Room 1A

08:00–10:00
M1A • Network Techno-economics
Presider: Victor Lopez; Telefonica I+D, Spain

M1A.1 • 08:00 Top Scored
Techno-economic Evaluations of 400G Optical Interconnect Implementations for Datacenter Networks, Theodoros Rokkas[2,1], Ioannis Neokosmidis[1], Behnam Shariati[3], Ioannis Tomkos[2]; *[1]inCITES Consulting, Luxembourg; [2]Athens Information Technology, Greece; [3]Universitat Politécnica de Catalunya (UPC), Spain.* The cost evolution and power consumption of different 400G transceivers are modeled and the benefits of constructing and scaling the Facebook's datacenter Fabric utilizing different technologies is presented through comparative cost and power consumption analysis

M1A.2 • 08:15
Fiber Type Dependent Benefits when Deploying Up-to-300Gb/S Elastic Transponders Adapting to Ageing of Margins, Jelena Pesic[3], Nicola Rossi[2], Thierry Zami[1]; *[1]Nokia Corporation, France; [2]Nokia Bell Labs, France; [3]Nokia Bell Labs, France.* We compare cost savings when planning a WDM French backbone network based on SSMF or LEAF, with 32 GBaud elastic optical transponders adapting their capacity from 100 to 300 Gb/s to the actual ageing margins.

Room 1B

08:00–10:00
M1B • Beyond 10G PON Evolution I
Presider: Elaine Wong; Univ. of Melbourne, Australia

M1B.1 • 08:00
Real-time Downstream 25Gbit/s PAM4 for High Speed TDM-PONs with both 25 and 12.5Gbit/s ONUs, Sylvain Barthomeuf[1,2], Fabienne Saliou[1], Luiz Anet Neto[1], Bertrand Le Guyader[1], Philippe Chanclou[1], Didier Erasme[2]; *[1]Orange Labs, France; [2]LTCI, Télécom ParisTech, France.* We experimentally achieved 40km, Real-time, N1 ODN class (29dB) compliant PAM4 transmission with PAM4/NRZ receptions on the same PON. The emitted PAM4 is interpreted either as PAM4 or NRZ to allow full or half line-rates.

M1B.2 • 08:15
Burst-mode Actively-filtered Receiver for TDM-PON Enabling Extended Reach and Improved Sensitivity, Robert Borkowski[1], Wolfgang Poehlmann[1], Rene Bonk[1], Thomas Pfeiffer[1]; *[1]Nokia Bell Labs, Germany.* We experimentally demonstrate an actively-filtered receiver for TDM-PON. Bias-current tuning of a DFB-based-filter enables tracking the wavelength-drift of DML under burst-mode operation. We measure >70% reach increase, >5dB sensitivity improvement, and 4.8dB higher extinction ratio.

Room 2

08:15–10:00
M1C • DSP Techniques for High-order QAM
Presider: Takayuki Kobayashi; NTT Network Innovation Laboratories, Japan

M1C.1 • 08:15 Top Scored
Single-carrier 48 GBaud PDM 256QAM Transmission over Unrepeated 100km Single-mode-fiber using Commercially Available µITLA and LN IQ Modulator, Asuka Matsushita[1], Masanori Nakamura[1], Fukutaro Hamaoka[1], Yoshiaki Kisaka[1]; *[1]NTT Corporation, Japan.* Record symbol-rate PDM-256QAM single-carrier transmission of 100km is achieved using commercially available laser and modulator with only applying compensation for linear frequency response of transceiver and receiver; device nonlinearity compensation is not used.

Room 6C

08:30–10:00
M1D • Subsea and Open Systems
Presider: Mei Du; Coriant, USA

Room 6D

08:15–10:00
M1E • Open Systems and Modules
Presider: Katharine Schmidtke; Facebook Inc., USA

M1E.1 • 08:15 Invited
Opening Up the Transport Infrastructure, Luis Martin Garcia[1]; *[1]Facebook, USA.* This talk will cover how Optical and IP transport networks are being disrupted by initiatives like the Telecom Infra Project to make networks more open, disaggregated and free of vendor lock-ins.

Room 6E

08:00–10:00
M1F • Optical Wireless - Systems
Presider: Ton Koonen; Technische Universiteit Eindhoven, Netherlands

M1F.1 • 08:00
A 84 Gb/s VSB-PAM8 VCSEL-based Fiber-FSO Convergence, Yun-Chieh Wang[1], Pei-Hsien Chew[1], Yu-Bo Jheng[1], Chung-Yi Li[1], Hai-Han Lu[1], Xu-Hong Huang[2], Wen-Shing Tsai[3]; *[1]National Taipei Univ. of Technology, Taiwan; [2]School of Information Science and Engineering, Fujian Univ. of Technology, China; [3]Department of Electrical Engineering, Ming Chi Univ. of Technology, Taiwan.* A 84 Gb/s VSB-PAM8 VCSEL-based fiber-fSO convergence with injection locking scheme and linear equalizer is demonstrated. Such proposed VSB-PAM8 VCSEL-based fiber-fSO convergence is a notable option with good transmission performances for providing high transmission rate.

M1F.2 • 08:15 Top Scored
Experimental Demonstration of a 12.5 Gb/s Indoor Optical Wireless Communication System with Silicon Integrated Photonic Circuit, Ke Wang[1,2], Ampalavanapillai Nirmalathas[3], Christina Lim[3], Elaine Wong[3], Kamal Alameh[4], Hongtao Li[2], Efstratios Skafidas[3]; *[1]Royal Melbourne Inst. of Technology, Australia; [2]Nanjing Univ. of Science and Technology, China; [3]The Univ. of Melbourne, Australia; [4]Edith Cowan Univ., Australia.* A high-speed indoor infrared optical wireless communication system using silicon photonics integrated beam steering circuit is experimentally demonstrated. Results show that up to 12.5 Gb/s error-free operation is achieved through over 140 cm free-space distance.

Room 6F

08:00–10:00
M1G • Advanced Modulation Formats
Presider: Magnus Karlsson; Chalmers Tekniska Hogskola, Sweden

M1G.1 • 08:00 **Tutorial**
Flexible Transceivers and the Rate/Reach Trade-off, Gabriella Bosco[1]; [1]*Politecnico di Torino, Italy.* This tutorial will review advanced modulation formats and digital signal processing techniques that can be used to increase the capacity and/or the reach of optical transmission systems, as well as the flexibility of optical transceivers.

Gabriella Bosco is an Associate Professor at Politecnico di Torino, Italy, where she received her PhD degree in Electronic and Communication Engineering in 2002. Her main research interests are focused on the performance analysis and design of optical transmission systems and sub-systems. She co-authored ~200 papers in leading journals/conferences and she served on the program committee of several international conferences, among which CLEO, APC, IPC and OFC, for which she acted as Program Chair in 2017. She is currently serving as an Associate Editor of JLT. She is Senior Member of IEEE and Fellow Member of OSA.

Room 7AB

08:30–10:00
M1H • Microwave Photonic Signal Processing I
Presider: Daniel Blumenthal; Univ. of California Santa Barbara, USA

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

Room 9

08:15–10:00
M1I • Lasers for Data Center Interconnects
Presider: Chongjin Xie; Alibaba Group, USA

M1I.1 • 08:15
Optimum VCSEL Apertures for High-speed Multimode Fiber Links, Justin Lavrencik[1], Johan S. Gustavsson[2], Erik Haglund[2], Anders G. Larsson[2], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Microtechnology and Nanoscience, Chalmers Univ., Sweden.* Cross-correlations of VCSEL transverse mode groups with different apertures are used to predict dispersion dependent RIN. Experiments with wideband multimode fiber confirm the noise enhancement dependence on aperture, which increases with fewer mode VCSELs.

NOTES

Room 1A

M1A • Network Techno-economics—Continued

M1A.3 • 08:30
A Statistical Assessment of Networking Merit of 2MxN WSS, Mattia Cantono[1], Stefano Piciaccia[2], Alberto Tanzi[2], Gabriele Maria Galimberti[2], Brian Smith[3], Marcello Bianchi[3], Vittorio Curri[1]; *[1]Politecnico di Torino, Italy; [2]Cisco Photonics, Italy; [3]Lumentum, Canada.* We assess the networking impact in terms of blocking probability and device counts of a novel low-contention probability network node. We show no significant penalties with respect to full-CDC solutions in a metro network scenario

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

Room 1B

M1B • Beyond 10G PON Evolution I—Continued

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

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

Room 2

M1C • DSP Techniques for High-order QAM—Continued

M1C.2 • 08:30
Improving Achievable Information Rates of 64-GBd PDM-64QAM by Nonlinear Transmitter Predistortion, Robert Elschner[1], Robert Emmerich[1], Carsten Schmidt-langhorst[1], Felix Frey[1,2], Pablo Wilke Berenguer[1], Johannes K. Fischer[1], Helmut Griesser[3], Danish Rafique[3], Joerg-peter Elbers[3], Colja Schubert[1]; *[1]Fraunhofer HHI, Germany; [2]Inst. of Communications Engineering, Ulm Univ., Germany; [3]ADVA Optical Networking SE, Germany.* We assess the gains in achievable information rate for 64-GBd PDM-64QAM signal transmission with Volterra-based digital predistortion of nonlinear transmitter components and show an improvement of up to 0.6 bit/4D-symbol over conventional linear predistortion.

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

Room 6C

M1D • Subsea and Open Systems—Continued

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

Room 6D

M1E • Open Systems and Modules—Continued

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

Room 6E

M1F • Optical Wireless - Systems—Continued

M1F.3 • 08:30 Invited
Use Cases for Optical Wireless Communication, Dominic Schulz[1], Pablo Wilke Berenguer[1], Jonas Hilt[1], Peter Hellwig[1], Anagnostis Paraskevopoulos[1], Ronald Freund[1], Volker Jungnickel[1]; *[1]Fraunhofer Heinrich Hertz Inst., Germany.* We present results from trials in three promising uses cases for optical wireless communication (OWC): Mobile backhaul, industrial wireless, and indoor Li-fi. We point out specific requirements and illustrate performance through measurements in typical scenarios.

Room 6F

M1G • Advanced Modulation Formats—Continued

Room 7AB

M1H • Microwave Photonic Signal Processing I—Continued

M1H.1 • 08:30
Fully Reconfigurable Silicon-based Waveguide Bragg Grating for Integrated Microwave Photonic Applications, Weifeng Zhang[1], Jianping Yao[1]; *[1]Univ. of Ottawa, Canada.* A fully reconfigurable silicon-based waveguide grating that is electrically reconfigurable for integrated microwave photonic applications is designed, fabricated and experimentally demonstrated. The employment of the grating to perform temporal differentiation and microwave frequency discrimination is reported.

M1H.2 • 08:45
Optical Generation and Transmission of Linearly Chirped Microwave Pulses with High Time-bandwidth Product, Luis Ernesto Ynoquio Herrera[1], Ricardo M. Ribeiro[2], Vladimir B. Jabulka[2], Jean P. von der Weid[1]; *[1]Puc-Rio, Brazil; [2]Telecommunications Engineering, Fluminense Federal Univ., Brazil.* This paper shows the generation of amplified and linearly chirped microwave pulses by using self-heterodyne technique leading to time-bandwidth products above 35,000. Undistorted transmission along > 40 km standard single-mode optical fiber is also shown.

Room 9

M1I • Lasers for Data Center Interconnects—Continued

M1I.2 • 08:30 Top Scored
726.7-gb/s 1.5-μm Single-mode VCSEL Discrete Multi-tone Transmission over 2.5-km Multicore Fiber, Joris Van Kerrebrouck[1], Lu Zhang[2,3], Rui Lin[2,5], Xiaodan Pang[2,4], Aleksejs Udalcovs[4], Oskars Ozolins[4], Silvia Spiga[6], Markus C. Amann[6], Geert Van Steenberge[7], Lin Gan[5], Ming Tang[5], Songnian Fu[5], Richard J. Schatz[2], Sergei Popov[2], Deming Liu[5], Weijun Tong[8], Shilin Xiao[3], Guy Torfs[1], Jiajia Chen[2], Johan Bauwelinck[1], Xin Yin[1]; *[1]IDLab, INTEC - imec, UGent, Belgium; [2]KTH Royal Inst. of Technology, Sweden; [3]SE-iEE, Shanghai Jiao Tong Univ., China; [4]Networking and Transmission Laboratory, RISE Acreo AB, Sweden; [5]Huazhong Univ. of Science and Technology, China; [6]Walter Schottky Institut, Germany; [7]CMST, INTEC, UGent, Belgium; [8]Yangtze Optical fiber and Cable Joint Stock Limited Company, China.* A 107Gb/s net-rate DMT optical signal was generated using a single-mode long-wavelength VCSEL with a modulation bandwidth of 23GHz. We experimentally demonstrated a total net-rate up to 726.7Gb/s at 1.5μm over 2.5km 7-core dispersion-uncompensated MCF.

M1I.3 • 08:45
51.56 Gbps PAM4 Transmission over up to 2.3 km OM4 Fiber using Mode Selective VCSEL, Reza Motaghian[1], Anna Tatarczak[1], Hao Chen[1], Jim Tatum[1], Chris Kocot[1]; *[1]Finisar, USA.* Record bit-rate-distance-products of 118.6 and 51.6 Gbps×km were achieved for PAM4 and NRZ transmission over a single OM4 fiber using mode-selective VCSEL. The OMA penalty was 3.1 dB for 51.56-gbps-PAM4 transmission over 1.6km OM4 at BER of 5×10^{-5}.

NOTES

M1A • Network Techno-economics—Continued

M1A.5 • 09:00 Invited

Agile Optical Networking: Beyond Filtered Solutions, Christine Tremblay[1], Émile Archambault[1], Michel Belanger[2], Paul Littlewood[2], William Clelland[2], Marija Furdek[3], Lena Wosinska[3]; [1]*Ecole de Technologie Supérieure, Canada;* [2]*Ciena Corp., Canada;* [3]*KTH Royal Inst. of Technology, Sweden*. Filterless optical networks based on broadcast-and-select nodes and coherent transceivers are attractive cost-effective and flexible solutions in core networks. In this talk, we explore the suitability of filterless architectures in metropolitan core and aggregation networks.

M1B • Beyond 10G PON Evolution I—Continued

M1B.5 • 09:00

Demonstration of 50Gb/s/λ Symmetric PAM4 TDM-PON with 10G-class Optics and DSP-free ONUs in the O-band, Kuo Zhang[1,2], Qunbi Zhuge[2], Haiyun Xin[1], Zhenping Xing[2], Meng Xiang[2], Sujie Fan[2], Lilin Yi[1], Weisheng Hu[1], David V. Plant[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*McGill Univ., Canada*. We demonstrate a 50Gb/s/λ PAM4 TDM-PON based on 10G-class DMLs and PDs in O-band with downlink pre-compensation and uplink post-equalization. Results show that, without any DSP in the ONU, 29dB optical power budget is achieved.

M1B.6 • 09:15

Optical vs. Electrical Duobinary Coding for 25 Gb/s PONs based on DSP-free Coherent Envelope Detection , Mario Rannello[1], Marco Presi[1], Ernesto Ciaramella[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy.* We investigate and experimentally compare 25 Gb/s serial-line rate optical and electrical duobinary signals combined with DSP-free, coherent envelope-detection for serial-line rate upgrade in future PONs. -37.3dBm sensitivity is achieved without applying any equalization.

M1C • DSP Techniques for High-order QAM—Continued

M1C.4 • 09:15

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

M1D • Subsea and Open Systems—Continued

M1D.2 • 09:00 Top Scored

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

M1D.3 • 09:15

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

M1E • Open Systems and Modules—Continued

M1E.3 • 09:15

Demonstration of 53.125 Gb/s, CWDM, PAM-4, Directly Modulated Laser Transmission over 20 km SMF, Prashant P. Baveja[1], Mingshan Li[1], YuJing Chen[1], Ding Wang[1], Huanlin Zhang[1], Yi Wang[1], Qin Li[1], Chong Wang[1], Hsiu-Che Wang[1], I-Lung Ho[1], Jun Zheng[1]; [1]*Applied Optoelectronics Inc, USA.* 20 km, 53.125 Gb/s, CWDM, O-band, PAM-4 DML transmission is demonstrated. -11 dBm outer OMA at KP-4 FEC threshold up to 70 °C TOSA case temperature is measured using a TO ROSA packaged using 26 GHz PIN PD, linear TIA and self-adaptive DSP.

M1F • Optical Wireless - Systems—Continued

M1F.4 • 09:00

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

M1F.5 • 09:15

230 Mbit/s Real-time Optical Wireless Transmission in Non-directed Line-of-sight Configuration, Giulio Cossu[1], Alessandro Messa[1], Wajahat Ali[1], Alessandro Sturniolo[1], Ernesto Ciaramella[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy.* We experimentally realized a Real-time optical wireless transmission in Non-directed Line-of-sight (i.e. without lens), by a low-cost infrared LED and FPGA-based DMT processing. We achieve from 230 to 100 Mbit/s over a 3 m^2 area.

Room 6F

M1G • Advanced Modulation Formats—Continued

M1G.2 • 09:00 Top Scored

11.5bits/s/Hz PM-256QAM Comb-based Superchannel Transmission by Combining Optical and Digital Pilots, Mikael Mazur[1], Jochen Schröder[1], Abel Lorences-Riesgo[1,2], Tsuyoshi Yoshida[1,3], Magnus Karlsson[1], Peter A. Andrekson[1]; *[1]Chalmers Univ. of Technology, Sweden; [2]IT-instituto de Telecomunicações, Portugal; [3]Mitsubishi Electric Corporation, Japan*. We demonstrate 44Tb/s transmission using three 50×24GBaud PM-256QAM comb-based superchannels. Each superchannel combines a single optical pilot tone with individual digital pilot symbols to minimize the total overhead, enabling record spectral-efficiency over the full C-band.

M1G.3 • 09:15

Flex-rate Transmission using Hybrid Probabilistic and Geometric Shaped 32QAM, Shaoliang Zhang[1], Zhen Qu[1,3], Fatih Yaman[1], Eduardo Mateo[2], Takanori Inoue[2], Kohei Nakamura[2], Yoshihisa Inada[2], Ivan Djordjevic[3]; *[1]NEC Laboratories America Inc, USA; [2]Submarine Network Division, NEC Corporation, Japan; [3]ECE, Univ. of Arizona, USA*. A novel algorithm to design geometric shaped 32QAM to work with probabilistic shaping is proposed to approach the Shannon limit within ~0.2 dB in SNR. The experimental results show ~0.2 dB SNR advantage over 64GBaud PAS-64QAM, and flex-rate transmission demonstrates > 500 km reach improvement over 32QAM.

Room 7AB

M1H • Microwave Photonic Signal Processing I—Continued

M1H.3 • 09:00 Invited

Silicon-based Brillouin Photonics and Signal Processing, Peter T. Rakich[1], Eric Kittlaus[1], Nils Otterstrom[1], Ryan Behunin[1,2], Zheng Wang[3]; *[1]Yale Univ., USA; [2]Physics, Northern Arizona Univ., USA; [3]Electrical and Computer Engineering, Univ. of Texas at Austin, USA*. We use a new class of optomechanical waveguides to we create strong stimulated Brillouin scattering in silicon waveguides. Harnessing these interactions, we create Brillouin-based narrow-band RF-photonic filters, optical amplifiers, and lasers in silicon photonics.

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

Room 9

M1I • Lasers for Data Center Interconnects—Continued

M1I.4 • 09:00

7×100 Gbps PAM-4 Transmission over 1-km and 10-km Single Mode 7-core Fiber using 1.5-μm SM-vCSEL, Xiaodan Pang[1,3], Joris Van Kerrebrouck[2], Oskars Ozolins[3], Rui Lin[1,4], Aleksejs Udalcovs[3], Lu Zhang[1], Silvia Spiga[5], Markus C. Amann[5], Geert Van Steenberge[6], Lin Gan[4], Ming Tang[4], Songnian Fu[4], Richard J. Schatz[1], Gunnar Jacobsen[3], Sergei Popov[1], Deming Liu[4], Weijun Tong[7], Guy Torfs[2], Johan Bauwelinck[2], Xin Yin[2], Jiajia Chen[1]; *[1]KTH Royal Inst. of Technology, Sweden; [2]IDLab, INTEC, Ghent Univ. – imec, Belgium; [3]Networking and Transmission Laboratory, Rise Acreo AB, Sweden; [4]Huazhong Univ. of Science and Technology, China; [5]Walter Schottky Institut, Technische Universität München, Germany; [6]CMST, Ghent Univ. – IMEC, Belgium; [7]Yangtze Optical Fiber and Cable Joint Stock Limited Company, China*. 100 Gbps/λ/core PAM-4 transmission is successfully demonstrated over 1-km and 10-km single mode 7-core fiber links, enabled by directly modulated 1.5-μm single mode VCSEL of 23 GHz modulation bandwidth with pre- and post- digital equalizations.

M1I.5 • 09:15

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

NOTES

Room 1A

M1A • Network Techno-economics—Continued

M1A.6 • 09:30
Minimizing the Cost and Augmenting the Resilience of Vulnerable Optical Transport Networks, Bodhisattwa Gangopadhyay[1], João Pedro[2], Stefan Spälter[2]; [1]*Global Technical Support, Coriant, Portugal;* [2]*Coriant, Portugal.* This paper proposes an architecture combining high density muxponders, universal OTN switching, flexi-rate line interfaces and a cost-optimized node clustering scheme to enhance network resiliency without compromising the total cost of ownership (TCO).

M1A.7 • 09:45
Modular SDN-enabled S-BVT Adopting Widely Tunable MEMS VCSEL for Flexible/Elastic Optical Metro Networks, Michela Svaluto Moreolo[1], Laia Nadal[1], Josep M. Fabrega[1], Javier Vílchez[1], Ramon Casellas[1], Raul Muñoz[1], Christian Neumeyr[2], Alberto Gatto[3], Paola Parolari[3], Pierpaolo Boffi[3]; [1]*Ctr Tecnològic de Telecom de Catalunya, Spain;* [2]*Vertilas GmbH, Germany;* [3]*Politecnico di Milano, Italy.* We propose an SDN-enabled S-BVT adopting directly-modulated tunable VCSEL with direct-detection for optical metro networks and spectrum defragmentation. We experimentally assess it over different network paths up to 185km and in presence of adjacent slices.

Room 1B

M1B • Beyond 10G PON Evolution I—Continued

M1B.7 • 09:30
Real-time FPGA Demonstration of PAM-4 Burst-mode All-digital Clock and Data Recovery for Single Wavelength 50G PON Application, Junwen Zhang[1], Xin Xiao[1], Jianjun Yu[1], Jun Shan Wey[1]; [1]*ZTE TX Inc, USA.* We demonstrate the burst-mode all-digital clock and data recovery for 26.20546-GBaud PAM-4 signal with Real-time FPGA processing. With a free-running ADC, clock recovery is achieved within 32 symbols based on the squaring timing recovery algorithm.

M1B.8 • 09:45
Adaptive Equalization Enabled 25Gb/s NRZ Modulation Based on 10-g Class Optics for Upstream Burst-mode Transmission, Jian Chen[1], Acai Tan[1], Zhengxuan Li[1], Yong Guo[2], Yongjia Yin[2], Qianwu Zhang[1], Yingxiong Song[1], Yingchun Li[1], Min Wang[1]; [1]*Shanghai Univ., China;* [2]*ZTE Corporation, China.* We demonstrate 10G-class optics based 25-gb/s upstream burst-mode transmission using adaptive equalization for ISI compensation. -23 dBm sensitivity at FEC limit of 1×10-3 is achieved, where tap adaption can be realized within 400 training bits.

Room 2

M1C • DSP Techniques for High-order QAM—Continued

M1C.5 • 09:30
Reception of Burst Mode High-order QAM Signals with Pilot-aided Digital Signal Processing, Chen Zhu[1], Noriaki Kaneda[1], Jeffrey Lee[1]; [1]*Bell Laboratories, Nokia, USA.* We present pilot-assisted burst mode DSP design for high-order QAM signals. Short preambles are used for frame, frequency synchronization and channel estimation. The proposed scheme is experimentally demonstrated to detect 16G-baud PDM 128/256/512-QAM bursts.

M1C.6 • 09:45
Digitally Enhanced DAC: Low-resolution Digital Pre-compensation for High Speed Optical Links, Yaron Yoffe[1], Eyal Wohlgemuth[1], Dan Sadot[1]; [1]*Ben Gurion Univ. of the Negev, Israel.* A novel algorithm is proposed to overcome bandwidth limitation using low resolution DACs. We demonstrate electrical back-to-back 32GBaud QAM-64 over 11GHz and optical 32GBaud QAM-4 over 5GHz using 4 bits and 2.6 bits DACs respectively

Room 6C

M1D • Subsea and Open Systems—Continued

M1D.4 • 09:30 Invited
Design of Submarine "Open" Cables, Pascal Pecci[1], Vincent LETELLIER[1], Olivier Gautheron[1], Alice Shelton[1], Olivier Courtois[1], Matteo Gumier[1], Vincent Chevalier[1], Paul Gabla[1]; [1]*ASN, France.* Digital coherent receiver and GN model moved submarine transmission systems into the "open" cables era. This new paradigm leads to consider new parameters to design and characterize open submarine systems independently of the terminal equipment.

Room 6D

M1E • Open Systems and Modules—Continued

M1E.4 • 09:30
Demonstration of Real-time 400G Single-carrier Ultra-efficient 1.2Tb/s Superchannel over Large A_{eff} Ultra-low Loss Terrestrial Fiber of 150km Single Span and 250km (2×125km Spans) using Only EDFA Amplification, Yu Rong Zhou[1], Kevin Smith[1], Mike Gilson[1], Jingxin Chen[2], Weiwei Pan[2], Youhui Chang[2], Shuangyuan Wu[2], Shipeng Wu[2], Derek Nesset[2], Ian Davis[3]; [1]*BT, UK;* [2]*Huawei Technologies, UK;* [3]*Corning Limited, UK.* We successfully demonstrated Real-time 400G (64GBaud DP-16QAM) single-carrier ultra-efficient 1.2Tb/s superchannel (6.25bit/s/Hz) over new ultra-low loss large A_{eff} terrestrial fiber with long term error-free performance over 150km single-span and 250km (2 spans) using only EDFAs.

M1E.5 • 09:45 Top Scored
Silicon Photonic Multi-rate DCO-CFP2 Interface for DCI, Metro, and Long-haul Optical Communications, Erwan Pincemin[1], Yann Loussouarn[1], Mike Pan[2], Glen Miller[2], Alan Gibbemeyer[2], Benny Mikkelsen[2]; [1]*Orange Labs, France;* [2]*Acacia Inc, USA.* For the first time, a 100/200-gbps DP-QPSK/8QAM/16QAM silicon photonic DCO-cFP2 interface using various FECs and consuming less than 19 Watts is presented and evaluated. Performances make the transceiver compliant with DCI, metro/regional, LH, and ULH applications.

Room 6E

M1F • Optical Wireless - Systems—Continued

M1F.6 • 09:30
Towards Dynamic Ultrahigh Capacity Symmetric Bidirectional Indoor Optical-wireless Communication, Ketemaw Addis Mekonnen[1], Zizheng Cao[1], Eduward Tangdiongga[1], Ton Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* By implementing optical carrier reuse concept, we demonstrate a novel full-duplex optical-wireless communication system using a reflective-modulator chip at the user terminal, equipped with localization/tracking functionalities, with unshared symmetric capacity of up to 40Gb/s.

M1F.7 • 09:45
LCoS-based Access Node for Bidirectional Optical Wireless Communications, Hsi-Hsir Chou[1], Jen-Hao Hsiao[1]; [1]*National Taiwan Univ of Science & Tech, Taiwan.* An LCoS-based access node using optical fibers as the transmitter and receiver to extend the high-speed data transmission from NG-PON 2 to indoor home area network through optical wireless communications without O/E/O conversions is reported.

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

Room 6F

M1G • Advanced Modulation Formats—Continued

M1G.4 • 09:30
Novel Low-complexity Fully-blind Density-centroid –tracking Equalizer for 64-QAM Coherent Optical Communication Systems, Junfeng J. Zhang[1], Chen Wei[1], Mingyi Gao[1], Bo W. Chen[1], Gangxiang Shen[1]; [1]*Soochow Univ., China.* We proposed a low-complexity non-data-aided density-centroid-tracking equalizer to improve the performance of 64-QAM coherent optical communication system. We experimentally demonstrated it over 80-km single mode fiber transmission and observed approximately 2-dB power penalty improvement.

M1G.5 • 09:45
Nonlinearity-tolerant 8D Modulation Formats By Set-partitioning PDM-QPSK, Djalal Falih Bendimerad[1], Hartmut Hafermann[1], Huijian Zhang[1]; [1]*Huawei Technologies France, France.* We present two new nonlinearity tolerant modulation formats at spectral efficiencies lower than 4bits/4D-symbol, obtained using a simplified bit-to-symbol mapping approach to set-partition PDM-QPSK in 8 dimensions.

Room 7AB

M1H • Microwave Photonic Signal Processing I—Continued

M1H.4 • 09:30
SBS-based OEO with High Tuning Resolution and Wide Tuning Range by Selecting Different-order Phase Modulation Sideband as Pump, Mengyue Shi[1], Lilin Yi[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China.* Optoelectronic oscillator with tuning resolution of 10MHz and tuning range up to 40GHz is realized based on stimulated Brillouin scattering. The sideband mode suppression ratio is 50dB and the SSB phase noise is -120dBc/Hz@100kHz.

M1H.5 • 09:45
Integrated Frequency-tunable Microwave Photonic Bandpass Filter on a Silicon Photonic Chip, Weifeng Zhang[1], Jianping Yao[1]; [1]*Univ. of Ottawa, Canada.* A photonic integrated frequency-tunable microwave photonic bandpass filter consisting of a high-speed phase modulator, a thermally-tunable high-q microdisk resonator, and a high-speed photodetector, fully integrated on a silicon platform, is designed, fabricated and characterized.

Room 9

M1I • Lasers for Data Center Interconnects—Continued

M1I.6 • 09:30
Parameter Extraction through Joint Optimization of Modulation Response and RIN Spectra, Alirio Melgar[1], Varghese A. Thomas[1], Justin Lavrencik[1], Stephen E. Ralph[1]; [1]*Georgia Inst. of Technology, USA.* Extraction of VCSEL rate equation model parameters through joint optimization of modulation response and RIN spectra is presented. It accurately accounts for both ISI and noise, and employs drive-dependent parasitics found in VCSELs.

M1I.7 • 09:45
A 14 Gb/s Directly Modulated Hybrid Microring Laser Transmitter, Ashkan Roshan Zamir[1], Kunzhi Yu[1], Di Liang[2], Chong Zhang[2], Cheng Li[2], Gaofeng Fan[1], Binhao Wang[2], Marco Fiorentino[2], Raymond Beausoleil[2], Samuel Palermo[1]; [1]*Texas A&M Univ., USA;* [2]*Hewlett Packard Labs, USA.* The first demonstration of a hybrid-integrated directly modulated microring laser transmitter operating up to 14 Gb/s operation is reported. A CMOS driver with an asymmetric 2-tap feed-forward compensates for the microring laser non-linear dynamics.

NOTES

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

Room 1A

10:30–12:30
M2A • 5G and Network Slicing
Presider: Reza Mirzaei Nejad; Universite Laval, Canada

M2A.1 • 10:30
Multi-tenant Hybrid Slicing with Cross-layer Heterogeneous Resource Coordination in 5G Transport Network, Qize Guo[1,2], Rentao Gu[1,2], Mingyu Cen[1], Xueyu Kang[1], Tianyi Zhao[1], Lin Bai[3], Yuefeng Ji[1,2]; *[1]Beijing Laboratory of Advanced Information Network, Beijing Univ. of Posts and Telecommunications, China; [2]Beijing Advanced Innovation Center for Future Internet Technology, Beijing Univ. of Technology, China; [3]Beijing Univ. of Posts and Telecommunications, China.* We proposed a multi-tenant slicing scheme with multi-domain, multi-layer and multivendor (M^3) features. The experimental demonstration shows the slicing created and modified around in 353ms and 150ms, with the hybrid resource isolation has offered.

M2A.2 • 10:45
On the Scalability of Connectivity Services in a Multi-operator Orchestrator Sandbox, Ajmal Muhammad[1], Andrea Sgambelluri[2], Olivier Dugeon[3], Jorge M. Pérez[4], Francesco Paolucci[2], Oscar Gonzalez de Dios[5], Fabio Ubaldi[6], Teresa Pepe[6], Carlos J. Cano[4], Paolo Monti[1]; *[1]KTH Royal Inst. of Technology, Sweden; [2]Scuola Superiore Sant'Anna, via Moruzzi 1, Italy; [3]Orange Lab, France; [4]Universidad Carlos III de Madrid, Spain; [5]TID Telefonica, Spain; [6]Ericsson Research, Via Moruzzi 1, Spain.* The paper investigates the performance of a multi-domain orchestrator (MdO) deployed in a real multi-domain European testbed. Results show how the MdO prototype scales well with the number of domains advertised and connectivity services provisioned.

Room 1B

10:30–12:30
M2B • Beyond 10G PON Evolution II
Presider: Derek Nesset; BT, Germany

M2B.1 • 10:30 Invited
What Applications Are Driving Higher Capacity In Access?, Phil Miguelez[1]; *[1]Comcast, USA.* The growth of consumer high speed data has continued to expand at a rate of nearly 50% year over year. This paper explores the key drivers of this exceptional growth and the network changes being implemented to meet current and future capacity requirements.

Room 2

10:30–12:30
M2C • Transmission Systems
Presider: Dmitri Foursa; TE SubCom, USA

M2C.1 • 10:30 Invited
ADC & DAC - Technology Trends and Steps to Overcome Current Limitations, Tomislav Drenski[1], Jens C. Rasmussen[1]; *[1]Socionext, UK.* ADC & DAC technology trends addressing Ultra Long Haul (ULH) to Very Short Reach (VSR) transmissions are presented. The challenges are reviewed and possible solutions to overcome current limitations for the different applications are discussed.

Room 6C

10:30–12:30
M2D • Energy Efficient Optical Links
Presider: Samuel Palermo; Texas A&M Univ., USA

M2D.1 • 10:30
A 34GBaud Linear Transimpedance Amplifier with Automatic Gain Control for 200Gb/s DP-16QAM Optical Coherent Receivers, Mostafa G. Ahmed[1], Tam N. Huynh[1], Christopher Williams[1], Yong Wang[1], Rahul Shringarpure[1], Reza Yousefi[1], Jose Roman[1], Noam Ophir[1], Alexander Rylyakov[1]; *[1]Elenion Technologies, LLC, USA.* A 34GBaud TIA achieves 1.5% THD at 1mAppd input, 20pA/sqrt(Hz) input referred noise density, output amplitude of up to 1Vppd and maintains 27GHz bandwidth over 43dB of transimpedance gain dynamic range, enabling a 200Gb/s dual-polarization 16QAM coherent receiver operation.

M2D.2 • 10:45
A 137-mW, 4 ch x 25-gbps Low-power Compact Transmitter Flip-chip-bonded 1.3-um LD-array-on-si, Toshiki Kishi[1], Munehiko Nagatani[1], Shigeru Kanazawa[2], Shinsuke Nakano[2], Hiroaki Katsurai[2], Takuro Fujii[1], Hidetaka Nishi[1], Takaaki Kakitsuka[1], Koichi Hasebe[1], Kota Shikama[1], Yuko Kawajiri[1], Atsushi Aratake[1], Hideyuki Nosaka[1], Hiroshi Fukuda[1], Shinji Matsuo[1]; *[1]NTT Device Technology Laboratories, Japan; [2]NTT Device Innovation Center, Japan.* A low-power compact 4-channel transmitter consisting of a 65-nm CMOS cascode shunt LD driver and flip-chip-bonded 1.3-um LD-array-on-si achieves 25-gbps 2-km-long SSMF error-free operation for each channel, with power consumption of 1.37 mW/Gbps.

Room 6D

10:30–12:30
M2E • Open and Dynamic Networking
Presider: Noboru Yoshikane; KDDI Research, USA

M2E.1 • 10:30 Invited
Progress toward an Open, SDN Controlled Photonic Network, Kathleen Tse[1]; *[1]AT&T Corp, USA.* AT&T is moving to a photonic layer that is fully software controlled and open. This allows us to deliver bandwidth when and where it is needed and optimize the network as it grows and changes.

Room 6E

10:30–12:30
M2F • Machine Learning and Performance Monitoring
Presider: Alan Pak Tao Lau; Hong Kong Polytechnic Univ., Hong Kong

M2F.1 • 10:30
Integration of Multivariate Gaussian Mixture Model for Enhanced PAM-4 Decoding Employing Basis Expansion, Feng Lu[1], Peng-Chun Peng[2], Siming Liu[1], Mu Xu[1], Shuyi Shen[1], Gee-Kung Chang[1]; *[1]School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA; [2]Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan.* For the first time, we introduced Gaussian-mixture-model (GMM) and basis expansion in the PAM-4 decoder after equalization to estimate and eliminate residual linear/nonlinear impairments. With 100-gbps testbed, we experimentally demonstrated 1 to 1.5-dB sensitivity improvement.

M2F.2 • 10:45
Transmission of 4×50-Gb/s PAM-4 Signal over 80-km Single Mode Fiber using Neural Network, Ming Luo[1], Gao Fan[2], Xiang Li[1], Zhixue He[1], Songnian Fu[2]; *[1]WRI, China; [2]HUST, China.* We apply neural network algorithms with two kinds of input features as the nonlinear DSP method, and realize 4×50-gb/s PAM-4 IM/DD transmission for 80-km fiber with ~2 dB power sensitivity improvement over conventional nonlinear algorithms.

Room 6F

10:30–12:00
M2G • Microwave Photonic Signal Processing II
Presider: Jose Azana; INRS-energie Materiaux et Telecom, Canada

M2G.1 • 10:30 Invited
Intelligent Remote Sensing Systems Based on Microwave Photonic Technologies, Antonella Bogoni[1,2]; [1]*CNIT, Italy;* [2]*TeCIP, Sant'Anna School of Advanced Studies, Italy.* This paper presents some recent evolutions of the concept of photonics-based radar. In particular, it reports on the coherent MIMO radar network and on the wideband RF scanning receiver, discussing their potentials.

Room 7AB

10:30–12:30
M2H • Panel: 400G Optics for Hyperscale Data Centers
Organizers: Xiaoxia Wu, Juniper, USA; Kenneth Jackson, Sumitomo Electric, USA

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

Panelists:

Rich Baca, *Microsoft, USA*

Andy Bechtolsheim, *Arista Networks, USA*

Chris Cole, *Finisar, USA*

Philip Gadd, *Intel, USA*

Benny Mikkelsen, *Acacia Communications, USA*

Osa Mok, *Innolight, USA*

Kohichi Tamura, *Oclaro, USA*

Xiang Zhou, *Google, USA*

Room 8

10:30–12:30
M2I • Emerging Devices and Materials
Presider: Dong Pan; Sifotonics, USA

M2I.1 • 10:30
Driver-less Sub-1 Vpp-operation of a Plasmonic-organic Hybrid Modulator at 100 GBd NRZ, Benedikt Baeuerle[1], Claudia Hoessbacher[1], Wolfgang Heni[1], Yuriy Fedoryshyn[1], Arne Josten[1], Christian Haffner[1], Tatsuhiko Watanabe[1], Delwin L. Elder[2], Larry R. Dalton[2], Juerg Leuthold[1]; [1]*ETH Zurich, Switzerland;* [2]*Department of Chemistry, Univ. of Washington, USA.* We demonstrate driver-less 100 GBd operation of a plasmonic intensity modulator. Drive voltages below 1V lead to low power consumption of 2.84 fJ/bit for 100 Gbit/s with a direct detected BER below the HD-fEC limit.

M2I.2 • 10:45
High Speed Modulator Based on Electro-optic Polymer Infiltrated Subwavelength Grating Waveguide Ring Resonator, Zeyu Pan[1], Xiaochuan Xu[2], Chi-Jui Chung[1], Hamed Dalir[2], Hai Yan[1], Ke Chen[1], Yaguo Wang[1], Ray Chen[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics, Inc., USA.* We present a high-speed modulator based on electro-optic polymer infiltrated subwavelength grating waveguide ring resonator. A 3-dB small signal modulation bandwidth of 41.36 GHz has been demonstrated.

Room 9

10:30–12:30
M2J • Fiber Lasers
Presider: Efstratios Kehayas; Gooch & Housego, UK

M2J.1 • 10:30 Invited
Ultra-large Mode Area Fibers for High Power Lasers, Cesar Jauregui[1], Jens Limpert[1,2], Andreas Tünnermann[1,2]; [1]*Friedrich-Schiller-Universität Jena, Germany;* [2]*Fraunhofer Inst. for Applied Optics and Precision Engineering, Germany.* The most recent advances on ultra-large mode area fibers for high-power operation will be presented. Moreover, an approach to synthetize ultra-large mode area fibers that circumvents technical limitations by using multi-core fibers will be discussed.

Room 10

10:30–12:30
M2K • Optical Wireless - Signal Processing
Presider: Tetsuya Kawanishi; Waseda Univ., Japan

M2K.1 • 10:30
Non-linear Compensation of Multi-CAP VLC System Employing Pre-distortion Base on Clustering of Machine Learning, Xingyu Lu[1], Mingming Zhao[1], Liang Qiao[1], Nan Chi[1]; [1]*Fudan Univ., China.* We proposed and experimentally demonstrated a pre-distortion scheme based on clustering algorithm of machine learning to mitigate nonlinear impairments for VLC system. BER degraded at least 50% over 5-band CAP16 transmission with pre-distortion.

M2K.2 • 10:45
Accurate Indoor Visible Light Positioning System utilizing Machine Learning Technique with Height Tolerance, Chin-wei Hsu[2,1], Siming Liu[1], Feng Lu[1], Chi-Wei Chow[2], Chien-Hung Yeh[3], Gee-Kung Chang[1]; [1]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA;* [2]*Department of Photonics, College of Electrical and Computer Engineering, National Chiao Tung Univ., Taiwan;* [3]*Department of Photonics, Feng Chia Univ., Taiwan.* An accurate, low-cost indoor visible light positioning system utilizing machine learning technique is proposed and experimentally demonstrated. The average position resolution of the system can achieve 3.65 cm with height tolerance range of 15 cm.

Room 1A

M2A • 5G and Network Slicing—Continued

M2A.3 • 11:00 Invited

Converged Access/Metro Infastructures for 5G services, Anna Tzanakaki[1,2], Markos Anastasopoulos[2], Dimitra E. Simeonidou[2]; [1]*Univ. of Athens, Greece;* [2]*Univ. of Bristol, UK.* This paper focuses on Converged Access/Metro Infrastructures for 5G services proposing the novel "Disaggregated RAN" architecture adopting "disaggregation" of hardware and software components across wireless, optical and compute/storage domains. The proposed approach is theoretically evaluated.

Room 1B

M2B • Beyond 10G PON Evolution II—Continued

M2B.2 • 11:00

56 Gbps IM/DD PON based on 10G-class Optical Devices with 29 dB Loss Budget Enabled by Machine Learning, Peixuan Li[1], Lilin Yi[1], Lei Xue[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China*. We demonstrate 56Gbps PAM4 PON transmission over 25km SSMF using 10G-class DML and APD with 6 GHz 3-dB bandwidth. 29 dB loss budget is achieved by a novel equalization technique based on convolutional neural network.

M2B.3 • 11:15

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

Room 2

M2C • Transmission Systems—Continued

M2C.2 • 11:00 Top Scored

Record 560 Gb/s Single-carrier and 850 Gb/s Dual-carrier Transmission over Transoceanic Distances, Ivan Fernandez de Jauregui Ruiz[1,2], Amirhossein Ghazisaeidi[1], Patrick Brindel[1], Rafael Rios-Muller[1], Aymeric Arnould[1], Haik Mardoyan[1], Omar Ait Sab[3], Jeremie Renaudier[1], Gabriel Charlet[1]; [1]*Nokia Bell Labs, France;* [2]*Telecom SudParis, France;* [3]*ASN, France*. We demonstrate record single-carrier 560-gb/s over 6,600 km and 430-gb/s transmission over 13,200 km, as well as dual-carrier 850-gb/s over 6,600km, and 1-tb/s over 3,960km, leveraging advanced DACs, wideband receiver, probabilistic shaping and nonlinear mitigation.

M2C.3 • 11:15

8×506-Gb/s 16QAM WDM Signal Coherent Transmission over 6000-km Enabled by PS and HB-cDM, Jianjun Yu[1], Junwen Zhang[1], Kaihui Wang[2], Benyuan Zhu[3], Steve Dzioba[4], Hungchang Chien[1], Xinying Li[1,2], Yi Cai[1], Xin Xiao[1], Jianyang Shi[2], Yufei Chen[5], Yan Xia[5], sheping shi[5]; [1]*ZTE TX Inc, USA;* [2]*Fudan Uni., China;* [3]*OFS USA, USA;* [4]*NeoPhotonics Corp, USA;* [5]*ZTE, China*. We experimentally demonstrate 506-gb/s/channel (66.125-GBaud/channel) eight-channel WDM probabilistically-shaped 16QAM signal coherent transmission over 6000-km fiber with BER under 4.2×10^{-2}. 150% transmission-distance improvement, and 0.216-bit/symbol achievable-information-rate improvement can be attained after probabilistic shaping.

Room 6C

M2D • Energy Efficient Optical Links—Continued

M2D.3 • 11:00

4x40 Gb/s 2 pJ/bit Optical RX with 8ns Power-on and CDR-lock Time in 14nm CMOS, Alessandro Cevrero[1], Ilter Ozkaya[1,7], Thomas Morf[1], Thomas Toifl[1], Yusuf Leblebici[7], Marc Seifried[1], Frank Ellinger[2], Mahdi Khafaji[2], Jan Pliva[2], Ronny Henker[2], Nikolay Ledentsov[3], Joerg Kropp[3], Vitaly Shchulin[3], Martin Zoldak[4], Leos Halmo[4], Ian Eddie[5], Jarek Turkiewicz[6]; [1]*IBM research, Switzerland;* [2]*TU Dresden, Germany;* [3]*VI system, Germany;* [4]*Argotech, Czechia;* [5]*CST Global Ltd, UK;* [6]*Warsaw technical Univ., Poland;* [7]*EPFL, Switzerland*. We report a low-power 4-channel NRZ optical RX including a digital burst-mode CDR measured up to 40Gb/s/lane in 14nm CMOS. The RX, designed for 850nm VCSEL based optical links, can wake-up and achieve phase-lock in 8ns at $BER<2*10^{-12}$.

M2D.4 • 11:15 Top Scored

FEC-free 60-Gb/s Silicon Photonic Link Using SiGe-driver ICs Hybrid-integrated with Photonics-enabled CMOS, Benjamin G. Lee[1], Nicolas Dupuis[1], Jason Orcutt[1], Javier Ayala[2], Karen Nummy[2], Herschel Ainspan[1], Jonathan E. Proesel[1], Christian Baks[1], Douglas M. Gill[1], Mounir Meghelli[1], William M. Green[1]; [1]*IBM TJ Watson Research Center, USA;* [2]*Globalfoundries, USA.* We report an error-free 60-gb/s link driven by SiGe ICs using a segmented-electrode Mach Zehnder modulator with optical-domain feed-forward equalization and a high-bandwidth Ge photodetector, both integrated in a commercial photonics-enabled CMOS process.

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.2 • 11:00

Estimating Network Throughput with an Adaptive Routing and Wavelength Assignment Algorithm, Robert J. Vincent[1], David J. Ives[1], Seb J. Savory[1]; [1]*Univ. of Cambridge, UK.* We propose an adaptive sequential loading algorithm that approaches the ILP throughput. Of 2,000 network realizations tested, shortest path routing achieves >90 % of the maximum throughput in 341 cases c.f. 1,904 with the proposed algorithm.

M2E.3 • 11:15

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

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.3 • 11:00 Invited

Optical Performance Monitoring in Fiber-optic Networks Enabled by Machine Learning Techniques, Faisal N. Khan[1], Chao Lu[1], Alan Pak Tao Lau[1]; [1]*The Hong Kong Polytechnic Univ., Hong Kong.* We review applications of machine learning (ML) in various aspects of optical communications including optical performance monitoring, fiber nonlinearity compensation, and software-defined networking. The future role of ML in optical communications is also discussed.

Room 6F

M2G • Microwave Photonic Signal Processing II—Continued

M2G.2 • 11:00
Frequency-agile and Filter-free Wireless Communication Transceiver based on Photonics, Filippo Scotti[1], Daniel Onori[2], Antonella Bogoni[1], Paolo Ghelfi[1]; *[1]CNIT, Italy; [2]TECIP, Scuola Superiore Sant'Anna, Italy.* A photonics-based tunable RF transceiver able to generate and receive signals, without any RF or optical filter, is proposed. Experimental results with WiFi traffic show flat and good performance over the whole 2-18GHz frequency range.

M2G.3 • 11:15
Photonic Sampling of Broadband QAM Microwave Signals Exploiting Interleaved Optical Nyquist Pulses, Valeria Vercesi[1], Daniel Onori[2], John Davies[3], Alwyn Seeds[1], Chin-Pang Liu[1]; *[1]Univ. College London, UK; [2]Scuola Superiore Sant'Anna, Italy; [3]Thales UK, UK.* We performed photonic sampling of 6 GBaud 16-QAM signals at 20 GHz sampling frequency by interleaving and time-aligning two 10 GHz Nyquist optical sampling pulse trains using a SMF as the dispersive medium

Room 7AB

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

Wireless Internet Access

SSID: OFC

Password: OFC2018

Room 8

M2I • Emerging Devices and Materials—Continued

M2I.3 • 11:00 Invited
Highly Efficient Silicon Photonics Phase Modulator using Graphene, Marco Romagnoli[1]; *[1]CNIT Photonic Networks and Technologies National Laboratory, Italy.* Compact graphene-silicon phase-shifter with 0.28Vcm modulation efficiency at 1550nm is reported. The 2V MZ modulator has been tested over 50km SMF link at 10Gb/s and the chirped EA modulator over 100km SMF fiber link.

Room 9

M2J • Fiber Lasers—Continued

M2J.2 • 11:00
Dual Repetition-rate Laser Based On In-cavity Fractional Temporal Self-imaging for Low-noise RF Signal Generation, Mohamed Seghilani[1], Xiao-Zhou Li[1], Luis Romero Cortés[1], Reza Maram[1], Jose Azana[1]; *[1]INRS-EMT, Canada.* We demonstrate a dual repetition-rate laser based on fractional temporal self-imaging. Experimental noise evaluation confirms that the environmental noise is nearly canceled when the laser's outputs are heterodyned, making the laser ideal for low-noise RF-generation.

M2J.3 • 11:15
Experimental Demonstration of Mid-IR Octave Spanning Supercontinuum Generation in Low Loss Silicon-germanium Waveguide, Milan Sinobad[1,2], Pan Ma[3], Barry Luther-Davies[3], Stephen Madden[3], David J. Moss[4], Regis Orobtchouk[2], Salim Boutami[5], Jean-Michel Hartmann[5], Jean-Marc Fedeli[5], Christelle Monat[2], Christian Grillet[2]; *[1]RMIT Univ., Australia; [2]Lyon Inst. of Nanotechnology, France; [3]Australian National Univ., Australia; [4]Centre for Microphotonics, Swinburne Univ. of Technology, , Australia; [5]CEA-leti, France.* We report supercontinuum extending from 3 to 6μm generated in $Si_{0.6}Ge_{0.4}$/Si waveguide pumping with ~200fs pulses at 4.15μm. Experimentally measured low propagation loss (0.4dB/cm in range 3.8-5.0μm) and dispersion engineering waveguide allowed us achieving ~5mW useful average power.

Room 10

M2K • Optical Wireless - Signal Processing—Continued

M2K.3 • 11:00
Experimental Demonstration of OQAM-OFDM based MIMO-NOMA over Visible Light Communications, Jin Shi[1], Yang Hong[2], J He[1], Deng Rui[1], Lian-Kuan Chen[2]; *[1]Hunan Univ., China; [2]The Chinese Univ. of Hong Kong , China.* We propose and experimentally demonstrate the first OQAM-OFDM based MIMO-nOMA for multi-user VLC. With the optimized power ratio, our scheme significantly outperforms conventional MIMO scheme, and an aggregate capacity of 3.2 Gbit/s can be achieved.

M2K.4 • 11:15
SNR-threshold based Adaptive Loading for PAM-fast-OFDM over Optical Wireless Communications, Yang Hong[1], Shuang Gao[1], Lian-Kuan Chen[1], Jian Zhao[2,3]; *[1]The Chinese Univ. of Hong Kong, Hong Kong; [2]Tyndall National Inst., Ireland; [3]Univ. College Cork, Ireland.* We propose and experimentally demonstrate the first adaptively-loaded PAM-fast-OFDM over OWC using a simple yet effective SNR-threshold based loading algorithm. Results show >4-dB sensitivity improvement, and a 5.2-gbit/s transmission with ~44% capacity enhancement is achieved.

