Room 1A

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

M1A.1 • 08:00
Telemetry-driven Optical 5G Serverless Architecture for Latency-sensitive Edge Computing, Istvan Pelle[1], Francesco Paolucci[3], Balazs Sonkoly[1], Filippo Cugini[2]; [1]*MTA-BME Network Softwarization Research Group, Hungary;* [2]*CNIT, Italy;* [3]*Scuola 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.

M1A.2 • 08:15
Flexible Optical Network Enabled Hybrid Recovery for Edge Network with Reinforcement Learning, Meng Lian[1], Rentao Gu[1], Yongyao Qu[1], Zihao Wang[1], Yuefeng Ji[1]; [1]*Beijing Laboratory 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.

Room 1B

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

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

Rui Morais received his Master of Science in Mathematics and his PhD in electrical engineering, both from the University of Aveiro. He joined Infinera (then NSN and after Coriant) in 2011. He is now serving as an enabler on the adoption of machine learning by identifying use-cases that would pave the way to the appearance of self-driving networks.

Room 2

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

M1C.1 • 08:00 Invited
Mid-infrared Gas Spectroscopy Using Fiber Laser Driven Supercontinuum, Camille-Sophie Brès[1], Davide Grassani[1], Eirini Tagkoudi[1]; [1]*Ecole 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.

Room 3

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

M1D.1 • 08:00 Tutorial
Graphene and Related Materials for Photonics and Optoelectronics, Andrea C. Ferrari[1]; [1]*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.

Andrea C. Ferrari is Professor of Nanotechnology at the University of Cambridge. He is the founding director of the Cambridge Graphene Centre and of the EPSRC Centre for Doctoral Training in Graphene Technology. He is the chair of the Management Panel and the Science and Technology Officer of the EU Graphene Flaghip.

Room 6C

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

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

Room 6D

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

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

Room 6E

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

M1G.1 • 08:00
Neural Network Assisted Geometric Shaping for 800Gbit/s and 1Tbit/s Optical Transmission, Maximilian Schaedler[1,2], Stefano Calabro[1], Fabio Pittalà[1], Georg Böcherer[3], Maxim Kuschnerov[1], Christian Bluemm[1], Stephan Pachnicke[2]; [1]*Huawei Munich Research Center, Germany;* [2]*Chair of Communications, Kiel Univ. (CAU), Germany;* [3]*Huawei Technologies France SASU, France.* End-to-end learning for amplified and unamplified links including binary-mapping is proposed to improve the performance of optical coherent systems. 1.0dB and 1.2dB gains are demonstrated on coherent 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 Bitachon[1], Amirhossein Ghazisaeidi[3], Benedikt Baeuerle[1,2], Marco Eppenberger[1], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland;* [2]*Polariton AG, Switzerland;* [3]*Nokia Bell Labs, France.* A new deep learning training method for digital back propagation (DBP) is introduced. It is invariant to polarization state rotation and phase noise. Applying the method one gains more than 1 dB over standard DBP.

Room 6F

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

M1H.1 • 08:00 Invited
Co-packaged TeraPHY Optical I/O Enables Next Generation of Data Center Applications, Vladimir Stojanovic[1]; [1]*Ayar Labs, USA.* Abstract not available.

Room 7

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

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

Room 8

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

M1J.1 • 08:00 Invited
Optically Controlled Beam-steering Wireless Systems, Ton Koonen[1], Ketema Mekonnen[1], Zizheng Cao[1], Frans Huijskens[1], Ngoc-Quan Pham[1], Eduward Tangdiongga[1]; [1]*Technische Universiteit Eindhoven, Netherlands.* Wavelength-controlled 2D steering of mm-wave beams and infrared beams provides high communication capacity, privacy and energy efficiency. Using diffractive elements and accurate user localization, delivery of multiple 10GbE video streams by infrared beams is demonstrated.

Room 9

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

M1K.1 • 08:00 Tutorial
The Telco Cloudification, from Opencord to SDN-enabled Broadband Access (SEBA), Saurav Das[1]; [1]*Open Networking Foundation, USA.* Abstract not available.

Room 1A

M1A • Edge Computing—Continued

M1A.3 • 08:30 Invited

Multi-layer Network Slicing for Accelerating Business Velocity for Edge Computing, Akihiro Nakao[1]; [1]*Interfaculty Initiative in Information Studies, The Univ. of Tokyo, Japan.* Abstract not available.

Room 1B

M1B • Cognitive Optical Networks—Continued

Room 2

M1C • Photonic Sensors—Continued

M1C.2 • 08:30

Proposal of Brillouin Optical Time Domain Collider for Dynamic Strain Measurement, Yin Zhou[1], Lianshan Yan[1], Xinpu Zhang[1], Wei Pan[1]; [1]*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 Chen[1], Chris Doerr[1], Shenghua Liu[1], Li Chen[1], Michelle Xu[1]; [1]*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.

Room 3

M1D • Novel Active Devices—Continued

Room 6C

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

M1E.2 • 08:30 Invited

Scalable Measurement-Device-Independent Quantum Key Distribution Networks with Untrusted Relays, Hoi-Kwong Lo[1], Wenyuan Wang[1], Feihu Xu[2]; [1]*Physics, Univ. of Toronto, Canada;* [2]*Univ. 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.

Room 6D

M1F • Next Generation TOSA/ROSA Components—Continued

M1F.2 • 08:30 Top-Scored

High Output Power and Compact LAN-WDM EADFB Laser TOSA for 4 × 100-Gbit/s/λ 40-km Fiber-Amplifier Less Transmission, Shigeru Kanazawa[1], Takahiko Shindo[1], Mingchen Chen[1], Naoki Fujiwara[1], Masahiro Nada[1], Toshihide Yoshimatsu[1], Atsushi Kanda[1], Yasuhiko Nakanishi[1], Fumito Nakajima[2], Kimikazu Sano[1], Yozo Ishikawa[3], Kazuyo Mizuno[3], Hideaki Matsuzaki[2]; [1]*NTT Device Innovation Center, Japan;* [2]*NTT Device Technology Labs., Japan;* [3]*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 Han[1], Seokjun Yun[1], Hyun-Do Jung[1], Seok-Tae Kim[1], Jang-Uk Shin[1], Sang-Ho Park[1], Seo-Young Lee[1], Yongsoon Baek[1]; [1]*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.

Room 6E

M1G • Machine Learning and its Applications—Continued

M1G.3 • 08:30
16-QAM Probabilistic Constellation Shaping by Learning the Distribution of Transmitted Symbols from the Training Sequence, Ahmad Fallahpour[1], Fatemeh Alishahi[1], Amir Minoofar[1], Kaiheng Zou[1], Ahmed Almaiman[1], Peicheng Liao[1], Huibin Zhou[1], Moshe Tur[2], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*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.

M1G.4 • 08:45
Assisted Adaptively Partitioned Entropy Loading for FBMC/OQAM System, Xi Chen[1,2], Shuangyi Yan[2], Ming Tang[1], Songnian Fu[1], Deming Liu[1], Dimitra Simeonidou[2]; [1]*Huazhong Univ of Science and Technology, China;* [2]*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.

Room 6F

M1H • Chip-to-chip Optical Interconnects—Continued

M1H.2 • 08:30
Phase Noise Spectral Properties Across Individual Comb Lines in Quantum-dot Mode-locked Lasers, Mustafa A. Al-Qadi[1], Maurice O'Sullivan[2], Chongjin Xie[3], Rongqing Hui[1]; [1]*Univ. of Kansas, USA;* [2]*R&D, Ciena Corporation, Canada;* [3]*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.

M1H.3 • 08:45
Experimental Demonstration of PAM-4 Transmission through Microring Silicon Photonic Clos Switch Fabric, Liang Yuan Dai[1], Yu-Han Hung[1], Qixiang Cheng[1], Keren Bergman[1]; [1]*Lightwave Research Laboratory, USA.* We present the first experimental demonstration of a 25 Gbps optical PAM4 signal transmission through a microring-based Clos topology under realistic operating conditions. We observe a 1.1-dBm power penalty at the bit error rate of 1.03×10−7.

Room 7

M1I • Optical Signal Processing—Continued

M1I.2 • 08:30
Experimental Demonstration of an Optical Second-order Volterra Nonlinear Filter using Wave Mixing and Delays to Equalize a 20-Gbaud 4-APSK Channel, Kaiheng Zou[1], Peicheng Liao[1], Huibin Zhou[1], Ahmad Fallahpour[1], Amir Minoofar[1], Ahmed Almaiman[1,2], Fatemeh Alishahi[1], Moshe Tur[3], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*King Saud Univ., Saudi Arabia;* [3]*Tel Aviv Univ., Israel.* We demonstrate an optical second-order Volterra filter using wave mixing and delays. We measure the frequency response and perform the compensation of a nonlinearly distorted 20-Gbaud 4-APSK signal with BER reduction from 8.2×10^{-3} to 3.2×10^{-3}.

M1I.3 • 08:45
Gain Ripple and Passband Narrowing due to Residual Chromatic Dispersion in Non-degenerate Phase-Sensitive Amplifiers, Shimpei Shimizu[1], Takushi Kazama[2], Takayuki Kobayashi[1], Takeshi Umeki[1,2], Koji Enbutsu[2], Ryoichi Kasahara[2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan;* [2]*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.

Room 8

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

M1J.2 • 08:30 ★ Top-Scored
High Speed 2D-PDA FSO Receiver for High Optical Alignment Robustness with Space Diversity, Toshimasa Umezawa[1], Yuki Yoshida[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2,1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Waseda Univ., Japan.* We present a free space optics receiver with high robustness for optical alignment using a large active area, high-speed 2D-PDA, and its demonstration of 40-Gbps (PAM4) signal detection using a space diversity technique in DSP.

M1J.3 • 08:45
Circumventing LoS Blocking in Beam-Steered Optical-wireless Systems with Real-time Tracking and Handover, Ketemaw Addis Mekonnen[1], Ngoc Quan Pham[1], Frans Huijskens[1], Eduward Tangdiongga[1], Ali Mefleh[2], Ton Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*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.

Room 9

M1K • Dis-aggregated Access Networks—Continued

Room 1A

M1A • Edge Computing—Continued

M1A.4 • 09:00
Deep Reinforced Energy Efficient Traffic Grooming in Fog-cloud Elastic Optical Networks, Ruijie Zhu[1], Shihua Li[1], Peisen Wang[1], Lulu Li[1], Aretor Samuel[1], Yongli Zhao[2]; *[1]Zhengzhou Univ., China; [2]Beijing Univ. of Posts and Telecommunications, China.* We propose a novel energy efficient traffic grooming algorithm based on deep reinforcement learning in fog-cloud elastic optical networks. Simulation results show that it can achieve much lower energy consumption than the state-of-art algorithm.

M1A.5 • 09:15
Multi-stage Aggregation and Lightpath Provisioning of Geo-distributed Data over EON Assisted by MEC, Zhen Liu[1], Jiawei Zhang[1], Zizheng Guo[1], Yuefeng Ji[1]; *[1]Beijing Univ. of Posts and Telecomm, China.* A multi-stage aggregation and lightpath provisioning algorithm is proposed for geo-distributed data in EON assisted by MEC. Simulation results show the algorithm can reduce the job completion time and bandwidth consumption.

Room 1B

M1B • Cognitive Optical Networks—Continued

M1B.2 • 09:00 ★ Top-Scored
Hybrid Learning Assisted Abstraction for Service Performance Assessment Over Multi-domain Optical Networks, Rui Wang[1], Xi Chen[1,2], Zhengguang Gao[1,3], Shuangyi Yan[1], Reza Nejabati[1], Dimitra Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]School of Electronic and Optical Information, Huazhong Univ. of Science and Technology, China; [3]State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China.* This paper demonstrates the field-trial validation for a novel machine learning-assisted lightpath abstraction strategy in multi-domain optical network scenarios. The proposed abstraction framework shows high accuracy for dynamic optical networks with 0.44 dB estimation error.

M1B.3 • 09:15
Exploiting Multi-task Learning to Achieve Effective Transfer Deep Reinforcement Learning in Elastic Optical Networks, Xiaoliang Chen[1], Roberto Proietti[1], Che-Yu Liu[1], Zuqing Zhu[2], S. J. Ben Yoo[1]; *[1]Univ. of California, Davis, USA; [2]Univ. of Science and Technology of China, China.* We propose a multi-task-learning-aided knowledge transferring approach for effective and scalable deep reinforcement learning in EONs. Case studies with RMSA show that this approach can achieve ~4x learning time reduction and ~17.7% lower blocking probability.

Room 2

M1C • Photonic Sensors—Continued

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

M1C.5 • 09:15
Phase-shifted Bragg Grating-based Mach-Zehnder Interferometer Sensor using an Intensity Interrogation Scheme, Enxiao Luan[1], Han Yun[1], Stephen Lin[1], Karen Cheung[1], Lukas Chrostowski[1], Nicolas Jaeger[1]; *[1]Universitiy of British Columbia, Canada.* We experimentally demonstrated the suitability of the phase-shifted Mach-Zehnder interferometric device to support real-time sensing monitoring using an intensity interrogation scheme. The proposed sensor presents a sensitivity of ~810 dB/RIU with a broadband light source.

Room 3

M1D • Novel Active Devices—Continued

M1D.2 • 09:00
128 Gbps NRZ and 224 Gbps PAM-4 Signals Reception in Graphene Plasmonic PDM Receiver, Yilun Wang[1], Yong Zhang[2], Zhibin Jiang[1], Wentao Deng[1], Xinyu Huang[2], Qizhi Yan[1], Liao Chen[1], Xiang Li[3], Lei Ye[2], Xinliang Zhang[1]; *[1]Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; [2]School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China; [3]State Key Laboratory of Optical Communication Technologies and Networks, China Information Communication Technologies Group Corporation, China.* We report high-data rate reception of polarization division multiplexing signals using graphene-on-plasmonic slot waveguide photodetectors with bandwidth exceeding 70 GHz. 128 Gbps NRZ and 224 Gbps PAM-4 signals reception are experimentally demonstrated at 1550 nm with high quality.

M1D.3 • 09:15
High-speed Plasmonic Modulator for Simultaneous C- and O-band Modulation with Simplified Fabrication, Andreas Messner[1], Pascal A. Jud[1], Joel Winiger[1], Wolfgang Heni[1,2], Benedikt Baeuerle[1,2], Marco Eppenberger[1], Koch Ueli[1], Christian Haffner[1,4], Huajun Xu[3], Delwin L. Elder[3], Larry R. Dalton[3], Ping Ma[1], Juerg Leuthold[1]; *[1]ETH Zurich, Switzerland; [2]Polariton Technologies AG, Switzerland; [3]Department of Chemistry, Univ. of Washington, USA; [4]National Inst. of Standards and Technology, USA.* A plasmonic modulator spanning both C- and O-band for dual-band data modulation up to 100 Gbit/s in one single device is presented. Fiber-to-fiber insertion loss can be as low as 11 dB.

Room 6C

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

M1E.3 • 09:00 Invited
Quantum Memory for Light – The Second Life of Rare-earth Crystals, Wolfgang Tittel[1]; *[1]TU Delft, Netherlands.* Abstract not available.

Room 6D

M1F • Next Generation TOSA/ROSA Components—Continued

M1F.4 • 09:00 Invited
Quasi-coherent Technology for Cost Efficient High Loss Budget Transmission, Jesper B. Jensen[1], Jose A. Altabas[1], Omar Gallardo[1], Michele Squartecchia[1], Guillermo Silva Valdecasa[1]; *[1]Bifrost Communications, Denmark.* In this paper, we present results achieved with real-time quasi-coherent receivers in context with challenges for next generation access networks. -35 dBm receiver sensitivity at 10 Gbps for NG-PON2 applications and 32.5 km 25 Gbps C-band transmission over an uncompensated SSMF link for 5G front/mid-haul is presented.

Room 6E

M1G • Machine Learning and its Applications—Continued

M1G.5 • 09:00 Tutorial

Machine Learning and its Applications in Optical Communication Systems, Faisal N. Khan[1], Qirui Fan[1], Jianing Lu[2], Gai Zhou[1], Chao Lu[2], Alan Pak Tao Lau[1]; [1]*Photonics Research Center, Department of Electrical Engineering, Hong Kong Polytechnic Univ., China;* [2]*Photonics Research Center, Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., China.* In this presentation, we will discuss the fundamentals of basic Machine Learning(ML) techniques. We will then provide an overview of current ML applications in optical communications and networks and highlight upcoming trends and challenges.

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 applications for various optical communication systems.

Room 6F

M1H • Chip-to-chip Optical Interconnects—Continued

M1H.4 • 09:00 Tutorial

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

Ashok Krishnamoorthy is Chairman and CEO of Axalume, an optical interconnect startup. He was formerly an Oracle Architect and its Chief Technologist, Photonics. 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.

Room 7

M1I • Optical Signal Processing—Continued

M1I.4 • 09:00

Generation and Coherent Detection of 2-µm-band WDM-QPSK Signals by On-chip Spectral Translation, Deming Kong[1], Yong Liu[1], Zhengqi Ren[2], Yongmin Jung[2], Minhao Pu[1], Kresten Yvind[1], Michael Galili[1], Leif Oxenløwe[1], David Richardson[2], Hao Hu[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Optoelectronics Research Centre, Univ. of Southampton, UK.* We have proposed and demonstrated the generation and coherent detection of 2-µm-band I/Q modulated signals for the first time using on-chip spectral translation. 6×32 Gbaud WDM-QPSK signals exhibit BERs below the 7% HD-FEC threshold.

M1I.5 • 09:15

Compensation of SOA Nonlinear Distortions by Mid-stage Optical Phase Conjugation, Aneesh Sobhanan[1], Mark Pelusi[2], Takashi Inoue[2], Deepa Venkitesh[1], Shu Namiki[2]; [1]*Indian Inst. of Technology Madras, India;* [2]*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 Q^2-factor improvement.

Room 8

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

M1J.4 • 09:00

Beyond 100-kbit/s Transmission over Rolling Shutter Camera-based VLC Enabled by Color and Spatial Multiplexing, Liqiong Liu[1], Rui Deng[1], Jin Shi[2], Jing He[2], Lian-Kuan Chen[1]; [1]*Department of Information Engineering, The Chinese Univ. of Hong Kong, Hong Kong;* [2]*College of Computer Science and Electornic Engineering, Hunan Univ., China.* The camera-based VLC (CVLC) is a promising technique for various application scenarios. For the first time, we demonstrate a rolling shutter based CVLC system with beyond 100-kbit/s data rate by employing color and spatial multiplexing.

M1J.5 • 09:15

Non-orthogonal Matrix Precoding based Faster-than-nyquist Signaling over Optical Wireless Communications, Zhouyi Hu[1], Chun-Kit Chan[1]; [1]*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.

Room 9

M1K • Dis-aggregated Access Networks—Continued

M1K.2 • 09:00

Two-stage Abstraction for Disaggregated Modular OLT Architecture Supporting OpenFlow Control, Keita Nishimoto[1], Kota Asaka[1], Jun-ichi Kani[1], Jun Terada[1]; [1]*NTT Access Network Service Systems Laboratories, Japan.* We implement our abstraction method for provisioning and controlling, via OpenFlow, the disaggregated PON-OLT that features separation of hardware module and softwarized OLT functions, and demonstrate its operation by utilizing open source controllers ONOS / VOLTHA.

M1K.3 • 09:15

Capacity Sharing Approaches in Multi-tenant, Multi-service PONs for Low-latency Fronthaul Applications Based on Cooperative-DBA, Arsalan Ahmad[1,2], Sanwal Zeb[1], Abdul Wahab[2], Rana Azhar Khan[2], Marco Ruffini[1]; [1]*Univ. of Dublin Trinity College, Ireland;* [2]*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

Room 1A

M1A • Edge Computing—Continued

M1A.6 • 09:30
Remote Human-to-Machine Distance Emulation through AI-Enhanced Servers for Tactile Internet Applications, Sourav Mondal[1], Lihua Ruan[1], Elaine Wong[1]; [1]*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 Zhang[1], Lu Cui[1], Zhen Liu[1], Yuefeng Ji[1]; [1]*Beijing Univ of Posts & Telecom, China.* We experimentally demonstrate a geo-distributed data processing and aggregation (GDPA) scheme in the MEC-empowered metro optical networks. The demonstration results show that the proposed scheme can improve resource utilization and reduce average job completion time.

Room 1B

M1B • Cognitive Optical Networks—Continued

M1B.4 • 09:30
Dynamically Controlled Flexible-Grid Networks Based on Semi-Flexible Spectrum Assignment and Network-state-value Evaluation, Ryuta Shiraki[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[2]; [1]*Information and Communication Engineering, Nagoya Univ., Japan;* [2]*The 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%.

Room 2

M1C • Photonic Sensors—Continued

M1C.6 • 09:30
Real-time Structured-light Depth Sensing Based on Ultra-compact, Non-mechanical VCSEL Beam Scanner, Ruixiao Li[1], Masashi Takanohashi[1], Shanting Hu[1], Xiaodong Gu[1], Fumio Koyama[1]; [1]*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 (<0.5mm^2) non-mechanical beam scanner. The peak output power can be as low as 1mW.

M1C.7 • 09:45
A Novel Frequency-modulation (FM) Demodulator for Microwave Photonic Links based on Polarization-Maintaining Fiber Bragg Grating, Dipenkumar Barot[1], Lingze Duan[1]; [1]*Univ. of Alabama in Huntsville, USA.* A novel scheme for demodulating frequency-modulated optical signals 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.

Room 3

M1D • Novel Active Devices—Continued

M1D.4 • 09:30
50 Gbit/s Silicon Modulator Operated at 1950 nm, Wenxiang Li[1], Miaofeng Li[2,3], Hongguang Zhang[2,3], Yuguang Zhang[2,3], Hucheng Xie[1], Xi Xiao[2,3], Ke Xu[1]; [1]*Harbin Inst. of Technology, China;* [2]*National Information Optoelectronics Innovation Center, China;* [3]*Wuhan 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
Quantum Random Number Generator based on Phase Diffusion in Lasers using an On-chip Tunable SOI Unbalanced Mach-Zehnder Interferometer (uMZI), Imran Muhammad[1], Vito Sorianello[2], Francesco Fresi[2], Luca Potì[2], Marco Romagnoli[2]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* A 12.5Gb/s QRNG based on phase diffusion in gain switched lasers is demonstrated using a packaged on-chip SOI tunable unbalanced MZI achieving minimum entropy/bit of 5.04 for 8 bit sample passing all NIST randomness tests.

Room 6C

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

M1E.4 • 09:30 Invited
Title to be Announced, Jungsang Kim[1]; [1]*Duke Univ., USA.* Abstract not available.

Room 6D

M1F • Next Generation TOSA/ROSA Components—Continued

M1F.5 • 09:30
25.78-Gbit/s Burst-mode Receiver for 50G-EPON OLT, Naruto Tanaka[1], Daisuke Umeda[2], Yoshiyuki Sugimoto[1], Tomoyuki Funada[2], Keiji Tanaka[1], Shoichi Ogita[1]; [1]*Transmission Devices Laboratory, Sumitomo Electric Industries, LTD, Japan;* [2]*Information Network R&D Center, Sumitomo Electric Industries, LTD, Japan.* We report the world›s first receiver optical sub-assembly equipped with 25G burst-mode TIA which is applicable for 50G-EPON OLT transceiver. We demonstrate its 25G/10G dual-rate burst-mode receiver characteristics.

M1F.6 • 09:45
PAM-X™: A 25Gb/s-PAM4 Optical Transceiver Chipset for 5G Optical Front-Haul, Lei Zhao[1], Xin Wang[2], Rui Bai[2], Juncheng Wang[2], Tao Xia[1], Yi Peng[2], Yuanxi Zhang[2], Lei Wang[2], Liujia Song[2], Shenglong Zhuo[1], Xuefeng Chen[2], Patrick Y. Chiang[1,2]; [1]*Fudan University, Shanghai, China,* [2]*PhotonIC 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 <30pJ/bit power efficiency.

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

Room 6E

M1G • Machine Learning and its Applications—Continued

Room 6F

M1H • Chip-to-chip Optical Interconnects—Continued

Room 7

M1I • Optical Signal Processing—Continued

M1I.6 • 09:30 Invited
Phase Reconstruction Scheme Using Dispersive Media in Direct Detection, Masayuki Matsumoto[1]; [1]*Wakayama Univ., Japan.* A non-iterative reconstruction scheme of phase-modulated signals using dispersive media in direct detection is described. The phase retrieval is performed by solving the temporal transport-of-intensity equation. Required carrier-to-signal power ratio and allowable carrier location in frequency are numerically studied.

Room 8

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

M1J.6 • 09:30
Ultrahigh-capacity Optical-wireless Communication Using 2D Gratings for Steering and Decoding of DPSK Signals, Ketemaw Addis Mekonnen[1], Eduward Tangdiongga[1], Ton Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* We demonstrate the use of a 2D-gratings beam-steering device also as a demodulator for multiple differentially-encoded optical-wireless signals. Using this novel concept, ~2bits/sec/Hz spectral-efficiency was achieved without any change in the system compared to on-off-keying.

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[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*KPN, Netherlands.* We present upstream signaling and localization for an indoor beam-steered OWC system using vision-based technology. We demonstrate a 1.2kbps upstream signaling and localization system which enables to identify a large number of users with <0.05° error.

Room 9

M1K • Dis-aggregated Access Networks—Continued

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]; [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.

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

M2A.1 • 10:30 ★ Top-Scored
Broadband 145GHz Photodetector Module Targeting 200GBaud Applications, Patrick Runge[1], Felix Ganzer[1], Jonas Gläsel[1], Sebastian Wünsch[1], Sven Mutschall[1], Martin Schell[1]; [1]*Fraunhofer Institut, Germany.* We demonstrate a photodetector module with a 0.8mm-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 Yuan[1,2], Zhihong Huang[1], Binhao Wang[1], Wayne Sorin[1], Di Liang[1], Joe C. Campbell[2], Raymond Beausoleil[1]; [1]*Hewlett Packard Labs, Hewlett Packard Enterprise, USA;* [2]*Department 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.

Room 1B

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

M2B.1 • 10:30
O-band Reflective Electroabsorption Modulator for 50 Gb/s NRZ and PAM-4 Colorless Transmission, Kebede Tesema Atra[2,1], Giancarlo Cerulo[2], Jean-Guy Provost[2], Filipe Jorge[2], Fabrice Blache[2], Karim Mekhazni[2], Alexandre Garreau[2], Frederic Pommereau[2], Carmen Gomez[2], Catherine Fortin[2], Cedric Ware[1], Didier Erasme[1], Franck Mallecot[2], Mohand Achouche[2]; [1]*LTCI, Télécom Paris, Institut Polytechnique de Paris, France;* [2]*III-V Lab (a joint laboratory between Nokia Bell Labs, Thales R&T and CEA Leti), France.* We present a 50 Gb/s O-band reflective electroabsorption modulator operating in both non-return-to-zero (NRZ) and PAM-4 modulation formats without equalization. We obtained >9 dB NRZ dynamic extinction ratio for a peak-to-peak voltage of 2.4 V.

M2B.2 • 10:45
In-Phase/Quadrature Modulation by Directly Reflectivity Modulated laser, Po Dong[1], Argishti Melikyan[1], Kwangwoong Kim[1], Noriaki Kaneda[2], Brian Stern[1], Yves Baeyens[2]; [1]*Nokia Bell Labs, USA;* [2]*Nokia Bell Labs, USA.* We report a directly reflectivity modulated laser that generates a 50-Gbaud QPSK signal with a BER of $2.2x10^{-5}$. We believe this is the first demonstration of a coherent transmitter made from a directly driven laser.

Room 2

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

M2C.1 • 10:30 Invited
Ultra-miniaturized Endoscopes with Multicore Fibers, Esben R. Andresen[1], Siddharth Sivankutty[2], Viktor Tsvirkun[2], Karen Baudelle[1], Olivier Vanvincq[1], Géraud Bouwmans[1], Hervé Rigneault[2]; [1]*Univ Lille 1 Laboratoire PhLAM, France;* [2]*Aix 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 multi-photon imaging. We put the work into perspective and outline remaining challenges.

Room 3

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

M2D.1 • 10:30 Invited
Record Ultra-high Full-fill Capacity Transatlantic Submarine Deployment Ushering in the SDM Era, Pierre Mertz[1], Stephen Grubb[2], Jeffrey Rahn[2], Warren Sande[3], Marc Stephens[3], James O'Connor[3], Matthew Mitchell[2], Stefan Voll[3]; [1]*Infinera Corporation, USA;* [2]*Facebook, USA;* [3]*Infinera 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.

Room 6C

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

M2E.1 • 10:30 Invited
Title to be Announced, Christine Silberhorn[1]; [1]*Univ. of Paderborn, Germany.* Abstract not available.

Room 6D

10:30–12:30
M2F • Digital Signal Processing and Radio-over-fiber Systems for 5G ▶
Presider: Anthony Ng'oma; Corning Inc, USA

M2F.1 • 10:30 Invited ▶
Enabling Techniques for Optical Wireless Communication Systems, Chi-Wai Chow[1], Chien-Hung Yeh[2], Y. Liu[3], Yin-Chieh Lai[1], Liang-Yu Wei[1], Chin-Wei Hsu[1], Guan-Hong Chen[1], X. L. Liao[4], K. H. Lin[4]; [1]*National Chiao Tung Univ., Taiwan;* [2]*Feng Chia Univ., Taiwan;* [3]*Philips, Hong Kong;* [4]*Industrial 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-diode (LD) based VLC systems. Several application scenarios using VLC were also discussed.

Room 6E

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.

Room 6F

10:30–12:30
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 Ankouri[1,2], Santiago Ruano Rincón[2], Gaël Simon[1], Luiz Anet Neto[1], Annie Gravey[2], Philippe Chanclou[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.

M2H.2 • 10:45 Invited

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

Room 7

10:30–12:30
M2I • Photonic Integrated Subsystems

Presider: Lu Li; SubCom, USA

M2I.1 • 10:30 Tutorial

Silicon Photonic Waveguide Bragg Gratings, Lukas Chrostowski[1]; [1]*Univ. of British Columbia, Canada*. Abstract not available.

Room 8

10:30–12:30
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.

Room 9

10:30–12:30
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 Skontranis[1], Adonis Bogris[2], 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.

M2K.2 • 10:45

A DFB-LD-based Photonic Neuromorphic Network for Spatiotemporal Pattern Recognition, Bowen Ma[1], Jianping Chen[1], Weiwen Zou[1]; [1]*Shanghai Jiao Tong Univ., China*. We present a photonic neuromorphic network using DFB-LDs for spatiotemporal pattern recognition. Complete input patterns are investigated theoretically and experimentally. The output peak powers decrease with the difference between the target pattern and other patterns.

Room 1A

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.[1,2], Lukasz Chorchos[1,2], Vitaly A. Shchukin[1], Vladimir P. Kalosha[1], Jaroslaw P. Turkiewicz[2], Nikolay Ledentsov[1]; [1]*VI Systems GmbH, Germany;* [2]*Inst. 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.

Room 1B

M2B • High-speed Integrated Modulators—Continued

M2B.3 • 11:00

Uncooled Operation of 53-Gbaud PAM4 EA-DFB Lasers in the Wavelength Range of 1510-1570 nm for 800-GbE Applications, Yoshihiro Nakai[1], Shigenori Hayakawa[1], Syunya Yamauchi[1], Yoriyoshi Yamaguchi[1], Tetsuyoshi Takamure[1], Hideaki Asakura[1], Ryosuke Nakajima[1], Shigetaka Hamada[1], Kazuhiko Naoe[1]; [1]*Lumentum Japan, Inc., Japan.* 53-Gbaud EA-DFB lasers—with four wavelengths in the 1500-nm region—for 800-GbE applications were developed. They demonstrated uncooled 53-Gbaud PAM4 operation with a TDECQ of lower than 2.5 dB over a wide temperature from 20 to 85°C.

M2B.4 • 11:15

25 Gbit/s Silicon Based Modulators for the 2 µm Wavelength Band, Wei Cao[1], Milos Nedeljkovic[1], Shenghao Liu[1], Callum G. Littlejohns[1], David Thomson[1], Frederic Gardes[1], Zhengqi Ren[1], Ke Li[1], Graham T. Reed[1], Goran Mashanovich[1,2]; [1]*Univ. of Southampton, UK;* [2]*School of Engineering, Univ. of Belgrade, Serbia.* We demonstrate high-speed silicon modulators optimized for operating at the wavelength of 2 µm. The Mach-Zehnder interferometer carrier-depletion modulator has a modulation efficiency $V_\pi.L_\pi$ of 2.89 V.cm at 4 V reverse bias. It operates at a data rate of 25 Gbit/s with an extinction ratio of 6.25 dB.

Room 2

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 Fukui[1], Yusuke Kohno[1], Rui Tang[1], Yoshiaki Nakano[1], Takuo Tanemura[1]; [1]*School of Engineering, The Univ. of Tokyo, Japan.* We experimentally demonstrate single-pixel imaging using a multimode fiber attached with optical phased-array chip. By driving 128 integrated phase shifters, speckle patterns are generated from the fiber to realize clear imaging with 490 resolvable points.

M2C.3 • 11:15

Low Return Loss Multicore Fiber-Fanout Assembly for SDM and Sensing Applications, Victor I. Kopp[1], Jongchul Park[1], Jon Singer[1], Dan Neugroschl[1], Andy Gillooly[2]; [1]*Chiral Photonics Inc, USA;* [2]*Fibercore House, Fibercore, UK.* SDM using uncoupled or coupled core multicore fibers promises to increase the bandwidth density in optical links. In addition, these fibers form a platform for various sensing systems, including 3D shape sensing. Both applications will be advanced by the low return loss fanout-multicore fiber assembly demonstrated here.

Room 3

M2D • Optimizing Network Capacity and Performance—Continued

M2D.2 • 11:00

Probabilistic-Shaping DP-16QAM CFP-DCO transceiver for 200G Upgrade of Legacy Metro/Regional WDM Infrastructure, Erwan Pincemin[1], Yann Loussouarn[1]; [1]*Orange 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 10G or 100G.

M2D.3 • 11:15 ★ Top-Scored

Field and Laboratory Demonstration of 48nm Optical Transport with Real-Time 32T (80×400G) over G.652 Fiber Distances up to 640km, Praveen Kumar[1], Deepak Sanghi[1], Sumit Chatterjee[1], Deng Pan[2], Xuefeng Tang[2], Zhuhong Zhang[2], Chuandong Li[2], Deng Jian[2], Dejiang Zhang[2]; [1]*Bharti Airtel Ltd, India;* [2]*huawei technologies, China.* We report first successful field trial and laboratory demonstration of 48nm extended C band transport. Error-free transmission of 32Tb/s (80×400Gb/s) is achieved over 640km G.652 link in laboratory and 42km G.652 link in field.

Room 6C

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 Bienfang[1]; [1]*NIST, USA.* Abstract not available.

Room 6D

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

M2F.2 • 11:00 ▶

Joint Optimization of Processing Complexity and Rate Allocation through Entropy Tunability for 64-/256-QAM Based Radio Fronthauling with LDPC and PAS-OFDM, Rui Zhang[1], Yon-Wei Chen[1], Shuyi Shen[1], Qi Zhou[1], Shuang Yao[1], Shang-Jen Su[1], Yahya Alfadhli[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA.* We experimentally demonstrate LDPC coded PAS-OFDM 64-/256-QAM signals in radio fronthauls. Through entropy allocation by adjusting the complexity and signal bandwidth, tunable power margins gain up to 3 dB and relaxed process latency are achieved.

M2F.3 • 11:15 ▶

Demonstration of Pattern Division Multiple Access with Message Passing Algorithm in MMW-RoF Systems, Shuyi Shen[1], You-Wei Chen[1], Qi Zhou[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA.* Implementing PDMA with MPA, ambiguous symbol recovery and 4-dB sensitivity improvement was achieved compared to conventional PD-NOMA-SIC. Experimental results show that PDMA enhances application flexibility by pattern variants tailored for different scenarios including grant-free uplinks.

Room 6E

M2G • Multiband and SDN for Capacity Scaling—Continued

M2G.2 • 11:00

Evaluation of the Flexibility of Switching Node Architectures for Spaced Division Multiplexed Elastic Optical Network, Si-cong Ding[1], Shan Yin[1], Zhan Zhang[1], Shanguo Huang[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China*. We present a flexibility model for quantitatively evaluating switching node architectures in terms of switching strategies, function and required components in SDM-EON, revealing designs with the most switching flexibility.

M2G.3 • 11:15 Top-Scored

Design Strategies Exploiting C+L-band in Networks with Geographically-dependent Fiber Upgrade Expenditures, Daniela A. Moniz[2,1], Victor Lopez[3], João Pedro[2]; [1]*Instituto de Telecomunicações, Portugal;* [2]*Infinera, Portugal;* [3]*Telefónica, 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.

Room 6F

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

M2H.3 • 11:15

PON Virtualisation with EAST-WEST Communications for Low-latency Converged Multi-access Edge Computing (MEC), Sandip Das[1], Marco Ruffini[1]; [1]*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.

Room 7

M2I • Photonic Integrated Subsystems—Continued

Room 8

M2J • Data Analytic-based Monitoring—Continued

M2J.2 • 11:00

Experimental Comparisons between Machine Learning and Analytical Models for QoT Estimations in WDM Systems, Qirui Fan[1], Jianing Lu[1], Gai Zhou[1], Derek Zeng[1], Changjian Guo[3,1], Linyue Lu[1], Jianqiang Li[4], Chongjin Xie[2], Chao Lu[1], Faisal N. Khan[1], Alan Pak Tao Lau[1]; [1]*The Hong Kong Polytechnic Univ., Hong Kong;* [2]*Alibaba Group, USA;* [3]*South China Normal Univ., China;* [4]*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.

M2J.3 • 11:15

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

Room 9

M2K • Neuromorphic I: Device-oriented—Continued

M2K.3 • 11:00 Invited

Scalable Photonic Integration of Neural Networks, Johnny Moughames[2], Javier Porte[2], Maxime Jacquot[2], Laurent Larger[2], Muamer Kadic[2], Daniel Brunner[1]; [1]*CNRS, France;* [2]*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.

Room 1A

M2A • Advanced Active Components—Continued

M2A.4 • 11:30
4×112 Gbps/fiber CWDM VCSEL Arrays for Co-packaged Interconnects, Binhao Wang[1], Wayne Sorin[1], Paul Rosenberg[1], Lennie Kiyama[1], Sagi Mathai[1], Michael R. Tan[1]; [1]*Hewlett Packard Enterprise, USA.* We demonstrate a 4×112 Gbps/fiber VCSEL link using a co-packaged coarse wavelength division multiplexing (CWDM) optical module. A complete co-packaged CWDM module can achieve a 2.668 Tb/s aggregated bandwidth by assembling four 1×6 VCSEL arrays.

M2A.5 • 11:45
Electrical and Optical Reliability Analysis of GeSi Electro-absorption Modulators, Artemisia Tsiara[1], Srinivasan Ashwyn Srinivasan[1], Sadhishkumar Balakrishnan[1], Marianna Pantouvaki[1], Philippe Absil[1], Joris Van Campenhout[1], Kristof Croes[1]; [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. After stress, electro-optical extracted parameters indicate no impact of temperature, bias or stress time.

Room 1B

M2B • High-speed Integrated Modulators—Continued

M2B.5 • 11:30
Mach-Zehnder Modulator using Membrane InGaAsP Phase Shifters and SOAs inside Interferometer Arms on Si Photonics Platform, Takuma Aihara[1], Tatsurou Hiraki[1], Takuro Fujii[1], Koji Takeda[1], Takaaki Kakitsuka[1], Tai Tsuchizawa[1], Shinji Matsuo[1]; [1]*NTT, Japan.* A Mach-Zehnder modulator having III-V membrane phase shifters and semiconductor optical amplifiers inside interferometer arms is heterogeneously integrated with Si waveguides. The device exhibits 6-dBm fiber output power and 40-Gbit/s NRZ modulations with clear eye-openings.

M2B.6 • 11:45
Taper-less III-V/Si Hybrid MOS Optical Phase Shifter using Ultrathin InP Membrane, Shuhei Ohno[1], Qiang Li[1], Naoki Sekine[1], Junichi Fujikata[2], Masataka Noguchi[2], Shigeki Takahashi[2], Kasidit Toprasertpong[1], Shinichi Takagi[1], Mitsuru Takenaka[1]; [1]*the Univ. of Tokyo, Japan;* [2]*Photonics Electronics Technology Research Association, Japan.* We present proof-of-concept taper-less 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 2

M2C • SDM Imaging and Sensing—Continued

M2C.4 • 11:30 Invited
Digital Holographic Endo-microscopes Based on Multimode Fibres, Tomas Cizmar[1,2]; [1]*Leibniz-Institut für Photonische Tech, Germany;* [2]*Microphotonics, Inst. of Scientific Instruments of the CAS, Czechia.* Here I review the recent progress of endo-microscopes based on holographic control of light transport through multimode fibres. I discuss the fundamental and technological bases as well as recent applications of the new imaging tool.

Room 3

M2D • Optimizing Network Capacity and Performance—Continued

M2D.4 • 11:30 Invited
Metro-haul Project Vertical Service Demo: Video Surveillance Real-time Low-latency Object Tracking, Annika Dochhan[1], Johannes Fischer[3], Bodo Lent[2], Achim Autenrieth[1], Behnam Shariati[3], Pablo Wilke Berenguer[3], Jörg-Peter Elbers[1]; [1]*ADVA Optical Networking, Germany;* [2]*Qognify GmbH, Germany;* [3]*Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany.* We report on the EU H2020 project METRO-HAUL use-case demonstration, including flexible allocation of storage and computing resources in different network locations and deployment of a network slice instance through a programmable multi-layer optical network.

Room 6C

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

M2E.3 • 11:30 Invited
Superconducting Nanowire Single Photon Detectors for Deep Space Optical Communication and Quantum Information Science, Matthew Shaw[1]; [1]*JPL, USA.* Abstract not available.

Room 6D

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

M2F.4 • 11:30
A MMW Coordinate Multi-Point Transmission System for 5G Mobile Fronthaul Networks based on a Polarization-Tracking-free PDM-RoF Mechanism, Jhih-Heng Yan[1,2], Jian-Kai Huang[1], Yu-Yang Lin[2], Jin-Wei Hsu[1], Kai-Ming Feng[1,2]; [1]*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan;* [2]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan.* A PDM-RoF mechanism is firstly experimentally demonstrated for MMW coordinate multi-point transmission system with a polarization-track-free RAU design. Without additional latency for PDM demultiplexing, we evaluate various coordinate multi-point joint transmission scenarios.

M2F.5 • 11:45 ★ Top-Scored
Wide FoV Autonomous Beamformer Supporting Multiple Beams and Multi-band Operation for 5G Mobile Fronthaul, Min-Yu Huang[1], You-Wei Chen[1], Run-Kai Shiu[1,2], Hua Wang[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*National Taipei Univ. of Technology, Taiwan.* An autonomous beamformer covering 24-37 GHz for fiber-wireless network demonstrates multi-beam and multi-band signal transmission with wide-FoV (110°-180°) self-steering beam-tracking/-forming over a 10-km fiber and 56-cm wireless link for future dynamic 5G-NR fronthaul applications.

Room 6E

M2G • Multiband and SDN for Capacity Scaling—Continued

M2G.4 • 11:30
Network Performance Assessment of C+L Upgrades vs. Fiber Doubling SDM Solutions, Emanuele E. Virgillito[1], Rasoul Sadeghi[1], Alessio Ferrari[1], Giacomo Borraccini[1], Antonio Napoli[2], Vittorio Curri[1]; [1]*Politecnico di Torino, Italy;* [2]*Infinera, 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.

M2G.5 • 11:45
Capacity Limits of C+L Metro Transport Networks Exploiting Dual -Band Node Architectures, Robert Emmerich[1], António Eira[2], Nelson Costa[2], Pablo Wilke Berenguer[1], Colja Schubert[1], Johannes Fischer[1], João Pedro[2,3]; [1]*Fraunhofer Inst. for Telecommunications Heinrich-Hertz-Inst., Germany;* [2]*Infinera Portugal, Portugal;* [3]*Instituto de Telecomunicações, Instituto Superior Técnico, Portugal.* We investigate capacity upgrade of metro networks using differentiated node architectures for C+L-bands. The combination of experimental results and network simulations highlights scenarios where low-cost unamplified L-band extensions can be leveraged for maximum capacity.

Room 6F

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

M2H.4 • 11:30
Asynchronous Multi-service Fiber-Wireless Integrated Network Using UFMC and PS for Flexible 5G Applications, You-Wei Chen[1], Rui Zhang[1], Shang-Jen Su[1], Shuyi Shen[1], Qi Zhou[1], Shuang Yao[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA.* A multi-service fiber-wireless integrated network is experimentally demonstrated using both UFMC and PS. Asynchronous transmission with suppressed inter-service interference and optimized information rate is verified through a 25-km fiber and a 5-m 60-GHz wireless link.

M2H.5 • 11:45 Invited
Gigabit/s Optical Wireless Access and Indoor Networks, Ampalavanapilla T. Nirmalathas[1], tingting Song[1], Sampath Edirisinghe[1], Tian Liang[1], Christina Lim[1], Elaine Wong[1], Ke Wang[2], Chathurika Ranaweera[3], Kamal Alameh[4]; [1]*Univ. of Melbourne, Australia;* [2]*RMIT Uiversity, Australia;* [3]*Deakin Univ., Australia;* [4]*Edith Cowan Univ., Australia.* Optical wireless networks are being explored as a wireless alternative for provision of multi gigabits/second wireless and this paper presents an overview of recent progress and outstanding challenges. and technologies.

Room 7

M2I • Photonic Integrated Subsystems—Continued

M2I.2 • 11:30
A Co-integrated Silicon-based Electronic-Photonic Wideband, High-power Signal Source, Saeed Zeinolabedinzadeh[1], Patrick Goley[2], Milad Frounchi[2], Sunil Rao[2], Christian Bottenfield[2], Gareeyasee Saha[2], Stephen E. Ralph[2], Mehmet Kaynak[3], Lars Zimmermann[3], Stefan Lischke[3], Christian Mai[3], John Cressler[2]; [1]*Arizona State Univ., USA;* [2]*Georgia Tech, USA;* [3]*IHP 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.

