Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB

Details on all Workshops (both Sunday and Monday) can be found on pages 10-13

12:00–13:30 Lunch Break *(on your own)*

13:30–15:30
M2A • Deployable Networks for Access & Metro

Presider: Xi Wang; Fujitsu Laboratories of America Inc, USA

M2A.1 • 13:30 Invited

Ad-Hoc Photonic Network Based on Movable and Deployable ICT Resource Unit to Meet Rapidly Changing Service Demands, Toshikazu Sakano[1], Tetsuro Komukai[1], Atsushi Takahara[1], Toshihiko Hirooka[2], Masataka Nakazawa[2]; *[1]NTT Network Innovation Laboratories, Japan; [2]Research Institute of Electrical Communication, Tohoku Univ., Japan.* This paper reviews an emerging photonic network architecture based on the movable and deployable ICT resource unit(MDRU). The architecture enables us to instantly deploy an ad-hoc network that can meet rapid changes in service demand.

13:30–15:30
M2B • Cross-connects & Switching Devices

Presider: Benjamin Lee; IBM TJ Watson Research Center, USA

M2B.1 • 13:30

Scaling Limits of Free-Space Tilt Mirror MEMS Switches for Data Center Networks, William Mellette[1], Joseph E. Ford[1]; *[1]Univ. of California San Diego, USA.* We present a first-principles analysis of the scaling of switch response speed as a function of port count, crosstalk, and insertion loss, based on physical optics and kinematics of canonical MEMS tilt mirror switch structures.

M2B.2 • 13:45

Multi-Core Fiber based Pluggable Add/Drop Link using Rotational Connector, Kotaro Saito[1], Takashi Matsui[1], Kazuhide Nakajima[1], Taiji Sakamoto[1], Fumihiko Yamamoto[1], Toshio Kurashima[1]; *[1]NTT, Japan.* We realize an arbitrary core access in multi-core fiber (MCF) by using a planar lightwave circuit and a rotational connector technologies. This enables easy and reconfigurable construction of a high-speed multiple link over an MCF.

13:30–15:30
M2C • Multimode Fiber

Presider: Scott Bickham; Corning Incorporated, USA

M2C.1 • 13:30

Experimental Investigation of Relation Between Mode-Coupling and Fiber Characteristics in Few-Mode Fibers, Ryo Maruyama[1], Nobuo Kuwaki[1], Shoichiro Matsuo[1], Masaharu Ohashi[2]; *[1]Optics and Electronics Laboratory, Fujikura.ltd, Japan; [2]Graduate School of Engineering, Osaka Prefecture Univ., Japan.* We experimentally clarify that relation between mode-coupling coefficient h and effective-index difference Δn_{eff} in few-mode fibers (FMFs) by impulse response technique and h in our fabricated FMFs with $\Delta n_{eff} \geq 1.7\times10^{-3}$ converges to 7.4×10^{-5} 1/km.

M2C.2 • 13:45 Top Scored

Low-Differential-Mode-Group-Delay 9-LP-Mode Fiber, Pierre Sillard[1], Denis Molin[1], Marianne Bigot-Astruc[1], Koen de Jongh[2], Frank Achten[2]; *[1]Prysmian Group, France; [2]Prysmian Group, Netherlands.* We report the fabrication of low-differential-mode-group-delay 9-LP-mode fibers using a standard bend-insensitive 50µm-diameter-core multimode process. Such 9-LP-mode fibers exhibit DMGDs <155ps/km at 1550nm.

13:30–15:30
M2D • VCSELs & Tunable Lasers

Presider: Daniel Kuchta; IBM TJ Watson Research Center, USA

M2D.1 • 13:30 Top Scored

Narrow linewidth sampled-grating distributed Bragg reflector laser with enhanced side-mode suppression, Michael Larson[1], Ashish Bhardwaj[1], Wei Xiong[1], Yan Feng[1], Xiao-dong Huang[1], Konstantin Petrov[1], Michael Moewe[1], Hongyan Ji[1], Alex Semakov[1], Chengwei Lv[1], Srivatsa Kutty[1], Aditi Patwardhan[1], Niki Liu[1], Zhaoming Li[1], Yujian Bao[1], Zonghua Shen[1], Sukhbir Bajwa[1], Fenhong Zhou[1], Ping-Chiek Koh[1]; *[1]JDSU, USA.* We demonstrate a thermally tuned SGDBR laser integrated with semiconductor optical amplifier and spectral filter achieving 70kHz spectral linewidth, 50dB SMSR, and +17dBm fiber-coupled output power over a 41nm wavelength range across the C-band.

M2D.2 • 13:45

High Efficiency and SMSR Distributed Feedback Laser Array Integrated with Passive Grating Reflector Based on Reconstruction-Equivalent-Chirp Technique, Yunshan Zhang[1,2], Jilin Zheng[1,3], Yuechun Shi[1], Shengping Liu[1], Wenting Wang[1], Jun Lu[1], Haiming Xu[4], Qi Tang[4], Xiangfei Chen[1]; *[1]Nanjing Univ., China; [2]Nanjing Univ. (Suzhou) High-Tech Insititute , China; [3]PLA Univ. of Science and Technology, China; [4]Wuhan Huagong Genuine Optics Tech Co., Ltd, China.* We reported a 4-channel DFB laser array integrated with passive-grating-reflector utilizing reconstruction-equivalent-chirp technique. 53.3% increase of slope efficiency, 27.3% decrease of threshold current are obtained with >60dB SMSR and wavelength spacing deviation<0.07nm.

13:30–15:30
M2E • Coherent Optical Processing

Presider: Periklis Petropoulos; Optoelectronics Research Centre, UK

M2E.1 • 13:30 Invited

Progress in Photonic Sampled Analog-to-Digital Conversion, Andreas O. Wiberg[1]; *[1]Univ. of California, San Diego, USA.* Recent advances in photonic sampled analog-to-digital conversion of wideband signals are reviewed in context of the parametric polychromatic sampling and cavity-less pulse source driven subsampling. Latest results and a new figure of merit are presented.

Details on all Workshops (both Sunday and Monday) can be found on pages 10-13

12:00–13:30 Lunch Break *(on your own)*

13:30–15:30
M2F • Free-Space Optical Communication

Presider: Michael Sauer; Corning Incorporated, USA

M2F.1 • 13:30 Top Scored

400-Gbit/s Free Space Optical Communications Link Over 120-meter Using Multiplexing of 4 Collocated Orbital-Angular-Momentum Beams, Yongxiong Ren[1], Zhe Wang[1], Peicheng Liao[1], Long Li[1], Guodong Xie[1], Hao Huang[1], Zhe Zhao[1], Yan Yan[1], Nisar Ahmed[1], Martin Lavery[1,2], Nima Ashrafi[3], Solyman Ashrafi[3], Roger Linquist[3], Moshe Tur[4], Ivan B. Djordjevic[5], Mark Neifeld[5], Alan Willner[1]; *[1]Department of Electrical Engineering, Univ. of Southern California, USA; [2]College of Science and Engineering, Univ. of Glasgow, UK; [3]NxGen Partners, USA; [4]Tel Aviv Univ., School of Electrical Engineering, Israel; [5]Dept. of Electrical and Computer Engineering, Univ. of Arizona, USA.* We experimentally demonstrate a 400-Gbit/s free-space optical communications link over 120 meters on the building roof by multiplexing four orbital angular momentum (OAM) modes (OAM l = ±1, ±3) each carrying a 100-Gbit/s data channel.

M2F.2 • 13:45

1.8-Gb/s WDM Visible Light Communication Over 50-meter Outdoor Free Space Transmission Employing CAP Modulation and Receiver Diversity Technology, Yiguang Wang[1], Xingxing Huang[1], Li Tao[1], Nan Chi[1]; *[1]Fudan Univ., China.* We experimentally demonstrate a WDM VLC system employing CAP modulation and receiver diversity technology. The record aggregate data rate of 1.8Gb/s with the BER less than 3.8×10^{-3} is successfully achieved over 50-m outdoor transmission.

13:30–15:30
M2G • High-Baud Rate Transceivers

Presider: Gabriella Bosco; Politecnico di Torino, Italy

M2G.1 • 13:30 Top Scored

160-Gbaud coherent receiver based on 100-GHz bandwidth, 240-GS/s analog-to-digital conversion, Gregory Raybon[1], Binbin Guan[1], Andrew Adamiecki[1], Peter J. Winzer[1], Nicolas K. Fontaine[1], Sai Chen[1], Peter Papalaikis[2], Roger Delbue[2], K. Doshi[2], B. Bhat[2], Alan Blankman[2], Agnieszka Konczykowska[3], Jean-Yves Dupuy[3], Filipe Jorge[3]; *[1]Alcatel-Lucent Bell Labs, USA; [2]Teledyne LeCroy, USA; [3]3III-V Lab, joint lab between Bell Labs, TRT and CEA/Leti, France.* We demonstrate a coherent receiver using a 100-GHz electrical bandwidth and 240-GS/s real-time oscilloscope as analog-to-digital converter in a 160-Gbaud QPSK system.

M2G.2 • 13:45

Bandwidth Scalable and High Fidelity Spectrally-Sliced Transmitter, Binbin Guan[1,2], Nicolas K. Fontaine[1], Roland Ryf[1], Sai Chen[1], Gregory Raybon[1], Chongjin Xie[1], Ryan P. Scott[2], S. J. B. Yoo[2]; *[1]Bell Laboratories, Alcatel-Lucent, USA; [2]Department of Electrical and Computer Engineering, Univ. of California Davis, USA.* We demonstrate a high-fidelity transmitter based on the synthesis of multiple spectral slices and transmit a 60-GBd PDM-QPSK waveform over 4480 km with a Q2-factor of 8.71 -dB using two slices.

13:30–15:30
M2H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV I

Presider: Marina Thottan; Alcatel-Lucent Bell Labs, USA

M2H.1 • 13:30 Invited

ONF: Applying SDN to Optical Transport, Dan Pitt[1]; *[1]Open Networking Foundation, USA.* One of the key tenets of SDN followed by the Open Networking Foundation is the abstraction of network behavior.This has enabled the separation of forwarding and control and led to faster innovation in both the forwarding plane and the control plane. In our work on optical transport, we have demonstrated common control for packet and optical switching, as well as application access to network topology and control. In this talk, we will describe ONF's SDN architectural view of the network in general and optical transport in particular and explain the extensions to OpenFlow that instantiate SDN for optical transport along with the requirements they satisfy.

M2H.2 • 13:50 Invited

Implementing SDN Controlled Flexible Optical Transport at AT&T, the Next Steps, Mehran Esfandiari[1]; *[1]AT&T, USA.* An overall view of AT&T's SDN based optical transport target architecture, role of flexible and feature rich network elements, SDN driven use cases to enable multi-layer packet/optical network in serving cloud applications, and practical & real implementation in the near term.

13:45–15:30
M2I • Impairment-Aware Network Design

Presider: Maite Brandt-Pearce; Univ. of Virginia, USA

M2I.1 • 13:45

Nonlinear Impairment Aware Resource Allocation in Elastic Optical Networks, Juzi Zhao[1], Henk Wymeersch[1], Erik Agrell[1]; *[1]Department of Signals and Systems, Chalmers Univ. of Technology, Sweden.* We propose a novel integer linear program formulation and low-complexity heuristics for nonlinear impairment-aware routing and spectrum allocation in OOFDM-based elastic optical networks. Results indicate 23% bandwidth reduction compared with a transmission reach-based benchmark method.

13:30–15:30
M2J • Next-Generation Mobile Fronthaul

Presider: Jun Shan Wey; LightNotes Consulting, USA

M2J.1 • 13:30

Mobile front-haul employing Ethernet-based TDM-PON system for small cells, Naotaka Shibata[1], Takayoshi Tashiro[1], Shigeru Kuwano[1], Naohiko Yuki[1], Jun Terada[1], Akihiro Otaka[1]; *[1]NTT, Japan.* We develop a mobile front-haul prototype based on TDM-PON (10G-EPON). The system can accommodate 3 CPRI option-3 links and 7 compressed CPRI option-3 links with reasonable latency under 100 µs.

M2J.2 • 13:45

Demonstration of Bandwidth-Efficient Mobile Fronthaul Enabling Seamless Aggregation of 36 E-UTRA-Like Wireless Signals in a Single 1.1-GHz Wavelength Channel, Xiang Liu[1], Frank Effenberger[1], Naresh Chand[1], Lei Zhou[2], Huafeng Lin[2]; *[1]Futurewei Technologies, USA; [2]Huawei Technologies, China.* We experimentally demonstrate a bandwidth-efficient mobile fronthaul system, where 36 E-UTRA-like wireless signals, six for each standardized bandwidth, 1.4/3/5/10/15/20 MHz, are aggregated in a single wavelength channel, achieving >30 dB loss budget for a 20-km SSMF link.

Room 402AB

M2A • Deployable Networks for Access & Metro—Continued

M2A.2 • 14:00
Self-Seeded RSOAs WDM PON Field Trial for Business and Mobile Fronthaul Applications, Fabienne Saliou[1], Gael Simon[1], Philippe Chanclou[1], Marco Brunero[2], Lucia Marazzi[2], Paola Parolari[2], Mario Martinelli[2], Romain Brenot[3], Anaelle Maho[3], Sophie Barbet[3], Giancarlo Gavioli[4], Giorgio Parladori[4], Simon Gebrewold[5], Juerg Leuthold[5]; [1]*Orange Labs, France;* [2]*Dip. Elettronica Informazione e Bioingegneria, Politecnico di Milano, Italy;* [3]*Alcatel-Thales III-V Laboratory, France;* [4]*Optics Division, Alcatel-Lucent Italy, Italy;* [5]*Institute of Electromagnetic Fields (IEF), ETH Zurich, Switzerland.* GEth, CPRI and 10 Gbit/s transmissions are experimented using amplified and standard self-seeded RSOA WDM PON systems. A field trial setup was exploited to test the system performance in terms of reach and optical budget.

M2A.3 • 14:15
Field Trial and Analysis of N:1 Redundant 10G-EPON Using Boost-type Semiconductor Optical Amplifier, Takuya Tsutsumi[1], Yoshihito Sakai[1], Takeshi Sakamoto[1], Manabu Kubota[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, Nippon Telegraph and Telephone Corp., Japan.* We demonstrate a high-reliable and long-reach N:1 redundant 10G-EPON system implemented on a commercial access network. We also develop an analysis method for estimating total reachable distance for 10G-EPON systems that use optical amplifiers.

Room 403A

M2B • Cross-connects & Switching Devices—Continued

M2B.3 • 14:00 Invited
Large-Port-Count MEMS Silicon Photonics Switches, Ming C. Wu[1], Sangyoon Han[1], Tae Joon Seok[1], Niels Quack[1]; [1]*Univ. of California Berkeley, USA.* Highly integrated optical circuit switch (OCS) with large port counts (~100x100) is achievable by combining silicon photonics and MEMS technologies. We will review the design trade-offs, performance scaling, and the current state of the art.

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

Room 403B

M2C • Multimode Fiber—Continued

M2C.3 • 14:00 Invited
Recent Advances in Low DGD Few-mode Fibre Design, Fabrication, Characterization and Experiments, Lars Grüner-Nielsen[1], Yi Sun[2], Rasmus Vincentz S. Jensen[1], Jeffrey W. Nicholson[3], Robert Lingle[2]; [1]*OFS, Denmark;* [2]*OFS, USA;* [3]*OFS Laboratories, USA.* Design principles for low loss and control of mode coupling, fabrication results for DGD control, and characterization techniques are briefly reviewed. Experimental results for fibers supporting three or six spatial modes are presented.

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

Room 404AB

M2D • VCSELs & Tunable Lasers—Continued

M2D.3 • 14:00
Single Output Tunable DFB Semiconductor Laser Array with Equivalent Phase Shift, Lianyan Li[1], Song Tang[1], Baoli Cao[1], Jun Lu[1], Xiangfei Chen[1]; [1]*Nanjing Univ., China.* We report single output tunable DFB semiconductor laser arrays in series and grating-matrix configuration designed by reconstruction equivalent chirp (REC) technique. By using interference lithography and photolithography for the grating fabrication, tunable laser arrays with good performance are experimentally realized with low cost.

M2D.4 • 14:15
Widely tunable Coupled Cavity Laser based on a Michelson Interferometer with doubled Free Spectral Range, Domenico D'Agostino[1], Daan Lenstra[1], Huub Ambrosius[1], Meint Smit[1]; [1]*Technische Universiteit Eindhoven, USA.* We present a 26 nm tunable Coupled Cavity Laser based on a novel interferometer and fabricated in a low-cost generic foundry process, with SMSR above 40 dB and fibre coupled power > 5mW.

Room 406AB

M2E • Coherent Optical Processing—Continued

M2E.2 • 14:00
Pump-Phase-Noise-Tolerant Wavelength Multicasting for QAM Signals using Flexible Coherent Multi-Carrier Pump, Guo-Wei Lu[1,2], Takahide Sakamoto[1], Tetsuya Kawanishi[1]; [1]*Natl. Inst. of Info. & and Comm. Tech., Japan;* [2]*Tokai Univ., Japan.* We propose and demonstrate pump-phase-noise-tolerant 1-to-7 wavelength multicasting for QAM signals using flexible coherent multi-carrier pump. Less than 0.8dB penalty is obtained after multicasting with the elimination of phase noise from pump using coherent pumping.

M2E.3 • 14:15
Low Noise Degenerate FWM of 12×100 Gb/s DP-QPSK Signals with Counter-Dithering of Pump and Idler Waves , Mark D. Pelusi[1], Karen Solis-Trapala[2], Hung Nguyen Tan[2], Takashi Inoue[2], Shu Namiki[2]; [1]*Univ. of Sydney, Australia;* [2]*National Institute of Advanced Industrial Science and Technology (AIST), Japan.* We demonstrate degenerate four-wave mixing of a 12×100 Gb/s DP-QPSK signal with counter-phase dithering by a phase modulator embedded in a fiber-loop. A ≈9 dB higher conversion efficiency enables an OSNR penalty of 0.7 dB at 10^{-3} BER.

Room 407

M2F • Free-Space Optical Communication—Continued

M2F.3 • 14:00
42.8 Gbit/s Indoor Optical Wireless Communication with 2-Dimensional Optical Beam-steering, Chin Wan (Joanne) Oh[1], Eduward Tangdiongga[1], A. M. J. Koonen[1]; [1]*Eindhoven Univ. of Technology, Netherlands.* To combat the imminent radio frequency spectrum crunch, we propose an infrared optical wireless communication solution for in-home networks, with remotely controlled 2-dimensional passive optical beam-steering, which exhibited 42.8 Gbit/s over 2.5 m free-space transmission.

M2F.4 • 14:15
Demonstration of M-ary Encoding/Decoding Using Visible-Light Bessel Beams Carrying Orbital Angular Momentum (OAM) For Free-Space Obstruction-Free Optical Communications, Jing Du[1], Shuhui Li[1], Yifan Zhao[1], Zhidan Xu[1], Long Zhu[1], Peng Zhou[1], Jun Liu[1], Jian Wang[1]; [1]*Huazhong Univ. of Sci. and Tech., China.* We experimentally demonstrate m-ary encoding/decoding using visible-light Bessel beams carrying OAM for free-space obstruction-free optical communications. A zero bit-error rate of hexadecimal encoding/decoding is observed after decoding 500 symbols with obstruction.

Room 408A

M2G • High-Baud Rate Transceivers—Continued

M2G.3 • 14:00 Invited
Spectrally Efficient 1Tb/s Transceivers, Jeremie Renaudier[1], Rafael Rios-Müller[1], Laurent Schmalen[2], Gabriel Charlet[1]; [1]*Bell Labs Alcatel-Lucent, France;* [2]*Bell Labs, Alcatel-Lucent, Germany.* Based on recent Terabit-class transmission experiment, we discuss the design of 1Tb/s transceivers for long-haul optical systems involving complex tradeoffs between constellation complexity, opto-electronics bandwidth limitations, ROADM cascade, advanced FEC...

Room 408B

M2H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV I—Continued

M2H.3 • 14:10 Invited
Architecting the Next Generation DCN for Flexibility and Scale with Optics and SDN, Katherine Barabash[1]; [1]*IBM, Israel.* Recent trends in cloud computing call for rethinking the Data Center Network (DCN) design for huge capacities, tremendous scale, and high levels of flexibility. On the other hand, business and environmental sustainability concerns call for improving the cost effectiveness and power efficiency. DCN architecture proposed by EU project COSIGN stands up for these challenges by combining optical technologies for data plane benefits, Software Defined Networking (SDN) for control plane programmability, and orchestration software for advanced network service provisioning.

Room 409AB

M2I • Impairment-Aware Network Design—Continued

M2I.2 • 14:00
Impact of Physical Layer Restrictions on the Dynamic Switching of Channels in Transparent Optical Networks, David Schenk[1], Peter M. Krummrich[1]; [1]*TU Dortmund, Germany.* Physical layer effects restricts the arbitrarily fast dynamic channel switching in transparent optical networks. We show the influence of these effects and how they limit the dynamic switching of channels.

M2I.3 • 14:15
Assessment of Options for Utilizing SNR Margin to Increase Network Data Throughput, David J. Ives[1], Polina Bayvel[1], Seb J. Savory[1]; [1]*Univ. College London, UK.* When optimizing an optical network should we adapt the SNR to the signal or adapt the signal to the available SNR? We show both approaches give comparable results but have different complexity trade-offs.

Room 411

M2J • Next-Generation Mobile Fronthaul—Continued

M2J.3 • 14:00
High-Capacity Mobile Fronthaul Supporting LTE-Advanced Carrier Aggregation and 8×8 MIMO, Ming Zhu[2,1], Xiang Liu[2], Naresh Chand[2], Frank Effenberger[2], Gee-Kung Chang[1]; [1]*Georgia Institute of Technology, USA;* [2]*Futurewei Technologies, Huawei R&D USA, USA.* We demonstrate a SCM-PON mobile fronthaul architecture supporting 4+G cell sites with 3 RRHs, 5 aggregated carriers, and 8×8 MIMO (60×20MHz per λ) using 2-GHz-bandwidth optical components with first demonstration of complete RF signal processing.

M2J.4 • 14:15
Split-PHY Processing Architecture to Realize Base Station Coordination and Transmission Bandwidth Reduction in Mobile Fronthaul, Kenji Miyamoto[1], Shigeru Kuwano[1], Jun Terada[1], Akihiro Otaka[1]; [1]*NTT Corporation, Japan.* We propose a new RAN architecture splitting BS functions within PHY layer. It reduces mobile fronthaul transmission bandwidth by 90 % and achieves BS coordination performance with 0.5 dB SNR degradation compared to conventional C-RAN.

M2A • Deployable Networks for Access & Metro—Continued

M2A.4 • 14:30 Invited

In-Network Experiences with Installed OTN Switched Metro Core Optical Systems, Michael Freiberger[1]; *[1]Verizon Communications Inc, USA.* Muxponders, while useful at the access edge, are no longer ideal for metro core network use. OTN switching in the metro core moves muxponders to the access edge, resulting in a more efficient metro core.

M2B • Cross-connects & Switching Devices—Continued

M2B.4 • 14:30 Top Scored

50x50 Digital Silicon Photonic Switches with MEMS-Actuated Adiabatic Couplers, Tae Joon Seok[1], Niels Quack[1], Sangyoon Han[1], Ming C. Wu[1]; *[1]Univ. of California, Berkeley, USA.* We report on monolithically integrated 50x50 digital silicon photonic switches with MEMS actuation, sub-microsecond switching time, low optical insertion loss (<9.6dB), high extinction ratio (50dB), broadband operation (1400-1700nm), and compact footprint (7.6x7.6mm^2).

M2B.5 • 14:45

32×32 Strictly Non-Blocking Si-Wire Optical Switch on Ultra-Small Die of 11×25 mm^2, Ken Tanizawa[1], Keijiro Suzuki[1], Munehiro Toyama[1], Minoru Ohtsuka[1], Nobuyuki Yokoyama[1], Kazuyuki Matsumaro[1], Miyoshi Seki[1], Keiji Koshino[1], Toshio Sugaya[2], Satoshi Suda[1], Guangwei Cong[1], Toshio Kimura[2], Kazuhiro Ikeda[1], Shu Namiki[1], Hitoshi Kawashima[1]; *[1]Natl Inst of Adv Industrial Sci & Tech, Japan; [2]Furukawa Electric. Co. Ltd., Japan.* We demonstrate an ultra-compact 32×32 path-independent-insertion-loss optical switch that integrates 1024 thermooptic MZ switches on SOI platform using ArF immersion lithography. On-chip loss of 19.7 dB and estimated crosstalk of -20 dB are achieved.

M2C • Multimode Fiber—Continued

M2C.4 • 14:30

Extra-Wide-Band OM4 MMF for Future 1.6Tbps Data Communications, Marianne Bigot[1], Denis Molin[1], Frank Achten[2], Adrian Amezcua-Correa[3], Pierre Sillard[1]; *[1]Prysmian Group, France; [2]Prysmian Group, Netherlands; [3]Prysmian Group, France.* We report the fabrication of a Highly Germanium and Fluorine co-doped MMF optimized according to effective bandwidth considerations, with OM4 performance over the 850-1000nm window. Such fiber opens the door to future 1.6Tbps data communications.

M2C.5 • 14:45

Zero Dispersion Modes and its Effects on Characterization of MMF Chromatic Dispersion, Bulent Kose[1], Rick Pimpinella[1], Jose M. Castro[1], Yu Huang[1], Asher Novick[1]; *[1]Panduit, USA.* The multiple zero dispersion wavelengths of multimode fiber modes are studied. The effect of these mode and the launch conditions on the characterization of chromatic dispersion is estimated.

M2D • VCSELs & Tunable Lasers—Continued

M2D.5 • 14:30 Invited

High Speed and High Temperature Operation of VCSELs, Petter Westbergh[1], Johan Gustavsson[1], Anders Larsson[1]; *[1]MC2 - Photonics Laboratory, Chalmers Univ. of Technology, Sweden.* We report on the high speed and high temperature characteristics of 850 nm VCSELs and VCSEL arrays capable of meeting the requirements for the next generation optical interconnect standards.

M2E • Coherent Optical Processing—Continued

M2E.4 • 14:30

Experimental Demonstration of Tunable Phase-Noise Mitigation and Automatic Frequency/Phase Locking for a 20-32 Gbaud QPSK Homodyne Receiver using Optical Mixing of Nonlinearly Generated Higher Harmonics, Amirhossein Mohajerin Ariaei[1], Morteza Ziyadi[1], Mohammad-Reza Chitgarha[1], Ahmed Almaiman[1], Yinwen Cao[1], Youichi Akasaka[2], Jeng-Yuan Yang[2], Motoyoshi Sekiya[2], joseph touch[3,1], Moshe Tur[4], Shigehiro Takasaka[5], Ryuichi Sugizaki[5], Carsten Langrock[6], Martin M. Fejer[6], Alan Willner[1]; *[1]Univ. of Southern California (USC), USA; [2]Fujitsu Laboratories of America, USA; [3]Information Sciences Institute, USA; [4]Tel Aviv Univ., Israel; [5]Fitel Photonics Laboratories, Japan; [6]Stanford Univ-Edward L. Ginzton Laboratory, USA.* We experimentally demonstrate tunable phase-noise mitigation and automatic frequency/phase locking to a "local" pump laser for a 20-32 Gbaud QPSK homodyne receiver using nonlinear optical signal processing. For the input noisy signal, open eye-diagrams are obtained for in-phase and quadrature components and ~2 dB OSNR gain is achieved at BER 10^{-3}.

M2E.5 • 14:45

Wavelength-preserving Temporal Phase Conjugation based on Intensity-only Detection and Modulation Devices, María R. Fernández-Ruiz[1], José Azaña[1]; *[1]INRS - EMT, Canada.* A novel temporal optical phase conjugator based on intensity-only devices is presented. As proof-of-concept, wavelength-preserving conjugation of arbitrarily-chirped pulses and a 16-QAM signal is demonstrated using a photodetector and Mach-Zehnder modulator, avoiding all electronic-domain processing.

Room 407

M2F • Free-Space Optical Communication—Continued

M2F.5 • 14:30
Experimental Demonstration of Free-Space Optical Communications Using OFDM-QPSK/16QAM-Carrying Fractional Orbital Angular Momentum (OAM) Multiplexing, Jian Wang[1], Jun Liu[1], Shuhui Li[1], Long Zhu[1], Chao Li[1], Ming Luo[2], Qi Yang[2], shaohua yu[2]; *[1]Huazhong Univ. of Science and Technology, China; [2]State Key Laboratory of Optical Comm. Technologies and Networks, China.* We report free-space optical communications exploiting fractional orbital angular momentum (OAM) multiplexing. Using OFDM-QPSK/16QAM signals over fractional OAM beams, fractional OAM communications are experimentally demonstrated even with a small OAM channel spacing of 0.6.

M2F.6 • 14:45
Performance Enhancement of an Orbital-Angular-Momentum-Based Free-Space Optical Communication Link through Beam Divergence Controlling, Long Li[1], Guodong Xie[1], Yongxiong Ren[1], Nisar Ahmed[1], Hao Huang[1], Zhe Zhao[1], Peicheng Liao[1], Martin Lavery[2], Yan Yan[1], Changjing Bao[1], Zhe Wang[1], Nima Ashrafi[3,4], Solyman Ashrafi[3], Roger Linquist[3], Moshe Tur[5], Alan Willner[1]; *[1]Univ. of Southern California, USA; [2]Univ. of Glasgow, UK; [3]NxGen Partners, USA; [4]Univ. of Texas at Dallas, USA; [5]Tel Aviv Univ., Israel.* Using beam divergence controlling to mitigate angular error effects in OAM-based FSO links is investigated through simulation and experiment. Results show that controlling beam divergence allows reducing power loss and angular error induced channel crosstalk.

Room 408A

M2G • High-Baud Rate Transceivers—Continued

M2G.4 • 14:30
Joint Adaptive Pre-Compensation of Transmitter I/Q Skew and Frequency Response for High Order Modulation Formats and High Baud Rates, Ginni Khanna[1], Stefano Calabrò[2], Bernhard Spinnler[2], Erik d. Man[2], Norbert Hanik[1]; *[1]Technical Univ. of Munich, Germany; [2]Coriant R&D GmbH, Germany.* We present a digital algorithm for joint pre-compensation of the low-pass frequency response and I/Q skew in transmitters. Experimental results for DP-16QAM to DP-256QAM at 37.41 GBaud are presented.

M2G.5 • 14:45
Impact of MAP Detection on the Mutual Information of a 1.2 Tb/s Three-Carrier DP 16-QAM Superchannel, Ali Rezania[1], John C. Cartledge[1]; *[1]Queen's Univ., Canada.* For a 1.206 Tb/s three-carrier DP 16-QAM superchannel, the mutual information is evaluated without and with fixed look-up table based maximum-a-posteriori detection at the receiver to mitigate pattern-dependent distortion in the transmitted signal.

Room 408B

M2H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV I—Continued

M2H.4 • 14:30 Invited
Towards a Control Orchestration Protocol for Multi-tenant Multi-domain SDN/PCE Transport Networks, Raul Muñoz[1], Ricard Vilalta[1], Ramon Casellas[1], Ricardo Martínez[1]; *[1]CTTC, Spain.* Intra-DC networks are composed of heterogeneous vendor domains. The definition of a common SDN/PCE orchestration architecture and protocol abstracting the specific control and transport technologies is key for providing end-to-end connectivity and virtual network services.

Discussion • 14:50

Room 409AB

M2I • Impairment-Aware Network Design—Continued

M2I.4 • 14:30
Demonstration of Multi-hop Optical Add-Drop Network with High Frequency Granular Optical Channel Defragmentation Nodes, satoshi shimizu[1], Gabriella . Cincotti[2], Naoya Wada[1]; *[1]NICT, Japan; [2]Univ. Roma Tre, Italy.* Four nodes optical add-drop network with high frequency granular optical channel defragmentation has been demonstrated. All channels presents error-free operation and power penalties are less than 4 dB even after multi-hop transmission.

M2I.5 • 14:45
How the distribution of superchannel size affects the effectiveness of the elastic WDM CONUS network, Thierry Zami[1], Bruno Lavigne[1]; *[1]Alcatel-Lucent, France.* By planning the CONUS WDM network featuring elastic Nyquist superchannels, we discuss why the distribution of their number of subcarriers can impact the insertion/extraction of traffic and the optimization of their WDM transmission.

Room 411

M2J • Next-Generation Mobile Fronthaul—Continued

M2J.5 • 14:30
Experimental Demonstrations of Next Generation Cost-Effective Mobile Fronthaul with IFoF technique, Seung-Hyun Cho[1], Hwan Seok Chung[1], Changyo Han[1], Sangsoo Lee[1], Jong Hyun Lee[1]; *[1]Electronics & Telecomm Res. Inst, Korea (the Republic of).* We described next generation mobile fronthaul based on IFoF technique and theoretically estimated its system performances. Based on our analysis, we also experimentally demonstrated mobile fronthaul with 12 IF carriers on a single wavelength.

M2J.6 • 14:45
Demonstration of CPRI over Self-seeded WDM-PON in Commercial LTE Environment, Yiran Ma[1], Zhiguang Xu[2], Huafeng Lin[2], Min Zhou[2], Heng Wang[2], Chengliang Zhang[1], Jingwen Yu[1], Xiaomu Wang[1]; *[1]China Telecom Corporation Limited, China; [2]Huawei, China.* CPRI between BBU and RRU equipment is carried by self-seeded WDM-PON prototype system within commercial LTE end-to-end environment. Delay and jitter meets CPRI requirements while services demonstrated show the same performance as bare fiber.

Room 402AB

M2A • Deployable Networks for Access & Metro—Continued

M2A.5 • 15:00
Cost Effective Metro Photonics Enabled by Coherent Optics, Fred Bartholf[1], Phillip Chang[1]; *[1]Comcast Corporation, USA.* We explore whether the coherent attributes of 100G PM-QPSK technologies allows for the removal of ROADMs from transport networks. Our design is limited to metro networks carrying internet-bound data traffic.

M2A.6 • 15:15
Field Demonstration of a Tunable WDM-PON System with Novel SFP+ Modules and Centralized Wavelength Control, Stephan Pachnicke[1], Stephen Mayne[2], Benoit Quemeneur[2], Daniel Sayles[2], Hendrik Schwuchow[3], Jiannan Zhu[4], Adrian Wonfor[4], Philipp Marx[5], Mirko Lawin[1], Markus Fellhofer[5], Richard Turner[2], Philipp Neuber[3], Marco Dietrich[3], Mike Wale[2], Richard V. Penty[4], Ian White[4], Joerg-Peter Elbers[1]; *[1]ADVA Optical Networking SE, Germany; [2]Oclaro Technology Ltd., UK; [3]ELCON Systemtechnik GmbH, Germany; [4]Center for Photonic Systems, Univ. of Cambridge, UK; [5]Energie AG Oberoesterreich Data GmbH, Austria.* We report on a demonstration of a novel tunable WDM-PON system over 25km of field deployed fiber. We show error-free operation at 1GbE with sensitivity better than -30dBm and centralized control of the ONU wavelengths.

