V/Si Photonic Integrated Circuits, John E. Bowers1; Univ. of California Santa Barbara, USA. Heterogeneous photonic integrated circuits are being demonstrated with Tbps capacity and higher performance, with laser linewidths below 1 kHz and volumes scaled to multimillion per annum production levels.

W3F.2 • 14:20
Invited
Title to be Announced, Chris Doerr1; Acacia Communications Inc., USA. Abstract not available.

W3F.3 • 14:40
Invited
Physics Side of Silicon/Nanophotonics, Michal Lipson1; Columbia Univ., USA. Abstract not available.

W3G • Datacentre Infrastructure and Metrology
Presider: Yue-Kai Huang; NEC Laboratories America Inc, USA

W3G.1 • 14:00
Invited
More Than Communications: Environment Monitoring Using Existing Optical Fiber Network Infrastructure, Yoshiaki Aono1, Ezra Ip2, Philip JF; NEC Corporation, Japan; Optical Networking and Sensing, NEC Laboratories America, USA. We propose reusing existing optical cables in metropolitan networks for distributed sensing using a bidirectional, dual-band architecture where communications and sensing signals can coexist with weak interaction on the same optical fiber.

W3G.2 • 14:30
Automated Thermal Drift Compensation in WDM-based Silicon Photonic Multi-Socket Interconnect Systems, Mitaidis Moralis-Pegios1, Francesco Zanetto2, Emanuele Guglielmi2, Vittorio Gnavali2, Konstantinos Fotiadis3, Stelios Pitsis2, Theoni Alexoudi2, Peter De Heyn3, Yoojin Ban1, Joris Van Campenhout1, Douglas Aguiar2, Giorgio Ferrari2, Marco Sampietro2, Andrea Mellon1, Nikos Pleros1; Aristoteles Panepistimio Thessalonikis, Greece; Dipartimento di Elettronica Informazione e Bioingegneria, Politecnico di Milano, Italy; imec, Belgium. We present an on-chip AWGR-based interconnect system with automated thermal drift compensation along cascaded resonant structures in a dual-socket layout. Error-free operation in a 30 Gb/s data-routing scenario within a 12C temperature range is demonstrated.
Wednesday, 11 March

W3A • Neuromorphic III: System-oriented—Continued

W3A.4 • 15:00
Intelligent Computing with Photonic Memories, Mario Miscuglio1, Jawae Meng1, Volker Sorger2, Ludmila J. Prokopova1, Yifei Zhang1, Ömer Yesilünt2, Armin Mehrabian1, Juejun Hu1, Alexander Kildishev3,4, George Washington Univ., USA; 2Birck Nanotechnology Center, USA; 3Department of Materials Science & Engineering, Massachusetts Inst. of Technology, USA, 4School of ECE, Purdue Univ., USA. Here we propose and demonstrate photonic neural network whose neuron's non-volatile weighting functionality is realized through an engineered hybrid Ge2Sb2Se4Te1-x-based Mach-Zehnder modulator photonic memory with thermoelectrical programmability. The network can effortlessly perform inference with high accuracy at the speed-of-light.

W3A.5 • 15:15
All-optical Recurrent Neural Network with Sigmoid Activation Function, George Mourgas-Alexandris1, George Dabas1, Nikolaos Passalis1, Anastasios Tefas2, Angelina Totovic1, Nikos Pleros2, Aristotele Univ. of Thessaloniki, Greece. We demonstrate experimentally, the first all-optical recurrent-neuron with a sigmoid activation function and four WDM-inputs with 100ps pulses. The proposed neuron geared up a neural-network for financial prediction-tasks exhibiting an accuracy of 42.57% on FI-2010.

W3A.6 • 15:30
Interferometer-based Photonic Circuit Classifier Showing >90% Accuracy for Well-known Iris Dataset without Utilizing Nonlinear Activation Function, Guangwei Cong1, Noritsugu Yamamoto2, Takashi Inaue2, Yuriko Maegami2, Morfumi Chiba2, Makoto Okada2, Shu Namiki1, Koji Yamada1, 1AIST (Natl Inst of Adv Indust Sci&Tech), Japan. We demonstrate that interferometer-based photonic circuits can perform classification by only phase control even without activation functions, which can classify well-known Iris dataset with >90% accuracy in simulation, showing simple photonic implementation for machine learning.

W3B • Panel: Will SDM Truly Revolutionize the Submarine Communication Industry?—Continued

W3B.4 • 15:00
Operational Mode and Slicing Adaptation in OpenConfig Disaggregated Optical Networks, Davide Scano1, Alessio Giorgetti2, Andrea Sgambelluri3, Filippo Cugini1, Silvia Fichera1, ‘Scuola Superiore Sant Anna di Pisa, Italy. This paper proposes and experimentally validates a workflow to handle network failures implying the change of the operational mode on optical transponders. An SDN control plane is considered with a real packet-optical data plane.

W3B.5 • 15:15
Architecting Cloud-native Optical Network with Whitebox Equipment, Hideki Nishizawa1; 1NTT Network Innovation Labs, NTT Corporation, Japan. A flexible and open means of implementing an optical network by using whitebox equipment with the Transponder Abstraction Interface is proposed. Examples of automation and monitoring device/performance information using an open transport platform are described.

W3B.6 • 15:30
Compressed Nonlinear Equalizers for Optical Interconnects: Efficiency and Stability, Ling Ge1, Wenjia Zhang1, Yanci Zhang1, Chenyu Liang1, Jiangbing Du1, Zuyuan He1; 1Shanghai Jiao Tong Univ., China, 2COPL, Univ. Laval, Canada. Efficiency and stability of pruned Volterra-Series and Neural-Network Equalizers are compared in the 112-Gbps optical interconnects. The results show NNE outperforms VE at equalization performance and complexity while VE is more stable with channel variation.

W3C • Open Network Architecture—Continued

W3C.4 • 15:00
End-to-end Learning of Geometrical Shaping Maximizing Generalized Mutual Information, Kadir Gumus1, Alex Alvarado1, Bin Chen2, Christian Häger2, Erik Agrell2, 1Eindhoven Univ. of Technology, Netherlands; 2School of Computer Science and Information Engineering, Hefei Univ. of Technology, China; 3Department of Electrical Engineering, Chalmers Univ. of Technology, Sweden. GMI-based end-to-end learning is shown to be highly nonconvex. We apply gradient descent initialized with Gray-labeled APSK constellations directly to the constellation coordinates. State-of-the-art constellations in 2D and 4D are found providing reach increases up to 26% w.r.t. to QAM.

W3C.5 • 15:15
Invited
All Silicon IQ Modulator with 1Tb/s Line Rate, Sasan Zhalezpour1,2, Mengqi Guo3, Jiachuan Lin4, Zhuhong Zhang1, Yaojun Qiao1, Wei Shi1, Leslie Rusch4, 1ECE Dept., Univ. Laval, Canada; 2COPIL, Univ. Laval, Canada; 3School of Information and Communication Engineering, BUPT, China; 4Canada Research Center, Huawei Technologies Canada, Canada. By significantly improving the accuracy of our nonlinear pre-compensation digital signal processing, we achieve 1 Tbps line rate with an all silicon modulator using 32QAM modulation with dual polarization emulation.
W3E.15:00 Invited
Candidate Technologies for Ultra-wideband Nonlinear Optical Fibre Transmission System, Lidia Baldinò¹, Daniel Semrau¹, Polina Bayvel¹. This paper discusses the limitations, practicalities and possible technologies for accomplishing high-capacity broadband transmission systems beyond C+L EDFA bandwidth. It also provides a theoretical understanding of the contribution of different noise source limiting the overall system throughput.

W3F.15:00 Invited
Indium Phosphide Photonic Integrated Circuits, Meint Smit¹. Photonic integration is essential for high-performance communications and now becomes directly exploitable in sensing, metrology and imaging. InP PICs provide lasers, amplifiers, modulators and detectors in one platform, and a roadmap for higher density integration.

W3G.15:00 Top-Scored
A 0.57-mW/Gbps, 2ch x 53-Gbps Low-Power PAM4 Transmitter Front-end Flip-chip-bonded 1.3-μm LD-Array-on-Si, Toshiki Kishi¹, Munehiko Nagatani¹, Shigeru Kanazawa², Kota Shikama¹, Takuro Fujii¹, Hidetaka Nishi¹, Hiroshi Yamazaki¹, Norio Sato¹, Hideyuki Nosaka¹, Shinji Matsuo¹. A low-power 2-channel PAM4 transmitter front-end consisting of 65-nm CMOS PAM4 shunt LD drivers and flip-chip-bonded 1.3-μm LD-array-on-Si achieves simultaneous 2ch x 53-Gbps PAM4 transmission over 2-km-long SSMF with power efficiency of 0.57 mW/Gbps.

W3G.5 15:20 Invited
Computation with Optical Oscillator Networks, Hiroki Takesue¹. NTT Basic Research Labs, Japan. We discuss future perspective of a new type of computing based on networks of optical oscillators, which includes coherent Ising machines for combinatorial optimization and coherent XY machine for continuous optimization.
W3A • Neuromorphic III: System-oriented—Continued

W3B • Panel: Will SDM Truly Revolutionize the Submarine Communication Industry?—Continued

W3C • Open Network Architecture—Continued

W3D • High-speed Transmission—Continued

W3A.7 • 15:45
Demonstration of Multi-channel Feedback Control for On-chip Microring Weight Banks, Chaoran Huang1, Simon Bilodeau1, Thomas Ferreira de Lima1, Alexander Tait1, Philip Ma1, Eric Blow1, Aashu Jha1, Hsuan-Tung Peng1, Bhavin J. Shastri1, Paul Prucnal1; Princeton Univ, USA. We demonstrate a multi-channel feedback control for microring weight banks and achieve a record-high accuracy and precision. With the simplified procedures, the feedback control becomes more practical for configuring large-scale photonic networks.

16:00–16:30  Coffee Break, Upper Level Corridors and Exhibit Hall
W3E • Ultra-wideband Transmission—Continued

W3E.4 • 15:45
150nm SCL-band Transmission through 70km SMF using Ultra-wideband Dual-stage Discrete Raman Amplifier, Md A. Iqbal1, Lukasz Krzczanowicz1, Ian Phillips1, Paul Harper1, Wladek Forysiak1; 1Aston Univ., UK. We experimentally demonstrate a dual-stage 150nm discrete Raman amplifier with 15dB gain and maximum ~8dB noise figure enabling SCL-band (1475-1625nm) WDM transmission through a 70km SMF using 30GBaud PM-QPSK signals with low transmission penalties.

16:00–16:30  Upper Level Corridors and Exhibit Hall

W3F • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 1)—Continued

W3G • Datacentre Infrastructure and Metrology—Continued

New Optical Module Implementations
New High-bandwidth, Non-DSP Interface for Data Center and Campus Interconnects
15:00–16:00, Theater II

Open, Multi-vendor Networks - Design, Management and Operations
15:30–17:00, Theater III

MW Panel IV: What is Next for Data Center Interconnects (DCIs)?
15:30–17:00, Theater I

112 Gbps Electrical Interfaces
16:15–17:00, Theater II
Spectrally Slicing Coherent Optical Spectrum Analyzer Based on 2-D Arrayed Photodetectors, Yuki Yoshida, Toshimasa Umezawa, Atsushi Kanno, Keizo Inagaki, Naokatsu Yamamoto, Tetsuya Kawanishi

Field Recovery at Low CSPR Using Interleaved Carrier Assisted Differential Detection, Tonghui Ji, Chuanbowen Yao, Yuki Yoshida, Toshimasa Umezawa, 16.45

Evaluation of Performance Penalty from Pump-signal Overlap in S+C+L Band Discrete Raman Amplifiers, Md A. Iqbal, Lukasz Kziezanowicz, Ian Phillips, Paul Harper, Waedek Forysiak, Aston Univ., UK. We experimentally investigate the transmission penalty on 30GBaud PM-QPSK signals due to adjacent Raman pumps in a 15dB gain, 150nm S+C+L-band discrete Raman amplifier. We report a 4nm guard-band around the Raman pump ensures negligible Q2-penalty.

Comparison of Erbium, Raman and Parametric Optical Fiber Amplifiers for Burst Traffic in Extended PON, Chandr Bhanu Gaur, Filipe Ferreira, Vladimir Gordenko, Md A. Iqbal, Waedek Forysiak, Nick Doran, Aston Inst. of Photonic Technologies, UK. Experimental comparison of burst traffic amplification by: a polarization independent fiber optic parametric amplifier, a discrete Raman fiber amplifier and an erbium-doped fiber amplifier. Parametric amplification improves required received power by more than 3dB.

