Telemetry-driven Optical 5G
Serverless Architecture for Latency-sensitive Edge Computing, Istvan Pelle1, Francesco Paolucci2, Balazs Sankoly1, Filippo Cugini1, MTA-BME Network Softwarization Research Group, Hungary; 1CNIT, Italy; 1Scuola 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 450ms.

Flexible Optical Network Enabled Hybrid Recovery for Edge Network with Reinforcement Learning, Meng Lian1, Rentao Gu1, Yongyao Qu1, Zihao Wang1, Yuefeng Ji1; Beijing Laborato-ry 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.

Mid-infrared Gas Spectroscopy Using Fiber Laser Driven Supercontinuum, Camille-Sophie Brès1, Davide Grassani1, Eirini Tagkoudi1; 1Ecole 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.

Graphene and Related Materials for Photonics and Optoelectronics, Andrea C. Ferrari1; Univ. 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.
M1G.1 • 08:00
Neural Network Assisted Geometric Shaping for 800Gbit/s and 1Tbit/s Optical Transmission, Maximilian Schaedler1,2, Stefano Calabro1, Fabio Pittalà1, Georg Böcherer3, Maxim Kuschnerov1, Christian Bluemm1, Stephane Pachnicke1, 1Huawei Munich Research Center, Germany; 2Chair of Communications, Kiel Univ. (CAU), Germany; 3Huawei 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 92GbaudDP-32QAM 800Gb/s and 82GbaudDP-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 Ghazisaeidi2, Benedict Baeuerle1, Marco Eppenberger1, Juerg Leuthold1, 1ETH Zurich, Switzerland; 2Polariton AG, Switzerland; 3Nokia 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.

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

M1I.1 • 08:00
Invited
Narrowband and Low-noise Brillouin Amplification for Coherent Communications, Mark D. Pelusi1, Takashi Inoue1, Shu Namiki1, 1National 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.
M1A.3 • 08:30  Invited
Multi-layer Network Slicing for Accelerating Business Velocity for Edge Computing, Akihiro Nakao1; Interfaculty 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, Yin Zhou1, Lianshan Yan1, Xinpu 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 Doern1, 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.

M1E.2 • 08:30  Invited
Scalable Measurement-Device-Independent Quantum Key Distribution Networks with Untrusted Relays, Hoi-Kwong Lo1, Wenyuan Wang1, Feihu Xu2; 1Physics, Univ. of Toronto, Canada; 2Univ. of Science and Technology of China, China. I review the recent developments of quantum key distribution networks with untrusted relays based on the Measurement-Device-Independent quantum key distribution MDI-QKD protocol.

M1F.2 • 08:30
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, Mingshen Chen1, Naoki Fujiwara1, Masahiro Nada1, Toshihide Yoshimatsu1, Atsushi Kanda1, Yasuhiko Nakashish1, Fumito Nakajima1, Kimikazu Sano1, Yozo Ishikawa2, Kazuyo Mizuma2, Hideaki Matsuzaki2; 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, Hyun-Do Jung1, Seok Tae Kim1, Jang-Uk Shin1, Sang Ho Park1, Seo-Young Lee1, Yongsoon 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.
Experimental Demonstration of an Optical Second-order Volterra Nonlinear Filter using Wave Mixing and Delays to Equalize a 20-Gbaud 4-APSK Channel, Kahieng Zou; Peicheng Liao; Huibin Zhou; Ahmad Fallahpour; Amir Minooifar; Ahmed Almaman; Fatemeh Alishahi; Moshe Tur, Alan E. Willner; ‘Univ. of Southern California, USA; ‘Tel 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. The effectiveness of this approach is verified by shaping 10 Gbaud 16QAM in simulation and experiment.

Phase Noise Spectral Properties Across Individual Comb Lines in Quantum-dot Mode-locked Lasers, Mustafa A. Al-Qadi; Maurice O’Sullivan; Chongjin Xie; Ronqiang Hui; ‘Univ. of Kansas, USA; ‘R&D, Ciena Corporation, Canada; ‘R&D, Alibaba Group, USA. We study phase-noise spectral properties of comb lines from a QD-MLL, show that their large linewidth variability attributes to the low-frequency phase variations, and has minimal effect on coherent system performance at practical symbol rates.

Assisted Adaptively Partitioned Entropy Loading for FBMC/OQAM System, Xi Chen; Shuangyi Yan; Ming Tang; Songjian Fu; Deming Liu; Dimitra Simeonidou; Huazhong University of Science and Technology, China; ‘High 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.

Gain Ripple and Passband Narrowing due to Residual Chromatic Dispersion in Non-degenerate Phase-Sensitive Amplifiers, Shimpei Shimizu; Takashi Kazama; Takayuki Kobayashi; Takeshi Umeki; Koji Endo; Ryuichi Kasahara; Yutaka Miyamoto; ‘NTT Network Innovation Laboratories, NTT Corporation, Japan; ‘NTT Device Technology 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.

Circumventing LoS Blocking in Beam-Steered Optical-wireless Systems with Real-time Tracking and Handover, Ketema Addis Mekonnen; Ngoc Quan Pham; Frans Huikens; Eduward Tandjiongga; Ali Metfleth; Ton Koonen; ‘Eindhoven Univ. of Technology, Netherlands; ‘KPN, Netherlands. This paper demonstrates a real-time user tracking and handover mechanism for indoor ultrahigh-speed beam-steered optical-wireless systems implementing a low-cost camera. This allows us to tackle LoS blocking by switching to a secondary beam-steering device automatically.
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-the-art algorithm.

We experimentally demonstrated a single-shot time-stretched interferometer for femtosecond and picosecond time detection is achieved with a sensitivity of ~810 dB/RIU with a broadband light source. The proposed and demonstrated signal reception in graphene plasmonic NRZ and PAM-4 signals is experimentally demonstrated at 1550 nm with high quality.
Machine Learning and its Applications—Continued

Alan Pak Tao Lau received his B.A.Sc., M.A.Sc. from University of Toronto and his Ph.D. in Electrical Engineering from Stanford University in 2008. He joined The Hong Kong Polytechnic University and is now a Professor. His research interests include DSP and 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.

Ashok Krishnamoorthy is Chairman and CEO of Axalume, an optical interconnect startup. He was formerly an Oracle Architect and its Chief Technologist, Photronics. Previously, he was a Distinguished Engineer and Director at Sun Microsystems, and prior to that President and CTO of Aralight, a Bell Labs VCSEL interconnect spinout.

Compensation of SOA Nonlinear Distortions by Mid-stage Optical Phase Conjugation, Anees Sathyanarayanan, Mark Pelusi, Takashi Inoue, Deepa Venkitesh, Shu Namiki, ‘Indian Inst. of Technology Madras, India; ‘National 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-3X12Gbaud 16-QAM signals show the ability to outperform a single device by 2dB average Q2-factor improvement.

Non-orthogonal Matrix Precoding based Faster-than-nyquist Signaling over Optical Wireless Communications, Zhuyu Hu, Chun-Kit Chan; ‘Chinese Univ. of Hong Kong, Hong Kong. We first investigate a novel non-orthogonal matrix precoding based faster-than-Nyquist signaling technology in OWC systems. Compared to the conventional schemes, it shows superior performance including PAPR reduction, improved sensitivity, and improved tolerance to narrow-bandwidth filtering.

Capacity Sharing Approaches in Multi-tenant, Multi-service PONs for Low-latency Fronthaul Applications Based on Cooperative-DBA, Arsalan Ahmad, Sanwal Zeb, Abdul Wahab, Rana Azhar Khan, Marco Ruffini, ‘Univ. of Dublin Trinity College, Ireland; ‘National 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.6 • 09:30
Remote Human-to-Machine Distance Emulation through AI-Enhanced Servers for Tactile Internet Applications, Sourav Mondal1, Li-hua 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.

M1A.7 • 09:45
Demonstration of Geo-distributed Data Processing and Aggregation in MEC-empowered Metro Optical Networks, Jiawei Zhang1, Lu Cui1, Zhen Liu1, Yuefeng Ji1; 'Univ. of Posts & Telecom, China. We experimentally demonstrate a geo-distributed data processing and aggregation (GDPA) scheme in the MEC-empowered metro optical network. The demonstration results show that the proposed scheme can improve resource utilization and reduce average job completion time.

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.6 • 09:30
Real-time Structured-light Depth Sensing Based on Ultra-compact, Non-mechanical VCSEL Beam Scanner, Ruixiao Li1, Masashi Takanoshita1, Shenting Hu1, Xiaodong Gu1, Fumio Kayama1; '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 (<0.5mm²) non-mechanical beam scanner. The peak output power can be as low as 1mW.

M1D.4 • 09:30
50 Gbit/s Silicon Modulator Operated at 1950 nm, Wenxiang Li1, Miaofeng Li2, Hongguang Zhang3, Yuguang Zhang1, 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.

M1D.5 • 09:45
A 12.5Gb/s QRNG based on phase diffusion in gain switched lasers is proposed. It uses polarization-maintaining fiber Bragg grating (PM-FBG) as a frequency discriminator. The basic principle and preliminary results of linearity and demodulation are presented.

M1E.4 • 09:30
Title to be Announced, Jungang Kim1; 'Duke Univ., USA. Abstract not available.

M1F.4 • 09:45
PAM-X™: A 25Gb/s-PAM4 Optical Transceiver Chipset for 5G Optical Front-Haul, Lei Zhao1, Xin Wang1, Ru Bai1, Juncheng Wang1, Tao Xia1, Yi Peng1, Yuanxi Zhang1, Lei Wang1, Liujia Song1, Shenglong Zhou1, Xuefeng Chen1, Patrick V. Chiang2, 1Fudan 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.
M1G • Machine Learning and its Applications—Continued

M1H • Chip-to-chip Optical Interconnects—Continued

M1I • Optical Signal Processing—Continued

M1J • Positioning Beam-steering for Advanced Wireless Communications—Continued

M1K • Dis-aggregated Access Networks—Continued

M1I.6 • 09:30 Invited
Phase Reconstruction Scheme Using Dispersive Media in Direct Detection, Masayuki Matsumoto, 1Wakayama 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 Mekonnen, 1, Eduward Tangdiongga, 1, Ton Koonen; 1Eindhoven 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, ~2 bits/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 Nishimoto, 1, Takahiro Suzuki, 1, Kota Asaka, 1, Jun-ichi Kani, 1, Jun Terada, 1; 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 Pham, 1, Ketema Mekonnen, 1, Eduward Tangdiongga, 1, Ali Mefleh, 2, Ton Koonen; 1Eindhoven Univ. of Technology, Netherlands; 2KPN, 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
Room 1A
10:30–12:30
M2A • Advanced Active Components
Presider: Hanxing Shi; Finisar Corporation, USA

Room 1B
10:30–12:30
M2B • High-speed Integrated Modulators
Presider: Argishti Melikyan; Nokia Bell Labs, USA

Room 2
10:30–12:30
M2C • SDM Imaging and Sensing
Presider: Rodrigo Amezquita Correa; Univ. of Central Florida, CREOL, USA

Room 3
10:30–12:30
M2D • Optimizing Network Capacity and Performance
Presider: Stephen Grubb; Facebook Inc., USA

Room 6C
10:30–12:30
M2E • Symposium: Quantum Information Science and Technology (QIST) in the Context of Optical Communications (Session 2)

Room 6D
10:30–12:30
M2F • Digital Signal Processing and Radio-over-Fiber Systems for 5G
Presider: Anthony Ng’oma; Corning Inc, USA

M2A.1 • 10:30
Broadband 145GHz Photodetector Module Targeting 200GBaud Applications, Patrick Runge1, Felix Granier1, Jonas Glaesel1, Sebastian Wünsch1, Sven Mutschall1, Martin Schell1; Fraunhofer 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 Sohn1, Di Liang1, Joe C. Campbell2, Raymond Beausoleil1; Hewlett Packard Labs, Hewlett Packard Enterprise, USA; 2Department of Electrical and Computer Engineering, Univ. of Virginia, 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 Multicores Fibers, Esben R. Andersen1, Siddharth Sivakumury2, Viktor Tsvirkun1, Karen Baudelle1, Olivier Vanvincq1, Gérard Bouwmans1, Hervé Rigneault2; Univ Lille 1 Laboratoire PHLAM, France; 2Aix Marseille Univ., CNRS, Centrale Marseille, Institut Fresnel, France. We take stock of the progress made into developing fiber-optic ultra-thin endoscopes assisted by wave front shaping. We focus on multi-core fiber-based lensless endoscopes intended for multimodal imaging. We put the work into perspective and outline remaining challenges.

M2B.2 • 10:45
In-Phase/Quadrature Modulation by Directly Reflectivity Modulated Laser, Po Dong1, Argishti Melikyan1, Kwangwoong Kim1, Nonaki Kaneda1, Brian Stern1; Yves Baeyens1, Nokia Bell Labs, USA, 2Nokia Bell Labs, USA. We report a directly reflectively modulated laser that generates a 50-Gbaud QPSK signal with a BER of 2.2×10^-3. We believe this is the first demonstration of a coherent transmitter made from a directly driven laser.

M2C.1 • 10:30
Record Ultra-high Full-fill Capacity Transatlantic Submarine Deployment ushering in the SDM Era, Pierre Mertz1, Stephen Grubb2, Jeffrey Rahn2, Warren Sande1, Marc Stephens1, James O’Connor2, Matthew Mitchell2, Stefan Voit1; Infineera Corporation, USA; 2Facebook, USA; 3Infineera Corporation, USA. A record capacity of 24 Tbps on a 6,644 km trans-Atlantic deployment using 16QAM is enabled by synthesized subcarriers, FEC gain sharing, multi-carrier wavelocking, and large-area, high dispersion fiber. Computer assisted optimization and automated protection facilitate full-fill deployments becoming prevalent as submarine cables enter the SDM era.

M2C.2 • 10:45
Enabling Techniques for Optical Wireless Communication Systems, Chi-Wai Chow1, Chien-Hung Yeh1, Y. Liu1, Yin-Chieh Lai1, Liang-Yu Wei1, Chin-Wei Hsu1, Guan-Hong Chen1, X. L. Liao1, K. H. Lin1; National Chiao Tung Univ., Taiwan; 2Feng Chia Univ., Taiwan; 3Philips, Hong Kong; 4Industrial Technology Research Inst., Taiwan. We summarized the recent progress of enabling techniques for the optical wireless communication (OWC) and visible light communication (VLC). Besides, we reported two high data-rate laser-dio (LD) based VLC systems. Several application scenarios using VLC were also discussed.

M2D.1 • 10:30
Invited
Title to be Announced, Christine Silverhorn1; 1Univ. of Paderborn, Germany. Abstract not available.
10:30–12:30  
M2G • Multiband and SDN for Capacity Scaling  
Presider: Mark Filer; Microsoft Corp., USA

M2G.1 • 10:30  
Invited  
Spatial Channel Network (SCN): Introducing Spatial Bypass Toward the SDM Era, Masahiko Jinno 1, Takahiro Kodama 1; 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 • Access Networks for Mobile and Multi-access Edge Computing  
Presider: Marco Ruffini; Univ. of Dublin Trinity College, Ireland

M2H.1 • 10:30  
Real-time Assessment of PtP/PtMP Fixed Access Serving RAN with MEC Capabilities, Anas El Amkouri 1, Santiago Ruano Rincon 1, Gael Simon 1, Luiz Anet Neto 1, Annie Gravey 1, Philippe Chancour 1; 1 Orange Labs, France; 2 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 • Photonic Integrated Subsystems  
Presider: Lu Li; SubCom, USA

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

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

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

M2K.1 • 10:30  
Temporal Resolution Enhancement in Quantum-dot Laser Neurons due to Ground State Quenching Effects, George Sarantoglou 1, Menelaos Skontrinis 1, Adonis Bogris 1, Charis Mesaritakis 1; 1 Univ. of the Aegean, Greece; 2 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.
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, Jaroslav 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 800G-GeV Applications, Yoshihiro Nakai1, Shigeru Hayakawa2, Syunya Yamachi1, Yorinori Yamaguchi1, Tetsuyoshi Takamura1, Hideaki Asakura1, Ryosuke Nakajima1, Shigetaka Hamada1, Kazuhiro Nase1; 1Lumentum Japan, Inc., Japan. The demonstrated uncooled 53-Gbaud PAM4 operation with a TDECQ of lower than 2.5 dB over a wide temperature from 20 to 85°C. 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.

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, Yusuho 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.

M2D • Optimizing Network Capacity and Performance—Continued

M2D.2 • 11:00 ★ Top-Scored
Probabilistic-Shaping DP-16QAM CFP-DCO transceiver for 200G Upgrade of Legacy Metro/Regional WDM Infrastructure, Erwan Pincevin1, Yann Loussouarn1; 1Orange Labs, France. We investigate here the capability of a newly developed CFP-DCO interface, operating at both 34 Gbaud with uniform DP-16QAM and 39 Gbaud with probabilistic-shaping DP-16QAM, for 200G upgrade of legacy metro/regional WDM infrastructure already working at 104 or 100G.

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

M2E.2 • 11:00 Invited
Pushing the Count-rate and Efficiency Limits of Single-photon Avalanche Diodes with RF Interferometry, Joshua Bienfang1, 1NIIST, USA. Abstract not available.
Room 6F

M2G • Multiband and SDN for Capacity Scaling—Continued

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

Room 7

M2I • Photonic Integrated Subsystems—Continued

Room 8

M2J • Data Analytic-based Monitoring—Continued

Room 9

M2K • Neuromorphic I: Device-oriented—Continued

M2G.2 • 11:00 Evaluation of the Flexibility of Switching Node Architectures for Spaced Division Multiplexed Elastic Optical Network, Si-cang 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.

M2H.3 • 11:15 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 Fronthaul (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.

M3J.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, Jianqiang Li1, Chongjin Xie1, Qilin Liu1; Alibaba 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.

M2K.3 • 11:00 Invited Scalable Photonic Integration of Neural Networks, Johnny Moughames1, Javier Porte2, Maxime Jacquot2, Laurent Langer1, Muamer Kadic1, Daniel Brunner1; CNRS, France; FEMTO-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.

M2G.3 • 11:15 Top-Scored Design Strategies Exploiting C+L-band in Networks with Geographically-dependent Fiber Upgrade Expenditures, Daniela A. Moniz2,1; Victor Lopez2,3; Joao Pedro2; Instituto de Telecomunicações, Portugal; Infinera, Portugal; Telefonica, 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.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 Fronthaul (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.

M2J.3 • 11:15 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 NULN is explained through simulation. Features from FBHs are applied to train an ANN to estimate linear and nonlinear NSRs with <5% error.
M2A.5 • 11:45
Electrical and Optical Reliability Analysis of GeSi Electro-absorption Modulators, Artemisia Tsaiara 1, Srinivasan Ashwyn Srinivasan 2, Sadhishkumar Balakrishnan 1, Manarana Pantouvaki 1, Philippe Absil 1, Joris Van Campenhout 1, Kristof Croux 1, 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. Under stress, electro-optical extracted parameters indicate no impact of temperature, bias or stress time.

M2B.6 • 11:45
Taperless III-V/Si Hybrid MOS Optical Phase Shifter using Ultrathin InP Membrane, Shuhei Ohno 1, Naoki Sekine 1, Junichi Fujikata 1, Masa-taka Nagouchi 1, Shigeki Takahashi 1, Ka-sidit Toprasertpong 1, Shinichi Takagi 1, Mitsuru Takenaka 1, the Univ. of Tokyo, Japan; 2Photonics Electronics Technology Research Association, Japan. We present proof-of-concept taperless III-V/Si hybrid MOS optical phase shifter. An ultrathin InP membrane enables low insertion loss despite no taper, with keeping high modulation efficiency owing to strong electron confinement at the MOS interface.
Room 6E

**M2G • Multiband and SDN for Capacity Scaling—Continued**

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

**M2I • Photonic Integrated Subsystems—Continued**

**M2J • Data Analytic-based Monitoring—Continued**

**M2K • Neuromorphic I: Device-oriented—Continued**

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**M2G.4 • 11:30 **

Network Performance Assessment of C+L Upgrades vs. Fiber Doubling SDM Solutions, Emanuele E. Virgilio1, Rasoul Sadeghi2, Alessio Ferrani1, Giacomo Boracchi1, Antonio Napoli1, Vittorio Curri1; 1Politecnico di Torino, Italy; 2Infinera, Germany. We investigate on the 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.

**M2H.4 • 11:30 **

Asynchronous Multi-service Fiber-Wireless Integrated Network Using UFMC and PS for Flexible 5G Applications, You-Wei Chen1, Rui Zhang1, Shang-Jun Su1, Shuyi Shen2, Qi Zhou3, Shuang Yao1, Gee-Kung Chang1; 1Georgia Inst. of Technology, USA; 2Georgia Tech, USA; 3Deakin Univ., Australia. We investigate on the combination of experimental results of asynchronous inter-service interference and optimized information rate verified through a 25-km fiber and a 5-m 60-GHz wireless link.

**M2I.2 • 11:30 **

A Co-integrated Silicon-based Electronic-Photonic Wideband, High-power Signal Source, Saeed Zeinalabedinzadeh1, Patrick Goley1, Milad Frounchi2, Sunil Rao2, Christian Bottenfield3, Gareyeesa Saha2, Stephen E. Ralph1, Mehmet Kaynak1, Lars Zimmermann4, Stefan Lischke1, Christian Mai2, John Cressler1; 1Arizona State Univ., USA; 2Georgia Tech, USA; 3IHP Microelectronics, Germany. A novel co-integrated electronic-photonic distributed photo-mixer-amplifier is presented that improves the bandwidth and gain of the system. An RF signal with an output power of 10 dBm across the bandwidth of 50 GHz was achieved.

**M2J.5 • 11:45 **

Self-adaptive Over-the-air RF Self-interference Cancellation Based on Signal-of-interest Driven Regular Triangle Algorithm, Lizhuo Zhang1, Zhiyang Liu2, Zhiyi Zhang1, Shilin Xiao1, Mable P. Fok1, Qidi Liu2; 1Georgia Inst. of Technology, USA; 2NIST, USA. Using waveforms from three distinct stages of signal demodulation, we assess performance, computational efficiency and benefits of using convolutional recurrent neural networks to simultaneously and independently estimate OSNR and launch power within a multi-channel system.

**M2K.5 • 11:45 **

Flexible Entanglement Distribution Overlay for Cloud/Edge DC Interconnect as Seed for IT-secure Primitives, Fabian Lautenbach1, Berhard Schrenk1, Martin Achleitner1, Nemanja Volcic1, Dinka Milovanovic1, Hannes Hübel1; 1AIT Austrian Inst. of Technology, Austria. We leverage spectral assets of entanglement and spatial switching to realize a flexible distribution map for cloud-to-edge and edge-to-edge quantum pipes that seed IT-secure primitives. Dynamic bandwidth allocation and co-existence with classical control are demonstrated.
Room 1A

M2A • Advanced Active Components—Continued

M2A.6 • 12:00
Compact Tunable DBR/Ring Laser Module Integrated with Extremely-high-Δ PLC Wavelength Locker. Maysayoshi Nishita1, Yasutaka Higa1, Nori-taka Matsuba1, Junchi Hasegawa1, Kazuki Yamakai1, Makao Aria1, Yasuke Inaba1, Masayoshi Kimura1, Masaki Wabaka1, Masahiko Yoshida1, Kazumi Maruyama1, Shunsuke Okuyama1, Toshitaka Suzuki1, Hiroyuki Ishii1, Vitaly Mikhailov1, Richard Seef1, Yasumasa Kawakita2, F. Fukuraku Electric Co Ltd., Japan; 1QST, 2KRC, Japan.

M2B • High-Speed Integrated Modulators—Continued

M2B.7 • 12:00 ★ Top-Scored
120 Gb/s Hybrid Silicon and Lithium Niobate Modulators with On-chip Termination Resistor. Shi-hao Sun1, Mingbo He1, Mengyue Xu1, Xiang Zhang1, Ziliang Ruan1, Liu Liu1, Xinjun Cai1, Sun Yuan2, Shen Niu1, China; 1South China Normal Univ., 2China. 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 Vπ of 2.25 V and low insertion loss of 2 dB.

M2C • SDM Imaging & Sensing—Continued

M2C.5 • 12:00
Characterization of Multi-core Fiber Group Delay with Correlation OTDR and Modulation Phase Shift Methods. Florian Azendorf1,2, Anrika Dochhan1, Patrik Urban1, Bernhard Schmauss1, Josep Fabrega4, Michael Eisel1, Krzysztof Wilczynski3, Lukasz Szostkowski2, Laia Nadal1, F. Javier Vilches1, Michela S. Moreolo1,2, ADVA Optical Networking, Germany; 1HFT, Germany; 2Pinotech, Poland; 3CTTC, Spain. We present a low-power all-digital radio-over-fiber transmitter for beyond 28-GHz using sigma-delta modulation, a 140-mW NRZ driver and parallel electro-absorption modulators. 5.25Gbps(2.625Gbps) 64-QAM is transported over 10-km SSMF with 1506nm wavelength and 7.6% (5.2%) EVM.