Room 1A

M2A • 5G and Network Slicing—Continued

M2A.4 • 11:30 Invited

Optical Networks Virtualization and Slicing in the 5G Era, Ricard Vilalta[1], Arturo Mayoral López-de-Lerma[2], Raul Muñoz[1], Ricardo Martínez[1], Ramon Casellas[1]; *[1]CTTC, Spain; [2]Wipro, Spain*. We provide an overview of operalization and deployment of the different data plane and control plane technologies used for Optical Network Virtualization and Network Slicing, which are two key enablers of future 5G networks.

Room 1B

M2B • Beyond 10G PON Evolution II—Continued

M2B.4 • 11:30

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

M2B.5 • 11:45

Spectrum-efficient 50-gbps Long-range Optical Access over 85-km SSMF via DML using Windowed OFDM Supporting Quasi-gapless Asynchronous Multiband Transmission, Shuyi Shen[1], Thavamaran Kanesan[2], Feng Lu[1], Mu Xu[1], Peng-Chun Peng[1], Siming Liu[1], Chin-Wei Hsu[1], Qi Zhou[1], Yahya M. Alfadhli[1], Hyung Joon Cho[1], Sufian M. Mitani[2], Jeff Finkelstein[3], Gee-Kung Chang[1]; *[1]ECE, Georgia Inst. of Technology, USA; [2]TM Research & Development, Malaysia; [3]Cox Communications, USA*. This paper demonstrates a long-range optical access network using windowed OFDM, providing 50.22-gbps data rate over 85-km SSMF transmission via DML. In multiband transmission, windowed OFDM has achieved 153% bandwidth gain with suppressed out-of-band leakage.

Room 2

M2C • Transmission Systems—Continued

M2C.4 • 11:30

Comparison of Nonlinearity Tolerance of Modulation Formats For Subcarrier Modulation, Keisuke Kojima[1], Tsuyoshi Yoshida[2,3], Kieran Parsons[1], Toshiaki Koike-Akino[1], David Millar[1], Keisuke Matsuda[2]; *[1]Mitsubishi Electric Research Labs, USA; [2]Mitsubishi Electric Corp., Japan; [3]Chalmers Univ. of Technology, Sweden*. We investigate the use of 4D constant modulus modulation format combined with subcarrier modulation. Compared to the star-8QAM format, the proposed format has an improved performance gain from reducing the baud rate down to 1 GBd.

M2C.5 • 11:45

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

Room 6C

M2D • Energy Efficient Optical Links—Continued

M2D.5 • 11:30

Energy-efficient 120-gbps DMT Transmission using a 1.3-μm Membrane Laser on Si, Nikolaos Panteleimon Diamantopoulos[1], Takuro Fujii[1], Hidetaka Nishi[1], Koji Takeda[1], Takaaki Kakitsuka[1], Shinji Matsuo[1]; *[1]NTT Device Technology Labs, Japan*. We report DMT transmissions of 120-gbps over 10-km SSMF (for SD-fEC) and 100-gbps over 2-km (for HD-fEC), by directly modulating a single-mode membrane laser grown on an InP/SiO_2/Si substrate, requiring only 28.2 mW for driving.

M2D.6 • 11:45 Invited

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

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.4 • 11:30 Invited

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

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.4 • 11:30

Joint Estimation of Linear and Nonlinear Signal-to-noise Ratio based on Neural Networks, Francisco Javier Vaquero Caballero[1], David J. Ives[1], Qunbi Zhuge[2], Maurice O'Sullivan[2], Seb J. Savory[1]; *[1]Electrical Engineering, Univ. of Cambridge, UK; [2]Ciena, Canada*. A novel technique estimating ASE and non-linear SNR is presented. Our method is evaluated by simulations obtaining a std error of 0.23 dB for both ASE and non-linear SNR

M2F.5 • 11:45

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

Room 6F

M2G • Microwave Photonic Signal Processing II—Continued

M2G.4 • 11:30

Fast and Linear Photonic Integrated Microwave Phase-shifter for 5G Beam-steering Applications, Fabio Falconi[2], Claudio Porzi[1], Sergio Pinna[1], Vito Sorianello[2], Giovanni Serafino[1], Marzio Puleri[3], Antonio D'Errico[3], Marco Romagnoli[2], Antonella Bogoni[1,2], Paolo Ghelfi[2]; *[1]TeCIP - Scuola Superiore Sant'Anna, Italy; [2]CNIT-national Photonics Labs, Italy; [3]Ericsson Telecomunicazioni SpA, Italy.* An integrated SOI photonic microwave phase-shifter employing optical deinterleaver and reverse-biased pn-junction waveguide for precise, continuous linear phase shift in excess of 360° with fast reconfiguration time below 1 ns for beam-steering applications is demonstrated.

M2G.5 • 11:45

Integrated Photonic True-time Delay Beamformer for a Ka-band Phased Array Antenna Receiver, Vanessa C. Duarte[1,2], João G. Prata[1], Carlos Ribeiro[1], Rogerio N. Nogueira[1,3], Georg Winzer[2], Lars Zimmermann[2], Rob Walker[4], Stephen Clements[4], Marta Filipowicz[5], Marek Napierala[5], Tomasz Nasilowski[5], Jonathan Crabb[6], Leontios Stampoulidis[6], Javad Anzalchi[7], Miguel V. Drummond[1]; *[1]Instituto de Telecomunicações, Portugal; [2]IHP - Innovations for High Performance Microelectronics, Germany; [3]Watgrid, Lda, Portugal; [4]aXenic Ltd, UK; [5]InPhoTech Sp. z o.o., Poland; [6]Gooch & Housego, UK; [7]Airbus Defence and Space, UK.* We demonstrate a silicon photonic 4x1 TTD beamformer operated in Real-time. Beamforming of a 1 Gb/s QPSK signal carried at 28 GHz was validated by a fourfold improvement in output amplitude and EVM.

Room 7AB

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

Room 8

M2I • Emerging Devices and Materials—Continued

M2I.4 • 11:30

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

M2I.5 • 11:45

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

Room 9

M2J • Fiber Lasers—Continued

M2J.4 • 11:30 Top Scored

Ultra-short Wavelength Operation of a Thulium Doped Fiber Laser in the 1620-1660nm Wavelength Band, Shaoxiang Chen[1,2], Yong-Min Jung[1], S.U Alam[1], Saurabh Jain[1], Morten Ibsen[1], R. Sidharthan[2], Daryl Ho[2], Seongwoo Yoo[2], David J. Richardson[1]; *[1]Univ. of Southampton, UK; [2]Nanyang Technological Univ., Singapore.* We present a tunable thulium-doped fiber laser (TDFL) incorporating a Tm/Ge co-doped fiber capable of accessing the U-band wavelength region (1620-1660nm). These results represents by far the shortest laser wavelengths so far for a TDFL.

M2J.5 • 11:45

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

Room 10

M2K • Optical Wireless - Signal Processing—Continued

M2K.5 • 11:30

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

M2K.6 • 11:45 Top Scored

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

Room 1A

M2A • 5G and Network Slicing—Continued

M2A.5 • 12:00 Top Scored

SDN-enabled Sliceable Multi-dimensional (Spectral and Spatial) Transceiver Controlled with YANG/NETCONF, Raul Muñoz[1], Noboru Yoshikane[2], Ramon Casellas[1], Josep Fabrega[1], Ricard Vilalta[1], Michela Svaluto Moreolo[1], Laia Nadal[1], Daiki Soma[2], Yuta Wakayama[2], Shohei Beppu[2], Seiya Sumita[2], Takehiro Tsuritani[2], Itsuro Morita[2]; *[1]CTTC, Spain; [2]KDDI Research, Japan*. We demonstrate the first SDN-enabled sliceable SDM-wDM transceiver providing multiple spectral-spatial super-cannels spanning different cores and modes over a 11-km 6-mode 19-core fiber. We define an open API based on YANG/NETCONF for disaggregated optical networks.

M2A.6 • 12:15 Top Scored

Experimental Demonstration of DDOS Mitigation over a Quantum Key Distribution (QKD) Network using Software Defined Networking (SDN), Emilio Hugues Salas[1], Foteini Ntavou[1], Yanni Ou[1], Jake Kennard[1], Catherine White[2], Dimitrios Gkounis[1], Konstantinos Nikolovgenis[1], George T. Kanellos[1], Chris Erven[1], Andrew Lord[2], Reza Nejabati[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]British Telecom (BT) Research and Innovation, UK*. We experimentally demonstrate, for the first time, DDOS mitigation of QKD-based networks utilizing a software defined network application. Successful quantum-secured link allocation is achieved after a DDOS attack based on Real-time monitoring of quantum parameters.

Room 1B

M2B • Beyond 10G PON Evolution II—Continued

M2B.6 • 12:00

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

M2B.7 • 12:15

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

Room 2

M2C • Transmission Systems—Continued

M2C.6 • 12:00

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

M2C.7 • 12:15

100Gb/s 16-QAM Transmission over 80 km SSMF Using a Silicon Photonic Modulator Enabled VSB-IM/DD System, Zhenping Xing[1], David Patel[1], Thang M. Hoang[1], Meng Qiu[1], Rui Li[1], Eslam El-Fiky[1], Meng Xiang[1], David V. Plant[1]; *[1]McGill Univ., Canada*. We demonstrate a VSB-iM/DD system using silicon photonic modulator. 25 GBaud 16 QAM over 80 km at a BER below 3.8×10^{-3} is achieved with either KK detection or our nonlinear equalization based SSBI mitigation method.

Room 6C

M2D • Energy Efficient Optical Links—Continued

M2D.7 • 12:15

93% Complexity Reduction of Volterra Nonlinear Equalizer by l_1-regularization for 112-gbps PAM-4 850-nm VCSEL Optical Interconnect, Wan-Jou Huang[1], Wei-Fan Chang[2], Chia-Chien Wei[3], Jun-Jie Liu[2], Yi-Ching Chen[2], Kai-Lun Chi[4], Chih-Lin Wang[1], Jin-Wei Shi[4], Jyehong Chen[2]; *[1]Integrated Photonics, Industrial Technology Research Inst., Taiwan; [2]Department of Photonics, National Chiao Tung Univ., Taiwan; [3]Department of Photonics, National Sun Yatsen Univ., Taiwan; [4]Department of Electrical Engineering, National Central Univ., Taiwan*. We successfully transmit a 112-gbps PAM-4 signal over 200-m OM4 fiber using 850-nm VCSEL and Volterra filter. Adopting l_1-regularization can reduce 93% of computation complexity of the Volterra filter at KP4 FEC limit.

Room 6D

M2E • Open and Dynamic Networking—Continued

M2E.5 • 12:00

Throughput Scaling for MMF-enabled Optical Datacenter Networks by Time-slicing-based Crosstalk Mitigation, Zhizhen Zhong[1], Nan Hua[1], Yufang Yu[1], Zhongying Wu[2], Juhao Li[2], Haozhe Yan[1], Shangyuan Li[1], Ruijie Luo[1], Jialong Li[1], Yanhe Li[1], Xiaoping Zheng[1]; *[1]Tsinghua Univ., China; [2]Peking Univ., China*. Modal crosstalk is the main bottleneck in MMF-enabled optical datacenter networks with direct detection. A novel time-slicing-based crosstalk-mitigated MDM scheme is first proposed, then theoretically analyzed and experimentally demonstrated.

M2E.6 • 12:15 Top Scored

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

Room 6E

M2F • Machine Learning and Performance Monitoring—Continued

M2F.6 • 12:00

An Accurate and Robust PDL Monitor by Digital Signal Processing in Coherent Receiver, Huihui Li[2], Guoxiu Huang[1], Zhenning Tao[2], Hao Chen[2], Shoichiro Oda[1], Yuichi Akiyama[1], Tomohiro Yamauchi[1], Takeshi Hoshida[1]; *[1]Fujitsu Laboratories Ltd., Japan; [2]Fujitsu R&D center, China*. An accurate and robust PDL monitor based on receiver side DSP is proposed and experimentally verified. The standard deviation of monitor error is 0.1 dB and the method tolerates various imperfections, such as unsynchronized clock.

M2F.7 • 12:15

An Accurate Algorithm to Quantitatively Identify the Performance Degradation Caused by Linear Crosstalk, Xiaofei Su[1], Yangyang Fan[1], Ke Zhang[1], Hao Chen[1], Zhenning Tao[1], Shoichiro Oda[2], Takeshi Hoshida[2]; *[1]Fujitsu R&D center, China; [2]Fujitsu Laboratories Ltd., Japan*. A new algorithm to estimate the signal impairment by linear crosstalk is proposed. Experiments demonstrate the linear relationship between the Q penalty and crosstalk indicator with R^2=0.98 under various transmission distances and conditions.

12:00–13:30 Lunch Break *(on own)*

Room 6F	Room 7AB	Room 8	Room 9	Room 10
M2G • Microwave Photonic Signal Processing II—Continued	**M2H • Panel: 400G Optics for Hyperscale Data Centers—Continued**	**M2I • Emerging Devices and Materials—Continued**	**M2J • Fiber Lasers—Continued**	**M2K • Optical Wireless - Signal Processing—Continued**
		M2I.6 • 12:00 Invited **Integrated Ferroelectric $BaTiO_3$/Si Plasmonic Modulator for 100 Gbit/s and Beyond,** Andreas Messner[1], Felix Eltes[2], Ping Ma[1], Stefan Abel[2], Benedikt Baeuerle[1], Arne Josten[1], Wolfgang Heni[1], Daniele Caimi[2], Jean Fompeyrine[2], Juerg Leuthold[1]; *[1]ETH Zurich, Switzerland; [2]IBM Research - Zurich, Switzerland.* We present an integrated ferroelectric $BaTiO_3$/Si plasmonic modulator and test its performance at 116 Gbit/s. The modulator has been tested to withstand temperatures up to 250°C.	**M2J.6 • 12:00** **Multi-wavelength Fiber Laser using a Single Multicore Erbium Doped Fiber,** Yong-Min Jung[1], J. R. Hayes[1], S.U Alam[1], David J. Richardson[1]; *[1]Optoelectronics Research Centre (ORC), UK.* We propose and demonstrate a simple multi-wavelength fiber laser based on a single multicore erbium doped fiber. An exemplary 7-wavelengths fiber laser was realized in a linear cavity by using 7-core EDF and an arrayed-waveguide-grating.	**M2K.7 • 12:00** Top Scored **Multichannel Analog and Digital Signal Transmission with Watt-class Electrical Power Delivery by Means of Power-over-fiber using a Double-clad Fiber,** Daisuke Kamiyama[1], Akira Yoneyama[1], Motoharu Matsuura[1]; *[1]Univ. of Electro-communications, Japan.* We have successfully achieved high transmission performance of multichannel analog and digital signals with over 7-watt electrical power delivery by means of power-over-fiber using a double-clad fiber, for the first time.
	OFC Management advises you to write your name on all your conference materials (Conference Program, USB Slapband, Buyers' Guide, and Short Course Notes). There is a cost for replacements.		**M2J.7 • 12:15** **Revolver Hollow-core Fibers and Raman Fiber Lasers,** Alexey Gladyshev[1], Alexey F. Kosolapov[1], Maxim S. Astapovich[1], Anton N. Kolyadin[1], Andrey D. Pryamikov[1], Maxim M. Khudyakov[1], Mikhail E. Likhachev[1], Igor A. Bufetov[1]; *[1]FORC RAS, Russia.* Hollow-core silica fiber with optical losses of ~1 dB/m at the wavelength of 4.4 μm is demonstrated. Based on this revolver fiber 4.4-μm fiber Raman laser is realized with output average power of 250 mW and quantum conversion efficiency as high as 36 %.	**M2K.8 • 12:15** **Dynamic Tuning of Contention Window for Optical Wireless Networks,** Sampath S. Edirisinghege[1], Christina Lim[1], Ampalavanapillai Nirmalathas[1,2], Elaine Wong[1], Ke Wang[3], Kamal Alameh[4]; *[1]Department of Electrical and Electronic Engineering, The Univ. of Melbourne, Australia; [2]Networked Society Inst., The Univ. of Melbourne, Australia; [3]School of Engineering, RMIT Univ., Australia; [4]Electron Science Research Inst., Edith Cowan Univ., Australia.* We propose a novel contention window tuning algorithm for multi-gigabit optical wireless networks based on IEEE 802.11 standard that improves the enhanced distributed coordination function and meets the stringent requirements of optical wireless

12:00–13:30 Lunch Break *(on own)*

Room 1A

14:00–16:00
M3A • Telemetry and Survivability
Presider: Ramon Casellas; Centre Tecnològic Telecomunicacions Catalunya, Spain

M3A.1 • 14:00
Experimental Demonstration of Active and Passive Optical Networks Telemetry, Luis Gifre[2], Jose Luis Izquierdo-Zaragoza[1], Behnam Shariati[1], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Universidad Autónoma de Madrid (UAM), Spain*. A distributed architecture enabling active and passive optical network telemetry is presented; a YANG data model is used for remotely configuring monitoring devices for telemetry purposes. Experimental demonstration is carried out for failure localization.

M3A.2 • 14:15
Field Trial of Monitoring On-demand at Intermediate-nodes Through Bayesian Optimization, Fanchao Meng[1], Alex Mavromatis[1], Yu Bi[1], Shuangyi Yan[1], Rui Wang[1], Yanni Ou[1], Konstantinos Nikolovgenis[1], Reza Nejabati[1], Dimitra E. Simeonidou[1]; [1]*Univ. of Bristol, UK*. We demonstrate an intelligent monitoring on-demand switching strategy at network nodes using Bayesian optimization. It is shown our proposed method achieves identical monitoring capability as complete system exploration while saving a lot of data.

Room 1B

14:00–16:00
M3B • Coherent and DSP Technologies for PON
Presider: Naoki Suzuki; Mitsubishi Electric Corporation, Japan

M3B.1 • 14:00 Invited
Recent Progress and Outlook for Coherent PON, Domaniç Lavery[1], M. Sezer Erkilinc[1], Polina Bayvel[1], Robert Killey[1]; [1]*Univ. College London, UK*. Coherent receivers offer high data rates and reach for optical access but, due to their complexity, have proved resistant to implementation. Here, recent research in low-complexity coherent PON is reviewed, and promising future research directions are identified.

Room 2

14:00–16:00
M3C • Probabilistic Shaping I
Presider: Qi Yang; State Key Laboratory of Optical Comm., China

M3C.1 • 14:00 Invited
Probabilistic Constellation Shaping: Challenges and Opportunities for Forward Error Correction, Laurent Schmalen[1]; [1]*Nokia Bell Labs, Germany*. We discuss the impact of probabilistic amplitude shaping on the forward error correction stage in future optical transceivers and highlight some potential pitfalls, as well as challenges and opportunities for future research that may arise.

Room 6C

14:00–16:00
M3D • Symposium: Challenges 5G brings to Optical Fiber Communications Systems I
Organizers: Phillipe Chanclou, Orange Labs, France; Gee-Kung Chang, Georgia Inst. of Technology, USA; Theodore Sizer, Nokia Bell Labs, USA

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

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Room 6D

14:00–16:00
M3E • Parametric Amplification Subsystems
Presider: Youichi Akasaka; Fujitsu Laboratories of America Inc, USA

M3E.1 • 14:00 Tutorial
Fundamentals and Applications of Optical Parametric Amplifiers, Peter A. Andrekson[1]; [1]*Chalmers Tekniska Hogskola, Sweden*. Advances of fiber-optic parametric amplifiers and their use in optical communication will be reviewed. Both phase-insensitive and phase-sensitive implementations will discussed, the latter being capable of noiseless amplification as well as mitigation of transmission-induced nonlinearities.

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

Room 6E

14:00–16:00
M3F • Data Center and Integration
Presider: Chen Ji; CAS Inst. of Semiconductors, China

M3F.1 • 14:00 Top Scored
AIM Process Design Kit (AIMPDKv2.0): Silicon Photonics Passive and Active Component Libraries on a 300mm Wafer, Erman Timurdogan[1], Zhan Su[1], Christopher Poulton[1], Matt J. Byrd[1], Simon Xin[1], Ren-Jye Shiue[1], Benjamin R. Moss[1], Ehsan S. Hosseini[1], Michael R. Watts[1]; [1]*Analog Photonics, USA*. A new process design kit (AIMPDKv2.0) is introduced that offers a verified silicon photonics component library on 300mm silicon-on-insulator wafers. The library includes multi-layer waveguides, polarization manipulation, switches, filters, and high-speed digital/analog detectors and modulators.

M3F.2 • 14:15
Wafer-scale High-density Edge Coupling for High Throughput Testing of Silicon Photonics, Robert Polster[1], Liang Y. Dai[1], Oscar Jimenez[1], Qixiang Cheng[1], Michal Lipson[1], Keren Bergman[1]; [1]*Columbia Univ., USA*. High-throughput functional testing of silicon photonics is a key challenge for scalable manufacturing. We present a technique for wafer-scale testing using high-density edge couplers that add excess loss of 2.2dB without requiring additional footprint.

Room 6F

14:00–16:00
M3G • Symposium: Future Photonic Devices and Materials for Optical Communications I
Organizers: Steven Koester, Univ. of Minnesota, USA; Gunther Roelkens, Ghent Univ., Belgium; Yoichi Taira, Keio Univ., Japan

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

M3G.1 • 14:00 Invited
Brillouin Scattering and Photon-phonon Signal Processing in Silicon, Peter T. Rakich[1]; [1]*Yale University, USA*. We explore emerging chip-scale technologies based on Brillouin interactions and their potential impact for optical communications. In particular, we examine the benefits of new chip-scale ultra-narrow linewidth laser sources and new Brillouin-based filtering technologies.

Room 7AB

14:00–16:00
M3H • Panel: Machine Learning and SDN: Towards Intelligent Data Centers
Organizer: Payman Samadi, Cornell Univ., USA

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

Panelists:

Omar Baldonado, *Facebook, USA*

Kevin Deierling, *Mellanox, USA*

Jamie Gaudette, *Microsoft, USA*

Uri Elzur, *Intel, USA*

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

Danish Rafique, *ADVA Optical Networking, Germany*

Room 8

14:00–16:00
M3I • Photonic Integration I
Presider: Piero Gambini; STMicroelectronics, Italy

M3I.1 • 14:00 Invited
Low-loss Silicon Photonic Switch Module Technology and its use for Transponder Aggregators in Optical Network Nodes, Shigeru Nakamura[1], Shigeyuki Yanagimachi[1], Hitoshi Takeshita[1], Akio Tajima[1]; [1]*NEC Corporation, Japan*. Silicon photonic switches are attractive for extensible optical switch systems required for optical networks in telecom areas and datacenters. We show our low-loss silicon photonic switch modules and their application to CDC-rOADMs using multiple modules.

Room 9

14:00–16:00
M3J • SDM/WDM Networking
Presider: Rui Morais; Instituto De Telecomunicacoes, USA

M3J.1 • 14:00
Impact of Fractionally Spatial Super-channel Time-slotted Switch Architecture Design, Yusuke Hirota[1], Jose Manuel Delgado Mendinueta[1], Satoshi Shinada[1], Ruben S. Luis[1], Hideaki Furukawa[1], Hiroaki Harai[1], Naoya Wada[1]; [1]*NICT, Japan*. We compare fractionally and whole spatial super-channel time-slotted switch architecture designs in terms of network-wide performance of its switching granularity and experimentally demonstrate collision avoidance functionality of SDM based transmission.

M3J.2 • 14:15
Modulation Format, Spectrum and Core Assignment in a Multicore Flexi-grid Optical Link, Cristina Rottondi[2], Paolo Martelli[1], Pierpaolo Boffi[1], Luca Barletta[1], Massimo Tornatore[1]; [1]*Politecnico di Milano, Italy;* [2]*Dalle Molle Inst. for Artificial Intelligence, Switzerland*. We model and solve the core and spectrum assignment problem in a multicore flexi-grid link, considering distance-adaptive reaches for different modulation formats and crosstalk impairments. Problem complexity and exemplifying numerical results on 19-core fibers are discussed.

Room 10

14:00–16:00
M3K • Optical Wireless - Technologies
Presider: Atsushi Kanno; NICT, Japan

M3K.1 • 14:00 Invited
Power-efficient Noise-tolerant Techniques for Achieving High-sensitivity Optical Communications, David O. Caplan[1], Jeffrey H. Shapiro[1,2]; [1]*MIT Lincoln Lab, USA;* [2]*Massachusetts Inst. of Technology, USA*. We present efficient techniques for generating high-fidelity waveforms and robust methods of achieving nearly-ideal transmitter and receiver implementations. Compatibility with multiple modulation formats provides versatile and sensitive performance options suitable for fiber and free-space applications.

Room 1A

M3A • Telemetry and Survivability—Continued

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

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

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

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

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

Room 2

M3C • Probabilistic Shaping I—Continued

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

Room 6C

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

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

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

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

Room 6D

M3E • Parametric Amplification Subsystems—Continued

Room 6E

M3F • Data Center and Integration—Continued

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

Room 6F

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

M3G.2 • 14:30 Invited

Plasmonics for Communications, Juerg Leuthold[1]; *[1]ETH Zurich, Switzerland.* Plasmonics has the potential to complement photonics and microwave photonics with ultrafast, energy efficient and most compact components. As a result, novel plasmonic modulators, detectors and microwave components emerge offering bandwidths beyond 100 GHz.

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

Room 7AB

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

Room 8

M3I • Photonic Integration I—Continued

M3I.2 • 14:30

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

M3I.3 • 14:45

TE Mode Input Operation of Waveguide Optical Isolator with Tapered Mode Converter and Magneto-optical Phase Shifter, Ryusuke Yamaguchi[1], Yuya Shoji[1], Tetsuya Mizumoto[1]; *[1]Tokyo Inst. of Technology, Japan.* A novel waveguide optical isolator operating for TE mode input is proposed with tapered mode converters and a magneto-optical phase shifter. A maximum isolation ratio of 6.4 dB is demonstrated at a wavelength of 1557 nm.

Room 9

M3J • SDM/WDM Networking—Continued

M3J.3 • 14:30

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

M3J.4 • 14:45

Comparison of SDM-WDM based Data Center Networks with Equal/unequal Core Pitch Multi-core Fibers, Hui Yuan[1], Arsalan Saljoghei[1], Adaranijo Peters[2], Georgios Zervas[1]; *[1]Univ. College London, UK; [2]Univ. of Bristol, UK.* A wavelength-dependent crosstalk calculation formula for bi-directional MCF with unequal core pitches is derived. SDM-wDM based DCN simulations indicate that MCF core density and layout play a significant role on optimizing various scales of DCNs.

Room 10

M3K • Optical Wireless - Technologies—Continued

M3K.2 • 14:30

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

M3K.3 • 14:45

10.72Gb/s Visible Light Communication System Based on Single Packaged RGBYC LED Utilizing QAM-DMT Modulation With Hardware Pre-equalization, Xin Zhu[2], Fumin Wang[1], Meng Shi[1], Nan Chi[1], Junlin Liu[2], Fengyi Jiang[2]; *[1]Fudan Univ., China; [2]National Inst. of LED on Silicon Substrate, Nanchang Univ., Nanchang 330096, People' s Republic of China, China.* In this paper, we experimentally demonstrated a 10.72Gb/s wavelengths multiplexing visible light communication system over 1-m indoor free space transmission using a single packaged RGBCY LED with hardware pre-equalization and post equalizer

Room 1A

M3A • Telemetry and Survivability—Continued

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

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

M3B.4 • 15:00
Simultaneous DPSK-ASK Modulated Dual-eML Transmitter for Coherent UDWDM-PON, Juan Camilo Velásquez Micolta[1], Marc Domingo[1], Victor Polo[1], Josep Prat[1]; [1]*Universitat Politécnica de Catalunya, Spain.* An integrated dual-eML is modulated to obtain a simultaneous DPSK/ASK signal. Rx sensitivity of -40 dBm at BER=10^{-3} was achieved at 5Gb/s with simple heterodyne detection.

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

Room 2

M3C • Probabilistic Shaping I—Continued

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

M3C.4 • 15:15
A Simple Nonlinearity-tailored Probabilistic Shaping Distribution for Square QAM, Eric Sillekens[1], Daniel Semrau[1], Gabriele Liga[1], Nikita Shevchenko[1], Zhe Li[1], Alex Alvarado[2], Polina Bayvel[1], Robert Killey[1], Domeniç Iavory[1]; [1]*Univ. College London, UK;* [2]*Eindhoven Univ. of Technology (TU/e), Netherlands.* A new probabilistic shaping distribution that outperforms Maxwell-boltzmann is studied for the nonlinear fiber channel. Additional gains of 0.1 bit/symbol MI or 0.2 dB SNR for both DP-256QAM and DP-1024QAM are reported after 200 km nonlinear fiber transmission.

Room 6C

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

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

Room 6D

M3E • Parametric Amplification Subsystems—Continued

M3E.2 • 15:00 Invited
Towards Practical Implementation of Optical Parametric Amplifiers based on PPLN Waveguides, Takeshi Umeki[1,2], Takushi Kazama[2], Takayuki Kobayashi[1], Koji Enbutsu[2], Tadanaga Osamu[2], Hirokazu Takenouchi[1,2], Ryoihi Kasahara[2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Labs, Japan;* [2]*NTT Device Technology Labs, Japan.* We review the capabilities of optical parametric amplifiers based on periodically poled $LiNbO_3$ (PPLN) waveguides. Specifically, we discuss the applicability of PSA for WDM, QAM, and PDM signals and simultaneous nonlinearity mitigation using CSI-oPC.

Room 6E

M3F • Data Center and Integration—Continued

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

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

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

M3G.3 • 15:00 Invited

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

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

M3I • Photonic Integration I—Continued

M3I.4 • 15:00

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

M3I.5 • 15:15

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

M3J • SDM/WDM Networking—Continued

M3J.5 • 15:00

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

M3J.6 • 15:15

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

M3K • Optical Wireless - Technologies—Continued

M3K.4 • 15:00

Demonstration of Inter-dimensional Adaptive Diversity Combining and Repetition Coding in Converged MMW/FSO Links for 5G and beyond Mobile Fronthaul, Feng Lu[1], Mu Xu[1], Shuyi Shen[1], Yahya M. Alfadhli[1], Hyung Joon Cho[1], Gee-Kung Chang[1]; *[1]Georgia Inst. of Technology, USA.* We firstly introduce inter-dimensional adaptive-diversity-combining-technique in fiber-wireless fronthaul. By adaptively combining symbols from millimeter-wave and free-space-optics links in time/frequency domain and applying repetition coding, we experimentally attained better tunability in power margins with improved reliability.

M3K.5 • 15:15

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

Room 1A

M3A • Telemetry and Survivability—Continued

M3A.6 • 15:30
Experimental Validation of Transport SDN Restoration of Signal-degraded Connections in Flexi-grid Networks, Ricardo Martínez[1], Ramon Casellas[1], Josep M. Fabrega[1], Ricard Vilalta[1], Raul Muñoz[1], Laia Nadal[1], Michela Svaluto Moreolo[1], Asier Villafranca[2], Pascual Sevillano[2]; [1]*Ctr Tecnologic de Telecoms de Catalunya, Spain;* [2]*Aragon Photonics Lab, Spain.* We validate experimentally the integration of a PCE-based T-SDN controller with an OAM Handler to restore signal-degraded flexi-grid connections. A distributed monitoring system is adopted where a RSMA algorithm exploits benefits of elastic optical networks.

M3A.7 • 15:45
Observe-decide-act: Experimental Demonstration of a Self-healing Network, Konstantinos Christodoulopoulos[2], Nicola Sambo[3], Nikos Argyris[1], Pietro Giardina[4], Giannis Kanakis[1], Aristotelis Kretsis[2], Francesco Fresi[3], Andrea Sgambelluri[3], Giacomo Bernini[4], Camille Delezoide[5], Filippo Cugini[3], Hercules Avramopoulos[1], Emmanouel Varvarigos[2,1]; [1]*National Technical Univ. of Athens, Greece;* [2]*Computer Technology Inst. and Press, Greece;* [3]*Scuola Superiore Sant'Anna, Italy;* [4]*Nextworks, Italy;* [5]*Nokia Bell Labs, France.* We experimentally demonstrate a self-healing network, following the observe-decide-act paradigm: monitoring reveals degradation, decision is taken, network is reconfigured to restore service. We also demonstrate, for the first time, pre-programmed resilience in integrated data/control testbed.

Room 1B

M3B • Coherent and DSP Technologies for PON—Continued

M3B.6 • 15:30 Invited
DSP for High-speed Fiber-wireless Convergence, Huaiyu Zeng[1], Xiang Liu[1], Sharief Megeed[1], Frank Effenberger[1]; [1]*Futurewei Technologies, USA.* We review recent advances in the common public radio interfaces (CPRI/eCPRI) between remote radio units and baseband units via optical fiber, and discuss how DSP may be used to support both CPRI and eCPRI to achieve high bandwidth efficiency and low processing latency.

Room 2

M3C • Probabilistic Shaping I—Continued

M3C.5 • 15:30
Experimental and Numerical Comparison of Probabilistically-shaped 4096 QAM and Uniformly-shaped 1024 QAM in All-raman Amplified 160 km Transmission, Seiji Okamoto[2,1], Masaki Terayama[2], Masato Yoshida[2], Keisuke Kasai[2], Toshihiko Hirooka[2], Masataka Nakazawa[2]; [1]*Nippon Telegraph & Telephone Corp, Japan;* [2]*Tohoku Univ., Japan.* We experimentally and numerically compared probabilistically-shaped 4096 QAM with uniformly-shaped 1024 QAM with a spectral efficiency of 15.3 bit/s/Hz after an all-raman 160 km transmission. The 1.4-dB power margin was improved by constellation shaping.

M3C.6 • 15:45
Residual Non-linear Phase Noise in Probabilistically Shaped 64-QAM Optical Links, Dario Pilori[1], Fabrizio Forghieri[2], Gabriella Bosco[1]; [1]*Politecnico di Torino, Italy;* [2]*Cisco Photonics Italy, Italy.* We show that the performance penalty for probabilistically-shaped constellations induced by residual non-linear phase noise after standard CPE is significantly higher in low-symbol rate systems, canceling the potential gain achievable through symbol rate optimization.

Room 6C

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

15:30 Panel Discussion

Room 6D

M3E • Parametric Amplification Subsystems—Continued

M3E.3 • 15:30
Fiber-optic Frequency Shifting of THz-range WDM Signal using Orthogonal Pump-signal Polarization Configuration, Tomoyuki Kato[1], Shigeki Watanabe[1], Takahito Tanimura[1], Robert Elschner[2], Carsten Schmidt-Langhorst[2], Colja Schubert[2], Takeshi Hoshida[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fraunhofer HHI, Germany.* We propose a nonlinear fiber-based optical frequency shifter using two CW pumps orthogonally polarized to signals and demonstrate THz-range error-free frequency shifting of 1.6-tb/s DP-16QAM WDM signal without guard-band midway through 160 km transmission.

M3E.4 • 15:45 Top Scored
Polarization-diversity In-line Phase Sensitive Amplifier for Simultaneous Amplification of Fiber-transmitted WDM PDM-16QAM Signals, Takeshi Umeki[1,2], Takushi Kazama[2], Takayuki Kobayashi[1], Shigehiro Takasaka[3], Yasuhiro Okamura[4], Koji Enbutsu[2], Tadanaga Osamu[2], Hirokazu Takenouchi[1,2], Ryuichi Sugizaki[3], Atsushi Takada[4], Ryoihi Kasahara[2], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Labs, Japan;* [2]*NTT Device Technology Labs, Japan;* [3]*Furukawa Electric Co., Ltd, Japan;* [4]*Faculty of Engineering, Tokushima Univ., Japan.* We developed in-line PSA for the simultaneous amplification of wavelength-multiplexed and polarization-multiplexed QAM signals. We achieved >20-dB gain and a 12-nm bandwidth for 16-channel PDM-16QAM signals with an inherent PSA characteristic of a 5.1-dB SNR advantage.

Room 6E

M3F • Data Center and Integration—Continued

M3F.6 • 15:30 Invited
VCSEL-based Optical Transceivers for Future Data Center Applications, Jim Tatum[1], Gary Landry[1], Deepa Gazula[1], Jerome K. Wade[1], Petter Westbergh[1]; [1]*Finisar Corporation, USA.* Progress on VCSELs and Photodiodes for 56Gbps/channel data links is reported for both PAM4 and NRZ modulation formats.

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

Room 6F

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

M3G.4 • 15:30 Invited

Superconducting Nanowire Single-Photon Detectors for Future Optical Communications, H Terai[1], Shigehito Miki[1], Taro Yamashita[1], Shigeyuki Miyajima[1], Masahiro Yakuno[1]; [1]*NICT, Japan*. Superconducting nanowire single-photon detector enable photon detection with >80% detection efficiency, low noise and precise timing, all these features are attractive for future optical communications such as quantum information technologies and deep space communications.

Room 7AB

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

Room 8

M3I • Photonic Integration I—Continued

M3I.6 • 15:30

Flexible Silicon Optical Splitters based on High Order Modes, Daigao Chen[1], Xi Xiao[1], Lei Wang[1], Yuguang Zhang[1], Xiao Hu[1]; [1]*State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts Telecommunications, China*. Based on the natural splitting in the intensity distribution of high order modes, and using three mode order converters, we demonstrate 0.5/0.5, 0.667/0.333 and 0.75/0.25 Y junction power splitters with high fabrication tolerance.

M3I.7 • 15:45

Ultra-broadband and Ultra-compact Optical 90° Hybrid Based on 2x4 MMI Coupler with Subwavelength Gratings on Silicon-on-insulator, Luhua Xu[1], Yun Wang[1], David Patel[1], Mohamed Morsy-Osman[1], Rui Li[1], Michael Hui[1], Mahdi Parvizi[2], Naim Ben-Hamida[2], David V. Plant[1]; [1]*McGill Univ., Canada;* [2]*Ciena Corporation, Canada*. We propose an ultra-broadband and ultra-compact optical 90° hybrid based on a subwavelength gratings dispersion-engineered 2x4 MMI coupler on silicon-on-insulator. Our device is only 41.3 μm in length, with an operating bandwidth over 150 nm.

Room 9

M3J • SDM/WDM Networking—Continued

M3J.7 • 15:30 Top Scored

Network Architecture in the Era of Integrated Optics, Nick Kucharewski[1], Cyriel Minkenberg[1], German Rodriguez[1]; [1]*Rockley Photonics, Switzerland*. Disparities in reach and cost between electrical and optical ports have important implications for network architecture. We quantify network cost, capturing the tradeoffs of pizzabox versus chassis switches and the potential impact of integrated optics.

M3J.8 • 15:45

Spectrally Efficient and Highly Resilient Grouped Routing Network Enhanced with Optical Performance Monitoring, Keisuke Kayano[1], Hiroshi Saito[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-Ichi Sato[1], Shoichiro Oda[2], Setsuo Yoshida[2], Takeshi Hoshida[2]; [1]*Nagoya Univ., Japan;* [2]*Fujitsu Limited, Japan*. We demonstrate a spectrally efficient and highly resilient grouped-routing optical network, whose Q-factor margin is precisely controlled with optical performance monitoring. Its effectiveness is confirmed via network analysis and transmission experiments on 200-gbps DP-16QAM signals.

Room 10

M3K • Optical Wireless - Technologies—Continued

M3K.6 • 15:30

Robust and Secure Indoor Optical Wireless Communications Supporting Multiple Users, Tian Liang[1], Ke Wang[2], Christina Lim[1], Elaine Wong[1], Tingting Song[1], Ampalavanapillai Nirmalathas[1]; [1]*The Univ. of Melbourne, Australia;* [2]*RMIT Univ., Australia*. We experimentally demonstrate a robust and secure multiple-access mechanism for indoor optical wireless communications using time-slot-coding and chaotic phase. Results show that it is secure against eavesdropper's exhaustive searching accuracy as high as 1e-10 and is robust against 67% (4-QAM) and 23% (16-QAM) code misalignment.

M3K.7 • 15:45 Top Scored

High-speed Two-dimensional Photodetector Array for 4-WDM 25-GBaud FSO Communication, Toshimasa Umezawa[1], Takahide Sakamoto[1,3], Atsushi Kanno[1], Kouichi Akahane[1], Atsushi Matsumoto[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[1,2]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Waseda Univ., Japan;* [3]*Japan Science and Technology Agency, Japan*. We present a newly developed 32-pixel high-speed 2D photodetector array operated at up to 39 GBaud, and its application for WDM FSO communications. 4-WDM 25-GBaud FSO parallel beams could be directly detected by the 2D-PDA.

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

Room 1A

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

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

Room 1B

Room 2

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

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

Room 6C

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

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

Room 6D

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

M4D.1 • 16:30
Demonstration of Weakly-coupled MDM-WDM Amplification and Transmission over 15-km FMF Employing IM/DD, Jinglong Zhu[1], Juhao Li[1], Dawei Ge[1], Zhongying Wu[1], Fang Ren[2], Zhenzhen Zhang[3], Xiaoying Li[3], Yichi Zhang[4], Zhengbin Li[1], Zhangyuan Chen[1], Yongqi He[1]; [1]*Peking Univ., China;* [2]*Univ. of Science and Technology Beijing, China;* [3]*Tianjin Univ., China;* [4]*Wuhan Research Inst. of Posts and Telecommunications, China*. We propose an all-fiber few-mode EDFA employing low-modal-crosstalk mode-selective couplers, based on which we experimentally demonstrate weakly-coupled MDM-wDM amplification and transmission over 2-mode 15-km FMF without MIMO processing.

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

Room 6E

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

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

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

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Room 6F

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

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

Room 7AB

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

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

Room 8

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

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

Room 9

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

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

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

Room 10

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

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

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

Room 1A

M4A • Modelling, Disaggregation & Networking Automation—Continued

M4A.2 • 17:00
Node Internal Modeling for Network Recovery with Emergency Optical Systems, Sugang Xu[1], Noboru Yoshikane[2], Masaki Shiraiwa[1], Takehiro Tsuritani[2], Hiroaki Harai[1], Yoshinari Awaji[1], Naoya Wada[1]; [1]*NICT, Japan;* [2]*KDDI Research, Japan*. We propose a ROADM internal model and demonstrate network recovery with the control of a lightweight emergency optical system, which has a highly customizable internal structure to meet the different requirements in disaster recovery.

M4A.3 • 17:15
Experimental Demonstration of Fully Disaggregated White Box including Different Types of Transponders and Monitors, Controlled by NETCONF and YANG, Nicola Sambo[1], Kostas Christodoulopoulos[2], Nikos Argyris[3], Pietro Giardina[4], Camille Delezoide[5], Andrea Sgambelluri[1], Aristotelis Kretsis[2], Giannis Kanakis[3], Francesco Fresi[1], Giacomo Bernini[4], Hercules Avramopoulos[3], Emmanouel Varvarigos[2], Piero Castoldi[1]; [1]*Sant' Anna di Pisa, Italy;* [2]*CTI, Greece;* [3]*NTUA, Greece;* [4]*Nextworks, Italy;* [5]*Nokia Bell Labs, France*. We experimentally demonstrated a fully disaggregated white box composed of two different types of transponders, monitors (including filtering effect parameters), add-drop multiplexers, and switches. NETCONF and YANG control the hardware.

Room 1B

Room 2

M4B • Practical Aspects in Fiber Transmission—Continued

M4B.2 • 17:00
Observation of Guided Acoustic-wave Brillouin Scattering and its Digital Compensation in Coherent QAM Transmission, Masataka Nakazawa[1], Masaki Terayama[1], Seiji Okamoto[1], Masato Yoshida[1], Keisuke Kasai[1], Toshihiko Hirooka[1]; [1]*Tohoku Univ., Japan*. Guided acoustic-wave Brillouin scattering (GAWBS) noise was observed in a digital coherent QAM transmission, which deteriorated the transmission performance. A new digital signal processing method is presented that compensates for the GAWBS noise.

M4B.3 • 17:15 Top Scored
Impact of Spontaneous Guided Acoustic-wave Brillouin Scattering on Long-haul Transmission, Maxim A. Bolshtyansky[1], Jin-Xing Cai[1], Carl Davidson[1], Matt Mazurczyk[1], Ding Wang[1], Milen Paskov[1], Oleg V. Sinkin[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; [1]*TE SubCom, USA*. We measure forward optical scattering coefficient of thermally excited acoustic modes of modern submarine transmission fiber to be -32 dB/Mm. We estimate 0.6 dB of Q-factor penalty in our testbed due to this effect.

Room 6C

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

M4C.2 • 17:00 Invited
Evolved Cable Access Networks to Support 5G Services, Zhensheng Jia[1], Luis Alberto Campos[1], Jing Wang[1], Lin Cheng[1], Curtis Knittle[1]; [1]*Cable Labs, USA*. We review HFC network evolution towards distributed architecture and Fiber Deep strategy, and explore the advantages of this evolved network with regard to backhaul capability, site and power availability, and resilient architecture for future 5G services.

Room 6D

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

M4D.3 • 17:00 Invited
Enabling Component Technologies for Space Division Multiplexing, Yong-Min Jung[1], S.U Alam[1], David J. Richardson[1]; [1]*Optoelectronics Research Centre (ORC), UK*. We present an overview of recent progress on SDM components. In particular, we will discuss in detail various recently developed SDM fiber isolators, pump couplers and mode field diameter adaptors.

Room 6E

M4E • Probabilistic Shaping II—Continued

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Room 6F

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

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

Room 7AB

M4G • Optical Coherence Control—Continued

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

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

Room 8

M4H • Photonic Integration II—Continued

M4H.2 • 17:00
Fast Frequency Tuning of Silicon-photonic Thermo-optic MZI Filters using "Turbo Pulse" Method, Hiroyuki Matsuura[1], Keijiro Suzuki[1], Satoshi Suda[1], Kazuhiro Ikeda[1], Hitoshi Kawashima[1], Shu Namiki[1]; [1]*AIST, Japan.* We discuss and demonstrate the application of Turbo Pulse method to the silicon-photonic MZI based tunable filter. The tuning time was shortened to no longer than 7.0 μs from 36 μs without the method.

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

Room 9

M4I • Deployments of Optical Access and Front Haul—Continued

Room 10

M4J • MMW & THz Systems—Continued

M4J.3 • 17:00
mmWave Beamforming using Photonic Signal Processing for Future 5G Mobile Systems, Hongbo Lu[1], Gengchen Liu[1], Roberto Proietti[1], Vincent Squitieri[1], Kaiqi Zhang[1], Alberto Castro[1], Q. Jane Gu[1], Zhi Ding[1], S. J. Ben Yoo[1]; [1]*UC Davis, USA.* We propose a photonic signal processing technique enabling reconfigurable multiple mmWave-beam forming for 5G cellular systems. We demonstrate the beamforming capability with a 4-by-4 patch array antenna, achieving 15-dBi antenna gain and 8-gbps throughput.

M4J.4 • 17:15 Top Scored
120Gb/s Wireless Terahertz-wave Signal Delivery by 375GHz-500GHz Multi-carrier in a 2×2 MIMO System, Xinying Li[2,1], Jianjun Yu[2,3], Kaihui Wang[2], Miao Kong[2], Wen Zhou[2], Zihang Zhu[2], Can Wang[2], Mingming Zhao[2], Gee-Kung Chang[1]; [1]*Georgia Inst. of Technology, USA;* [2]*Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [3]*ZTE (TX) Inc., USA.* We experimentally demonstrate 6×20-gb/s six-channel PDM-QPSK THz-wave signal delivery over 10-km SMF-28 and 142-cm wireless 2×2 MIMO link with a BER under 3.8×10^{-3}, which realizes the first 2×2 MIMO wireless transmission of multi-channel THz-wave signal.

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M4A • Modelling, Disaggregation & Networking Automation—Continued

M4A.4 • 17:30 Invited

OpenROADM over ONOS, Marc De Leenheer[1], Yuta Higuchi[2], Guru Parulkar[3,1]; [1]*Open Networking Foundation, USA;* [2]*NEC America, USA;* [3]*Stanford Univ., USA*. We discuss the integration of OpenROADM data models into ONOS, the network OS built for high performance, scale and high availability. We review experimental data, deployment considerations, lessons learned, and next steps.

M4A.5 • 18:00

P4-based Multi-layer Traffic Engineering Encompassing Cyber Security, Francesco Paolucci[1], Filippo Cugini[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* The design and experimental validation of effective P4-based solutions for dynamic optical bypass, traffic offload and cyber security without involving SDN controller are proposed. P4 switch latency scalability versus installed flow entry size is demonstrated.

M4B • Practical Aspects in Fiber Transmission—Continued

M4B.4 • 17:30

Proactive Detection of Optical Cable Failure Caused by Water Freezing Using 1-μm-band Mode-detection OTDR, Atsushi Nakamura[1]; [1]*NTT Corporation, Japan*. An experiment shows that information allowing the prediction of optical loss increases due to icing in cable conduits can be extracted by using OTDR measurements in the 2-IP mode region of the fibers under test.

M4B.5 • 17:45

Laboratory Measurements of SOP Transients due to Lightning Strikes on OPGW Cables, Fabio Pittalà[1], Christopher Stone[2], David Clark[2], Maxim Kuschnerov[1], Changsong Xie[1], A Manu Haddad[2]; [1]*Huawei Technologies Duesseldorf GmbH, Germany;* [2]*Advanced High Voltage Engineering Research Centre, School of Engineering, Cardiff Univ., UK*. We report laboratory experiments in which lightning current impulses of magnitudes up to and above 150kA were applied to OPGW cables of length up to 18m. Unprecedentedly, fast SOP speeds exceeding 8Mrad/s were measured.

M4B.6 • 18:00 Invited

Requirements for Simulation-aided Design of SDM Systems, Igor Koltchanov[1], Stefanos Dris[1], Alexander Uvarov[2], Andre Richter[1]; [1]*VPIphotonics, Germany;* [2]*VPI Development Center, Belarus*. We discuss general requirements and implementation options for an efficient simulation framework supporting the design of SDM systems, as well as aspects regarding the analysis, comparison and optimization of underlying technology and component options.

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

M4C.3 • 17:30 Invited

FTTA/PTTA Connectivity Solutions - On the Way to 5G, Josef Gramsamer[1]; [1]*Rosenberger, Germany.* To support multiple applications and achieve seamless integration, 5G networks and related services require different end-to-end network design.

18:00 Panel Discussion

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

M4D.4 • 17:30

A Novel Fabrication Method for Photonic Lanterns, Neethu M. Mathew[1], Lars Grüner-Nielsen[2], Mario A. Usuga[1], Karsten K. Rottwitt[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Danish Optical Fiber Innovation, Denmark*. A new fabrication method for photonic lanterns using a low index UV curable polymer is presented. The insertion loss is predicted, and measurements show a loss lower than 3 dB.

M4D.5 • 17:45

Mode Selective Photonic Lantern with Graded Index Core, Juan Carlos Alvarado Zacarias[1,2], Nicolas K. Fontaine[2], Jose Enrique Antonio-Lopez[1], Zeinab Sanjabi Eznaveh[1], Md Selim Habib[1], Haoshuo Chen[2], Roland Ryf[2], Pierre Sillard[3], Adrian Amezcua-Correa[3], Sergio G. Leon-Saval[4], Dennis Van Ras[3], Cedric Gonnet[3], Rodrigo Amezcua-Correa[1]; [1]*CREOL, The College of Optics & Photonics, USA;* [2]*Nokia Bell Labs, USA;* [3]*Prysmian Group, France;* [4]*Univ. of Sidney, Australia*. We demonstrate a mode selective photonic lantern with a graded index core ,which modes are a better match when splicing to graded index transmission fiber compare to those from a photonic lantern with step index core.

M4E • Probabilistic Shaping II—Continued

M4E.2 • 17:30

Low-complexity Variable-length Output Distribution Matching with Periodical Distribution Uniformalization, Tsuyoshi Yoshida[2,1], Magnus Karlsson[2], Erik Agrell[2]; [1]*Mitsubishi Electric Corporation, Japan;* [2]*Chalmers Univ. of Technology, Sweden*. Run-length code based distribution matching (DM) for probabilistic shaping is combined with a uniformalizer to realize low-complexity fixed-length DM. The proposed method is 0.4 dB better than previous low-complexity DM methods.

M4E.3 • 17:45

Experimental Verification of Rate Flexibility and Probabilistic Shaping by 4D Signaling, Fabian Steiner[1], Francesco Da Ros[2], Metodi P. Yankov[2], Georg Böcherer[1], Patrick Schulte[1], Søren Forchhammer[2], Gerhard Kramer[1]; [1]*Technical Univ. of Munich, Germany;* [2]*DTU Fotonik, Technical Univ. of Denmark, Denmark*. The rate flexibility and probabilistic shaping gain of 4-dimensional signaling is experimentally tested for short-reach, unrepeated transmission. A rate granularity of 0.5 bits/QAM symbol is achieved with a distribution matcher based on a simple look-up table.

M4E.4 • 18:00

Universal Hybrid Probabilistic-geometric Shaping Based on Two-dimensional Distribution Matchers, Zhen Qu[1,2], Shaoliang Zhang[1], Ivan Djordjevic[2]; [1]*NEC Laboratories America, USA;* [2]*Univ. of Arizona, USA.* We propose universal distribution matchers applicable to any two-dimensional signal constellation. We experimentally demonstrate that the performance of 32-ary QAM, based on hybrid probabilistic-geometric shaping, is superior to probabilistically shaped 32QAM and regular 32QAM.