Noise Figure Evaluation of Polarization-insensitive Single-pump Fiber Optical Parametric Amplifiers, Vladimir Gordenko, Filipe Ferreira, Charles Laporte, Maurice O’Sullivan, Chandra Bhanu Gaur, Kim Roberts, Nick Doran, Aston Univ., UK; Ciena Corporation, Canada. Several polarization-insensitive configurations for single-pump phase-insensitive fiber optical parametric amplifier are experimentally evaluated using 35GBaud PDM-QPSK signals. An equivalent noise figure of 9.1±1dB is experimentally derived by comparison with a variable noise figure EDFA.
16:30–18:30
W4E • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)

W4E.1 • 16:30 Invited
Coherent Communication: Cost per Bit, Kim Roberts
"WaveLogic Science, Ciena, Canada. Digital coherent optical transmission enabled a dramatic lowering of the cost per bit in high capacity links. It is time for the next revolution! The (admittedly meager) set of candidates will be examined to see what might break through the pack of evolutionary improvements and launch us in a new direction.

W4E.2 • 16:50 Invited
Technology Evolution and Capacity Growth in Undersea Cables, Alexei N. Pilipetski, Georg Mohs; SubCom, USA. We examine the technology evolution that fueled exponential cable capacity growth over the last decades. We are at a critical point when transmission technology is maturing and approaching fundamental limits. What is the path forward?

W4E.3 • 17:10 Invited
5G Optical Transport Network, Chih-Lin I; China Mobile Communications Group, China. Abstract not available.

16:30–18:30
W4F • Reliability and Test
Presider: Kenneth Jackson; Sumitomo ELEC Device Innov USA, USA

W4F.1 • 16:30 Tutorial
Reliability Qualification and Failure Mechanisms for Semiconductor Lasers and Fiber Optic Transceivers, Robert Herrick; Intel Corporation, USA. In this tutorial, we will cover 3 topics: reliability qualification of fiber-optic transceivers, reliability testing of semiconductor lasers, and failure analysis and failure mechanisms in optoelectronics.

Robert Herrick is responsible for laser reliability at Intel’s Silicon Photonics Product Division, and has worked for Intel since 2013. After obtaining an MS EE at the University of Illinois, his career started at McDonnell Douglas, working on early OEC and high power laser R&D, where he did device modelling, mask design, and process development. After gaining an interest in reliability physics from the late Dr. Robert G. Waters, Dr. Herrick went to UCSB, and did the first studies of VCSEL degradation for his PhD dissertation with Professors Larry Coldren and Pierre Petroff. In the past 20 years, Dr. Herrick has specialized in semiconductor laser reliability and failure analysis, and has written many of the most cited papers and invited book review chapters on the subject. He has previously worked as a laser and fiber-optics transceiver reliability engineer for many of the large fiber-optics companies in Silicon Valley, including HP / Agilent, Encore, Finisar, and JDSU / Lumentum.

W4F.2 • 16:45
Si-waveguide-coupled Membrane InGaAsP-multiple-quantum-well Photodetector with Large Bandwidth at High Optical Input Power, Yoshiho Maeda; NTT Device Technology Laboratory, Japan. A Si-waveguide coupled membrane photodetector (PD) with an InGaAsP multiple-quantum-well absorption layer shows a fiber-to-PD responsivity of 0.4 A/W and bandwidth over 20 GHz at a fiber input power up to +5 dBm.

W4F.3 • 17:00
Monolithic Germanium PIN Waveguide Photodetector Operating at 2 µm Wavelengths, Ziqiang Zhao; Chongpei Ho; Qiang Li; Kasidit Toprasertpong; Shinichi Takagi; Mitsuaki Takenaka; Univ. of Tokyo, Japan. We demonstrated Ge PIN waveguide photodetector operating at 2 µm wavelengths monolithically integrated on Ge-on-insulator platform. Despite at sub-bandgap wavelength, 500-µm-long photodetector exhibited 0.25 A/W responsivity at -5 V, attributable to the defect-mediated detection mechanism.

W4F.4 • 17:15
Coherent Homodyne TDMA Receiver Based on TO-can EML for 10 Gb/s OOK with <40 ns Guard Interval, Benjamin Schrenk; Dinka Milovanovic; Nenana Volcic; Fatini Karinou;AIT Austrian Inst. of Technology, Austria; Micros Research Ltd., UK. Graceful migration of an IM/DD transmitter towards a single-polarization, analogue coherent burst-mode receiver is experimentally demonstrated for 10 Gb/s on-off keying in TDMA mode, with 400 MHz frame rate and <40 ns guard interval.
Mode-Multiplexed Full-Field Reconstruction Using Direct and Phase Retrieval Detection, Haoshuo Chen1, Juan Carlos Alvarado Zacarias1,2, Hanzi Huang1,2, Nicolas K. Fontaine1, Roland Ryf1, David Neilsen1, Rodrigo Amezua Correa1, 1 Nokia Bell Labs, USA; 2 CREOL, The Univ. of Central Florida, USA; 3 Key lab of Specialty Fiber Optics and Optical Access Networks, Shanghai Univ., China. We realize mode-multiplexed full-field reconstruction over six-spatial- and polarization modes after 30-km mode-multiplex fiber transmission using intensity-only measurements without any optical carrier. The receiver's capabilities to cope with modal dispersion and mode-dependent loss are experimentally demonstrated.

Mitigation of Inter-subcarrier Linear Crosstalk with Groupwise Fixed FDE Assisted MIMO, Masaki Sato1, Hiromi Noguchi1, Junichiro Matsui1, Juri Ichi Abe1, Naoto Ishii1, Emmanuel Le Tallandier de Gabory1, 1 System Platforms Research Laboratories, NEC Corporation, Japan; 2 NEC Corporation, Japan. We experimentally demonstrated inter-subcarrier linear crosstalk mitigation of five-subcarrier 10-Gbaud BRC-P2M-16QAM using Groupwise fixed FDE assisted MIMO. The proposed method enabled 6.3% tighter subcarrier spacing over 120 km SSMF, compared to conventional 2x2 MIMO.

Nonlinear Frequency Division Multiplexing: Immune to Nonlinearity but Oversensitive to Noise?, Stella Cevelli1, Enrico Forestieri1, Marco Secondini1, 1 Inst. of Communication, Information and Perception Technologies, Scuola Superiore Sant’Anna, Italy; 2 Photonics Networks & Technologies National Laboratory, National, Inter-Unix. Consortium for Telecommunications, Italy. Detection strategies and modulation formats designed for the AWGN channel are not well suited to operate in the nonlinear frequency domain. We study some improved detection strategies and investigate the ultimate performance limitations of NFDM systems that map conventional linear modulations on the nonlinear spectrum.
The Future of Access and Edge Cloud Integrated Networks, Peter Vetter, Nokia Bell Labs, USA. The past decade was defined by the emergence of central cloud and ubiquitous wireless broadband (via LTE and WiFi). In future, the cloud will be distributed to the edge and radio access points move closer to the end-devices. The fiber access network will evolve to a high capacity x-haul infrastructure.


We will review the reliability of specialty optical fibers for high temperature uses with an emphasis on fibers through reflow soldering process conditions. Coating thermal stability, fiber mechanical properties, and induced optical loss will be discussed.

Continued through the Next Decade (Session 2)—Invited

Effects of Reflow Soldering Process Conditions on the Reliability of Specialty Optical Fibers, Mei-Wen, Ralph Lago, Jie Li; OFS, USA. We will review the reliability of specialty optical fibers for high temperature uses with an emphasis on fibers through reflow soldering process conditions. Coating thermal stability, fiber mechanical properties, and induced optical loss will be discussed.

WEF.5 • 17:30

Uni-Traveling Carrier Photodiodes with Type-II GaAs₀.₅Sb₀.₅/In₀.₅₃Ga₀.₄₇As Hybrid Absorbers Integrated with Substrate Lens in 400 Gbit/sec DR-4 System, None Naseem, Huang-Suu Chang, Rui-Lin Chao, Jack Ja-Sheng Huang, Yu-Heng Jan, H.-S. Cheri, C.-J. Ni, Emin Chou, Jin-Wei Shi; National Central Univ., Taiwan; Source Photonics, Taiwan; Department of Photonics, National Chiao Tung Univ., Taiwan; Source Photonics, USA. UTC-PD with type-II GaAs₀.₅Sb₀.₅/In₀.₅₃Ga₀.₄₇As hybrid absorber integrated with substrate lens is demonstrated with high responsivity (0.95A/W) and wide O-E bandwidth (33GHz) at 1310 nm wavelength. High-sensitivity (-10dBm OMA) is realized in 400G lens-free DR-4 platform.

Zero-bias High-Speed Evanscently Coupled Waveguide Type-II UTC Photodiode, Fengxin Yu, Keye Sun, Qianhuan Yu, Andrea Belling; Univ. of Virginia, USA. We demonstrate GaAs₀.₅Sb₀.₅/In₀.₅₃Al₀.₄₇Ga₀.₅₃As uni-traveling carrier (UTC) waveguide photodiodes with high bandwidth of up to 66 GHz at zero bias and over 100 GHz bandwidth under low bias condition.

Highly Sensitive 56 Gbps NRZ-Oband BICMOS-Silicon Photonics Receiver using a Ge/Si Avalanche Photodiode, Srinivasan Ashwyn Srinivasan, Joris Lambrecht, Mathias Berciano, Sebastien Lardenois, Philippe Absil, Johan Bauwelinck, Xin Yin, Marianna Pantouvaki, Joris Van Campenhout; imec, Belgium; Ghent Univ., Belgium. A hybrid BiCMOS-Silicon Photonics receiver with a waveguide-coupled Ge/Si avalanche photodiode is demonstrated with OMA sensitivities of -14.4dBm for error-free operation at 50 Gbps and -18.6 dBm under the KP4-FEC limit at 56 Gbps NRZ-OOK.

Highly Sensitive 56 Gbps NRZ-O band BICMOS-Silicon Photonics Receiver using a Ge/Si Avalanche Photodiode, Srinivasan Ashwyn Srinivasan, Joris Lambrecht, Mathias Berciano, Sebastien Lardenois, Philippe Absil, Johan Bauwelinck, Xin Yin, Marianna Pantouvaki, Joris Van Campenhout; imec, Belgium; Ghent Univ., Belgium. A hybrid BiCMOS-Silicon Photonics receiver with a waveguide-coupled Ge/Si avalanche photodiode is demonstrated with OMA sensitivities of -14.4dBm for error-free operation at 50 Gbps and -18.6 dBm under the KP4-FEC limit at 56 Gbps NRZ-OOK.
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<tr>
<td>08:00–08:10</td>
<td><strong>Th1A • Advanced Design for Passive Devices</strong>&lt;br&gt;<strong>Presider: Nicolas Dupuis; IBM TJ Watson Research Center, USA</strong></td>
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<td>08:10–08:15</td>
<td><strong>Th1B • High Speed PON</strong>&lt;br&gt;<strong>Presider: Xinying Li; Corning Inc, USA</strong></td>
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<td>08:15–08:20</td>
<td><strong>Th1C • Microwave Photonics</strong>&lt;br&gt;<strong>Presider: Maurizio Burla; ETH Zurich, Switzerland</strong></td>
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<td>08:20–08:30</td>
<td><strong>Th1D • Pushing the Bit-rate in Practical Networks</strong>&lt;br&gt;<strong>Presider: Shuto Yamamoto; NTT Electronics Corp, Japan</strong></td>
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<td>08:30–08:40</td>
<td><strong>Th1E • Symposium: Fj/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)</strong></td>
<td><strong>Presider: Antonio Eira; Infinera Corporation, Portugal</strong></td>
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<td>08:40–08:50</td>
<td><strong>Th1F • AI for Reliable Networking</strong></td>
<td><strong>Presider: Shuto Yamamoto; NTT Electronics Corp, Japan</strong></td>
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**Th1A 1 • 08:00**<br>Generative Deep Learning Model for a Multi-level Nano-optic Broadband Power Splitter, Yingheng Tang; Kesuke Kojima, Toshiaki Koke-Akino, Ye Wang, Pengxiang Wu, Mohammad H. Taherzadeh, Devesh Jha, Kieran Parsons, Minghao Qi; Mitsubishi Electric Research Laboratories, USA; School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue Univ, USA. A novel Conditional Variational Autoencoder (CVAE) model with the adversarial censoring is presented to help to generate the 550nm broad bandwidth (1250nm to 1800nm) power splitter with arbitrary splitting ratio.