Room 403A

M2B • Cross-connects & Switching Devices—Continued

M2B.6 • 15:00
Compact and Low-Loss 8x8 Silicon Photonic Switch Module for Transponder Aggregators in CDC-ROADM Application, Shigeru Nakamura[1], Shigeyuki Yanagimachi[1], HItoshi Takeshita[2], Akio Tajima[2], Tomoaki Katoh[2], Tomoyuki Hino[2], Kiyoshi . Fukuchi[2]; *[1]Green Platform Res. Labs., NEC Corporation, Japan; [2]Green Platform Res. Labs., NEC Corporation, Japan.* We present 8x8 silicon photonic switch modules with newly designed spot size converters on a silicon chip. Averaged module excess loss as low as 7.2 dB on all 64 paths is achieved along with 0.15-ms switching.

M2B.7 • 15:15
Power-efficient Gray-scale Control of Silicon Thermo-optic Phase Shifters by Pulse Width Modulation Using Monolithically Integrated MOSFET, Guangwei Cong[1], Takashi Matsukawa[1], Keijiro Suzuki[1], Ken Tanizawa[1], Sang-Hun Kim[1], Tadashi Chiba[1], Hirofumi Tadokoro[1], Masashi Yanagihara[1], Morifumi Ohno[1], Haruhiko Kuwastuka[1], Yasushi Igarashi[1], Meishoku Masahara[1], Hiroshi Ishikawa[1], Kazuhiro Ikeda[1], Shu Namiki[1], Hitoshi Kawashima[1]; *[1]AIST, Japan.* We first-time demonstrate gray-scale control by pulse-width modulation for silicon thermo-optic (TO) phase shifters using monolithic MOSFET. This work enables simple and power efficient control of TO modules without using DAC and analog current drivers.

Room 403B

M2C • Multimode Fiber—Continued

Networking • 15:00

Room 404AB

M2D • VCSELs & Tunable Lasers—Continued

M2D.6 • 15:00
Energy Efficient 850 nm Vertical-Cavity Surface-Emitting Lasers with Extremely Low Driving-Current Density for >40 Gbit/sec Error-Free Transmissions from RT to 85ºC, Jin-Wei Shi[1], Jason (Jyehong) Chen[2], Chia-Chien Wei[3], Y.-J. Yang [4], Kai-Lun Chi[1], Jia-Wei Jiang[1], Jia-Liang Yen[5], I-Cheng Lu[2], Hao-chung Kuo[2]; *[1]Dept. of EE, National Central Univ., Taiwan; [2]Department of Photonics, National Chiao-Tung Univ., Taiwan; [3]Department of Photonics, National Sun Yat-sen Univ., Taiwan; [4]EE, National Taiwan Univ., Taiwan; [5]Department of Information Technology, Takming Univ. of Science and Technology, Taiwan.* 850nm VCSELs with record-low driving-current-density (8kA/cm^2), small resistance (60Ω), wide-bandwidth (26GHz), and small energy-to-data-rate ratio (228fJ/bit, 3.5mA) for >41Gbit/sec error-free transmission over 100 (2) meter OM4 fiber at room-temperature (85°C) have been demonstrated.

M2D.7 • 15:15
Digital Coherent Communications With a 1550 nm VCSEL, Tam N. Huynh[1], Vidak Vujicic[1], M.D. Gutierrez Pascual[1], Prince Anandarajah[1], Liam P. Barry[1]; *[1]Dublin City Univ., Ireland.* We experimentally demonstrate for the first time the use of a single mode 1550 nm VCSEL in a standard coherent communication system employing QPSK modulation format. The phase noise of the VCSEL is also characterized in detail.

Room 406AB

M2E • Coherent Optical Processing—Continued

M2E.6 • 15:00
Loop-Assisted Multi-Input-Multi-Output Coherent Matched Detector for Ultra High-Bandwidth Parallel Optical Time-Frequency Domain Sampling, Takahide Sakamoto[1], Guo-Wei Lu[1], Tetsuya Kawanishi[1]; *[1]National Institute of Information and Communications Technology, Japan.* We demonstrate loop-assisted multi-input-multi-output coherent matched detector, enabling ultra-wideband parallel optical sampling in time-frequency domain. 8-subchannels packed in 80 GHz in single polarization was simultaneously captured in parallel only using a single 10-Gbaud coherent receiver.

Networking • 15:15

15:30–16:00 Coffee Break, *400 Rooms Foyer*

Room 407

M2F • Free-Space Optical Communication—Continued

M2F.7 • 15:00
Experimental Demonstration of Full-Duplex Optical Wireless Personal Area Communication System with 16-CAP Modulation, Ke Wang[1,2], Ampalavanapilla T. Nirmalathas[1], Christina Lim[1], Efstratios Skafidas[1,2]; *[1]Department of Electrical and Electronic Engineering, Univ. of Melbourne, Australia; [2]Centre for Neural Engineering, The Univ. of Melbourne, Australia.* In this paper, we experimentally demonstrate a full-duplex high-speed indoor optical wireless communication system with 16 Carrierless-Amplitude-Phase (CAP) modulation. Results show that 10 Gb/s downlink and 2 Gb/s uplink can be realized simultaneously.

M2F.8 • 15:15
Optical Wireless LED Link for the Backhaul of Small Cells, Dominic Schulz[1], Michael Schlosser[1], Christos Alexakis[1], Kai Habel[1], Jonas Hilt[1], Ronald Freund[1], Volker Jungnickel[1]; *[1]Fraunhofer Heinrich Hertz Institute, Germany.* We demonstrate experimentally that optical wireless (OW) links using an infrared LED can meet the bitrate, distance and latency requirements for low-cost small-cell wireless backhaul in Long-Term Evolution (LTE) mobile networks.

Room 408A

M2G • High-Baud Rate Transceivers—Continued

Networking • 15:00

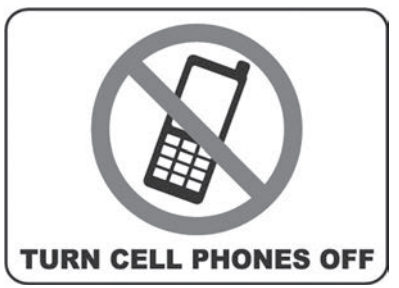
Room 408B

M2H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV I—Continued

Room 409AB

M2I • Impairment-Aware Network Design—Continued

M2I.6 • 15:00 **Invited**
Network Optimization Strategies and Control Plane Impacts, Rosanna Pastorelli[1]; *[1]Cisco Systems, Inc., Italy.* Network planning strategies based on GN-model are explored and compared to identify the best solution that maximizes network flexibility. An optical architecture for real-time network optimization is presented and implications at optical control plane discussed.



Room 411

M2J • Next-Generation Mobile Fronthaul—Continued

M2J.7 • 15:00 **Invited**
Next Generation Mobile Fronthaul Architectures, Thomas Pfeiffer[1]; *[1]Alcatel-Lucent Bell Labs, Germany.* The evolution to ever higher radio bandwidths and the massive introduction of new services and technologies in 5G networks, along with their challenging requirements in the time and frequency domain will warrant revisiting the present CPRI fronthaul approach.

15:30–16:00 Coffee Break, *400 Rooms Foyer*

Room 402AB

16:00–18:00
M3A • ROADM and Flexible Networks
Presider: Tom Issenhuth; Microsoft, USA

M3A.1 • 16:00 Invited
True Value of Flexible Networks, Glenn Wellbrock[1], Tiejun J. Xia[1]; [1]*Verizon Communications Inc, USA*. This presentation illustrates how new Packet Optical platforms will leverage coherent optics along with CDC-F ROADM advances to significantly improve network reliability, scalability and flexibility to reduce the overall cost of transport infrastructure.

M3A.2 • 16:30
Real-Time Demonstration of Software-Defined Elastic Interface for Flexgrid Networks, Arnaud Dupas[1], Eric Dutisseuil[1], Patricia Layec[1], Philippe Jennevé[1], Silvano Frigerio[1], Yan Yan[2], Emilio Hugues-Salas[2], Georgios Zervas[2], Dimitra E. Simeonidou[2], Sébastien Bigo[1]; [1]*alcatel-lucent, France;* [2]*High Performance Networks Group, Univ. of Bristol, UK*. We demonstrate a real-time Elastic Interface for future flex-grid networks with a software-defined symbol rate transmission. Using PDM-QPSK modulation, live experiments show a line rate adaptation from 10.7 to 107Gbit/s with a sub-millisecond reconfiguration time.

Room 403A

16:15–18:00
M3B • Devices and Fibers for Data Center and Inter-Data Center Links
Presider: Jose Castro; Panduit Corp, USA

M3B.1 • 16:15
850-950nm WideBand OM4 Multimode Fiber for Next-Generation WDM Systems, Denis Molin[1], Marianne Bigot[1], Frank Achten[2], Adrian Amezcua[3], Pierre Sillard[1]; [1]*Prysmian Group France, France;* [2]*Prysmian Group Netherlands, Netherlands;* [3]*Prysmian Group, France*. A wideband OM4 multimode fiber for 850-950nm operation was fabricated by optimizing the Alpha value of the index profile. Bandwidth, differential-mode-delay, bit-error-rate measurements are presented. This wideband fiber offers OM4 performance over the 850-950nm window.

M3B.2 • 16:30 Invited
Techno-economic Comparison of Silicon Photonics and Multimode VCSELs, Daniel Mahgerefteh[1], Craig Thompson[1]; [1]*Finisar Corporation, USA*. We compare Silicon Photonics and multi-mode short wavelength VCSEL technologies for various optical interconnect applications using addressable volume, relative cost, transmission reach, power consumption, and bandwidth-density as metrics.

Room 403B

16:00–18:00
M3C • Detector
Presider: Andreas Steffan; Finisar Corporation, Germany

M3C.1 • 16:00 Invited
Recent Advances in Avalanche Photodiodes, Joe C. Campbell[1]; [1]*Univ. of Virginia, USA*. This paper will review recent advances in linear- and Geiger mode avalanche photodiodes (APDs).

M3C.2 • 16:30
High-linearity Avalanche Photodiode for 40-km transmission with 28-Gbaud PAM4, Masahiro Nada[1], Shigeru Kanazawa[2], Hiroshi Yamazaki[1], Yasuhiko Nakanishi[2], Wataru Kobayashi[1], Yoshiyuki Doi[2], Takaharu Ohyama[2], Tetsuichiro Ohno[2], Kiyoto Takahata[2], Toshikazu Hashimoto[1], Hideaki Matsuzaki[1]; [1]*NTT Device Technology Laboratories, NTT Corporation, Japan;* [2]*NTT Device Innovation Center, NTT Corporation, Japan*. We present a high-linearity avalanche photodiode (APD) for 28-Gbaud PAM4, namely, 56 Gbit/s/λ. With an optical receiver incorporating the APD, a 40-km transmission with -17 dBm receiver sensitivity was successfully demonstrated for the first time.

Room 404AB

16:00–18:00
M3D • Specialty Fiber and Sensor
Presider: Takashi Sasaki; Sumitomo Electric Industries Ltd, Japan

M3D.1 • 16:00
Design of a Family of Ring-Core Fiber for OAM, Charles Brunet[1], Pravin Vaity[1], Bora Ung[2], Younès Messaddeq[1], Sophie LaRochelle[1], Leslie A. Rusch[1]; [1]*Universite Laval, Canada;* [2]*Department of Electrical Engineering, Ecole de Technologie Superieure, Canada*. We present the design, simulation, and experimental characterization of a family of ring-core fibers suitable for OAM transmission. The simplicity of design and easily fabricated multiplicity of fibers facilitates analysis and modeling as compared to other OAM fibers.

M3D.2 • 16:15
Demonstration of low-loss flexible fiber with Zeonex tube-lattice cladding for Terahertz transmission, Wenliang Lu[1], Shuqin Lou[1], Xin Wang[1], Yan Shen[1], Xinzhi Sheng[1]; [1]*Beijing Jiaotong Univ., USA*. A Zeonex hollow-core terahertz fiber was developed successfully. The lowest loss is 1dB/m at the frequency below 1THz, which is much lower than THz fibers reported. The loss is still below 5dB/m when it is bent.

M3D.3 • 16:30 Invited
New Trends in Fiber Based Sensors, Tanya M. Monro[1,2]; [1]*The Univ. of South Australia, Australia;* [2]*Centre for Nanoscale BioPhotonics (CNBP) and Institute for Photonics and Advanced Sensing (IPAS), Univ. of Adelaide, Australia*. Optical fibres can be imbued with the properties of nanomaterials and by introducing surface chemistries one can create sensors to detect specific small molecules or proteins. An overview of emerging sensing architectures will be presented with a focus on devices for biosensing.

Room 406AB

16:15–18:00
M3E • Microwave Photonics Systems
Presider: Paul Matthews; Northrop Grumman Corp, USA

M3E.1 • 16:15
Widely Tunable OEO Based on a Directly Modulated DFB Laser under Optical Injection, Peng Wang[1,2], Jintian Xiong[2], Tingting Zhang[1,2], Jilin Zheng[2], Tao Pu[2], Xiangfei Chen[1]; [1]*Nanjing Univ., China;* [2]*PLA Univ. of Science and Technology, China*. A widely tunable optoelectronic oscillator based on a directly modulated distributed feedback (DFB) semiconductor laser under optical injection is demonstrated. Microwave signals with frequency tuned from 5.98 to 15.22 GHz are generated.

M3E.2 • 16:30
Experimental Demonstration of Long-Distance Analog Transmission over Few-Mode Fibers, He Wen[1,2], Hongjun Zheng[2,4], Benyuan Zhu[3], Guifang Li[2,1]; [1]*Tianjin Univ., China;* [2]*Univ. of Central Florida, USA;* [3]*OFS Lab, USA;* [4]*Liaocheng Univ., China*. We demonstrate the first FMF-based analog fiber-optic link to increase link gain and reduce intermodulation distortions. Compared with SMF, FMF-based link increased input power by 3 dB and reduced third-order intermodulation distortion by 3 dB.

Room 407

16:00–18:00
M3F • Applications of All-optical Frequency Conversion
Presider: Michael Vasilyev; Univ. of Texas at Arlington, USA

M3F.1 • 16:00
Versatile Coherent In-line 4-, 16-, 32-QAM Subcarrier Add/Drop-Multiplexing by Optical Frequency Conversion, Carsten Schmidt-Langhorst[1], Thomas Richter[1], Robert Elschner[1], Tomoyuki Kato[2], Takahito Tanimura[2], Shigeki Watanabe[2], Colja Schubert[1]; [1]*Fraunhofer Heinrich Hertz Institute, Germany;* [2]*Fujitsu Laboratories Ltd., Japan.* We experimentally investigate the modulation format scalability & agility of a coherent add/drop node. Extinction of 25 dB yields OSNR penalties up to 1.1-dB for 3.2GBd intra-format subcarrier add/drop up to 32QAM and 0.8-dB for inter-format 4QAM-by-16QAM add/drop.

M3F.2 • 16:15 Top Scored
Broadband Coherent-Optical Add/Drop Multiplexing over 400-GHz Bandwidth by Fiber Frequency Conversion, Tomoyuki Kato[1], Takahito Tanimura[1], Thomas Richter[2], Carsten Schmidt-Langhorst[2], Robert Elschner[2], Colja Schubert[2], Shigeki Watanabe[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fraunhofer Heinrich Hertz Institute, Germany.* We investigate coherent-optical subcarrier processing by fiber frequency conversion using an optical comb based beat signal to implement a broadband coherent add/drop architecture. Erasure and replacement of subcarriers over 400-GHz processing bandwidth is successfully demonstrated.

M3F.3 • 16:30
Dynamic Parametric Dispersion Compensation Using FPGA Pump Controller and Dispersion Monitor, Ken Tanizawa[1], Hiroyuki Matsuura[1], Kensuke Ogawa[2], Toshimitsu Kaneko[3], Eiichi Banno[3], Katsumi Uesaka[3], Shigehiro Takasaka[4], Hidenori Iwai[5], Kazuya Ota[5], Haruhiko Kuwatsuka[1], Yoichi Oikawa [5], Takeshi Yagi[4], Hajime Shoji[3], Shu Namiki[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan;* [2]*Fujikura Ltd., Japan;* [3]*Sumitomo Electric Industries Ltd., Japan;* [4]*FURUKAWA Electric Co. Ltd., Japan;* [5]*Trimatiz Ltd., Japan.* We demonstrate an autonomous fast parametric dispersion compensator with a fast TDA-CSG-DR laser and a dispersion monitor based on spectral shearing interferometer. A response time of less than 17 ms, potentially sub millisecond, is achieved.

Room 408A

16:00–18:00
M3G • High Symbol Rate & High Spectral Efficiency Transmission
Presider: Chongjin Xie; Alibaba Group, USA

M3G.1 • 16:00 Tutorial
High Symbol Rate Transmission Systems for Data Rates from 400 Gb/s to 1Tb/s, Gregory Raybon[1]; [1]*Alcatel-Lucent Bell Labs, USA.* We review high symbol rate (80 to 107 Gbaud) single and dual carrier coherent optical transmission systems as we approach the goal of reaching Terabit/s optical interfaces.

Gregory Raybon is a Member of Technical Staff at Bell Laboratories, Alcatel Lucent in Holmdel NJ. High-speed optical transmission systems have been the focus of his research since a record-breaking 8 Gbit/s OTDM transmission system in 1988. Today the research continues on coherent optical transmission systems approaching speeds of 1 Tb/s achieved through advances in high-speed electrical and opto-electrical components. Greg received the B. S. degree in Electrical Engineering from Penn State University in 1984, the M. S. degree in Material Science from Stevens Institute of Technology in 1989 and was recently named an OSA fellow.

Room 408B

16:00–18:00
M3H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV II
Presider: Dimitra Simeonidou; Univ. of Bristol, UK

M3H.1 • 16:00 Invited
Emerging Open Technology and Optics for the Next Generation Mega Data Centers, Yuval Bachar[1]; [1]*Facebook Inc., USA.* I will talk about how 2015 is the year of the change for mega data centers. The industry is shifting to open hardware and software. An important part of this is the optical interconnect industry is targeting now the high volume data centers first changing the development, manufacturing, and pricing models.

M3H.2 • 16:20 Invited
How Server Designs Will Change as Interface Bandwidth Demands Continue to Increase, Daniel Dreps[1]; [1]*IBM, USA.* This paper explores the trade-offs of how system designs will change as interface designs migrate from 10 to 25 to 56Gbit/lane applied to traditional scale-out systems and disaggregrated systems.

Room 409AB

16:00–18:00
M3I • Network Resiliency
Presider: Massimo Tornatore; Politecnico di MIlano, Italy

M3I.1 • 16:00
An Optimization Approach for Multi-Domain Disaster Recovery, Kaile Liang[1], Mahsa Pourvali[2], Mahshid R. Naeini[3], Feng Xu[4], Samee Khan[5], Nasir Ghani[2]; [1]*ECE, Univ. of New Mexico, USA;* [2]*EE, Univ. of South Florida, USA;* [3]*CS, Texas Tech Univ., USA;* [4]*R&D, Cisco Systems, USA;* [5]*ECE, North Dakota State Univ., USA.* This paper develops a novel optimization scheme for multi-domain optical network protection under multiple probabilistic failures arising from large-scale disasters. The model is solved using an approximation approach and the results compared with some advanced heuristics.

M3I.2 • 16:15
Rapid Data Evacuation for Large-Scale Disasters in Optical Cloud Networks, Sifat Ferdousi[1], M. Farhan Habib[1], Massimo Tornatore[1], Biswanath Mukherjee[1]; [1]*UC Davis, USA.* In case of large-scale disasters, cloud networks may be vulnerable to data loss. We propose a rapid data-evacuation strategy to move maximum amount of data from disaster regions using survived resources under strict time constraints.

M3I.3 • 16:30
Cascading-Failure-Resilient Interconnection for Interdependent Power Grid – Optical Networks, M. Farhan Habib[1], Massimo Tornatore[1], Biswanath Mukherjee[1]; [1]*Univ. of California Davis, USA.* In interdependent power grid – optical networks, a single failure may cause iterative cascade of failures, resulting in network-wide disruptions. We propose schemes to design cascading-failure-resilient interconnection between power grid and optical network.

Room 411

16:15–18:00
M3J • DSP-based Optical Access
Presider: Neda Cvijetic; NEC Laboratories America Inc, USA

M3J.1 • 16:15
Novel Delay-Division-Multiplexing OFDMA Passive Optical Networks Enabling Low-Sampling-Rate ADC, Chia Chien Wei[1], Huan-Ching Liu[2], Chun-Ting Lin[2]; [1]*National Sun Yat-sen Univ., Taiwan;* [2]*National Chiao Tung Univ., Taiwan.* Without extra hardware, the proposed delay-division-multiplexing scheme reduces sampling rate and FFT size at ONUs in OFDMA-PONs to 1/2~1/32 of conventional ones. Sending preprocessed signals, various aliasing-free subcarriers can be received dynamically by controlling delays.

M3J.2 • 16:30 Invited
Silicon Photonics and FDMA PON: Insights from the EU FP7 FABULOUS Project, Silvio Abrate[1], Roberto Gaudino[2], Guido Giuliani[3], Enrito Temporiti[4], Peter O'Brien[5], Guang-Hua Duan[6], Sylvie Menezo[7], Benoit Charbonnier[8]; [1]*Istituto Superiore Mario Boella, Italy;* [2]*Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino, Italy;* [3]*Dipartimento di Elettronica, Università degli Studi di Pavia, Italy;* [4]*STMicroelectronics, Italy;* [5]*Tyndall National Institute, Univ. College Cork, Ireland;* [6]*III-V Lab, France;* [7]*CEA-LETI, France;* [8]*Orange Labs, France.* The FABULOUS EU project aims at demonstrating the effectiveness of a self-coherent reflective FDMA WDM PON architecture, achieving record transmission performances and demonstrating an ONU as a silicon-photonics PIC with unprecedented level of integration.

M3A • ROADM and Flexible Networks—Continued

M3A.3 • 16:45
Spectral engineering technique to mitigate 37.5-GHz filter-cascade penalty with real-time 32-GBaud PDM-16QAM, Oriol Bertran-Pardo[1], Thierry Zami[1], Bruno Lavigne[1], Maël Le Monnier[1]; [1]*Alcatel-Lucent, France.* We investigate the potential of spectral engineering to mitigate the penalties on 32-Gbaud 256-Gb/s PDM-16QAM channels passing through the deployed cascade of 37.5-GHz wide filters in case of wavelength detuning and real-time coherent detection.

M3A.4 • 17:00 **Invited**
Next Generation ROADM Technology and Applications, Mitsunori Fukutoku[1]; [1]*NTT Network Innovation Laboratories, Japan.* I introduce next generation ROADM technologies and application. A combination of PLC technology and free space optics will be the key to realizing simple CD/CDC ROADM. The defragmentation and re-grooming of optical paths will be important for utilizing network resources.

M3B • Devices and Fibers for Data Center and Inter-Data Center Links—Continued

M3B.3 • 17:00
Reliability and Non-Hermetic Properties of Ge/Si Optoelectronic Devices, Su Li[1], Liangbo Wang[1], Tuo Shi[1], Pengfei Cai[1], Mengyuan Huang[1], Wang Chen[1], Chingyin Hong[1], Dong Pan[1]; [1]*SiFotonics Technologies Co., Ltd., USA.* Our CMOS-foundry mass-produced Ge/Si optoelectronic devices have passed the high temperature accelerated aging test, THB test and HAST test, which demonstrate satisfactory reliability and promising potential for non-hermetic applications.

M3B.4 • 17:15
Capability of High Optical-Feedback Tolerance and Non-Hermetic-Packaging for Low-Cost Interconnections Using Lens-Integrated Surface-Emitting Laser, Takanori Suzuki[1], Koichiro Adachi[1], Aki Takei[1], Yuki Wakayama[1], Akira Nakanishi[2], Kazuhiko Naoe[2], Kouji Nakahara[2], Shigehisa Tanaka[2], Kazuhisa Uomi[2]; [1]*Hitachi, Ltd., Japan;* [2]*Oclaro Japan, Inc., Japan.* Low-cost optical assemblies for optical interconnections using lens-integrated surface-emitting laser are proposed. High coupling efficiency with single-mode-fibers of over -1.9dB and RIN below -140dB/Hz with large back reflection and 85°C/85% storage test are demonstrated.

M3C • Detector—Continued

M3C.3 • 16:45
High Performance DP-QPSK Receiver Module incorporating InP-based Integrated Coherent Detection Chip, Yongbo Tang[1], Fang Wu[1], Yury Logvin[1], Jiangqing Lei[2], Guolin Liu[2], Ke luo[2], Chris Watson[1], Kirill Pimenov[1], Yingying Bai[2], Denis Masson[1], Valery Tolstikhin[1], Hong Xie[2], Yimin Hua[2]; [1]*ArtIC Photonics Inc, Canada;* [2]*O-Net Communication Ltd, China.* We report an integrated InP-based coherent receiver chip, exhibiting the highest reported responsivity (0.2A/W), better than -26dB CMRR and larger than 30GHz detector bandwidth. A miniature version suitable for CFP2 application was also demonstrated.

M3C.4 • 17:00
Monolithic photonic-electronic QPSK receiver for 28Gbaud, Georg Winzer[1], Marcel Kroh[1], Stefan Lischke[1], Dieter Knoll[1], Karsten Voigt[2], Hui Tian[1], Christian Mai[1], Despoina Petousi[1], Daniel Micusik[3], Lars Zimmermann[1], Bernd Tillack[1], Klaus Petermann[2]; [1]*IHP, Germany;* [2]*Hochfrequenztechnik, Technische Universitaet Berlin, Germany;* [3]*Rohde & Schwarz, Germany.* The paper presents the first fully monolithic photonic-electronic single-polarization QPSK receiver for 56Gbps (28Gbaud). The receiver sub-system was realized in photonic BiCMOS technology and demonstrates integration capabilities for state-of-the-art coherent systems.

M3C.5 • 17:15
A 64 Gb/s PAM-4 Linear Optical Receiver, Bart Moeneclaey[1], Giannis Kanakis[2], Jochen Verbrugghe[1], Nikos Iliadis[2], Wouter Soenen[1], Dimitrios Kalavrouziotis[2], Christos Spatharakis[2], Stefanos Dris[2], Xin Yin[1], Paraskevas Bakopoulos[2], Elad Mentovich[3], Hercules Avramopoulos[2], Johan Bauwelinck[1]; [1]*Ghent Univ., Belgium;* [2]*National Technical Univ. of Athens, Greece;* [3]*Mellanox Technologies, Israel.* We present a linear optical receiver realized on 130 nm SiGe BiCMOS. Error-free operation assuming FEC is shown at bitrates up to 64 Gb/s (32 Gbaud) with 165 mW power consumption, corresponding to 2.578 pJ/bit.

M3D • Specialty Fiber and Sensor—Continued

M3D.4 • 17:00 **Invited**
First Demonstration of Hollow-Core Fiber for Intra Data Center Low Latency Connectivity with a Commercial 100Gb/s Interface, Brian J. Mangan[1], Maxim Kuschnerov[2], Jeffrey W. Nicholson[1], John Fini[1], Linli Meng[1], Robert Windeler[1], Eric Monberg[1], Anthony Desantolo[1], Vitaly Mikhailov[1]; [1]*OFS Laboratories, USA;* [2]*Coriant GmbH, Germany.* For the first time 100Gb/s transmission using commercial low latency hardware is demonstrated over the longest manufactured hollow-core fiber (2.75km) to date, proving the feasibility of ultra-low latency intra-data center connectivity.

M3E • Microwave Photonics Systems—Continued

M3E.3 • 16:45
Generalized Frequency Division Multiplexing for Photonic-Assisted Millimeter-Wave Carrier Aggregation, Feng Lu[1], Lin Cheng[1], Ming Zhu[1], Jing Wang[1], Mu Xu[1], Xiaoli Ma[1], Gee-Kung Chang[1]; [1]*Georgia Institute of Technology, USA.* We propose a spectrum efficient, photonic-assisted millimeter-wave carrier aggregation method using generalized frequency division multiplexing. For the first time, an experiment aggregating 18 component carriers demonstrates better EVM performance than OFDM with reduced guard bands.

M3E.4 • 17:00
Tunable dual-frequency lidar exploiting a mode-locked laser for integrated coherent radar-lidar architecture, Valeria Vercesi[1], Daniel Onori[1], Arismar Cerqueira[2], Antonella Bogoni[3], Mirco Scaffardi[3]; [1]*Sant' Anna di Pisa, Italy;* [2]*National Institute of Telecommunication, Brazil;* [3]*Consorzio Nazionale Interuniversitario per le Telecomunicazioni, Italy.* A mode-locked laser-based dual-frequency lidar with tunable tones separation is demonstrated, allowing a dynamic tradeoff among robustness and sensitivity of measurement and enabling integration with photonic-based radar. Velocity measurements for different tones separation are demonstrated.

M3E.5 • 17:15
Tunable DC-40 GHz RF Generation with High Side-mode Suppression Utilizing a Dual Loop Brillouin Optoelectronic Oscillator, Huanfa Peng[1], Cheng Zhang[1], Peng Guo[1], Xiaopeng Xie[1], Tao Sun[1], Xiaoqi Zhu[1], Feiya Chen[1], Lixin Zhu[1], Weiwei Hu[1], Zhangyuan Chen[1]; [1]*Peking Univ., China.* An agilely tunable DC to 40 GHz RF generation using a dual-loop optoelectronic oscillator based on Stimulated Brillouin Scattering is experimentally demonstrated. The side-mode suppression ratio is measured to be 43.1 dB at 20 GHz.

Room 407

M3F • Applications of All-optical Frequency Conversion—Continued

M3F.4 • 16:45 Top Scored

First Demonstration of Wavelength Translation for 1.376-Tbit/s DP-QPSK Nyquist OTDM Signal, Hung Nguyen Tan[1], Takashi Inoue[1], Takayuki Kurosu[1], Shu Namiki[1]; [1]*AIST Tokyo, Japan*. Seamless wavelength translation of a single-carrier 1.376-Tbit/s DP-QPSK Nyquist OTDM signal over 30nm range is successfully demonstrated. Polarization-insensitive coherent detection using linear sampling is employed to demodulate dual-polarization Nyquist-OTDM signal for the first time.

Networking • 17:00

Room 408A

M3G • High Symbol Rate & High Spectral Efficiency Transmission—Continued

M3G.2 • 17:00 Top Scored

Single-Channel 1.92 Tbit/s, 64 QAM Coherent Orthogonal TDM Transmission of 160 Gbaud Optical Nyquist Pulses with 10.6 bit/s/Hz Spectral Efficiency, David O. Otuya[1], Koudai Harako[1], Keisuke Kasai[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan*. We demonstrate a 1.92-Tbit/s (160-Gbaud), PDM-64-QAM transmission over 150 km with a net potential spectral efficiency of 10.6 bit/s/Hz. This ultrahigh channel capacity and spectral efficiency were achieved simultaneously with an orthogonal TDM scheme.

M3G.4 • 17:15

Hybrid Modulation Formats Outperforming 16QAM and 8QAM in Transmission Distance and Filtering with Cascaded WSS, Fred Buchali[1], Wilfried Idler[1], Henning Buelow[1], Karsten Schuh[1]; [1]*Alcatel-Lucent Bell Labs, Germany*. We developed time-domain hybrid-modulation with adaptive symbolrates to optimize the reach and margin of WSS routed 400 Gb/s systems. Experimental comparisons show, that a DP-8QAM/16QAM hybrid format can outperform the benchmark DP-8QAM and DP-16QAM formats in distance when up to 18 WSS are incorporated.

Room 408B

M3H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV II—Continued

M3H.3 • 16:40 Invited

Programmable Hardware in Software Defined Networking, Gordon Brebner[1]; [1]*Xilinx Labs., USA*. Software presents performance difficulties if it is the sole means of allowing programmability in high-speed optical SDN and NFV. Programmable hardware offers an ideal companion for implementing flexible SDN data planes and accelerating NFV functions.

M3H.4 • 17:00 Invited

SDN Control of a Coherent Open Line System, Jeff Cox[1]; [1]*Microsoft, USA*. Microsoft is beginning the development of a SDN control plane for an Open Line System (OLS). This paper discusses some of the issues surrounding the effort and some potential approaches for controlling the OLS and coherent sources and receivers.

Discussion • 17:20

Room 409AB

M3I • Network Resiliency—Continued

M3I.4 • 16:45 Top Scored

Scheme for Optical Network Recovery Schedule to Restore Virtual Networks after a Disaster, Chen Ma[1,2], Jie Zhang[1], Yongli Zhao[1], M. Farhan Habib[2]; [1]*Beijing Univ. of Post and Tel., China;* [2]*Univ. of California, Davis, USA*. Virtual networks mapped over a physical network can suffer from network disconnection due to disasters. We propose an integer linear programming model to restore physical links with maximizing connectivity of virtual networks.

M3I.5 • 17:00

Maximize Protected Capacity for Shared Backup Path Protected Optical Networks with Time Domain Hybrid Modulation, Hua Dai[1], Yongcheng Li[1], Lian Xiang[1], Xiaoling Wang[1], Gangxiang Shen[1]; [1]*Soochow Univ., China*. We apply the time domain hybrid modulation (TDHM) transmission technique to maximize the protected capacity of a shared backup path protected (SBPP) optical network. Simulation results show that compared with discrete modulations, the TDHM scheme can significantly increase total protected network capacity.

M3I.6 • 17:15

A Novel IPoOTN Packet-Optical Architecture for Economical and Fast Protection of Link/IP Port Failures, Srivatsan Balasubramanian[1], Steven J. Hand[1], Pravin Mahajan[1], Serge Melle[1], Soumya Roy[1], Thirukumaran Velusamy[1], Jay Perrett[2], Omar A. Assil[2]; [1]*Infinera, USA;* [2]*Aria Networks, UK*. We analyze two operationally deployable multi-layer restoration architectures for packet-optical networks that protect against port and link failures. An IPoOTN architecture using Layer 3 and Layer 1 protection mechanisms reduces IP port use by 46% compared to IPoWDM.

Room 411

M3J • DSP-based Optical Access—Continued

M3J.3 • 17:00 Invited

Advanced DSP for Optical Access Networks: Challenges and Opportunities, Noriko Iiyama[1], Jun-ichi Kani[1], Ken-Ichi Suzuki[1], Akihiro Otaka[1]; [1]*NTT Corporation, Japan*. Employing DSP technology is an attractive way to enhance standardized 10-Gbps per wavelength PONs toward the converged optical-wireless network. For TDM-based co-existence of digital coherent PON and existing PONs, burst mode coherent receivers for uplink and hierarchical modulation for downlink are introduced.

Room 402AB

M3A • ROADM and Flexible Networks—Continued

M3A.5 • 17:30 DEMO

Degree-Expandable Colorless, Directionless, and Contentionless ROADM Without Drop-Side EDFAs, Wen-Jr Jiang[1], Alexander Lebedev[1], Yu-Min Lin[1], Ilya Vorobeichik[1], Igor Gopp[1], Alexey Plotskiy[1], Winston I. Way[1]; [1]*NEOPhotonics Corp, USA*. By using an NxM multicast switch, where N is expandable from 4 to ≥16, and M is 16, we experimentally demonstrate that in a metro optical network with OSNR ≥17dB, the sensitivity of an intradyne coherent receiver can reach < -34dBm for 28Gbaud DP-QPSK signals, thereby enabling a CDC ROADM with no drop-side EDFAs.

M3A.6 • 17:45

Impact of Channel Add/Drop on Nonlinear Performance in Uncompensated 100G Coherent Systems, Steven Searcy[1], Sorin Tibuleac[1]; [1]*ADVA Optical Networking, USA*. We examine nonlinear performance of uncompensated coherent systems in which neighboring channels are added and dropped at ROADM nodes along the path; we investigate dependence on fiber type and initial dispersion on the added channels.