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

M4F.3 • 17:30 Invited

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

M4F.4 • 18:00 Invited

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

M4G • Optical Coherence Control—Continued

M4G.4 • 17:30 Invited

On-chip Quantum Optical Frequency Comb Sources, Christian Reimer[1], Michael Kues[1], Piotr Roztocki[1], Stefania Sciara[1], Luis Romero Cortés[1], Benjamin Wetzel[1], Yanbing Zhang[1], Alfonso Cino[2], Sai Chu[3], Brent Little[4], David J. Moss[5], Lucia Caspani[6], Jose . Azana[1], Roberto Morandotti[1]; [1]*INRS-eMT, Canada;* [2]*Univ. of Palermo, Italy;* [3]*City Univ. of Hong Kong, China;* [4]*Xi'an Inst. of Optics and Precision Mechanics, China;* [5]*Swinburne Univ. of Technology, Australia;* [6]*Univ. of Strathcylyde, UK.* Integrated optical frequency comb sources, based on nonlinear microring resonators, can be used to generate complex quantum states. In particular, we achieved multi-photon and high-dimensional entangled quantum states, as well as their coherent control.

M4G.5 • 18:00

Optical Crosstalk Reduction using Amplified Spontaneous Emission (ASE), Haoshuo Chen[1], Nicolas K. Fontaine[1], Roland Ryf[1], Juan Carlos Alvarado[2], John van Weerdenburg[3], Rodrigo Amezcua-Correa[2], Chigo Okonkwo[3], Ton Koonen[3]; [1]*Nokia Bell Labs, USA;* [2]*CREOL, Univ. of Central Florida, USA;* [3]*Inst. for Photonic Integration, Univ. of Technology, Netherlands.* We employ spectrally filtered amplified spontaneous emission as the signal carrier and matched local oscillator to mitigate optical crosstalk. We demonstrate polarization crosstalk reduction in single-mode fiber transmission and modal crosstalk reduction over multimode fiber.

M4H • Photonic Integration II—Continued

M4H.4 • 17:30

An Integrated Silicon Bragg Grating Filter without Circulator, Rulei Xiao[1], Yuechun Shi[1], Yong Zhao[1], Xiangfei Chen[1]; [1]*Nanjing Univ., China.* We demonstrated an integrated silicon Bragg grating filter with an equivalent circulator. The reflected power by the Bragg grating will not be reflected to the launched port, but be dropped at a third port.

M4H.5 • 17:45

Bandwidth Tunable Filter with Large Bandwidth and Wavelength Tuning Range, Tingge Dai[1], Gencheng Wang[1], Jianfei Jiang[1], Yuehai Wang[1], Yubo Li[1], Hui Yu[1], Xiaoqing Jiang[1], Jianyi Yang[1]; [1]*Zhejiang Univ., China.* We demonstrate a silicon-multiple-microring-based Vernier optical filter with both large bandwidth and wavelength tuning range. The bandwidth can be tuned from 0.3 nm to 1.2 nm. The wavelength tuning range can cover C-band.

M4H.6 • 18:00 Top Scored

Fully Flexible Filtering Element on SOI with 7-80 GHz Bandwidth Tunability and Full FSR Tuning, Giannis Poulopoulos[1], Giannis Giannoulis[1], Nikos Iliadis[1], Wahlbrink Thorsten[3], Anna Lena Giesecke[3], Dimitrios Kalavrouziotis[2], Dimitrios Apostolopoulos[1], Hercules Avramopoulos[1]; [1]*NTUA, Greece;* [2]*Mellanox Technologies Ltd, Israel;* [3]*AMOGmbH, Germany.* We demonstrate a fully tunable Silicon-on-insulator filtering element, relying on a 2nd order micro ring resonator equipped with three variable optical couplers. Experimental results revealed bandwidth tunability between 7-80 GHz and full FSR tuning.

M4I • Deployments of Optical Access and Front Haul—Continued

M4I.2 • 17:30

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

M4I.3 • 17:45

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

M4I.4 • 18:00 Invited

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

M4J • MMW & THz Systems—Continued

M4J.5 • 17:30 Invited

Radio-over-fiber-based Seamless Fiber–wireless Convergence for Small Cell and Linear Cell Networks, Pham Tien Dat[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]; [1]*National Inst. of Information and Communication Technology, Japan;* [2]*Waseda Univ., Japan.* We present radio-over-fiber technologies for fiber and wireless convergence for small cell and linear cell networks, including a flexible and low-latency mobile fronthaul for ultra-dense small cells, and high-speed wireless backhaul system for high-speed trains.

M4J.6 • 18:00

Four-channel RoF Transmission over Polarization Maintaining Elliptical Ring Core Fiber, Reza Mirzaei Nejad[1], Farzan Tavakoli[1], Lixian Wang[1], Xun Guan[1], Sophie LaRochelle[1], Leslie A. Rusch[1]; [1]*Universite Laval, Canada.* Transmission of four RoF streams over polarization maintaining elliptical ring core fiber is demonstrated. RoF streams are recovered without MIMO processing; signals on two polarizations of a mode could be recovered even under severe bending.

Room 1A	Room 1B	Room 2	Room 6C	Room 6D	Room 6E
M4A • Modelling, Disaggregation & Networking Automation—Continued		**M4B • Practical Aspects in Fiber Transmission—Continued**	**M4C • Symposium: Challenges 5G brings to Optical Fiber Communications Systems II—Continued**	**M4D • Mode Multiplexors and Components for Space-division Multiplexed Systems—Continued**	**M4E • Probabilistic Shaping II—Continued**
M4A.6 • 18:15 **Fast and Accurate Lightpath Validation for SDN Controllers,** Rui M. Morais[1,2], João Pedro[1,2]; [1]*Coriant Portugal, Portugal;* [2]*Instituto De Telecomunicacoes, Portugal.* We present a method to quickly and accurately evaluate the feasibility of an optical path in online routing scenarios. The method is based on performance metrics that compress the set of all feasible paths.					**M4E.5 • 18:15** **Efficient Offline Evaluation of FEC Codes Based on Captured Data with Probabilistic Shaping,** Tsuyoshi Yoshida[2,1], Magnus Karlsson[2], Erik Agrell[2]; [1]*Mitsubishi Electric Corporation, Japan;* [2]*Chalmers Univ. of Technology, Sweden.* We propose a tool for reusing experimental or simulation data of probabilistically shaped signals with different FEC codes. A single recorded histogram of log-likelihood ratios is sufficient to examine arbitrary coding at low BERs.

NOTES

Room 6F	Room 7AB	Room 8	Room 9	Room 10
M4F • Symposium: Future Photonic Devices and Materials for Optical Communications II—Continued	**M4G • Optical Coherence Control—Continued**	**M4H • Photonic Integration II—Continued**	**M4I • Deployments of Optical Access and Front Haul—Continued**	**M4J • MMW & THz Systems—Continued**
		M4H.7 • 18:15 **Integrated Optical Ultra-broadband Add-drop Filter in Silicon-on-insulator Platform,** Sumi R[1], Ramesh K[1], Nandita DasGupta[1], Bijoy K. Das[1]; [1]*Indian Inst. of Technology Madras, India.* A sub-wavelength grating waveguide is designed and integrated in two arms of a 2 × 2 Mach-Zehnder interferometer in silicon-on-insulator which is capable of dropping(adding) ultra-broad wavelength bands centering at λ~1550nm with band-edge extinction exceeding 35-dB.		**M4J.7 • 18:15** **Probabilistically Shaped 16QAM Signal Transmission in a Photonics-aided Wireless Terahertz-wave System,** Kaihui Wang[1], Xinying Li[2], Miao Kong[1], Pengqi Gou[1], Wen Zhou[1], Jianjun Yu[1,2]; [1]*Fudan Univ., China;* [2]*ZTE TX inc, USA.* The 16QAM signal adopting probabilistic shaping (PS) technology is transmitted in a photonics-aided wireless Terahertz-wave system. The experimental results show an improvement of BER performance compared to the uniform distribution.

NOTES

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

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

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

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

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

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

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

14:00–16:00 Tu2A • Coupling and Packaging

Presider: Hiroyuki Tsuda; Keio Univ., Japan

Tu2A.1 • 14:00
Expanded-beam Through-substrate Coupling Interface for Alignment Tolerant Packaging of Silicon Photonics, Nivesh Mangal[1,2], Jeroen Missinne[2], Gunther Roelkens[3], Joris Van Campenhout[1], Geert Van Steenberge[2], Brad Snyder[1]; [1]*imec, Belgium;* [2]*Centre for Microsystems Technology, Ghent Univ., Belgium;* [3]*Photonics Research Group, Ghent Univ.-imec, Belgium.* We demonstrate an alignment tolerant through-substrate coupling interface by combining an optimized downward-directionality grating on a silicon photonic chip with a hybrid integrated polymer lens, generating a collimated beam at λ=1310nm for more than 600μm.

14:00–16:00 Tu2B • Data Center & PON Transponder Technology

Presider: Yongpeng Zhao; Luster Lightech Corp., China

Tu2B.1 • 14:00 Invited
Revolutionizing the Data Centers and HPCs - Optical Interconnects, Tolga Tekin[1]; [1]*Fraunhofer IZM, Germany.* Abstract not available.

14:00–16:00 Tu2C • Short Reach I

Presider: Xi Chen; Nokia Bell Labs, USA

Tu2C.1 • 14:00 Invited
DSP-free Coherent Receivers for Data Center Links, Jose Paulo Krause Perin[1], Anujit Shastri[1], Joseph M. Kahn[1]; [1]*Stanford Univ., USA.* We review low-power DSP-free coherent receiver architectures for DP-QPSK that exhibit performance comparable to their DSP-based counterparts, while consuming an estimated ~4 W for 200 Gbit/s DP-QPSK in 90-nm CMOS.

14:00–16:00 Tu2D • Kramers-Kronig Transmissions

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

Tu2D.1 • 14:00 Invited
The Kramers-Kronig Receiver, Antonio Mecozzi[1], Cristian Antonelli[1], Mark Shtaif[2], Xi Chen[3], Sethumadhavan Chandrasekhar[3], Peter J. Winzer[3]; [1]*Physical and Chemical Sciences, Univ. of L'Aquila, Italy;* [2]*Department of Physical Electronics, Tel Aviv Univ., Israel;* [3]*Nokia Bell Labs, USA.* This presentation reviews the operation principles and various implementations of the Kramers-Kronig (KK) receiver. Some of the recently published experimental demonstrations are reviewed.

14:00–16:00 Tu2E • Coherent and Tunable Devices

Presider: Michael Larson; Lumentum, USA

Tu2E.1 • 14:00
Compact Silicon Microring Modulator with Tunable Extinction Ratio and Wide FSR, Hossam A. Shoman[1], Hasitha Jayatilleka[1], Anthony Park[1], Nicolas Jaeger[1], Sudip Shekhar[1], Lukas Chrostowski[1]; [1]*Electrical and Computer Engineering, Univ. of British Columbia, Canada.* A tunable two-point coupling scheme for a microring modulator on a silicon-on-insulator platform, that achieves a >30 dB extinction ratio while maintaining a large (19.23 nm) free spectral range, is presented.

14:00–16:00 Tu2F • Capacity Planning

Presider: João Pedro; Coriant, Portugal

Tu2F.1 • 14:00 Tutorial
The Software-defined Flexible Optical Network, António Eira[1,2]; [1]*Coriant, Portugal;* [2]*Instituto de Telecomunicações, Portugal.* This tutorial discusses how hardware and software flexibility affect the design of optical networks. It covers the interworking between multi-rate/flow interfaces, universal OTN switching, FlexE enabled clients, and how SDN controllers can leverage this flexibility effectively.

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Room 6F	Room 7AB	Room 8	Room 9	Room 10

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

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

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

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

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

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

14:00–16:00 Tu2G • Content Distribution and Edge Computing

Presider: Werner Weiershausen; Deutsche Telekom Technik GmbH, Germany

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

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

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

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

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14:00–16:00 Tu2I • Underwater Free Space Optics Systems

Presider: Richard DeSalvo; Harris Corporation, USA

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

14:00–16:00 Tu2J • Fiber Optic and Wavelength Devices

Presider: Nicolas Fontaine; Nokia Bell Labs, USA

Tu2J.1 • 14:00 Top Scored
Demonstration of Multiple Kerr-frequency-comb Generation using Different Lines from Another Kerr Comb Located up to a 50 km Distance, Peicheng Liao[1], Changjing Bao[1], Ahmed Almaiman[1], Arne Kordts[2], Maxim Karpov[2], Martin Hubert Peter Pfeiffer[2], Lin Zhang[3], Fatemeh Alishahi[1], Yinwen Cao[1], Amirhossein Mohajerin Ariaei[1], Kaiheng Zou[1], Ahmad Fallahpour[1], Moshe Tur[4], Youichi Akasaka[5], Tobias Kippenberg[2], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Ecole Polytechnique Federale de Lausanne, Switzerland;* [3]*Tianjin Univ., China;* [4]*Tel Aviv Univ., Israel;* [5]*Fujitsu Laboratories of America, USA.* We experimentally demonstrate multiple Kerr-frequency-comb generation using different lines from another Kerr comb located up to a 50 km distance. The master and generated slave combs are mutually coherent and have a small variance of frequency error.

14:00–16:00 Tu2K • Low Latency Services & XHaul over PON

Presider: Thomas Pfeiffer; Nokia Bell Labs, Germany

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

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Show Floor Programming

Data Center Optical Interconnect - Technologies and Markets
10:15–12:15
For more details, see page 13

Product Showcase
Huawei
10:15–10:45
For more details, see page 23

■ **MW Panel I: State of the Industry - Analyst Panel**
10:30–12:00

Open Management and Monitoring of Multilayer Webscale and Carrier Networks
OpenConfig
11:00–12:30

■ **MW Panel II: Optical Bearer Technologies for 5G Networks**
12:30–14:00

Ethernet Roadmaps Update
Ethernet Alliance
12:45–13:45

Fog Computing and Optical Networking - What's Next?
IEEE and OpenFog Consortium
12:45–14:15

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

Enabling the Key Applications for Transport SDN
OIF
14:30–15:30

■ **MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics**
14:30–16:00

Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.2 • 14:15
Characterization of Coupling Properties of Vertically Curved Si Surface Optical Coupler Designed for Coupling with 5-μm-MFD SMF, Yuki Atsumi[1], Tomoya Yoshida[1], Emiko Omoda[1], Youichi Sakakibara[1]; [1]*AIST, Japan*. A 5-μm-spot-size surface optical coupler based on vertically-curved Si waveguide showed 150nm/0.5dB spectrum bandwidth, ~5dB coupling loss for TE polarization, and incident angle and alignment tolerance of 6 degrees and ±1.5μm in 5-μm-spot SMF coupling.

Tu2A.3 • 14:30 Invited
Packaging and Assembly Challenges for 50G Silicon Photonics Interposers, Brad Snyder[1], Nivesh Mangal[1], Guy Lepage[1], Sadhishkumar Balakrishnan[1], Xiao Sun[1], Nicolas Pantano[1], Michal Rakowski[1], Lieve Bogaerts[1], Peter De Heyn[1], Peter Verheyen[1], Andy Miller[1], Marianna Pantouvaki[1], Philippe Absil[1], Joris Van Campenhout[1]; [1]*imec, Belgium*. We address the challenges in realizing low-loss, broadband optical interfaces for high-density fiber or polymer waveguides along with through-silicon via interconnects in a 50 GHz silicon photonics interposer platform suitable for 2.5D/3D packaging with advanced CMOS logic.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

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

Room 2

Tu2C • Short Reach I—Continued

Tu2C.2 • 14:30
Investigation on the Dispersion Tolerance in Dual-drive MZM-based DAC-less Optical PAM4 Transmission, Kuo Zhang[1,2], Qunbi Zhuge[2,3], Haiyun Xin[1], Zhenping Xing[2], Rui Li[2], Meng Xiang[2], Sujie Fan[2], Lilin Yi[1], Weisheng Hu[1], David V. Plant[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*McGill Univ., Canada;* [3]*Ciena, Canada*. We investigate the chirp characteristics of the two PAM4 generation methods based on dual-drive MZM. Prominent difference in transmission performance between the two methods is experimentally shown for 112Gb/s PAM4 signals when chromatic dispersion exists.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.2 • 14:30
16×112Gb/s Single-sideband PAM4 WDM Transmission over 80km SSMF with Kramers-Kronig Receiver, Yixiao Zhu[1], Mingxuan Jiang[1], Xiaoke Ruan[1], Chenjia Li[1], Fan Zhang[1]; [1]*Peking Univ., China*. Based on Kramers-Kronig receiver and phase alignment operation, we demonstrate 56GBaud single-sideband PAM4 16-channel WDM transmission over 80km SSMF. Single channel 80km transmission of 80GBaud SSB-PAM4 signal is also demonstrated.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

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

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

Room 6E

Tu2F • Capacity Planning—Continued

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

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

Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

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

Room 7AB

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

tural elements and main drivers and innovation opportunities.

Speakers:

Hans-Juergen Schmidtke, *Facebook, USA*

Martin Birk, *AT&T, USA*

Gert Grammel, *Juniper, USA*

Diego López, *Telefónica, Spain*

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.2 • 14:15
Sea-trial of an Ethernet-based Underwater VLC Communication System, Giulio Cossu[1], Alessandro Sturniolo[1], Alessandro Messa[1], Simone Grechi[2], David Scaradozzi[3], Andrea Caiti[2], Ernesto Ciaramella[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy;* [2]*Univ. of Pisa, Italy;* [3]*Università Politecnica delle Marche, Italy.* We experimentally demonstrate at NATO site in Spezia a bi-directional underwater optical wireless transmission compliant with 10Base-t Ethernet. Zero packet loss was achieved up to 10 m distance in a real harbour, with shallow murky waters and daylight.

Tu2I.3 • 14:30 Invited
Optical based Underwater Communications, Jen-Chieh Chang[1], Yun-Chieh Wang[1], De-Yu Chen[1], Chung-Yi Li[1], Hai-Han Lu[1], Xu-Hong Huang[2], Wen-Shing Tsai[3]; [1]*National Taipei Univ. of Technology, Taiwan;* [2]*School of Information Science and Engineering, Fujian Univ. of Technology, China;* [3]*Department of Electrical Engineering, Ming Chi Univ. of Technology, Taiwan.* A high-speed 24 Gb/s PAM4 optical-based underwater communication (OBUC) with afocal scheme for reducing/expanding collimated beam diameter is demonstrated. Such proposed OBUC link is better than existing OBUC given its practicability for high-speed underwater link.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Tu2J.2 • 14:15
Linearly Polarized Multi-wavelength Comb via Rayleigh Scattering induced Brillouin Random Lasing Resonance, Liang Zhang[1], Yuan Wang[1,2], Yanping Xu[1], Liang Chen[1], Xiaoyi Bao[1]; [1]*Univ. of Ottawa, Canada;* [2]*Inst. of Optoelectronic Technology, China Jiliang Univ., China.* A linearly polarized kHz-linewidth multi-wavelength comb in the telecom spectral window with over-40-dB optical sighnal-to-noise ratio was experimentally demonstrated by randomly distributed Rayleigh scattering induced Brillouin lasing oscillation in polarization maintaining fibers.

Tu2J.3 • 14:30
A Fiberized Metamaterial Device for Ultrafast Control of Coherent Optical Signals, Iosif Demirtzioglou[1], Angelos Xomalis[1], Eric Plum[1], Yong-Min Jung[1], Cosimo Lacava[1], Kevin F. MacDonald[1], Periklis Petropoulos[1], David J. Richardson[1], Nikolay I. Zheludev[1]; [1]*ORC, UK.* We demonstrate selective transmission and absorption of 1-ps pulses, pulse shaping and 1-ps dark pulse generation in a fiber-optic device based on a plasmonic metamaterial, providing an example of all-optical signal processing with THz bandwidth.

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

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

Show Floor Programming

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

Enabling the Key Applications for Transport SDN
OIF
14:30–15:30

■ **MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics**
14:30–16:00

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

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

Room 1A

Tu2A • Coupling and Packaging—Continued

Tu2A.4 • 15:00 Invited

In-line Optical Amplification for Silicon Photonics Platform by Flip-chip Bonded InP-SOAs, Takeshi Matsumoto[1], Teruo Kurahashi[1], Ryotaro Konoike[2], Ken Tanizawa[2], Keijiro Suzuki[2], Ayahito Uetake[1], Kazumasa Takabayashi[1], Kazuhiro Ikeda[2], Hitoshi Kawashima[2], Suguru Akiyama[1], Shigeaki Sekiguchi[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*National Inst. of Advanced Industrial Science and Technology (AIST), Japan.* We reviewed hybrid-integration of InP semiconductor optical amplifier on silicon photonics chip, and our in-line integration using precise flip-chip bonding technology. We demonstrated loss-less operation of 4x4 switches with 4ch-sOA array.

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

Tu2B.3 • 14:45

Low-cost Hybrid-integrated Micro-intradyne Coherent Receiver using FPCB Wirings, Seo Young Lee[1], Young-Tak Han[1], Jong-Hoi kim[1], Young-Ho Ko[1], Hyun-Do Jung[1], Joong-Seon Choe[1], Chun Ju Youn[1], Won-Seok Han[1], Seok-Tae Kim[1], Yongsoon Baek[1]; [1]*ETRI, Korea.* We report on a low-cost hybrid-integrated Micro-iCR based on a silica DP-oH and InP WG-pDs. RF and DC FPCB wirings provide low-cost and good RF performance. A 3-dB bandwidth is measured to be ~36 GHz.

Tu2B.4 • 15:00 Invited

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

Room 2

Tu2C • Short Reach I—Continued

Tu2C.3 • 14:45

Dispersion-uncompensated Transmission of NRZ and PAM-4 Single-sideband Signals using D-EML, Mohamed Essghair Chaibi[1], Laurent Bramerie[1], Didier Erasme[2], Christophe Peucheret[1]; [1]*FOTON Laboratory, France;* [2]*LTCI, Telecom ParisTech, Paris-Saclay Univ., France.* The generation of optical SSB signals using a D-eML is demonstrated for NRZ and PAM-4 modulations. Transmission at 10.7Gb/s of NRZ signals over 100-km SSMF and at 21.4Gb/s of PAM-4 signals over 50km is reported.

Tu2C.4 • 15:00

A 50Gb/s-PAM4 CDR with On-chip Eye Opening Monitor for Reference-level and Clock-sampling Adaptation, Liu Chang[1], Bozhi Yin[1], Tingyu Yao[1], Nan Qi[2], Dan Li[3], Jingbo Shi[1], Juncheng Wang[1], Shang Hu[1], Rui Bai[4], Xuefeng Chen[4], Nan Chi[5], Jiangbing Du[6], Patrick Y. Chiang[1]; [1]*School of Microelectronics, Fudan Univ., China;* [2]*Inst. of Semiconductors, CAS, China;* [3]*Xian Jiaotong Univ., China;* [4]*PhotonIC Technologies, China;* [5]*Department of Communication Science and Engineering, Fudan Univ., China;* [6]*Shanghai Jiaotong Univ., China.* A 50Gb/s-PAM4 Clock/Data Recovery (CDR) transceiver is designed in a 40nm-cMOS process. An on-chip Eye Opening Monitor (EOM) is introduced that enables adaptive reference level and timing sampling placement for non-uniform and distorted PAM4-inputs.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

Tu2D.3 • 14:45

Transmission in 125-km SMF with 3.9 bit/s/Hz Spectral Efficiency using a Single-drive Mzm and a Direct-detection Kramers-Kronig Receiver without Optical CD Compensation, Marco Presi[1], Giulio Cossu[1], Giampiero Contestabile[1], Ernesto Ciaramella[1], Cristian Antonelli[2], Antonio Mecozzi[2], Mark Shtaif[3]; [1]*TeCIP Inst., Scuola Superiore Sant' Anna Univ., Italy;* [2]*Physical and Chemical Sciences,, Univ. of l'Aquila, Italy;* [3]*School of Electrical Engineering, Tel Aviv Univ., Israel.* We demonstrate single channel transmission in 125-km SMF of 59 Gbit/s in a 15 GHz optical bandwidth (3.9 bit/s/Hz gross spectral efficiency) using a single-drive Mach-Zehnder modulator and Kramers-Kronig detection without optical chromatic dispersion compensation.

Tu2D.4 • 15:00

Performance of Digital Back-propagation in Kramers-Kronig Direct-detection Receivers, Zhe Li[1], Lidia Galdino[1], Tianhua Xu[2], M. Sezer Erkilinc[1], Kai Shi[3,1], Eric Sillekens[1], Benn C. Thomsen[3,1], Polina Bayvel[1], Robert Killey[1]; [1]*Univ. College London, UK;* [2]*Univ. of Warwick, UK;* [3]*Microsoft Research Ltd, UK.* We report the first investigation of fiber nonlinearity compensation by digital back-propagation in Kramers-Kronig direct-detection receivers. Improvements in performance of 112 Gb/s/λ WDM transmission over single-span SSMF links of up to 160 km are demonstrated.

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

Tu2E.4 • 14:45

CMOS-compatible Silicon Photonic IQ Modulator for 84 GBaud 16QAM and 70 GBaud 32QAM, Jiachuan Lin[1], Hassan Sepehrian[1], Leslie A. Rusch[1], Wei Shi[1]; [1]*Université Laval, Canada.* Using an all-silicon modulator, we demonstrate single-polarization 336 Gb/s (84 GBaud) 16QAM and 350 Gb/s (70 GBaud) 32QAM at BER well below 20% FEC-threshold. We achieved a net rate of 291 Gb/s on a single polarization.

Tu2E.5 • 15:00 Tutorial

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

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

continued on page 76

Room 6E

Tu2F • Capacity Planning—Continued

Tu2F.2 • 15:00

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

Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

Tu2G.2 • 15:00
Demonstration of SDN Application for Multilayer Video Contribution Network Service, Konstantinos Antoniou[1], Paul Wright[2], Kristan Farrow[2], Andrew Lord[2], Reza Nejabati[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]BT, UK.* This paper describes a demonstration of an end-to-end, SDN-controlled Video Contribution Network providing dynamic service set-up, using optical switching to enable flexible provisioning of resources. We show seamless operation of legacy and future technologies.

Room 7AB

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

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.4 • 15:00
Effect of Limited Aperture Size on a Retro-reflected Communication Link between a Ground Station and a UAV using Multiplexing of Orbital-angular-momentum Beams, Long Li[1], Runzhou Zhang[1], Peicheng Liao[1], Hao Song[1], Kaiheng Zou[1], Guodong Xie[1], Zhe Zhao[1], Cong Liu[1], Haoqian Song[1], Kai Pang[1], Guillaume Labroille[2], Pu Jian[2], Dmitry Starodubov[1], Brittany Lynn[3], Robert Bock[4], Moshe Tur[5], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]CAILabs, France; [3]Space & Naval Warfare Systems Center, USA; [4]R-dEX System, USA; [5]School of Electrical Engineering, Tel Aviv Univ., Israel.* We experimentally demonstrate and investigate the effect of limited aperture size on a 200-gbit/s retro-reflected free-space optical link between a ground station and a UAV up to ~100-m roundtrip distance by multiplexing 2 OAM beams.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Tu2J.4 • 14:45
Dynamic Multiwavelength Optical Reflection Filter Induced in a Suspended-core Fiber Bragg Grating by Amplitude Modulated Acoustic Waves, Ricardo E. Da Silva[1,2], Martin Becker[1], Manfred Rothhardt[1], Hartmut Bartelt[1], Alexandre A. Pohl[2]; *[1]Leibniz Inst. of Photonic Technology, Germany; [2]Federal Univ. of Technology-paraná (UTFPR), Brazil.* A new technique to generate a multiwavelength reflection spectrum by modulating a 1cm long fiber Bragg grating with an amplitude modulated acoustic wave is reported. Up to 15 wavelength peaks with ~5pm bandwidth are achieved.

Tu2J.5 • 15:00
Silicon-graphene Hybrid Slot Waveguide with Enhanced Four-wave Mixing Efficiency, Yuxing Yang[1], Jiang Xinhong[1], Zhenzhen Xu[1], Yong Zhang[1], Ciyuan Qiu[1], Xuhan Guo[1], Yikai Su[1]; *[1]Shanghai Jiao Tong Univ., China.* An enhanced four-wave mixing in a silicon-graphene hybrid slot waveguide is proposed and experimentally demonstrated. The conversion efficiency is -48.8 dB, showing 3.2-dB and 0.5-dB improvements relative to silicon slot waveguide and strip waveguide, respectively.

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

Tu2K.2 • 15:00 Top Scored
A Novel Data-compression Technology for Digital Mobile Fronthaul with Lloyd Algorithm and Differential Coding, Mu Xu[1,2], Zhensheng Jia[2], Jing Wang[2], L. Alberto Campos[2], Gee-Kung Chang[1]; *[1]Georgia Inst. of Technology, USA; [2]CableLabs, USA.* A data-compression technology with differential-coded Lloyd algorithm is envisioned to improve bandwidth efficiencies in digital-mobile-fronthaul networks. We experimentally demonstrated transmissions of 180 Gbps over 80-km fronthaul links encapsulating 64×100-mHz 1024-QAM 5G-nR carriers with lower-than-0.5% EVM.

Show Floor Programming

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

Enabling the Key Applications for Transport SDN
OIF
14:30–15:30

■ **MW Panel III: Challenges and Solutions for Delivering 400G+ Client and Line Side Optics**
14:30–16:00

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

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

Room 1A

Tu2A • Coupling and Packaging—Continued

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

Room 1B

Tu2B • Data Center & PON Transponder Technology—Continued

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

Room 2

Tu2C • Short Reach I—Continued

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

Tu2C.6 • 15:30
Real-time Demonstration of Polarization-multiplexed PAM using Compact Silicon Photonics Device, Antonello Nespola[2], Sean Anderson[3], Paolo Savio[2], Dario Pilori[5], Luca Bertignono[1], Matt Traverso[3], Mark Webster[3], Fabrizio Forghieri[4], Roberto Gaudino[1]; *[1]Dipartimento di Elettronicae Telecomunicazioni (DET), Politecnico di Torino, Italy; [2]ISMB, Istituto Superiore Mario Boella, Italy; [3]Cisco Systems, USA; [4]Cisco Photonics Italy srl, Italy; [5]Dipartimento di Elettronicae Telecomunicazioni (DET), Politecnico di Torino, Italy.* We experimentally demonstrate doubling capacity per wavelength using polarization-multiplexed PAM and direct-detection polarization recovery using a compact silicon photonic integrated device. Moreover, we present fundamental theoretical curves for PM-PAM performance.

Room 6C

Tu2D • Kramers-Kronig Transmissions—Continued

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

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

Room 6D

Tu2E • Coherent and Tunable Devices—Continued

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

Room 6E

Tu2F • Capacity Planning—Continued

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

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

Room 6F

Tu2G • Content Distribution and Edge Computing—Continued

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

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

Room 7AB

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

Room 8

Tu2I • Underwater Free Space Optics Systems—Continued

Tu2I.5 • 15:15
Experimental Effect of Scattering on an 80-Gbit/s QPSK Wireless Link using 4 Orbital-angular-momentum Beams, Runzhou Zhang[1], Long Li[1], Zhe Zhao[1], Guodong Xie[1], Peicheng Liao[1], Hao Song[1], Cong Liu[1], Haoqian Song[1], Kai Pang[1], Robert Bock[3], Moshe Tur[2], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]School of Electrical Engineering, Tel Aviv Univ., Israel; [3]R-dEX system, USA.* We experimentally investigate the effect of multiple scattering on the performance of an 80-gbit/s orbital angular momentum (OAM) multiplexed optical wireless link regarding both power loss and channel crosstalk.

Tu2I.6 • 15:30
An IF-free TDM Fronthaul Aggregating Two 128-MIMO Signals with Enhanced Spectral Efficiency Using Baseband Sample Interleaved Gathering, Longsheng Li[1], Meihua Bi[1,2], Yunhao Zhang[1], Kuo Zhang[1], Xin Miao[1], Weisheng Hu[1]; *[1]Shanghai Jiao Tong Univ., China; [2]College of Communication Engineering, Hangzhou Dianzi Univ., China.* We demonstrate a novel signal-sample-interleaved-gathering scheme in the TDM-based analog fronthaul, where signal aggregation is completely realized by simple DSP without intermediate-frequency (IF)-conversion. Experiment aggregating two 128-MIMO signals verifies that ~25% signal bandwidth is reduced.

Room 9

Tu2J • Fiber Optic and Wavelength Devices—Continued

Tu2J.6 • 15:15 Invited
Multi-material and Multi-functional Optical Fibers, Fabien Sorin[1]; *[1]Ecole Polytechnique Fédérale de Lausanne, Switzerland.* We will present the material science behind thermal drawing that enables us to impart optical fibers with novel architectures and advanced optoelectronic functionalities, as well as propose a new avenue for soft optical devices.

Room 10

Tu2K • Low Latency Services & XHaul over PON—Continued

Tu2K.3 • 15:15
First Demonstration of an Ultra-low-latency Fronthaul Transport Over a Commercial TDM-PON Platform, Sarvesh S. Bidkar[1], Joseph Galaro[2], Thomas Pfeiffer[1]; *[1]Access Research, Nokia Bell Labs, Germany; [2]Access Research, Nokia Bell Labs, USA.* We demonstrate for the first time, feasibility of latency-critical mobile fronthaul (CPRI) transport over a 6 km PON infrastructure with co-existing residential broadband traffic using a standards-compliant commercial TDM-PON platform with a sub-200 µs round trip delay.

Tu2K.4 • 15:30 Invited
Low Latency Networks: Future Service Level Use Cases and Requirements, Michael Freiberger[1], Mark T. Watts[1]; *[1]Verizon Communications Inc, USA.* The Tactile Internet with mobile and machine-to-machine (M2M) applications, along with long-standing financial and storage applications, are driving optical services to provide higher bandwidth, higher availability, and increasingly lower latency.

Show Floor Programming

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

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

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

Room 1A	Room 1B	Room 2	Room 6C	Room 6D	Room 6E
Tu2A • Coupling and Packaging—Continued	**Tu2B • Data Center & PON Transponder Technology—Continued**	**Tu2C • Short Reach I—Continued**	**Tu2D • Kramers-Kronig Transmissions—Continued**	**Tu2E • Coherent and Tunable Devices—Continued**	**Tu2F • Capacity Planning—Continued**

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

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

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

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

NOTES

Room 6F	Room 7AB	Room 8	Room 9	Room 10
Tu2G • Content Distribution and Edge Computing—Continued	**Tu2H • Open Platform Summit: Open Platforms for Optical Innovation—Continued**	**Tu2I • Underwater Free Space Optics Systems—Continued**	**Tu2J • Fiber Optic and Wavelength Devices—Continued**	**Tu2K • Low Latency Services & XHaul over PON—Continued**
Tu2G.5 • 15:45 **Dynamic Routing of Y-00 Quantum Stream Cipher in Field-deployed Dynamic Optical Path Network,** Fumio Futami[1], Takayuki Kurosu[2], Ken Tanizawa[1], Kentaro Kato[1], Satoshi Suda[2], Shu Namiki[2]; [1]*Tamagawa Univ., Japan;* [2]*National Inst. of Advanced Industrial Science and Technology (AIST), Japan*. Secure GbE communication by Y-00 protocol using noise masking for inter-datacenter connections is demonstrated in a dynamic optical path network testbed in Tokyo. We achieve dynamic path change with key re-synchronization between Y-00 cipher transceivers.		**Tu2I.7 • 15:45** **Free Space Intra-datacenter Interconnection Utilizing 2D Optical Beam Steering,** Behnam Shariati[1], Adonis Bogris[2,3], Paul V. Dijk[4], Chris G. H. Roeloffzen[4], Ioannis Tomkos[5], Dimitris Syvridis[3]; [1]*Universitat Politécnica de Catalunya, Spain;* [2]*Technological Educational Inst. of Athens (TEI), Greece;* [3]*National and Kapodistrian Univ. of Athens (UOA), Greece;* [4]*LioniX International, Netherlands;* [5]*Athens Information Technology (AIT), Greece.* We evaluate the performance and benefits of novel integrated Free-space-optics (FSO) transceivers, supporting optical beam steering at low power consumption with ns steering speed. A proper intra-datacenter network architecture is also presented.		

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

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Room 1A

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

Tu3A.1 • 16:30
Ultra-compact Silicon Multi-mode Waveguide Bend based on Sub-wavelength Asymmetric Y-junction, Weijie Chang[1], Luluzi Lu[1], Deming Liu[1], Minming Zhang[1]; [1]*Huazhong Univ. of Science and Tech, China*. An ultra-compact multi-mode bend composed of a pair of asymmetric Y junction based on inverse-designed subwavelength structures is proposed and experimentally demonstrated with inter-mode crosstalk < -24 dB, a footprint of 3.6 × 3.6 μm^2.

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

Room 1B

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

Tu3B.1 • 16:30 Invited
Recent Progress and Outlook on Multicore Fiber for Practical Use, Tomohiro Gonda[1], Katsunori Imamura[1], Kohei Kawasaki[1], Ryuichi Sugizaki[1], Shinichi Arai[1], Masayoshi Tsukamoto[1], Masato Shiino[1]; [1]*Furukawa Electric, Japan*. We review our recent achievement on uncoupled MCF for practical use. We introduce 4core-MCF with 125μm cladding which has upgradability from standard SMF system to MCF system, connecting technology and ultra-high density MCF-cable.

Room 2

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

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

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

Room 6C

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

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

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

Room 6D

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

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

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

Room 6E

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

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

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

Room 6F

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

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

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

continued on page 83

Room 7AB

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

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

Panelists:

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

Room 8

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

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

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

Room 9

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

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

Room 10

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

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

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

Show Floor Programming

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

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

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

Room 1A

Tu3A • Planar Waveguide Platforms—Continued

Tu3A.3 • 17:00
A Compact Thin-film Lithium Niobate Platform with Arrayed Waveguide Gratings and MMIs, Mathias Prost[1], Guangyao Liu[1], S. J. Ben Yoo[1]; *[1]Department of Electrical and Computer Engineering, Univ. of California, Davis, USA.* We design and demonstrate a thin-film z-cut Lithium Niobate photonic platform. We report experimental transmission measurement of different passive photonic building blocks at 1.55 μm central wavelength including AWG and MMI splitter.

Tu3A.4 • 17:15
32-port 5.5%-Δ Silica-based Connecting Device for Low-loss Coupling between SMFs and Silicon Waveguides, Junichi Hasegawa[1], Kazuhiro Ikeda[2], Keijiro Suzuki[2], Shintaro Yamasaki[1], Go Kobayashi[1], Masanori Takahashi[1], Hitoshi Kawashima[2]; *[1]Furukawa Electric Co., Ltd., Japan; [2]National Inst. of Advanced Industrial Science and Technology, Japan.* We report a low-loss connecting technique between silicon waveguides and standard single-mode fibers using a unique extremely-high-Δ silica-based PLC. 32-port coupling with coupling losses of 1.4-1.6 dB/facet and pitch conversion has been demonstrated.

Room 1B

Tu3B • SDM Fibers—Continued

Tu3B.2 • 17:00 Invited
Few-mode and Multicore Amplifiers for SDM Transmissions, Laurent Bigot[1], Jean-Baptiste Trinel[1], Géraud Bouwmans[1], Esben Ravn Andresen[1], Yves Quiquempois[1]; *[1]CNRS - Université Lille 1, PhLAM, France.* The optical performances of few-mode and multicore fiber amplifiers will strongly influence the future of SDM for long-haul transmission. We review this topic with a special focus on a new generation of few-mode erbium-doped fiber.

Room 2

Tu3C • Coding and Modulation—Continued

Tu3C.3 • 17:00 Invited
Coded Modulation for Next-generation Optical Communications, David Millar[1], Tobias Fehenberger[1], Toshiaki Koike-Akino[1], Keisuke Kojima[1], Kieran Parsons[1]; *[1]Mitsubishi Electric Research Labs, USA.* We review coded modulation for next-generation coherent optical communications systems. Geometric constellation shaping is discussed in detail, along with strategies to maintain complexity at levels comparable to a conventional square quadrature amplitude modulation (QAM) with bit-interleaved coded modulation (BICM) architecture.

Room 6C

Tu3E • Transport Network Design—Continued

Tu3E.3 • 17:00 Invited
Data Analytics based Optical Performance Monitoring Technique for Optical Transport Networks, Takahito Tanimura[1,2], Takeshi Hoshida[1], Tomoyuki Kato[1], Shigeki Watanabe[1], Hiroyuki Morikawa[2]; *[1]Fujitsu Laboratories Ltd., Japan; [2]The Univ. of Tokyo, Japan.* We experimentally demonstrate that a convolutional neural network (CNN) can acquire an accurate OSNR estimation functionality from asynchronously sampled data right after intradyne coherent detection, while the feature selection before the CNN can be omitted.

Room 6D

Tu3F • Silicon Photonic Interconnection Networks—Continued

Room 6E

Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued

Room 6F

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

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

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

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

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Room 7AB

Tu3I • Panel: Flexible Grid Deployments—Continued

Room 8

Tu3J • 5G Photonic Systems—Continued

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

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

Room 9

Tu3K • Heterogeneous Integration—Continued

Tu3K.2 • 17:00 Invited
Heterogeneously Integrated III-V Lasers Fabricated Using Epitaxial Growth on an InP/SiO_2/Si Substrate, Takuro Fujii[1,2], Koji Takeda[1,2], Hidetaka Nishi[1,2], Shinji Matsuo[1,2]; [1]*NTT Device Technology Laboratories, Japan;* [2]*NTT Nanophotonics Center, Japan.* We present a III-V/Si integration technology that employs epitaxially-grown active layers on an InP/SiO_2/Si substrate for low-cost fabrication of PICs. Based on it, a directly-modulated membrane-laser array exhibiting a low, VCSEL-like operating energy is reported.

Room 10

Tu3L • Software - Defined Access—Continued

Tu3L.3 • 17:00
Experimental Demonstration for over Mbps Baseband-over-modulation AMCC Implementation in PtP WDM-PON, Zhongwei Tan[1], Chuanchuan Yang[1], Zhaopeng Xu[1], Lei Chen[2], Xingang Huang[2], Haipeng Guo[1], Ziyuan Zheng[1], Fan Zhang[1], Ziyu Wang[1]; [1]*Peking Univ., China;* [2]*ZTE Corporation, China.* Up to 10 Mbps transmission of nonlinear baseband-over-modulation AMCC implementation in different modulation index over 10 Gbps PtP WDM-PON is experimentally demonstrated. The results confirm lower power penalty for PON signal in AMCC superimposition.

Tu3L.4 • 17:15
Wavelength Adjustment of Upstream Signal using AMCC with Power Monitoring for WDM-PON in 5G Mobile Era, Kazuaki Honda[1], Hirotaka Nakamura[1], Kazutaka Hara[1], Kyosuke Sone[2], Goji Nakagawa[2], Yoshio Hirose[2], Takeshi Hoshida[2], Jun Terada[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, NTT, Japan;* [2]*Fujitsu Limited, Japan.* We propose the wavelength adjustment method of the upstream signal using the AMCC complied with G.989.3 against the wavelength drift in WDM-PON and demonstrate it in the evaluation platform implementing the AMCC processor.

Room 1A

Tu3A • Planar Waveguide Platforms—Continued

Tu3A.5 • 17:30 Invited

3µm Silicon Photonics, Timo T. Aalto[1], Matteo Cherchi[1], Mikko Harjanne[1], Fei Sun[1], Markku Kapulainen[1]; [1]*VTT Technical Research Centre of Finland, Finland*. This paper presents the latest progress in the development of compact and low-loss photonic integrated circuits on 3-micron silicon-on-insulator platform that covers both near and mid-infrared applications.

Room 1B

Tu3B • SDM Fibers—Continued

Tu3B.3 • 17:30

Inter-core Skew Measurements in Temperature Controlled Multi-core Fiber, Benjamin J. Puttnam[1], Georg Rademacher[1], Ruben S. Luis[1], Jun Sakaguchi[1], Yoshinari Awaji[1], Naoya Wada[1]; [1]*National Inst Info & Comm Tech (NICT), Japan*. We investigate propagation delay (skew) between cores of an MCF and 2 spans of SMF in a temperature controlled environment. Temperature variations increase measured skew-fluctuations with skew-variation in SMF orders of magnitude larger than between MCF cores.

Tu3B.4 • 17:45

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

Room 2

Tu3C • Coding and Modulation—Continued

Tu3C.4 • 17:30

An Iterative Soft Interference Cancellation for Pilot-assisted Optical-OFDM with LDPC Code Optimized by EXIT Chart, Noboru Osawa[1], Shinsuke Ibi[1], Koji Igarashi[1], Seiichi Sampei[1]; [1]*Osaka Univ., Japan*. This paper proposes an iterative soft interference canceller with the assistance of LDPC code for mitigating beat interference in a pilot-assisted optical-OFDM. The LDPC code is analytically optimized by EXIT chart based on Turbo principle.

Tu3C.5 • 17:45

Irregular Polar Turbo Product Coding for High-throughput Optical Interface, Toshiaki Koike-Akino[1], Congzhe Cao[2], Ye Wang[1], Keisuke Kojima[1], David Millar[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*Electrical & Computer Engineering, Univ. of Alberta, Canada*. We propose polar turbo product code (TPC) to enable parallel/pipeline decoding, for high-throughput transmission. With irregular polar codes, the computational complexity and latency can be significantly reduced, yet outperforming BCH-constituent TPC by 0.5dB.

Room 6C

Tu3E • Transport Network Design—Continued

Tu3E.4 • 17:30

Towards a Route Planning Tool for Open Optical Networks in the Telecom Infrastructure Project, Brian Taylor[1], Gilad Goldfarb[1], Saumil Bandyopadhyay[1], Vittorio Curri[2], Hans-Juergen Schmidtke[1]; [1]*Facebook, USA;* [2]*Politecnico di Torino, Italy*. We explore the validity of the Gaussian-noise (GN) model as the basis for an open-source optical network planning tool. Comparison of experimental results and TIP-PSE GN-model based predictions suggest the GN model a feasible choice.

Tu3E.5 • 17:45

Demonstrating Network-scale Gain Transient Impact of Multiple Series EDFAs in Link Failure Cases, Yusuke Hirota[1], Masaki Shiraiwa[1], Hideaki Furukawa[1], Hiroaki Harai[1], Naoya Wada[1]; [1]*NICT, Japan*. This paper identifies that a link failure causes temporal QoT degradation propagation of 40.2% existing paths in a whole network by conventional EDFA and experimentally demonstrates this transient degradation can be suppressed by burst-mode EDFA.

Room 6D

Tu3F • Silicon Photonic Interconnection Networks—Continued

Tu3F.2 • 17:30

Autonomous Dynamic Bandwidth Steering with Silicon Photonic-based Wavelength and Spatial Switching for Datacom Networks, Yiwen Shen[1], Alexander Gazman[1], Ziyi Zhu[1], Min Yee Teh[1], Maarten Hattink[1], Sebastien Rumley[1], Payman Samadi[1], Keren Bergman[1]; [1]*Columbia Univ., USA*. We present an autonomous SDN network architecture that leverages the spatial and wavelength switching capabilities of silicon photonics microring-based circuits for self-adaptive bandwidth steering. These functionalities are seamlessly integrated and demonstrated in a datacom testbed.

Tu3F.3 • 17:45

Reconfigurable Silicon Photonic Platform for Memory Scalability and Disaggregation, Erik F. Anderson[1], Alexander Gazman[1], Ziyi Zhu[1], Maarten Hattink[1], Keren Bergman[1]; [1]*Columbia Univ., USA*. We demonstrate a bi-directional optically-connected memory architecture based on a silicon photonic platform. Optical multicast and sub-microsecond spatial switching is demonstrated to minimize reconfiguration times of 10Gbps data-streams between a CPU and two memory nodes.

Room 6E

Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued

Tu3G.2 • 17:30 Invited

Deployed Systems for Quantum Communications, Qiang Zhang[1]; [1]*Univ. of Science and Technology of China, China*. Quantum cryptography can provide information theoretical secure communicaiton. I shall review the deployed quantum communication systems in China, including metropolitan, backbone and satellite based international network, the technology challenging, the performance and an outlook.

Room 6F

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

Tu3H.1 • 16:30 Invited

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

Tu3H.2 • 16:54 Invited

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

Room 7AB

Tu3I • Panel: Flexible Grid Deployments—Continued

Room 8

Tu3J • 5G Photonic Systems—Continued

Tu3J.4 • 17:30

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

Tu3J.5 • 17:45

Power-fading-free IF-over-fiber Transmission with DEMZM using Simple Chirp Control for High-capacity Mobile Fronthaul Links, Shota Ishimura[1], Abdelmoula Bekkali[1], Kazuki Tanaka[1], Kosuke Nishimura[1], Masatoshi Suzuki[1]; [1]*KDDI Research, Inc., Japan.* We propose a simple power-fading-free IF-over-fiber transmission scheme with DEMZM. We successfully transmitted signals over 20-km SMF with 589.7-gb/s CPRI-equivalent data rate and achieved better performance than the parallel IM/PM transmission system.

Room 9

Tu3K • Heterogeneous Integration—Continued

Tu3K.3 • 17:30 Invited

High-efficiency, Low-loss Optical Phase Modulator based on III-V/Si Hybrid MOS Capacitor, Mitsuru Takenaka[1], Jae-Hoon Han[1], Jin-Kwon Park[1], Frederic Boeuf[1], Junichi Fujikata[2], Shigeki Takahashi[2], Shinichi Takagi[1]; [1]*Univ. of Tokyo, Japan;* [2]*Photonics Electronics Technology Research Association, Japan.* We present efficient, low-loss phase modulation using III-V/Si hybrid MOS capacitor on Si photonics platform, which will be an essential building-block for universal photonic integrated circuits monolithically integrated with driver circuits based on InGaAs MOSFETs.

Room 10

Tu3L • Software - Defined Access—Continued

Tu3L.5 • 17:30

Multi-vendor Interoperation of SFP+ Transceivers for CPRI Signal Transmission with Superimposed AMCC for Mobile Fronthaul, Goji Nakagawa[2], Kyosuke Sone[2], Setsuo Yoshida[1], Shoichiro Oda[1], Yoshio Hirose[2], Takeshi Hoshida[2]; [1]*Fujitsu Laboratories Limited, Japan;* [2]*Fujitsu Limited, Japan.* We have experimentally investigated electrical superimposition and detection characteristics of AMCC signal employing three different vendor of SFP+ transceivers and clarified the characteristics of multi-vendor interoperation, as well as the receiver sensitivity characteristics of AMCC signal.

Tu3L.6 • 17:45

10-gbps Real-time Burst-frame Synchronization Using Dual-stage Detection for Full-software Optical Access Systems, Takahiro Suzuki[1], Sangyeup Kim[1], Jun-Ichi Kani[1], Akihiro Otaka[1], Toshihiro Hanawa[2]; [1]*NTT, Japan;* [2] *The Univ. of Tokyo, Japan.* For realizing full-software optical access systems, we propose a novel burst-frame synchronization algorithm with reduced computation complexity using dual-stage detection and, for the first time, demonstrate its 10-gbps Real-time implementation on a GPU.

Room 1A

Tu3A • Planar Waveguide Platforms—Continued

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

Room 1B

Tu3B • SDM Fibers—Continued

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

Tu3B.6 • 18:15
Realistic Model for Frequency-dependent Crosstalk in Weakly-coupled Multicore Fiber, Lin Gan[1], Ming Tang[1], Li Shen[1], Chen Xing[1], Changjian Ke[1], Chen Yang[2], Weijun Tong[2], Songnian Fu[1], Deming Liu[1]; [1]*Next Generation Internet Access National, USA;* [2]*Yangtze Optical Fiber and Cable Joint Stock Limited Company, China*. We established a realistic channel model that describes frequency-dependent crosstalk precisely for weakly-coupled multicore fibers. The crosstalk variations induced by relative time delay, polarization mode dispersion and calculation step size have been discussed.

Room 2

Tu3C • Coding and Modulation—Continued

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

Room 6C

Tu3E • Transport Network Design—Continued

Tu3E.6 • 18:00 Invited
Design and Deployment of Optical White Box, Niall A. Robinson[1]; [1]*ADVA Optical Networking AG, USA*. White box solutions have been deployed inside data centers for many years. Like SDN this technological approach is spilling into the transmission world. Let's review current industry status and explore the future of this exciting space.

Room 6D

Tu3F • Silicon Photonic Interconnection Networks—Continued

Tu3F.4 • 18:00 Invited
Silicon Photonics and Plasmonics towards Network-on-chip Functionalities for Disaggregated Computing, Nikos Pleros[1]; [1]*Dept of Informatics, Aristotle Univ. of Thessaloniki, Greece*. The main challenges in today's landscape of chip-scale computational settings are overviewed, discussing about the potential of silicon photonics and plasmonics to yield Network-on-chip technologies and architectures capable of overcoming the limitations of current infrastructures.

Room 6E

Tu3G • Nonlinearity Compensation and Encrypted Communication—Continued

Tu3G.3 • 18:00
Chaotic Laser based Online Physical Random Bit Streaming System and its Application to High-throughput Encryption, Kenichi Arai[1], Susumu Shinohara[2], Peter Davis[3], Satoshi Sunada[4], Takahisa Harayama[2]; [1]*NTT Corporation, Japan;* [2]*Waseda Univ., Japan;* [3]*Telecognix Corporation, Japan;* [4]*Kanazawa Univ., Japan*. We developed a high-speed entropy source using a compact chaotic laser module for streaming unpredictable random bits. It achieved 4 Gbps streaming of random bits to an encryption application via a general-purpose API.