M2I.3 • 11:45
Self-adaptive Over-the-air RF Self-interference Cancellation Based on Signal-of-interest Driven Regular Triangle Algorithm, Lizhuo Zheng[1], Zhiyang Liu[1], Zhiyi Zhang[1], Shilin Xiao[1], Mable P. Fok[2], Qidi Liu[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*The Univ. of Georgia, USA.* A signal-of-interest driven self-adaptive RF self-interference cancellation system has been proposed based on regular-triangle algorithm. A weak 16-QAM OFDM signal-of-interest at 18.35GHz has been successfully retrieved with small converge steps in an in-band full-duplex transmission.

Room 8

M2J • Data Analytic-based Monitoring—Continued

M2J.4 • 11:30
Low Complexity Soft Failure Detection and Identification in Optical Links using Adaptive Filter Coefficients, Siddharth Varughese[1], Daniel Lippiatt[1], Thomas Richter[2], Sorin Tibuleac[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*ADVA Optical Networking, USA.* We demonstrate an autoencoder scheme that utilizes readily available adaptive filter coefficients to accurately detect and identify soft-failures in optical links with >99% accuracy. Detected impairments include low OSNR, nonlinearity, ROADM filtering and adjacent-channel crosstalk.

M2J.5 • 11:45
Convolutional Recurrent Machine Learning for OSNR and Launch Power Estimation: A Critical Assessment, Hyung Joon Cho[1], Siddharth Varughese[1], Daniel Lippiatt[1], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, 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.

Room 9

M2K • Neuromorphic I: Device-oriented—Continued

M2K.4 • 11:30
Real-time Operation of Silicon Photonic Neurons, Thomas Ferreira de Lima[1], Chaoran Huang[1], Simon Bilodeau[1], Alexander Tait[2], Hsuan-Tung Peng[1], Philip Ma[1], Eric Blow[1], Bhavin J. Shastri[3], Paul Prucnal[1]; [1]*Princeton Univ., USA;* [2]*NIST, USA;* [3]*Queen's Univ., Canada.* In this paper, we use standard silicon-photonic components in order to implement a neuromorphic circuit with two neurons. The network exhibits reconfigurable weights and nonlinear transfer functions, enabling high-bandwidth analog signal processing tasks.

M2K.5 • 11:45
Flexible Entanglement Distribution Overlay for Cloud/Edge DC Interconnect as Seed for IT-secure Primitives, Fabian Laudenbach[1], Bernhard Schrenk[1], Martin Achleitner[1], Nemanja Vokic[1], Dinka Milovancev[1], Hannes Hübel[1]; [1]*AIT 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, Masayoshi Nishita[1], Yasutaka Higa[1], Noritaka Matsubara[1], Junichi Hasegawa[1], Kazuki Yamaoka[1], Maiko Ariga[1], Yusuke Inaba[1], Masayoshi Kimura[1], Masaki Wakaba[1], Masahiro Yoshida[1], Kazuomi Maruyama[1], Shunsuke Okuyama[1], Toshihito Suzuki[1], Hiroyuki Ishii[1], Vitaly Mikhailov[2], Richard Sefel[3], Yasumasa Kawakita[1]; [1]*Furukawa Electric Co Ltd., Japan;* [2]*OFS Laboratories, USA;* [3]*FETI, Hungary.* A compact tunable laser module integrating a newly developed DBR/Ring laser and an extremely-high-Δ PLC wavelength locker is demonstrated with narrow spectral linewidth of <100 kHz across the full C-band.

M2A.7 • 12:15
Bandwidth Enhancement of Directly Modulated Lasers Butt-coupled with Silica-based AWG by External Optical Feedback Effect, Seokjun Yun[1], Young-Tak Han[1], Seok-Tae Kim[1], Jang-Uk Shin[1], Sang-Ho Park[1], Dong-Hoon Lee[1], Seo-Young Lee[1], Yongsoon Baek[1]; [1]*ETRI, Korea (the Republic of).* By external optical feedback effect on DMLs butt-coupled with a silica-based AWG, we present that 3-dB bandwidths of a DML submodule can be extended to ~37.5 GHz (@ 90 mA) using commercial 28-Gbaud DML chips.

Room 1B

M2B • High-Speed Integrated Modulators—Continued

M2B.7 • 12:00 ★ Top-Scored
120 Gb s^{-1} Hybrid Silicon and Lithium Niobate Modulators with On-chip Termination Resistor, Shihao Sun[1], Mingbo He[1], Mengyue Xu[1], Xian Zhang[2], Ziliang Ruan[2], Liu Liu[2], Xinlun Cai[1]; [1]*Sun Yat-Sen Univ., China;* [2]*South China Normal Univ., China.* We demonstrated hybrid silicon and lithium niobate Mach-Zehnder modulators with on-chip termination resistor. The device shows high electro-optic bandwidth up to 60 GHz, low V_π of 2.25 V and low insertion loss of 2 dB.

M2B.8 • 12:15 ★ Top-Scored
High-speed-operation of Compact All-Silicon Segmented Mach-Zehnder Modulator Integrated with Passive RC Equalizer for Optical DAC Transmitter, Yohei Sobu[1], Shinsuke Tanaka[1], Yu Tanaka[1], Yuichi Akiyama[1], Takeshi Hoshida[1]; [1]*Fujitsu Limited, Japan.* We experimentally demonstrated 70Gbaud PAM4 and 90Gbaud NRZ operations of all-silicon segmented modulator for optical DAC transmitter. Monolithic integration of MIM capacitor enabled broad EO bandwidth of 43.9GHz and small footprint of 300×600μm^2.

Room 2

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 Azendorf[1,2], Annika Dochhan[1], Patryk Urban[3], Bernhard Schmauss[2], Josep Fabrega[4], Michael Eiselt[1], Krzysztof Wilczynski[3], Lukasz Szostkiewicz[3], Laia Nadal[4], F. Javier Vilchez[4], Michela S. Moreolo[4]; [1]*ADVA Optical Networking, Germany;* [2]*LHFT, Germany;* [3]*InPhoTech, Poland;* [4]*CTTC, Spain.* Using a Correlation-OTDR and a modulation phase shift method we characterized four multi-core fibers. The results show that the differential delay depends on the position of the core in the fiber and varies with temperature.

M2C.6 • 12:15
Investigation of Brillouin Dynamic Grating in 4-LP-mode Fiber with a Ring-cavity Configuration for Distributed Temperature and Strain Sensing Application, Yinping Liu[1,2], Guangyao Yang[1,2], Ning Wang[2], Lin Ma[1], Juan Carlos Alvarado Zacarias[2], Jose Enrique Antonio-Lopez[2], Pierre Sillard[3], Adrian Amezcua-Correa[3], Rodrigo Amezcua Correa[2], Xin Yu Fan[1], Zuyuan He[1], Guifang Li[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Univ. of Central Florida , USA;* [3]*Parc des Industried Artois Flandres, France.* We investigate temperature and strain dependency of Brillouin dynamic grating in 4-LP-mode fiber with a ring-cavity configuration. Sensitivities of 3.20 MHz/°C and -0.0384 MHz/με are achieved. We demonstrate measurement with 300-m range and 1-m resolution.

Room 3

M2D • Optimizing Network Capacity and Performance—Continued

M2D.5 • 12:00 Invited
Leveraging Photonic Flexibility in Multi-layer Resilient Networks, John K. Oltman[1]; [1]*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 6C

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 6D

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, Haolin Li[1], Joris Van Kerrebrouck[1], Hannes Ramon[1], Laurens Bogaert[1], Joris Lambrecht[1], Chia-Yi Wu[1], Laurens Breyne[1], Jakob Declercq[1], Johan Bauwelinck[1], Xin Yin[1], Peter Ossieur[1], Piet Demeester[1], guy Torfs[1]; [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 140mW NRZ driver and parallel electro-absorption modulators. 5.25Gb/s (2.625Gb/s) 64-QAM is transported over 10-km SSMF at 1560nm with 7.6% (5.2%) EVM.

M2F.7 • 12:15
<500ns Latency Overhead Analog-to-digital-compression Radio-over-fiber (ADX-RoF) Transport of 16-channel MIMO, 1024QAM Signals with 5G NR Bandwidth, Paikun Zhu[1], Yuki Yoshida[2], Ken-ichi Kitayama[1,2]; [1]*The Graduate School for the Creation of New Photonics Industries, Japan;* [2]*National 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 61.44MHz 1024QAM-OFDM signals of 5G NR-class is delivered with ~4-Gb/s optical OOK interface, maintaining EVM<1.4%.

12:30–14:00 Lunch Break *(on own)*

Room 6E

M2G • Multiband and SDN for Capacity Scaling—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. Sarwar[1], Takeshi Sakamoto[2], Takeshi Hoshida[2], Tomoyuki Kato[2]; [1]*Fujitsu Network Communications Inc, USA;* [2]*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.

Room 6F

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

M2H.6 • 12:15

Hybrid W-band/Baseband Transmission for Fixed-mobile Convergence Supported by Heterodyne Detection with Data-Carrying Local Oscillator, Shuyi Shen[1], Qi Zhou[1], You-Wei Chen[1], Shuang Yao[1], Rui Zhang[1], Yahya M. Alfadhli[1], Shang-Jen Su[1], Jeffrey Finkelstein[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*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.

Room 7

M2I • Photonic Integrated Subsystems—Continued

M2I.4 • 12:00 Invited

Novel Electro-optic Components for Integrated Photonic Neural Networks, Pascal Stark[1], Jacqueline Geler-Kremer[1,2], Felix Eltes[1], Daniele Caimi[1], Jean Fompeyrine[1], Bert J Offrein[1], Stefan Abel[1]; [1]*IBM Research GmbH, Switzerland;* [2]*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.

Room 8

M2J • Data Analytic-based Monitoring—Continued

M2J.6 • 12:00

Machine Learning Based Fiber Nonlinear Noise Monitoring for Subcarrier-multiplexing Systems, Xiaomin Liu[1], Huazhi Lun[1], Mengfan Fu[1], Lilin Yi[1], Weisheng Hu[1], Qunbi Zhuge[1]; [1]*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.

M2J.7 • 12:15

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

Room 9

M2K • Neuromorphic I: Device-oriented—Continued

M2K.6 • 12:00 Invited

Microresonator-enhanced, Waveguide-coupled Emission from Silicon Defect Centers for Superconducting Optoelectronic Networks, Alexander Tait[1], Sonia Buckley[1], Adam McCaughan[1], Jeffrey Chiles[1], Sae Woo Nam[1], Richard Mirin[1], Jeffrey Shainline[1]; [1]*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.

12:30–14:00 Lunch Break *(on own)*

Room 1A

14:00–16:00
M3A • New Photonic Materials
Presider: Hideyuki Nasu; Furukawa Electric, Japan

M3A.1 • 14:00 Invited
Indium Phosphide Membrane Photonic Integrated Circuits on Silicon, Kevin A. Williams[1]; [1]*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.

Room 1B

14:00–16:00
M3B • Propagation Effects in SMF and SDM Fibers
Presider: Cristian Antonelli; Universita degli Studi dell'Aquila, Italy

M3B.1 • 14:00 Invited
Nonlinear Impairment Scaling in Multi Mode Fibers for Mode Division Multiplexing, Peter M. Krummrich[1], Marius Brehler[1], Georg Rademacher[2], Klaus Petermann[3]; [1]*Technische Universitaet Dortmund, Germany;* [2]*NICT, Japan;* [3]*Technische Universitaet Berlin, Germany.* The scaling of nonlinear effects in multi mode transmission fibers with mode count has been investigated. Results indicate that transmission reaches comparable to standard single mode fibers are achievable for at least 100 modes.

Room 2

14:00–16:00
M3C • Panel: Is it Time to Shift the Research Paradigm in Access Networks from a Focus on More Capacity

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

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

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

Room 3

14:00–16:00
M3D • VCSELS & Surface Normal Devices
Presider: Michael Tan; Hewlett Packard Enterprise, USA

M3D.1 • 14:00 Invited
Optical Interconnects Using Singe Mode and Multi Mode VCSEL and Multi Mode Fiber, Nikolay Ledentsov[1]; [1]*VI Systems GmbH, Germany.* Single mode (SM) VCSELs, produced in industrial 4» technology, are suitable for 100Gb/s PAM2 and >160Gb/s PAM4 data transmission. >107Gb/s transmission over 1km of multimode (MM) fiber at 850nm and 910nm is realized.

Room 6C

14:00–16:00
M3E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 1)

M3E.1 • 14:00 Invited
Deep Learning for Inverse Design of Optical Device, Keisuke Kojima[1]; [1]*Mitsubishi Electric Research Labs, USA.* We review the recent progress of the design and optimization of optical devices using machine learning. The emphasis is on the regression and the generative deep learning models for nanophotonic devices.

Room 6D

14:00–16:00
M3F • Wavelength Selective Devices
Presider: Kenya Suzuki; NTT Device Innovation Center, Japan

M3F.1 • 14:00 Invited
Recent Progress on Wavelength Selective Switch, Yiran Ma[1], Ian Clarke[1], Luke Stewart[1]; [1]*II-VI Incorporated, Australia.* WSS application scenarios have been illustrated from network core to edge. WSS in core network is focused on higher port count and outstanding performance, while cost is the key factor for WSS in edge network.

Room 6E

14:00–16:00
M3G • Submarine Transmission
Presider: Oleg Sinkin; TE SubCom, USA

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 Arnould[1], Amirhossein Ghazisaeidi[1], Dylan Le Gac[1], Maria Ionescu[1], Patrick Brindel[1], Jeremie Renaudier[1]; [1]*Nokia Bell Labs France, France.* We demonstrate a record 300 Gb/s per-channel bitrate over 20570 km across the full C-band. The measured 41 channels are modulated with 99 GBd PDM-QPSK using CMOS DACs and optical pre-emphasis, avoiding nonlinear compensation.

M3G.2 • 14:15
Transmission Performance of Hybrid-shaped 56APSK Modulation Formats from 34.7 to 74.7 GBd Over Transoceanic Distance, Jin-Xing Cai[1], Matt Mazurczyk[1], William Patterson[1], Carl Davidson[1], Yue Hu[1], Oleg V. Sinkin[1], Maxim Bolshtyansky[1], Dmitri G. Foursa[1], Alexei N. Pilipetskii[1]; [1]*SubCom, USA.* We experimentally study the impact of symbol rate on transmission performance. From 34.7 to 74.7Gbd SNR decreases by ~1.5dB; hardware and nonlinear transmission effects cause 0.7dB and 0.8dB respectively. NLC benefit decreases at higher rates.

Room 6F

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

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

Room 7

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

M3I.1 • 14:00 Invited
Li-Fi for Industrial Wireless Applications, Volker Jungnickel[1], Pablo Wilke Berenguer[1], Sreelal Maravanchery Mana[1], Malte Hinrichs[1], Sepideh Mohammadi Kouhini[1], Kai Lennert Bober[1], Christoph Kottke[1]; [1]*Fraunhofer Inst Nachricht Henrich-Hertz, Germany.* We propose a new system concept for LiFi in industrial wireless applications. A distributed MU-MIMO architecture is used, enabling seamless mobility, reliable low-latency communications, and integration with positioning and 5G.

Room 8

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

M3J.1 • 14:00
Recovery of DC Component in Kramers-Kronig Receiver Utilizing AC-coupled Photo-Detector, Tianwai Bo[1], Hoon Kim[1]; [1]*Korea Advanced Inst of Science & Tech, Korea (the Republic of).* We propose and demonstrate a simple DSP method for recovering the DC component in Kramers-Kronig receiver implemented by using AC-coupled photo-detector, 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, Qiulin Zhang[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong.* The signal-signal beat noise mitigation performances of the original received signal, the square root processed signal, and the Kramers-Kronig processed signal are experimentally compared in a 110 Gbit/s probabilistically-shaped 64 QAM direct detection system.

Room 9

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

M3K.1 • 14:00 Tutorial
Open Optical Transport, Martin Birk[1]; [1]*AT&T Labs, USA.* This tutorial will cover open optical transport for coherent fiber optic transmission systems, starting with the data plane, describing different open projects and efforts. The second section will address the control plane, identifying industry efforts and models used. Following that will be a view of Orchestrator and Controller projects. The last part will describe life cycle efforts (designing, planning, operating) of open optical transport networks.

Martin Birk received his master's and doctorate degrees from Germany's University of Ulm in 1994 and 1999, respectively. Since 1999, he has been with AT&T Labs in New Jersey, working on high-speed optical transmission at data rates of 40Gbit/s, 100Gb/s and above. In 2016, he received the AT&T Fellow award.

Room 1A

M3A • New Photonic Materials—Continued

M3A.2 • 14:30
1.6Tbps Coherent 2-channel Transceiver Using a Monolithic Tx/Rx InP PIC and Single SiGe ASIC, Vikrant Lal[1], Pavel Studenkov[1], Thomas Frost[1], Huan-Shang Tsai[1], Babak Behnia[1], John Osenbach[1], Stefan Wolf[1], Robert Going[1], Stefano Porto[1], Robert Maher[1], Hossein Hodaei[1], Jiaming Zhang[1], Carlo Di Giovanni[1], Koichi Hoshino[1], Thomas Vallaitis[1], Bryan Ellis[1], Jeanne Yan[1], King Fong[1], Ehsan Sooudi[1], Matthias Kuntz[1], Sanketh Buggaveeti[1], Don Pavinski[1], Steve Sanders[1], Zhenxing Wang[1], Gloria Höfler[1], Peter Evans[1], Scott Corzine[1], Tim Butrie[1], Mehrdad Ziari[1], Fred Kish[1], David Welch[1]; [1]*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.

M3A.3 • 14:45
Data-mining-assisted Resonance Labeling in Ring-Based DWDM Transceivers, Peng Sun[1], Jared Hulme[1], Ashkan Seyedi[1], Marco Fiorentino[1], Raymond Beausoleil[1]; [1]*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.

Room 1B

M3B • Propagation Effects in SMF and SDM Fibers—Continued

M3B.2 • 14:30
Experimental Comparison of Fiber Nonlinearity Mitigation: Intra-modal FWM versus Inter-modal FWM, Isaac Sackey[2,1], Carsten Schmidt-Langhorst[1], Colja Schubert[1], Johannes Fischer[1], Ronald Freund[1]; [1]*Fraunhofer Inst. for Telecommunication, Heinrinch Hertz Inst., Germany;* [2]*Techische Universität Berlin, Germany.* We experimentally compare fiber nonlinearity mitigation by optical phase conjugation based on either intra- or inter-modal four-wave mixing. When adjusted for same conversion efficiency, both realizations achieve similar performance in 800-km dispersion-managed single-mode fiber link.

M3B.3 • 14:45
All-optical Spectral Magnification of WDM Signals after 50 km of Dispersion Un-Compensated Transmission, Frederik Klejs[1], Mads Lillieholm[1], Michael Galili[1], Leif Oxenløwe[1]; [1]*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.

Room 2

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

Topics may include, but will not be limited to:

Intelligent Operation and protection

Network resilience, or more resilient network in access

Ultra-low latency in access network

Reducing the power consumption: more "Green" access network

New ODN to improve performance, efficiency or service

Network Virtualization in Access

New Emerging applications that drive the developments of access

Speakers:

Larry Wolcott; *Comcast, USA*

Jim Zou; *ADVA Optical Networking, Germany*

Jun Terada; *NTT Corp., Japan*

Glenn Wellbrock; *Verizon, USA*

Peter Vetter, *Nokia Bell Labs, USA*

Room 3

M3D • VCSELS & Surface Normal Devices—Continued

M3D.2 • 14:30
106 Gb/s Normal-incidence Ge/Si Avalanche Photodiode with High Sensitivity, Bin Shi[1], Fan Qi[1], Pengfei Cai[1], Xueping Chen[1], Zengwen He[1], Yanhui Duan[1], Guanghui Hou[1], Tzungi Su[1], Su Li[1], Wang Chen[1], Chingyin Hong[1], Rang-Chen Yu[1], Dong Pan[1]; [1]*Si-Fotonics Technologies, USA.* 106 Gb/s (53GBaud PAM4) normal-incidence Ge/Si APDs were demonstrated with sensitivities of -16.8 dBm. To our knowledge, this is the best sensitivity reported for 100G APD.

M3D.3 • 14:45
Ultra-thin III-V Photodetectors Epitaxially Integrated on Si with Bandwidth Exceeding 25 GHz, Svenja Mauthe[1], Yannick Baumgartner[1], Saurabh Sant[2], Qian Ding[2], Marilyne Sousa[1], Lukas Czornomaz[1], Andreas Schenk[2], Kirsten Moselund[1]; [1]*IBM Research - Zurich, Switzerland;* [2]*Department 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.

Room 6C

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

M3E.2 • 14:30 Invited
Advances in Deep Learning for Digital Signal Processing in Coherent Optical Modems, Maxim Kuschnerov[1], Maximilian Schaedler[1], Christian Bluemm[1], Stefano Calabro[1]; [1]*Huawei, Germany.* We analyze the advances of deep learning in optical coherent modems on the physical layer with respect to modulation design, equalization and signal detection and give an outlook on a combined control and physical layer optimization using neural networks.

Room 6D

M3F • Wavelength Selective Devices—Continued

M3F.2 • 14:30 Top-Scored
24 1x12 Wavelength-selective Switches Using a 312-port 3D Waveguide and a Single 4k LCoS, Peter Wilkinson[2], Brian Robertson[2], Sam Giltrap[2], Oliver Snowdon[2], Harry Prudden[2], Haining Yang[2,3], Daping Chu[1,2]; [1]*Univ. of Cambridge, UK;* [2]*Roadmap Systems Ltd, UK;* [3]*Southeast Univ., China.* A switch module with a 4k LCoS is enabled by a 312-port waveguide array to produce 24 independent 1x12 WSSs. The average/best insertion losses were 8.4/7.2 dB, with crosstalk suppression of 26.9/40.5 dB.

M3F.3 • 14:45
Five-core 1×6 Core Selective Switch and Its Application to Spatial Channel Networking, Masahiko Jinno[1], Takahiro Kodama[1], Tsubasa Ishikawa[1]; [1]*Kagawa Univ., Japan.* We design and prototype a 5-core 1×6 core selective switch (CSS) with an integrated input and output multi-core-fiber collimator and spatial multiplexer/demultiplexer array. Spatial bypassing and spectral grooming using a CSS-based hierarchical cross-connect are demonstrated.

Room 6E

M3G • Submarine Transmission—Continued

M3G.3 • 14:30
Experimental Demonstration of Widely Tunable Rate/Reach Adaptation From 80 km to 12,000 km Using Probabilistic Constellation Shaping, Joan M. Gené[1,2], Xi Chen[2], Junho Cho[2], Chandrasekhar Sethumadhavan[2], Peter Winzer[2]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Nokia Bell Labs, USA.* We experimentally demonstrate the rate/reach adaptability of probabilistically constel-lation-shaped quadrature amplitude modulation across from 80 km to 12,000 km using the same 32-GBaud transponder hardware and highlight the roles of template and shaping distribution.

M3G.4 • 14:45
System Performance and Pre-emphasis Strategies for Submarine Links with Imperfect Gain Equalization, Yue Hu[1], Carl Davidson[1], Lee J. Richardson[1], Maxim Bolshtyansky[1], Dmitri G. Foursa[1], Dmitriy Kovsh[1], Alexei N. Pilipetskii[1]; [1]*Subcom, USA.* We studied C-band system performance penalties due to gain tilt. Several transmission pre-emphasis strategies for penalty compensation were considered. The overall penalties were small and minor differences between strategies were observed for investigated tilt range.

Room 6F

M3H • Microwave Photonic Filters—Continued

M3H.2 • 14:30
Reconfigurable Radiofrequency Photonic Filters Based on Soliton Microcombs, Jianqi Hu[1], Jijun He[2], Arslan S. Raja[2], Junqiu Liu[2], Tobias J. Kippenberg[2], Camille-Sophie Brès[1]; [1]*STI-IEL, Ecole Polytechnique Federale de Lausanne, Switzerland;* [2]*SB-IPHYS, Ecole Polytechnique Federale de Lausanne, Switzerland.* We demonstrate soliton based radiofrequency filters using a 104 GHz Si_3N_4 microresonator. The filter passband frequencies are widely reconfigured via inherent soliton states of perfect soliton crystals and two-soliton microcombs, without any external pulse shaping.

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

Room 7

M3I • Optical Wireless: Technology and Applications—Continued

M3I.2 • 14:30
LiFi Experiments in a Hospital, Sreelal Maravanchery Mana[1], Peter Hellwig[1], Jonas Hilt[1], Kai Lennert Bober[1], Volker Jungnickel[1], Klara Hirmanova[3], Petr Chvojka[2], Stanislav Zvánovec[2], Radek Janca[2]; [1]*Fraunhofer HHI, Germany;* [2]*3Faculty of Electrical Engineering, Czech Technical Univ., Czechia;* [3]*Department of Medical Technology, Motol Univ. Hospital, Czechia.* We present LiFi channel measurements in a neurosurgery room of Motol Univ. Hospital in Prague. Individual channels are combined into a virtual multiuser MIMO link. We report achievable data rates for different LiFi transmission schemes.

M3I.3 • 14:45
Miniature R/G/V-LDs+Y-LED Mixed White-lighting Module with High-Lux and High-CRI for 20-Gbps Li-Fi, Yi-Chien Wu[1,2], Chia-Yu Su[1,2], Huai-Yung Wang[1,2], Chih-Hsien Cheng[1,2], Gong-Ru Lin[1,2]; [1]*Graduate Inst. of Photonics and Optoelectronics, and Department of Electrical Engineering, National Taiwan Univ., Taiwan;* [2]*NTU-Tektronix Joint Research Center, National Taiwan Univ., Taiwan.* Miniature white-lighting beam mixed by R/G/V-LDs+Y-LED module with high illuminance of 12800 lux, high color-rendering-index of >60 is demonstrated for vehicle light fidelity or distant optical wireless lighting transmission at data rate beyond 20 Gbps.

Room 8

M3J • Short-reach Systems I—Continued

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

M3J.4 • 14:45
FTN SSB 16-QAM Signal Transmission and Direct Detection using a THP-MIMO-FFE, Shaohua An[1], Jingchi Li[1], Hongxin Pang[1], Xingfeng Li[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China.* 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 a 28-GBaud 16-QAM signal transmission with a record 16.67% FTN ratio.

Room 9

M3K • Open Network Control & Orchestration—Continued

Room 1A

M3A • New Photonic Materials—Continued

M3A.4 • 15:00
On-chip Mode-division Multiplexing with Modal Crosstalk Mitigation, Yetian Huang[1], Ruihuan Zhang[2], Haoshuo Chen[3], Hanzi Huang[1], Qingming Zhu[2], Yu He[2], Yingxiong Song[1], Nicolas K. Fontaine[3], Roland Ryf[3], Yong Zhang[2], Yikai Su[2], Min Wang[1]; [1]*Shanghai Univ., China;* [2]*Shanghai Jiao Tong Univ., China;* [3]*Nokia Bell Labs, USA.* We experimentally demonstrate modal crosstalk mitigation over an on-chip mode-division multiplexing link employing low-coherence matched detection. 20-Gbaud QPSK and 8-PSK mode-multiplexed signals are successfully transmitted with a maximum modal crosstalk of -6.5 dB.

M3A.5 • 15:15 Invited
Analysis and Demonstration of Ultra-broadband Mach-Zehnder Hybrid Polymer/Sol-Gel Waveguide Modulators, Yasufumi Enami[1,2]; [1]*Headquarters for Innovative Society-Academia Cooperation, Univ. of Fukui, Japan;* [2]*Lightwave Logic, USA.* A bandwidth of the hybrid modulators is calculated numerically and analytically based on experimentally obtained device parameters, which is >130 GHz. The electro-optic response is reduced by < 2 dB at 67 GHz. The electrical transmission S_{21} is reduced by 5 dB at 110 GHz (upper limit) of a vector network analyzer, which also assured the bandwidth.

Room 1B

M3B • Propagation Effects in SMF and SDM Fibers—Continued

M3B.4 • 15:00 Invited
Linear and Nonlinear Features of Few-mode Fibers with Partial Coupling Among Groups of Quasi-degenerate Modes, Filipe Ferreira[1,2]; [1]*Aston Univ., UK;* [2]*Univ. 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.

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

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 Toyonaka[1], Hiroshi Hamada[1], Shigehisa Tanaka[1], Masatoshi Arasawa[1], Ryu Washino[1], Yasushi Sakuma[1], Kazuhiko Naoe[1]; [1]*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.

M3D.5 • 15:15 Invited
Development of Next Generation Data Communication VCSELs, Laura Giovane[1]; [1]*Optical Systems Division, Broadcom, Inc., USA.* This paper reviews the advancement in VCSEL technology at Broadcom to support the next generation of 850nm multi-mode data communication links at channel bit rates beyond 100Gb/s.

Room 6C

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

M3E.3 • 15:00 Invited
Workshop on Machine Learning for Optical Communication Systems: a summary, Joshua A. Gordon[1], Abdella Battou[3], Daniel C. Kilper[2]; [1]*Communications Tech Lab, NIST, USA;* [2]*Optical Sciences, Univ. of Arizona, USA;* [3]*Information Tech Lab, NIST, USA.* A summary of a public workshop on machine learning for optical Communication systems held on August 2nd 2019, by the Communications Technology Laboratory in cooperation with the Information Technology Laboratory at NIST in Boulder, CO.

Room 6D

M3F • Wavelength Selective Devices—Continued

M3F.4 • 15:00
Low-loss Silicon 2 × 4λ Multiplexers Composed of On-chip Polarization-splitter-rotator and 2 × 2 and 2 × 1 Mach-Zehnder Filters for 400GbE, Junya Takano[1], Takeshi Fujisawa[1], Yusuke Sawada[1], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan.* 2×4λ 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.5 • 15:15
Four-channel, Silicon Photonic, Wavelength Multiplexer-demultiplexer With High Channel Isolations, Mustafa Hammood[1], Ajay Mistry[1], Han Yun[1], Minglei Ma[1], Lukas Chrostowski[1], Nicolas Jaeger[1]; [1]*Univ. 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 device›s maximum insertion-loss is 0.72 dB.

Room 6E

M3G • Submarine Transmission—Continued

M3G.5 • 15:00 Tutorial
SDM Power-efficient Ultra-high Capacity Long-haul Submarine Transmission Systems, Alexei N. Pilipetskii[1], Maxim Bolshtyansky[1], Dmitri G. Foursa[1], Oleg V. Sinkin[1]; [1]*SubCom, USA.* Submarine long-haul systems have a unique set of challenges to address the capacity demand. The tutorial will examine the need for power efficiency, SDM solutions for capacity and greater economy, and ways to move forward.

Alexei Pilipetskii received his PhD in 1990 in nonlinear fiber optics. Later his interests shifted to the fiber optic data transmission. Alexei currently leads Forward Looking Team at SubCom. He is an author and co-author of more than 200 publications and 25 patent applications. He is an IEEE Photonics Society Fellow.

Room 6F

M3H • Microwave Photonic Filters—Continued

M3H.4 • 15:00
Adaptive Microwave Photonic Spectral Shaper for RF Response Tailoring, Qidi Liu[1], Mable P. Fok[1]; [1]*The Univ. of Georgia, USA.* A photonic-enabled fully-programmable RF spectral shaper capable of point-by-point precise manipulation of wideband RF spectrum with 30-MHz resolution is experimentally demonstrated. Over 10 spectral-control points are achieved with the optimized spectral decomposition and reconstruction algorithm.

M3H.5 • 15:15
Photonic-enabled Real-time Frequency-spectrum Tracking of Broadband Microwave Signals at a Nanosecond Scale, Saikrishna R. Konatham[1,3], Luis R. Cortés[1,3], Junho chang[2,3], Leslie Rusch[2,3], Sophie LaRochelle[2,3], Jose Azana[1,3]; [1]*EMT, INRS, Canada;* [2]*Universite Laval, Canada;* [3]*Centre for Optics, Photonics and Lasers (COPL), Canada.* We demonstrate real-time and gap-free continuous frequency-spectrum analysis of broadband (GHz-bandwidth) microwave signals with unprecedented nanosecond resolutions through an analog time-mapped spectrogram approach, enabling detection of frequency interferences and transients with durations down to ~5ns.

Room 7

M3I • Optical Wireless: Technology and Applications—Continued

M3I.4 • 15:00
20.09-Gbit/s Underwater WDM-VLC Transmission Based on a Single Si/GaAs-substrate Multichromatic LED Array Chip, Fangchen Hu[1], Guoqiang Li[1], Peng Zou[1], Jian Hu[2], Shouqing Chen[2], Qingquan Liu[3], Jianli Zhang[2], Fengyi Jiang[2], Shaowei Wang[3], Nan Chi[1]; [1]*Fudan Univ., China;* [2]*Nanchang Univ., China;* [3]*Shanghai Inst. of Technical Physics, China.* We demonstrated a record-breaking 20.09-Gbit/s WDM-VLC transmission over 1.2 m underwater link with PS-bitloading-DMT modulation. A silicon-substrate multichromatic LED array chip and a feasible optical-filter scheme are proposed for future LED-based WDM-VLC system.

M3I.5 • 15:15
2.4-Gbps Ultraviolet-C Solar-blind Communication Based on Probabilistically Shaped DMT Modulation, Omar Alkhazragi[1], Fangchen Hu[2], Peng Zou[2], Yinaer Ha[2], Yuan Mao[1], Tien Khee Ng[1], Nan Chi[2], Boon S. Ooi[1]; [1]*King Abdullah Univ. of Sci. & Technology, Saudi Arabia;* [2]*Fudan Univ., China.* We present a record-breaking 2.4-Gbps/1-m ultraviolet-C (UVC) line-of-sight (LOS) optical wireless communication link with 2.0 Gbps data rate maintained over 5 m. We also demonstrate a UVC diffuse-LOS link maintained over ± 5.5-degree angle changes.

Room 8

M3J • Short-reach Systems I—Continued

M3J.5 • 15:00
Parallel Implementation of KK Receiver Enabled by Heading-frame Architecture and Bandwidth Compensation, Yuyang Liu[1], Yan Li[1], Jingwei Song[1], Honghang Zhou[1], Lei Yue[1], Xiang Li[2], Ming Luo[2], Jian Wu[1]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Wuhan research Inst. of post and telecommunications, China.* We propose an improved parallel KK receiver based on heading-frame architecture and bandwidth compensation. By adopting the proposed scheme, a 112-Gbit/s 16-QAM signal is successfully transmitted over 1440-km SSMF.

M3J.6 • 15:15
A Transition Metric in Polar Co-ordinates for MLSE of a Complex Modulated DML, Marti Sales Llopis[1], Seb J. Savory[1]; [1]*Univ. of Cambridge, UK.* We propose a metric for MLSE-Viterbi differential decoding of complex modulation of directly modulated lasers (CM-DML) that reports SNR gains of 1.8 dB at BER=10^{-3} on a simulated PAM4 signal with a typical linewidth enhancement factor α=4.

Room 9

M3K • Open Network Control & Orchestration—Continued

M3K.2 • 15:00
An OLS Controller for Hybrid Fixed / Flexi Grid Disaggregated Networks with Open Interfaces, Ramon Casellas[1], F. Javier Vilchez[1], Laura Rodriguez[1], Ricard Vilalta[1], Josep M. Fabrega[1], Ricardo Martínez[1], Laia Nadal[1], Michela Svaluto Moreolo[1], Raul Muñoz[1]; [1]*CTTC, Spain.* We report the design and implementation of an OLS controller in a hierarchical (partial & full) disaggregation, using open standard data models. We detail the constrained path computation in hybrid fixed/flexi networks and its testbed validation.

M3K.3 • 15:15 Invited
Design and Control of Open Disaggregated Metro Optical Networks for Mobile-centric Services, Takehiro Tsuritani[1]; [1]*KDDI R&D Laboratories, Japan.* We present open design and control of disaggregated multi-vendor metro ROADM network integrated Layer-2/3 switches with 100Gbps WDM CFP2-DCO pluggable optics considering low latency mobile services based on 5G.

Room 1A

M3A • New Photonic Materials—Continued

M3A.6 • 15:45 ★ Top-Scored

Chip-scale, Optical-frequency-stabilized PLL for DSP-Free, Low-Power Coherent QAM in the DCI, Grant M. Brodnik[1], Mark W. Harrington[1], Debapam Bose[1], Andrew M. Netherton[1], Wei Zhang[2], Liron Stern[2], Paul A. Morton[3], John E. Bowers[1], Scott B. Papp[2,4], Daniel J. Blumenthal[1]; [1]*Univ. of California Santa Barbara, USA;* [2]*Time and Frequency Division 688, National Inst. of Standards and Technology, USA;* [3]*Morton Photonics, USA;* [4]*Department of Physics, Univ. of Colorado, USA.* We demonstrate a DSP-free 16-QAM/50GBd link based on independent transmit and LO frequency-stabilized ultra-narrow-linewidth SBS lasers, with ~40Hz integral linewidths and $7x10^{-14}$ fractional frequency stability. The low-BW optical-frequency-stabilized-PLL with $3x10^{-4}$ rad^2 phase error operates within 1% of DSP and self-homodyne.

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

M3D.6 • 15:45

Scalable Arrays of 107 Gbit/s Surface-normal Electroabsorption Modulators, Stefano Grillanda[1], Ting-Chen Hu[1], David Neilson[2], Nagesh Basavanhally[1], Yee Low[1], Hugo Safar[1], Mark Cappuzzo[1], Rose Kopf[1], Al Tate[1], Gregory Raybon[2], Andrew Adamiecki[2], Nicolas K. Fontaine[2], Mark Earnshaw[1]; [1]*Nokia Bell Labs, USA;* [2]*Nokia Bell Labs, USA.* We demonstrate arrays of surface-normal electroabsorption modulators with ultrawide bandwidth (>>65 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.

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

M3F.6 • 15:30 ▶

Ultra-low loss and fabrication tolerant silicon nitride (Si3N4) (de-)muxes for 1-µm CWDM optical interconnects, Stanley Cheung[1], Michael R. Tan[1]; [1]*Hewlett 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 < -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 Yen[1], Yung-Jr Hung[1]; [1]*National 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.

Room 6E

M3G • Submarine Transmission—Continued

Room 6F

M3H • Microwave Photonic Filters—Continued

M3H.6 • 15:30 Invited

Photonic Integration for RF Beamforming in Phased Array Systems, Paul A. Morton[1], Jacob B. Khurgin[2], Chao Xiang[3], Warren Jin[3], Christopher Morton[1], John E. Bowers[3]; [1]*Morton Photonics Inc., USA;* [2]*Johns Hopkins Univ., USA;* [3]*UCSB, USA.* A novel photonics based approach to RF Beamforming in a receive-mode electronically scanned array (Rx-ESA) is described, enabled by heterogeneous photonic integrated circuits (PICs), with future applications including 5G RF Beamforming (a.k.a. Massive MIMO).

Room 7

M3I • Optical Wireless: Technology and Applications—Continued

M3I.6 • 15:30

Modulation Classification based on Deep Learning for DMT Subcarriers in VLC System, Wu Liu[1], Xiang Li[1], Chao Yang[1], Ming Luo[1]; [1]*Wuhan Research Inst. of Post & Tele, China.* We propose a deep learning(DL) enabled modulation classification scheme using only dozens of received symbols. For each DMT subcarrier in VLC system, experiments achieve 100% classification accuracy rate using 75 symbols received at BER threshold.

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 Wei[1], Li Zhang[2,3], Lei Wang[2], Chien-Ju Chen[4], Alberto Pepe[1], Xin Liu[1], Kai-Chia Chen[4], Yuhan Dong[2,3], Meng-Chyi Wu[4], Lai Wang[2], Yi Luo[2], H.Y. Fu[1]; [1]*Tsinghua-Berkeley Shenzhen Inst., China;* [2]*Department of Electronic Engineering, Tsinghua Univ., China;* [3]*Tsinghua Shenzhen International Graduate School, Tsinghua Univ., China;* [4]*Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan.* We demonstrate a 3-meter 4-Gbps QAM-OFDM VLC system with 3.2×10^{-3} 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.

Room 8

M3J • Short-reach Systems I—Continued

M3J.7 • 15:30

Multilevel Coding with Flexible Probabilistic Shaping for Rate-adaptive and Low-power Optical Communications, Tsuyoshi Yoshida[1,2], Magnus Karlsson[3], Erik Agrell[3]; [1]*Mitsubishi Electric Corporation, Japan;* [2]*Osaka Univ., Japan;* [3]*Chalmers Univ. of Technology, Sweden.* A novel multilevel coded modulation scheme with probabilistic shaping is presented. It can reduce the power consumption up to 9 times compared with uniform signaling in the regime of typical hard-decision FEC thresholds.

M3J.8 • 15:45

80-GBd Probabilistic Shaped 256QAM Transmission over 560-km SSMF Enabled by Dual-virtual-carrier Assisted Kramers-Kronig Detection, An Li[1], Wei-Ren Peng[1], Yan Cui[1], Yusheng Bai[1]; [1]*FutureWei Technologies, Inc., USA.* We demonstrate transmission of 80-GBd probabilistic shaped 256QAM over 560-km SSMF, a record reach at 400-Gb/s line rate using single laser and direct detection, enabled by probabilistic constellation shaping and dual-virtual-carrier assisted Kramers-Kronig detection.

Room 9

M3K • Open Network Control & Orchestration—Continued

M3K.4 • 15:45

Collaborative Routing in Partially-trusted Relay based Quantum Key Distribution Optical Networks, Xingyu Zou[1], Xiaosong Yu[1], Yongli Zhao[1], Avishek Nag[2], Jie Zhang[1]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*School of Electrical and Electronic Engineering Univ. College, Ireland.* This paper proposes a collaborative routing scheme in partially-trusted relay based quantum key distribution optical networks. Simulation results show it achieves good performance in terms of key distribution success rate.

Room 6A

14:00–16:15
M3Z • OFC Demo Zone

M3Z.1
OpenConfig-extension for VLAN-based End-to-end Network Slicing Over Optical Networks, Abubakar Siddique Muqaddas[1], Alessio Giorgetti[2], Rodrigo Stange Tessinari[1], Thierno Diallo[1], Andrea Sgambelluri[2], Reza Nejabati[1], Dimitra Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]Scuola 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 Li[1], Xianyi Guo[1], Tianshun Zhan[1], Wu Jia[2], Yudan Su[2], Guangsheng Yang[1], Jinglei Sun[1], Yan Shao[2], Yuefeng Ji[3], Guangquan Wang[2]; *[1]Beijing Laboratory of Advanced Information Networks, Beijing Univ. of Posts and Telecommunications, China; [2]Network Technology Research Inst., China Unicom, China; [3]State 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, Kristif Prifti[3], Rui Santos[1], Jang-Uk Shin[2], HongJu Kim[4], Netsanet Tessema[3], Ripalta Stabile[3], Steven Kleijn[1], Luc Augustin[1], HyunDo Jung[2], Sang-Ho Park[2], Yongsoon Baek[2], Sungkyu Hyun[4], Nicola Calabretta[3]; *[1]SMART Photonics, Netherlands; [2]Department of Photonic-Wireless Convergence Component Research, ETRI, Korea (the Republic of); [3]IPI Research Insititute, TU/e Eindhoven Univ. of Technology, Netherlands; [4]R&D Center, Coweaver Co, Korea (the Republic of).* We demonstrate a C-band optical cross-connect switch based on InP integrated photonics, 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 ROADM Networks, Kiyo Ishii[1], Sugang Xu[2], Noboru Yoshikane[5], Atsuko Takefusa[3], Shigeyuki Yanagimachi[4], Takeshi Hoshida[6], Kohei Shiomoto[7], Tomohiro Kudoh[8], Takehiro Tsuritani[9], Yoshinari Awaji[2], Shu Namiki[1]; *[1]AIST, Japan; [2]NICT, Japan; [3]NII, Japan; [4]NEC Corporation, Japan; [5]KDDI Research, Japan; [6]Fujitsu Limited, Japan; [7]Tokyo City Univ., Japan; [8]The Univ. of Tokyo, Japan.* Automated mapping of real hardware composition onto a ROADM-based model is demonstrated. The functional-block-based model precisely describing 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, Abhinava Sadasivarao[1], Loukas Paraschis[1]; *[1]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-source software technologies.

M3Z.6
Demonstration of Alarm Correlation in Partially Disaggregated Optical Networks, Quan Pham Van[1], Victor López[2], Arturo Mayoral López-de-Lerma[2], Konrad Mrówka[3], Rafal Mrówka[3], Sebastian Auer[4], Huu-Trung Thieu[5], Quang-Huy Tran[5], Dominique G. Verchere[5], Gary Atkinson[1], Achim Autenrieth[3], Stephan Neidlinger[3], Lubo Tancevski[6]; *[1]ENSA Lab, Nokia Bell Labs, USA; [2]Telefónica I+D/Global CTO, Spain; [3]ADVA Optical Networking, Germany; [4]ION BU, NOKIA, Switzerland; [5]ENSA Lab, Nokia Bell Labs, France; [6]ION BU, NOKIA, USA.* We present and demonstrate the alarm correlation capability executed as an SDN application in an open, partially disaggregated multi-vendor optical network. This SDN application reconciles device alarms from Open Terminals with service alarms from an Open Line System controller to perform fault isolation, alarm correlation, and optical restoration

M3Z.7
Hands-on Demonstration of Open-Source Filterless-aware Offline Planning and Analysis Tool for WDM Networks, Pablo Pavon Marino[1,2], Miquel Garrich Alabarce[1], Francisco Javier Moreno Muro[1], Marco Quagliotti[4], Emilio Riccardi[4], Albert Rafel[3], Andrew Lord[3]; *[1]Universidad Politécnica de Cartagena, Spain; [2]E-lighthouse Networks Solutions, Spain; [3]British Telecom, UK; [4]TIM-Telecom Italia, Italy.* We demonstrate an open-source filterless-aware multilayer WDM-network planning tool, that allows hands-on creation of mixed filterless/ed topologies and the application of built-in or user-developed algorithms and analysis tools for line engineering, spectrum and cost planning.