Room 403A

M3B • Devices and Fibers for Data Center and Inter-Data Center Links—Continued

M3B.5 • 17:30 Invited

High-Speed Avalanche Photodiode for 100-Gbit/s Ethernet, Fumito Nakajima[1], Masahiro Nada[2], Toshihide Yoshimatsu[1]; [1]*NTT Device Innovation Center, Japan;* [2]*NTT Device Technology laboratories, Japan*. We demonstrate a 25-Gbit/s avalanche photodiode with an inverted p-down structure and its application to a 100GbE receiver optical subassembly. The performance indicates a record minimum receiver sensitivity of -20 dBm and 50-km error-free transmission.

Room 403B

M3C • Detector—Continued

M3C.6 • 17:30

High-Power THz-Wave Generation by Using Ultra-Fast (315 GHz) Uni-Traveling Carrier Photodiode with Novel Collector Design and Photonic Femtosecond Pulse Generator, Jin-Wei Shi[1], Ci-Ling Pan[2], C.-B. Huang [3], Jhih-Min Wun[1], Hao-Yun Liu[3], Yu-Lun Zeng[1]; [1]*Dept. of EE, National Central Univ., Taiwan;* [2]*Department of Physics, National Tsing-Hua Univ., Taiwan;* [3]*Institute of Photonics Technologies, National Tsing-Hua Univ., Taiwan*. UTC-PDs with novel collector design, flip-chip package, and ultra-wide bandwidth (315GHz) are successfully demonstrated. Under optical femtosecond pulse train illumination with THz repetition rate, it achieves record-high maximum CW output power (1.04 mW) at 280GHz operation.

M3C.7 • 17:45

Zero-Bias Operational Ultra-Broadband UTC-PD above 110 GHz for High Baud Rate PD-Array in High-Density Photonic Integration, Toshimasa Umezawa[1], Kouichi Akahane[1], Naokatsu Yamamoto[1], Keizo Inagaki[1], Atsushi Kanno[1], Tetsuya Kawanishi[1]; [1]*National Inst of Information & Comm Tech, Japan*. We have successfully developed a zero-bias operational ultra-broadband uni-traveling-carrier photodiode (UTC-PD) with a frequency bandwidth above 110 GHz using a low carrier concentration of 3×10^{14} cm^{-3} in the carrier collection layer.

Room 404AB

M3D • Specialty Fiber and Sensor—Continued

M3D.5 • 17:30 Invited

Selective Excitation of High Order Modes in Few Mode Fibres Using Optical Microfibres, Bernard Oduro[1], Rand Ismaeel[1], Timothy Lee[1], Gilberto Brambilla[1,2]; [1]*Univ. of Southampton, UK;* [2]*EPSRC Centre for Innovative Manufacturing in Photonics, UK*. Selective modal multiplexing and demultiplexing is demonstrated in few-mode fibers using weakly-fused microfiber couplers.

Room 406AB

M3E • Microwave Photonics Systems—Continued

M3E.6 • 17:30 Invited

Fully Photonics-based Radar Demonstrator: Concept and Field Trials, Paolo Ghelfi[1], Francesco Laghezza[1], Filippo Scotti[1], Giovanni Serafino[2], Sergio Pinna[2], Daniel Onori[2], Claudio Porzi[1], Mirco Scaffardi[1], Antonio Malacarne[1], Valeria Vercesi[2], Emma Lazzeri[1], Antonella Bogoni[1]; [1]*National Laboratory of Photonic Networks, CNIT, Italy;* [2]*TeCIP, Scuola Superiore Sant'Anna, Italy*. This work shows the concept, performance, and field-trials of the first photonics-based radar. The comparative in-field experiments in aerial and naval scenarios against a state-of-the-art commercial system show the photonics potentials in enabling software-defined radars.

INTERNATIONAL YEAR OF LIGHT 2015

IEEE PHOTONICS SOCIETY 50th ANNIVERSARY 1965 2015

Room 407

M3F • Applications of All-optical Frequency Conversion—Continued

Room 408A

M3G • High Symbol Rate & High Spectral Efficiency Transmission—Continued

M3G.3 • 17:30
5 x 1-Tb/s PDM-16QAM Transmission over 1,920 km Using High-Speed InP MUX-DAC Integrated Module, Akihide Sano[1], Munehiko Nagatani[2], Hideyuki Nosaka[3], Yutaka Miyamoto[1]; *[1]NTT Network Innovation Laboratories, Japan; [2]NTT Device Innovation Center, Japan; [3]NTT Device Technology Laboratories, Japan.* We demonstrate WDM transmission of 75-Gbaud PDM-16QAM signals over 1,920 km. InP-based high-speed and compact MUX-DAC integrated modules (bandwidth exceeds 40 GHz) enable the long haul transport of 1-Tb/s superchannels composed of just two subcarriers.

M3G.5 • 17:45
Silicon IQ Modulator Based 480km 80x453.2Gb/s PDM-eOFDM Transmission on 50GHz Grid with SSMF and EDFA-only Link, Yuanyuan Fang[1], Lei Liu[1], Chi Yan Wong[1], Sen Zhang[1], Tao Wang[2], Gordon Ning Liu[1], Xiaogeng Xu[1]; *[1] Transmission Technology Research Department, Huawei Technologies, China; [2]European Research Center, Huawei Technologies Düsseldorf GmbH, Germany.* We report 480km transmission of C-band 80×453.2Gb/s PDM-eOFDM hybrid 8-64QAM DWDM signals over G.652 fiber and EDFA-only link at 9b/s/Hz spectral efficiency based on silicon IQ modulator and 84.48G sample/s DAC.

Room 408B

M3H • Enabling the Cloud: Unleashing the Capabilities of Emerging Flexible Optical Transport through SDN and NFV II—Continued

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

Room 409AB

M3I • Network Resiliency—Continued

Networking • 17:30

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

Room 411

M3J • DSP-based Optical Access—Continued

M3J.4 • 17:30
Practical Considerations on Discrete Multi-tone Transmission for Cost-effective Access Networks, Zhixin Liu[1], Thomas Richter[2], Colja Schubert[2], David J. Richardson[1], Radan Slavík[1]; *[1]Optoelectronics Research Centre, Univ. of Southampton, UK; [2]Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany.* We demonstrate that digital pre-emphasis is of limited value in directly modulated discrete multi-tone transmitters and that the use of larger bandwidth discrete multi-tone is ineffective when the transmission capacity is limited by dispersion.

M3J.5 • 17:45
Beyond 25 Gbit/s Directly Modulated, Directly Detected OFDM Using Channel Flattening by a Fabry-Perot Filter, Luiz Anet Neto[1], Mathilde Gay[1], Laurent Bramerie[1], Christophe Peucheret[1], Yann Frignac[2], Jean-Claude Simon[1], Monique . Thual[1], Michel Joindot[1], Christophe Levallois[1], Cyril Paranthoen[1], Siddharth Joshi[3], Nicolas Chimot[3], Francois Lelarge[3], Philippe Chanclou[4]; *[1]CNRS UMR 6082 FOTON ENSSAT, France; [2]Institut Télécom SudParis, France; [3]III-V Lab, France; [4]Orange Labs, France.* We experimentally demonstrate the joint use of OFDM and channel flattening effect provided by a Fabry-Perot filter to allow higher than 25 Gbit/s direct intensity modulated, directly detected transmissions over up to 75 km SSMF.

Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB	Room 407

08:00–10:00 Tu1A • Plenary Session, *Concourse Hall*

10:00–14:00 Unopposed Exhibit-Only Time, *Exhibit Hall*

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall*

12:00–14:00 Awards and Ceremony, *Petree Hall D*

12:00–14:00 Poster Preview, *Exhibit Hall K*

14:00–16:00 Tu2A • Advanced Modulators

Presider: Larry Coldren; Univ. of California Santa Barbara, USA

Tu2A.1 • 14:00 Invited

Silicon-Organic Hybrid (SOH) and Plasmonic-Organic Hybrid (POH) Integration, Christian Koos[1], Juerg Leuthold[2], Wolfgang Freude[1], Manfred Kohl[1], Larry Dalton[3], Wim Bogaerts[4], Anna Lena Giesecke[5], Matthias Lauermann[1], Argishti Melikyan[1], Sebastian Koeber[1], Stefan Wolf[1], Claudius Weimann[1], Sascha Muehlbrandt[1], Kira Koehnle[1], Joerg Pfeifle[1], Robert Palmer[1], Luca Alloatti[1], Delwin Elder[1], Thorsten Wahlbrink[5], Jens Bolten[5]; *[1]Karlsruhe Institute of Technology KIT, Germany; [2]Swiss Federal Institute of Technology, Switzerland; [3]Univ. of Washington, USA; [4]Photonics Research Group, Ghent Univ. – imec, Belgium; [5]AMO GmbH, Germany.* Silicon-organic hybrid (SOH) and plasmonic-organic hybrid (POH) integration combines organic electro-optic materials with silicon photonic and plasmonic waveguides. The concept enables fast and power-efficient modulators that support advanced modulation formats such as QPSK and 16QAM.

14:00–16:00 Tu2B • Dynamic Optical Network Control

Presider: Hiroaki Harai; National Inst of Information & Comm Tech, Japan

Tu2B.1 • 14:00 Tutorial

Control Architectures for Multi-layer Networking: Distributed, Centralized, or Something in Between?, Ori Gerstel[1]; *[1]Sedona Systems, Israel.* Multi-layer control is multi-faceted: while use cases like restoration call for a level of distributed control; network optimization requires high degree of centralization. We will discuss how various multi-layer scenarios are impacted by practical considerations .

Ori Gerstel is founder/CTO of Sedona Systems – a startup specializing in Multi-layer SDN control. Until 2014, Ori was responsible for driving the architecture of router-transport integration at Cisco. Before 2003, Ori held

continued on pg 74

14:00–16:00 Tu2C • Sources and Amplifiers

Presider: Lutz Rapp; Coriant, Germany

Tu2C.1 • 14:00

Extreme Short Wavelength Operation (1.65 – 1.7 μm) of Silica-Based Thulium-Doped Fiber Amplifier, Zhihong Li[1], Yong-min Jung[1], J. M. O. daniel[1], Nikita Simakov[1], P.C. Shardlow[1], A. M. Heidt[1], Andy Clarkson[1], Shaif-Ul Alam[1], David J. Richardson[1]; *[1]Optoelectronics Research Centre (ORC), UK.* We report the first demonstration of silica-based thulium-doped fiber amplifier (TDFA) working in the 1.65 – 1.7 μm waveband. Up to 29 dB small signal gain and noise figure as low as 6.5 dB are achieved.

14:45–16:00 Tu2D • Few-Moded Fibers

Presider: Francesco Poletti; Univ. of Southampton, UK

14:00–16:00 Tu2E • SDN and New Access Paradigms

Presider: Antonio Teixeira; DETI, Instituto de Telecomunicacoes, Portugal

Tu2E.1 • 14:00 Invited

Next-generation Optical Access Networks for C-RAN, Keiji Tanaka[1], Akira Agata[1]; *[1]KDDI R&D Laboratories, Japan.* This paper reviews the required specifications to optical fronthaul links for C-RAN and presents key technologies of optical transmissions and a CPRI data compression for next-generation optical access networks.

14:15–16:00 Tu2F • Chip-scale All-optical Processing

Presider: Ping Piu Kuo; Univ. of California, San Diego, USA

Room 408A	Room 408B	Room 409AB	Room 411

08:00–10:00 Tu1A • Plenary Session, *Concourse Hall*

10:00–14:00 Unopposed Exhibit-Only Time, *Exhibit Hall*

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall*

12:00–14:00 Awards and Ceremony, *Petree Hall D*

12:00–14:00 Poster Preview, *Exhibit Hall K*

14:00–16:00
Tu2G • Visible Light Communication

Presider: Andreas Stöehr; Universität Duisburg-Essen, Germany

Tu2G.1 • 14:00 DEMO

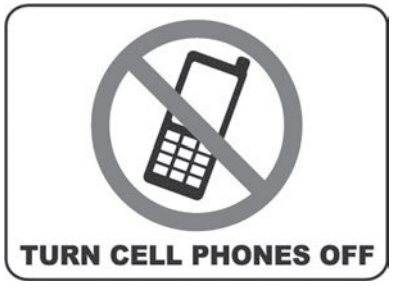
750Mbit/s Visible Light Communications employing 64QAM-OFDM Based on Amplitude Equalization Circuit, Xingxing Huang[1], Jianyang Shi[1], Jiehui Li[1], Yiguang Wang[1], Yuanquan Wang[1], Nan Chi[1]; [1]*Department of Communication Science and Engineering, Fudan Univ., China.* Using the designed amplitude equalization circuit, we first demonstrate the highest data rate and longest transmission for VLC system with 750Mbit/s data rate employing 64QAM-OFDM after 2m free-space transmission.

14:00–16:00
Tu2H • Data Center and Cloud Architecture and Technology

Presider: Adel Saleh; Univ. of California Santa Barbara, USA

Tu2H.1 • 14:00

High-Speed Long-Wavelength VCSELs for Energy-Efficient 40 Gbps Links up to 1 km Without Error Correction, Antonio Malacarne[1], Vito Sorianello[1], Aidan Daly[2], Benjamin Kogel[2], Markus Ortsiefer[2], Suzanne Melo[3], Christian Neumeyr[2], Marco Romagnoli[1], Antonella Bogoni[1]; [1]*National Laboratory of Photonic Networks, CNIT, Italy;* [2]*VERTILAS, Germany;* [3]*TeCIP, Scuola Superiore Sant'Anna, Italy.* A high-speed VCSEL is characterized and directly modulated up to 40Gbps with power consumption ~14mW. BER performance exhibits error-free operation($<10^{-9}$) up to 1km of SMF with 1.6dB of penalty without optical amplification.



14:30–16:00
Tu2I • Elastic Network Architecture

Presider: João Pedro; Coriant Portugal, Portugal

14:00–16:00
Tu2J • Panel: Optics in Access: Technology and Standards

Moderator: Frank Effenberger[1]; [1]*FutureWei Technologies, Inc., USA*

Organizer: Frank Effenberger[1]; [1]*FutureWei Technologies, Inc., USA*

Optical access has become a mainstream component of operators' networks, and they are also being stretched to perform new roles and serve new applications. NG-PON2's standardization is nearing completion, while next generation EPON is just starting this process. In addition to the active electronics part of the network, new techniques are being applied to the passive infrastructure. PON technology is being used to back-haul traffic from very high speed copper systems, and now it seems likely that wireless front-haul will be a major push in the market. Coaxial networks are also being merged with PON systems to bring about various types of distributed architecture. This panel brings together leaders from across the industry to review both where we are now in terms of technologies and their standardization, and what might be coming next.

Speakers:

Jun-ichi Kani; *NTT Access Service Systems Laboratories, Japan*

Osman Gebizlioglu; *Huawei Technologies Co., Ltd., USA*

Philippe Chanclou; *Orange Labs, France*

Curtis Knittle; *CableLabs, USA*

Show Floor Programming

■ **Market Watch**

10:30–12:00
Panel I: Reality Check on Maturity of Metro 100G and Beyond
For more details, see page 39

12:30–14:30
Panel II: State of the Market/ Industry: 2014 in Review
For more details, see page 39

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

Tu2A • Advanced Modulators—Continued

Tu2A.2 • 14:30 Top Scored

Plasmonic Mach-Zehnder Modulator with >70 GHz Electrical Bandwidth Demonstrating 90 Gbit/s 4-ASK, Wolfgang Heni[1], Argishti Melikyan[3], Christian Haffner[1], Yuriy Fedoryshyn[1], Benedikt Baeuerle[1], Arne Josten[1], Jens Niegemann[1], David Hillerkuss[1], Manfred Kohl[3], Delwin Elder[2], Larry Dalton[2], Christian Hafner[1], Juerg Leuthold[1]; *[1]Institute of Electromagnetic Fields, ETH Zurich, Switzerland; [2]Department of Chemistry, Univ. of Washington, USA; [3]Karlsruhe Institute of Technology, Germany.* A high-extinction-ratio plasmonic Mach-Zehnder modulator with an electrical bandwidth exceeding 70GHz is demonstrated. The BER is below 4×10^{-5} and 2×10^{-2} for a BPSK and 4-ASK signal with line rates of 72Gbit/s and 108Gbit/s, respectively.

Room 403A

Tu2B • Dynamic Optical Network Control—Continued

senior architecture positions at IBM, Tellabs and Nortel. For his contribution he was awarded the grade of IEEE Fellow (2008) and OSA Fellow (2014). Ori published ~100 papers in top conferences and journals, as well as several book chapters. He holds 35 granted patents, and ~35 pending patents. He serves as editor-in-chief for JOCN and steering committee member for OFC. Ori holds a Ph.D. from the Technion, Israel.

Room 403B

Tu2C • Sources and Amplifiers—Continued

Tu2C.2 • 14:15

Multi frequency components generation using cascaded time lenses based on space-time duality, TIng Yang[1], Jianji Dong[1], Qi Yang[2], Xinliang Zhang[1]; *[1]Wuhan National Lab for Optoelectronics, China; [2]Wuhan Research Institute of Post and Telecommunication, State Key Laboratory of Optical Communication Technologies and Networks, China.* We simulate and experimentally demonstrate a cascaded time lenses scheme to generate multi frequency components with frequency spacing tunable. The two time lenses are used to implement frequency-to-time mapping and spectral Talbot effect, respectively.

Tu2C.3 • 14:30 Invited

Extra-solar Planets Exploration using Frequency Comb: Infrared Doppler Instrument for the Subaru Telescope (IRD), Motohide Tamura[2,1], IRD team[1]; *[1]National Astronomical Observatory Japan, Japan; [2]Astronomy, UTokyo, Japan.* The Infrared Doppler (IRD) instrument is a fiber-fed, high-precision spectrometer with a resolution of R~70,000 covering 0.97-1.75 mm. We employ our original laser frequency comb in the near-infrared as an extremely stable wavelength standard.

Room 404AB

Tu2D • Few-Moded Fibers—Continued

Room 406AB

Tu2E • SDN and New Access Paradigms—Continued

Tu2E.2 • 14:30

Handover Reduction via Mobility-Prediction-Based VPON Formation in Optical-Access-Enabled Cloud-RAN, Xinbo Wang[1], Saigopal Thota[1], Massimo Tornatore[2], Sang-Soo Lee[2,1], Han-Hyub Lee[3], Soomyung Park[3], Biswanath Mukherjee[1]; *[1]Computer Science, Univ. of California, Davis, USA; [2]Dipartimento di Elettronica e Informazione, Politecnico di Milano, Italy; [3]Electronics and Telecommunications Research Institute, Korea (the Republic of).* Next-generation radio-access networks will experience excessive handover due to shrinking cell sizes (to support more users) and increasing user mobility. We form Virtual Passive Optical Network (VPON) using mobility-prediction information to reduce handovers in CRAN.

Room 407

Tu2F • Chip-scale All-optical Processing—Continued

Tu2F.1 • 14:15

Polarization Insensitive Wavelength Conversion of 40 Gb/s DPSK Signals in a Silicon Germanium Waveguide, Mohamed A. Ettabib[1], Victor Rancaño[1], Francesca Parmigiani[1], Alexandros Kapsalis[2], Adonis Bogris[2,3], Kyle R. Bottrill[1], Mohammad Belal[1], Mickael Brun[4], Pierre Labeye[4], Sergio Nicoletti[4], Kamal Hammani[5], Dimitris Syvridis[2], David J. Richardson[1], Periklis Petropoulos[1]; *[1]Optoelectronics Research Centre, Univ. of Southampton, UK; [2]Department of Informatics and Telecommunications, National and Kapodistrian Univ. of Athens, Greece; [3]Department of Informatics, Technological Educational institute of Athens, Greece; [4]CEA-Leti MINATEC Campus, France; [5]Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB), France.* We demonstrate polarization insensitive FWM-based wavelength conversion of 40-Gb/s DPSK signals in a SiGe waveguide, with 0.42-dB polarization-dependent loss. A 1.5-dB power penalty was measured at a BER of 10^{-9}.

Tu2F.2 • 14:30

Wavelength Conversion of a 640 Gbit/s DPSK Nyquist Channel Using a Low-Loss Silicon Nanowire, Hua Ji[1], Hao Hu[1], Yunhong Ding[1], Haiyan Ou[1], Kresten Yvind[1], Leif K. Oxenlowe[1]; *[1]DTU Fotonik, Denmark.* 640 Gbit/s N-OTDM DPSK wavelength conversion is demonstrated in a Si-nanowire. All 64 tributaries are converted within an average power penalty of 1 dB at the FEC BER-limit 3E-3. Only 22-fJ/bit switching energy is required.

Room 408A

Tu2G • Visible Light Communication—Continued

Tu2G.2 • 14:15

Experimental Verification of Visible Light Communications based on Multi-Band CAP Modulation, Paul A. Haigh[1,2], Petr Chvojka[2], Stanislav Zvanovec[2], Zabih Ghassemlooy[3], Son T. Le[4], Thavamaran Kanesan[5], Elias Giacoumidis[4], Nick Doran[4], Ioannis Papakonstantinou[1], Izzat Darwazeh[1]; *[1]Univ. College London, UK; [2]Faculty of Electromagnetic Fields, Czech Technical Univ. in Prague, Czech Republic; [3]Northumbria Univeristy, UK; [4]Aston Univ., UK; [5]Telekom R&D, Malaysia.* A multi-band CAP system is experimentally demonstrated for the first time in VLC. We show that with an 8-CAP testbed spectral efficiencies (~4.75 b/s/Hz) at a realistic distance of 1 m can be reached.

Tu2G.3 • 14:30

High-Diversity Space Division Multiplexing Visible Light Communication Utilizing a Fisheye-Lens-Based Imaging Receiver, Te Chen[1], Zhong Zheng[1], Lu Liu[1], Weiwei Hu[1]; *[1]State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking Univ., China.* The verification experiment of the high-spatial-diversity fisheye-lens-based SDM VLC system is demonstrated. High spatial diversity is obtained, and an aggregate data rate of over 1.1 Gbit/s is achieved.

Room 408B

Tu2H • Data Center and Cloud Architecture and Technology—Continued

Tu2H.2 • 14:15

Single-VCSEL 100-Gb/s Short-Reach System Using Discrete Multi-Tone Modulation and Direct Detection, Chongjin Xie[1], Po Dong[1], Sebastian Randel[1], Dario Pilori[1], Peter J. Winzer[1], Silvia Spiga[2], Benjamin Kögel[3], Christian Neumeyr[3], Markus Amann[2]; *[1]Alcatel-Lucent Bell Labs, USA; [2]Walter Schottky Institut, TU München, Germany; [3]VERTILAS GmbH, Germany.* We demonstrate an up to 115-Gb/s line-rate short-reach system using a single 1550-nm VCSEL with discrete multi-tone modulation and direct detection, which can cover 500-m to 4-km standard-single-mode fiber at 95-Gb/s to 105-Gb/s bit rates.

Tu2H.3 • 14:30

Programmable Wavelength Locking and Routing in a Silicon-Photonic Interconnection Network Implementation, David Calhoun[1], Qi Li[1], Colm Browning[2,1], Nathan C. Abrams[1], Yang Liu[3], Ran Ding[3], Liam P. Barry[2], Thomas W. Baehr-Jones[3], Michael Hochberg[3], Keren Bergman[1]; *[1]Electrical Engineering, Columbia Univ., USA; [2]Dublin City Univ., Ireland; [3]Coriant Advanced Technology Group, USA.* A programmable control system for wavelength locking WDM channels on microring arrays is used to demonstrate arbitrary demultiplexing and selection of fast switchable wavelengths. Successful data measurements verify the functionality within an interconnection network implementation.

Room 409AB

Tu2I • Elastic Network Architecture—Continued

Tu2I.1 • 14:30 Invited

Evaluating Flexibility Degrees in Optical Networks, Konstantinos Christodoulopoulos[1,2], Emmanouel Varvarigos[1,2]; *[1]Univ. of Patras, Greece; [2]Computer Technology Institute and Press - Diophantus, Greece.* We consider an IP over flexgrid network and present a joint IP routing, distance-adaptive routing and spectrum allocation formulation. We evaluate the performance of fixed- and flex-grid switches, fixed transponders, single- and multi-flow bandwidth-variable transponders.

Room 411

Tu2J • Panel: Optics in Access: Technology and Standards—Continued

Show Floor Programming

■ **Market Watch**

12:30–14:30
Panel II: State of the Market/ Industry: 2014 in Review
For more details, see page 39

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

Tu2A • Advanced Modulators—Continued

Tu2A.3 • 14:45
Tunable Transmitter for Serial 100 Gb/s Connectivity Inside Flexible Data Centers Using Hybrid Polymer Integration, Vasilis Katopodis[1], Ziyang Zhang[2], Panos Groumas[1], Agnieszka Konczykowska[3], Jean-Yves Dupuy[3], Antonio Beretta[4], Alberto Dede[4], Eric Miller[5], Jung Han Choi[2], Parisa Harati[2], Filipe Jorge[3], Virginie Nodjiadjim[3], Raluca Dinu[5], Giulio Cangini[5], Antonello Vannucci[4], Norbert Keil[2], Heinz-Gunter Bach[2], Norbert Grote[2], Hercules Avramopoulos[1], Christos Kouloumentas[1]; *[1]National Technical Univ. of Athens, Greece; [2]Photonic Components, Fraunhofer Institute for Telecommunications, HHI, Germany; [3]III-V Lab, France; [4]Linkra Srl, Italy; [5]GigOptix Inc., USA.* We introduce a platform based on passive and electro-optic polymers, and present a serial 100G transmitter with 22-nm tunability. We achieve 100-Gb/s transmission over 1625-m, and demonstrate the flexibility of the transmitter inside data-center networks.

Tu2A.4 • 15:00
50GHz Ge Waveguide Electro-Absorption Modulator Integrated in a 220nm SOI Photonics Platform, Shashank Gupta[1,2], Srinivasan Ashwyn Srinivasan[2,3], Marianna Pantouvaki[2], Hongtao Chen[2,3], Peter Verheyen[2], Guy Lepage[2], Dries V. Thourhout[3], Gunther Roelkens[3], Krishna Saraswat[1], Philippe Absil[2], Joris V. Campenhout[2]; *[1]Stanford Univ., USA; [2]IMEC, Belgium; [3]Ghent Univ., Belgium.* We report waveguide-integrated Ge electro-absorption modulators operating at 1615nm wavelength with 3dB bandwidth beyond 50GHz and a capacitance of 10fF. A 2V voltage swing enables 4.6dB DC extinction ratio for 4.1dB insertion loss.

Room 403A

Tu2B • Dynamic Optical Network Control—Continued

Tu2B.2 • 15:00
Cross-Layer Orchestration for Elastic and Resilient Packet Service in a Reconfigurable Optical Transport Network, Young Jin Kim[1], Jesse E. Simsarian[1], Marina Thottan[1]; *[1]Bell-Labs, Alcatel-Lucent, USA.* We demonstrate a cross-layer orchestration for packet service over IP-optical networks, in terms of availability and elasticity. Our orchestration built over SDN concept self-adjustably and cost-efficiently responds to dynamics on network paths, impairments/failures, and topology.

Room 403B

Tu2C • Sources and Amplifiers—Continued

Tu2C.4 • 15:00
High Power Sub-Picosecond Pulsed SWIR Source Based on Thulium Assisted Raman Wavelength Shifting, Steevy Cordette[1], Svyatoslav Kharitonov[1], Adrien Billat[1], Camille-Sophie Bres[1]; *[1]Photonic Systems Laboratory(PHOSL), Ecole Polytechnique Federale de Lausanne, Switzerland.* We demonstrate 1.5W sub-picosecond pulsed source near 2μm. Cavity-less source is based on integrated association of 3rd order Raman wavelength-shifting and thulium amplification. Coherent spectrum of 61.5nm with 34% pump power conversion efficiency is achieved.

Room 404AB

Tu2D • Few-Moded Fibers—Continued

Tu2D.1 • 14:45
Impact of Linear Mode Coupling on the Group Delay Spread in Few-Mode Fibers, Filipe Ferreira[1], Stylianos Sygletos[1], Andrew D. Ellis[1]; *[1]Aston Institute of Photonic Technologies, Aston Univ., UK.* We report an investigation on the group delay spread in few-mode fibers operating in the weak and strong linear coupling regimes, and for the first time, we study the transition region between them. A single expression linking the group delay spread to the fiber correlation length is validated for any coupling regime, considering 3 guided modes.

Tu2D.2 • 15:00
Equipartition multiplexing technique for equalizing channel dependent degradation in MDM transmission, Takayoshi Mori[1], Taiji Sakamoto[1], Masaki Wada[1], Takashi Yamamoto[1], Nobutomo Hanzawa[1], Fumihiko Yamamoto[1]; *[1]NTT Corporation, Japan.* We employ a novel equipartition multiplexing technique in mode-division-multiplexed transmission for equalizing channel dependent impairment induced by mode dependent loss and modal crosstalk, and successfully achieve 2-LP mode-multiplexed transmission with a low signal quality difference.

Room 406AB

Tu2E • SDN and New Access Paradigms—Continued

Tu2E.3 • 14:45
Novel Optical Access Network Virtualization and Dynamic Resource Allocation Algorithms for the Internet of Things, Jing Wang[2,1], Neda Cvijetic[2], Konstantinos Kanonakis[2], Ting Wang[2], Gee-Kung Chang[1]; *[1]Georgia Institute of Technology, USA; [2]NEC Laboratories America, USA.* Novel optical access network virtualization and resource allocation algorithms for Internet-of-Things support are proposed and implemented on a real-time SDN-controller platform. 30-50% gains in served request number, traffic prioritization, and revenue are demonstrated.

Tu2E.4 • 15:00 **Invited**
Software-Defined Transceivers for Dynamic Access Networks, David Hillerkuss[1], Juerg Leuthold[1]; *[1]ETH Zurich, Switzerland.* Software-defined transceivers are about to be established in long-haul optical communications. But will they be of equal importance in dynamic access networks? And which technology seems most promising?

Room 407

Tu2F • Chip-scale All-optical Processing—Continued

Tu2F.3 • 14:45
Nonlinear Phase Noise Reduction for 20-Gbit/s NRZ-QPSK Signals Using InP on SOI Photonic Crystal Nanocavity, Trung-Hien Nguyen[1], Mathilde Gay[1], Laurent Bramerie[1], Kevin Lengle[1], Christophe Peucheret[1], Olivier Sentieys[2], Jean-Claude Simon[1], Alexandre Bazin[3], Rama Raj[3], Fabrice Raineri[3,4]; *[1]FOTON Laboratory, CNRS, Univ. of Rennes 1, ENSSAT, France; [2]INRIA / IRISA, Campus de Beaulieu, France; [3]Laboratoire de Photonique et de Nanostructures, CNRS, UPR20, France; [4]Université Paris Diderot, Sorbonne Paris Cité, France.* All-optical nonlinear phase noise reduction using an InP-over-SOI PhC nanocavity is experimentally demonstrated for 20-Gbit/s NRZ-QPSK signals. The phase-preserving intensity-limiting function results in an OSNR penalty reduction of 3.5 dB at a BER of 10^{-3}.

Tu2F.4 • 15:00 **Invited**
Phase-sensitive Optical Processing in Silicon Waveguides, Klaus Petermann[1], Andrzej Gajda[1], Giannino Dziallas[1], Mahmoud Jazayerifar[1], Lars Zimmermann[2], Bernd Tillack[2], Francesco Da Ros[3], Dragana Vukovic[3], Kjeld Dalgaard[3], Michael Galili[3], Christophe Peucheret[4]; *[1]Technische UniversitÃ¤t Berlin, Germany; [2]IHP, Germany; [3]Technical Univ. of Denmark, Denmark; [4]Univ. of Rennes, France.* Parametric optical signal processing is reviewed for silicon nano-rib-waveguides with a reverse-biased pin-junction. Phase-sensitive parametric amplification with a phase-sensitive extinction of more than 20 dB has been utilized for the regeneration of DPSK signals.

Room 408A

Tu2G • Visible Light Communication—Continued

Tu2G.4 • 14:45
Experimental Demonstration of Femtocell Visible Light Communication System Employing Code Division Multiple Access, Zhong Zheng[1], Te Chen[1], Lu Liu[1], Weiwei Hu[1]; [1]*Peking Univ. , China.* This paper experimentally demonstrates a femtocell visible light communication system employing CDMA for multiple users, in which the intracells and intercells interference is alleviated, resulting in a significant aggregate capacity improvement.

Tu2G.5 • 15:00 **Tutorial**
Visible Light Communication, Harald Haas[1,2]; [1]*Univ. of Edinburgh, UK;* [2]*pureLiFi Ltd, UK.* We comprehensively explore the use of LEDs for pervasive high-speed wireless communications – from point-to-point links to fully developed multiuser networks. Topics covered are channel models, digital modulation, optical MIMO, diversity, multiuser access, and interference mitigation.

Professor Haas holds the Chair of Mobile Communications at the University of Edinburgh. He first introduced 'Li-Fi' which was listed among

continued on pg 79

Room 408B

Tu2H • Data Center and Cloud Architecture and Technology—Continued

Tu2H.4 • 14:45
40Gb/s Pure Photonic Packet Switch for Data Centers, Xiaoling Yang[1], Hamid Mehrvar[1], Huixiao Ma[1], Yan Wang[1], Lulu Liu[1], HY Fu[1], Dongyu Geng[1], Dominic J. Goodwill[1], Eric Bernier[1]; [1]*Huawei Technology, Canada.* We demonstrate a pure 40G photonic packet switch for datacenters based on photonic wrap/un-wrap, separation of control from data path and a synchronization scheme to align packets of all nodes at the photonic switch inputs.

Tu2H.5 • 15:00 **Invited**
Evolution of Telecom Carrier Networks to meet Explosions of Cloud Services, Stuart Elby[1]; [1]*Infinera Corporation, USA.* Cloud is driving traffic growth, causing Service Providers to increase capacity and network efficiency. Towards these ends a new type of network is emerging – Data Center Interconnect. Differences between DCI and traditional networks are discussed.

Room 409AB

Tu2I • Elastic Network Architecture—Continued

Tu2I.2 • 15:00 Top Scored
Multiple Fiber, Flexgrid Elastic Optical Network Design using MaxEnt Optimization, Michael C. Parker[1], Paul Wright[2], Andrew Lord[2]; [1]*Lexden Technologies Ltd, UK;* [2]*BT Design & Innovation, BT, UK.* We demonstrate how maximum entropy (MaxEnt) allocation strategies can optimally determine links within a flexgrid elastic optical network requiring multiple fiber-pairs to support 100% capacity growth with 34.3% improvement in the uniformity of spectrum allocations.

Room 411

Tu2J • Panel: Optics in Access: Technology and Standards—Continued

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Show Floor Programming

■ **Market Watch**

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

Tu2A • Advanced Modulators—Continued

Tu2A.5 • 15:15
64 GBd Operation of a Silicon-Organic Hybrid Modulator at Elevated Temperature, Matthias Lauermann[1], Stefan Wolf[1], Robert Palmer[1], Anna Bielik[2], Lars Altenhain[2], Joachim Lutz[2], Rolf Schmid[2], Thorsten Wahlbrink[3], Jens Bolten[3], Anna Lena Giesecke[3], Wolfgang Freude[1,4], Christian Koos[1,4]; *[1]Institute of Photonics and Quantum Electronics, Karlsruhe Institute of Technology, Germany; [2]Micram Microelectronic GmbH, Germany; [3]AMO GmbH, Germany; [4]Institute of Microstructure Technology, Karlsruhe Institute of Technology, Germany.* We show 64 GBd 4ASK signaling with a silicon-organic hybrid Mach-Zehnder modulator, allowing data rates of up to 128 Gbit/s. The device is operated at room temperature and at 80 °C.