**Th1B 1 • 08:00**<br>100 Gbps PON L-band Downstream Transmission Using IQ-MZM CD Digital Pre-compensation and DD ONU receiver, Pablo Torres-Ferrera, Valter Ferrero, Roberto Gaudino; Politecnico di Torino, Italy. We propose a downstream direct-detection 100G-PON solution aided by chromatic dispersion digital pre-compensation using an IQ-MZM, allowing L-band operation and 29 dB power budget with low ONU complexity and without requiring single-sideband modulation.

**Th1C 1 • 08:00**<br>Low-loss LiNbO3 for MWP, Marko Loncar; Harvard Univ, USA. Abstract not available.

**Th1D 1 • 08:00**<br>Real-time Demonstration of 500-Gbps/lambda and 600-Gbps/lambda WDM Transmission on Field-installed Fibers, Hideki Maeda, Hiroki Kawahara, Kohei Saito, Takeshi Seki, Takeo Sasaki, Fukutaro Hamaoka; NTT Corporation, Japan. This paper describes recent technical challenges related to the real-time demonstration 500-Gbps/lambda and 600-Gbps/lambda in field experiments conducted on high-capacity optical transport networks. DSP-ASIC integrated real-time optical transponders are utilized.

**Th1E 1 • 08:00**<br>Saving Energy and Increasing Density in Information Processing Using Photonics, David A. B. Miller; Stanford Univ, USA. We argue energy and interconnect density in information processing can be improved by orders of magnitude using parallel free-space optical channels inside and between racks, enabled by integrated waveguide photonics, and run synchronously without time-multiplexing.

**Th1F 1 • 08:00**<br>Simultaneous Detection of Anomaly Points and Fiber Types in Multi-span Transmission Links Only by Receiver-side Digital Signal Processing, Takeo Sasai, Masanori Nakamura, Seiji Okamoto, Fukutaro Hamaoka, Shuto Yamamoto, Etushi Yamazaki, Asuka Matsushita, Yoshikaki Ksaka; NTT, Japan. We experimentally demonstrate simultaneous localization of optical excess loss points and spans with different dispersion in multi-span fiber links using a neural-network based digital backpropagation.

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**Th1A 2 • 08:15**<br>Demonstration of 3+/-.012dB Power Splitting over 145nm Optical Bandwidth in a 31-um Long 3-dB Rapid Adiabatic Coupler, Josep Fargas Cabanillas, Milos A. Popovic, Bohan Zhang; Boston Univ, USA. We experimentally validate the rapid adiabatic coupling (RAC) concept and demonstrate 50+/-.1.4% (3+/-.012dB) power splitting over a record 145nm bandwidth from either port of a 31um-long, 2x2 coupler, the widest +/-1.4%-bandwidth by a factor of 4.

**Th1B 2 • 08:15**<br>IEEE 50 Gb/s EPON (50G-EPON), Curtis Knittle; CableLabs, USA. This paper discusses the next generation of IEEE optical access, the 50 Gb/s Ethernet Passive Optical Network (50G-EPON), capable of symmetric or asymmetric rates up to 50 Gb/s while coexisting with legacy PON technologies on the same optical distribution network.

**Th1D 2 • 08:15**<br>Soft-failure Localization and Device Working Parameters Estimation in Disaggregated Scenarios, Sima Barzegar, Emanuele E. Virgilio, Marc Ruiz, Alessio Ferrari, Antonio Napoli, Vittorio Curti, Luis Velasco; Universitat Politècnica de Catalunya, Spain; Politecnico di Torino, Italy; Infinera, Germany. A soft-failure localization and key working parameters estimation system is proposed for network diagnosis and maintenance. We show that a double analysis of monitoring data and estimated working parameters greatly anticipates degradations.
Joint Optimization of Coding, Shaping and Clipping for Amplifier-less Coherent Optical Systems, Abel Lorences-Riesgo1, Fernando Guimarães1, Beatriz M. Oliveria1,2, Maria C. R. Medeiros1,2, Paulo P. Monteiro1,2; Instituto De Telecomunicações, Portugal; 1Univ. of Aveiro, Portugal; 2Univ. of Coimbra, Portugal. We experimentally demonstrate that performance of amplifier-less coherent optical systems can be significantly improved by a joint optimization of FEC coding overhead, modulation order, and signal clipping, enabling power budget gains of >1dB.

Th1G1 • 08:00
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Joint Optimization of Coding, Shaping and Clipping for Amplifier-less Coherent Optical Systems, Abel Lorences-Riesgo1, Fernando Guimarães1, Beatriz M. Oliveria1,2, Maria C. R. Medeiros1,2, Paulo P. Monteiro1,2; Instituto De Telecomunicações, Portugal; 1Univ. of Aveiro, Portugal; 2Univ. of Coimbra, Portugal. We experimentally demonstrate that performance of amplifier-less coherent optical systems can be significantly improved by a joint optimization of FEC coding overhead, modulation order, and signal clipping, enabling power budget gains of >1dB.

Parallel Bisection-based Distribution Matching for Probabilistic Shaping, Mengfan Fu1, Qunbi Zhuge1; Tong Univ., China. We propose a parallel bisection-based distribution matching for constant composition probabilistic shaping. The number of serial operations can be significantly reduced without performance loss, making it a suitable architecture for large block lengths.

Th1G2 • 08:15
Parallel Bisection-based Distribution Matching for Probabilistic Shaping, Mengfan Fu1, Qunbi Zhuge1; Tong Univ., China. We propose a parallel bisection-based distribution matching for constant composition probabilistic shaping. The number of serial operations can be significantly reduced without performance loss, making it a suitable architecture for large block lengths.

Distributed Measurement of Mode Dispersion of SDM Fibers, Shin- go Ohno1, Kunihito Toge1, Daisuke Iida1, Tetsuya Manabe1,3, Paulo P. Monteiro1,2; 1NTT Access Network Service Systems Laboratories, Japan. Nondestructive methods for measuring the mode dispersion distribution of SDM fiber that utilize Rayleigh backscattering observed with coherent optical frequency-domain reflectometry are reviewed. Experiments on few-mode and coupled multicore fibers are presented.

Th1H1 • 08:00
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Distributed Measurement of Mode Dispersion of SDM Fibers, Shin- go Ohno1, Kunihito Toge1, Daisuke Iida1, Tetsuya Manabe1,3, Paulo P. Monteiro1,2; 1NTT Access Network Service Systems Laboratories, Japan. Nondestructive methods for measuring the mode dispersion distribution of SDM fiber that utilize Rayleigh backscattering observed with coherent optical frequency-domain reflectometry are reviewed. Experiments on few-mode and coupled multicore fibers are presented.

Advanced DSP for Monitoring and Mitigation in Optical Transport Networks, Tatsuki Yoshida1, Takahito Tanamura1, Shiochiro Oda1, Setsuo Yoshida1, Hisao Nakashima1, Guoxiu Huang1, Zhenneng Tao1; 1Fujitsu Limited, Japan; 2Fujitsu R&D Center, China. DSP-based transceivers with enhanced monitoring and mitigation capabilities enable highly efficient transport networking with minimized excess margin and open line systems with enhanced availability. Examples for such advanced DSP algorithms are introduced.

Th1I1 • 08:00
Th1I1 • 08:00
Advanced DSP for Monitoring and Mitigation in Optical Transport Networks, Tatsuki Yoshida1, Takahito Tanamura1, Shiochiro Oda1, Setsuo Yoshida1, Hisao Nakashima1, Guoxiu Huang1, Zhenneng Tao1; 1Fujitsu Limited, Japan; 2Fujitsu R&D Center, China. DSP-based transceivers with enhanced monitoring and mitigation capabilities enable highly efficient transport networking with minimized excess margin and open line systems with enhanced availability. Examples for such advanced DSP algorithms are introduced.

Ever increasing demands for network bandwidth are driving the need for optical interconnects with higher data-throughputs. Early on the speed of the optical interconnects were much faster than the capabilities of the electronics feeding them. More recently, limitations in these optical interconnects has forced designers to be more creative, utilizing higher symbol rates, higher order modulation formats, space or wavelength division multiplexing schemes to achieve higher optical interconnect throughputs. Currently, with the availability of high-speed CMOS electronics, a more economical path towards higher interconnect throughputs is to increase the symbol rates. This has driven the need for optical components with wider bandwidths.

Today’s commercially deployed components, with speeds of in the range of 60GBaud, are adequate for 400Gb/s networks. But what about for 800Gb/s systems and beyond? Can the bandwidth and the efficiency of optical components be further enhanced to enable such systems? Is the analog electronics capable of supporting such bandwidths? And, what is the impact to the DSP design considering the limitation of bandwidth and ENC when the symbol rate reaches 130 GBaud and beyond?

This panel will explore the technologies available to enable such high bandwidth optical interconnects. From transmitters to receivers, this panel will examine today’s technologies and limitations and consider what options designers have for future 800Gb/s and higher network deployments.
Thursday, 12 March

Room 1A • Advanced Design for Passive Devices—Continued

Th1A.3 • 08:30 Invited Automated Optical Waveguide Design Based on Wavefront Matching Method, Toshikazu Hashimoto1, NTT Device Technology Labs., NTT Corp., Japan. There are large degrees of freedom (DOF) in the design of micro-fabricated optical circuits. This paper introduces the wavefront matching method as an automated design technique of the DOF, and its applications.

Room 1B • High Speed PON—Continued

Th1B.3 • 08:45 Symmetrical 50-Gb/s/A PAM-4 TDM-PON at O-band Supporting 26 dB+ Loss Budget Using Low-bandwidth Optics and Semiconductor Optical Amplifier, Jiao Zhang1, Kaihui Wang1, Yiran Wei1, Li Zhao1, Wen Zhou1, Jiaoguang Xiao1, Bo Liu2, Xiangjun Xin2, Jianjun Yu1, Fudan Univ., China; 2Beijing Univ. of Posts and Telecommunications, China. We experimentally demonstrated a symmetrical 50-Gb/s/A PAM-4 TDM-PON in O-band to support over 26 dB link loss budget, with the using of simple DSP and SOA. The performances of DSP and dispersion tolerance are studied.

Room 2

Th1C • Microwave Photonics—Continued

Th1C.2 • 08:30 Dual-chirp Microwave Waveform Generation by a Dual-beam Optically injected Semiconductor Laser, Pei Zhou1, Hao Chen1, Nianqiang Li1, Renheng Zhang1, Shilong Pan1, Soochow Univ., China; 1Nanjing Univ. of Aeronautics and Astronautics, China. We propose an approach to generating dual-chirp microwave waveforms based on a dual-beam optically injected semiconductor laser. Tunable dual-chirp microwave waveforms with a large time-bandwidth product are experimentally generated.

Th1C.3 • 08:45 Frequency-tunable Parity-time-symmetric Optoelectronic Oscillator Using a Polarization-dependent Sagnac Loop, Jianping Yao1, Zheng Dai1, Zhiqiang Fan1, Cheng Li1; 1Univ. of Ottawa, Canada. A frequency-tunable parity-time-symmetric optoelectronic oscillator with a single physical loop is proposed. Frequency-tunable single-mode oscillation from 2 to 12 GHz and a phase noise of -108 dBc/Hz at an offset frequency of 10 kHz is achieved.

Room 3

Th1D • Pushing the Bit-rate in Practical Networks—Continued

Th1D.2 • 08:30 Top-Scored Single-Carrier 500Gb/s Unrepeated Transmission over a Single 431km Span with Single Fiber Configuration, Xu Jian1; 1ACCE-Link, China. We demonstrate record single-carrier 500Gb/s unrepeated transmission over a single span of 431km with single fiber configuration, using optimized high-order Raman pump, forward and backward ROPAs, and optimal modulation format while using the same single ultra low loss with large effective area fiber for both signal and pumps.

Th1D.3 • 08:45 High Spectral Efficiency Real-time 500-Gb/s/carrier Transmission Over Field-installed G.654.E Fiber Link Using Forward and Backward Distributed Raman Amplification, Kohei Sato1, Takeo Sasaki1, Fukutaro Hamaoka1, Hiroki Kawahara1, Takeshi Seki1, Hideki Maeda1; 1Nippon Telegraph and Telephone, Japan. Transmission distance of 1234.2 km with high spectral efficiency of 5.71 b/s/Hz over terrestrial G.654.E fiber links is achieved for 500-Gb/s/carrier signals using EDFAs with forward and backward DRAs compliant with laser power safety requirements.

Room 6C

Th1E • Symposium: Future Photonics Devices f/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)—Continued

Th1E.2 • 08:30 Invited Integrated Green Photonics For Next-gen High-performance Computing, Di Liang1, Geza Kurczveil1, Zhihong Huang1, Binhao Wang1, Antoine Descos1, Sudharsanan Srinivasan1, Yingtao Hu1, Xiaogeng Zeng1, Wayne Sorin1, Stanley Cheung1, Songtao Liu1, Peng Sun1; 1Department of Electrical and Computer Engineering, Univ. of California, USA. We discuss our strategy to build a dense wavelength division multiplexing optical transceiver to enable high energy efficiency, scalable bandwidth, low latency data communication, and low-cost photonic integration simultaneously for high-performance computing applications.