M3Z.8
Packaged Graphene Photodetectors with 50 GHz RF bandwidth operating at 1550 nm and 2 μm wavelength, Galip Hepgüler[1], Abbas Madani[1], Stefan Wagner[1], Daniel Schall[1,2]; *[1]AMO GmbH, Germany; [2]Black Semiconductor, Germany.* In this demonstration we show packaged graphene photodetectors operating at 1550 nm and 2 μm wavelength with a bandwidth of 50 GHz. We are presenting the first graphene photonic device prototypes approaching TRL 5 level.

M3Z.9
Demonstration of Software-defined Packet-optical Network Emulation with Mininet-optical and ONOS, Bob Lantz[1,2], Alan A. Díaz Montiel[3], Jiakai Yu[1], Christian D. Rios[1], Marco Ruffini[3], Daniel C. Kilper[1]; *[1]College of Optical Sciences, Univ. of Arizona, USA; [2]Mininet Project, USA; [3]CONNECT 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, Federico Civerchia[1], Francesco Giannone[1], Koteswararao Kondepu[1], Piero Castoldi[1,3], Luca Valcarenghi[1], Andrea Bragagnini[2], Fabrizio Gatti[2], Antonia Napolitano[2], Justine Cris Borromeo[1]; *[1]Scuola Superiore Sant Anna di Pisa, Italy; [2]TIM, Italy; [3]Department of Excellence in Robotics and A.I., Scuola Superiore Sant'Anna, Italy.*The demo shows the effectiveness of a low latency remote control based on 5G and image processing at the edge exploiting artificial intelligence and GPUs to make a robot rover slalom between posts.

M3Z.11
Experimental Demonstration of multiple Disaggregated OLTs running Virtualised Multi-tenant DBA, over a Xeon Processor, Frank Slyne[1], Marco Ruffini[1], Robin Giller[2], David Coyle[2], Jasvinder Singh[2], Rory Sexton[2], Brendan Ryan[2], Michael O'Hanlon[2]; *[1]Trinity College Dublin, Ireland; [2]Intel Corporation, Ireland.* We demonstrate an Optical Line Terminal with fully softwarised data plane and virtual Dynamic Bandwidth Allocation in a sliceable, multi-tenant PON architecture. We evaluate performance results for 6 OLTs sharing the same general purpose processor.

M3Z.12
Demonstration of Open and Disaggregated ROADM Networks Based on Augmented OpenConfig Data Model and Node Controller, Dou Liang[1], Lei Wang[1], Sai Chen[3], Cheng Jingchi[3], Zhao Sun[1], Ming Xia[4], Huan Zhang[3], Li Xiao[2], Xu Jian[2], Kiekui Yu[2], Chongjin Xie[1]; *[1]Alibaba Group, China; [2]Accelink Technologies Co. Ltd, China; [3]Alibaba Group, China; [4]Alibaba Group, USA.* By augmenting OpenConfig data model of *optical-wavelength-router*, we demonstrate a ROADM network with disaggregated devices. Node level controller is implemented in our network management system with various operations on both degrees and media channels.

M3Z.13
OpenROADM-controlled White Box encompassing Silicon Photonics Integrated Reconfigurable Switch Matrix, Andrea Sgambelluri[1], Philippe Velha[1], Claudio Jose Oton Nieto[1], Alessio Giorgetti[1], Antonio D'Errico[2], Stefano Stracca[2], Filippo Cugini[3]; *[1]Scuola Superiore Sant Anna di Pisa, Italy; [2]Ericsson, Italy; [3]CNIT, 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 SDON Platform, Zhuotong Li[1], Yongli Zhao[1], Yajie Li[1], Sabidur Rahman[2], Ying Wang[3], Xiaosong Yu[1], Lizhong Zhang[4], Guoli Feng[4], Jie Zhang[1]; *[1]BUPT, China; [2]Univ. of California, USA; [3]State Grid Information & Telecommunication Company, China; [4]State Grid Ningxia Electric Power Co., Ltd. Information and Communication Company, China.* We demonstrate construction of alarm knowledge graphs, which is helpful for fault localization in software defined optical networks (SDON). The demonstration shows the method of constructing alarm knowledge graphs on ONOS-based platform using knowledge extraction.

M3Z • OFC Demo Zone—Continued

M3Z.15
Disaggregated, Sliceable and Load-aware Optical Metro Access Network for 5G Applications and Service Distribution in Edge Computing, Bitao Pan[1], Xuwei Xue[1], Fu Wang[1], Eduardo Magalhães[1], Roberto Morro[2], Emilio Riccardi[2], Nicola Calabretta[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*TIM, Italy.* A disaggregated, sliceable metro-access ring with SDN control is demonstrated with the use case of service distribution in the edge computing nodes. Successful SDN controlled dynamic network slicing generation, load-aware bandwidth resources assignment is implemented.

M3Z.16
Withdrawn

M3Z.17
Physical-layer Awareness: GNPy and ONOS for End-to-end Circuits in Disaggregated Networks, Jan Kundrát[1,2], Andrea Campanella[4], Esther Lerouzic[3], Alessio Ferrari[5], Ondrej Havliš[1,8], Michal Hazlinsky[1], Gert Grammel[6], Gabriele Galimberti[7], Vittorio Curri[5]; [1]*CESNET, Czechia;* [2]*Telecom Infra Project, USA;* [3]*Orange Labs, France;* [4]*Open Networking Foundation, USA;* [5]*Politecnico di Torino, Italy;* [6]*Juniper Networks, Germany;* [7]*Cisco Photonics, Italy;* [8]*Faculty 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/B5G Backhaul Network with Machine Learning Engine, Rentao Gu[1], Yongyao Qu[1], Meng Lian[1], Hongbiao Li[2], Zihao Wang[1], Yinan Zhu[2], Qize Guo[1], Jianjun Yang[3], Dajiang Wang[2], Yuefeng Ji[1]; [1]*Beijing Univ. of Posts and Telecomm, China;* [2]*ZTE Corporation, China;* [3]*China United Network Communications Co. Ltd., China.* It demonstrates a flexible optical network enabled "Network Restructuring as Traffic Changes" for 5G/B5G backhaul network, which realizes proactive cross-layer network generation and mitigation based network recovery, powered by cognitive enhancement and decision deduction.

M3Z.19
Demonstration of Monitoring and Data Analytics-triggered Reconfiguration in Partially Disaggregated Optical Networks, Lluis Gifre Renom[1], Fabien Boitier[1], Camille Delezoide[1], Marc Ruiz[2], Marta Buffa[3], Annalisa Morea[3], Ramon Casellas[4], Luis Velasco[2], Patricia Layec[1]; [1]*Nokia Bell Labs, France;* [2]*Universitat Politecnica de Catalunya, Spain;* [3]*Nokia, Italy;* [4]*Centre Tecnològic Telecomunicacions Catalunya (CTTC), Spain.* We demonstrate a novel agent for optical disaggregated optical networks. When the Monitoring and Data Analytics detects a degradation, it recommends the SDN controller to trigger a network reconfiguration computed by a novel planning tool.

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

NOTES

Room 1A

16:30–18:30
M4A • Quantum Security Subsystems
Presider: Fumio Futami; Tamagawa Univ., Japan

M4A.1 • 16:30 Invited
Technology Trends for Mixed QKD/WDM Transmission up to 80 km, Romain Alléaume[1], Raphael Aymeric[1], Cedric Ware[1], Yves Jaouen[1]; [1]*Telecom Paris, France*. We give a survey of some of the recent progress made in deploying quantum and classical communications over a shared fiber, focusing in particular on results obtained using continuous-variable QKD.

Room 1B

16:30–18:30
M4B • Panel: Automotive Communications and Technologies for 10G and Beyond

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.

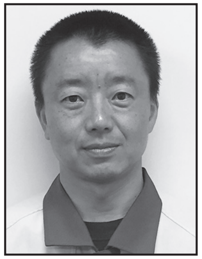
These autonomous vehicles impose paradigm shift in the car communication systems, essentially turning it to a small "data center on wheels". Consequently, new technologies should be developed and/or adopted for this application, including plastic optical fibers (POF), VCSELs, photonic integrated circuits (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.

Room 2

16:30–18:30
M4C • MCF Amplifiers and Cable
Presider: Hidehisa Tazawa; Sumitomo Electric Industries Ltd, Japan

M4C.1 • 16:30 Tutorial
Ultra-low Loss Multicore Fibers, Amplifiers and Components, Takemi Hasegawa[1]; [1]*Sumitomo Electric Industries Ltd, Japan*. Ultra-low loss multicore fibers will enable to scale the capacity of middle to long-distance transmission by overcoming spatial limitation. This tutorial will cover progresses in fibers, amplifiers and components, and challenges for practical applications.



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/PS.

Room 3

16:30–18:30
M4D • Network Design and Switching Architecture
Presider: Takafumi Tanaka; NTT Network Innovation Laboratories, Japan

M4D.1 • 16:30 Invited
Design and Operation Strategies for Optical Transport Networks with Reduced Margins Service-provisioning, Daniela A. Moniz[1,2], João Pedro[1,2], João Pires[2]; [1]*Infinera Corporation, Portugal;* [2]*Instituto de Telecomunicações, Portugal*. This paper overviews the key architectures and network design and operation solutions to efficiently exploit low margin provisioning in optical transport networks

Room 6C

16:30–18:30
M4E • Symposium: The Role of Machine Learning for the Next-generation of Optical Communication Systems and Networks (Session 2)

M4E.1 • 16:30 Invited
Active vs Transfer Learning Approaches for QoT Estimation with Small Training Datasets, Dario Azzimonti[2], Cristina Rottondi[1], Alessandro Giusti[2], Massimo Tornatore[3], Andrea Bianco[1]; [1]*Dept. of Electronics and Telecommunications, Politecnico di Torino, Italy;* [2]*Dalle Molle Inst. for Artificial Intelligence, Switzerland;* [3]*Dept. of Electronics, Information and Bioengineering, Politecnico di Milano, Italy*. We compare the level of accuracy achieved by active learning and domain adaptation approaches for quality of transmission estimation of an unestablished lightpath, in presence of small-sized training datasets.

Room 6D

16:30–18:15
M4F • High Order Direct Detect Formats
Presider: Sorin Tibuleac; ADVA Optical Networking, USA

M4F.1 • 16:30
280 Gb/s IM/DD PS-PAM-8 Transmission Over 10 km SSMF at O-band For Optical Interconnects, Jiao Zhang[1], Kaihui Wang[1], Yiran Wei[1], Li Zhao[1], Wen Zhou[1], Jiangnan Xiao[1], Bo Liu[2], Xiangjun Xin[2], Feng Zhao[3], Ze Dong[4], Jianjun Yu[1]; [1]*Fudan Univ., China;* [2]*Beijing Univ. of Posts and Telecommunications, China;* [3]*Xi'an Univ. of Posts and Telecommunications, China;* [4]*Huaqiao Univ., China*. We experimentally demonstrated single-lane 200G+ IM/DD PAM-*N* system at O-band using SOA and probabilistic shaping (PS) for high-speed short reach optical interconnects. 280 Gb/s PS-PAM-8 signals can transmit over 10 km SSMF.

M4F.2 • 16:45
30 Gbaud 128 QAM SSB Direct Detection Transmission over 80 km with Clipped Iterative SSBI Cancellation, Son T. Le[1], Vahid Aref[1], Karsten Schuh[1], Hung Nguyen Tan[2]; [1]*Nokia Bell Labs, USA;* [2]*Da Nang Univ., Viet Nam*. We demonstrate a novel SSBI cancellation technique operable without digital upsampling for a 30 Gbaud 128 QAM SSB transmission with a record low CSPR of 5 dB, showing 4.6 dB performance improvement compared to the Kramers-Kronig scheme.

Room 6E

16:30–18:30
M4G • Open Networking Summit: Optical Metro/ Aggregation Networks to Support Future Services over 5G

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.

Room 6F

16:30–18:30
M4H • Silicon Photonics and High Density Integration

Presider: Erman Timurdogan; Analog Photonics, USA

M4H.1 • 16:30 Invited

Si PIC Based on Photonic Crystal for Lidar Application, Toshihiko Baba[1], Hiroyuki Ito[1], Hiroshi Abe[1], Takemasa Tamanuki[1], Yosuke Hinakura[1], Ryo Tetsuya[1], Jun Maeda[1], Mikiya Kamata[1], Ryo Kurahashi[1], Ryo Shiratori[1]; [1]*Yokohama National Univ., Japan.* Wide-range nonmechanical beam steering is available by an array of Si photonic crystal slow-light waveguides and their switching without complicated control. FMCW LiDAR action is obtained with this beam steering on a Si photonics chip.

Room 7

16:30–18:30
M4I • Advanced Radio Over-fiber Technology

Presider: Sangyeup Kim; NTT Access Service Systems Laboratories, Japan

M4I.1 • 16:30 Invited

Radio-over-fiber Technology: Present and Future, Christina Lim[1]; [1]*Univ. of Melbourne, Australia.* This paper reviews the recent research in the area of radio-over-fiber technology focusing on physical layer investigations and demonstrations, and also provides a brief discussion on the future outlook.

Room 8

16:30–18:30
M4J • Digital Signal Processing I

Presider: Alex Alvarado; Eindhoven Univ. of Technology, Netherlands

M4J.1 • 16:30 Tutorial

Few-mode Fiber Transmission, Guifang Li[1]; [1]*Univ. of Central Florida, USA.* This tutorial will describe different types of few-mode fibers and their unique properties, followed by fiber-optic transmission systems that they potentially enable, and the prospects of these transmission systems making realistic impacts in the commercial world.

Guifang Li is currently Professor of Optics & Photonics at the University of Central Florida and Editor-in-Chief of *Advances in Optics & Photonics* (OSA). His research interests include optical communications and networking, RF photonics, optical signal processing. He is a recipient of the *NSF CAREER* award, the *Office of Naval Research Young Investigator* award. He is a fellow of IEEE, SPIE, the Optical Society and the National Academy of Inventors. He previously served as a Deputy Editor for Optics Express, and an associate editor for Chinese Optics Letters, IEEE Photonics Technology Letters, IEEE Photonics Journal and Optica.

Room 9

16:30–18:15
M4K • High-speed Long-haul Transmission

Presider: Hisao Nakashima; Fujitsu Limited, USA

M4K.1 • 16:30 Invited

Long-haul WDM Transmission with Over-1-Tb/s Channels Using Electrically-synthesized High-symbol-rate Signals, Takayuki Kobayashi[1], Masanori Nakamura[1], Fukutaro Hamaoka[1], Munehiko Nagatani[1,2], Hiroshi Yamazaki[1,2], Hideyuki Nosaka[1,2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*NTT Device Technology Laboratories, Japan.* Recent technical progress on 1-Tb/s/λ-class transmission systems based-on high-speed electronics are reviewed. And this paper discusses key technologies and issues of the beyond-1-Tb/s/λ WDM transmission systems with over-100-Gbaud symbol-rate for achieving long-haul transport.

Room 1A

M4A • Quantum Security Subsystems—Continued

M4A.2 • 17:00
Two-level Optical Encryption for Secure Optical Communication, Yetian Huang[1], Haoshuo Chen[2], Hanzi Huang[1], Qianwu Zhang[1], Zhengxuan Li[1], Nicolas K. Fontaine[2], Roland Ryf[2], Min Wang[1]; [1]*Shanghai Univ., China;* [2]*Nokia Bell Labs, USA.* We demonstrate 60 Gbit/s transmission over 43-km SMF using low-coherence matched detection combined with spectral phase coding as two-layer optical encryption. Encrypted signal and carrier are multiplexed through polarization diversity and demultiplexed using polarization tracking.

M4A.3 • 17:15
Photonic Generation of Quantum Noise Assisted Cipher at Microwave Frequencies for Secure Wireless Links, Ken Tanizawa[1], Fumio Futami[1]; [1]*Tamagawa Univ., Japan.* We propose novel wireless physical layer encryption utilizing signal masking by truly random quantum noise. 12-Gbit/s cipher with sufficient masking is generated in 30-GHz band by optical heterodyne, and secure microwave wireless transmission is achieved.

Room 1B

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

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

Speakers:
Kasia Balakier; *AIRBUS Satellite and Defense, UK*

Daniel Adler; *Valens, Israel*

Ton Koonen; *Eindhoven University of Technology, Netherlands*

Shilong Pan; *Nanjing University of Aeronautics and Astronautic, China*

Room 2

M4C • MCF Amplifiers and Cable—Continued

Room 3

M4D • Network Design and Switching Architecture—Continued

M4D.2 • 17:00
Colorless, Partially Directional, and Contentionless Architecture for High-degree ROADMs, Yongcheng Li[1], Liangjia Zong[2], Mingyi Gao[1], Biswanath Mukherjee[1], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*Transmission Technology Research Department, Huawei, China.* We design a Colorless, partially Directional, and Contentionless (CpDC) architecture for high-degree ROADMs, in which a fixed interconnection pattern is developed to connect different nodal degrees and add/drop modules. Simulation results show the advantages of the proposed architecture.

M4D.3 • 17:15
Reliable Slicing with Isolation in Optical Metro-aggregation Networks, Andrea Marotta[1], Dajana Cassioli[1], Massimo Tornatore[2,3], Yusuke Hirota[4], Yoshinari Awaji[4], Biswanath Mukherjee[3]; [1]*Univ. of L'Aquila , Italy;* [2]*Politecnico di Milano, Italy;* [3]*Univ. of California, USA;* [4]*National Inst. of Information and Communications Technology, Japan.* We discuss how different degrees of slice isolation influence resource allocation in protected optical metro-aggregation networks. The case of slice reliability with dedicated protection at lightpath is modelled and numerically evaluated.

Room 6C

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

M4E.2 • 17:00 Invited
Neural Network Training for OSNR Estimation - from Prototype to Product, Andrew Shiner[1], Mohammad E. Mousa-Pasandi[1], Meng Qiu[1], Michael A. Reimer[1], Eui Young Park[1], Michael Hubbard[1], Qunbi Zhuge[2,1], Francisco J. Vaquero Caballero[3,1], Maurice O'Sullivan[1]; [1]*Ciena, Canada;* [2]*Shanghai Jiao Tong Univ., China;* [3]*Cambridge Univ., UK.* A method for in-service OSNR measurement with a coherent transceiver is presented and experimentally verified. A neural network is employed to identify and remove the nonlinear noise contribution to the estimated OSNR.

Room 6D

M4F • High Order Direct Detect Formats—Continued

M4F.3 • 17:00 Top-Scored
Novel Optical Field Reconstruction for IM/DD with Receiver Bandwidth Well Below Full Optical Signal Bandwidth, Qian Hu[1], Robert Borkowski[1], Mathieu Chagnon[1], Karsten Schuh[1], Fred Buchali[1], Henning Bülow[1]; [1]*Nokia Bell Labs, Germany.* We propose a novel signal reception scheme for IM/DD enabling optical field reconstruction. We experimentally demonstrate 60-GBd PAM-4 transmission over 80-km without active and passive optical managements, with 33-GHz electrical bandwidth at transmitter and receiver.

M4F.4 • 17:15
Demonstration of 214Gbps per lane IM/DD PAM-4 Transmission using O-band 35GHz-class EML with Advanced MLSE and KP4-FEC, Weiyu Wang[1], Zhilei Huang[1], Biwei Pan[1], Huanlu Li[1], Guanpeng Li[1], Jian Tang[1], Yuchun Lu[1]; [1]*Huawei Technologies Co. Ltd., China.* A single-wavelength single-polarization 35GHz-class (112Gbps-class) commercial EML-based IM/DD 214Gbps PAM4 signal transmission is experimentally demonstrated. By using advanced MLSE with low complexity and power consumption, the BER is below standard KP4-FEC requirement of 2×10^{-4}.

Room 6E

M4G • Open Networking Summit: Optical Metro/ Aggregation Networks to Support Future Services over 5G—Continued

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 Wellbrock; *Verizon Transport Networks, USA*

Jun Terada; *NTT Access Networks Labs, Japan*

Andrew Lord; *BT Labs, UK*

Jan Söderström; *Ericsson, USA*

Attilio Zani; *Telecom Infra Project, UK*

Room 6F

M4H • Silicon Photonics and High Density Integration—Continued

M4H.2 • 17:00

Polarization-diverse Silicon Photonics WDM Receiver with a Reduced Number of OADMs and Balanced Group Delays, Jovana Nojic[2], Dominik Schoofs[2], Saeed Sharif Azadeh[2,1], Florian Merget[2], Jeremy Witzens[2]; [1]*Max Planck Inst. of Microstructure Physics, Germany;* [2]*Inst. of Integrated Photonics, RWTH Aachen Univ., Germany.* We experimentally validate a 10-channel polarization diverse WDM receiver with only one ring based add-drop multiplexer per channel and on-chip optical delay lines balancing the two polarization paths for speeds up to 28 Gb/s.

M4H.3 • 17:15

A 400 Gb/s O-band WDM (8×50 Gb/s) Silicon Photonic Ring Modulator-based Transceiver, Stelios Pitris[1], Miltiadis Moralis-Pegios[1], Theoni Alexoudi[1], Konstantinos Fotiadis[1], Yoojin Ban[2], Peter De Heyn[2], Joris Van Campenhout[2], Nikos Pleros[1]; [1]*Department of Informatics, Center for Interdisciplinary Research & Innovation, Aristotle Univ. of Thessaloniki, Greece;* [2]*imec, Belgium.* We present a 400 (8×50) Gb/s-capable RM-based Si-photonic WDM O-band TxRx with 1.17nm channel spacing for high-speed optical interconnects and demonstrate successful 50Gb/s-NRZ TxRx operation achieving a ~4.5dB Tx extinction ratio under 2.15Vpp drive.

Room 7

M4I • Advanced Radio Over-fiber Technology—Continued

M4I.2 • 17:00

100 Gb/s Real-Time Transmission over a THz Wireless Fiber Extender Using a Digital-coherent Optical Modem, Carlos Castro[1], Robert Elschner[1], Thomas Merkle[2], Colja Schubert[1], Ronald Freund[1]; [1]*Fraunhofer Inst. for Telecommunications Heinrich Hertz Inst., Germany;* [2]*Fraunhofer-Institut für Angewandte Festkörperphysik IAF, Germany.* We demonstrate the real-time transmission of a 34-GBd 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.

M4I.3 • 17:15

A Broadly Tunable Noise Radar Transceiver on a Silicon Photonic Chip, Daniel Onori[1], José Azaña[1]; [1]*Énergie, Matériaux et Télécommunications (EMT), Institut National de la Recherche Scientifique (INRS), Canada.* We experimentally demonstrate the first on-chip broadly-tunable noise radar transceiver, using silicon photonic technology. By exploiting an innovative and simple lasers' noise referencing architecture, the device shows reconfigurable operation in the range 0.5-35GHz, with antennas-remoting capability.

Room 8

M4J • Digital Signal Processing I—Continued

Room 9

M4K • High-speed Long-haul Transmission—Continued

M4K.2 • 17:00

49.2-Tbit/s WDM Transmission over 2x93-km Field-Deployed Fiber, Karsten Schuh[1], Fred Buchali[1], Roman Dischler[1], Mathieu Chagnon[1], Vahid Aref[1], Henning Bülow[1], Qian Hu[1], Florian Pulka[2], Massimo Frascolla[3], Esmaeel Alhammadi[4], Adel Samhan[4], Islam Younis[5], Mohamed El-Zonkoli[5], Peter Winzer[6]; [1]*Nokia Bell Labs, Germany;* [2]*Nokia, France;* [3]*IP, Nokia, Italy;* [4]*Etisalat, United Arab Emirates;* [5]*Nokia UAE, United Arab Emirates;* [6]*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/λ, Masanori Nakamura[1], Takayuki Kobayashi[1], Hiroshi Yamazaki[1,2], Fukutaro Hamaoka[1], Munehiko Nagatani[1,2], Hitoshi Wakita[2], Hideyuki Nosaka[1,2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*NTT Device Technology Laboratories, Japan.* We apply symbol-rate and entropy optimization to over-100-GBaud PS-36QAM signal generation. It enables 800-Gbps/λ signal transmission over 2400 km in 125GHz-spaced WDM system by maximization of SNR margin from the required SNR at FEC limit.

Room 1A

M4A • Quantum Security Subsystems—Continued

M4A.4 • 17:30
Compact Differential Phase-shift Quantum Receiver Assisted by a SOI / BiCMOS Micro-ring Resonator, Nemanja Vokic[1], Dinka Milovancev[1], Winfried Boxleitner[1], Hannes Hübel[1], Bernhard Schrenk[1]; [1]*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.5 • 17:45 Invited
Progress on Quantum Key Distribution Using Ultralow Loss Fiber, Alberto Boaron[1], Davide Rusca[1], Gianluca Boso[1], Raphael Houlmann[1], Cédric Vulliez[1], Misael Caloz[1], Matthieu Perrenoud[1], Gaetan Gras[1], Claire Autebert[1], Félix Bussières[1], Ming-Jun Li[2], Daniel Nolan[2], Anthony Martin[1], Hugo Zbinden[1]; [1]*Univ. of Geneva, Switzerland;* [2]*Corning Incorporated, USA.* We use a 2.5 GHz clocked quantum key distribution system to perform long-distance and high-speed quantum key distribution. Taking benefit from superconducting detectors optimized for each operation regime and low-loss fiber, we achieve state-of-the-art performance.

Room 1B

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

Room 2

M4C • MCF Amplifiers and Cable—Continued

M4C.2 • 17:30
Power Efficient All-fiberized 12-core Erbium/ytterbium Doped Optical Amplifier, Gilles Melin[1], Romain Kerampran[2], Achille Monteville[3], Sylvain Bordais[2], Thierry Robin[1], David Landais[3], Aurelien Lebreton[4], Yves Jaouen[4], Thierry Taunay[3]; [1]*iXblue, France;* [2]*Lumibird, France;* [3]*Photonics Bretagne, France;* [4]*TELECOM Paris, France.* 20dB gain in C-band with only 5.3W 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 ★ Top-Scored
Full C-band and Power Efficient Coupled-multi-core Fiber Amplifier, Masaki Wada[1], Taiji Sakamoto[1], Shinichi Aozasa[1], Ryota Imada[1], Takashi Yamamoto[1], Kazuhide Nakajima[1]; [1]*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.

Room 3

M4D • Network Design and Switching Architecture—Continued

M4D.4 • 17:30
Is There a Most Appropriate Channel Spacing in WDM Networks When Individually Routing 67 GBaud Carriers?, Thierry Zami[1], Bruno Lavigne[1]; [1]*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.

M4D.5 • 17:45
Experimental Assessment of a Programmable VCSEL-based Photonic System Architecture over a Multi-hop Path with 19-Core MCF for Future Agile Tb/s Metro Networks, Michela Svaluto Moreolo[1], Josep M. Fabrega[1], Laia Nadal[1], Ricardo Martínez[1], Ramon Casellas[1], F. Javier Vilchez[1], Raul Muñoz[1], Ricard Vilalta[1], Alberto Gatto[2], Paola Parolari[2], Pierpaolo Boffi[2], Christian Neumeyr[3], David Larrabeiti[4], Gabriel Otero[4], Juan P. Fernández-Palacios[5]; [1]*Ctr Tecnològic de Telecom de Catalunya, Spain;* [2]*Politecnico di Milano, Italy;* [3]*Vertilas GmbH, Germany;* [4]*Universidad Carlos III de Madrid, Spain;* [5]*Telefonica Global CTO, Spain.* An SDN-enabled photonic system adopting VCSEL technology is experimentally analyzed targeting dynamic 5G-supportive MAN. Direct and coherent detection modules are compared and programmability assessed over up to 6-hop 160km HL4-HL2/1 connection including 25km 19-core MCF .

Room 6C

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
Towards Intelligent Optical Networks: The Role of Intellectual Property, Sebastian Gäde[1], Céline Borsier[1], Asa Ribbe[1]; [1]*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.

Room 6D

M4F • High Order Direct Detect Formats—Continued

M4F.5 • 17:30
160-Gb/s Nyquist PAM-4 Transmission with GeSi-EAM Using Artificial Neural Network Based Nonlinear Equalization, Lei Zhang[1], Fan Yang[1], Hao Ming[1], Yixiao Zhu[2], Xiaoke Ruan[1], Yanping Li[1], Fan Zhang[1]; [1]*Peking Univ., China;* [2]*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.

M4F.6 • 17:45 Invited
Why Data Science and Machine Learning Need Silicon Photonics, Benjamin Klenk[1], Larry Dennison[1]; [1]*NVIDIA 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

Room 6E

M4G • Open Networking Summit: Optical Metro/ Aggregation Networks to Support Future Services over 5G—Continued

Room 6F

M4H • Silicon Photonics and High Density Integration—Continued

M4H.4 • 17:30 Invited

Uncovering Reflection Insensitive Semiconductor Lasers for Silicon Photonic Integration, Frederic Grillot[1,2]; [1]*Institut Polytechnique de Paris, France;* [2]*The 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.

Room 7

M4I • Advanced Radio Over-fiber Technology—Continued

M4I.4 • 17:30

Dual-wavelength Integrated K-band Multi-Beamformer Operating over 1-km 7-core Multicore Fiber, Maria Morant[1], Ailee Trinidad[2], Eduward Tangdiongga[2], Ton Koonen[2], Roberto Llorente[1]; [1]*Nanophotonics Technology Center, Universitat Politècnica de València, Spain;* [2]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands.* A dual-wavelength broadband photonic integrated beamformer over 1-km MCF provides independent angles with up to 350 ps increment to 3-GHz or 260 ps to 4-GHz BW signals over two different wavelengths and K-band frequencies.

M4I.5 • 17:45

Flexible Data Rate THz-wave Communication Using Nyquist Pulses and Optical-domain Reception Signal Processing, Koichi Takiguchi[1], Nozomu Nishio[1]; [1]*Department of Electrical and Electronic Engineering, Ritsumeikan Univ., Japan.* We report variable capacity THz-wave communication using Nyquist pulses, which is realized by changing the channel number and optical-domain filtering of received signals. We carried out 10 to 40 Gsymbol/s communication in the 300 GHz-band.

Room 8

M4J • Digital Signal Processing I—Continued

M4J.2 • 17:30

Multi-channel Equalization for Comb-based Systems, Mikael Mazur[1], Jochen Schröder[1], Magnus Karlsson[1], Peter Andrekson[1]; [1]*Chalmers Tekniska Hogskola, Sweden.* We propose and demonstrate a frequency comb-enabled joint DSP. With joint processing, the required guard-bands decreases and the optimal roll-off factor increases, reducing penalties from non-ideal transceiver electronics while simultaneously increasing the spectral efficiency.

M4J.3 • 17:45

Cycle-Slip Rate Analysis of Blind Phase Search DSP Circuit Implementations, Erik Börjeson[1], Per Larsson-Edefors[1]; [1]*Department 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.

Room 9

M4K • High-speed Long-haul Transmission—Continued

M4K.4 • 17:30

Spectrally Efficient DP-1024QAM 640 Gb/s Long Haul Transmission using a Frequency Comb, Frederik Klejs[1], Edson Porto da Silva[2], Mads Lillieholm[1], Metodi P. Yankov[1], Toshio Morioka[1], Leif Oxenløwe[1], Michael Galili[1]; [1]*DTU, Denmark;* [2]*Federal Univ. of Campina Grande, Brazil.* We experimentally investigate the long haul transmission of an 8 GBd DP-1024QAM over fully Raman amplified fiber spans using an optical frequency comb. We reach a potential spectral efficiency of 8.7 bit/s/Hz at 3000 km transmission and a potential data rate of 640 Gb/s.

M4K.5 • 17:45

800ZR+ DWDM Demonstration over 600km G.654D Fiber Enabled by Adaptive Nonlinear TripleX Equalization, Fabio Pittalà[1], Maximilian Schaedler[1], Christian Bluemm[1], Gernot Goeger[1], Stefano Calabro[1], Maxim Kuschnerov[1], Changsong Xie[1]; [1]*Huawei 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.

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

M4C.4 • 18:00
Real-time Optical Gain Monitoring for Coupled Core Multi-Core EDFA with Strong Inter-Core Crosstalk, Hitoshi Takeshita[1], Keiichi Matsumoto[1], Hidemi Noguchi[1], Emmanuel Le Taillandier de Gabory[1]; [1]*NEC 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.5 • 18:15 ★ Top-Scored
Spatial Mode Dispersion Control in a Coupled MCF using High Density Cabling Parameters, Yusuke Yamada[1], Taiji Sakamoto[1], Yuto Sagae[1], Masaki Wada[1], Saki Nozoe[1], Yoko Yamashita[1], Hisashi Izumita[1], Kazuhide Nakajima[1], Hiroaki Tanioka[1]; [1]*NTT, 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.

Room 3

M4D • Network Design and Switching Architecture—Continued

M4D.6 • 18:00
Network Design Framework Exploiting Low-margin Provisioning of Optical Shared Restoration Resources, Daniela A. Moniz[1,2], João Pedro[1,2], João Pires[2]; [1]*Infinera Corporation, Portugal;* [2]*Instituto de Telecomunicações, Portugal*. This paper proposes a network design framework tailored to support optical restoration with low-margins by exploiting real-time performance monitoring. Simulation results highlight that it enables resource savings without additional risks of traffic disruption.

Room 6C

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

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.

Room 6D

M4F • High Order Direct Detect Formats—Continued

Room 6E

M4G • Open Networking Summit: Optical Metro/ Aggregation Networks to Support Future Services over 5G—Continued

Room 6F

M4H • Silicon Photonics and High Density Integration—Continued

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], Tsurugi Sudo[1]; [1]*II-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

InP/Silicon Hybrid External-cavity Lasers (ECL) Using Photonic Wirebonds as Coupling Elements, Yilin Xu[1,2], Pascal Maier[1,2], Matthias Blaicher[1], Philipp-Immanuel Dietrich[1,3], Pablo Marin-Palomo[1], Wladislaw Hartmann[1], Muhammad R. Billah[1,3], Ute Troppenz[4], Martin Moehrle[4], Sebastian Randel[1], Wolfgang Freude[1], Christian Koos[1,3]; [1]*Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology (KIT), Germany;* [2]*Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany;* [3]*Vanguard Automation GmbH, Germany;* [4]*Fraunhofer Heinrich-Hertz-Inst. (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.

Room 7

M4I • Advanced Radio Over-fiber Technology—Continued

M4I.6 • 18:00 **Invited**

Opto-electronic Terahertz Transceivers for Wireless 5G Backhaul, Sebastian Randel[1], Tobias Harter[1], Christoph Füllner[1], Sandeep Ummethala[1], Christian Koos[1], Wolfgang Freude[1]; [1]*Inst. of Photonics and Quantum Electronics, Karlsruhe Inst. of Technology, Germany.* Wireless communication links at terahertz frequencies are a promising option for high-capacity 5G backhaul. In this work, we review recent progress in the field and discuss performance-vs.-complexity trade-offs for different opto-electronic terahertz transceiver designs.

Room 8

M4J • Digital Signal Processing I—Continued

M4J.4 • 18:00

Clock Recovery Limitations in Probabilistically Shaped Transmission, Fabio A. Barbosa[1], Sandro M. Rossi[2], Darli A. Mello[1]; [1]*School of Electrical and Computer Engineering, Univ. of Campinas, Brazil;* [2]*Division of Optical Technologies, CPqD, Brazil.* We assess the performance of the modified Gardner timing error detector under probabilistic shaping. The results indicate severe limitations in specific combinations of shaping and roll-off factors. The results are validated by simulations and experiments.

M4J.5 • 18:15

Baud-rate Timing Phase Detector for Systems with Severe Bandwidth Limitations, Nebojsa Stojanovic[1], Talha Rahman[1], Stefano Calabro[1], Jinlong Wei[1], Changsong Xie[1]; [1]*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.

Room 9

M4K • High-speed Long-haul Transmission—Continued

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 Burtsev[1], Steven Searcy[1], Sorin Tibuleac[1]; [1]*ADVA, 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.

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

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

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

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

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

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

Room 1A

14:00–16:00
T3A • Linear and Nonlinear Space Division Multiplexing
Presider: Sophie LaRochelle; Universite Laval, Canada

T3A.1 • 14:00 Tutorial
SDM Optical Communications, Nicolas K. Fontaine[1]; [1]*Nokia Bell Labs, USA.* Abstract not available.

Room 1B

14:00–16:00
T3B • Novel Materials
Presider: Yikai Su; Shanghai Jiao Tong Univ., China

T3B.1 • 14:00 Invited
On-chip Optical Isolators, Tetsuya Mizumoto[1], Yuya Shoji[1]; [1]*Tokyo Inst. of Technology, Japan.* Magneto-optical phase shift is effective to realize on-chip optical isolators. Optical isolators are fabricated on SOI platforms with isolation ratios of 30 and 16 dB for TM and TE mode input, respectively.

Room 2

14:00–16:00
T3C • Lasers for Communications and Sensing
Presider: Yasuhiro Matsui; Finisar Corporation, USA

T3C.1 • 14:00
50-GHz Gain Switching and Period Doubling Using an Optical Injection Locked Cavity-enhanced DFB Laser, Zhixin Liu[1], Yasuhiro Matsui[2], Richard Schatz[3], Ferdous Khan[2], Martin Kwakernaak[2], Tsurugi Sudo[2]; [1]*Univ. College London, UK;* [2]*Finisar Corporation, USA;* [3]*Royal Inst. of Technology, Sweden.* We demonstrate gain-switched pulse generation at a record-high repetition rate of 50GHz by injection locking a cavity-enhanced DFB laser. More than 50GHz carrier-photon resonance is achieved by using the detuned-loading and photon-photon resonance effects.

Room 3

14:00–16:00
T3D • Quantum and Secure Communications
Presider: Andrew Shields; Toshiba Research Europe Ltd, UK

T3D.1 • 14:00 Invited
Entanglement-based Fiber Optic and Satellite QKD Systems, Rupert Ursin[1]; [1]*Austrian Academy of Sciences, Austria.* Abstract not available.

Room 6C

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

T3E.1 • 14:00 Invited
Title to be Announced, Andrew Wilkinson[1]; [1]*Ericsson, Sweden.* Abstract not available.

Room 6D

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

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

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

Speakers:

Yoshiaki Aono; *NEC Corp., Japan*

Zahra Bakhtiari; *Microsoft, USA*

Biondo Biondi, *Stanford University, USA*

Mattia Cantono; *Google, USA*

Petar Djukic; *Ciena, Canada*

Room 6E	Room 6F	Room 7	Room 8	Room 9

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

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

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

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

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

Room 6E

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; *Infinera, USA*
Knocking on Shannons' Door

Room 6F

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

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

T3H.1 • 14:00 Top-Scored
1.6Tbps Silicon Photonics Integrated Circuit for Co-packaged Optical-IO Switch Applications, Saeed Fathololoumi[1], Kimchau Nguyen[1], Hari Mahalingam[1], Meer N. Sakib[1], Zhi Li[1], Christopher S. Seibert[1], Mohammad Montazeri[1], Jian Chen[1], Jonathan K. Doylend[1], Hasitha Jayatilleka[1], Catherine Jan[1], John Heck[1], Ranju Venables[1], Harel Frish[1], Reece A. Defrees[1], Randal S. Appleton[1], Summer Hollingsworth[1], Sean P. Mccargar[1], Richard Jones[1], Daniel Zhu[1], Yuliya Akulova[1], Ling Liao[1]; [1]*SPPD, Intel Corporation, USA.* We demonstrate 1.6Tbps Silicon Photonic Integrated Circuit (SiPIC) meeting co-packaged optics requirements for network switch applications. It has sixteen 106Gbps PAM4 optical channels, including lasers, modulators and V-grooves. Post-FEC error-free operation over temperature is demonstrated.

Room 7

14:00–16:00 T3I • Short-reach Systems II

Presider: Yi Cai; ZTE TX, Inc., USA

T3I.1 • 14:00
102 Gbaud PAM-4 Transmission Over 2 km Using a Pulse Shaping Filter with Asymmetric ISI and Thomlinson Harashima Precoding, Xueyang Li[1], Zhenping Xing[1], Samiul Alam[1], Maxime Jacques[1], David Plant[1]; [1]*McGill Univ., Canada.* We introduce the asymmetric-ISI pulse shaping filter with Tomlinson-Harashima precoding to increase the receiver RF swing, and demonstrate 102 Gbaud PAM-4 transmission over 2 km with a BER below 3.8×10^{-3} using linear equalizer at receiver.

Room 8

14:00–16:00 T3J • Orchestration and Control

Presider: Paolo Monti; Chalmers Tekniska Hogskola, Sweden

T3J.1 • 14:00
Blockchain-anchored Failure Responsibility Management in Disaggregated Optical Networks, Silvia Fichera[1], Andrea Sgambelluri[1], Alessio Giorgetti[1], Filippo Cugini[2], Francesco Paolucci[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*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.

Room 9

14:00–16:00 T3K • Intra Data Center Networks I

Presider: Reza Nejabati; Univ. of Bristol, UK

T3K.1 • 14:00
Demonstrating Optically Interconnected Remote Serial and Parallel Memory in Disaggregated Data Centers, Vaibhawa Mishra[1], Joshua L. Benjamin[1], Georgios S. Zervas[1]; [1]*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.

Show Floor Programming

Ethernet Interoperability and Deployments – New and Legacy Solutions Work Together
Ethernet Alliance
10:15–11:15, *Theater II*

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

■ MW Panel I: State of the Industry
10:30–12:00, *Theater I*

AIM Photonics Member Successes and Updates
AIM Photonics
11:00–12:00, *Theater III*

■ Data Center Summit: Keynote and Panel
11:30–13:45, *Theater II*

5G Architectures and Service Considerations
Nokia
12:15–13:15, *Theater III*

■ MW Panel II: 5G and Re–thinking Access Networks
12:30–14:00, *Theater I*

400ZR Specification Update
OIF
13:30–14:30, *Theater III*

Preparing the Transport Network for 5G
Session sponsored by Juniper Networks
13:50–14:50, *Theater II*

Room 1A

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 narrow-band spectral slices. Since June 2011, he has been a member of the technical staff at Bell Laboratories at Crawford Hill, NJ in the advanced photonics division. At Bell Labs, he develops devices for space-division multiplexing in multi-core and few mode fibers, builds wavelength crossconnects and filtering devices, and investigates spectral slice coherent receivers for THz bandwidth waveform measurement. In his free time he enjoys learning jazz piano.

Room 1B

T3B • Novel Materials—Continued

T3B.2 • 14:30
Integrable Magnetless Thin Film Waveguide Optical Isolator based on Bismuth Iron Garnet Material, Vincent Stenger[1], Dolendra Karki[2], Andrea Pollick[1], Miguel Levy[2]; [1]*SRICO, Inc., USA;* [2]*Michigan Technological Univ., USA.* A passive magnetless integrated optic Faraday isolator has been demonstrated that features ~3 dB total insertion loss and 25 dB isolation. The compact 500 µm long ridge waveguide isolator is integrable with silicon photonic platforms.

Room 2

T3C • Lasers for Communications and Sensing—Continued

T3C.2 • 14:15
Analysis of TDECQ Dependence on Skew and Extinction Ratio with 106-Gb/s PAM-4 modulation of Directly Modulated Submicron Ridge Localized Buried Heterostructure Lasers, Kazuki Suga[1], Kouji Nakahara[1], Kaoru Okamoto[1], Shigenori Hayakawa[1], Masatoshi Arasawa[1], Tetsuya Nishida[1], Ryu Washino[1], Takeshi Kitatani[1], Masatoshi Mitaki[1], Hironori Sakamoto[1], Yasushi Sakuma[1], Shigehisa Tanaka[1]; [1]*Lumentum Japan, Inc., Japan.* The importance of high relaxation oscillation frequency to obtain superior 106-Gb/s PAM-4 waveforms was revealed for SR-LBH lasers. In addition, clear 56-Gb/s NRZ eye openings were first demonstrated up to 85°C using SR-LBH laser.

T3C.3 • 14:30
10-Gbit/s Sky-blue Distributed Feedback Laser Diode-based Visible Light Communication, Meiwei Kong[1], Jorge A. Holguin Lerma[1], Omar Alkhazragi[1], Xiaobin Sun[1], Tien Khee Ng[1], Boon S. Ooi[1]; [1]*Photonics Laboratory, King Abdullah Univ. of Science and Technology (KAUST), Saudi Arabia.* A novel sky-blue (~480 nm) InGaN-based distributed feedback laser diode is developed for high-speed visible light communication. With a 3-dB system bandwidth of ~1.5 GHz, 10 Gbit/s is achieved by using orthogonal frequency-division multiplexing technology.

Room 3

T3D • Quantum and Secure Communications—Continued

T3D.2 • 14:30
10 Tbit/s QAM Quantum Noise Stream Cipher Coherent Transmission over 160 km, Masato Yoshida[1], Takashi Kan[1], Keisuke Kasai[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We present the first 10 Tbit/s secure physical layer transmission over 160 km with a spectral efficiency of 6 bit/s/Hz by using digital coherent QAM quantum noise stream cipher (QNSC) and injection-locked WDM techniques.

Room 6C

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

T3E.2 • 14:30 Invited
Title to be Announced, Thomas Pfeiffer[1]; [1]*Nokia Bell Labs, Germany.* Abstract not available.

Room 6D

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

Room 6E	Room 6F	Room 7	Room 8	Room 9

Room 6E

T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?—Continued

Shaoliang Zhang; *Acacia, USA*
Pushing the Limits of Performance with the Flexibility to Manage Link Margin in the Field

Andreas Leven; *Nokia, Germany*
High-performance Transponders: Data Sheets and Real-world Performance

Elizabeth Rivera Hartling; *Facebook Inc., USA*
Assessing Capacity: It's in the Noise

Room 6F

T3H • Silicon Photonics Applications—Continued

T3H.2 • 14:15 Top-Scored
400G Silicon Photonics Integrated Circuit Transceiver Chipsets for CPO, OBO, and Pluggable Modules, Erman Timurdogan[1], Zhan Su[1], Ren-Jye Shiue[1], Matthew Byrd[1], Christopher Poulton[1], Kenneth Jabon[1], Christopher DeRose[1], Benjamin Moss[1], Ehsan Hosseini[1], Ivan Duzevik[1], Michael Whitson[1], Ronald Millman[1], Dogan Atlas[1], Michael Watts[1]; [1]*Analog Photonics, USA.* 400G-FR4 silicon photonics transmit-receive chipsets, compatible with co-packaged-optics, on-board-optics, and pluggable form factors, were demonstrated with a combined bandwidth density of 94Gb/s/mm, energy efficiency of <10pJ/bit, and -5.4dBm OMA sensitivity at the KP4 pre-FEC-BER=2.4e-4.