Tu2A.6 • 15:30
High-Performance Si Photonics Interposer Featuring RF Travelling-wave Electrode (TWE) via Cu-BEOL, Yan Yang[1,2], Qing Fang[1], Mingbin Yu[1], Xiaoguang Tu[1], Junfeng Song[1], . Rusli[2], Guoqiang Lo[1]; *[1]Institute of Microelectronics, A*STAR, Singapore; [2]School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore.* A silicon Cu-photonics interposer, consisting of monolithically integrated Si modulators and Ge photodetectors, has been explored for integrated optical communication. Up to 33.7 GHz-bandwidth of this integrated circuit are enabled by travelling-wave electrode via Cu-BEOL.

Room 403A

Tu2B • Dynamic Optical Network Control—Continued

Tu2B.4 • 15:15
Experimental Assessment of GMPLS/PCE-controlled Multi-Flow Optical Transponders in FlexGrid Networks, Ricardo Martínez [1], Ramon Casellas[1], Ricard Vilalta[1], Raül Muñoz[1]; *[1]Ctr Tecnologic de Telecoms de Catalunya, Spain.* We propose and implement required GMPLS/PCE routing and signaling protocol extensions for the configuration/control of MF OTPs. A novel online RSMA algorithm allows experimentally evaluating the automatic provisioning of LSPs including MF OTPs.

Tu2B.3 • 15:30
Fragmentation-Aware Spectrum Assignment for Elastic Optical Networks with Fully-Distributed GMPLS, Tatsuya Fukuda[1], Lei Liu[3], Ken-ichi Baba[2], Shinji Shimojo[4], S. J. B. Yoo[3]; *[1]Graduate School of Information Science and Technology, Osaka Univ., Japan; [2]Kogakuin Univ., Japan; [3]Univ. of California, Davis, USA; [4]Cybermedia Center, Osaka Univ., Japan.* This paper proposes two types of fragmentation aware spectrum assignment for fully-distributed GMPLS framework. The cut-avoidance approach achieves lower blocking probability and the block-assign approach improves performance more when requested slot sizes are known.

Room 403B

Tu2C • Sources and Amplifiers—Continued

Tu2C.5 • 15:15
Telecom to Mid-infrared Supercontinuum Generation in a Silicon Germanium Waveguide, Mohamed A. Ettabib[5], Lin Xu[5], Adonis Bogris[1,2], Alexandros Kapsalis[1], Mohammad Belal[5], Emerick Lorent[3], Pierre Labeye[3], Sergio Nicoletti[3], Kamal Hammani[4], Dimitris Syvridis[1], Jonathan Price[5], David J. Richardson[5], Periklis Petropoulos[5]; *[1]Department of Informatics and Telecommunications, National and Kapodistrian Univ. of Athens, Greece; [2]Technological Educational institute of Athens, Department of Informatics, Greece; [3]CEA-Leti MINATEC Campus, France; [4]Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB), France; [5]Optoelectronics Research Centre, Univ. of Southampton, UK.* We report the first demonstration of broadband supercontinuum generation in silicon-germanium waveguides. Upon propagation of ultra-short femtosecond pulses in a 3-cm-long waveguide, the broadening extended from 1.455μm to 2.788μm (at the -30-dB point).

Tu2C.6 • 15:30
Holmium Doped Fiber Amplifier for Optical Communications at 2.05 - 2.13 μm, Nikita Simakov[2,1], Zhihong Li[1], Shaif-Ul Alam[1], P.C. Shardlow[1], J. M. O. daniel[1,2], Deepak Jain[1], Jayanta K. Sahu[1], Alexander Hemming[2], Andy Clarkson[1], David J. Richardson[1]; *[1]Univ. of Southampton, UK; [2]CEWD, DSTO, Australia.* We report the realization of a wideband holmium doped fiber amplifier designed for optical communications over 2050–2130 nm, providing up to 28 dB small signal gain and 4–9.5 dB noise figure.

Room 404AB

Tu2D • Few-Moded Fibers—Continued

Tu2D.3 • 15:15
Experimental Characterization of a Graded-Index Ring-Core Fiber Supporting 7 LP Mode Groups, Feng Feng[1], George S. Gordon[1], X.Q. Jin[2], D.C. O'Brien[2], F.P. Payne[2], Yong-min Jung[3], Q. Kang[3], J. K. Sahu[3], S. U. Alam[3], David J. Richardson[3], Timothy D. Wilkinson[1]; *[1]Univ. of Cambridge, UK; [2]Univ. of Oxford, UK; [3]Univ. of Southampton, UK.* We design and characterize a graded-index-ring-core fiber supporting 7 LP mode-groups (13 spatial modes) for mode multiplexed transmission with low MIMO processing complexity. Spatial and temporal modal properties are analyzed using an SLM-based mode multiplexer/demultiplexer.

Tu2D.4 • 15:30 Invited
Modal Dispersion Properties of Few-Mode Spun Fibers, Luca Palmieri[1]; *[1]Univ. of Padova, Italy.* The effects of spin on the modal properties of few mode fibers are numerically investigated showing that, at least in the cases considered here, the spin may even increase modal dispersion rather than decreasing it.

Room 406AB

Tu2E • SDN and New Access Paradigms—Continued

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

Tu2E.5 • 15:30
Experimental End-to-End Demonstration of Shared N:1 Dual Homed Protection in Long Reach PON and SDN-Controlled Core, Séamas McGettrick[1], Frank Slyne[1], Nattapong Kitsuwan[1], David B. Payne[1], Marco Ruffini[1]; *[1]CTVR, The Telecommunications Research Centre, Trinity College Dublin, Ireland.* We demonstrate fast restoration of PON services with a dual-homed, shared-OLT protection mechanism. Using the SDN-controlled pan-European GEANT core network, we demonstrate PON protection and end-to-end service restoration times within 40ms and 155ms respectively.

Room 407

Tu2F • Chip-scale All-optical Processing—Continued

Tu2F.5 • 15:30 Invited
Photonics Subsystems for Optical Packet/Burst Switches Based on Heterogeneous SOI and III-V integration, Dries Van Thourhout[1], Martijn Tassaert[1], peter de heyn[1], Oded Raz[2], Nicola Calabretta[2], Gunther Roelkens[1]; *[1]Ghent Univ., INTEC, Belgium; [2]Department of Electrical Engineering, TU/e, Netherlands.* In this paper we describe how high-quality silicon photonic ICs and III-V membrane switches integrated on this platform can be used to build photonic subsystems for optical packet switches.

Room 408A

Tu2G • Visible Light Communication—Continued

the 50 best inventions in TIME Magazine 2011. Haas was an invited speaker at TEDGlobal 2011. His talk has been watched more than 1.5 million times. He published more than 350 papers including a Science paper. In 2012, he was the only recipient of the prestigious Established Career Fellowship from the EPSRC within ICT. In 2014, Haas was selected as one of ten RISE 'Recognising Inspirational Scientists and Engineers' Leaders, and has been shortlised for an IET Innovation Award.

Room 408B

Tu2H • Data Center and Cloud Architecture and Technology—Continued

Tu2H.6 • 15:30 Invited

SDN and Routing Strategies for Cloud-Scale Data Center Traffic, David Maltz[1]; [1]*Microsoft Corp, USA*. Networks for Cloud-Scale Data Centers are challenged by the need to support multiple diverse traffic patterns and traffic types across a single shared physical network. This talk lays out challenges and shows how software-defined networking combined with simple physical networks meets the need.

Room 409AB

Tu2I • Elastic Network Architecture—Continued

Tu2I.3 • 15:15

Optimization of Client-to-Line-Side Switching in DWDM Networks using Sliceable Bandwidth-Variable Transponders, António Eira[2,1], João Pedro[2,1], João Pires[1], Juan Pedro Gimenez[3]; [1]*Instituto de Telecomunicações, Portugal;* [2]*Coriant, Portugal;* [3]*Telefonica I+D, Spain*. We evaluate the impact of electrical switching capacity on the cost-efficiency of SBVT-enabled backbone networks through a novel grooming and equipment provisioning algorithm. The results stress how the switch design is critical in balancing client-card and switch matrix costs.

Tu2I.4 • 15:30

Impact of Multi-wavelength sliceable transponders in Elastic Optical Networks, Matteo Dallaglio[1], Alessio Giorgetti[1], Nicola Sambo[1], Luis Velasco[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy;* [2]*UPC, Spain*. The utilization of sliceable bandwidth variable transponders based on multi-wavelength technology is evaluated in EONs. A routing and spectrum assignment scheme is proposed specifically designed to consider the constraints introduced by multi-wavelength technology.

Room 411

Tu2J • Panel: Optics in Access: Technology and Standards—Continued

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Show Floor Programming

■ **Market Watch**

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

Tu2A • Advanced Modulators—Continued

Tu2A.7 • 15:45
SiGe-based carrier-injection Mach-Zehnder modulator with enhanced plasma dispersion effect in strained SiGe, Younghyun Kim[1], Junichi Fujikata[2], Shigeki Takahashi[2], Mitsuru Takenaka[1], Shinichi Takagi[1]; *[1]Univ. of Tokyo, Japan; [2]PETRA, Japan*. We demonstrate strained SiGe-based carrier-injection MZ optical modulator with low driving current of 1.47 mA owing to the enhanced plasma dispersion effect in SiGe. The 10 Gbps modulation with clear eye opening is also obtained.

Room 403A

Tu2B • Dynamic Optical Network Control—Continued

Tu2B.5 • 15:45
Multi-domain Overarching Control of Flexi-grid Networks with GMPLS as Inter-SDN Controller Communication, Ramon Casellas[1], Ricardo Martínez[1], Raül Muñoz[1], Ricard Vilalta[1], Lei Liu[2]; *[1]Ctr Tecnològic de Telecom de Catalunya, Spain; [2]Univ. of California Davis, USA*. We report the experimental assessment of a hybrid control plane for multi-domain, heterogeneous networks based on abstraction and hierarchical TE. A mesh of SDN controllers use GMPLS protocols as East/West interfaces, forming an abstracted topology.

Room 403B

Tu2C • Sources and Amplifiers—Continued

Tu2C.7 • 15:45
High Temperature Operation of an Integrated Erbium-Doped DBR Laser on an Ultra-Low-Loss Si_3N_4 Platform, Michael Belt[1], Daniel J. Blumenthal[1]; *[1]Univ. of California Santa Barbara, USA*. We demonstrate record high temperature operation, 400 °C, of an integrated Al_2O_3:Er^{3+} DBR laser on an ultra-low-loss Si_3N_4 waveguide platform. Additionally, the device exhibits an uncompensated temperature dependent wavelength shift of 1.92 GHz/°C and maintains over 1.5 mW of output power throughout the entire temperature range.

Room 404AB

Tu2D • Few-Moded Fibers—Continued

Room 406AB

Tu2E • SDN and New Access Paradigms—Continued

Tu2E.6 • 15:45
λ-Tuning Protection Scheme Achieving Under 50-ms Protection Time Based on MPCP and Backup-Wavelength Pre-assignment on WDM/TDM-PONs, Shin Kaneko[1], Tomoaki Yoshida[1], Shunji Kimura[2], Ken-Ichi Suzuki[1], Akihiro Otaka[1]; *[1]NTT Access Network Service Systems Lab., Japan; [2]NTT Device Innovation Center, Japan*. We propose a fast WDM/TDM-PON OLT-protection method based on ONU λ-tuning to pre-assigned backup wavelength and normal MPCP without discovery procedure. The fabricated system with 40-km SMF transmission achieves protection times of under 50 ms.

Room 407

Tu2F • Chip-scale All-optical Processing—Continued

16:00–16:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

NOTES

Room 408A	Room 408B	Room 409AB	Room 411
Tu2G • Visible Light Communication—Continued	**Tu2H • Data Center and Cloud Architecture and Technology—Continued**	**Tu2I • Elastic Network Architecture—Continued**	**Tu2J • Panel: Optics in Access: Technology and Standards—Continued**

Tu2I.5 • 15:45 Top Scored
Resource Allocation in Nonlinear Flexible-Grid Fiber-Optic Networks, Li Yan[1], Erik Agrell[1], Henk Wymeersch[1]; [1]*Chalmers Univ. of Technology, Sweden*. We describe a novel method for joint resource allocation in flexible-grid networks based on a nonlinear impairment model. Compared with the fixed-grid WDM benchmark,our algorithm achieves 38% bandwidth saving and significant transmission distance extension.

16:00–16:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

NOTES

Show Floor Programming

■ **Market Watch**

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

16:30–18:30
Tu3A • Wavelength Filtering/Switching
Presider: Roland Ryf; Alcatel-Lucent, USA

Tu3A.1 • 16:30
FSR-Free Filter Based on a Coupled Microring Grating System, Huang Qiangsheng[1], Keqi Ma[1], Sailing He[1,2]; [1]*Centre for Optical and Electromagnetic Research, JORCEP [Sino-Sweden Joint Research Center of Photonics], Zhejiang Provincial Key Laboratory for Sensing Technologies, Zhejiang Univ., China;* [2]*Department of Electromagnetic Engineering, Royal Institute of Technology, Sweden.* A coupled microring grating system is theoretically and experimentally demonstrated. It can be used as a no free spectral range filter, with an extinction ratio larger than 25dB and a 3dB bandwidth of 0.8nm.

Tu3A.2 • 16:45
High Performance Narrow Bandpass Filters Based on Integrated Bragg Gratings in Silicon-on-Insulator, Alexandre D. Simard[1], Sophie LaRochelle[1]; [1]*Department of Electrical and Computer Engineering, Universite Laval, Canada.* We show that a dispersion-less filter with a narrow square-shaped passband exhibiting sidelobe suppression ratio reaching 13 dB can be fabricated in SOI using the superposition apodization technique and a phase noise reduction approach.

Room 403A

16:30–18:30
Tu3B • FEC and Non-linear Compensation
Presider: Chris Fludger; Cisco Optical GmbH, Germany

Tu3B.1 • 16:30 Tutorial
Power Efficient Implementation of Soft-Decision FEC and DSP for Optical Transceivers, Sameep Dave[1], Fan Mo[1]; [1]*ViaSat, Inc., USA.* SDFECs provide excellent error correction performance at the cost of additional complexity / power. We provide an overview of various aspects of SDFEC including techniques / trade-offs for low power implementation of SDFEC and DSP.

Sameep Dave is currently the Chief Technology Officer at ViaSat – Cleveland. Mr. Dave has been working at ViaSat for the last 15 years. His focus has been researching new Forward Error Correction (FEC) and Digital Signal Processing (DSP) technologies for a variety of telecommunications applications including Satellite Communications and Optical (Fiber and Free Space) Communications. A key area of expertise has been finding efficient algorithms and architectures to facilitate high speed implementation of these technologies in FPGA and ASIC based designs. Mr. Dave has several patents approved and several patents pending.

Room 403B

16:30–18:30
Tu3C • Few-mode Amplifier
Presider: Peter Krummrich; Technische Universitaet Dortmund, Germany

Tu3C.1 • 16:30 Invited
Recent Progress in the Development of Few Mode Fiber Amplifier, Shaif-Ul Alam[1], Yongmin Jung[1], Qiongyue Kang[1], Francesco Poletti[1], Jayanta K. Sahu[1], David J. Richardson[1]; [1]*Univ. of Southampton, UK.* We review the performances of both core and cladding pumped few-mode erbium doped fiber amplifiers supporting 6 spatial modes (4 mode groups) which incidentally the highest mode count demonstrated to date.

Room 404AB

16:30–18:30
Tu3D • Photonic Subsystem for Networking Applications
Presider: David Neilson; Alcatel-Lucent Bell Labs, USA

Tu3D.1 • 16:30
Ultra-Selective Flexible Add-Drop Multiplexer Using Rectangular Stimulated Brillouin Scattering Filters, Wei Wei[1,2], Lilin Yi[1,2], Yves Jaouën[2], Michel Morvan[3], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Institut Télécom, Télécom ParisTech, France;* [3]*Institut Télécom, Télécom Bretagne, France.* We demonstrate optical separation-aggregation of a ~2-GHz sub-band for a multi-band OFDM signal in QPSK and 16-QAM formats. The band gap is 300-MHz by using a rectangular optical filter based on stimulated Brillouin scattering.

Tu3D.2 • 16:45
High-speed Polarization Shift Keying Lightpath Labeling of 100 Gb/s DP-QPSK for Programmable Photonic Networks, Goji Nakagawa[1], Mark D. Feuer[2], Vitaly Mikhailov[3], Vinay A. Vaishampayan[2], Shoichiro Oda[1], Kyosuke Sone[1], Setsuo Yoshida[1], Yasuhiko Aoki[1], Jens C. Rasmussen[1]; [1]*Fujitsu Laboratories Limited, Japan;* [2]*Engineering Science and Physics, City Univ. of New York, USA;* [3]*OFS Laboratories, USA.* We present theoretical and experimental results on PolSK lightpath labels for 100 Gb/s DP-QPSK signals. A 100 Mb/s label data rate is confirmed, with several coding overhead ratios and PDL tolerance of up to 2dB.

Room 406AB

16:30–18:30
Tu3E • TWDM-PON
Presider: Peter Vetter; Alcatel-Lucent, USA

Tu3E.1 • 16:30 Top Scored
Demonstration of 512-ONU real-time dynamic-load-balancing with few wavelength reallocations for λ-tunable WDM/TDM-PON, Yumiko Senoo[1], Shin Kaneko[1], Tomoaki Yoshida[1], Jun Sugawa[2], Koji Wakayama[2], Shunji Kimura[1], Ken-Ichi Suzuki[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, Japan;* [2]*Central Research Laboratory, Hitachi, Ltd., Japan.* We demonstrate dynamic-load-balancing for the λ-tunable WDM/TDM-PON. Experiments confirm that our algorithm can distribute 512-ONU traffic loads fairly in real-time with 1/125 fewer λ-reallocations compared to the round-robin, and little impact on average latency.

Tu3E.2 • 16:45 DEMO
Cross-talk in TWDM-PON beyond NG-PON2, Rene Bonk[1], Wolfgang Poehlmann[1], Harald Schmuck[1], Thomas Pfeiffer[1]; [1]*Alcatel-Lucent - Bell Labs, Germany.* We assess the influence of cross-talk on the capability of upgradability of TWDM-PON beyond NG-PON2 for a higher number of connected customers and for a higher number of wavelength channels using experiments and simulations.

Room 407

16:30–18:30
Tu3F • Microwave Photonics Devices
Presider: Leif Johansson; Freedom Photonics, LLC, USA

Tu3F.1 • 16:30 Invited
Optically Phase-locked Lasers for RF Photonics Applications, Michel Poulin[1], Simon Ayotte[1], François Costin[1], André Babin[1], Dominic Faucher[1], Maryse Aubé[1], Christine Latrasse[1], Simon Savard[1], Guillaume Robidoux[1], Mathieu Lailberté[1], François Pelletier[1]; [1]*TeraXion, Canada.* Optically phase-locked lasers with low phase noise have the potential of being used in many RF photonic applications. In this paper, we review the work performed to offer high performance, robust and automated phase-locking solutions using semiconductor lasers. Implementation using a silicon photonic chip is presented.

Room 408A

16:30–18:30
Tu3G • Advanced Circuit for Data Com
Presider: The'Linh Nguyen; Finisar Corporation, USA

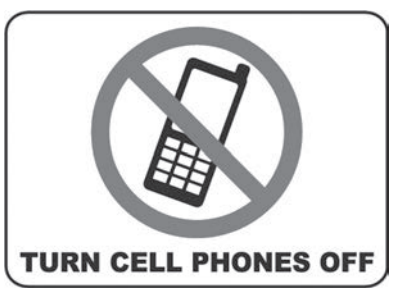
Tu3G.1 • 16:30
A 26-Gb/s 1.80-pJ/b CMOS-Driven Transmitter for 850-nm Common-Cathode VCSELs, Masumi Shibata[1], Anthony Chan Carusone[1]; *[1]Univ. of Toronto, Canada*. A 26-Gb/s, 1.80-pJ/b transmitter composed of a 65-nm bulk-CMOS driver and an 850-nm VCSEL array in a QFN package is demonstrated. The VCSEL's anode is directly modulated without a negative supply voltage at 0.82-dBm OMA.

Tu3G.2 • 16:45
A 50-Gb/s NRZ-modulated Optical Transmitter based on a DFB-LD and a 0.18-μm SiGe BiCMOS LD Driver, Takashi Takemoto[1], Yasunobu Matsuoka[1], Yoshikazu Sugiyama[2], Hidenori Yonezawa[1], Hiroki Yamashita[1], Koichiro Adachi[1], Takahiro Nakamura[1], Etsuko Nomoto[1], Kouji Nakahara[1], Hideo Arimoto[1], Kenichi Osada[1], Tatemi Ido[1]; *[1]Central Research Laboratory, Hitachi Ltd., Japan; [2]Yokohama Research Laboratory, Hitachi Ltd., Japan*. A 50-Gb/s optical transmitter, consisting of a DFB-LD with a bandwidth of 20 GHz and a SiGe BiCMOS LD driver, was developed. At 43-50 Gb/s, it enhanced a LD bandwidth and demonstrated wide eye openings.

Room 408B

16:30–18:30
Tu3H • Deployable Networks for Inter-Data Center & Core
Presider: Takehiro Tsuritani; KDDI R&D Laboratories, USA

Tu3H.1 • 16:30 **Invited**
Scalable and Flexible Transport Networks for Inter-Datacenter Connectivity, Vijay Vusirikala[1], Bikash Koley[1], Tad Hofmeister[1], Vinayak Dangui[1], Valey Kamalov[1], Xiaoxue Zhao[1]; *[1]Google, USA*. We provide an overview of the underlying drivers for capacity growth and discuss technologies and emerging management models (e.g., SDN) to actualize and manage this capacity in terrestrial long haul and subsea links.



Room 409AB

16:30–18:30
Tu3I • Lasers & Multiwavelength Transmitters
Presider: Michael Larson; JDSU, USA

Tu3I.1 • 16:30 **Invited**
400-Gb/s Operation of Flip-chip Interconnection EADFB Laser Array Module, Shigeru Kanazawa[1], Takeshi Fujisawa[3], Kiyoto Takahata[1], Hiroaki Sanjoh[1], Ryuzo Iga[2], Yuta Ueda[1], Wataru Kobayashi[2], Hiroyuki Ishii[2]; *[1]NTT Device Innovation Center, Japan; [2]NTT Device Technology Laboratories, Japan; [3]NTT Photonics Laboratories (currently: Hokkaido Univ.), Japan*. The flip-chip interconnection 8-channel EADFB laser array module is developed. The flip-chip interconnection technique provides low crosstalk. After 10-km transmission, clear eye opening is obtained for all eight lanes under 8 x 50-Gb/s simultaneous operation.

Room 411

16:30–18:30
Tu3J • Panel: Tunable and Programmable Modulation Format Transceivers

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

Organizers: Steve Plote[1], [2]Alan Pak Tao Lau; *[1]BTI Systems, USA; [2]Hong Kong Polytechnic Univ., Hong Kong*

ROADM flexible grid spectrum arrangements are standardized. We have options for adaptive modulation techniques to be path adaptive. Bit-rate adaptive transceivers are rolling out. The concept of elastic optical networks is being well received. Are the network operators ready to take full advantages of the bandwidth/data-rate flexible optical layer functions? Do we need/Can we achieve a higher degree of flexibility at the physical layer?

Speakers:

Signal Processing ASICs: Ready and Able, Norman L. Swenson; *ClariPhy, USA*

ROADM Networks are Undergoing a Generational Transition with the Simultaneous Introduction of the Route and Select Architecture, Colorless, Directionless (CD) and Optionally Contentionless (CDC), Brandon Collings; *JDSU, USA*

The Keys to Freedom… …or Living off the Grid, David W. Boertjes; *Ciena Corporation, Canada*

Flexible Optical Network: Technology is Not Ready, Darli Augusto de Arruda Mello; *University of Campinas, Brazil*

Network Optimization at the Physical Layer, Steve Joiner; *Finisar, USA*

Flexible Transceivers for Next Generation Elastic Optical Network, David V. Plant; *McGill University, Canada*

Path to Flexible Optical Networking for 100G and Beyond, Zhensheng Jia; *ZTE, USA*

Show Floor Programming

■ **Market Watch**

15:00–17:00
Panel III: What's New in Integrated Photonics Technologies?
For more details, see page 39

Room 402AB

Tu3A • Wavelength Filtering/Switching—Continued

Tu3A.3 • 17:00
Experimental Demonstration of Compact 16 channels-50 GHz Si_3N_4 Arrayed Waveguide Grating, Shibnath Pathak[1], Kuanping Shang[1], S. J. B. Yoo[1]; [1]*Electrical and Computer Engineering, Univ. of California, Davis, USA*. Abstract: We experimentally demonstrate 16 channel-50 GHz arrayed waveguide gratings (AWG) on Si_3N_4 for DWDM applications. The device achieves 1.8 dB loss, -20 dB crosstalk, phase errors below ± π/10 on a 3.7×0.7 mm² footprint.

Tu3A.4 • 17:15
Fine Resolution Spectral Filtering Using a 25GHz Free-Spectral Range Arrayed Waveguide Grating, Noam Goldshtein[1], Leonid Pascar[1], David Sinefeld[1], Ori Golani[1], Dan M. Marom[1]; [1]*HUJI, Israel*. Spectrally dispersed light from a fine resolution AWG is spectrally filtered at ~1 GHz resolution with an SLM. AWG phase errors were permanently trimmed waveguide-by-waveguide with an excimer laser by inducing stress in the glass.

Tu3A.5 • 17:30 Top Scored
Optical Nyquist-Filtering Multi/Demultiplexer with PLC for 1-Tb/s Class Super-Channel Transceiver, Takashi Goh[1], Mikitaka Itoh[1], Hiroshi Yamazaki[1], Takashi Saida[2], Toshikazu Hashimoto[1]; [1]*NTT Device Technology Laboratories, NTT Corporation, Japan;* [2]*NTT Device Innovation Center, NTT Corporation, Japan*. We developed a 37.5-GHz-spaced 8-subcarrier Nyquist-filtering multi/demulti-plexer with inverse sinc compensation using integrated planar optics. We successfully demonstrated super-channel generation/reception with an OSNR penalty of 0.2 dB using the multi/demultiplexers and 32-Gbaud DP-QPSK subcarriers.

Room 403A

Tu3B • FEC and Nonlinear Compensation—Continued

Tu3B.2 • 17:30 Invited
Cycle Slip Tolerant, Differential Encoding Aware, Soft-Decision FEC, Andreas Bisplinghoff[1], Stefan Langenbach[1], Eliana Silvia Vercelli[2], Rosanna Pastorelli[2], Theodor Kupfer[1]; [1]*Cisco Optical GmbH, Germany;* [2]*Cisco Photonics Italy Srl, Italy*. We compare hybrid turbo differential decoding with other FEC-schemes that reduce the penalty usually associated with differential encoding applied for cycle slip mitigation. We discuss implementation aspects and show robust FEC-performance in nonlinear transmission experiments.

Room 403B

Tu3C • Few-mode Amplifier—Continued

Tu3C.2 • 17:00
Amplification of 12 OAM States in an Air-Core EDF, Qiongyue Kang[1], Patrick Gregg[2], Yongmin Jung[1], Eeleong Lim[1], Shaif-Ul Alam[1], Siddharth Ramachandran[2], David J. Richardson[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [2]*Electrical and Computer Engineering Department, Boston Univ., USA*. We propose the amplification of 12 OAM modes in an air-core EDF using either core- or cladding- pumping at 980nm. Differential modal gains of only 0.25dB among all the 12-modes are achieved over the C-band.

Tu3C.3 • 17:15
L-band 2-LP mode EDFA with low modal dependent gain, Masaki Wada[1], Taiji Sakamoto[1], Shinichi Aozasa[1], Takayoshi Mori[1], Takashi Yamamoto[1], Nobutomo Hanzawa[1], Fumihiko Yamamoto[1]; [1]*NTT Corporation, USA*. We experimentally investigate mode-dependent gain (MDG) controllability in an Lband 2-LP mode amplifier, and realize a low MDG and flat-gain (<1 dB) in the 1570–1600 nm range by using a ring-core erbium-doped fiber amplifier.

Tu3C.4 • 17:30 Top Scored
Experimental Analysis of the Impact of Beating between Signal Modes on Few-Mode Erbium Doped Fiber Amplifier Performance, Simon Akhtari[1], Martin Finkenbusch[1], Richard Winfield[2], Peter M. Krummrich[1]; [1]*Technische Universität Dortmund, USA;* [2]*Univ. of College Cork, Ireland*. We analyze the impact of beating effects between signal modes experimentally by comparing gain values for modulated and CW signals. We measure noticeable differences because of mode beating and mode dependent EDFA saturation.

Room 404AB

Tu3D • Photonic Subsystem for Networking Applications—Continued

Tu3D.3 • 17:00 Invited
Advanced ROADM Technology and Architecture, Brandon C. Collings[1]; [1]*JDSU, USA*. This paper reviews the dependencies between the node-level architecture, the wavelength selective switches, the multiplexer/demultiplexers, and the transceivers within advanced reconfigurable optical add/drop multiplexing networks supporting colorless, directionless and contentionless multiplexing/demultiplexing.

Tu3D.4 • 17:30 Invited
Fast Non-blocking NxN Optical Switch Using Diffractive MOEMS, Pierre-Alexandre Blanche[1], Brittany Lynn[1], Alex Miles[1], John Wissinger[1], Robert Norwood[1], Nasser Peyghambarian[1]; [1]*Univ. of Arizona, USA*. We present a scalable free-space optical switch with a 12 microsecond reconfiguration time that can be implemented into a cross connect for data center or WSS for telecommunication network.

Room 406AB

Tu3E • TWDM-PON—Continued

Tu3E.3 • 17:00
Simultaneous multi-ONU wavelength switching method for coexistence of different λ-tuning times in WDM/TDM-PON, Jun Sugawa[1], Koji Wakayama[1], Hidehiro Toyoda[1]; [1]*Hitachi, Ltd., Central Research Laboratory, Japan*. We propose OLT architecture and OLT internal control method utilizing multi wavelength-switching queues to realize simultaneous multi-ONU wavelength switching in λ-tunable WDM/TDM-PON. Suppression of latency degradation was demonstrated when ONUs of different λ-tuning times coexist.

Tu3E.4 • 17:15
High-Splitting-Ratio WDM/TDM-PONs Using Automatic Gain Controlled SOAs Designed for Central Office Use, Masamichi Fujiwara[1], Ryo Koma[1], Katsuhisa Taguchi[1]; [1]*NTT Access Network Service Systems Labor, Japan*. Our AGC-SOAs implement a modified gain control scheme that effectively increases splitting ratio even if they are located in central office; they provide network operators with significant benefits from the viewpoint of CAPEX and OPEX.

Tu3E.5 • 17:30
Fast Tunable Silicon Ring Resonator Filter For Access Networks, Alban Leliepvre[1], Romain Brenot[1], Guang-Hua Duan[1], Anaelle Maho[1]; [1]*Alcatel-Thales III-V Laboratory, France*. We demonstrate a silicon photonics filter based on ring resonator for an integrated receiver in access networks. This filter is rapidly tunable (15μs) and performs well in a 4x200GHz scheme, with BER better than 10-9.

Room 407

Tu3F • Microwave Photonics Devices—Continued

Tu3F.2 • 17:00
Photonic Generation of High-Power Pulsed Microwave Signals with Peak Powers up to 7.2 Watt, Xiaojun Xie[1], Qiugui Zhou[1], Andreas Beling[1], Joe C. Campbell[1]; [1]*Electrical and Computer Engineering, Univ. of Virginia, USA*. Using a modified uni-traveling carrier photodiode we demonstrate photonic generation of pulsed 1 GHz and 10 GHz signals with peak power levels as high as 38.6 dBm (7.2 W) and 36.4 dBm (4.4 W), respectively.

Tu3F.3 • 17:15
A Si_3N_4 integrated programmable signal processor with a record high resolution for RF signal processing, Hongchen Yu[1], Minghua Chen[1], Qiang Guo[1], Hongwei Chen[1], Sigang Yang[1], Shizhong Xie[1]; [1]*Tsinghua Univ., China*. A programmable integrated RF signal processor with a record high resolution of 145 MHz has been proposed and experimentally demonstrated. The application to the signal extraction of OFDM-QAM signal has also been presented.

Tu3F.4 • 17:30 Invited
Integrated Optical Beamformers, Chris Roeloffzen[2], Ruud Oldenbeuving[2], Roelof Bernardus Timens[2], Paulus van Dijk[2], Caterina Taddei[1], Arne Leinse[5], Marcel Hoekman[5], Rene G. Heideman[5], Leimeng Zhuang[6], David Marpaung[3], Maurizio Burla[4]; [1]*Universiteit Twente, Netherlands;* [2]*Satrax, Netherlands;* [3]*CUDOS, Univ. of Sydney, Australia;* [4]*IRNS, Canada;* [5]*LioniX, Netherlands;* [6]*Monash Univ., Australia*. This paper gives an overview of three different types of integrated optical beamfoming networks (OBFNs). A binary tree true time delay based OBFN, a hardware compressed multi-wavelength OBFN, and a multi-beaming Nolen matrix based OBFN.

Room 408A

Tu3G • Advanced Circuit for Data Com—Continued

Tu3G.3 • 17:00
A WDM-Compatible 4 × 32-Gb/s CMOS-Driven Electro-Absorption Modulator Array, Benjamin G. Lee[1], Renato Rimolo-Donadio[1,3], Alexander Rylyakov[1], Jonathan Proesel[1], John Bulzacchelli[1], Christian W. Baks[1], Mounir Meghelli[1], Clint L. Schow[1], Anand Ramaswamy[2], Jonathan E. Roth[2], Jaehyuk Shin[2], Brian Koch[2], Daniel K. Sparacin[2], Greg Fish[2]; *[1]IBM TJ Watson Research Center, USA; [2]Aurrion Inc., USA; [3]Costa Rica Institute of Technology (ITCR), Costa Rica*. A four-channel electro-absorption-modulator array, driven by 32-nm CMOS drivers providing 2-V peak-to-peak output swing, operates with BER < 10^{-12} at a data rate of 4 × 32 Gb/s and dissipates 170 mW of power.

Tu3G.4 • 17:15
25.78-Gb/s VCSEL-Based Optical Transceiver with Retimer-embedded Driver and Receiver ICs, Yukito Tsunoda[1], Takayuki Shibasaki[2], Hideki Oku[1], Satoshi Ide[1], Toshihiko Mori[2], Yoichi Koyanagi[2], Kazuhiro Tanaka[1], Tomohiro Ishihara[2], Hirotaka Tamura[2]; *[1]Photonics Laboratories, Fujitsu Laboratories Ltd., Japan; [2]Server Technologies Laboratories, Fujitsu Laboratories Ltd., Japan*. The 25.78-Gb/s VCSEL transceiver with retimer-embedded ICs was firstly developed. We succeeded to suppress the power as low as 200 mW/lane for retime function and realized transmission over 300-m by jitter suppression with the retimer.