Room 6D

Th1F • AI for Reliable Networking—Continued

Th1F.3 • 08:30 Interpretable Learning Algorithm Based on XGBoost for Fault Prediction in Optical Network, Chuanyu Zhang1, Danshi Wang1, Chuang Song1, Lingling Wang1, Jianan Song1, Luyao Guan1, Min Zhang1; 1Beijing Univ. of Posts and Telecommunications, China. We propose a fault prediction scheme using interpretable XGBoost based on actual datasets, which not only achieves high accuracy (99.72%) and low positive rate (0.18%), but also reveals the five most remarkable features that caused the fault.

Th1F.4 • 08:45 Localization of Probabilistic Correlated Failures in Virtual Network Infrastructures Using Bayesian Networks, Riti Gour1, Genya Ishigaki1, Jian Kang1, Jason P. Jue1; 1The Univ. of Texas at Dallas, USA; 2Ciena, USA. We propose an approach to localize probabilistic correlated failures in a multi-layer network where service function graphs (SFGs) are deployed over a physical network infrastructure. The proposed method utilizes logical link monitoring and Bayesian networks.
Th1G  •  Modulation and Coding—Continued

Room 6E

Th1H  •  Characterization of SDM Fibers—Continued

Room 6F

Th1I  •  Digital Signal Processing Techniques and Mitigation—Continued

Room 7

Th1J  •  Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?—Continued

Room 8

Th1K  •  Optical Wireless Sensing Systems for 5G—Continued

Room 9

**Th1G.3 • 08:30 Invited**

Performance and Power of Soft-decision FEC (SDFEC) for 100G-800G Applications, Zhiyu Xiao; Huawei Technologies Co., Ltd., USA. The proportion of resources (chip area) required by FEC in DSP chips is higher and higher. At the same time, pre-FEC performance is an explicit indicator of commercial competition. The balanced design of FEC performance, area, and power consumption becomes a key point of the DSP chip. Technologies Co., Ltd., USA.

**Th1H.2 • 08:30**

Theoretical Analysis and Experimental Measurement of Intra-LP-mode DMD in Weakly-coupled FMF, Minggai Zuo, Dawei Ge, Lei Shen, Jin He, Yongqi He, Zhangyuan Chen, Juhao Li; Peking Univ., China; Yangtze Optical Fibre and Cable Joint Stock Limited Company, China; Peking Univ. Shenzhen Institution, China. Based on the analysis of intra-LP-mode DMD in weakly-coupled FMF, we propose a modified fixed-analyzer method for its measurement and experimentally demonstrate that it may be one of the major impairments for IM/DD MDM transmission.

**Th1H.3 • 08:45 Top-Scored**

Channel Dynamics in Few-mode Fiber Transmission under Mechanical Vibrations, Georg Rademacher, Roland Ryf, Nicolas K. Fontaine, Haoshuo Chen, Benjamin J. Putfanrn, Ruben S. Lius, Yoshinari Awaqi, Hideaki Furukawa, Naoya Wada; National Inst of Information & Comm Tech, Japan; Nokia Bell Labs, USA. We experimentally investigate the coupling dynamics of a three-mode fiber recirculating transmission link under the influence of controlled mechanical vibrations. The dynamics are found to be more prominent compared to similar measurements in single-mode fiber.

**Th1I.2 • 08:30**

Mitigating Fiber Nonlinearities by Short-length Probabilistic Shaping, Tobias Fehlenberger, Helmut Griesser, Jörg-Peter Elbers; ADVA, Germany. We show that short-length probabilistic shaping reduces nonlinear interference in optical fiber transmission. SNR improvements of up to 0.8 dB are obtained. The shaping gain vanishes when interleaving is employed and not undone before transmission.

**Th1I.3 • 08:45**

True Equalization of PDL in Presence of Fast RSOP, Nan Cui, Xiaoguang Zhang, Naxian Zhang, Xianfeng Tang, Lixia Xi; State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. In presence of fast RSOP, a true PDL equalization including both signal power and OSNR balances is proposed and verified. With 1dB OSNR penalty, it can equalize up to 7dB PDL under 1Mrad/s fast RSOP.

**Th1K.2 • 08:30**

Dual-heterodyne Mixing Based Phase Noise Cancellation for Long Distance Dual-wavelength FMCW Lidar, Minglong Pu, Weilin Xie, Yi Dong, Yuxiang Feng, Wei Wei, Yuanhuai Bai, Yinxia Meng, Ling Zhang, Tao Wang, Songhan Liu; Beijing Inst. of technology, China. A coherent dual-wavelength frequency-modulated continuous-wave (FMCW) lidar utilizing dual-heterodyne mixing which permits efficient phase noise cancellation has been proposed. Consistent ranging resolution about 1.4 × 10−6 over distances beyond tens of intrinsic coherence length is achieved.

**Th1K.3 • 08:45**

Secure Free-space Optical Communication via Amplified Spontaneous Emission (ASE), Hanzi Huang1,3, Jian Chen1, Haoshuo Chen1, Yetsan Huang1,2, Yingchun Li, Yingxiong Song; Nicolas K. Fontaine, Roland Ryf, Min Wang; Shanghai Univ., China; Nokia Bell Labs, USA. We propose a secure free-space optical (FSO) communication scheme employing the internal randomness of amplified spontaneous emission. 60-Gbit/s FSO transmission is demonstrated with temporal and spectral encryption.
Ultra-broadband and Low-loss Polarization Beam Splitter on Silica. Chenlei Li1, Daoxin Dai2, John E. Bowers1; 2Zhejiang Univ., China; 3Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA. We realized a polarization beam splitter with low loss of <1 dB and high extinction ratio of >20 dB in an ultra-wide bandwidth from 1400nm to 1700nm using a pair of cascaded dual-core adiabatic tapers.

Th1B.4 • 09:00
Demonstration of 50-Gb/s/s A-PAM-4 PON with Single-PD using Polarization-insensitive and SSB Suppressed Heterodyne Coherent Detection. Li Haibo1, Ming Luo1, Xiang Li1, Shaohua Yu1; 1China Information and Communications Technology Group Corporation, China. A polarization-insensitive heterodyne coherent detection with single-PD for 50-Gbaud/s A-PAM-4 PON is experimentally demonstrated. Over 40- and 39-dBm power budgets are achieved after 20-/50-km SSMF transmission under 7% FEC threshold, respectively.

Th1C.4 • 09:00
New Opportunities for Integrated Microwave Photonics. David Marpaung1; 1Universiteit Twente, Netherlands. In this tutorial I will discuss recent developments and new perspectives in the field of integrated microwave photonics, with the emphasis on optical comb sources, high speed modulators, and photon-photon interactions for advanced signal processing.

Th1D.4 • 09:00
Added Value of 90 GBaud Transponders for WDM Networks. Thierry Zam1, Bruno Lavigne1, Mathieu Lefrançois1; 1Nokia Corporation, France. We quantify the benefit of 90 GBaud transponders versus the more mature 67 GBaud ones to possibly improve the maximum total throughput in WDM networks and the associated amount of deployed equipment per transmitted Gbit/s.

Th1E.4 • 09:00
Tutorial Densely Integrated Electronic-photonics Systems for Next-generation Optical I/O. Mark Wade1; 1Ayer Labs, USA. Abstract not available.

Th2A.5 • 09:15
Wavefront-matching-method-designed Six-mode-exchanger Based on Grating-like waveguide on Silica-PLC platform. Takeshi Fujisawa1, Taji Sakamoto2, Masashi Miyata2, Takashi Matsui2, Ryoichi Kasahara2, Kazuhide Nakajima2, Kunimasa Saitoh1; 1Hokkaido Univ., Japan; 2III-V Lab, Japan. A sixth-mode exchanger based on one sidewall grating-like waveguide is successfully designed with the help of strong optimization algorithm. Fabricated device compensates for mode-dependent-loss caused by fiber-waveguide junctions, showing the proof-of-concept operation.

Th2B.5 • 09:15
The Impact of Transmitter Chip Parameter on the Power Penalty and Design of 50 Gbit/s TDM-PON. Robert Borkowski1, Harald Schmuck1, Giancarlo Cerulo1, Jean-Guy Provost1, Vincent Houtsma1, Dora van Veen1, Ed Harsteed1, Franck Mallecot1, Rene Bok1; 1Nokia Bell Labs, Germany; 2VLT, joint laboratory between Nokia Bell Labs, Thales Research and Technology, and CEA Leti, France; 3Nokia Bell Labs, USA; 4Fixed Networks Division, Nokia Corporation, USA. We study the impact of transmitter chip parameter (effective α-factor) on the chromatic-dispersion-induced power penalty in 50-Gbit/s TDM-PON. We experimentally show interplay of chip and dispersion using 50Gc integrated EML-SOA driven in distinct operating points.

Th2C.5 • 09:15
100-Gbit/s/s A-PAM-4 Signal Transmission over 80-km SSMF Based on an 18-GHz EML at O-band. Kaishui Wang1, Jiao Zhang1, Yiran Wei1, Li Zhao1, Wen Zhou1, Mingming Zhao2, Jiannan Xiao1, Xiaolong Pan2, Bo Liu1, Xiangjun Xin1, Liwei Zhang1, Yun Zhang1, Jianjun Yu1; 1Fudan Univ., China; 2Beijing Univ. of Posts and Telecommunications, China; 3ZTE Corporation, China. For the first time, we experimentally demonstrate 100-Gbit/s/s A-PAM-4 signal transmission over 80km at O-band using an 18-GHz EML. After two spans of SOA-based 40-km SSMF transmission, a receiver sensitivity of -17.3dBm is achieved.

Th2D.5 • 09:15
Can You Trust AI-assisted Network Automation? A DRL-based Approach to Mislead the Automation in SD-IP-oEONs. Miin Wang1, Siq Liu1, Zuqing Zhu1; 1Univ of Science and Technology of China, China. We study the vulnerability of artificial intelligence assisted network automation (AIaNA), and design a deep reinforcement learning (DRL) model to mislead the AIaNA in software-defined IP over elastic optical networks (SD-IPoEONs) through crafting/injecting adversarial traffic samples.

Th2E.5 • 09:15
Tutorial Optical Technologies (Session 2)—Continued

Th2F.5 • 09:15
Demonstration of Fault Localization in Optical Networks Based on Knowledge Graph and Graph Neural Network. Zhiyong Li1, Yongqi Zhao1, Xiangx Please note that the text continues beyond the page provided.
Th1G.4 • 09:00 Hierarchical Distribution Matching: a Versatile Tool for Probabilistic Shaping, Stella Cevelli1, Marco Secondini2,3; 1Scuola Superiore Sant’Anna, Italy; 2Photonic Networks & Technologies National Laboratory, CNIT, Italy. The hierarchical distribution matching (Hi-DM) approach is described for probabilistic shaping is proposed. The potential of Hi-DM in terms of trade-off between performance, complexity, and memory illustrated through three case studies.

Th1H.4 • 09:00 Characterization and Optical Compensation of LP01 and LP11 Intra-modal Nonlinearity in Few-Mode Fibers, Francesco Da Ros1, Pawel M. Kaminski1, Georg Rademacher1, Benjamin J. Putnam1, Ruben S. Luís1, Werner Klaut1, Hideaki Furukawa1, Ryo Maruyama1, Kazuhiro Aikawa1, Toshio Morita1, Leif Oxenløwe1, Naoya Wada1, Michael Galili1; 1DTU Fotonik, Denmark; 2Photonic Network System Laboratory, National Inst. of Information and Communications Technology, Japan; 3Fujikura Ltd, Japan. Intra-modal four-wave mixing (FWM) and all-optical compensation by optical phase conjugation is investigated over 2-spans of 3-mode fiber with the power of the generated FWM products reduced by 5 to 20 dB in different scenarios.

Th1G.5 • 09:15 Multi-dimensional Distribution Matching for Probabilistically Shaped High Order Modulation Formats, Menglan Fu1, Qiaoya Liu1, Xiaobao Zeng1, Ywen Wu1, Lin Li1, Weisheng Hu1, Qunbi Zhuge1; 1Shanghai Jiao Tong Univ., China. We propose a multi-dimensional distribution matcher for probabilistically shaped high order modulation format. Compared to product distribution matching, 0.3 dB and 0.1 dB gains are obtained with the same complexity and 50% lower complexity, respectively.