T3H.3 • 14:30
45nm CMOS - Silicon Photonics Monolithic Technology (45CLO) for Next-generation, Low Power and High Speed Optical Interconnects, Michal Rakowski[1], Colleen Meagher[2], Karen Nummy[2], Abdelsalam Aboketaf[3], Javier Ayala[2], Yusheng Bian[1], Brendan Harris[3], Kate Mclean[3], Kevin McStay[2], Asli Sahin[2], Louis Medina[2], Bo Peng[1], Zoey Sowinski[2], Andy Stricker[3], Thomas Houghton[2], Crystal Hedges[3], Ken Giewont[2], Ajey Jacob[1], Ted Letavic[2], Dave Riggs[2], Anthony Yu[2], John Pellerin[1]; [1]*Photonics Technology Solutions, GlobalFoundries, USA;* [2]*GlobalFoundries, USA;* [3]*GlobalFoundries, USA.* GlobalFoundries monolithic 45nm CMOS-Silicon Photonics 300mm high-volume manufacturing platform based on 45nm RF technology node, and optimized for high performance and low power short-reach optical interconnects for on-chip and chip-to-chip applications will be discussed.

Room 7

T3I • Short-reach Systems II—Continued

T3I.2 • 14:15
84-GBaud/λ PAM-4 Transmission over 20-km using 4-λ LAN-WDM TOSA and ROSA with MLSE Based on Nonlinear Channel Estimation, Hiroki Taniguchi[1], Shuto Yamamoto[1], Yoshikaki Kisaka[1], Shigeru Kanazawa[2], toshihide yoshimatsu[2], yozo ishikawa[3], Kazuyo Mizuno[3]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*NTT Device Innovation Center, Japan;* [3]*Furukawa electric Co. Ltd., Japan.* We demonstrate 168-Gbps/λ PAM-4 transmission over 20-km using 4-λ 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.

T3I.3 • 14:30 Top-Scored
O-Band 10-km Transmission of 93-Gbaud PAM4 Signal Using Spectral Shaping Technique Based on Nonlinear Differential Coding with 1-Tap Precoding, Shuto Yamamoto[1], Hiroki Taniguchi[1], Masanori Nakamura[1], Yoshikaki Kisaka[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan.* We propose a simple and flexible spectral shaping technique based on nonlinear differential coding for short-reach IM-DD transmission. Experimental results show the achievement of 7% HD-FEC threshold in 186-Gb/s 10-km transmission with 14-GHz bandwidth limitation.

Room 8

T3J • Orchestration and Control—Continued

T3J.2 • 14:15 Invited
Network Control and Orchestration in SDM and WDM Optical Networks, Raul Muñoz[1], Noboru Yoshikane[2], Ricard Vilalta[1], Ramon Casellas[1], Ricardo Martínez[1], Takehiro Tsuritani[2], Itsuro Morita[2]; [1]*CTTC, Spain;* [2]*KDDI Research, Japan.* We present the first SDN-enabled multi-domain multi-layer (WDM/SDM) control architecture for partially disaggregated optical networks with multiple WDM and SDM OLS domains and transponders to provision end-to-end TAPI connectivity services involving spatial and optical channels.

Room 9

T3K • Intra Data Center Networks I—Continued

T3K.2 • 14:15
Analysis of Service Blocking Reduction Strategies in Capacity-limited Disaggregated Datacenters, Albert Pagès[1], Fernando Agraz[1], Salvatore Spadaro[1]; [1]*Universitat Politècnica de Catalunya (UPC), Spain.* Disaggregated DCs offer multiple benefits. However, transmission capacity limitations at blade level can severely degrade their performance. We analyze several strategies to enhance their service acceptance.

T3K.3 • 14:30 Invited
Advanced Software Architectures and Technologies in High Performance Computing and Data Centers, Juan Jose Vegas Olmos[1], Liran Liss[1], Tzahi Oved[1], Zachi Binshtock[1], Dror Goldenberg[1]; [1]*Mellanox Technologies, Denmark.* This paper reviews advanced software architectures and technologies that support innetworking 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.

Show Floor Programming Continued

400ZR Specification Update
OIF
13:30–14:30, *Theater III*

Preparing the Transport Network for 5G
Session sponsored by Juniper Networks
13:50–14:50, *Theater II*

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

Room 1A

T3A • Linear and Nonlinear Space Division Multiplexing—Continued

T3A.2 • 15:00
Novel Fuseless Optical Fiber Side-coupler based on Half-taper for Cladding Pumped EDFAs, Charles Matte-Breton[1], Ruohui Wang[1], Younès Messaddeq[1], Sophie LaRochelle[1]; [1]*Universite Laval, Canada.* We present a novel method for optical fiber side-coupler fabrication that does not require to heat the fibers. More than 94% of average coupling efficiency is demonstrated for input pump power ranging from 1.4 W to 20.7 W.

Room 1B

T3B • Novel Materials—Continued

T3B.3 • 14:45
Heterogeneous Co-integration of BTO/Si and III-V technology on a Silicon Photonics Platform, Pascal Stark[1], Felix Eltes[1], Yannick Baumgartner[1], Daniele Caimi[1], Youri Popoff[1,2], Norbert Meier[1], Lukas Czornomaz[1], Jean Fompeyrine[1], Bert J Offrein[1], Stefan Abel[1]; [1]*IBM Research - Zurich, Switzerland;* [2]*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.

T3B.4 • 15:00 Tutorial
Non-volatile Photonic Applications with Phase Change Materials, Matthias Wuttig[1]; [1]*Rheinish Westfalische Tech Hoch Aachen, Germany.* Abstract not available.

Room 2

T3C • Lasers for Communications and Sensing—Continued

T3C.4 • 14:45
High Performance BH InAs/InP QD and InGaAsP/InP QW Mode-locked Lasers as Comb and Pulse Sources, Marlene Zander[1], Wolfgang Rehbein[1], Martin Moehrle[1], Kevin Kolpatzeck[2], Jan Balzer[2], Steffen Breuer[1], Dieter Franke[1], Martin Schell[1]; [1]*Fraunhofer Heinrich-Hertz-Inst., Germany;* [2]*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.

T3C.5 • 15:00 Invited
VCSELs for 3D Sensing Applications, Chun Lei[1]; [1]*Lumentum, USA.* We present the high-volume design and manufacturing process of 9XXnm high-power vertical-cavity surface-emitting laser (VCSEL) arrays for consumer 3D sensing applications, such as facial and gesture recognitions. We will focus on performance and reliability.

Room 3

T3D • Quantum and Secure Communications—Continued

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

T3D.4 • 15:00
Spectrally-shaped Continuous-Variable QKD Operating at 500 MHz Over an Optical Pipe Lit by 11 DWDM Channels, Dinka Milovancev[1], Nemanja Vokic[1], Fabian Laudenbach[1], Christoph Pacher[1], Hannes Hübel[1], Bernhard Schrenk[1]; [1]*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.

Room 6C

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

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

Room 6D

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

Room 6E

T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?—Continued

Room 6F

T3H • Silicon Photonics Applications—Continued

T3H.4 • 14:45 Invited

Silicon Photonics for 100 Gbaud, Jianying Zhou[1], Jian Wang[1], Qun Zhang[2]; [1]*NEOPhotonics Corp, USA;* [2]*Minnesota State Univ., USA.* We reviewed recent breakthroughs on silicon photonic 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.

Room 7

T3I • Short-reach Systems II—Continued

T3I.4 • 14:45

Single lane 176Gb/s Single Sideband PAM-4 Transmission over 400km with a Silicon Photonic Dual-drive Mach-Zehnder Modulator, Lei Zhang[1], Fan Yang[1], Xiaoke Ruan[1], Yanping Li[1], Fan Zhang[1]; [1]*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 Fu[1,2], Deming Kong[2], Haiyun Xin[1,2], Meihua Bi[1,3], Shi Jia[2], Kuo Zhang[1], Weisheng Hu[1], Hao Hu[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Fotonik, Technical Univ. of Denmark, Denmark;* [3]*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).

Room 8

T3J • Orchestration and Control—Continued

T3J.3 • 14:45

Dual Use SDN Controller for Management and Experimentation in a Field Deployed Testbed, Jiakai Yu[1], Craig Gutterman[2], Artur Minakhmetov[3], Michael Sherman[4], Tingjun Chen[2], Shengxiang Zhu[1], Gil Zussman[2], Ivan Seskar[4], Daniel C. Kilper[1]; [1]*College of Optical Sciences, Univ. of Arizona, USA;* [2]*Electrical Engineering, Columbia Univ., USA;* [3]*LTCI, Télécom Paris, Institut Polytechnique de Paris, France;* [4]*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 Vilalta[1], Juan Luis de la Cruz[1], Arturo Mayoral López-de-Lerma[2], Victor Lopez[2], Ricardo Martínez[1], Ramon Casellas[1], Raul Muñoz[1]; [1]*CTTC, Spain;* [2]*Telefónica gCTIO/I+D, Spain.* We present a cloud-native architecture for Optical SDN Controllers based on ABNO architecture and gRPC interfaces, which is demonstrated and evaluated. Autoscaling mechanisms for high request loads and auto-healing support are evaluated.

Room 9

T3K • Intra Data Center Networks I—Continued

T3K.4 • 15:00

Real-time Node Local Control for Ultra-dynamic and Deterministic All-optical Intra Data Center Networks, Mijail Szczerban[1], José Estarán Tolosa[1], Nihel D. Benzaoui[1], Haik Mardoyan[1], Yvan Pointurier[1]; [1]*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.

Show Floor Programming Continued

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

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

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

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

Room 1A

T3A • Linear and Nonlinear Space Division Multiplexing—Continued

T3A.3 • 15:15
Low-loss Low-MDL Core Multiplexer for 3-Core Coupled-core Multi-core Fiber, Sjoerd P. van der Heide[2,1], Juan Carlos Alvarado Zacarias[2,3], Nicolas K. Fontaine[2], Roland Ryf[2], Haoshuo Chen[2], Rodrigo Amezcua Correa[3], Ton Koonen[1], Chigo M. Okonkwo[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Nokia Bell Labs, USA;* [3]*CREOL, Univ. of Central Florida, USA.* A fiber-based core multiplexer is designed, fabricated, and evaluated. Insertion losses vary between 0.74 dB and 0.91 dB. Digital holography reveals mode-dependent loss fluctuates between 0.3 dB and 0.9 dB across C- and L-band.

T3A.4 • 15:30 Invited
Optical Thermodynamics of Nonlinear Highly Multimoded Systems, Demetrios N. Christodoulides[1]; [1]*Univ. 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

Room 2

T3C • Lasers for Communications and Sensing—Continued

T3C.6 • 15:30
850 nm Single-mode Surface-emitting DFB Lasers with Surface Grating and Large-area Oxidized-aperture, Can Liu[1], Qiaoyin Lu[1], Weihua Guo[1], Pengfei Zhang[1], MinWen Xiang[1], Xiang Ma[1], Chun Jiang[1], Gonghai Liu[1], Quanan Chen[1], Bao Tang[2]; [1]*Huazhong Univ. of Science and Technology, China;* [2]*China 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 (2×50 μm²).

Room 3

T3D • Quantum and Secure Communications—Continued

T3D.5 • 15:15
Digital Self-coherent Continuous Variable Quantum Key Distribution System, Tobias A. Eriksson[1,2], Ruben S. Luis[1], Kadir Gumus[3], Georg Rademacher[1], Benjamin J. Puttnam[1], Hideaki Furukawa[1], Naoya Wada[1], Yoshinari Awaji[1], Alex Alvarado[3], Masahide Sasaki[1], Masahiro Takeoka[1]; [1]*National Inst of Information & Comm Tech (NICT), Japan;* [2]*Royal Inst. of Technology (KTH), Sweden;* [3]*Eindhoven Univ. of Technology, Netherlands.* We investigate a continuous variable quantum key distribution system with digital tracking of both polarization and phase. Stable operation over 25km for 36 hours with secret key rates between 1.9 and 2.8 Mbit/s is demonstrated.

T3D.6 • 15:30
Variational Quantum Demodulation for Coherent Optical Multi-dimensional QAM, Toshiaki Koike-Akino[1], Toshiki Matsumine[2], Ye Wang[1], David S. Millar[1], Keisuke Kojima[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*Yokohama National Universsity, 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 6C

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

T3E.4 • 15:30 Invited
Evolution to Mesh 5G X-Haul Networks, Jiakai Yu[1], Shengxiang Zhu[1], Daniel C. Kilper[1]; [1]*Univ. 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.

Room 6D

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

Room 6E

T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?—Continued

Room 6F

T3H • Silicon Photonics Applications—Continued

T3H.5 • 15:15
Real-time Demonstration of Silicon-photonics-based QSFP-DD 400GBASE-DR4 Transceivers for Datacenter Application, Chongjin Xie[1], Peter Magill[2], David Li[3], Yinxing Zhang[1], Long Zheng[3], Anbin Wang[1], Yun Bao[1], Chunchun Sui[1], Matthew Streshinsky[2], Jianwei Mu[3], Sigeng Yang[3], Wanju Sun[3]; [1]*Alibaba Group, USA;* [2]*Elenion Technologies, USA;* [3]*Hisense Broadband, China.* We demonstrate a real-time silicon-photonics-based 400GBASE-DR4 transceiver packaged in a QSFP-DD form factor. The performance of the transmitter including TDECQ, extinction ratio and OMA and receiver sensitivity are measured, all satisfying IEEE 400GBASE-DR4 specifications.

T3H.6 • 15:30
400Gbps Fully Integrated DR4 Silicon Photonics Transmitter for Data Center Applications, Haijiang Yu[1], Pierre Doussiere[1], David Patel[1], Wenhua Lin[1], Kadhair Al-hemyari[1], Jung Park[1], Catherine Jan[1], Robert Herrick[1], Isako Hoshino[1], Lincoln Busselle,[1], Michael Bresnehan[1], Adam Bowles[1], George Ghiurcan[1], Harel Frish[1], Shane Yerkes[1], Ranju Venables[1], Pegah Seddighian[1], Xavier Serey[1], Kimchau Nguyen[1], Animesh Banerjee[1], Siamak Amiralizadeh Asl,[1], Qing Zhu[1], Sushant Gupta[1], Avi Fuerst[1], Avsar Dahal[1], Jian Chen[1], Yann Malinge[1], Hari Mahalingam[1], Mike Kwon[1], Gupta Sanjeev[1], Agrawal Ankur[1], Raghuram Narayan[1], Daniel Zhu[1], Yuliya Akulova[1]; [1]*Intel Corporation, USA.* A 400Gbps PAM-4 fully integrated DR4 silicon photonics transmitter with four heterogeneously integrated DFB lasers has been demonstrated for data center applications over a temperature range of 0~70°C and a reach of up to 2km.

Room 7

T3I • Short-reach Systems II—Continued

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, Urs Hecht[1], Nikolay Ledentsov Jr.[2], Lukasz Chorchos[2], Patrick Kurth[1], Nikolay Ledentsov[2], Friedel Gerfers[1]; [1]*TU Berlin, Germany;* [2]*VI 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.

T3I.7 • 15:30
Dual-SSB Modified Duobinary PAM4 Signal Transmission in a Direct Detection System without using Guard Band, Jingchi Li[1], Shaohua An[1], Xingfeng Li[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China.* We experimentally demonstrate a single-carrier dual-SSB signal generation without guard band based on a low-cost DDMZM. A 112-Gb/s dual-SSB modified duobinary PAM4 signal is transmitted over 80-km SMF by using a MIMO linear equalizer.

Room 8

T3J • Orchestration and Control—Continued

T3J.5 • 15:15 Invited
Supporting Low-latency Service Migrations in 5G Transport Networks, Jun Li[1], Jiajia Chen[1]; [1]*Chalmers Univ. of Technology, USA.* This paper concentrates on low-latency service migration in transport networks, where edge computing is employed for ultra-low end-to-end latency communications in 5G, and demonstrates that rapid service migration significantly reduces end-to-end packet delay.

Room 9

T3K • Intra Data Center Networks I—Continued

T3K.5 • 15:15
Coherently Sub-grouped µDC-Pod and -Interconnect with Analogue EML Transceivers Operated in TDMA, Bernhard Schrenk[1], Nemanja Vokic[1], Dinka Milovancev[1], Paraskevas Bakopoulos[2], Fotini Karinou[3]; [1]*AIT Austrian Inst. of Technology, Austria;* [2]*Mellanox Technologies Ltd, Israel;* [3]*Microsoft Research Ltd., UK.* We exploit an IM/DD transmitter as coherent receiver for filterless micro-datacenter pods and their interconnect. A transistor-outline EML performs coherent homodyne reception under a 240kHz TDMA frame with 139ns guard interval between free-running transmitters.

T3K.6 • 15:30
Data Analytics Practice for Reliability Management of Optical Transceivers in Hyperscale Data Centers, Jianqiang Li[1], Zhicheng Wang[2], Chunxiao Wang[2,3], Qin Chen[2], Peng Wang[2], Rui Lu[2], Songnian Fu[3], Chongjin Xie[4]; [1]*Alibaba Group, USA;* [2]*Alibaba Group, China;* [3]*Huazhong Univ. of Science and Technology, China;* [4]*Alibaba Group, USA.* There are limitations when directly interpreting reliability information of optical transceivers from manufacturers to end users. Data analytics in a large optical transceivers' population is studied for data center operators with a case study.

Show Floor Programming Continued

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

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

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

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

T3A • Linear and Nonlinear Space Division Multiplexing—Continued

T3B • Novel Materials—Continued

T3C • Lasers for Communications and Sensing—Continued

T3C.7 • 15:45

Micro-transfer-printed III-V-on-silicon Distributed Feedback Lasers, Bahawal Haq[1,2], Sulakshna Kumari[1,2], Jing Zhang[1,2], Agnieszka Gocalinska[3], Emanuele Pelucchi[3], Brian Corbett[3], Gunther Roelkens[1,2]; [1]*INTEC, Ghent Univ.-imec, Belgium;* [2]*Center of Nano- and Biophotonics, Belgium;* [3]*Tyndall 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 • Quantum and Secure Communications—Continued

T3D.7 • 15:45

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

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

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

Room 6E	Room 6F	Room 7	Room 8	Room 9
T3G • Panel: As we Approach Shannon Limit, How do we Precisely Assess the Performance of Coherent Transponders for Field Deployment?—Continued	**T3H • Silicon Photonics Applications—Continued**	**T3I • Short-reach Systems II—Continued**	**T3J • Orchestration and Control—Continued**	**T3K • Intra Data Center Networks I—Continued**
	T3H.7 • 15:45 **A Fully Integrated 25 Gb/s Si Ring Modulator Transmitter with a Temperature Controller,** Minkyu Kim[1], Min-Hyeong Kim[1], Youngkwan Jo[1], Hyun-Kyu Kim[1], Stefan Lischke[2], Christian Mai[2], Lars Zimmermann[2,3], Woo-Young Choi[1]; [1]*Department of Electrical and Electronics Engineering, Yonsei Univ., Korea (the Republic of);* [2]*IHP, Germany;* [3]*Technische 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,** Kaixuan Zhan[1], Hui Yang[1], Qiuyan Yao[1], Xudong Zhao[1], Ao Yu[1], Jie Zhang[1], Young Lee[2]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China;* [2]*Huawei 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 Maniotis[1], Laurent Schares[1], Benjamin Lee[1], Marc Taubenblatt[1], Daniel Kuchta[1]; [1]*IBM 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*

Show Floor Programming Continued

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

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

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

Accelerating ROI on the Road to SDN
SDN
16:00–17:00, *Theater III*

OIDA Roadmap on Quantum Photonics
16:15–17:00, *Theater I*

Tuesday, 10 March

Room 1A

16:30–18:00
T4A • Radio-over-fiber Technologies for 5G
Presider: HyunDo Jung

T4A.1 • 16:30 Invited

5G mmWave Commercial Trial for Vertical Applications, Jongsik Lee[1]; [1]*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.

Room 1B

16:30–18:00
T4B • Machine Learning for Fiber Amplifier and Sensors
Presider: Chigo Okonkwo; Technische Universiteit Eindhoven, Netherlands

T4B.1 • 16:30

Intelligent Gain Flattening of FMF Raman Amplification by Machine Learning Based Inverse Design, Yufeng Chen[1], Jiangbing Du[1], Yuting Huang[1], Ke Xu[2], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Harbin Inst. of Technology (Shenzhen), China*. We report an intelligent gain flattering method for rapid, precise and objective driven FMF Raman amplifier design, by using machine learning based inverse design method to optimize the pump wavelengths, powers and mode contents.

T4B.2 • 16:45 ★ Top-Scored

Experimental Demonstration of Arbitrary Raman Gain-profile Designs Using Machine Learning, Uiara C. de Moura[1], Francesco Da Ros[1], Ann Margareth Rosa Brusin[2], Andrea Carena[2], Darko Zibar[1]; [1]*DTU Fotonik, Technical Univ. of Denmark, Denmark;* [2]*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.

Room 2

16:30–18:00
T4C • Neuromorphic II: Entire Aspect
Presider: To be Announced

T4C.1 • 16:30

VCSELs for Fast Neuromorphic Photonic Systems Operating at GHz Rates, Matěj Hejda[1], Joshua Robertson[1], Julián Bueno[1], Antonio Hurtado[1]; [1]*Inst. of Photonics, Dept. of Physics, Univ. of Strathclyde, UK*. We report experimentally on VCSEL-based artificial optical spiking neurons with ultrafast spiking refractory period; hence allowing operation at GHz rates. This feature is used to demonstrate all-optical digital-to-spiking information format conversion at 1.0 Gbps.

T4C.2 • 16:45

Micro-ring-resonator Based Passive Photonic Spike-time-dependent-Plasticity Scheme for Unsupervised Learning in Optical Neural Networks, Charis Mesaritakis[1], Menelaos Skontranis[1], George Sarantoglou[1], Adonis Bogris[2]; [1]*Univ. of the Aegean, Greece;* [2]*Informatics and Computer Engineering, Univ. of West Attica, Greece*. In this work, a photonic spike-time-dependent-plasticity scheme based on high-order passive ring resonators is demonstrated. Numerical simulations confirmed the validity of the approach assuming post and pre-synaptic quantum dot laser neurons.

Room 3

16:30–18:30
T4D • AI Assisted Access Networks
Presider: Elaine Wong; Univ. of Melbourne, Australia

T4D.1 • 16:30

Combining Efficient Probabilistic Shaping and Deep Neural Network to Mitigate Capacity Crunch in 5G Fronthaul, Qi Zhou[1], Rui Zhang[1], You-Wei Chen[1], Shuyi Shen[1], Shang-Jen Su[1], Jeffrey Finkelstein[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Cox Communications, Georgia*. We experimentally demonstrate a capacity-approaching transmission in 5G fronthaul utilizing PS-PAM8 and DNN. An 80-Gb/s over 20-km SSMF transmission performance is realized with a beyond 7.3-dB gross gain over uniform PAM modulations with linear post-equalization.

T4D.2 • 16:45

FPGA Implementation of Deep Neural Network Based Equalizers for High-Speed PON, Noriaki Kaneda[1], Ziyi Zhu[2], Chun-Yen Chuang[1], Amitkumar Mahadevan[1], Bob Farah[1], Keren Bergman[2], Dora van Veen[1], Vincent Houtsma[1]; [1]*Nokia Bell Labs, USA;* [2]*Columbia Univ., USA*. A fixed-point deep neural network-based equalizer is implemented in FPGA and is shown to outperform MLSE in receiver sensitivity for 50 Gb/s PON downstream link. Embedded parallelization is proposed and verified to reduce hardware resources.

Room 6C

16:30–18:30
T4E • Symposium: Emerging Network Architectures for 5G Edge Cloud (Session 2)

T4E.1 • 16:30 Invited

Multi-Access Edge Computing Architecture for Application-specific New Radio Access Networks, Gee-Kung Chang, *Georgia Institute of Technology, USA*. Perspective and challenge of the MEC implementation, merging with the RAN 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.

Room 6D

16:30–18:00
T4F • Quantum Networking and Artifiicial Intelligence
Presider: Bruce Cortez; AT&T Labs, USA

T4F.1 • 16:30 Tutorial

Toward a Scalable Hybrid Quantum Cloud, Maria Spiropulu[1]; [1]*California Inst. of Technology, USA*. Abstract not available.

Room 6E

16:30–18:00
T4G • Optical Transmitter Sub-systems
Presider: Ben Puttnam; National Inst Info & Comm Tech (NICT), Japan

T4G.1 • 16:30
Transmitter Bandwidth Extension Using Optical Time-interleaving Modulator and Digital Spectral Weaver, Hiroshi Yamazaki[2], Masanori Nakamura[2], Takashi Goh[3], Toshikazu Hashimoto[1], Yutaka Miyamoto[2]; [1]*NTT Device Technology Laboratories, Japan;* [2]*NTT Network Innovation Laboratories, Japan;* [3]*NTT Device Innovation Center, Japan.* We generate 150-Gbaud QAM signals by using an optical time-interleaving modulator driven with 38.1-GHz-bandwidth sub-signals. A digital spectral weaver enables generation of arbitrary bandwidth-extended signals with a simple filter-less optical configuration.

T4G.2 • 16:45
Fixed-rate-breaking All-optical OFDM System Using Time-domain Hybrid PAM with Sparse Subcarrier Multiplexing and Power-loading for Optical Short-reach Transmission, Takahiro Kodama[1,2], Akihiro Maruta[2], Naoya Wada[3], Gabriella Cincotti[4]; [1]*Kagawa Univ., Japan;* [2]*Department of Electrical, Electronics and Information Engineering, Osaka Univ., Japan;* [3]*National Inst. of Information and Communications Technology (NICT), Japan;* [4]*Engineering Department, Univ. Roma Tre, Italy.* All-optical TDHP-OFDM system with four-sparse-subcarrier-multiplexing and power-loading has been proposed for data-rate-adaptive transmission. 40-Gbit/s, 60-Gbit/s, and 80-Gbit/s can be selected by changing the ratio of PAM2 and PAM4, and all BERs achieve the FEC limit.

Room 6F

16:30–18:00
T4H • Quantum Dots and Novel III-V Devices
Presider: Geert Morthier; Ghent Univ., INTEC, Belgium

T4H.1 • 16:30
Thermal Impedance and Gain Switching of 1550 nm Room Temperature Continuous-wave Electrically Pumped Laser Diode Monolithically Grown on Silicon, Bei Shi[1], Sergio Pinna[1], Hongwei Zhao[1], Bowen Song[1], Jonathan Klamkin[1]; [1]*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.

T4H.2 • 16:45
High Performance 1.3 μm Aluminum-Free Quantum Dot Lasers Grown by MOCVD, Lei Wang[1], Hongwei Zhao[1], Bei Shi[1], Sergio Pinna[1], Simone S. Brunelli[1], Fengqiao Sang[1], Bowen Song[1], Jonathan Klamkin[1]; [1]*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.

Room 7

16:30–18:00
T4I • Long-haul Systems and Non-linear Mitigation
Presider: Rene-Jean Essiambre; Nokia Corporation, USA

T4I.1 • 16:30 Invited
Advanced Nonlinear Perturbation Theory in Coherent WDM Systems, Amirhossein Ghazisaeidi[1]; [1]*Nokia Bell Labs France, France.* We review the theoretical efforts to develop models to analyze fiber-optic coherent systems using perturbation analysis. We start with models for the nonlinear signal-signal distortions and continue to address nonlinear signal-noise interactions and SOA-induced distortions.

Room 8

16:30–18:30
T4J • Multi-core Fibers
Presider: Taiji Sakamoto; NTT Access Service Systems Laboratories, Japan

T4J.1 • 16:30
Asymmetrically Arranged 8-core Fibers with Center Core Suitable for Side-view Alignment in Datacenter Networks, Yusuke Sasaki[1], Masaki Ozeki[1], Katsuhiro Takenaga[1], Kazuhiko Aikawa[1]; [1]*Optical Technologies R&D Center, Fujikura Ltd., Japan.* Eight-core multicore fiber with the center core and a cladding diameter of 125 μm is designed and fabricated. Side-view alignment with core identification is realized owing to asymmetrically core arrangement for the first time.

T4J.2 • 16:45
Distributed Supermode Coupling Measurements in Multi-core Optical Fibers, Riccardo Veronese[1], Juan Carlos Alvarado Zacarias[2], Sjoerd van der Heide[2], Rodrigo Amezcua Correa[3], Haoshuo Chen[2], Roland Ryf[2], Nicolas K. Fontaine[2], Marco Santagiustina[1], Andrea Galtarossa[1], Luca Palmieri[1]; [1]*Universita degli Studi di Padova, Italy;* [2]*Nokia Bell Labs, USA;* [3]*CREOL, The Univ. of Central Florida, USA.* Coupling of supermodes in multicore fibers is investigated exploiting an OFDR to measure each core when injecting light into another one. Distributed analysis of cross-core coupling is reported for the first time in multicore fibers.

Room 9

Show Floor Programming Continued

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

Accelerating ROI on the Road to SDN
SDN
16:00–17:00, *Theater III*

OIDA Roadmap
16:15–17:00, *Theater I*

Room 1A

T4A • Radio-over-fiber Technologies for 5G—Continued

T4A.2 • 17:00
Silicon Photonics to Add 5G RoF Services to PONs Employing Carrier Reuse, Leslie Rusch[1], Mingyang Lyu[1], Wei Shi[1]; [1]*ECE 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.

T4A.3 • 17:15
Design of Flexible Fronthaul Featuring Per-UE Granularity and RU-level Puncturing for URLLC Applications, Yahya M. Alfadhli[1], Shuang Yao[1], Muhammad Shameer Omar[1], Shang-Jen Su[1], Shuyi Shen[1], Rui Zhang[1], You-Wei Chen[1], Peng-Chun Peng[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Department 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.

Room 1B

T4B • Machine Learning for Fiber Amplifier and Sensors—Continued

T4B.3 • 17:00
Load Aware Raman Gain Profile Prediction in Dynamic Multi-band Optical Networks, Ann Margareth Rosa Brusin[1], Uiara C. de Moura[2], Andrea D'Amico[1], Vittorio Curri[1], Darko Zibar[2], Andrea Carena[1]; [1]*Politecnico di Torino, Italy;* [2]*Technical 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.

T4B.4 • 17:15
Hybrid Machine Learning EDFA Model, Shengxiang Zhu[1], Craig Gutterman[2], Alan D. Montiel[3], Jiakai Yu[1], Marco Ruffini[3], Gil Zussman[2], Daniel C. Kilper[1]; [1]*Univ. of Arizona, USA;* [2]*Columbia Univ., USA;* [3]*Trinity 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.

Room 2

T4C • Neuromorphic II: Entire Aspect—Continued

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

Room 3

T4D • AI Assisted Access Networks—Continued

T4D.3 • 17:00 Invited
Neural Network-based Equalization in high-speed PONs, Lilin Yi[1], Tao Liao[1], Lei Xue[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* We introduce neural network (NN)-based equalization in high-speed passive optical networks. Data feature engineering is proposed to improve performance of NN-based equalization. Besides, an unsupervised learning scheme for NN-based equalizer is proposed to train the model without known symbols of received signal.

Room 6C

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

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

Room 6D

T4F • Quantum Networking and Artifiicial Intelligence—Continued

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

Room 6E

T4G • Optical Transmitter Sub-systems—Continued

T4G.3 • 17:00
32-Channel WDM Transmitter Based on a Single Off-the-shelf Transceiver and a Time Lens, Mads Lillieholm[1], Xiaoyu Xu[1], Peter D. Ekner[1], Michael Galili[1], Leif Oxenløwe[1], Pengyu Guan[1]; [1]*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.

T4G.4 • 17:15
Full-duplex Coherent Optical System Enabled by Comb-Based Injection Locking Optical Process, Haipeng Zhang[1], Mu Xu[1], Junwen Zhang[1], Zhensheng Jia[1], Luis Alberto Campos[1]; [1]*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-GBd DP-16QAM signal over 80-km fiber is achieved with remote LO delivery.

Room 6F

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

T4H.3 • 17:00
High Efficiency, High Gain and High Saturation Output Power Quantum Dot SOAs Grown on Si and Applications, Songtao Liu[1], Yeyu Tong[2], Justin Norman[1], Mario Dumont[1], Arthur Gossard[1], Hon K. Tsang[2], John E. Bowers[1]; [1]*Univ. of California, Santa Barbara, USA;* [2]*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-Gbit/s NRZ transmission system over temperatures from 20°C to 60°C.

T4H.4 • 17:15
Monolithic Polarization Controller on Regrowth-free InGaAsP/InP Platform with Strained MQW Layer, Maiko Ito[1], Kosuke Okawa[1], Takahiro Suganuma[1], Takuo Tanemura[1], Yoshiaki Nakano[1]; [1]*School of Engineering, The Univ. of Tokyo, Japan.* Carrier-injection-based polarization controller with strained MQW layer is demonstrated. Based on novel design concept, both polarization-rotating and phase-shifting sections are integrated monolithically on regrowth-free InGaAsP/InP platform to achieve efficient conversion over the entire Poincare sphere.

Room 7

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

T4I.2 • 17:00
Fast Adaptive Digital Back-propagation Algorithm for Unrepeatered Optical Systems, José Hélio Cruz Júnior[1,2], Tiago Sutili[1], Sandro M. Rossi[1], Rafael Carvalho Figueiredo[1], Darli A. Mello[2]; [1]*CPQD, Brazil;* [2]*School of Electrical and Computer Engineering, Univ. of Campinas, Brazil.* We propose a gradient descent method with momentum for the estimation of γ in DBP for unrepeatered links. Fast convergence is achieved in the experimental transmission of 17x200-Gb/s DP-16QAM over a 350-km heterogeneous link.

T4I.3 • 17:15
Analysis of 34 to 101GBaud Submarine Transmissions and Performance Prediction Models, Jean-christophe Antona[1], Alexis C. Carbó Meseguer[1], Vincent Letellier[1], Sébastien Dupont[1], Richard Garuz[1], Philippe Plantady[1], Alain Calsat[1]; [1]*Alcatel Submarine Networks, France.* We analyze more than 100 subsea 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.

Room 8

T4J • Multi-core Fibers—Continued

T4J.3 • 17:00
Experimental and Theoretical Analyses of GAWBS Phase Noise in Multi-core Fiber for Digital Coherent Transmission, Naoya Takefushi[1], Masato Yoshida[1], Keisuke Kasai[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; [1]*Research Inst. of Electrical Communication, Tohoku Univ., Japan.* We present the phase noise caused by guided acoustic-wave Brillouin scattering (GAWBS) in a 125-μm four-core-fiber. Phase noise induced by higher-order $TR_{n,m}$ modes was found to be dominant rather than that of the $R_{0,m}$ mode.

T4J.4 • 17:15
Evaluation of Dynamic Skew on Spooled and Deployed Multicore Fibers Using O-band Signals, Ruben S. Luis[1], Benjamin J. Puttnam[1], Georg Rademacher[1], Andrea Marotta[2], Cristian Antonelli[2], Antonio Mecozzi[2], Tetsuya Hayashi[3], Tetsuya Nakanishi[3], Satoshi Shinada[1], Yoshinari Awaji[1], Hideaki Furukawa[1], Naoya Wada[1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Physical and Chemical Sciences, Univ. of L'Aquila, Italy;* [3]*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.

Room 9

Show Floor Programming

Tuesday, 10 March

Room 1A

T4A • Radio-over-fiberr Technologies for 5G—Continued

T4A.4 • 17:30
Experimental Demonstration of A-RoF SDN for Radio Access Sharing Applications, Luiz Anet Neto[1], Wang Minqi[1], Gaël Simon[1], Feizheun Lehanneur[1], Anas El Ankouri[1], Guillaume Lopere[1], Dylan Chevalier[1], Philippe Chanclou[1]; [1]*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.

T4A.5 • 17:45 ★ Top-Scored
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 Ruggeri[1], Apostolos Tsakyridis[1], Christos Vagionas[1], George Kalfas[1], Ruud M. Oldenbeuving[2], Paul W. Dijk[2], Chris G. Roeloffzen[2], Yigal Leiba[3], Nikos Pleros[1], Amalia Miliou[1]; [1]*Aristotle Univ. of Thessaloniki, Greece;* [2]*LIONIX International B.V, Netherlands;* [3]*Siklu Communication Ltd., Israel.* Four Wavelength Division Multiplexed 1Gb/s QAM16 streams are transmitted through 10km fiber, an Optical Add/Drop Multiplexer and a V-band beamsteering antenna with 90° steering, demonstrating the first 5G Fiber-Wireless A-RoF architecture with 360° coverage.

Room 1B

T4B • Machine Learning for Fiber Amplifier and Sensors—Continued

T4B.5 • 17:30
Robust Convolutional Neural Network Model for Wavelength Detection in Overlapping Fiber Bragg Grating Sensor Network, Baocheng Li[1,2], Zhi-Wei Tan[1], Perry Ping Shum[1,2], Dora Juan Juan Hu[3], Chenlu Wang[1,2], Yu Zheng[1,2], Shuhui Liu[4]; [1]*Nanyang Technological Univ., Singapore;* [2]*CINTRA CNRS/NTU/Thales, Singapore;* [3]*Inst. for Infocomm Research, Agency for Science, Technology and Research, Singapore;* [4]*Hubei Key Laboratory of Optical Information and Pattern Recognition, China.* We have designed a CNN model to detect Bragg wavelengths in overlapping spectra. The mean RMS error of 0.123pm and mean testing time of 12.4ms are achieved, which outperforms most of the existing techniques.

Room 2

T4C • Neuromorphic II: Entire Aspect—Continued

Room 3

T4D • AI Assisted Access Networks—Continued

T4D.4 • 17:30
Transfer Learning Aided Neural Networks for Nonlinear Equalization in Short-reach Direct Detection Systems, Zhaopeng Xu[1], Chuanbowen Sun[1], Tonghui Ji[1,2], Honglin Ji[1], William Shieh[1]; [1]*Univ. of Melbourne, Australia;* [2]*Univ. of Science and Technology Beijing, China.* Transfer learning-aided NNs are proposed for nonlinear equalization in a 50-Gb/s 20-km PAM4 link. About 90% reduction in epochs and 56% in training symbols are achieved with NNs transferred from the most similar source system.

T4D.5 • 17:45
Service-oriented DU-CU Placement Using Reinforcement Learning in 5G/B5G Converged Wireless-optical Networks, Yuming Xiao[1], Jiawei Zhang[1], Zhengguang Gao[1], Yuefeng Ji[1]; [1]*Beijing Univ of Posts & Telecom, China.* We propose a reinforcement learning based DU-CU placement scheme to accommodate diversified services in 5G/B5G networks. It outperforms ILP model and widely used heuristics in terms of the service-scale and resource-saving respectively.

Room 6C

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

T4E.3 • 17:30 Invited
Title to be Announced, Thomas Haynes[1]; [1]*Verizon Wireless Plan, USA.* Abstract not available.

Room 6D

T4F • Quantum Networking and Artifiicial Intelligence—Continued

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17:15–18:15 Exhibitor Happy Hour, *Center Terrace*

18:15–19:00 Celebrating 50 Years of Light-speed Connections - Keynote Presentation, *Ballroom 20BCD*

19:00–20:30 Celebrating 50 Years of Light-speed Connections, Conference Reception, *Sails Pavilion*

19:30–21:30 Rump Session: When Will Copackaged Optics Replace Pluggable Modules in the Datacenter?, *Room 6D*

Room 6E	Room 6F	Room 7	Room 8	Room 9

Show Floor Programming

T4G • Optical Transmitter Sub-systems—Continued

T4G.5 • 17:30

Overcoming Low-power Limitations on Optical Frequency Combs Using a Micro-ring Resonator, Bill P. Corcoran[1], Chawaphon Prayoonyong[1], Andreas Boes[2], Xingyuan Xu[3], Mengxi Tan[3], Sai T. Chu[4], Brent E. Little[5], Roberto Morandotti[6,7], Arnan Mitchell[2], David J. Moss[3]; [1]*Electical and Computer Systems Engineering, Monash Univ., Australia;* [2]*School of Engineering, RMIT Univ., Australia;* [3]*Centre for Micro-Photonics, Swinburne Univ., Australia;* [4]*Dept. Physics and Material Science, City Univ. of Hong Kong, China;* [5]*Xi'an Inst. of Optics and Precision Mechanics, Chinese Academy of Sciences, China;* [6]*EMT, INRS, Canada;* [7]*ITMO Univeristy, 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[1], Grant M. Brodnik[1], Travis C. Briles[2], Jordan R. Stone[2], Richelle H. Streater[2], Scott B. Papp[2,3], Daniel J. Blumenthal[1]; [1]*Univ. of California at Santa Barbara, USA;* [2]*Time and Frequency Division 688, National Inst. of Standards and Technology, USA;* [3]*Univ. 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 ~4.0kHz integral linewidths for high-capacity coherent WDM.

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

T4H.5 • 17:30 Invited

III-V Micro- and Nano-lasers Grown on Silicon Emitting in the Telecom Band, Kei May Lau[1], Yu Han[1], Si Zhu[1], Wei Luo[1], Ying Xue[1]; [1]*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.

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

T4I.4 • 17:30

Cost-effective Solution for High-Capacity Unrepeatered Transmission, Tiago Sutili[1], Pedro F. Neto[2], Fábio D. Simões[1], Gabriel Junco Suzigan[2], Rafael Carvalho Figueiredo[1]; [1]*CPQD, Brazil;* [2]*Padtec S.A., Brazil.* A cost-effective 310-km SSMF unrepeatered optical link employing off-the-shelf EDFAs, 1st-order DRAs, and a ROPA is experimentally demonstrated. An iterative optimization process enabled a 12.8-Tbps net transmission (37.5-GHz spaced 128 channels x 100 Gbps).

T4I.5 • 17:45

Demonstration of 3,010 km WDM Transmission in 3.83 THz Bandwidth Using SOAs, Matt Mazurczyk[1], Jin-Xing Cai[1], Milen Paskov[1], William Patterson[1], Oleg V. Sinkin[1], Yue Hu[1], Carl Davidson[1], Patrick Corbett[1], Timothy Hammon[1], Maxim Bolshtyansky[1], Dmitri G. Foursa[1], Alexei N. Pilipetskii[1]; [1]*SubCom, USA.* We transmit 5.53Tb/s over 3,010km using SOAs, ultralow-loss fibers (0.145dB/km) and a new coded modulation format with SE=1.5 b/s/Hz. C-band transmission capacity in a ~602km circulating loop testbed with 3.83THz bandwidth is confirmed with FEC

T4J • Multi-core Fibers—Continued

17:15–18:15 Exhibitor Happy Hour, *Center Terrace*

18:15–19:00 Celebrating 50 Years of Light-speed Connections - Keynote Presentation, *Ballroom 20BCD*

19:00–20:30 Celebrating 50 Years of Light-speed Connections, Conference Reception, *Sails Pavilion*

19:30–21:30 Rump Session: When Will Copackaged Optics Replace Pluggable Modules in the Datacenter?, *Room 6D*

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

07:30–08:00 Morning Coffee, *Upper Level Corridors*

Room 1A

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

W1A.1 • 08:00 Invited

Ultrafast Laser-written Sub-components for Space Division Multiplexing, Simon Gross[1], Andrew Ross-Adams[1], Nicolas Riesen[2], Sergio G. Leon-Saval[3], Michael J. Withford[1]; [1]*Macquarie Univ., Australia;* [2]*Univ. of South Australia, Australia;* [3]*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.

Room 1B

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

W1B.1 • 08:00 Invited

Deep Learning Imaging through Specialty Multi-mode Fibers, Jian Zhao[2,1], Shengli Fan[1], Jose Enrique Antonio-Lopez[1], Axel Schülzgen[1]; [1]*Univ. of Central Florida, USA;* [2]*Photonics 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.

Room 2

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

W1C.1 • 08:00

Improved Nd Doped Silica Fiber for E-band Amplification, Leily S. Kiani[1], Paul Pax[1], Derrek R. Drachenberg[1], Jay Dawson[1], Charles Boley[1], Cody Mart[1], Victor Khitrov[1], Charles Yu[1], Robert Crist[1], Matthew Cook[1], Nick Schenkel[1], Michael Runkel[1], Michael Messerly[1]; [1]*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 Lei[1], Hanlin Feng[1], Lixian Wang[2], Younès Messaddeq[1], Sophie LaRochelle[1]; [1]*Center for Optics, Photonics and Lasers, Université Laval, Canada;* [2]*Huawei 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.

Room 3

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

W1D.1 • 08:00 Invited

Low-power Data Center Transponders Enabled by Micrometer-scale Plasmonic Modulators, Benedikt Baeuerle[2,1], Wolfgang Heni[2,1], Claudia Hoessbacher[2,1], Yuriy Fedoryshyn[1], Arne Josten[1], Ueli Koch[1], Christian Haffner[1,6], Tatsuhiko Watanabe[1], Christopher Uhl[3], Horst Hettrich[4], Delwin L. Elder[5], Larry R. Dalton[5], Michael Möller[3,4], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland;* [2]*Polariton Technologies Ltd., Switzerland;* [3]*Chair of Electronics and Circuits, Saarland Univ., Germany;* [4]*MICRAM Microelectronic GmbH, Germany;* [5]*Department of Chemistry, Univ. of Washington, USA;* [6]*Physical 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 700mV. The compact footprint enables dense integration and makes plasmonic modulators a promising solution for next-generation optical interconnects.

Room 6C

08:00–10:00
W1E • Advances in Coherent PON
Presider: Derek Nesset; Huawei Technologies, Germany

W1E.1 • 08:00 Top-Scored

High-performance Preamble Design and Upstream Burst-mode Detection in 100 -Gb/s/λ TDM Coherent-PON, Junwen Zhang[1], Zhensheng Jia[1], Mu Xu[1], Haipeng Zhang[1], Luis Alberto Campos[1], Curtis Knittle[1]; [1]*CableLabs, USA.* We propose robust, high-efficient preamble design and signal processing for upstream burst-mode detection in 100-Gb/s/λ TDM Coherent-PON. Using a 71.68-ns preamble, we achieve 36-dB power budget after50-km SMF and 20-dB dynamic range.