Tu3G.5 • 17:30 Tutorial
High Speed Circuits for Short Reach Optical Communications, Alexander Rylyakov[1]; *[1]IBM TJ Watson Research Center, USA*. The main focus of the tutorial will be on high speed circuits and equalization methods for Silicon Photonics and VCSEL based optical short reach links in the context of highly parallel, high bandwidth applications.

continued on pg 87

Room 408B

Tu3H • Deployable Networks for Inter-Data Center & Core—Continued

Tu3H.2 • 17:00 Invited
Agile Network Re-optimization Supporting Seamless Service Migration, Yutaka -. Takita[1,2], Tomohiro Hashiguchi[1,2], Kazuyuki Tajima[1,2], Toru Katagiri[1,2], Takao Naito[1,2], Qiong Zhang[3], Xi Wang[3], Inwoong Kim[3], Paparao Palacharla[3], Motoyoshi Sekiya[3]; *[1]Fujitsu Labs. Ltd., Japan; [2]Fujitsu Limited, Japan; [3]Fujitsu Laboratories of America Inc , USA*. We demonstrate novel re-optimization design techniques for realizing agile and seamless service migration with minimum connection disruptions. We also show the effectiveness of our integer linear programming based approach through network simulations.

Tu3H.3 • 17:30 Invited
Opportunities for Bandwidth-on-Demand between Large Datacenters, John Hollingsworth[1]; *[1]IBM TJ Watson Research Center, USA*. Cloud computing has numerous use cases requiring bursts of inter-cloud bandwidth while maintaining a lower average network utilization. We describe the applications driving these requirements and network programmability from a cloud service provider perspective.

Room 409AB

Tu3I • Lasers & Multiwavelength Transmitters—Continued

Tu3I.2 • 17:00
Monolithically integrated directly modulated DFB laser array with MMI coupler for 100GBASE-LR4 application, Wataru Kobayashi[1], Shigeru Kanazawa[2], Yuta Ueda[2], Tetsuichiro Ohno[2], Toshihide Yoshimatsu[2], Takahiko Shindo[1], Hiroaki Sanjoh[2], Hiroyuki Ishii[1], Shinji Matsuo[1], Mikitaka Itoh[1]; *[1]NTT Device technology laboratories, NTT Corporation, Japan; [2]NTT Device innovation center, NTT Corporation, Japan*. We developed the first 1.3-μm, 4×25-Gbit/s directly modulated DFB laser array monolithically integrated with an MMI coupler suitable for 100GBASE-LR4 application. Error-free operation was achieved for a 30-km SMF transmission when modulating four DMLs simultaneously.

Tu3I.3 • 17:15
1.3 μm External-Cavity Quantum-Dot Comb Laser for Temperature Control Free Operation, Nami Yasuoka[1], Mitsuru Ishida[2], Masaomi Yamaguchi[2], Ayashito Uetake[2], Tsuyoshi Yamamoto[2], Yasuhiko Arakawa[1]; *[1]The Univ. of Tokyo, Japan; [2]Fujitsu Laboratories Ltd., Japan*. Temperature-dependence of a 1.3 μm external-cavity quantum-dot laser was evaluated. Four-wavelength simultaneous oscillation and wide-eye openings under 25-Gbps NRZ signal using the filtered individual longitudinal mode were demonstrated between 40 °C and 80 °C.

Tu3I.4 • 17:30
Quantum Dash Passively Mode-Locked Lasers for Tbit/s Data Interconnects, Vidak Vujicic[1], Cosimo Calò[2], Regan Watts[1], Francois Lelarge[3], Colm Browning[1], Kamel Merghem[2], Anthony Martinez[2], Abderrahim Ramdane[2], Liam P. Barry[1]; *[1]School Of Electronic Engineering, Dublin City Univ., Ireland; [2]CNRS, Laboratory for Photonics and Nanostructures, France; [3]III-V Lab, a joint Laboratory of "Alcatel Lucent Bell Labs" and "Thales Research & Technology" and CEA-LETI, France*. We demonstrate for the first time Tbit/s transmission using Q-Dash mode-locked laser sources with FSR of 44.7 and 22.7GHz. The aggregate capacities achieved were 1.128Tb/s for 44.7GHz and 2.256Tb/s for 22.7GHz Q-Dash PMLL using IM/DD-SSB-OFDM.

Room 411

Tu3J • Panel: Tunable and Programmable Modulation Format Transceivers—Continued

Show Floor Programming

Room 402AB

Tu3A • Wavelength Filtering/Switching—Continued

Tu3A.6 • 17:45 DEMO
Ring-based interleaver for Nyquist filtering and WDM multiplexing, Leimeng Zhuang[1], Benjamin Foo[1], Chen Zhu[1], Bill Corcoran[1], Binhuang Song[1], Arthur Lowery[1]; [1]*Monash Univ., Australia*. We analyze the system performance of a novel ring-resonator circuit for simultaneous Nyquist pulse shaping and (de)multiplexing, which features a roll-off factor of 0.025 and is able to dramatically reduce the digital signal processing workload.

Tu3A.7 • 18:00
Ultra-High Port Count Wavelength Selective Switch Employing Waveguide-Based I/O Frontend, Kenya Suzuki[1], Yuichiro Ikuma[1], Etsu Hashimoto[1], Keita Yamaguchi[2], Mikitaka Itoh[2], Tetsuo Takahashi[1]; [1]*NTT Device Innovation Center, NTT Corporation, Japan;* [2]*NTT Device Technology Laboratories, NTT Corporation, Japan*. We propose an ultra-high port count wavelength selective switch employing a waveguide-based input/output frontend that scales the port count to the order of hundreds. We demonstrate a 1 x 95 WSS and confirm its feasibility.

Room 403A

Tu3B • FEC and Nonlinear Compensation—Continued

Tu3B.3 • 18:00 Invited
Practical Techniques for Nonlinear Compensation and Mitigation, Kiyoshi . Fukuchi[1], Atsufumi Shibayama[1], Kohei Hosokawa[1], Wakako Maeda[1], Hidemi Noguchi[1], Jun'ichi Abe[1]; [1]*NEC Corporation, Japan*. Challenges of circuit resource reduction in digital back propagation toward practical implementation is demonstrated. A linear filter circuit resource is effectively reduced using frequency domain processing and filter coefficient optimization for 100Gbps and beyond.

Room 403B

Tu3C • Few-mode Amplifier—Continued

Tu3C.5 • 17:45 Top Scored
Amplification of 5 modes carrying each 100Gb/s with a few mode EDFA, Philippe Genevaux[1], Christian Simonneau[1], Guillaume Le Cocq[2], Yves Quiquempois[2], Laurent Bigot[2], Jean-François Morizur[3], Gabriel Charlet[1]; [1]*Alcatel-Lucent Bell Labs France, France;* [2]*Phlam, France;* [3]*CAILabs, France*. We built an optical Few Mode Amplifier supporting 5 modes. Moderate crosstalk between modes has been measured thanks to careful design and alignment optimization. Simultaneous amplification of 100Gbits/ PDM-QPSK signal over 5 modes is demonstrated.

Tu3C.6 • 18:00 Invited
Challenges in Higher Order Mode Fiber Raman Amplifiers, Karsten K. Rottwitt[1], Kristian Nielsen[1], Søren M. Friis[1], Mario A. Castaneda[1]; [1]*DTU Fotonik, Technical Univ. of Denmark, Denmark*. A higher order Raman amplifier model that take random mode coupling into account is presented. Mode dependent gain and signal power fluctuations at the output of the higher order mode Raman amplifier are discussed.

Room 404AB

Tu3D • Photonic Subsystem for Networking Applications—Continued

Networking • 18:00

Room 406AB

Tu3E • TWDM-PON—Continued

Tu3E.6 • 17:45
Experimental Study of C-band EML based ONU Burst-mode Transmitter for 40 Gbit/s TWDM-PON, Tetsuro Ashida[1], Satoshi Yoshima[1], Susumu Ihara[2], Daisuke Mita[1], Masaki Noda[1]; [1]*MitsubishiElectric, Japan;* [2]*MitsubishiElectric, Japan*. Using single 10Gbit/s EML with a wide operating temperature range, we achieved 40km transmission with a low dispersion penalty of less than 0.8dB over a wavelength range of 2.7nm covering 4-channel at 100GHz grid spacing.

Tu3E.7 • 18:00
Compact silicon-based DML Transmitter with Extinction Ratio improved for 40G TWDM PON OLT scenarios, Qiang Zhang[1], Quan Cao[1], Shengmeng Fu[1], Ruiqiang Ji[1], Li Zeng[1]; [1]*Huawei, China*. An ER improved 4×10Gbps DML WDM transmitter based on Silicon MRR for 40G TWDM-PON is proposed. The ER improvement is more than 6dB with sensitivity of -30.6dBm at 10^{-3} BER after 20km transmission.

Room 407

Tu3F • Microwave Photonics Devices—Continued

Tu3F.5 • 18:00 Top Scored
Ideal Rectangular Microwave Photonic Filter with High Selectivity Based on Stimulated Brillouin Scattering, Lilin Yi[1], Wei Wei[1,2], Yves Jaouen[2], Weisheng Hu[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Télécom ParisTech, France*. We have demonstrated an ideal rectangular microwave photonic filter with flexible tenability on bandwidth, central frequency and selectivity. The 20-dB shape factor is 1.056, which is the best for microwave photonic filters in ~GHz bandwidth.

Room 408A

Tu3G • Advanced Circuit for Data Com—Continued

Alexander Rylyakov is a research staff member at the IBM T.J. Watson Research Center. His main current research interests are in the areas of high speed integrated circuits for optical communications and high performance digital phase-locked loops. Dr. Rylyakov has an M.S. from Moscow Institute of Physics and Technology and a Ph.D. from State University of New York at Stony Brook, both in physics.

Room 408B

Tu3H • Deployable Networks for Inter-Data Center & Core—Continued

Tu3H.4 • 18:00

Field Demonstration of up to 3Tb/s Real-Time Superchannel Transport over 359km Using a Fully Managed Flexible Grid Infrastructure with Net Spectral Efficiency of 5.97bit/s/Hz, Yu Rong Zhou[1], Kevin Smith[1], Roger Payne[1], Andrew Lord[1], Jonathan Hopewell[1], John Weatherhead[1], Jingxin Chen[2], Jiankang Yao[2], Wei Liu[2], Chen Zhao[2], Yong Xiong[2], Zhimin Xiao[2], Peiyuan Du[2]; *[1]BT, UK; [2]Huawei, UK.* We report the first successful field trial of up to 3Tb/s real-time DP – 16QAM superchannel over 359km EDFA-amplified, fully managed flexible grid infrastructure using production grade hardware and software, achieving net spectral efficiency of 5.97bit/s/Hz.

Room 409AB

Tu3I • Lasers & Multiwavelength Transmitters—Continued

Tu3I.5 • 17:45

Simultaneous Phase Noise Reduction of 30 Comb Lines from a Quantum-Dash Mode-Locked Laser Diode Enabling Coherent Tbit/s Data Transmission, Joerg Pfeifle[1], Regan Watts[2], Igor Shkarban[1], Stefan Wolf[1], Vidak Vujicic[2], Pascal Landais[2], Nicolas Chimot[3], Siddharth Joshi[3], Kamel Merghem[4], Cosimo Calò[4], Marc Weber[1], Abderrahim Ramdane[4], Francois Lelarge[3], Liam P. Barry[2], Wolfgang Freude[1], Christian Koos[1]; *[1]Karlsruhe Institute of Technology (KIT), Germany; [2]Dublin City Univ. (DCU), Ireland; [3]III-V Lab, France; [4]Laboratoire de Photonique et Nanostructures, France.* A feed-forward heterodyne scheme is shown to simultaneously reduce the phase noise of many comb lines from a quantum-dash mode-locked laser diode (QD-MLLD). This enables the first coherent data transmission using QD-MLLD as multi-wavelength source.

Tu3I.6 • 18:00

Heterogeneously Integrated III-V on Silicon Distributed Feedback Lasers at 1310 nm, Helene Duprez[1], Antoine Descos[1], Thomas Ferrotti[2,1], Julie Harduin[1], Christophe Jany[1], Tiphaine Card[1], Andre Myko[1], Corrado Sciancalepore[1], Sylvie MENEZO[1], Badhise BEN BAKIR[1]; *[1]CEA-Leti, France; [2]38, ST Microelectronics, France.* We report performances of hybrid III-V on silicon distributed feedback lasers at 1310 nm. Continuous wave regime is achieved up to 55°C, with room-temperature threshold of 35 mA, while mode-hope-free operation with side-mode suppression ratio above 55 dB is measured. The -3dB bandwidth is 6.7 GHz.

Room 411

Tu3J • Panel: Tunable and Programmable Modulation Format Transceivers—Continued

Thank you for attending OFC. Look for your post-conference survey via email and let us know your thoughts on the program.

Show Floor Programming

INTERNATIONAL YEAR OF LIGHT 2015

Room 402AB

Tu3A • Wavelength Filtering/Switching—Continued

Tu3A.8 • 18:15
LCOS-based Flexible Grid 1x40 Wavelength Selective Switch Using Planar Lightwave Circuit as Spot Size Converter, Masaki Iwama[1], Masanori Takahashi[1], Masayoshi Kimura[1], Yasuyoshi Uchida[1], Junichi Hasegawa[1], Ryo Kawahara[1], Nobuyuki Kagi[1]; [1]*FURUKAWA ELECTRIC CO., LTD., Japan.* A high port count WSS using planar lightwave circuit at optical input/output ports is presented. We demonstrate a LCOS-based 1x40 WSS with less than 8.0 dB insertion loss and ±17 GHz 0.5 dB passband width.

Room 403A

Tu3B • FEC and Non-linear Compensation—Continued

Room 403B

Tu3C • Few-mode Amplifier—Continued

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

Room 404AB

Tu3D • Photonic Subsystem for Networking Applications—Continued

Room 406AB

Tu3E • TWDM-PON—Continued

Tu3E.8 • 18:15
Burst-Off-Level Power Reduction in λ-Tunable Transmitter Using a Reverse Bias Voltage Controlled Burst-Mode Booster SOA for 256-Split WDM/TDM-PON, Katsuhisa Taguchi[1], Kota Asaka[1], Shunji Kimura[2], Ken-Ichi Suzuki[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, NTT, Japan;* [2]*NTT Device Innovation Center, NTT, Japan.* We propose a burst-off-level power reduction technique for a burst-mode booster SOA implemented λ-tunable transmitter. A large power reduction of 8.2 dB and a low crosstalk penalty of <0.1 dB in 256-split WDM/TDM-PON are achieved.

Room 407

Tu3F • Microwave Photonics Devices—Continued

Tu3F.6 • 18:15
A full-band RF photonic receiver based on the integrated ultra-high Q bandpass filter, Hongchen Yu[1], Minghua Chen[1], Qiang Guo[1], Marcel Hoekman[2], Hongwei Chen[1], Arne Leinse[2], Rene G. Heideman[2], Sigang Yang[1], Shizhong Xie[1]; [1]*Tsinghua Univ., China;* [2]*LioniX Company, Netherlands.* A full-band RF receiver ranging from L- to W-band based on the ultra-high Q bandpass filter has been proposed and experimentally demonstrated. The SFDR of the receiver from C- to K-band are larger than 114dB-$Hz^{2/3}$.

18:30–21:30 Conference Reception, *Concourse Hall* ***Celebrating the International Year of Light***

19:30–21:30 Rump Session, *Room 409 AB*

NOTES

Room 408A

Tu3G • Advanced Circuit for Data Com—Continued

Room 408B

Tu3H • Deployable Networks for Inter-Data Center & Core—Continued

Tu3H.5 • 18:15
Experimental Demonstration of Overshoot Suppression for Cascaded WSS-based ROADMs, João Januario[1], Miquel G. Alabarce[1], Benjamin Sarti[1], Neil G. Gonzalez[1], Juliano R. Oliveira[1]; *[1]CPqD Foundation, Brazil.* Cascaded WSS-based ROADMs using conventional controllers may amplify optical power fluctuations leading to undesired overshoots. We propose and experimentally demonstrate an optical channel power controller and a technique to suppress overshoots.

Room 409AB

Tu3I • Lasers & Multiwavelength Transmitters—Continued

Tu3I.7 • 18:15
Ultra-Broadband Bidirectional Dual-Band Quantum-Dot Semiconductor Optical Amplifier, Holger Schmeckebier[1], Benjamin Lingnau[2], Swen Koenig[3,4], Kathy Lüdge[2], Christian Meuer[5], Anissa Zeghuzi[1], Dejan Arsenijević[1], Mirko Stubenrauch[1], Rene Bonk[7], Christian Koos[3], Colja Schubert[6], Thomas Pfeiffer[7], Dieter Bimberg[1]; *[1]Department of Solid-State Physics, Technische Universitaet Berlin, Germany; [2]Department of Theoretical Physics, Technische Universitaet Berlin, Germany; [3]Karlsruhe Institute of Technology (KIT), Germany; [4]Infinera Corporation, USA; [5]Department of Telecommunication Systems, Technische Universitaet Berlin, Germany; [6]Heinrich-Hertz-Institute, Fraunhofer Institute for Telecommunications, Germany; [7]Alcatel Lucent Bell Labs, Germany.* By exploiting different discrete optical transitions in a QD SOA, we demonstrate theoretical and experimental distortion-free simultaneous amplification of two counter-propagating 40 Gbit/s OOK signals separated by 93 nm for a wide operating-parameter range.

Room 411

Tu3J • Panel: Tunable and Programmable Modulation Format Transceivers—Continued

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

18:30–21:30 Conference Reception, *Concourse Hall* ***Celebrating the International Year of Light***

19:30–21:30 Rump Session, *Room 409 AB*

NOTES

Show Floor Programming

Room 402AB

08:00–10:00
W1A • Mode Division Multiplexing I
Presider: Jochen Schroeder; Royal Melbourne Institute of Technology, Australia

W1A.1 • 08:00 Invited
LCOS Based Devices for Mode-division Multiplexing, Joel A. Carpenter[1], Benjamin J. Eggleton[1], Jochen B. Schroeder[2]; [1]*Univ. of Sydney, Australia;* [2]*Royal Melbourne Institute of Technology, Australia.* The applications of spatial light modulators for mode division multiplexing will be discussed, including multiplexing, characterization and wavelength switching and filtering.

Room 403A

08:00–10:00
W1B • Silicon Photonics I
Presider: Po Dong; Alcatel-Lucent Bell Labs, USA

W1B.1 • 08:00 Tutorial
Silicon Photonic Integrated Circuits, John E. Bowers[1]; [1]*Univ. of California Santa Barbara, USA.* We review the many breakthroughs in silicon photonic technology and components and describe progress in silicon photonic integrated circuits. The impact active silicon photonic integrated circuits could have on interconnects, telecommunications and on silicon electronics is reviewed.

John Bowers holds the Kavli Chair in Nanotechnology, and is Director of the Institute for Energy Efficiency and Professor in the Departments of Electrical and Computer Engineering and Materials at UCSB. He is a cofounder of Aurrion and Calient Networks. Dr. Bowers received a Ph.D. degree from Stanford University and worked for AT&T Bell Laboratories. Dr. Bowers is a member of the National Academy of Engineering and a fellow of the IEEE, OSA and the American Physical Society. He is a recipient of the OSA/IEEE Tyndall Award, the OSA Holonyak Prize, and the IEEE William Streifer Award.

Room 403B

09:00–10:00
W1C • Amplification and Modulation Technologies for Coherent DWDM
Presider: Haruki Ogoshi; Furukawa Electric, Japan

Room 404AB

08:00–10:00
W1D • Data Center Topologies & Technologies
Presider: Nathan Farrington; Rockley Photonics, USA

W1D.1 • 08:00
50 Gb/s 4-PAM over 200 m of High Bandwidth MMF using a 850 nm VCSEL, Jose M. Castro[1], Rick Pimpinella[1], Bulent Kose[1], Yu Huang[1], B Lane[1], Krzysztof Szczerba[2], Petter Westbergh[2], tamas lengyel[2], Johan Gustavsson[2], Anders Larsson[2], Peter A. Andrekson[2]; [1]*Panduit corp., USA;* [2]*Microtechnology and Nanoscience, Chalmers Univ. of Technology, Sweden.* Transmission of 50 Gb/s over 200 m of dispersion compensated MMF using 4-PAM and directly modulated VCSELs is presented.

W1D.2 • 08:15
DORIOS: Demonstration of an All-Optical Distributed CPU, Memory, Storage Intra DCN Interconnect, George Saridis[1], Emilio Hugues-Salas[1], Yan Yan[1], Shuang Yi Yan[1], Simon Poole[2], Georgios S. Zervas[1], Dimitra E. Simeonidou[1]; [1]*Univ. of Bristol , UK;* [2]*Finisar Australia, Australia.* We show an all-optical ultra-low latency server-to-remote memory/storage data center interconnection, exploiting programmable, flexible, bi-directional and data-rate transparent 4x16 Spectrum Selective Switches and supporting elastic WDM/TDM services using fast nanosecond tunable lasers.

Room 406AB

08:00–10:00
W1E • Carrier Phase Recovery
Presider: Pontus Johannisson; Chalmers Univ. of Technology, Sweden

W1E.1 • 08:00
High Performance Carrier Phase Recovery for Coherent Optical QAM, Nikolaos Argyris[1], Stefanos Dris[1], Christos Spatharakis[1], Hercules Avramopoulos[1]; [1]*National Technical Univ. of Athens, Greece.* A simple feedforward phase recovery algorithm for M-QAM constellations is presented. Performance is evaluated as a function of laser linewidth and SNR for 16- and 64-QAM, and is compared to that of the Blind Phase Search algorithm.

W1E.2 • 08:15
Multiplier-Free, Carrier-Phase Recovery for Real-Time Receivers Using Processing in Polar Coordinates, Benedikt Baeuerle[1], Arne Josten[1], Felix C. Abrecht[1,2], Edwin Dornbierer[1], Jonathan Boesser[1], Michael Dreschmann[2], Juergen Becker[2], Juerg Leuthold[1], David Hillerkuss[1]; [1]*ETH Zurich, Switzerland;* [2]*Karlsruhe Institute of Technology (KIT), Germany.* A novel low-complexity, multi-format carrier-phase estimation algorithm for QPSK and 16QAM is demonstrated. Our multiplier-free hardware implementation is enabled by operating in polar coordinates and allows for detection of QPSK signals beyond 38 GBd.

Room 407

08:00–10:00
W1F • Radio-over-Fiber I
Presider: Christina Lim; Univ. of Melbourne, Australia

W1F.1 • 08:00
Efficient Carrier-Reuse for MMW-RoF Access Network Architecture with Orthogonal Phase-Correlated Modulation, Jianyu Zheng[1,2], Mu Xu[2], Lixian Wang[3], Zhongle Wu[2], Lin Cheng[2], Ibrahim Khalil[2], Jianguo Liu[1], Ninghua Zhu[1], Sophie LaRochelle[3], Gee-Kung Chang[2]; [1]*Chinese Academy of Sciences, China;* [2]*School of Electrical and Computer Engineering, Georgia Institute of Technology, USA;* [3]*Centre d'Optique, Photonique et Laser (COPL), Université Laval, Canada.* We propose and demonstrate a bandwidth-efficient full-duplex millimeter-wave radio-over-fiber access link based on orthogonal phase-correlated modulation enabled by polarization maintaining fiber Bragg gating. In our scheme, backscattering noise is eliminated completely in the upstream link.

W1F.2 • 08:15
Radio Over Colorless WDM-PON With Wavelength Reuse Based on Polarization Multiplexing and Coherent Detection Incorporating Digital Phase Noise Cancellation, Xiang Chen[1], Jianping Yao[1]; [1]*Univ. of Ottawa, Canada.* A bidirectional radio over a colorless wavelength division multiplexing (WDM) passive optical network (PON) with wavelength reuse based on polarization multiplexing and coherent detection incorporating digital phase noise cancellation is proposed and experimentally demonstrated.

Room 408A

08:00–10:00
W1G • Deployable Networks with SDN & Virtualization

Presider: Richard Younce; Tellabs, USA

W1G.1 • 08:00
Scalability of Telecom Cloud Architectures for Live-TV Distribution, Adrian Asensio[1], Luis Miguel Contreras[2], Marc Ruiz[1], Víctor Lopez[2], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain;* [2]*Telefónica, Spain.* hierarchical distributed telecom cloud architecture for live-TV distribution exploiting flexgrid networking and SBVTs is proposed. Its scalability is compared to that of a centralized architecture. Cost savings as high as 32 % are shown.

W1G.2 • 08:15
Demonstrating a Software Defined Network (SDN) using Carrier Ethernet Switch Routers in a Provider Network, Ashwin Gumaste[1], Sarvesh Bidkar[1], Aniruddha Kushwaha[1], Saurabh Hote[1], Puneet Ghodasara[1], Peeyush Agrawal[2]; [1]*Indian Institute of Technology, Bombay, India;* [2]*MTNL, India.* We demonstrate SDN in a service provider network using adapted Carrier Ethernet Switch Routers developed based on principles of segment routing. SDN based service composition and delivery is showcased and validated.

Room 408B

08:00–10:00
W1H • Beyond the Gold Box: The Future of Integrated Optics I

Presider: Chris Fludger; Cisco Optical GmbH, Germany

W1H.1 • 08:00 Invited
Beyond CFP2-ACO, Ian Betty[1]; [1]*Ciena, USA.* Why the CFP2-ACO? Where is it now? Where is it going? Does a CFP4-ACO make any sense? The EO component space evolution over the next 3 years and the roles for ACO and board mounted components.

W1H.2 • 08:20 Invited
Device Technologies for Integrated Packaged Transceivers, Robert A. Griffin[1]; [1]*Oclaro, Inc., USA.* InP-based PICs have enabled a first generation of CFP2-ACO modules for line-side 100Gb/s deployment. A number of options are available to scale to higher volumes and enable high density transport up to 400Gb/s.

Room 409AB

08:00–10:00
W1I • Resource Allocation and Migration to EON

Presider: Masahiko Jinno; Kagawa Univ., Japan

W1I.1 • 08:00 Top Scored
Routing, Code, and Spectrum Assignment (RCSA) in Elastic Optical Networks, Nicola Sambo[3], Gianluca Meloni[1], Filippo Cugini[1], Antonio D'Errico[2], Luca Potì[1], Paola Iovanna[2], Piero Castoldi[3]; [1]*CNIT, Italy;* [2]*Ericsson, Italy;* [3]*Scuola Superiore Sant'Anna, Italy.* This paper introduces the concept of code selection in RSA for EONs. Simulations show that code-adaptive time frequency packing reduces blocking probability by one order of magnitude with respect to format-adaptive Nyquist WDM.

W1I.2 • 08:15
A Novel Routing and Frequency Slot Assignment Scheme that Can Adapt to Transmission Speed Migration, Zhi-shu Shen[1], Taiki Kusano[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; [1]*Nagoya Univ., Japan.* We propose a dynamic control algorithm for flexible grid networks that can seamlessly adapt to transition channel capacity changes. Long-term network performance is numerically evaluated and the effectiveness of the proposed algorithm is verified.

Room 410

08:00–10:00
W1J • WDM-based Optical Access

Presider: Jun-ichi Kani; NTT Access Service Systems Laboratories, Japan

W1J.1 • 08:00 Invited
Demystification of Self-Seeded WDM Access, Romain Brenot[1]; [1]*III-V Lab, France.* The operating principles of a self-seeded cavity are explained, and its main characteristics are described. Some practical implementation cases are also discussed.

Room 411

08:00–10:00
W1K • Optical Processing

Presider: Camille-Sophie Bres; Ecole Polytechnique Federale de Lausanne, Switzerland

W1K.1 • 08:00
Mitigation of Nonlinear Distortion in OPC Module with Backward Raman Pumping, Chaoran Huang[1], Yajun Wu[1], Xiaojie Guo[1], Ming Li[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong.* Nonlinear distortion is suppressed in Raman-assisted optical phase conjugation of CO-OFDM signals, resulting in improvement of 10 dB in optimized output power, 1.2 dB in Q factor, and 7 dB in input power dynamic range.

W1K.2 • 08:15
A study of a saturated parametric mixer non-reciprocity dependence on the pump wavelength, Ana Pejkic[1], Ron R. Nissim[1], Evgeny Myslivets[1], Andreas O. Wiberg[1], Nikola Alic[1], Stojan Radic[1]; [1]*Univ. of California, San Diego, USA.* We study the non-reciprocal saturated parametric amplifier response dependence on the pump wavelength. The available pump depletion bandwidth and signal induced pump depletion level were characterized and the optimum pump wavelength and propagation direction identified.

Show Floor Programming

■ **Service Provider Summit**

08:30–09:00
Keynote Presentation: Carrier's View on Future SDN/NFV Deployment
For more details, see page 41

09:00–10:30
Panel I: Value and Cost of Multi-Layer SDN
For more details, see page 41

Room 402AB

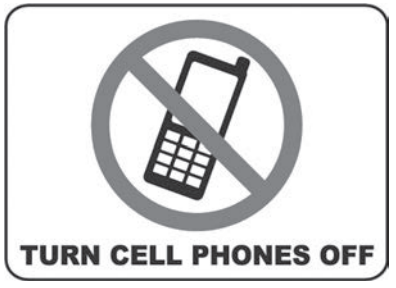
W1A • Mode Division Multiplexing I—Continued

W1A.2 • 08:30
Monolithically Integrated Mode Multiplexer/De-multiplexer on Three-dimensional SiOx-waveguide Platform, Tatsurou Hiraki[1,2], Tai Tsuchizawa[1,2], Hidetaka Nishi[1,2], Tsuyoshi Yamamoto[2], Koji Yamada[1,2]; *[1]Nanophotonics Center, NTT, Japan; [2]NTT Device Technology Labs., Japan.* We proposed a compact and multiplicity-scalable mode multiplexer using three-dimensional silicon-rich silica waveguide on a silicon chip. Experimental results showed a feasibility demonstration of demultiplexing 3 modes with a chip area of ~0.6 mm².

W1A.3 • 08:45 Top Scored
Hitless Monitoring of Wavelength and Mode-Division Multiplexed Channels on a Silicon Photonic Chip, Stefano Grillanda[1], Francesco Morichetti[1], Nicola Peserico[1], Pietro Ciccarella[1], Andrea Annoni[1], Marco Carminati[1], Marco Sampietro[1], Andrea Melloni[1]; *[1]Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy.* On-chip non-invasive monitoring of WDM-MDM channels transmitted through silicon-photonic waveguides is achieved with a ContactLess Integrated Photonic Probe (CLIPP). Simultaneous monitoring of four intensity-modulated 10 Gbit/s channels is demonstrated with no penalty on system performance.

Room 403A

W1B • Silicon Photonics I—Continued



Room 403B

W1C • Amplification and Modulation Technologies for Coherent DWDM—Continued

Room 404AB

W1D • Data Center Topologies & Technologies—Continued

W1D.3 • 08:30
High-Speed and Duo-Mode 850 nm VCSELs for 47 Gbps Optical Interconnect over 1 km OM4 Fiber, I-Cheng Lu[1], Chia-Chien Wei[2], Hsing-Yu Chen[1,3], Kuan-Zhou Chen[2], Cheng-Hsiang Huang[1], Kai-Lun Chi[4], Jin-Wei Shi[4], Fan-I Lai[5], Dan-Hua Hsieh[1], Hao-Ching Kuo[1], Wei Lin[6], Shi-Wei Chiu[6], Jason (Jyehong) Chen[1]; *[1]National Chiao Tung Univ., Taiwan; [2]National Sun Yat-sen Univ., Taiwan; [3]Industrial Technology Research Institute, Taiwan; [4]National Central Univ., Taiwan; [5]Yuan Ze Univ., Taiwan; [6]LandMark Optoelectronics Corporation, Taiwan.* Novel duo-mode 850nm VCSELs with short (l/2) cavity, oxide-relief and Zn-diffusion apertures are demonstrated to balance the trade-off of speed and reaching bottleneck of VCSELs. Extremely-high data rate (47-Gbps) over 1005m OM4-fiber transmission is reported.

W1D.4 • 08:45
A 4-λ, 40Gb/s/λ Bandwidth Extension of Multimode Fiber in the 850nm range, Daniel Kuchta[1], Tam Huynh[1], Fuad Doany[1], Alexander Rylyakov[1], Clint Schow[1], Petar Pepeljugoski[1], Deepa Gazula[2], Ed Shaw[2], Jim Tatum[2]; *[1]IBM TJ Watson Research Center, USA; [2]Finisar Inc., USA.* The bandwidth capacity of 50/125 mm multimode fiber is extended by using four VCSELs with wavelengths coarsely separated at 30nm and with each wavelength operating at 40Gb/s. All four wavelengths achieve BER <1E-12 at 100m.

Room 406AB

W1E • Carrier Phase Recovery—Continued

W1E.3 • 08:30
Symbol-by-Symbol Joint Polarization and Phase Tracking in Coherent Receivers, Cristian B. Czegledi[1], Erik Agrell[1], Magnus Karlsson[1]; *[1]Chalmers Univ. of Technology, Sweden.* An analytical model to describe the combined drift of the state of polarization and absolute phase is presented. To compensate for this drift, a novel, modulation format independent algorithm is proposed, which outperforms state-of-the-art algorithms.

W1E.4 • 08:45
256 QAM (Polarization-multiplexed, 5 Gsymbol/s) Coherent Transmission with an Injection-locked Homodyne Detection Technique, Keisuke Kasai[1], Shohei Beppu[1], Yixin Wang[1], Masataka Nakazawa[1]; *[1]Tohoku Univ., Japan.* We demonstrate an 80 Gbit/s-256 QAM coherent optical transmission with a fiber laser-based injection-locked homodyne detection circuit. The circuit enabled low phase-noise carrier-phase synchronization, and an 80-Gbit/s data signal was successfully transmitted over 150 km.

Room 407

W1F • Radio-over-Fiber I—Continued

W1F.3 • 08:30 Invited
Reconfigurable Radio-Over-Fiber Networks, Juan Jose[1], Vegas Olmos[1], Idelfonso Tafur Monroy[1]; *[1]Technical Univ. of Denmark, Denmark.* This paper discusses reconfigurable Radio-over-Fiber networks, including activities in coherent remote access units, silicon photonics for microwave photonics and optical switching.

Room 408A

W1G • Deployable Networks with SDN & Virtualization—Continued

W1G.3 • 08:30 Invited

Network Control and Virtualization for Cloud and Mobile Services from Carrier's Point of View, Itsuro Morita[1]; [1]*KDDI R&D Laboratories, Inc., Japan.* Network virtualization is a promising technology to reduce CAPEX and OPEX of telecommunication networks together with providing new service agility. This paper reviews recent research activities on network virtualization to enhance its benefits.

Room 408B

W1H • Beyond the Gold Box: The Future of Integrated Optics I—Continued

W1H.3 • 08:40 Invited

Impact of Pluggable Analog Coherent Optics Modules on Line Card Architecture and DSP Functionality, Thomas Duthel[1], James E.A. Whiteaway[1], Theodor Kupfer[1]; [1]*Cisco Optical GmbH, Germany.* Pluggable analog coherent optics modules will change the architecture of line cards. Associated benefits like lower cost, installation on-demand and higher faceplate densities will come at the price of more complex DSP algorithms.