Room 1B

M2D • Optimizing Network Capacity and Performance—Continued

M2D.5 • 12:00 ★ Invited
Leveraging Photonic Flexibility in Multi-layer Resilient Networks. John K. Oltman1,2, Ciena Corporation, USA. Planning and operation of large-scale deployments of photonic networks and working with a variety of constraints to offer a resilient photonic layer.

Room 2

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

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

Room 3

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

M2F.6 • 12:00 ★ Top-Scored
Low Power All-digital Radio-over-Fiber Transmission for 28-GHz Band Using Parallel Electro-absorption Modulators. Hasin Li1, Jinis Van Kerrebrouck1, Hannes Ramon1, Laurens Boggaert1, John Bare brake1, Chia-Yi Wu1, Laurens Buyenne1, Jakob Declercq1, Johann Bauermeister1, Xin Yin1, Peter Ossieur1, Piet Deemeester1, guy Torfs1,1 Univ. Ghent-imec, Belgium. We present a low-power all-digital radio-over-fiber transmitter for beyond 28-GHz using sigma-delta modulation, a 140-mW NRZ driver and parallel electro-absorption modulators. 5.25Gbps(2.625Gbps) 64-QAM is transported over 10-km SSMF at 1506nm wavelength and 7.6% (5.2%) EVM.

Room 6C

M2G • 12:15
500ns Latency Overhead Analog-to-digital-compression Radio-over-fiber (ADX-RoF) Transport with 16-channel MIMO. 1024QAM Signals with 5G NR Bandwidth. Pau-kun Zhu1, Yuki Yoshida1, Ken-ichi Kitayama1,2,1 The 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 64-QAM 1024QAM-OFDM signals of 5G NR-class is delivered with ~4-Gb/s optical QOK interface, maintaining EVM=1.4%.

Room 6D

M2H • 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, Pau-kun Zhu1, Yuki Yoshida1, Ken-ichi Kitayama1,2,1 The 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 64-QAM 1024QAM-OFDM signals of 5G NR-class is delivered with ~4-Gb/s optical QOK interface, maintaining EVM=1.4%.
Monday, 9 March

Room 6E

M2G • Multiband and SDN for Capacity Scaling—Continued

Room 6F

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

Room 7

M2I • Photonic Integrated Subsystems—Continued

Room 8

M2J • Data Analytic-based Monitoring—Continued

Room 9

M2K • Neuromorphic I: Device-oriented—Continued

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 Sakamoto2, 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, Yahya M. Alfadhl1, 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 Olfein1, 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
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 Tast1, Sonja 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, Zhiwen He1, Lingheng Meng1, Jie Li1, Xiang Lu1, Shaohua Yu1; State Key Laboratory of Optical Communications 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.

12:30–14:00 Lunch Break (on own)
Indium Phosphide Membrane Photonic Integrated Circuits on Silicon, Kevin A. Williams; Technische 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.

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.
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, Amirhossein Ghazisaeidi1, Dylan Le Gac1, Maria Ionescu1, Patrick Bindo1, Jeremie Renaudier1; 1Nokia 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. Pilipetski1; 1SubCom, USA. We experimentally study the impact of symbol rate on transmission performance. From 34.7 to 74.7 Gbd 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; 1Department 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.

M3H.2 • 14:15
Signal-signal Beat Noise Mitigation by Square Root Processing of the Detected Photocurrent, Qinlin Zhang1, Chester Shu1; 1Chinese 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.

M3I.1 • 14:00 • Invited
Recovery of DC Component in Kramers-Kronig Receiver Utilizing AC-coupled Photodetector, Tianwai Bo1, Hoon Kim1; 1Korea 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.1 • 14:00
Recovery of DC Component in Kramers-Kronig Receiver Utilizing AC-coupled Photodetector, Tianwai Bo1, Hoon Kim1; 1Korea 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, Qinlin Zhang1, Chester Shu1; 1Chinese 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; 1AT&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 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 40Gbit/s, 100Gbit/s and above. In 2016, he received the AT&T Fellow award.
Monday, 9 March

Room 1A
M3A • New Photonic Materials—Continued

Room 1B
M3B • Propagation Effects in SMF and SDM Fibers—Continued

Room 2
M3C • Panel: Is it Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity—Continued

Room 3
M3D • VCSELs & Surface Normal Devices—Continued

Room 6C
M3E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 1)—Continued

Room 6D
M3F • Wavelength Selective Devices—Continued

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M3A.2 • 14:30
1.6Tbps Coherent 2-channel Transceiver Using a Monolithic Tx/Rx InP PIC and Single SiGe ASIC, Vikrant Lal1, Pavel Studenkov1, Thomas Frost1, Huan-Shang Tsai1, Babak Behnia1, John Osenbach1, Stefan Wolf1, Robert Goging1, Stefano Porto1, Robert Maher1, Hossein Hodaie1, Jaiming Zhang1, Carlo Di Giovanni1, Koichi Hoshino1, Thomas Vallaitis1, Bryan Ellis1, Jeanne Yan1, King Fong1, Ehsan Souodi1, Matthias Kuntz1, Sanketh Buggaveti1, Don Pavinski1, Steve Sanders1, Zhenxing Wang1, Gloria Höfler1, Peter Evans1, Scott Corzine1, Tim Butrie1, Mehrdad Ziari1, Fred Kish1, David Welch1, Infinera Corporation, USA. We present a 1.6Tbps coherent transceiver delivering 800Gbps/wave transmission using integrated Tx/Rx functions with 50GHz bandwidth and 50kHz linewidth tunable lasers on a single two channel InP PIC, paired with a SiGe Driver and TIA ASIC.

M3B.2 • 14:30
14:45
106 Gb/s Normal-incidence Ge/Si Avalanche Photodiode with High Sensitivity, Bin Shi1, Fan Qi1, Penglei Cai1, Xueping Chen1, Zengwen He1, Yanhu Duan1, Guanghui Hou1, Tuzing Su1, Su Li1, Wang Chen1, Chingyin Hong1, Reng-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 • 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

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

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M3A.3 • 14:45
Data-mining-assisted Resonance Labeling in Ring-Based DWDM Transceivers, Peng Sun1, Jared Hulme1, Ashkan Seyedi1, Marco Fiorantino2, Raymond Beausoleil1, 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.3 • 14:45
All-optical Spectral Magnification of WDM Signals after 50 km of Dispersion-UnCompensated Transmission, Frederik Kleis1, Mads Lilieholm1, Michael Galli1, Leif Oxenløve1, DTU, Denmark. We successfully demonstrate an optical time lens system operating on data signals that are not dispersion compensated after fiber transmission. We demonstrate 4x spectral magnification after 50 km of dispersion un-compensated transmission, with BER <1E-9.

M3C.3 • 14:45
Ultra-thin III-V Photodetectors Epitaxially Integrated on Si with Bandwidth Exceeding 25 GHz, Svenja Mauhie1, Yannick Baumgartner1, Saurabh Santi1, Gian Dingi1, Marlyne Sousa1, Lukas Czornomza1, 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.

M3D.3 • 14:45
Five-core 1x6 Core Selective Switch and Its Application to Spatial Channel Networking, Masahiko Jinno1, Takehiro Kodama1, Tsubasa Ishikawa1, Kaga- wa Univ., Japan. We design and prototype a 5-core 1x6 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.
Experimental Demonstration of Widely Tunable Rate/Reach Adaptation From 80 km to 12,000 km Using Probabilistic Constellation Shaping. Dmitri G. Foursa, Dmitriy Kovsh, Alexei N. Pilipetskii, Peter Winzer, Junho Cho, Chandrasekhar Sethumadhavan, USA. We studied C-band frequency Brillouin fiber laser. We experimentally demonstrated a 28-GBaud SSB 16-QAM signal transmission with a record 16.67% FTN ratio. 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. For investigated tilt range, differences between strategies were observed. The overall penalties were small and minor for penalty compensation were considered. Several transmission pre-emphasis strategies were considered. System performance penalties due to gain tilt. A joint equalization scheme consisting of Tomlinson-Harashima precoding and MIMO-FFE is proposed to effectively mitigate the ISI induced by FTN signaling. 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.
M3A • New Photonic Materials—Continued

M3A.4 • 15:00
On-chip Mode-division Multiplexing with Modal Crosstalk Mitigation, Yatian Huang1, Ruohuan Zhang1, Haoshuo Chen1, Hanzi Huang2, Qingming Zhu3, Yu He1, Yingxiang Song1, Nicolas K. Fontaine1, Roland Ryf1, Yong Zhang1, Yikai Su1, Min Wang1, Shangshuai Jiang1, 2Lightwave Logic, USA.

We demonstrate and experimentally demonstrate modal crosstalk mitigation using 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.

M3B • Propagation Effects in SMF and SDM Fibers—Continued

M3B.4 • 15:00
Linear and Nonlinear Features of Few-mode Fibers with Partial Coupling Among Groups of Quasi-degenerate Modes, Filipe Ferreira1,2; Aston Univ., UK; 3Univ College London, UK. We review different solution methods for the linear coupling operator in the coupled nonlinear Schrödinger equations for few-mode propagation. Models are compared for different differential mode delay and linear coupling regimes.

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, Shigeiwa Takaaki1, Masatoshi Arasawa1, Ryu Washino1, Yasushi Sakuma1, Kazuhiko Naoe1; Device 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

M3E.3 • 15:00
Workshop on Machine Learning for Optical Communication Systems: a summary, Joshua A. Gordon1, Abdella Battou3, Daniel C. Kilper2; Communications Technology Development Center, Lumentum Japan, Inc.; 2 × 1 Mach-Zehnder Filters for 400GBe, Junya Takano1, Takeshi Fujisawa1, Yusuke Sawada1, Kunisasa Saitoh1; Hokkaido 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.

M3E.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, Kunisasa Saitoh1; Hokkaido 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.

M3F • Wavelength Selective Devices—Continued

M3F.4 • 15:00
Four-channel, Silicon Photonic, Wavelength Multiplexer-demultiplexer With High Channel Isolation, Mustafa Hammood1, Ajay Mistry1, Han Yun1, Minglei Ma1, Lukas Chrostowski1, Nicolas Jaeger2; 3Univ. of British Columbia, Canada. We present a four-channel, silicon photonic, wavelength multiplexer-demultiplexer made using cascaded contra-directional couplers with adjacent and non-adjacent channel isolations of at least 37 dB and 45 dB, respectively. The devices maximum insertion-loss is 0.72 dB.
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. Netherton1, Wei Zhang2, Liron Stern3, Paul A. Morton4, John E. Bowers4, Scott B. Papp4; 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/50GBd link based on independent transmit and LO frequency-stabilized ultranarrow-linewidth SBS lasers, with ~40Hz integral linewidths and 7\times10^{-14} fractional frequency stability. The low-BW optical-frequency-stabilized PLL with 3\times10^{-4} rad^2 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 Neilson2, Nagesh Basavanahally1, Yee Lou1, Hugo Satar2, Mark Cappuzzo1, Rose Kopf1, Al Tate1, Gregory Raybon1, Andrew Adamiecki2, Nicolas K. Fontaine1, Mark Earnshaw1; 1Nokia Bell Labs, USA; 2Nokia Bell Labs, USA. We demonstrate arrays of surface-normal electroabsorption modulators with ultrawide bandwidth (>\approx 55 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; 1Hewlett Packard Labs, USA. Low-loss, fabrication-tolerant Si3N4 CWDM lattice filters and AWGs are demonstrated for 990 – 1065nm bottom-emitting VCSELs. Channel separation of 25 nm, XT < 0.35 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, Yung-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 Xiang3, Warren Jen4, Christopher Morton5, John E. Bowers6; 1Morton Photonic Inc., USA; 2Johns Hopkins Univ., USA; 3UCSB, 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).

M3I.6 • 15:30
Modulation Classification based on Deep Learning for DMT Subcarriers in VLC System, Wu Liu1, Xiang Li1, Chao Yang1, Ming Luo1; 1Wuhan 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.

M3I.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 Zhang2, Lei Wang1, Chien-Ji Chen1, Alberto Pepe1, Xin Liu1, Kai-Chia Chen1, Yuhang Dong1, Meng-Chyi Wu1, Lai Wang2, Yi Luo1, H.Y. Fu1; 1Tsinghua-Berkeley Shenzhen Inst., China; 2Department of Electronic Engineering, Tsinghua Univ., China; 3Tsinghua Shenzhen International Graduate School, Tsinghua Univ., China; 4Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan. We demonstrate a 3-meter 4-Gbps QAM-OFDM VLC system with 3.2×10^10 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.7 • 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, Yusheng Bai1; 1FutureWei 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.
M3Z.1 OpenConfig-extension for VLAN-based End-to-end Network Slicing Over Optical Networks, Abbubaker Siddique Musaaddas1, Alessio Giorgetti1, Rodrigo Stange Tessinari2, Thierno Diallo3, Andrea Sgamellini4, Reza Nejabati1, Dimitra Simeonidou1; 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, Xianyi Guo1, Tianshun Zhang1, Wu Jia1, Yudan Su1, Guangsheng Yang2, Jinglie Sun3, Yan Shao2, Yuefeng Ji1, Guangjuan Wang1; 1Beijing Laboratory of Advanced Information Networks, Beijing Univ. of Posts and Telecommunications, China; 2Networld-Forge Research Inst., China Unicom, China; 3State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We demonstrate a carrying capability evaluation system, which can evaluate and predict the access network capacity and efficiency by extracting detail network status and trends from hybrid data sources based on machine learning.

M3Z.3 All-optical Cross-connect Switch for Data Center Network Application, Kristo Prifti1, Rui Santos1, Jiang-uk Shin1, Hangju Kim1, Neteens Tessema1, Ripalta Stabile2, Steven Kleijn1, Luc Augustin1, HuynDo Jung1, Sang-Ho Park1, Yongsoon Baek1, Sungkyu Hyun1, Nicola Calabrèse1; 1SMART Photonics, Netherlands; 2Department of Photonics-Wireless Convergence Component Research, ETRI, Korea (the Republic of), 1IPi Research Institute, TU/e Eindhoven Univ. of Technology, Netherlands; 3R&D Center, Coweaver Co, Korea (the Republic of). We demonstrate a C-band optical cross-connect switch based on InP integrated photonicics, 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, Kyio Ishii1, Sugang Xu1, Noboru Yoshikane1, Atsuko Takefusa1, Shigeyuki Yanagamichi1, Takeshi Hoshiba1, Kohei Ishida1, Tomohiro Kudo1, Takehiro Tsutani1, Yoshinari Awaji1, Shu Namiki1; 1AIST, Japan; 2NICT, Japan; 3NPO, Japan. We demonstrate practical implementation of real hardware composition onto a ROADAM-based model is demonstrated. The functional-block based model precisely describes the physical layer structures can act as a hardware abstraction layer for more abstracted models like OpenROADM.

M3Z.5 Demonstration of Extensible Threshold-based Streaming Telemetry for Open DWDM Analytics and Verification, Abhinasva Sadasivavaro1, Loukas Paraschis1, Infinera Corporation, USA. A novel and practical threshold-based extension of streaming telemetry that advances open WDM analytics and introduces network verification, is demonstrated employing an extensible NOS application agent combined with standard NETCONF/YANG and open SDN control technologies.

M3Z.6 Demonstration of Alarm Correlation in Partially Disaggregated Optical Networks, Quan Pham Van1, Victor López1, Áurea Moya López-de-Lerma1, Konrad Mrówka3, Saeed Sgambelluri1, Andrea Sgambelluri1, Luc Augustin1, HyunDo Jung2, Sang-Ho Park1; 1Institute of Photonics and Electronics, Berlin, Germany; 2Department of Electrical and Electronic Engineering, Trinity College Dublin, Ireland; 3ADVA Optical Networks, Netherlands. We demonstrate a C-band optical cross-connect switch based on InP integrated photonicics, 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 m wavelength, Galip Hepgüler1, Abd-Madani2, Stefan Wagner1, Daniel Schwab3, Brendan O’Connor4, Alejandro Castellanos5, 1AMO GmbH, Germany; 2Black Semiconductor, Germany. In this demonstration we show packaged graphene photodetectors operating at 1550 nm with a bandwidth of 50 GHz. We are presenting the first graphene photonic device prototypes approaching TRIL 5 level.

M3Z.9 Demonstration of Software-defined Packet-optical Network Emulation with Mininet-optical and ONOS, Bob Lantz1, Alan A. Diaz Montiel2, Ji-akai Yu1, Christian D. Riss1, Marco Ruffini1, Daniel C. Kilper2; 1College of Optical Sciences, Univ. of Arizona, USA; 2Mininet Project, USA. 1CONNECT Centre, Trinity College, Ireland. 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, Feng Cui1,2, Francesco Giancone1, Koteswararoa Kondepudi2, Pietro Castoldi1, Luca Valcarceghi2, Andrea Bragagnolo3, Fabrizio Gatti1, Antonia Napolitano1, Justine Cris Berromeo1, 1Scuola Superiore Sant’Anna, Italy; 2Ericsson, Italy; 3CNT, Italy. A fully packaged 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.14 Demonstration of Alarm Knowledge Graph Construction for Fault Localization on ONOS-based SDN Platform, Zhenguo Li1, Yongli Zhao1, Yajie Li1, Sabidur Rahman2, Ying Wang2, Xiaosong Yu1, Luohang Zhang1, Guo Li3, Rahul Dandawate1; 1AUST National University, Singapore; 2Akamai Technologies, USA; 3University of California, USA. We demonstrate construction of an alarm knowledge graph, 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.15
Disaggregated, Sliceable and Load-aware Optical Metro Access Network for 5G Applications and Service Distribution in Edge Computing, Bitao Pan1, Xuwei Xue1, Fu Wang1, Eduardo Magalhães1, Roberto Moro1,6, Emilio Riccardi2,6, Nicola Calabretta3,6, Eindhoven Univ. of Technology, Netherlands; 1TIM, 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.16
Withdrawn

M3Z.17
Physical-layer Awareness: GNPy and ONOS for End-to-end Circuits in Disaggregated Networks, Jan Kundrátí1,2, Andrea Campanella1, Esther Lerouzirc,1, Alessio Ferrari1, Orihav1,2, Michael Hazlinsky1, Gert Grammel1, Gabriele Galimberti1, Vittoria Curri1, CESNET, Czechia; 1Telecom Infra Project, USA; 2Orange Labs, France; 3Open Networking Foundation, USA; 4Politecnico di Torino, Italy; 5Juniper Networks, Germany; 6Cisco Photonics, Italy; 7Faculty of Electrical Engineering and Communication, Brno Univ. of Technology, Czechia. 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.18
Flexible Optical Network Enabled Proactive Cross-layer Restructuring for 5G/6G Backhaul Network with Machine Learning Engine, Rentao Gu1, Yongyao Qu2, Meng Lian1, Hongbiao Li2, Zihao Wang1, Yinan Zhu2, Guo Ziz1, Jianjun Yang1, Dajiang Wang1, Yufeng Ji1, Beijing Univ. of Posts and Telecom, China; 1ZTE Corporation, China; 2China United Network Communications Co. Ltd., China. It demonstrates a flexible optical network enabled “Network Restructuring as Traffic Changes” for 5G/6G 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 Girafe Renom1,2, Fabien Boitier1, Camille Delezoide1, Camille Delezoide3, Patrick Loeve1, Marta Buffa2,3, Annalisa Morea3,4,5, Ramon Casellas4,5, Luis Velasco2,5, NHS Bell Labs, France; 1Universitat Politecnica de Catalunya, Spain; 2Nokia, Italy; 3Centre Tecnologic 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
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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 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 for unprecedented coordination among the traffic. This requires efficient inter-vehicle and road-side communications, where microwave photonics and optical wireless communication become important candidate technologies.

Takemi Hasegawa is Group Leader in Optical Communications Laboratory, Sumitomo Electric Industries, Ltd (SEI) in charge of R&D on transmission and specialty fibers. Since joining SEI in 1999, he has been engaged in design and application of fibers. He received his Master of Engineering degree from the University of Tokyo in 1999. He is a member of OSA and IEEE/IPS.
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.
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

M4A.2 • 17:00
Two-level Optical Encryption for Secure Optical Communication, Ye-tian Huang1, Haoshuo Chen2, Hanzi Huang1, Qianwu Zhang3, Zhenguan Li1, Nicolas K. Fontaine1, Roland Ryf4, Min Wang1; 1Shanghai Univ., China; 2Nokia Bell Labs, USA. We demonstrate 60 Gbit/s transmission over 43-km SMF using low-coherence matched detection combined with spectral phase coding as a two-layer optical encryption. Encrypted signal and carrier are multiplexed through polarization diversity and demultiplexed using polarization tracking.

 Speakers:
Daniel Adler; Valens, Israel
Ton Koonen; Eindhoven University of Technology, Netherlands
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 Tanizawa1, Fumio Futami1; 1Tamagawa 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 Baklakier; AIRBUS Satellite and Defense, UK
Daniel Adler; Valens, Israel
Ton Koonen; Eindhoven University of Technology, Netherlands
Shilong Pan; Nanjing University of Aeronautics and Astronautics, China

M4D.2 • 17:00
Colorless, Partially Directional, and Contentionless Architecture for High-degree ROADMs, Yongcheng Li1, Liangjia Zong1, Mingyi Gao1, Biswanath Mukherjee1, Gangxiang Shen1; 1Soochow Univ., China; 2Transmission 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 Marotta1, Dajana Casini1, Massimo Tornatore2, Yusuke Hirota1, Yoshinari Awaji1, Biswanath Mukherjee1; 1Univ. of L’Aquila, Italy; 2Politecnico di Milano, Italy; 3Univ. of California, USA; 4National 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.2 • 17:00
Invited Neural Network Training for OSNR Estimation - from Prototype to Product, Andrew Shiner1, Moham-mad E. Mousa-Pasandi2, Meng Qiu3, Michael A. Reimer1, Eui Young Park1, Michael Hubbard1, Qunbi Zhuge1,2,3; 1Univ. of L’Aquila, Italy; 2Shanghai Jiao Tong Univ., China; 3Cambridge 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.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 Yu Wang1, Zhilei Huang1, Biwei Pan1, Huanlu Li1, Guanpeng Li1, Jian Tang1, Yuchun Lu1; 1Huawei Technologies Co. Ltd., China. A single-wavelength single-polarization 35GHz-class (112Gbps-class) commercial EML-based IM/DD 214Gbps PAM-4 signal transmission is experimentally demonstrated. By using advanced MLSE with low complexity and power consumption, the BER is below standard KP4-FEC requirement of $2\times10^{-2}$.
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 (r)evolution. 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 Wellbrook; 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.3 • 17:15**

A 400 Gb/s O-band WDM (8×50 Gb/s) Silicon Photonic Ring Modulator-based Transceiver, Stelios Pinitsi, Miltiadis Moralis-Pegios, Theoni Alexoudi, Konstantinos Fotiadis, Yoojin Ban, Peter De Heyn, Jan Van Campenhout, Nikos Piersios, Department of Informatics, Center for Interdisciplinary Research & Innovation, Aristotle Univ. of Thessaloniki, Greece; imec, Belgium. We present a 400 (8×50) Gb/s-capable RM-based Si-photonic WDM O-band T×R with 1.17nm channel spacing for high-speed optical interconnects and demonstrate successful 50Gb/s-NIR T×R operation achieving a ~4.5dB Tx extinction ratio under 2.15Vpp drive.

**M4I.2 • 17:00**

100 Gb/s Real-Time Transmission over a THz Wireless Fiber Extender Using a Digital-coherent Optical Modem, Carlos Castro, Robert Elschner, Thomas Merkel, Colja Schubert, Ronald Freund, Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany; Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Germany. We demonstrate the real-time transmission of a 34-Gb/d 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.

**M4K.2 • 17:00**

49.2-Tbit/s WDM Transmission over 2×93-km Field-Deployed Fiber, Karsten Schu, Fred Buchal, Roman Dischler, Mathieu Chagnon, Vahid Aref, Henning Bulow, Qian Hu, Florian Pulka, Massimo Frascolla, Esmaeel Alhammadi, Adel Samhan, Islam Younis, Mohamed El-Zonkoli, Peter Wirtz, Nokia Bell Labs, Germany; Nokia, France; IP, Nokia, Italy; Etsalat, United Arab Emirates; Nokia UAE, United Arab Emirates; Nokia Bell Labs, USA, USA. We present 40 channel WDM transmission experiments over one and two spans of 93-km field-deployed SSMF achieving net capacities of 51.5-Tbit/s and 49.2-Tbit/s for PCS-256-QAM with 7.5 bits entropy and 45.9-Tbit/s and 45.1-Tbit/s for 64-QAM transmission, respectively.