Room 6D

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

W1F.1 • 08:00

FOSphere: A Scalable and Modular Low Radix Fast Optical Switch Based Data Center Network, Fulong Yan[1], Elham Kahan[1], Xiaotao Guo[1], Fu Wang[1], Bitao Pan[1], Xuwei Xue[1], Shaojuan Zhang[1], Nicola Calabretta[1]; [1]*Technology Univ. of Eindhoven, Netherlands.* We propose a novel scalable and modular low-radix fast optical switch based DCN with sphere topology (FOSphere). Numerical analyses on 10880-server indicates that FOSphere achieves 4.1 μs server-to-server latency and 2.6E-3 packet loss at load 0.4.

W1F.2 • 08:15

High-throughput Optical Circuit Switch for Intra-datacenter Networks Based on Spatial Super-channels, Eiji Honda[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[2]; [1]*Nagoya Univ., Japan;* [2]*The 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 1,536×1,536 optical switch and its performance is experimentally confirmed. The total throughput of the switch reaches 2.1 Pbps.

Room 6E	Room 6F	Room 7	Room 8	Room 9	Show Floor Programming

07:30–08:00 Morning Coffee, *Upper Level Corridors*

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 Toyoshima[1]; [1]*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.

08:00–10:00 W1H • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 1)

W1H.1 • 08:00 Invited

Electronic and Photonic Co-optimization for fJ/bit Optical Links, Clint Schow[1]; [1]*Univ. of California Santa Barbara, USA.* Abstract not available.

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

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

However, modern optical networks with flexible 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

08:00–10:00 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 Slovak[1], Wolfgang Schairer[1], Donato Sperti[2], Pedro Capela[2], Silvestre Martins[2], Uffe Andersen[3], Anders Lindgren[4], Joakim Tjäder[4], Stefan Melin[4]; [1]*Infinera 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, Kaida Kaeval[1], Danish Rafique[1], Kamil Blawat[1], Klaus Grobe[1], Helmut Griesser[1], Jörg-Peter Elbers[1], Piotr Rydlichowski[2], Artur Binczewski[2], Marko Tikas[3]; [1]*ADVA 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.

08:45–10:00 W1K • Machine Learning for Optical Communication Systems

Presider: Antonio Napoli; Infinera Corporation, Germany

Room 1A

W1A • Optical Input/Output and Filters—Continued

W1A.2 • 08:30
Tapered Self-written Waveguide between Silicon Photonics Chip and Standard Single-mode Fiber, Yohei Saito[1], Kota Shikama[1], Tai Tsuchizawa[1], Hidetaka Nishi[1], Atsushi Aratake[1], Norio Sato[1]; [1]*NTT Device Technology Laboratories, Japan.* The first self-written waveguide applied to silicon photonics with a spot-size converter using a SiON waveguide achieves low coupling loss and high alignment tolerance between a standard single-mode fiber and silicon photonics chip.

W1A.3 • 08:45
Vertical Optical Fiber Assembly on Silicon Photonic Chips Using 3D-curved Silicon Waveguide Couplers, Youichi Sakakibara[1], Tomoaki Kiriyama[2], Tomoya Yoshida[1], Yuki Atsumi[1], Emiko Omoda[1], Katsuhiro Iwasaki[2], Takashi Kato[2]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan;* [2]*Kohoku Kogyo Co., Ltd., Japan.* Using UV adhesive mixed with glass spacer beads, vertical surface connection of optical fibers to silicon photonic chips via elephant couplers was realized with wavelength and polarization insensitiveness at temperatures from -18.5°C to 90°C.

Room 1B

W1B • Multi-mode Fiber Technology—Continued

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

W1B.3 • 08:45
Ultra-low Inter-mode-group Crosstalk Ring-Core Fiber Optimized Using Neural Networks and Genetic Algorithm, Chumin Shi[1], Lei Shen[2], Junwei Zhang[1], Junyi Liu[1], Lei Zhang[2], Jie Luo[2], Jie Liu[1], Siyuan Yu[1]; [1]*Sun Yat-Sen Univ., China;* [2]*YOFC, China.* We design and fabricate a ring-core fiber whose refractive-index profile is optimized using neural networks and genetic algorithm under fabrication constraints. Experimental results confirm ultra-low inter-mode-group crosstalk of <-55 dB/km.

Room 2

W1C • Novel Doped Fiber Amplifier—Continued

W1C.3 • 08:30 Invited
Recent Advances on Radiation-hardened Optical Fiber Technologies, Sylvain Girard[1], Thierry Robin[2], Adriana Morana[1], Gilles Mélin[2], Alexandre Barnini[2], Aziz Boukenter[1], Benoit Cadier[2], Emmanuel Marin[1], Laurent Lablonde[1], Arnaud Laurent[2], Youcef Ouerdane[1]; [1]*Universite Jean Monnet, France;* [2]*iXblue, 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

Room 3

W1D • Short-reach Interconnects—Continued

W1D.2 • 08:30
Distortion-aware 2D Soft Decision for VCSEL-MMF Optical PAM Interconnection, Lin Sun[1,2], Jiangbing Du[1], Wenjia Zhang[1], Nan Chi[3], Chao Lu[2], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Hong Kong Polytechnic Univ., Hong Kong;* [3]*Fudan Univ., China.* A distortion-aware 2D soft decision method of PAM signals have been proposed for VCSEL-MMF interconnection system. Improvements and application potential have been experimentally investigated on a 112-Gbps optical PAM-4/8 system using a multimode VCSEL.

W1D.3 • 08:45
168Gbps PAM-4 Multimode Fiber Transmission through 50m using 28GHz 850nm Multimode VCSELs, Justin Lavrencik[1], Siddharth Varughese[1], Nikolay Ledentsov Jr.[2,3], Lukasz Chorchos[2,3], Nikolay Ledentsov[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*VI Systems GmbH, Germany;* [3]*Warsaw Univ. of Technology, Poland.* We experimentally demonstrate PAM-4 data rates beyond 160Gbps over 50m OM5 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.

Room 6C

W1E • Advances in Coherent PON—Continued

W1E.2 • 08:15 Tutorial
Transceiver Technologies for Next-generation PON Networks, Dora van Veen[1], Vincent Houtsma[1]; [1]*Nokia 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.

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.

Room 6D

W1F • Intra Data Center Networks II—Continued

W1F.3 • 08:30 Invited
Scaling PULSE Data Center Network Architecture and Scheduling Optical Circuits in Sub-microseconds, Joshua L. Benjamin[1], Georgios S. Zervas[1]; [1]*Univ. 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 blades, achieves >95% sustained throughput, with low median 1.23μs and tail 145μs latencies, while consuming 115pJ/bit and costing $9.04/Gbps.

Room 6E

W1G • Trends in Free Space Optics Communications—Continued

Room 6F

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 Nozaki[2,1], Shinji Matsuo[2,3], Takuro Fujii[2,3], Koji Takeda[2,3], Eiichi Kuramochi[2,1], Akihiko Shinya[2,1], Masaya Notomi[2,1]; [1]*NTT Basic Research Laboratories, Japan;* [2]*NTT Nanophotonics Center, Japan;* [3]*NTT Device Technology Laboratories, Japan.* We use a photonic-crystal platform to demonstrate opto-electronic devices and integrated functions with a femtofarad 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.

Room 7

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

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*

Room 8

W1J • Advanced Transmission Path Metrics—Continued

W1J.3 • 08:30 Invited

Standardizing Performance Metrics for Submarine Transmission Paths, Priyanth Mehta[1]; [1]*Ciena Canada, Canada.* This paper describes the progress and obstacles towards defining a universal performance metric for ultralong haul submarine transmission paths. Sources of error and quantitative assessment of capacity prediction is also addressed.

Room 9

W1K • Machine Learning for Optical Communication Systems—Continued

W1K.1 • 08:45 Invited

Advancing Classical and Quantum Communication Systems with Machine Learning, Darko Zibar[1], Uiara C. de Moura[1], Hou Man Chin[1], Ann Margareth Rosa Brusin[2], Nitin Jain[1], Francesco Da Ros[1], Sebastian Kleis[3], Christian Schaeffer[3], Tobias Gehring[1], Ulrik L. Andersen[1], Andrea Carena[2]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Politecnico Di Torino, Italy;* [3]*Helmut 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.

Show Floor Programming

Room 1A

W1A • Optical Input/Output and Filters—Continued

W1A.4 • 09:00
Ultra-high Q Resonators and Sub-GHz Bandwidth Second Order Filters in an SOI Foundry Platform, Deniz Onural[1], Hayk Gevorgyan[1], Bohan Zhang[1], Anatol Khilo[1], Miloš A. Popović[1]; *[1]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.

W1A.5 • 09:15
Design and Characterization of Arbitrary Filters with an Integrated Spiral Si_3N_4/SiO_2 Waveguide, Yi-Wen Hu[1], Shengjie Xie[1], Jiahao Zhan[1], Yang Zhang[1], Sylvain Veilleux[1], Mario Dagenais[1]; *[1]Univ. of Maryland, USA.* We report the optimization of reconstruction algorithm and experiment for an integrated arbitrary filter. A 43-notch filter near 1550 nm is implemented with an ultra-low-loss Si_3N_4/SiO_2 spiral waveguide. All notches have uniform depths/widths of about 20 dB/0.2 nm.

Room 1B

W1B • Multi-mode Fiber Technology—Continued

W1B.4 • 09:00 Tutorial
Advances in Few-mode Fiber Design and Manufacturing, Pierre Sillard[1]; *[1]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.

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

Room 2

W1C • Novel Doped Fiber Amplifier—Continued

W1C.4 • 09:00
O-band Bismuth-doped Fiber Amplifier with 67 nm Bandwidth, Aleksandr Khegai[1], Yan Ososkov[1], Sergei Firstov[1], Konstantin Riumkin[1], Sergey Alyshev[1], Alexander Kharakhordin[1], Elena Firstova[1], Fedor Afanasiev[2], Vladimir Khopin[2], Alexey Guryanov[2], Mikhail Melkumov[1]; *[1]Fiber Optics Research Center of the Russian Academy of Sciences, Russian Federation; [2]G.G. Devyatykh Inst. of Chemistry of High-Purity Substances 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

W1C.5 • 09:15
Bismuth-doped Fiber Amplifier Operating in the Spectrally Adjacent to EDFA Range of 1425-1500 nm, Vladislav Dvoyrin[1,2], Valery Mashinsky[3], Sergei Turitsyn[1,2]; *[1]Aston Inst. of Photonic Technologies, Aston Univ., UK; [2]Aston-NSU Centre for Photonics, Novosibirsk State Univ., Russian Federation; [3]Fiber Optics Research Center, Russian Federation.* We demonstrate a Bi-doped fiber amplifier operating in the range of 1425-1500 nm with the maximum gain of 27.9 dB, the lowest noise figure of ~5 dB, and the maximum output power of 505 mW.

Room 3

W1D • Short-reach Interconnects—Continued

W1D.4 • 09:00
4×56-GBaud PAM-4 SDM Transmission Over 5.9-km 125-μm-Cladding MCF Using III-V-on-Si DMLs, Nikolaos Panteleimon Diamantopoulos[1], Hidetaka Nishi[1], Takuro Fujii[1], Kota Shikama[1], Takashi Matsui[2], Koji Takeda[1], Takaaki Kakitsuka[1,3], Kazuhide Nakajima[2], Shinji Matsuo[1]; *[1]NTT Device Technology Labs, NTT Corporation, Japan; [2]NTT Access Networks Service Systems Labs, NTT Corporation, Japan; [3]Graduate School of Information, Production and Systems, Waseda Univ., Japan.* We demonstrate 4×56-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 (@12 mA). A reach extension of ~15x is achieved compared to previous works.

W1D.5 • 09:15
1.12 Tbit/s Fiber Vector Eigenmode Multiplexing Transmission Over 5-km FMF with Kramers-Kronig Receiver, Jianbo Zhang[1], Xiong Wu[1], Linyue Lu[1], Jianping Li[2], Jiajing Tu[3], Zhaohui Li[4], Chao Lu[1]; *[1]The Hong Kong Polytechnic Univ., Hong Kong; [2]Guangdong Univ. of Technology, China; [3]Jinan Univ., China; [4]Sun Yat-sen Univ., China.* We demonstrate a 1.12 Tb/s MIMO-free vector eigenmode multiplexed signal transmission over 5-km 4-mode few-mode-fiber using HE11 and EH11 vector modes, 5 wavelengths and 28 GBaud 16-QAM signal with direct-detection Kramers-Kronig receiver.

Room 6C

W1E • Advances in Coherent PON—Continued

W1E.3 • 09:15
Performance Comparison of Coherent and Direct Detection Schemes for 50G PON, Yixiao Zhu[1], Bo Yang[1], Yiming Zhong[1], Zheng Liu[1], Yong Guo[1], Jun Shan Wey[2], Xingang Huang[1], Zhuang Ma[1]; *[1]ZTE Corporation, China; [2]ZTE(Tx) Inc., USA.* We investigate various coherent and direct detection schemes with 50Gb/s/λ NRZ signal through simulation. The receiver sensitivity, the influence of frequency offset, LO power, laser linewidth, and fiber dispersion are studied for each structure.

Room 6D

W1F • Intra Data Center Networks II—Continued

W1F.4 • 09:00
A 25.6 Tbps capacity 1024-port Hipoλaos Optical Packet Switch Architecture for Disaggregated Datacenters, Nikolaos Terzenidis[1,2], Apostolos Tsakyridis[1,2], George Giamougiannis[1,2], Miltiadis Moralis-Pegios[1,2], Konstantinos Vyrsokinos[3,2], Nikos Pleros[3,2]; *[1]Informatics, Aristotle Univ. of Thessaloniki, Greece; [2]Center for Interdisciplinary Research & Innovation, Greece; [3]Physics, Aristotle Univ. of Thessaloniki, Greece.* We demonstrate experimentally the feasibility of a 25.6Tb/s capacity Hipoλaos optical packet switch architecture with 1024 in/out ports operating at 25Gb/s, presenting successful contention resolution and error-free operation with a control plane latency of 97.28ns.

W1F.5 • 09:15
Experimental Assessments of a Flexible Optical Data Center Network Based on Integrated Wavelength Selective Switch, Xuwei Xue[1], Fumi Nakamura[2], Kristif Prifti[1], Bitao Pan[1], Fulong Yan[1], Fu Wang[1], Xiaotao Guo[1], Hiroyuki Tsuda[2], Nicola Calabretta[1]; *[1]Eindhoven Univ. of Technology, Netherlands; [2]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 1.75μs end-to-end latency and 0.015 packet-loss at 0.6 load.

Room 6E	Room 6F	Room 7	Room 8	Room 9	Show Floor Programming

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 Pang[1], Haoqian Song[1], Xinzhou Su[1], Kaiheng Zou[1], Zhe Zhao[1], Hao Song[1], Ahmed Almaiman[1], Runzhou Zhang[1], Cong Liu[1], Nanzhe Hu[1], Shlomo Zach[2], Nadav Cohen[2], Brittany Lynn[3], Andreas F. Molisch[1], Robert W. Boyd[4], Moshe Tur[2], Alan E. Willner[1]; [1]*Universit of Southern California, USA;* [2]*Tel Aviv Univ., Israel;* [3]*Space & Naval Warfare Systems Center, Pacific, USA;* [4]*Univ. of Rochester, USA.* We experimentally utilize orthogonal combinations of multiple Laguerre-Gaussian modes in a 400-Gbit/s free-space link with limited-size aperture or misalignment. Power loss and crosstalk could be reduced by up to ~15 dB and ~40 dB, respectively.

W1G.3 • 09:1 Top-Scored

Simultaneous Turbulence Mitigation and Mode Demultiplexing using one MPLC in a Two-Mode 200-Gbit/s Free-space OAM-multiplexed Link, Hao Song[1], Xinzhou Su[1], Haoqian Song[1], Runzhou Zhang[1], Zhe Zhao[1], Kaiheng Zou[1], Cong Liu[1], Kai Pang[1], Nanzhe Hu[1], Ahmed Almaiman[1,3], Moshe Tur[2], Alan E. Willner[1], Shlomo Zach[2], Nadav Cohen[2], Andreas F. Molisch[1], Robert W. Boyd[4,5]; [1]*Univ. of Southern California, USA;* [2]*Tel Aviv Univ., Israel;* [3]*King Saudi Univ., Saudi Arabia;* [4]*Univ. of Ottawa, Canada;* [5]*Univ. 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 Leuthold[1]; [1]*ETH Zurich, Switzerland.* Abstract not available.

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

W1J • Advanced Transmission Path Metrics—Continued

W1J.4 • 09:00 Tutorial

From the Acceptance of Turnkey Systems to Open Networks with G-SNR, Elizabeth Rivera Hartling[1], Stephen Grubb[1], Tim Stuch[1], Herve Fevrier[1]; [1]*Facebook Inc., USA.* This tutorial will discuss collaboratively formed industry recommendations for characterizing Open Subsea Cables, with the intent of assessment, maximization and understanding of capacity potential, utilizing methodologies to test key parameters such as G-SNR, among others.

Elizabeth Rivera Hartling is a Subsea Optical Network Architect at Facebook, focused on optimizing Facebook's Subsea Open Cable designs, to build a scalable, high capacity, cost-effective subsea network to meet Facebook's growing bandwidth demands. Hartling has been designing and executing coherent solutions on subsea cables since 2008.

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 Cho[1], Chandrasekhar Sethumadhavan[1], Erixhen Sula[3], Samuel Olsson[4], Ellsworth C. Burrows[1], Gregory Raybon[1], Roland Ryf[1], Nicolas K. Fontaine[1], Jean-christophe Antona[5], Stephen Grubb[2], Peter Winzer[1], Andrew Chraplyvy[1]; [1]*Nokia Bell Labs, USA;* [2]*Facebook, USA;* [3]*EPFL, Swaziland;* [4]*Nokia, USA;* [5]*ASN, France.* We experimentally achieve a 19% capacity gain per Watt of electrical supply power in a 12-span link by eliminating gain flattening filters and optimizing launch powers using deep neural networks in a parallel fiber context.

Wednesday, 11 March

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

W1A • Optical Input/Output and Filters—Continued

W1B • Multi-mode Fiber Technology—Continued

W1C • Novel Doped Fiber Amplifier—Continued

W1C.6 • 09:30
Tetrahedral-Cr Enhancement Employing Dielectric Coating for Higher Gain of Broadband Cr-doped Fiber Amplifiers, Chia-Ming Liu[1], Jhuo-Wei Li[1], Liu Chun-Nien[1], Wei-Chih Cheng[1], Charles Tu[1], Tien-Tsorng Shih[2], Sheng-Lung Huang[3], Wood-Hi Cheng[1]; [1]*Graduate Inst. of Optoelectronic Engineering, National Chung Hsing Univ., Taiwan;* [2]*Department of Electronic Engineering, National Kaohsiung Univ. of Applied Sciences, Taiwan;* [3]*Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan.* We report gross gain of 8.4-dB for 300-nm broadband single-mode Cr-doped crystalline core fiber (SMCCDF) employing dielectric coating, thermal annealing, and polarization pumping techniques. This gross gain is the highest yet demonstrated of the SMCDCCFs.

W1D • Short-reach Interconnects—Continued

W1D.6 • 09:30
Single λ 500-Gbit/s PAM Signal Transmission for Data Center Interconnect Utilizing Mode Division Multiplexing, Fan Li[1], Dongdong Zou[1]; [1]*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 (3.8×10^{-3}) is demonstrated for 400-G Data Center Interconnect without DSP for mode de-multiplexing. This scheme shows good potential for future 800-G/1.6-T DCI.

W1E • Advances in Coherent PON—Continued

W1E.4 • 09:30
Real-Time Demonstration of 20-Gb/s QPSK Burst-mode Digital Coherent Reception for PON Upstream under Clock Frequency Mismatch of 1.0 MHz, Noriko Iiyama[1], Masamichi Fujiwara[1], Takuya Kanai[1], Hiro Suzuki[1], Jun-ichi Kani[1], Jun Terada[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan.* We demonstrate real-time burst-mode coherent reception of 10-Gsymbol/s QPSK signals under 1.0-MHz clock frequency difference between Tx and Rx. Our sampling recovery proposal enables the dynamic range of 26.5 dB at BER of 10E-3.

W1E.5 • 09:45
Rate-flexible Single-wavelength TFDM 100G Coherent PON based on Digital Subcarrier Multiplexing Technology, Junwen Zhang[1], Zhensheng Jia[1], Haipeng Zhang[1], Mu Xu[1], Jingjie Zhu[1], Luis Alberto Campos[1]; [1]*CableLabs, 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 • Intra Data Center Networks II—Continued

W1F.6 • 09:30 Invited
Beyond Edge Cloud: Distributed Edge Computing, Nihel D. Benzaoui[1]; [1]*Nokia 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.

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*

Room 6E

W1G • Trends in Free Space Optics Communications—Continued

W1G.4 • 09:30
Beyond Terabit/s WDM Optical Wireless Transmission using Wavelength-transparent Beam Tracking and Steering, Yang Hong[1], Feng Feng[2], Kyle Bottrill[1], Natsupa Taengnoi[1], Ravinder Singh[2], Grahame Faulkner[2], Dominic O'Brien[2], Periklis Petropoulos[1]; [1]*Univ. of Southampton, UK;* [2]*Univ. of Oxford, UK.* We report up to 1.165-Tb/s optical wireless WDM transmission using a wavelength-transparent beam tracking and steering system. Over a 3.5-m perpendicular distance, beyond 1-Tb/s capacity was achieved across a lateral coverage up to 1.8 m.

W1G.5 • 09:45
C-band PS 4096QAM OFDM FSO Transmission with 6.98bit/s/Hz Net SE Based on Kramers-Kronig Detection, Yiran Wei[1], Yingjun Zhou[1], Cuiwei Liu[1], Feng Wang[1], Kaihui Wang[1], Junting Shi[1], Nan Chi[1], Jianjun Yu[1]; [1]*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.

Room 6F

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

W1H.4 • 09:30 Invited
Ultra-efficient Optical Switching based on a Large Pockels Effect embedded in Silicon Photonics, Felix Eltes[1], Jean Fompeyrine[1], Stefan Abel[1]; [1]*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.

Room 7

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

Room 8

W1J • Advanced Transmission Path Metrics—Continued

Room 9

W1K • Machine Learning for Optical Communication Systems—Continued

W1K.3 • 09:30
Experimental Prediction and Design of Ultra-wideband Raman Amplifiers Using Neural Networks, Xiaoyan Ye[1], Aymeric Arnould[1], Amirhossein Ghazisaeidi[1], Dylan Le Gac[1], Jeremie Renaudier[1]; [1]*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, Huazhi Lun[1], Xiaomin Liu[1], Meng Cai[1], Mengfan Fu[1], Yiwen Wu[1], Lilin Yi[1], Weisheng Hu[1], Qunbi Zhuge[1]; [1]*Shanghai Jiao Tong Univ., China.* We propose a receiver DSP based scheme to localize WSS anomaly in an optical link. Through extensive simulations, we show that the accuracy reaches up to 96.4% with a good generalization performance.

Show Floor Programming

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*

10:30–12:30
W2A • Poster Session I

W2A.1

300 Gb/s Net-Rate Intra-datacenter Interconnects with a Silicon Integrated Optical Frequency Comb Modulator, Deming Kong[1], Haiyun Xin[1,2], Kwangwoong Kim[3], Yong Liu[1], Leif Oxenløwe[1], Po Dong[3], Hao Hu[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China;* [3]*Nokia Bell Labs, USA.* We propose and demonstrate intra-datacenter interconnects based on a silicon optical frequency comb modulator consisting of four cascaded microring modulators. The generated 4×50 Gbaud WDM-PAM4 signals exhibit BERs below 33% HD-FEC threshold after 2-km transmission.

W2A.2

A Passively Mode-locked Quantum Dot Laser with 10.8 Tbit/s Transmission Over 100-km SSMF, Guocheng Liu[1], Zhenguo Lu[1], Jiaren Liu[1], Youxin Mao[1], Martin Vachon[1], Chunying Song[1], Philip Poole[1]; [1]*National Research Council Canada, Canada.* We demonstrate 10.8 Tbit/s (16-QAM 48×28 GBaud PDM) coherent 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.

W2A.3

2-dimentional Fiber Array with Reflow Compatibility for High-density Optical Interconnection, Tsutaru Kumagai[1], Hajime Arao[1], Hong Nguyen[1], Tetsuya Nakanishi[1]; [1]*Sumitomo Electric Industries, Ltd., 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 < 1.0 dB after reflow process at 260°C.

W2A.4

Sub-nanosecond Optical Switching Using Chip-based Soliton Microcombs, Sophie Lange[1], Arslan S. Raja[2], Kai Shi[1], Maxim Karpov[2], Raphael Behrendt[1], Daniel Cletheroe[1], Istvan Haller[1], Fotini Karinou[1], Xin Fu[2], Junqiu Liu[2], Anton Lukashchuk[2], Benn C. Thomsen[1], Krzysztof Jozwik[1], Paolo Costa[1], Tobias J. Kippenberg[2], Hitesh Ballani[1]; [1]*Microsoft Research, UK;* [2]*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.

W2A.5

Reliability Failure Modes of an Integrated Ge Photodiode for Si Photonics, Stewart Rauch[1], Dongho Lee[1], Alexey Vert[2], Lin Jiang[1], Byoung Min[1]; [1]*GlobalFoundries, USA;* [2]*Cisco, USA.* Major failure modes of Germanium photodiodes are proposed with a model. These are: catastrophic breakdown driven by thermal runaway due to localized self-heating and electrical defect generation/activation driven by electric field with photocurrent localization effect.

W2A.6

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

W2A.7

Dual-band Optical Filters Using Integrated Multimode Bragg Gratings, Jonathan Cauchon[1], Wei Shi[1]; [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.

W2A.8

Ultra-Compact Silicon TM-pass Polarizer with a Photonic Crystal Nanobeam Structure, Yu He[1], Yong Zhang[1], Ruihuan Zhang[1], Lu Sun[1], Yikai Su[1]; [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.

W2A.9

Metasurface Beam Deflector Array on a 12-inch Glass Wafer, Nanxi Li[1], Yuan Hsing Fu[1], Yuan Dong[1], Ting Hu[1], Zhengji Xu[1], Qize Zhong[1], Dongdong Li[1], Yanyan Zhou[1], Keng Heng Lai[1], Vladimir Bliznetsov[1], Hou-Jang Lee[1], Wei Loong Loh[1], Shiyang Zhu[1], Qunying Lin[1], Navab Singh[1]; [1]*Inst. of Microelectronics, Agency for Science Technology and Research, Singapore.* We have demonstrated a large-area metasurface beam deflector array patterned directly on a 12-inch glass wafer using immersion lithography. The captured random points at 940 nm wavelength show a good match with the design.

W2A.10

Performance Evaluation of a Comb-based Transmission System Employing Multi-functional Active Demultiplexers, Prajwal Doddaballapura Lakshmijayasimh[1], Aleksandra Kaszubowska-Anandarajah[2], Pascal Landais[1], Prince M. Anandarajah[1]; [1]*School of Electronics Engineering, Dublin City Univ., Ireland;* [2]*CONNECT Research Centre, Trinity College Dublin, Ireland.* A compact OFC-based transmitter for short-reach applications is demonstrated. A single device is employed to implement OFC demultiplexing, amplification and direct modulation. Using this method, error free data transmission over 3km of fiber is achieved.

W2A.11

A Single-loop PT-symmetric Sub-kHz Fiber Laser Based on an Integrated Microdisk Resonator, Jianping Yao[1], Zhiqiang Fan[1], Zheng Dai[1], Qi Qiu[2]; [1]*Univ. of Ottawa, Canada;* [2]*Univ. of Electronic Science and Technology of China, China.* A single physical loop parity-time symmetric sub-kHz laser based on a microdisk resonator is demonstrated. Single-mode lasing with a wavelength-tunable range from 1552.953 to 1554.147 nm and a linewidth of 640 Hz is achieved experimentally.

W2A.12

Lossless Monolithically Integrated Photonic InP Neuron for All-optical Computation, Bin Shi[1], Kristif Prifti[1], Eduardo Magalhães[1], Nicola Calabretta[1], Ripalta Stabile[1]; [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 operation/s with an 89% accuracy.

W2A.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]; [1]*Corning 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 100G CWDM4 transceiver.

W2A.14

Miniature Optical Connector with Magnetic Physical Contact, Kota Shikama[1], Norio Sato[1], Atsushi Aratake[1], Satoshi Shigematsu[1], Takeshi Sakamoto[1]; [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.

W2A.15

Inverse Design of Few-mode Fiber by Neural Network for Weak-coupling Optimization, Zhiqin He[1], Jiangbing Du[1], Weihong Shen[1], Yuting Huang[1], Chang Wang[1], Ke Xu[1], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China.* We use a neural network to inversely design a four-ring few-mode fiber for weak-coupling optimization so as to support MIMO-less MDM optical communication. This method provides high-accuracy, high-efficiency and low-complexity for complexed fiber design.

W2A.16

Investigation of Tolerance of OFDR-Based DAS to Vibration-induced Beat Frequency Offset, Tatsuya Okamoto[1], Daisuke Iida[1], Hiroyuki Oshida[1]; [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.

W2A.17

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

W2A.18

Training-free Feature Extraction of BOTDA Based on Sparse Representation, Hongxiu Tan[1], Yating Xiang[1], Hao Wu[1], Li Shen[1], Kangjie Li[1], Maoqi Zhang[1], Can Zhao[1], Lin Gan[1], Songnian Fu[1], Ming Tang[1]; [1]*Huazhong Univ. of Science and Technology, China.* We propose a method based on sparse representation to extract amplitude, linewidth, and Brillouin frequency shift (BFS) in BOTDA using dictionary-learning algorithm without feedback and off-line training, which enables more accurate BFS measurements in real-time.

W2A • Poster Session I—Continued

W2A.19
Rayleigh Speckles Obtained from Single Mode Fiber for Wavelength Measurement, Yangyang Wan[1], Xin Yu Fan[1], Shuai Wang[1], Zhaopeng Zhang[1], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China.* We propose a novel wavemeter using Rayleigh speckle obtained by optical time domain reflectometry. It is experimentally demonstrated that the system can resolve multi-wavelength signal with 6 fm wavelength resolution and 25 nm bandwidth.

W2A.20
Experimental Demonstration of Using Wet-mate Connector in Offshore Long-distance Raman Amplified Optical Links, Steinar Bjørnstad[2,1], Rolf Bøe[3], Kris Sanapi[4], W.R.L Clements[4], Bernard Shum-tim[4], Luigi Carlomusto[5], Soren Michaelsen[5]; [1]*NTNU, Norway;* [2]*Tampnet, Norway;* [4]*MPB communications, Canada;* [5]*Ciena, Canada.* Deploying fibre cables to offshore installations may desire a pluggable construction for sub-sea use. Sub-sea connection of fibre cables, carrying high power Raman pump power, using a wet-mate connector is demonstrated for the first time.

W2A.21
GOSNR Characterization by Optical Spectrum Analysis, Gang He[1], Steven Searcy[2], Daniel Gariepy[1], Sorin Tibuleac[2]; [1]*EXFO Inc, Canada;* [2]*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[1], Fulong Yan[1], George Exarchakos[1], Xuwei Xue[1], Bitao Pan[1], Nicola Calabretta[1]; [1]*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% 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[1], Vimal Bhatia[1], Shashi Prakash[2]; [1]*IIT Indore, India;* [2]*Photonics Laboratory, Devi Ahilya Univ., India.* In spectrally-spatially flexible optical network (SS-FON), crosstalk (XT)-margin overprovisioning is unavoidable due to transmission reach granularity of modulation schemes. We show that heterogeneous multicore fibers of specific core designs can achieve zero-XT-margin. We also propose a core-type selection method to minimize XT-margin in SS-FONs.

W2A.24
Recurrent Neural Networks for Short-term Forecast of Lightpath Performance, Sandra Aladin[1], Stéphanie Allogba[1], Anh Vu Stephan Tran[1], Christine Tremblay[1]; [1]*Ecole de Technologie Supérieure, Canada.* We show how the Recurrent Neural Networks can be used for performance prediction of lightpaths using field bit error rate data. Moreover, we illustrate how the forecast horizons and observation windows affect the forecast accuracy.

W2A.25
Optimal Upstream Spectrum Resource Allocation on IP-over-EONs Access Links, Junyi Shao[1], Weiqiang Sun[1], Weisheng Hu[1]; [1]*Shanghai 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[1], Xuwei Xue[1], Fulong Yan[1], Fu Wang[1], Eduardo Magalhães[1], Nicola Calabretta[1]; [1]*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 Maier[1], Leila Askari[1], Sebastian Troia[1], Ligia M. Moreira Zorello[1], Francesco Musumeci[1], Massimo Tornatore[1]; [1]*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
Low-latency Federated Reinforcement Learning-based Resource Allocation in Converged Access Networks, Lihua Ruan[1], Sourav Mondal[1], Imali Dias[1], Elaine Wong[1]; [1]*The Univ. of Melbourne, Australia.* We propose a federated reinforcement learning (FedRL) solution to innovate resource allocation in converged access networks. FedRL lowers network latency with reinforcement-learnt bandwidth decision and achieves fast learning with federated learning efforts.

W2A.29
Demonstration of AI-assisted Energy-efficient Traffic Aggregation in 5G Optical Access Network, Luyao Guan[1], Min Zhang[1], Danshi Wang[1]; [1]*Beijing Univ of Posts & Telecom, China.* We propose an AI-assisted energy-efficient traffic aggregation scheme, which is demonstrated in software-defined optical network testbed. The experimental results show proposed scheme can efficiently reduce energy consumption by traffic aggregation according to traffic prediction.

W2A.30
Real-Time Demonstration of 2.4Tbps (200Gbps/λ) Bidirectional Coherent DWDM-PON Enabled by Coherent Nyquist Subcarriers, Amir Rashidinejad[1], An Nguyen[2], Magnus Olson[3], Steven Hand[2], David Welch[2]; [1]*Infinera Canada, Canada;* [2]*Infinera Corporation, USA;* [3]*Infinera Sweden, Sweden.* We demonstrate real-time 2.4Tbps bidirectional coherent DWDM-PON (12λ×200Gbps/λ) 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.31
Nonlinear Pre-Distortion Based on Indirect Learning Architecture and Cross-correlation-enabled Behavioral Modeling for 120-Gbps Multi-mode Optical Interconnects, Chenyu Liang[1], Wenjia Zhang[1], Line Ge[1], Jiangbing Du[1], Zuyuan He[1]; [1]*Shanghai 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, Yukui Yu[1], Tianwai Bo[1], Che Yi[1], Daeho Kim[1], Hoon Kim[1]; [1]*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[1], Shengxiang Zhu[1], Mark M. Filer[1], Christos Gkantsidis[1], Francesca Parmigiani[1], Thomas Karagiannis[1]; [1]*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.

Show Floor Programming

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

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

NOS Keynote
10:30–11:15, *Theater I*

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

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

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

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

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

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

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

NOS Panel II
13:30–15:00, *Theater I*

W2A • Poster Session I—Continued

W2A.34
Laser Diode Chirp Requirements in Wideband Analog Photonic Signal Processing, Farzad M. Koushyar[1], McKay B. Bradford[2], Monireh Moayedi Pour Fard[2], Thien-An Nguyen[2], Sriram Vishwanath[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*GenXComm Inc., USA.* Distortions added to a 150 MHz OFDM signal in a photonic link comprised of a 4-tap filter and a directly modulated laser is simulated to study the laser chirp impact on the link dynamic range.

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

W2A.36
Scalable and Fast Optical Circuit Switch Created with Silicon-photonic Tunable-filter-based Local Oscillator Bank and Colorless Coherent Detection, Ryosuke Matsumoto[1], Takashi Inoue[1], Ryotaro Konoike[1], Hiroyuki Matsuura[1], Keijiro Suzuki[1], Yojiro Mori[2], Kazuhiro Ikeda[1], Shu Namiki[1], Ken-ichi Sato[1]; [1]*AIST, Japan;* [2]*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 475.1-Tbps switch bandwidth (1,856 × 1,856 at 256 Gbps) and switching times under 3.52 µs.

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

W2A.38
81.37-Gbps 2×2 MIMO 60-GHz OFDM-RoF System Employing I/Q Nonlinear Compensation Filtering Algorithm, Zhen-Xiong Xie[1], Bo-Jiun Lin[1], Pin-Xyuan Ding[1], Tsung-Hung Tsai[1], Ping-Yao Huang[1], Chia-Chien Wei[2], Chun-Ting Lin[1]; [1]*National Chiao Tung Univ., Taiwan;* [2]*National Sun Yat-sen Univ., Taiwan.* We demonstrate 2x2 MIMO 60-GHz RoF system with nonlinear compensation. The proposed I/Q Volterra nonlinear compensation not only improves data rate up to 81.37Gbps but also extends wireless distance to 42 meters with data rate of >70Gbps.

W2A.39
52.58-Gbps Fiber-wireless 60-GHz 2×2 MIMO System Integrating Optical Mode Division Multiplexing and Wireless MIMO, Ping-Yao Huang[1], Wei-Ling Li[1], Tsung-Hung Tsai[1], Zhen-Xiong Xie[1], Chun-Ting Lin[1]; [1]*National Chiao Tung Univ., Taiwan.* Optical LP_{01} and LP_{11} mode are utilized to carry 2×2 MIMO signals for 60-GHz wireless signals. The proposed system can achieve data rate of 52.58-Gbps for fiber-wireless system with 5-km FMF and 3-m air link.

W2A.40
Hybrid Fiber-optical/THz-wireless Link Transmission Using Low-cost IM/DD Optics, Francisco M. Rodrigues[1], Ricardo Ferreira[1], Carlos Castro[2], Robert Elschner[2], Thomas Merkle[3], Colja Schubert[2], António Teixeira[4,1]; [1]*PICadvanced S.A., Portugal;* [2]*Fraunhofer Heinrich Hertz Inst., Germany;* [3]*Fraunhofer-Institut für Angewandte Festkörperphysik, Germany;* [4]*Instituto de Telecomunicações, Portugal.* Hybrid fiber-optical/THz wireless transmission of 16 GBd 16-QAM 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.41
Quantum Dash Passively Mode Locked Laser for Optical Heterodyne Millimeter-wave Analog Radio-over-fiber Fronthaul Systems, Amol Delmade[1], Theo Verolet[2,3], Colm Browning[1], Yi Lin[1], Guy Aubin[2], F Lelarge[3,4], Abderrahim Ramdane[2], Liam Barry[1]; [1]*Dublin City Univ., Ireland;* [2]*Centre de Nanosciences et de Nanotechnologies, Université Paris- Sud, Université Paris-Saclay, France;* [3]*III-V Lab, France;* [4]*Almae Technologies, France.* In mm-wave systems, carrier phase noise limits the performance of analog multicarrier signal transmission. Experimental results show the successful use of a passively mode-locked laser with optical feedback in a 60GHz A-RoF heterodyne 25km system.

W2A.42
Delivery of 138.88Gpbs Signal in a RoF Network with Real-time Processing Based on Heterodyne Detection, Can Wang[1], Xinying Li[1], Mingming Zhao[1], Kaihui Wang[1], Jiao Zhang[1], Miao Kong[1], Wen Zhou[1], Jiangnan Xiao[1], Jianjun Yu[1]; [1]*Fudan 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.43
Neural-network-enabled Multivariate Symbol Decision in a 100-Gb/s Complex Direct Modulation System, Di Che[1]; [1]*Nokia Bell Labs, USA.* We reveal a neural network can be exploited for multivariate symbol decision simply by feeding multiple signal features as its inputs. The concept is verified in a digital coherent receiver which detects dual-polarization 25-GBaud directly-modulated PAM-4 signals.

W2A.44
Artificial Neural Network-Based Compensation for Transceiver Nonlinearity in Probabilistic Shaping Systems, Tu T. Nguyen[1], Tingting Zhang[1], Mahmood Abu-Romoh[1], Andrew Ellis[1]; [1]*Aston Univ., UK.* Artificial neural network for transceiver nonlinearity compensation in dual-polarization probabilistically shaped 28 GBaud systems is experimentally investigated with achieved SNR performance gain up to 1 dB.

W2A.45
Cascade Recurrent Neural Network Enabled 100-Gb/s PAM4 Short-reach Optical Link Based on DML, Zhaopeng Xu[1], Chuanbowen Sun[1], Tonghui Ji[1,2], Honglin Ji[1], William Shieh[1]; [1]*Univ. of Melbourne, Australia;* [2]*Univ. of Science and Technology Beijing, China.* A cascade RNN-based equalizer is proposed which outperforms traditional NN-based equalizers for short-reach optical links. A cascade RNN-enabled 100-Gb/s PAM4 link is experimentally demonstrated over 15-km fiber using a 16-GHz DML in C-band.

W2A.46
Experimental Demonstration of C-band 112-Gb/s PAM4 over 20-km SSMF with Joint Pre- and Post-equalization, Xizi Tang[1,2], Yaojun Qiao[1], Gee-Kung Chang[2]; [1]*School of Information and Communication Engineering, Beijing Univ. of Posts and Telecommunications, China;* [2]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA.* We demonstrate C-band 112-Gb/s PAM4 over 20-km transmission with pre- and post-equalization. Pre-filter coarsely pre-compensates system bandwidth at transmitter while FFE-DFE with erasure technology jointly post-compensates residual bandwidth limitation and dispersion-induced power fading at receiver.

W2A.47
DSP-based Mode-dependent Loss and Gain Estimation in Coupled SDM Transmission, Ruby S. Bravo Ospina[1,2], Chigo M. Okonkwo[1], Darli A. Mello[2]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Univ. of Campinas, Brazil.* We model analytically the MDG/MDL estimation process in coupled SDM transmission using equalizer coefficients of coherent receivers. We show that estimation errors can be partially compensated in moderate regimes of SNR and MDL/MDG.

W2A.48
Efficient Echo-cancellation Algorithms for Full Duplex Coherent Optical Systems, Mu Xu[1], Zhensheng Jia[1], Junwen Zhang[1], Haipeng Zhang[1], Luis Alberto Campos[1]; [1]*CableLabs, USA.* A digital echo-cancellation method to identify and mitigate reflection impairments in full duplex coherent optical links is proposed. More-than 6 dB improvements in echo power tolerance are experimentally verified in a 32-GBd full-duplex DP-QPSK link.

W2A.49
Amplifier Considerations in ROADM–free Space–switched Nonlinear Optical Links, Robert J. Vincent[1], David J. Ives[1], Seb J. Savory[1]; [1]*Univ. of Cambridge, UK.* Power fluctuations accumulate in ROADM-free space-switched networks. Thousands of randomized nonlinear transmissions demonstrate that capacity with an inventory of {5,10,15,20}dB gain amplifiers is within 10% of optimal and triple that with {10,20}dB amplifiers over 1,000km.

W2A.50
Real-time Transmission Measurements from 200 Gb/s to 600 Gb/s over Links with Long 122 km Fiber Spans, John D. Downie[1], Jason Hurley[1], Xiaojun Liang[1], James Himmelreich[1], Sergejs Makovejs[2], Donald Govan[3], Giacomo Losio[4]; [1]*Corning Research & Development Corp, USA;* [2]*Corning Incorporated, UK;* [3]*Lumentum, UK;* [4]*Lumentum, Italy.* We present results for real-time coherent transmission with data rates from 200 Gb/s to 600 Gb/s in 50 Gb/s increments over a re-circulating loop with 122 km spans of ultra-low loss, large effective area fiber.

W2A.51
Long-haul and High-speed Key Distribution Based on Oneway Non-dual Arbitrary Basis Transformation in Optical Fiber Link, Chao Lei[1], Jie Zhang[1], Yajie Li[1], Yongli Zhao[1], Bo Wang[1], Hang Gao[1], Junjia Li[1], Mingrui Zhang[1]; [1]*Beijing Univ. of Posts and Telecommunications, China.* We propose a long-haul and high-speed key distribution based on one-way non-dual arbitrary basis transformation in optical fiber link. The key distribution rate of 277 Kbit/s with free key error rate is demonstrated over 300km.

W2A • Poster Session I—Continued

W2A.52
A Method to Separate the Penalties Caused by Various Nonlinear Signal-pump Impairments in Raman Amplified System, Jingnan Li[1], Yangyang Fan[1], Zhenning Tao[1], Tong Ye[1], Hiroyuki Irie[2], Hisao Nakashima[2], Kousuke Komaki[2], Takeshi Hoshida[2]; [1]*Fujitsu R&D Center, China;* [2]*Fujitsu Ltd., Japan.* We separate various nonlinear impairments caused by pump laser RIN in Raman amplified system. Experiment shows that nonlinear polarization scattering has more impact than phase noise does, and the gain fluctuation has the least impact.

W2A.53
On-chip Continuous-variable Quantum Key Distribution(CV-QKD) and Homodyne Detection, Yuan Shen[1], Lin Cao[2,1], Xuyang Wang[1], Jun Zou[1], Wei Luo[1], Yunxiang Wang[1], Hong Cai[3], Bin Dong[4], Xianshu Luo[4], Weijun Fan[1], Leong Chuan Kwek[1], Aiqun Liu[1]; [1]*Nanyang Technological Univ., Singapore;* [2]*Peking Univ., China;* [3]*Institude of Microelectronics, Singapore;* [4]*Advanced Micro Foundry, Singapore.* An on-chip continuous-variable quantum key distribution(CV-QKD) system is integrated using silicon photonics fabrication process and demonstrates the capability of transceiving Gaussian-modulated coherent states and homodyne detection.

W2A.54
Stochastic EXIT Design for Low-latency Short-block LDPC Codes, Toshiaki Koike-Akino[1], David S. Millar[1], Keisuke Kojima[1], Kieran Parsons[1]; [1]*Mitsubishi 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, Shen Li[1], Magnus Karlsson[1], Erik Agrell[1]; [1]*Chalmers Univ. of Technology, Sweden.* We investigate a modified split-step Fourier method (SSFM) by including low-pass filters in the linear steps. This method can simultaneously achieve a higher simulation accuracy and a slightly reduced complexity.