16:30–18:30 Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, *Room 6A* (extended coffee break)

17:15–18:45 Exhibitor Happy Hour, *Center Terrace*

18:30–20:00 Conference Reception, *Sails Pavilion*

19:30–21:30 Rump Session: When Will Coherence Replace Direct Detection in the Data Center?, *Room 6F*

Room 6F	Room 7AB	Room 8	Room 9	Room 10
Tu3H • Symposium: Network Management Evolution to Streaming Analytics and Cognitive Systems—Continued	**Tu3I • Panel: Flexible Grid Deployments—Continued**	**Tu3J • 5G Photonic Systems—Continued**	**Tu3K • Heterogeneous Integration—Continued**	**Tu3L • Software - Defined Access—Continued**
Tu3H.3 • 17:18 Invited **Key Enablers of Automated Optical Networks,** Vinayak Dangui[1]; [1]*Facebook, USA*. For an automated optical network, the following are key elements: (1) streamlined API to network elements, (2) optimized telemetry parameters, and (3) predictive maintenance framework. We present how these components enable automation in Facebook's network. **Tu3H.4 • 17:42** Invited **Network Monitoring for Cloud,** Martin Machacek[1]; [1]*Oracle, USA*. The goal of the talk is to analyze monitoring system requirements specific to cloud infrastructure networks and identify device functions allowing to address them. I'll summarize typical properties of cloud data networks, identify requirements for monitoring systems and outline key paradigms and technologies suitable for supporting them. **Tu3H.5 • 18:06** Invited **Intent Based Networking,** David Erickson[1]; [1]*Forward Networks, USA*. In this talk David will describe the goals and promises of Intent Based Networking, where it is at today, and example use cases driving operational value in production today.		**Tu3J.6 • 18:00** **Blind Compensation of Nonlinear Waveform Distortions in Radio-over-fiber System,** Byung Gon Kim[1], Sung Hyun Bae[1], Hoon Kim[1], Yun Chur Chung[1]; [1]*KAIST, Korea*. We propose a DSP-based nonlinearity compensation technique for RoF links which does not require any prior knowledge about the links. By using this technique, we successfully transport twelve 198-mHz-bandwidth 64-QAM f-OFDM signals over 20 km of SSMF. **Tu3J.7 • 18:15** **A PDM based Spectral Aggregation and Cell Densification for 5G Point-to-multipoint Mobile Fronthaul with a Polarization-tracking-free RAU Design,** Jhih-Heng Yan[1], Mu Xu[2], Hsu-Hung Huang[3], Mengzhe Liao[1], Kai Ming Feng[1,3], Gee-Kung Chang[2]; [1]*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan;* [2]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA;* [3]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan*. A point-to-multipoint PDM spectral aggregation and cell densification in 5G mobile fronthaul is proposed without requiring laborious polarization tracking in RAUs. A 25-km SMF transmission experiment shows less-than-1-dB power sensitivity differences between two polarization signals.	**Tu3K.4 • 18:00** **High-speed Heterogeneous InP-on-Si Capacitive Phase Modulators,** Sylvie Menezo[1], Torrey Thiessen[2], Philippe Grosse[1], Joyce K. Poon[2], Christophe Jany[1], Jérémy Da Fonseca[1], Bertrand Szelag[1], Benoit Charbonnier[1], Georgio El Zammar[1], Olivier Lemonnier[1], Patricia Bilondeau[1], Stéphane Malhouitre[1], Brigitte Montmayeul[1], Loic Sanchez[1]; [1]*CEA-IETI, France;* [2]*Univ. of Toronto, Canada*. We present O-band InP-on-si phase modulators with 0.5dB IL, 1V.cm $V_{\pi}L$ and >25GHz bandwidth for 250µm long sections. 25 Gbps operation without optical amplifiers or pre-emphasis is demonstrated with an MZM integrating such phase modulators.	**Tu3L.7 • 18:00** Invited **Flexible Access System Architecture (FASA),** Kota Asaka[1], Hirotaka Ujikawa[1], Jun-Ichi Kani[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, Japan*. To quickly meet diverse requirements given by emerging new services, we recently proposed a new concept of Flexible Access System Architecture (FASA). The paper reviews our activities on FASA along with disaggregation of time-critical functions.

16:30–18:30 Tu3D • Open Platform Summit: SDN/NFV Demonstration Zone, *Room 6A* (extended coffee break)

17:15–18:45 Exhibitor Happy Hour, *Center Terrace*

18:30–20:00 Conference Reception, *Sails Pavilion*

19:30–21:30 Rump Session: When Will Coherence Replace Direct Detection in the Data Center?, *Room 6F*

Room 6A

16:30–18:30
Tu3D • SDN/NFV Demonstration Zone

Tu3D.1
Integrated Optical-wireless Resource Slicing Management for 5G Service-based Architecture and Multi-level RAN, Rentao Gu[1,2], Mingyu Cen[1], Luhan Wang[1], Qize Guo[1,2], Yuanjiong Diao[3], Han Li[4], Chen Aimin[3], Lin Bai[1], Yuefeng Ji[1,2]; *[1]Beijing Univ. of Posts and Telecommunications, China; [2]Beijing Advanced Innovation Center for Future Internet Technology, Beijing Univ. of Technology, China; [3]ZTE Corporation, China; [4]China Mobile Research Inst., China.* This demo provides an integrated end-to-end optical-wireless slicing cross latest SBA based core network, backhaul network and two-level fronthaul networks, presenting consistent heterogeneous coordination capabilities on different multi-vendor transport equipment and computing resources.

Tu3D.2
Demonstration of Routing and Spectrum Assignment Automation in a Transport SDN Framework, Srivatsan Balasubramanian[1], Satyajeet Ahuja[1], Marco Rizzi[1], Gaya Nagarajan[1]; *[1]Facebook Inc, USA.* We demonstrate a use case of transport SDN which can help with automation of routing and spectrum assignment thereby removing an error and delay prone manual planning phase.

Tu3D.3
High Performance Streaming Telemetry in Optical Transport Networks, Abhinava Sadasivarao[1], Sachin Jain[1], Sharfuddin Syed[1], Khuzema Pithewan[1], Pravin Kantak[1], Biao Lu[1], Loukas Paraschis[1]; *[1]Infinera Corporation, USA.* We demonstrate streaming telemetry capabilities for optical networks implemented as modular software service. The telemetry system is capable of user-defined configurable streaming to an external collector at very high frequencies of all critical optical performance metrics.

Tu3D.4
Demonstration of Real Time VNF Implementation of OLT with Virtual DBA for Sliceable Multi-tenant PONs, Frank Slyne[1], Amr Elrasad[1], Christian Bluemm[1], Marco Ruffini[1]; *[1]CONNECT Centre, Trinity College Dublin, Ireland.* We demonstrate the VNF implementation of a sliceable PON architecture enabling true multi-tenancy, giving Virtual Network Operators full control over capacity scheduling. We analyze resource sharing efficiency and latency performance for different NFV co-location scenarios.

Tu3D.5
CASTOR: An Architecture to Bring Cognition to Transport Networks, Luis Velasco[1], Luis Gifre[2], Jose Luis Izquierdo-Zaragoza[1], Guillermo Julián[3], Jorge Lopez de Vergara[3]; *[1]Universitat Politecnica de Catalunya, Spain; [2]Universidad Autónoma de Madrid (UAM), Spain; [3]Naudit, Spain.* CASTOR architecture to enable cognitive networking is demonstrated. Extended nodes make local decisions, whilst a centralized system beside the network controller makes network-wide decisions. Interaction with ONOS, Net2Plan, and passive monitoring devices is exhibited.

Tu3D.6
Flow/Application Triggered SDN control in Hybrid Data-center Network "HOLST", Yukihiro Imakiire[1], Masayuki Hirono[1], Masaki Murakami[1], Satoru Okamoto[1], Naoaki Yamanaka[1]; *[1]Keio Univ., Japan.* We have proposed a new data-center network architecture "HOLST" with dynamic and adaptive network configuration for reducing power consumption. This demonstration shows the method of detecting and assigning flows from traffic and application trigger.

Tu3D.7
Topology Description Generation and Path Computation Framework for Dynamic Optical Path Network with Heterogeneous Switches, Kiyo Ishii[1], Atsuko Takefusa[2], Shu Namiki[1], Tomohiro Kudoh[3,1]; *[1]AIST, Japan; [2]National Inst. of Informatics, Japan; [3]The Univ. of Tokyo, Japan.* A topology description scheme, a topology generation system, and a path computation system for dynamic optical path networks which support dynamic generation of wide area performance-guaranteed network slices will be demonstrated.

Tu3D.8
Towards IP & Transport Network Transformation Using Standardized Transport NorthBound Interfaces, Ricard Vilalta[1], Victor Lopez[2], Young Lee[3], Haomian Zheng[4], Lin Yi[4], Ramon Casellas[1], Oscar Gonzalez de Dios[2], Ricardo Martínez[1], Raul Muñoz[1]; *[1]CTTC, Spain; [2]Telefónica, Spain; [3]Huawei, USA; [4]Huawei, China.* This demo proposes the usage of standardized YANG data models for multi-vendor and multi-layer optical control interoperability. L2/L3 network service establishment will be demonstrated as part of the network transformation strategy for SDN/NFV.

Tu3D.9
Automated Management and Control of a Multi-vendor Disaggregated Network at the L0 Layer, Omer F. Yilmaz[1], Stephane St-Laurent[1], Matthew Mitchell[1]; *[1]Infinera Corporation, USA.* We propose to demonstrate automated service management and automated optical power controls over Infinera and Lumentum Open Optical Line Systems using an Infinera Layer-0 SDN controller.

Tu3D.10
Joint Optimal Service Chain Allocation, VNF instantiation and Metro Network Resource Management Demonstration, Francisco-Javier Moreno-Muro[1], Cesar San-Nicolas-Martinez[1], Elena Martin-Seoane[1], Miquel Garrich[1,3], Pablo Pavon-Marino[1], Oscar Gonzalez de Dios[2], Victor Lopez[2]; *[1]Politechnical Univ. of Cartagena, Spain; [2]Telefonica GCTO, Spain; [3]Optical Technologies Division, CPqD, Brazil.* In a metro network with VIMs orchestrated by an ETSI-oSM instance, and an optical transport controller, we demonstrate optimized service chain provisioning using the open-source Net2Plan tool with interfaces to OSM (new) and transport controller

Tu3D.11
Network Slicing Resource Allocation and Monitoring over Multiple Clouds and Networks, Ricardo Martínez[1], Ricard Vilalta[1], Ramon Casellas[1], Raul Muñoz[1], Li Fei[2], Pengcheng Tang[2], Victor Lopez[3]; *[1]Ctr Tecnologic de Telecoms de Catalunya, Spain; [2]Huawei, China; [3]Telefonica Global CTO, Spain.* This demo presents an in-operation network slice resource allocator, which is able to consider networking and cloud infrastructure. Monitoring cloud and network resources allows enhancing the (re-)allocation of network slices, while accommodating novel slice requests.

Tu3D.12 •
Fully Disaggregated ROADM White Box with NETCONF/YANG Control, Telemetry, and Machine Learning-based Monitoring, Andrea Sgambelluri[2], Jose Luis Izquierdo-Zaragoza[3], Alessio Giorgetti[2], Luis Gifre[4], Luis Velasco[3], Francesco Paolucci[2], Nicola Sambo[2], Francesco Fresi[2], Piero Castoldi[2], Anna Chiado Piat[5], Roberto Morro[5], Emilio Riccardi[5], Antonio D'Errico[6], Filippo Cugini[1]; *[1]CNIT, Italy; [2]Scuola Superiore Sant'Anna, Italy; [3]Optical Communications Group (GCO), Universitat Politcnica de Catalunya (UPC), Spain; [4]Universidad Autónoma de Madrid (UAM), Spain; [5]TIM, Italy; [6]Ericsson, Italy.* A first demonstration of ROADM White Box augmented with machine learning capabilities is demonstrated. The white box includes various level of disaggregation, NETCONF/YANG control, telemetry and spectrum-based advanced monitoring functionalities.

Tu3D.13
O2CMF: Experiment-as-a-service for Agile Fed4Fire Deployment of Programmable NFV, Isabella D. Ceravolo[1], Diego G. Cardoso[1], Cristina K. Dominicini[1], Rodolfo D. Villaça[1], Moises R. Ribeiro[1], Magnos Martinello[1,2], Reza Nejabati[2], Dimitra E. Simeonidou[2]; *[1]Software Defined Networks Research Group, Federal Univ. of Espirito Santo (UFES), Brazil; [2]High Performance Networks Group, Univ. of Bristol, UK.* An open platform over OpenStack for control and management of experiments (O2CMF) for merging and adapting wireless and optical federated testbeds with proper cloud infrastructure is presented. TOSCA-enabled orchestration provides programmability for NFV experiments.

Tu3D.14
Demonstration of NFV for Mobile Edge Computing on an Optically Disaggregated Datacentre in a Box, Michael P. Enrico[1], Vaibhawa Mishra[2], Arsalan Saljoghei[2], Maciej Bielski[3], Evert Pap[4], Ilias Syrigos[5], Oscar Gonzalez de Dios[6], Dimitris Theodoropoulos[7], Dionisios Pnevmatikatos[7], Andrea Reale[8], Dimitris Syrivelis[8], Georgios Zervas[2], Nick J. Parsons[1], Kostas Katrinis[8]; *[1]HUBER+SUHNER Polatis Ltd, UK; [2]Univ. College London, UK; [3]Virtual Open Systems SAS, France; [4]Sintecs BV, Netherlands; [5]Univ. of Thessaly, Greece; [6]Telefonica I+D, Spain; [7]FORTH, Greece; [8]IBM Research - Ireland, Ireland.* This demonstrator showcases the hardware and software integration achieved by the dReDBox project [1] towards realization of a novel architecture using dynamically-reconfigurable optical interconnects to create a flexible, scalable and efficient disaggregated datacentre infrastructure.

Tu3D.15
Network Orchestration for Dynamic Network Slicing for Fixed and Mobile Vertical Services, Rodolfo Alvizu[2], Sebastian Troia[1], Van Minh Nguyen[2], Guido Alberto Maier[2], Achille Pattavina[2]; *[1]Politecnico di Milano, Italy; [2]SWAN networks, Italy.* We demonstrate how a hybrid and hierarchical transport-SDN control plane based on a network orchestrator and an SDN controller can provide dynamic network slicing for enterprise-networking services and mobile metro-core networks.

NOTES

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

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

08:00–10:00 W1A • Connector - Something Old, Something New

Presider: Alan Evans; Corning Research & Development Corp, USA

W1A.1 • 08:00
20-year Reliability Test Results For SC Connector Installed on Outside Plant, Yoshiteru Abe[1], Kota Shikama[2], Shuichiro Asakawa[3], Shuichi Yanagi[1]; *[1]NTT Access Network Service Systems Laboratories, NTT Corporation, Japan; [2]NTT Device Technology Laboratories, NTT Corporation, Japan; [3]NTT Device Innovation Center, NTT Corporation, Japan*. Since 1997 we have tested the reliability of SC connectors installed outdoors in hot and humid environments. SC connectors with optimized ferrule end dimensions have maintained good optical performance for 20 years.

W1A.2 • 08:15
Novel Image Processing Methods for IL Estimation of Field Terminated Connectors, Jose Castro[1], Yu Huang[1], Rick Pimpinella[1], Bulent Kose[1], Alex Berian[1], Asher Novick[1], Brett Lane[1]; *[1]Panduit, USA*. Investigation of novel methods to estimate insertion loss (IL) in field terminated connector based on radiation pattern variations as a function of the loss

08:00–10:00 W1B • High Capacity Transmission Systems

Presider: Fred Buchali; Nokia Bell Labs, Germany

W1B.1 • 08:00 Invited
Advances in 400 GbE Field Trials, Lynn E. Nelson[1]; *[1]AT&T Labs, USA*. We review two recent 400G field trials in AT&T's network. We demonstrated 400Gb/s Ethernet end-to-end circuits, with CFP8 client interfaces and dual-wavelength 16QAM or single-wavelength 32QAM lineside, and SDN-controlled creation, deletion, and re-routing of 400G services.

08:15–10:00 W1C • Optical Switching in Data Centers

Presider: Payman Samadi; Cornell Univ., USA

W1C.1 • 08:15
dReDBox: Demonstrating Disaggregated Memory in an Optical Data Centre, Arsalan Saljoghei[1], Michael P. Enrico[2], Dimitris Syrivelis[3], Kostas Katrinis[3], Andrea Reale[3], Maciej Bielski[4], Ilias Syriogs[6], Dionisios Pnevmatikatos[5], Dimitris Theodoropoulos[5], Nick J. Parsons[2], Georgios Zervas[1], Vaibhawa Mishra[1]; *[1]Univ. College London, UK; [2]Huber+Suhner Polatis, UK; [3]IBM-research Ireland, Ireland; [4]Virtual Open Systems, France; [5]Foundation of Research and Technology Hellas, Greece; [6]Univ. of Thessaly, Greece*. This paper showcases the first experimental demonstration of disaggregated memory using the dRedBox optical Data Centre architecture. Experimental results demonstrate the 4-tier network scalability and performance of the system at the physical and application layer.

08:00–10:00 W1D • Machine Learning and Network Availability

Presider: Qiong Zhang; Fujitsu Laboratories of America Inc, USA

W1D.1 • 08:00
Guaranteed-availability Network Function Virtualization in Inter-datacenter Networks, Jian Kong[1], Inwoong Kim[2], Xi Wang[2], Qiong Zhang[2], Weisheng Xie[3], Hakki C. Cankaya[3], Nannan Wang[2], Tadashi Ikeuchi[2], Jason P. Jue[1]; *[1]The Univ. of Texas, Dallas, USA; [2]Fujitsu Laboratories of America, USA; [3]Fujitsu Network Communications, USA*. Considering the availability of the datacenter's network elements, we propose a coordinated protection mechanism that adopts both backup path protection and SFC replicas distributed among datacenters to support high availability while reducing total cost.

W1D.2 • 08:15 Tutorial
Data Analytics and Machine Learning Applied to Transport Layer, Massimo Tornatore[1,2]; *[1]Politecnico di Milano, Italy; [2]Computer Science, Univ. of California, Davis, USA*. After a generic introduction to machine-learning concepts and tools, some applications of machine learning in optical networks are introduced and discussed, with a focus on QoT estimation, failure detection and failure identification.

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08:00–10:00 W1E • Devices for Mode Mulitplexing

Presider: Joel Carpenter; Univ. of Queensland, Australia

W1E.1 • 08:00 Tutorial
Optical Channel Switching in the Wavelength and Space Dimensions for SDM and WDM Networks, Dan M. Marom[1]; *[1]Hebrew Univ. of Jerusalem, Israel*. This tutorial surveys the modifications of ROADM architecture and its underlying hardware elements, in support of increased capacity transmission schemes: for WDM-based networks, improved bandwidth utilization, elasticity, and increased transmission window beyond the C-band; in SDM networks, introduction of additional SMF fibers, cores, or spatial modes.

Dan M. Marom is a Full Professor in the Applied Physics Department at Hebrew University, Israel, heading the Photonic Devices Group and currently serving as the Department Chair. He received the B.Sc. Degree in Mechanical Engineering and the M.Sc. Degree in Electrical Engineering, both from Tel-Aviv University, Israel, in 1989 and 1995, respectively, and was awarded a Ph.D. in Electrical Engineering from the University of California, San Diego

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08:00–10:00 W1F • Radio-over-fiber I

Presider: Rod Waterhouse; Pharad, LLC, USA

W1F.1 • 08:00
10 Gb/s Radio-over-fiber at 28 GHz Carrier Frequency Link based on 1550 nm VCSEL Chirp Enhanced Intensity Modulation after 2 km Fiber, Joris Van Kerrebrouck[1], Haolin Li[1], Silvia Spiga[2], Markus C. Amann[2], Xin Yin[1], Johan Bauwelinck[1], Piet Demeester[1], Guy Torfs[1]; *[1]IDLab, INTEC - imec, UGent, Belgium; [2]Walter Schottky Institut, Germany*. 10Gb/s, 28GHz radio-over-fiber transmission using a directly-modulated single-mode C-band VCSEL is demonstrated over 2km. The chirp of the VCSEL is translated into intensity modulation to extend the fiber-reaches and increase the power budget with 10dB.

W1F.2 • 08:15
Full-duplex and Scalable MIMO Fiber–Wireless Seamless System in W-band for Future Mobile Networks, Pham Tien Dat[1], Atsushi Kanno[1], Naokatsu Yamamoto[1], Tetsuya Kawanishi[2]; *[1]Network System Research Inst., National Inst. of Information and Communication Technology, Japan; [2]Waseda Univ., Japan*. We present a scalable fiber–wireless system in W-band for the simultaneous transmission of MIMO signals in both downlink and uplink directions. Satisfactory performance is confirmed for 2 × 2 MIMO OFDM and LTE-a signals.

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

08:15–10:00
W1G • Performance Monitoring and Nonlinear Transmission

Presider: Sethumadhavan Chandrasekhar; Nokia Bell Labs, USA

W1G.1 • 08:15 Invited

Learning from the Optical Spectrum: Soft-failure Identification and Localization, Luis Velasco[1], Behnam Shariati[1], Alba P. Vela[1], Jaume Comellas[1], Marc Ruiz[1]; [1]*Universitat Politecnica de Catalunya, Spain*. The availability of coarse-resolution cost-effective Optical Spectrum Analyzers (OSA) allows its widespread deployment in operators' networks. In this paper, several machine learning approaches for failure identification and localization that take advantage of OSAs are presented.

08:00–10:00
W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?

Organizers: Thomas Pfeiffer, Nokia Bell Labs, Germany; Volker Jungnickel, Fraunhofer HHI, Germany

Optical access networks today are typically deployed as single path, single channel connections from the metro domain towards the end users. This architecture, however, will not be appropriate for accommodating business critical services, and particularly x-haul services in wireless and copper networks. Redundant, flexible and manageable access links will increasingly be required. Likewise, network designs will be needed allowing for reliably handling different kinds of traffic patterns with varying needs for capacity and latency, such as sustained capacity per node, sporadic traffic or aggregate peak rates even exceeding the capacity that the network was designed for.

The panel shall identify shortcomings of current access network architectures and provide proposals how to improve their resilience both on the physical and MAC layer as well as on the traffic engineering level. Which operational benefits can be gained from monitoring means and SDN-type of resource management? How can increased requirements on network management and maintenance be met also in access? What is the acceptable ratio of equipment and software efforts vs. improved quality and availability of services?

08:00–10:00
W1I • Devices for Interconnects

Presider: Kouji Nakahara; Oclaro Japan, Inc., Japan

W1I.1 • 08:00 Invited

Silicon Photonics for 56G NRZ Optical Interconnects, Joris Van Campenhout[1], Yoojin Ban[1], Peter De Heyn[1], Ashwyn Srinivasan[1], Jeroen De Coster[1], Sebastien Lardenois[1], Brad Snyder[1], Sadhishkumar Balakrishnan[1], Guy Lepage[1], Negin Golshani[1], Sofie Janssen[1], Alicja Lesniewska[1], Kristof Croes[1], Andy Miller[1], Peter Verheyen[1], Marianna Pantouvaki[1], Philippe Absil[1]; [1]*imec, Belgium*. We discuss recent progress in the performance of modulators and photodetectors co-integrated in a silicon photonics platform, and capable of operation in the O-band or C-band at 56Gb/s single-lane NRZ data rates and beyond.

08:00–10:00
W1J • Short Reach II

Presider: Qunbi Zhuge; Ciena Corporation, Canada

W1J.1 • 08:00

112Gb/s Self-heterodyne Stokes Vector Detection with Compact Receiver for Short Reach Optical Communications, An Li[1], Samina Chowdhury[1], Yangjing Wen[1], Wei-Ren Peng[1], Yan Cui[1], Yusheng Bai[1]; [1]*Futurewei Technologies, Inc., USA*. We propose a novel self-heterodyne Stokes vector detection (SH-sVD) system with only two balanced photodiodes and two analog-to-digital converters at receiver. A single-λ 112-gb/s 16QAM signal was successfully received after 80km transmission.

W1J.2 • 08:15

Application of Tomlinson-Harashima Precoding (THP) for Short-reach Band-limited Nyquist PAM and Faster-than-Nyquist PAM Signaling, Nobuhiko Kikuchi[1], Riu Hirai[1], Takayoshi Fukui[2]; [1]*Hitachi Ltd, Japan;* [2]*Oclaro Japan, Inc., Japan*. We experimentally prove the effectiveness of Tomlinson-Harashima Precoding for IM/DD Nyquist PAM signals with severe transmitter-side bandwidth limitation despite the increase of optical signal levels, and its application to 50-GBaud Faster-than-Nyquist PAM4 is also demonstrated.

08:00–10:00
W1K • Optical Fiber Sensors

Presider: Rogerio Nogueira; Instituto De Telecomunicacoes, Portugal

W1K.1 • 08:00 Invited

Improving Distributed Sensing with Continuous Gratings in Single and Multi-core Fibers, Paul Westbrook[1], Tristan Kremp[1], Kenneth Feder[1], Wing Ko[1], Eric Monberg[1], Hongchao Wu[1], Debra Simoff[2], Roy Ortiz[1]; [1]*OFS Laboratories, USA;* [2]*OFS Fitel, USA*. We review advances in single and multicore continuous fiber grating array sensor technology. Grating enhanced backscattering offers order of magnitude signal improvements for distributed sensing of shape, temperature and strain over lengths up to 1km.

Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.3 • 08:30
Small Footprint Air-gap Multi Fiber Connector with Low Loss and Low Mating Force, Hajime Arao[1], Sho Yakabe[1], Fumiya Uehara[1], Dai Sasaki[1], Takayuki Shimazu[1]; [1]*Sumitomo Electric Industries, Ltd., Japan.* Multi-fiber connector with low mating force (3N) has been developed by applying gap between fibers. The proposed multi-mode/single-mode connector has achieved an average loss of 0.49dB/0.67dB and more than 38dB/60dB return loss without anti-reflection coating.

W1A.4 • 08:45
Edge Coupling Integrated Optics Packaging Concept using Liquid Crystal Element, Alex Paquet[1], Daniel B. Landry[1], Yan Desroches[1], Christine Alain[1]; [1]*INO, Canada.* Many packaging approaches for integrated optics cannot meet the industry demand. We propose a post-assembly correction concept, using a liquid crystal element compatible with small form-factor pluggable modules, which may significantly reduce costs.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.2 • 08:30
Comparison of WDM Bandwidth Loading Using Individual Transponders, Shaped, and Flat ASE Noise, Thomas Richter[1], Jie Pan[1], Sorin Tibuleac[1]; [1]*ADVA Optical Networking North America Inc., USA.* Channel emulation is compared for 100-gb/s PDM-QPSK from commercial transponders with channel-like spectrally carved noise and flat noise bands. The performance is evaluated in experiments and simulations on standard SMF and TW-rS DWDM transmission links.

W1B.3 • 08:45
DSP-enabled Frequency Locking for Near-Nyquist Spectral Efficiency Superchannels utilizing Integrated Photonics, Jefferey Rahn[1], Lee Dardis[1], David Krause[2], Mark Rice[1], Chris Berry[1], Aleš Kumpera[2], Alan Nilsson[1], Xian Xu[1], Parmijit Samra[1], Kenneth Weidner[1], Zulfikar Morbi[1], Scott DeMars[1], Charles Chen[1], Paul Freeman[1]; [1]*Infinera Corporation, USA;* [2]*Infinera Canada, Canada.* Digitally synthesized near-Nyquist subcarriers and photonic integration are shown to improve spectral efficiency. Spectral utilization 3.3% over baud rate is enabled by 1% Root-raised-cosine shaping and precision adjacent-channel wavelocking σ <100 MHz.

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.2 • 08:30
Disaggregated Optical Data Center in a Box Network using Parallel OCS Topologies, Hui Yuan[1], Arsalan Saljoghei[1], Adaranijo Peters[2], Georgios Zervas[1]; [1]*Univ. College London, UK;* [2]*Univ. of Bristol, UK.* Two parallel OCS topologies are proposed that deliver 95 nsec round-trip latency on disaggregated optical data center in a box system. They offer 40% cost and 68% power consumption efficiency at maximum IT resource utilization.

W1C.3 • 08:45 Invited
Bridging the Last Mile for Optical Switching in Data Centers, Hitesh Ballani[1], Paolo Costa[1], Istvan Haller[1], Krzysztof Jozwik[1], Kai Shi[1], Benn C. Thomsen[1], Hugh Williams[1]; [1]*Microsoft Research, UK.* Optical switches promise to revolutionize data centers by providing high bandwidth and low latency at low cost. This paper discusses some of the remaining challenges that need to be solved to make this technology successfully deployed in production.

Room 6C

W1D • Machine Learning and Network Availability—Continued

Massimo Tornatore is an Associate Professor with the Department of Electronics, Information, and Bioengineering, at Politecnico di Milano. He also holds an appointment as Adjunct Full Professor in the Department of Computer Science, University of California, Davis. His research interests include performance evaluation, optimization and design of communication and cloud networks (with an emphasis on the application of optical-networking technologies). He currently serves as an Editor for Photonic Network Communications, Optical Switching and Networking and IEEE Communication Surveys and Tutorials. He is a co-author of more that 250 scientific publications and was the co-recipient of ten best-paper awards.

Room 6D

W1E • Devices for Mode Mulitplexing—Continued

(UCSD), in 2000. Prof. Marom is a Fellow of the Optical Society of America and a Senior Member of the IEEE Photonics Society. He was awarded the IEEE Photonics Society Distinguished Lecturer Award for 2014 and 2015, and is currently serving on the Society's Board of Governors. From 1996 through 2000, he was a Fannie and John Hertz Foundation Graduate Fellow at UCSD, and was a Peter Brojde Scholar in 2006-2007.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.3 • 08:30
Full-duplex Coherent Radio-over-fiber Transmission over 1:128 Split PON using an EML as Bidirectional RRH Optics, Bernhard Schrenk[1]; [1]*AIT Austrian Inst. of Technology, Austria.* A lean coherent optical transceiver interface is presented. Simultaneous analogue 64QAM-OFDM down-/uplink transmission is experimentally demonstrated exploiting a single EML as coherent receiver and transmitter. No optical DSP is required in either signal chain.

W1F.4 • 08:45
Transmitter-embedded AMCC, LTE-A and OTDR signal for Direct Modulation Analog Radio over Fiber Systems, Luis Ernesto Ynoquio Herrera[1], Felipe Calliari[1], Diego Rodrigo Villafani Caballero[1], Gustavo C. do Amaral[1], Patryk Urban[2], Jean P. von der Weid[1]; [1]*Puc-rio, Brazil;* [2]*Ericsson Research, Sweden.* AMCC, LTE-a and OTDR signals are embedded in a single transmitter. Experiments show little impact on data transmission under in-service monitoring. Fault localization capability is verified with 10 dB dynamic range and 10 m resolution.

Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.2 • 08:45
White Gaussian Noise Based Capacity Estimate and Characterization of Fiber-optic Links, Roland Ryf[1], John van Weerdenburg[2], Roberto A. Alvarez-Aguirre[1,3], Nicolas K. Fontaine[1], René-Jean Essiambre[1], Haoshuo Chen[1], Juan Carlos Alvarado Zacarias[1,3], Rodrigo Amezcua Correa[3], Ton Koonen[2], Chigo Okonkwo[2]; *[1]Nokia Bell Labs, USA; [2]Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands; [3]CREOL, The Univ. of Central Florida, USA*. We use white Gaussian noise as a test signal for single-mode and multimode transmission links and estimate the link capacity based on a calculation of mutual information. We also extract the complex amplitude channel estimations and mode-dependent loss with high accuracy.

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.2 • 08:30
Error-free Loopback of a Compact 25 Gb/s x 4 ch WDM Transceiver Assembly Incorporating Silicon (De)Multiplexers with Automated Phase-error Correction, Tomoyuki Akiyama[1,2], Tsuyoshi Aoki[1,2], Takasi Simoyama[1], Akio Sugama[1,2], Shigeaki Sekiguchi[1,2], Yohei Sobu[1], Shinsuke Tanaka[1,2], Yu Tanaka[1,2], Seok-Hwan Jeong[1,2], Motoyuki Nishizawa[1], Nobuaki Hatori[1], Akinori Hayakawa[1,2], Toshihiko Mori[1,2]; *[1]PETRA, Japan; [2]Fujitsu Laboratories Ltd., Japan*. We propose (de)multiplexers based on tunable cascaded asymmetric Mach-Zehnder interferometers to exclude necessity of highly-scaled expensive Si process by fully-automated fabrication error correction, and demonstrate an error-free loopback with a 12x12 mm transceiver assembly.

W1I.3 • 08:45
A Single-laser Flexible-grid WDM Silicon Photonic Transmitter using Microring Modulators, Yelong Xu[1], Jiachuan Lin[1], Raphaël Dubé-Demers[1], Sophie LaRochelle[1], Leslie A. Rusch[1], Wei Shi[1]; *[1]Université Laval, Canada*. We report a flexible-grid WDM silicon photonic transmitter by monolithic integration of a microring modulator based comb generator with multi-channel modulators. It shows simultaneous multi-channel data transmission at different channel spacings without significant signal degradation

Room 9

W1J • Short Reach II—Continued

W1J.3 • 08:30
Performance Enhanced IM/DD 112 Gb/s/λ Transmission using Constellation Switching PAM4, Meng Xiang[1], Qunbi Zhuge[2,1], Zhenping Xing[1], Kuo Zhang[1], Thang M. Hoang[1], Fangyuan Zhang[1], David V. Plant[1]; *[1]ECE, McGill Univ., Canada; [2]Ciena Corporation, Canada*. We experimentally demonstrate a single wavelength 112 Gb/s IM/DD transmission system using constellation switching PAM4. Significant improvement is observed with respect to the conventional PAM4 system at the KP4 FEC threshold.

W1J.4 • 08:45
Single Photodiode-per-polarization Receiver for 400G Systems, Bill P. Corcoran[1,2], Benjamin Foo[1,3], Arthur Lowery[1,2]; *[1]Monash Univ., Australia; [2]Centre for Ultrahigh-bandwidth Devices for Optical Systems, Australia; [3]Microtechnology and Nanoscience (MC2), Chalmers Univ. of Technology, Sweden*. We present a simplified heterodyne receiver using one single ended photodiode per polarization for polarization multiplexed coherent signals. We demonstrate this receiver for the reception of PM-16QAM over field-installed metro-area fibers at distances up to 306-km.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.2 • 08:30
> 10 dB SNR Enhancement in Distributed Acoustic Sensors through First Order Phase Noise Cancellation, María R. Fernández-Ruiz[1], Juan Pastor-Graells[1], Hugo F. Martins[2], Andres Garcia-Ruiz[1], Sonia Martin-Lopez[1], Miguel Gonzalez Herraez[1]; *[1]Universidad de Alcalá (UAH), Spain; [2]FOCUS S.L, Spain*. The performance of Rayleigh-based distributed acoustic sensors (DAS) is strongly dependent on the coherence of the laser source. We present a simple methodology to reduce the impact of the laser phase noise in chirped-pulse DAS.

W1K.3 • 08:45
Long-range, Power-efficient Distributed Flow Measurements Using Chirped-pulse Phase-sensitive Reflectometry, Andres Garcia-Ruiz[1], Alejandro Dominguez-Lopez[1], Juan Pastor-Graells[1], Hugo F. Martins[2], Sonia Martin-Lopez[1], Miguel Gonzalez Herraez[1]; *[1]Universidad de Alcalá, Spain; [2]R&D, FOCUS S.L., Spain*. We demonstrate a technique allowing to perform distributed wind speed measurements over >17 km with <0.6 km/h uncertainty at only 60 mW/m of power dissipation. Applications in dynamic line rating and catenary monitoring are envisaged.

Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.5 • 09:00 Invited

Ultra-high-density MCF Connector Technology, Tetsu Morishima[1], Osamu Shimakawa[1], Jun Ito[1], Takayuki Shimazu[1], Hajime Arao[1], Toshihisa Yokochi[1], Fumiya Uehara[1], Masaki Ohmura[1], Tetsuya Nakanishi[1], Tomomi Sano[1], Tetsuya Hayashi[1]; [1]*Sumitomo Electric Industries, Ltd., Japan*. This talk will present our single-/multi-fiber multi-core fiber (MCF) connectors with the insertion loss of less than 1 dB and physical contact achieved by rotational fiber alignment mechanism and MCF-optimized end face polishing method, respectively.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.4 • 09:00

The Trade-off between Tranceiver Capacity and Symbol Rate, Lidia Galdino[1], Domaniç Lavery[1], Zhixin Liu[1], Katarzyna Balakier[1], Eric Sillekens[1], Daniel Elson[1], Gabriel Saavedra[1], Robert Killey[1], Polina Bayvel[1]; [1]*Univ. College London, UK*. The achievable throughput using high symbol rate, high order QAM is investigated for a CMOS-based DAC/ADC. The optimum symbol rate and modulation format is found to be 80GBd DP-256QAM, with a 800Gb/s net data rate.

W1B.5 • 09:15 Top Scored

31.2-tb/s Real Time Bidirectional Transmission of 78x400 Gb/s Interleaved Channels over C band of one 90-km SMF Span, Thierry Zami[1], Bruno Lavigne[1], Oriol Bertran Pardo[1], Stefan Weisser[1], Julien David[1], Mael Le Monnier[1], Jean Paul Faure[1]; [1]*Nokia Corporation, France*. We transmit 78x400Gb/s PDM-64QAM 50GHz-spaced channels over one 90-km SSMF span with real time transponder, transporting 31.2 Tb/s with 8 bit/s/Hz spectral efficiency

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.4 • 09:15

Decision Tree Classification based Mix-flows scheduling in Optical Switched DCNs, Cen Wang[1,2], Hong Cao[1], Shenzhen Yang[1], Junyuan Guo[1], Hongxiang Guo[1], Jian Wu[1]; [1]*BUPT, China;* [2]*Optical transmission and network, KDDI Research Lab, Japan*. We propose a novel mix-flows scheduling strategy assisted with decision tree based flow classification for optical switched DCNs. Experimental results show it can effectively lower the completion time of small interactive flows and Coflows.

Room 6C

W1D • Machine Learning and Network Availability—Continued

W1D.3 • 09:15

Q-availability based Virtual Optical Network Provisioning, Inwoong Kim[1], Xi Wang[1], Martin Bouda[1], Olga Vassilieva[1], Qiong Zhang[1], Paparao Palacharla[1], Tadashi Ikeuchi[1]; [1]*Fujitsu Laboratories of America, USA*. We show significant gain in Virtual Optical Network (VON) capacity by provisioning based on Q-availabilities of optical channels instead of fixed Q-margin. The Q-availability is calculated using stochastic simulations based on GN model.

Room 6D

W1E • Devices for Mode Mulitplexing—Continued

W1E.2 • 09:00 Top Scored

Over-100-spatial-channel Programmable Spectral Processor for SDM Signal Monitoring, Mitsumasa Nakajima[1], Kenya Suzuki[1,2], Kazuno Seno[1,2], Takashi Goh[1], Ryoihi Kasahara[1], Mitsunori Fukutoku[2], Yutaka Miyamoto[2], Toshikazu Hashimoto[1]; [1]*NTT Device Technology Labs., Japan;* [2]*NTT Netwok Innovation Labs, Japan*. We propose a densely integrated programmable spectral processor array that handles over 100ch optical signals. Using the device, we achieved the optical performance monitoring for 100 spatial channels over C-band.

W1E.3 • 09:15 Top Scored

Reconfigurable 3-channel All-optical MIMO Circuit on Silicon Based on Multi-plane Light Conversion, Rui Tang[1]; [1]*The Univ. of Tokyo, Japan*. We demonstrate reconfigurable all-optical MIMO demultiplexing on a compact silicon chip. 3-mode demultiplexing is realized experimentally with wavelength-dependent loss less than 3 dB and modal crosstalk less than -13 dB over 26-nm optical bandwidth.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.5 • 09:00 Invited

Research to Field Trial, A RoF Journey, Thavamaran Kanesan[1]; [1]*TM Research & Development, Malaysia*. Abstract not available.

Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.3 • 09:00
Non-linearity Modeling at Ultra-high Symbol Rates, Pierluigi Poggiolini[1], Gabriella Bosco[1], Andrea Carena[1], Fernando P. Guiomar[1], Mahdi Ranjbar Zefreh[1], Fabrizio Forghieri[2], Stefano Piciaccia[2]; *[1]Politecnico di Torino, Italy; [2]CISCO Photonics, Italy.* We investigate the accuracy of several versions of the GN and EGN models for symbol rates up to 426 GBaud, over about 2THz of optical bandwidth, considering PM-32/64/128/256 QAM and addressing non-linear phase-noise mitigation.

W1G.4 • 09:15
Observing the Interaction of PMD with Generation of NLI in Uncompensated Amplified Optical Links, Mattia Cantono[1], Dario Pilori[1], Alessio Ferrari[1], Andrea Carena[1], Vittorio Curri[1]; *[1]Politecnico di Torino, Italy.* We present simulative analyses displaying how PMD has negligible interaction with the generation of nonlinear interference, and show that the GN-model is accurate yet conservative in estimating the generalized SNR also in wide-bandwidth transmission.

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.4 • 09:00
Monolithic Optical Transceivers in 65 nm Bulk CMOS, Amir H. Atabaki[1], Sajjad Moazeni[2], Fabio Pavanello[3], Hayk Gevorgyan[4], Jelena Notaros[3], Luca Alloatti[1], Mark Wade[3], Chen Sun[2], Seth Kruger[5], Kenaish Alqubaisi[4], Imbert Wang[4], Bohan Zhang[4], Anatol Khilo[4], Christopher Baiocco[5], Milos Popovic[4], Vladimir Stojanovic[2], Rajeev Ram[1]; *[1]Massachusetts Inst. of Technology, USA; [2]Univ. of California, Berkeley, USA; [3]Univ. of Colorado, Boulder, USA; [4]Boston Univ., USA; [5]Colleges of Nanoscale Science and Engineering, SUNY Polytechnic Inst., USA.* We present the integration of optical passive and active components next to millions of nano-scale bulk silicon transistors through a single deposited layer of polysilicon on silicon oxide islands. We demonstrate 10 Gb/s monolithic O-band optical transceivers on this platform.

W1I.5 • 09:15
Zn-diffusion/Oxide-relief 940 nm VCSELs with Excellent High-temperature Performance for 50 Gbit/sec Transmission, Jin-Wei Shi[1], Kai-Lun Chi[1], Zheng-Ting Xie[1], Mikel Agustin[2], Jörg Kropp[2], Nikolay Ledentsov[2], Kuo-Feng Tseng[3], Ling-Gang Yang[3]; *[1]National Central Univ., Taiwan; [2]VI Systems, Germany; [3]Hon Hai Precision Ind. Co. LTD., Taiwan.* 940nm VCSELs with small resistances (3**5Ω**) and ultra-wide E-o bandwidths from room-temperature (31GHz) to 85°C (29GHz) operations are demonstrated. It achieves 50Gbps error-free transmission over 50m OM5 fiber without using equalization and pre-emphasis techniques.

Room 9

W1J • Short Reach II—Continued

W1J.5 • 09:00
112 Gb/s/λ CAP Signals Transmission over 480 km in IM-DB System, Jianyang Shi[1,2], Junwen Zhang[2], Xinying Li[2,3], Nan Chi[1], Gee-Kung Chang[3], Jianjun Yu[2]; *[1]Fudan, China; [2]ZTE, USA; [3]Georgia Inst. of Technology, USA.* We demonstrate a 112 Gbit/s/λ CAP over 480 km of SSMF with low-cost direct detection. A joint processing algorithm is employed to improve system performance. To the best of our knowledge, this is the first time that single-wavelength 100G signal transmission is experimentally achieved over 480 km of SSMF with CAP-16 and direct detection.

W1J.6 • 09:15
448-Gb/s PAM4 Transmission Over 300-km SMF-28 Without Dispersion Compensation Fiber, Zhixin Liu[1], Tianhua Xu[1,2], Gabriel S. Mondaca[1], Polina Bayvel[1]; *[1]Univ. College London, UK; [2]Univ. of Warwick, UK.* We report on 4×112Gb/s direct-detection PAM4 transmission over 300-km standard single mode fiber. Chromatic dispersion is digitally compensated at the transmitter side.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.4 • 09:00 Invited
From Spider Webs to a Biomimetic Optical Fibre Sensor, Kenny Hey Tow[1], Desmond Chow[1], Fritz Vollrath[2], Isabelle Dicaire[4], Tom Gheysens[3], Luc Thévenaz[1]; *[1]Ecole Polytechnique Fédérale de Lausanne, Switzerland; [2]Univ. of Oxford, UK; [3]Univ. of Ghent, Belgium; [4]CCTT Optech, Canada.* Can we use spider silk threads as natural, biological optical fibre sensors? In this communication, we will see how we can harness the optical properties of spider dragline silk and use it for sensing.

Room 1A

W1A • Connector - Something Old, Something New—Continued

W1A.6 • 09:30
Physical-contact 256-core MPO Connector with Flat Polished Multi-core Fibers, Yuki Saito[1], Tetsu Morishima[1], Ken Manabe[1], Tetsuya Nakanishi[1], Tomomi Sano[1], Tetsuya Hayashi[1]; *[1]Sumitomo Electric Industries, Ltd., Japan*. Physical contact of all the cores of ultra-high-density 256-core MPO connectors with 32 strands of 8-core fibers was achieved with a 22-n mating force by polishing method realizing flat fiber facets and small fiber-protrusion difference.

W1A.7 • 09:45
Multicore-fiber LC Receptacle with Compact Fan-in/Fan-out for Short-reach Transceivers, Kota Shikama[1], Yoshiteru Abe[1], Toshiki Kishi[1], Koji Takeda[1], Takuro Fujii[1], Hidetaka Nishi[1], Takashi Matsui[1], Atsushi Aratake[1], Kazuhide Nakajima[1], Shinji Matsuo[1]; *[1]Nippon telegraph and telephone, Japan*. We describe a multicore-fiber LC receptacle with a compact fan-in/fan-out as a new transceiver interface for connecting LDs and PDs. We achieve low-loss coupling with the receptacle between a 4-core MCF and a laser array.

Room 1B

W1B • High Capacity Transmission Systems—Continued

W1B.6 • 09:30 Invited
High-capacity SDM Transmission over Transoceanic Distances, Alexey V. Turukhin[1], Oleg V. Sinkin[1], Hussam Batshon[1], Matt Mazurczyk[1], Maxim A. Bolshtyansky[1], Dmitri Foursa[1], Alexei Pilipetskii[1]; *[1]TE SubCom, USA*. We review recent experimental and theoretical works that discuss capacity and power efficiency improvements achievable in transoceanic transmission with SDM. We outline challenges and potential solutions for increasing the capacity of future SDM undersea transmission.

Room 2

W1C • Optical Switching in Data Centers—Continued

W1C.5 • 09:30 Invited
An Overview of the Open Compute Project and Next-generation Data Centers, Omar Baldonado[1]; *[1]Facebook Inc., USA*. This talk covers the Open Compute Project (OCP), a collaborative community focused on redesigning hardware technology to efficiently support the growing demands on compute infrastructure. This is especially relevant for optics in next-generation data centers.

Room 6C

W1D • Machine Learning and Network Availability—Continued

W1D.4 • 09:30
Real-time Spectrum Surveillance in Filterless Optical Networks, Behnam Shariati[1], Marc Ruiz[1], Andrea Sgambelluri[2], Filippo Cugini[3], Luis Velasco[1]; *[1]Universitat Politecnica de Catalunya, Spain; [2]Scuola Superiore Sant'Anna, Italy; [3]CNIT, Italy*. A monitoring system exploiting data analytics and cost-effective optical spectrum analyzers with under 1.2GHz resolution is proposed. Its performance is demonstrated in a filterless network experimental test-bed. The system enables prompt action before lightpath disruption.

W1D.5 • 09:45
Applying Data Visualization for Failure Localization, Alba P. Vela[1], Marc Ruiz[1], Luis Velasco[1]; *[1]Universitat Politecnica de Catalunya, Spain*. Data visualization is applied to BER measures in a bigdata repository. Bubble charts are produced to identify lightpaths with increasing BER and spectrum color maps are then used to identify the most likely degraded link.

Room 6D

W1E • Devices for Mode Mulitplexing—Continued

W1E.4 • 09:30 Top Scored
Silicon Chip-to-chip Mode-division Multiplexing, Jan M. Baumann[1], Edson Porto da Silva[1], Yunhong Ding[1], Valerija Kamchevska[1], Michael Galili[1], Kjeld Dalgaard[1], Lars Frandsen[1], Leif K. Oxenlowe[1], Toshio Morioka[1]; *[1]DTU Fotonik, Denmark*. A chip-to-chip mode-division multiplexing connection is demonstrated using a pair of multiplexers/demultiplexers fabricated on the silicon-on-insulator platform. Successful mode multiplexing and demultiplexing is experimentally demonstrated, using the LP_{01}, LP_{11a} and LP_{11b} modes.

W1E.5 • 09:45
Symmetric Lithium-niobate Waveguide Fabricated by Bonding for Mode-division-multiplexing Applications, Mengruo Zhang[2], Kaixin Chen[2], Wei Jin[1], Kin S. Chiang[1,2]; *[1]City Univ. of Hong Kong, Hong Kong; [2]Univ. of Electronic Science and Technology of China, China*. We fabricate a symmetric lithium-niobate waveguide that supports six fiber-compatible spatial modes by a bonding process and demonstrate the feasibility of forming vertical directional couplers with such a waveguide for fiber-based mode-division-multiplexing applications.

Room 6E

W1F • Radio-over-fiber I—Continued

W1F.6 • 09:30
W-band Radio-over-fiber Link Based on Self-oscillating Optical Frequency Comb Generator, G.K.M. Hasanuzzaman[1], Atsushi Kanno[2], Pham Tien Dat[2], Stavros Iezekiel[1]; *[1]Univ. of Cyprus, Cyprus; [2]NICT, Japan*. A 94.8 GHz radio-over-fiber link was implemented with a self-oscillating frequency comb. An LTE Advanced OFDM FDD 64-QAM signal of 20 MHz bandwidth was transmitted over 1.3 m wireless distance with an EVM of 2.23%.

W1F.7 • 09:45
Physical Layer 1 Gb/s Secret Wireless Data Transmission at W-band using a Photonic Duffing System, Rafael Puerta[1], Alvaro Morales[2], Simon Rommel[1], Inwoong Kim[3], Olga Vassilieva[3], Tadashi Ikeuchi[3], Idelfonso Tafur Monroy[2]; *[1]Technical Univ. of Denmark, Denmark; [2]Electrical Engineering, Eindhoven Univ. of Technology, Netherlands; [3]Fujitsu Laboratories of America, USA*. First demonstration of photonically-enabled 1 Gb/s secret wireless data transmission at W-band based on Duffing chaotic systems. The presented results validate a new methodology to increase security by exploiting chaos for gigabit data transmissions.

10:00–17:00 Exhibition and Show Floor Programs, Coffee Break, *Exhibit Hall*
and OFC Career Zone Live, *Exhibit Hall C*

Room 6F

W1G • Performance Monitoring and Nonlinear Transmission—Continued

W1G.5 • 09:30
A Novel Detection Strategy for Nonlinear Frequency-division Multiplexing, Stella Civelli[1,2], Enrico Forestieri[1,2], Marco Secondini[1,2]; *[1]Tecip, Scuola Superiore Sant'Anna, Italy; [2]Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy.* A novel decision feedback detection strategy exploiting a causality property of the nonlinear Fourier transform is introduced. The novel strategy achieves a considerable performance improvement compared to previously adopted strategies in terms of Q-factor.

W1G.6 • 09:45
100 Gbps b-modulated Nonlinear Frequency Division Multiplexed Transmission, Son T. Le[1], Karsten Schuh[1], Fred Buchali[1], Henning Bülow[1]; *[1]Nokia Bell Labs, Germany.* We demonstrate that the performance of 100 Gb/s NFDM system employing the continuous nonlinear spectrum is significantly enhanced by modulating only the b-coefficient, providing a gain up to 1.5 dB over the conventional OFDM system

Room 7AB

W1H • Panel: Is the Lack of Resilience in Access Networks a Potential Showstopper for Future 5G Services?—Continued

Room 8

W1I • Devices for Interconnects—Continued

W1I.6 • 09:30
85°C Operation of 850 nm VCSELs Deliver a 42 Gb/s Error-free Data Transmission for 100 meter MMF Link, Hsiao-Lun Wang[1], Junyi Qiu[1], Xin Yu[1], Milton Feng[1], Nick Holonyak[1]; *[1]Micro and Nanotechnology Laboratory, USA.* 850nm VCSELs record performance of 46Gb/s (RT), 43Gb/s (75°C) and 42Gb/s (85°C) error-free transmission for a 100 meter MMF link are reported without the use of equalizer or forward error correction.