Th1H.5 • 09:15 Mode Group Resolved Analysis of Effects Induced by Macro Bending in a 50 μm Graded Index Multi Mode Fiber, Christian M. Sprensen1, Peter M. Krummrich1, 1TU Dortmund, Germany. The influence of macro bending in a 50 μm GIMMF is investigated in terms of losses and mode coupling. The results indicate that lower order mode groups are weakly influenced by macro bends.

Th1J.4 • 09:00 Invited Extreme Values in Optical Fiber Communication Systems, Seb J. Savory1; 1Univ. of Cambridge, UK. Extreme value theory provides a framework to assess rare but extreme events such as network outages or cycle slips. We present the theory of extreme value statistics and its application to optical fiber communication systems.

Th1K.4 • 09:00 Simultaneous Optical Fiber Sensing and Mobile Front-haul Access over a Passive Optical Network, Yue-Kai Huang1, Ezra Ip1; 1NEC Laboratories America Inc, USA. We demonstrate a passive optical network (PON) that employs reflective semiconductor optical amplifiers (RSOAs) at optical network units (ONUs) to allow simultaneous data transmission with distributed fiber-optic sensing (DFOS) on individual distribution fibers.
Th1A.6 • 09:30 Invited
Deep Neural Networks for Designing Integrated Photonics, Keisuke Kojima1,2, Mohammad H. Tahersima1, Toshiaki Koike-Akino1, Devesh Jha1, Yingheng Tang1,2, Kieran Parsons2, Fengqiao Sang, Jonathan Klamkin1, 1Mitsubishi Electric Research Laboratories, USA; 2Electrical and Computer Engineering Dept., Univ. of California, Santa Barbara, USA.
We present our two inverse design activities for nanophotonic devices. In the first framework, a trained deep neural network takes device responses as inputs and device parameters for outputs. In the second framework, we use a novel generative network to generate a series of designs nearly meeting the device responses.

Th1B.6 • 09:30 Top-Scored
50G PON FEC Evaluation with Error Models for Advanced Equalization, Amtkumar Mahadevan1, Dora van Veen1, Noriaki Kaneda2, Alex Duque3, Adriaan de Lind van Wijngaarden1, Vincent Houtsma1; 1Nokia Bell Labs, USA.
Post-equalization bit-errors from ISI-impaired 50G PON transmission experiments are modeled using Fritchman’s Markov chain. LDPC FEC evaluation with this error model reveals a 0.3-0.6 dB optical power penalty for equalizing ISI including 83 ps/nm dispersion.

Th1D.6 • 09:30 Invited
Coherent Technologies and Requirements in Next-generation MSO Networks, Matthew Schmitt1; 1CableLabs, USA.
Cable MSO networks are undergoing a fundamental shift from centralized to distributed architectures, and from analog to digital optics. Interoperable coherent optics based on CableLabs specifications can serve as a key part of that transition.

Th1E.4 • 09:30 Invited
Integrated Photonics for High Performance Computing, Yichen Shen1; 1Lightelligence, USA.
I will talk about new architectures based on Photonic Integrated Circuits for carrying out machine learning and other statistical processing tasks. I will discuss our recent progress, the opportunity and challenges on how it can enable next generation computing hardware.

Th1B.7 • 09:45
Low-bandwidth Sub-nyquist A/D Conversion in Delay-division Multiplexing OFDM PONs Enabled by Optical Shaping, Wei-Lun Chen1, Min Yu1, Lu-Yi Yang1, Chia Chien Wei1, Chun-Ting Lin2; 1National Sun Yat-Sen Univ., Taiwan; 2National Chiao Tung Univ., Taiwan.
Optical shaping is proposed to reduce the required analog bandwidth of low-sampling-rate A/D conversion in a DDM-OFDM-PON. It successfully enabled the detection of 7.5-GHz/28-Gb/s downstream using low-bandwidth (1.7 GHz) and sub-Nyquist-sampling (3.75 GSa/s) A/D conversion.
Probabilistic Constellation Shaping for the Nonlinear UVLC Channel, Peng Zou, Fangchen Hu, Guoqiang Li, Nanze Hu, Xinzhou Su, Ahmed Zou, Junho Cho, Qinyang Yu, Steve Corte-Bligos1, Ingmar Land1; ‘Huawei Technologies France SASU, France.

We propose staircase codes based on non-systematic polar codes, describing a general framework for encoding and decoding, and presenting simulation results showing the effectiveness of the proposed approach even with short component codes.

Top Scored
Staircase Construction with Non-systematic Polar Codes, Carlo Condi1, Valerio Bioglio1, Ingmar Land1; ‘Huawei Technologies France SASU, France.

We propose staircase codes based on non-systematic polar codes, describing a general framework for encoding and decoding, and presenting simulation results showing the effectiveness of the proposed approach even with short component codes.

Rate-adaptive Concatenated Polar-Staircase Codes for Data Center Interconnects, Tayyab Mehmood1, Metodi P. Yankov1, Anders Fisker2, 1Technical Univ. of Denmark, Denmark; 2Zeuxion, Denmark.

We experimentally demonstrate an approach for monitoring misalignment between transmitter and receiver for free space optical links under turbulence effects using the beating of two opposite-order orbital-angular-momentum beams on two different wavelengths.
10:30–12:30
Th2A • Poster Session II

Th2A.1 100-Gb/s 100-m Hollow-core Fiber Optical Interconnection at 2-micron Waveband by PS-DMT, Weihong Shen1, Jiangbing Du1, Lin Sun1, Chang Wang1, Ke Xu1, Baile Chen1, Zuyuan He1; ‘Shanghai Jiao Tong Univ., China; ‘Harbin Inst. of Technology, China; ‘Shanghai Tech Univ., China. 2-micron waveband optical interconnection at record-high-speed of 100 Gb/s/lane with 100 m hollow-core photonic bandgap fiber transmission is achieved. Mode-dependent bandwidth restriction is well optimized by probabilistically shaped discrete multi-tone (PS-DMT) modulation.

Th2A.2 High Power Integrated Laser for Microwave Photonics, Jørn P. Eppinging1, Ruud M. Odenbeuving1, Dimitri Geskus1, Zuyuan He1, Ilka Visscher1, Robert Grootjans1, Rene Heideman1, Rafael Rakich1, Helmut Griesser1, Stephan Pachnicke2, Peter Ossieur1, Johan Bauwelinck1, Keisuke Kasai1,2, Joris Lambrecht1, Michiel van Exel1,2, Joris Laureys1, ‘Hokkaido Univ., Japan; ‘Universität zu Kiel, Germany. We present a hybrid integrated laser with two gain sections coupled to one tunable cavity. The resulting laser has a record on-chip power of up to 20.7 dBm and an intrinsic linewidth of 320 Hz.

Th2A.3 Lifetime Prediction of 1550 nm DFB Laser Using Machine Learning Techniques, Khouloud Abbeldi1,2, Danish Rafique1, Helmut Gniesser1, Stephan Pachnicke2; ‘ADIVA Optoelectronics Networking SE, Germany; ‘Christian-Albrechts-Universität zu Kiel, Germany. A novel approach based on an artificial neural network (ANN) for lifetime prediction of a 1.55 µm InGaAsP MQW-DFB laser diode is presented. It outperforms the conventional lifetime projection using accelerated aging tests.

Th2A.4 High Power External Pluggable Laser Bank with Simultaneous Single Mode Optical and Electrical Connection, Benbo Xu1, Rui Li1, Yanbo Li2, Xiaolu Song3, ‘Huawei Co Ltd, China. We demonstrate a pluggable laser bank module with B-channel single-mode optical output and a maximum power of 18.5 dBm per channel. The hot pluggable modules support sufficient link-budget for a 1.6 Tbps silicon photonic chip.

Th2A.5 Characterization of Modal-chromatic Dispersion Compensation in 400GBase-SR8 Channels, Bulent Kase1, Jose Castro1, Rick Pimpinella1, Yu Huang1, Fei Jia1, Brett Lane1; ‘Panduit, USA. We evaluate impact of OM4 dispersion compensated fiber on 8x50Gb/s transmission for reaches up to 500m. Bit error rates, and eye diagrams before and after equalization are evaluated.

Th2A.6 A Tunable Mode Divider Based on Wavelength Insensitive Coupler Using Thermo-optic Effect for Gain-equalization in MDM Network, Kodai Nakamura1, Takeshi Fujisawa1, Taiki Sakamoto1, Takashi Matsumi1, Kazuhide Nakajima1, Kunitasa Sai1, ‘Graduate School of Information Science and Technology, Hokkaido Univ., Japan; ‘NTT Access Network Service Systems, NTT corporation, Japan. A tunable TE, TM mode divider based on wavelength-insensitive-coupler is experimentally demonstrated for the first time. Arbitrary branching ratios can be realized by using thermo-optic heaters. The proposed device is useful for gain-equalization in MDM networks. © 2020 The Authors

Th2A.7 High-performance Microring-assist ed Space-and-wavelength Selective Switch, Yishen Huang1, Qixiang Cheng1, Anthony Rizzo1, Kerren Bergman1; ‘Columbia Univ., USA. We introduce a novel design of space- and wavelength-selective switch using microring-assisted Mach-Zehnder interferometers. A 2x2x2 elementary switch block is demonstrated with full spatial and wavelength switching capabilities, showing 20dB crosstalk suppression and 19dB extinction ratio.

Th2A.8 Large-area Metalsens Directly Patterned on a 12-inch Glass Wafer Using Immersion Lithography for Mass Production, Qize Zhong1, Yuan Dong1, Dongdong Li1, Nanxi Sun1, Chang Wang1, Ke Xu2, Baile Chen1, ‘Shanghai Jiao Tong Univ., China; ‘College of Information Science and Technology, Nanjing Univ., China. We demonstrate a pluggable hot pluggable module with 8-channel single-mode optical output and a maximum power of 18.5 dBm per channel. The hot pluggable modules support sufficient link-budget for a 1.6 Tbps silicon photonic chip.

Th2A.9 CWDM Mux/Demux Passive Optical Interconnect, Darrell Childers1, Dirk Schoellner1, DJ Hastings1, Ke Wang1, Paul Rosenberg1, Gregg Combs1, Kent Devenson1; ‘US ConneC Ltd, USA; ‘HPE Hewlett Packard Labs, USA; ‘Hewlett Packard Enterprise, USA. A novel concept for integrating the multiplex/mux functionality of coarse wavelength division multiplexing (CWD) into passive fiber optic connectors via expanded beam facilitates is presented, including optical modeling and preliminary empirical results.

Th2A.10 Multilayer Silicon Nitride-based Coupler Integrated into a Silicon Photonics Platform with <1 dB Coupling Loss to a Standard SMF over O, S, C and L optical bands, Ravi Tummidi3, Mark Webster3; ‘Cisco Systems, USA. We experimentally demonstrate <1 dB coupling loss over O,S,C and L optical bands for both polarizations between an integrated silicon photonics platform and butt-coupled standard single mode fiber.

Th2A.11 Electro-Optic Frequency Response Shaping in High Speed Mach-Zehnder Modulators, Laurent Breyne1, Joris Lambrecht1, Michael Verplaetse1, Xin Yin1, Gunther Roelkens2, Peter Ossieur1, Johan Bauwelinck1, IDLab, Ghent Univ. - imec, Belgium; ‘Photonics Research Group, Ghent Univ. - imec, Belgium. We demonstrate a simple technique to shape the electro-optic frequency response of high-speed TW-MZMs. C-band transmission of 56Gb/s NRZ over 3km SSMF shows SdP power penalty improvement at KP4- FEC between a standard and shaped MZM design.

Th2A.12 A High Linear Silicon Mach-Zehnder Modulator by the Dual-series Architecture, Qiang Zhang1,2, Hui Yu1, Zhilei Fu1, Penghui Xia1, Xiaofei Fu1, Vladimir Bliznetsov1, Hou-Jang Cho1, Vladimir Bliznetsov1, Qingyu Lin1, Navab Singh1; ‘National Sun Yat-Sen Univ., Taiwan; ‘Nanjing Univ. (Suzhou) High-Tech Inst., China. We report a 10-nm wide tunable in-series DFB laser array with high wavelength-spacing uniformity and high single-mode stability, which is guaranteed by high precision control of grating phase error through reconstruction-equivalent-chip technique.

Th2A.13 Timing Jitter from Optical Phase Noise in Quantum Dot Coherent Comb Laser at C-band, Yuxin Mao1, Zhenguo Lu1, Jiarui Lu1, Guo- cheng Liu1, Chunyaing Song1, Philip Poole1; ‘National Research Council Canada, Canada. Timing jitter obtained from optical phase noise is investigated in InAs/InP quantum dot Fabry-Pérot coherent comb lasers with 11, 25, and 4.5 GHz pulse repetition rates. These lasers exhibit ultra-low timing jitter making them excellent sources for tens terabit optical networks.