W2A.56
Deployment Opportunities for DPS-QKD in the Co-existence Regime of Lit GPON / NG-PON2 Access Networks, Nemanja Vokic[1], Dinka Milovancev[1], Bernhard Schrenk[1], Michael Hentschel[1], Hannes Hübel[1]; [1]*AIT Austrian Inst. of Technology, Austria.* We demonstrate cost-effective QKD integration for GPON and NG-PON2. Operation at 5.1×10^{-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.

Show Floor Programming Continued

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

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

NOS Keynote
10:30–11:15, *Theater I*

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

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

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

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

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

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

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

NOS Panel II
13:30–15:00, *Theater I*

Room 1B

14:00–16:00
W3A • Neuromorphic III: System-oriented
Presider: Hideaki Furukawa; National Inst of Information & Comm Tech, Japan

W3A.1 • 14:00
Hardware Architecture and Algorithm Co-design for Multi-layer Photonic Neuromorphic Network with Excitable VCSELs-SA, Shuiying Xiang[1,2], Zhenxing Ren[1], Yahui Zhang[1], Xingxing Guo[1], Ziwei Song[1], Aijun Wen[1], Yue Hao[2]; [1]*State Key Laboratory of Integrated Service Networks, Xidian Univ., China;* [2]*State Key Discipline Laboratory of Wide Bandgap Semiconductor Technology, School of Microelectronics, Xidian Univ., China.* We design a multi-layer photonic spiking neural network with excitable VCSELs-SA. Numerical results based on the rate-equation models show that the proposed neuromorphic network architecture is capable of solving the classical XOR problem by supervised-learning.

W3A.2 • 14:15
Wavelength-space Domain High-throughput Artificial Neural Networks by Parallel Photoelectric Matrix Multiplier, Mehmet Berkay On[1], Hongbo Lu[1], Humphry Chen[1], Roberto Proietti[1], S. J. Ben Yoo[1]; [1]*ECE, Univercity of California Davis, USA.* We propose a massively parallel neural network architecture with photonic matrix-vector multiplication in the wavelength and space domains with balanced photodetectors and nonlinear transfer functions in MZI modulators. An experimental proof-of-principle demonstration is also discussed.

W3A.3 • 14:30 Invited
Accelerating Artificial Intelligence with Silicon Photonics, Nicholas Harris[1], Ryan Braid[1], Darius Bunandar[1], Jim Carr[1], Brad Dobbie[1], Carlos Dorta[1], Jonathan Elmhurst[1], Martin Forsythe[1], Michael Gould[1], Shashank Gupta[1], Sukesh Kannan[1], Tyler Kenney[1], Gary Kong[1], Tomo Lazovich[1], Scott McKenzie[1], Carl Ramey[1], Chithira Ravi[1], Michael Scott[1], John Sweeney[1], Ozgur Yildirim[1], Katrina Zhang[1]; [1]*Lightmatter Inc., USA.* As Moore's law and Dennard scaling come to an end, new devices and computing architectures are being explored. The development of computing hardware designed to address the rapidly growing need for computational power to accelerate artificial intelligence applications has prompted investigations into both.

Room 2

14:00–16:00
W3B • Panel: Will SDM Truly Revolutionize the Submarine Communication Industry?

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 submarine 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, 16FPs…). The main effort shifted from maximizing the capacity per FP to maximizing the capacity per cable. During this workshop, experts will discuss the impact on each element of the submarine cable linked to the new SDM cable paradigm and will give their insight on the future of submarine communication.

Topics to cover:

Definition and drivers for SDM cable in subsea cable

SDM cable impacts on subsea cable components

Cable/fiber design: linear vs. non-linear regime

Repeater design: very high power (20+dBm per Fiber Pair) to pump farming (16-18dBm per FPs)

Branching Unit: ROADM unit equipped with WSS vs. FPs switched BU

SLTE: Approaching Shannon limit vs. low cost SLTE

SDM cable impact to subsea network topology: point to point vs. mesh subsea network

Open cable access: managed spectrum vs. managed FP as a granularity

Speakers:

Tim Stronge; *Telegeography, USA*

Massimiliano Salsi; *Google, USA*

Priyanth Mehta; *Ciena, Canda*

Eduardo Mateo; *NEC Corporation, Japan*

Olivier Courtois; *ASN, France*

Masaaki Hirano; *Sumitomo Electric Industries Ltd., Japan*

Stephen Grubb; *Facebook Inc., USA*

Room 6C

14:00–15:45
W3C • Open Network Architecture
Presider: Ramon Casellas; CTTC, Spain

W3C.1 • 14:00
Experimental Demonstration of Service Deployment in Open Packet-optical Networks, Oscar Gonzalez de dios[1], Minoru Yamaguchi[2], Guillermo Pajares Martin[1], Masatoshi Saito[2], Samier Barguil Giraldo[5], Toshihiro Yokoi[2], Alfredo Gonzalez[3], Andrea Campanella[4], Yoshinori Koike[2], Victor Lopez[1], Hiroata Yoshioka[2]; [1]*Telefonica, Spain;* [2]*NTT, Japan;* [3]*Wipro, Spain;* [4]*ONF, Italy;* [5]*UAM, Spain.* Disaggregation breaks conventional closed systems into components connected by open interfaces. This paper shows the experimental demonstration of service provisioning and partial replacement of network OS in a disaggregated open packet and optical converged network based on open interfaces and open source software.

W3C.2 • 14:15
Experimental Validation of an Open Source Quality of Transmission Estimator for Open Optical Networks, Alessio Ferrari[1], Mark M. Filer[2], Karthikeyan Balasubramanian[2], Yawei Yin[2], Esther Lerouzic[3], Jan Kundrát[4], Gert Grammel[5], Gabriele Galimberti[6], Vittorio Curri[1]; [1]*Politecnico di Torino, Italy;* [2]*Microsoft Corp., USA;* [3]*Orange Labs, France;* [4]*CESNET, Czechia;* [5]*Juniper Networks, Germany;* [6]*Cisco Photonics, Italy.* We test the QoT-E of the GNPy library fed by data from the network controller against experimental measurements on mixed-fiber, Raman-amplified, multi-vendor scenarios on the full C-band: an excellent accuracy within 1 dB is shown.

W3C.3 • 14:30 Invited
Demonstration of Joint Operation across Open ROADM Metro Network, OpenFlow Packet Domain, and Open-Stack Compute Domain, Andrea Fumagalli[1], Behzad Mirkhanzadeh[1], Shweta Vachhani[2], Balagangadhar G. Bathula[2], Gilles Thouenon[3], Christophe Betoule[3], Ahmed Triki[3], Martin Birk[2], Olivier Renais[3], Tianliang Zhang[1], Miguel Razo[1], Marco Tacca[1]; [1]*Univ. of Texas at Dallas, USA;* [2]*AT&T Labs, USA;* [3]*Orange Labs, France.* Progress on the recent implementation of OpenROADM MSA functionalities is reported along with a description of the related TransportPCE SDN controller and PROnet multi-domain resource orchestrator software modules. These functionalities enable the described use cases.

Room 6D

14:00–16:00
W3D • High-speed Transmission
Presider: Timo Pfau; Acacia Communications, Inc., USA

W3D.1 • 14:00 ★ Top-Scored
Demodulation of Eigenvalue Modulated Signal Based on Eigenvalue-domain Neural Network, Ken Mishina[1], Shingo Sato[1], Shohei Yamamoto[1], Yuki Yoshida[2,1], Daisuke Hisano[1], Akihiro Maruta[1]; [1]*Graduate School of Engineering, Osaka Univ., Japan;* [2]*National Inst. of Information and Communications Technology, Japan.* A demodulation scheme for an eigenvalue modulated signal based on an eigenvalue-domain neural network is demonstrated experimentally. Successful demodulation is demonstrated at 2.5 Gb/s over a transmission distance of up to 3,000 km.

W3D.2 • 14:15
Neural Network-based Soft-demapping for Nonlinear Channels, Maximilian Schaedler[1,2], Stefano Calabro[1], Fabio Pittalà[1], Christian Bluemm[1], Maxim Kuschnerov[1], Stephan Pachnicke[2]; [1]*Huawei Munich Research Center, Germany;* [2]*Chair of Communications, Kiel Univ. (CAU), Germany.* Conventional soft demappers designed for AWGN channels suffer from performance loss under realistic channels. We propose a neural network soft demapper and show a gain of 0.35dB in an 800Gb/s coherent transmission experiment using DP-32QAM.

W3D.3 • 14:30 Invited
Model-Based Machine Learning for Joint Digital Backpropagation and PMD Compensation, Christian Häger[1], Henry D. Pfister[2], Rick M. Bütler[3], Gabriele Liga[3], Alex Alvarado[3]; [1]*Chalmers Tekniska Hogskola, Sweden;* [2]*Duke Univ., USA;* [3]*Eindhoven Univ. of Technology, Netherlands.* We propose a model-based machine-learning approach for polarization-multiplexed systems by parameterizing the split-step method for the Manakov-PMD equation. This approach performs hardware-friendly DBP and distributed PMD compensation with performance close to the PMD-free case.

Room 6E

14:00–16:00
W3E • Ultra-wideband Transmission
Presider: Johannes Fischer; Fraunhofer Heinrich-Hertz-Institut, Germany

W3E.1 • 14:00 Tutorial

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

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

Room 6F

14:00–16:00
W3F • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 1)

W3F.1 • 14:00 Invited

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

W3F.2 • 14:20 Invited

Title to be Announced, Chris Doerr[1]; [1]*Acacia Communications Inc., USA*. Abstract not available.

W3F.3 • 14:40 Invited

Physics Side of Silicon/Nanophotonics, Michal Lipson[1]; [1]*Columbia Univ., USA*. Abstract not available.

Room 7

14:00–16:00
W3G • Datacentre Infrastructure and Metrology
Presider: Yue-Kai Huang; NEC Laboratories America Inc, USA

W3G.1 • 14:00 Invited

More Than Communications: Environment Monitoring Using Existing Optical Fiber Network Infrastructure, Yoshiaki Aono[1], Ezra Ip[2], Philip Ji[2]; [1]*NEC Corporation, Japan;* [2]*Optical Networking and Sensing, NEC Laboratories America, USA*. We propose reusing existing optical cables in metropolitan networks for distributed sensing using a bidirectional, dual-band architecture where communications and sensing signals can coexist with weak interaction on the same optical fiber.

W3G.2 • 14:30

Automated Thermal Drift Compensation in WDM-based Silicon Photonic Multi-Socket Interconnect Systems, Miltiadis Moralis-Pegios[1], Francesco Zanetto[2], Emanuele Guglielmi[2], Vittorio Grimaldi[2], Konstantinos Fotiadis[1], Stelios Pitris[1], Theoni Alexoudi[1], Peter De Heyn[3], Yoojin Ban[3], Joris Van Campenhout[3], Douglas Aguiar[2], Giorgio Ferrari[2], Marco Sampietro[2], Andrea Melloni[2], Nikos Pleros[1]; [1]*Aristoteleio Panepistimio Thessalonikis, Greece;* [2]*Dipartimento di Elettronica Informazione e Bioingegneria, Politecnico di Milano, Italy;* [3]*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.

Show Floor Programming Continued

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

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

NOS Panel II
13:30–15:00, *Theater I*

Product Showcases
14:30–15:30, *Theater III*

Room 1B	Room 2	Room 6C	Room 6D

W3A • Neuromorphic III: System-oriented—Continued

W3A.4 • 15:00

Intelligent Computing with Photonic Memories, Mario Miscuglio[1], Jiawei Meng[1], Volker Sorger[1], Ludmila J. Prokopeva[2,4], Yifei Zhang[3], Omer Yesiliurt[2,4], Armin Mehrabian[1], Juejun Hu[3], Alexander Kildishev[2,4]; [1]*George Washington Univ., USA;* [2]*Birck Nanotechnology Center, USA;* [3]*Department of Materials Science & Engineering, Massachusetts Inst. of Technology, USA;* [4]*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 $Ge_2Sb_2Se_4Te_1$-silicon Mach-Zehnder modulator photonic memory with thermoelectrical programmability. The network can effortlessly perform inference with high accuracy at the speed-of-light.

W3A.5 • 15:15

All-optical Recurrent Neural Network with Sigmoid Activation Function, George Mourgias-Alexandris[1], George Dabos[1], Nikolaos Passalis[1], Anastasios Tefas[1], Angelina Totovic[1], Nikos Pleros[1]; [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 100psec pulses. The proposed neuron geared up a neural-network for financial prediction-tasks exhibiting an accuracy of 42.57% on FI-2010.

W3A.6 • 15:30

Interferometer-based Photonic Circuit Classifier Showing >90% Accuracy for Well-known Iris Dataset without Utilizing Nonlinear Activation Function, Guangwei Cong[1], Noritsugu Yamamoto[1], Takashi Inoue[1], Yuriko Maegami[1], Morifumi Ohno[1], Makoto Okano[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

W3C • Open Network Architecture—Continued

W3C.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.

W3C.5 • 15:15 Invited

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.

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[3], Erik Agrell[3]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*School of Computer Science and Information Engineering, Hefei Univ. of Technology, China;* [3]*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

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.

W3D.6 • 15:30 ★ Top-Scored

All Silicon IQ Modulator with 1Tb/s Line Rate, Sasan Zhalehpour[1,2], Mengqi Guo[3], Jiachuan Lin[4], Zhuhong Zhang[4], Yaojun Qiao[3], Wei Shi[1,2], Leslie Rusch[1,2]; [1]*ECE Dept., Univ. Laval, Canada;* [2]*COPL, 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.

Room 6E

W3E • Ultra-wideband Transmission—Continued

W3E.2 • 15:00 Invited

Candidate Technologies for Ultra-wideband Nonlinear Optical Fibre Transmission System, Lidia Galdino[1], Daniel Semrau[1], Polina Bayvel[1]; [1]*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.

W3E.3 • 15:30

Comparative Investigations between SSMF and Hollow-core NANF for Transmission in the S+C+L-bands, Yang Hong[1], Thomas Bradley[1], Natsupa Taengnoi[1], Kyle Bottrill[1], John Hayes[1], Gregory Jasion[1], Hans Mulvad[1], Francesco Poletti[1], Periklis Petropoulos[1], David Richardson[1]; [1]*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.

Room 6F

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

W3F.4 • 15:00 Invited

Indium Phosphide Photonic Integrated Circuits, Meint Smit[1], K. A. Williams; [1]*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.

W3F.5 • 15:20 Invited

Computation with Optical Oscillator Networks, Hiroki Takesue[1]; [1]*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.

W3F.6 • 15:40 Invited

Title to be Announced, Peter Winzer[1]; [1]*Independent Consultant, USA.* Abstract not available.

Room 7

W3G • Datacentre Infrastructure and Metrology—Continued

W3G.3 • 14:45

BER and TDECQ Correlation for Different Impairments in 400Gbps PAM4 system, Ying Zhao[1], Chris Doerr[1], Li Chen[1], Ninghui Zhu[1], Dinh Ton[1], Ricardo Aroca[1], Xue Huang[1], Michelle Xu[1]; [1]*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[1], Munehiko Nagatani[1], Shigeru Kanazawa[2], Kota Shikama[1], Takuro Fujii[1], Hidetaka Nishi[1], Hiroshi Yamazaki[1], Norio Sato[1], Hideyuki Nosaka[1], Shinji Matsuo[1]; [1]*NTT Device Technology Laboratories, Japan;* [2]*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-Gps PAM4 transmission over 2-km-long SSMF with power efficiency of 0.57 mW/Gbps.

W3G.5 • 15:15 Invited

The Role of Optics In Future AI-driven Intra-DC Infrastructure, Brad Booth[1]; [1]*Microsoft Corp, USA.* The next generation of artificial intelligence and machine learning requires the ability to connect multiple nodes across an ever-increasing scale. This growth is driving an increased role of optics to build these next generation system.

Show Floor Programming Continued

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

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

NOS Panel II
13:30–15:00, *Theater I*

Product Showcases
14:30–15:30, *Theater III*

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*

Room 1B	Room 2	Room 6C	Room 6D

W3A • Neuromorphic III: System-oriented—Continued

W3A.7 • 15:45
Demonstration of Multi-channel Feedback Control for On-chip Microring Weight Banks, Chaoran Huang[1], Simon Bilodeau[1], Thomas Ferreira de Lima[1], Alexander Tait[1], Philip Ma[1], Eric Blow[1], Aashu Jha[1], Hsuan-Tung Peng[1], Bhavin J. Shastri[1], Paul Prucnal[1]; [1]*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.

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

W3C • Open Network Architecture—Continued

W3D • High-speed Transmission—Continued

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

Room 6E

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. Iqbal[1], Lukasz Krzczanowicz[1], Ian Phillips[1], Paul Harper[1], Wladek Forysiak[1]; [1]*Aston 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.

Room 6F

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

Room 7

W3G • Datacentre Infrastructure and Metrology—Continued

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

Show Floor Programming 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*

Room 2

16:30–18:30
W4A • Digital Signal Processing II
Presider: Dan Sadot; Ben Gurion Univ. of the Negev, Israel

W4A.1 • 16:30
Spectrally Slicing Coherent Optical Spectrum Analyzer for Measuring Complex Field Waveforms of Optical QAM Signals, Yasuhiro Kawabata[1], Naoki Urakawa[1], Kotaro Kinoshita[1], Koji Igarashi[1]; [1]*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[1], Toshimasa Umezawa[1], Atsushi Kanno[1], Keizo Inagaki[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Waseda Univ., Japan.* Sample complexity, or equivalently the required number of photodetectors, of a carrier-less phase-retrieving coherent receiver is investigated numerically based on the experimental data; it can achieve comparable complexity to conventional coherent receivers.

W4A.3 • 17:00
Field Recovery at Low CSPR Using Interleaved Carrier Assisted Differential Detection, Tonghui Ji[1,2], Chuanbowen Sun[1], Honglin Ji[1], Zhaopeng Xu[1], William Shieh[1]; [1]*The Univ. of Melbourne, Australia;* [2]*Univ. of Science and Technology Beijing, China.* We propose an interleaved subcarrier loading scheme for double-sideband signals to relax the high CSPR requirement for self-coherent detection systems. Experimental result demonstrates a successful 100-Gb/s OFDM signal transmission over 160-km SSMF at 3.5-dB CSPR.

W4A.4 • 17:15
WDM Operation and Multiple Dispersion Elements for a Direct-detection System using Phase Retrieval, Huibin Zhou[1], Kaiheng Zou[1], Peicheng Liao[1], Ahmed Almaiman[1,2], Fatemeh Alishahi[1], Ahmad Falahpour[1], Amir Minoofar[1], Moshe Tur[3], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*King Saud Univ., Saudi Arabia;* [3]*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.

Room 6C

16:30–18:30
W4B • Nonlinear Devices & Amplifiers
Presider: Francesca Parmigiani; Microsoft Research Ltd, UK

W4B.1 • 16:30
Time-wavelength-mode Equalization by PSO for Random Fiber Laser Based FMF Raman Amplifier, Yufeng Chen[1], Jiangbing Du[1], Jiaxiong Li[1], Lei Shen[2], Jie Luo[2], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Yangtze Optical Fibre and Cable Joint Stock Limited Company, China.* We report an FMF Raman amplifier based on random fiber laser with optimized timewavelength-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.

W4B.2 • 16:45
Evaluation of Performance Penalty from Pump-signal Overlap in S+C+L Band Discrete Raman Amplifiers, Md A. Iqbal[1], Lukasz Krzczanowicz[1], Ian Phillips[1], Paul Harper[1], Wladek Forysiak[1]; [1]*Aston Univ., UK.* We experimentally investigate the transmission penalty on 30GBaud PM-QPSK signals due to adjacent Raman pumps in a 15dB gain, 150nm S+C+L-band discrete Raman amplifier. We report 4nm guard-band around the Raman pump ensures negligible Q^2-penalty.

W4B.3 • 17:00
Comparison of Erbium, Raman and Parametric Optical Fiber Amplifiers for Burst Traffic in Extended PON, Chandra Bhanu Gaur[1], Filipe Ferreira[1], Vladimir Gordeinko[1], Md A. Iqbal[1], Wladek Forysiak[1], Nick Doran[1]; [1]*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.

W4B.4 • 17:15
Noise Figure Evaluation of Polarization-insensitive Single-pump Fiber Optical Parametric Amplifiers, Vladimir Gordienko[1], Filipe Ferreira[1], Charles Laperle[2], Maurice O'Sullivan[2], Chandra Bhanu Gaur[1], Kim Roberts[2], Nick Doran[1]; [1]*Aston Univ., UK;* [2]*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.

Room 6D

16:30–18:30
W4C • Novel Passive Devices
Presider: Yuqing Jiao; Technische Universiteit Eindhoven, Netherlands

W4C.1 • 16:30 Invited
Topological Photonics in Integrated Waveguide, Xin-Tao He[1], Meng-Yu Li[1], Hao-Yang Qiu[1], Xiao-Dong Chen[1], Jian-wen Dong[1]; [1]*Sun Yat-sen Univ., China.* In this talk, we will show our recent works about exploration of valley photonic crystal waveguides towards the discovery of topological integrated photonics, particular for the silicon-on-insulator slab in telecommunication wavelength.

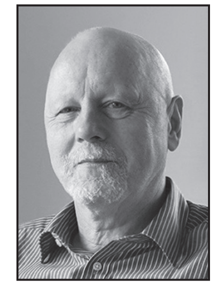
W4C.2 • 17:00
Ultra-compact and Broadband Silicon Two-mode Multiplexer Based on Asymmetric Shallow Etching on a Multi-mode Interferometer, Zhen Wang[1], Chunhui Yao[1], Yong Zhang[1], Yikai Su[1]; [1]*Shanghai Jiao Tong Univ., China.* We present a silicon two-mode multiplexer with a footprint of 1.5×7.24 μm². The operation principle is based on simultaneous multi-mode conversion. In the wavelength range of 1521nm~1571nm, the crosstalk is below –15 dB.

W4C.3 • 17:15
A Metalens Array on a 12-inch Glass Wafer for Optical Dot Projection, Ting Hu[1], Qize Zhong[1], Nanxi Li[1], Yuan Dong[1], Zhengji Xu[1], Dongdong Li[1], Yuan Hsing Fu[1], Yanyan Zhou[1], Keng Heng Lai[1], Vladimir Bliznetsov[1], Hou-Jang Lee[1], Wei Loong Loh[1], Shiyang Zhu[1], Qunying Lin[1], Navab Singh[1]; [1]*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.

Room 6E

16:30–18:30
W4D • Speciality Fibers
Presider: Eric Numkam Fokoua; University of Southampton, UK

W4D.1 • 16:30 Tutorial
Recent Developments in Photonic Crystal Fibre, Philip S. Russell[1]; [1]*Max-Planck-Inst Physik des Lichts, Germany.* The tutorial will cover a selection of recent developments, including GHz optoacoustic mode-locking, the properties of chiral PCF, and gas-filled hollow core PCF for pulse compression and generation of UV light at multi-MHz repetition rates.



Philip Russell is based at the MPI for the Science of Light and the University of Erlangen-Nuremberg. Among his awards include the 2005 Körber Prize for European Science, the 2013 EPS Light Prize, the 2014 Berthold Leibinger Zukunftspreis, the 2015 IEEE Photonics Award and the 2018 Rank Prize Optoelectronics Prize.

Room 6F

16:30–18:30
W4E • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)

W4E.1 • 16:30 Invited

Coherent Communication: Cost per Bit, Kim Roberts[1]; [1]*WaveLogic Science, Ciena, Canada.* Digital coherent optical transmission enabled a dramatic lowering of the cost per bit in high capacity links. It is time for the next revolution! The (admittedly meager) set of candidates will be examined to see what might break through the pack of evolutionary cost improvements and launch us in a new direction.

W4E.2 • 16:50 Invited

Technology Evolution and Capacity Growth in Undersea Cables, Alexei N. Pilipetskii[1], Georg Mohs[1]; *SubCom, USA.* We examine the technology evolution that fueled exponential cable capacity growth over the last decades. We are at a critical point when transmission technology is mature and approaching fundamental limits. What is the path forward?

W4E.3 • 17:10 Invited

5G Optical Transport Network, Chih-Lin I[1]; [1]*China Mobile Communications Group, China.* Abstract not available.

Room 7

16:30–18:30
W4F • Reliability and Test
Presider: Kenneth Jackson; Sumitomo Elec Device Innov USA, USA

W4F.1 • 16:30 Tutorial

Reliability Qualification and Failure Mechanisms for Semiconductor Lasers and Fiber Optic Transceivers, Robert Herrick[1]; [1]*Intel Corporation, USA.* In this tutorial, we will cover 3 topics: reliability qualification of fiber-optic transceivers, reliability testing of semiconductor lasers, and failure analysis and failure mechanisms in optoelectronics.

Robert Herrick is responsible for laser reliability at Intel's Silicon Photonic Product Division, and has worked for Intel since 2013. After obtaining an MSEE 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.

Room 8

16:30–18:30
W4G • Photodetectors and Receivers
Presider: Dong Pan; Sifotonics, USA

W4G.1 • 16:30

Heterogeneous Photodiodes on Silicon Nitride Waveguides with 20 GHz Bandwidth, Qianhuan Yu[1], Junyi Gao[1], Nan Ye[1], Boheng Chen[1], Keye Sun[1], Linli Xie[1], Kartik Srinivasan[2], Michael Zervas[3], Gabriele Navickaite[3], Michael Geiselmann[3], Andreas Beling[1]; [1]*Univ. of Virginia, USA;* [2]*Microsystems and Nanotechnology Division, National Inst. of Standards and Technology, USA;* [3]*LIGENTEC, Switzerland.* We demonstrate InGaAs/InP modified uni-traveling carrier photodiodes on Si_3N_4 waveguides with 20 GHz bandwidth and record-high external (internal) responsivities of 0.8 A/W (0.94 A/W) and 0.33 A/W (0.83 A/W) at 1550 nm and 1064 nm, respectively. Balanced photodiodes have 10 GHz bandwidth.

W4G.2 • 16:45

Si-waveguide-coupled Membrane InGaAsP-multiple-quantum-well Photodetector with Large Bandwidth at High Optical Input Power, Yoshiho Maeda[1], Tatsurou Hiraki[1], Takuma Aihara[1], Takuro Fujii[1], Koji Takeda[1], Tai Tsuchizawa[1], Shinji Matsuo[1]; [1]*NTT Device Technology Laboratory, Japan.* A Si-waveguide coupled membrane photodetector (PD) with an InGaAsP multiple-quantum-well absorption layer shows a fiber-to-PD responsivity of 0.4 A/W and bandwidth over 20 GHz at a fiber input power up to +5 dBm.

W4G.3 • 17:00

Monolithic Germanium PIN Waveguide Photodetector Operating at 2 µm Wavelengths, Ziqiang Zhao[1], Chongpei Ho[1], Qiang Li[1], Kasidit Toprasertpong[1], Shinichi Takagi[1], Mitsuru Takenaka[1]; [1]*Univ. of Tokyo, Japan.* We demonstrated Ge PIN waveguide photodetector operating at 2 µm wavelengths monolithically integrated on Ge-on-insulator platform. Despite at sub-bandgap wavelength, 500-µm-long photodetector exhibited 0.25 A/W responsivity at -5 V, attributable to the defect-mediated detection mechanism.

W4G.4 • 17:15

Coherent Homodyne TDMA Receiver Based on TO-can EML for 10 Gb/s OOK with <40 ns Guard Interval, Bernhard Schrenk[1], Dinka Milovancev[1], Nemanja Vokic[1], Fotini Karinou[2]; [1]*AIT Austrian Inst. of Technology, Austria;* [2]*Microsoft Research Ltd., UK.* Graceful migration of an IM/DD transmitter towards a single-polarization, analogue coherent burst-mode receiver is experimentally demonstrated for 10 Gb/s on-off keying in TDMA mode, with 400 kHz frame rate and <40 ns guard interval.

Show Floor Programming Continued

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*

Wednesday, 11 March

Room 2

W4A • Digital Signal Processing II—Continued

W4A.5 • 17:30 Top-Scored

Mode-Multiplexed Full-Field Reconstruction Using Direct and Phase Retrieval Detection, Haoshuo Chen[1], Juan Carlos Alvarado Zacarias[1,2], Hanzi Huang[1,3], Nicolas K. Fontaine[1], Roland Ryf[1], David Neilson[1], Rodrigo Amezcua Correa[2]; [1]*Nokia Bell Labs, USA;* [2]*CREOL, The Univ. of Central Florida, USA;* [3]*Key lab of Specialty Fiber Optics and Optical Access Networks, Shanghai Univ., China.* We realize mode-multiplexed full-field reconstruction over six-spatial-and-polarization modes after 30-km 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.

W4A.6 • 17:45

Mitigation of Inter-subcarrier Linear Crosstalk with Groupwise Fixed FDE Assisted MIMO, Masaki Sato[1], Hidemi Noguchi[1], Junichiro Matsui[2], Jun'ichi Abe[1], Naoto Ishii[1], Emmanuel Le Taillandier de Gabory[1]; [1]*System Platform Research Laboratories, NEC Corporation, Japan;* [2]*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.

W4A.7 • 18:00 Invited

Nonlinear Frequency Division Multiplexing: Immune to Nonlinearity but Oversensitive to Noise?, Stella Civelli[1,2], Enrico Forestieri[1,2], Marco Secondini[1,2]; [1]*Inst. of Communication, Information and Perception Technologies, Scuola Superiore Sant'Anna, Italy;* [2]*Photonic Networks & Technologies National Laboratory, National, Inter-Univ. Consortium for Telecommunications, Italy.* Detection strategies and modulation formats designed for the AWGN channel are not well suited to operate in the nonlinear frequency domain. We study some improved detection strategies and investigate the ultimate performance limitations of NFDM systems that map conventional linear modulations on the nonlinear spectrum.

Room 6C

W4B • Nonlinear Devices & Amplifiers—Continued

W4B.5 • 17:30

Weakly-coupled Few-mode Gain-flattening Filter Using Long-period Fiber Grating in Double-cladding FMF, Jinglong Zhu[1], Yu Yang[1], Junchi Jia[1], Jin He[2], Zhangyuan Chen[1,2], Yongqi He[1], Juhao Li[1,2]; [1]*Peking Univ., China;* [2]*Peking Univ. Shenzhen Institution, 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.

W4B.6 • 17:45

Differential Modal Gain Reduction Using a Void Inscribed in a Two-mode-erbium Doped Fiber, Yoko Yamashita[1], Takashi Matsui[1], Masaki Wada[1], Shinichi Aozasa[1], Taiji Sakamoto[1], Kazuhide Nakajima[1]; [1]*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.

W4B.7 • 18:00

Strongly Coupled Few-mode Erbium-doped Fiber Amplifiers with Ultralow Differential Modal Gain, Yaping Liu[1], Xutao Wang[1], Zhiqun Yang[1], Lin Zhang[1], Guifang Li[2]; [1]*Tianjin Univ., China;* [2]*CREOL, USA.* We propose new few-mode EDFAs based on strong mode coupling, which can be realized by distributed long-period gratings. As a result, an ultralow differential modal gain of 0.5 dB can be achieved with layered doping.

Room 6D

W4C • Novel Passive Devices—Continued

W4C.4 • 17:30

Demonstration of an Ultra-compact Bend for Four Modes Based on Pixelated Meta-structure, Hucheng Xie[2], Yingjie Liu[2], Wenxiang Li[2], Jiangbing Du[1], Yong Yao[2], Qinghai Song[2], Ke Xu[2]; [1]*State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., Shanghai, China;* [2]*Harbin Inst. of Technology (Shenzhen), China.* A multimode bend for TE_0, TE_1, TE_2 and TE_3 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.

W4C.5 • 17:45

Ultrabroadband Polarization Insensitive Hybrid Using Multiplane Light Conversion, Nicolas K. Fontaine[2], Yuanhang Zhang[1,2], Haoshuo Chen[2], Roland Ryf[2], David Neilson[2], Guifang Li[1], Mark Cappuzzo[3], Rose Kopf[3], Al Tate[3], Hugo Safar[3], Cristian Bolle[3], Mark Earnshaw[3], Joel Carpenter[4]; [1]*Univ. of Central Florida, CREOL, USA;* [2]*Nokia Bell Labs, USA;* [3]*Nokia Bell Labs, USA;* [4]*The Univ. of Queensland, Australia.* We designed, fabricated and tested an optical hybrid that supports an octave of bandwidth (900-1800 nm) and below 4-dB insertion loss using multiplane light conversion. Measured phase errors are below 3° across a measurement bandwidth of 390 nm.

W4C.6 • 18:00 Invited

Integrated Quantum Photonics on Silicon Platform, Yunhong Ding[1,2], Daniel Llewellyn[3], Imad Faruque[3], Stefano Paesani[3], Davide Bacco[1,2], Karsten Rottwitt[1,2], Anthony Laing[3], Mark Thompson[3], Jianwei Wang[4], Leif Oxenløwe[1,2]; [1]*Department of Photonics Engineering, Danmarks Tekniske Universitet, Denmark;* [2]*Center for Silicon Photonics for Optical Communication (SPOC), Technical Univ. of Denmark, Denmark;* [3]*H. H. Wills Physics Laboratory and Department of Electrical and Electronic Engineering, Univ. of Bristol, UK;* [4]*State Key Laboratory for Mesoscopic Physics and Collaborative Innovation Center of Quantum Matter, School of Physics, Peking Univ., China.* We present our recent study on silicon integrated quantum photonics, from single photon sources to applications of quantum communication, generation and manipulation of high-dimensional quantum entanglement states, and sampling of quantum state of light.

Room 6E

W4D • Speciality Fibers—Continued

W4D.2 • 17:30

25 Gb/s Transmission Over 1-km Graded-Index Single-mode Fiber Using 910 nm SM VCSEL, Adrian A. Juarez[1], Xin Chen[1], Kangmei Li[1], James Himmelreich[1], Jason Hurley[1], Snigdharaj Mishra[1], Christian Fiebig[4], Gunter Larisch[3], Dieter Bimberg[3,2], Ming-Jun Li[1]; [1]*Corning Inc., USA;* [2]*Institude of Solid State Physics, Technische Universtität Berlin, Germany;* [3]*Bimberg Chinese-German Center for Green Photonics, China;* [4]*Advanced Optical Technologies, Corning Optical Communications GmbH and Co. KG, Germany.* We investigate experimentally the feasibility of single-mode VCSEL transmission at 910 nm over a graded-index single-mode fiber and achieve a BER < 10^{-12} for a transmission distance of 1-km at 25 Gb/s.

W4D.3 • 17:45

Low Loss, Large Bandwidth Antiresonant Hollow-core Fiber Design for Short-Reach Links, William Shere[1], Gregory Jasion[1], Eric Numkam Fokoua[1], Francesco Poletti[1]; [1]*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 lower loss and twice as wide bandwidths than solid, multi-mode, graded index fibres are possible.

W4D.4 • 18:00 Invited

Single-mode VCSEL Transmission Over Graded-index Single-mode Fiber Around 850 nm, Ming-Jun Li[1], Kangmei Li[1], Xin Chen[1], Snigdharaj Mishra[1], Adrian A. Juarez[1], Jason Hurley[1], Jeff Stone[1]; [1]*Corning Incorporated, USA.* We discuss fiber designs of graded-index profile single-mode fiber for both 1310 nm single-mode transmission and 850 nm few-mode transmission and present fiber characterization and system transmission performance results using a single-mode VCSEL.

Room 6F

W4E • Special Chairs Session: Vision 2030: Taking Optical Communications through the Next Decade (Session 2)—Continued

W4E.4 • 17:30

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.

W4E.5 • 17:50

Choice of Optical Access Innovations to Meet Today's Needs and Support the Challenges of Tomorrow, Philippe Chanclou[1], Luiz Anet Neto[1], Gaël Simon[1], Fabienne Saliou[1], Nicolas Neyret[1], Erick Thily[1], Daniel Abgrall[1], David Minodier[1]; *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.

W4E.6 • 18:10

Title to be Announced, Hong Liu, *Google, USA*. Abstract not available.

Room 7

W4F • Reliability and Test—Continued

W4F.2 • 17:30 Invited

Effects of Reflow Soldering Process Conditions on the Reliability of Specialty Optical Fibers, Mei Wen[1], Ralph Lago[1], Jie Li[1]; [1]*OFS, USA*. We will review the reliability of specialty optical fibers for high temperature uses with an emphasis on fibers through reflow soldering process conditions. Coating thermal stability, fiber mechanical properties, and induced optical loss will be discussed.

W4F.3 • 18:00

TDECQ Sensitivity to Algorithmic Implementation and Noise Characterization, Varghese A. Thomas[1], Alirio Melgar[1], Siddharth Varughese[1], Daniel Garon[1], Kan Tan[2], Shane Hazzard[2], Maria Agoston[2], Pavel Zivny[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Tektronix, 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.

W4F.4 • 18:15

Accelerating TDECQ Assessments using Convolutional Neural Networks, Siddharth Varughese[1], Daniel Garon[1], Alirio Melgar[1], Varghese A. Thomas[1], Pavel Zivny[2], Shane Hazzard[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Tektronix Incorporated, USA*. We experimentally demonstrate the use of convolutional neural networks to accelerate TDECQ assessments for 400G direct-detect transmitter qualification. The method estimates TDECQ from static eye-diagrams ~1000 times faster than conventional methods with <0.25dB mean discrepancy.

Room 8

W4G • Photodetectors and Receivers—Continued

W4G.5 • 17:30

Uni-Traveling Carrier Photodiodes with Type-II $GaAs_{0.5}Sb_{0.5}/In_{0.53}Ga_{0.47}As$ Hybrid Absorbers Integrated with Substrate Lens in 400 Gbit/sec DR-4 System, None Naseem[1], Hsiang-Szu Chang[2], Rui-Lin Chao[1,3], Jack Jia-Sheng Huang[2,4], Yu-Heng Jan[2,4], H.-S. Chen[2], C.-J. Ni[2], Emin Chou[2], Jin-Wei Shi[1]; [1]*National Central Univ., Taiwan;* [2]*Source Photonics, Taiwan;* [3]*Department of Photonics, National Chiao Tung Univ., Taiwan;* [4]*Source Photonics, USA*. UTC-PD with type-II $GaAs_{0.5}Sb_{0.5}/In_{0.53}Ga_{0.47}As$ 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.

W4G.6 • 17:45

Zero-bias High-Speed Evanescently Coupled Waveguide Type-II UTC Photodiode, Fengxin Yu[1], Keye Sun[1], Qianhuan Yu[1], Andreas Beling[1]; [1]*Univ. of Virginia, USA*. We demonstrate $GaAs_{0.5}Sb_{0.5}/In_{0.53}Al_yGa_{0.47-y}As$ uni-traveling carrier (UTC) waveguide photodiodes with high bandwidth of up to 66 GHz at zero bias and over 100 GHz bandwidth under low bias condition.

W4G.7 • 18:00

Highly Sensitive 56 Gbps NRZ O-band BiCMOS-Silicon Photonics Receiver using a Ge/Si Avalanche Photodiode, Srinivasan Ashwyn Srinivasan[1], Joris Lambrecht[2], Mathias Berciano[1], Sebastien Lardenois[1], Philippe Absil[1], Johan Bauwelinck[2], Xin Yin[2], Marianna Pantouvaki[1], Joris Van Campenhout[1]; [1]*imec, Belgium;* [2]*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.

W4G.8 • 18:15

64Gbps PAM4 Modulation for a Low Energy SiGe Waveguide APD with Distributed Bragg Reflectors, Zhihong Huang[1], Binhao Wang[1], Yuan Yuan[1,2], Di Liang[1], Marco Fiorentino[1], Raymond Beausoleil[1]; [1]*Hewlett Packard laboratories, USA;* [2]*Univ. of Virginia, USA*. We demonstrate a low-voltage waveguide Si-Ge APD that integrates a distributed Bragg reflector (DBR). Quantum efficiency has been improved from 60\% to 90\% at 1550nm while still achieving a 25GHz bandwidth. The device under 64Gbps PAM4 modulation showed 30\% increase in OMA, which enables 1.2dB improvement in receiver sensitivity.

Show Floor Programming

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00 Th1A • Advanced Design for Passive Devices

Presider: Nicolas Dupuis; IBM TJ Watson Research Center, USA

Th1A.1 • 08:00
Generative Deep Learning Model for a Multi-level Nano-optic Broadband Power Splitter, Yingheng Tang[1,2], Keisuke Kojima[1], Toshiaki Koike-Akino[1], Ye Wang[1], Pengxiang Wu[1], Mohammad H. Tahersima[1], Devesh Jha[1], Kieran Parsons[1], Minghao Qi[2]; [1]*Mitsubishi Electric Research Laboratories, USA;* [2]*School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue Univ., USA.* A novel Conditional Variational Autoencoder (CVAE) model with the adversarial censoring is presented to help to generate the 550nm broad bandwidth (1250nm to 1800nm) power splitter with arbitrary splitting ratio.

Th1A.2 • 08:15
Demonstration of 3+/-0.12dB Power Splitting over 145nm Optical Bandwidth in a 31-um Long 3-dB Rapid Adiabatic Coupler, Josep Fargas Cabanillas[1], Miloš A. Popović[1], Bohan Zhang[1]; [1]*Boston Univ., USA.* We experimentally validate the rapid adiabatic coupling (RAC) concept and demonstrate 50+/-1.4% (3+/-0.12dB) power splitting over a record 145nm bandwidth from either port of a 31um-long, 2x2 coupler, the widest +/-1.4%-bandwidth by a factor of 4.

08:00–10:00 Th1B • High Speed PON

Presider: Xinying Li; Corning Inc, USA

Th1B.1 • 08:00
100 Gbps PON L-band Downstream Transmission Using IQ-MZM CD Digital Pre-Compensation and DD ONU receiver, Pablo Torres-Ferrera[1], Valter Ferrero[1], Roberto Gaudino[1]; [1]*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.

Th1B.2 • 08:15 Invited
IEEE 50 Gb/s EPON (50G-EPON), Curtis Knittle[1]; [1]*CableLabs, USA.* This paper discusses the next generation of IEEE optical access, the 50 Gb/s Ethernet Passive Optical Network (50G-EPON), capable of symmetric or asymmetric rates up to 50 Gb/s while coexisting with legacy PON technologies on the same optical distribution network.

08:00–10:00 Th1C • Microwave Photonics

Presider: Maurizio Burla; ETH Zurich, Switzerland

Th1C.1 • 08:00 Invited
Low-loss LiNbO3 for MWP, Marko Loncar[1]; [1]*Harvard Univ., USA.* Abstract not available.

08:00–10:00 Th1D • Pushing the Bit-rate in Practical Networks

Presider: Shuto Yamamoto; NTT Electronics Corp, Japan

Th1D.1 • 08:00 Invited
Real-time Demonstration of 500-Gbps/lambda and 600-Gbps/lambda WDM Transmission on Field-installed Fibers, Hideki Maeda[1], Hiroki Kawahara[1], Kohei Saito[1], Takeshi Seki[1], Takeo Sasai[1], Fukutaro Hamaoka[1]; [1]*NTT Corporation, Japan.* This paper describes recent technical challenges related to the real-time demonstration 500-Gbps/lambda and 600-Gbps/lambda in field experiments conducted on high-capacity optical transport networks. DSP-ASIC integrated real-time optical transponders are utilized.

08:00–10:00 Th1E • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)

Th1E.1 • 08:00 Invited
Saving Energy and Increasing Density in Information Processing Using Photonics, David A. B. Miller[1]; [1]*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.

08:00–10:00 Th1F • AI for Reliable Networking

Presider: António Eira; Infinera Corporation, Portugal

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 Sasai[1], Masanori Nakamura[1], Seiji Okamoto[1], Fukutaro Hamaoka[1], Shuto Yamamoto[1], Etsushi Yamazaki[1], Asuka Matsushita[1], Yoshikaki Kisaka[1]; [1]*NTT , Japan.* We experimentally demonstrate simultaneous localization of optical excess loss points and spans with different dispersion in multi-span fiber links using a neural-network based digital backpropagation.

Th1F.2 • 08:15
Soft-failure Localization and Device Working Parameters Estimation in Disaggregated Scenarios, Sima Barzegar[1], Emanuele E. Virgillito[2], Marc Ruiz[1], Alessio Ferrari[2], Antonio Napoli[3], Vittorio Curri[2], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Politecnico di Torino, Italy;* [3]*Infinera, Germany.* A soft-failure localization and key working parameters estimation system is proposed for network diagnosis and maintenance. We show that a double analysis of monitoring data and estimated working parameters greatly anticipates degradations.

Room 6E	Room 6F	Room 7	Room 8	Room 9

Show Floor Programming

07:30–08:00 Morning Coffee, *Upper Level Corridors*

08:00–10:00
Th1G • Modulation and Coding
Presider: Zhensheng Jia; CableLabs, USA

Th1G.1 • 08:00
Joint Optimization of Coding, Shaping and Clipping for Amplifier-less Coherent Optical Systems, Abel Lorences-Riesgo[1], Fernando Guiomar[1], Beatriz M. Oliveria[1,2], Maria C. R. Medeiros[1,3], Paulo P. Monteiro[1,2]; [1]*Instituto De Telecomunicacoes, Portugal;* [2]*Univ. of Aveiro, Portugal;* [3]*Univ. of Coimbra, Portugal.* We experimentally demonstrate that performance of amplification-less coherent optical systems can be significantly improved by a joint optimization of FEC coding overhead, modulation order, and signal clipping, enabling power budget gains of >1dB.

Th1G.2 • 08:15
Parallel Bisection-based Distribution Matching for Probabilistic Shaping, Mengfan Fu[1], Qiaoya Liu[1], Xiaobo Zeng[1], Yiwen Wu[1], Lilin Yi[1], Weisheng Hu[1], Qunbi Zhuge[1]; [1]*Shanghai Jiao Tong Univ., China.* We propose a parallel bisection-based distribution matching for constant composition probabilistic shaping. The number of serial operations can be significantly reduced without performance loss, making it a suitable architecture for large block lengths.