**M4K.3 • 17:15**

Entropy and Symbol-rate Optimized 120 Gbaud PS-36QAM Signal Transmission over 2400 km at Net-rate of 800 Gbps/A, Masa-nori Nakamura, Takayuki Kobayashi, Hiroshi Yamazaki, Fukutaro Hamasaka, Munehiko Nagatani, Hitoshi Wakita, Hideyuki Nosaka, Yutaka Miyamoto, NTT Network Innovation Laboratories, Japan; NTT 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.
Room 1B

**M4A • Symposium: Quantum Security Subsystems—Continued**

*Compact Differential Phase-shift Quantum Receiver Assisted by a SOI / BICMOS Micro-ring Resonator*, Ne-manja Vakic1, Dinka Milovancev1, Winfried Baxleitner2, Hannes Hübel1, Bernhard Schrenk1; AIT Austrian Inst. of Technology, Austria. We demonstrate a phase-selective and colorless quantum receiver assisted by a silicon-on-insulator microring, 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.4 • 17:30 Invited**

*Progress on Quantum Key Distribution Using Ultralow Loss Fiber*, Alberto Balzarotti1, Davide Rusca1, Gianluca Boso1, Raphael Houlmann1, Cédric Vuilliez2, Misael Caloz3, Matthieu Perrenoud1, Gaetan Gras1, Claire Aubert1, Félix Bussières1, Ming-Jun Li2, Daniel Nolan2, Anthony Martin1, Hugo Zbinden1; 1Univ. of Geneva, Switzerland; 2Corning Incorporated, USA.

**M4A.5 • 17:45 Invited**

*Power Efficient All-fiberized 12-core Erbium/ytterbium Doped Optical Amplifier*, Gilles Melin1, Romain Keramman1, Achille Monteville1, Sylvain Bondas2, Thierry Robin2, David Landais2, Aurelien Lebreton2, Yves Jaouen2, Thierry Taunay2, iXblue2, France; iLumibird2, France; iPhotonics Bretagne, France; TELECOM Paris, France. 20dB gain in C-band with only 3.3W 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.

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

**M4B.2 • 17:30**

*Full C-band and Power Efficient Coupled-multi-core Fiber Amplifier*, Masaki Wada1, Taiji Sakamoto1, Shinichi Aozasa1, Ryota Imada1, Takashi Yamamoto1, Kazuhide Nakajima1; NTT 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.

**M4B.3 • 17:45 Top-Scored**

*Experimental Assessment of a Programmable VCSel-based Photonic System Architecture over a Multi-hop Path with 19-Core MCF for Future Agile Tbit/s Metro Networks*, Michela Svaluto Moreolo1, Josep M. Fabrega2, Laia Nadal2, Ricardo Martinez2, Ramon Casellas2, F. Javier Vilchez2, Raúl Muñoz2, Ricard Vilalta2, Alberto Gatto2, Paola Parolari2; 1Nokia Corporation, Porcari, Italy; 2Politecnico di Torino, Italy.

**M4B.4 • 17:30**

*Top-Scored* Is There a Most Appropriate Channel Spacing in WDM Networks When Individually Routing 67 Gbaud Carriers?, Thierry Zami1, Bruno Lavigne1, Nokia 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.

**M4B.5 • 17:30**

*Towards Intelligent Optical Networks: The Role of Intellectual Property*, Sebastian Gade1, Céline Borsier1, EPO, Germany. An overview of worldwide patenting activity covering machine learning and artificial intelligence in the field of optical communication is presented. The results emphasize a worldwide growing market offering benefits for both providers and customers.

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

**M4C.2 • 17:30**

*Power Effcient All-fiberized 12-core Erbium/ytterbium Doped Optical Amplifier*, Gilles Melin1, Romain Keramman1, Achille Monteville1, Sylvain Bondas2, Thierry Robin2, David Landais2, Aurelien Lebreton2, Yves Jaouen2, Thierry Taunay2, iXblue2, France; iLumibird2, France; iPhotonics Bretagne, France; TELECOM Paris, France. 20dB gain in C-band with only 3.3W 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.

**M4C.3 • 17:45**

*Full C-band and Power Efficient Coupled-multi-core Fiber Amplifier*, Masaki Wada1, Taiji Sakamoto1, Shinichi Aozasa1, Ryota Imada1, Takashi Yamamoto1, Kazuhide Nakajima1; NTT 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**

*Top-Scored* Is There a Most Appropriate Channel Spacing in WDM Networks When Individually Routing 67 Gbaud Carriers?, Thierry Zami1, Bruno Lavigne1, Nokia 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 • 17:30**

*Experimental Assessment of a Programmable VCSel-based Photonic System Architecture over a Multi-hop Path with 19-Core MCF for Future Agile Tbit/s Metro Networks*, Michela Svaluto Moreolo1, Josep M. Fabrega2, Laia Nadal2, Ricardo Martinez2, Ramon Casellas2, F. Javier Vilchez2, Raúl Muñoz2, Ricard Vilalta2, Alberto Gatto2, Paola Parolari2; 1Nokia Corporation, Porcari, Italy; 2Politecnico di Torino, Italy.

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

**M4D.2 • 17:30**

*Beyond—Continued Technologies for 10G and Cable—Continued* Erbium/ytterbium Doped Optical Amplifier, Gilles Melin1, Romain Keramman1, Achille Monteville1, Sylvain Bondas2, Thierry Robin2, David Landais2, Aurelien Lebreton2, Yves Jaouen2, Thierry Taunay2, iXblue2, France; iLumibird2, France; iPhotonics Bretagne, France; TELECOM Paris, France. 20dB gain in C-band with only 3.3W 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.

**M4D.3 • 17:45**

*Full C-band and Power Efficient Coupled-multi-core Fiber Amplifier*, Masaki Wada1, Taiji Sakamoto1, Shinichi Aozasa1, Ryota Imada1, Takashi Yamamoto1, Kazuhide Nakajima1; NTT 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.

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**M4D.5 • 17:30**

*Experimental Assessment of a Programmable VCSel-based Photonic System Architecture over a Multi-hop Path with 19-Core MCF for Future Agile Tbit/s Metro Networks*, Michela Svaluto Moreolo1, Josep M. Fabrega2, Laia Nadal2, Ricardo Martinez2, Ramon Casellas2, F. Javier Vilchez2, Raúl Muñoz2, Ricard Vilalta2, Alberto Gatto2, Paola Parolari2; 1Nokia Corporation, Porcari, Italy; 2Politecnico di Torino, Italy.

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

**M4E.3 • 17:30 Invited**

*160-Gb/s Nyquist PAM-4 Transmission with GeSi-EAM Using Artificial Neural Network Based Nonlinear Equalization*, Lei Zhang1, Fan Yang1, Hao Ming1, Yixiao Zhu1, Xiaoke Ruan1, Yanping Li1, Fan Zhang1; Peking Univ., China; ZTE, China. We experimentally demonstrate optical interconnects of PAM-4 signal with a single lane bit rate of 160Gb/s generated by a compact silicon based GeSi electro-absorption modulator using artificial neural network based nonlinear equalization.

**M4E.4 • 17:30**

*Top-Scored* Is There a Most Appropriate Channel Spacing in WDM Networks When Individually Routing 67 Gbaud Carriers?, Thierry Zami1, Bruno Lavigne1, Nokia 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.

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

**M4F.3 • 17:30**

*Why Data Science and Machine Learning Need Silicon Photonics*, Benjamin Klenk1, Larry Dennison2; 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.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.3 • 17:45
Cycle-Slip Rate Analysis of Blind Phase Search DSP Circuit Implementations, Erik Börjeson1, Per Larsson-Edefors1; 1Department of Computer Science and Engineering, Chalmers Univ. of Technology, Sweden. Using FPGA-accelerated simulations, we study the cycle-slip rate of 16QAM blind phase search implementations. While block averaging suffers from degraded BER when compared to sliding-window averaging, it results in lower cycle-slip rates and power dissipation.

M4K.5 • 17:45
800ZR+ DWDM Demonstration over 600km G.654D Fiber Enabled by Adaptive Nonlinear TripleX Equalization, Fabio Pittalà1, Maximilian Schaedler1, Christian Blummen1, Gernot Goerg1, Stefano Calabro1, Maxim Kucherov1, Changsong Xie1; 1Huawei Technologies, Germany. We demonstrate the feasibility of 800ZR+ by transmitting 32×96-GBaud DP-32QAM over 600km of G.654D fiber using a generic interoperability FEC. Superior performance is achieved by advanced nonlinear components compensation.
M4A • Quantum Security Subsystems—Continued

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

Monday, 9 March

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, Hitoshi 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 fluctuate due to the inter-core crosstalk.

M4C.4 • 18:00
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, Hiroaki 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.

M4D.6 • 18:00
Network Design Framework Exploiting Low-margin Provisioning of Optical Shared Restoration Resources, Daniela A. Moniz¹, João Pedro¹, João Pires²; ¹Infinera Corporation, Portugal; ²Instituto de Telecomunicações, Portugal. This paper proposes a network design framework tailor 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.

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.
M4H.5 • 18:00 Grating Coupled Laser (GCL) for Si Photonics, Shiyun Lin,1, Ding Wang,1, Ferdous Khan,1, Jeannie Chen,1, Alexander Nickel,1, Brian Kim,1, Yasuhiro Matsui,1, Bruce Young,1, Martin Kwakernaak,1, Glen Carey,1, Tsunugi Sudo,1; HI-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 Mauer3,4, Matthias Blaicher1, Philipp-Immanuel Dietrich1, Pablo Marin-Palomo1, Wladislav Hartmann1, Muhammad R. Billah1,2, Ute Troppenz1, Martin Moehrle1, Sebastian Randel1, Wolfgang Freude1, Christian Koos1,3; Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology (KIT), Germany; Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany; Vanguard Automation GmbH, Germany; Fraunhofer Heinrich-Hertz-Institut (HHI), 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.

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.

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; Huawei 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.

M4G • Open Networking Summit: Optical Metro/Aggregation Networks to Support Future Services over 5G—Continued
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>07:30–08:00</td>
<td>Plenary Session Coffee Break, Upper Level Corridors, Ballroom 20 Lobby</td>
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<tr>
<td>08:00–10:00</td>
<td>Plenary Session, Room Ballroom 20BCD</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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<tr>
<td>10:00–17:00</td>
<td>Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall)</td>
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<tr>
<td>10:00–14:00</td>
<td>OFC Career Zone Live, Exhibit Hall B2</td>
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<tr>
<td>12:00–14:00</td>
<td>OFC and Co-Sponsors Awards and Honors Ceremony and Luncheon, Upper Level, Room Ballroom 20A</td>
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**Tuesday, 10 March**

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
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| 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)  
T3F • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks? |

**T3A.1 • 14:00 Tutorial**

**T3B.1 • 14:00 Invited**

**T3C.1 • 14:00 Invited**

**T3D.1 • 14:00 Invited**

**T3E.1 • 14:00 Invited**

With the advent of powerful computer 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 Djukic; Ciena, Canada
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 Meaklim; Ciena, Canada  
Approaching the Shannon Limit of Subsea Networks  
Pierre Mertz; Infinea, USA  
Knocking on Shannons’ Door

14:00–16:00
T3H • Silicon Photonics Applications  
Presider: Dominic Goodwill; Huawei Technologies R&D, Canada

T3I • Short-reach Systems II  
Presider: Yi Cai; ZTE TX, Inc., USA

T3J • Orchestration and Control  
Presider: Paolo Monti; Chalmers Tekniska Hogskola, Sweden

T3K • Intra Data Center Networks I  
Presider: Reza Nejabati; Univ. of Bristol, UK

14:00–16:00
T3L.1 • 14:00  
Top-Scored  
1.6Tbps Silicon Photonics Integrated Circuit for Co-packaged Optical-IO Switch Applications  
Saeed Pathololoum1, Kimchau Nguyen1, Hari Mahalingam1, Meer N. Sabki1, Zhi Li1, Christopher S. Seibert1, Mohammad Montazer1, 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 Liao1, 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 106Gbps PM4 optical channels, including lasers, modulators and V-grooves. Post-FEC error-free operation over temperature is demonstrated.

T3J.1 • 14:00  
Top-Scored  
102 Gbaud PAM-4 Transmission Over 2 km Using a Pulse Shaping Filter with Asymmetric ISI and Tomin son Harashima Precoding, Xuexiang Li1, Zhenping Xing1, Samuel 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 3.8×10-10 using linear equalizer at receiver.

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.

14:00–16:00
T3E.1 • 14:00  
Top-Scored  
Blockchain-anchored Failure Responsibility Management in Disaggregated Optical Networks, Silvia Fichera1, Andrea Giamello1, Alessio Giorgetti1, 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.

14:00–16:00
T3F.1 • 14:00  
Top-Scored  
Preparing the Transport Network for 5G  
Session sponsored by Juniper Networks  
13:50–14:50, Theater II

14:00–16:00
T3G.1 • 14:00  
Top-Scored  
Prepared Network for 5G  
Session sponsored by Juniper Networks  
13:50–14:50, Theater II

14:00–16:00
T3H.1 • 14:00  
Top-Scored  
1.6Tbps Silicon Photonics Integrated Circuit for Co-packaged Optical-IO Switch Applications  
Saeed Pathololoum1, Kimchau Nguyen1, Hari Mahalingam1, Meer N. Sabki1, Zhi Li1, Christopher S. Seibert1, Mohammad Montazer1, 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 Liao1, 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 106Gbps PM4 optical channels, including lasers, modulators and V-grooves. Post-FEC error-free operation over temperature is demonstrated.

14:00–16:00
T3I.1 • 14:00  
102 Gbaud PAM-4 Transmission Over 2 km Using a Pulse Shaping Filter with Asymmetric ISI and Tomlinson Harashima Precoding, Xuexiang Li1, Zhenping Xing1, Samuel 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 3.8×10-10 using linear equalizer at receiver.

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T3A • Linear and Nonlinear Space Division Multiplexing—Continued

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.

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

Tuesday, 10 March

Room 1A

Room 1B

Room 2

Room 3

Room 6C

Room 6D

T3A.2 • 14:30
Integrable Magnetless Thin Film Waveguide Optical Isolator based on Bismuth Iron Garnet Material, Vincent Stenger1, Dolendra Karki2, Andrea Pollick1, Miguel Levy1, SRICO, Inc., USA; 1SRICO, Inc., 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 photonics platforms.

T3B.2 • 14:30
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 Nakahara1, Kaoru Okamoto1, Shigenori Hayakawa1, Masatoshi Arasaki2, Tetsuya Nishida1, Ryu Washino1, Takeshi Kitatani1, Masatoshi Mitaki1, Hironori Sakamoto1, Yasushi Sakuma1, Shigehisan Tanaka1; 1Lumentum 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.

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; 1Photonics 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, Keniuke Kasa1, Toshihiko Hirooka1, Masatake 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 (QNSC) and injection-locked WDM techniques.

T3E.2 • 14:30
Invited Title to be Announced, Thomas Pfeiffer1; 1Nokia Bell Labs, Germany. Abstract not available.
Assessing Capacity: It's in the Noise

Andreas Leven; Nokia, Germany

High-performance Transponders for Field Deployment?—Continued

Shaoliang Zhang; Acacia, USA

Continued

Perfor

48G Silicon Photonics Applications—Continued

High-performance Transponders—Data Sheets and Real-world Performance

Elizabeth Rivera Hartling, Facebook Inc., USA

400G Silicon Photonics Integrated Circuits Transceiver Chips for CPO, OBO, and Pluggable Modules, Erman Timurdoğan1, Zhan Su1, Ren-Jye Shiu3, Matthew Byrd3, Christopher Poulton1, Kenneth Jabon1, Christopher DeRose1, Benjamin Moss1, Ehsan Hosseini1, Ivan Duzevik1, Michael Whitson1, Ronald Millman1, Dagen Atlas1, 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 940Gb/s/mm, energy efficiency of <10pJ/bit, and -5.4dBm OMA sensitivity at the KP4 pre-FEC-BER=2.4e-4.

T3H.2 • 14:15
40G SiPH Integrated Circuits Transceivers for CPO, OBO, and Pluggable Modules, Erman Timurdoğan, Zhan Su, Ren-Jye Shiu, Matthew Byrd, Christopher Poulton, Kenneth Jabon, Christopher DeRose, Benjamin Moss, Ehsan Hosseini, Ivan Duzevik, Michael Whitson, Ronald Millman, Dagen Atlas, Michael Watts, 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 940Gb/s/mm, energy efficiency of <10 pJ/bit, and -5.4 dBm OMA sensitivity at the KP4 pre-FEC-BER=2.4e-4.

45nm CMOS - Silicon Photonics

Top-Scored

45nm CMOS - Silicon Photonics Monolithic Technology (45CLO) for Next-generation, Low Power and High Speed Optical Interconnects, Michal Rakowski1, Colleen Meagher1, Karen Nummy2, Abdelsalam Bian1, Brendan Harris3, Kate Mclean3, Laura Medina1, Bo Peng1, Zeyi Sowinski1, Andy Stricker1, Thomas Houghton2, Kevin McStay2, Asli Sahin2, Louis Michael Watts1, Analog Photonics, USA, 2GlobalFoundries, USA. 45nm CMOS - Silicon Photonics Monolithic 300nm 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.

T3H.3 • 14:30

45nm CMOS - Silicon Photonics Monolithic Technology (45CLO) for Next-generation, Low Power and High Speed Optical Interconnects, Michal Rakowski1, Colleen Meagher1, Karen Nummy2, Abdelsalam Bian1, Brendan Harris3, Kate Mclean3, Laura Medina1, Bo Peng1, Zeyi Sowinski1, Andy Stricker1, Thomas Houghton2, Kevin McStay2, Asli Sahin2, Louis Michael Watts1, Analog Photonics, USA, 2GlobalFoundries, USA. 45nm CMOS - Silicon Photonics Monolithic 300nm 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.

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T3L.2 • 14:15

84-Gbaud PAM-4 Transmission over 20 km using 4-A LAN-WDM TOSA and ROSA with MLSE Based on Nonlinear Channel Estimation, Hiroki Taniguchi1, Shuto Yamamoto1, Yoshikane1, Yoshibumi1, Kazuyuki Maunon1, NTT Network Innovation Laboratories, Japan. We demonstrate 1.68-Gbps/PAM-4 transmission over 20-km using 4-A LAN-WDM TOSA and ROSA with BER below the HD-FEC limit under 24-GHz bandwidth limitation and -39.7-ps/nm chromatic dispersion by applying MLSE based on nonlinear channel estimation.

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84-Gbaud PAM-4 Transmission over 20 km using 4-A LAN-WDM TOSA and ROSA with MLSE Based on Nonlinear Channel Estimation, Hiroki Taniguchi1, Shuto Yamamoto1, Yoshikane1, Yoshibumi1, Kazuyuki Maunon1, NTT Network Innovation Laboratories, Japan. We demonstrate 1.68-Gbps/PAM-4 transmission over 20-km using 4-A LAN-WDM TOSA and ROSA with BER below the HD-FEC limit under 24-GHz bandwidth limitation and -39.7-ps/nm chromatic dispersion by applying MLSE based on nonlinear channel estimation.

T3L.3 • 14:30

B-400G Silicon Photonics Integrated Circuits Transceiver Chips for CPO, OBO, and Pluggable Modules, Erman Timurdoğan1, Zhan Su1, Ren-Jye Shiu3, Matthew Byrd3, Christopher Poulton1, Kenneth Jabon1, Christopher DeRose1, Benjamin Moss1, Ehsan Hosseini1, Ivan Duzevik1, Michael Whitson1, Ronald Millman1, Dagen Atlas1, 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 940Gb/s/mm, energy efficiency of <10pJ/bit, and -5.4dBm OMA sensitivity at the KP4 pre-FEC-BER=2.4e-4.

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T3K.2 • 14:15

Analysis of Service Blocking Reduction Strategies in Capacity-limited Disaggregated Datacenters, Albert Pages1, Fernando Agraz1, Salvatore Spadaro1, Universitat Politècnica de Catalunya (UPC), Spain. Disaggregated networks offer multiple benefits. However, transmission capacity limitations at blade level can severely degrade their performance. We analyze several strategies to enhance their service acceptance.

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T3K.3 • 14:30

Disaggregated DCs: Advanced Software Architectures and Technologies in High Performance Computing and Data Centers, Juan Jose Vegas Olmos1, Liran Liss1, Tzahi Oved1, Zachi Bitshotik1, Dror Goldberg1, Melanox Technologies, Denmark. This paper reviews advanced software architectures and technologies that support in-network computing and improve the overall performance of data centers and high-performance computing clusters; the ability to converge software and hardware allows for new solutions, such as artificial intelligence, to be deployed massively.
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<td><strong>T3A</strong> • Linear and Nonlinear Space Division Multiplexing—Continued</td>
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<td><strong>T3C</strong> • Lasers for Communications and Sensing—Continued</td>
<td><strong>T3D</strong> • Quantum and Secure Communications—Continued</td>
<td><strong>T3E</strong> • Emerging Network Architectures for 5G Edge Cloud (Session 1)—Continued</td>
<td><strong>T3F</strong> • Panel: How Can Machine Learning or, More Broadly, Artificial Intelligence Help Improve Optical Networks?—Continued</td>
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**T3B.3 • 14:45**
Heterogeneous Co-integration of BTO/Si and III-V technology on a Silicon Photonics Platform, Pascal Stark1, Felix Eltes1, Yannick Baumgartner1, Daniele Caimi1, Younes Messaddeq1, Norbert Meier1, Lukas Czornomaz1, Jean Pompey细则1, Bert J Offrein1, Stefan Abel1; IBM Research – Zürich, Switzerland; Empa, 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 Rehhbein1, Martin Moehrle1, Kevin Kolpatzek1, Jan Balzer1, Stefan Breuer1, Dieter Franke1, Martin Schell1; Fraunhofer Heinrich-Hertz Inst., Germany; Univ. of Duisburg-Essen, 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.4 • 14:00**
Spectrally-shaped Continuous-Variable QKD Operating at 500 MHz Over an Optical Pipe Lit by 11 DWDM Channels, Dinka Milovancev1, Nemanja Vokic1, Fabian Ladenbach1, Christoph Pacher1, Hannes Hüb1, Bernhard Schrenk1; AIT 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.

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

**T3F.3 • 15:00**
Invited Title to be Announced, Eric Heaton1; Intel, USA. Abstract not available.
T3H • Silicon Photonics Applications—Continued

T3H.4 • 14:45  Invited  Silicon Photonics for 100 Gbaud, Ji- anying Zhou1, Jian Wang1, Qin 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.

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.

T3I.5 • 15:00  Computationally Efficient 120 Gb/s/ PWL Equalized 2D-TCM-PAM8 in Dispersion Unmanaged DML-DD System, Yan Fu1,2, Deming Kong2, Haiyan Xin1,2, Meihua Bu1,2, Shi Jia1, Kuo Zhang1, Weisheng Hu1, Hao Hu2; ‘Shanghai Jiao Tong Univ., China; ‘Fotonik, Technical Univ. of Denmark, Denmark; ‘Hangzhou Dianzi Univ., China. We proposed a PWL equalizer in 120 Gb/s 2D-TCM-PAM8 based DML-DD system to correct eye skew. Computationally efficient 120 Gb/s 8-state 2D-TCM-PAM8 over 2 km C-band transmission is demonstrated below HD-FEC(3.8e-3).

T3J.3 • 14:45  Dual Use SDN Controller for Management and Experimentation in a Field Deployed Testbed, Jakai Yu1, Craig Gutierrez1, Artur Minakhmetov1, Michael Sherman1, Tingjun Chen1, Shengxiong Zhu1, Gil Zusman2, Ivan Sesar3, Daniel C. Kilper1; ‘College of Optical Sciences, Univ. of Arizona, USA; ‘Electrical Engineering, Columbia Univ., USA; ‘LTCS, Telecom 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.

T3J.4 • 15:00  uABNO: A Cloud-native Architecture for Optical SDN Controllers, Ricard Vilalta1, Juan Luis de la Cruz1, Arturo Mayoral López-de-Lerma1, Victor Lopez1, Ricardo Martinez1, Ramon Casellas1, Raúl Muñoz1, ‘CTTC, Spain; ‘Telefónica gCTIO/+/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.

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. Bennazrou1, 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.
### Room 1A
**T3A** • Linear and Nonlinear Space Division Multiplexing—Continued

**T3A.3 • 15:15**
Low-loss Low-MLD Core Multiplexer for 3-Core Coupled-core Multi-core Fiber, Sjoerd P. van der Heide¹, Juan Carlos Alvarado Zacarias¹,², Nicolas K. Fontaine¹, Roland Ryf², Haoshuo Chen¹, Rodrigo Amezcua Correa¹, Ton Koonen¹, Chigo M. Okonkwo¹; ¹Eindhoven Univ. of Technology, Netherlands; ²Nokia Bell Labs, 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 fluctuations between 0.3 dB and 0.9 dB across C- and L-band.