Room 409AB

W1I • Resource Allocation and Migration to EON—Continued

W1I.3 • 08:30 Invited

Evaluating the Potential for Spectrally-Efficient Super-Channel Formats in Brownfield Networks with Legacy Services, Joao Santos[1]; [1]*R&D SDN, Coriant Portugal, Portugal.* This paper shows that a successful combination of super-channels and highly-granular flexible grid networks is intrinsically dependent on the existence of legacy traffic and the occurrence of traffic churn during the network lifetime.

Room 410

W1J • WDM-based Optical Access—Continued

W1J.2 • 08:30

20-Gb/s Operation of RSOA using Polar Return-to-Zero 4-PAM Modulation Format and Direct Detection , HyunKyu Shim[1], Hoon Kim[1], Yun Chur Chung[1]; [1]*Korea Advanced Inst of Science & Tech, Korea (the Republic of).* We demonstrate the upstream transmission of 20-Gb/s polar RZ 4-PAM signal over 20 km of loopback SSMF link by using a directly-modulated RSOA and a direct-detection receiver.

W1J.3 • 08:45

RSOA Intensity Modulator Frequency Chirp-Enabled 40Gb/s over 25km IMDD PON Systems, Jianming Tang[1], Bingyao Cao[1], Mingliang Deng[1], Roger Giddings[1], Xiao Duan[1], Qianwu Zhang[2], Min Wang[2]; [1]*Bangor Univ., UK;* [2]*Shanghai Univ. , China.* Adaptive bit and power loading of optical OFDM (OOFDM) enables full utilizations of RSOA intensity modulator (RSOA-IM) frequency chirps to significantly enhance system performances. 1GHz-RSOA-IMs can support 40Gb/s@25km OOFDM transmissions in simple IMDD PON systems.

Room 411

W1K • Optical Processing—Continued

W1K.3 • 08:30 Invited

All-Optical Polarization Control for Telecom Applications, Pierre-Yves Bony[1], Massimiliano Guasoni[1], Stéphane Pitois[1], Antonio Picozzi[1], Dominique Sugny[1], Hans Jauslin[1], Guy Millot[1], Stefan Wabnitz[2], Julien Fatome[1]; [1]*CNRS - Universite de Bourgogne, France;* [2]*Università di Brescia, Italy.* We describe a phenomenon of self-organization of the light state-of-polarization in optical fibers based on a nonlinear cross-polarization interaction between an incident signal and its backward replica. Several proof-of-principles for telecom applications are reported.

Show Floor Programming

■ **Service Provider Summit**

08:30–09:00
Keynote Presentation: Carrier's View on Future SDN/NFV Deployment
For more details, see page 41

09:00–10:30
Panel I: Value and Cost of Multi-Layer SDN
For more details, see page 41

Room 402AB

W1A • Mode Division Multiplexing I—Continued

W1A.4 • 09:00 Invited

Efficient and Mode-selective Spatial Multiplexer Based on Multi-plane Light Conversion, Jean-François Morizur[1], Pu Jian[1], Bertrand Denolle[1], Olivier Pinel[1], Nicolas Barré[1], Guillaume Labroille[1]; [1]*CAILabs, France.* We report on a 6-mode spatial multiplexer based on multi-plane light conversion with 4.6 dB insertion loss and -23 dB mode-to-mode crosstalk, designed for few-mode fibre transmission systems that do not rely on complex electronic post-processing.

Room 403A

W1B • Silicon Photonics I—Continued

W1B.2 • 09:00

High-Throughput Multiple Dies-to-Wafer (D2W) Bonding for III/V-on-Si Hybrid Lasers, Xianshu Luo[1], Yulian Cao[2], Junfeng Song[1], Xiaonan Hu[2], Tsung-Yang Liow[1], Mingbin Yu[1], Qijie Wang[2], Guoqiang Lo[1]; [1]*Institute of Microelectronics, Singapore;* [2]*Photonics Center of Excellence (OPTIMUS), School of Electrical & Electronic Engineering, Nanyang Technological Univ., Singapore.* We propose and demonstrate high-throughput multiple dies-to-wafer bonding method with up to 104 dies through temporary-bonding dies to handle wafer for batch processing. Various hybrid III/V-on-silicon lasers are demonstrated with CW operation at room temperature.

W1B.3 • 09:15

A 25Gb/s, 520mW, 6.4Vpp Silicon-Photonic Mach-Zehnder Modulator with Distributed Driver in CMOS, Nan QI[1], Xianyao Li[2], Hao Li[1], Xi Xiao[3], Lei Wang[3], Zhiyong Li[2], Zhuo Gao[4], Yude Yu[2], Miki Moyal[5], Patrick Y. Chiang[1,6]; [1]*School of Electrical Engineering and Computer Science, Oregon State Univ., USA;* [2]*Institute of Semiconductors, Chinese Academy of Sciences, China;* [3]*Wuhan Research Institute of Post & Telecommunications, China;* [4]*Analog Devices, China;* [5]*Toga Networks Ltd., Israel;* [6]*Fudan Univ., China.* A 25Gb/s heterogeneously-integrated Silicon-Photonic transmitter is designed entirely in CMOS, consisting of a high-swing driver wire-bonded to a MZ modulator. Measurement results demonstrate clean optical eye diagrams with > 4dB extinction ratio while consuming 0.52W.

Room 403B

W1C • Amplification and Modulation Technologies for Coherent DWDM—Continued

W1C.1 • 09:00 Tutorial

Raman Amplification: an Enabling Technology for High-Capacity, Long-Haul Transmission, Wayne S. Pelouch[1]; [1]*Xtera Communications Inc., USA, USA.* Tutorial will cover basics of Raman amplification, design rules for Raman amplifiers, control and dynamics, scaling for large-area fibers, Raman in submarine systems, safety limits, practical considerations, examples of links that benefit from Raman amplification.

Wayne Pelouch is the Director of Photonics at Xtera Communications where he has worked on Raman communication systems for over 13 years. He leads all Photonics activities including research, product development, and system network design. Dr. Pelouch received a Ph.D. from Cornell University in Applied Physics ('92) and has authored numerous publications and patents related to Raman technology.

Room 404AB

W1D • Data Center Topologies & Technologies—Continued

W1D.5 • 09:00 Invited

Facebook's Data Center Infrastructure: OpenCompute, Disaggregated Rack, and Beyond, Jason Taylor[1]; [1]*Facebook, USA.* This talk describes critical elements in Facebook's latest data center architectural design. From rack disaggregation, to the strategy for optical interconnect deployment; we describe how these concepts become initiatives in the Open Compute Project (OCP).

Room 406AB

W1E • Carrier Phase Recovery—Continued

W1E.5 • 09:00

Decision-Directed-Free Blind Phase Noise Estimation for CO-OFDM, Son T. Le[1], Mary McCarthy[1], Naoise Mac Suibhne[1], Paul A. Haigh[2,3], Elias Giacoumidis[1], Nick Doran[1], Andrew D. Ellis[1], Sergei K. Turitsyn[1]; [1]*Photonics research group, Aston Univ, UK;* [2]*Univ. College London, UK;* [3]*Czech Technical Univ. in Prague, Czech Republic.* We demonstrate an effective decision-directed-free blind phase noise compensation method for CO-OFDM transmission. By applying this technique, the common phase error can be accurately estimated using as few as three test phases.

W1E.6 • 09:15

Performance and Complexity Comparison of CPE Algorithms for 256-QAM Optical Signals, Syed Muhammad Bilal[1], Gabriella Bosco[1], Jingchi Cheng[2,3], Alan P. Lau[2], Chao Lu[2]; [1]*DET, Politecnico di Torino, Italy;* [2]*Photonics Research Center, The Hong Kong Polytechnic Univ., China;* [3]*Next Generation Internet Access National Engineering Lab, Huazhong Univ. of Science and Technology, China.* A detailed analysis of different CPE schemes for 256- QAM signals is presented. Viterbi&Viterbi algorithms demonstrate very poor performance, while the best compromise between complexity and performance is achieved using the BPS+MLE algorithm.

Room 407

W1F • Radio-over-Fiber I—Continued

W1F.4 • 09:00

Efficient Centralized Light Sources for RoF-WDM-PON Based on Weak-Resonant-Cavity Fabry-Perot Laser Diode, Zhongle Wu[1,2], Mu Xu[1], Jianyu Zheng[1], Cheng-Ting Tsai[3], Yu-Chieh Chi[3], Gong-Ru Lin[3], Gee-Kung Chang[1]; [1]*School of Electrical and Computer Engineering, Georgia Institute of Technology, USA;* [2]*State Key Lab of Information Photonics & Optical Communications, Beijing Univ of Posts & Telecom, China;* [3]*Graduate Institute of Photonics & Optoelectronics and Department of Electrical Engineering, National Taiwan Univ., Taiwan.* We demonstrate a novel RoF-WDM-PON system to efficiently manage the light sources in the central office for both upstream and downstream links. A WRC-FPLD was employed as the key component to generate multi-wavelength lightwaves.

W1F.5 • 09:15

Bidirectional Transmission of LTE-A Carrier Aggregation Signal over a Seamless Fiber-Wireless System in W-Band, Pham Tien Dat[1], Atsushi Kanno[1], Tetsuya Kawanishi[1]; [1]*National Inst Information & Comm Tech, Japan.* We present a high-speed and low-latency seamless fiber-millimeter-wave system for future mobile front-haul networks. The bidirectional transmission of a downlink interband and an uplink intraband carrier aggregation LTE-A signal over the system is successfully demonstrated.

Room 408A

W1G • Deployable Networks with SDN & Virtualization—Continued

W1G.4 • 09:00 Tutorial

SDN Control of Packet-over-optical Networks, Guru Parulkar[1], Tom Tofigh[2], Marc De Leenheer[1]; [1]*Stanford Univ., USA;* [2]*AT&T Labs, USA*. This tutorial addresses the challenges of managing multilayer service provider networks using SDN. It reviews ON.Lab's implementation of converged packet/optical network abstractions, supporting on-demand network applications, flexible bandwidth sharing, and multilayer resiliency.

Guru Parulkar, Executive Director, ON.Lab, is a consulting professor of electrical engineering and the executive director of the Open Network Research Center (ONRC) at Stanford University. He is also the executive director and event chair of the Open Networking Summit. Dr. Parulkar has over 30 years of experience in the field of networking.

continued on pg 97

Room 408B

W1H • Beyond the Gold Box: The Future of Integrated Optics I—Continued

W1H.4 • 09:00 Invited

Integrated Devices for Metro Applications, Michael Eiselt[1]; [1]*ADVA Optical Networking AG SE, Germany.* We discuss recent developments in optical and electro-optical integration and their benefits in the realization of optical interfaces for metro networks.

W1H.5 • 09:20 Invited

Integrated Devices for High-Performance Optical Links, Merhdad Ziari[1], P. Evans[1], V. Lal[1], S. Corzine[1], T. Butrie[1], M. Missey[1], D. Pavinski[1], J. Tang[1], J. Summers[1], P. Studenkov[1], T. Vallaitas[1], M. Kuntz[1], F. Sedgwick[1], M. Fisher[1], H-S Sai[1], J. Zhang[1], P. Samra[1], J. Pleumeekers[1], J. Rahn[1], V. Dominic[1], P. Schindler[1], R. Schmogrow[1], S. Kumar[1], Henry Sun[1], K-T Wu[1], M. Mitchell[1], M. Kauffman[1], M. Reffle[1], F. Kish[1], D. Welch[1]; [1]*Infinera Corporation, USA.* We present the development of large scale Photonic Integrated Circuits, high capacity optical module integration and their performance in a variety of data-center / metro and long-haul coherent optical link applications.

Room 409AB

W1I • Resource Allocation and Migration to EON—Continued

W1I.4 • 09:00

Brown-Field Migration from Fixed Grid to Flexible Grid in Optical Networks, Xiaosong Yu[1], Massimo Tornatore[2], Ming Xia[3], Yongli Zhao[1], Jie Zhang[1], Biswanath Mukherjee[4]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Politecnico di Milano, Italy;* [3]*Ericsson, USA;* [4]*Univ. of California, Davis, USA.* We investigate the problem of gradual migration from fixed grid to flexible grid in optical networks by designing heuristics to selectively upgrade WSSs on ROADMs. We evaluate the performance of our scheme under different traffic profiles.

W1I.5 • 09:15

Evaluating the Optimum Filter Resolution and Sub-Channel Spectrum Granularity for Flexible Super-Channels, Pouria Sayyad Khodashenas[1], Jose Manuel Rivas-Moscoso[1], Dimitrios Klonidis[1], Dan M. Marom[2], Ioannis Tomkos[1]; [1]*Athens Information Technology, Greece;* [2]*Applied Physics, The Hebrew Univ. of Jerusalem, Israel.* The optimum spectrum granularity for sub-channel allocation within super-channels is evaluated according to the Nyquist-shaping characteristics of ultra-fine resolution filters. Optimized blocking performance is achieved for 3.125GHz granularity using novel fine resolution technologies.

Room 410

W1J • WDM-based Optical Access—Continued

W1J.4 • 09:00 Invited

Energy Efficient Tunable Light Sources for Next Generation Flexible Access Networks, Fumio Koyama[1]; [1]*Tokyo Institute of Technology, Japan.* Tunable lasers are reviewed for colorless ONUs in next-generation access networks. In particular, advanced VCSEL technologies toward athermal and widely tunable operations, ultra-high-speed & low-chirp direct modulation, and ultra-compact modulator integration are presented.

Room 411

W1K • Optical Processing—Continued

W1K.4 • 09:00

Continuous-wave nonlinear optics in low-stress silicon-rich nitride waveguides, Clemens Krueckel[1], Attila Fülöp[1], Peter A. Andrekson[1], Victor Torres-Company[1]; [1]*Chalmers Univ. of Technology, Sweden.* We demonstrate CW-pumped wavelength conversion in low-stress silicon-rich nitride waveguides. The ability to grow thick silicon-rich layers simultaneously enables high-field confinement, dispersion engineering and handling high-power levels without two-photon absorption effects.

W1K.5 • 09:15 Top Scored

Electrically-Tunable Fiber-Optics Pulse Repetition-Rate Multiplier, Reza Maram[1], Luis Romero Cortés[1], José Azaña[1]; [1]*INRS-Energie Materiaux et Telecom, Canada.* We propose and experimentally demonstrate a novel, simple and all-fiber method for repetition-rate multiplication of picosecond optical pulse trains based on temporal self-imaging, involving temporal phase modulation and dispersion, with an electrically reconfigurable repetition-rate multiplication factor.

Show Floor Programming

■ **Service Provider Summit**

08:30–09:00
Keynote Presentation: Carrier's View on Future SDN/NFV Deployment
For more details, see page 41

09:00–10:30
Panel I: Value and Cost of Multi-Layer SDN
For more details, see page 41

Room 402AB

W1A • Mode Division Multiplexing I—Continued

W1A.5 • 09:30
6-mode Spatial Multiplexer with Low Loss and High Selectivity for Transmission over Few Mode Fiber, Philippe Genevaux[1], Christian Simonneau[1], Guillaume Labroille[2], Bertrand Denolle[2], Olivier Pinel[2], Pu Jian[2], Jean-François Morizur[2], Gabriel Charlet[1]; [1]*Alcatel-Lucent Bell Labs France, France;* [2]*CAILabs, France*. We present a spatial 6-mode multiplexer with low loss and high mode selectivity. We demonstrate 100Gbit/s error-free transmission over 20km for 6 modes and over 40km bi-directional transmission with 3 modes in each direction.

W1A.6 • 09:45
SOI based Photonic Interconnection for Multi-Dimensional Multiplexed System, Mengyuan Ye[1], Yuchan Luo[1], Yu Yu[1], Weili Yang[1], Jinghui Zou[1], Chaotan Sima[1], Xinliang Zhang[1]; [1]*Wuhan National Lab for Optoelectronics, Huazhong Univ. of Science and Technology, China*. An on-chip polarization insensitive interconnection is proposed and fabricated based on SOI platform. The proposed circuit is experimentally demonstrated in fiber-optic communication system utilizing wavelength, polarization and mode multiplexing techniques with power penalty of 3.2dB.

Room 403A

W1B • Silicon Photonics I—Continued

W1B.4 • 09:30 Invited
Silicon Photonics Systems - Nonidealities and Nonlinearities, Shuyu Yang[1], Ari Novack[1], Yangjin Ma[1], Ruizhi Shi[1], Michael Hochberg[1], Thomas W. Baehr-Jones[1]; [1]*Coriant Advanced Technology Group, USA*. In this talk, we will provide an overview of nonlinearities and non-idealities in high-confinement silicon photonic waveguides, focusing in particular on the effects that are most relevant to realistic transceivers.

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

Room 403B

W1C • Amplification and Modulation Technologies for Coherent DWDM—Continued

Room 404AB

W1D • Data Center Topologies & Technologies—Continued

W1D.6 • 09:30 Invited
Technology Trends to Speed up the Delivery of Wall Street Data, David Lariviere[1]; [1]*Columbia University, USA*. Networking is having a profound and increasingly dominant role in modern financial markets. This talk will present an overview of electronic trading systems, trends in the underlying technologies, and areas of opportunity for researchers.

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

Room 406AB

W1E • Carrier Phase Recovery—Continued

W1E.7 • 09:30
Rate Equation-Based Phase Recovery for Semiconductor Laser Coherent Transmitters, Molly Piels[1], Miguel Iglesias Olmedo[1,2], Xiaodan Pang[3], Richard Schatz[2], Gunnar Jacobsen[2,3], Sergei Popov[2], Darko Zibar[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Optics division, Royal Institute of Technology (KTH), Sweden;* [3]*Networking and Transmission Laboratory, Acreo AB, Sweden*. We present a novel carrier recovery technique for coherent systems with semiconductor lasers that incorporates the laser dynamics. A sensitivity improvement of 8dB over a decision-directed phase-locked loop is achieved experimentally for 28GBd DP-16QAM.

W1E.8 • 09:45
Image Processing Based Common Phase Estimation for Coherent Optical Orthogonal Frequency Division Multiplexing System, Tianwai Bo[1], Lingchen Huang[1,2], Chun-Kit Chan[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong;* [2]*Centre for Optical and Electromagnetic Research of Zhejiang Univ., China*. A novel common phase error estimation method based on image processing technique is proposed. Both numerical simulations and experiments prove its feasibility to compensate phase noise with improved spectral efficiency than the pilot-subcarrier aided method.

Room 407

W1F • Radio-over-Fiber I—Continued

W1F.6 • 09:30 Top Scored
Optical Fronthaul of LTE-Advanced MIMO by Spatial Multiplexing in Multicore Fiber, Maria Morant[1], Andrés Macho[1], Roberto Llorente[1]; [1]*Nanophotonics Technology Center, Universitat Politècnica de València, Spain*. Optical wireless fronthaul of dual Mx2x2 MIMO LTE-A systems by radio-over-fiber spatial multiplexing is demonstrated over 125m 4-core fiber using 16QAM and 64QAM subcarrier mapping. 3GPP LTE MIMO algorithms in-place successfully mitigate core-to-core impairments.

Networking • 09:45

10:00–12:00 W2A • Interactive Demo and Poster Session I, *Exhibit Hall K*

10:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall (concession available)*

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall*

Room 408A

W1G • Deployable Networks with SDN & Virtualization—Continued

Tom Tofigh, Principal Member of Staff, AT&T Domain 2.0 Architecture. Tom is responsible for planning and implementation of large-scale telecommunications equipment. He has extensive experience that spans across many disciplines including mobility, networking, cross layer design. He is currently involved at ON.Lab in virtualization use case activities.

Room 408B

W1H • Beyond the Gold Box: The Future of Integrated Optics I—Continued

W1H.6 • 09:40 Invited

Future Narrow Linewidth Lasers, Toshikazu Mukaihara[1], Toshio Kimura[1], Hiroyuki Koshi[1]; [1]*Photonic Devices Dept., Telecommunication & Energy Laboratories, Furukawa Electric Co., Ltd., Japan*. We describe the challenges and solutions for future narrow linewidth lasers with small footprint. We fabricated DR laser array based narrower linewiedth TLS. We introduce ITXA of a co-packaged DFB array based TLS and InP-based modulator.

Room 409AB

W1I • Resource Allocation and Migration to EON—Continued

W1I.6 • 09:30 Top Scored

Data-Oriented Malleable Reservation to Revitalize Spectrum Fragments in Elastic Optical Networks, Wei Lu[1], Zuqing Zhu[1], Biswanath Mukherjee[2]; [1]*Univ of Science and Technology of China, China;* [2]*Univ. of California, Davis, USA*. This paper investigates malleable reservation (MR) for data-oriented requests to revitalize spectrum fragments in elastic optical networks. We formulate a mixed integer linear programming model and propose a time-efficient heuristic to solve the MR problem.

W1I.7 • 09:45

Protection Path-based Hitless Spectrum Defragmentation in Elastic Optical Networks: Shared Backup Path Protection, Chao Wang[1], Gangxiang Shen[1], Bowen Chen[1], Limei Peng[2]; [1]*Soochow Univ., China;* [2]*Ajou Univ., Korea (the Republic of)*. We propose two protection path-based spectrum defragmentation algorithms to improve the spectrum utilization for an elastic optical network with shared backup path protection (SBPP). Results show that the proposed algorithms can significantly improve spectrum efficiency compared to the case without defragmentation.

Room 410

W1J • WDM-based Optical Access—Continued

W1J.5 • 09:30

Low-Cost Transceiver in Single TO-can Outline Supporting WDM-Overlay in Filterless PONs, Bernhard Schrenk[1], Gerhard Humer[1], Martin Stierle[1], Helmut Leopold[1]; [1]*AIT Austrian Institute of Technology, Austria*. We demonstrate a single-fiber low-cost 1.25 Gb/s transceiver able to switch between transmission and reception mode. Crosstalk suppression with <1dB penalty is achieved through filtered reception mode for WDM-loaded power-splitting PONs with >20dB optical budget.

W1J.6 • 09:45 Top Scored

Fully-Passive Resiliency Switch for Agile PON Restoration, Bernhard Schrenk[1], Roland Lieger[1], Thomas Lorünser[1], Paraskevas Bakopoulos[2], Andreas Poppe[1], Martin Stierle[1], Hercules Avramopoulos[2], Helmut Leopold[1]; [1]*Austrian Institute of Technology, Austria;* [2]*National Technical Univ. of Athens, Greece*. We present a network recovery concept based on fully-passive inline demarcation nodes powered through energy scavenging at low optical feed level of -10dBm. Protection switching in 10.7 ms is experimentally demonstrated at the PON feeder.

Room 411

W1K • Optical Processing—Continued

W1K.6 • 09:30

Photonic Implementation of a Neuronal Learning Algorithm based on Spike Timing Dependent Plasticity, Ryan Toole[1], Mable P. Fok[1]; [1]*College of Engineering, Univ. of Georgia, USA*. A photonic system exemplifying the biological neural process of spike timing dependent plasticity (STDP) is experimentally demonstrated using nonlinear polarization rotation. STDP represents the neuronal responses for learning based on input/output timing, order, and sequence.

Networking • 09:45

10:00–12:00 W2A • Interactive Demo and Poster Session I, *Exhibit Hall K*

10:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall (concession available)*

10:00–17:00 Exhibition and Show Floor, *Exhibit Hall*

Show Floor Programming

■ **Service Provider Summit**

08:30–09:00
Keynote Presentation: Carrier's View on Future SDN/NFV Deployment
For more details, see page 41

09:00–10:30
Panel I: Value and Cost of Multi-Layer SDN
For more details, see page 41

10:00–12:00
W2A • Interactive Demo & Poster I

Tu3A.6	W2A.48	W4D.7
W2A.1	W2A.64	Th3F.6
W2A.9	W3I.5	
W2A.30	W3I.6	

For the full list of Interactive Demo Posters, please refer to page 18.

W2A.1 DEMO

The Non-Contact Connector: A New Category of Optical Fiber Connector, Benjamin Jian[1]; [1]*Arrayed Fiberoptics Corporation, USA.* We report on a new category of fiber connectors called non-contact connectors. By introducing a gap between anti-reflection coated fiber facets, a connector with outstanding optical performance, reliability and low cost is achieved.

W2A.2

2.8FITs of Field Reliability of 1480nm/14xx-nm Pump Lasers, Junji Yoshida[1], Chihomi F. Hayamizu[1], Hirokazu Itoh[1], Masakazu Miura[1], Taketsugu Sawamura[1], Satoshi Irino[1], Tetsuya Takeuchi[1], Toshio Kimura[1], Naoki Tsukiji[1]; [1]*Furukawa Electric, Japan.* Recent progress of high power and high reliable 1480nm/14xx-nm pump lasers as FOL14** series of FITEL is reported. Field reliability was estimated for over one million shipments and failure mode was analyzed by returned products.

W2A.3

Optical Design Optimization for High-Speed Active Optical Cables, Aramais Zakharian[1], Sergey Kuchinsky[2], Xue Liu[3], Davide Fortusini[1], James West[1], Mathieu Charbonneau Lefort[4], Eric ten Have[5], Andrey Kobyakov[3]; [1]*Corning Incorporated, USA;* [2]*Corning Scientific Center, Russian Federation;* [3]*Corning Cable Systems, USA;* [4]*Corning West Technology Center, USA;* [5]*Corning Optical Communications GmbH & Co. KG, Germany.* We introduce a Monte Carlo-based optimization to quantify the trade-off between optical loss and misalignment tolerances in active optical cables. Fibers with large core diameters are shown to outperform standard MMF at 20 Gb/s.

W2A.4

Parallel Optical Engine Using Vertical Coaxial Alignment, Xiaochen Sun[1], Ning-Ning Feng[1], Fuxin Li[1], Zhian Shao[1]; [1]*LaXense, Inc., USA.* A compact parallel optical engine platform using Si optical bench technology to realize highly manufacturable vertical coaxial alignment approach is demonstrated and an in-production 40G optical engine using this platform is presented.

W2A.5

Road to commercialize ArF technology for Si photonics through wafer-level assessment, Haifeng Zhou[1], Win Kay Thi[1], Chen Kok Kiong[1], Chao Li[1], Huijuan zhang[1], Eu-Jin Lim[1], Mingbin Yu[1], Guoqiang Lo[1]; [1]*IME of A*Star, Singapore, Singapore.* The development and assessment of ArF technology in a 200mm FAB line are described. Wafer-level measurement is implemented to examine a set of Si photonics devices and explore the dummy effect to wafer uniformity.

W2A.6

Advances in Multimode Fiber Transmission for the Data Center, Rich Baca[1], Paul Kolesar[1], Jim Tatum[2], Deepa Gazula[2], Edward Shaw[2], Timothy Gray[2]; [1]*Commscope, Inc., USA;* [2]*Finisar, USA.* Recent advances in VCSEL manufacturing and designed multimode fibers has opened an avenue to implement WDM for short distance links. This paper will focus on transmission performance of a new multimode fiber coupled with high speed VCSELs operating in a range of wavelengths from 850-980nm to deliver parallel transmission on a single fiber.

W2A.7

Silicon Waveguide Optical Isolator Integrated with TE-TM Mode Converter, Akihrio Fujie[1], Yuya Shoji[1], Tetsuya Mizumoto[1]; [1]*Tokyo Institute of Technology, Japan.* A Si waveguide optical isolator is integrated with an asymmetrical slit Si waveguide TE-TM mode converter. A maximum isolation of 26.7 dB is demonstrated at a wavelength of 1553 nm for TE mode input light.

W2A.8

Silicon Quadruple Series-Coupled Vernier Racetrack Resonators: Experimental Signal Quality, Robert Boeck[1], Michael Caverley[1], Lukas Chrostowski[1], Nicolas A.F. Jaeger[1]; [1]*Electrical and Computer Engineering, Univ. of British Columbia, Canada.* A tunable silicon quadruple Vernier racetrack resonator filter has been experimentally demonstrated. Data was sent through our filter at 12.5 Gbps which resulted in open eye diagrams, even at a suppressed through port notch.

W2A.9 DEMO

Mode-Group-Selective Photonic Lantern Using Graded-Index Multimode Fibers, Bin Huang[2,1]; [1]*Univ. of Central Florida, USA;* [2]*Bell Laboratory / Alcatel-Lucent, USA.* We fabricate mode-group-selective photonic lanterns using multimode graded-index fibers. The use of the multimode graded-index fibers in the taper can significantly relax the adiabaticity requirement in comparison with using single-mode fibers.

W2A.10

A Four-port Polarization Diversity Coupler for Vertical Fiber-Chip Coupling, Jinghui Zou[1], Yu Yu[1], Mengyuan Ye[1], Lei Liu[2], Shupeng Deng[2], Xinliang Zhang[1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Huawei Technologies Co., Ltd, China.* We propose and fabricate a novel four-port polarization diversity coupler for vertical coupling. With the help of 45° reflectors and improved 2x1 couplers, an ultralow coupling loss of -4.8dB is experimentally measured with polarization insensitivity.

W2A.11

Ultra-Compact 8-Arrayed 8×1 Switch Consists of ZrO_2-SiO_2-Based High Δ PLC, Yasuyoshi Uchida[1], Shintaro Yamasaki[1], Masanori Takahashi[1], Junichi Hasegawa[1], Takeshi Yagi[1]; [1]*Furukawa Electric co., ltd., Japan.* We report an ultra-compact 21mm × 9mm 8-arrayed 8×1 switch based on the ZrO_2-SiO_2 PLC. Low insertion loss of less than 3.2dB in C-band was achieved by low loss coupling technique using a high-Δ fiber.

W2A.12

A compact and wide-band polarization beam splitter based on wedge-shaped MMI coupler in silicon-on-insulator, Wei Yang[1], Yue Xu[1], Yanping Li[1], Xingjun Wang[1], Ziyu Wang[1]; [1]*Peking Univ., China.* A compact polarization beam splitter is demonstrated in SOI employing a 1×3 wedge-shaped MMI coupler and a 2×2 MMI coupler. The measured extinction ratios are higher than 12dB within a wide wavelength range covering C-band.

W2A.13

All-Fiber Spatial Mode Selective Filter for Compensating Mode Dependent Loss in MDM Transmission Systems, Yong-min Jung[1], Shaif-Ul Alam[1], David J. Richardson[1]; [1]*Optoelectronics Research Centre (ORC), UK.* We demonstrate a simple all-fiber spatial mode-selective filter based on splicing a short segment of small-core SMF between two few-mode-fibers. An 8dB-MDL equalization range with less than 2dB-IL is demonstrated for a 2-mode fiber device.

W2A.14

DPSK-Demodulation based on Ultra-Compact micron-scale SOI platform, Konstantinos Vysrokinos[2], Christos Vagionas[1], Charoula Mitsolidou[1], Matteo . Cherchi[3], Mikko Harjanne[3], Sami Ylinen[3], Markku Kapulainein[3], Timo Aalto[3], Amalia Miliou[1]; [1]*Department of Informatics, Aristotle Univ. of Thessaloniki, Greece;* [2]*Department of Physics, Aristotle Univ. of Thessaloniki, Greece;* [3]*VTT Technical Research Centre of Finland, Finland.* We present the error-free demodulation of a 10Gb/s DPSK-signal based on a novel Delayed Interferometer with ultra-small footprint. The device is fabricated on thick um-scale SOI platform and exhibits similar dimension with nanophotonic based DIs.

W2A.15

6 port 3x3 Wavelength Selective Cross-Connect by Software-Only Reprogramming of a 1xN Wavelength Selective Switch, Jochen B. Schroeder[1], Joel A. Carpenter[2], Steve Frisken[3], Michael A. Roelens[3], Benjamin J. Eggleton[2]; [1]*Royal Melbourne Institute of Technology, Australia;* [2]*School of Physics, The Univ. of Sydney, Australia;* [3]*Finisar Australia, Australia.* We demonstrate a wavelength selective cross-connect that can route any wavelength of any of the inputs to any output. The device is created by simple reprogramming a conventional 1xN wavelength selective switch, without hardware changes.

W2A.16

Mode-Group-Selective Photonic Lantern based on Integrated 3D Devices Fabricated by Ultrafast Laser Inscription , Binbin Guan[1,2], Burcu Ercan[1], Nicolas K. Fontaine[2], Ryan P. Scott[1], S. J. B. Yoo[1]; [1]*Department of Electrical and Computer Engineering, Univ. of California Davis, USA;* [2]*Bell Laboratories, Alcatel-Lucent, USA.* We demonstrate a three-dimensional adiabatically-tapered mode-group-selective space- division multiplexer fabricated by ultrafast laser inscription. The device supports two mode groups at 1550 nm, has a loss of <4 dB, and is scalable to more modes.

W2A.17

III-V/SOI Vertical Cavity Laser with In-plane Output into a Si Waveguide, Gyeong Cheol Park[1], Weiqi Xue[1], Elizaveta Semenova[1], Krestin Yvind[1], Jesper Mørk[1], Ilsug Chung[1]; [1]*Technical Univeristy of Denmark, Denmark.* We experimentally demonstrate an optically-pumped III-V-on-SOI hybrid vertical-cavity laser that outputs light into an in-plane Si waveguide, using CMOS-compatible processes. The laser operates at 1.49 μm with a side-mode suppression-ratio of 27 dB and has a similar threshold as long-wavelength VCSELs.

W2A.18

Separation of semiconductor laser intrinsic linewidth and 1/f noise using multiple fiber lengths with the delayed self-heterodyne method, Keisuke Kojima[1], Yuichi Horiguchi[2], Toshiaki Koike-Akino[1], Yasuhisa Shimakura[2], Kentaro Enoki[2], Eiji Yagyu[2]; [1]*Mitsubishi Electric Research Laboratories, USA;* [2]*Advanced Technology R&D Center, Mitsubishi Electric Corp., Japan.* We propose a method of measuring the intrinsic linewidth of semiconductor lasers, by using self-heterodyne method with multiple measurements of different delay fiber lengths. By eliminating the 1/f noise effects, the linewidth becomes much smaller than the conventional measurement method.

INTERNATIONAL YEAR OF LIGHT 2015

W2A • Interactive Demo & Poster I—Continued

W2A.19
Coherent Terabit Communications using a Quantum-Dash Mode-Locked Laser and Self-Homodyne Detection, Joerg Pfeifle[1], Igor Shkarban[1], Stefan Wolf[1], Juned N. Kemal[1], Claudius Weimann[1], Wladislaw Hartmann[1], Nicolas Chimot[2], Siddharth Joshi[2], Kamel Merghem[3], Anthony Martinez[3], Marc Weber[1], Abderrahim Ramdane[3], Francois Lelarge[2], Wolfgang Freude[1], Christian Koos[1]; [1]*Karlsruhe Institute of Technology (KIT), Germany;* [2]*III-V Lab, France;* [3]*Laboratoire de Photonique et Nanostructures, France.* We transmit 18 GBd 16QAM signals on 25 spectral lines of a quantum-dash mode-locked laser diode, achieving a 1.562 Tbit/s aggregate data rate. Phase noise is cancelled by self-homodyne detection using LO tones transmitted with the signal.

W2A.20
Dilute Nitride SOAs for High-Speed Data Processing in Variable Temperature Conditions, Giannis Giannoulis[1], Ville M. Korpijärvi[2], Nikos Iliadis[1], Jaakko Mäkelä[2], Jukka Viheriälä[2], Dimitrios Apostolopoulos[1], Mircea Guina[2], Hercules Avramopoulos[1]; [1]*National Technical Univ. of Athens, Greece;* [2]*Optoelectronics Research Centre, Technical Univ. of Tampere, Finland.* We present the first experimental study of a Dilute Nitride SOA with high-speed gain dynamics and attractive thermal characteristics as a data processing element at 10Gb/s and at different operating temperatures.