08:00–10:00
Th1H • Characterization of SDM Fibers
Presider: Tetsuya Hayashi; Sumitomo Electric Industries Ltd, Japan

Th1H.1 • 08:00 Invited
Distributed Measurement of Mode Dispersion of SDM Fibers, Shingo Ohno[1], Kunihiro Toge[1], Daisuke Iida[1], Tetsuya Manabe[1]; [1]*NTT Access Network Service Systems Laboratories, Japan.* Nondestructive methods for measuring the mode dispersion distribution of SDM fiber that utilize Rayleigh backscattering observed with coherent optical frequency-domain reflectometry are reviewed. Experiments on few-mode and coupled multicore fibers are presented.

08:00–10:00
Th1I • Digital Signal Processing Techniques and Mitigation
Presider: Jianjun Yu; Fudan Univ., China

Th1I.1 • 08:00 Invited
Advanced DSP for Monitoring and Mitigation in Optical Transport Networks, Takeshi Hoshida[1], Takahito Tanimura[1], Shoichiro Oda[1], Setsuo Yoshida[1], Hisao Nakashima[1], Guoxiu Huang[1], Zhenning Tao[2]; [1]*Fujitsu Limited, Japan;* [2]*Fujitsu R&D Center, China.* DSP-based transceivers with enhanced monitoring and mitigation capabilities enable highly efficient transport networking with minimized excess margin and open line systems with enhanced availability. Examples for such advanced DSP algorithms are introduced.

08:00–10:00
Th1J • Panel: Devices and Systems at 130 Gbaud and Above: What is the Outlook?

Ever increasing demands for network bandwidth are driving the need for optical interconnects with higher data-throughputs. Early on the speed of the optical interconnects were much faster than the capabilities of the electronics feeding them. More recently, limitations in these optical interconnects has forced designers to be more creative, utilizing higher symbol rates, higher order modulation formats, space or wavelength division multiplexing schemes to achieve higher optical interconnect throughputs. Currently, with the availability of high-speed CMOS electronics, a more economical path towards higher interconnect throughputs is to increase the symbol rates. This has driven the need for optical components with wider bandwidths.

Today's commercially deployed components, with speeds of in the range of 60GBaud, are adequate for 400Gb/s networks. But what about for 800Gb/s systems and beyond? Can the bandwidth and the efficiency of optical components be further enhanced to enable such systems? Is the analog electronics capable of supporting such bandwidths? And, what is the impact to the DSP design considering the limitation of bandwidth and 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.

08:00–10:00
Th1K • Optical Wireless Sensing Systems for 5G
Presider: Gee-Kung Chang; Georgia Inst. of Technology, USA

Th1K.1 • 08:00 Invited
Visible Light Communications for Automotive Intelligence, Takaya Yamazato[1]; [1]*Nagoya Univ., Japan.* In this talk, the author looks back to the brief history of vehicle automation and related communication technologies. He then introduces visible light communication and its application for automotive intelligence.

Room 1A

Th1A • Advanced Design for Passive Devices—Continued

Th1A.3 • 08:30 Invited

Automated Optical Waveguide Design Based on Wavefront Matching Method, Toshikazu Hashimoto[1]; [1]*NTT Device Technology Labs., NTT Corp., Japan*. There are large degrees of freedom (DOF) in the design of micro-fabricated optical circuits. This paper introduces the wavefront matching method as an automated design technique of the DOF, and its applications.

Room 1B

Th1B • High Speed PON—Continued

Th1B.3 • 08:45

Symmetrical 50-Gb/s/λ PAM-4 TDM-PON at O-band Supporting 26 dB+ Loss Budget Using Low-bandwidth Optics and Semiconductor Optical Amplifier, Jiao Zhang[1], Kaihui Wang[1], Yiran Wei[1], Li Zhao[1], Wen Zhou[1], Jiangnan Xiao[1], Bo Liu[2], Xiangjun Xin[2], Jianjun Yu[1]; [1]*Fudan Univ., China;* [2]*Beijing Univ. of Posts and Telecommunications, China.* We experimentally demonstrated 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.

Room 2

Th1C • Microwave Photonics—Continued

Th1C.2 • 08:30

Dual-chirp Microwave Waveform Generation by a Dual-beam Optically injected Semiconductor Laser, Pei Zhou[1], Hao Chen[2], Nianqiang Li[1], Renheng Zhang[1], Shilong Pan[2]; [1]*Soochow Univ., China;* [2]*Nanjing Univ. of Aeronautics and Astronautics, China.* We propose an approach to generating dual-chirp microwave waveforms based on a dual-beam optically injected semiconductor laser. Tunable dual-chirp microwave waveforms with a large time-bandwidth product are experimentally generated.

Th1C.3 • 08:45

Frequency-tunable Parity-time-symmetric Optoelectronic Oscillator Using a Polarization-dependent Sagnac Loop, Jianping Yao[1], Zheng Dai[1], Zhiqiang Fan[1], Cheng Li[1]; [1]*Univ. of Ottawa, Canada.* A frequency-tunable parity-time-symmetric optoelectronic oscillator with a single physical loop is proposed. Frequency-tunable single-mode oscillation from 2 to 12 GHz and a phase noise of -108 dBc/Hz at an offset frequency of 10 kHz is achieved.

Room 3

Th1D • Pushing the Bit-rate in Practical Networks—Continued

Th1D.2 • 08:30 ★ Top-Scored

Single-Carrier 500Gb/s Unrepeatered Transmission over a Single 431km Span with Single Fiber Configuration, Xu Jian[1]; [1]*ACCELINK, China.* We demonstrate record single-carrier 500Gb/s unrepeatered transmission over a single span of 431km with single fiber configuration, using optimized high-order Raman pump, forward and backward ROPAs, and optimal modulation format while using the same single ultra low loss with large effective area fiber for both signal and pumps.

Th1D.3 • 08:45

High Spectral Efficiency Real-time 500-Gb/s/Carrier Transmission Over Field-installed G.654.E Fiber Link Using Forward and Backward Distributed Raman Amplification, Kohei Saito[1], Takeo Sasai[1], Fukutaro Hamaoka[1], Hiroki Kawahara[1], Takeshi Seki[1], Hideki Maeda[1]; [1]*Nippon Telegraph and Telephone, Japan.* Transmission distance of 1234.2 km with high spectral efficiency of 5.71 b/s/Hz over terrestrial G.654.E fiber links is achieved for 500-Gb/s/carrier signals using EDFAs with forward and backward DRAs compliant with laser power safety requirements.

Room 6C

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

Th1E.2 • 08:30 Invited

Integrated Green Photonics For Next-gen High-performance Computing, Di Liang[1], Geza Kurczveil[1], Zhihong Huang[1], Binhao Wang[1], Antoine Descos[1], Sudharsanan Srinivasan[1], Yingtao Hu[1], Xiaoge Zeng[1], Wayne Sorin[1], Stanley Cheung[1], Songtao Liu[2], Peng Sun[1], Thomas Van Vaerenbergh[1], Marco Fiorentino[1], John E. Bowers[2], Raymond Beausoleil[1]; [1]*Hewlett Packard Labs, Hewlett Packard Enterprise, USA;* [2]*Department of Electrical and Computer Engineering, Univ. of California, USA.* We discuss our strategy to build a dense wavelength division multiplexing optical transceiver to enable high energy efficiency, scalable bandwidth, low latency data communication, and low-cost photonic integration simultaneously for high-performance computing applications.

Room 6D

Th1F • AI for Reliable Networking—Continued

Th1F.3 • 08:30

Interpretable Learning Algorithm Based on XGBoost for Fault Prediction in Optical Network, Chunyu Zhang[1], Danshi Wang[1], Chuang Song[1], Lingling Wang[1], Jianan Song[1], Luyao Guan[1], Min Zhang[1]; [1]*Beijing Univ. of Posts and Telecomm, China.* We propose a fault prediction scheme using interpretable XGBoost based on actual datasets, which not only achieves high accuracy (99. 72%) and low positive rate (0. 18%), but also reveals the five most remarkable features that caused the fault.

Th1F.4 • 08:45

Localization of Probabilistic Correlated Failures in Virtual Network Infrastructures Using Bayesian Networks, Riti Gour[1], Genya Ishigaki[1], Jian Kong[2], Jason P. Jue[1]; [1]*The Univ. of Texas at Dallas, USA;* [2]*Ciena, USA.* We propose an approach to localize probabilistic correlated failures in a multi-layer network where service function graphs (SFGs) are deployed over a physical network infrastructure. The proposed method utilizes logical link monitoring and Bayesian networks.

Room 6E

Th1G • Modulation and Coding—Continued

Th1G.3 • 08:30 Invited

Peformance and Power of Soft-decision FEC (SDFEC) for 100G -800G Applications, Zhiyu Xiao[1]; [1]*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.

Room 6F

Th1H • Characterization of SDM Fibers—Continued

Th1H.2 • 08:30

Theoretical Analysis and Experimental Measurement of Intra-LP-mode DMD in Weakly-coupled FMF, Mingqing Zuo[1], Dawei Ge[1], Lei Shen[2], Jin He[3], Yongqi He[1], Zhangyuan Chen[1,3], Juhao Li[1,3]; [1]*Peking Univ., China;* [2]*Yangtze Optical Fibre and Cable Joint Stock Limited Company, China;* [3]*Peking Univ. Shenzhen Institution, China.* Based on the analysis of intra-LP-mode DMD in weakly-coupled FMF, we propose a modified fixed-analyzer method for its measurement and experimentally demonstrate that it may be one of the major impairments for IM/DD MDM transmission.

Th1H.3 • 08:45 Top-Scored

Channel Dynamics in Few-mode Fiber Transmission under Mechanical Vibrations, Georg Rademacher[1], Roland Ryf[2], Nicolas K. Fontaine[2], Haoshuo Chen[2], Benjamin J. Puttnam[1], Ruben S. Luis[1], Yoshinari Awaji[1], Hideaki Furukawa[1], Naoya Wada[1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Nokia Bell Labs, USA.* We experimentally investigate the coupling dynamics of a three-mode fiber recirculating transmission link under the influence of controlled mechanical vibrations. The dynamics are found to be more prominent compared to similar measurements in single-mode fiber.

Room 7

Th1I • Digital Signal Processing Techniques and Mitigation—Continued

Th1I.2 • 08:30

Mitigating Fiber Nonlinearities by Short-length Probabilistic Shaping, Tobias Fehenberger[1], Helmut Griesser[1], Jörg-Peter Elbers[1]; [1]*ADVA, Germany.* We show that short-length probabilistic shaping reduces nonlinear interference in optical fiber transmission. SNR improvements of up to 0.8 dB are obtained. The shaping gain vanishes when interleaving is employed and not undone before transmission.

Th1I.3 • 08:45

True Equalization of PDL in Presence of Fast RSOP, Nan Cui[1], Xiaoguang Zhang[1], Nannan Zhang[1], Xianfeng Tang[1], Lixia Xi[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China.* In presence of fast RSOP, a true PDL equalization including both signal power and OSNR balances is proposed and verified. With 1dB OSNR penalty, it can equalize up to 7dB PDL under 1Mrad/s fast RSOP.

Room 8

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

Speakers:

Chris Doerr; *Acacia Communications Inc., USA*

Yoshihiro Ogiso; *NTT Device Innovation Center, Japan*
Challenges and Solutions for DSP Aided Coherent Modem at 138GBaud

Zhuhong Zhang; *Huawei Technologies Co Ltd, Canada*
Some Implementation Implications of Coherent Transceivers Operating at >=130Gbd

Maurice O'Sullivan; *Ciena Corp., Canada*
High Symbol Rates and Parallelism in Co-integrated Designs

Peter Winzer; *Independent Consultant, USA*

Jun Cao; *Broadcom, USA*
CMOS Data Converters for Coherent Optical Links beyond 100Gbaud

Room 9

Th1K • Optical Wireless Sensing Systems for 5G—Continued

Th1K.2 • 08:30

Dual-heterodyne Mixing Based Phase Noise Cancellation for Long Distance Dual-wavelength FMCW Lidar, Minglong Pu[1], Weilin Xie[1], Yi Dong[1], Yuxiang Feng[1], Wei Wei[1], Yuanshuo Bai[1], Yinxia Meng[1], Ling Zhang[1], Tao Wang[1], Songhan Liu[1]; [1]*Beijing Inst. of technology, China.* A coherent dual-wavelength frequency-modulated continuous-wave (FMCW) lidar utilizing dual-heterodyne mixing which permits efficient phase noise cancellation has been proposed. Consistent ranging resolution about 1.4 × 10−6 over distances beyond tens of intrinsic coherence length is achieved.

Th1K.3 • 08:45

Secure Free-space Optical Communication via Amplified Spontaneous Emission (ASE), Hanzi Huang[1,2], Jian Chen[1], Haoshuo Chen[2], Yetian Huang[1,2], Yingchun Li[1], Yingxiong Song[1], Nicolas K. Fontaine[2], Roland Ryf[2], Min Wang[1]; [1]*Shanghai Univ., China;* [2]*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.

Show Floor Programming

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

Room 1A

Th1A • Advanced Design for Passive Devices—Continued

Th1A.4 • 09:00
Ultra-broadband and Low-loss Polarization Beam Splitter on Silicon, Chenlei Li[1], Daoxin Dai[1,2], John E. Bowers[3]; [1]*Zhejiang Univ., China;* [2]*Ningbo Research Inst., Zhejiang Univ., China;* [3]*Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA.* We realized a polarization beam splitter with low loss of <1 dB and high extinction ratio of >20 dB in an ultra-broad bandwidth from 1400nm to 1700nm using a pair of cascaded dual-core adiabatic tapers.

Th1A.5 • 09:15
Wavefront-matching-method-designed Six-mode-exchanger Based on Grating-like waveguide on Silica-PLC platform, Takeshi Fujisawa[1], Taiji Sakamoto[2], Masashi Miyata[2], Takashi Matsui[2], Toshikazu Hashimoto[2], Ryoichi Kasahara[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan;* [2]*NTT, Japan.* A first six-mode exchanger based on one sidewall grating-like waveguide is successfully designed with the help of strong optimization algorithm. Fabricated device compensates for mode-dependent-loss caused by fiber-waveguide junctions, showing the proof-of-concept operation.

Room 1B

Th1B • High Speed PON—Continued

Th1B.4 • 09:00
Demonstration of 50-Gb/s/λ PAM-4 PON with Single-PD Using Polarization-insensitive and SSBI Suppressed Heterodyne Coherent Detection, Li Haibo[1], Ming Luo[1], Xiang Li[1], Shaohua Yu[1]; [1]*China Information Communication Technologies Group Corporation, China.* A polarization-insensitive heterodyne coherent detection with single-PD for 50-Gb/s/λ 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.

Th1B.5 • 09:15
The Impact of Transmitter Chirp Parameter on the Power Penalty and Design of 50 Gbit/s TDM-PON, Robert Borkowski[1], Harald Schmuck[1], Giancarlo Cerulo[2], Jean-Guy Provost[2], Vincent Houtsma[3], Dora van Veen[3], Ed Harstead[4], Franck Mallecot[2], Rene Bonk[1]; [1]*Nokia Bell Labs, Germany;* [2]*III-V Lab, joint laboratory between Nokia Bell Labs, Thales Research and Technology, and CEA Leti, France;* [3]*Nokia Bell Labs, USA;* [4]*Fixed Networks Division, Nokia Corporation, USA.* We study the impact of transmitter chirp parameter (effective α-factor) on the chromatic-dispersion-induced power penalty in 50-Gbit/s TDM-PON. We experimentally show interplay of chirp and dispersion using 50G-class integrated EML-SOA driven in distinct operating points.

Room 2

Th1C • Microwave Photonics—Continued

Th1C.4 • 09:00 Tutorial
New Opportunities for Integrated Microwave Photonics, David Marpaung[1]; [1]*Universiteit Twente, Netherlands.* In this tutorial I will discuss recent developments and new perspectives in the field of integrated microwave photonics, with the emphasis on optical comb sources, high speed modulators, and photon-phonon interactions for advanced signal processing.

David Marpaung joined the University of Twente, the Netherlands in 2018 as an associate professor leading the Nonlinear Nanophotonics group. From 2012 to 2017 he was leading the integrated microwave photonics research activities at CUDOS University of Sydney, Australia. His research interests include RF photonics, optomechanics, nonlinear optics, and phononics.

Room 3

Th1D • Pushing the Bit-rate in Practical Networks—Continued

Th1D.4 • 09:00
Added Value of 90 GBaud Transponders for WDM Networks, Thierry Zami[1], Bruno Lavigne[1], Mathieu Lefrancois[1]; [1]*Nokia Corporation, France.* We quantify the benefit of 90 GBaud transponders versus the more mature 67 GBaud ones to possibly improve the maximum total throughput in WDM networks and the associated amount of deployed equipment per transmitted Gb/s.

Th1D.5 • 09:15
100-Gbit/s/λ PAM-4 Signal Transmission over 80-km SSMF Based on an 18-GHz EML at O-band, Kaihui Wang[1], Jiao Zhang[1], Yiran Wei[1], Li Zhao[1], Wen Zhou[1], Mingming Zhao[1], Jiangnan Xiao[1], Xiaolong Pan[2], Bo Liu[2], Xiangjun Xin[2], Liwei Zhang[3], Yun Zhang[3], Jianjun Yu[1]; [1]*Fudan Univ., China;* [2]*Beijing Univ. of Posts and Telecommunications, China;* [3]*ZTE Corporation, China.* For the first time, we experimentally demonstrate 100-Gbit/s PAM-4 signal transmission over 80km at O-band using an 18-GHz EML. After two spans of SOA-based 40-km SSMF transmission, a receiver sensitivity of -17.3dBm is achieved.

Room 6C

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

Th1E.3 • 09:00 Invited
Densely Integrated Electronic-photonic Systems for Next-generation Optical I/O, Mark Wade[1]; [1]*Ayer Labs, USA.* Abstract not available.

Room 6D

Th1F • AI for Reliable Networking—Continued

Th1F.5 • 09:00
Demonstration of Fault Localization in Optical Networks Based on Knowledge Graph and Graph Neural Network, Zhuotong Li[1], Yongli Zhao[1], Yajie Li[1], Sabidur Rahman[2], Xiaosong Yu[1], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecommunications, China;* [2]*Univ. of California, Davis,, USA.* A fault localization method for optical networks using knowledge graph and graph neural network is proposed. Experimental demonstration shows that the proposed method is effective in automating the localizing of optical network faults.

Th1F.6 • 09:15
Can You Trust AI-assisted Network Automation? A DRL-based Approach to Mislead the Automation in SD-IPoEONs, Min Wang[1], Siqi Liu[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China.* We study the vulnerability of artificial intelligence assisted network automation (AIaNA), and design a deep reinforcement learning (DRL) model to mislead the AIaNA in software-defined IP over elastic optical networks (SD-IPoEONs) through crafting/injecting adversarial traffic samples.

Room 6E

Th1G • Modulation and Coding—Continued

Th1G.4 • 09:00
Hierarchical Distribution Matching: a Versatile Tool for Probabilistic Shaping, Stella Civelli[1,2], Marco Secondini[1,2]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*Photonic Networks & Technologies National Laboratory, CNIT, Italy.* The hierarchical distribution matching (Hi-DM) approach for probabilistic shaping is described. The potential of Hi-DM in terms of trade-off between performance, complexity, and memory is illustrated through three case studies.

Th1G.5 • 09:15
Multi-dimensional Distribution Matching for Probabilistically Shaped High Order Modulation Format, Mengfan Fu[1], Qiaoya Liu[1], Xiaobo Zeng[1], Yiwen Wu[1], Lilin Yi[1], Weisheng Hu[1], Qunbi Zhuge[1]; [1]*Shanghai 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.

Room 6F

Th1H • Characterization of SDM Fibers—Continued

Th1H.4 • 09:00
Characterization and Optical Compensation of LP_{01} and LP_{11} Intra-modal Nonlinearity in Few-Mode Fibers, Francesco Da Ros[1], Pawel M. Kaminski[1], Georg Rademacher[2], Benjamin J. Puttnam[2], Ruben S. Luis[2], Werner Klaus[2], Hideaki Furukawa[2], Ryo Maruyama[3], Kazuhiko Aikawa[3], Toshio Morioka[1], Leif Oxenløwe[1], Naoya Wada[2], Michael Galili[1]; [1]*DTU Fotonik, Denmark;* [2]*Photonic Network System Laboratory, National Inst. of Information and Communications Technology, Japan;* [3]*Fujikura Ltd, Japan.* Intra-modal four-wave mixing (FWM) and all-optical compensation by optical phase conjugation is investigated over 2-spans of 3-mode fiber with the power of the generated FWM products reduced by 5 to 20 dB in different scenarios.

Th1H.5 • 09:15
Mode Group Resolved Analysis of Effects Induced by Macro Bending in a 50 µm Graded Index Multi Mode Fiber, Christian M. Spenner[1], Peter M. Krummrich[1]; [1]*TU 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.

Room 7

Th1I • Digital Signal Processing Techniques and Mitigation—Continued

Th1I.4 • 09:00 Invited
Extreme Values in Optical Fiber Communication Systems, Seb J. Savory[1]; [1]*Univ. 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.

Room 8

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

Room 9

Th1K • Optical Wireless Sensing Systems for 5G—Continued

Th1K.4 • 09:00
Simultaneous Optical Fiber Sensing and Mobile Front-haul Access over a Passive Optical Network, Yue-Kai Huang[1], Ezra Ip[1]; [1]*NEC 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.

Th1K.5 • 09:15
Spectrum Sensing Applications of FWM-based Optical Cyclostationary Processor, Jerrod Langston[1,2], Richard DeSalvo[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*L3Harris, 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.

Show Floor Programming

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

Th1A • Advanced Design for Passive Devices—Continued

Th1A.6 • 09:30 Invited

Deep Neural Networks for Designing Integrated Photonics, Keisuke Kojima[1,2], Mohammad H. Tahersima[1], Toshiaki Koike-Akino[1], Devesh Jha[1], Yingheng Tang[1,3], Kieran Parsons[1], Fengqiao Sang[2], Jonathan Klamkin[2]; [1]*Mitsubishi Electric Research Laboratories, USA;* [2]*Electrical and Computer Engineering Dept., Univ. of California, Santa Barbara, USA;* [3]*Electrical and Computer Engineering Dept., Purdue Univ., USA.* We present our two inverse design activites for nanophtonic 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 • High Speed PON—Continued

Th1B.6 • 09:30 ★ Top-Scored

50G PON FEC Evaluation with Error Models for Advanced Equalization, Amitkumar Mahadevan[1], Dora van Veen[1], Noriaki Kaneda[1], Alex Duque[1], Adriaan de Lind van Wijngaarden[1], Vincent Houtsma[1]; [1]*Nokia 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.

Th1B.7 • 09:45

Low-bandwidth Sub-nyquist A/D Conversion in Delay-division Multiplexing OFDM PONs Enabled by Optical Shaping, Wei-Lun Chen[1], Min Yu[1], Lu-Yi Yang[1], Chia Chien Wei[1], Chun-Ting Lin[2]; [1]*National Sun Yat-Sen Univ., Taiwan;* [2]*National 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.

Th1C • Microwave Photonics—Continued

Th1D • Pushing the Bit-rate in Practical Networks—Continued

Th1D.6 • 09:30 Invited

Coherent Technologies and Requirements in Next-generation MSO Networks, Matthew Schmitt[1]; [1]*CableLabs, 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 • Symposium: Future Photonics Devices fJ/bit Optical Networks Enabled by Emerging Optical Technologies (Session 2)—Continued

Th1E.4 • 09:30 Invited

Integrated Photonics for High Performance Computing, Yichen Shen[1]; [1]*Lightelligence, 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.

Th1F • AI for Reliable Networking—Continued

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*

Room 6E

Th1G • Modulation and Coding—Continued

Th1G.6 • 09:30
Staircase Construction with Non-systematic Polar Codes, Carlo Condo[1], Valerio Bioglio[1], Ingmar Land[1]; [1]*Huawei Technologies France SASU, France.* We propose staircase codes based on non-systematic polar codes, describing a general framework for encoding and decoding, and presenting simulation results showing the effectiveness of the proposed approach even with short component codes.

Th1G.7 • 09:45 ★ Top-Scored
FPGA Implementation of Prefix-free Code Distribution Matching for Probabilistic Constellation Shaping, Qinyang Yu[1,2], Steve Corteselli[2], Junho Cho[2]; [1]*Shanghai Univ., China;* [2]*Nokia Bell Labs, USA.* We implement rate-adaptable prefix-free code distribution matching in FPGA, demonstrating its real-time feasibility with substantially less hardware resources than low-density parity-check coding.

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 Alvarado Zacarias[2,1], Nicolas K. Fontaine[2], Roland Ryf[2], Haoshuo Chen[2], Sjoerd van der Heide[3], Jose Enrique Antonio-Lopez[1], Steffen Wittek[1], Guifang Li[1], Chigo M. Okonkwo[3], Marianne Bigot-Astruc[4], Adrian Amezcua-Correa[4], Pierre Sillard[4], Rodrigo Amezcua Correa[1]; [1]*CREOL, The College of Optics & Photonics, USA;* [2]*Nokia Bell Labs, USA;* [3]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands;* [4]*Prysmian Group, France.* 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.5 • 09:30
On the Performance under Hard and Soft Bitwise Mismatched-decoding, Tsuyoshi Yoshida[1,2], Mikael Mazur[3], Jochen Schröder[3], Magnus Karlsson[3], Erik Agrell[3]; [1]*Mitsubishi Electric Corporation, Japan;* [2]*Osaka Univ., Japan;* [3]*Chalmers 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.6 • 09:45
Rate-adaptive Concatenated Polar-Staircase Codes for Data Center Interconnects, Tayyab Mehmood[1], Metodi P. Yankov[1], Anders Fisker[2], Kim Gormsen[2], Søren Forchhammer[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Zeuxion, Denmark.* A rate-adaptive concatenated code, consisting of an outer staircase code and an inner polar code is proposed. Short blocklength inner polar codes offers rate-adaptivity and more than 0.35 dB gain compared to the 400ZR data-center-interconnect error-correcting code.

Room 8

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

Room 9

Th1K • Optical Wireless Sensing Systems for 5G—Continued

Th1K.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 Zhang[1], Nanzhe Hu[1], Xinzhou Su[1], Ahmed Almaiman[1], Haoqian Song[1], Zhe Zhao[1], Hao Song[1], Kai Pang[1], Cong Liu[1], Moshe Tur[2], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*School 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.

Th1K.7 • 09:45
Optimized QAM Order with Probabilistic Shaping for the Nonlinear Underwater VLC Channel, Peng Zou[1], Fangchen Hu[1], Guoqiang Li[1], Nan Chi[1]; [1]*Fudan 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.

Show Floor Programming

Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics
Cisco
10:15–11:15, *Theater II*

Product Showcase
Huawei Technologies USA
10:15–10:45, *Theater III*

■ Market Watch Panel V: Inside the Data Center
10:30–12:00, *Theater I*

■ Market Watch Panel VI: Advanced Packaging and Photonic Integration
12:30–14:00, *Theater I*

Transforming Network Operations through Automation
12:45–13:45, *Theater II*

POFTO Symposium
POFTO
13:45–14:45, *Theater III*

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*

10:30–12:30
Th2A • Poster Session II

Th2A.1
100-Gbps 100-m Hollow-core Fiber Optical Interconnection at 2-micron Waveband by PS-DMT, Weihong Shen[1], Jiangbing Du[1], Lin Sun[1], Chang Wang[1], Ke Xu[2], Baile Chen[3], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Harbin Inst. of Technology, China;* [3]*Shanghai 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, Jörn P. Epping[1], Ruud M. Oldenbeuving[1], Dimitri Geskus[1], Ilka Visscher[1], Robert Grootjans[1], Chris G. Roeloffzen[1], René Heideman[1]; [1]*LioniX 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 Abdelli[1,2], Danish Rafique[1], Helmut Griesser[1], Stephan Pachnicke[2]; [1]*ADVA Optical Networking SE, Germany;* [2]*Christian-Albrechts-Universität zu Kiel,, Germany.* A novel approach based on an artificial neural network (ANN) for lifetime prediction of 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 Xu[1], Rui Li[1], Yanbo Li[1], Xiaolu Song[1]; [1]*Huawei 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, Bulent Kose[1], Jose Castro[1], Rick Pimpinella[1], Yu Huang[1], Fei Jia[1], Brett Lane[1]; [1]*Panduit, 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 Nakamura[1], Takeshi Fujisawa[1], Taiji Sakamoto[2], Takashi Matsui[2], Kazuhide Nakajima[2], Kunimasa Saitoh[1]; [1]*Graduate School of Information Science and Technology, Hokkaido Univ., Japan;* [2]*NTT Access Network Service Systems, NTT corporation, Japan.* A tunable TE_0-TE_1 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-assisted Space-and-wavelength Selective Switch, Yishen Huang[1], Qixiang Cheng[1], Anthony Rizzo[1], Keren Bergman[1]; [1]*Columbia Univ., USA.* We introduce a novel design of space-and-wavelength selective switch using microring-assisted Mach-Zehnder interferometers. A 2×2×2λ 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 Zhong[1], Yuan Dong[1], Dongdong Li[1], Nanxi Li[1], Ting Hu[1], Zhengji Xu[1], Yanyan Zhou[1], Keng Heng Lai[1], Yuan Hsing Fu[1], Vladimir Bliznetsov[1], Hou-Jang Lee[1], Wei Loong Loh[1], Shiyang Zhu[1], Qunying Lin[1], Navab Singh[1]; [1]*Inst. of Microelectronics, Agency for Science Technology and Research, Singapore.* We developed a technology to directly process 12-inch glass wafers using 193 nm immersion lithography for metasurface devices fabrication. An 8-mm-dimeter metalens working at 940 nm wavelength has been demonstrated as a proof-of-concept functional device.

Th2A.9
CWDM Mux/Demux Passive Optical Interconnect, Darrell Childers[1], Dirk Schoellner[1], DJ Hastings[1], Ke Wang[1], Paul Rosenberg[2], Gregg Combs[3], Kent Devenport[3]; [1]*US Conec Ltd, USA;* [2]*HPE Hewlett Packard Labs, USA;* [3]*Hewlett Packard Enterprise, USA.* A novel concept for integrating the mux/demux functionality of coarse wavelength division multiplexing (CWDM) into passive fiber optic connectors via expanded beam ferrules is presented, including optical modeling and preliminary empirical results.

Th2A.10
Multilayer Silicon Nitride-based Coupler Integrated into a Silicon Photonics Platform with <1 dB Coupling Loss to a Standard SMF over O, S, C and L optical bands, Ravi Tummidi[1], Mark Webster[1]; [1]*Cisco Systems, USA.* We experimentally demonstrate <1 dB coupling loss over O,S,C and L optical bands for both polarizations between an integrated silicon photonics platform and butt-coupled standard single mode fiber.

Th2A.11
Electro-Optic Frequency Response Shaping in High Speed Mach-Zehnder Modulators, Laurens Breyne[1,2], Joris Lambrecht[1], Michiel Verplaetse[1], Xin Yin[1], Gunther Roelkens[2], Peter Ossieur[1], Johan Bauwelinck[1]; [1]*IDLab, Ghent Univ. - imec, Belgium;* [2]*Photonics Research Group, Ghent Univ. - imec, Belgium.* We demonstrate a simple technique to shape the electro-optic frequency response of high-speed TW-MZMs. C-band transmission of 56Gb/s NRZ over 3km SSMF shows 5dB power-penalty improvement at KP4-FEC between a standard and shaped MZM design.

Th2A.12
A High Linear Silicon Mach-Zehnder Modulator by the Dual-series Architecture, Qiang Zhang[2], Hui Yu[1], Zhilei Fu[1], Penghui Xia[1], Xiaofei Wang[1]; [2]*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 109.5/100.5 dB×$Hz^{2/3}$ at 1/10 GHz.

Th2A.13
Timing Jitter from Optical Phase Noise in Quantum Dot Coherent Comb Laser at C-Band, Youxin Mao[1], Zhenguo Lu[1], Jiaren Liu[1], Guocheng Liu[1], Chunying Song[1], Philip Poole[1]; [1]*National Research Council Canada, Canada.* Timing jitter obtained from optical phase noise is investigated in InAs/InP quantum dot Fabry-Pérot coherent comb lasers with 11, 25, and 34.5 GHz pulse repetition rates. These lasers exhibit ultra-low timing jitter making them excellent sources for tens terabit optical networks.

Th2A.14
10 GHz, 6.2 ps Transform-limited Coherent Optical Pulse Generation from a 1.55 µm, Self-injection Gain-switched DFB-LD, Keisuke Kasai[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We demonstrate coherent optical pulse generation from a 1.55 µm, self-injection gain-switched DFB-LD. By using external spectral shaping, we generated a transform-limited 10-GHz, 6-ps Gaussian-pulse, which had neatly repetitive longitudinal modes with a 7 kHz-linewidth.

Th2A.15
10-nm-wide Tunable In-series Laser Array with High Single-mode Stability, Zhenxing Sun[1], Rulei Xiao[1], Zhirui Su[1], Gen Lv[1], Zhao Chen[2], Jilin Zheng[1], Yunshan Zhang[1], Jun Lu[1], Yuechun Shi[1,4], Yi-jen Chiu[3], Xiangfei Chen[1]; [1]*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;* [2]*School of Electronic and Electrical Engineering, Wuhan Textile Univ., China;* [3]*Inst. of Electro-Optical Engineering and Semiconductor Technology Research Development Center, National Sun Yat-Sen Univ., Taiwan;* [4]*Nanjing Univ. (Suzhou) High-Tech Inst., China.* We report a 10-nm-wide tunable in-series DFB laser array with high wavelength-spacing uniformity and high single-mode stability, which is guaranteed by high-precision control of grating phase error through reconstruction-equivalent-chirp technique.

Th2A.16
Low Parasitic Capacitance III-V/Si Hybrid MOS Optical Modulator toward High-speed Modulation, Qiang Li[1], Chongpei Ho[1], Junichi Fujikata[2], Masataka Noguchi[2], Shigeki Takahashi[2], Kasidit Toprasertpong[1], Shinichi Takagi[1], Mitsuru Takenaka[1]; [1]*Univ. of Tokyo, Japan;* [2]*PETRA, 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 • Poster Session II—Continued

Th2A.17
Multicore Fiber Fabricated by Modified Cylinder Method, Masanori Takahashi[1], Koichi Maeda[1], Ryuichi Sugizaki[1], Masayoshi Tsukamoto[1]; [1]*Furukawa Electric, Japan.* MCF made by modified cylinder method (MCM) is demonstrated. Optimized cylinder with single hole show potentials for cost reduction and higher productivity. Attenuation loss of the MCF made by MCM is 0.190dB/km at 1550nm.

Th2A.18
1000-nm IR Supercontinuum Due to Raman Soliton Supported by Four-wave Mixing, Marina Zajnulina[1]; [1]*Aston Inst. of Photonic Technologies, Aston Univ., UK.* Simple, low-cost, and robust telecom-fiber-based single-pass system is introduced and numerically studied to generate a supercontinuum ranging from 1500 nm to 2500 nm despite the optical loss due to infrared absorption in optical fibers.

Th2A.19
Refractive Index Grading Optimization for Rectangular Core Fiber, Lior Rechtman[1], Dan M. Marom[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* We optimize the refractive index grading for rectangular core fibers in support of mode division multiplexing. Designs maximizing the effective index separations for MIMO-less support and others minimizing the differential group delays are identified.

Th2A.20
Ultra-small Optical Fiber Fabry-Pérot Cavities Fabricated by Laser-Induced Photothermal Effect, Jiwon Choi[1], Gyeongho Son[1], Yeonghoon Jin[1], Kyoungsik Yu[1]; [1]*KAIST, South Korea.* We proposed the HF etching method using laser-induced photothermal effect and found that curvatures of cavities can affect its Q-factor. We also show the potential for the novel metal coating process for the cavity surface.

Th2A.21
Twining Plant Inspired Pneumatic Soft Robotic Spiral Gripper with High-birefringence Fiber Optic Sensor, Mei Yang[1], Liam Cooper[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* Twining plant-inspired pneumatic soft-robotic spiral gripper embedded with a high-birefringence fiber-optic sensor is designed and emonstrated. The fiber-optic sensor enables the spiral-gripper to sense the twining angle and target cylinder radius as small as 1mm.

Th2A.22
Wavelength-tunable PT-symmetric Single-longitudinal-mode Fiber Laser with a Single Physical Loop, Jianping Yao[1], Zheng Dai[1], Zhiqiang Fan[1]; [1]*Univ. of Ottawa, Canada.* A wavelength-tunable parity-time (PT)-symmetric single-longitudinal-mode fiber laser with a single physical loop is demonstrated. Single-longitudinal-mode lasing with a tunable range from 1549.2 to 1550.3 nm and a linewidth of 670 Hz is achieved experimentally.

Th2A.23
A Frequency Digital Pre-distortion Compensation Method for FMCW LiDAR System, Ting-Hui Chen[1], Chien-Ying Huang[1], Tim Kuei Shia[4], Sin-Jhu Wun[1], Ching-Hsiang Hsu[1], Kai-Ning Ku[1], Chi-Sen Lee[1], Chen-Yu Lin[1], Po-Chih Chang[1], Chung-Chih Wang[1], Shang-Chun Chen[1], Chien-Chung Lin[1,3], Chih-I Wu[1,2]; [1]*Electronic and Optoelectronic System Research Laboratories, Industrial Technology Research Inst., Taiwan;* [2]*National Taiwan Univ., Taiwan;* [3]*National Chiao Tung Univ., Taiwan;* [4]*Information and Communications Research Laboratories, Industrial Technology Research Inst., Taiwan.* We propose a digital pre-distortion (DPD) compensation method for FMCW LiDAR system and demonstrate that the proposed method can enhance the ranging accuracy more than three times in our FMCW ranging experiment.

Th2A.24
Enabling the Scalability of Industrial Networks by Independent Scheduling Domains, Konstantinos (Kostas) Christodoulopoulos[1], Wolfram Lautenschlaeger[1], Florian Frick[2], Nihel D. Benzaoui[3], Torben Henke[2], Ulrich Gebhard[1], Lars Dembeck[1], Armin Lechler[2], Yvan Pointurier[3], Sebastien Bigo[3]; [1]*Nokia Bell Labs Germany, Germany;* [2]*Univ. of Stuttgart, Germany;* [3]*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 Minakhmetov[1], Craig Gutterman[2], Tingjun Chen[2], Jiakai Yu[3], Cedric Ware[1], Luigi Iannone[1], Daniel C. Kilper[3], Gil Zussman[2]; [1]*LTCI, Telecom Paris, France;* [2]*Electrical Engineering, Columbia Univ., USA;* [3]*College of Optical Sciences, Univ. of Arizona, USA.* We investigate dynamic network resource allocation using software-defined networking optical controller with software-defined radios on the COSMOS testbed. 10 Gb/s capacity, deterministic low latency are maintained through user equipment wireless handover via optical switching.

Th2A.26
Threshold Plasticity of Hybrid Si-VO_2 Microring Resonators, Zhi Wang[1], Qiang Li[1], Ziling Fu[1], Andrew Katumba[2], Florian Denis-le Coarer[3], Damien Rontani[3], Marc Sciamanna[3], Peter Bienstman[2]; [1]*Inst. of Optical Information, Key Laboratory of Luminescence and Optical Information, Ministry of Education, Beijing Jiaotong Univ., China;* [2]*Photonic Research Group, Ghent Univ. - IMEC, Belgium;* [3]*Univ. of Paris-Saclay, and Univ. of Lorraine, France.* We theoretically simulate the threshold plasticity of a high-Q-factor silicon-on-insulator microring resonator integrated with VO_2. 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 Shiraiwa[1], Yoshinari Awaji[1], Massimo Tornatore[2,3], Biswanath Mukherjee[2], Hideaki Furukawa[1], Naoya Wada[1]; [1]*National Inst. of Information and Communications Technology, Japan;* [2]*Univ. of California, Davis, USA;* [3]*Politecnico di Milano, Italy.* We develop an SDN-based control for optical-multicast packet transmission and experimentally demonstrate multicast functionality by validating it using an application-layer network service for efficient content duplication in Optical Packet/Circuit Integrated (OPCI) network.

Th2A.28
Adaptive DNN Model Partition and Deployment in Edge Computing-enabled Metro Optical Interconnection Network, Mingzhe Liu[1], Yajie Li[1], Yongli Zhao[1], Hui Yang[1], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecommunications, China.* A DNN model partition and deployment algorithm is proposed between edge nodes and cloud in metro optical network. Simulation results show that the algorithm can deploy more DNN tasks with the same network resource.

Th2A.29
DeepCoop: Leveraging Cooperative DRL Agents to Achieve Scalable Network Automation for Multi-Domain SD-EONs, Baojia Li[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China.* We design DeepCoop to realize service provisioning in multi-domain software-defined elastic optical networks (SD-EONs) with cooperative deep reinforcement learning (DRL) agents.

Th2A.30
Disruption-minimized Re-adaptation of Virtual Links in Elastic Optical Networks, Nashid Shahriar[1], Mubeen Zulfiqar[1], Shihabur Rahman Chowdhury[1], Sepehr Taeb[1], Massimo Tornatore[2], Raouf Boutaba[1], Jeebak Mitra[3], Mahdi Hemmati[3]; [1]*Univ. of Waterloo, Canada;* [2]*Politecnico di Milano, Italy;* [3]*Huawei Technologies Canada Research Center, Canada.* We present a novel re-adaptation approach to accommodate bandwidth increase of virtual links in elastic optical networks. Our approach can incorporate different objectives, as minimizing disruption, by choosing among a comprehensive set of re-adaptation actions.

Show Floor Programming

Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics
Cisco
10:15–11:15, *Theater II*

Product Showcase
Huawei Technologies USA
10:15–10:45, *Theater III*

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Intel
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12:45–13:45, *Theater II*

POFTO Symposium
POFTO
13:45–14:45, *Theater III*

Th2A • Poster Session II—Continued

Th2A.31
What if AI Fails: Protection against Failure of AI-Based QoT Prediction, Ningning Guo[1], Longfei Li[1], Lian Xiang[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*IIT, India.* We propose a new mechanism to protect against the failure of AI-based QoT prediction. Simulation results shows the efficiency of the mechanism in guaranteeing reliability of lightpath services, while not increasing network spectrum resources used.

Th2A.32
HeCSON: Heuristic for Configuration Selection in Optical Network Planning, Sai Kireet Patri[1,2], Achim Autenrieth[1], Danish Rafique[1], Jörg-Peter Elbers[1], Carmen Mas Machuca[2]; [1]*ADVA Optical Networking SE, Germany;* [2]*Technical 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 execution time, 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 Liu[1,2], Shuangyi Yan[2], Gerald Q. Migure Jr.[1], Yanlong Li[3], Dimitra Simeonidou[2]; [1]*KTH, Sweden;* [2]*HPN group, Univ. of Bristol, UK;* [3]*Tsinghua National Laboratory for Information Science and Technology, China.* A SDM/WDM ROADM is proposed with low port-count WSSs. Fiber-core bypassing reduces the number of and port-count of WSSs in the implementation. The design requires less hardware without compromising on network performance with the developed routing core and wavelength assignment algorithm.

Th2A.34
Energy-efficient Coherent PON System with Access-span Length Difference Between ONUs Using Marginal IQ Power Loading in Downlink Transmission, Takahiro Kodama[1], Kouki Arai[2]; [1]*Kagawa Univ., Japan;* [2]*Graduate Faculty of Interdisciplinary Research, Univ. of Yamanashi, Japan.* 2.7 dB power efficiency improvement consistent with theory was experimentally obtained by marginal IQ distorted QPSK signal with and DD-CPR in the case of the 57 km downlink access span length difference between two ONUs.

Th2A.35
Novel Low Cost PON Protection via Harvested Power, Neil Parkin[1], Albert Rafel[1]; [1]*BT, 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 Shibata[1], Shin Kaneko[1], Kazuaki Honda[1], Jun Terada[1]; [1]*NTT, 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 3.9Gbps to 7.9Gbps.

Th2A.37
Comparison of PAM Formats for 200 Gb/s Short Reach Transmission Systems, Tom Wettlin[1], Talha Rahman[2], Jinlong Wei[2], Stefano Calabro[2], Nebojsa Stojanovic[2], Stephan Pachnicke[1]; [1]*Kiel Univ. , Germany;* [2]*European Research Center, Huawei Technologies, Germany.* We compared the performance of PAM4, PAM6 and PAM8 experimentally at 224/225 Gb/s using different DSP schemes including Tomlinson-Harashima precoding (THP). 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 Coherent Data-center Interconnect Receivers, Christoffer Fougstedt[1], Oscar Gustafsson[2], Cheolyong Bae[2], Erik Börjeson[1], Per Larsson-Edefors[1]; [1]*Department of Computer Science and Engineering, Chalmers Univ. of Technology, Sweden;* [2]*Department of Electrical Engineering, Linköping Univ., Sweden.* We perform exploratory 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-superposition Aided SSB Nyquist 16QAM Synthesis from Twin-SSB Nyquist QPSK with Reduced DAC Resolution Requirement, Guo-Wei Lu[1], Hong-Bo Zhang[2], Zhe Li[3]; [1]*Tokai Univ., Japan;* [2]*Chengdu Univ. of Info. and Tech., China;* [3]*II-VI Incorporated, USA.* An FWM-based coherent self-superposition technique is proposed and demonstrated to synthesize 12.5-Gb/s SSB Nyquist 16QAM 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 Modulator Using Antenna-coupled Electrode and $LiNbO_3$ Film Stacked on Low-*k* Substrate for Millimeter-Wave Radar System, Hiroshi Murata[1], Hiroto Yokohashi[1]; [1]*Mie Univ., Japan.* Antenna-coupled-electrode $LiNbO_3$ optical modulators have been designed, fabricated, and demonstrated experimentally for the calibrations of millimeter-wave radars and imagers. A over 50-dB signal-to-noise ratio of the re-converted signal was obtained in the 1-GHz IF band.

Th2A.41
Photonics-enabled 2Tx/2Rx Coherent MIMO Radar System Experiment with Enhanced Cross Range Resolution, Antonella Bogoni[2,1], Paolo Ghelfi[1], Salvatore Maresca[2], Leonardo Lembo[2,3], David Ricardo Sanchez Jacome[4,2], Filippo Scotti[1], Giovanni Serafino[2], Antonio Malacarne[2], Carsten Rockstuhl[4]; [1]*CNIT, Italy;* [2]*Sant'Anna School, Italy;* [3]*Naval Experimentation and Support Center, Italy;* [4]*Karlsruhe Inst. of Technology, Germany.* Photonics enables a multi-target experiment of coherent MIMO radar. It confirms that coherence introduces almost one order of magnitude improvement in the cross-range resolution. Simulations demonstrates the coherent bi-band operation benefits on the system performance.