**T3A.4 • 15:30**
Invited talk
Optical Thermodynamics of Nonlinear Highly Multimoded Systems, Demetrios N. Christodoulides¹; ¹Univ. of Central Florida, USA. We present a consistent thermodynamical theory capable of describing in a universal fashion the complex behavior of nonlinear highly multimoded optical fibers. New equations of state are derived based on the second law of thermodynamics.

### Room 1B
**T3B** • Novel Materials—Continued

**T3B.3 • 15:15**
Digital Self-coherent Continuous Variable Quantum Key Distribution System, Tobias A. Eriksson¹,², Ruben S. Luis¹, Kadir Gumus¹, Georg Rademacher¹, Benjamin J. Puttnam¹, Hideaki Furukawa¹, Naoya Wada¹, Yoshinari Awaji¹, Alex Alvarado¹, Masahide Sasaki¹, Masahiro Takeoka¹; ¹National Inst. of Information & Comm Tech (NICT), Japan; ²Royal Inst. of Technology (KTH), Sweden; ³Eindhoven Univ. of Technology, Netherlands. We investigate a continuous variable quantum key distribution system with digital tracking of both polarization and phase. Stable operation over 25 km for 36 hours with secret key rates between 1.9 and 2.8 Mbps is demonstrated.

**T3B.4 • 15:30**
Invited talk
Optical Thermodynamics of Nonlinear Highly Multimoded Systems, Demetrios N. Christodoulides¹; ¹Univ. of Central Florida, USA. We present a consistent thermodynamical theory capable of describing in a universal fashion the complex behavior of nonlinear highly multimoded optical fibers. New equations of state are derived based on the second law of thermodynamics.

### Room 2
**T3C** • Lasers for Communications and Sensing—Continued

**T3C.6 • 15:30**
Variational Quantum Demodulation for Coherent Optical Multi-dimensional QAM, Toshiaki Koike-Akino¹, Toshiki Matsumine², Ye Wang¹, David S. Millar¹, Keisuke Kojima¹, Kieran Parsons²; ¹Mitsubishi Electric Research Labs, USA; ²Yokohama National University, Japan. 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.

**T3D** • Quantum and Secure Communications—Continued

**T3D.5 • 15:15**
850 nm Single-mode Surface-emitting DFB Lasers with Surface Grating and Large-area Oxidized-aperture, Can Liu¹, Qiaoqin Li¹, Weihua Guo¹, Pengfei Zhang¹, Minwen Xiang¹, Chun Jiang¹, Gonghai Liu¹, Quanran Chen¹, Baohang Tang¹, Huazhong Univ. of Science and Technology, China; ¹China Information and Communication Technology Group Corporation, China. 850 nm single-mode surface-emitting DFB laser based on surface gratings has achieved a threshold current of 1.8 mA and a side-mode suppression-ratio of 47 dB for a large-area oxidized-aperture ($2\times50 \mu m^2$).

**T3D.6 • 15:30**
Variational Quantum Demodulation for Coherent Optical Multi-dimensional QAM, Toshiaki Koike-Akino¹, Toshiki Matsumine², Ye Wang¹, David S. Millar¹, Keisuke Kojima¹, Kieran Parsons²; ¹Mitsubishi Electric Research Labs, USA; ²Yokohama National University, Japan. 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.

### Room 3
**T3E** • Emerging Network Architectures for 5G Edge Cloud (Session 1)—Continued

**T3E.4 • 15:30**
Evolution to Mesh 5G X-Haul Networks, Jiakai Yu¹, Shengxiang Zhu¹, Daniel C. Kilper¹; ¹Univ. of Arizona, USA. Development of optical x-haul networks is driven by 5G wireless radio requirements. The potential of a mesh optical x-haul architecture merging WDM-PON and DWDM-ROADM networks is examined with respect to 5G requirements in metropolitan networks.

**T3E.5 • 15:30**
Invited talk
Evolution to Mesh 5G X-Haul Networks, Jiakai Yu¹, Shengxiang Zhu¹, Daniel C. Kilper¹; ¹Univ. of Arizona, USA. Development of optical x-haul networks is driven by 5G wireless radio requirements. The potential of a mesh optical x-haul architecture merging WDM-PON and DWDM-ROADM networks is examined with respect to 5G requirements in metropolitan networks.
T3H.5 • 15:15
Real-time Demonstration of Silicon-photonic-based QSF-DD 400GBASE-DR4 Transceivers for Datacenter Applications, Chongjin Xie1, Peter Magill2, David Li1, Yinxiang Zhang1, Long Zheng1, Anbin Wang1, Yun Bao1, Chunchun Sui1, Matthew Streshinsky1, Jianwei Mu1, Sigeng Yang1, Wanju Sun1; 1Alibaba Group, USA; 2Elenion Technologies, USA.

We demonstrate a real-time silicon-photonic-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, Hajiang Yu1, Pierre Doussiere1, David Patel1, Wenhua Lin1, Kadhair Al-hemyari1, Jung Park1, Catherine Jan1, Robert Herrick1, Isako Hashino1, Lincoln Busse1, Michael Bresnahan1, Adam Bowles1, George Ghircan1, Harel Frish1, Shane Yerkes1, Ranju Venables1, Pegah Seddighian1, Xavier Serey1, Kimchau Nguyen1, Animash Banergee1, Siamak Amirali-zadehasl1, Jing Zhu1, Sushant Gupta1, Avi Fuerst1, Avsar Dahai1, Jian Chen1, Yann Malinge1, Han Mahalingam1, Mike Kwon1, Gupta Sanjeev1, Agrawal Anku2, Raghuram Narayan1, Daniel Zhu1, Yuliya Akulova1; 1Intel Corporation, USA. A 400Gbps PAM-4 fully integrated DR4 silicon photonics transmitter with four heterogeneously integrated DBR lasers has been demonstrated for data center applications over a temperature range of 0–70°C and a reach of up to 2km.

T3I.6 • 15:15
Up to 30-fold BER Improvement Using a Data-dependent FFE Switching Technique for 112Gbit/s PAM-4 VCSEL Based Links, Un Hecht1, Nikolay Ledentsov Jr1, Lulasa Chorchos1, Patrick Kurth1, Nikolay Ledentsov2, Friedel Gerfers2; 1TU Berlin, Germany; 2VI Systems, Germany. In this paper, a dynamic non-linear data-dependent FFE coefficient switching technique, achieving an up to 30-fold decrease in BER in comparison to the linear FFE, is presented. Using the structure 56Gbaud PAM-4 is demonstrated.

T3J.6.6 • 15:30
Data Analytics Practice for Reliability Management of Optical Transceivers in Hyperscale Data Centers, Jianqiang Liu1, Zhicheng Wang1, Chuxiao Wang1,2, Qin Chen1, Peng Wang1, Rui Lu1, Songnian Fu3, Chongjin Xie1; 1Alibaba Group, USA; 2Alibaba Data Center Applications, Shenzhen, China; 3Alibaba Data Center Applications, Hangzhou, China. We present the data analytics practice for the Alibaba Group’s optical transceivers’ population with a case study.
Tuesday, 10 March

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, Bahawal Haq1,2, Sulakshna Kumari1,2, Jing Zhang1,2, Agnieszka Gocalinska3, Emanuele Pelucchi1, Brian Corbett2, Gunther Roelkens1,2. INTEC, Ghent Univ.-imec, Belgium; 2Center of Nano- and Biophotonics, Belgium; 3Tyndall National Inst., Ireland. 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 Agnesi1, Luca Calderaro1, Marco Avesani1, Andrea Stanco2, Giulio Foletto1, Mujtaba Zahidy1, Alessia Scriminich1, Francesco Vedovato1, Giuseppe Valzanne1. 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-Hyeong Kim¹, Young-kwan Jo¹, Hyun-Kyu Kim¹, Stefan Lischke¹, Christian Mai¹, Lars Zimmermann¹, 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 25Gb/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 Lee¹; 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.

16:00–16:30 Coffee Break, Upper Level Corridors and Exhibit Hall
5G mmWave Commercial Trial for Vertical Applications, Jong-Sik 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.

T4A.1 • 16:30
5G mmWave Commercial Trial for Vertical Applications
Jong-Sik 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, Jianguibing Du¹, Yuting Huang¹, Ke Xu¹, Zuyuan He¹; Shanghai Jiao Tong Univ., China; ²Harbin 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 wavelength, powers and mode contents.

T4C.1 • 16:30
VCSELs for Fast Neuromorphic Photonic Systems Operating at GHz Rates
Matěj Hejda¹, Joshua Robertson¹, Julián Bueno²; Dept. of Electronics, 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 1.6 Gbps.

T4D.1 • 16:30
Combining Efficient Probabilistic Shaping and Deep Neural Network to Mitigate Capacity Crunch in 5G Fronthaul
Qizhi Zhou¹, Rui Zhang¹, You-Wei Chen¹, Shuyi Shen¹, Shang-Jen Su¹, Jeffrey Finkelstein¹, Gee-Kung Chang¹; Georgia Inst. of Technology, USA.

T4C.2 • 16:45
Experimental Demonstration of Arbitary Raman Gain-profile Designs Using Machine Learning
Ulisse C. de Moura¹, Francesco Da Ros¹, Ann Margareth Rosa Brusini¹, Andrea Carera¹, Darko Zibar¹; DTU Fotonik, Technical Univ. of Denmark, Denmark; DET, Politecnico di Torino, Italy. A machine learning framework for Raman amplifier design is experimentally tested. Performance in terms of maximum error over the gain profile is investigated for various fiber types and lengths, demonstrating highly-accurate designs.

T4D.2 • 16:45
FPGA Implementation of Deep Neural Network Based Equalizers for High-Speed PON
Norisuki Kaneda¹, Ziyu Zhu¹, Chun-Yen Chuang¹, Noriaki Matsumoto¹; Univ. of Melbourne, Australia.

T4E.1 • 16:30
Multi-Access Edge Computing Architecture for Application-specific New Radio Access Networks
Gee-Kung Chang¹; Georgia Institute of Technoloy, USA. Perspective and challenge of the MEC implementation, merging with the 5G architecture for beyond-5G mobile networks are discussed from futuristic use-cases point-of-view, including mobile operators and application developers. Featuring demonstrations with AI/ML are also highlighted.

T4F.1 • 16:30
Tutorial Toward a Scalable Hybrid Quantum Cloud
Maria Spiropulu¹; California Inst. of Technology, USA. Abstract not available.
Hybrid PAM with Sparse Subcarrier Multiplexing and Power-loading has been proposed for data-rate-breaking all-optical configuration. Each Transmitter Bandwidth Extension Using Optical Time-interleaving Modulator and Digital Spectral Weaver, Hiroshi Yamazaki, Masanori Nakamura, Takashi Goh, Toshikazu Hashimoto, Yutaka Miyamoto, and Gabriella Cincotti.

Thermal Impedance and Gain Switching of $1550\text{ nm}$ Room Temperature Continuous-wave Electrically Pumped Laser Diode Monolithically Grown on Silicon, Bei Shi, Sergio Pinna, Hongwei Zhao, Bowen Song, Jonathan Klaman, Univ. of California Santa Barbara, USA. A room-temperature continuous-wave electrically pumped quantum-well laser was realized on-on-axis (001) silicon. Measurements demonstrated lasing up to 65°C, a thermal impedance of 8.1°C/W, and a narrow gain-switched optical pulse width of 1.5 ns.

High Performance 1.3 $\mu$m Aluminum-Free Quantum Dot Lasers Grown by MOCVD, Lei Wang, Hongwei Zhao, Bei Shi, Sergio Pinna, Simone S. Brunelli, Fengqiao Song, Bowen Song, Jonathan Klaman, Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA. MOCVD grown aluminum-free quantum dot lasers have been demonstrated with a maximum wall-plug efficiency of 30%, a lowest threshold current of 8 mA, and a maximum single-facet output power of 200 mW.
T4A.2 • 17:00
Silicon Photonics to Add 5G RoF Services to PONs Employing Carrier Reuse, Leslie Rusch1, Mingyang Lyu1, Wei Shi1; 1ECE 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.3 • 17:00
Load Aware Raman Gain Profile Prediction in Dynamic Multi-band Optical Networks, Ann Margareth Rosa Brusin1, Ulara C. de Moura1, 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.

T4A.3 • 17:15
Design of Flexible Fronthaul Featuring Per-UE Granularity and RU-level Puncturing for URLLC Applications, Yahya M. Alfadhli1, Shuang Yao1, Muhammad Shameer Omar1, Shang-Jen Su1, Shuyi Shen1, Rui Zhang1, You-Wei Chen1, Peng-Chun Peng1, 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.

T4B.4 • 17:15
Hybrid Machine Learning EDFA Model, Shengxiang Zhu1, Craig Guterman2, Alan D. Mantei2, Jiakai Yu1, Marco Ruffin1, Gil Zussman2, 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.

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

T4D.3 • 17:00
Neural Network-based Equalization in high-speed PONs, Lilin Yi1, Tao Liao1, Lei Xue1, Weisheng Hu1; 1Shanghai 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.2 • 17:00
Title to be Announced, Rafael Francis1; 1Ciena, USA. Abstract not available.
T4G.3 • 17:00
32-Channel WDM Transmitter Based on a Single Off-the-shelf Transceiver and a Time Lens, Mads Lilleholm1, Xiaoyu Xu1, Peter D. Ekner1, Michael Gallil1, Laild Oxenløwe1, Pengyu Guan1; "Technical Univ. of Denmark, Denmark. 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.

T4H.3 • 17:00
High Efficiency, High Gain and High Saturation Output Power Quantum Dot SOAs Grown on Si and Applications, Songtao Liu1, Yeu Yung Tung1, Justin Norman1, Mario Dumont1, Arthur Gossard1, Hon K. Tsang1, John E. Bowers1; "Univ. of California, Santa Barbara, USA; "Electronic Engineering, The Chinese Univ. of Hong Kong, China. A high-performance quantum dot semiconductor optical amplifier directly grown on a CMOS-compatible Si substrate is demonstrated to improve the receiver sensitivity in a filterless 60-Gb/s NRZ transmission system over temperatures from 20°C to 60°C.

T4H.4 • 17:15
Full-duplex Coherent Optical System Enabled by Comb-Based Injection Locking Optical Process, Haipeng Zhang1, Mu Xu1, Junwen Zhang1, Zhenheng Ju1, Luis Alberto Campo1; "CableLabs, USA. A full-duplex coherent optical link based on optical frequency comb and injection-locking optical process is demonstrated. Simultaneous bi-directional transmission of 32-Gb/s DP-16QAM signal over 80-km fiber is achieved with remote LO delivery.

T4I.3 • 17:15
Analysis of 34 to 101Gbaud Submarine Transmissions and Performance Prediction Models, Jean-christophe Antona1, Alexis C. Carbó Meseguer1, Vincent Le Tellier1, Sébastien Dupont1, Richard Garuz1, Philippe Plantady1, Alain Calsat1; "Alcatel Submarine Networks, France. We analyze more than 100 submarine experiments with various configurations of rates, modulations, powers, reach and show a format and rate agnostic, accurate QoT prediction tool. We particularly show the impact of signal droop and the connection between GAWBS models based on spectral measurements and system impact.

T4J.3 • 17:15
Multi-core Fibers Using O-band Signals, Ruben S. Luis2, Benjamin J. Puttnam1, Georg Rademaker1, Andrea Marcella1, Cristian Antonelli2, Antonio Meoazzzi1, Tetsuya Hayashi3, Tetsuya Nakashii1, Satoshi Shinoda1, Yoshinari Awaji1, Hideaki Furukawa1, Naoya Wada1; "Research Inst. of Electronics and Communication, Tokohu Univ., Japan. We present the phase noise caused by guided acoustic-wave Brillouin scattering (GAWBS) in a 125-µm core fiber. Phase noise induced by higher-order TR modes was found to be dominant rather than that of the Rm mode.

T4I.4 • 17:15
Evaluation of Dynamic Skew on Spooled and Deployed Multicore Fibers Using O-band Signals, Ruben S. Luis2, Benjamin J. Puttnam1, Georg Rademaker1, Andrea Marcella1, Cristian Antonelli2, Antonio Meoazzzi1, Tetsuya Hayashi3, Tetsuya Nakashii1, Satoshi Shinoda1, Yoshinari Awaji1, Hideaki Furukawa1, Naoya Wada1; "National Inst of Information & Comm Tech, Japan; "Physical and Chemical Sciences, Univ. of L’Aquila, Italy; "Sumitomo Electric Industries Ltd., Japan. We compare fluctuations of propagation delay and inter-core skew on spooled and field-deployed multicore fibers. Our observations show a reduction of propagation delay fluctuations over deployed fibers but similar inter-core skew behavior.
Experimental Demonstration of A-RoF SDN for Radio Access Sharing Applications, Luiz Anet Neto1, Wang Ming1, Gaël Simon1, Feiheun Lehanneur1, 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.

Robust Convolutional Neural Network Model for Wavelength Detection in Overlapping Fiber Bragg Grating Sensor Network, Baocheng Li1,2, Zhi-Wei Tan1, Perry Ping Shum1, Dora Juan Juan Hu3, Chenju Wang1, Yu Zheng1, Shuhui Liu4, 1Nanyang Technological Univ., Singapore; 2CINTRA CNRS/NTU/Thales, Singapore; 3Inst. for Infocomm Research, Agency for Science, Technology and Research, Singapore; 4Hubei 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.

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.

Flexible 360o 5G mmWave Small Cell Coverage through WDM 4x1 Gb/s Fiber Wireless Fronthaul and a Si3N4 OADM-assisted Massive MIMO Phased Array Antenna, Eugenio Ruggeri1, Apostolos Tokyridis1, Christos Vagionas1, George Kalfas1, Ruud M. Oldenbeuving2, Paul W. Dijkstra3, Chris G. Roeloffzen3, Yigal Leiba3, Nikos Pleros1, Amalia Miliou1; 1Aristotle Univ. of Thessaloniki, Greece; 2LIONIX International B.V, Netherlands; 3Siklu 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.

Service-oriented DU-CU Placement Using Reinforcement Learning in 5G/BSG Converged Wireless-optical Networks, Yuming Xiao1, Jiawei Zhang1, Zhengguang Gao1, Yuefeng Ji2; 1Beijing Univ. of Posts & Telecom, China. We propose a reinforcement learning based DU-CU placement scheme to accommodate diversified services in 5G/BSG networks. It outperforms ILP model and widely used heuristics in terms of the service-scale and resource-saving respectively.
T4G • Optical Transmitter Sub-systems—Continued

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

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

T4J • Multi-core Fibers—Continued

T4G.5 • 17:30 Overcoming Low-power Limitations on Optical Frequency Combs Using a Micro-ring Resonator, Bill P. Conzorz, Chawaphon Prayoonyong, Andreas Boes, Xingyan Xu, Mengxi Tan, Sai T. Chu, Brent E. Little, Roberto Marandoti, Aman Mitchell, David J. Moss.

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; 5X'an Inst. of Optics and Precision Mechanics, Chinese Academy of Science, 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 Harrington, Grant M. Brodsk, Travis C. Biles, Jordan R. Stone, Richelle H. Streater, Scott B. Papp, Daniel J. Blumenthal, Univ. 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 microring resonator. We measure the frequency noise of each of 25 C-band individual comb lines yielding ultra-low ~10Hz fundamental and ~40kHz integral linewidths for high-capacity coherent WDM.

T4H.5 • 17:30 Invited III-V Micro- and Nano-lasers Grown on Silicon Emitting in the Telecom Band, Kei May Lau, Yu Han, Si Zhu, Wei Luo, Ying Xue, 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 Mazurczyk, Jin-Xing Cai, Milen Paskov, William Patterson, Oleg V. Sinkin, Yue Hu, Carl Davidson, Patrick Corbett, Timothy Hammon, Dmitri G. Foursa, 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.

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
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. Leon-Saval2, Michael J. Withford3; Macquarie Univ., Australia; 3Univ. of South Australia, Australia; The 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 Fan1, Jose Enrique Antonio-Lopez1, Axel Schülgze1, Univ. of Central Florida, USA; 2Photonics 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  Invited  
Improved Nd Doped Silica Fiber for E-band Amplification, Leil Y. Khan1,2, Paul Pax1, Derek R. Drachenberg1, Jay Dawson1, Charles Boyle1, Cody Martin1, Victor Khitrov1, Charles Yu1, Robert Crist1, Matthew Cook1, Nick Schenkel1, Michael Runkel1, Michael Messerly1, 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, Luxian Wang1, Yaunès 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  Top-Scored  
Low-power Data Center Transponders Enabled by Micrometer-scale Plasmonic Modulators, Benedikt Baueerle1, Wolfgang Hen1, Claudia Hoessbach1, Yurii Fedoryshyn1, Arne Josten1, Ueli Koch1, Christian Haffner1,2, Tatsuhiko Watanabe1, Christopher Uh1, Horst Hettrich1, Delwin L. Elder1, Larry R. Dalton1, Michael Müller1,4, Juerg Leuthold1; ETH Zurich, Switzerland; 2Palantion Technologies Ltd., Switzerland; Chair of Electronics and Circuits, Saarland Univ., Germany; 3MICRAM Microelectronic GmbH, Germany; 4Department of Chemistry, Univ. of Washington, USA; 5Physical Measurement Laboratory, National Inst. of Standards and Technology, USA. Plasmonic modulators allow for high-speed data modulation beyond 200Gbd at the micrometer-scale and low driving voltages below 750mV. The compact footprint enables dense integration and makes plasmonic modulators a promising solution for next-generation optical interconnects.

W1E.1 • 08:00  Top-Scored  
High-performance Preamble Design and Upstream Burst-mode Detection in 100-Gb/s/A TDM Coherent-PON, Junwen Zhang1, Zhensheng Jia1, Mu Xu1, Haipeng Zhang1, Luis Alberto Campos1, Curtis Knittle1; CableLabs, USA. 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  Top-Scored  
FOSphere: A Scalable and Modular Low Radix Fast Optical Switch Based Data Center Network, Fulong Yan1, Elham Kahani1, Xiaotao Guo1, Fu Wang1, Bitoa Pan1, Xuwe Xue1, Shaohuan Zhang1, Nicola Calabretta1,2; 2Technologie 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.2 • 08:15  
High-throughput Optical Circuit Switch for Intra-datacenter Networks Based on Spatial Superchannels, Eiji Honda1, Yojiro Mori2, Hiroshi Hasegawa1, Ken-ichi Sato2; 1Nagoya Univ., Japan; 2The 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 1.536x1.536 optical switch and its performance is experimentally confirmed. The total throughput of the switch reaches 2.1 Tbps.
08:00–10:00
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.

08:00–10:00
W1I • Panel: Pros and Cons of Low-margin Optical Networks

08:45–10:00
W1K • Machine Learning for Optical Communication Systems
Presider: Antonio Napoli; Infinera Corporation, Germany

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

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 Lindgren4, Joakim Tjäder4, Stefan Melin4; 1Infinera Germany, Germany; 2 Infinera Portugal, Portugal; 3 Telia Carrier, Denmark; 4 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, Kaido Kaevall1, Danish Rafique1, Kamil Blawat1, Klaus Grobe1, Helmut Griesser1, Jörg-Peter Elbers2, Piotr Rydlichowski2, Artur Binczewski2, Marko Tikas3; 1ADVA Optical, Germany; 2 Poznan Supercomputing and Networking Center, Poland; 3 Tele2 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.

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 ROADMs, 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.

Continued on page 99
W1A • Optical Input/Output and Filters—Continued

W1B • Multi-mode Fiber Technology—Continued

W1C • Novel Doped Fiber Amplifier—Continued

W1D • Short-reach Interconnects—Continued

W1E • Advances in Coherent PON—Continued

W1F • Intra Data Center Networks II—Continued

W1.A.2 • 08:30
Tapered Self-written Waveguide between Silicon Photonic Chip and Standard Single-mode Fiber, Yohei Sato1, Kota Shikama1, Tai Tsuchizawa2, Hidetaka Nishi3, Atsushi Aratake1, Norio Sato1; 1NTT 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.

W1.A.3 • 08:45
Vertical Optical Fiber Assembly on Silicon Photonic Chips Using 3D-curved Silicon Waveguide Couplers, Yoichi Sakakibara1, Tomohiko Kitayama1, Tomoya Yoshida1, Yuki Atsumi1, Emiko Omoda1, Katsunori Iwasaki1, Takashi Kato1; 1Natl Inst of Adv Industrial Sci & Tech, Japan; 2Huawei 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.

W1.B.2 • 08:30
Modeling the Breakdown in Degeneracy for High-index-contrast Ring Core Fiber, Mai Banawan1, Lixian Wang1, Sophie Lapochelle1, Leslie Rusch1; 1Department of Electrical and Computer Engineering, COP, Universite Laval, Canada; 2Huawei 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.

W1.B.3 • 08:45
Ultra-low Inter-mode-group Cross-talk Ring-Core Fiber Optimized Using Neural Networks and Genetic Algorithm, Chunmin Shi1, Lei Shen2, Junwei Zhang1, Junyi Liu1, Lei Shen2; 1Sun Yat-sen Univ., China; 2Hong Kong Polytechnic Univ., Hong Kong; 3Fudan 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.