W1I.7 • 09:45
High-speed High-efficiency Broadband Silicon Photodiodes for Short-reach Optical Interconnects in Data Centers, Soroush Ghandiparsi[1], Aly F. Elrefaie[2], Hilal Consizoglu[1], Yang Gao[1], Cesar Bartolo-Perez[1], Hasina H. Mamtaz[1], Ahmed Mayet[1], Toshishige Yamada[2], Ekaterina Ponizovskaya Devine[2], Shih-Yuan Wang[2], M. Saif Islam[1]; *[1]Electrical and Computer Engineering, Univ. of California, Davis, USA; [2]W&WSens Devices, Inc., USA.* We demonstrate a silicon-based surface-illuminated CMOS-compatible broadband photodiode with ≤30ps FWHM and above 55% EQE at 850nm for up to 50Gb/s by using photon-trapping micro/nano-structures. This is the fastest reported response for a Silicon photodiode.

Room 9

W1J • Short Reach II—Continued

W1J.7 • 09:30
4×100G PAM-4 Transmission in Faster-than-Nyquist Systems Incorporating Eigenvalue-space Precoding, Mu Xu[1,2], Zhensheng Jia[2], Peng-Chun Peng[1], Siming Liu[1], Feng Lu[1], Curtis Knittle[2], Gee-Kung Chang[1]; *[1]Georgia Inst. of Technology, USA; [2]CableLabs, USA.* An eigenvalue-space precoding is proposed to combat narrow-filtering effect in optical PAM-4 systems. Transmissions at 24, 60, and 120Gbps/wavelength with 6-dB bandwidths of 4, 7.5, and 17.5 GHz are experimentally demonstrated over up-to-30-km SSMF.

W1J.8 • 09:45
Low Complexity Frequency-domain Nonlinear Equalization for 40-Gb/s/wavelength Long-reach PON, Junwei Zhang[1], Changjian Guo[2], Jie Liu[1], Xiong Wu[1], Alan Pak Tao Lau[3], Chao Lu[2], Siyuan Yu[1,4]; *[1]School of Electronics and Information Technology, Sun Yat-sen Univ., China; [2]Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., China; [3]Department of Electrical Engineering, The Hong Kong Polytechnic Univ., China; [4]Merchant Venturers School of Engineering, Univ. of Bristol, UK.* We propose to use a frequency-domain nonlinear equalization (FD-nE) for long-reach PONs. Compared with time-domain NE, similar performance with 63% complexity reduction is achieved utilizing FD-nE in a 40.08-gbit/s OFDM-iM-dD transmission system over 60-km SSMF.

Room 10

W1K • Optical Fiber Sensors—Continued

W1K.5 • 09:30
Stretchable Multi-function Fiber Sensor for Tension, Bending and Torsion Sensing, Li Xu[1], Ning Liu[1], Jia Ge[1], Xianqiao Wang[1], Mable P. Fok[1]; *[1]Univ. of Georgia, USA.* We demonstrate a stretchable fiber-optic sensor by embedding a sinusoidal-structured fiber Bragg grating in a silicone sheet at an off-center position, which uniquely enables 30% of elongation and facilitates tension, torsion direction, and bending measurement.

W1K.6 • 09:45
Stable Torsion Sensor with Tunable Sensitivity and Rotation Direction Discrimination Based on a tapered Trench-assisted Multi Core Fiber, Fengze Tan[1], Zhengyong Liu[1], Jiajing Tu[1], Changyuan Yu[1], Chao Lu[1], Hwa-Yaw Tam[1]; *[1]Hong Kong Polytechnic Univ., Hong Kong.* A tapered Trench-assisted Multi Core Fiber (TA-MCF) is firstly proposed and experimentally demonstrated for torsion sensing. The rotation direction can be discriminated and the torsion sensitivity is tunable up to 1.1 nm/°.

10:00–17:00 Exhibition and Show Floor Programs, Coffee Break, *Exhibit Hall* **and OFC Career Zone Live,** *Exhibit Hall C*

10:30–12:30
W2A • Joint Poster Session I

W2A.1
Highly Accurate and Efficient Maintenance Technology for Optical Cables and Utility Poles, Takashi Goto[1], Masaki Waki[1], Kazunori Katayama[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan*. We propose a highly efficient and accurate maintenance method for outdoor facilities that employs a point cloud to measure the angle and bend in utility poles and the vertical clearance for communication cables.

W2A.2
8.74kW Pump-gain Integrated Functional Laser Fiber, Huan Zhan[1], Yuying Wang[1], Kun Peng[1], Shuang Liu[1], Yuwei Li[1], Li Ni[1], Xiaolong Wang[1], Cong Gao[1], Shihao Sun[1], Lihua Zhang[1], Juan Yu[1], jIanjun Wang[1], Feng Jing[1], Aoxiang Lin[1]; [1]*China Academy of Engineering Physics, China*. We fabricated a (8+1)-type pump-gain integrated functional laser fiber with 8 passive pump-fibers and 1 signal-gain fiber. 8.74 kW laser output with optical-to-optical efficiency of 81% was achieved in counter-pump MOPA setup.

W2A.3
Modal Dispersion Compensation Module for 100G SWDM Transmission Using OM4 Multimode Fiber, Xin Chen[1], Jason E. Hurley[1], Dong Gui[1], Jeff Stone[1], Ming-Jun Li[1]; [1]*Corning Research & Development Corp, USA*. A low insertion loss modal dispersion compensation module for SWDM applications including a two-band MUX/DEMUX and modal dispersion compensating fiber was fabricated. Extended transmission distance over OM4 MMF in 100G SWDM transmission experiment is demonstrated.

W2A.4
Novel In-service OSNR Monitoring Method for Reconfigurable Coherent Networks, Daniel Gariepy[1], Steven Searcy[2], Michel Leclerc[1], Pascal Gosselin-Badaroudine[1], Gang He[1], Sorin . Tibuleac[2]; [1]*EXFO, Canada;* [2]*ADVA Optical Networking, USA*. A novel in-service OSNR monitoring technique is experimentally validated on tightly filtered polarization-multiplexed signals for a range of network operating conditions and reconfigurations. The results demonstrate sufficient accuracy and robustness for measurements in practical networks.

W2A.5
Multimode EDFA Designs with Reduced MDG by Considering Spatially Dependent Saturation Effects, Steffen Jeurink[1], Peter M. Krummrich[1]; [1]*Chair for High Frequency Technology, TU Dortmund, Germany*. We propose a spatial gain equalization strategy for multimode EDFAs which considers transversally non-uniform saturation. Characteristic minima of the MDG are observed along the fiber. The fiber length is adjusted to achieve low MDG.

W2A.6
Nonlinear Absorption in Single-photon Detector and Ultrafast Mode-locked Laser Pulse Characterization, Zhengyong Li[1], XK Zhan[1], HY Wang[1], SC Wang[1], BC Wang[1]; [1]*Beijing Jiaotong Univ., China*. We observe novel nonlinear absorption in a bialkali-cathode single-photon detector, and propose mutual-correlation scheme to characterize precisely the time-jitter of ultrafast pulses, while demonstrate it with error less than 0.828 fs.

W2A.7
Enabling Simultaneous DAS and DTS Measurement Through Multicore Fiber Based Space-division Multiplexing, Zhiyong Zhao[2], Ming Tang[3], Liang Wang[1], Songnian Fu[3], Weijun Tong[4], Chao Lu[2]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*The Hong Kong Polytechnic Univ., Hong Kong;* [3]*Huazhong Univ. of Science and Technology, China;* [4]*Yangtze Optical Fiber and Cable Joint Stock Limited Company , China*. Through space-division multiplexing using multicore fiber, simultaneous measurements of DAS and DTS have been achieved based on Φ-oTDR and ROTDR, respectively. Wavelet transform denoising has been employed to improve the temperature uncertainty to 0.5 °C.

W2A.8
100km Quasi-lossless Fiber-optic Transmission with a Novel Cascaded Random Raman Fiber Laser, Han Wu[1], Bing Han[1], Zinan Wang[1], Yunjiang Rao[1]; [1]*UESTC, China*. Ultra-long distance (100km) quasi-lossless fiber-optic transmission is experimentally performed by using the 3rd-order Raman amplification pumped by a novel 1280nm cascaded random Raman fiber laser, which is the longest quasi-lossless transmission system reported to date.

W2A.9
Programmable and Fast-switchable Passively Harmonic Mode-locking Fiber Laser, Guoqing Pu[1], Lilin Yi[1], Li Zhang[1], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China*. Programmable harmonic mode-locking are achieved in graphene-based mode-locking fiber laser enabled by mode-locking discrimination algorithm and fast polarization tuning. Fundamental, second-order and third-order harmonic mode-locking states can be switched in microsecond level.

W2A.10
Silica Capillary based Whispering Gallery Mode Resonators and Functional Fiber Devices, Xiaobei Zhang[1], Jiawei Wang[1], Ming Yan[1], Hai Xiao[2], Tingyun Wang[1]; [1]*Shanghai Univ., China;* [2]*Clemson Univ., USA*. A novel and compact silica capillary based Whispering Gallery Mode resonators and functional fiber devices are demonstrated with Fano resonances observed, while the temperature, refractive index and strain sensing are also investigated.

W2A.11
Polarization-insensitive and Bandwidth-adjustable Anisotropic Dynamic Gratings based on Synthesis of Optical Coherence Function Method, Pan Xu[1], Peng Gan[1], Jun Wang[1], Zhengliang Hu[1], Yongming Hu[1]; [1]*National Univ of Defense Technology, China*. We demonstrated a linear type polarization-insensitive and bandwidth-adjustable anisotropic dynamic grating in a piece of non-birefringent erbium-doped fiber (EDF) by utilizing phase modulation method.

W2A.12
Simultaneous Distributed Temperature and Vibration Measurement with UWFBG based Coherent OTDR, Fan Ai[1], Hao Li[1], Tao He[1], Zhijun Yan[1], Deming Liu[1], Qizhen Sun[1]; [1]*Huazhong Univ of Science and Technology, China*. An UWFBG based coherent OTDR is proposed to realize distributed temperature and vibration sensing simultaneously. Ultra-high temperature accuracy of 0.05K and ultra-high response frequency of up to 100kHz is demonstrated.

W2A.13
Highly Sensitive Temperature Sensor Based on Hybrid Photonic Crystal Fiber, Zhilin Xu[1], Juan Juan Hu[2], Slawomir Ertman[4], Tomasz Wolinski[4], Weijun Tong[3], Ping Shum[1]; [1]*Nanyang Technological Univ., Singapore;* [2]*Smart Energy & Environment Cluster, Infrastructure Department Inst. for Infocomm Research, AStar, Singapore;* [3]*Yangtze Optical Fibre and Cable JointStock Co. Ltd., China;* [4]*Warsaw Univ. of Technology, Poland*. A hybrid guiding mechanism in photonic crystal fiber (PCF) is realized by selectively infiltrating liquid crystal 5CB into a twin-core PCF. Due to the introduction of PBG guiding mechanism into the index-guiding twin-core PCF, the hybrid PCF shows strong temperature responsiveness and thus possesses good potential for sensing applications.

W2A.14
Highly Mode Selective 3-mode Photonic Lantern through Geometric Optimization, Li Shen[1], Lin Gan[1], Chen Yang[2], Weijun Tong[2], Songnian Fu[1], Deming Liu[1], Ming Tang[1]; [1]*Huazhong Univ. of Sci. and Tech., China;* [2]*YOFC, China*. We demonstrated that core geometry has a great impact on mode selectivity of photonic lanterns and designed an optimized 3-mode photonic lantern with >20 dB mode selectivity and >95% coupling efficiency for all modes.

W2A.15
Performance Comparison and Analysis of Non-local Means and Wavelet Denoising for BOTDA Sensor, Huan Wu[1], Liang Wang[1], Zhiyong Zhao[2], Chester Shu[1], Chao Lu[2]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*The Hong Kong Polytechnic Univ., Hong Kong*. We experimentally compare and analyse the performance (i.e. measurement accuracy/spatial resolution) of NLM and WD for denoising BOTDA signals under different SNR improvement and sampling point number.

W2A.16
112 Gb/s PAM4 Transmission over 2 km SMF using a C-band GeSi Electro-absorption Modulator, Eslam Elfiky[1], Peter De Heyn[2], Mohamed Morsy-Osman[1], Ashwyn Srinivasan[2], Alireza Samani[1], Marianna Pantouvaki[2], Mohammed Sowailem[1], Joris Van Campenhout[2], David V. Plant[1]; [1]*McGill Univ., Canada;* [2]*Imec, Belgium*. We demonstrate 112 Gb/s 4-level pulse amplitude modulation over 2 km of SMF using a C-band GeSi electro-absorption modulator for data-center interconnects. Also, we present first results towards 400 Gb/s wavelength division multiplexed transmission.

W2A.17
In-service Crosstalk Monitoring and Tracing for Short-reach Space-division Multiplexing (SDM) Optical Networks, Ruijie Luo[1], Nan Hua[1], Yufang Yu[1], Zhizhen Zhong[1], Zhongying Wu[2], Juhao Li[2], Xiaoping Zheng[1], Bingkun Zhou[1]; [1]*Tsinghua Univ., China;* [2]*Peking Univ., China*. We propose an in-service crosstalk monitoring and tracing method using fine-grained monitoring optical time slices for SDM-enabled intra-datacenter and HPC systems. Modal crosstalk below -36.01dB was successfully monitored and traced in an MMF transmission system.

W2A.18
OCBridge: An Efficient Topology Reconfiguration Strategy in Optical Data Center Network, YiNan Tang[1], Hongxiang Guo[1], Jian Wu[1]; [1]*Beijing Univ. of Posts and Telecommunications, China*. We proposed an algorithm named OCBridge to effectively reconfigure the topology of optical data center network. Simulation results show it can reduce hotspots and achieve better throughput in data center networks compared with relative proposals.

W2A • Joint Poster Session I—Continued

W2A.19
Real-time 100 Gbps/λ/core NRZ and EDB IM/DD Transmission over 10 km Multicore Fiber, Rui Lin[2,1], Xiaodan Pang[1,3], Joris Van Kerrebrouck[4], Michiel Verplaetse[4], Oskars Ozolins[3], Aleksejs Udalcovs[3], Lu Zhang[1], Lin Gan[2], Ming Tang[2], Songnian Fu[2], Richard J. Schatz[1], Urban Westergren[1], Sergei Popov[1], Deming Liu[2], Weijun Tong[5], Timothy D. Keulenaer[6], Guy Torfs[4], Johan Bauwelinck[4], Xin Yin[4], Jiajia Chen[1]; [1]*The Royal Inst. of Technology (KTH), Sweden;* [2]*School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China;* [3]*Networking and Transmission Laboratory, RISE Acreo AB , Sweden;* [4]*Department of Information Technology(INTEC)-iDLab, Univ. of Ghent-imec, Belgium;* [5]*Yangtze Optical Fiber and Cable Joint Stock Limited Company (YOFC), China;* [6]*BiFAST spin-off of IDLab, Ghent Univ.-imec, Belgium.* A BiCMOS chip-based Real-time IM/DD spatial division multiplexing system is experimentally demonstrated for short-reach communications. 100 Gbps/λ/core NRZ and EDB transmission is achieved below 7%-overhead HD-fEC limit after 10km 7-core fiber with optical dispersion compensation.

W2A.20
Wavelength Reuse for Scalable Multicasting: A Cross-layer Perspective, Houman Rastegarfar[1], Kamran Keykhosravi[2], Erik Agrell[2], Nasser Peyghambarian[1]; [1]*Univ. of Arizona, USA;* [2]*Chalmers Univ. of Technology, Sweden.* We examine the feasibility of ultrahigh-scale datacenter multicasting by simultaneously taking into account the choice of architecture, modulation, and coding. Our Monte Carlo simulations indicate the dominant impact of in-band crosstalk on the throughput performance.

W2A.21
SDN-based Application Driven In-band Adaptive Coding in Data Centers, Mingwei Yang[1], Houman Rastegarfar[1], Ivan Djordjevic[1]; [1]*Univ. of Arizona, USA.* A software-defined adaptive coding scheme is experimentally implemented and evaluated for 50 Gbps 4-PAM optical switching in wavelength-routing DCs. Up to 1 dB reduction in transmission power is achieved with switching latencies of hundreds of milliseconds.

W2A.22
Demonstration of 30Gbit/s QPSK-to-PAM4 Data-format and Wavelength Conversion to Enable All-optical Gateway from Long-haul to Datacenter , Ahmad Fallahpour[1], Amirhossein Mohajerin Ariaei[1], Ahmed Almaiman[1], Yinwen Cao[1], Fatemeh Alishahi[1], Changjing Bao[1], Peicheng Liao[1], Bishara Shamee[1], Morteza Ziyadi[1], Dmitry Starodubov[1], Moshe Tur[2], Carsten Langrock[3], Martin Fejer[3], Joseph Touch[4], Alan E. Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Tel Aviv Univ., Israel;* [3]*Stanford Univ., USA;* [4]*Information Sciences Inst., USA.* A tunable optical QPSK to PAM4 converter is experimentally demonstrated. The proposed method maps four symbols of QPSK signal to four different amplitude levels which can be directly detected in photo-diode. Open eyes are obtained for the detected PAM4 signal.

W2A.23
A Novel Scalable and Low Latency Hybrid Data Center Network Architecture based on Flow Controlled Fast Optical Switches, Fu L. Yan[1], Gonzalo Guelbenzu[1], Nicola Calabretta[1]; [1]*TU/e, Netherlands.* We present a novel hybrid DCN based on flow-controlled fast optical switches. Results show packet loss <1.4E-5 and latency <2.4μs for 100,000 servers (0.3 load). Costs and power consumptions are also compared with current technologies.

W2A.24
All-fiber Full-duplex Bidirectional Data Transmission for Data Center Networks (DCNs) over 2-km Orbital Angular Momentum (OAM) Fiber using Commercial SFP+ Transceivers and Mode Selective Couplers, Yifan Zhao[1], Yize Liang[1], Xinzhou Su[1], Wei Zhou[1], Yan Luo[1], Zongyuan Huang[1], Shuhui Li[1], Jian Wang[1]; [1]*Huazhong Univ of Science and Technology, China.* We demonstrate an all-fiber full-duplex bidirectional data transmission link for data center networks (DCNs) using orbital angular momentum (OAM) multiplexing over 2-km OAM fiber. Commercial SFP+ transceivers and mode selective couplers are employed to excite OAM_{+1} and OAM_{-1} modes carrying 10Gbase-t signals, achieving less than -15.11 dB crosstalk.

W2A.25
BlockONet: Blockchain-based Trusted Cloud Radio over Optical Fiber Network for 5G Fronthaul, Hui Yang[1], Yizhen Wu[2], Jie Zhang[1], Haowei Zheng[1], Yuefeng Ji[1], Young Lee[2]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Huawei Technologies Co., Ltd, China.* We first present a blockchain-based trusted cloud radio over optical fiber network architecture (BlockONet) with anonymous access identification for future 5G fronthaul. The feasibility and efficiency of the architecture are experimentally verified on our testbed.

W2A.26
Demonstration of Triple-mode Controller Recovery with Multiple Integrated Services in SDN, Muhammad Irfan[1], Muhammad Faizan[1], Syed Waleed[1], Maheen Iqbal[2]; [1]*FEST, Iqra Univ., Pakistan;* [2]*Designing, Cybernet, Pakistan.* We present the first completely orchestrated and automatic failure recovery scheme employed various services utilizing the intelligence of SDN. Our proposed three step mechanism can safeguard controllers from failures with a recovery time of 11ms.

W2A.27
Scheduling Algorithm for All-optical Switch under Non-uniform Traffic Condition, Jongtae Song[1], Kyeong-Eun Han[1], Dae-Ub Kim[1], Chansung Park[1], Kwangjoon Kim[1]; [1]*ETRI, Korea.* We introduce a scheduling algorithm for all-optical data center switch supporting high throughput and low delay for non-uniform traffic condition. Simulation result shows that our system achieves 100% throughput and shorter delay than existing methods.

W2A.28
Maximizing Availability-weighted Slice Capacity for Sliceable Wireless-optical Broadband Access Networks, Ke Chen[1], Chao Guo[1], Longfei Li[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*Department of Electrical and Electronic Engineering, Indian institution of technology, India.* We consider a sliceable wireless-optical broadband access network (WOBAN) to maximize its availability-weighted capacity. For this, Integer Linear Programming (ILP) models and corresponding heuristic algorithms are developed. Simulation results show the proposed approaches are efficient to maximize slices' availability-weighted capacity.

W2A.29
Demonstration of XHaul Architecture for 5G over Converged SDN Fiber Network, Jim (Shihuan) Zou[1], Anthony Magee[2], Michael Eiselt[1], Andrew Straw[2], Ardel Iddin[2], Tim Edwards[2], Paul Wright[3], Andrew Lord[3]; [1]*ADVA Optical Networking SE, Germany;* [2]*ADVA Optical Networking Ltd., UK;* [3]*British Telecommunications, UK.* We proposed and showcased an XHaul architecture converging front- and backhaul for 5G networks. The solution leveraged agile functional placement and hosting for cell sites and agile optical transmission based on the wavelength-agnostic WDM technology.

W2A.30
Extended Reach 40km Transmission of C-band Real-time 53.125 Gbps PAM-4 Enabled with a Photonic Integrated Tunable Lattice Filter Dispersion Compensator, Grant M. Brodnick[1], Catia Pinho[2], Frank Chang[3], Daniel J. Blumenthal[1]; [1]*Univ. of California Santa Barbara, USA;* [2]*Instituto de Telecomunicações (IT), Univ. of Aveiro, Portugal;* [3]*Inphi Corp., USA.* Reach-extended C-band transmission of Real-time 53.125Gbps PAM-4 data over 40km SSMF is enabled using a dispersion compensating photonic-integrated programmable lattice filter. Transmission of 100GHz spaced channels error-free below the FEC threshold is demonstrated.

W2A.31
100Gb/s PolMux-NRZ Transmission at 1550nm over 30km Single Mode Fiber Enabled by a Silicon Photonics Optical Dispersion Compensator, Vito Sorianello[1], Gabriele De Angelis[1], Francesco Fresi[2], Fabio Cavaliere[4], Luca Potì[1], Michele Midrio[3], Marco Romagnoli[1]; [1]*CNIT - National Laboratory of Photonic Networks, Italy;* [2]*Scuola Superiore Sant'Anna, TeCIP Inst., Italy;* [3]*CNIT - Università degli Studi di Udine, Italy;* [4]*Ericsson, Italy.* We demonstrate 100Gb/s PolMux-nRZ transmission at 1550nm over 30km SM-fiber with a power penalty of 2.5dB by means of a silicon photonics integrated circuit including optical dispersion compensators and an integrated polarization active controller.

W2A.32
Single-wire DAC/ADC Control and Feedback of Silicon Photonic Ring Resonator Circuits for Wavelength Switching, Ziyi Zhu[1], Alexander Gazman[1], David Gidony[1], Yiwen Shen[1], Kenneth Shepard[1], Keren Bergman[1]; [1]*Columbia Univ., USA.* We develop a robust and scalable solution for control and feedback of silicon photonic circuits used for optical unicast and multicast. A single-wire DAC and ADC feedback architecture is evaluated with 20Gb/s PAM-4 data streams.

Show Floor Programming

COBO Specification Overview and Next Steps
COBO
10:15–11:45

Product Showcase
Huawei
10:15–10:45
For more details, see page 23

■ **Network Operator Summit**

Keynote:
10:30–11:00

Panel I: The Role of "Open Transport" in the New Metro and Inter-data-center Architectures
11:00–12:30

Product Showcase *Xilinx*
11:00–11:30
For more details, see page 23

Product Showcase *Xilinx*
11:30–12:00
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Server Fibreless Optical Networking
Open19 Foundation
12:00–13:00

Product Showcase
Hengtong Optic-Electric Co., Ltd.
12:00–12:30
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Product Showcase
Colorchip
12:30–13:00
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Product Showcase
ATOP
13:00–13:30
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Industry Visions for a Converged Optical Networking Roadmap
ON2020
13:15–15:15

Next Generation Coherent: Architectures and Technologies
Session Sponsored by Acacia Communications
13:30–14:30

■ **Network Operator Summit**

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30–15:00

W2A • Joint Poster Session I—Continued

W2A.33
Experimental Demonstration of Real-time Add/Drop Operations in DSP-enabled Flexible ROADMs for Converging Fixed and Mobile Networks, Roger P. Giddings[1], Ehab Al-Rawachy[1,2], Jianming Tang[1]; *[1]Bangor Univ., UK; [2]College of Electronics Engineering, Ninevah Univ., Iraq.* Low-cost and versatile DSP-enabled ROADMs with excellent transparency are vital for seamlessly converging fixed and mobile networks, we demonstrate, for the first time, Real-time add/drop operations providing switching at sub-wavelength and spectrally-overlapped sub-band levels.

W2A.34
Coarse and Fine Continuously Tunable Optical Delay Using the Time of Flight in Fiber Bragg Gratings and Wavelength Conversion, Ahmed Almaiman[1], Yinwen Cao[1], Amirhossein Mohajerin-Ariae[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Dmitry Starodubov[1], Peicheng Liao[1], Changjing Bao[1], Shlomo Zach[2], Nadav Cohen[2], Moshe Tur[2], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]School of Electrical Engineering, Tel Aviv Univ., Israel.* We use the time-of-flight in arrayed, channelized and chirped fiber Bragg gratings along with wavelength conversion in PPLN waveguides to build continuously coarse- and fine-tunable delay line. More than 20 ns continues tuning range is achieved with less-than-0.6dB OSNR penalty for a 10 GBaud QPSK signal.

W2A.35
Doubly Differential Two-level 8PSK for Enabling Optical Packet Switching in Coherent Systems, Fan Liu[1,2], Yi Lin[2], Anthony J. Walsh[2], Yonglin Yu[1], Liam Barry[2]; *[1]Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; [2]School of Electronic Engineering, Dublin City Univ., Ireland.* We demonstrate that a doubly differential two-level 8 phase shift keying (PSK) modulation format can be used to reduce the waiting time in packet switched spectrally efficient coherent systems due to high frequency offset tolerance

W2A.36
A Novel OFDM Training Sequence Strategy Based on a Sliding Window for Optical Burst Traffic, Bing Han[1], Paulette Gavignet[1], Erwan Pincemin[1]; *[1]Orange Labs, France.* In order to mitigate the transients occurring in the coherent receivers facing an absence of burst, a novel channel estimator, using a sliding window, is proposed here for optical DP-16QAM-OFDM burst traffic. Our experimental results show a significant performance gain of this new estimator resulting in an error threshold cancellation.

W2A.37
Photonic Generation of Pseudo Random Microwave Waveform based on a Random Fiber Grating, Hong Deng[1], Ping Lu[2], Stephen Mihailov[2], Jianping Yao[1]; *[1]Univ. of Ottawa, Canada; [2]National Research Council Canada, Canada.* A photonic approach to pseudo-random waveform generation based on a random fiber grating is proposed and demonstrated. A pseudo-random waveform with a temporal duration of 10 ns and a time-bandwidth product of 322.4 is demonstrated.

W2A.38
Reconfigurable Inter-core Switching within Multicore Fiber, Ruoxu Wang[1], Qiong Wu[1], Ming Tang[1], Songnian Fu[1], Deming Liu[1]; *[1]Huazhong Univ. of Sci.& Tech., China.* We achieved a reconfigurable inter-core signal switching using directional bending of long period grating in multicore fibers. Wavelength selective switching of 6×224 Gb/s OFDM signals in 3 cores is experimentally demonstrated.

W2A.39
A 10Gb/s All-optical Match-line for Optical Content Addressable Memory (CAM) Rows, George Mourgias-Alexandris[1], Chris Vagionas[1], Apostolos Tsakyridis[1], Pavlos Maniotis[1], Nikos Pleros[1]; *[1]Department of Informatics, Aristotle Univ. of Thessaloniki, Greece.* We experimentally demonstrate the first all-optical match-line for a two Optical CAM-cell-based address look-up row, using wavelength encoding and an AWG-multiplexer. Error-free 2-bit search memory operation at 10Gb/s is experimentally demonstrated.

W2A.40
Optical Signal Processing in the Discrete Nonlinear Frequency Domain, Shi Li[1], Jonas Koch[1], Stephan Pachnicke[1]; *[1]Christian-Albrechts Univ. zu Kiel, Germany.* We investigate the possibility of optical signal processing (OSP) for the nonlinear discrete spectrum. OSP is used to generate and separate a fifth-order soliton optically by a novel transmitter and receiver setup with highly-nonlinear fiber.

W2A.41
Automatic Tuning of Microring-based Hitless Reconfigurable Add-drop Filters, Douglas O. Aguiar[1], Maziyar Milanizadeh[1], Emanuele Guglielmi[1], Francesco Zanetto[1], Marco Sampietro[1], Francesco Morichetti[1], Andrea Melloni[1]; *[1]Politecnico di Milano, Italy.* Exploiting a novel channel labeling scheme, we demonstrate automated tuning and locking of a hitless silicon microring-resonator filter. Hitless tuning with more than 30 dB isolation is achieved, enabling application in add-drop reconfigurable architectures.

W2A.42
Gray-encoded Set-partition 8QAM for Per-wavelength 200-Gb/s Application, Wei-Ren Peng[1], Yanjun Zhu[1], An Li[1], Yan Cui[1], Yusheng Bai[1]; *[1]High-speed Optical Lab, Futurewei Technologies Inc., USA.* A simple Gray-encoding scheme, using a pair of small-sized tables, to reduce the non-gray penalty for set-partition 8QAM is demonstrated. The experimental results show that a 42.3-GBd PDM-sP-8QAM signal, for 200-gb/s per channel use, can exhibit ~0.5-dB OSNR benefit with this encoding method

W2A.43
Convolutional Neural Network based Nonlinear Classifier for 112-Gbps High Speed Optical Link, C. Y. Chuang[1], Li-Chun Liu[1], Chia-Chien Wei[2], Jun-Jie Liu[1], Lindor Henrickson[4], Wan-Jou Huang[3], Chih-Lin Wang[3], Young-Kai Chen[5], Jyehong Chen[1]; *[1]National Chiao Tung Univ., Taiwan; [2]Department of Photonics, National Sun Yat-Sen Univ., Taiwan; [3]Integrated Photonics Department, Industrial Technology Research Inst., Taiwan; [4]Department of Electrical Engineering, National Chung Hsing Univ., Taiwan; [5]Nokia Bell Labs, USA.* We have designed a novel convolutional neural network based nonlinear classifier that outperforms traditional Volterra nonlinear equalizers. A BER of 3.5×10^{-6} is obtained for a 112-gbps PAM4 EML-based optical link over 40-km SMF transmission.

W2A.44
Probabilistically Shaped 1024-QAM OFDM Transmission in an IM-DD System, Jianyang Shi[1,2], Junwen Zhang[2], Nan Chi[1], Yi Cai[2], Xinying Li[2,1], Yun Zhang[2], Qi Zhang[3], Jianjun Yu[2]; *[1]Fudan, China; [2]ZTE, USA; [3]Beijing Univ. of Posts and Telecommunication, China.* We experimentally demonstrate a 28.95 Gbit/s/λ PS-1024-QAM DFT-s OFDM over 40 km of SSMF in a low-cost IM-DD system. A 1.85 Gbit/s capacity increment is achieved using PS- 1024-QAM format. To the best of our knowledge, this is the first time to employ high order PS- QAM format in OFDM modulation.

W2A.45
First Demonstration of FPGA-based Hitless Flexible Receiver with Blind Modulation Format Identification, Gengchen Liu[1], Kaiqi Zhang[1], Roberto Proietti[1], Hongbo Lu[1], Zhi Ding[1], S. J. Ben Yoo[1]; *[1]Univ. of California Davis, USA.* We present a FPGA-based flexible receiver with Real-time DSP at 10 GBd that adapts to the modulation format of the incoming signal automatically. Hitless switching between 1.024-μs long QPSK and 16-QAM frames has been experimentally demonstrated.

W2A.46
100Gbps IM/DD Transmission over 25km SSMF using 20G-class DML and PIN Enabled by Machine Learning, Peixuan Li[1], Lilin Yi[1], Lei Xue[1], Weisheng Hu[1]; *[1]Shanghai Jiao Tong Univ., China.* We experimentally demonstrate 100Gb/s/lambda IM/DD transmission over 25km SSMF using 20G-class DML and PIN enabled by convolutional neural network based equalization technique. Transmission performance in C-band and O-band using PAM-8 and PAM-16 are compared.

W2A.47
Single-wavelength, Single-photodiode per Polarization 276 Gb/s PDM 8-QAM over 100 km of SSMF, Rafael Puerta[1,2], Tomohiro Yamauchi[2], Takahito Tanimura[2], Yuichi Akiyama[2], Tomoo Takahara[2], Idelfonso Tafur Monroy[3], Takeshi Hoshida[2]; *[1]Technical Univ. of Denmark, Denmark; [2]Fujitsu Laboratories Ltd, Japan; [3]Eindhoven Univ. of Technology, Netherlands.* We demonstrate heterodyne detection of 46 GBaud polarization-multiplexed QAM signaling using a transmitter based on a conventional dual-polarization I/Q modulator and a receiver consisting of two single-photodiodes without a local oscillator.

W2A.48
Exploring the Stokes Space by Non-orthogonal Polarization Modulation for a Smooth Upgrade of Optical Link Capacity, Bernhard Schrenk[1], Hannes Hübel[1]; *[1]AIT Austrian Inst. of Technology, Austria.* We experimentally demonstrate transmission at 4 bits/symbol through 2-dimensional Stokes vector modulation while retaining a direct detection receiver. Robustness against channel-induced state transform is confirmed through measurements over 40 km of field-deployed fiber.

W2A.49
Real-time Carrier Phase Recovery for 16-QAM Utilizing the Nonlinear Least Squares Algorithm, Ioannis-Vatistas Kostalampros[1], Christos Spatharakis[1], Konstantinos Maragos[1], Georgios Lentaris[1], Nikos Argyris[1], Stefanos Dris[2], Andre Richter[2], Hercules Avramopoulos[1], Dimitrios Soudris[1]; *[1]National Technical Univ. of Athens, Greece; [2]VPIphotonics GmbH, Germany.* NLS carrier phase recovery for 16-QAM is implemented Real-time on a Virtex-7 FPGA and demonstrated at 36 GBd, operating on simulated and experimental data; 64 GBd operation is shown to be feasible in larger FPGAs.

W2A.50
Single-IFFT Real-time Layered/Enhanced ACO-OFDM Transmitter, Qibing Wang[1], Binhuang Song[1], Bill Corcoran[1], Arthur Lowery[1]; *[1]Monash Univ., Australia.* Using only a single middle-out Fourier transform, we are able to generate all layers of a 16-QAM-encoded layered/enhanced ACO-OFDM transmitter. We transmit over 10-km of standard single-mode fiber without error propagation in the receiver.

W2A • Joint Poster Session I—Continued

W2A.51
Laser Phase Noise Tolerance of Probabilistically-shaped Constellations, Seiji Okamoto[1], Fukutaro Hamaoka[1], Masanori Nakamura[1], Yoshiaki Kisaka[1]; [1]*Nippon Telegraph & Telephone Corp, Japan.* We numerically confirmed that required-oSNR gain was obtained by probabilistically-shaped 64/256 QAM compared with uniformly-shaped 16/64 QAM in not only arbitrary white Gaussian noise condition but also in phase noise condition.

W2A.52
System Performance Enhancement using Asymmetric Multi-dimensional PAM for Short-reach Optical Transmission, Shuto Yamamoto[1], Akira Masuda[1], Hiroki Taniguchi[1], Mitsunori Fukutoku[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan.* We propose an asymmetric multi-dimensional modulation that enhances the total performance in multi-lane IM-dD transmissions. Simulation results show the improvement of system tolerance to chromatic dispersion and experimental results show the applicability to 120-gb/s signals.

W2A.53
A PMD-adaptive DBP Receiver based on SNR Optimization, Gabriele Liga[1], Cristian B. Czegledi[2], Polina Bayvel[1]; [1]*UCL, UK;* [2]*Electrical Engineering, Chalmers Univ. of Technology, Sweden.* We propose a novel adaptive digital backpropagation (DBP) scheme that tracks the fiber polarization-mode dispersion via the optimization of the signal-to-noise ratio. Gains of up to 1.4 dB over conventional DBP are achieved.

W2A.54
Flexible Transmission Enabled by Novel M²-QAM Formats with Record Distance - Spectral Efficiency Tuneability, Fred Buchali[1], Qian Hu[1], Mathieu Chagnon[1], Karsten Schuh[1], Sergejs Makovejs[2]; [1]*Nokia Bell Labs, Germany;* [2]*Corning, UK.* We propose a variable M²-QAM format and coding scheme and demonstrate record distance - spectral efficiency tuneability by 6.4 bit/s/Hz and ΔL≈18x, respectively, at 400 and 600 Gb/s per carrier and report record terrestrial reach for high spectral efficient up to 256QAM.

W2A.55
Kramers-Kronig Detection of Polarization Multiplexing Signals by a Single-ended Photodiode, Qiulin Zhang[1], Chester Shu[1]; [1]*CUHK, Hong Kong.* We demonstrate that polarization multiplexing signals can be detected by a single-ended photodiode after beating with a pair of orthogonal and staggered carriers. The feasibility of proposed scheme is verified by 8GBaud PDM-QPSK signals.

W2A.56
Weighted Filter Penalty Prediction for QoT Estimation, Camille Delezoide[1], Petros Ramantanis[1], Patricia Layec[1]; [1]*Nokia Bell Labs, France.* We experimentally show that noise distribution with regards to filters impacts the QoT by several dB. We thus propose a new QoT prediction method achieving up to 1.7dB margin reduction for links with high hop counts.

W2A.57
Numerical Estimation of Nonlinear Impairments in a 62.5 µm MMF for MDM Transmission, Marius Brehler[1], Peter M. Krummrich[1]; [1]*Chair for High Frequency Technology, TU Dortmund, Germany.* The nonlinear propagation in a multimode fiber using 78 spatial modes is investigated numerically. We show that nonlinear impairments are no obstacle for using fibers with such a high mode count for mode-division multiplexing.

W2A.58
Digital Nonlinearity Compensation Considering Signal Spectral Broadening Effects in Dispersion-managed Systems, Boris P. Karanov[1], Tianhua Xu[2], Nikita A. Shevchenko[1], Domaniç Lavery[1], Gabriele Liga[1], Robert Killey[1], Polina Bayvel[1]; [1]*Univ. College London, UK;* [2]*Univ. of Warwick, UK.* The impact of spectral broadening on the performance of nonlinear compensation applied to legacy submarine dispersion-managed links is studied. An additional 2.2 dB SNR improvement at optimum launch power is achieved by optimizing the compensated bandwidth.

W2A.59
Noise Robust Receiver for Eigenvalue Communication Systems, Rasmus T. Jones[1], Simone Gaiarin[1], Metodi P. Yankov[1], Darko Zibar[1]; [1]*Technical Univ. of Denmark, Denmark.* It is demonstrated that in the presence of losses and noise a receiver based on the direct NFT is not optimal. A neural network based receiver is proposed that enables transmission of up to 2000km.

W2A.60
Challenges and Advances of Direct Detection Systems for DCI and Metro Networks, Jinlong Wei[1], Qiang Zhang[1], Liang Zhang[1], Nebojša Stojanović[1], Cristian Prodaniuc[1], Fotini Karinou[1], Changsong Xie[1]; [1]*Huawei Technologies Duesseldorf GmbH, Germany.* A 56-gb/s NRZ direct detection system is demonstrated with record 15.5-dB (16.2-dB) OSNR sensitivity over 320-km (640-km) SMF. Furthermore, the challenges and recent advances of direct detection systems for DCIs and metro networks are reviewed.

W2A.61
Successive Four-dimensional Stokes-space Direct Detection, Amir Tasbihi[1], Frank R. Kschischang[1]; [1]*Electrical and Computer Engineering Department, Univ. of Toronto, Canada.* We present a successive detection scheme for the fourth dimension in a four-dimensional Stokes space direct detection receiver. At the expense of a small number of electrical-domain computations, the additional information rate can be substantial.

W2A.62
An Efficient Nonlinear Equalizer for 40-Gb/s PAM4-PON Systems, Xizi Tang[1], Ji Zhou[1], Mengqi Guo[1], Jia Qi[1], Tiantian Zhang[1], Zhenshan Zhang[1], Yueming Lu[1], Yaojun Qiao[1]; [1]*Beijing Univ Posts & Telecommunications, China.* We firstly propose a decision feedback equalizer (DFE) based on a novel nonlinear filter structure for 40-gb/s PAM4-PON systems. The proposed equalizer achieves similar performance with Volterra DFE at only 21.7% tap numbers.

W2A.63
Noise Prediction and Cancellation Algorithm for the Bandwidth Limited PAM-4 System in the Presence of Intra-channel Homodyne Crosstalk, Tianjian Zuo[1], Tianyu Song[1], Sen Zhang[1], Lei Liu[1], Weiqiang Cheng[2], Xiaofei Xu[1]; [1]*Huawei Technologies Co., Ltd., China;* [2]*China Mobile Research Inst., China.* As a low-complexity solution, this paper proposes the use of noise prediction and cancellation (NPC) algorithm in a PAM-4 system, which achieves similar performance as the MLSE based PAM-4 receiver and increases tolerance towards intra-channel homodyne crosstalk.

W2A.64
Improving the Performance of Coherent Quantum Communications with Bayesian Inference, Sebastian Kleis[1], Christian G. Schaeffer[1]; [1]*Helmut Schmidt Univ, Univ of FAF Hamburg, Germany.* Laser phase noise limits reach in coherent quantum communications. We experimentally investigate the usefulness of Bayesian inference methods to reduce the impact. An excess noise improvement of 15% is shown, resulting in improved reach and key rate.

12:30–14:00 Unopposed Exhibit-only Time, *Exhibit Hall* (concessions available)

Show Floor Programming

COBO Specification Overview and Next Steps
COBO
10:15–11:45

Product Showcase
Huawei
10:15–10:45
For more details, see page 23

■ **Network Operator Summit**

Keynote:
10:30–11:00

Panel I: The Role of "Open Transport" in the New Metro and Inter-data-center Architectures
11:00–12:30

Product Showcase *Xilinx*
11:00–11:30
For more details, see page 23

Product Showcase *Xilinx*
11:30–12:00
For more details, see page 23

Server Fibreless Optical Networking
Open19 Foundation
12:00–13:00

Product Showcase
Hengtong Optic-Electric Co., Ltd.
12:00–12:30
For more details, see page 23

Product Showcase
Colorchip
12:30–13:00
For more details, see page 23

Product Showcase
ATOP
13:00–13:30
For more details, see page 23

Industry Visions for a Converged Optical Networking Roadmap
ON2020
13:15–15:15

Next Generation Coherent: Architectures and Technologies
Session Sponsored by Acacia Communications
13:30–14:30

■ **Network Operator Summit**

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30–15:00

Room 2

14:00–16:00
W3A • Nonlinearity Compensation
Presider: Andrea Carena; Politecnico di Torino, Italy

W3A.1 • 14:00 Tutorial

Equalization for Combating the Effects of Nonlinear Noise in Long-haul Transmission: Limits And Prospects, Mark Shtaif[1]; [1]*Tel-aviv Univ., Israel.* The tutorial will review the relevant mechanisms of nonlinear interference in modern coherent fiber communications systems, and discuss various methods for mitigating their effect. The prospects of nonlinearity mitigation will be considered.

Mark Shtaif is a Professor of EE at the School of EE at Tel-Aviv University, and currently he is functioning as the head of this school. His research interests include nonlinear-propagation, optical nonlinearities, polarization phenomena, communication theory, and signal processing. Prof. Shtaif is a fellow of the IEEE and OSA.

Room 6C

14:00–16:00
W3B • Connected OFCity Challenge 2018: Lighting Up the Emerging World
Organizers: Marco Ruffini, Trinity College Dublin, Ireland; Inder Monga, ESNet, USA; Jun Shan Wey, ZTE, USA

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

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

The scenarios will provide a realistic insight into the major issues faced by the communications industry in the region, which include network reliability, environmental restrictions, limited funds, regulatory issues, and more.

We will discuss the development of a cost-effective broadband infrastructure to foster pervasive education, health care and future services, using technologies such as interactive AR/VR. Audience members will gain awareness of optimal design solutions for broadband development and important services in emerging regions. In this updated edition, the audience will play an active role in the challenge, not only to provide feedback and questions, but also have a chance to show their knowledge on this emerging area.

Requirement Task Group:

CSquared
Based in Nairobi, Kenya, CSquared is a large whole sale broadband infrastructure supplier of metro fiber and WiFi networks to mobile operators and ISPs in Ghana, Uganda, and soon in Liberia.

Network Startup Resource Center (NSRC)
NSRC is a non-profit group that develops Internet infrastructure and network engineering expertise throughout Africa, Asia-Pacific, Latin America/Caribbean, and the Middle East. NSRC collaborates with network operators, universities, and government agencies in the regions to improve Internet access and services.

Design Task Groups:

Alibaba
AIS (Alibaba Infrastructure Service) is to develop innovative technologies and build efficient infrastructure to support Alibaba online platforms and Alibaba cloud services.

Google

Room 6D

14:00–16:00
W3C • Multimode Fibers for Datacenters
Presider: Ming-Jun Li; Corning Research & Development Corp, USA

W3C.1 • 14:00 Invited

Recent Advances on MMFs for WDM and MDM, Denis Molin[1], Marianne Bigot[1], Adrian Amezcua-Correa[1], Pierre Sillard[1]; [1]*PRYSMIANGROUP, USA.* We show how multimode fibers, that have always been flexible transmission media, can be adapted to wavelength division multiplexing in data communications and mode division multiplexing in telecommunications to keep up with capacity increase.

W3C.2 • 14:30 Invited

Universal Fibers for Both Single-mode and Multimode Transmissions in Data Centers, Xin Chen[2], Jason E. Hurley[2], Jeff Stone[2], Aramais Zakharian[2], Bruce Chow[3], Doug Coleman[1], Ming-Jun Li[2]; [1]*3. Corning Optical Communications LLC, USA;* [2]*1. Corning Research and Development Corporation, USA;* [3]*2. Corning Optical Fiber and Cable, Corning Incorporated, USA.* Universal fiber is a single medium that can support both multimode and single-mode transmission. We present the fiber properties and system performance at 100G and discuss the benefit of using it in data center.

Room 6E

14:00–16:00
W3D • Fiber Amplifiers
Presider: Francesca Parmigiani; Univ. of Southampton, UK

W3D.1 • 14:00 Tutorial

Optical Amplification in Extended Wavelength Windows, Mikhail Melkumov[1]; [1]*Fiber Lasers and Amplifiers Lab., FORC RAS, Russia.* Latest results in the field of bismuth-doped fiber amplifiers for extended wavelength windows are presented. Fundamental and technical challenges toward the development of efficient amplifiers on bismuth fibers are discussed.

Mikhail Melkumov received M.S. in 2001 from Lomonosov Moscow State University, Russia. In 2006 he received his PhD degree from the Prokhorov General Physics Institute of the Russian Academy of Sciences. Currently he is a head of Fiber lasers and amplifiers laboratory in the Fiber optics research center (FORC RAS), Moscow, Russia. His research interests include: Raman and Rear-earth-doped fiber lasers, Bi-doped fiber lasers and amplifiers, spectroscopy of active centers in silica-based glasses and fibers.

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Room 6F

14:00–16:00
W3E • All-optical Impairment Mitigation
Presider: Robert Elschner; Fraunhofer Inst Nachricht Henrich-Hertz, Germany

W3E.1 • 14:00 Top Scored
Optical Mitigation of Inter-channel Crosstalk for Multiple Spectrally Overlapped 40-Gbit/s QPSK WDM Channels using Nonlinear Wave Mixing, Amirhossein Mohajerin Ariaei[1], Fatemeh Alishahi[1], Ahmad Fallahpour[1], Yinwen Cao[1], Ahmed Almaiman[1], Changjing Bao[1], Peicheng Liao[1], Bishara Shamee[1], Joseph Touch[2], Moshe Tur[3], Carsten Langrock[4], Martin Fejer[4], Alan E. Willner[1]; *[1]Univ. of Southern California (USC), USA; [2]Information Sciences Inst., USA; [3]Tel Aviv Univ., Israel; [4]Stanford Univ., USA.* Using an all-optical method and without multi-channel detection, the inter-channel interferences of overlapped WDM data channels are mitigated simultaneously. We experimentally demonstrate performance improvement for 20-GBaud QPSK overlapped channels under different channel spacing.

W3E.2 • 14:15
Optical Phase Conjugation in Installed Optical Networks, Gabriel Saavedra[1], Yujia Sun[2], Kyle Bottrill[2], Lidia Galdino[1], Zhixin Liu[1], Francesca Parmigiani[2], David J. Richardson[2], Periklis Petropoulos[2], Robert Killey[1], Polina Bayvel[1]; *[1]Univ. College London, UK; [2]Univ. of Southampton, UK.* We demonstrate a record throughput of 5.7 Tbit/s employing an optical phase conjugator to jointly compensate chromatic dispersion and increase the nonlinear threshold in an installed optical network using commercially available lumped amplifiers.

W3E.3 • 14:30
Link-placement Characterization of Optical Phase Conjugation for Nonlinearity Compensation, Francesco Da Ros[1], Metodi P. Yankov[1], Edson P. da Silva[1], Mads Lillieholm[1], Søren Forchhammer[1], Michael Galili[1], Leif K. Oxenlowe[1]; *[1]Technical Univ. of Denmark, Denmark.* The impact of the OPC offset on the nonlinearity compensation is experimentally investigated, achieving gains up to 0.6-dB SNR and 0.17-bit/symbol mutual information with optimal mid-link OPC for dispersion-compensated transmission up to 966 km.

W3E.4 • 14:45
Silicon Waveguide with Lateral p-i-n Diode for Nonlinearity Compensation by On-chip Optical Phase Conjugation, Andrzej Gajda[1], Francesco Da Ros[2], Edson P. da Silva[2], Anna M. Peczek[3], Erik Liebig[4], Andreas Mai[1], Michael Galili[2], Leif K. Oxenlowe[2], Klaus Petermann[4], Lars Zimmermann[1]; *[1]IHP, Germany; [2]DTU Fotonik, Technical Univ. of Denmark, , Denmark; [3]IHP Solutions GmbH, Germany; [4]Institut für Hochfrequenz- und Halbleiter-systemtechnologien, TU Berlin, Germany.* A 1-dB Q-factor improvement through optical phase conjugation in a silicon waveguide with a lateral p-i-n diode enables BER<HD-fEC after 644-km dispersion-compensated transmission for all channels of a 5xWDM 16-QAM single-polarization signal.

Room 9

14:00–15:45
W3F • Nanophotonic Devices
Presider: Maura Raburn; Google, USA

W3F.1 • 14:00 Invited
Nanophotonic Technology for Chip-based Quantum Light Sources, Marcelo I. Davanco[1]; *[1]National Inst of Standards & Technology, USA.* Nanophotonics is enabling for photonic quantum technologies, providing means to effectively control light-matter interactions on chip. This talk will discuss the use of nanophotonic geometries for creation of efficient and versatile chip-based quantum light sources.

W3F.2 • 14:30
Low Threshold Current 1.3 μm Fabry-Perot III-V Quantum Dot Lasers on (001) Si with Superior Reliability, Daehwan Jung[1], Justin Norman[1], Mj Kennedy[1], Robert Herrick[2], Chen Shang[1], Catherine Jan[1], Art Gossard[1], John Bowers[1]; *[1]UCSB, USA; [2]Intel Corp., USA.* We report 1.3 μm quantum dot lasers monolithically integrated on Si substrate. A threshold current of 6.2 mA, output power of 185 mW, and excellent device lifetimes of more than a million hours were achieved

W3F.3 • 14:45
High Performance 1550 nm Quantum Dot Semiconductor Optical Amplifiers Operating at 25-100 °C, Ori Eyal[1,4], Amnon Willinger[1,2], Vissarion B. Mikhelashvili[1], Saddam Banyoudeh[3], Florian Schnabel[3], Vitalii Sichkovsky[3], Johann P. Reithmaier[3], Gad Eisenstein[1,4]; *[1]Electrical Engineering, Technion-Israeli Inst. of Technology, Israel; [2]Spectra Physics Tel Aviv, Israel; [3]Technological Physics, Inst. of Nano-structure Technologies and Analytics, Univ. of Kassel, Germany; [4]Russel Berrier Nanotechnology Inst., Israel.* We report static and dynamic properties of 1550 nm quantum dot semiconductor optical amplifiers operating at 25-100 ^{0}C. Amplification of a single and two 28 Gbit/s channels separated by 2 nm were demonstrated over the entire temperature range.

Show Floor Programming

Industry Visions for a Converged Optical Networking Roadmap
ON2020
13:15–15:15

Next Generation Coherent: Architectures and Technologies
Session Sponsored by Acacia Communications
13:30–14:30

■ **Network Operator Summit**

Panel II: On the Road to 100G PON (Beyond 10G PON)
13:30–15:00

■ **MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality**
15:30–17:00

Machine Learning: Developing Efficiency in Customer Networks
15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?
15:45–17:00

Room 2

W3A • Nonlinearity Compensation—Continued

W3A.2 • 15:00
Multi-dimensional Pulse-shaping FIR Filter for Nonlinear Interference Alignment, Toshiaki Koike-Akino[1], David Millar[1], Kieran Parsons[1], Keisuke Kojima[1]; [1]*Mitsubishi Electric Research Labs, USA*. We design an irregular pulse-shaping filter to mitigate nonlinear distortion in optical fiber transmission. Our optimized four-dimensional filter allowing nonphysical rotations achieves up to 0.55dB gain over standard root-raised-cosine (RRC) Nyquist shaping.