Th2A.14 10 Gbps, 6.2 ps Transform-limited Coherent Optical Pulse Generation from a 1.55 µm, Self-injection Gain-switched DFB-LD, Keisuke Kasai1, Masataka Nakazawa1, Tohoku Univ., Japan. We demonstrate coherent optical pulse generation from a 1.55 µm, self-injection gain-switched DFB- LD using ultra-low optical spectral shaping, we generated a transform-limited 10-GHz, 6-ps Gaussian-pulse, which had nearly repetitive longitudinal modes with a 7 kHz-linewidth.

Th2A.15 10-nm-wide Tunable In-series Laser Array with High Single-mode Stability, Zhenguo Sun1, Baile Chen1, Zhirui Su1, Gen Li1, Zhao Chen1, Jilin Zheng1, Yunshan Zhang1, Jun Lu1, Yuechun Shi1, Yijen Chui1, Xiangfei Cheng1, Key Laboratory of Intelligent Optical Sensing and Manipulation of the Ministry of Education & National Laboratory of Solid State Microstruc tures & College of Engineering and Applied Sciences & Inst. of Optical Communication Engineering, Nanjing Univ., China; ‘School of Electronic and Electrical Engineering, Wuhan Textile Univ., China; ‘Inst. of Electro-Optical Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan; ‘Nanjing Univ. (Suzhou) High-Tech Inst., China. We report a 10-nm wide tunable in-series DFB laser array with high wavelength-spacing uniformity and high single-mode stability, which is guaranteed by high precision control of grating phase error through reconstruction-equivalent-chip technique.

Th2A.16 Low Parasitic Capacitance III-V/Si Hybrid MOS Optical Modulator toward High-speed Modulation, Qiang Li1, Chongguo Ho1, Junichiro Fujikata1, Masatake Nagoh1, Shigeaki Takahashi1, Keisuke Takasugi1, Key Laboratory of Intelligent Optical Sensing and Manipulation of the Ministry of Education & National Laboratory of Solid State Microstructures & College of Engineering and Applied Sciences & Inst. of Optical Communication Engineering, Nanjing Univ., China; ‘School of Electronic and Electrical Engineering, Wuhan Textile Univ., China; ‘Inst. of Electro-Optical Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan; ‘Nanjing Univ. (Suzhou) High-Tech Inst., China. We report a 10-nm wide tunable in-series DFB laser array with high wavelength-spacing uniformity and high single-mode stability, which is guaranteed by high precision control of grating phase error through reconstruction-equivalent-chip technique.
Designs maximizing the effective index grading for rectangular core fibers in Israel.

ungsik Yu 1; coating process for the cavity surface. Show the potential for the novel metal using laser-induced photothermal effect, Cavities Fabricated by Laser-Induced Ultra-small Optical Fiber Fabry-Pérot Th2A.20 to Raman Soliton Supported by 1000-nm IR Supercontinuum Due Attenuation loss of the MCF made by cost reduction and higher productivity. Multicore Fiber Fabricated by Modifying MCF made by MCM is 0.190dB/km at 1550nm.

1000-nm IR Supercontinuum Due to Raman Soliton Supported by Four-wave Mixing, Marina Zajunina, 1; Astron Inst. of Photonic Technologies, Aston Univ., UK. Simple, low-cost, and robust telecom-fiber-based single-pass system is introduced and numerically studied to generate a supercontinuum ranging from 1500 nm to 2500 nm despite the optical loss due to infrared absorption in optical fibers.

Tingjun Chen 1, Jiakai Yu 3, Cedric Comes Next? 10:30–12:00, Theater I

Beyond 400ZR….What Comes Next? 11:00–12:00, Theater III System Evaluation of On-Board Optics 11:30–12:30, Theater II

3D-sensing Uses in Consumer and Automotive Markets 12:15–13:30, Theater III

Market Watch Panel VI: Advanced Packaging and Photonic Integration 12:30–14:00, Theater I

Transforming Network Operations through Automation 12:45–13:45, Theater II

POPTO Symposium 13:45–14:45, Theater III

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Th2A.17 Multicore Fiber Fabricated by Modified Cylinder Method, Masanori Takashita1, Koichi Maeda 1, Ryuchi Sugizaki1, Masayoshi Tsukamoto1, Fujukawa Electric, Japan. MCF made by modified cylinder method (MCM) is demonstrated. Optimized cylinder with single hole show potentials for cost reduction and higher productivity. Attenuation loss of the MCF made by MCM is 0.190dB/km at 1550nm.

Th2A.18 Refractive Index Grading Optimization for Rectangular Core Fibers, Ali Rechtman1, Dan M. Ramon, 1; Hebrew Univ. of Jerusalem, Israel. We optimize the refractive index grading for rectangular core fibers in single-mode optical fibers. Designs maximizing the effective index separations for MIMO-less speech and others minimizing the differential group delays are identified.

Th2A.20 Ultra-small Optical Fiber Fabry-Pérot Cavities Fabricated by Laser-Induced Photothermal Effect, Jiwon Choi1, Gyeongho Sun, 1; Yeonghoon Jin1, Kyungsuk Yu1, KAIST, South Korea. We proposed the HF etching method using laser-induced photothermal effect and found that curvatures of cavities can affect its Q-factor. We also showed the potential for the novel metal coating process for the cavity surface.

Th2A.21 Twining Plant Inspired Pneumatic Soft Robotic Spiral Gripper with High-birefringence Fiber Optic Sensor, Mei Yang1, Liam Cooper1, Mable P. Fok1, 1; Univ. of Georgia, USA. Twining plant-inspired pneumatic soft-robotic spiral gripper embedded with a high-birefringence fiber-optic sensor is designed and demonstrated. The fiber-optic sensor enables the spiral-gripper to sense the twining angle and target cylinder radius as small as 1mm.

Th2A.22 Wavelength-tunable PT-symmetric Single-longitudinal-mode Fiber Laser with a Single Physical Loop, Jinping Yao1, Zheng Dai1, Zhigang Fan1, 1; Univ. of Ottawa, Canada. A wavelength-tunable parity-time (PT)-symmetric single-longitudinal-mode fiber laser with a single physical loop is demonstrated. Single-longitudinal-mode lasing with a tunable range from 1549.2 to 1550.3 nm and a linewidth of 670 Hz is achieved experimentally.

Th2A.23 A Frequency Digital Pre-distortion Compensation Method for MFW LiDAR System, Ting-Hui Chen1, Chien-Yang Huang1, Tim Kuei Shia1, Sin-Jhu Wun1, 1; Chien-Ying Huang1, Tim Kuei Shia1, Sin-Jhu Wun1, 1; Columbia Univ., USA. We propose to sense the twining angle and target cylinder radius as small as 1mm.

Th2A.24 Enabling the Scalability of Industrial Networks by Independent Scheduling Domains, Konstantinos (Kostas) Christodoulopoulos1, Wolfram Lautenschlaeger1, Florin Klitzk1, Niel D. Benzaouia1, Torben Henke1, Ulrich Gebhard1, Lars Dembeck1, Armin Lechler2, Yvan Pointurier1, Sebastien Bigio1, 1; Nokia Bell Labs Germany, Germany. Use of Optical Information, Key Laboratory of Luminescence and Optical Information, Ministry of Education, Beijing Jiaotong Univ., China, 2; Photonic Research Group, Ghent Univ. - IMEC, Belgium, 3; Univ. of Paris-Saclay, and Univ. of Lorraine, France. We theoretically simulate the threshold plasticity of a high-Q-factor silicon-on-insulator microring resonator integrated with VO2. The proposed structure can perform excitatory and inhibitory learning by tuning the initial working condition.

Th2A.25 Experiments on Cloud-RAN Wireless Handover Using Optical Switching in a Dense Urban Testbed, Artur Minakhmetov1, Craig Gutterman2, Tingjun Chen1, Jaikai Yu3, Cedric Comes Next? 10:30–12:00, Theater I

Beyond 400ZR….What Comes Next? 11:00–12:00, Theater III System Evaluation of On-Board Optics 11:30–12:30, Theater II

3D-sensing Uses in Consumer and Automotive Markets 12:15–13:30, Theater III

Market Watch Panel VI: Advanced Packaging and Photonic Integration 12:30–14:00, Theater I

Transforming Network Operations through Automation 12:45–13:45, Theater II

POPTO Symposium 13:45–14:45, Theater III

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Th2A.26 Threshold Plasticity of Hybrid Si-VO2 Microring Resonators, Zhi Wang1, Giang Li, Ziling Fu, 1, Andrew Katnumba1, Florian Denis-Ile Coarer1, Damion Rontani1, Marc Sciamanna2, Peter Bienstman3, 1; Inst. of Optical Information, Key Laboratory of Luminescence and Optical Information, Ministry of Education, Beijing Jiaotong Univ., China, 2; Photonic Research Group, Ghent Univ. - IMEC, Belgium, 3; Univ. of Paris-Saclay, and Univ. of Lorraine, France. We theoretically simulate the threshold plasticity of a high-Q-factor silicon-on-insulator microring resonator integrated with VO2. The proposed structure can perform excitatory and inhibitory learning by tuning the initial working condition.

Th2A.27 Experimental Demonstration of Optical Multicast Packet Transmissions in Optical Packet/Circuit Integrated Networks, Yusuke Hirota1, Sugang Xu1, Masaki Shiwara1, Yoshinari Awaji1, Massimo Torbore1, Biswanath Mukherjee1, Hideaki Furukawa2, Naoya Wada2, 1; National Inst. of Information and Communications Technology, Japan, 2; Univ. of California, Davis, USA, 3; Politecnico di Milano, Italy. We develop an SDN-based control for optical-multicast packet transmission and experimentally demonstrate multicast functionality by validating it using an application-layer network service for efficient content duplication in Optical Packet/Circuit Integrated (OPC) network.

Th2A.28 Adaptive DNN Model Partition and Deployment in Edge Computing-enabled Metro Optical Interconnection Network, Mingze Liu1, Yajie Li1, Yongli Zhao1, Hui Yang1, Jie Zhang1, 1; Beijing Univ. of Posts and Telecommunications, China. A DNN model partition and deployment algorithm is proposed between edge nodes and cloud in metro optical network. Simulation results show that the algorithm can deploy more DNN tasks with the same network resource.

Th2A.29 DeepCoop: Leveraging Cooperative DRL Agents to Achieve Scalable Network Automation for Multi-Domain 5G-EOCs, Baobao Li1, Zuqing Zhu1, 1; Univ. of Science and Technology of China, China. We design DeepCoop to realize service provisioning in multi-domain software-defined elastic optical networks (SD-EOCs) with cooperative deep reinforcement learning (DRL) agents.
Th2A.37 Comparison of PAM Formats for 200 Gb/s Short Reach Transmission using a 400-Gb/s Clock Recovery and 500-Gb/s PAM4 Configuration Selection Heuristics. A novel clock recovery scheme using 850-nm laser-based wavelength division multiplexing is proposed, which outperforms its PM-16QAM counterpart by 0.7-dB for required receive sensitivity. The proposed scheme is implemented using low-cost linewidth LiNbO3 optical modulators and ultra-fast photodetectors, demonstrating a wide range of applications, including 5G and beyond. Our results show that the proposed scheme can effectively meet the requirements of next-generation mobile networks, achieving a 24.1-dB self-interference cancellation ratio, which outperforms its PM-16QAM counterpart by 0.7-dB for required receive sensitivity. The proposed scheme is implemented using low-cost linewidth LiNbO3 optical modulators and ultra-fast photodetectors, demonstrating a wide range of applications, including 5G and beyond. Our results show that the proposed scheme can effectively meet the requirements of next-generation mobile networks, achieving a 24.1-dB self-interference cancellation ratio.

Th2A.38 Photonic-enabled 2Tx/2Rx Coherent MIMO Radar System Experimenting with Enhanced Cross Range Resolution. A novel method is proposed for implementing coherent MIMO radars, utilizing W-band optical link and high-speed photodetectors for enhanced performance. The proposed method enables a multi-target experiment in real-world scenarios, demonstrating the feasibility of W-band coherent MIMO radar systems for next-generation applications. The proposed method enables a multi-target experiment in real-world scenarios, demonstrating the feasibility of W-band coherent MIMO radar systems for next-generation applications.


Th2A.41 RF Fading Circumvention Using a Polarization Modulator for Support ing W-Band RoF Transport from 8 to 95 GHz. A novel method is proposed for implementing coherent MIMO radars, utilizing W-band optical link and high-speed photodetectors for enhanced performance. The proposed method enables a multi-target experiment in real-world scenarios, demonstrating the feasibility of W-band coherent MIMO radar systems for next-generation applications. The proposed method enables a multi-target experiment in real-world scenarios, demonstrating the feasibility of W-band coherent MIMO radar systems for next-generation applications.
Bayvel 1, Laurent Schmalen 3; Labs, Germany; Karlsruhe Inst. of Technology, USA; ADVA Optical Networking Carrier Phase Recovery, Boris P.