W1.C.3 • 08:30
Recent Advances on Radiation-hardened Optical Fiber Technologies, Sylvain Girard1, Thierry Robin2, Adriana Morana3, Gilles Melin4, Alexandre Bérmín5, Åsa Boukenter6, Benoît Cadier7, Emmanuel Marin7, Laurent Lablond8, Arnaud Laurent9, Youcef Ouederna10; 1Université Jean Monnet, France; 2ولي, France. Optical fibers possess key advantages for integration in radiation-rich environments as parts of communication systems, laser 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.

W1.D.2 • 08:30
Distortion-aware 2D Soft Decision for VCSEL-MMF Optical PAM Interconnection, Lin Sun1,2, Jiangbing Du1, Wenjia Zhang1, Nan Chi1, Chao Lu2, Zuyuan He1, 1Shanghai Jiao Tong Univ., China; 2Hong Kong Polytechnic Univ., Hong Kong; 3Fudan 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.

W1.D.3 • 08:45
16Gbps PAM-4 Multimode Fiber Transmission through 50m using 28GHz 850nm Multimode VCSELs, Justin Lavrenc1, Siddharth Varughese1, Nikolay Ledentsov Jr.1,2, Lukasz Chorchos1,2, Nikolay Ledentsov1; 1Georgia Inst. of Technology, USA; 2VI Systems GmbH, Germany. 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.

Dora van Veen received her PhD in electrical engineering from University of Twente, Enschede. She is a Distinguished Member of Technical Staff at Nokia Bell Labs. Dr. van Veen has widely published and holds many patents in the area of optical access, her current research is focused on high-speed PON.

W1.E.2 • 08:15
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-, TWDM- and WDM-PONs based on low cost optical and DSP technologies.

W1.F.3 • 08:30
Scaling PULSE Data Center Network Architecture and Scheduling Optical Circuits in Sub-microseconds, Joshua L. Benjamin1, Georgios S. Zervas1; 1Univ. College London, UK. PULSE, an optical circuit switched data center network, employs custom ASIC schedulers to reconfigure circuits in 240 ns. The revised PULSE architecture scales to 10,000s of blades, achieves >95% sustained throughput, with low median 1.23μs and tail 145μs latencies, while consuming 115pJ/bit and costing $9.04/Gbps.
W1G • Trends in Free Space Optics Communications—Continued

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 Matsuo1,2, Takuro Fujii2,3, Koji Takeda1,3, Eiichi Kurokochi1, Akiko Shinya1, Massaya Notomo1,2,3, NTT Basic Research Laboratories, Japan; 1NTT Nanophotonics Center, Japan; 2NTT 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.

Speakers:
David Boertjes, Ciena Corp., Canada
Camille Delezoide, Nokia Bell Labs, France
Esther Le Rouzic, Orange Labs, France
Daniel Kilper, University of Arizona, USA
Juraj Slovak, Infinera, Germany
Tim Stuch; Facebook Inc., USA

W11 • Panel: Pros and Cons of Low-margin Optical Networks—Continued

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.1 • 08:45  Invited  Advancing Classical and Quantum Communication Systems with Machine Learning, Darko Zibarić, Uliara C. de Moura1, Hou Man Chin1, Ann Margaret Rosa Brusin2, Nitin Jain1, Francesco Da Ros1, Sebastian Kleis2, Christian Schaeffer2, Tobias Gehring3, Ulrik L. Andersen1, Andrea Carena4; Technical Univ. of Denmark, Denmark; 2Politecnico Di Torino, Italy; 3Helmholtz 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.

Speakers:
David Boertjes, Ciena Corp., Canada
Camille Delezoide, Nokia Bell Labs, France
Esther Le Rouzic, Orange Labs, France
Daniel Kilper, University of Arizona, USA
Juraj Slovak, Infinera, Germany
Tim Stuch; Facebook Inc., USA
W1A • Optical Input/Output and Filters—Continued

W1B • Multi-mode Fiber Technology—Continued

W1C • Novel Doped Fiber Amplifier—Continued

W1D • Short-reach Interconnects—Continued

W1E • Advances in Coherent PON—Continued

W1F • Intra Data Center Networks II—Continued

W1A.4 • 09:00
Ultra-high Q Resonators and Sub-GHz Bandwidth Second Order Filters in an SOI Foundry Platform, Demiz Onural1, Hayk Georgyani1, Bohan Zhang1, Anatol Khila1, Milos A. Popovic1; Boston Univ., USA. We demonstrate racetrack resonators with record-high quality factors reaching 6.6 million in a standard 220 nm silicon photonics foundry platform, and first/second order filters with passbands as narrow as 200 MHz, and 1.5 dB insertion loss.

W1B.4 • 09:00
Advances in Few-mode Fiber Design and Manufacturing, Pierre Sillard1, Prysmian Group, France. 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.

W1C.4 • 09:00
O-band Bismuth-doped Fiber Amplifier with 67 nm Bandwidth, Alexandre Khegai1, Yen Oosokov1, Sergei Firstov1, Konstantin Riumkin1, Sergey Alyshev1, Alexander Kharakhorin1, Elena Firstova1, Fedor Afanasiev2, Vladimir Khopin1, Alexey Gyunyanov2, Mikhail Melikumov1; Fiber Optics Research Center of the Russian Academy of Sciences, Russian Federation. We present 30 dB Bi-P-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.

W1D.4 • 09:00
4x56-Gbaud PAM-4 SDM Transmission Over 5.9-km 125-μm-Cladding MCF Using III-V-on-Si DMLs, Nikolaos Panteleimon Diamantopoulos1, Hidetaka Nishi1, Takuro Fujii1, Kotah Shikama1, Takashi Matsui1, Koji Take-dai1, Takaaki Kakitsuka1, Kazuhide Nakajima1, Shinji Matsuo1; NTT Device Technology Labs, NTT Corporation, Japan; NTT Access Networks Service Systems Labs, NTT Corporation, Japan; Graduate School of Information, Production and Systems, Waseda Univ., Japan. We demonstrate 4x56-Gbaud PAM-4 signals over 125-μm-cladding, 4-core fiber by simultaneous, direct modulation of four 1.3-μm membrane III-V-on-silicon lasers, each requiring <25-mWatts (<812 mW). A reach extension of ~15x is achieved compared to previous works.

W1E.3 • 09:15
Performance Comparison of Coherent and Direct Detection Schemes for 50G PON, Yi-xiao Zhu1, Bo Yang1, Yiming Zhang1, Zheng Liu1, Yong Guo1, Jiahao Zhan1, Yang Zhang1, Sylvain Veilleux1, Mario Dagena1s1; Univ. of Maryland, USA. We report the optimization of reconstruction algorithm and experimental data for an integrated arbitrary filter. A 43-notch filter near 1550 nm is implemented with an ultra-low-loss Si3N4/SiO2 spiral waveguide. All notches have uniform depths/widths of about 20 dB/0.2 nm.

W1F.5 • 09:15
Experimental Assessments of a Flexible Optical Data Center Network Based on Integrated Wavelength Selective Switch, Xiuxi Xue1, Fumi Nakamura2, Kristof Pfitz1, Bitao Pan1, Fulong Yan1, Fu Wang1, Xiaotao Guo1, Hirojuki Tsuda1, Nicola Calabretta1, Endhaven Univ. of Technology, Netherlands; Keio Univ., Japan. A novel bandwidth-reconfigurable optical DCN exploiting photonic-integrated WSS is experimentally assessed. Results show that optical bandwidth can be automatically reallocated according to the traffic patterns with 1.73ps end-to-end latency and 0.015 packet-loss at 0.6 load.
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, Kashieng Zou1, Zhe Zhao1, Hao Song1, Ahmed Almamain2, Runzhou Zhang1, Cong Liu1, Nanhe Hu1, Shlomo Zach2, Nadav Cohen3, Brittany Lynn4, Andreas F. Molisch5, Robert W. Boyd1, Moshe Tur6, Alan E. Willner1; 1Univ. of Southern California, USA; 2Tel Aviv Univ., Israel; 3King Saudi Univ., Saudi Arabia; 4Univ. of Ottawa, Canada; 5Univ. 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 MPLC in a Two-Mode 200-Gbit/s Free-space OAM-multiplexed Link, Hao Song1, Xinzhou Su1, Haoqian Song1, Runzhou Zhang1, Zhe Zhao1, Kaisheng Zou1, Cong Liu1, Kai Pang1, Nanhe Hu1, Ahmed Almamain2, Moshe Tur6, Alan E. Willner1, Shlomo Zach2, Nadav Cohen3, Andreas F. Molisch5, Robert W. Boyd1; 1Univ. of Southern California, USA; 2Tel Aviv Univ., Israel; 3King Saudi Univ., Saudi Arabia; 4Univ. of Ottawa, Canada; 5Univ. of Rochester, USA. We experimentally utilize a multi-plane light convertor (MPLC) 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 Plasmonics - Enabling Highest-speed Communications with fJ/bit Power Consumption, Juerg Leuthold1; 1ETH Zurich, Switzerland. Abstract not available.

W1H.4 • 09:00 Tutorial From the Acceptance of Turnkey Systems to Open Networks with G-SNR, Elizabeth Rivera Hartling1, Stephen Grubb1, Tim Stuch1, Herve Fevrier2, 1Facebook 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.

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

W1I.4 • 09:00 Tutorial From the Acceptance of Turnkey Systems to Open Networks with G-SNR, Elizabeth Rivera Hartling1, Stephen Grubb1, Tim Stuch1, Herve Fevrier2, 1Facebook 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.

W1J • Advanced Transmission Path Metrics—Continued

W1J.2 • 09:15 Maximizing Fiber Cable Capacity Under A Supply Power Constraint Using Deep Neural Networks, Junho Cho1, Chandrasekar Sethumadhavan1, Erxhen Sula1, Samuel Olsson1, Ellis worth C. Burrows1, Gregory Raybon1, Roland Ryf1, Nicolas K. Fontaine2, Jean-christophe Antona1, Stephen Grubb1, Peter Winzer1, Andrew Chraplyvy1; 1Facebook 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, Chandrasekar Sethumadhavan1, Erxhen Sula1, Samuel Olsson1, Ellis worth C. Burrows1, Gregory Raybon1, Roland Ryf1, Nicolas K. Fontaine2, Jean-christophe Antona1, Stephen Grubb1, Peter Winzer1, Andrew Chraplyvy1; 1Facebook 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.
W1C.6 • 09:30
Tetrahedral-Cr Enhancement Employing Dielectric Coating for Higher Gain of Broadband Cr-doped Fiber Amplifiers, Chia-Ming Liu1, Jhuo-Wei Li1, Liu Chun-Nien2, Wei-Chih Cheng1, Charles Tu1, Tien-Tsong Shih2, 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. 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.

W1D.6 • 09:30
Single λ 500-Gbit/s PAM Signal Transmission for Data Center Interconnect Utilizing Mode Division Multiplexing, Fan Li1, Dongdong Zou2, Sun Yat-Sen Univ., China. Single wavelength 502.5-Gbit/s MDM-PAM-6 signal transmission over 20-m OM2 fiber with BER below HD-FEC threshold ($3.8\times10^{-3}$) is demonstrated for 400-G Data Center Interconnect without DSP for mode de-multiplexing. This scheme shows good potential for future 800-G/T DCI.

W1E.5 • 09:45
Rate-flexible Single-wavelength TFDM 100G Coherent PON based on Digital Subcarrier Multiplexing Technology, Junwen Zhang1, Zhensheng Jia1, Haipeng Zhang1, Mu Xu1, Jingjie Zhu1, Luis Alberto Campos1; 1CableLabs, USA. We propose a novel rate-flexible single-wavelength 100G time-and-frequency-division multiplexing coherent PON architecture based on digital subcarrier multiplexing technology. The architecture implementation with four subcarriers is demonstrated, achieving -38-dB sensitivity after 50-km fiber transmission.

W1F.6 • 09:30
Invited
Beyond Edge Cloud: Distributed Edge Computing, Nihel D. Benzaoui1; 1Nokia Bell Labs France, France. High bandwidth demands combined with low latency applications lead the move from centralized cloud to distributed Edge Computing. We discuss how this paradigm shift impacts network interconnects design and the key network features to truly enable 5G and beyond.
W1G • Trends in Free Space Optics Communications—Continued

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

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

W1G.4 • 09:30 Beyond Terabit/s WDM Optical Wireless Transmission using Wave-length-transparent Beam Tracking and Steering, Yang Hong, Feng Feng, Kyle Bottrill, Natsupa Taengnoi, Ravinder Singh, Grahame Faulkner, Dominic O'Brien, Penklos Petropoulos, 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.

W1H.4 • 09:30 Invited Ultra-efficient Optical Switching based on a Large Pockels Effect embedded in Silicon Photonics, Felix Eltes, Jean Pompeyvine, Stefan Abel, 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.5 • 09:45 C-band PS 4096QAM OFDM FSO Transmission with 6.98bit/s/Hz Net SE Based on Kramers-Kronig Detection, Yiran Wei, Yingjun Zhou, Cuiwei Liu, Feng Wang, Kaihui Wang, Jianjun Yu, 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.

W1K.3 • 09:30 Experimental Prediction and Design of Ultra-wideband Raman Amplifiers Using Neural Networks, Xiaoyan Ye, Aymeric Arnould, Amirhossein Ghaeisaeidi, Dylan Le Gac, Jerome Renaudier, Nokia Bell Labs France, France. A machine learning method for Raman gain prediction and multi-pump 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, Huashi Lun, Xiaomin Liu, Meng Cai, Mengfan Fu, Yiwen Wu, Lilin Yi, Weisheng Hu, Qunbi Zhuge, Shang-hai 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
W2.A.2 A Passively Mode-Locked Quantum Dot Laser with 10.8 Tbps Transmission Over 100-km SSMF, Guocheng Liu 1, Zhenguo Lu 1, Jieren Liu 1, Yuxin Mao 1, Martin Vachon 1, Chunying Song 1, Philip Poole 1, Jieren Liu 1, Zhenguo Lu 1, Jiaren Liu 1, Youxin Mao 1, Martin Vachon 1, Chunying Song 1.

We present and demonstrate quantum dot mode-locked lasers operating in the 1-2 THz regime. Using a chip-scale laser cavity design, we achieved a record 10.8 Tbps 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. The laser was fabricated at the University of Ottawa, Canada.

W2.A.3 2-dimensional Fiber Array with Re-flow Compatibility for High-density Optical Interconnection, Tatsuya Kumatani 1, Hajime Arai 1, Hong Nguyen 1, Tetsuya Nakashima 1, Sumitomo Electric Industries, Ltd. 1, Japan. We developed a 2-dimensional fiber array (2D-FA) as an optical interconnection device for co-packaged optics. The 2D-FA was capable of maintaining a low connection loss of < 0.1 dB after reflow process at 260°C.

W2.A.4 Sub-nanosecond Optical Switching Using Chip-based Soliton Micro-combs, Sophie Lange 1, Arslan S. Raja 1, Kai Shi 1, Maxim Karpov 1, Raphael Behrendt 1, Daniel Cletteboe 1, Istvan Haller 1, Fatosi Kannou 1, Xin Fu 1, Junqi Liu 1, Anton Lukashchuk 1, Benn C. Thomesen 1, Krzysztof Jazwik 1, Paolo Costa 1, Tobias J. Kippenberg 1, Hitesh Ballani 1, Microsoft Research, UK 1, Lab of Photonics & Quantum Measurements, Swiss Federal Inst. of Technology Lausanne (EPFL), Switzerland. We demonstrate sub-nanosecond wavelength switching, using a chip-based soliton microcomb and a semiconductor optical amplifier-based wavelength selector. 50-Gbps PAM4 transmission is achieved with discrete components and 25-Gbps NRZ with a photonic integrated wavelength selector.

W2.A.5 Reliability Failure Modes of an Integrated Ge Photodiode for Si Photonics, Stewart Rauch 1, Dongho Lee 1, Alexey Vert 2, Lin Jiang 1, Byung Min 1, GlobalFoundries 1, USA. The reliability of 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.

W2.A.6 Vertically-curved Si Surface Optical Coupler for Coupling with Standard Single-mode Optical Fibers, Yuki Atsumi 1, Tomoya Yoshida 1, Emiko Omouda 1, Youchi Sakakibara 1, Nat 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 a 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.

W2.A.7 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.

W2.A.8 Ultra-Compact Silicon TM-pass Polarizer with a Photonic Crystal Nano beam Structure, Yu He 1, Yong Zhang 1, Ruihuan Zhang 1, Lu Sun 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.

W2.A.9 Metasurface Beam Deflector Array on a 12-inch Glass Wafer, Nanxi Li 1, Yuan Hsing Fu 1, Yuan Dong 1, Ting Su 1, 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.

W2.A.10 Performance Evaluation of aComb-based Transmission System Employing Multi-functional Active Demultiplexers, Prayal Doddaballapura Lakshmijayasimha 1, Aleksandria Kasszubsowska-Ananadarama 1, Pascale Landais 1, Prince M. Anandaraja 1, School of Electronics Engineering, Dublin City Univ, Ireland. We propose a simple and compact adapter using specially designed multi-channel single-mode fiber for fundamental mode transmission through multimode fiber and demonstrate error-free transmission over 1-km multimode fiber using a 10G CWDM transceiver.

W2.A.11 A Single-loop PT-symmetric Sub-kHz Fiber Laser Based on an Integrated Microdisk Resonator, Jinping Yao 1, Zhiqiang Fan 1, Zheng Dai 1, Weihong Shen 1, Yuting Huang 1, Chang Wang 1, Ke Xuyu 1, Shanghui Jiao 1, Taiyong Univ., China. 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.

W2.A.12 Lossless Monolithically Integrated Photonic MPP Neural for All-optical Computation, Bin Shi 1, Kristof Pritz 1, Eduardo Magalhães 1, Nicola Calabretta 1, Ripalita Stabile 1, Technische Universiteit Eindhoven, Netherlands. We demonstrate a monolithically integrated SOA-based photonic neuron, including both the weighted addition and a wavelength converter with tunable laser as nonlinear function, allowing for lossless computation of 8 Giga operations/s with an 8% accuracy.

W2.A.13 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 transmission over 1-km multimode fiber using a 10G CWDM transceiver.

W2.A.14 Miniature Optical Connector with Magnetic Physical Contact, Kota Shikama 1, Norito Sato 1, Atsuhi Arakate 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 return losses comparable to those of a conventional connector.

W2.A.15 Inverse Design of Few-mode Fiber by Neural Network for Weak-coupling Optimization, Zhiqun He 1, Jiangbing Du 1, Weihong Shen 1, Yuting Huang 1, Chang Wang 1, Ke Xuyu 1, Shanghui Jiao 1, Taiyong Univ., China. We use a neural network to inversely design a four-neg few-mode fiber for weak-coupling optimization so as to support MIMO-less DMDM optical communication. This method provides high-accuracy, high-efficiency and low-complexity for complex fiber design.

W2.A.16 Investigation of Tolerance of OFDR-Based DAS to Vibration-induced Beat Frequency Offset, Tatsuya Okamoto 1, Daikuke lida 1, Hirokyo Oshida 1, NTT, Japan. We investigate the statistical property of Rayleigh backscattered light to confirm the tolerance to vibration-induced beat frequency offset, which forces us to interrogate an unintentionally-positioned sensor. A long sensor is capable of measuring vibrations correctly.

W2.A.17 Compensating Model of Nonlocal Effects in a Brillouin Optical Time-domain Analysis System, Can Liu 1, Lianshan Yan 2, 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.

W2.A.18 Training-free Feature Extraction of BOTDA Based on Sparse Representation, Hongwu Tan 1, Ziyang Wang 1, Hao Wu 1, Li Shen 1, Kanglie Ji 1, Maosong 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.
Rayleigh Speckles Obtained from Single Mode Fiber for Wavelength Measurement, Yangyang Wan, Xin Yu Fan, Shuai Wang, Zhao peng Zhang, Zuyuan He, Shanghui Jiao Tong Univ., China. We propose a novel wave-meter 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 Us ing Wet-mate Connector in Offshore Long-distance Raman Amplified Optical Links, Steinar Bjerntvedt, Rolf Bae, Kris Sanapi, W.R.L. Clements, Bernard Shum-tim, Luigi Carlomusto, Soren Michaelsen, NTNU, Norway; ‘Tapmnet, Norway, ‘MPB communications, Canada; ‘Ciena, Canada. Deploying fibre cables to offshore installations may desire a plausible 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 Spectral Analysis, Gang He, Steven Seary, Daniel Gariery, Sorin Tibuleac, EXPLO Inc, Canada; ‘ADVA, 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 Guo, Fu-long Yan, George Exarchakos, Xuwei Xue, Bitao Pan, Nicola Calabretta, ‘Eindhoven 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 33.4% 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 Agrawal, Vimal Bhatia, Joseph Allogba, Anh Vu Stephan Tran, Vimal Bhatia, Shashi Prakash, Jeju Institute of Technology, Netherlands. We propose a novel type selection method to minimize XT-margin. We also propose a core-heterogeneous multicore fibers of SS-FON, crosstalk (XT)-margin overprovisioning is unavoidable due to transmission reach granularity of the system achieves 30.6% higher workloads acceptance rate, 12.9% higher resource utilization, and 33.4% more power saving compared with the server-centric.

W2A.24
Recurrent Neural Networks for Short-term Forecast of Lightpath Performance, Sandra Aladini, Stéph anye Alioglu, Anh Vu Stephan Tran, Christine Tremblay, ‘Ecole de Technologie Supérieure, Canada. We show how the Recurrent Neural Networks can be used for performance prediction of lightpath 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 Shao, Weiqiang Sun, Weisheng Hu, Shanghui 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, Bitao Pan, Xuwei Xue, Fu-long Yan, Fu Wang, Eduardo Magalhães, Nicola Calabretta, ’Eindhoven 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 Maer, Leila Askari, Sebastian Troia, Ligia M. Moreira Zadelo, Francesco Musumeci, Massimo Tomatoret, Politecnico 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
Real-Time Demonstration of 2.4Tbps (200Gbps/A) Bidirectional Coherent DWDM-PON Enabled by Coherent Nyquist Subcarriers, Amir Rashidinejad, An Nguyen, Magnus Olson, Steven Hand, David Welch, Infineer Canada, Canada; ‘Infineer Corporation, USA; ‘Infineer Sweden, Sweden. We demonstrate real-time 2.4Tbps bidirectional coherent DWDM-PON (12x200Gbps/A) over 100km SMF, enabled by multiplexing Nyquist subcarriers. Further, through proof-of-concept experiments, we show the advantage of coherent subcarrier aggregation in next-generation point-to-multipoint bidirectional access networks.

W2A.29
Demonstration of AI-assisted Energy-efficient Traffic Aggregation in 5G Optical Access Network, Luyao Guan, Min Zhang, Dashi Wang, Beijing 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
Towards All Optical DCI Networks, Ginni Khanna, Shengxiang Zhu, Mark M. Filer, Christos Gkantzis, Francesca Parmigiani, Thomas Karagiannis, Microsoft, UK. 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-Shift WWE-enabled Behavioral Modeling for 120-Gbps Multi-mode Optical Interconnects, Chengyu Liang, Wenzhi Zhang, Line Ge, Jiangdong Du, Zuyuan He, Shanghui 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.32
Low-complexity Equalizer based on Volterra Series and Piecewise Linear Function for DML-based IM/DD System, Yukai Yu, Tanwai Bo, Che Yi, Daoho Kim, Hoon Kim, KAIST, Korea, South Korea. We propose and demonstrate a low-complexity equalizer specifically designed for DML-based IM/DD system using Volterra series and piecewise linear function. The proposed equalizer performs similarly to the Volterra equalizer, but reduces the complexity by >90%.

W2A.33
Towards All Optical DCI Networks, Ginni Khanna, Shengxiang Zhu, Mark M. Filer, Christos Gkantzis, Francesca Parmigiani, Thomas Karagiannis, Microsoft, UK. 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.34 Laser Diode Chip Requirements in Wideband Analog Photonic Signal Processing, Farzad M. Koushanian, Mckay B. Bradford, Monireh Moayedi Pour Fard, Thi-en-An Nguyen, Sriman Vishwanath,‡, University of Texas at Austin, USA, 1GenXComm 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-chip Linear Frequency Modulation Signaling Generation Utilizing a Dual-polarization Dual-parallel Mach-Zehnder Modulator, Peng Li1, Lianshan Yan1, Jia Ye1, Xihua Zou1, Bin Luo1, Wei Pan1, School of Information Science and Technology, Southwest Jiaotong Univ., China. A photonic method to generate switchable down-, up- and dual-chip linear frequency-modulated (LFM) signals is proposed. Such signals with a carrier frequency of 5 GHz and a chirp rate of 1 GHz/chirp rate is experimentally demonstrated.