W3A.3 • 15:15
FEC-assisted Perturbation-based Nonlinear Compensation for WDM Systems, Edson Porto da Silva[1], Metodi P. Yankov[1], Toshio Morioka[1], Leif K. Oxenlowe[1]; [1]*DTU Fotonik, Denmark*. A FEC-assisted iterative perturbation-based nonlinear post-compensation scheme is proposed and experimentally investigated. Improved compensation performance is observed for a 5xWDM-dP 32-GBd dispersion-uncompensated transmission over 3500 and 840 km for 16QAM and 64QAM, respectively.

W3A.4 • 15:30
Nonlinear Interference Mitigation via Deep Neural Networks, Christian Häger[1,2], Henry D. Pfister[2]; [1]*Department of Electrical Engineering, Chalmers Univ. of Technology, Sweden;* [2]*Department of Electrical and Computer Engineering, Duke Univ., USA*. A neural-network-based approach is presented to efficiently implement digital backpropagation (DBP). For a 32x100km fiber-optic link, the resulting "learned" DBP significantly reduces the complexity compared to conventional DBP implementations.

W3A.5 • 15:45
Efficient Time-domain DBP using Random Step-size and Multi-band Quantization, Celestino Sanches Martins[1], Luca Bertignono[2], Antonello Nespola[3], Andrea Carena[2], Fernando Guiomar[2], Armando Pinto[1]; [1]*Universidade de Aveiro, Portugal;* [2]*Politecnico di Torino, Italy;* [3]*Istituto Superiore Mario Boella, Italy*. Employing step-size randomization and multi-band quantization, we propose a reduced complexity time-domain (TD) digital backpropagation (DBP) and experimentally demonstrate penalty-free operation at an average number of ~ 4 bits per FIR coefficient.

Room 6C

W3B • Connected OFCity Challenge 2018: Lighting Up the Emerging World—Continued

Room 6D

W3C • Multimode Fibers for Datacenters—Continued

W3C.3 • 15:00
Study of Dispersion Compensating Multimode Fiber for Future VCSEL PAM-4 Channels at Data Rates over 100 Gb/s, Asher S. Novick[1], Jose Castro[1], Bulent Kose[1], Yu Huang[1], Rick Pimpinella[1], Brett Lane[1]; [1]*CRD, Panduit, USA*. We study the effects of dispersion compensating multimode fiber for data rates exceeding 100 GB/s using 4-level pulse amplitude modulation (PAM-4). Performances of different data rates, fibers, and VCSEL bias currents are compared.

W3C.4 • 15:15
Spectral Dependence of Multimode Fiber Modal Bandwidth, Jose Castro[1], Rick Pimpinella[1], Bulent Kose[1], Yu Huang[1], Asher S. Novick[1], Brett Lane[1]; [1]*Panduit, USA*. We theoretically and experimentally investigate the modal bandwidth spectral dependence behavior of OM3 and OM4 fibers in support of the development of future multi-wavelength transceivers.

W3C.5 • 15:30
Graded-index Seven-core Fiber Optimized for High Density and Ultra-Wideband Parallel Transmission Application, Yinping Liu[1], Lin Ma[1], Chen Yang[2], Weijun Tong[2], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*State Key Laboratory of Optical Fiber and Cable Manufacture Technology, China*. We propose graded-index seven-core fiber optimized for high density and ultra-wideband parallel transmission application. We demonstrated both 1 km-propagation at 850 nm and 12.4 km-propagation at 1310 nm simultaneously at a data rate of 7×10-gb/s.

W3C.6 • 15:45
Reference-less Method for Computing the Transmission Matrix of a Multimode Fiber, Moussa N'Gom[1], Theodore B. Norris[1], Eric Michielssen[1], Raj Nadakuditi[1]; [1]*Univ. of Michigan - Ann Arbor, USA*. A simple imaging system together with complex semidefinite programming is used to generate the transmission matrix of a multimode fiber. The optical design does not contain a reference arm and no interferometric measurements are required. The input signal is modulated in phase to induce strong mode interference at the fiber output.

Room 6E

W3D • Fiber Amplifiers—Continued

W3D.2 • 15:00
C + L Band Distributed Few-mode Raman Amplification with Flattened Gain for Mode-Division-multiplexed Optical Transmission Over 75-km Few-mode Fiber, Jiaxiong Li[1], Lulu Wang[2], Jiangbing Du[1], Zuyuan He[1], Chengkun Cai[2], Long Zhu[2], Andong Wang[2], Jian Wang[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Huazhong Univ. of Science and Technology, China*. We first experimentally demonstrate a C + L band few-mode Raman amplifier with 4-dB flat on-off gain. In the1530-1605 nm range, the wavelength dependent gain for both LP01 and LP11 modes is less than 0.6-dB. The amplifier was successfully employed in MDM transmission.

W3D.3 • 15:15
Low Penalty, Dual Stage, Broadband Discrete Raman Amplifier for High Capacity WDM Metro Networks, Lukasz Krzczanowicz[1], Md. Asif Iqbal[1], Ian Phillips[1], Mingming Tan[1], Pavel Skvortcov[1], Paul Harper[1], Wladek Forysiak[1]; [1]*Aston Univ., UK*. We present a broadband (>70nm), dual stage, discrete Raman amplifier built with small and standard core fibre with ~19.5dB net gain. We transmit 120Gb/s DP-QPSK signals over 3040km with 38 amplifications for a preFEC BER<$3.8x10^{-3}$.

W3D.4 • 15:30
Reduced Crosstalk, Polarization Insensitive Fiber Optical Parametric Amplifier (PI FOPA) for WDM Applications, Marc F. Stephens[1], Vladimir Gordienko[1], Nick Doran[1]; [1]*Aston Univ., UK*. We demonstrate a novel PI FOPA architecture with up to 11.5dB reduction of WDM crosstalk over a conventional scheme when amplifying 22 channels at 10dB to 20dB net gain. Noise figure is increased by ≤1.5dB.

W3D.5 • 15:45
Optical Add-drop Filter based on Raman-assisted Phase-sensitive Amplifiers, Bofang Zheng[1], Qijie Xie[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong*. We demonstrate an optical add-drop filter based on Raman-assisted phase-sensitive amplifiers. Bit error rate measurements with multi-channel signals in QPSK and 16-QAM formats reveal its enhanced selectivity over conventional phase-sensitive amplifiers.

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

Room 6F

W3E • All-optical Impairment Mitigation—Continued

W3E.5 • 15:00 **Tutorial**

All-optical Signal Processing Techniques for Flexible Networks, Alan E. Willner[1]; [1]*Univ. of Southern California, USA.* This tutorial will highlight challenges in achieving efficient flexible optical networks. Various optical approaches that enable key functions will be discussed, including: dynamic bandwidth allocation, format conversion, increasing spectral efficiency, and phase-sensitive operations.

Alan Willner (Ph.D., Columbia) worked at AT&T Bell Labs and Bellcore, and is the Sample Chaired Professor of Engineering at USC. He received the following: Member US National Academy of Eng., Int'l Fellow U.K. Royal Society of Eng., IEEE Eric Sumner Award, NSF Presidential Faculty Fellows Award from White House, IET JJ Thomson Medal, Packard Foundation Fellowship, OSA Forman Eng. Excellence Award, IEEE Photonics Society Eng. Achievement Award, SPIE President's Award, Fellow National Academy of Inventors, Globecom Best Paper Award, and Eddy Best Technical Paper Award from Pennwell. He is a AAAS, IEEE, OSA, and SPIE Fellow. He was co-chair of National Academies' Committee on Optics and Photonics, president OSA, president IEEE Photonics Society, Optics Letters editor-in-chief, Journal of Lightwave Technology editor-in-chief, IEEE JSTQE editor-in-chief, CLEO general co-chair, and OFC steering/program committee member.

Room 9

W3F • Nanophotonic Devices—Continued

W3F.4 • 15:00

Lateral Current Injection Membrane Buried Heterostructure Lasers Integrated on 200-nm-thick Si Waveguide, Takuma Aihara[1], Tatsurou Hiraki[1], Koji Takeda[1], Koichi Hasebe[1], Takuro Fujii[1], Tai Tsuchizawa[1], Takaaki Kakitsuka[1], Shinji Matsuo[1]; [1]*NTT, Japan.* Heterogeneous integration of lasers and 200-nm-thick Si waveguides is the key to realizing high-performance transmitters. A 500-μm-long DFB laser on Si waveguide exhibits 4.6-mW fiber coupled output power at 25°C and lasing up to 130°C.

W3F.5 • 15:15 **Invited**

Nanoscale Optical Modulators: Application Drivers and Recent Developments, Gordon A. Keeler[1]; [1]*DARPA, USA.* Tiny active components will enable a new generation of integrated photonics for communications and sensing. This paper discusses highlights from ongoing programs that seek to reduce the footprint of optical modulators using strong light-matter interaction.

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

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

Show Floor Programming

Industry Visions for a Converged Optical Networking Roadmap
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13:15–15:15

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Machine Learning: Developing Efficiency in Customer Networks
15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?
15:45–17:00

Room 1A

16:30–18:30
W4A • Deployable Transport Networks
Presider: Jean-luc Auge; Orange Labs, France

W4A.1 • 16:30 Invited
Benefits of Performance Awareness in Coherent Dynamic Optical Networks, Juraj Slovak[1], Wolfgang Schairer[1], Maximilian Herrmann[1], Klaus Pulverer[1], Enrico Torrengo[2]; [1]*Coriant R&D, Germany;* [2]*Coriant R&D, Portugal*. Awareness of optical network performance and its accurate prediction enables squeezing of margins allocated for stable operation. We discuss potential of online performance assessment by leveraging functionalities of bandwidth variable transponders in flexible optical networks.

Room 1B

16:30–18:30
W4B • Radio-over-fiber II
Presider: Gee-Kung Chang; Georgia Inst. of Technology, USA

W4B.1 • 16:30 Tutorial
Microwave Photonic Systems for Sensing Applications, Dalma Novak[1], Rod Waterhouse[1]; [1]*Pharad, LLC, USA*. Microwave photonic (MWP) technology provides many opportunities to extend the capabilities of a range of systems. This tutorial discusses recent advances in MWP technologies for application in remote sensing systems.

Dalma Novak is VP of Engineering at Pharad, LLC; a high technology company located in MD developing advanced RF-over-fiber and antenna products. She is a Fellow of the IEEE and has over 25 years of experience working in the fields of optical and wireless telecommunications. She has published more than 280 papers in these technical areas, including seven book chapters. Prior to Pharad she held positions at The University of Melbourne, Dorsal Networks, and Corvis Corporation. She received her PhD in Electrical Engineering in 1992. Dalma was the President of the IEEE Photonics Society for 2014-2015.

Room 2

16:30–17:45
W4C • Space Division Multiplexed Transmission
Presider: Takayuki Mizuno; NTT Network Innovation Laboratories, Japan

W4C.1 • 16:30 Top Scored
266.1-Tbit/s Repeatered Transmission over 90.4-km 6-mode Fiber Using Dual C+L-band 6-mode EDFA, Yuta Wakayama[1], Daiki Soma[1], Shohei Beppu[1], Seiya Sumita[1], Koji Igarashi[1,2], Takehiro Tsuritani[1]; [1]*KDDI Research, Inc., Japan;* [2]*Osaka Univ., Japan*. We demonstrate 6-mode and 580-wavelength multiplexed transmission with an in-line dual C+L-band cladding-pumped few-mode EDFA. A total capacity of 266.1 Tbit/s is achieved over a 90.4-km transmission line at a spectral efficiency of 36.7 bit/s/Hz.

W4C.2 • 16:45 Top Scored
Mode-multiplexed 16-QAM Transmission over 2400-km Large-effective-area Depressed-cladding 3-mode Fiber, John van Weerdenburg[1,2], Roland Ryf[1], Roberto A. Alvarez-Aguirre[1,3], Nicolas K. Fontaine[1], René-Jean Essiambre[1], Haoshuo Chen[1], Juan Carlos Alvarado Zacarias[1,3], Rodrigo Amezcua Correa[3], Simon Gross[4], Nicolas Riesen[5], Michael Withford[4], David Peckham[6], Alan McCurdy[6], Robert Lingle[6], Ton Koonen[2], Chigo Okonkwo[2]; [1]*Nokia Bell Labs, USA;* [2]*Inst. for Photonic Integration, Eindhoven Univ. of Technology, Netherlands;* [3]*CREOL, the Univ. of Central Florida, USA;* [4]*MQ Photonics Research Centre, Macquarie Univ.,, Australia;* [5]*Univ. of South Australia, Australia;* [6]*OFS, USA*. We demonstrate 2400 km mode-multiplexed 16-QAM transmission over a low DMGD (27.1 ps/km) and low MDL (1.75 dB) 3-mode fiber link. The large effective-area 3-mode fiber is shown to outperform a standard single-mode fiber for distances up to 4500km

Room 6C

16:30–18:15
W4D • High Speed Devices for Data Centers
Presider: Kazuhiko Kurata; PETRA, Japan

W4D.1 • 16:30
56 Gb/s DAC-less and DSP-free PAM-4 Using A Silicon Photonic Dual-drive Michelson Interferometric Modulator, Rui Li[1], David Patel[1], Eslam El-Fiky[1], Alireza Samani[1], Zhenping Xing[1], Yun Wang[1], David V. Plant[1]; [1]*McGill Univ., Canada*. We present a silicon photonic dual-drive Michelson interferometric modulator for DAC-less and DSP-free PAM-4 signal generation. 56 Gb/s PAM-4 transmission over 2 km of SSMF is successfully achieved, with a BER below HD FEC threshold.

W4D.2 • 16:45
106-Gbit/s PAM4 40-km Transmission using an Avalanche Photodiode with 42-gHz Bandwidth, Masahiro Nada[1], Toshihide Yoshimatsu[2], Yoshifumi Muramoto[2], Tetsuichiro Ohno[2], Nakajima Fumito[1], Hideaki Matsuzaki[1]; [1]*NTT Device Technology Laboratories, NTT, Japan;* [2]*NTT Device innovation Center, Japan*. 106-gbit/s PAM4 transmission over 40-km single-mode fiber is demonstrated using an avalanche photodiode (APD) with a gap-grading layer for high-speed operation. The APD shows maximum bandwidth of 42GHz with 0.5-a/W responsivity at unity gain.

Room 6D

16:30–18:30
W4E • Kramers-Kronig Receivers
Presider: Andre Richter; VPIphotonics, Germany

W4E.1 • 16:30 Invited
A Comparative Study of Technology Options for Next Generation Intra- and Inter-datacenter Interconnects, Mohamed Morsy-Osman[1], David V. Plant[1]; [1]*McGill Univ., Canada*. We review signaling schemes, whose receiver relies on signal self-beating or signal beating with accompanying CW tone, and compare their transceiver architectures, spectral efficiencies, receiver bandwidths and enabling digital signal processing.

Room 6E

16:30–18:30
W4F • Machine Learning for Network Control and Management
Presider: Mazen Khaddam; Cox Communications, Inc., USA

W4F.1 • 16:30
Realizing AI-assisted Multi-layer Restoration in a Software-defined IP-over-EON with Deep Learning: An Experimental Study, Siqi Liu[1], Baojia Li[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China*. By using deep learning, we experimentally demonstrate AI-assisted multi-layer restoration in an IP-over-EON, which recovers affected traffic timely with congestion-avoidance rerouting.

W4F.2 • 16:45
Deep-RMSA: A Deep-reinforcement-learning Routing, Modulation and Spectrum Assignment Agent for Elastic Optical Networks, Xiaoliang Chen[1], Jiannan Guo[2], Zuqing Zhu[2], Roberto Proietti[1], Alberto Castro[1], S. J. Ben Yoo[1]; [1]*Univ. of California Davis, USA;* [2]*Univ. of Science and Technology of China, China*. This paper demonstrates Deep-RMSA, a deep reinforcement learning based self-learning RMSA agent that can learn successful policies from dynamic network operations while realizing cognitive and autonomous RMSA in EONs.

Room 6F

16:30–18:30
W4G • Advanced Technologies for High Speed PON
Presider: Volker Jungnickel; Fraunhofer HHI, Germany

W4G.1 • 16:30
High-order Polarization Overlay for Future Optical Access, Bernhard Schrenk[1], Fabian Laudenbach[1], Hannes Hübel[1]; [1]*AIT Austrian Inst. of Technology, Austria*. We demonstrate non-orthogonal Stokes vector modulation at 4 bits/symbol while retaining direct photodetection. 20Gb/s transmission is obtained over a loss budget of 22dB. Pilot-assisted receiver training mitigates the polarization transform along 40km of field-deployed fiber.

W4G.2 • 16:45
Bandwidth Enhancement for an Optical Access Link by using a Frequency Interleaved DAC, Christian Schmidt[1,2], Christoph Kottke[1,2], Ronald Freund[1,2], Volker Jungnickel[1]; [1]*Fraunhofer HHI, Germany;* [2]*Technical Univ. of Berlin, Germany.* We present the experimental realization of the frequency interleaved DAC concept for an IM/DD based access link. The first open 80 GBd PAM-4 electrical eye diagram of the frequency-interleaved DAC without using post-equalization is presented.

Room 7AB

16:30–18:30
W4H • Panel: 2020 Network Vision 5G and Optical Networking
Organizers: Douglas Freimuth, IBM TJ Watson Research Center, USA; Gee-Kung Chang, Georgia Inst. of Technology, USA; Christina Lim, Univ. of Melbourne, Australia; Rod Waterhouse, Pharad, LLC, USA

The network vision of 2020 includes 5G and the multitude of services and applications it enables. 5G and these associated services and applications will have a potential impact on the backhaul, fronthaul, metro and access networks. Carriers and optical equipment providers are working together to define product roadmaps to handle the increased bandwidth and potential architectural changes 5G will bring to the optical infrastructure.This panel will discuss the potential changes 5G will bring to the optical network. We will discuss business drivers, progress in standards and prototypes and services/applications including IoT, media distribution and mobile broadband services. We will further discuss bandwidth requirements in the backhaul and fronthaul optical networks and potential architectural changes when new applications and services are enabled on 5G.

Panelists:

Philippe Chanclou, *Orange Labs, France Telecom, France*

Paul Littlewood, *Ciena, USA*

Jun Shan Wey, *ZTE, USA*

Tod Sizer, *Nokia, USA*

Room 8

16:30–18:30
W4I • Data Center Traffic Management
Presider: Ken-ichi Kitayama; Graduate School for the Creation of New, Japan

W4I.1 • 16:30 Invited
Network Traffic Characteristics of Data Centers in the Wild Revisited, Theophilus Benson[1]; [1]*Brown Univ., USA.* Although there is tremendous interest in designing improved networks for data centers, very little is known about the network-level traffic characteristics of current data centers. In this paper, we conduct an empirical study of the network traffic in 10 data centers belonging to three different types of organizations, including university, enterprise, and cloud data centers. Our definition of cloud data centers includes not only data centers employed by large online service providers offering Internet-facing applications, but also data centers used to host data-intensive (MapReduce style) applications. We collect and analyze SNMP statistics, topology, and packet-level traces. We examine the range of applications deployed in these data centers and their placement, the flow-level and packet-level transmission properties of these applications, and their impact on network utilization, link utilization, congestion, and packet drops. We describe the implications of the observed traffic patterns for data center internal traffic engineering as well as for recently proposed architectures for data center networks.

Room 9

16:30–18:00
W4J • Imaging, Spectroscopy, and Transmission
Presider: Maxim Bolshtyansky; TE SubCom, USA

W4J.1 • 16:30 Invited
Image Transmission through Multi-mode Fibers, Demetri Psaltis[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland.* Myltimode fibers can support more than a hundred thousand modes. We will show escribe how to transmit images with the same number of pixels as the number of modes.

Room 10

16:30–18:30
W4K • Novel Fiber Concepts
Presider: Francesco Poletti; Univ. of Southampton, UK

W4K.1 • 16:30 Invited
Orbital Angular Momentum (OAM) of Light in Fiber, Siddharth Ramachandran[1]; [1]*Boston Univ., USA. Light carries spin (polarization) and orbital angular momentum (OAM). We review recent work on the stable propagation and nonlinear properties of such states in fibers, which have spawned applications ranging from telecommunications to biomedical imaging.*

Show Floor Programming

■ **MW Panel IV: High Capacity, Long Distance Transport: Innovation vs. Reality**
15:30–17:00

Machine Learning: Developing Efficiency in Customer Networks
15:30–17:00

400G Standards, MSAs and Related Technologies: What is on the Horizon?
15:45–17:00

Room 1A

W4A • Deployable Transport Networks—Continued

W4A.2 • 17:00 Invited

Extension of SDN Networks to the Satellite Domain; Integration of a SDN Enabled WAN Network, with Terrestrial and Submarine Elements, with Command and Control of Multiple Satellite Constellations, Robert Kimball[1], Richard Williams[2], John Connelly[1], Nathen McNeal[1], Charles Cynamon[2], Robert Hughes[2], Kurt Richardson[2]; [1]*Ciena Corporation, USA;* [2]*LinQuest Corporation, USA.* Dynamic software controlled terrestrial fiber networks combined with an agile satellite communications (SATCOM) service management system increases system resiliency; bringing resources into the operational environment. This includes failover of critical communications paths over different technologies.

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Room 1B

W4B • Radio-over-fiber II—Continued

Room 2

W4C • Space Division Multiplexed Transmission—Continued

W4C.3 • 17:00

93.34 Tbit/s/mode (280 Tbit/s) Transmission in a 3-mode Graded-index Few-mode Fiber, Georg Rademacher[1], Ruben S. Luis[1], Benjamin J. Puttnam[1], Roland Ryf[2], Hideaki Furukawa[1], Ryo Maruyama[3], Kazuhiko Aikawa[3], Akihiro Maruta[4], Yoshinari Awaji[1], Naoya Wada[1]; [1]*National Inst of Information & Comm Tech, Japan;* [2]*Nokia Bell Labs, USA;* [3]*Fujikura Ltd, Japan;* [4]*Osaka Univ., Japan.* We transmit 381x24.5 GBaud PDM-64-QAM modulated channels per mode of a 30 km graded-index three-mode fiber, resulting in a record per-mode data-rate of 93.34 TBit/s and an aggregated net-data-rate of 280 Tbit/s.

W4C.4 • 17:15

First Demonstration of Orbital Angular Momentum (OAM) Distributed Raman Amplifier over 18-km OAM Fiber with Data-carrying OAM Multiplexing and Wavelength-division Multiplexing, Long Zhu[1], Jiaxiong Li[2], Guoxuan Zhu[3], Lulu Wang[1], Chengkun Cai[1], Andong Wang[1], Shuhui Li[1], Ming Tang[1], Zuyuan He[2], Siyuan Yu[3,4], Cheng Du[5], Wenyong Luo[5], Jie Liu[3], Jiangbing Du[2], Jian Wang[1]; [1]*Wuhan National Lab for Optoelectronics, China;* [2]*Shanghai Jiao Tong Univ., China;* [3]*Sun Yat-sen Univ., China;* [4]*Univ. of Bristol, UK;* [5]*Fiberhome Telecommunication Technologies Co. Ltd, China.* We propose and demonstrate orbital angular momentum (OAM) distributed Raman amplifier over 18-km OAM fiber with 2 OAM modes multiplexing and 16 wavelength-division multiplexing. The on-off gain of the two OAM modes are about 3 dB from 1530 nm to 1565 nm.

Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.3 • 17:00

Monolithic Dual-polarization Silicon Modulator for 180 Gb/s DMT Signal Transmission, Xinru Wu[1,2], Yang Hong[1], Yeyu Tong[1], Lin Chang[2], Wen Zhou[1], Lian-Kuan Chen[1], John Bowers[2], Hon Ki Tsang[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*Univ. of California, Santa Barbara, USA.* We present a monolithic dual-polarization modulator based on two silicon Mach-Zehnder modulators and a two-dimensional grating coupler as the dual-polarization output coupler. Data transmission at 180 Gb/s using discrete multi-tone modulation is demonstrated.

W4D.4 • 17:15 Invited

100 Gb/s DAC-less and DSP-free Transmitters using GeSi EAMs for Short-reach Optical Interconnects, Jochem Verbist[1,2], Michiel Verplaetse[1], Joris Lambrecht[1], Ashwyn Srinivasan[3], Joris Van Kerrebrouck[1], Peter De Heyn[3], Timothy De Keulenaer[4], Ramses Pierco[4], Renato Vaernewyck[4], Arno Vyncke[4], Philippe Absil[3], Guy Torfs[1], Xin Yin[1], Joris Van Campenhout[3], Gunther Roelkens[2], Johan Bauwelinck[1]; [1]*IDLab, Ghent Univ. - IMEC, Belgium;* [2]*Photonics Research Group, Ghent Univ. - imec, Belgium;* [3]*imec, Belgium;* [4]*BiFast, Belgium.* We present single-lane 100-gb/s NRZ, electrical duobinary and PAM-4 transmitters using silicon photonics GeSi electro-absorption modulators. No DSP, DAC or traveling-wave structures are required, enabling compact and low-power transceivers for data center interconnects.

Room 6D

W4E • Kramers-Kronig Receivers—Continued

W4E.2 • 17:00 Top Scored

Kramers-Kronig Receiver without Digital Upsampling, Tianwai Bo[1], Hoon Kim[1]; [1]*School of Electrical Engineering, KAIST, Korea.* We propose a new Kramers-Kronig receiver which does not require digital upsampling. The experimental demonstration performed in 80-km transmission of 112-gb/s SSB-OFDM signal shows that our proposed receiver exhibits similar performance to the conventional one.

W4E.3 • 17:15 Top Scored

Transmission of 80-GBd 16-QAM over 300 km and Kramers-Kronig Reception using a Low-complexity FIR Hilbert Filter Approximation, Christoph Füllner[1], Stefan Wolf[1], Juned Kemal[1], Joachim Lutz[2], Lars Altenhain[2], Rolf Schmid[2], Wolfgang Freude[1], Christian Koos[1], Sebastian Randel[1]; [1]*Karlsruhe Inst. of Technology, Germany;* [2]*Micram Microelectronic GmbH, Germany.* We demonstrate Kramers-Kronig reception at a net rate of 267 Gb/s using a single high-bandwidth photodiode. We propose a low complexity DSP implementation, analyze back-to-back performance, and show transmission over up to 300 km.

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.3 • 17:00

ANN-based Transfer Learning for QoT Prediction in Real-time Mixed Line-rate Systems, Weiyang Mo[1,2], Yuekai Huang[2], Shaoliang Zhang[2], Ezra Ip[2], Daniel Kilper[1], Yoshiaki Aono[3], Tsutomu Tajima[3]; [1]*The Univ. of Arizona, USA;* [2]*NEC Laboratories America, USA;* [3]*Converged Network Division, NEC Corporation, Japan.* Quality of transmission prediction for Real-time mixed line-rate systems is realized using artificial neural network based transfer learning with SDN orchestrating. 0.42 dB accuracy is achieved with a 1000 to 20 reduction in training samples.

W4F.4 • 17:15 Invited

Machine Learning-assisted Management of a Virtualized Network, Michiaki Hayashi[1]; [1]*KDDI Research Inc., Japan.* Toward proactive network management, machine learning is expected especially from enhancing fault management and sustaining automated system itself. This paper describes the motives for using machine learning, and provides some proof-of-concept demonstrations.

Room 6F

W4G • Advanced Technologies for High Speed PON—Continued

W4G.3 • 17:00 Invited

Bandwidth Extension Techniques for High-speed Access Networks, Christoph Kottke[2,1], Christian Schmidt[2,1], Ronald Freund[2,1], Volker Jungnickel[2]; [1]*Technische Universität Berlin, Germany;* [2]*Fraunhofer Heinrich Hertz Inst., Germany.* Recent advances in bandwidth extension techniques for high-speed access environments are presented together with own transmission experiments. Current issues and critical aspects are highlighted.

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

Room 7AB

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

Room 8

W4I • Data Center Traffic Management—Continued

W4I.2 • 17:00

Leveraging Deep Learning to Achieve Efficient Resource Allocation with Traffic Evaluation in Datacenter Optical Networks, Ao Yu[1], Hui Yang[1], Wei Bai[1], Linkuan He[1], Hongyun Xiao[2], Jie Zhang[1]; [1]*BUPT, China;* [2]*ZTE, China.* This paper first presents a deep learning-based resource allocation strategy supported by global evaluate factor in intra-datacenter optical networks. Numerical results show the proposed strategy improves traffic prediction accuracy and has superior performance.

W4I.3 • 17:15

A Novel Buffering Design and Performance Evaluation of Optical Flow Switch with Smart Scheduling Algorithms, Yuh-Jiuh Cheng[1], Yhi Shiau[1], Bor-Tauo Chen[1]; [1]*Broadband Networks Laboratory, TL, Chunghwa Telecom Co., Ltd., Taiwan.* In this paper, buffering design and performance evaluation of OFS with smart scheduling algorithms are proposed. The buffer scheduling methods are used for a hybrid switching module or all-optical switching module on the data center.

Room 9

W4J • Imaging, Spectroscopy, and Transmission—Continued

W4J.2 • 17:00

Demonstration of Stable 3x10 Gb/s Mode Group-multiplexed Transmission over a 20 km Few-mode Fiber, Huiyuan Liu[1], He Wen[1,3], Juan Carlos Alvarado Zacarias[1], Jose Enrique Antonio-Lopez[1], Ning Wang[1], Pierre Sillard[2], Rodrigo Amezcua Correa[1], Guifang Li[1,3]; [1]*Univ. of Central Florida, USA;* [2]*Prysmian Group, France;* [3]*Tianjin Univ., China.* We experimentally demonstrate stable 3x10 Gb/s mode group-multiplexed transmission over a 20 km few-mode fiber using OOK modulation and direct detection. Stability in transmission was achieved by combining all degenerate modes at the receiver.

W4J.3 • 17:15

3×4×10-gb/s MDM-wDM Transmission over 21-km OM3 MMF with OOK Modulation and Direct Detection, Zhongying Wu[1], Juhao Li[1], Yu Tian[1], Dawei Ge[1], Jinglong Zhu[1], Yichi Zhang[2], Jinyi Yu[1], Zhengbin Li[1], Zhangyuan Chen[1], Yongqi He[1]; [1]*Peking Univ., China;* [2]*Fiberhome, China.* 3×4×10-gb/s IM-dD MDM-wDM transmission over OM3 MMF is experimentally demonstrated. 3 modes with large Δn_{eff} are selectively excited as independent-spatial-channels. Enabled by cascaded low-modal-crosstalk MSCs and wavelength-interleaved scheme, a record distance of 21-km is achieved.

Room 10

W4K • Novel Fiber Concepts—Continued

W4K.2 • 17:00

Phase Purity Measurement of Ultra-broadband Orbital Angular Momentum Mode Excited by Meta-facet Few-mode Fiber, Yifan Zhao[1], Jinrun Zhang[1], Jian Wang[1]; [1]*Huazhong Univ of Science and Technology, China.* We design and fabricate metasurface on the facet of few-mode fiber (FMF). Ultra-broadband orbital angular momentum modes (OAM_{+1} and OAM_{-1}) are excited in the fiber and the phase purity from 1480-1640 nm is measured through one interferogram image.

W4K.3 • 17:15

Design of a Weakly-coupled Ring-core FMF and Demonstration of 6-mode 10-km IM/DD Transmission, Dawei Ge[1], Juhao Li[1], Jinglong Zhu[1], Lei Shen[2], Yuyang Gao[1], Jinyi Yu[1], Zhongying Wu[1], Zhengbin Li[1], Zhangyuan Chen[1], Yongqi He[1]; [1]*Peking Univ., China;* [2]*Yangtze Optical Fibre and Cable Joint Stock Limited Company, China.* We design and fabricate a weakly-coupled ring-core 6-mode fiber with a minimum Δn_{eff} of 1.49×10^{-3}, based on which 6-mode 10-km MDM transmission with OOK modulation and direct detection is experimentally demonstrated.

Room 1A

W4A • Deployable Transport Networks—Continued

W4A.3 • 17:30 Top Scored
Capacity Enhancement in Optical Networks using Margin Extraction, Mohammad Sheikh Zefreh[1]; [1]*Ciena, Canada*. In this paper, the value of margin extraction in optical networks is investigated. Simulation results for a sample network show that up to 64% of multi-rate transponders can run with higher rates using extracted margins.

W4A.4 • 17:45
Demonstration of Automatic Connection Pair Discovery and Path Setting in Filter-less Point-to-point WDM Systems, Yutaka Takita[1], Masatake Miyabe[1], Kazuyuki Tajima[1], Hiroshi Tomonaga[1], Takeshi Hoshida[1]; [1]*Fujitsu Labs. Ltd., Japan*. We propose the filter-less point-to-point WDM system with IP-layer driven automatic optical connection pair discovery and path setting function. We confirmed its basic operation in a 100km span 32-lambdas WDM system with enhanced transponders.

Room 1B

W4B • Radio-over-fiber II—Continued

W4B.2 • 17:30
Experimental Study of Distributed Massive MIMO (DM-MIMO) in In-building Fiber-wireless Networks , Solomon T. Abraha[1], Dave Castellana[1], Xiaojun Liang[1], Anthony Ng'oma[1], Andrey Kobyakov[1]; [1]*Corning Research & Development Corp, USA*. We experimentally demonstrate up to 10x greater system capacity using Distributed M- MIMO compared to Collocated M-MIMO in an indoor environment. We further show that user-distribution-driven antenna placement enables significant infrastructure savings up to 25%.

W4B.3 • 17:45
Mitigation of Multi-user Access Impairments in 5G A-RoF-based Mobile Fronthaul utilizing Machine Learning for an Artificial Neural Network Nonlinear Equalizer, Siming Liu[1,2], Yahya M. Alfadhli[2], Shuyi Shen[2], Huiping Tian[1], Gee-Kung Chang[2]; [1]*School of Information and Communication Engineering, Beijing Univ. of Posts and Telecom, China;* [2]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA*. We propose a complex-valued multi-level artificial neural network nonlinear equalizer (ANN-nLE) in bandwidth-efficient radio-over-fiber mobile fronthaul systems. The proposed ANN-nLE is experimentally demonstrated to mitigate intra/inter-band interferences caused by nonlinear impairments in multi-user environments.

Room 2

W4C • Space Division Multiplexed Transmission—Continued

W4C.5 • 17:30
Maximum Submarine Cable Capacity Analysis with C-band, C+L-band, and Multicore Fiber C-band, John D. Downie[1]; [1]*Corning Research & Development Corp, USA*. The maximum capacity of fixed voltage submarine cables is analyzed using single-core fibers with C- and C+L-band systems, and multi-core fibers (MCFs) with C-band transmission. Extra losses for C+L and MCFs limit their relative capacity.

Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.5 • 17:45
Assessment of Integrated Ge Franz-Keldysh Modulator for Discrete Multi-tone Modulation, Yeyu Tong[1], Xinru Wu[1], Jie Liu[1], Chester Shu[1], Hon Ki Tsang[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong*. We measure the second order and third order spurious-free dynamic range (SFDR) of an integrated germanium Franz-Keldysh modulator and assess the performance of the modulator for discrete multi-tone (DMT) modulation without any pre-equalization.

Room 6D

W4E • Kramers-Kronig Receivers—Continued

W4E.4 • 17:30
Comparison of Chromatic Dispersion Sensitivity between Kramers-Kronig and SSBI Iterative Cancellation Receiver, Chuanbowen Sun[1], Di Che[1], William Shieh[1]; [1]*Univ. of Melbourne, Australia*. We compare the chromatic dispersion (CD) sensitivity between Kramers-Kronig (KK) and SSBI iterative cancellation (IC) receiver. It is shown that KK receiver is sensitive to CD while IC receiver is insensitive.

W4E.5 • 17:45
264 Gb/s Twin-SSB-KK Direct Detection Transmission Enabled by MIMO Processing, Sujie Fan[1,2], Qunbi Zhuge[3,2], Zhenping Xing[2], Kuo Zhang[2], Thang M. Hoang[2], Mohamed Morsy-Osman[2], Mohammed Sowailem[2], Yan Li[1], Jian Wu[1], David V. Plant[2]; [1]*Beijing Univ. of Posts & Telecommunications, China;* [2]*McGill Univ., Canada;* [3]*Ciena Corporation, Canada*. We experimentally demonstrate the transmission of 264 Gb/s twin-SSB-KK single carrier signals over 80 km SSMF, enabled by a novel MIMO processing scheme to remove the crosstalk between sideband signals caused by non-ideal optical filters.

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.5 • 17:45
Field Trial of Gaussian Process Learning of Function-agnostic Channel Performance Under Uncertainty, Fanchao Meng[1], Shuangyi Yan[1], Konstantinos Nikolovgenis[1], Yanni Ou[1], Rui Wang[1], Yu Bi[1], Emilio H. Salas[1], Reza Nejabati[1], Dimitra E. Simeonidou[1]; [1]*Univ. of Bristol, UK*. We successfully demonstrated a novel performance learning method using monitoring and Gaussian process. After 436km dark fiber transmission the model captures most of the test data with 0.7dB mean error and enables robust QoT predictor.

W4G • Advanced Technologies for High Speed PON—Continued

W4G.4 • 17:30
60-km Transmission of 28-Gb/s QPSK Upstream Signal in RSOA-based WDM PON Using SBS Suppression Technique, Daeho Kim[1], Byung Gon Kim[1], Hoon Kim[1]; *[1]KAIST, Korea.* We experimentally demonstrate the 60-km transmission of 28-gb/s QPSK signal in RSOA-based coherent WDM-PON. The frequency dithering of seed laser and fast carrier-phase estimator are employed to suppress SBS and track the laser's phase, respectively.

W4G.5 • 17:45
Novel DDM-OFDM-PON with Hybrid Sub-Nyquist Sampling Rates Featuring Heterogeneous ONUs with Different Capacities, Jhih-Hao Hsu[1], Min Yu[1], Chia Chien Wei[1], Chi-Hsiang Lin[2], Chun-Ting Lin[2], Fumin Liu[3], Lei Zhou[3], LiMing Fang[3]; *[1]National Sun Yat-Sen Univ., Taiwan; [2]National Chiao Tung Univ., Taiwan; [3]Huawei Technologies, China.* We propose a delay-division-multiplexing-OFDM-PON (DDM-OFDM-PON) with hybrid sub-Nyquist sampling rates, wherein heterogeneous ONUs can request different capacities. 26-dB loss budget in 25-km 25-gbps DDM-OFDM-PON was achieved using hybrid sampling at (1/32,1/16,1/8) or (1/32,1/8,1/2) Nyquist rates.

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

W4I • Data Center Traffic Management—Continued

W4I.4 • 17:30
Optical Networks Throughput Enhancement via TCP Stop-and-wait on Hybrid Switches, Artur Minakhmetov[1], Cédric Ware[1], Luigi Iannone[1]; *[1]Telecom ParisTech, France.* We report on possible 50% throughput increase in Optical Packet Switching (OPS) data-center networks by replacing all-optical switches with optical switches with shared electronic buffers further enhanced with TCP Stop-and-wait algorithms.

W4I.5 • 17:45
Optical Circuit Switching Enabled Reconfigurable HPC Network for Traffic Pattern, Yu Shang[1], Bingli Guo[1], Wenzhe Li[1], Yu Zhou[1], Xin Li[1], Yunquan Zhang[2,3], Shanguo Huang[1]; *[1]BUPT, China; [2]National Supercomputer Center, China; [3]State Key Laboratory of Computer Architecture, Inst. of Computing Technology,Chinese Academy of Sciences, China.* We propose a reconfigurable hybrid network architecture using optical circuit switches for HPC systems, and evaluate the performance of different topologies according to different traffic patterns through high throughput and low latency.

W4J • Imaging, Spectroscopy, and Transmission—Continued

W4J.4 • 17:30 Invited
Applications of Multimode Fibers for Spectroscopy and Polarization Control, Hui Cao[1]; *[1]Yale Univ., USA.* A multimode fiber spectrometer is developed with ultrahigh resolution and extreme broad bandwidth. Shaping the input wavefront enables an effective control of output polarization states of a multimode fiber with random polarization and mode coupling.

W4K • Novel Fiber Concepts—Continued

W4K.4 • 17:30
PANDA-type Elliptical-core Multimode Fiber with Fully Lifted Eigenmodes for Low-crosstalk Direct Fiber Vector Eigenmode Space-division Multiplexing, Shi Chen[1], Jian Wang[1]; *[1]Wuhan National Lab for Optoelectronics, China.* We propose a PANDA-type elliptical-core MMF featuring an elliptical core and two symmetrical circular stress-applying parts. With proper fiber geometric dimension and doping concentration, the designed fiber is able to support 24 fully lifted eigenmodes with minimum Δn_{eff} between adjacent modes larger than 1.30×10^{-4} over the whole C+L band.

W4K.5 • 17:45 Invited
Outlook on In-fiber Silicon Photonics, Anna C. Peacock[1]; *[1]Univ. of Southampton, UK.* This paper reviews the recent advancements in the fabrication and application of silicon optical fibers. Particular focus is placed on novel materials and device designs for use in optical signal processing systems.

Room 1A

W4A • Deployable Transport Networks—Continued

W4A.5 • 18:00
How Much is CD ROADM Contention Blocking?, Guangzhi Li[1], Kerong Yan[2], Li Huang[2], Bin Xia[2], Fanhua Kong[2], Yang Li[2]; [1]*Futurewei Technology Inc., USA;* [2]*Huawei Technologies, China.* This paper models CD ROADM network contention blocking and shows that the contention blocking impact is marginal when CD ROADM add/drop port usage is less than 75%. Numerical results verify the effectiveness.

W4A.6 • 18:15
Influence of the Maturity of Technology on the Benefit of 75 Ghz-Spaced 64 GBaud Channels in WDM Elastic Networks, Thierry Zami[1], Bruno Lavigne[1], Marco Bertolini[1]; [1]*Nokia Corporation, France.* We quantify how the benefit of 75 GHz-spaced 64 GBaud channels in WDM core networks depends on both the associated elastic modulation set and the maturity of transponder implementation correlated to the WDM transmission reaches

Room 1B

W4B • Radio-over-fiber II—Continued

W4B.4 • 18:00
Experimental Demonstration of Analog IFoF-based Seamless Fiber-wireless Interface for 5G Indoor DAS Supporting 8 FA and 2×2 MIMO configuration, Joonyoung Kim[1], Minkyu Sung[1], Eon-Sang Kim[1], Seung-Hyun Cho[1], Jong Hyun Lee[1]; [1]*ETRI, Korea.* We demonstrate analog IFoF-based seamless fiber-wireless interface for 5G indoor DAS that provides down-to 2-% EVM for ambient temperature from -20 to 60 °C with up-to 17 dB power budget, allowing >40 power split-ratio.

W4B.5 • 18:15
Experimental Demonstration of Analog Transmission using Mode Division Multiplexing, Cheng Xu[1], Guanjun Gao[1], Pengyue Deng[1], Ruihuan Wu[1], Tianwei Jiang[1], Yifan Shen[1], Jie Zhang[1]; [1]*Beijing Univ. of Posts & Telecom, China.* We demonstrate MDM-based analog fiber-optic link to further increase link gain and reduce nonlinearity. Compared with using LP11 mode only in FMF, MDM-based link increases the SFDR by 4.6dB.

Room 2

W4C • Space Division Multiplexed Transmission—Continued

Room 6C

W4D • High Speed Devices for Data Centers—Continued

W4D.6 • 18:00 Top Scored
56GHz Waveguide Ge/Si Avalanche Photodiode, Mengyuan Huang[1], Pengfei Cai[1], Su Li[1], Guanghui Hou[1], Naichuan Zhang[1], Tzung-I Su[1], Chingyin Hong[1], Dong Pan[1]; [1]*SiFotonics Technologies, USA.* We report a waveguide Ge/Si APD with ultra-high 3dB-bandwidths: 56GHz with a 1310nm responsivity of 1.08A/W and 36GHz with a 1310nm responsivity of 6A/W, which, to our knowledge, are the best performance among all reported APD devices.

Room 6D

W4E • Kramers-Kronig Receivers—Continued

W4E.6 • 18:00
Frequency-resolved Measurements of Signal, Noise, and Signal-signal Beat Interference in Self-coherent Direct-detection Receivers, Xi Chen[1], Sethumadhavan Chandrasekhar[1], Peter J. Winzer[1]; [1]*Nokia Bell Labs, USA.* We demonstrate a novel measurement technique that uniquely identifies the power spectral densities of signal, signal-signal-beat interference, and noise in direct-detection receivers.

W4E.7 • 18:15
Single Wavelength 480 Gb/s Direct Detection Transmission Over 80 km SSMF Enabled by Stokes Vector Receiver and Reduced-complexity SSBI Cancellation, Thang M. Hoang[1], Qunbi Zhuge[2,1], Zhenping Xing[1], Mohammed Sowailem[1], Mohamed Morsy-Osman[1], David V. Plant[1]; [1]*McGill Univ., Canada;* [2]*Ciena Corporation, Canada.* We experimentally demonstrate a 4-dimensional modulation direct detection system based on Stokes vector receiver and a novel reduced-complexity SSBI cancellation algorithm for signal linearization. A 480 Gb/s data rate over 80 km SSMF is achieved

Room 6E

W4F • Machine Learning for Network Control and Management—Continued

W4F.6 • 18:00
Analytics-driven Fault Discovery and Diagnosis for Cognitive Root Cause Analysis, Danish Rafique[1], Thomas Szyrkowiec[1], Achim Autenrieth[1], Joerg-Peter Elbers[1]; [1]*ADVA Optical Networking, Germany.* We propose an SDN-integrated framework for distributed cognitive fault discovery and diagnosis across end-to-end network infrastructure. The approach is evaluated on a real-world use-case and proactively identifies root cause of autonomously-detected optical power level anomalies.

W4F.7 • 18:15 Top Scored
Experimental Demonstration of Cognitive Provisioning and Alien Wavelength Monitoring in Multi-domain EON, Roberto Proietti[1], Xiaoliang Chen[1], Alberto Castro[1], Gengchen Liu[1], Hongbo Lu[1], Kaiqi Zhang[1], Jiannan Guo[2], Zuqing Zhu[2], Luis Velasco[3], S. J. Ben Yoo[1]; [1]*Univ. of California Davis, USA;* [2]*Univ. of Science and Technology of China, China;* [3]*Universitat Politècnica de Catalunya , Spain.* This paper proposes a cognitive multi-domain EON architecture with machine-learning aided RMSA and alien wavelength monitoring. Testbed experiments show modulation format recognition, QoT monitoring and cognitive routing for a 160 GBd alien multi-wavelength lightpath.

17:00–19:30 Photonic Society of Chinese-Americans Workshop & Social Networking Event, *Room 14A*

Room 6F

W4G • Advanced Technologies for High Speed PON—Continued

W4G.6 • 18:00

Improved Performance of High-order QAM OFDM based on Probabilistically Shaping in the Datacom, Jianyang Shi[1,2], Junwen Zhang[2], Xinying Li[2], Nan Chi[1], Yun Zhang[2], Qi Zhang[3], Jianjun Yu[2]; [1]*Fudan, China;* [2]*ZTE, USA;* [3]*Beijing Univ. of Posts and Telecommunication, China.* We experimentally demonstrated a PS-256-QAM OFDM fiber transmission in a low-cost IM-dD system. Compared with uniform 128-QAM, the proposed PS-256-QAM obtains the same entropy of 7 bits/QAM symbol, but higher achievable-information-rate performance and stronger nonlinearity robustness.

W4G.7 • 18:15

Realization of Tunable Frequency Response in Polarization Modulation and Direct Detection Scheme for High-speed Optical Access System, Siming Liu[1,3], Peng-Chun Peng[2,3], Chin-Wei Hsu[3], Huiping Tian[1], Gee-Kung Chang[3]; [1]*School of Information and Communication Engineering, Beijing Univ. of Posts and Telecom, China;* [2]*Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan;* [3]*School of Electrical and Computer Engineering, Georgia Inst. of Technology, USA.* We are the first to transmit 80-gbps 16QAM signals through a single mode fiber in a polarization-modulation-direct-detection (PolM-dD) system. The PolM-dD system has a tunable frequency response and can overcome the chromatic-induced power fading effect.

Room 7AB

W4H • Panel: 2020 Network Vision 5G and Optical Networking—Continued

Room 8

W4I • Data Center Traffic Management—Continued

W4I.6 • 18:00 Invited

Role of Standards in Web-scale Datacenters, Mark M. Filer[1]; [1]*Microsoft Corp., USA.* Standards play an increasingly important role for cloud providers considering the dramatic growth that cloud services are experiencing. Distinctions are made between open consortia, multi-source agreements, and standards, and case studies with lessons learned are presented.

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

Room 9

W4J • Imaging, Spectroscopy, and Transmission—Continued

Room 10

W4K • Novel Fiber Concepts—Continued

W4K.6 • 18:15

Interfacing Telecom Fibers and Silicon Core Fibers with Nano-spikes for In-fiber Silicon Devices, Ozan Aktas[1], Haonan Ren[1], Antoine F. Runge[1], Anna C. Peacock[1], Thomas Hawkins[2,3], John Ballato[2,3], Ursula J. Gibson[4,5]; [1]*Univ. of Southampton, UK;* [2]*Center for Optical Materials Science and Engineering Technologies (COMSET), Clemson Univ., USA;* [3]*Department of Materials Science and Engineering, Clemson Univ., USA;* [4]*Department of Physics, Norwegian Univ. of Science and Technology, Norway;* [5]*Applied Physics Department, KTH Royal Inst. of Technology, Sweden.* We report fabrication of tapered silicon core fibers with nano-spikes enabling efficient optical coupling into the core, as well as their seamless integration with single mode fibers. A proof-of-concept integrated in-fiber silicon device is demonstrated.

17:00–19:30 Photonic Society of Chinese-Americans Workshop & Social Networking Event, *Room 14A*

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

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

08:00–10:00
Th1A • Advances in Coherent Design and Measurement
Presider: Sorin Tibuleac; ADVA Optical Networking, USA

Th1A.1 • 08:00 Invited
Novel OSNR Measurement Techniques for Coherent-detection Systems, Daniel Gariepy[1], Steven Searcy[2], Gang He[1], Sorin Tibuleac[2]; *[1]EXFO, Canada; [2]ADVA Optical Networking, USA*. We discuss in-service OSNR measurement options independent of coherent receiver metrics. We review a spectral analysis technique for discriminating ASE when fiber nonlinearities contribute "Gaussian-like" noise and evaluate its performance in practical network scenarios.

08:30–10:00
Th1B • 5G Transport
Presider: Jiajia Chen; Kungliga Tekniska Hogskolan, Sweden

09:00–10:00
Th1C • Wideband Transmission
Presider: Robert Killey; Univ. College London, UK

08:00–10:00
Th1D • Application Awareness and Online Optimization
Presider: Ramon Casellas; Centre Tecnològic Telecomunicacions Catalunya, Spain

Th1D.1 • 08:00 Tutorial
The Role of Open-source Network Optimization Software in the SDN/NFV World, Pablo Pavon-Marino[1,2], Miquel Garrich[3,1], Francisco-Javier Moreno-Muro[1]; *[1]Universidad Politécnica de Cartagena, Spain; [2]E-lighthouse Network Solutions, Spain; [3]Optical Technologies Division, CPqD, Brazil*. SDN/NFV means an unprecedented network control, for an unprecedented resource dynamicity. Manual optimization is unmanageable. This tutorial covers open source optimization software initiatives for offline planning and online provisioning and orchestration of SDN/NFV networks.

Pablo Pavón Mariño is Full Professor in the Technical University of Cartagena (Spain), leader of the Net2Plan open-source network planning software initiative (www.net2plan.com) and co-founder of E-lighthouse Network Solutions spin-off (www.e-lighthouse.com). His research interests include optimization and planning of multi-layer optical networks and SDN/NFV infrastructures.

08:00–10:00
Th1E • Components for Future PON
Presider: Lilin Yi; Shanghai Jiao Tong Univ., China

Th1E.1 • 08:00 Invited
Components for High Speed 5G Access, Helene Debregeas[1], Robert Borkowski[2], Rene Bonk[2], Thomas Pfeiffer[2], Francois Lelarge[3], Mohand Achouche[1]; *[1]III-V Lab, France; [2]Nokia Bell Labs, France; [3]Almae-technologies, France*. Emerging access networks require specific components. We present a counter-heating method for wavelength stabilization in NG-PON2 TWDM-PON systems, and a +6dBm-high-power externally modulated laser at 10Gb/s and 28Gb/s for XGS-PON or 25G-ePON systems.

08:00–10:00
Th1F • High Capacity Subsystems
Presider: Sebastian Randel; Karlsruhe Inst. of Technology, Germany

Th1F.1 • 08:00 Invited
Entropy Loading for Band-limited Meshed-optical-networks: The Multicarrier Advantage, Di Che[1], William Shieh[1]; *[1]Univ. of Melbourne, Australia*. Modern meshed optical networks deploy plentiful cascaded-rOADMs to enhance the network flexibility, which induce severe filter narrowing effect. We reveal the linear advantage of multicarrier by the optimum power allocation and capacity-approaching modulation.