Th2A.42
Novel Compressed Digital Radio Fronthaul over Photonically-generated THz Wireless Bridge, Tongyun Li[1], Luis Gonzalez-Guerrero[2], Haymen Shams[2], Cyril Renaud[2], Alwyn J. Seeds[2], Martyn Fice[2], Ian White[1], Richard Penty[1]; [1]*Centre for Photonic Systems, Electrical Division, Engineering Department, Univ. of Cambridge, UK;* [2]*Department of Electronic and Electrical Engineering, Univ. College London, UK.* Compressed DRoF-based fronthaul links enable cost-effective last-mile wireless coverage. This paper demonstrates a novel system which carries 12 LTE services over both optical fibre and photonically-generated THz wireless links with over 40 dB dynamic range.

Th2A.43
RF Fading Circumvention Using a Polarization Modulator for Supporting W-Band RoF Transport from 85 to 95 GHz, Run-Kai Shiu[1,2], Shang-Jen Su[2], Yon-Wei Chen[2], Qi Zhou[2], Justin Chiu[1], Guan-Ming Shao[1], Li Zhao[2], P. C. Peng[1], Gee-Kung Chang[2]; [1]*National Taipei Univ. of Technology, Taiwan;* [2]*Georgia 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.44
500-Gb/s PAM4 FSO-UWLT Integration Utilizing R/G/B Five-wavelength Polarization-multiplexing Scenario, Shi-Cheng Tu[1], Yong-Cheng Huang[1], Jing-Yan Xie[1], Qi-Ping Huang[1], Song-En Tsai[1], Wen-Shing Tsai[2], Hai-Han Lu[1]; [1]*National Taipei Univ. of Technology, Taiwan;* [2]*Department of Electrical Engineering, Ming Chi Univ. of Technology, Taiwan.* A 500-Gb/s PAM4 FSO-UWLT integration utilizing red/green/blue polarization-multiplexing scenario is constructed. With five-wavelength polarization-multiplexing scenario, the transmission rate is substantially multiplied. Such demonstrated PAM4 FSO-UWLT integration brings imperative enhancement featured by optical wireless communications.

Th2A.45
Few-subcarrier QPSK-OFDM Wireless Ka-band Delivery with Pre-coding-assisted Frequency Doubling, Wen Zhou[1,2], Jianjun Yu[1], Li Zhao[1,2], Kaihui Wang[1], Miao Kong[1], Jiao Zhang[1], You-Wei Chen[2], Shuyi Shen[2], Gee-Kung Chang[2]; [1]*Shanghai Inst. for Advanced Communication and Data Science, Fudan Univ., China;* [2]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA.* We experimentally demonstrated a Ka-band dual/four-subcarrier QPSK-OFDM delivery over 25-km SMF and 1-m wireless link. To our knowledge, this is the first time to achieve few-subcarrier QPSK-OFDM signal generation and wireless transmission using pre-coding technique.

Th2A.46
Centralized Digital Self-interference Cancellation Technique to Enable Full-duplex Operation of Next Generation Millimeter Wave over Fiber Systems, Qi Zhou[1], Shuyi Shen[1], Shang-Jen Su[1], You-Wei Chen[1], Shuang Yao[1], Yahya M. Alfadhli[1], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA.* We propose and experimentally demonstrate a centralized digital self-interference cancellation scheme in a mm-wave over fiber system for full-duplex next-generation mobile networks. A 24.1-dB self-interference cancellation over 1-GHz bandwidth is realized with successful signal-of-interest recovery.

Th2A.47
Four-dimensional 8-bit Modulation with KP4 Non-binary FEC for Short-reach Coherent Optical Transmissions, Liangjun Zhang[1], Hung-chang Chien[1], Yi Cai[1], Weiming Wang[1], Weiqin Zhou[1], Zihe Hu[1]; [1]*ZTE Corporation, China.* C4-256 four-dimensional 8-bit modulation with non-binary FEC is firstly proposed and demonstrated for coherent optical transmissions, which outperforms its PM-16QAM counterpart by 0.7-dB for required OSNR at 10^{-8} post-FEC BER.

Th2A • Poster Session II—Continued

Th2A.48
Concept and Experimental Demonstration of Optical IM/DD End-to-end System Optimization using a Generative Model, Boris P. Karanov[1,2], Mathieu Chagnon[2], Vahid Aref[2], Domaniç Lavery[1], Polina Bayvel[1], Laurent Schmalen[3]; [1]*Univ. College London, UK;* [2]*Nokia Bell Labs, Germany;* [3]*Karlsruhe Inst. of Technology, Germany.* We perform an experimental end-to-end transceiver optimization via deep learning using a generative adversarial network to approximate the test-bed channel. Previously, optimization was only possible through a prior assumption of an explicit simplified channel model.

Th2A.49
Joint Linear and Nonlinear Noise Estimation of Optical Links by Exploiting Carrier Phase Recovery, Daniel Lippiatt[1], Siddharth Varughese[1], Thomas Richter[2], Sorin Tibuleac[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*ADVA Optical Networking, USA.* We demonstrate joint linear and nonlinear noise estimation by extracting the optical signal-to-noise ratio (OSNR) and launch power directly from phase noise metrics readily available within existing digital signal processing algorithms.

Th2A.50
Optical Labelling and Performance Monitoring in Coherent Optical Wavelength Division Multiplexing Networks, Chao Yang[1], Xiang Li[1], Ming Luo[1], Zhixue He[1], Haibo Li[1], Cai Li[1], Shaohua Yu[1]; [1]*Wuhan Research Inst. of Post & Tele, China.* We propose and experimentally demonstrate an optical labelling scheme in coherent optical WDM network to simultaneously recognize labels in each wavelength and monitor the OSNR using only one photodetector based on subcarrier index modulation technology.

Th2A.51
Reduction in Complexity of Volterra Filter by Employing l_0-Regularization in 112-Gbps PAM-4 VCSEL Optical Interconnect, Yi-Yu Lin[1], Chun-Jui Chen[1], Hong-Minh Nguyen[2], Chun-Yen Chuang[2], Chia Chien Wei[1], Jyehong Chen[2], Jin-Wei Shi[3]; [1]*National Sun Yat-Sen Univ., Taiwan;* [2]*National Chiao Tung Univ., Taiwan;* [3]*National Central Univ., Taiwan.* We employ l_0-regularization to reduce Volterra filter complexity by up to 90% in 112-Gbps PAM-4 VCSEL transmission. Compared to l_1-regularization, l_0-regularization achieves lower complexity and more precise weights without retraining after sparse identification.

Th2A.52
Nonlinear Tolerance Enhancement Based on Perturbation Theory for Optical Phase Conjugation Systems, Tu T. Nguyen[1], Paul Harper[1], Sunish O.S. Kumar[2], Andrew Ellis[1]; [1]*Aston Univ., UK;* [2]*Memorial Univ. of Newfoundland, Canada.* We show more than 1 dB of additional SNR improvement by deploying perturbation-based nonlinearity DSP at the receiver side for 30 GBaud dual-polarization 16-QAM transmission over a 2560 km link with a mid-link optical phase conjugation.

Th2A.53
The Impact of Nonlinear Phase Noise Induced from Low-speed Optical Supervisory Channel on Soft-decision FEC Performance, Hiroki Kawahara[1], Kohei Saito[1], Takeshi Seki[1], Takeshi Kawasaki[1], Hideki Maeda[1]; [1]*NTT Network Service System Labolatories, Japan.* 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.

Th2A.54
17 GBd Sub-photon Level Heterodyne Detection for CV-QKD Enabled by Machine Learning, Max Rückmann[1], Sebastian Kleis[1], Christian Schaeffer[1]; [1]*Helmut-Schmidt-Univ., Germany.* We experimentally 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.

Th2A.55
Recent Progress in the Characterization of the G-SNR and the OSNR of Future SDM-based Subsea Open Cables, Alexis C. Carbó Meseguer[1], Philippe Plantady[1], Alain Calsat[1], Suwimol Dubost[1], Vincent Letellier[1]; [1]*Alcatel Submarine Networks, France.* We characterized the G-SNR and the OSNR of an SDM-compatible submarine optical cable with different modulation formats and symbol rates up to 101 GBd, observing good agreement between all G-SNR measurements.

Th2A.56
Secure Optical Communication Based on Common-injection-induced Synchronization of Wideband Complex Signals, Ning Jiang[1], Anke Zhao[1], Shiqin Liu[1], Yiqun Zhang[1], Kun Qiu[1]; [1]*Univ of Electronic Science & Tech China, China.* We propose and experimentally demonstrate a novel secure optical communication scheme that supports high encryption efficiency and high-speed transmissions over Gbit/s with satisfactory BER performance, by achieving common-injection-induced synchronization between two wideband complex entropy sources.

Show Floor Programming Continued

Design Consideration of Next Generation Ethernet Switches with Higher Speed Optics
Cisco
10:15–11:15, *Theater II*

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Intel
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12:30–14:00, *Theater I*

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12:45–13:45, *Theater II*

POFTO Symposium
POFTO
13:45–14:45, *Theater III*

Room 1A

14:00–16:00
Th3A • Disaggregation, Open Platform, SDN, NFV
Presider: David Boertjes; Ciena Corporation, Canada

Th3A.1 • 14:00
Disaggregated Packet Transponder Field Demonstration Exercising Multi-format Transmission with Multi-vendor, Open Packet Optical Network Elements, Geraldine Francia[2], Ryoji Nagase[3], Wataru Ishida[3], Yoshiaki Sone[3], Lalit Kumar[4], Srikanth Krishnamohan[4], Victor López[1]; [1]*Telefonica R&D, Spain;* [2]*Telefonica Peru, Peru;* [3]*NEL America, USA;* [4]*IP 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, Zhensheng Jia[1]; [1]*CableLabs, USA.* Based on new design of consolidated inter-hub CDC architecture, end-to-end video delivery is demonstrated with 2-us latency from multicast switch and 11us from interoperable coherent muxponder, and full-duplex operation is also presented in such network.

Room 1B

14:00–16:00
Th3B • Optical Switching
Presider: Richard Jensen; Huber Suhner Polatis, Inc., USA

Th3B.1 • 14:00 Invited
Large-scale Photonic Integrated Cross-connects for Optical Communication and Computation, Ripalta Stabile[1], Nicola Calabretta[1], Bin Shi[1]; [1]*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.

Room 2

14:00–16:00
Th3C • High-speed and Multi-wavelength Devices
Presider: Kouji Nakahara; Lumentum Japan Inc., Japan

Th3C.1 • 14:00 ★ Top-Scored
Direct Modulation of a 54-GHz Distributed Bragg Reflector Laser with 100-GBaud PAM-4 and 80-GBaud PAM-8, Di Che[1], Yasuhiro Matsui[2], Richard Schatz[3], Roberto Rodes[4], Ferdous Khan[2], Martin Kwakernaak[2], Tsurugi Sudo[2], Chandrasekhar Sethumadhavan[1], Junho Cho[1], Xi Chen[1], Peter Winzer[1]; [1]*Nokia Bell Labs, USA;* [2]*Finisar Corporation, USA;* [3]*Applied Physics, Photonics, KTH Royal Inst. of Technology, Sweden;* [4]*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 Gb/s.

Th3C.2 • 14:15
High Linearity and Uniform Characteristics of InP-based 8-CH Waveguide Avalanche Photodiode Array for 400 GbE, Takuya Okimoto[1,2], Ken Ashizawa[2], Koji Ebihara[2], Satoru Okamoto[2], Takumi Endo[2], Kazuhiko Horino[2], Tatsuya Takeuchi[2], Toru Uchida[2], Hideki Yagi[1,2], Yoshihiro Yoneda[2,1]; [1]*Sumitomo Electric Industries, Ltd., Japan;* [2]*Sumitomo Electric Device Innovations, Inc., Japan.* InP-based 8-channel waveguide APD arrays were demonstrated towards 400GbE for the first time. They exhibited maximum 3dB-bandwidth of 23GHz under high-optical input of -10dBm and uniformity of avalanche breakdown voltage less than 0.1V between channels.

Room 3

14:00–16:00
Th3D • Machine Learning for Optical Network Performance
Presider: Maite Brandt-Pearce; Univ. of Virginia, USA

Th3D.1 • 14:00
Evol-TL: Evolutionary Transfer Learning for QoT Estimation in Multi-domain Networks, Che-Yu Liu[1], Xiaoliang Chen[1], Roberto Proietti[1], S. J. Ben Yoo[1]; [1]*Univ. of California, Davis, USA.* We propose an evolutionary transfer learning approach for QoT estimation in multi-domain optical networks. The results demonstrate that our approach can reduce the amounts of required training data by 10x while achieving accuracies of >90%.

Th3D.2 • 14:15 ★ Top-Scored
Assessment of Domain Adaptation Approaches for QoT Estimation in Optical Networks, Riccardo di Marino[1], Cristina Rottondi[1], Alessandro Giusti[2], Andrea Bianco[1]; [1]*Politecnico di Torino, Italy;* [2]*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.

Room 6C

14:00–16:00
Th3E • Optimizing Coherent Transponders ▶
Presider: Hongbin Zhang; Acacia Communications, USA

Th3E.1 • 14:00 Tutorial ▶
Performance Oriented DSP Design for Flexible Coherent Transmission, Chris R. Fludger[1]; [1]*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.

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.

Room 6D

14:00–16:00
Th3F • Novel Fiber Optic Sensors ▶
Presider: Sergio Leon-Saval; Univ. of Sydney, Australia

Th3F.1 • 14:00 Invited ▶
Calibrated Fiber Grating Wavelength Combs Enable High Accuracy Biosensing, Jacques Albert[1]; [1]*Carleton Univ., Canada.* Simulation-based calibrations of measured spectra are used to find the exact optical properties of multi-resonant fiber gratings, resulting in elimination of cross-sensitivities, lower noise and orders of magnitude improvements in biochemical sensor limits of detection.

Room 6E

14:00–16:00
Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond

The market for coherent pluggable optics supporting reaches between 10 km and 120 km is emerging for many applications, such as telco metro-access router-to-router interconnects, point-to-point data center interconnect, mobile and cable aggregation applications. The ongoing 400ZR project at the Optical Internetworking Forum (OIF) defines a digital coherent 400ZR interface primarily for DCI applications. There have also been other standardization activities defining coherent interfaces by other industry organizations addressing various applications. Products compliant to these specifications are coming out and early commercial deployments are expected to be in 2020.

Panelists from network operators, system companies, and module manufacturers will review recent progress in terms of network deployment requirements/schedule, interoperability, DSP/module development status, and share their views of the coherent pluggable optics roadmap in the next decade.

Speakers:

Christian Rasmussen; *Acacia Communications Inc., USA*

Satoshi Ide; *Fujitsu Optical Components, Japan*

Xiang Zhou; *Google, USA*

Matthew Schmitt; *Cable Labs, USA*

Eric Maniloff; *Ciena, Canada*

Room 6F

14:00–15:30
Th3H • SDM Transmission

Presider: Werner Klaus; National Inst of Information & Comm Tech, Japan

Th3H.1 • 14:00 Top-Scored

10.66 Peta-Bit/s Transmission over a 38-core-three-mode Fiber, Georg Rademacher[1], Benjamin J. Puttnam[1], Ruben S. Luis[1], Jun Sakaguchi[1], Werner Klaus[1], Tobias A. Eriksson[1,2], Yoshinari Awaji[1], Tetsuya Hayashi[3], Takuji Nagashima[3], Tetsuya Nakanishi[3], Toshiki Taru[3], Taketoshi Takahata[4], Tetsuya Kobayashi[4], Hideaki Furukawa[1], Naoya Wada[1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*AlbaNova Univ. Center, Royal Inst. of Technology (KTH), Sweden;* [3]*Sumitomo Electric Industries, Ltd.,, Japan;* [4]*Optoquest Co. Ltd., Japan.* We demonstrate transmission of 368-WDM-38-core-3-mode x 24.5-GBaud 64- and 256-QAM signals over 13 km. Record data-rate and spectral-efficiency of 1158.7 b/s/Hz were enabled by a low DMD 38-core-3-mode fiber with high uniformity amongst cores.

Th3H.2 • 14:15

Real-time Strongly-coupled 4-core Fiber Transmission, Shohei Beppu[2], Koji Igarashi[1], Hiroshi Mukai[3], Masahiro Kikuta[3], Masahiro Shigihara[3], Daiki Soma[2], Takehiro Tsuritani[2], Itsuro Morita[2]; [1]*Osaka Univ., Japan;* [2]*KDDI Research, Inc., Japan;* [3]*NEC Platforms, Ltd., Japan.* We show a real-time optical coherent MIMO receiver for 4-mode division multiplexed transmission. With the receiver, we demonstrate real-time strongly-coupled 4-core fiber transmission of WDM DP-QPSK signals over 60 km.

Room 7

14:00–16:00
Th3I • Optical and Thermal Connectivity

Presider: Alan McCurdy; OFS, Fiber Design & Simulation Group, USA

Th3I.1 • 14:00 Invited

Optical Connectivities for Multicore Fiber, Ryo Nagase[1]; [1]*Faculty of Engineering, Chiba Inst. of Technology, Japan.* Multicore fiber is proposed for use in space-division multiplexing for ultra-wide-band optical transmission systems. This paper introduces recent progress on multicore fiber connection technologies for simplex and multifiber connectors.

Room 8

14:00–15:30
Th3J • Direct Detection Systems and Subsystems

Presider: To be Announced

Th3J.1 • 14:00 Invited

Modem Module Development for NASA's Orion Spacecraft: Achieving FSO Communications over Lunar Distances, David J. Geisler[1]; [1]*Massachusetts Inst of Tech Lincoln Lab, USA.* NASA's Orion spacecraft will employ free-space optical communications over 400,000- km from the lunar vicinity to Earth, using an 80-Mb/s downlink and a 20-Mb/s uplink. This paper discusses an overview of the link and optical modem.

Room 9

14:00–16:00
Th3K • Future and Emerging Access Network Technologies

Presider: Junwen Zhang; CableLabs, USA

Th3K.1 • 14:00

Modeling and Experiments for Reliable Operation of Single-mode Transceivers Over Multimode Fiber, Jose Castro[1], Fei Jia[1], Rick Pimpinella[1], Yu Huang[1], Bulent Kose[1], Brett Lane[1]; [1]*Panduit, USA.* We define metrics to predict the transmission performance of SMF transceivers over MMF links at 40Gbps and 100Gbps based on simulation and experiments.

Th3K.2 • 14:15 Invited

Overturning the Eight Fallacies of Distributed Computing with the Octopus Edge Network, Sebastien Bigo[1]; [1]*Nokia Bell Labs, USA.* Named after the mollusk nervous system, the Octopus network is a sequel of low-latency ultra-reliable edge networks. Its dynamic and deterministic characteristics open a new era for computing by breaking the notorious eight fallacies of distributed computing.

Show Floor Programming Continued

POFTO Symposium
POFTO
13:45–14:45, *Theater III*

Introduction to OpenROADM MSA, Latest Update, and Show Floor Demo Overview
14:00–15:00, *Theater II*

The World's First Intercontinental Connections... Contrasting Early Terrestrial-subsea Networks with the Present
Telecom Infra Project (TIP)
15:05–16:00, *Theater II*

■ **Market Watch Panel VII: IP+WDM Architecture Evolution**
14:30–16:00, *Theater I*

Room 1A

Th3A • Disaggregation, Open Platform, SDN, NFV—Continued

Th3A.3 • 14:30 Invited

Optical Node Disaggregation Management and Interoperability, Emilio Riccardi[1], Marco Schiano[1]; [1]*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.

Room 1B

Th3B • Optical Switching—Continued

Th3B.2 • 14:30

Polarization-diversity Microring-based Optical Switch Fabric in a Switch-and-select Architecture, Hao Yang[1], Qixiang Cheng[1], Rui Chen[1], Keren Bergman[1]; [1]*Columbia Univ., USA.* We propose a polarization-diversity microring-based optical switch fabric in a switch-and-select architecture with polarization splitter-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.

Th3B.3 • 14:45 ★ Top-Scored

Integrated SiPh Flex-LIONS Module for All-to-all Optical Interconnects with Bandwidth Steering, Xian Xiao[1], Roberto Proietti[1], Gengchen Liu[1], Hongbo Lu[1], Yi-Chun Ling[1], Yu Zhang[1], S. J. Ben Yoo[1]; [1]*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.

Room 2

Th3C • High-speed and Multi-wavelength Devices—Continued

Th3C.3 • 14:30

SOH Mach-Zehnder Modulators for 100 GBd PAM4 Signaling With Sub-1 dB Phase-shifter Loss, Clemens Kieninger[1], Christoph Füllner[1], Heiner Zwickel[1], Yasar Kutuvantavida[1], Juned Nassir Kemal[1], Carsten Eschenbaum[1], Delwin L. Elder[2], Larry R. Dalton[2], Wolfgang Freude[1], Sebastian Randel[1], Christian Koos[1]; [1]*Karlsruhe Inst. of Technology, Germany;* [2]*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 π-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

High-speed and 16λ-WDM Operation of Ge/Si Electro-absorption Modulator for C-band Spectral Regime, Junichi Fujikata[1], Masataka Noguchi[1], Seok H. Jeong[1], Yosuke Onawa[1,2], Daisuke Shimura[1,2], Kazuki Kawashita[3], Riku Katamawari[3], Hideaki Okayama[1,2], Shigeki Takahashi[1], Hideki Ono[1], Hiroyuki Takahashi[1,2], Hiroki Yaegashi[1,2], Yasuhiko Ishikawa[3], Takahiro Nakamura[1]; [1]*PETRA, Japan;* [2]*Oki Electric Industry Co., Ltd., Japan;* [3]*Toyohashi Univ. of Technology, Japan.* We present high-speed of 100Gbps for PAM-4 signal and 16λ-WDM operations of a Ge/Si EAM in C-band. Operation wavelengths could be controlled by Ge/Si stack width, and 16 λ operation was demonstrated at 50 Gbps.

Room 3

Th3D • Machine Learning for Optical Network Performance—Continued

Th3D.3 • 14:30

Fast and High-Precision Optical Performance Evaluation for Cognitive Optical Networks, Rui M. Morais[1], Bruno Pereira[1], João Pedro[1]; [1]*Infinera, Portugal.* We propose a methodology for accurate and fast optical performance estimation exploiting cognitive awareness. It is composed by low and high precision estimators and a calibration engine, allowing to control open vs. proprietary implementations.

Th3D.4 • 14:45

Modeling Filtering Penalties in ROADM-based Networks with Machine Learning for QoT Estimation, Ankush Mahajan[1], Konstantinos (Kostas) Christodoulopoulos[2], Ricardo Martínez[1], Salvatore Spadaro[3], Raul Muñoz[1]; [1]*CTTC, Spain;* [2]*Nokia Bell Labs, Germany;* [3]*UPC, Spain.* Monitoring 3dB bandwidth and other spectrum related parameters at ROADMs 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.

Room 6C

Th3E • Optimizing Coherent Transponders—Continued

Room 6D

Th3F • Novel Fiber Optic Sensors—Continued

Th3F.2 • 14:30

A Novel Demodulation Method of Fiber Bragg Grating Sensor Array Based on Wavelength-to-time Mapping and Multiloop Optoelectronic Oscillator, Wenxuan Wang[1], Yi Liu[2], Xinwei Du[2], Yaxi Yan[2], Changyuan Yu[2], Xiangfei Chen[1]; [1]*Key Laboratory of Intelligent Optical Sensing and Manipulation of the Ministry of Education & National Laboratory of Solid State Microstructures & College of Engineering and Applied Sciences, Nanjing Univ., China;* [2]*The Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong.* We propose a novel demodulation method of strong FBG sensor array based on wavelength-to-time mapping and multiloop OEO. The oscillating frequency shift caused by the time shift encodes measurable variation and location information.

Th3F.3 • 14:45

Femtosecond Laser Fabricated All-multicore-fiber Parallel Fabry-Perot Interferometers for Dual-parameter Sensing, Cong Zhang[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1]; [1]*School of Optical and Electronic Information, Huazhong Univ of Science and Technology, China.* We demonstrate all-multicore-fiber parallel Fabry-Perot interferometers (FPIs) with individually variable cavity length of 26-61µm by femtosecond laser selective micro-machining and fiber fusion splicing, leading to the successful mitigation of cross-sensitivity arising in dual-parameter sensing.

Room 6E

Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond—Continued

Room 6F

Th3H • SDM Transmission—Continued

Th3H.3 • 14:30 ★ Top-Scored

Long-Haul DMD-Unmanaged 6-mode-multiplexed Transmission Employing Cyclic Mode-group Permutation, Kohki Shibahara[1], Takayuki Mizuno[1], Hirotaka Ono[2], Kazuhide Nakajima[3], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan;* [2]*NTT Device Technology Laboratories, Japan;* [3]*NTT Access Network Service Systems Laboratories, Japan.* We demonstrate 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 Essiambre[1], Roland Ryf[1], Sjoerd van der Heide[1,2], Juan I. Bonetti[1,4], Hanzi Huang[1,3], Murali Kodialam[1], Francisco Javier Garcia-Gomez[1,5], Ellsworth C. Burrows[1], Juan Carlos Alvarado Zacarias[1,6], Rodrigo Amezcua Correa[6], Xi Chen[1], Nicolas K. Fontaine[1], Haoshuo Chen[1]; [1]*Nokia Corporation, USA;* [2]*Electrical Engineering, Eindhoven Univ. of Technology, Netherlands;* [3]*Specialty Fiber Optics and Optical Access Networks, Shanghai Univ., China;* [4]*Grupo de Comunicaciones Opticas, Instituto Balseiro, Argentina;* [5]*Inst. for Commun. Engineering, Technical Univ. of Munich, Germany;* [6]*CREOL, The Univ. of Central Florida, USA.* We demonstrate the first transmission of a space-division multiplexed 12D modulation format over a 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.

Room 7

Th3I • Optical and Thermal Connectivity—Continued

Th3I.2 • 14:30

Simple-structure LC-type Multi-core Fiber Connector with Low Insertion Loss, Tetsu Morishima[1], Ken Manabe[1], Shuhei Toyokawa[1], Tetsuya Nakanishi[1], Tomomi Sano[1], Tetsuya Hayashi[1]; [1]*Sumitomo Electric Industries, 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.

Th3I.3 • 14:45

High Durability Molded Lens Connector for SMFs, Akihiro Nakama[1]; [1]*Fujikura 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.

Room 8

Th3J • Direct Detection Systems and Subsystems—Continued

Th3J.2 • 14:30

5.2dB Sensitivity Enhancement in 25Gbps APD-based Optical Receiver Using Dynamic Biasing, Payman Zarkesh-Ha[1,2], Robert Efroymson[1], Earl Fuller[1], Joe Campbell[3], Majeed Hayat[1,4]; [1]*Dynamic Photonics Inc., USA;* [2]*Center for High Technology Materials and ECE Dept, Univ. of New Mexico, USA;* [3]*Department of Electrical and Computer Engineering, Univ. of Virginia, USA;* [4]*Department 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.

Th3J.3 • 14:45

Low-cost TI-ADC Timing Calibration Circuit, Hananel Faig[1], Shai Cohen[2], Liron Gantz[2], Dan Sadot[1]; [1]*Ben-Gurion Univ. of the Negev, Israel;* [2]*Mellanox 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 sub-blocks, and enables flexible tradeoff of complexity versus performance.

Room 9

Th3K • Future and Emerging Access Network Technologies—Continued

Th3K.3 • 14:45

Demonstration of SOA-based IM/DD 1T (280Gbit/s×4) PS-PAM8 Transmission over 40km SSMF at O-band, Kaihui Wang[1], Jiao Zhang[1], Mingming Zhao[1], Wen Zhou[1], Li Zhao[1], Jiangnan Xiao[1], Feng Zhao[2], Yun Zhang[3], Bo Liu[4], Xiangjun Xin[4], Ze Dong[5], Jianjun Yu[1]; [1]*Fudan Univ., China;* [2]*Xian Univ. of Posts and Telecommunications, China;* [3]*ZTE Corp, China;* [4]*Beijing Univ. of Posts and Telecommunications, China;* [5]*Huaqiao 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.

Show Floor Programming Continued

POFTO Symposium
POFTO
13:45–14:45, *Theater III*

Introduction to OpenROADM MSA, Latest Update, and Show Floor Demo Overview
14:00–15:00, *Theater II*

The World's First Intercontinental Connections… Contrasting Early Terrestrial-subsea Networks with the Present
Telecom Infra Project (TIP)
15:05–16:00, *Theater II*

■ Market Watch Panel VII: IP+WDM Architecture Evolution
14:30–16:00, *Theater I*

Room 1A

Th3A • Disaggregation, Open Platform, SDN, NFV—Continued

Th3A.4 • 15:00
Demonstration of Containerized vDU/vCU Migration in WDM Metro Optical Networks, Jiaxin Feng[1], Jiawei Zhang[1], Yuefeng Ji[1], Yuming Xiao[1]; [1]*Beijing 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.

Th3A.5 • 15:15
First Proof That Geographic Location on Deployed Fiber Cable Can Be Determined by Using OTDR Distance Based on Distributed Fiber Optical Sensing Technology, Tiejun J. Xia[1], Glenn Wellbrock[1], Ming-Fang Huang[2], Milad Salemi[2], Yuheng Chen[2], Ting Wang[2], Yoshiaki Aono[3]; [1]*Verizon Communications Inc, USA;* [2]*NEC Laboratories America, USA;* [3]*NEC Corporation, Japan.* We demonstrated for the first time that geographic locations on deployed fiber cables can be determined accurately by using OTDR distances. The method involves vibration stimulation near deployed cables and distributed fiber optical sensing technology.

Room 1B

Th3B • Optical Switching—Continued

Th3B.4 • 15:00 ★ Top-Scored
O-band Strictly Non-blocking 8 × 8 Silicon-photonics Switch, Keijiro Suzuki[1], Ryotaro Konoike[1], Guangwei Cong[1], Koji Yamada[1], Shu Namiki[1], Hitoshi Kawashima[1], Kazuhiro Ikeda[1]; [1]*National 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.

Th3B.5 • 15:15
Fast Switching of 84 μs for Silica-based PLC Switch, Osamu Moriwaki[1], Kenya Suzuki[1]; [1]*NTT Device Innovation Center, NTT Corporation, Japan.* We have reduced the switching time of a silica-based thermo-optic switch to 84 μs by utilizing a thin cladding layer and a novel driving techniques. The resultant high-speed switch should be suitable for intra-datacenter networks.

Room 2

Th3C • High-speed and Multi-wavelength Devices—Continued

Th3C.5 • 15:00 Tutorial
Data Center Links Beyond 100 Gbit/s Per Wavelength, Joseph M. Kahn[1], Jose Krause Perin[2], Anujit Shastri[3]; [1]*Stanford Univ., USA;* [2]*Aeva, Inc., USA;* [3]*Aayuna, Inc., USA.* We review intra- and inter-data center link options, including those based on direct detection, digital or analog coherent detection, Stokes vector detection or Kramers-Kronig detection, comparing them in terms of spectral efficiency, optical power efficiency, complexity and power consumption.

Joseph M. Kahn is Professor of Electrical Engineering at Stanford University. Achievements include: first synchronous (coherent) detection in fiber optics (1989); first probabilistic shaping in optical communications (1999); founding StrataLight Communications, leader in first-generation phase-modulated fiber transmission systems (2000); first electronic compensation of fiber Kerr nonlinearity (2002), leading to digital backpropagation (2008).

Room 3

Th3D • Machine Learning for Optical Network Performance—Continued

Th3D.5 • 15:00 ★ Top-Scored
How Uncertainty on the Fiber Span Lengths Influences QoT Estimation Using Machine Learning in WDM Networks, Jelena Pesic[1], Matteo Lonardi[1], Nicola Rossi[2], Thierry Zami[2], Emmanuel Seve[1], Yvan Pointurier[1]; [1]*Nokia-Bell-Labs, France;* [2]*Nokia, 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.

Th3D.6 • 15:15
A Three-stage Training Framework for Customizing Link Models for Optical Networks, Xiaomin Liu[1], Huazhi Lun[1], Mengfan Fu[1], Yunyun Fan[1], Lilin Yi[1], Weisheng Hu[1], Qunbi Zhuge[1]; [1]*Shanghai 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.

Room 6C

Th3E • Optimizing Coherent Transponders—Continued

Th3E.2 • 15:00 ▶ ★ Top-Scored
1.1 Tb/s/l at 9.8 bit/s/Hz DWDM Transmission over DCI Distances Supported by CMOS DACs, Fred Buchali[1], Vincent Lauinger[2], Mathieu Chagnon[1], Karsten Schuh[1], Vahid Aref[1]; [1]*Nokia Bell Labs, Germany;* [2]*KIT, Germany.* We report on a 16-nm CMOS DAC based transmitter optimization enabling bitrates up to 1.15 Tb/s. We successfully demonstrate DWDM transmission over DCI distances up to 118 km at 1.1 Tb/s and spectral efficiencies of 9.8 bit/s/Hz.

Th3E.3 • 15:15 Invited ▶
Maximizing Throughput via Vertical Optimization of the Coherent MODEM, Robert Maher[1], Mehdi Torbatian[2], An Nguyen[1], Zhenxing Wang[1], Swen Koenig[1], Mark Missey[1], Alban Le Liepvre[1], Ryan Going[1], Stefan Wolf[1], Parmijit Samra[1], Pat Day[1], Stephanie Tremblay[2], Mehrdad Ziari[1], Fred Kish[1], Steve Sanders[1], Parthiban Kandappan[1]; [1]*Infinera Corporation, USA;* [2]*Infinera, Canada.* Vertical optimization of DSP algorithms, analog electronics, optical components and PCB design is critical to maximize the SNR limit of the digital coherent MODEM. We demonstrate a record net ISD of 10.82b/s/Hz for a vertically optimized 256QAM transceiver operating at a symbol rate >50GBd

Room 6D

Th3F • Novel Fiber Optic Sensors—Continued

Th3F.4 • 15:00 ▶
Sub-mK and Nano-strain Discrimination Using Frequency Stabilized Lasers and Polarization Maintaining π-shifted Fibre Bragg Gratings, Stefanos Andreou[1], Roel van der Zon[1], Kevin A. Williams[1], Erwin Bente[1]; [1]*Electrical Engineering, Eindhoven Univ. of Technology, Netherlands.* We report on a sensing system which discriminates strain and temperature with 5.5 nanostrain and 0.39 mK resolutions respectively. The system deploys frequency stabilized integrated InP-based lasers and a heterodyne-based read-out system.

Th3F.5 • 15:15 ▶
Distortion-suppressed Sampling Rate Enhancement in Phase-OTDR Vibration Sensing with Newly Designed FDM Pulse Sequence for Correctly Monitoring Various Waveforms, Yoshifumi Wakisaka[1], Daisuke Iida[1], Hiroyuki Oshida[1]; [1]*NTT corp., Japan.* The FDM-based sampling rate enhancement method proposed herein detects vibration waveforms more accurately than previous methods while reducing phase unwrapping failures; it can measure vibrations with larger amplitude and higher frequency than heretofore.

Room 6E

Th3G • Panel: Pluggable Coherent Optics for Short-haul/Edge Applications and Beyond—Continued

Room 6F

Th3H • SDM Transmission—Continued

Th3H.5 • 15:00 ★ Top-Scored

0.596 Pb/s S, C, L-Band Transmission in a 125 μm Diameter 4-core Fiber Using a Single Wideband Comb Source, Benjamin J. Puttnam[1], Ruben S. Luis[1], Georg Rademacher[1], Lidia Galdino[2], Domaniç Lavery[2], Tobias Eriksson[1], Yoshinari Awaji[1], Hideaki Furukawa[1], Polina Bayvel[2], Naoya Wada[1]; [1]*National Inst Info & Comm Tech (NICT), Japan;* [2]*Optical Networks Group, Univ. Collage London, UK.* We demonstrate 596.4 Tb/s over a standard cladding diameter fiber with 4 single-mode cores, using a single wideband optical comb source to provide 25 GHz spaced carriers over 120 nm range across S, C and L bands.

Th3H.6 • 15:15

First Experimental Demonstration of Cross-SDM/WDM Q-difference Compensation at Multicore Fiber Transmission, Hidenori Takahashi[1], Daiki Soma[1], Takehiro Tsuritani[1]; [1]*KDDI Research, Inc., Japan.* The Q-difference compensation scheme among SDM/WDM signals is evaluated at 192-km 4-core-path MCF transmission line. The Q-difference is mitigated within 0.1 dB and the Q-factor of the worst quality signal is improved as 0.7 dB.

Room 7

Th3I • Optical and Thermal Connectivity—Continued

Th3I.4 • 15:00

A CMOS Compatible Monolithic Fiber Attach Solution with Reliable Performance and Self-alignment, Bo Peng[1,3], Tymon Barwicz[2], Asli Sahin[3], Thomas Houghton[3], Brittany Hedrick[3], Yusheng Bian[1], Michal Rakowski[1], Shuren Hu[3], Javier Ayala[3], Colleen Meagher[3], Zoey Sowinski[3], Karen Nummy[3], Andy Stricker[3], Jorge Lubguban[3], Hui Chen[3], Benjamin Fasano[3], Ian Melville[3], Zhuo-jie Wu[3], Jae K. Cho[3], Ajey Jacob[1], Dave Riggs[3], Daniel Berger[3], Ted Letavic[3], Anthony Yu[3], John Pellerin[3], Ken Giewont[3]; [1]*Globalfoundries CTO Research, USA;* [2]*IBM T. J. Watson Research Center, USA;* [3]*GlobalFoundries, USA.* We report a fiber-attach solution interfacing self-aligned, standard-cleaved fibers to monolithic photonic integrated circuits, fabricated in Globalfoundries 300-mm CMOS production facilities. Statistical yield analysis and reliability assessment were performed to demonstrate the robustness of the proposed solution.

Th3I.5 • 15:15 Invited

Optoelectronic Glass Substrates for Co-packaging Optics and ASICs, Lars Brusberg[1], Aramais Zakharian[1], Ekin Kocabas[1], Jason G. Grenier[1], Chad Terwilliger[1], Alan F. Evans[1]; [1]*Corning Research & Development Corporation, USA.* A glass packaging substrate with integrated waveguides and evanescent couplers for silicon photonic chiplets is introduced for fiber to chip interconnects with high-channel counts required for co-packaging of optics and switch ASICs in next-generation datacenters.

Room 8

Th3J • Direct Detection Systems and Subsystems—Continued

Th3J.4 • 15:00 ★ Top-Scored

Beyond 100-Gb/s Direct-detection Transmission Using an Optical Receiver Co-integrated with a 28-nm CMOS Gain-tunable Fully-differential TIA, Yang Hong[1], Ke Li[1], Cosimo Lacava[1], Shenghao Liu[1], David Thomson[1], Fanfan Meng[1], Xiaoke Ruan[2], Fan Zhang[2], Graham T. Reed[1], Periklis Petropoulos[1]; [1]*Univ. of Southampton, UK;* [2]*Peking Univ., China.* We demonstrate up to 173.22-Gb/s direct-detection transmission using a balanced photodetector wire-bonded to a 28-nm CMOS fully-differential gain-tunable TIA. Both 100-Gb/s PAM4 and capacity-maximized adaptively-loaded DMT are studied for up to 2-km SSMF transmission.

Th3J.5 • 15:15

Real-Time 28 Gb/s NRZ over 80 km SSMF in C-band using Analog Electronic Precompensation, Michiel Verplaetse[1], Laurens Breyne[1], Joris Lambrecht[1], Xin Yin[1], Peter Ossieur[1], guy Torfs[1]; [1]*IDLab, Ghent Univ.-imec, Belgium.* We demonstrate real-time C-band transmission of direct detected 28Gb/s NRZ/OOK over 80km SSMF using a Dual-Drive MZM and custom-designed SiGe BiCMOS 5-tap analog FIR filters to compensate chromatic dispersion without digital signal processing.

Room 9

Th3K • Future and Emerging Access Network Technologies—Continued

Th3K.4 • 15:00

112-Gb/s/lambda Downstream Transmission for TDM-PON with 31-dB Power Budget using 25-Gb/s Optics and Simple DSP in ONU, Siyu Luo[1], Zhengxuan Li[1], Yuanzhe Qu[1], Yingxiong Song[1], Jian Chen[1], Yingchun Li[1], Min Wang[1]; [1]*Shanghai Univ., China.* We experimentally demonstrate 112-Gb/s/lambda PAM-4 transmission based on 25-Gb/s optics. Over 31-dB power budget is achieved by using OLT-side pre-equalization, amplification and only simple FFE in ONU.

Th3K.5 • 15:15 Invited

Opportunities and Challenges When Using Low Bandwidth Optics for Higher Capacity PON Systems, Roberto Gaudino[1], Pablo Torres-Ferrera[1], Haoyi Wang[1], Maurizio Valvo[2], Annachiara Pagano[2], Roberto Mercinelli[2], Valter Ferrero[1]; [1]*Politecnico di Torino, Italy;* [2]*TIM, Telecom Italia, Italy.* Next generation PON physical layer, targeting 50 Gbit/s/lambda, has to deal with optoelectronics bandwidth limitation. In this invited paper, we review the resulting required bandwidths and discuss the trade-off between receivers with or without equalization

Show Floor Programming Continued

The World's First Intercontinental Connections… Contrasting Early Terrestrial-subsea Networks with the Present
Telecom Infra Project (TIP)
15:05–16:00, *Theater II*

■ Market Watch Panel VII: IP+WDM Architecture Evolution
14:30–16:00, *Theater I*

Fibre Types and Amplifiers: Choices and Trade-offs
Fiberstory
15:00–16:00, *Theater III*

Room 1A	Room 1B	Room 2	Room 3	Room 6C	Room 6D

Th3A • Disaggregation, Open Platform, SDN, NFV—Continued

Th3A.6 • 15:30 Invited
Progress in 100G Lambda MSA Based on 100G PAM4 Technology, Mark Nowell[1], Matt Traverso[1], Marco Mazzini[1], Kumar Lakshmikumar[1], Mark Webster[1], Peter De Dobbelaere[1]; [1]*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.

Th3B • Optical Switching—Continued

Th3B.6 • 15:30 ★ Top-Scored
5.7-dB Fiber-to-fiber Loss 8 × 8 Silicon Photonics Switch with Port-alternated Switch-and-select Architecture, Ryotaro Konoike[1], Keijiro Suzuki[1], Hitoshi Kawashima[1], Kazuhiro Ikeda[1]; [1]*National Inst. of Advanced Industrial Science and Technology (AIST), Japan.* We propose and demonstrate a Port-Alternated Switch-and-Select architecture that has both low insertion loss and low path dependency. Using silicon photonics platform, we realized an 8 × 8 switch with 5.7-dB Fiber-to-Fiber insertion loss.

Th3B.7 • 15:45
Low Loss Optical Switch with Precisely Rotationally-aligned Multicore Fiber Array, Osamu Shimakawa[1], Ryouichi Kobayashi[1], Hidehisa Tazawa[1]; [1]*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.

Th3C • High-speed and Multi-wavelength Devices—Continued

Th3D • Machine Learning for Optical Network Performance—Continued

Th3D.7 • 15:30
Efficient Classification of Polarization Events Based on Field Measurements, Kyle Guan[1], Jesse E. Simsarian[1], Fabien Boitier[1], Daniel C. Kilper[2], Jelena Pesic[1], Michael Sherman[3]; [1]*Nokia Bell Labs, USA;* [2]*College of Optical Sciences, Univ. of Arizona, USA;* [3]*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.

Th3E • Optimizing Coherent Transponders—Continued

Th3F • Novel Fiber Optic Sensors—Continued

Th3F.6 • 15:30 ▶ ★ Top-Scored
Vibration Sensing for Deployed Metropolitan Fiber Infrastructures, Ilaria Di Luch[1], Maddalena Ferrario[1], Giuseppe Rizzelli Martella[2], Roberto Gaudino[2], Pierpaolo Boffi[1]; [1]*Politecnico di Milano, Italy;* [2]*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.

Th3F.7 • 15:45 ▶
Sensors Based on Dual Supermode Interferometers, Joel Villatoro[1,3], Jose Enrique Antonio-Lopez[2], Axel Schülzgen[2], Rodrigo Amezcua Correa[2]; [1]*Univ. of the Basque Country UPV/EHU, Spain;* [2]*CREOL, The College of Optics & Photonics, Univ. of Central Florida, USA;* [3]*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.

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

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

Room 6E	Room 6F	Room 7	Room 8	Room 9
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**
		Th3I.6 • 15:45 **High-durability Coating for Improved Thermal Management of Pluggable Optical Modules,** Reid Chesterfield[1], Pradyumna Goli[1], Sarrah Querelle-Halverson[1], Elizabeth Sullivan[1], Zachary Hoyt[1], Kevin Olson[1], Matthew Bren[1], Attila Aranyosi[2], S Doan[2], V Le[2]; [1]*Henkel Corporation, USA;* [2]*Juniper Networks, USA.* We introduce a new high-durability thermal interface coating designed to improve pluggable optical module to heat sink thermal transfer. Performance data and test methods for thermal resistance, durability, and long-term reliability are presented.		**Th3K.6 • 15:45** **Bus-type Optical Access Using DRA and Asymmetric Power Splitters for Accommodating Rural Users,** Ryo Igarashi[1], Masamichi Fujiwara[1], Takuya Kanai[1], Kazutaka Hara[1], Atsuko Kawakita[1], Hiro Suzuki[1], Jun-ichi Kani[1], Jun Terada[1]; [1]*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*

Show Floor Programming Continued

The World's First Intercontinental Connections… Contrasting Early Terrestrial-subsea Networks with the Present
Telecom Infra Project (TIP)
15:05–16:00, *Theater II*

■ Market Watch Panel VII: IP+WDM Architecture Evolution
14:30–16:00, *Theater I*

Fibre Types and Amplifiers: Choices and Trade-offs
Fiberstory
15:00–16:00, *Theater III*