W2A.36 Scalable and Fast Optical Circuit Switch Created with Silicon-photonic Tunable Network-on-Chip Local Oscillator Bank and Colorless Coherent Detection, Ryosuke Matsumoto1, Takashi Inoue1, Yoritomo Konoike2, Hiroyuki Matsuura3, Kenjiro Suzaki1, Yojiro Morii1, Kazuhiro Ikeda1, Shu Namiki1, Ken-ichi Sato2, AIST, Japan; Nagoya Univ., Japan. We propose a large-scale fast optical circuit switch created with Silicon-photonic-tunable-filter-based LO bank and colorless coherent detection. Experiments verify 475 Gb/s switch bandwidth (1,856 × 1,856 at 256 Gbps) and switching times under 3.5 ns.

W2A.39 52.58-Gbps Fiber-wireless 60-GHz 2×2 MIMO System Integrating Optical Mode Division Multiplexing and Analog Radio-Fiber over-fiber Fronthaul Systems, Amol Deshmukh1, Theo Verelst2, Colm Browning1, Yi Lin1, Guy Aubin1, F. Lelarge1, Abdessamad Ramdane1, Liang Dai2, Dublin Hybrid Optical/Thz wireless transmission of 16 Gb/s is demonstrated over 20 km of fiber. Transmission of 50 Gb/s net rate is achieved using low-cost IM/DD optics and wireless front-ends operating at 306 GHz.

W2A.40 Hybrid Fiber-optical/Thz-wireless Link Transmission Using Low-cost IM/DD Optics, Francisco M. Rodrigo1, Ricardo Ferreira1, Carlos Castro2, Robert Elschner2, Thomas Merkle1, Colja Schubert1, Antonio Texeira1,1, P’Advanced S.A., Portugal; 2Fraunhofer Heinrich Hertz Inst., Germany; 3Fraunhofer-Institut für Angewandte Festkörperphysik, Germany. A hybrid system is proposed to generate and detect LFM signals in the 90-GHz band over DL and UL direction.

W2A.41 Quantum Dash Passively Mode Locked Laser for Optical Heterodyne Millimeter-wave Analog Radio-Fiber over-fiber Fronthaul Systems, Amol Deshmukh1, Theo Verelst2, Colm Browning1, Yi Lin1, Guy Aubin1, F. Lelarge1, Abdessamad Ramdane1, Liang Dai2, Dublin Hybrid Optical/Thz wireless transmission of 16 Gb/s is demonstrated over 20 km of fiber. Transmission of 50 Gb/s 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 Wang1, Xinying Li1, Mingming Zhao1, Kailai Wang1, Jiao Zhang1, Miao Kong1, Wen Zhou1, Jianqiang Xiao1, Jianjun Yu1, Pandu Univ., China. We experimentally demonstrate 138.88-Gb/s PDM-QPSK signal delivery in a RoF network based on real-time processing based on heterodyne coherent detection, and error-free delivery can be realized if SD-FEC with 27% overhead is enabled.
W2A.52 A Method to Separate the Penalties Caused by Various Nonlinear Signal-pump Impairments in Raman Amplified System, Jingnan Li1, Yangyang Fan1, Zhenning Tao1, Tong Ye1, Hirokazu Inoue1, Hisao Nakashima1, Kou-suke Komaki1, Takeshi Hashida1; 1Fujitsu R&D Center, China; 2Fujitsu 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 Shen1, Lin Caot1, Xuyang Wang1, Jun Zou1, Wei Luo1, Yunxiang Wang1, Hong Cai1, Bin Dong1, Xianzhu Luo1, Weijun Fan1, Leong Chuan Kwek1, Aiqun Liu1; 1Nanyang Technological Univ., Singapore; 2Peking Univ., China; 3Institute of Microelectronics, Singapore; 4Advanced 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 transmitting Gaussian-modulated coherent states and homodyne detection.

W2A.54 Stochastic EXIT Design for Low-latency Short-block LDPC Codes, Toshiaki Koike-Akino1, David S. Millar1, Keisuke Kojima1, Kieran Parsons1; 1Mitsubishi Electric Research Labs, USA. 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 1.2dB gain over recently proposed scattered EXIT design.

W2A.55 Improved Simulation Accuracy of the Split-step Fourier Method in the Co-existence Regime of Lit GPON / NG-PON2 Access Networks, Nemanja Vokic1, Dinka Milovancev1, Bernhard Schrenk1, Michael Hentschel1, Hannes Hüb1; 1AIT 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.

W2A.56 Deployment Opportunities for DPS-QKD in the Co-existence Regime of GPON / NG-PON2 Access Networks, Toshiaki Koike-Akino1, David S. Millar1, Keisuke Kojima1, Kieran Parsons1; 1Mitsubishi Electric Research Labs, USA. 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 1.2dB gain over recently proposed scattered EXIT design.
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 submaarine cable building blocks: fiber design with large effective area (110, 130 and then 150) 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 submaarine 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 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 pump 16-18dBm per FPs Branching Unit: ROADM unit equipped with WSS vs. FP's 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 Strong; Telegeography, USA
Massimiliano Salsi; Google, USA
Priyath Mehta; Ciena, Canada
Eduardo Mateo; NEC Corporation, Japan
Olivier Courtois; ASN, France
Masaaki Hirano; Sumitomo Electric Industries Ltd., Japan
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Stephen Grubb; Facebook Inc., USA
14:00–16:00
**W3E • Ultra-wideband Transmission**

Presider: Johannes Fischer; Fraunhofer Heinrich-Hertz-Institut, Germany

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

**W3G • Datacentre Infrastructure and Metrology**

Presider: Yue-Kai Huang; NEC Laboratories America Inc, USA

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**W3E.1 • 14:00**

**Tutorial**

Ultra-wideband Transmission and High-symbol Rate Signal Handling Technologies, Fukutaro Hamaoka; 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.

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**W3F.1 • 14:00**

**Invited**

Terabit Transmitters Using Heterogeneous III-V/Si Photonic Integrated Circuits, John E. Bowers; 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.

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**W3G.1 • 14:00**

More Than Communications: Environment Monitoring Using Existing Optical Fiber Network Infrastructure, Yoshiaki Aono, Ezra Ip, 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.

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**W3F.2 • 14:20**

**Invited**

Title to be Announced, Chris Doerr; Acacia Communications Inc, USA. Abstract not available.

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**W3F.3 • 14:40**

**Invited**

Physics Side of Silicon/Nanophotonics, Michal Lipson; Columbia Univ, USA. Abstract not available.

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**W3G.2 • 14:30**

Automated Thermal Drift Compensation in WDM-based Silicon Photonic Multi-Socket Interconnect Systems, Miltiadis Moralis-Pegios, Francesco Zanettor, Emanuele Guglielmi, Vittorio Grandi, Konstantinos Fotiadis, Stelios Pitriss, Theoni Alexoudi, Peter De Heyn, Youn Bin; Joris Van Campenhout, Douglas Aguilar, Giorgio Ferrari, Marco Sampietro, Andrea Melloni, Nikos Pleros; Aristoteleio 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.
### W3A • Neuromorphic III: System-oriented—Continued

**W3A.4 • 15:00**

**Intelligent Computing with Photonic Memories**, Mario Miscuglio\(^1\), Jawei Meng\(^1\), Volker Sorger\(^2\), Ludmila J. Prokopova\(^3\), Yifei Zhang\(^3\), Omer Yesiliurt\(^1\), Armin Mehrabian\(^1\), Juejun Hu\(^1\), Alexander Kildishev\(^2\), \(^3\)George Washington Univ., USA; \(^2\)Birck Nanotechnology Center, USA; \(^1\)Department of Materials Science & Engineering, Massachusetts Inst. of Technology, USA; \(^3\)School 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 Ge\(_2\)Sb\(_2\)Se\(_4\)Te\(_1\)-silicon Mach-Zehnder modulator photonic memory with thermo-electrical 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-Alexandris\(^1\), George Dabos\(^1\), Nikolaos Passalis\(^1\), Anastasios Tefas\(^2\), Angelina Totovic\(^1\), Nikos Plenos\(^2\), \(^1\)Aristotle 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 is realized through an engineered hybrid Ge\(_2\)Sb\(_2\)Se\(_4\)Te\(_1\)-silicon Mach-Zehnder modulator photonic memory with thermo-electrical programmability. The network can effortlessly perform inference with high accuracy at the speed-of-light.

**W3A.6 • 15:30**

**Interferometer-based Photonic Circuit Classifier Showing >90% Accuracy for Well-known Iris Dataset without Utilizing Nonlinear Activation Function**, Guangwei Cong\(^1\), Noritsugu Yamamoto\(^1\), Takashi Inaua\(^1\), Yuriko Maegami\(^1\), Morfumi Chiba\(^1\), Makoto Okada\(^1\), Shu Namiki\(^1\), Koji Yamada\(^1\), \(^1\)AIST (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 Scano\(^1\), Alessio Giorgetti\(^1\), Andrea Sgambelluri\(^1\), Filippo Cugini\(^1\), Silvia Fichera\(^1\), \(^1\)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 Nishizawa\(^1\), \(^1\)NTT 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 Ge\(^1\), Wenjia Zhang\(^1\), Yanci Zhang\(^1\), Chenyu Liang\(^1\), Jiangbing Du\(^1\), Zuyuan He\(^1\), \(^1\)Shanghai Jiao Tong Univ., China. 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**

**All-optical Recurrent Neural Network with Sigmoid Activation Function**, George Mourgas-Alexandris\(^1\), George Dabos\(^1\), Nikolaos Passalis\(^1\), Anastasios Tefas\(^2\), Angelina Totovic\(^1\), Nikos Plenos\(^2\), \(^1\)Aristotle 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 is realized through an engineered hybrid Ge\(_2\)Sb\(_2\)Se\(_4\)Te\(_1\)-silicon Mach-Zehnder modulator photonic memory with thermo-electrical programmability. The network can effortlessly perform inference with high accuracy at the speed-of-light.

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**Architecting Cloud-native Optical Network with Whitebox Equipment**, Hideki Nishizawa\(^1\), \(^1\)NTT 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.

**W3C.6 • 15:30**

**End-to-end Learning of Geometrical Shaping Maximizing Generalized Mutual Information**, Kadir Gumus\(^1\), Alex Alvarado\(^1\), Bin Chen\(^2\), Christian Häger\(^2\), Erik Agrell\(^3\), \(^1\)Eindhoven Univ. of Technology, Netherlands; \(^3\)School of Computer Science and Information Engineering, Hefei Univ. of Technology, China; \(^2\)Department 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.

### W3D • High-speed Transmission—Continued

**W3D.4 • 15:00**

**End-to-end Learning of Geometrical Shaping Maximizing Generalized Mutual Information**, Kadir Gumus\(^1\), Alex Alvarado\(^1\), Bin Chen\(^2\), Christian Häger\(^2\), Erik Agrell\(^3\), \(^1\)Eindhoven Univ. of Technology, Netherlands; \(^3\)School of Computer Science and Information Engineering, Hefei Univ. of Technology, China; \(^2\)Department 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.

**W3D.5 • 15:15**

**End-to-end Learning of Geometrical Shaping Maximizing Generalized Mutual Information**, Kadir Gumus\(^1\), Alex Alvarado\(^1\), Bin Chen\(^2\), Christian Häger\(^2\), Erik Agrell\(^3\), \(^1\)Eindhoven Univ. of Technology, Netherlands; \(^3\)School of Computer Science and Information Engineering, Hefei Univ. of Technology, China; \(^2\)Department 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.

**W3D.6 • 15:30**

**All Silicon IQ Modulator with 1Tb/s Line Rate**, Sasan Zalahpour\(^1\); Mengqi Guo\(^1\), Jachuan Lin\(^1\), Zhuhong Zhang\(^1\), Yaojun Qiao\(^1\), Wei Shi\(^1\), Leslie Rusch\(^2\), \(^1\)ECE Dept., Univ. Laval, Canada; \(^2\)COPH, Univ. Laval, Canada; \(^3\)School of Information and Communication Engineering, BUPT, China; \(^4\)Canada Research Center, Huawei Technologies Canada, Canada. By significantly improving the accuracy of our nonlinear pre-compensation digital signal processing, we achieve 1 Tb/s line rate with an all silicon modulator using 32QAM modulation with dual polarization emulation.
W3E.2 • 15:00  Invited
Candidate Technologies for Ultra-wideband Nonlinear Optical Fibre Transmission System, Lidia Galdino°, Daniel Semrau', Polina Bayvel'; °Univ. College London, UK. 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.4 • 15:00  Invited
Indium Phosphide Photonic Integrated Circuits, Meinit Smit', K. A. Williams'; Technical Univ. Eindhoven, Netherlands. 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.

W3E.3 • 15:30  Invited
Comparative Investigations between SSMF and Hollow-core NANF for Transmission in the S+C+L-bands, Yang Hong', Thomas Bradley', Natsupa Taengnoi', Kyle Bottrill', John Hayes', Gregory Jason', Hans Mulvad', Francesco Poletti', Periklis Petropoulos', David Richardson'; °Univ. of Southampton, UK. An experimental study reveals that hollow-core nested anti-resonant-nodeless fibers exhibit a broader bandwidth, lower latency, and offer >20% capacity enhancement in short-reach >100-Gb/s adaptively-loaded DMT transmission, relative to a standard SMF of a similar length.

W3G • Datacentre Infrastructure and Metrology—Continued

W3G.3 • 14:45  BER and TDECQ Correlation for Different Impairments in 400Gbps PAM4 system, Ying Zhao', Chris Doerr', Li Chen', Ninghui Zhu', Dinh Tran', Ricardo Aroca', Xue Huang', Michelle Xu'; °Acacia Communication Inc., USA. Closed-form bit-error rate (BER) expression as a function of transmitter dispersion eye closure quaternary (TDECQ) is derived. Based on a silicon-photonics 400-Gbps PAM4 transceiver, BER and TDECQ correlation is verified for different impairments.

W3G.4 • 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 Kishi', Munehiko Nagatani', Shigenu Kanazawa', Kota Shikama', Takuro Fujii', Hidetaka Nishi', Hiroshi Yamazaki', Norio Sato', Hideyuki Nosaka', Shinji Matsuo'; °NTT Device Technology Laboratories, Japan; °NTT Device Innovation Center, Japan. 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 Takesue'; °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.

W3G.6 • 15:40  Invited
Title to be Announced, Peter Winzer'; °Independent Consultant, USA. Abstract not available.
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
WA4.1 • 16:30
time-wavelength mode equalization by PSO for random fiber laser based FWM Raman amplifier, Yufeng Chen, Jianbing Du, Jiaxiong Li, Lei She, Jie Luo, Zuyuan He, Shanghai Jiao Tong Univ, China; Yangtze Optical Fibre and Cable Joint Stock Limited Company, China. We report an FFM Raman amplifier based on random fiber laser with optimized time-wavelength-mode equalization by PSO method, achieving 1.3-dB spectral gain flatness, 2.3-dB temporal SPV, and 0.03-dB MDG with 15-dB on-off gain.

WA4.2 • 16:45
Evaluation of Performance Penalty from Pump-signal Overlap in S+L Band Discrete Raman Amplifiers, Md A. Ibqai, Lukasz Krazzawicz, Ian Phillips, Paul Harper, Waddek 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+L-band discrete Raman amplifier. We report 4nm guard-band around the Raman pump ensures negligible Q2-penalty.

WA4.3 • 17:00
Comparison of Erbium, Raman and Parametric Optical Fiber Amplifiers for Burst Traffic in Extended PON, Chan- Bhanu Gaur, Filipe Ferreira, Vladimir Gordenko, Md A Ibqai, Waddek 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.

WA4.4 • 17:15
Noise Figure Evaluation of Polarization-insensitive Single-pump Fiber Optical Parametric Amplifiers, Vladimir Gordenko, Filipe Ferreira, Charles Laperle, 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.

WA4.5 • 17:15
A Metalens Array on a 12-inch Glass Wafer for Optical Dot Projection, Ting Hu, Qize Zhong, Nank Li, Yuan Dong, Zhengxi Xu, Dongdong Li, Yuan Hsing Fu, Yanan Zhou, Keng Heng Lai, Vladimir Bliemetsov, Hou-Jang Lee, Wei Loong Loh, Shiyan Zhu, Quyning Lin, Navab Singh, IME, A*Star, Singapore. Singapore. We report the first demonstration of a metalens array fabricated on a 12-inch glass wafer for dot projection. Good uniformity in dot size is achieved, with a maximum deviation of 8% to the simulated value.

W4A.1 • 16:30
Spectrally Slicing Coherent Optical Spectrum Analyzer for Measuring Complex Field Waveforms of Optical QAM Signals, Yasuhiro Kawabata, Naoki Urakawa, Kotaro Kinoshita, Koji Igashira, Osaka Univ., Japan. We propose spectrally slicing scheme without any bandwidth limitation for measuring complex field waveforms of optical QAM signals. With our scheme, complex filed waveforms of 12.5-Gbaud 16QAM signals are measured even with 300-MHz bandwidth.

W4A.2 • 16:45
On the Sample Complexity of Phase-retrieval Receiver Based on 2-D Arrayed Photodetectors, Yuki Yoshida, Toshimasa Umezawa, Atsushi Kannai, Keizo Inagaki, Naokatsu Yamamoto, Tetsuya Kawanishi.

W4A.3 • 17:00
The Sample Complexity of Phase-retrieval Receiver Based on 2-D Arrayed Photodetectors, Yuki Yoshida, Toshimasa Umezawa, Atsushi Kannai, Keizo Inagaki, Naokatsu Yamamoto, Tetsuya Kawanishi.

W4A.4 • 17:15
WDM Operation and Multiple Dispersion Elements for a Direct-detection System using Phase Retrieval, Hsiu-bin Zhou, Kaiheng Zou, Peschong Liao, Ahmed Almamari, Fatemeh Alisahi, Ahmad Falahpour, Amir Minoofar, Moshe Tur, Alan E. Willner, Univ. of Southern California, USA; King Saud Univ., Saudi Arabia; School of Electrical Engineering, Tel Aviv Univ., Israel. We by simulation and experimentally investigate appropriate dispersion values and numbers of the dispersion elements for a phase retrieval based direct-detection system. A 149.5-Gbits/s QPSK transmission using phase retrieval with two dispersion elements is demonstrated in a WDM system.
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 innovations. We are at a critical point where transmission technology is mature and approaching fundamental limits. What is the path forward?

Robert Herrick is responsible for laser reliability at Intel's Silicon Photonic Product Division, and has worked for Intel since 2013. After obtaining an MS in EE at the University of Illinois, his career started at McDonnell Douglas, working on early OEIC 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, Emcore, Finisar, and JDSU / Lumentum.

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### Room 2

**W4A** • Digital Signal Processing II—Continued

### Room 6C

**W4B** • Nonlinear Devices & Amplifiers—Continued

### Room 6D

**W4C** • Novel Passive Devices—Continued

### Room 6E

**W4D** • Speciality Fibers—Continued

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#### W4A.5 • 17:30 Top-Scored

**Mode-Multiplexed Full-Field Reconstruction Using Direct and Phase Retrieval Detection**, Haoshuo Chen, Juan Carlos Alvarado Zacarias, Hanzhi Huang, Nicolas K. Fontaine, Roland Ryf, David Neilsen, Rodrigo Amezua Correa, Nokia Bell Labs, USA; CREOL, The Univ. of Central Florida, USA; 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 multimode 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.

#### W4B.3 • 17:30

**Weakly-coupled Few-mode Gain-flattening Filter Using Long-period Fiber Grating in Double-cladding FMF**, Jinglong Zhu, Yu Yang, Junchi Jia, Jin Hei, Zhangyuan Chen, Yongqiao Ji, Juhao Li, Peking Univ., China; Peking Univ. Shenzhen Institute, China. A weakly-coupled few-mode gain-flattening filter (FM-GFF) based on long-period fiber gratings (LPFGs) in double-cladding few-mode fiber is proposed. Utilizing the FM-GFF, we demonstrate that the gain spectra of each core mode can be independently flattened.

#### W4C.4 • 17:30

**Demonstration of an Ultra-compact Bend for Four Modes Based on Pixelated Meta-structure**, Hucheng Ke, Yingjie Liu, Wenxiang Li, Jiangbing Du, Yong Yao, Qinhai Song, Ke Xu, State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China. A multimode bend for TE1, TE2, and TE3 modes with a radius of 3.9 μm is demonstrated. The insertion loss is measured to be < 1.8 dB, and the crosstalk is below -17 dB.

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#### W4A.6 • 17:45

**Mitigation of Inter-subcarrier Linear Crosstalk with Groupwise Fixed FDE Assisted MIMO**, Masaki Sato, Kunihiro Noguchi, Junichi Matsui, Naoto Ishii, Emmanuel Le Taillander de Gabory, System Platform Research Laboratories, NEC Corporation, Japan; NEC Corporation, Japan.

We experimentally demonstrated inter-subcarrier linear crosstalk mitigation of five-subcarrier 10-Gbaud RRC-PM-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.

#### W4B.5 • 17:45

**Differential Modal Gain Reduction Using a Void Inscribed in a Two-mode-erbium Doped Fiber**, Yoka Yamashita, Takashi Matsui, Masaki Wada, Shinichi Aozasa, Taka Saka moto, Kazuhide Nakajima, NTT, Japan. Differential modal gain (DMG) reduction technique that uses laser-inscribed void is proposed. We reveal that DMG can be successfully controlled by introducing one void into two-mode-EDF while keeping the initial gain, NF and flatness.

#### W4C.5 • 17:45

**Low Loss, Large Bandwidth Antiresonant Hollow-core Fiber Design for Short-Reach Links**, William Shere, Gregory Jasion, Eric Numkam Fokoua, Francesco Petletti, Optoelectronics Research Centre, UK. We present antiresonant hollow-core optical fibre designs for VCSEL-based short-reach transmission applications in the 850nm band. Our simulations show that low loss and twice as wide bandwidths than solid, multi-mode, graded index fibres are possible.
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.

Choice of Optical Access Innovations to Meet Today’s Needs and Support the Challenges of Tomorrow, Philippe Chancou, Luiz Anet Neto, Gael Simon, Fabienne Saliou, Nicolas Neyret, Erick Thily, Daniel Abgrall, David Minodier, Orange Labs, France. The aims of this paper are to illustrate the major trends for optical access innovations capable of meeting present and future requirements. It also highlights what are the main technology enablers for identified use cases.

Title to be Announced, Hong Liu, Google, USA. Abstract

Hong Liu, Google, USA. Title to be Announced, W4E.6 • 18:10

W4E.5 • 17:30

Uni-Traveling Carrier Photodiodes with Type-II GaAs0.5Sb0.5/In0.53Ga0.47As Hybrid Absorbers Integrated with Substrate Lens in 400 Gb/s/sec DR-4 System, None Naseem1, Hsiang-Szu Chang1, Rui-Lin Chao2, Jack Jia-Sheng Huang1, Yu-Heng Jan3, H. S. Cheri1, C.-J. Niu2, Emin Chou1, Jin-Wei Shi1; 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.

Acceleration of Convolutional Neural Networks, Siddharth Varughese, Daniel Garon, Kan Tan, Shane Hazzard, Maria Agoston, Alirio Melgar, Varghese A. Thomas, Shane Hazzard, 1Georgia Inst. of Technology, USA; 2Tektronix, USA. We demonstrate that TDECQ is sensitive to algorithmic implementation and to receiver noise. It is inherently challenging to quantify transmitter performance when receiver equalization is estimated computationally. Methods to reduce uncertainty are identified.

Highly Sensitive 56 Gbps NRZ-O band BICMOS-Silicon Photonics Receiver using a Ge/ Si Avalanche Photodiode, Srinivasan Ashwyn Srinivasan, Joris Lambrecht, Mathias Bericiano, Sebastien Lardenois, Philippe Abbi1, Johan Bauwelinck1, Xin Yin1, Marianna Pantouvaki1, Joris Van Campenhout1; 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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Th1A • Advanced Design for Passive Devices
Presider: Nicolas Dupuis; IBM TJ Watson Research Center, USA

Th1B • High Speed PON
Presider: Xinying Li; Corning Inc, USA

Th1C • Microwave Photonics
Presider: Maurizio Burla; ETH Zurich, Switzerland

Th1D • Pushing the Bit-rate in Practical Networks
Presider: Shuto Yamamoto; NTT Electronics Corp, Japan

Th1E • Symposium: Future Photonics Devices f/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)

Th1F • AI for Reliable Networking
Presider: António Eira; Infinera Corporation, Portugal

Th1A.1 • 08:00
Generative Deep Learning Model for a Multi-level Nano-optic Broadband Power Splitter, Yingheng Tang1,2, Kesuke Kojima1, Yoshiaki Koke-Akino1, Ye Wang1, Pengxiang Wu1, Mohammad T. Ahsan1, Devash Jha1, Kieran Parsons1, Minghao Qi2, 1Mitsubishi Electric Research Laboratories, USA; 2School 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 splitters with arbitrary splitting ratio.