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

08:15–10:00 Th1G • Photonic Networks for Data Centers

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

Th1G.1 • 08:15 Top Scored
Microsecond Optical Switching Network of Processor SoCs with Optical I/O, Sajjad Moazeni[1], Johannes Henriksson[1], Tae Joon Seok[2,1], Mark Wade[3], Chen Sun[3], Ming Wu[1], Vladimir Stojanovic[1]; [1]*UC Berkeley, USA;* [2]*Gwangju Inst. of Science and Technology, Korea;* [3]*Ayar Labs, Inc., USA.* We demonstrate an OCS network with microsecond switching time between processors featuring monolithic ring-resonator-based WDM-compatible optical I/Os. This solution can solve EPS scalability challenge and enable novel architectures for emerging disaggregated and heterogeneous data-centers and HPC.

08:00–10:00 Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks

Organizers: Danny Peterson, Verizon, USA; Alan McCurdy, OFS, Fiber Design & Simulation Group, USA; Jing Li, Yangtze Optical Fibre and Cable, China

In the last year there has been an ever-increasing flurry of announcements of optical network expansions to support applications in the evolving data and telecommunications markets. Standards organizations, governments and businesses are anticipating enormous growth in connectivity over the next 5 years with the advent of 5G wireless, enhanced cloud services, the Internet of Things, smart cities etc. Analysts have projected a required spend of $130 – 150B in the US alone in the next 5- 7 years to meet the needs. To support this future demand, plans are being made now for an expansion of fiber-based networks to provide the required high capacity communication links via small cells, enhanced edge network capability, better data center interconnects, metro backhaul and more. The burden of this expansion has been placed on carriers, ICPs, MSOs, municipalities as well as various private enterprises. In this Panel, experts from these organizations will discuss their view of the upcoming transport demand and their plans for near term network expansions to address these needs. Questions to be addressed include: What applications are driving this expansion? Who are the relevant customers? What are the preferred fiber and cable types? How will the expanded architecture address the current demand and evolve in the future?

continued on page 117

08:15–10:00 Th1I • Comb Lasers

Presider: Zhiping Zhou; Peking Univ., China

Th1I.1 • 08:15
Monolithic Mode Locked Laser-based Optical Frequency Comb for OFDM Integrated on InP Generic Technology Platform, Mu-Chieh Lo[1], Robinson Cruzoe Guzmán Martínez[1], Guillermo Carpintero[1]; [1]*Universidad Carlos III de Madrid , Spain.* We report on-chip optical frequency comb structures based on mode-locked lasers, fabricated on generic platform, enabling on-chip integration with optical multiplexers/demultiplexers and modulators. The comb structures feature wide spectral bandwidth and mode spacing selectability.

08:15–10:00 Th1J • Optical Switching I

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

Th1J.1 • 08:15 Invited
Large-scale Silicon Photonic Switch, Eric Bernier[1], Dominic Goodwill[1], Patrick Dumais[1], Hamid Mehrvar[1], Dritan Celo[1], Jia Jiang[1], Chunshu Zhang[1], Fei Zhao[2], Xin Tu[2], Chunhui Zhang[2], Shengyong Yan[2], Jifang He[2], Ming Li[2], Wanyuan Liu[2], Yuming Wei[2], Dongyu Geng[2]; [1]*Huawei Technologies Canada Co., Ltd., Canada;* [2]*Huawei Technologies Co., Ltd., China.* A packaged and fully operational 32x32 silicon photonic switch chip having 448 switch cells and 1856 crossings is demonstrated. Development of low loss optical components is essential to the operation of complex Mach-Zehnder switch fabrics.

08:30–10:00 Th1K • SDM Amplifiers & Components

Presider: Karsten Rottwitt; Danmarks Teknishe Universitet, Denmark

Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.2 • 08:30
OSNR Measurement Comparison in Systems with ROADM Filtering for Flexible Grid Networks, Jie Pan[1], Thomas Richter[1], Sorin Tibuleac[1]; *[1]ADVA Optical Networking, USA.* OSNR measurement methods are compared for a ROADM-enabled flexible grid system with different noise loading scenarios using both experiment and simulation. The impact of the noise loading location on the filtering penalty is also investigated.

Th1A.3 • 08:45
Real-time 10Gbps Polarization Independent Quasicoherent Receiver for NG-PON2 Access Networks, Jose A. Altabas[1], Guillermo Silva Valdecasa[2], Morten Didriksen[2], Jose Antonio Lazaro[3], Ignacio Garces[1], Idelfonso Tafur Monroy[4], Jesper B. Jensen[2]; *[1]Universidad de Zaragoza, Spain; [2]Bifrost Communications, Denmark; [3]Universitat Politècnica de Catalunya, Spain; [4]Inst. for Photonics Integration, Eindhoven Univ. of Technology, Netherlands.* A Real-time 10Gbps polarization independent quasicoherent receiver for NG-PON2 access networks is proposed and experimentally validated. The sensitivity of this receiver is -33dBm and making feasible a 35dB power budget (required for E2 class).

Room 1B

Th1B • 5G Transport—Continued

Th1B.1 • 08:30
Access Network Economics: A Total-cost-of-ownership Perspective, Christoph Lange[1], Dirk Kosiankowski[1], Sandro Krauß[1], Andreas Gladisch[1]; *[1]Deutsche Telekom, Germany.* Several fiber-based access solutions are compared regarding TCO and NPV using an analytic framework and real service area data. Fiber-copper and fixed-wireless solutions show improved TCO and NPV efficiency short-term, FTTH in longer-term constellations.

Th1B.2 • 08:45
Software Defined 5G Converged Access as a Viable Techno-economic Solution, Andrea Marotta[1], Koteswararao Kondepu[2], Dajana Cassioli[1], Cristian Antonelli[1], Luis M. Correia[3], Luca Valcarenghi[2]; *[1]Univ. of L'Aquila, Italy; [2]Scuola Superiore Sant'Anna, Italy; [3]INESC-ID/INOV, Instituto Superior Técnico - Univ. of Lisbon, Portugal.* Software Defined Converged Access represents a feasible solution to effectively address 5G traffic demands. This paper proposes an integrated mobile-optical control for wavelength and bandwidth allocation. Evaluations of bandwidth utilization and techno-economic viability are provided.

Room 2

Th1C • Wideband Transmission—Continued

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Room 6D

Th1E • Components for Future PON—Continued

Th1E.2 • 08:30
Beyond 25 Gb/s Directly-modulated Widely Tunable VCSEL for Next Generation Access Network, Alberto Gatto[1], Paola Parolari[1], Christian Neumeyr[2], Pierpaolo Boffi[1]; *[1]Politecnico di Milano - DEIB, Italy; [2]Vertilas GmbH, Germany.* We demonstrate capacities beyond 25Gb/s up to 40 km in the whole C-band range without any dispersion compensation by DMT direct modulation and direct detection exploiting widely tuneable MEMS-vCSELs for future low-cost high-capacity access networks.

Th1E.3 • 08:45
10Gb/s Low-cost Directly Modulated Multi-electrode Laser with Suppressed Thermal Wavelength Drift for Burst-mode Upstream Transmission in TWDM-PONs, Stefano Porto[1,2], Dora van Veen[1], Vincent Houtsma[1], Nagesh Basavanhally[1], Cris Bolle[1], Harald Schmuck[3], Paul D. Townsend[2], Mark Earnshaw[1], Thomas Pfeiffer[3]; *[1]Bell Labs, Nokia, USA; [2]Tyndall National Inst., Univ. College Cork, Ireland; [3]Bell Labs, Nokia, Germany.* We report on a novel 10Gb/s low-cost multi-electrode DML employed as a very wavelength stable burst-mode source for upstream TWDM-PONs. 10X wavelength drift reduction is achieved compared to conventional DMLs enabling transmission on 100GHz grid.

Room 6E

Th1F • High Capacity Subsystems—Continued

Th1F.2 • 08:30
4096 QAM (72 Gbit/s) Single-carrier Coherent Optical Transmission with a Potential SE of 15.8 bit/s/Hz in All-Raman Amplified 160 km Fiber Link, Masaki Terayama[1], Seiji Okamoto[1], Keisuke Kasai[1], Masato Yoshida[1], Masataka Nakazawa[1]; *[1]Tohoku Univ., Japan.* We have successfully achieved a 4096 QAM (72 Gbit/s) - 160 km transmission with a potential spectral efficiency of 15.8 bit/s/Hz by employing precise digital polarization demultiplexing and an all-Raman amplified 160 km fiber link.

Th1F.3 • 08:45
Achievement of 90-GBaud PAM-4 with MLSE based on 2nd Order Volterra Filter and 2.88-Tb/s O-band Transmission using 4-λ LAN-wDM and 4-core Fiber SDM, Akira Masuda[1], Shuto Yamamoto[1], Hiroki Taniguchi[1], Mitsunori Fukutoku[1]; *[1]NTT, Japan.* We achieve 180-gb/s PAM-4 transmission under 32-gHz bandwidth limitation applying MLSE based on 3-memory T-spaced 2nd order Volterra filter. We experimentally demonstrate 2.88-tb/s O-band transmission using 4-λ LAN-wDM and SDM over 2-km 4-core fiber.

Th1G • Photonic Networks for Data Centers—Continued

Th1G.2 • 08:30
Automated Calibration of Balanced Control to Optimize Performance of Silicon Photonic Switch Fabrics, Yishen Huang[1], Qixiang Cheng[1], Keren Bergman[1]; [1]*Columbia Univ., USA*. Highly-efficient, fabric-wide calibration of balanced control for optical switch fabrics without built-in power-detectors is first realized with fully-automated implementation. This technique co-optimizes thermo-optic and electro-optic phase elements, correcting phase-error and power-imbalance simultaneously for optimized performance.

Th1G.3 • 08:45 Invited
The ARPA-E ENLITENED Program - Integrated Photonic Technology for Energy-efficient Data Center Networks, Michael W. Haney[1]; [1]*Advanced Research Projects Agency-Energy, USA*. The recently launched ARPA-e *ENLITENED* program aims to exploit integrated photonic interconnect and switching technologies to provide transformative energy efficiency improvements in future data centers. The program's motivation, goals, and progress are reviewed.

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Panelists:

Christina (Colasanto) Bassett, *Verizon, USA*

Robert Howald, *Comcast, USA*

Trevor Smith, *Commscope, USA*

Danny Thornton, *Microsoft, USA*

Th1I • Comb Lasers—Continued

Th1I.2 • 08:30
A Heterogeneously Integrated III-V/Si Colliding Pulse Mode-locked Laser with On-chip Feedback, Songtao Liu[1], Komljenovic Tin[1], Srinivasan Sudharsanan[2], Norberg Erik[2], Gregory Fish[2], John Bowers[1]; [1]*Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA;* [2]*Juniper Networks, USA*. We demonstrate a heterogeneously integrated O-band III-V/Si colliding pulse mode-locked laser with tunable on-chip external feedback for pulse stabilization. The 3-dB RF linewidth is 13.8 kHz , a reduction by a factor of 2.9x with the adjustment of external feedback.

Th1I.3 • 08:45
Temporal Soliton Locked in a Micro-resonator Pumped by a Diode Laser without an Amplifier, Nicolas Volet[1], Xu Yi[2], Qi-Fan Yang[2], Eric Stanton[1], Paul A. Morton[3], Ki Youl Yang[2], Kerry J. Vahala[2], John Bowers[1]; [1]*Univ. of California Santa Barbara, USA;* [2]*California Inst. of Technology, USA;* [3]*Morton Photonics, USA*. A single-soliton state is generated in a micro-resonator using a customized low-noise diode laser. This demonstration greatly simplifies the soliton generation setup and represents a significant step forward to a fully integrated soliton comb system.

Th1J • Optical Switching I—Continued

Th1J.2 • 08:45
Crosstalk Spectrum Optimisation for Stacked Wavelength Selective Switches Based on 2D Beam Steering, Haining Yang[2], Philip Dolan[2], Brian Robertson[2], Peter Wilkinson[2,1], Daping Chu[2,1]; [1]*Univ. of Cambridge, UK;* [2]*Roadmap Systems Ltd, UK*. We report a 4(1×8) WSS prototype using 2D beam steering with minimum insertion loss of 4.7dB and uniform passband step of 1GHz. The worst-case crosstalk was suppressed to <-30dB with optimised spectrum profile for improved OSNR.

Th1K • SDM Amplifiers & Components—Continued

Th1K.1 • 08:30
Pump Mode Characterization of Annular Cladding Erbium-doped Fibers Using Low-coherence Interferometry, Huiyuan Liu[4,1], Haoshuo Chen[4], Nicolas K. Fontaine[4], Roland Ryf[4], Jian Chen[3], Qianwu Zhang[3], Yingchun Li[3], Cang Jin[2], Sophie LaRochelle[2], Guifang Li[1]; [1]*Univ. of Central Florida, USA;* [2]*COPL, Université Laval, Canada;* [3]*Shanghai Univ., China;* [4]*Nokia Bell Labs, USA*. We characterize core and cladding pump modes of annular cladding 6-core 3-mode erbium-doped fibers using low-coherence interferometry (LCI). Efficient mode conversion at pump wavelength for modal gain equalization is also demonstrated and characterized by LCI.

Th1K.2 • 08:45 Top Scored
EDF Length Dependence of Amplification Characteristics of Cladding Pumped 19-core EDFA, Shigehiro Takasaka[1], Koichi Maeda[1], Kohei Kawasaki[1], Kazuaki Yoshioka[1], Hajime Oshio[1], Ryuichi Sugizaki[1], Hidenori Takahashi[2], Takehiro Tsuritani[2], Masato Shiino[1]; [1]*Furukawa Electric Co., Ltd., Japan;* [2]*KDDI Research Inc., Japan*. We demonstrate a C-band cladding pumped 19-core EDFA. Optimum EDF length and output power of the EDFA agree with those of a cladding pumped 7-core EDFA. High output power is brought by sufficiently long EDF.

Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.4 • 09:00
World's First TO-can Coherent Transceiver, Bernhard Schrenk[1], Fotini Karinou[2]; [1]*AIT Austrian Inst. of Technology, Austria;* [2]*Huawei Technologies, Germany.* We fit both, coherent homodyne receiver and transmitter, in a transistor-outline package with single fiber/RF port. Full-duplex 2.5Gb/s transmission over 27.5km reach, 28dB loss budget and coherent Ethernet connectivity are demonstrated without optical-layer DSP functions.

Th1A.5 • 09:15
Coherent Analog Low Power, Small Size 400/200/100Gb/s Receiver Based on Bipolar SiGe Technology, Edem Ibragimov[1], Hong Jiang[1], Pushui Xu[1], Xiangtao Li[1]; [1]*Greensand Networks, USA.* We demonstrate first to our knowledge analog coherent engine (ACE). Simulations show power consumption under 2W for 400Gb/s ACE. Combination of ACE with CMOS direct detection unit is good candidate for short reach communications.

Room 1B

Th1B • 5G Transport—Continued

Th1B.3 • 09:00
DBA Capacity Auctions to Enhance Resource Sharing across Virtual Network Operators in Multi-tenant PONs, Nima Afraz[1], Amr Elrasad[1], Marco Ruffini[1]; [1]*CONNECT Center, Trinity College Dublin, Ireland.* We propose an economic-robust auction mechanism for multi-tenant PON's capacity sharing that operates within the DBA process. We demonstrate that our mechanism improves PON utilization by providing economic sharing incentives across VNOs and infrastructure providers.

Th1B.4 • 09:15
Deep Neural Network Based Dynamic Resource Reallocation of BBU Pools in 5G C-RAN ROADM Networks, Weiyang Mo[1], Craig Gutterman[2], Yao Li[1], Gil Zussman[2], Daniel Kilper[1]; [1]*The Univ. of Arizona, USA;* [2]*Electrical Engineering, Columbia Univ., USA.* An LSTM network is developed to predict BBU pool traffic in 5G C-RAN ROADM networks. 5G throughput improvement and resource savings are observed with resource reallocation by reconfiguring the optical network 30 minutes in advance.

Room 2

Th1C • Wideband Transmission—Continued

Th1C.1 • 09:00
On the Effects of Transmitter Induced Channel Correlation in Broadband WDM Transmission, Jin-Xing Cai[1], Yue Hu[1], Alexey V. Turukhin[1], Matt Mazurczyk[1], Milen Paskov[1], Hussam Batshon[1], Carl Davidson[1], Maxim A. Bolshtyansky[1], Dmitri Foursa[1]; [1]*TE SubCom, USA.* We investigate how transmitter-induced correlations impact channel performance in experiments and simulations. We observe performance impacts ranging from ~0.7 dB after 600 km to be negligible beyond 4,000 km over 9.74 THz bandwidth. Correlation impact on NLC is discussed.

Th1C.2 • 09:15
Transmission Performance Improvement using Broadband Incoherent Counter-pumped Distributed Raman Amplification, Md A. Iqbal[1], Paul Harper[1], Mingming Tan[1]; [1]*Aston Univ., UK.* We propose a novel dual-order counter-pumped distributed Raman amplification technique using broadband incoherent 1st-order pump to suppress RIN transfer and improve Q-factor and transmission reach by 0.3dB and 833km respectively compared with conventional narrowband pumping.

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Th1D.2 • 09:00
Hysteresis-based Margin Allocation for Adaptive Coding in SDN-enabled Optical Networks, Yao Li[1], Mingwei Yang[2], Weiyang Mo[1], Shengxiang Zhu[2], Zhen Qu[2], Ivan Djordjevic[2], Daniel Kilper[1]; [1]*College of Optical Sciences, The Univ. of Arizona, USA;* [2]*Department of Electrical and Computer Engineering, The Univ. of Arizona, USA.* Hysteresis-based margin-allocation for adaptive coding is experimentally investigated against PDL-induced OSNR fluctuations in a SDN-enabled multi-domain optical network. Up to 90% network outage reduction can be observed under different margins.

Th1D.3 • 09:15
An Automated Service-downgrade Negotiation Scheme for Application-centric Networks, Antonio Marsico[1], Marco Savi[1], Domenico Siracusa[1], Elio Salvadori[1]; [1]*FBK CREATE-NET, Italy.* We propose a novel negotiation scheme for an application-driven relaxation of different requirements in multi-layer networks. Simulative results show that it improves service acceptance while keeping requirements' degradation much lower than applications' worst-case acceptable values.

Room 6D

Th1E • Components for Future PON—Continued

Th1E.4 • 09:00 **Tutorial**
Photonic Integrated Circuits for NGPON2 Tunable ONUs, John O'Carroll[1]; [1]*Eblana Photonics, Ltd., Ireland.* In comparison to current single wavelength standards tunable NGPON2 transceivers will be more complex. This tutorial reviews photonic integration technologies that could meet this challenge and the potential to leverage technologies developed for other applications.

John O'Carroll joined Eblana Photonics in 2004 and is the director of technical development in the company's optical communications business unit where he worked on developing the product road map, business strategy and applications engineering activities.
 He received the B.Eng and M.Eng degrees from the University of Limerick and a Ph.D. from Dublin City University. His research interests include the development of high speed laser diodes and photonic integrated circuits for use in next generation optical networks with a particular focus on PON and Datacom networks.

Room 6E

Th1F • High Capacity Subsystems—Continued

Th1F.4 • 09:00 **Tutorial**
Scaling Optical Networking Technologies for Next Generation SDM Systems, Peter J. Winzer[1]; [1]*Nokia Bell Labs, USA.* Based on the need to scale optical networks beyond WDM, we discuss the techno-economics of parallel spatial paths (SDM) and highlight integration options across all network elements to continue historic cost/bit and energy/bit reductions.

Peter Winzer has contributed to many aspects of optical communications and networking, high-speed coherent transmission, and spatial multiplexing. He has amply published and patented and is actively involved within the IEEE and the OSA. He is a Highly Cited Researcher, a Fellow of Bell Labs, IEEE, and OSA, and a Member of the National Academy of Engineering.

Th1G • Photonic Networks for Data Centers—Continued

Th1G.4 • 09:15

System-level Demonstration of a Dynamically Reconfigured Burst-mode Link using a Nanosecond Si-photonic Switch, Alex Forencich[1,2], Valerija Kamchevska[1,3], Nicolas Dupuis[1], Christian Baks[1], Benjamin G. Lee[1], George Papen[2], Laurent Schares[1]; *[1]IBM TJ Watson Research Center, USA; [2]Univ. of California at San Diego, USA; [3]Technical Univ. of Denmark, Denmark.* Using a novel FPGA-based network emulator, microsecond-scale packets with 12.5-20-gb/s data are generated, routed through a nanosecond Si-photonic switch, and received in a fast-locking burst-mode receiver. Error-free links with <382-ns system-level switching are demonstrated.

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Th1I • Comb Lasers—Continued

Th1I.4 • 09:00

An InAs/InP Quantum dot C-band Coherent Comb Laser, Zhenguo Lu[1], Jiaren Liu[1], Chunying Song[1], John Webber[1], Yuexin Mao[1], Shoude Chang[1], Heping Ding[1], Philip Poole[1], Pedro Barrios[1], Daniel Poitras[1], Siegfried Janz[1], Maurice O'Sullivan[2]; *[1]National Research Council Canada, Advanced Electronics and Photonics Research Centre, Canada; [2]Ciena, Canada.* We have developed InAs/InP quantum-dot 34.462-gHz C-band coherent comb laser modules with low relative intensity and phase noises over its filtered 45 channels, which can be used for data center and coherent communication systems.

Th1I.5 • 09:15

Ultra-narrow Linewidth Quantum Dot Coherent Comb Lasers, Zhenguo Lu[1], Jiaren Liu[1], Philip Poole[1], Chunying Song[1], Shoude Chang[1]; *[1]National Research Council Canada, Advanced Electronics and Photonics Research Centre, Canada.* We have developed a secondary-cavity self-injection feedback locking system to simultaneously reduce the linewidths of over 39 individual channels of an InAs/InP quantum-dot coherent comb laser from a few MHz to less than 200 kHz.

Th1J • Optical Switching I—Continued

Th1J.3 • 09:00

Integrated Wavelength Selective Switch Array for Space Division Multiplexed Network with Ultra-low Inter-spatial Channel Crosstalk, Keita Yamaguchi[1], Kenya Suzuki[1], Kazuno Seno[1], Hiroki Kawahara[1], Mitsunori Fukutoku[1], Toshikazu Hashimoto[1], Yutaka Miyamoto[1]; *[1]NTT Corporation, Japan.* We propose a novel optics for integrated wavelength selective switch (WSS) array that suppresses inter-sub WSS crosstalk for space-division multiplexed network. A crosstalk level of as low as –50 dB has been achieved.

Th1J.4 • 09:15 Invited

Fast, High-radix Silicon Photonic Switches, Tao Chu[1], Lei Qiao[2], Weijie Tang[1], Defeng Guo[2], Weike Wu[1]; *[1]College of Information Science and Electronic Engineering, Zhejiang Univ., China; [2]Inst. of Semiconductors, Chinese Academy of Sciences, China.* With a limited number of built-in power monitors to detect the optimum operating points of all switch units, we demonstrated a 32 × 32 MZI-based silicon electro-optical switch operating with nanosecond speeds.

Th1K • SDM Amplifiers & Components—Continued

Th1K.3 • 09:00 Top Scored

Low-loss and Low-crosstalk All-fiber-based Six-mode Multiplexer and Demultiplexer for Mode-multiplexed QAM Signals in C-band, Koji Igarashi[2,1], Yuta Wakayama[2], Daiki Soma[2], Takehiro Tsuritani[2], Itsuro Morita[2], Kyung Park[3], Byoung Kim[4]; *[1]Osaka Univ., Japan; [2]KDDI Research Inc., Japan; [3]KS Photonics, Korea; [4]KAIST, Korea.* We show all-fiber-based six-mode multiplexer and demultiplexer. The OSNR penalty due to six-mode multiplexing is suppressed to be 2 dB in DP-16QAM with 12x12MIMO and 3 dB in DP-QPSK even with 4x4/2x2MIMO over C-band.

Th1K.4 • 09:15

Tilted Fiber Bragg Gratings for Selective Coupling in a Multicore Optical Fiber, David Barrera[1], Javier Madrigal[1], Salvador Sales[1]; *[1]Photonics Research Labs, ITEAM, Universitat Politecnica de Valencia, Spain.* We have produced a device for the selective light coupling among the seven cores of a multicore optical fiber. We have used a tilted fiber Bragg grating for increasing 40dB the crosstalk between the cores.

Room 1A

Th1A • Advances in Coherent Design and Measurement—Continued

Th1A.6 • 09:30 Invited

Power Efficient DSP and Optical Integration, Timo Pfau[1], Ricardo Aroca[1], Chris Doerr[1], Jonas Geyer[1], Hongbin Zhang[1], Christian Rasmussen[1]; [1]*Acacia Communications, Inc., USA.* We review the technical innovations in ASIC technology, DSP, and photonic integration over the past years that enabled to reduce the footprint and power/Gbit/s of coherent modules by a factor of 10.

Room 1B

Th1B • 5G Transport—Continued

Th1B.5 • 09:30

Joint Optimization of BBU Pool Allocation and Selection for C-RAN Networks, Yao Li[1], Mariya Bhopalwala[1], Sandip Das[2], Jiakai Yu[3], Weiyang Mo[1], Marco Ruffini[2], Daniel Kilper[1]; [1]*College of Optical Sciences, The Univ. of Arizona, USA;* [2]*CONNECT Research Centre, Univ. of Dublin, Trinity College, Ireland;* [3]*Department of Electrical and Computer Engineering, The Univ. of Arizona, USA.* BBU pool allocation and selection are jointly optimized for maximizing wireless traffic capacity while minimizing wavelength resource occupation in optical networks. Numerical results show optimal BBU pool locations under different traffic patterns and network capacities.

Th1B.6 • 09:45

MixCo: Optimal Cooperative Caching for Mobile Edge Computing in Fiber-wireless Access Networks, Ning Wang[1], Weidong Shao[1], Sanjay K. Bose[2], Gangxiang Shen[1]; [1]*Soochow Univ., China;* [2]*Department of Electrical and Electronic Engineering, Indian institution of technology, India.* We consider the optimal content caching problem among Mobile Edge Computing (MEC) servers in a Fiber-wireless (FiWi) access network, to minimize the average content delivery latency subject to limited storage and computing capacity of each server. An MILP model and a Mix-cooperative (MixCo) caching strategy are developed for efficient performance.

Room 2

Th1C • Wideband Transmission—Continued

Th1C.3 • 09:30

Inter-channel Stimulated Raman Scattering and its Impact in Wideband Transmission Systems, Gabriel Saavedra[1], Daniel Semrau[1], Mingming Tan[2], Md. Asif Iqbal[2], Daniel Elson[1], Lidia Galdino[1], Paul Harper[2], Robert Killey[1], Polina Bayvel[1]; [1]*Univ. College London, UK;* [2]*Aston Inst. of Photonic Technologies, UK.* The impact of inter-channel stimulated Raman scattering (ISRS) in wideband optical transmission systems is studied. ISRS cross-talk due to channel modulation was found to be negligible and a good agreement was found with theoretical results.

Th1C.4 • 09:45

Experiments on Stimulated Raman Scattering in S- and L-bands 16-QAM Signals for Ultra-wideband Coherent WDM Systems, Kyo Minoguchi[1], Seiji Okamoto[1], Fukutaro Hamaoka[1], Asuka Matsushita[1], Masanori Nakamura[1], Etsushi Yamazaki[1], Yoshiaki Kisaka[1]; [1]*NTT Network Innovation Laboratories, Japan.* We experimentally evaluated stimulated Raman scattering (SRS) effect between S- and L-bands over 210-km SSMF 16-QAM transmission. SRS mainly induced power transition from S- to L-band, and was not the cause of nonlinear crosstalk penalty.

Room 6C

Th1D • Application Awareness and Online Optimization—Continued

Th1D.4 • 09:30 Invited

Application Aware Multilayer Control and Optimization of Elastic WDM Switched Optical Networks, Ioannis Tomkos[1], Ciril Rozic[1], Marco Savi[2], Pontus Sköldström[3], Victor Lopez[4], Mohit Chamania[5], Domenico Siracusa[2], Chris Matrakidis[1], Dimitrios Klonidis[1], Ori Gerstel[6]; [1]*Athens Information Technology Center, Greece;* [2]*FBK, Italy;* [3]*RISE Acreo AB, Sweden;* [4]*Telefonica I+D/GCTO, Spain;* [5]*ADVA Optical Networking, Germany;* [6]*Sedona Systems, Israel.* In dynamic networks with diverse application requirements, Software Defined Networking (SDN) principles enable application-aware in-operation planning. EU project ACINO built a network orchestrator as the connecting component between network applications and the underlying network infrastructure.

Room 6D

Th1E • Components for Future PON—Continued

Room 6E

Th1F • High Capacity Subsystems—Continued

Papers are available online for download. Visit www.ofcconference.org and select the Download Digest Papers link.

10:00–16:00 Exhibition and Show Floor Programs, Coffee Break, *Exhibit Hall* **and OFC Career Zone Live,** *Exhibit Hall C*

Room 6F

Th1G • Photonic Networks for Data Centers—Continued

Th1G.5 • 09:30
O-band Energy-efficient Broadcast-friendly Interconnection Scheme with SiPho Mach-Zehnder Modulator (MZM) & Arrayed Waveguide Grating Router (AWGR), Stelios Pitris[1,2], Charoula Mitsolidou[1,2], Theoni Alexoudi[1,2], Diego Pérez-Galacho[3], Laurent Vivien[3], Charles Baudot[4], Peter De Heyn[5], Joris Van Campenhout[5], Delphine Marris-Morini[3], Nikos Pleros[1,2]; *[1]Department of Informatics, Aristotle Univ. of Thessaloniki, Greece; [2]Center for Interdisciplinary Research and Innovation, Aristotle Univ. of Thessaloniki, Greece; [3]Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Université Paris-sud, Université Paris-saclay, France; [4]ST Microelectronics, France; [5]imec, Belgium*. We present an O-band energy-efficient broadcast-friendly optical architecture relying on a silicon photonics broadband MZM and an 8×8 AWGR. Experimental validation is demonstrated at 10Gb/s followed by an energy-saving analysis for the proposed broadcast scheme.

Th1G.6 • 09:45
Integrated, Scalable and Reconfigurable Silicon Photonics based Optical Switch for Colorless, Directionless and Contentionless Operation, Stefano Tondini[1], Astghik Chalyan[1], Giorgio Fontana[1], Lorenzo Pavesi[1], Nikola Zečević[3], Michael Hofbauer[3], Horst Zimmermann[3], Stefano Stracca[4], Alberto Bianchi[4], Costanza Manganelli[2], Philippe Velha[2], Paolo Pintus[2], Fabrizio Di Pasquale[2], Claudio Oton[2], Christophe Kopp[5], Guido Chiaretti[6], Aina Serrano[7], Jose Ayucar[7], Giovan B. Preve[2], Jong Lee[8], Francesco Testa[4]; *[1]Univ. of Trento, Italy; [2]Scuola S. Anna, Italy; [3]TU Wien, Austria; [4]Ericsson, Italy; [5]Cea Leti, France; [6]STMicroelectronics, Italy; [7]Universitat Politècnica de València, Spain; [8]ETRI, Korea*. We demonstrate a BCD8sP electronic-photonic integrated device for low cost, low power, mass–manufacturable optical switching. Our network on-chip has 1000 photonic components driven by dedicated electronic controls. Total insertion loss is -22dB, including input and output coupling, and channel isolation is better than 35dB, in a chip area of 1cm^2.

Room 7AB

Th1H • Panel: Near Term, Large Scale Fiber Deployments for Evolving Networks—Continued

Room 8

Th1I • Comb Lasers—Continued

Th1I.6 • 09:30
InP Photonic Integrated Comb Generator made by a cascade of Optical Modulators, Tommaso Cassese[1], Nicola Andriolli[1], Marco Chiesa[1], Ángel Rubén Criado Serrano[2], Giampiero Contestabile[1,3]; *[1]Scuola Superiore Sant'Anna, Italy; [2]Luz wavelabs, Spain; [3]CNIT, Italy.* We report the first InP photonic integrated comb generator made by cascading a DBR laser, one Mach-Zehnder intensity modulator and two phase modulators. The photonic circuit also includes a booster SOA at the output.

Th1I.7 • 09:45
Wide, Continuously Swept VCSEL Using a Novel Air-cavity-dominant Design, Pengfei Qiao[1], Kevin T. Cook[1], Jipeng Qi[1], Larry A. Coldren[2], Connie J. Chang-Hasnain[1]; *[1]EECS Dept. and Tsinghua-Berkeley Shenzhen Inst., Univ. of California, Berkeley, USA; [2]Department of Electrical and Computer Engineering, Univ. of California, Santa Barbara, USA*. We report electrically-pumped MEMS-vCSELs with a record 70 nm continuous wavelength sweep at 1057-nm with 600 kHz rate using a novel air-cavity-dominant design. Such devices are promising for swept-source OCT and 3D sensing applications.

Room 9

Th1J • Optical Switching I—Continued

Th1J.5 • 09:45 Top Scored
Dual 8x16 MCS using Hybrid-integrated Silica PLC and Polymer TIR Switch Array, Jang-Uk Shin[1], Sangho Park[1], Young-Tak Han[1], Yongsoon Baek[1], Byeong Kwon Choi[2], Joonoh Park[2], Chulhee Park[3]; *[1]Electronics & Telecomm Res. Inst, Korea; [2]ChemOptics, Korea; [3]Wooriro Co., Ltd., Korea*. We firstly report the design and fabrication of silica-polymer hybrid-integrated (chip-to-chip bonded) dual 8x16 multicast switch for contentionless ROADM. We used silica PLCs for passive waveguide devices and polymer TIR switch as switching devices.

Room 10

Th1K • SDM Amplifiers & Components—Continued

Th1K.5 • 09:30
Non-circularly-symmetric Mode-group Demultiplexer Based on Fused-type FMF Coupler for MGM Transmission, Yuyang Gao[1], Juhao Li[1], Chuanyan Du[1], Cen Xia[2], Yan Liu[2,3], Zhengbin Li[1], Yongqi He[1], Zhangyuan Chen[1], Guifang Li[2]; *[1]Peking Univ., China; [2]Univ. of Central Florida, USA; [3]Beijing Jiaotong Univ., China*. A mode-group demultiplexer (MG-dEMUX) based on fused-type FMF coupler is proposed and fabricated for the LP_{11} mode group, based on which 2×5-gb/s weakly-coupled MGM transmission over 10-km TMF is experimentally demonstrated with simple direct detection.

Th1K.6 • 09:45
Mode-selective Polished Fiber Couplers based on Fiber Gratings, Sebastian Schlangen[1], Kort Bremer[1], Andreas Isaak[3], Marc C. Wurz[3], Gabriel Pelegrina Bonilla[2], Jörg Neumann[2], Bernhard Roth[1], Ludger Overmeyer[1]; *[1]HOT - Leibniz Universtaet Hannover, Germany; [2]Laser Zentrum Hannover e.V., Germany; [3]IMPT-Leibniz Universität Hannover, Germany*. A key challenge for using multimode fibers for optical data transmission lies in the development of efficient mode-selective fiber couplers. Here, we present a novel and easy-to-implement process for their realization and first experimental results.

10:00–16:00 Exhibition and Show Floor Programs, Coffee Break, *Exhibit Hall* **and OFC Career Zone Live,** *Exhibit Hall C*

10:30–12:30
Th2A • Joint Poster Session II

Th2A.1
O-band Silicon Photonics 8×8 Arrayed Waveguide Grating Router (AWGR) for 1.6 Tb/s On-chip Routing, Stelios Pitris[1,2], George Dabos[1,2], Charoula Mitsolidou[1,2], Theoni Alexoudi[1,2], Peter De Heyn[3], Joris Van Campenhout[3], Ronald Broeke[4], George T. Kanellos[5], Nikos Pleros[1,2]; *[1]Department of Informatics, Aristotle Univ. of Thessaloniki, Greece; [2]Center for Interdisciplinary Research and Innovation, Aristotle Univ. of Thessaloniki, Greece; [3]imec, Belgium; [4]Bright Photonics BV, Netherlands; [5]High Performance Networks Group, Univ. of Bristol, UK*. We present an 8×8 silicon photonics AWGR with 10 nm channel spacing for O-band cyclic-routing operation. Successful transmission at 25 Gb/s is demonstrated for all 8×8 AWGR channel combinations with a maximum power penalty of 0.82 dB.

Th2A.2
Poly-crystalline Silicon Waveguide Devices on Hollow Deep Trench Isolation in Standard Foundry Bulk Silicon Process, Sungwon Chung[1], Makoto Nakai[1], Edward Preisler[2], Hossein Hashemi[1]; *[1]Univ. of Southern California, USA; [2]TowerJazz, USA*. We first demonstrate poly-crystalline silicon waveguide devices on deep-trench isolation in a commercial bulk 180nm SiGe BiCMOS process without any process modifications or post-processing. At 1550nm, the measured loss for the poly-crystalline silicon waveguide and an MMI compatible with the waveguide are around 3.0 dB/mm and 0.38 dB, respectively.

Th2A.3
Integrated InP Polarization Rotator Using the Plasmonic Effect, Shinmo An[1], O-Kyun Kwon[1]; *[1]ETRI, Korea*. An InP based polarization rotator is demonstrated using the plasmonic effect. It operates as a half-wave retarder. Simple device structure ensures large fabrication tolerance. The device exhibits polarization extinction ratio of 20 dB over C-band.

Th2A.4
Thermo-optical Phase Shifter with Integrated Diodes for Multiplexed Control, Antonio R. Alves[1,2], Wim Bogaerts[1,2]; *[1]Ghent Univ. - IMEC, Photonics Research Group, Belgium; [2]Center for Nano and Biophotonics (NB-photonics), UGent, Belgium*. We present a thermo-optic silicon phase shifter with diodes for multiplexed control and demonstrate that such heaters can be driven using digital signals to increases the linearity of the phase shift response of the device.

Th2A.5
Integrated Polarization Beam Splitter Module for Polarization-encoded Free-space BB84 QKD, Joong-Seon Choe[1], Heasin Ko[1], Byung-Seok Choi[1], Kap-Joong Kim[1], Chun Ju Youn[1]; *[1]ETRI, Korea*. We present an integrated polarization beam splitter module for free-space BB84 quantum key distribution. The module is based on silica PLC birefringent Mach-Zehnder interferometer chip, and replaces successfully the bulk-optic-based polarization splitting subsystem of BB84 quantum key distribution test-bed operating at 780 nm.

Th2A.6
Compact Grating Coupler for Higher-order Mode Coupling, Yaxiao Lai[1], Yu Yu[1], Songnian Fu[1], Jing Xu[1], Perry Ping Shum[2], Xinliang Zhang[1]; *[1]Wuhan National Lab for Optoelectronics, China; [2]School of Electrical and Electronics Engineering, Nanyang Technological Univ., Singapore*. An on-chip LP_{11}-tE_1 mode grating coupler is experimentally demonstrated by utilizing double-grating structure and a Y-junction. A 0.6 dB improvement of coupling efficiency with a quarter taper length is achieved comparing with conventional grating coupler.

Th2A.7
Compact and Power Efficient 2 × 2 Thermo-optical Switch based on Dual-nanobeam MZI, Jiang Xinhong[1], Hongxia Zhang[1], Ciyuan Qiu[1], Yong Zhang[1], Yikai Su[1], Richard A. Soref[2]; *[1]Shanghai Jiao Tong Univ., China; [2]Univ. of Massachusetts, USA*. A compact 2×2 thermo-optical switch based on a dual-nanobeam MZI is experimentally demonstrated. The footprint is 38 μm×84 μm. The heating powers for the cross and bar states are ~2.66 mW and ~2.36 mW, respectively.

Th2A.8
Broadband SOI Mode Order Converter based on Topology Optimization, Min Teng[1,2], Keisuke Kojima[1], Toshiaki Koike-Akino[1], Bingnan Wang[1], Chungwei Lin[1], Kieran Parsons[1]; *[1]Mitsubishi Electric Research Labs, USA; [2]Purdue Univ., USA*. Topology optimized SOI mode order converters are proposed to allow mutual conversion between TE_0, TE_1 and TE_2. Broadband conversion efficiency around 85% can be realized on an ultra-compact (~ 4 μm) footprint.

Th2A.9
Design, Fabrication and Demonstration of Ultra-broadband Orbital Angular Momentum (OAM) Modes Emitter and Synthesizer on Silicon Platform, Zhou Nan[1], Shuang Zheng[1], Xiaoping Cao[1], Shengqian Gao[2], Shimao Li[2], Mingbo He[2], Jian Wang[1], XinLun Cai[2]; *[1]Wuhan National Laboratory for Optoelectr, China; [2]State Key Laboratory of Optoelectronic Materials and Technologies and School of Physics and Engineering, Sun Yatsen Univ., China*. We design, fabricate and demonstrate chip-scale ultra-broadband orbital angular momentum (OAM) emitter and synthesizer on a silicon platform. The maximum purity of OAM_{+1} and synthesized OAM_{+1} and OAM_{-1} are 0.93 and 0.9 in telecommunication band.

Th2A.10
Ultra-compact Silicon Polarization Beam Splitter with a Short Coupling Length of 0.768 μm, Yong Zhang[1], Xiaodong Wang[1], Xuhan Guo[1], Ciyuan Qiu[1], Xiulan Cheng[1], Yikai Su[1], Richard A. Soref[2]; *[1]Shanghai Jiao Tong Univ., China; [2]Univ. of Massachusetts, USA*. We demonstrate an ultra-compact silicon polarization beam splitter with a coupling length of 0.768 μm. Lower than 2-dB insertion losses and over 10-dB extinction ratios are achieved over a wavelength range of 60 nm.

Th2A.11
Inter-die Fabrication Uniformity of Silicon Photonic Fiber-to-waveguide Edge Couplers, Junrong Ong[1], Thomas Ang[1], Xin Guo[2], Ezgi Sahin[3], Soon Thor Lim[1], Dawn Tan[3], Wang Hong[2], Ching Eng, Jason Png[1]; *[1]Inst. of High Performance Computing , Singapore; [2]Nanyang Technological Univ., Singapore; [3]Singapore Univ. of Technology and Design, Singapore*. Silicon-on-insulator fiber-to-waveguide inverse taper edge couplers of different tip widths of 120nm to 200nm are fabricated using a multi-project wafer service. The coupling efficiencies and the inter-die fabrication uniformity of the edge couplers are compared.

Th2A.12
A Simple, Robust Two- tone Method to Measure the Dynamic Nonlinear Characteristics of Phase Shifter in Silicon Mach-Zehnder Modulator, Tong Ye[1], Yanhui Qi[1], Hao Chen[1], Zhenning Tao[1], Tomofumi Oyama[2], Hisao Nakashima[2], Takeshi Hoshida[2], Haowen Shu[3], Xingjun Wang[3]; *[1]Fujitsu R&D Center, China; [2]Fujitsu Laboratories Ltd, Japan; [3]Peking Univ., China*. A simple and robust method is proposed to measure high-frequency nonlinear phase-voltage relationship of phase shifter in silicon Mach-Zehnder modulator. Experiments show that static and dynamic characteristics are different, and nonlinearity decreases along with frequency.

Th2A.13
A Large-signal Equivalent Circuit for Depletion-type Silicon Ring Modulators, Minkyu Kim[1], Myungjin Shin[1], Min-Hyeong Kim[1], Byung-Min Yu[1], Christian Mai[2], Stefan Lischke[2], Lars Zimmermann[2], Woo-Young Choi[1]; *[1]Yonsei Univ., Korea; [2]IHP, Germany*. We demonstrate an accurate and easy-to-use large-signal equivalent circuit for depletion-type Si ring modulators. Design optimization of a 25-gbps Si photonic transmitter including the driver and the modulator is carried out entirely with SPICE simulation.

Th2A.14
Narrow Linewidth Hybrid InP-triPleX Photonic Integrated Tunable Laser based on Silicon Nitride Micro-ring Resonators, Yi Lin[1], Colm Browning[1], Roelof Bernardus Timens[2], Douwe H. Geuzebroek[2], Chris G. H. Roeloffzen[2], Dimitri Geskus[2], Ruud M. Oldenbeuving[2], René G. Heideman[2], Youwen Fan[3,2], Klaus J. Boller[3], Jialin Zhao[4], Liam Barry[1]; *[1]Dublin City Univ., Ireland; [2]LioniX International, Netherlands; [3]Univ. of Twente, Netherlands; [4]Huawei Technologies Co., China*. Detailed characterization of a hybrid integrated tunable laser based on micro-ring resonators shows a tuning range of 50 nm with ~40 kHz linewidth. The device demonstrates performance comparable with commercial external cavity lasers in 16QAM coherent system.

Th2A.15
High Performance Self-injection Locked 524 nm Green Laser Diode for High Bitrate Visible Light Communications, Md. Hosne Mobarok Shamim[1], Mohamed Shemis[1], Chao Shen[2], Hassan Oubei[2], Tien K. Ng[2], Boon Ooi[2], Mohammed Z. Khan[1]; *[1]Electrical Engineering, King Fahd Univ. of Petroleum & Minerals, Saudi Arabia; [2]King Abdullah Univ. of Science and Technology, Saudi Arabia*. First demonstration of self-injection locking on 524 nm visible laser diode is presented. Enhancement by ~440 MHz (~30%) in modulation bandwidth, ~7 times reduction in lasing linewidth, and ~10 dB improvement in SMSR is achieved.

Th2A.16
High Throughput Bandwidth Characterization of Silicon Photonic Modulators using Offset Frequency Combs, Nathan Abrams[1], Robert Polster[1], Liang Y. Dai[1], Keren Bergman[1]; *[1]Columbia Univ., USA*. We develop a low complexity, high-throughput testing technique for concurrently characterizing the bandwidths of multiple in-series modulators with independent frequency combs. The approach is demonstrated on two serial modulators at 9.2 GHz and 15.5 GHz.

Th2A.17
Phase Noise Characterization of a Mode-locked Quantum-dot Coherent Optical Frequency Comb Source Laser, Kristian Zanette[1], John C. Cartledge[1], Rongqing Hui[3], Maurice O'Sullivan[2]; *[1]Queen's Univ. at Kingston, Canada; [2]Ciena, Canada; [3]Univ. of Kansas, USA*. The amplitude fluctuations and correlation times of the two contributions to the phase noise of a quantum-dot optical frequency comb source laser are characterized using simultaneously recovered phase noise trajectories for pairs of comb lines.

Th2A.18
A 520-nm Green GaN LED with High Bandwidth and Low Current Density for Gigabits OFDM Data Communication, Chien Ju Chen[1], Jhih-Heng Yan[2], De-Hua Chen[3], Kai-Hsiang Lin[2], Kai Ming Feng[2,3], Meng Chyi Wu[1,3]; *[1]Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan; [2]Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; [3]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan*. We develop 520-nm green GaN LEDs with a 340-mHz E-o bandwidth. For the first time, an OFDM signal modulates the green LED, which data rate achieves 2.16 Gb/s at a low current density 679 A/cm^2.

Th2A • Joint Poster Session II—Continued

Th2A.19
Modeling and Design Aspects of a Monolithically Integrated Opto-electronic Chip enabling 64GBaud Operation, Danish Rafique[1], Benjamin Wohlfeil[1], Gilda Mehrpoor[1], Helmut Griesser[1], Despoina Petousi[2], Pedro Rito[2], Iria Lopez[2], Lars Zimmermann[2], Michael Eiselt[1], Joerg-Peter Elbers[1]; *[1]ADVA Optical Networking, Germany; [2]IHP GmbH, Germany.* We report on the modeling of silicon photonic IQ-modulators with monolithically co-integrated BiCMOS segmented drivers. The structure is evaluated for coherent inter-dCI applications with symbol rates up to 64GBd and modulation formats up to DP-64QAM.

Th2A.20
Silicon Photonic Modulator based on Coupled Bragg Grating Resonators used as Phase Shifters, Omid Jafari[1], Hassan Sepehrian[1], Wei Shi[1], Sophie LaRochelle[1]; *[1]Electrical Engineering, Laval Univ., Canada.* Bragg gratings with phase-shifts are inserted in a Mach-Zehnder modulator to enhance phase modulation, reduce device length and improve efficiency ($V_\pi \times L$=0.28 Vcm). Simulations show 3 nm optical bandwidth corresponding to 50 K operating temperature range.

Th2A.21
Block-wise Time Domain Large Signal Model of Carrier-depletion Mach-Zehnder Silicon Photonic Modulators, Qun Zhang[1,2], Jianying Zhou[2], Jin Hong[2]; *[1]Minnesota State Univ. Mankato, USA; [2]NeoPhotonics Corporation, USA.* Time domain large signal model operating in block signal mode is proposed for traveling-wave silicon photonic (SiPh) modulators based on carrier depletion. The underlying theory, implantation algorithm details, and waveform level simulation results are summarized.

Th2A.22
Demonstration of a Rectangularly-arranged Strongly-coupled Multi-core Fiber, Shota Saitoh[1], Katsuhiro Takenaga[1], Kazuhiko Aikawa[1]; *[1]Fujikura Ltd, Japan.* We present a novel design of strongly-coupled multi-core fibers for MIMO-less transmission. The modal crosstalk between two propagating modes (LP_{01}-like and LP_{11a}-like) of a fabricated fiber is less than -23 dB/km over the C+L band.

Th2A.23
Cladding-rods-assisted Depressed-core 9-lP-mode Fiber with Improved Modal Spacing, Jiawei Han[1], Jie Zhang[2], Guanjun Gao[2], Yongli Zhao[2], Shanglin Hou[3]; *[1]Tianjin Normal Universirity, China; [2]Beijing Univ. of Posts and Telecommunications, China; [3]Lanzhou Univ. of Technology, China.* We report the design of a cladding-rods-assisted depressed-core 9-lP-mode fiber featuring more equally spaced modal effective indices, suitable for high-spatial-density uncoupled mode-division-multiplexing systems. It exhibits improved modal spacing ($\geq 1.0\times10^{-3}$) and large modal effective areas ($\geq$127μm^2).

Th2A.24
Design, Fabrication, Measurement and MDM Tranmission of a Novel Weakly-coupled Ultra Low Loss FMF, Lei Shen[1,2], Su Chen[1,2], Xueting Sun[1,2], Yaping Liu[1,2], Lei Zhang[1,2], Tao Hu[3], Juhao Li[3]; *[1]Key Laboratory of Optical Fiber and Cable Manufacture Technology, China; [2]Yangtze Optical Fiber and Cable Joint Stock Limited Company, China; [3]Peking Univ., China.* A novel weakly-coupled ultra low loss FMF is designed and fabricated, and we demonstrate 4-mode MDM transmission over 20-km ultra low loss FMF with 10-gb/s OOK modulation and direct detection.

Th2A.25
Numerical Analysis of Power Coupling in Few-mode Step Index Fibers, Gianluca Guerra[1], Andrea Galtarossa[1], Luca Palmieri[1]; *[1]Department of Information Engineering, Universita' degli Studi di Padova, Italy.* Power coupling in few-mode step index fibers is studied for different kinds of perturbation. The analysis shows that coupling may change depending on perturbation even in the asymptotic regime.

Th2A.26
Observation of Fiber Fuse Propagation Speed Oscillation Due to Inter-mode Interference in Two-mode Fibers, Shoulin Jiang[1], Lin Ma[1], Xinyu Fan[1], Shuai Wang[1], Zuyuan He[1]; *[1]Shanghai Jiao Tong Univ., China.* We investigated fiber fuse propagation speed oscillation in two-mode fibers by combining heterodyne detection and time-frequency analysis. We confirmed that the propagation speed oscillation was caused by the inter-mode interference between LP_{01} and LP_{11} modes.

Th2A.27
Solid Type Low-latency Single-mode Fiber with Large Effective Area and Low Loss, Yuto Sagae[1], Takashi Matsui[1], Kyozo Tsujikawa[1], Kazuhide Nakajima[1]; *[1]NTT, Japan.* A novel solid type low-latency single-mode fiber (SMF) is proposed. Proposed small core dual-cladding structure successfully achieves a 0.3% latency reduction from a silica-core fiber while maintaining a 121.4 μm^2 effective-area and 0.194 dB/km loss.

Th2A.28
Toward Multilayer Disaggregated Node Telemetry and Local Decision Making, Luis Velasco[1], Luis Gifre[2], Jose Luis Izquierdo-Zaragoza[1]; *[1]Universitat Politecnica de Catalunya, Spain; [2]Universidad Autónoma de Madrid (UAM), Spain.* A generic node agent supporting disaggregated node telemetry is presented. Data collection close to devices enable making local decisions, leveraging SDN controllers for network-wide operations. The agent is demonstrated in a BER-triggered transponder reconfiguration scenario.