W2A.21
Monolithically integrated laser with weak optical feedback demonstrating suppressed relaxation-oscillation dynamics, Domenico D'Agostino[1], Daan Lenstra[1], Huub Ambrosius[1], Meint Smit[1]; [1]*Technische Universiteit Eindhoven, USA.* We experimentally demonstrate a laser with weak optical feedback, which shows broad regions of operation without relaxation-oscillation induced instabilities. Here, the side mode suppression is above 40 dB, independent of the feedback phase.

W2A.22
1.4 mA (70 mV) Peak-to-Peak Drive of 1.25 Gb/s Frequency Modulated Laser for WDM Coherent Access Networks, Raffaele Corsini[1], Christophe Kazmierski[2], Marco Presi[1], Stefano Faralli[1], J G. Provost[2], Romain Brenot[2], Ernesto Ciaramella[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*III-5 Lab, France.* A new laser suitable for access-systems with FM efficiency up to 7 GHz/mA and negligible amplitude modulation is presented. It enables 1.25/2.5 Gb/s operations with extremely low driving signals: 70 mVpk-pk and 250 mVpk-pk respectively.

W2A.23
Optical-Comb-Line Selection from a Low-Power/Low-OSNR Comb using a Low-Coherence Semiconductor Laser for Flexible Ultra-Dense Short Range Transceivers, Aaron Albores-Mejia[1], Toshimitsu Kaneko[2], Eiichi Banno[2], Katsumi Uesaka[2], Hajime Shoji[2], Haruhiko Kuwastuka[1]; [1]*National Institute of AIST, USA;* [2]*Sumitomo Electric Industries, Ltd, Japan.* 6.25GHz-spaced optical-comb-line selection either by low-coherence injection-locked laser (LC-ILLD) or with a combination ultra-narrow-filter and low-noise-fiber-amplifier (UNF-FA) is assessed. In a 144Gbps DP-64QAM transmission the LC-ILLD outperforms the UNF-FA approach for comb-OSNR-levels below 30dB.

W2A.24
Monolithically Integrated Quantum-Dot Optical Modulator with Semiconductor Optical Amplifier for 1.3-μm Waveband Error-free 10-km-long Transmission, Naokatsu Yamamoto[1], Kouichi Akahane[1], Toshimasa Umezawa[1], Tetsuya Kawanishi[1]; [1]*National Institute of Information and Communications Technology, Japan.* A monolithically integrated quantum-dot (QD) optical gain modulator with semiconductor optical amplifier was developed for successful demonstration of error-free Gb/s-order high-speed, 10-km-long transmissions using 1.3-μm multiple wavelength channels from a QD comb laser.

W2A.25
Optical information capacity of silicon, Dimitris Dimitropoulos[1], Bahram Jalali[2]; [1]*-, Greece;* [2]*Electrical Engineering, Univesity of Californa, USA.* We have established bounds on information capacity of silicon and have identified new types of noise from which the bounds originate. Our results suggest solutions to extending the limit via coding and coherent signaling.

W2A.26
Dynamic Frequency Chirp Properties of QD-SOAs, Motoharu Matsuura[1], Hiroaki Ohta[1], Ryota Seki[1]; [1]*Univ. of Electro-Communications, Japan.* We experimentally show dynamic frequency chirp properties induced in a quantum-dot semiconductor optical amplifier (QD-SOA), for the first time. We also compare the dynamic chirp properties of the QD-SOA with those of a common SOA.

W2A.27
Photonic Integrated Wavelength Converter based on Double Stage Cross Gain Modulation in SOAs, Francesca Bontempi[1], Nicola Andriolli[1], Giampiero Contestabile[1]; [1]*Scuola Superiore Sant Anna di Pisa, Italy.* We report a new monolithic InP Photonic-Integrated-Circuit (PIC) for all-optical wavelength conversion. The PIC exploits double stage crossgain-modulation in SOAs and an integrated DBR laser. We report device characterization and 10 Gb/s wavelength conversion operation.

W2A.28
Highly Sensitive Photonic Crystal Cavity Laser Noise Measurements using Bayesian Filtering, Molly Piels[1], Weiqi Xue[1], Christian Schäffer[2], Yi Yu[1], Elizaveta Semenova[1], Luisa Ottaviano[1], Krestin Yvind[1], Idelfonso Tafur Monroy[1], Jesper Mørk[1], Darko Zibar[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Faculty of Electrical Engineering, Helmut Schmidt Univ., Germany.* We measure for the first time the frequency noise spectrum of a photonic crystal cavity laser with less than 20 nW of fiber-coupled output power using a coherent receiver and Bayesian filtering.

W2A.29
Germanium-tin on Silicon p-i-n Photodiode with Low Dark Current due to Sidewall Surface Passivation, Yuan Dong[1], Wei Wang[1], Dian Lei[1], Xiao Gong[1], Qian Zhou[1], Shuh Ying Lee[2], Wan Khai Loke[2], Soon-Fatt Yoon[2], Gengchiau Liang[1], Yee-Chia Yeo[1]; [1]*National Univ. of Singapore, Singapore;* [2]*Nanyang Technological Univ. , Singapore.* We demonstrate that the surface leakage current of a $Ge_{0.95}Sn_{0.05}$/Si p-i-n photodiode can be significantly reduced by ~two orders by Si surface passivation. Furthermore, a dark current density of 0.073A/cm^2 (V_{bias} = -1 V) is achieved.

W2A.30 DEMO
A fully integrated DQPSK receiver based on Compact Silicon-on-Insulator Micro-Ring, Philippe Velha[1], Stefano Faralli[1], Giampiero Contestabile[1]; [1]*Scuola Sant'Anna, Italy.* We demonstrate an ultra-compact integrated Silicon receiver for DQPSK signals based on two tunable SOI microring resonators and four Germanium photodetectors. The device operation was characterized on a range extending from 7.5 to over 15 Gbaud.

W2A.31
20Gb/s PAM-4 Transmission from 35 to 90°C by modulating a Silicon Ring Resonator Modulator with 2Vpp, Olivier Dubray[1], Sylvie Menezo[1], Benjamin Blampey[1], Sonia Messaoudene[1], Badhise Ben Bakier[1], Maryse Fournier[1], Patrick Le Maitre[2], Jean Francois Carpentier[2]; [1]*CEA-LETI, France;* [2]*ST Microelectronics, France.* A PAM-4 transmission is established by modulating a Si-RRM with a 2Vpp driving voltage. A 20Gb/s bit-rate is achieved with an 8GHz bandwidth, and maintained while the Si-chip temperature is varied from 35 to 90°C.

W2A.32
Low-Crosstalk Semi-Trench-Assisted Multicore Flat Fiber, Ghafour Amouzad Mahdiraji[1]; [1]*Univ. of Malaya, Malaysia.* 250-m long 125-μm×315-μm size semi-trench-assisted multicore flat fiber is fabricated using undoped-secondary-cladding as the trench. Crosstalk at 630 nm is fully suppressed in the fiber with 4.2-μm and 27.5-μm core and pitch size, respectively.

W2A.33
Quantitative Evaluation of Fiber Fuse Initiation Probability in Typical Single-mode Fibers, Shin-ichi Todoroki[1]; [1]*National Institute for Materials Science, Japan.* 5.5W@1480nm five-second-long light irradiation through a SMF-28e+ fiber on a highly Co-doped borosilicate glass surface gave 10% probability of fiber fuse initiation. This method is useful to evaluate relative fiber fuse tolerance for various fibers.

W2A.34
Demonstration of a 9 LP-Mode Transmission Fiber with Low DMD and Loss, Rasmus V. Jensen[1], Lars Grüner-Nielsen[1], Nicholas H. Wong[2], Yi Sun[3], Yong-min Jung[2], David J. Richardson[2]; [1]*OFS, Denmark;* [2]*Optoelectronics Research Centre, Univ. of Southhampton, UK;* [3]*OFS, USA.* We experimentally demonstrate a 9 LP-mode (15 spatial modes) fiber with low DMD, confirmed by both time of flight and S^2 measurements. Low loss (~0.2dB/km) is verified by OTDR measurement of the individual mode groups.

W2A.35
Coupled Mode Analysis of Crosstalk in Multicore Fiber with Random Perturbations , Ming-Jun Li[1], Shenping Li[1], Robert A. Modavis[1]; [1]*Corning Incorporated, USA.* A simple, general crosstalk formula is derived for multicore fibers with random perturbations using coupled mode theory. Analytical crosstalk expressions under exponential and Gaussian correlation length distributions are presented. Experimental results agree well with theory.

For more details, see page 41

W2A • Interactive Demo & Poster I—Continued

W2A.36
Extremely Low Loss THz Guidance Using Kagome Lattice Porous Core Photonic Crystal Fiber, Md. Anwar Hossain[1]; [1]*Univ. of the Ryukyus, USA.* A novel porous core Kagome lattice photonic crystal fiber is proposed for extremely low loss THz waves guiding. It has been reported that 82.5% of bulk effective material loss of Topas can be reduced.

W2A.37
Volume Manufacturing of Hollow Core Photonic Band Gap Fibers: Challenges and Opportunities, Gregory T. Jasion[1], Francesco Poletti[1], John Shrimpton[2], David J. Richardson[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [2]*Faculty of Engineering and the Environment, Univ. of Southampton, UK.* A fluid dynamics model is used to investigate yield increase in hollow-core bandgap fibers. 100km of good fiber from one preform seems feasible; for higher yields some observed distortions would need to be addressed.

W2A.38
Characterization of electrostriction nonlinearity in a standard single-mode fiber based on cross-phase modulation, Rongqing Hui[1], Charles Laperle[2], Andrew D. Shiner[2], Michael Reimer[2], Maurice O'Sullivan[2]; [1]*Univ. of Kansas, USA;* [2]*Ciena, Canada.* Electrostriction nonlinearity in a standard single mode fiber is characterized with a phase-diversity coherent optical receiver. Measured differences in the polarizations of crosstalk signatures caused by Kerr and electrostriction nonlinearities are reported.

W2A.39
Ultra-High-Resolution Tunable PC-OTDR for PON Monitoring in Avionics, Gustavo C. do Amaral[1], Luis Y. Herrera[1], Jean Pierre von der Weid[1]; [1]*PUC-Rio, USA.* We present a setup for detecting and evaluating fiber curvatures using high-resolution Photon-Counting OTDR. Our setup is based on a Time-to-Digital Converter which can account for a resolution of up to 2 centimeters.

W2A.40
Design of Orbital Angular Momentum (OAM) Erbium Doped Fiber Amplifier with Low Differential Modal Gain, Jingwen Ma[2,1], Fei Xia[2,1], Shuhui Li[2,1], Jian Wang[2,1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Wuhan National Laboratory for Optoelectronics , China.* We propose a design of orbital angular momentum (OAM) Erbium doped fiber amplifier (OAM-EDFA) supporting 22 modes with 18 OAM ones. Numerical simulation suggests that differential modal gain (DMG) of the optimum design is lower than 0.28 dB with mode-dependent gain (MDG) over 20 dB at C-band.

W2A.41
Double-slot Hybrid Plasmonic Cavity Used for Phase Modulation and Sensing, Xu Sun[1], Lech Wosinski[1]; [1]*Material and Nanophysics, KTH, Sweden.* Highly-efficient double-slot hybrid plasmonic cavity is demonstrated. By measuring phase change with different liquids, we show that this sub-wavelength structure has better modulation efficiency than Si-based one for applications in ultra-compact highly-efficient sensors and modulators.

W2A.42
Power-efficient Coherent Supercontinuum Generation by Two-color Pulses Pumping in a Highly Nonlinear Fiber, Dong Wang[1], Li Huo[1], Min Li[1], Yue Wu[1], Caiyun Lou[1]; [1]*Tsinghua Univ., USA.* A coherent supercontinuum generator based on coherent two-color pulses pumping in a highly nonlinear fiber is proposed. Supercontinuum with a 20-dB width of 150 nm is achieved at a modest pump power of 24 dBm.

W2A.43
The Impact of Pump Phase-Modulation and Filtering on WDM Signals in a Fibre Optical Parametric Amplifier, Marc F. Stephens[1], Alexey Redyuk[2], Stylianos Sygletos[1], Ianlan Phillips[1], Paul Harper[1], Keith Blow[1], Nick Doran[1]; [1]*Aston Univ., UK;* [2]*Institute of Computational Technologies, Russian Federation.* WDM signal degradation from pump phase-modulation in a one-pump 20dB net-gain fibre optical parametric amplifier is experimentally and numerically characterised for the first time using 10x59Gb/s QPSK signals.

W2A.44
An Ultimately Fast Frequency-scanning Brillouin Optical Time Domain Analyzer, Ido Sovran[1], Avi Motil[1], Orr Danon[1], Moshe Tur[1]; [1]*Tel-Aviv Univ., Israel.* A polarization-independent fast frequency-scanning Brillouin optical time-domain analysis technique is presented, capable of acquiring the full Brillouin gain spectrum at a speed limited only by the fiber length and the employed frequency scanning granularity.

W2A.45
Optical Chaos and Hybrid WDM/TDM Based Large Capacity Quasi-distributed Sensing Network with Real-time Fiber Fault Monitoring, Yiyang Luo[1], Li Xia[1], Wei Li[1], Zhilin Xu[1], Qizhen Sun[1], Deming Liu[1]; [1]*National Engineering Laboratory for Next Generation Internet Access System, School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China.* Optical chaos and hybrid WDM/TDM based large capacity quasi-distributed sensing network with real-time fiber fault monitoring is proposed and proof-of-concept demonstrated. The multiplexing capacity can promisingly reach to 512.

W2A.46
Real-time spectral dynamics of femtosecond solitons under free-carrier nonlinearity in silicon photonic crystals, Heng Zhou[4], Shu-Wei Huang[1], Kenneth.K.Y Wong[2], Mingbin Yu[3], Guoqiang Lo[3], Dim-Lee Kwong[3], Kun Qiu[4], Chee Wei Wong[1]; [1]*Columbia Univ., USA;* [2]*The Univ. of Hong Kong, China;* [3]*IME , Singapore;* [4]*Univ. of Electronic Science and Technology of China, China.* We demonstrate real-time single-shot dynamics of soliton spectral broadening and Cerenkov radiation predominately induced by slow-light enhanced free-carrier nonlinearity in silicon photonic crystals. Ultra-stable free-carrier dispersion based continuum generation is identified for the first time.

W2A.47
A low-phase-noise 18 GHz Kerr frequency comb spanning 65 THz, Jinghui Yang[2], Shu-Wei Huang[2], Heng Zhou[3], Mingbin Yu[1], Dim-Lee Kwong[1], Chee Wei Wong[2]; [1]*Institute of Microelectronics, Singapore;* [2]*Univ. of California, Los Angeles, USA;* [3]*Univ. of Electronic Science and Technology of China, China.* We report a low-phase-noise on-chip 18GHz Kerr comb, with 3,600 phase-locked comb modes spanning 65THz. The lowest phase noise floor is achieved to date, with -130 dBc/Hz at 1 MHz offset for the 18GHz carrier.

W2A.48 DEMO
Passive Linear-Optics 640 Gbit/s Logic NOT Gate, Reza Maram[1], Deming Kong[2,3], Michael Galili[2], Leif K. Oxenlowe[2], José Azaña[1]; [1]*INRS-Energie Materiaux et Telecom, Canada;* [2]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [3]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China.* We experimentally demonstrate a 640 Gbit/s all-optical NOT gate for high-speed telecommunication on-off-keying (OOK) data signals. We employ linear optical signal processing based on spectral phase-only (all-pass) optical filtering to perform the target logic NOT operation.

W2A.49
Experimental Demonstration of Optical Signal Level Swapping and Multi-level Amplitude Noise Mitigation using Three Parametric Gain Regions, Yinwen Cao[1], Morteza Ziyadi[1], Youichi akasaka[2], Amirhossein Mohajerin-Ariaei[1], Jeng-Yuan Yang[2], Ahmed Almaiman[1], Peicheng Liao[1], Shigehiro Takasaka[3], Ryuichi Sugizaki[3], Joseph Touch[1,4], Motoyoshi Sekiya[2], Moshe Tur[5], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Fujitsu Laboratories of America, USA;* [3]*Fitel Photonics Laboratories, Furukawa Electric Co., Japan;* [4] *Information Sciences Institute, Univ. of Southern California, USA;* [5]*School of Electrical Engineering, Tel Aviv Univ., Israel.* An optical signal level swapping function and a multi-level amplitude noise mitigation method are proposed using three parametric gain regions. Experiments demonstrate less than 1% EVM-penalty for swapping and multi-level amplitude noise mitigation is achieved.

W2A.50
Reflowable Thermoplastic Optical Lens Module for 10-Gbit/s Transmission with 850-nm VCSEL, Takayuki Shimazu[1], Michiko Harumoto[1], Tomomi Sano[1], Takuro Watanabe[2], Koji Katayama[3], Shouhei Okabe[3], Satoshi Yamasaki[1], Shinya Nishikawa[1]; [1]*Sumitomo Electric Industries, Ltd., Japan;* [2]*Japan Communications Accessories Manufacturing, Japan;* [3]*Sumitomo Electric Fine Polymer Inc., Japan.* We successfully developed reflowable thermoplastic optical lens module by electron beam cross-linking and fabricated MM-based 10-Gbit/s optical transmitter unit. Experimental result shows good durability for reflow process up to 260 °C.

W2A.51
High-Bandwidth Optical I/O Link with Optical MCM, Hsiang-Han Hsu[1], Masao Tokunari[1], Shigeru Nakagawa[1]; [1]*IBM Research Toyoko, Japan.* A high-bandwidth optical I/O link with developed optical MCM is demonstrated. High speed link tests for 24 channels show that the TX operates at 25 Gb/s, and the optical I/O link operates at 20 Gb/s.

W2A.52
Narrow linewidth tunable laser using coupled resonator mirrors, Tin Komljenovic[1], Michael davenport[1], sudharsanan srinivasan[1], Jared Hulme[1], John E. Bowers[1]; [1]*UCSB, USA.* A novel fully integrated tunable single mode hybrid silicon laser is demonstrated. We report a linewidth of 260kHz which is the lowest reported for a monolithically integrated laser. The side-mode suppression ratio is >40dB.

W2A.53
25.8Gbps Direct Modulation AlGaInAs DFB Lasers of Low Power Consumption and Wide Temperature Range Operation for Data Center, Naoki Nakamura[1], Masaaki Shimada[1], Go Sakaino[1], Takashi Nagira[1], Harunaka Yamaguchi[1], Yuichiro Okunuki[1], Atsushi Sugitatsu[1], Masayoshi Takemi[1]; [1]*Mitsusbishi Electric Corporation, Japan.* 25.8Gbps Direct Modulation AlGaInAs DFB lasers were demonstrated for lower consumption in a wide temperature range. The DFB lasers achieved excellent eye opening from –20°C to 85°C at low current less than 56.5mA.

W2A.54
Wide-temperature-range 103.2 (25.8 x 4)-Gb/s Optical link for Datacenter Interconnects using a 1.3-µm Lens-integrated Surface-emitting Laser array, Koichiro Adachi[1], Yasunobu Matsuoka[1], Takashi Takemoto[1], Takanori Suzuki[1], Shigehisa Tanaka[2], Akira Nakanishi[2], Kazuhiko Naoe[2]; [1]*Hitachi, Ltd., CRL, Japan;* [2]*Oclaro Japan, Inc., Japan.* A 103.2 (25.8 x 4)-Gb/s optical link using a 1.3-µm lens-integrated surface-emitting laser array was demonstrated. A power penalty after 2-km transmission was small (<1dB) at 25°C. Moreover, error-free transmission up to 70°C was achieved.

W2A • Interactive Demo & Poster I—Continued

W2A.55
Direct Measurement of Transverse Mode Correlation and MPN using 900nm VCSELs, Justin Lavrencik[1], Sriharsha Kota Pavan[1], David K. Haupt[1], Stephen Ralph[1]; [1]*Georgia Institute of Technology, USA.* Cross-correlations between VCSEL transverse modes are measured using 40GSps synchronous observations of spatially separated modes. Positive correlation and anti-correlation behaviors are observed as well as low, distinct $k_{mpn,}$ contrary to assumptions of the IEEE model.

W2A.56
Single-mode board-level interconnects for silicon photonics, Lars Brusberg[1], Dionysios Manessis[2], Christian Herbst[2], Marcel Neitz[2], Beatrice Schild[2], Michael Töpper[1], Henning Schröder[1], Tolga Tekin[1,2]; [1]*Fraunhofer IZM, Germany;* [2]*TU Berlin, Germany.* An optical interconnection technology for 1310/1550nm has been successfully developed with single-mode glass waveguide panels characterizes loss of 0.05dB/cm. The glass has been integrated into a multi-layer electrical printed circuit board for silicon photonic assembly.

W2A.57
Multiple Microwave Frequencies Measurement Using Stimulated Brillouin Scattering with Improved Measurement Precision, Hengyun Jiang[1], Lianshan . Yan[1], Ye Jia[1], Zhiyu Chen[1], Wei Pan[1], Bin Luo[1], Xihua Zou[1]; [1]*Southwest Jiaotong Univ., China.* A photonic scheme to realize multiple microwave frequencies measurement using stimulated Brillouin scattering is proposed. By coarsely/precisely determine the frequency band/frequency, multiple frequencies with improved precision of <1MHz can be achieved.

W2A.58
Ultra-high Peak Rejection Notch Microwave Photonic Filter Using a Single Silicon Microring Resonator, Yun Long[1], Han Zhang[1], Chao Li[1,2], Chengcheng Gui[1], Qi Yang[2], Jian Wang[1]; [1]*Wuhan National Laboratory for Optoelectronics, China;* [2]*State Key Laboratory of Optical Comm. Technologies and Networks, China.* We propose a simple approach to realize ultra-high peak rejection notch microwave photonic filter (MPF). Using a conventional phase modulator and a tunable bandpass filter, we achieve a notch MPF with an ultra-high peak rejection > 60 dB based on a single notch silicon microring resonator.

W2A.59
Photonic-Assisted Microwave Frequency Doubling based on Silicon Ring modulator, Haifeng Shao[1], Xiaoqing Jiang[1], Jianyi Yang[1], Yingtao Hu[2], Gunther Roelkens[2], Hui Yu[1]; [1]*Zhejiang Univ., China;* [2]*Gent Univ., Belgium.* We experimentally demonstrate an integrated optical millimeter-wave signal generator based on a silicon ring modulator. A 20 GHz microwave signal with 17 dB suppression ratio is obtained with a 10 GHz input signal.

W2A.60
Photonic Generation of Chirped Microwave Pulses with Precisely Targeted and Tuned Parameters Using External Modulation, Xinkai Liu[1], Wei Pan[1], Xihua Zou[1], Shilong Pan[2], Di Zheng[1], Bin Luo[1], Lianshan Yan[1]; [1]*Southwest Jiaotong Univ., China;* [2]*Univ. of Aeronautics and Astronautics, China.* A photonic approach to generate chirped microwave pulses with precisely targeted and tuned parameters including central frequency, pulse repetition frequency, and chirp rate, is proposed. Such chirped pulses at 15 and 20GHz are experimentally demonstrated.

W2A.61
High-speed tunable microwave photonic notch filter based on phase modulator incorporated loop mirror filter, Jia Ge[1], Hanlin Feng[2], Guy Scott[1], Mable P. Fok[1]; [1]*College of Engineering, Univ. of Georgia, USA;* [2]*The State Key Laboratory of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China.* We present a frequency tunable microwave photonic notch filter with tens of GHz tuning speed. High notch rejection ratio of 50-dB is experimentally obtained over a continuously frequency tuning range from 1.5 to 10 GHz.

W2A.62
Wavelet Transform-OFDM in indoor visible light communication, Yiqin Chen[2], Chao Yang[2], Qi Yang[1], Wu Liu[1], Chao Li[2], DaWei Zhang[2]; [1]*Wuhan Research Institute of Post & Tele, China;* [2]*Huazhong Univ. of Science and Technology, China.* We demonstrate that wavelet transform (WT)-OFDM without cyclic prefix has the similar BER performance with conventional Fourier transform (FT)-OFDM in VLC, while effectively improves the transmission distance by 20% due to less PAPR and better nonlinear tolerance.

W2A.63
Experimental Demonstration of Optical Wireless Indoor Localization System with Background Light Power Estimation, Ke Wang[1,2], Ampalavanapilla T. Nirmalathas[1], Christina Lim[1], Efstratios Skafidas[1,2]; [1]*Department of Electrical and Electronic Engineering, Univ. of Melbourne, Australia;* [2]*Centre for Neural Engineering, The Univ. of Melbourne, Australia.* In this paper, an optical wireless based indoor localization system with background light power estimation capability is proposed and experimentally demonstrated. Results show that an average localization error of 2.41 cm is achieved.

W2A.64 DEMO
Nonlinear Modulation Characteristics of White LEDs in Visible Light Communications, Peng Deng [1], Mohsen Kavehrad[1], Mohammadreza A. Kashani[1]; [1]*The Pennsylvania State Univ., USA.* The nonlinear dependence of the modulation bandwidth and electrical to optical conversion on the drive current of white LEDs were investigated by comparing novel analytical modeling and experimental measurement for visible light communications.

W2A.65
First Demonstration of Seamless Optical and Radio Transmission with Plural W-band Wireless Sections, Abdelmoula Bekkali[1], Masayuki Oishi[1], Kosuke Nishimura[1], Keiji Tanaka[1]; [1]*KDDI R&D Laboratories Inc., Japan.* We demonstrated the feasibility of seamless optical and radio transmissions with plural W-band wireless sections for the first time. A 5-Gbaud QPSK signal was successfully transmitted over 2x20-km SMF spans and 2x2-m W-band wireless links.

W2A.66
A hybrid lightwave transmission system based on fiber-VLLC convergence, Chung-Yi Li[1], Hai-Han Lu[1], Chun-Yu Lin[1], Min-Chou Chen[1], Jian-Hua Chen[1], Chien-An Chu[1]; [1]*National Taipei Univ. of Technology, Taiwan.* A hybrid lightwave transmission system based on SMF and VCSEL-based VLLC convergence with light injection and optoelectronic feedback techniques is proposed. Over 40-km SMF and 10-m free-space VLLC transport, CNR/CSO/CTB/BER performs brilliantly for CATV/16-QAM/16-QAM-OFDM transmission.

W2A.67
Ultra-Fast Tunable True-Time Delay Using Complementary Phase-Shifted Spectra (CPSS), Romain Bonjour[1], Simon Arega Gebrewold[1], David Hillerkuss[1], Christian Hafner[1], Juerg Leuthold[1]; [1]*Institute of Electromagnetic Fields (IEF), ETH Zurich, Switzerland.* We introduce an ultra-fast, continuously tunable true-time delay, featuring settling times of tens of picoseconds. Our solution operates for large bandwidth signals, has a low complexity, low losses, and can be fully integrated.

W2A.68
RF frequency quadrupling utilizing selective polarization rotation for wavelength-free radio-over-fiber, Yosuke Akamatsu[1], Akito Chiba[1], Kazumasa Takada[1]; [1]*Gunma Univ., Japan.* We propose rf frequency quadrupling based on selective suppression of optical carrier by a polarizer, for wavelength-free operation. Frequency-upconverted rf signal is successfully obtained experimentally, from generated two-tone optical signal with 25.7-dB carrier-suppression ratio.

Show Floor Programming

■ **Service Provider Summit**

11:00–12:30
Panel II: Packet Optical: Does the Bumpy Road lead to a Promising Destination?
For more details, see page 41

Room 402AB

13:00–15:00
W3A • Silicon Photonics II
Presider: Jonathan Klamkin; Boston Univ., USA

W3A.1 • 13:00 Invited
Recent Progress in Silicon Photonics R&D and Manufacturing on 300mm Wafer Platform, Frederic Boeuf[1], Sebastien Cremer[1], Enrico Temporiti[2], Massimo Fere'[3], Mark Shaw[3], Nathalie Vulliet[1], Bastien Orlando[1], Delia Ristoiu[1], Alexis Farcy[1], Thierry Pinguet[4], Attila Mekis[4], Gianlorenzo Masini[4], Peng Sun[4], Yuemeng Chi[4], Herve Petiton[1], Sebastien Jan[1], Jean-Robert Manouvrier[1], Charles Baudot[1], Patrick Le-Maitre[1], Jean Francois Carpentier[1], Laurent Salager[1], Matteo Traldi[3], Luca Maggi[3], Danilo Rigamonti[3], Chiara Zaccherini[3], Carolina Elemi[3], Bernard Sautreuil[1], Luigi Verga[3]; *[1]STMicroelectronics, France; [2]STMicroelectronics, Italy; [3]STMicroelectronics, Italy; [4]Luxtera, USA.* A low cost 28Gbits/s Silicon Photonics platform using 300mm SOI wafers is demonstrated. Process, 3D integration of Electronic and Photonic ICs, device performance, circuit results and low cost packaging are discussed.

Room 403A

13:00–15:00
W3B • Mode Division Multiplexing II
Presider: Dan Marom; Hebrew Univ. of Jerusalem, Israel

W3B.1 • 13:00 Tutorial
Femtosecond Laser Inscribed Waveguides for New Optical Circuit Applications, Peter R. Herman[1]; *[1]Univ. of Toronto, Canada.* Abstract Not Available

Room 403B

13:00–15:00
W3C • Super Channel Optical Signal Processing
Presider: Tsuyoshi Konishi; Osaka Univ., Japan

W3C.1 • 13:00
Fractional OFDM based Transmitter and Receiver for Time/Frequency Multiplexing in Gridless, Elastic Networks, Takuya Murakawa[1], Gabriella Cincotti[2], Satoshi Shimizu[3], Tomotaka Nagashima[1], Makoto Hasegawa[1], Kuninori Hattori[4], Masayuki Okuno[4], Shinji Mino[4], Akira Himeno[4], Naoya Wada[3], Hiroyuki Uenohara[5], Tsuyoshi . Konishi[1]; *[1]Osaka Univ., Japan; [2]Univ. Roma Tre, Italy; [3]NICT, Japan; [4]NTT Electronics Co. Ltd., Japan; [5]Tokyo Institute of Technology, Japan.* We demonstrate for the first time optical fractional OFDM system, based on intermediate grids between time and frequency axes. Using reconfigurable wavelength selective switches, we demonstrated open eye diagrams, and performance below the FEC-limit.

W3C.2 • 13:15 DEMO
All-optical coherent OFDM transmission of 8 × 40 Gb/s using an on-chip AWGR-FT 1 × 8 decoder circuit, Leimeng Zhuang[1], Chen Zhu[1], Bill Corcoran[1], Arthur Lowery[1]; *[1]Monash Univ., Australia.* We experimentally demonstrate an 8 × 40 Gb/s all-optical coherent-OFDM system using an on-chip 1 × 8 Fourier-transform based on a modified arrayed-waveguide grating router, showing simultaneous receiving of 8 subcarriers with similar signal qualities.

Room 404AB

13:00–15:00
W3D • Data Center Switching
Presider: George Papen; Univ. of California, San Diego, USA

W3D.1 • 13:00
Large-Scale Optical-switch Prototype Compactly Implemented with Novel Functional Configuration, Koh Ueda[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1], Toshio Watanabe[2]; *[1]Nagoya Univ., Japan; [2]NTT Device Innovation Center, Japan.* We propose a novel optical-switch architecture that can be compactly implemented with novel functional configuration. A highly-integrated 180x180 optical switch prototype is fabricated using PLC technologies and its good performance is experimentally confirmed.

W3D.2 • 13:15 Top Scored
A 25 Gb/s Burst-Mode Receiver for Low Latency Photonic Switch Networks, Alexander Rylyakov[1], Jonathan Proesel[1], Sergey Rylov[1], Benjamin G. Lee[1], John Bulzacchelli[1], Abhijeet Ardey[1], Clint Schow[1], Mounir Meghelli[1]; *[1]IBM TJ Watson Research Center, USA.* A DC-coupled burst-mode receiver performs optical power calibration in 12.5ns, achieves phase lock in 18.5ns and tracks input data using a CDR. The sensitivity of the 4.4pJ/bit receiver is 10.9dBm (BER < 10^{-12}) at 25Gb/s.

Room 406AB

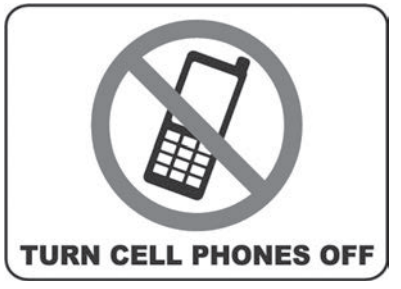
13:00–15:00
W3E • Next Generation Deployable Systems
Presider: Joerg-Peter Elbers; ADVA Optical Networking SE, Germany

W3E.1 • 13:00 Invited
400Gb/s Trials on Commercial Systems Using Real-time Bit-rate-adaptive Transponders for Next Generation Networks, Bruno Lavigne[1]; *[1]Alcatel-Lucent France, France.* We review recent field trials employing real time 400Gb/s dual-carrier PDM-16 QAM channels. The results demonstrate their compliance not only with nowadays 50-GHz grid network but also with next generation flexgrid networks carrying super-channels.

Room 407

13:00–15:00
W3F • Radio-over-Fiber II
Presider: Tetsuya Kawanishi; National Inst of Information & Comm Tech, Japan

W3F.1 • 13:00 Invited
Fiber-based Solutions for In-door Multi-Gbit/s Wireless Access, Hejie Yang[1], Anthony Ng'oma[1], Boris Shih[1], Leonid Kazovsky[2], Apurva Gowda[2]; *[1]Corning Incorporated, USA; [2]Stanford Univ., USA.* Growth of wireless technologies requires high-capacity and energy-efficient infrastructures. Fiber-based RoF solutions provide multi-Gbit/s capacity with easy-upgrade, costeffective and energy efficient features.



Room 408A

13:00–15:00
W3G • Long Distance Transmission
Presider: Lara Garrett; TE SubCom, USA

W3G.1 • 13:00 Top Scored
51.1-Tbit/s MCF Transmission over 2,520 km Using Cladding Pumped 7-core EDFAs, Koki Takeshima[2], Takehiro Tsuritani[2], Yukihiro Tsuchida[1], Koichi Maeda[1], tsunetoshi Saito[1], Kengo Watanabe[1], Toru Sasa[1], Katsunori Imamura[1], Ryuichi Sugizaki[1], Koji Igarashi[2], Itsuro Morita[2], Masatoshi Suzuki[2]; [1]*Furukawa Electric Co. Ltd., Japan;* [2]*KDDI R&D Laboratories, Inc., Japan*. We demonstrate 51.1-Tb/s multi-core fiber transmission using cladding pumped 7-core EDFAs and confirmed a reachable distance of 2,520 km with 73 x 100-Gbit/s Nyquist-pulse-shaped DP-QPSK signals per core.

W3G.2 • 13:15 Top Scored
Transmission of Single-Carrier Nyquist-Shaped 1-Tb/s Line-Rate Signal over 3,000 km, Haik Mardoyan[1], Rafael Rios-Müller[1], Miquel A. Mestre[1], Philippe Jennevé[1], Laurent Schmalen[2], Amirhossein Ghazisaeidi[1], Patrice Tran[1], Sébastien Bigo[1], Jeremie Renaudier[1]; [1]*Alcatel-Lucent Bell Laboratories, France;* [2]*Alcatel-Lucent Bell Labs, Germany.* We synthesize a single-carrier optical signal at a record 1-Tb/s line-rate, out of multiple spectral slices by joint optical and digital signal processing. The 127.9-GBd signal is successfully transmitted and detected after 3,000km distance.