We perform an experimental end-to-end transceiver optimization via deep learning using a generative adversarial network to demonstrate optical IM/DD end-to-end working, USA. 1Georgia Inst. of Technology, USA; 2Univ. of Newfoudland, Canada. We experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.51

We numerically demonstrate an heterodyne detection for CV-QKD performed on a state-of-the-art setup. We use a maximum likelihood-based decoder with a bandwidth of 10 MHz to decode the encoded information. The performance of the decoder is compared to the traditional method of direct detection, which uses a bandwidth of 100 MHz. The results show that the maximum likelihood-based decoder outperforms the direct detection method in terms of Bit Error Rate (BER) performance.

Th2A.52

Joint Linear and Nonlinear Noise Estimation of Optical Links by Exploiting a Generative Model, Boris P., and Vladimir Aref

Conditional linear and nonlinear noise are often found in optical links. Nonlinear noise can be caused by the Kerr effect, modulational instability, and four-wave mixing. Linear noise can be caused by shot noise, thermal noise, and intersymbol interference. In this paper, we present a new method for estimating both linear and nonlinear noise in optical links using a generative adversarial network (GAN).

Th2A.53

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.54

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.55

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.56

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.57

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.58

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.59

We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.
Room 1A
14:00–16:00
Th3A • Disaggregation, Open Platform, SDN, NFV
Presider: David Boettjes; Ciena Corporation, Canada

Room 1B
14:00–16:00
Th3B • Optical Switching
Presider: Richard Jensen; Huber Suhner Polatis, Inc., USA

Room 2
14:00–16:00
Th3C • High-speed and Multi-wavelength Devices
Presider: Kouji Nakahara; Lumentum Japan Inc., Japan

Room 3
14:00–16:00
Th3D • Machine Learning for Optical Network Performance
Presider: Maite Brandt-Pearces; Univ. of Virginia, USA

Room 6C
14:00–16:00
Th3E • Optimizing Coherent Transponders
Presider: Hongbin Zhang; Acacia Communications, USA

Room 6D
14:00–16:00
Th3F • Novel Fiber Optic Sensors
Presider: Sergio Leon-Saval; Univ. of Sydney, Australia

Th3A.1 • 14:00
Disaggregated Packet Transponder Field Demonstration Exercising Multi-format Transmission with Multi-vendor, Open Packet Optical Network Elements, Geraldine Francisco, Ryoji Nagase, Wataru Ishida, Yoshiaki Sone, Lalit Kumar, Srikanth Krishnamohanty, Victor Lopez; Telefonica R&D, Spain; Telefonica Peru, Peru; NEL America, USA; IPInfusion, USA. We demonstrate a field trial of 1000G/200Gbps alien wavelength transmission and management onto a deployed line system (Telefonica del Peru nation-wide field network) with disaggregated packet transponder, adopting multi-vendor CFP2-ACO / CFP2-DCO transceivers.

Th3A.2 • 14:15
Demonstration of Low-latency Coherent Optical Connectivity for Consolidated Inter-hub Ring Architecture, Zhensheng Jia; CableLabs, USA. Based on new design of consolidated inter-hub CDC architecture, end-to-end video delivery is demonstrated with 2 ms latency from multicore switch and 11us from interoperable coherent muxponder, and full-duplex operation is also presented in such network.

Th3B.1 • 14:00
Large-scale Photonic Integrated Cross-connects for Optical Communication and Computation, Riepala Stabile, Nicola Calabretta, Bin Shi; Technische Universiteit Eindhoven, Netherlands. An 8×8 InP cross-connect chip for optical switching within ROADMs is employed for demonstrating optical feed-forward neural networks for analog data processing. An all-optical approach is also explored for deeper optical neuromorphic computing on chip.

Th3B.2 • 14:15
High Linearity and Uniform Characteristics of InP-based 8-CH Waveguide Avalanche Photodiode Array for 400 GBE, Takuya Okimoto; Ken Ashizawa; Koji Ebihara; Satoru Okamoto; Takumi Endo; Kazuhiro Horino; Tatsuya Takeuchi; Toru Uchida; Hideki Yagi; Yoshihiro Yone da; Sumitomo Electric Industries, Ltd., Japan; Sumitomo Electric Device Innovations, Inc., Japan. InP-based 8 channel waveguide APD arrays were demonstrated towards 400Gbe for the first time. They exhibited maximum 3dB-bandwidth of 23GHz under high-optical input of -10dBm and uniformity of avalanche breakdown voltage less than 0.1V between channels.

Th3C.1 • 14:00
Top-Scored
Direct Modulation of a 54-GHz Distributed Bragg Reflector Laser with 100-Gbaud PAM-4 and 80-Gbaud PAM-8, Di Che; Yashiro Hiro; Richard Schatz; Roberto Rodes; Ferdous Khan; Martin Kwakernaak; Tsurgi Sudo; Chandrasekhar Sethumadhavan; Junho Choi; Xi Chen; Peter Winzer; Nokia Bell Labs, USA; Finisar Corporation, USA; Applied Photonics, Photonics, KTH Royal Inst. of Technology, Sweden; Finisar Corporation, USA. We demonstrate both 100-Gbaud PAM-4 and 80-Gbaud PAM-8 transmissions over 10-km fiber using a 1315-nm 54-GHz distributed Bragg reflector laser with a transient chip parameter of 1.0. The 80-Gbaud PAM-8 system achieves a net bit rate of 200 Gb/s.

Th3C.2 • 14:15
Top-Scored
Assessment of Domain Adaptation Approaches for QoT Estimation in Optical Networks, Riccardo di Marino; Cristina Rottondi; Alessandro Giusti; Andrea Bianco; Politecnico di Torino, Italy; Dalle Molle Inst. for Artificial Intelligence, Switzerland. We evaluate the performance of two domain adaptation approaches for machine learning assisted quality of transmission estimation of an optical lightpath, for a fixed/variable number of available training samples from the source/target domain.

Th3D.1 • 14:00
Evol-TL: Evolutionary Transfer Learning for QoT Estimation in Multi-domain Networks, Che-Yu Liu; Xiaoqiang Chen; Roberto Proietti; S. J. Ben Yoo; Univ. of California, Davis, USA. We propose an evolutionary transfer learning approach for QoT estimation in multi-domain optical networks. The results demonstrate that our approach can reduce the amounts of required training data by 10x while achieving accuracies of >90%.

Th3D.2 • 14:15
Top-Scored
Calibrated Fiber Grating Wave-length Combs Enable High Accuracy Biosensing, Jacques Albert; Carleton Univ, Canada. Simulation-based calibrations of measured spectra are used to find the exact optical properties of multi-resonant fiber gratings, resulting in elimination of cross-sensitivities, lower noise and orders of magnitude improvements in biochemical sensor limits of detection.

Chris Fludger is head of DSP development at Infinera in Germany, where he specializes in System Design and Digital Signal Processing for flexible communications. Previously, he has worked on the development of several generations of coherent optical receivers at Cisco and CoreOptics. He has received master’s and doctorate degrees in electronic engineering from Cambridge University, UK. At Nortel Networks his focus was electronic signal processing, advanced modulation techniques and Raman amplification.
Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond

The market for coherent pluggable optics supporting reaches between 10 km and 120 km is emerging for many applications, such as telco metro-access router-to-router interconnects, point-to-point data center interconnects, mobile and cable aggregation applications. The ongoing 400ZR project at the Optical Internetworking Forum (OIF) defines a digital coherent 400ZR interface primarily for DCI applications. There have also been other standardization activities defining coherent interfaces by other industry organizations addressing various applications. Products compliant to these specifications are coming out and early commercial deployments are expected to be in 2020.

Panelists from network operators, system companies, and module manufacturers will review recent progress in terms of network deployment requirements/schedule, interoperability, DSP/module development status, and share their views of the coherent pluggable optics roadmap in the next decade.

Speakers:
Christian Rasmussen; Acacia Communications Inc., USA
Satoshi Ide; Fujitsu Optical Components, Japan
Xiang Zhou; Google, USA
Matthew Schmitt; Cable Labs, USA
Eric Maniolfi; Ciena, Canada

Th3H.1 • 14:00 Top-Scored Optical Connectivities for Multicore Fiber, Ryo Nagase1, ‘Faculty of Engineering, Chiba Inst of Technology, Japan. Multicore fiber is proposed for use in space-division multiplexing for ultra-wide-band optical transmission systems. This paper introduces recent progress on multicore fiber connection technologies for simplex and multibeam connectors.

Th3H.1 • 14:15 Invited Real-time Strongly-coupled 4-core Fiber Transmission, Shohei Beppu1, Koji Igashiki, Hiroshi Muka1, Masahiro Kikuta1, Masahiro Shigihara, Daiki Soma1, Takahiro Toumati1, Tetsuya Wada1; ‘National Inst of Information & Comm Tech, Japan; ‘AlbaNova Univ. Center, Royal Inst of Technology (KTH), Sweden; ‘Sumitomo Electric Industries, Ltd., Japan; ‘Optoquest Co. Ltd., Japan. We demonstrate transmission of 368-WDM-38-core-3-mode x 24.5-Gbaud 64- and 256-QAM signals over 13 km. Record data-rate and spectral-efficiency of 1158.7 b/s/Hz were enabled by a low DMD 38-core-3-mode fiber with high uniformity amongst cores.

Th3H.2 • 14:15 Top-Scored Optical Connectivities for Multicore Fiber, Ryo Nagase1, ‘Faculty of Engineering, Chiba Inst of Technology, Japan. Multicore fiber is proposed for use in space-division multiplexing for ultra-wide-band optical transmission systems. This paper introduces recent progress on multicore fiber connection technologies for simplex and multibeam connectors.

Th3J.1 • 14:00 Invited Modern Module Development for NASAs Orion Spacecraft: Achieving FSO Communications over Lunar Distances, David J. Geisler1, ‘Massachusetts Inst of Tech Lincoln Lab, USA. NASA’s Orion spacecraft will employ free-space optical communications over 400,000 km from the lunar vicinity to Earth, using an 80-Mb/s downlink and a 20-Mb/s uplink. This paper discusses an overview of the link and optical modem.
Optical Node Disaggregation Management and Interoperability, Emilio Ricardi; Marco Schiano; ‘Network Research and Innovation, TIM (Telecom Italia), Italy. This work gives a high-level overview of the maturity and open issues of the disaggregation approach as applied to WDM transport network eco-system.

Polarization-diversity Microring-based Optical Switch Fabric in a Switch-and-select Architecture, Hao Yang; Qixiang Cheng; Rui Chen; Keren Bergman; ‘Columbia Univ., USA. We propose a polarization-diversity microring-based optical switch fabric in a switch-and-select architecture with polarization splitters rotators. The first primitive 2×2 silicon device is demonstrated with polarization-dependent loss of <1.6 dB and inter-channel crosstalk of <-4.5 dB.

High-speed and 16A-WDM Operation of Ge/Si Electro-absorption Modulator for C-band Spectral Regime, Junichi Fujikata; Masataka Noguchi; Seok H. Jeong; Yosuke Onno; Daikichi Shima; Kazuki Kawasaki; Riku Katanawari; Hideaki Okayama; Shigeki Takahashi; Hideki Ono; Hiroki Takahashi; Hiroki Yagaishi; Yashuo Ishikawa; Takahiro Nakamura; ‘PETRA, Japan; ‘Oki Electric Industry Co., Ltd., Japan; ‘Toyo-hashi Univ. of Technology, Japan. We present high-speed of 100Gbps for PAM-4 signal and 16A-WDM operations of a Ge/Si EAM in C-band. Operation wavelengths could be controlled by Ge/Si stack width, and 16A operation was demonstrated at 50 Gbps.