Th2A.29
First Experimental Demonstration of Disaggregated Emergency Optical System for Quick Disaster Recovery, Masaki Shiraiwa[1], Noboru Yoshikane[2], Sugang Xu[1], Takehiro Tsuritani[2], Naoki Miyata[3], Tatsuo Mori[3], Masatake Miyabe[4], Toru Katagiri[4], Sota Yoshida[5], Masaki Tanaka[5], Tomofumi Hayashi[6], Hidetsugu Sugiyama[6], Ikuo Satou[7], Mashito Mikuni[8], Satoru Okamoto[8], Yoshinari Awaji[1], Naoya Wada[1]; *[1]National Inst Information & Comm Tech, Japan; [2]KDDI Research, Inc., Japan; [3]NTT Communications Corporation, Japan; [4]Fujitsu Limited, Japan; [5]Mitsubishi Electric Corporation, Japan; [6]Red Hat K. K, Japan; [7]OA Laboratory Corporation, Japan; [8]Keio Univ. , Japan.* We demonstrated the effectiveness of a portable emergency optical system in disaster recovery. The system replaces functional units of damaged optical network and recovers a control-plane network by taking the advantage of surviving wireless access.

Th2A.30
Orchestrating Lightpath Adaptation and Flexible Functional Split to Recover Virtualized RAN Connectivity, Koteswararao Kondepu[1], Nicola Sambo[1], Francesco Giannone[1], Piero Castoldi[1], Luca Valcarenghi[1]; *[1]Scuola Superiore Sant'Anna, Italy.* This study shows that a two-step recovery scheme orchestrating lightpath transmission adaptation and evolved NodeB (eNB) functional split reconfiguration preserves the Virtualized RAN fronthaul connectivity even when network capacity is scarce.

Th2A.31
Cross-layer Aware Packet-optical Link Management in Software-defined Network Operating System, Young-Jin Kim[1], Jesse E. Simsarian[1], Nakjung Choi[1], Nishok Mohanasamy[1], Marina Thottan[1]; *[1]Nokia Bell-labs, USA.* Software-defined network management systems presently lack joint link-status awareness on both packet and optical layers. Using a NOS with cross-layer link awareness, we demonstrate faster service restoration of packet links over failed optical links.

Th2A.32
VPN Service Provisioning via Virtual Router Deployment and Quantum Key Distribution, Alejandro Aguado[1], Victor Lopez[2], Jesus Martinez-Mateo[1], Diego R. Lopez[2], Momtchil Peev[3], Vicente Martin[1]; *[1]Center for Computational Simulation, Universidad Politécnica de Madrid , Spain; [2]Telefonica I+D, Spain; [3]Quantum Communication and Computing Laboratory, Huawei Technologies Dusseldorf GmbH , Germany.* Here we demonstrate, for the first time, VPN services integrated within a virtual router using QKD to perform encryption and authentication. Any management operation is also secured using QKD, providing a whole quantum-safe ecosystem.

Th2A.33
On the Benefits of Programmable Optics for Post-failure VM Migrations in Data-centers, Ashwin Gumaste[1], Kushwaha Aniruddha[1], Admela Jukan[2]; *[1]Indian Inst. of Technology, Bombay, India; [2]ECE, Technicsche Universitat Braunschweig, Germany.* The role of programmable optics in data-center edges is investigated as a method for achieving high VNF availability in post-failure scenarios, while making the VM migrations simple and cost-effective.

Th2A.34
Joint Intra- and Inter-datacenter Network Optimization and Orchestration, Giada Landi[2], Marco Capitani[2], Aristotelis Kretsis[1], Panagiotis Kokkinos[1], Kostas Christodoulopoulos[1], Emmanouel Varvarigos[1,3]; *[1]Univ. of Patras, Greece; [2]Nextworks, Italy; [3]National Technical Univ. of Athens, Greece.* We present a hierarchical orchestration platform for inter-domain datacenter networks that includes hybrid optical-electrical intra-datacenter networking and inter-datacenter networking utilizing elastic technologies. We demonstrate dynamic and joint allocation of capacity in an emulated testbed.

400G Coherent: What Does it Mean to You?
OIF
10:15–11:15

Product Showcase
Huawei
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For more details, see page 23

■ **MW Panel V: Software Innovations in the Next-generation Optical Transport**
10:30–12:00

POF Symposium
POFTO
11:00–13:00

Preparing for the GDPR: The EU's Sweeping Data Privacy Reform Initiative
IEEE
11:30–12:30

■ **MW Panel VI: IP and Optical Integration: Physical or Control/Management Plane?**
12:30–14:00

Standardization in ITU-T Study Group 15 – Networks, Technologies and Infrastructures for Transport, Access and Home
ITU
12:45–13:45

Understanding Optical Signal-to-Noise Ratio
13:15–14:15

Th2A • Joint Poster Session II—Continued

Th2A.35
Disaggregating Optical Nodes in a Multi-layer SDN Orchestrator for the Integration of an In-operation Planning Tool, Federico Pederzolli[1], Mohit Chamania[2], Michele Santuari[1], Thomas Szyrkowiec[3], Chris Matrakidis[4], Ciril Rozic[4], Dimitrios Klonidis[4], Victor Lopez[5], Domenico Siracusa[1]; *[1]FBK CREATE-NET, Italy; [2]ADVA Optical Networking, Germany; [3]ADVA Optical Networking, Germany; [4]AIT, Greece; [5]Telefonica I+D, Spain.* Optical disaggregation can provide the intermediate models required by In-operation planning to compute feasible configurations in IP/Optical networks. We demonstrate disaggregation on a real SDN-orchestrated testbed, and quantify its benefits and costs.

Th2A.36
CAPEX Optimization with Joint Allocation of Hybrid RF/FSO and Optical Fibre Resources in 5G Backhaul, Da Feng[1], Weiqiang Sun[1], Weisheng Hu[1]; *[1]SJTU, China.* We optimize CAPEX of a 5G backhaul with hybrid RF/FSO links and storage by exploiting matching between source nodes and destination nodes for allocation of links to minimize total required resources.

Th2A.37
A Shared Segment Protection Approach for Distributed Sub-tree Based Optical Multicasting Scheme in Elastic Optical Datacenter Networks, Tao Gao[1], Xin Li[1], Bingli Guo[1], Shan Yin[1], Shanguo Huang[1]; *[1]Beijing Univ of Posts & Telecom, China.* We design a shared segment protection approach for multicast requests provisioned by distributed sub-trees in elastic optical datacenter networks. It outperforms conventional protection schemes in terms of spectrum efficiency, blocking probability, and notification time.

Th2A.38
Joint Optimization of Unicast, Anycast, Multicast and Manycast Traffics in Elastic Optical Networks, Xiao Luo[1], Chen Shi[2], Xue Chen[1], Liqian Wang[1]; *[1]Beijing Univ of Posts & Telecom, China; [2]Iowa State Univ., USA.* We estimate a hybrid communication scheme with unicast, anycast, multicast and manycast traffics in elastic optical networks. A request classification gene encoding based approach is proposed which optimizes hybrid traffics jointly to improve network efficiency.

Th2A.39
On Multi-layer Restoration in Optical Networks with Encryption Solution Deployment, Xin Jin[1], Wei Lu[1], Siqi Liu[1], Zuqing Zhu[1]; *[1]Univ of Science and Technology of China, China.* We consider the scenario in which an optical network with encryption solution deployment can be affected by electrical layer failures, and propose an algorithm to improve the cost-effectiveness of multi-layer restoration in it.

Th2A.40
Reliability Gains of Infrastructure Programmability in an Optical C-RAN, Houman Rastegarfar[1], Tommy Svensson[2], Nasser Peyghambarian[1]; *[1]Univ. of Arizona, USA; [2]Chalmers Univ. of Technology, Sweden.* We study the interplay of optical, wireless, and control domains in a software-defined C-RAN architecture in terms of survivability. Our analysis indicates the significant advantage of optical network programmability under a negligible fronthaul latency penalty.

Th2A.41
Techno Economic Assessment of Immersive Video Services in 5G Converged Optical/Wireless Networks, Ioannis Neokosmidis[1], Theodoros Rokkas[1], Pietro Paglierani[2], Claudio Meani[2], Karim M. Nasr[3], Klaus Moessner[3], Muhammad Shuaib Siddiqui[4], Pouria Sayyad Khodashenas[4]; *[1]inCITES Consulting SARL, Luxembourg; [2]Italtel SpA, Italy; [3]Inst. for Communication Systems, 5G IC, Univ. of Surrey, UK; [4]i2CAT Foundation, Spain.* The economic feasibility of a 5G media service in converged optical/wireless networks for crowded events in venues shows a ~6.5years payback period. Sensitivity analysis highlights the impact of tariffs and CAPEX on net present value.

Th2A.42
Towards Secure Optical Networks: A Framework to Aid Localization of Harmful Connections, Federico Pederzolli[1], Marija Furdek[2], Domenico Siracusa[1], Lena Wosinska[2]; *[1]FBK CREATE-NET, Italy; [2]KTH Royal Inst. of Technology, Sweden.* We model the scope of optical signal insertion attacks by defining attack syndromes for each connection, and present a cost-efficient routing heuristic that aids localization of harmful connections by reducing syndrome ambiguity in the network.

Th2A.43
Impact of WSS Filtering Penalty on the Capacity of Elastic WDM Ring Optical Networks, Haining Yang[2], Paul Wright[3], Brian Robertson[2], Peter Wilkinson[2], Philip Dolan[2], Andrew Lord[3], Daping Chu[2,1]; *[1]Univ. of Cambridge, UK; [2]Roadmap Systems Ltd, UK; [3]British Telecom Laboratories, UK.* Our network model shows that the 3dB width of the Gaussian spectrum intensity profile in WSSs needs to be <6GHz for realising the ~30% capacity increase in a WDM ring network as promised by the flexible-spectrum standard.

Th2A.44
Multiplane Orbital Angular Momentum and Wavelength Switch based on Integrated Tunable Vortex Emitters, Mirco Scaffardi[1], Nicola Andriolli[2], Muhammad N. Malik[2,1], Ning Zhang[3], Emma Lazzeri[2], Charalambos Klitis[3], Martin Lavery[3], Marc Sorel[3], Antonella Bogoni[1,2]; *[1]CNIT - Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy; [2]Sant' Anna di Pisa, Italy; [3]Univ. of Glasgow, UK.* A multiplane switch architecture exploiting OAM and wavelength domains is characterized in terms of BER, scheduling/reconfiguration latency, and power consumption. Doubling the exploited OAM modes reduces the latency by 42% and the power by 17%.

Th2A.45
When CORD Meets Hub, Qingya She[1], Kirsten Rundberget[1], Weisheng Xie[1]; *[1]Fujitsu Networks Communications Inc., USA.* Architectures of CORD at the nodal level and Hub at the metro network level are studied. Ways in which they can cooperate, as well as the impact on network operations and economics, are also analyzed.

Th2A.46
Ultra-fast Hitless 100Gbit/s Real-time Bandwidth Variable Transmitter with SDN Optical Control, Arnaud Dupas[1], Patricia Layec[1], Dominique Verchere[1], Quan Pham Van[1], Sébastien Bigo[1]; *[1]Nokia Corporation, France.* We designed an ultra-fast Real-time bandwidth-variable transmitter achieving zero-packet loss with ~10µs switching time, ~40x faster than previous record. We use a new coding scheme to generate baud rates and measure reconfiguration through SDN control.

Th2A.47
Regenerator Allocation in Nonlinear Elastic Optical Networks WITH Random Data Rates, Li Yan[1], Yuxin Xu[2], Maite Brandt-Pearce[2], Nishan Dharmaweera[1], Erik Agrell[1]; *[1]Chalmers Univ. of Technology, Sweden; [2]Univ. of Virginia, USA.* We optimize the regenerator allocation in nonlinear elastic networks whose traffic demands have random data rates. Compared with previous regenerator allocation algorithm, our method achieves the same blocking probability with 11% less regenerator sites.

Th2A.48
Real-time Demonstration of Adaptive Functional Split in 5G Flexible Mobile Fronthaul Networks, Yahya M. Alfadhli[1], Mu Xu[1], Siming Liu[1], Peng-Chun Peng[1,2], Gee-Kung Chang[1]; *[1]Georgia Inst. of Technology, USA; [2]Department of Electro-optical Engineering, National Taipei Univ. of Technology, Taiwan.* We experimentally demonstrate a flexible and reconfigurable Fronthaul-i with analog RoF integration that aims to optimally serve different 5G applications. RoF integration can reduce the latency by more than %15 to support URLLC applications.

Th2A.49
Experimental Demonstration of SDN-controlled Variable-rate Fronthaul for Converged LTE-over-PON, Pedro Alvarez[1], Frank Slyne[1], Christian Blumm[1], Johann Marquez-Barja[2], Luiz DaSilva[1], Marco Ruffini[1]; *[1]Univ. of Dublin Trinity College, Ireland; [2]Univ. of Antwerp - IMEC, Belgium.* We introduce the concept of variable-rate fronthaul and provide experimental validation over PONs. Our SDN controller dynamically modifies the wireless cell bandwidth depending on load, thus varying the fronthaul rate with sub-second end-to-end reconfiguration times.

Th2A.50
A Flexible Low-latency Metro-access Converged Network Approach based on Time-synchronized TWDM-PON, Jialong Li[1], Nan Hua[1], Yufang Yu[1], Zhizhen Zhong[1], Xiaoping Zheng[1], Bingkun Zhou[1]; *[1]Tsinghua Univ, China.* A flexible time-synchronized TWDM-PON (TS-TWDM-PON) architecture is proposed and implemented for low-latency metro-access communication. Results show that a two-order-of-magnitude reduction in end-to-end delay can be achieved with the new TS-tWDM-PON architecture.

Th2A.51
K-means Clustering based Multi-dimensional Quantization Scheme for Digital Mobile Fronthaul, Lu Zhang[1,2], Xiaodan Pang[2], Oskars Ozolins[3], Aleksejs Udalcovs[3], Sergei Popov[2], Shilin Xiao[1], Jiajia Chen[2]; *[1]Shanghai Jiao Tong Univ., China; [2]School of ICT, KTH,Royal Inst. of Technology , Sweden; [3]RISE Acreo Swedish ICT AB, Sweden.* We propose to group highly-correlated neighboring samples into multi-dimensional vectors and adopt k-means clustering for quantization in mobile fronthaul. 30-gbit/s transmissions have been experimentally demonstrated for up to 40 100MHz LTE channels over 20km fiber.

Th2A.52
Improved Link Budget (35 dB) of 2×25 Gb/s WDM/TDM-PON by using Crosstalk-free SOA and FEC, Han Hyub Lee[1], Kyeong-Hwan Doo[1], Kwangok Kim[1], Sil-Gu Mun[1], Seung Hwan Kim[1], Hwan Seok Chung[1]; *[1]Electronics & Telecomm Res. Inst, Korea.* We demonstrated a link budget improved 2×25 Gb/s WDM/TDM-PON by using O-band SOA with an assist light and FEC. When the assist light is used to the SOA, gain-saturation induced crosstalk of SOA was successfully mitigated. 50G-ethernet PON traffic was transmitted over 20-km reach and 256-split.

Th2A.53
High Optical Budget PtP DWDM System in Overlay with CWDM for Mobile XHaul with Remote Wavelength Tuning and Monitoring in Tunable SFPs, Sylvain Barthomeuf[1], Fabienne Saliou[1], Naveena Genay[1], Luiz Anet Neto[1], Philippe Chanclou[1], Erik Pennings[2], Jin Hyung Ahn[2], Sun Keun Yu[2], Sung Eun Hong[2]; *[1]Orange Labs, France; [2]SOLiD, Korea.* We experimentally achieved 33dB optical budget with real time monitoring and wavelength tuning within a DWDM system in a fronthaul architecture. Compatibility with commercial RAT and remote control of the Tunable-sFPs are demonstrated.

Th2A.54
Highly Flexible WDM PON System with a Single TDM Time Lens Source Enabling Record 150 km Downstream Reach, Pengyu Guan[1], Francesco Da Ros[1], Mads Lillieholm[1], Kjeld Dalgaard[1], Michael Galili[1], Palle Jeppesen[1], Toshio Morioka[1], Leif K. Oxenlowe[1]; *[1]Technical Univ. of Denmark, Denmark.* We propose a new OLT transmitter for WDM-PON based on optical Fourier transformation of a single-source TDM-PON signal to WDM-PON signals. We demonstrate flexible bit rates (10×1-to-64×2Gb/s) and 40×1Gb/s WDM-PON record unamplified downstream transmission reach of 150 km.

Th2A • Joint Poster Session II—Continued

Th2A.55
Using Raman Gain to Offset Excess Losses of an Intelligent Optical Distribution Network in a TWDM PON, Michael Straub[1], Patrick Iannone[1]; [1]*Nokia Bell Labs, USA*. We use bi-directional distributed Raman amplification to offset the excess losses of an intelligent splitter module. We demonstrate this technique in a 42-km, 1:32 split, TWDM PON.

Th2A.56
Redundancy for Long-reach TWDM PON, Liang B. Du[1], Shuang Yin[1], Xiangjun Zhao[1], Tao Zhang[1], Adam Barratt[1], Joy Jiang[1], Daoyi Wang[1], Cedric F. Lam[1]; [1]*Google, USA*. A redundancy design for long-reach TWDM PON without backup OLTs is proposed, protecting the truck fiber and optionally the CO. Network modeling shows availability of redundant long-reach PONs is better than traditional PONs.

Th2A.57
Simultaneous Multiband WSN, WLAN, LTE-a, and Gb/s 4-PAM Signals Transmission over 50 m 1 mm Core Diameter POF for Home Area Network, Federico Forni[1,2], N.C. Tran[2], H.P.A. v. Boom[1], Eduward Tangdiongga[1], Ton Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Genexis, Netherlands.* FourWireless-sensors-network channels were transmitted over 50m GI-pOF and 12m wireless together with a WLAN signal, 9 64-QAM LTE-a bands with reduced PAPR, and 1.66Gb/s 4-PAM baseband signal for multi-standard wired-wireless smart-home and in-home networks.

Th2A.58
Linearized Photonic Down-conversion Using Second-harmonic Generation, Gregory S. Kanter[1], Paul Moraw[1], Daniel Reilly[1]; [1]*NuCrypt, USA*. We demonstrate that second harmonic generation effectively doubles the modulation index of a phase modulator, and simulate a photonic down-conversion system that exploits the enhanced modulation index to improve linearity without substantially reducing gain.

Th2A.59
Achievable Information Rate Enhancement of Visible Light Communication Using Probabilistically Shaped OFDM Modulation, Zhixue He[1], Wu Liu[1], ChenHui Xie[2], Songnian Fu[2], Xiang Li[1], Chao Yang[1], Qi Yang[1]; [1]*State Key Laboratory of Optical Comm. Technologies and Networks, China;* [2]*School of Optics and Electronic Information, Huazhong Univ. of Science and Technology, China*. We experimentally demonstrate a visible light communication (VLC) system based on the probabilistically shaped (PS) OFDM modulation. The overall achievable information rate (AIR) can be improved by 13.6% in comparison with conventional bit-loading scheme.

Th2A.60
PAM-4 Wireless Transmission based on Look-up-table Pre-distortion and CMMA Equalization at V-band, Wen Zhou[1], Pengqi Gou[1], Kaihui Wang[1], Miao Kong[1], Xinying Li[1,2], Li Zhao[1], Zihang Zhu[1], Jianjun Yu[1,2]; [1]*Shanghai Inst. for Advanced Communication and Data Science, Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Univ., China;* [2]*ZTE (TX) Inc., USA*. We introduce new DSP including look-up-table pre-distortion at transmitter-side and cascaded multi-modulus-algorithm equalization at receiver-side to improve the ROF transmission performance. We experimentally achieved 6.5GBaud PAM-4 wireless transmission with 9m free space distance at V-band.

Th2A.61
Spectrally Efficient SSB signals for W-band Links Enabled by Kramers-Kronig Receiver, Luis Gonzalezguerrero[1], Haymen Shams[1], Irshaad Fatadin[2], Martyn Fice[1], Mira Naftaly[2], Alwyn Seeds[1], Cyril Renaud[1]; [1]*Univ. College London, UK;* [2]*National Physical Laboratory, UK*. We demonstrate a radio-over-fiber link based on the Kramers-Kronig receiver for the first time. Using this technique, we recover an 11 GBd single sideband signal with a net spectral efficiency of 3.4 (bit/s)/Hz at W-band.

Th2A.62
Modal Dispersion and Feed Light Crosstalk Mitigations by using Center- and Offset-launching for Optically-powered Radio-over-multimode Fiber Systems, Hayao Kuboki[1], Motoharu Matsuura[1]; [1]*Univ. of Electro-communications, Japan*. We have successfully achieved high RoF transmission performance with around 10-watt feed power-over-fiber using a conventional multimode fiber. The modal dispersion and feed light crosstalk are effectively mitigated by the combination of center- and offset-launching.

Th2A.63
Multipath Interference Free Multi-LED Visible Light Communications with Gold Sequence Multiplexing, Jhih-Heng Yan[1], Ya-Jou Cheng[1], Kai-Hsiang Lin[1], De-Hua Chen[2], Chien Ju Chen[3], Kai Ming Feng[1,2]; [1]*Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan;* [2]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan;* [3]*Inst. of Electronics Engineering, National Tsing Hua Univ., Taiwan*. We experimentally demonstrate a multi-LED VLC system with low complexity Gold sequence multiplexed OFDM signals. Without time synchronization or uplink feedback mechanism, the received signal qualities are uniform and ubiquitously isolated from wireless multipath interferences.

Th2A.64
MISO Visible Light Communication System Utilizing MCMMA Aided Pre-convergence of STBC Decoding, Liang Qiao[1], Xingyu Lu[1], Shangyu Liang[1], Nan Chi[1]; [1]*Fudan Univ., China*. We experimentally apply the MCMMA algorithm to reduce BER in VLC-mISO system. Experiments demonstrate the performance with MCMMA algorithm can achieve higher Baud Rate than the scheme of STBC without MCMMA.

Th2A.65
Enhanced Emission and Modulation Properties of Localized Surface Plasma Coupled GaN-based Green Light-emitting Diodes, Jiehui Li[1], Pengqi Gou[1], Nan Chi[1], Haiyan Ou[2]; [1]*Fudan Univ., China;* [2]*Technical Univ. of Denmark, Denmark*. A localized surface plasma coupled LED with modulation bandwidth of 152MHz which was enhanced by 1.65 times relative to grid LED was fabricated for high-speed VLC system, while the light power increased by 1.67 times.

Th2A.66
Simultaneous Temperature and Strain Measurement using Deep Neural Networks for BOTDA Sensing System, Biwei Wang[2], Liang Wang[1], Changyuan Yu[2], Chao Lu[2]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*The Hong Kong Polytechnic Univ., Hong Kong*. DNN is used for the first time in simultaneous measurement of temperature and strain along a large-effective-area fiber (LEAF) in a BOTDA system with short processing time.

Th2A.67
Linearized Phase Modulation Microwave Photonics Link via Optimizing Processing of Optical Sidebands, Ruihuan Wu[1], Tianwei Jiang[1], Song Yu[1], Jianming Shang[1], Chenxia Liu[1], Wanyi Gu[1]; [1]*Beijing Univ. of Posts & Telecomm., China*. A multi-order nonlinear distortions suppression in phase modulation microwave photonics link via optimizing processing of optical sidebands is presented. Experimental results show the SFDR increases by 21.1 dB compared to that without nonlinear compensation.

Th2A.68
Photonic Design Parameters for AWG-based RF Channelized Receivers, Kyle S. Davis[1], Andrew Stark[1], Benjamin Yang[1], Anthony Lentine[2], Christopher DeRose[2], Michael Gehl[2]; [1]*Georgia Tech Research Inst., USA;* [2]*Sandia National Laboratory, USA*. An 11-channel 1-gHz bandwidth silicon photonic AWG was fabricated and measured in the lab. Two photonic architectures are presented: (1) RF-envelope detector, and (2) RF down-convertor for digital systems. The RF-envelope detector was modeled based on the demonstrated AWG characteristics to determine estimated system-level RF receiver performance.

Th2A.69
Digital Radio over Fiber Distribution using Millimetre Wave Bridging, Haymen Shams[1], Tongyun Li[2], Cyril Renaud[1], Alwyn Seeds[1], Richard V. Penty[2], Martyn Fice[1], Ian White[2]; [1]*Univ. College London, UK;* [2]*Centre for Photonic Systems, Electrical Division, Department of Engineering, Univ. of Cambridge, UK*. This paper demonstrates a novel digital radio-over-fiber system using a millimeter-wave bridge giving access where fiber cannot. The system can transport multiple digitised LTE-compatible signals with high spectral efficiency, low latency, and wide dynamic range.

12:30–14:00 Unopposed Exhibit-only Time, *Exhibit Hall* (concessions available)

Show Floor Programming

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OIF
10:15–11:15

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ITU
12:45–13:45

Understanding Optical Signal-to-Noise Ratio
13:15–14:15

Room 1A

14:00–15:00
Th3A • Current Topics in Long Haul/ Metro Transmission
Presider: Nitin Goel; Facebook Inc., USA

Th3A.1 • 14:00 Invited
Traffic Engineering and Topology Programming, Monia Ghobadi[1]; [1]*Microsoft, USA*. With the adoption of ROADMs in long-haul networks, providers have the ability to change the physical layer of networks. We propose a graph abstraction for the practical adoption of programmable topologies into traffic engineering schemes.

Th3A.2 • 14:30 Invited
Pizzabox Transponders Deployment in the Field and Related Issues, Giuseppe Rizzelli[2], Andrew Sutters[1], Nitin K. Goel[1]; [1]*Facebook, USA;* [2]*Facebook, UK*. Pizzabox transponders deployment in metro and backbone networks allows us to achieve large power and space savings. However, to reduce time to market, many basic software features are left out, thus making operations more complex.

Room 6C

14:00–16:00
Th3B • Directly Modulated Lasers
Presider: Yasuhiro Matsui; Finisar Corporation, USA

Th3B.1 • 14:00 Tutorial
Ultra-high-speed Optical-cavity-enhanced DMLs, Richard J. Schatz[1]; [1]*Applied Physics, Royal Inst. of Technology (KTH), Sweden*. The modulation bandwidth of directly modulated lasers for Datacom can be enhanced by utilizing the wavelength selectivity of the laser cavity. Three effects will be discussed; detuned loading, photon-photon resonance and chirp to intensity conversion. A review of the field will be presented, including recent theoretical and experimental results.

Richard Schatz (Ph.D. 1995, Docent 2014) has since 1987 conducted research at Royal Institute of Technology (KTH), Stockholm, on the modeling, design and characterization of fiber-optical transmitters (edge emitter lasers, VCSELs and modulators) and links, both for on-off keying and multilevel modulation formats. He is the developer of the software LaserMatrix, used by industry for interactive design of high-speed and low noise semiconductor lasers.

Room 6D

14:00–16:00
Th3C • Optical Switching II
Presider: Richard Jensen; Polatis, Inc., USA

Th3C.1 • 14:00
Wide-range Automated Wavelength Calibration over a Full FSR in a Dual-ring based Silicon Photonic Switch, Qingming Zhu[1], Hongxia Zhang[1], Ruiyuan Cao[1], Ning Zhao[1], Jiang Xinhong[1], Danping Li[2], Yanbo Li[2], Xiaolu Song[2], Xuhan Guo[1], Yong Zhang[1], Ciyuan Qiu[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Huawei Technologies Co., Ltd., China*. We demonstrate an automated wavelength calibration scheme for a dual-ring based silicon electro-optic switch. By using an improved saddle point searching algorithm, the calibration over a full free spectral range of 6 nm is achieved.

Th3C.2 • 14:15
Self-holding Operation of Magneto-optical Switch using Thin-film Magnet, Ken Okazeri[1], Kenji Muraoka[1], Yuya Shoji[1], Shigeki Nakagawa[1], Nobuhiko Nishiyama[1], Shigehisa Arai[1], Tetsuya Mizumoto[1]; [1]*Tokyo Inst. of Technology, Japan.* A novel self-holding switch is demonstrated by a magneto-optical waveguide switch. The switching state is flipped by a pulsed current and maintained without any power supply by virtue of the non-volatility of thin-film magnet.

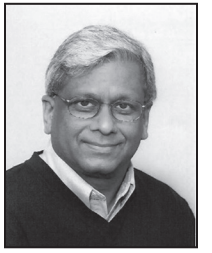
Th3C.3 • 14:30 Tutorial
Photonic Switch Fabrics in Computer Communications Systems, Benjamin G. Lee[1]; [1]*IBM TJ Watson Research Center, USA*. Dense, efficient, and potentially low-cost photonic switches show promise for transforming Computercom networks. This talk will cover the fundamentals of photonic switching technologies, as well as the architectures and packaging features that can enable scaling.

continued on page 128

Room 6E

14:00–16:00
Th3D • Nonlinear Fiber Effects
Presider: Wladek Forysiak, UK

Th3D.1 • 14:00 Tutorial
Nonlinearity of Optical Fibers, Govind P. Agrawal[1]; [1]*Univ. of Rochester, USA*. Fiber nonlinearities are regarded as being harmful for optical communication systems, although they are useful for applications such as Raman amplification and supercontinuum generation. In this tutorial I review them and discuss their practical implications.



Govind Agrawal is James Wyant Professor of Optics at University of Rochester. He is an author of about 450 research papers and eight books. His books on Nonlinear Fiber Optics and Fiber-Optic Communication Systems are used worldwide. Prof. Agrawal is a Fellow of IEEE and OSA. He received IEEE Quantum Electronics Award in 2012 and was awarded OSA'sEsther Hoffman Beller Medal in 2015. Since 2014, he is serving as Editor-in-Chief of Advances in Optics and Photonics.

Room 6F

14:00–15:45
Th3E • Advanced Transmission Technology
Presider: Antonio Napoli; Coriant, Germany

Th3E.1 • 14:00 Invited

Digital Pre-compensation Techniques Enabling Cost-efficient High-order Modulation Formats Transmission, Dan Sadot[1,2], Yaron Yoffe[1], Hananel Feig[1], Gil Paryanti[1]; [1]*Electrical and Computer Engineering, Ben Gurion Univ. of the Negev, Israel;* [2]*MultiPhy, Israel.* Digital precompensation complementary to post equalization increases the DSP compensation envelope. Implementable parallel least square of nonlinear bandlimited channel, asymmetric imbalance predistortion of MZM impairments, and quantization noise preshaping minimizing DAC resolution requirement are presented

Th3E.2 • 14:30 Invited

Secure Transmission using QAM Quantum Noise Stream Cipher with Continuous Variable QKD, Masataka Nakazawa[1], Masato Yoshida[1], Takuya Hirano[2]; [1]*Tohoku Univ., Japan;* [2]*Gakusyuin Univ., Japan.* We describe a Real-time 70 Gbit/s, 128 QAM quantum noise stream cipher transmission system with a continuous variable quantum key distribution system, which enables encrypted data to be transmitted over 100 km.

Room 7AB

14:00–15:00
Th3F • Data Center Interconnect Deployments
Presider: Bruce Cortez; AT&T, USA

Th3F.1 • 14:00 Invited

Present and Future Optical Technology Deployments in Facebook's Terrestrial Networks, Gaya Nagarajan[1]; [1]*Facebook, USA.* We discuss the current state and future evolution of Facebook terrestrial networks, for long-haul and metro. We highlight the underlying architectural principles, for both hardware blocks and software APIs, that result in scalable, efficient, automated networks.

Th3F.2 • 14:30

Leveraging Predictive Analytics to Achieve Knowledge-defined Orchestration in a Hybrid Optical/Electrical DC Network: Collaborative Forecasting and Decision Making, Wei Lu[1], Lipei Liang[1], Bingxin Kong[1], Baojia Li[1], Zuqing Zhu[1]; [1]*Univ of Science and Technology of China, China.* We design and experimentally demonstrate a hybrid optical/electrical DC network that achieves knowledge-defined orchestration with two collaborative machine learning modules.

Th3F.3 • 14:45

Service Function-oriented Topology Aggregation in Multi-domain Inter-dC Elastic Optical Networks, Boyuan Yan[1], Yongli Zhao[1], Xiaosong Yu[1], Wei Wang[1], Jie Zhang[1]; [1]*Beijing Univ. of Posts and Telecom, China.* A service function-oriented topology aggregation is proposed, based on which a routing and resource assignment algorithm is designed for service function chain construction in multi-domain optical networks. Simulation results show it can achieve high efficiency.

Room 8

14:00–16:00
Th3G • Hybrid Access Networks for Wireless Delivery
Presider: Hwan Seok Chung; ETRI, Korea

Th3G.1 • 14:00 Invited

Ultrafast Beam Steering Enabled by Photonics & Plasmonics , Juerg Leuthold[1], Romain Bonjour[1], Yannick Salamin[1], Claudia Hoessbacher[1], Wolfgang Heni[1], Christian Haffner[1], Arne Josten[1], Benedikt Baeuerle[1], Masafumi Ayata[1], Andreas Messner[1], Ueli Koch[1], Tatsuhiko Watanabe[1], Yuriy Fedoryshyn[1], Ping Ma[1], Maurizio Burla[1]; [1]*ETH Zurich, Switzerland.* Photonics and plasmonics offer unique opportunities to realize ultrafast millimeter wave beam steering concepts relying on phased array antennas. We discuss recent advances and experiments demonstrating settling times in the order of 10s of ps.

Th3G.2 • 14:30

Wireless Extension for 2.5 Gbit/s GPON, Rattana Cheunchom[1]; [1]*Univ. of Duisburg Essen, Germany.* We report on a coherent RoF architecture for connecting multiple ONUs in a GPON network via a 71-76 GHz E-band wireless link to the OLT. Novel coherent photonic mixer (CPX) modules providing up to +17 dBm RF output power in the E-band are used for direct optic-to-rF conversion.

Th3G.3 • 14:45

Enabling 5G Services in PON with a Novel Smart Edge Based on SiP MRM, Xun Guan[1], Yelong Xu[1], Jiachuan Lin[1], Mingyang Lyu[1], Raphaël Dubé-Demers[1], Sophie LaRochelle[1], Wei Shi[1], Leslie A. Rusch[1]; [1]*Department of elctronic and computer engineering, Centre for optics, photonics and lasers, Canada.* We propose a novel passive optical network (PON) smart edge supporting 5G services by exploiting silicon photonic (SiP) microring modulators (MRM) with advantages of compactness, low-cost, low power and colorless operation. We validate the proposal experimentally.

Room 9

14:00–15:45
Th3H • Optical Switching Sub-systems
Presider: Leif Oxenlowe; DTU Fotonik, Denmark

Th3H.1 • 14:00

4 OAM x 4 WDM Optical Switching Based on an Innovative Integrated Tunable OAM Multiplexer, Ning Zhang[1], Mirco Scaffardi[2], Muhammad N. Malik[2,3], Veronica Toccafondo[2], Charalambos Klitis[1], Martin Lavery[1], Gianluca Meloni[2], Francesco Fresi[3], Emma Lazzeri[3], Diego Marini[1], Jiangbo Zhu[4], Xinlun Xinlun[5], Siyuan Yu[4], Luca Poti[2], Giovan B. Preve[2], Antonella Bogoni[2,3], Marc Sorel[1]; [1]*Univ. of Glasgow, UK;* [2]*CNIT - Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy;* [3]*Sant' Anna di Pisa, Italy;* [4]*Univ. of Bristol, UK;* [5]*State Key Laboratory of Optoelectronic Materials and Technologies, Sun Yat-sen Univ., China.* A 4OAMx4WDM switching experiment has been carried out combining an innovative integrated tunable OAM multiplexer based on 4-concentric omega-shaped silicon waveguides and a refractive element-based OAM demultiplexer; operation is demonstrated up to 120Gb/s.

Th3H.2 • 14:15 Top Scored

83.33 Tb/s Coherent PDM-8PSK SDM-TDM Spatial Superchannel and High-speed Core-joint Switching System, Jose Manuel Delgado Mendinueta[1], Satoshi Shinada[1], Yusuke Hirota[1], Ruben S. Luis[1], Hideaki Furukawa[1], Naoya Wada[1]; [1]*NICT, Japan.* We experimentally demonstrate a record 83.33 Tb/s switching capacity on a time-division spatial super-channel 2x2 switching node making use of core-joint, ns switching-speed and transparent electro-absorption optical switches.

Th3H.3 • 14:30 Invited

Large-scale Optical Circuit Switch Architecture for Intra-datacenter Networking, Yojiro Mori[1], Ken-Ichi Sato[1]; [1]*Nagoya Univ., Japan.* This paper reviews recently developed large-scale optical-circuit-switch architectures suitable for intra-datacenter networking that synergistically combine space switches and wavelength-routing switches. Tunable laser and tunable filter based wavelength-routing schemes are compared in terms of hardware requirements.

Room 1A

Th3A • Current Topics in Long Haul/ Metro Transmission—Continued

Room 6C

Th3B • Directly Modulated Lasers—Continued

Th3B.2 • 15:00 Top Scored

Monolithic Integration of an 8-channel Directly Modulated Membrane-laser Array and a SiN AWG Filter on Si, Hidetaka Nishi[1], Takuro Fujii[1], Nikolaos Panteleimon Diamantopoulos[1], Koji Takeda[1], Erina Kanno[1], Takaaki Kakitsuka[1], Tai Tsuchizawa[1], Hiroshi Fukuda[1], Shinji Matsuo[1]; [1]*NTT, Japan*. Eight-channel 56-gbit/s PAM-4 direct modulations are demonstrated using a 1.3-μm WDM transmitter, consisting of membrane lasers and a SiN AWG filter. Direct bonding, epitaxial regrowth, and low-temperature SiN deposition are employed for integration on Si.

Th3B.3 • 15:15

Superior BER Transmission of 106-Gb/s/lane Skewless PAM4 over 10 km by Utilizing 1.3-μm Directly Modulated InGaAlAs-mQW BH Lasers and Incoherent Multiplexing of Two NRZ Signals, Kouji Nakahara[1], Riu Hirai[2], Takeshi Kitatani[1], Nobuhiko Kikuchi[2], Takayoshi Fukui[1], Kaoru Okamoto[1], Yasushi Sakuma[1], Kohichi Tamura[1], Shigehisa Tanaka[1]; [1]*Oclaro Japan, Inc., Japan;* [2]*Center for Technology Innovation, Hitachi , Japan*. We firstly demonstrate incoherent multiplexing of two NRZ signals utilizing directly modulated lasers transmits 106-gb/s/lane PAM-4 signals over 10 km without non-linear compensation. Skewless eye diagram of this method attained lower BERs than conventional method.

Th3B.4 • 15:30

Mode Selective Active Multimode Interferometer Laser Diode with over 40 GHz Direct Modulation Bandwidth, Bingzhou Hong[1], Tomotaka Mori[1], Haisong Jiang[1], Kiichi Hamamoto[1]; [1]*Kyushu Univ., Japan*. Mode selective active multimode interferometer laser diode demonstrated high speed modulation capacity. Over 40 GHz direct modulation bandwidth was confirmed for the both 0th and 1st order modes.

Room 6D

Th3C • Optical Switching II—Continued

Benjamin G. Lee received the B.S. degree from Oklahoma State University in 2004, and the M.S. and Ph.D. degrees from Columbia University in 2006 and 2009, respectively, all in electrical engineering. He subsequently became a Postdoctoral Researcher at IBM Thomas J. Watson Research Center, where he is currently a Research Staff Member. His research interests include silicon photonic devices, integrated optical switches and networks for high-performance computing systems and datacenters, and highly parallel multimode transceivers. He is a Member of the Optical Society and the IEEE Photonics Society. He currently serves on the Board of Governors for the Photonics Society.

Th3C.4 • 15:30

Demonstration of On-chip 640-Gbit/s Throughput, Granularity-flexible Programmable Optical Filtering and Reconfigurable Optical Add/drop Multiplexing on Silicon Platform, Shuang Zheng[1], Yun Long[1], Dingshan Gao[1], Yan Luo[1], Lulu Wang[1], Jinrun Zhang[1], Andong Wang[1], Long Zhu[1], Zhou Nan[1], Meng Huang[1], Zhengsen Ruan[1], Li Shen[1], Jian Wang[1]; [1]*Wuhan National Laboratory for Optoelectr, China*. By integrating cascaded arrayed-waveguide gratings with array switches on silicon platform, we design and fabricate an on-chip multi-functional photonic signal processor. 640-gbit/s throughput, granularity-flexible programmable optical filtering and reconfigurable optical add/drop multiplexing are demonstrated experimentally.

Room 6E

Th3D • Nonlinear Fiber Effects—Continued

Th3D.2 • 15:00 Top Scored

Blue-enhanced Supercontinuum Generation in a Graded-index Fluorine-doped Multimode Fiber, Zeinab Sanjabi Eznaveh[1], Mohammad Amin Eftekhar[1], Jose Enrique Antonio-Lopez[1], Miroslav Kolesik[2], Helena Lopez-Aviles[1], Frank W. Wise[3], Demetrios Christodoulides[1], Rodrigo Amezcua Correa[1]; [1]*CREOL, Univ. of Central Florida, USA;* [2]*College of Optical Sciences | The Univ. of Arizona, USA;* [3]*Applied and Engineering Physics, Cornell, USA*. We demonstrate blue-enhanced white-light supercontinuum generation in a fluorine-doped parabolic-index multimode fiber. The spectrum expands from 450–2,400nm with excellent spectral flatness and a beam quality factor of M2~1.7 at 1064nm.

Th3D.3 • 15:15

Nonlinear Propagation Equations for Arbitrary Levels of Random Linear Coupling between Modes, Shaival Buch[1,2], Sami Mumtaz[1,2], Rene-Jean Essiambre[2], Antonia M. Tulino[2], Govind P. Agrawal[1]; [1]*Univ. of Rochester, USA;* [2]*Nokia Bell Laboratories, USA*. We derive expressions that enable the study of the impact of arbitrary levels of linear coupling between spatial modes on nonlinear propagation in space-division multiplexed transmission systems, valid for both multimode and coupled-core fibers.

Th3D.4 • 15:30

Stable Measurement of Effective Area in Coupled Multi-core Fiber, Elaine S. Chou[1,2], Tetsuya Hayashi[1], Takuji Nagashima[1], Joseph M. Kahn[2], Tetsuya Nakanishi[1]; [1]*Optical Communications Laboratory, Sumitomo Electric Industries, Ltd., Japan;* [2]*Edward L. Ginzton Laboratory, Stanford Univ., USA*. We achieved stable near-field and far-field patterns measurements and effective area evaluation of randomly coupled multi-core fibers by using a wide-bandwidth light source to average intensity over wavelength and eliminate time-varying intensity fluctuations.

Th3E • Advanced Transmission Technology—Continued

Th3E.3 • 15:00
Single-laser Differential Phase Shift Transmitter for Small Form-factor Quantum Key Distribution Optics, Bernhard Schrenk[1], Michael Hentschel[1], Hannes Hübel[1]; *[1]AIT Austrian Inst. of Technology, Austria*. A cost-effective QKD transmitter based on a phase-modulated laser with integrated pulse carving is experimentally demonstrated. A raw key rate of 4.5kb/s at 2.65% quantum bit error ratio is obtained after 27 km fiber transmission.

Th3E.4 • 15:15
96-GBaud PDM-8QAM Single Channel Transmission over 9,600 km by Nonlinear Tolerance Enhancement using PPLN-based Optical Phase Conjugation, Takayuki Kobayashi[1], Takeshi Umeki[2], Ryoihi Kasahara[2], Hiroshi Yamazaki[2], Munehiko Nagatani[2], HItoshi wakita[2], Hirokazu Takenouchi[2], Yutaka Miyamoto[1]; *[1]NTT Network Innovation Laboratories, Japan; [2]NTT Device Technology Laboratories, Japan*. 96-GBaud PDM-8QAM single carrier long-haul transmission is demonstrated employing polarization-diverse PPLN-based optical phase conjugator which increased the optimal fiber input power by 4dB and extends the transmission distance from 7,040 km to 9,600km.

Th3E.5 • 15:30
Compensation of Mode Coupling in MDM Transmission System using Digital Optical Phase Conjugation, Sung Hyun Bae[1], Youngho Jung[1], Byoung Gon Kim[1], Jun Ho Chang[1], Hoon Kim[1], Yun Chur Chung[1]; *[1]School of electrical engineering, KAIST, Korea*. We propose and demonstrate the compensation of mode coupling in MDM systems by using digital optical phase conjugation. We achieve BERs better than 0.0001 without electrical MIMO processing in FMF link having large mode coupling.

Th3F • Data Center Interconnect Deployments—Continued

Th3G • Hybrid Access Networks for Wireless Delivery—Continued

Th3G.4 • 15:00
First Demonstration of Doppler Compensation Technique using Period-one Nonlinear Semiconductor Laser Dynamics for OFDM-RoF Coherent Detection, Yu-Han Hung[1], Jhih-Heng Yan[2], Hsu-Hung Huang[3], Chin-Hao Tseng[1], Kai Ming Feng[2,3], Sheng-Kwang Hwang[1,4]; *[1]Department of Photonics, National Cheng Kung Univ., Taiwan; [2]Inst. of Communications Engineering, National Tsing Hua Univ., Taiwan; [3]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan; [4]National Cheng Kung Univ., Advanced Optoelectronic Technology Center, Taiwan*. A Doppler compensation technique is proposed and demonstrated for OFDM-RoF coherent detection through frequency synchronization based on period-one nonlinear dynamics of semiconductor lasers. A 28-gHz chirped microwave with +-100 kHz variation is frequency-synchronized in Real-time.

Th3G.5 • 15:15
Demonstration of Ultra-high-resolution Photonics-based Ka-band Inverse Synthetic Aperture Radar Imaging, Yao Yao[1], Fangzheng Zhang[1], Ying Zhang[1], Xingwei Ye[1], Daiyin Zhu[1], Shilong Pan[1]; *[1]NUAA, China*. We demonstrate a photonics-based Ka-band radar system with 12 GHz bandwidth by optical signal generation and de-chirp processing. Inverse synthetic aperture radar imaging with a range resolution as high as ~1.3 cm high-resolution is achieved.

Th3G.6 • 15:30
Extremely Wide Bandwidth Microwave Photonic Phase Shifter for W-band Chirped Monopulse Radar, Bohao Liu[1], Jhih-Min Wun[2], Nathan O'Malley[1], Daniel Leaird[1], Nan-Wei Chen[3], Jin-Wei Shi[2], Andrew Weiner[1]; *[1]Purdue Univ., USA; [2]National Central Univ., Taiwan; [3]Yuan Ze Univ., Taiwan*. Phase-shifting of extremely wide-band chirped pulses (80-95 GHz) is realized using optically shaped pulses and dual photonic transmitters. Sum/difference radiation patterns with ~15 dB extinction ratio are demonstrated, offering prospects for W-band monopulse radar.

Th3H • Optical Switching Subsystems—Continued

Th3H.4 • 15:00
T/O-band Wavelength Routing System using Quantum Dot Semiconductor Devices and 1081-channel AWG Router, Ryogo Kubo[1], Takuto Fujimoto[1], Takahiro Shobudani[1], Yudai Okuno[1], Masaki Suzuki[1], Hiroyuki Tsuda[1], Makoto Sudo[2], Tadashi Hajikano[2], Yasunori Tomomatsu[3], Katsumi Yoshizawa[4]; *[1]Keio Univ., Japan; [2]Optoquest Co., Ltd., Japan; [3]Koshin Kogaku Co., Ltd., Japan; [4]Pioneer Micro Technology Corporation, Japan*. We demonstrate a wavelength routing system that covers a broad wavelength range of 1000–1360 nm, i.e., T/O-band. The system includes our developed T/O-band-specific quantum dot semiconductor devices and 1081-channel arrayed waveguide grating (AWG) router.

Th3H.5 • 15:15
Next-generation ROADM Employing Bandwidth-adaptive Silicon-photonic Filters for Flexible Drop Operation, Yojiro Mori[1], Koh Ueda[1], Keijiro Suzuki[2], Hiroyuki Matsuura[2], Ken Tanizawa[2], Kazuhiro Ikeda[2], Shu Namiki[2], Hitoshi Kawashima[2], Ken-Ichi Sato[1,2]; *[1]Nagoya Univ., Japan; [2]National Inst. of Advanced Industrial Science and Technology (AIST), Japan*. As one step in realizing next-generation flexible ROADMs, we demonstrate the effectiveness of a bandwidth-adaptable silicon-photonic filter, through transmission experiments on 10-gbps OOK, 40-gbps DQPSK, 100-gbps DP-QPSK, 400-gbps 2-subchannel DP-16QAM, and 1-tbps 5-subchannel DP-16QAM signals.

Th3H.6 • 15:30
Experimental Utilization of Repeated Spatial-mode Shifting for Achieving Discrete Delays in a Free-space Recirculating Loop, Ahmed Almaiman[1], Amirhossein Mohajerin-Ariae[1], Guodong Xie[1], Zhe Zhao[1], Fatemeh Alishahi[1], Yinwen Cao[1], Peicheng Liao[1], Changjing Bao[1], Ahmad Fallahpour[1], Bishara Shamee[1], Youichi Akasaka[2], Shlomo Zach[3], Nadav Cohen[3], Moshe Tur[3], Alan E. Willner[1]; *[1]Univ. of Southern California, USA; [2]Fujitsu Laboratories of America, USA; [3]School of Electrical Engineering, Tel Aviv Univ., Israel*. We demonstrate an all-optical free-space recirculating delay loop by shifting the spatial mode order using the orbital-angular momentum (OAM) basis. The orthogonality of the OAM modes is used to easily select the desirable delay at the loop output.

Room 1A	Room 6C	Room 6D	Room 6E
Th3A • Current Topics in Long Haul/ Metro Transmission—Continued	**Th3B • Directly Modulated Lasers—Continued**	**Th3C • Optical Switching II—Continued**	**Th3D • Nonlinear Fiber Effects—Continued**
	Th3B.5 • 15:45  **A Fully-integrated Multi-λ Hybrid DML Transmitter,** Di Liang[1], Chong Zhang[1], Ashkan Roshan-Zamir[2], Kunzhi Yu[2], Cheng Li[1], Geza Kurczveil[1], Yingtao Hu[1], Wenqing Shen[3], Marco Fiorentino[1], Satish Kumar[3], Samuel Palermo[2], Raymond Beausoleil[1]; *[1]Hewlett Packard Labs, USA; [2]Department of Electrical and Computer Engineering, Texas A&M Univ., USA; [3]School of Mechanical Engineering, Georgia Inst. of Technology, USA.* A multi-wavelength, hybrid directly-modulated laser (DML) transmitter with integrated thermal shunt, MOS capacitor and CMOS driver circuit is fabricated. 14 Gb/s operation from conventional direct current modulation and a novel MOS-type laser modulation are demonstrated.	**Th3C.5 • 15:45**  **Low-crosstalk, Low-power Mach-Zehnder Interferometer Optical Switch based on III-V/Si Hybrid MOS Phase Shifter,** Qiang Li[1], Jae-Hoon Han[1,2], Chong Pei Ho[1,3], Shinichi Takagi[1], Mitsuru Takenaka[1]; *[1]The Univ. of Tokyo, Japan; [2]Korea Inst. of Science and Technology, Korea; [3]Japan Society for Promotion of Sciences Fellowship, Japan.* An optical switch with InGaAsP/Si hybrid metal-oxide-semiconductor phase shifter is demonstrated with low crosstalk (-28.6 dB) and low power consumption (1.3 nW) due to the large electron-induced refractive index change and small absorption in InGaAsP.	**Th3D.5 • 15:45**  **Non-invasive Distributed Characterization in Phase and Intensity of the Nonlinear Stage of Modulation Instability,** Corentin Naveau[1], Pascal Szriftgiser[1], François Copie[1], Alexandre Kudlinski[1], Matteo Conforti[1], Stefano Trillo[2], Arnaud Mussot[1]; *[1]Univ. Lille, CNRS, UMR 8523-phLAM – Physique des Lasers Atomes et Molécules, France; [2]Department of Engineering, Univ. of Ferrara, Italy.* We report a novel experimental setup to perform distributed characterization in intensity and phase of the nonlinear stage of modulation instability by means of a non-invasive experimental setup : a heterodyne time domain reflectometer.

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

16:30–18:30 Postdeadline Sessions, *Rooms 6C, 6D, 6E, 6F*

NOTES

Room 6F	Room 7AB	Room 8	Room 9
Th3E • Advanced Transmission Technology—Continued	**Th3F • Data Center Interconnect Deployments—Continued**	**Th3G • Hybrid Access Networks for Wireless Delivery—Continued**	**Th3H • Optical Switching Subsystems—Continued**

Th3G.7 • 15:45
Efficient Mobile Fronthaul using Windowed OFDM Exhibiting High CFO Tolerance and Strong OOB-leakage Suppression with Low DSP Complexity, Shuyi Shen[1], Thavamaran Kanesan[2], Feng Lu[1], Mu Xu[1], Lin Cheng[1], Jing Wang[1], Yahya M. Alfadhli[1], Hyung Joon Cho[1], Sufian M. Mitani[2], Gee-Kung Chang[1]; *[1]ECE, Georgia Inst. of Technology, USA; [2]TM Research & Development, Malaysia*. A novel windowed-OFDM transmission scheme is demonstrated to achieve 2.2-dB improvement of carrier-frequency-offset tolerance and 20-dB out-of-band-leakage suppression for MMW-RoF mobile fronthaul, with low computational complexity and no additional overhead owing to effective time-domain windowing.

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

16:30–18:30 Postdeadline Sessions, *Rooms 6C, 6D, 6E, 6F*

NOTES