Th1B.1 • 08:00
100 Gbps PON L-band Downstream Transmission Using IQ-MZM CD Digital Pre-compensation and DD ONU receiver, Pablo Torres-Ferrera1, Valter Ferrero1, Roberto Gaudino1, 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
Low-loss LiNbO3 for MWP, Marko Loncar1, 1Harvard Univ, USA. Abstract not available.

Th1D.1 • 08:00
Real-time Demonstration of 500-Gbps/lambda and 600-Gbps/lambda WDM Transmission on Field-installed Fibers, Hideki Maeda1, Hiroki Kawahara1, Kohei Saito1, Takeshi Seki1, Takeo Sasaki1, Fukutaro Hamaoka1, 1NTT 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
Saving Energy and Increasing Density in Information Processing Using Photonics, David A. B. Miller1, 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
Simultaneous Detection of Anomaly Points and Fiber Types in Multi-span Transmission Links Only by Receiver-side Digital Signal Processing, Takeo Sasai1, Masanori Nakamura1, Seiji Okamoto1, Fukutaro Hamaoka1, Shuto Yamamoto1, Etsumi Yamazaki1, Asuka Matsushita1, Yoshikaki K saga1, 1NTT, 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.

Th1F.2 • 08:15
Soft-failure Localization and Device Working Parameters Estimation in Disaggregated Scenarios, Sima Barzegar1, Emanuele E. Virgilio1, Marc Ruiz1, Alessio Ferrari2, Antonio Napoli3, Vittorio Curti1, Luis Velasco1, 1Universitat Politècnica de Catalunya, Spain; 2Politecnico di Torino, Italy; 3Infinera, 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.
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 have 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 ENOB 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.
applications.

There are large degrees of freedom (DOF) in the design of passive optical networks (PONs). There is an increasing demand for higher bandwidth and services to support multimedia and computing applications. To simultaneously address the challenges of high-performance computing, low latency data communication, energy efficiency, scalable bandwidth, and low power, photonic integration offers promising potential.

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.

We propose an approach to generating dual-chirp microwave waveforms using the same single ultra low loss pump, forward and backward ROPAs, and backward DRAs compliant with laser backward DRAs compliant with laser signals using EDFAs with forward and backward ROPAs, 431 km span 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 fiber with large effective area fiber for both signal and pumps.

We demonstrate record high spectral efficiency real-time 500 Gb/s transmission over terrestrial G.654.E fiber links for 500 Gb/s/carrier transmission over terrestrial G.654.E fiber links. The achieved spectral efficiency is 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.

We demonstrate a symmetrical 50-Gb/s/λ PAM-4 TDM-PON in O-band supporting 26 dB+ loss budget using low-bandwidth optics and semiconductor optical amplifier, Jianjun Yu, Jiajun Xiao, Xiangjun Xin, Li Zhao, Wen Zhou, Jianguan Xiao, Bo Liu, Xiangjun Xin, Jianjun Yu, Fudan Univ., China; “Beijing Univ. of Posts and Telecommunications, China. We theoretically generated a symmetrical 50-Gb/s/λ 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.

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.

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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 of coherent optical communication.

Theoretical Analysis and Experimental Measurement of Intra-LP-mode DMD in Weakly-coupled FMF, Ming-gang Zu, 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. 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.

Mitigating Fiber Nonlinearities by Short-length Probabilistic Shaping, Tobias Fehenerberger, Helmut Griesser, Jörg-Peter Elbers, FMCW Lidar, Minglong Pu, Weilin Song, Yen-Chung Weng, Wei Wei, Yuanhua Bai, Yuxin 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 $1.4 \times 10^{-6}$ over distances beyond tens of intrinsic coherence length is achieved.

True Equalization of PDL in Presence of Fast RSOA, Nan Cui, Xiaoguang Zhang, Nannan 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 RSOA, 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 RSOA.

Secure Free-space Optical Communication via Amplified Spontaneous Emission (ASE), Hanzi Huang, Hai Huang, Jian Chen, Haoshuo Chen, Yetian Huang, Yingchun Li, Yingxiang 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.
Th1A.4 • 09:00
Ultra-broadband and Low-loss Polarization Beam Splitter on Silica Plc platform, Takeshi Fukasawa1, Taiji Sakamoto2, Masashi Miyata2, Takashi Matsu1, Toshikazu Hashimoto2, Ryuchi Kasahara3, Kazuhide Nakajima2, Kunisama Saitoh1, 1Hokkaido Univ., Japan; 2NTT, Japan.

We realized a polarization beam splitter with low loss of <1 dB and high extinction ratio of >20 dB in an ultra-broad bandwidth from 1400nm to 1700nm using a pair of cascaded dual-core adiabatic tapers.

Th1B.5 • 09:15
Wavefront-matching-method-designed Six-mode-exchanger Based on Grating-like waveguide on Silica, Chenlei L1, Daolin Dai2, John E. Bowers1, Zhejiang Univ., China; 2Nanjing Research Inst., Zhejiang Univ., China; 3Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA.

We studied a polarization beam splitter with low loss of <1 dB and high extinction ratio of >20 dB in an ultra-broad bandwidth from 1400nm to 1700nm using a pair of cascaded dual-core adiabatic tapers.

Th1C.4 • 09:00 Tutorial
New Opportunities for Integrated Microwave Photonics. David Marpaung1; 1Universiteite 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 photonic interactions for advanced signal processing.

Th1D.4 • 09:00
Demonstration of 50-Gb/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 Communication Technologies Group Corporation, China. A polarization-insensitive heterodyne coherent detection with single-PD for 50-Gb/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.

Th1E.3 • 09:00 Invited
Densely Integrated Electronic-photon Systems for Next-generation Optical I/O, Mark Wade1, 1Ayer Labs, USA. Abstract not available.

Th1F.6 • 09:15
Can You Trust AI-assisted Network Automation? A DRL-based Approach to Muddle the Automation in 5G IP-over-EONs, Min Wang1, Siq Liu1, Zuqiang 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 muddle the AIaNA in software-defined IP over elastic optical networks (SD-IPoEONs) through crafting/injecting adversarial traffic samples.
Th1G.4 • 09:00 Hierarchical Distribution Matching: a Versatile Tool for Probabilistic Shaping—Continued
Hierarchical Distribution Matching: a Versatile Tool for Probabilistic Shaping—Continued

Hierarchical Distribution Matching (Hi-DM) is described. The potential of Hi-OM in terms of trade-off between performance, complexity, and memory is illustrated through three case studies.

Th1H.4 • 09:00 Characterization and Optical Compensation of LP_{01} and LP_{11} Intra-modal Nonlinearity in Few-Mode Fibers—Continued
Characterization and Optical Compensation of LP_{01} and LP_{11} Intra-modal Nonlinearity in Few-Mode Fibers, Francesco Da Ros1, Pawel M. Kaminski1, Georg Rademacher2, Benjamin J. Putnam3, Ruben S. Luis4, Werner Klau5, Hideaki Furukawa5, Ryo Maruyama5, Kazuhiro Aikawa6, Toshio Moroika6, Naoya Wada6, Michael Galili7, DTU Fotonik, Denmark; 2Photonic Network System Laboratory, National Inst. of Information and Communications Technology, Japan; 3Univ. of Cambridge, UK. 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.

Th1I.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.

Th1J.4 • 09:00 Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?—Continued
Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?—Continued

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.

Th1G.5 • 09:15 Multi-dimensional Distribution Matching for Probabilistically Shaped High Order Modulation Format—Continued
Multi-dimensional Distribution Matching for Probabilistically Shaped High Order Modulation Format, Menglan Fu1, Gaojia Liu1, Xiaobo Zeng1, Yawen Wu1, Lilin Yi1, 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—Continued
Mode Group Resolved Analysis of Effects Induced by Macro Bending in a 50 μm Graded Index Multi Mode Fiber, Christian M. Spennier1, Peter M. Krummrich1, DTU Fotonik, Denmark; 2TU 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.

Th1I.5 • 09:15 Spectrum Sensing Applications of FWM-based Optical Cyclostationary Processor—Continued
Spectrum Sensing Applications of FWM-based Optical Cyclostationary Processor, Jerrod Langston1,2, Richard DeSalvo2, Stephen E. Ralph2; 1Georgia Inst. of Technology, USA; 2L3Harris, USA. We demonstrate a large instantaneous bandwidth optical cyclostationary processor that computes the spectral correlation function. Post-processing of experimentally measured SCFs is applied for waveform characterization, specifically baud rate and pulse-shaping roll-off estimation of QAM signals.
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 Parsons1,2, Fengqiao Sang1,2, Jonathan Klamkin3; 1Mitsubishi Electric Research Laboratories, USA; 2Electrical and Computer Engineering Dept., Univ. of California, Santa Barbara, USA; 3Electrical and Computer Engineering Dept., Purdue Univ., 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 Kaneda1, Alex Duque1, Adriaan de Lind van Wijngaarden1, Vincent Houtsmma1; 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, Tichen 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 Lin1; 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 GS/s) A/D conversion.
### Room 6E

**Th1G • Modulation and Coding—Continued**

- **Th1G.6 • 09:30**  
  Staircase Construction with Non-systematic Polar Codes, Carlo Condo¹, Valerio Bioglio¹, Ingmar Land¹; ¹Huawei 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.

### Room 6F

**Th1H • Characterization of SDM Fibers—Continued**

- **Th1H.6 • 09:30**  
  Top-Scored Assembly and Characterization of a Multimode EDFA Using Digital Holography, Juan Carlos Alvarez Zacarias¹, Nicolas K. Fontaine¹, Roland Ryf², Haoshuo Chen³, Sjoerd van der Heide¹, Jose Enrique Antonio-Lopez¹, Steffen Wittek¹, Guifang Li¹, Chigo M. Okonkwo³, Marianne Bigot-Astruc¹, Adrian Amezcua-Correa¹, Pierre Sillard¹, Rodrigo Amezua-Correa¹; ¹CREOL, The College of Optics & Photonics, USA; ²Nokia Bell Labs, USA; ³Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands. We present the assembly and characterization of a multimode EDFA supporting up to 45 modes using digital holography to measure the transfer matrix of the system at each step and obtain mode dependent loss and crosstalk characteristics of the amplifier.

### Room 7

**Th1I • Digital Signal Processing Techniques and Mitigation—Continued**

- **Th1I.6 • 09:30**  
  On the Performance under Hard and Soft Bitwise Mismatched-decoding, Tsuyoshi Yoshida²,³, Mikael Mazer¹, Jochen Schröder¹, Magnus Karlsson¹, Erik Aellig¹; ¹Mitsubishi Electric Corporation, Japan; ²Osaka Univ., Japan; ³Chalmers Univ. of Technology, Sweden. We investigated a suitable auxiliary channel setting and the gap between Q-factors with hard and soft demapping. The system margin definition should be reconsidered for systems employing complex coded modulation with soft forward error correction.

- **Th1I.5 • 09:30**  
  Rate-adaptive Concatenated Polar-Staircase Codes for Data Center Interconnects, Tayyab Mehmood¹, Metodi P. Yankov⁵, Anders Fisker²,³, Metodi P. Yankov¹, Anders Fisker²,³; ¹Univ. of Southern California, USA; ²School of Electrical Engineering, Tel Aviv Univ., Israel. We experimentally demonstrate rate-adaptivity and more than 0.35 dB gain compared to the adjacent order for 80.57% in net transmission rate.

### Room 8

**Th1J • Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?—Continued**

- **Th1J.6 • 09:30**  
  Alignment Monitor for Free-space Optical Links in the Presence of Turbulence using the Beating of Opposite-order Orbital-angular-Momentum Beams on Two Different Wavelengths, Runzhou Zhang¹, Nanze Hu¹, Xinzhao Su¹, Ahmed Almamari¹, Haoqian Song¹, Zhe Zhao¹, Hao Song¹, Kai Pang¹, Cong Liu¹, Moshe Tur¹, Alan E. Willner¹; ¹Univ. of Southern California, USA; ²School of Electrical Engineering, Tel Aviv Univ., Israel. 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.

### Room 9

**Th1K • Optical Wireless Sensing Systems for 5G—Continued**

- **Th1K.6 • 09:30**  
  Optimized QAM Order with Probabilistic Shaping for the Nonlinear Underwater VLC Channel, Peng Zou¹, Fangchun Hu¹, Guoqiang Li¹, Nan Chi¹; ¹Fudan Univ., China. We found the optimum QAM order with PS for the nonlinear UVLC channel is not the adjacent integer of entropy. Higher order QAM can outperform adjacent order for 80.57% in net transmission rate.

### Thursday, 12 March

**10:00–13:00**  
**Unopposed Exhibit-only Time, Exhibit Hall (coffee services 10:00–10:30)**

**Lunch Break (on own)**

**10:00–16:00**  
**Exhibition and Show Floor, Exhibit Hall (concessions available in Exhibit Hall) OFC Career Zone Live, Exhibit Hall B2**
Thursday, 12 March

**Exhibit Hall B**

**Th2A • Poster Session II**

**Th2A.1**

100-Gbps 100-m Hollow-core Fiber Optical Interconnection at 2-micron Waveband by PS-DMT. Wei-hong Shen1, Jiangbing Du1, Lin Sun1, Chang Wang1, Ke Xu1, Baile Chen1, Zuyuan He1, 2Shanghai Jiao Tong Univ., China; 2Harbin Inst. of Technology, China; 3Shanghai Tech Univ., China. 2-micron waveband optical interconnection at record-high speed of 100 Gbps/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, Jörg P. Epping1, Ruid M. Olenbeuving1, Dimitri Geskus1, Ilka Visscher1, Robert Grootjans1, Chris G. Roeloffzen1, René Heidemann1, 1LioniX International BV, 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 Abdeli1,2, Danish Rafique1, Helmut Gnesser1, Stephan Pachnicke2, 1AIDA Optics, Netzwerks SE, Germany; 2Christian-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 Li1, Xiaolu Song1, 1Huawei Co Ltd., China. We demonstrate a pluggable laser bank module with 8-channel single-mode optical output and a maximum power of 18.5 dBm per channel. The hot pluggable module supports sufficient link-budget for a 1.6 Tb/s silicon photonic chip.

**Th2A.5**

Characterization of Modal-chromatic Dispersion Compensation in 400GBase-SR8 Channels, Bülent Kase1, Jose Castro1, Rick Pimpinella1, Yu Huang1, Fei Jia1, Brett Lane1, 2Panduit, USA. We evaluate impact of OM4 dispersion compensated fiber on 8x50Gbps 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 Fujiwara1, Taiji Sakamoto1, Takashi Matsui1, Kazuhito Nakajima1, Kunitaka Saikai1, 1Graduate School of Information Science and Technology, Hokkaido Univ., Japan; 2NTT Access Network Service Systems, NTT corporation, Japan. A tunable TE/TE, 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 Razo2, Keren Bergman1, 1Columbia Univ., USA. We introduce a novel design of space- and-wavelength selective switch using microring-assisted Mach-Zehnder interferometers. A 2×2×2 elementary switch block is demonstrated with full spatial and wavelength switching capabilities, showing 20dB crosstalk suppression and 19dB extinction ratio.

**Th2A.8**

Large-area Metalens Directly Patterned on a 12-inch Glass Wafer Using Immersion Lithography for Mass Production, Qize Zhong1, Yuyong Fu1, Dongdong Li1, Nanxi Song1, Qixiang Lin1, Navab Singh1, 1Inst. of Microelectronics, Agency for Science, Technology and Research, Singapore. We developed a technology to directly process 12-inch glass wafers by using 193 nm immersion lithography for mass production of silicon photonic chips. We experimentally demonstrated 12-inch glass wafers with <1 dB coupling loss over 3mm SSMF showing ≤1 dB power penalty improvement at KP4-FEC between a standard and shaped MZM design.

**Th2A.9**

A High Linear Silicon Mach-Zehnder Modulator by the Dual-series Architecture, Qiang Zhang1, Hui Yu1, Zhilei Fu1, Penghui Xia1, Xiaofei Wang1, 1Carleton College of Information Science and Electronic Engineering, Zhejiang Univ., China. We experimentally demonstrate a highly linear dual-series silicon modulator by tuning properly the power splitting ratio of the driving RF signal on the its two sub-MZMs, with SFDR of 109.5%/100-kHz at 10 GHz.

**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 Tummidi1, Mark Webster1, 1Cisco 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, Laurens Jörn P. Epste1, 1Inst. of Optics & Applied Sciences & College of Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan; 2Nanjing Univ. (Suzhou) High-Tech Inst., China. We report a 10-GHz 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.12**

Low Parasitic Capacitance III-V/Si Hybrid MOS Optical Modulator toward High-speed Modulation, Qi Yang1, Dongtai Li1, Junping Li1, 1TU Dresden, Germany; 2PETRA, Japan. We present advanced design of III-V/Si hybrid MOS optical modulator to reduce parasitic capacitance and resistance toward high-speed modulation. We successfully achieved 21 times smaller RC constant, improving the trade-off between modulation efficiency and bandwidth.

**Th2A.13**

Timing Jitter from Optical Phase Noise in Quantum Dot Coherent Comb Laser at C-band, Yuxun Mao1, Zhenguo Lu1, Jiaran Li1, Guo- cheng Liu1, Chunying Song1, Philip Poole1, 1National Research Council Canada, Canada. Timing jitter obtained from optical phase noise is investigated in InAs/GaIn quantum dot Fabry-Pérot coherent comb lasers with 11, 25, and 34.5 GHz pulse repetition rates. These lasers exhibit ultra-low timing jitter making them excellent sources for tens terabit optical networks.

**Th2A.14**

Optical Interconnection at 2-micron Waveband by PS-DMT, Jörg P. Epping1, Ruid M. Olenbeuving1, Dimitri Geskus1, Ilka Visscher1, Robert Grootjans1, Chris G. Roeloffzen1, René Heidemann1, 1LioniX International BV, 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.15**

10-nm-wide Tunable In-series Laser Array with High Single-mode Stability, Zhenying Sun1, Ruile Xiao1, Zhirui Su1, Gen Lu1, Zhao Chen1, Jilin Zheng1, Yunshan Zhang1, Jun Lu1, Yuechun Shi1, Yi-jen Chiu1, Xiangfei Chen1, 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; 3School of Electronic and Electrical Engineering, Wuhan Textile Univ., China; 4Inst. of Electro-Optical Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan; 2National University of Singapore, Singapore. 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**

10 Gb/s 6.2 ps Transform-limited Coherent Optical Pulse Generation from a 1.55 μm, Self-injection Gain-switched DFB-LD, Keisuke Kasai1, Masatake Nakazawa1, 1Tokohu Univ., Japan. We demonstrate coherent optical pulse generation from a 1.55 μm, self-injection gain-switched DFB-LD using 193 nm immersion lithography for precise shaping, we generate a transform-limited 10-GHz, 6-ps Gaussian-pulse, which had nearly repetitive longitudinal modes with a 7 kHz-linewidth.

**Th2A.17**

High-performance Microring-assist ed Space-and-wavelength Selective Switch, Yishen Huang1, Qixiang Cheng1, Anthony Razo2, Keren Bergman1, 1Columbia Univ., USA. We introduce a novel design of space- and-wavelength selective switch using microring-assisted Mach-Zehnder interferometers. A 2×2×2 elementary switch block is demonstrated with full spatial and wavelength switching capabilities, showing 20dB crosstalk suppression and 19dB extinction ratio.

**Th2A.18**

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 Tummidi1, Mark Webster1, 1Cisco 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.19**

Electro-Optic Frequency Response Shaping in High Speed Mach-Zehnder Modulators, Laurens Jörn P. Epste1, 1Inst. of Optics & Applied Sciences & College of Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan; 2Nanjing Univ. (Suzhou) High-Tech Inst., China. We report a 10-GHz 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.20**

Low Parasitic Capacitance III-V/Si Hybrid MOS Optical Modulator toward High-speed Modulation, Qi Yang1, Dongtai Li1, Junping Li1, 1TU Dresden, Germany; 2PETRA, Japan. We present advanced design of III-V/Si hybrid MOS optical modulator to reduce parasitic capacitance and resistance toward high-speed modulation. We successfully achieved 21 times smaller RC constant, improving the trade-off between modulation efficiency and bandwidth.
group delays are identified. Separations for MIMO-less support grading for rectangular core fibers in Israel.ungsik Yu 1; coating process for the cavity surface. proposed the HF etching method fied Cylinder Method,Masanori Photothermal Effect, Cavities Fabricated by Laser-Induced Th2A.20 Attenuation loss of the MCF made by MCM is 0.190 dB/km at 1550 nm. Cost reduction and higher productivity. optical fibers. loss due to infrared absorption in numerically studied to generate a single-pass system is introduced and experimentally demonstrated. Optimized cylinder method (MCM) is 0.190 dB/km at 1550 nm. MCF made by modified cylinder method (MCM) is 0.190 dB/km at 1550 nm. An optimized cylinder method with a cylindrical radius as small as 1 mm. Twisting Plant Inspired Preamplifier Soft Rotational Spiral Gripper with High-birefringence Fiber Optic Sensor, Mei Yang 1, Lian Cooper 1, Mable P. Fok 1; Univ. of Georgia, USA. Twining plant-inspired pneumatic soft-rotating 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 1 mm.

Wavelength-tunable PT-symmetric Single-longitudinal-mode Fiber Laser with a Single Physical Loop, Ji-angbing Yao 1, Zheng Dai 1, Zhiqiang Fan 1; Univ. of Ottawa, Canada. A wavelength-tunable, time-division-tunable (PD-T) 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 MCW LiDAR System, Ting-Hui Chen 1, Chien-Ying Huang 1, Tim Kuei Shia 1, Sin-Jhu Wu 1, Ching-Hsiang Hsu 1, Ting-Min Lin 1, Po-Chin Chang 1, Chung-Chih Wang 1, Shan-Chun Chen 1, Chien-Chung Lin 1, Chih-I Wu 1,2; Electronic and Optoelectronic System Research Laboratories, Industrial Technology Research Institute, Taiwan. A frequency digital pre-distortion compensation method for MCW LiDAR system is demonstrated and the proposed method can enhance the ranging accuracy more than three times in our MCW ranging experiment.

Th2A.24 Enabling the Scalability of Industrial Networks by Independent Scheduling Domains, Konstantinos (Kostas) Christodouloulopouls 1, Wolfram Lautenbach 2, Florin C. Frick 1, Niel D. Benzaouis 1, Torben Henke 1, Ulrich Gebhard 1, Lars Dembecki 1, Armin Lechler 1, Jan Potzinier 1, Sebastien Bigot 1; Nokia Bell Labs Germany, Germany; ’Univ. of Stuttgart, Germany; ’Nokia Bell Labs France, France. We propose to extend the scalability of Time Sensitive Industrial Networks, by partitioning them into time/scheduling domains and interconnect domain-devices through an optical backbone acting asynchronously to them. We show drastic scalability improvements and a proof of concept.

Th2A.25 Experiments on Cloud-RAN Wireless Handover Using Optical Switching in a Dense Urban Testbed, Artur Maksimovet 1, Craig Gutterman 2, Tingjun Chen 1, Jakai Yu 1, Cedric Ware 1, Luigi Iannone 1, Daniel C. Kliper 1, Gil Zusman 1, LTCI, Telecom Paris, France; 2Electrical Engineering, Columbia Univ., USA; ’College of Optical Sciences, Univ. of Arizona, USA. We investigate dynamic network resource allocation using software-defined networking controller with software-defined optical controllers and experimentally demonstrate cross-node functionality by validating it using an application-layer network service for efficient content distribution in Optical Packet/Circuit Integrated (OPI) network.

Th2A.26 Threshold Plasticity of Hybrid SI-VO, Microring Resonators, Zhi Wang 1,2, Giang Lu 1, Ziling Fu 1, Andrew Kautz 1, Florian Denis-le Coarer 2, Remo Rontani 1, Marc Sicamanna 1, Peter Bienstman 1; ’Inst. of Optical Information, Key Laboratory of Luminescence and Optical Information, Ministry of Education, Beijing Jiaotong Univ., China; ’Photicom Research Group, Ghent Univ. - IMEC, Belgium; ’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 Hirota 1, Sugang Xu 1, Masaki Shiwata 1, Yoshinari Awaji 1, Masimmo Tortorelli 2, Biswannah Mukherjee 1, Hideaki Furukawa 1, Naoya Wada 1; ’National Inst. of Information and Communications Technology, Japan; ’Univ. of California, Davis, USA; ’Politecnico di Milano, Italy. We develop an SDN-based control for optical-multicast packet transmission and experimentally demonstrate the multicast functionality by validating it using an application-layer network service for efficient content distribution in Optical Packet/Circuit Integrated (OPI) network.

Th2A.28 Adaptive DNN Model Partition and Deployment in Edge Computing-enabled Metro Optical Interconnection Network, Mingze Liu 1, Yajie Li 1, Yongli Zhao 1, Hui Yang 1, Je Zhang 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.31 What if AI Fails: Protection against Failure of AI-Based QoT Prediction, Ningjin Guo1, Long Li1, Jialei Xiang1, Sanjay K. Bose2, Gangxiang Shen1, 1Soochow Univ., China; 2IT, India. We propose a new mechanism to protect against the failure of AI-based QoT prediction. Simulation results show the efficiency of the mechanism in guaranteeing reliable of lightpath services, while not increasing network spectrum resources used.