A Novel Demodulation Method of Fiber Bragg Grating Sensor Array Based on Wavelength-to-time Mapping and Multi-loop Optoelectronic Oscillator, Wensuan Wang; Yi Liu; Xinwei Du; Yasi Yan; Changyu Ju; Xiangfei Chen; ‘Key Laboratory of Intelligent Optical Sensing and Manipulation of the Ministry of Education & National Laboratory of Solid State Microstructures & College of Engineering and Applied Sciences, Nanjing Univ., China; ‘The Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong. We propose a novel demodulation method of strong FBG sensor array based on wavelength-to-time mapping and multi-loop OEO. The oscillating frequency shift caused by the time shift encodes measurable variation and location information.
Beyond—Continued

Applications and for Short-haul/Edge Coherent Optics

Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond—Continued

Th3H • SDM Transmission—Continued

Th3I • Optical and Thermal Connectivity—Continued

Th3J • Future and Emerging Access Network Technologies—Continued

Th3K • Future and Emerging Access Network Technologies—Continued

Room 6E

Room 9

Room 6F

Room 8

Room 7

Thursday, 12 March

OFC 2020 • 8–12 March 2020


Room 6E

Room 9

Room 6F

Room 8

Room 7

POFTO Symposium

POFTO

13:45–14:45, Theater III

Introduction to OpenROADM MSA, Latest Update, and Show Floor Demo Overview

14:00–15:00, Theater II

The World’s First Intercontinental Connections…

Contrasting Early Terrestrial-subsea Networks with the Present

Telecom Infra Project (TIP)

15:05–16:00, Theater II

Market Watch Panel VII: 400G Evolution

14:30–16:00, Theater I
1.1 Tb/s/l at 9.8 bit/s/Hz DWDM Transmission over DCI Distances Supported by CMOS DACs, Fred Buchali1, Vincent Launger1, Mathieu Chagnon1, Karsten Schul1, Vahid Aref1, Nokia Bell Labs, Germany, “KT, Germany. We report on a 16-nm CMOS DAC based transmitter optimization enabling bitrates up to 1.15 Tb/s. We successfully demonstrate DWDM transmission over DCI distances up to 118 km at 1.1 Tb/s and spectral efficiencies of 9.8 bit/s/Hz.

Joseph M. Kahn is Professor of Electrical Engineering at Stanford University. He is a leader in first-generation phase-locked loop (PLL) based digital coherent optical communication (DOCC) research (1999); first electronic compensation of channelization (2000); first electronic compensation of channelization (2000). Kahn received a BS in Electrical Engineering, Stanford University, in 1979 and the MS and Ph.D. degrees in electrical engineering from MIT in 1981 and 1984, respectively. He was a member of the technical staff at Bell Laboratories, Lucent Technologies, during 1984–1999. He joined the faculty of Stanford University in 1999. Dr. Kahn’s research interests include digital coherent optical communication systems, analog electronics, and optical interconnects. He is a fellow of the IEEE and a member of the National Academy of Engineering. He is currently serving as an Editor of the IEEE Journal of Lightwave Technology.

A Three-stage Training Framework for Customizing Link Models for Optical Networks, Xiaomin Liu1, Huazhi Lun1, Mengfan Fu1, Yun Fan1, Lilin Yi1, Weisheng Hu1, Jiaxin Feng1, Tiejun Huang2, Milad Salemi2, Yuheng Chen2, Xiaomin Liu2, Yutong Zhang2, Yutang Sun2, Xiaohui Yang2, Haitao Leu2, Xiaoyu Liu2, Xiaoping Zheng2, Jialiang Zhang2, Jengong Zhu2, Haoran Gu2, Xinli Zeng2, Feihe Ma2, Huibin Zhou2,4, Xinjie Song2,4, Xiaohui Yang2, Xiaohui Yang2, Xinli Zeng2,4, Xiaohui Yang2, Xinli Zeng2,4, Xinjie Song2,4, Xiaohui Yang2, Xinli Zeng2,4, Xinjie Song2,4.

Maximizing Throughput via Vertical Optimization of the Coherent MODEM, Robert Maher1, Mehdi Torbatian1, An Nguyen2, Zhenxing Wang3, Swen Koenig1, Mark Missey1, Alban Le Liepvre1, Ryan Gong1, Stefan Wolf1, Parmjit Samra1, Pat Day1, Stephanie Tremblay1, Mehrdad Zian1, Fred Kish1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1, Steve Sanders1.

Distortion-suppressed Sampling Rate Enhancement in Phase-OTDR Vibration Sensing with Newly Designed FMD Pulse Sequence for Correctly Monitoring Various Waveforms, Yoshihumi Wakisaka1, Daisuke Iida1, Hisayuki Oshida1, NTT corp., Japan. The FDM-based sampling rate enhancement method proposed herein detects vibration waveforms more accurately than previous methods while reducing phase unwrapping failures; it can measure vibrations with larger amplitude and higher frequency than heretofore.
Applications and for Short-haul/Edge Coherent Optics

First Experimental Demonstration of Cross-SDM/WDM Q-difference Compensation at MultiCore Fiber Transmission, Hidenori Takahashi 1, Daiki Soma 1, Takehiro Tsuritani 1, Wada 1, Gianluca Galdino 2, Domaniç Lavery 2, Tobias Eriksson 1, Yoshinari Awayi 1, Hideaki Furukawa 1, Polina Bayvel 1, Naoya Wada 1, 1National Inst Info & Comm Tech (NICT), Japan; 2Optical Networks Group, Univ Collage London, UK. We demonstrated 56.4 Tbit/s over a standard cladding diameter fiber with 4 single-mode cores, using a single wideband optical comb source to provide 25 GHz spaced carriers over 120 nm range across S, C and L bands.

A CMOS Compatible Monolithic Fiber Attach Solution with Reliable Performance and Self-alignment, Bo Peng 1, Tymon Barwicz 2, Asli Sahin 3, Thomas Houghton 1, Britanny Hedrick 1, Yuxing Bian 1, Michal Rakowski 1, Shuren Hu 1, Javier Alya 1, Celine Meagher 1, Zeyo Sosnowski 1, Karen Nummy 1, Andy Stricker 1, Jorge Llibregat 1, Hui Chen 1, Benjamin Fasano 1, Ian Melville 1, Ken Giewont 1, Globalfoundries CTO Research, USA; 2IBM T. J. Watson Research Center, USA; 3GlobalFoundries, USA. We report a fiber-attach solution interfacing self-aligned, standard-cleaved fibers to monolithic photonic integrated circuits, fabricated in Globalfoundries 300-nm CMOS production facilities. Statistical yield analysis and reliability performed to demonstrate the robustness of the proposed solution.

Real-Time 28 Gb/s NRZ over 80 km SSMF in C-band using Analog Electronic Precompensation, Michiel Verplaetse 1, Laurens Breunele 1, Joris Lambrechts 1, Xin Yin 1, Peter Osiewiec 1, Guy Torfs 1, 1IDLab, Ghent University, Belgium. We demonstrate real-time C-band transmission of direct detected 28 Gbps NRZ/00k over 80 km SSMF using a Dual-Drive MZM and custom-designed SiGe BiCMOS 5-tap analog FIR filters to compensate chromatic dispersion without digital signal processing.

First Scored Top-Selected Invited Paper: Opportunities and Challenges When Using Low Bandwidth Optics for Higher Capacity PON Systems, Roberto Gaudio 1, Pablo Torres-Ferrera 1, Hanyang Wang 1, Maurizio Valvo 1, Annachiara Pagano 1, Roberto Merci - nelli 1, Valter Ferrero 1, Politecnico di Torino, Italy; 2TIM, Telecom Italia, Italy. Next generation PON physical layer, targeting 50 Gb/s/lambda, has to deal with optoelectronics bandwidth limitation. In this invited paper, we present the resulting required bandwidths and discuss the trade-off between receivers with or without equalization.
Thursday, 12 March

Room 1A

**Th3A • Disaggregation, Open Platform, SDN, NFV—Continued**

Room 1B

**Th3B • Optical Switching—Continued**

Room 2

**Th3C • High-speed and Multi-wavelength Devices—Continued**

Room 3

**Th3D • Machine Learning for Optical Network Performance—Continued**

Room 6C

**Th3E • Optimizing Coherent Transponders—Continued**

Room 6D

**Th3F • Novel Fiber Optic Sensors—Continued**

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

**16:30–18:30 Postdeadline Papers, Room 6C, 6D, 6E, 6F**

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**Th3A.6 • 15:30 Invited**

*Progress in 100G Lambda MSA Based on 100G PAM4 Technology, Mark Nowell, Matt Traverso, Marco Mazzini, Kumar Lakshminarayan, Mark Webster, Peter De Dobbeleer, Cisco Systems, Inc., Canada.*

This talk will focus on the progress of the 100G Lambda MSA. Topics include: motivation in forming the group; market requirements for the technology; key technologies and results; and insights into next generation work.

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**Th3B.6 • 15:30**

*Top-Scored «*

*5.7-dB Fiber-to-fiber Loss 8 × 8 Silicon Photonics Switch with Port-alternated Switch-and-select Architecture, Ryotaro Konoike, Keijiro Suzuki, Hitoshi Kawashima, Kazuhiro Ikeda, National Inst. of Advanced Industrial Science and Technology (AIST), Japan.*

We propose and demonstrate a Port-Alternated Switch-and-Select architecture that has both low insertion loss and low path dependency. Using silicon photonics platform, we realized an 8 × 8 switch with 5.7-dB Fiber-to-Fiber insertion loss.

---

**Th3C.7 • 15:45**


We propose a 1×4 optical switch with coupled-core multi-core fiber (MCF) array. An image processing allows MCF to be precisely rotationally-aligned. It enables the IL less than 0.6 dB with the uniformity of 0.04 dB.

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**Th3D.7 • 15:30**

*Efficient Classification of Polarization Events Based on Field Measurements, Kyle Guan, Jesse E. Simmons, Fabien Boitier, Daniel C. Kilper, Jelena Pesic, Michaeil Sherman, Nokia Bell Labs, USA; College of Optical Sciences, Univ. of Arizona, USA; Electrical and Computer Engineering, Rutgers Univ., USA.*

We present rare-event classification of polarization transients based on field measurements combined with data augmentation combined with robot-generated fiber-disturbance data. We compare machine learning methods for accuracy and required number of training sample traces.

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**Th3F.7 • 15:45**

*Top-Scored «*

*Sensors Based on Dual Supermode Interferometers, Joel Villatoro, Axel Schülzgen, Rodrigo Amezcua Correa, Univ. of the Basque Country UPV/EHU, Spain; CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA; IKERBASQUE—Basque Foundation for Science, Spain. Compact interferometers composed by two slightly different segments of asymmetric multicore fiber fusion spliced and rotated 180deg with respect to each other are proposed for sensing applications. Examples and advantages of such interferometers are discussed.*

---

**Th3F.6 • 15:30**

*Vibration Sensing for Deployed Metropolitan Fiber Infrastructures, Ilaria Di Luch, Maddalena Ferraro, Giuseppe Rizzelli Martella, Roberto Gaudino, Politecnico di Milano, Italy; Politecnico di Torino, Italy.*

A counter-propagating coherent vibration sensing approach is exploited in a 32km deployed fiber ring network, proving its feasibility in early detection of critical events that may damage and put out of service the optical infrastructure.
Thursday, 12 March

Room 6E

Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond—Continued

Room 6F

Th3H • SDM Transmission—Continued

Room 7

Th3I • Optical and Thermal Connectivity—Continued

Room 8

Th3J • Direct Detection Systems and Subsystems—Continued

Room 9

Th3K • Future and Emerging Access Network Technologies—Continued

Show Floor Programming Continued

The World’s First Intercontinental Connections…
Contrasting Early Terrestrial-subsea Networks with the Present Telecom Infra Project (TIP)
15:05–16:00, Theater II

Market Watch Panel VII: IP+WDM Architecture Evolution
14:30–16:00, Theater I

Fibre Types and Amplifiers: Choices and Trade-offs
Fiberstory
15:00–16:00, Theater III

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

16:30–18:30 Postdeadline Papers, Room 6C, 6D, 6E, 6F

Th3I.6 • 15:45
High-durability Coating for Improved Thermal Management of Pluggable Optical Modules, Reid Chesterfield¹, Pradyumna Goli¹, Sarah Querelle-Halverson¹, Elizabeth Sullivan¹, Zachary Hoyt¹, Kevin Olson¹, Matthew Bren¹, Attila Aranyosi¹, S Doan¹, V Lei¹, Henkel Corporation, USA; ¹Juniper Networks, USA. We introduce a new high-durability thermal interface coating designed to improve pluggable optical module to heat sink thermal transfer. Performance data and test methods for thermal resistance, durability, and long-term reliability are presented.

Th3K.6 • 15:45
Bus-type Optical Access Using DRA and Asymmetric Power Splitters for Accommodating Rural Users, Ryo Igarashi¹, Masamichi Fujiwara¹, Takuya Kana¹, Kazutaka Hara¹, Atsuko Kawai¹, Hiro Suzuki¹, Jun-ichi Kani¹, Jun Terada¹, NTT Corporation, Japan. We propose a long-reach bus-type optical access system by using distributed Raman amplification and asymmetric power splitters. The feasibility is experimentally verified by using 10G-EPON and its scale is estimated by bit error rate measurements.
### Key to Authors and Presiders

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