Th2A.32 HeCSON: Heuristic for Configuration Selection in Optical Network Planning, Sai Kireet Patri1, Achim Autenrieth1, Danish Rafique1, Jörg-Peter Elbers1, Carmen Mas Machuca2; 1KTH, Sweden; 2HPN group, Photonic Technologies, Germany. We present a transceiver configuration selection heuristic combining Enhanced Gaussian Noise (EGN) models, which shows a 40% increase in throughput and 87% decrease in equipment, compared to only approximate EGN and Full-Form EGN respectively.

Th2A.33 Hardware-efficient ROADM Design with Fiber-core Bypassing for WDM/SDM Networks, Lida Lu1, Shuangy Yang1, Gerald Q. Miguez Jr.1, Yanlong Li2, Dimitra Simeoni1,2; 1ADVA Optical Networking SE, Germany; 2Technical Univ. of Munich, Germany. We present a transceiver configuration selection heuristic combining Enhanced Gaussian Noise (EGN) models, which shows a 40% increase in throughput and 87% decrease in equipment, compared to only approximate EGN and Full-Form EGN respectively.

Th2A.34 Energy-efficient Coherent PON System with Access-span Length Difference Between ONUs Using Marginal IQ Power Loading in Downlink Transmission, Takahiro Kodama1, Kouki Arata1; 1Kagawa Univ., Japan; 2Graduate Faculty of Interdisciplinary Research, Univ. of Yamashina, Japan. 2.7 dB power efficiency improvement consistent with theory was experimentally obtained by marginal IQ distorted QPSK signal with and DOP-CPR in the case of the 75 km downlink access span length difference between two ONUs.

Th2A.35 Novel Low Cost PON Protection via Harvested Power, Neil Parkin1, Albert Rafel1; 1IT, UK. PON protection is costly due to the necessary redundant equipment. We describe a method utilising harvested optical power and show test results using commercial equipment, which prove protection could be provided at very low cost.

Th2A.36 Deterministic Layer-2 Ring Network with Autonomous Dynamic Gate Shaping for Multi-service Convergence in 5G and Beyond, Naotaka Shibata1, Shin Kameko1, Kazuki Honda1, Jun Terada1; 1NTT, Japan. We propose autonomous dynamic gate shaping and rerouting according to real-time traffic-state for enhancing IoT-traffic throughput on deterministic layer-2 network that also accommodates latency-sensitive mobile front-haul. System-level demonstrations show throughput improvement from 3.9 Gbps to 7.9 Gbps.

Th2A.37 Comparison of PAM Formats for 200 Gb/s Short Reach Transmission, Tom Wittstein1, Talal Vahedi1, Joanne Ng1, Wei Li1, Jialin Jiang1, Ji Long Lu2, Stefano Calabro1, Nebojsa Stojanovic1, Stefan Pachnicke1; 1Kiel Univ., Germany; 2European Research Center, Huawei Technologies, Germany. We compared the performance of PAM4, PAM6 and PAM8 experimentally at 224.225 Gb/s using different DCP schemes includ- ing Timon-Tarshishamara2; 1ThP. PAM6 shows the best overall performance. For PAM4 THP shows a large gain.

Th2A.38 ASIC Design Exploration for DSP and FEC of 400-Gbit/s CPE Data-center Interconnect Receivers, Christoffer Fougstedt1, Oscar Gustafsson1, Cheolyoung Bae1, Erik Börjesson1, Per LarssonEdelfors1; 1Department of Computer Science and Engineering, Chalmers Univ. of Technology, Sweden; 2Department of Electro- nics Engineering, Linköping Univ., Sweden. We perform experimental ASIC design of key DSP and FEC units for 400-Gbit/s coherent data-center interconnect receivers. In 22-nm CMOS, the considered units together dissipate 5 W, suggesting implementation feasibility in power- constrained form factors.

Th2A.39 Coherent Self-superoorption Aid ed SSB Nyquist 1QAM Synthe sis from Twin-SSB Nyquist QPSK with Reduced DAC Resolution Requirement, Guo-Wei Lu1, Hong-Bo Zhang1, Shi Li2, Takai Univ., Japan; 2Chengdu Univ. of Info. and Tech., China; 3II-VI Incorporated, USA. An FWM-based coherent self-superoorption technique is proposed and demonstrated to synthesize 12.5 Gb/s SSB Nyquist 1QAM from Twin-SSB Nyquist QPSK, which effectively relaxes DAC resolution requirement. An equalization algorithm is also proposed for such approach’s detection.

Th2A.40 80-GHz Band Electro-optic Modula tor Using Antenna-coupled Electric Field Utilization on Low-k Substrate for Millimeter Wave Radar System, Hiroshi Murata1, Hirono Yoko-kashi1, Misue Mie1, Jun-Ichi Tanaka1, Jin-Lin Chang1, Na-tional Taipei Univ. of Technology, Taiwan; 2Georgia Inst. of Technology, Georgia. RF fading in an RoF system is circumvented by managing the frequency notch through the control of a polarization modulator. W-band signals centralized at 90 GHz with 10GHz operation bandwidth are fully utilized with stable EVM performance.

Th2A.41 Photonics-enabled 2Tx2Rx Coher ent MIMO Radar System Experi ments with Enhanced Cross Range Resolution, Antonella Bogoni1,2, Paolo Ghelli1, Salvatore Maresca1, Leonardo Lenzo1, David Ricardo Sanchez Jacome1, Filippo Scott1, Giovanni Serafin1, Antonio Malacarme1, Carsten Rockstuhl1, CNIT, Italy; 2Sant’Anna School, Italy; 3Na-tional Research Council, Italy. We compared a Ka-band dual/four-element phased antenna array integrated utilizing r

Th2A.42 Novel Compressed Digital Radio Fronthaul over Photonically-generated THz Wireless Bridge, Longchi Chen1, Yi-Cai2, Weiming Wang1, Weigang Zhou1, Zhile Hu1, ZTE Corpora- tion, China; 2C4-256 four-dimensional 8-bit modulation with non-binary FEC is proposed and demonstrated for coherent optical transmissions, which outperforms its PM-16QAM counterpart by 0.7dB for required OSNR at 10−3 post-FEC BER.

Th2A.43 Novel Four-dimensional 8-bit Modulation with KP4 Non-binary FEC for Short-reach Coherent Optical Transmissions, Liangjun Zhang1, Hung-chang Chien1, Yi-Cai2, Weiming Wang1, Weigang Zhou1, Zhile Hu1, ZTE Corpora- tion, China. C4-256 four-dimensional 8-bit modulation with non-binary FEC is proposed and demonstrated for coherent optical transmissions, which outperforms its PM-16QAM counterpart by 0.7dB for required OSNR at 10−3 post-FEC BER.
Bayvel 1, Laurent Schmalen 3; Labs, Germany; Karlsruhe Inst. of Technology, Germany. We perform an experimental end-to-end transceiver optimization via deep learning using a generative adversarial network to demonstrate heterodyne detection at a SNR of less than -20 dB with machine learning based optimized carrier phase estimation. Successful 17 GBaud BPSK signal demodulation is achieved without the use of pilot signals.

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.

We characterize the statistics of the nonlinear phase noise induced from low-speed optical supervisory channel wavelength-multiplexed outside the EDFA amplification band and how it affects the behavior and performance of soft-decision FEC.

We numerically analyze the statistics of the nonlinear phase noise induced from a low-speed optical supervisory channel wavelength-multiplexed outside the EDFA amplification band and how it affects the behavior and performance of soft-decision FEC.

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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 Francia2, Ryoji Nagase1, Wataru Ishida2, Yoshiaki Sone2, Lalit Kumar1, Srikanth Krishnamohan3, Victor López2; Telefonica R&D, Spain; Telefonica Peru, Peru; NEL America, USA; IIP Infusion, USA. We demonstrate a field trial of 100G/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[1].

Th3A.2 • 14:15

Demonstration of Low-latency Coherent Optical Connectivity for Consolidated Inter-hub Ring Architecture

Takuya Okimoto1,2, Koji Ebihara2, Satoru Horino2, Tatsuya Takeuchi2, Toru Uchida3, Hideki Yagi1, Yoshihiro Yoneida1; Sumitomo Electric Industries, Ltd., Japan; Sumitomo Electric Device Innovations, Inc., Japan. InP-based 8-channel waveguide AFD arrays were demonstrated towards 400Gbps 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.

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 transceivers 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.

Th3B.1 • 14:00

Large-scale Photonic Integrated Cross-connects for Optical Connectivity and Computation

Ripalda Stabile1, Nicola Calabretta1, Bin Shi2; 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

Ken Ashizawa1, Koji Ebihara2, Satoru Horino2, Tatsuya Takeuchi2, Toru Uchida3, Hideki Yagi1, Yoshihiro Yoneida1; Sumitomo Electric Industries, Ltd., Japan; Sumitomo Electric Device Innovations, Inc., Japan. InP-based 8-channel waveguide AFD arrays were demonstrated towards 400Gbps 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 Che1, Yasuhiro Matsui2, Richard Schatz2, Roberto Rodes3, Ferdous Khan3, Martin Kwaerknaak1, Tsurugi Sudo1, Chandrasekhar Sethumadhavan1, Junho Choi1, Xi Chen1, Peter Winzer1; Nokia Bell Labs, USA; Finisar Corporation, USA; Applied Optoelectronics, USA; 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 chirp parameter of 1.0. The 80-Gbaud PAM-8 system achieves a net bit rate of 200 Gbs.

Th3C.2 • 14:15

Top-Scored

Assessment of Domain Adaptation Approaches for QoT Estimation in Optical Networks

Jacques Albert1; Univ. of Sydney, Australia. 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

Top-Scored

Evol-TL: Evolutionary Transfer Learning for QoT Estimation in Multi-domain Networks

Che-Yu Liu1, Xiaoqiang Chen1, Roberto Proietti1, S. J. Ben Yoo1; 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

Assessment of Domain Adaptation Approaches for QoT Estimation in Optical Networks

Riccardo di Mauro1, Cristina Rottondi2, Alessandro Giusti2, Andrea Bianco1; 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.

Th3E.1 • 14:00

Top-Scored

Performance Oriented DSP Design for Flexible Coherent Transmission

Chris R. Fludger1; Infinera GmbH, Germany. We review the impact of DSP in terms of performance and flexibility in the data network. DSP has addressed the optimization of capacity against reach and power. Future DSP targets cost-reduction through flexible point-to-multi-point architectures.

Th3F.1 • 14:00

Tutorial

Calibrated Fiber Grating Wave-length Combs Enable High Accuracy Biosensing

Jacques Albert1; Univ. of Virginia, USA. 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.
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 on multicore fiber systems. This paper introduces recent progress on multicore fiber connection technologies for simplex and multifiber connectors.

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
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<td>Th3A • Disaggregation, Open Platform, SDN, NFV—Continued</td>
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<td>Th3E • Optimizing Coherent Transponders—Continued</td>
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<td>Th3F • Novel Fiber Optic Sensors—Continued</td>
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**Th3A.3 • 14:30**<br>Invited Paper: Optical Node Disaggregation Management and Interoperability<br>Emilio Riccardi1, Marco Schiano1; ‘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.

**Th3B.2 • 14:30**<br>Polarization-diversity Microring-based Optical Switch Fabric in a Switch-and-select Architecture, Hao Yang1, Qixiang Cheng1, Rui Chen1, Keren Bergman1; ‘Columbia Univ., USA. We propose a polarization-diversity microring-based optical switch fabric in a switch-and-select architecture with polarization split-rotators. The first primitive 2×2 silicon device is demonstrated with polarization-dependent loss of <1.6 dB and inter-channel crosstalk of <45 dB.

**Th3C.3 • 14:30**<br>SOH Mach-Zehnder Modulators for 100 Gbd PAM4 Signaling With Sub-1 dB Phase-shifter Loss, Clemens Kieninger1, Christoph Fullner1, Heiner Zwickel1, Yasar Kutuvantavida1, Juned Nasir Kemal1, Carsten Eschenbaum1, Delwin L. Elder1, Larry R. Dalton1, Wolfgang Freude1, Sebastian Randel1, Christian Koos1; ‘Karlsruhe Inst. of Technology, Germany; ‘Department of Chemistry, Univ. of Washington, USA. We demonstrate 280 μm-long silicon-organic hybrid (SOH) modulators with optical phase-shifter losses of 0.7dB and 11-voltages of 1.5V. We show OOK and PAM4 signaling at 100 Gbd with a BER below the 7% HD-FEC limit.

**Th3C.4 • 14:45**<br>Top-Scored Paper: Integrated SiPh Flex-LIONS Module for All-to-all Optical Interconnects with Bandwidth Steering, Xian Xiao1, Roberto Proietti1, Hongbo Liu1, Hon-gbo Liu1, Yi-Chun Ling1, Yu Zhang1, S. J. Ben Yoo1; ‘Univ. of California, Davis, USA. We experimentally demonstrate the first all-to-all optical interconnects with bandwidth steering using an integrated 8×8 SiPh Flex-LIONS module. Experimental results show a 5-dB worst-case crosstalk penalty and 25 Gb/s to 100 Gb/s bandwidth steering.

**Th3D.4 • 14:45**<br>Modeling Filtering Penalties in ROADM-based Networks with Machine Learning for QoT Estimation, Arunkumar Mahajan1, Konstantinos (Kostas) Christodouloupolos1, Ricardo Martinez1, Salvatore Spadaro1, Raúl Muñoz1; ‘CTTC, Spain; ‘Nokia Bell Labs, Germany; ‘UPC, Spain. Monitoring 3dB bandwidth and other spectrum related parameters at ROADM provides information about quality of their filters. We propose a machine-learning model to estimate end-to-end filtering penalty for more accurate QoT estimation of future connections.

**Th3F.2 • 14:30**<br>Femtosecond Laser Fabricated All-multicore-fiber Parallel Fabry-Perot Interferometers for Dual-parameter Sensing, Cong Zhang1, Songoian Fu1, Ming Tang1, Deming Liu1; ‘School of Optical and Electronic Information, Huazhong Univ of Science and Technology, China. We demonstrate all-multicore-fiber parallel Fabry-Perot interferometers (FPFs) with individually variable cavity length of 26-61μm by femtosecond laser selective micromachining and fiber fusion splicing, leading to the successful mitigation of cross-sensitivity arising in dual-parameter sensing.
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 • Direct Detection Systems and Subsystems—Continued

Th3K • Future and Emerging Access Network Technologies—Continued

Th3H.3 • 14:30 ★ Top-Scored Long-Haul DMD-Unmanaged 6-mode-multiplexed Transmission Employing Cyclic Mode-group Permutation, Kohki Shibahara1, Takayuki Mizuno1, Hirotaka Ono1, Kazuhide Nakajima1, Yutaka Miyamoto1; 1NTT Network Innovation Laboratories, Japan; 2NTT Device Technology Laboratories, Japan; 3NTT Access Network Service Systems Laboratories, Japan. We demonstrate a long-haul 6-mode-multiplexed WDM transmission with a record reach of 3250 km. Newly-developed mode-group permutation technique mitigated modal-dispersion-impact by >70%. We also show diversity-enhanced MIMO transmission extending the achievable reach over 9000 km.

Th3H.4 • 14:45 First Transmission of a 12D Format Across Three Coupled Spatial Modes of a 3-core Coupled-core Fiber at 4 bits/s/Hz, Rene-Jean Essiambre1, Roeland Ryf1, Jaap van der Heide1,2, Juan I. Bonetti1,2, Hanzi Huang1,3, Murali Kodialam1, Francisco Javier Garcia-Gomez1,4, Ellisworth C. Burrows1, Juan Carlos Alvarado Zacarias1,2, Rodrigo Amezquita Correa1,2,3, Xi Chen1, Nicolas K. Fontaine1, Haoshuo Chen1, Nokia Corporation, USA; 2Electrical Engineering, Eindhoven Univ. of Technology, Netherlands; 3Specialty Fiber Optics and Optical Access Networks, Shanghai Univ., China; 4Instituto de Comunicaciones Opticas, Instituto Balseiro, Argentina; 5Inst. for Commun. Engineering, Technical Univ. of Munich, Germany. We demonstrate the first transmission of a space-division multiplexed 12D modulation format over three-core coupled-core multicore fiber. The format occupies a single time slot spread across all three linearly-coupled spatial modes and shows improvements in MI and GMI after transmission compared to PDM-QPSK.

Th3I.2 • 14:30 5.2dB Sensitivity Enhancement in 25Gbps APD-based Optical Receiver Using Dynamic Blasing, Payman Zarkesh-Ha1,2, Robert Efroymson1, Earl Fuller1, Joe Campbell1, Majed Hayat1,4; 1Dynamic Photonics Inc., USA; 2Center for High Technology Materials and ECE Department, Univ. of New Mexico, USA; 3Department of Electrical and Computer Engineering, Univ. of Virginia, USA; 4Department of Electrical and Computer Engineering, Marquette Univ., USA. First demonstration of dynamically biased 25Gbps avalanche photodiode-based receiver operating at 1.55 mm is reported. A 5.2dB improvement in receiver sensitivity and 10,000-fold reduction in bit-error-rate 25-Gbps are experimentally demonstrated using a commercially available InGaAs-InP APD.

Th3I.3 • 14:45 High Durability Molded Lens Connector for SMFs, Akihiro Nakama1,2, Fujisawa Ltd., Japan. We have achieved IL of <0.7dB and RL of >50dB in molded lens connector for single-mode fibers and confirmed its excellent durability, the maximum IL change is 0.06dB without cleaning during mating 250 times.

Th3J.2 • 14:30 Simple-structure LC-type Multi-core Fiber Connector with Low Insertion Loss, Tetsu Morishima1, Ken Manabe1, Shuhei Toyokawa1, Tetsuya Nakanimi1, Tomomi Sano1, Tetsuya Hayashi1; 1Sumitomo Electric Industries, Ltd., Japan; 2Fujikura Ltd., Japan. We demonstrated a single-fiber multi-core fiber (MCF) connector without additional or high-precision parts for rotational alignment. Fabricated MCF connectors achieved low insertion loss of 0.07 dB in average and passed Telcordia GR-326-CORE mechanical reliability test.

Th3J.3 • 14:45 Low-cost Ti-ADC Timing Calibration Circuit, Hananel Faig1, Shai Cohen1, Liron Gantz1, Dan SadoT1, Ben-Gurion Univ. of the Negev, Israel; 2Mellanox Technologies, Israel. An efficient timing skew calibration of time-interleaved ADC (Ti-ADC) for high-speed link is proposed and experimentally validated. The method is based on the CDR’s existing subblocks, and enables flexible tradeoff of complexity versus performance.

Th3K.3 • 14:45 Demonstration of SOA-based IM/DD 1T (280Gbit/s×4) PS-PAM8 Transmission over 40km SSMF at O-band, Kaihui Wang1, Jiao Zhang1, Mingming Zhao1, Wen Zhou1, Li Zhao1, Jiayinan Xiao1, Peng Zhao1, Yun Zhang1, Bo Liu1, Xiangjun Xie1, Ze Dong1, Jianjun Yu1; 1Fudan Univ., China; 2Xiamen Univ., China; 3Xiamen Univ. of Posts and Telecommunications, China; 4ZTE Corp., China; 5Beijing Univ. of Posts and Telecommunications, China; 6Huaqiao Univ., China. We experimentally demonstrate a four-lane O-band IM/DD system. With the aid of semiconductor optical amplifiers and probabilistic shaping, a record bit rate of 1.12Tb/s (280Gbit/s×4) PS-PAM8 signal can be successfully transmitted over 40-km SSMF.
Demonstration of Containerized vDU/vCU Migration in WDM Metro Optical Networks, Jiaxin Feng1, Jiawei Zhang1, Yuefeng Ji1, Yuming Xiao1; 1Beijing Univ. of Posts and Telecomm, China. We experiment on a containerized vDU/vCU migration for load balancing among processing pools over WDM metro networks. Two stateful migration strategies to reduce migration time are verified on a converged edge access network platform.

O-band Strictly Non-blocking 8 × 8 Silicon-photonic Switch, Keijiro Suzuki1, Ryutaro Kanoike1, Guangwei Cong1, Koji Yamada1, Shu Namiki1, Hitoshi Kawashima1, Kazuhiro Ikeda1; 1National Inst. of Advanced Industrial Science and Technology (AIST), Japan. We report a double Mach-Zehnder path-independent insertion-loss 8 × 8 switch operating in the O-band. The average on-chip loss was 5.4-dB, and the crosstalk was less than -30-dB in a wavelength range of 1290-1360 nm.

First Proof That Geographic Locating on Deployed Fiber Cable Can Be Determined by Using OTDR Distance Based on Distributed Fiber Optical Sensing Technology, Tiejun Xia1, Ting Wang2, Yoshiaki Aono3; 1Shanghai Jiao Tong Univ., China; 2NEC Communications Inc., USA; 3Aayuna, Inc., USA. We demonstrated suitable for intra-datacenter networks. and a novel driving techniques. The method involves vibration stimulation near deployed fiber cables and distributed fiber optical sensing technology.

How Uncertainty on the Fiber Span Lengths Influences QoT Estimation Using Machine Learning in WDM Networks, Jelena Pesic1, Matteo Lonardi2, Nicola Rrossi2, Thierry Zami2, Emmanuel Seve1, Yvan Pointurier1; 1Nokia-Bell-Labs, France; 2Nokia, France. We investigate how a machine learning-based QoT estimator performs depending on different features selections, on homogeneity of the learned light paths and on uncertainty of their span lengths using artificial database for the France43 network.

A Three-stage Training Framework for Customizing Link Models for Optical Networks, Xiaomin Liu1, Huazhi Lün1, Mengfan Fu1, Yunyun Fan1, Lin Lin2, Weisheng Hu1, Qunfei Zhuge1; 1Shanghai Jiao Tong Univ., China. We propose a link model customization framework to increase modeling accuracy for each specific link in an optical network. In addition, an active acquisition method is employed in this framework to improve tolerance to link parameter uncertainties.

A fast switching speed of 84 μs for silica-based PLC switch, Osamu Moriwaki1, Kenya Suzuki1; 1NTT Device Innovation Center, NTT Corporation, Japan. We have reduced the switching time of a silica-based thermo-optic switch from 84 μs by utilizing a thin cladding layer and a novel driving techniques. The result high-speed switch should be suitable for intra-datacenter networks.

We report a 16-nm CMOS double zero-dispersion (ZD) free spectral range (FSR) photonic crystal Mach-Zehnder interferometer-based PLC switch, J. Xia1, Glenn Wellbrock1, Ming-Fang Onda1, An Nguyen1, Zhenxing Wang1, Xiaomin Liu1, Swen Koenig1, Mark Missey1, Alban Liepvre1, Ryan Going1, Stefan Wolf1, Joseph M. Kahn is Professor of Electrical Engineering at Stanford University. Achievements include: first synchronous (coherent) detection in optical fiboptics (1989); first probabilistic shaping in optical communications (1999); founding StratsLight Communications, leader in first-generation phase-modulated fiber transmission systems (2000); first electronic compensation of fiber Kerr nonlinearity (2002), leading to digital backpropagation (2008).
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

Thursday, 12 March
Progress in 100G Lambda MSA Based on 100G PAM4 Technology, Mark Nowell, Matt Traverso, Marco Mazzini, Kumar Lakshminarayanan, 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.

Low Loss Optical Switch with Precisely Rotationally-aligned Multicore Fiber Array, Osamu Shimakawa, Ryuichi Kabayashi, Hidehisa Tazawa, ‘Sumitomo Electric Industries, Ltd., Japan. 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.

Efficient Classification of Polarization Events Based on Field Measurements, Kyle Guan, Jesse E. Simsarian, Fabien Boitier, Daniel C. Kilper, Jelena Pesic, Michael 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 with data augmentation combined with robot-generated fiber-disturbance data. We compare machine learning methods for accuracy and required number of training sample traces.

Vibration Sensing for Deployed Metropolitan Fiber Infrastructures, Ilaria Di Luchia, Maddalena Ferrano, 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.

Sensors Based on Dual Supermode Interferometers, Joel Villatoro, Jose Enrique Antonio Lopez, Axel Schulzgen, 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.
Th3I • Optical and Thermal Connectivity—Continued

Th3J • Direct Detection Systems and Subsystems—Continued

Th3K • Future and Emerging Access Network Technologies—Continued

Th3L • 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 Le1; Henkel Corporation, 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 Fujiiwa1, Takuya Kana1, Kazutaka Hara1, Atsuko Kawaiwa1, Hiro Suzuki1, Jun-ichi Kan1, 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.

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

16:30–18:30 Postdeadline Papers, Room 6C, 6D, 6E, 6F