Room 408B

13:00–15:00
W3H • Beyond the Gold Box: The Future of Integrated Optics II
Presider: Clint Schow; IBM T.J. Watson Res. Ctr., USA

W3H.1 • 13:00 Invited
InP Photonic Integrated Circuits for High Efficiency Pluggable Optical Interfaces, Yuliya Akulova[1]; [1]*Communications and Commercial Optical Products, JDSU Corp., USA*. InP PIC integration platforms enable high efficiency pluggable transceivers. Design and performance of widely tunable and fixed wavelength PICs with electro-absorption and Mach-Zehnder modulators for 100 Gb/s datacom and telecom applications will be reviewed.

W3H.2 • 13:20 Invited
High Bandwidth Transceivers Using Heterogeneous Integration on Silicon, Greg Fish[1]; [1]*Aurrion Inc., USA*. The heterogeneous integration of InP material into a silicon photonics wafer flow enables high bandwidth transceivers to be fabricated using established silicon foundry infrastructure for both fabrication and packaging

Room 409AB

13:00–15:00
W3I • Sensing and Measurements
Presider: Victor Kopp; Chiral Photonics Inc, USA

W3I.1 • 13:00
A Noise Suppression Method for Optical Spectrum Measurement Utilizing SBS-based Filter, Deng Pan[1,2], Changjian Ke[1,2], Songnian Fu[1,2], Deming Liu[1,2], Alan Willner[3]; [1]*National Engineering Laboratory for Next Generation Internet Access System, Huazhong Univ. of Science and Technology, China;* [2]*School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China;* [3]*Department of Electrical Engineering, Univ. of Southern California, USA*. A comprehensive noise suppression method for SBS-based filter is proposed and experimentally demonstrated. Accompanied with linearization, the processed spectral dynamic range of an OOK signal can be improved from ~10 dB to ~60 dB.

W3I.2 • 13:15
Complete Dispersive Fourier Transform in near-field for single-shot spectroscopy, Gao Hongbiao[1,2], Mohammad Asghari[2], Bahram Jalali[2]; [1]*Tsinghua Univ., China;* [2]*Electrical Engineering, Univ. of California, Los Angeles, USA*. We show that analog temporal phase modulation enables complete Dispersive Fourier Transform in near-field. As for proof of the concept, acetylene gas absorption spectrum is measured at 37 million frames/second update rate with high sensitivity.

Room 410

13:00–15:00
W3J • Flexible and Reconfigurable Optical Nooks
Presider: Ron Johnson; Cisco Systems, Inc., USA

W3J.1 • 13:00 Invited
Large Scale Optical Cross-connect: Architecture, Performance Analysis, and Feasibility Demonstration, Hiroshi Hasegawa[1]; [1]*Nagoya Univ., Japan.* A cost-effective and scalable photonic node architecture that interconnects small-scale optical cross-connect systems is presented. Its routing performance and technical feasibility are verified through numerical experiments and development of a prototype.

Room 411

13:00–15:00
W3K • Coded Modulation
Presider: David Millar; MERL, USA

W3K.1 • 13:00 Tutorial
Information-theoretic Limits on Coherent Nonlinear Optical-fiber Communication, Frank R. Kschischang[1]; [1]*Univ. of Toronto, Canada*. Information theory establishes fundamental limits on the rate of reliable communication over noisy channels. This talk reviews basic information-theoretic concepts, particularly as they apply to coherent optical data transmission over nonlinear optical fibers.

Frank R. Kschischang holds the title of *Distinguished Professor of Digital Communications* in the Department of Electrical and Computer Engineering at the University of Toronto, where he has been a faculty member since 1991. His research interests are in channel coding techniques applied to wireless, wireline, and optical communications systems. He is an IEEE Fellow and a Fellow of the Royal Society of Canada. He has received a number of awards recognizing teaching and research, including the 2010 IEEE Communications Society and Information Theory Society Joint Paper Award. He currently serves as Editor-in-Chief of the *IEEE Transactions on Information Theory*.

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel IV: Monetization of Optical Networks – Need for New Business Models
For more details, see page 40

Room 402AB

W3A • Silicon Photonics II—Continued

W3A.2 • 13:30
Reconfigurable Four-Channel Polarization Diversity Silicon Photonic WDM Receiver, Po Dong[1], Young-Kai Chen[1], Lawrence L. Buhl[1]; [1]*Alcatel-Lucent Bell Labs, USA.* We report a silicon photonic 4x25 Gb/s polarization-insensitive wavelength-division multiplexing receiver with a fiber-to-photodiode responsivity >0.26 A/W and crosstalk <-20 dB in 200-GHz channel spacing. Both central wavelengths and channel spacing are tunable.

W3A.3 • 13:45 Top Scored
An Adjustable Self-Equalizing Photo Detector, Behrooz Abiri[1], Andy Zhou[1], Firooz Aflatouni[1,2], Ali Hajimiri[1]; [1]*California Institute of Technology, USA;* [2]*Electrical and Systems Engineering, Univ. of Pennsylvania, USA.* An optically-wideband adjustable self-equalizing photo-detector (ASEPD), capable of reviving eye closure due to limited bandwidth of electro-optical components in an optical link, is presented. The ASEPD enables use of various slower electro-optical components in faster data links.

Room 403A

W3B • Mode Division Multiplexing II—Continued

Room 403B

W3C • Super Channel Optical Signal Processing—Continued

W3C.3 • 13:30 Invited
Generation of Ultra-dense Superchannels using Frequency Conversion in Optical Fibers, Thomas Richter[1], Carsten Schmidt-Langhorst[1], Robert Elschner[1], Tomoyuki Kato[2], Takahito Tanimura[2], Shigeki Watanabe[2], Colja Schubert[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany;* [2]*Fujitsu Laboratories Ltd., Japan.* A concept for distributed ultra-dense frequency-division multiplexing is presented which enables precise frequency allocations without the need of absolute optical frequency control at the multiplexing nodes. We review experiments with OFDM and zero-guard-band Nyquist-WDM to demonstrate the precise generation of superchannels.

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

Room 404AB

W3D • Data Center Switching—Continued

W3D.3 • 13:30 Invited
HPC Networks: Challenges and the Role of Optics, Cyriel Minkenberg[1]; [1]*IBM Research–Zurich, Germany.* Cost, rather than power, poses the main challenge for exascale HPC interconnection networks. To deliver byte-per-FLOP ratios on par with today's petaflop-scale systems, price-performance of active optical links must improve by two orders of magnitude.

Room 406AB

W3E • Next Generation Deployable Systems—Continued

W3E.2 • 13:30
Dual-Carrier 400G Field Trial Submarine Transmission over 6,577-km using 60-GBaud Digital Faster-Than-Nyquist Shaping PDM-QPSK Modulation Format, Ke Wang[1], Yanzhao Lu[1], Ling Liu[1]; [1]*Huawei Technologies Co Ltd, USA.* We demonstrate successful field trial dual-carrier 400G undersea transmission using 60-GBaud PDM-QPSK modulation format based on digital faster-than-Nyquist shaping on the transmitter side DSP jointed with receiver SOFTN and 20% SD-FEC decoding.

W3E.3 • 13:45
400 Gbps Real-Time Coherent Nyquist-WDM DP-16QAM Transmission over Legacy G.652 or G.655 Fibre Infrastructure with 2 dB Margins, Yann Loussouarn[2], Erwan Pincemin[2], Mengdi Song[2], Serge Gauthier[2], Yang Chen[1], Zhong Shengqian[1]; [1]*Huawei Technologies, China;* [2]*Orange, France.* We experimentally demonstrate uncompensated error-free transmission of 400 Gbps real-time coherent DP-16QAM with Nyquist filtering (5.33 bit/s/Hz) over 500 km (resp. 300 km) of G.652 (resp. G.655) fibre using purely EDFA amplification and taking into account 2 dB margins.

Room 407

W3F • Radio-over-Fiber II—Continued

W3F.2 • 13:30
Direct-Detection PDM-OFDM RoF System for 60-GHz Wireless MIMO transmission without Polarization Tracking, Hou-Tzu Huang[1], Chung-Shin Sun[1], Chun-Ting Lin[1], Chia-Chien Wei[2], Wei-Siang Zeng[1], His-Yu Chang[1], Boris Shih[3], Anthony Ng'oma[4]; [1]*National Chiao-Tung Univ., Institute of Photonic System, Taiwan;* [2]*National Sun Yat-sen Univ., Department of Photonics, Taiwan;* [3]*Corning Research Center Taiwan, Taiwan;* [4]*Corning Inc., USA.* This work experimentally demonstrates a 60-GHz direct-detection PDM-OFDM system without polarization tracking at the receiver. A BER of 3.8×10^{-3} was achieved with all states of polarization over 10-km fiber and 3-m wireless MIMO transmission.

W3F.3 • 13:45
Photonic-assisted Broadband Wireless Communication with On-line Channel Compression, Yihan Li[1], Andrew M. Weiner[1]; [1]*Ultrafast Optics and Fiber Communications Laboratory, Purdue Univerisity, USA.* Based on photonic-assisted radio-frequency arbitrary waveform generation, a wireless communication system is assembled to experimentally demonstrate channel sounding, on-line channel distortion compensation and error-free data transmission for ultrabroadband (2-18 GHz) radio-frequency signals.

Room 408A

W3G • Long Distance Transmission—Continued

W3G.3 • 13:30 Top Scored

Trans-Pacific Transmission of Quad-Carrier 1Tb/s DP-8QAM Assisted by LUT-based MAP Algorithm, Shaoliang Zhang[1], Fatih Yaman[1], Yue-Kai Huang[1], Takanori Inoue[2], Kohei Nakamura[2], Eduardo Mateo[2], Yoshihisa Inada[2], Ting Wang[1], Takaaki Ogata[2]; *[1]NEC Laboratories America Inc, USA; [2]Submarine Network Division, NEC Corporation, Japan.* 1Tb/s quad-carrier DP-8QAM transmission over 9280 km is reported at a spectral efficiency of 4.54 b/s/Hz thanks to the proposed joint transmitter maximum a posterior (MAP) pre-distortion and receiver correction scheme.

W3G.4 • 13:45

70 nm Seamless Band Transmission of 17.3 Tb/s over 40x100km of Fiber using Complementary Raman/EDFA , Benyuan Zhu[1], Chongjin Xie[2], Lynn E. Nelson[3], Xin Jiang[4], David Peckham[5], Robert Lingle[5], Patrick W. Wisk[1], Man F. Yan[1], David J. DiGiovanni[1]; *[1]OFS Laboratories, USA; [2]Bell Labs, Alcatel-lucent, USA; [3]AT&T Labs, USA; [4]CUNY, USA; [5]OFS, USA.* We demonstrated 70nm seamless band transmission of 173x128Gb/s QPSK signals over 40x100km of TeraWave™ fiber. The complementary Raman/EDFAs and wide-band single-stage discrete Raman amplifiers were used to achieve this 17.3Tb/s capacity ultra-wide single-band transmission.

Room 408B

W3H • Beyond the Gold Box: The Future of Integrated Optics II—Continued

W3H.3 • 13:40 Invited

Silicon Photonics … With The Photons, Alfredo Viglienzoni[1]; *[1]Skorpios Inc, USA.* Skorpios technology platform that delivers on all promises of Silicon Photonics will be described. Skorpios' proprietary process monolithically integrates III-V material into SOI wafers and allows the production of a wide variety of laser sources.

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Room 409AB

W3I • Sensing and Measurements—Continued

W3I.3 • 13:30 Invited

Advanced Coding Techniques for Long-range Raman/BOTDA Distributed Strain and Temperature Measurements, Mohammad Taki[1], Yonas Muanenda[1], Tiziano Nannipieri[1], Alessandro Signorini[1], Claudio J Oton[1], Fabrizio Di Pasquale[1]; *[1]Scuola Superiore Sant Anna di Pisa, Italy.* We describe the use of pulse coding for long-range distributed Raman and Brillouin optical time domain analysis sensors and for implementing hybrid Raman/BOTDA distributed sensors for simultaneous strain and temperature measurement on the same fiber.

Room 410

W3J • Flexible and Reconfigurable Optical Nooks—Continued

W3J.2 • 13:30

Function Placement and Configuration for Power Balanced Network Function Programmable Optical Nodes, Hui Yuan[1], Miquel G. Alabarce[2], Emilio Hugues Salas[1], Georgios S. Zervas[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]CPqD Foundation, Brazil.* Synthesis, placement and configuration of SSS and EDFAs for different power balance scenarios is presented, for the first time, for function programmable optical node architectures. Comparison on device's number and OSNR performance are reported.

W3J.3 • 13:45

Multidirectional Routing in Wavelength Selective Switches , Ahmad Rostami[1], Björn Skubic[1]; *[1]Ericsson Research, Sweden.* We present a novel configuration of bidirectionally-utilized WSSs, which enables routing of wavelengths between tributary ports. The proposed configuration enables realization of OXCs and ROADMs with fewer numbers of WSSs than would conventionally be required.

Room 411

W3K • Coded Modulation—Continued

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel IV: Monetization of Optical Networks – Need for New Business Models
For more details, see page 40

Room 402AB

W3A • Silicon Photonics II—Continued

W3A.4 • 14:00 Invited

Silicon Photonics for the Data Center, Bert J. Offrein[1]; [1]*IBM Research GmbH, Switzerland.* To fully benefit from silicon photonics technology at the system-level, novel electro-optical assembly techniques are required enabling a close integration with the processor or switch chip. Optical coupling and signal distribution options are discussed.

Room 403A

W3B • Mode Division Multiplexing II—Continued

W3B.2 • 14:00

C-Band Mode-Selective Couplers Fabricated by the Femtosecond Laser Direct-Write Technique, Simon Gross[1], Nicolas N. Riesen[2,3], John D. Love[3], Michael J. Withford[1]; [1]*Macquarie Univ., Australia;* [2]*The Univ. of Adelaide, Australia;* [3]*The Australian National Univ., Australia.* Asymmetric mode-selective couplers for multiplexing the LP_{11} modes of an optical fiber fabricated by the femtosecond laser direct-write technique are demonstrated. The devices feature high coupling ratios, excellent mode extinction ratios and low insertion losses.

W3B.3 • 14:15

Six Spatial Modes Photonic Lanterns, Amado M. Velazquez-Benitez[1,3], Juan C. Alvarado-Zacarias[2,3], Gisela Lopez-Galmiche[2,3], Enrique Antonio-Lopez[3], Axel Schülzgen[3], Dennis Van Ras[4], Pierre Sillard[4], Chigo M. Okonkwo[5], Rodrigo Amezcua-Correa[3]; [1]*Inst. de Investigaciones en Materiales, Mexico;* [2]*INAOE, Mexico;* [3]*Univ. of Central Florida, CREOL, The College of Optics and Photonics, USA;* [4]*Prysmian Group, France;* [5]*COBRA Research Institute, Netherlands.* Low-loss all-fiber mode selective photonic-lanterns capable of exciting six spatial fiber modes (4 LP modes) are demonstrated. Mode field profile characterization of photonic lanterns using both step and graded index fibers is presented.

Room 403B

W3C • Super Channel Optical Signal Processing—Continued

W3C.4 • 14:00

A Novel Detection Scheme for Nyquist Optical Time-division Multiplexed Signal with Coherent Matched Sampling, Deming Kong[1], Jizhao Zang[1], Miao Yu[1], Yan Li[1], Siyuan Zhou[1], Hongxiang Guo[1], Jian Wu[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China.* A novel detection scheme for N-OTDM signal with coherent matched sampling is proposed to suppress inter-symbol-interference. 9 dB required-OSNR improvement is observed under 3.9 ps pulse-width in 160 Gbaud proof-of-concept experiment compared with Gaussian-shaped sampling.

W3C.5 • 14:15

Flexible Power-efficient Nyquist-OTDM transmitter, using a WSS and time-lens effect, Gabriella . Cincotti[2], Satoshi Shimizu[3], Takuya Murakawa[1], Takahiro Kodama[1], Kuninori Hattori[4], Masayuki Okuno[4], Shinji Mino[4], Akira Himeno[4], Tomotaka Nagashima[1], Makoto Hasegawa[1], Naoya Wada[3], Hiroyuki Uenohara[5], Tsuyoshi . Konishi[1]; [1]*Osaka Univ., Japan;* [2]*Univ. Roma Tre, Italy;* [3]*NICT, Japan;* [4]*NTT Electronics Co. Ltd., Japan;* [5]*Tokyo Institute of Technology, Japan.* Power-efficient, flexible, Nyquist 4.88-ps *sinc*-pulses generation and OTDM multiplexing is demonstrated, using fractional Fourier transform subcarriers and time-lens effect. OTDM users are generated and multiplexed by a WSS, without rectangular spectral shaping.

Room 404AB

W3D • Data Center Switching—Continued

W3D.4 • 14:00 Invited

A Torus Datacenter Network Based on OPS/OCS/VOCS Enabled by Smart Flow Management, Ryo Takahashi[1], Salah Ibrahim[1], Toru Segawa[1], Tatsushi Nakahara[1], Hiroshi Ishikawa[1], Yasumasa Suzaki[1], Yue-Cai Huang[2], Ken-ichi Kitayama[2], Atsushi Hiramatsu[3]; [1]*NTT Device Technology Laboratories, Japan;* [2]*Osaka Univ., Japan;* [3]*NTT Advanced Technology, Japan.* We present an energy-efficient, low-latency, torus-topology intra-data-center network with the deployment of 100-Gb/s hybrid optoelectronic routers, where OPS, OCS and virtual OCS are all supported on a single hardware platform enabled by smart flow management.

Room 406AB

W3E • Next Generation Deployable Systems—Continued

W3E.4 • 14:00 Invited

Operational Issues Facing Commercial Raman Amplifier System: Safety Measures and System Designs, Akira Naka[1], Toshiya Matsuda[1]; [1]*Network Service Systems Laboratories, NTT, Japan.* We overview operational issues in Raman amplifier system deployment from the viewpoints of precautions and countermeasures against potential hazards and optical signal-to-noise ratio system design for stable commercial use.

Room 407

W3F • Radio-over-Fiber II—Continued

W3F.4 • 14:00 Invited

Photonic-enabled Millimeter-wave Wireless Data Transmission Links Based on Photonic Integrated Circuits, Guillermo Carpintero[1], Katharzyna Balakier[2], Robinson Guzmán[1], Gael Kervella[3], Martyn Fice[2], Mourad Chitoui[4], Frédéric van Dijk[3], Cyril C. Renaud[2], Xavier Leijtens[5], Alwyn Seeds[2]; [1]*Universidad Carlos III de Madrid, Spain;* [2]*Univ. College London, UK;* [3]*III-V LAB, France;* [4]*Thales, France;* [5]*Technical Univ. Eindhoven, Netherlands.* Different approaches to millimeter wave carrier signal generation based on photonic integrated circuits are presented. One approach is based on dedicated fabrication run, and another on a multi-project wafer run on a generic integration platform. A wireless data transmission at 1 Gbps data rate is shown.

Room 408A

W3G • Long Distance Transmission—Continued

W3G.5 • 14:00 Tutorial

High Capacity Submarine Transmission Systems, Alexei N. Pilipetskii[1]; *[1]TE SubCom, USA.* Today's state-of- the-art submarine transmission systems carry tens of Tb/s of transmission capacity. This tutorial will examine specifics of undersea data transmission, enabling technologies and their limitations. The fundamental issues challenging further long-term transmission capacity growth will be reviewed.

Alexei Pilipetskii received M.S. degree in physics from Moscow State University in 1985. From 1985 to 1994 he was with the General Physics Institute, Russia. He received his Ph.D. in 1990 for the research in nonlinear fiber optics. From 1994 to 1997 he was with the UMBC, where his interests shifted to the fiber optic data transmission. In 1997 he joined AT&T Submarine Systems, currently TE SubCom, where he was a member of the Forward Looking Team focused on the research and introduction of the new technologies with an aim at increase in long-haul undersea transmission capacity. He currently leads the transmission research department (Forward Looking Team) at TE SubCom.

Room 408B

W3H • Beyond the Gold Box: The Future of Integrated Optics II—Continued

W3H.4 • 14:00 Invited

Photonic Packaging in High-Throughput Microelectronic Assembly Lines for Cost-Efficiency and Scalability, Tymon Barwicz[1], Yoichi Taira[2], Ted W. Lichoulas[3], Nicolas Boyer[4], Hidetoshi Numata[2], Yves Martin[1], Jae-Woong Nah[1], Shotaro Takenobu[5], Alexander Janta-Polczynski[4], Eddie Kimbrell[3], Robert Leidy[6], Marwan Khater[1], Swetha Kamlapurkar[1], Sebastian Engelmann[1], Yurii A. Vlasov[1], Paul Fortier[4]; *[1]IBM T.J Watson Research Center, USA; [2]IBM Research – Tokyo, Japan; [3]AFL Telecommunications, USA; [4]IBM Bromont, Canada; [5]Asahi Glass Co., Japan; [6]IBM Microelectronics Division, USA.* We demonstrate silicon photonic packaging that can be fully exercised in existing microelectronic packaging facilities. We show low optical loss and point towards notably improved assembly cost and scalability in both volume and optical port-count.

W3H.5 • 14:20 Invited

Embracing Diversity: Interconnecting Different Materials and Components for the Lowest $/Gb, Bardia Pezeshki[1]; *[1]Kaiam, USA.* Highest performance and lowest cost optical functions are best obtained in the shortest time by using proven and mature building blocks. We show the use of a MEMS breadboard to interconnect glass PLCs, InP lasers, and silicon photonics for a variety of functions.

Room 409AB

W3I • Sensing and Measurements—Continued

W3I.4 • 14:00

Coherent BOTDA Sensor with Suppressed Chromatic Dispersion, Zonglei Li[1], Lianshan Yan[1], Liyang Shao[1], Wei Pan[1], Bin Luo[1]; *[1]Southwest Jiaotong Univ., China.* Intensity modulated probe is utilized in coherent BOTDA sensor to reduce chromatic dispersion effect instead of phase modulated probe. Reduction of ~6-MHz decoding error in Brillouin gain spectrum is achieved along 40-km sensing distance.

W3I.5 • 14:15 DEMO

Optical pulse compression reflectometry with 10 cm spatial resolution based on pulsed linear frequency modulation, Weiwen Zou[1], Shuo Yang[1], Xin Long[1], Jianping Chen[1]; *[1]Shanghai Jiao Tong Univ., China.* A new scheme based on pulsed linear frequency modulation is proposed to improve the stability and spatial resolution of optical pulse compression reflectometry. 10 cm spatial resolution over 5.4 km measurement range is experimentally demonstrated.

Room 410

W3J • Flexible and Reconfigurable Optical Nooks—Continued

W3J.4 • 14:00 Invited

Flexible Node Architectures for Metro Networks, Marco Schiano[1], Alessandro Percelsi[1], Marco Quagliotti[1]; *[1]Telecom Italia, Italy.* This paper analyzes the optical transport requirements of future Metro nodes using the traffic forecasts available today. In a large metro network with 8 million users, flexgrid ROADM nodes can support the 2018 estimated traffic.

Room 411

W3K • Coded Modulation—Continued

W3K.2 • 14:00

Nonlinear Fourier Transformation Based Coherent Detection Scheme for Discrete Spectrum, Henning Buelow[1]; *[1]ZBL/ON/S, Bell Labs, Aclatel-Lucent, Germany.* Joint decision on eigenvalue patterns and on corresponding amplitudes was experimentally demonstrated using the discrete part of the nonlinear Fourier transform calculated after coherent detection of a high power 16-GBd two symbol QPSK burst signal.

W3K.3 • 14:15

Experimental Demonstration of the Improvement of System Sensitivity Using Multiple State Trellis Coded Optical Modulation with QPSK and 16QAM Constellations, Emmanuel Le Taillandier de Gabory[1], Tatsuya Nakamura[1], Hidemi Noguchi[1], Wakako Maeda[1], Sadao Fujita[1], Jun'ichi Abe[1], Kiyoshi . Fukuchi[1]; *[1]Green Platform Research Laboratories, NEC Corporation, Japan.* We evaluated experimentally 2, 8, 32 state 32Gbaud TCM-QPSK and TCM-16QAM. TCM offers finer configuration for flexible transponders increasing SE, on 1.1dB wider ranges. TCM may also be used with HD-FEC in lower power transceivers.

Show Floor Programming

■ **Market Watch**

13:00–15:00

Panel IV: Monetization of Optical Networks – Need for New Business Models

For more details, see page 40

Room 402AB

W3A • Silicon Photonics II—Continued

W3A.5 • 14:30
Dual-illuminated Parallel-fed Traveling Wave Germanium Photodetectors, Chia-Ming Chang[1], Jeffrey H. Sinsky[1], Po Dong[1], Guilhem de Valicourt[1], Young-Kai Chen[1]; [1]*Alcatel-Lucent Bell Labs, USA.* We report 4-stage dual-illuminated Ge traveling wave photodetectors (TWPDs). Dual-illumination doubles the optical channels and boosts DC and RF power handling, resulting in a record figure-of-merit of an RF power-bandwidth area density of 0.66 mW-GHz/μm^2.

W3A.6 • 14:45
25Gb/s Hybrid-Integrated Silicon Photonic Receiver with Microring Wavelength Stabilization, Kunzhi Yu[1], Chin-Hui Chen[2], Cheng Li[2], Hao Li[3], Alex Titriku[1], Binhao Wang[1], Ayman Shafik[1], Zhongkai Wang[4], Marco Fiorentino[2], Patrick Y. Chiang[3,2], Samuel Palermo[1]; [1]*Electrical Engineering, Texas A&M Univ., USA;* [2]*Hewlett Packard,, USA;* [3]*Oregon State Univ., USA;* [4]*Fudan Univ., China.* A 25Gb/s hybrid-integrated microring receiver which includes a thermal tuning loop that stabilizes the drop filter resonance wavelength is implemented. The multi-channel 65nm CMOS source-synchronous receiver achieves -8.2 dBm sensitivity at BER<10^{-12} and 0.68pJ/b.

Room 403A

W3B • Mode Division Multiplexing II—Continued

W3B.4 • 14:30 Invited
Tapered Mode Multiplexers for Single Mode to Multi Mode Fibre Mode Transitions, Stephanos Yerolatsitis[1], Itandehui Gris Sánchez[1], Tim Birks[1]; [1]*Univ. of Bath, UK.* Three-mode multiplexers were made by post-processing existing SMF-28 fibres. The input was three identical SMFs which were fused together and adiabatically tapered to form a multimode output core. The light was converted to the LP_{01} and two LP_{11} with low loss (0.6-0.7 dB). The mode multiplexers were broadband.

Room 403B

W3C • Super Channel Optical Signal Processing—Continued

W3C.6 • 14:30 Top Scored
All-Optical Ultra-High-Speed OFDM to Nyquist-WDM Conversion, Pengyu Guan[1], Kasper Røge[1], Hans Christian Mulvad[1], Michael Galili[1], Hao Hu[1], Toshio Morioka[1], Leif K. Oxenlowe[1]; [1]*Technical Univ. of Denmark, Denmark.* We propose an all-optical ultra-high-speed OFDM to Nyquist-WDM conversion scheme based on complete OFT. An 8-subcarrier 640 Gbit/s DPSK OFDM super-channel is converted to eight 80-Gbit/s Nyquist-WDM channels with BER<10^{-9} performance for all channels.

Networking • 14:45

Room 404AB

W3D • Data Center Switching—Continued

W3D.5 • 14:30
Experimental Demonstration of 75 ns End-to-End Latency in an Optical Top-of-Rack Switch, Paris Andreades[1], Yujia Wang[1], Jeffrey Shen[1], Shiyun Liu[1], Philip M. Watts[1]; [1]*Univ. College London, UK.* We experimentally demonstrate 75 ns end-to-end latency for server to server Ethernet traffic in an FPGA implementation of an optical data center top-of-rack switch control plane.

W3D.6 • 14:45
Demonstration of a Photonic Integrated Network-on-chip with Multi Microrings, Fabrizio Gambini [1,2], Paolo Pintus[1,2], Stefano Faralli[1], Nicola Andriolli[1], Isabella Cerutti[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* A multi-microring network-on-chip for datacom applications is demonstrated on a silicon-on-insulator platform. Measurements on the photonic integrated circuit are in good agreement with simulations, achieving a 3dB-bandwidth of 39 GHz and a worst-case crosstalk of -12dB.

Room 406AB

W3E • Next Generation Deployable Systems—Continued

W3E.5 • 14:30
150 x 120 Gb/s Transmission over 3,780 km of G.652 Fiber Using All-Distributed Raman Amplification, Sergey Burtsev[1], Hector de Pedro[1], Do-Il Chang[1], Wayne S. Pelouch[1], Herve Fevrier[1], Sergey Ten[2], Sergejs Makovejs[2], Christopher Towery[2]; [1]*Xtera Communications Inc, USA;* [2]*Corning Inc, USA.* Commercial all-distributed Raman system is demonstrated to support real-time error-free transmission of 150 channels x 120 Gb/s at 50 GHz channel spacing over 3,780 km of G.652 fiber with backward Raman pumping.

Networking • 14:45

Room 407

W3F • Radio-over-Fiber II—Continued

W3F.5 • 14:30 Top Scored
High-Diversity Millimeter-Wave CoMP Transmission based on Centralized SFBC in Radio-over-Fiber Systems, Lin Cheng[1], Malik M. Gul[1], Anthony Ng'oma[2], Feng Lu[1], Xiaoli Ma[1], Gee-Kung Chang[1]; [1]*Georgia Institute of Technology, USA;* [2]*Corning Incorporated, USA.* We propose a space-frequency block coding transmission method enabled by centralized radio-over-fiber systems to improve diversity gain in millimeter-wave coordinated multipoint transmission. A real-time end-to-end experiment reveals improved signal quality and stability.

W3F.6 • 14:45
40-Watt Power-Over-Fiber Using a Double-Clad Fiber for Optically Powered Radio-Over-Fiber Systems, Jun Sato[1], Hidehito Furugori[1], Motoharu Matsuura[1]; [1]*Univ. of Electro-Communications, Japan.* We have successfully demonstrated bidirectional radio-over-fiber transmission using a double-clad fiber with 40-Watt (W) optical power feeding. The error-vector-magnitude penalties of the transmitted signals were less than 0.06% with and without 40-W optical power feeding.

15:00–15:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

Room 408A	Room 408B	Room 409AB	Room 410	Room 411
W3G • Long Distance Transmission—Continued	**W3H • Beyond the Gold Box: The Future of Integrated Optics II—Continued**	**W3I • Sensing and Measurements—Continued**	**W3J • Flexible and Reconfigurable Optical Nooks—Continued**	**W3K • Coded Modulation—Continued**
		W3I.6 • 14:30 DEMO **Optical fiber distributed acoustic communication,** Fei Peng[1], Yunjiang Rao[1], Zinan Wang[1]; *[1]UESTC, China.* A new concept of distributed acoustic communication– sound over fiber (SoF) based on optical fiber distributed acoustic sensing is presented. The concept is validated over an acoustic communication experiment in air, which demonstrates its unique advantages.	**W3J.5 • 14:30** **Measuring Flexibility and Design Trade-offs of N x M SSS-based ROADMs and BVTs,** Adaranijo Peters[1], Emilio Hugues-Salas[1], Georgios Zervas[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, USA.* We quantitatively measure and evaluate the flexibility of key optical devices of ROADMs considering maximum system entropy. We analyze the dependency and trade-offs between flexibility, connectivity, capacity, granularity and spectral efficiency, key design performance indicators.	**W3K.4 • 14:30** **Joint Coding Rate and Modulation Format Optimization for 8QAM Constellations Using BICM Mutual Information,** Rafael Rios-Müller[1], Jérémie Renaudier[1], Laurent Schmalen[2], Gabriel Charlet[1]; *[1]Bell Labs Alcatel-Lucent, France; [2]Bell Labs Alcatel-Lucent, Germany.* We compare the BICM mutual information of different 8QAM constellations and we show that Circular-8QAM is attractive for high coding rates while quadrature optimized Rect-8QAM provides best performance for low coding rates, both outperforming Star-8QAM.
	Networking • 14:40	**Networking • 14:45**	**W3J.6 • 14:45** **Demonstration of Large-Port-Count and Compact ROADM that Exhibits Virtual-C/D/C Performance,** Shoichi Takashina[1], Hiroto Ishida[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1], Toshio Watanabe[2]; *[1]Nagoya Univ., Japan; [2]NTT Device Innovation Center, Japan.* We demonstrate novel large-scale and cost-effective ROADM architecture exploiting the subsystem-modular express switches and tailored transponder banks for add/drop functionality. Simulations show that the proposed ROADM offers virtual-C/D/C performance. Good transmission characteristics are experimentally confirmed.	**W3K.5 • 14:45** **Experimental Demonstration of the 8-state Trellis-coded 4D-QPSK Optical Modulation Format,** Shota Ishimura[1], Kazuro Kikuchi[1]; *[1]The Univ. of Tokyo, Japan.* We experimentally evaluate the bit-error-rate (BER) performance of the 8-state Trellis-coded 4D-QPSK format that we proposed previously. At BER=10^{-3}, 4-dB receiver- sensitivity improvement against DP-QPSK is obtained with a simple encoder structure.

15:00–15:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel IV: Monetization of Optical Networks – Need for New Business Models
For more details, see page 40

Room 402AB

15:30–17:30
W4A • Advanced Photonic Integration Platforms
Presider: Mark Feuer; CUNY College of Staten Island, USA

W4A.1 • 15:30 Invited
Atomic Cladding Waveguide, Uriel Levy[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* We present recent results on our atomic clad waveguide including strong interactions at moderate temperatures, all optical switching and Doppler free lines. We also discuss coupled photonic-atomic resonances and their potential for stabilizing telecom sources.

Room 403A

15:30–17:30
W4B • Advances in Optical Connectors
Presider: Rich Baca; Commscope, Inc., USA

W4B.1 • 15:30 Invited
Splice-on Connectors: Design, Application and Development Trend, Kazuhiro Takizawa[1]; [1]*Fujikura Ltd., USA.* This paper describes the latest field-installable connectors, such as the mechanical splice-on connectors and fusion splice-on connectors, as well as, the recent trends and developments of splice-on connectors.

Room 403B

15:30–17:30
W4C • Phase Sensitive Amplifiers
Presider: Leif Oxenlowe; DTU Fotonik, Denmark

W4C.1 • 15:30 Tutorial
Phase Sensitive Amplifiers and their Applications, Francesca Parmigiani; *University of Southampton, UK.* We review recent advances on phase sensitive parametric amplifiers for all-optical signal processing and low-noise amplification. Their basic principles and practical implementations are provided with insights in the challenges ahead to further improve their performance.

Francesca Parmigiani graduated with honours in Electronic Engineering at Politecnico di Milano, Milano, Italy, in 2002, and received the Ph.D. degree in optical communication systems at the Optoelectronics Research Centre (ORC), University of Southampton, in 2006. She is currently a Senior Research Fellow at the ORC. In April 2010 she was awarded a prestigious Postdoctoral Research Fellowships from the Royal Academy of Engineering, in support of her research on the combination of all-optical signal processing and advanced modulation formats. Her research has produced more than 160 papers in journals and conferences in the field of optical communications and nonlinear optics.

Room 404AB

15:30–17:30
W4D • Performance Monitoring
Presider: Alan Pak Tao Lau; Hong Kong Polytechnic Univ., Hong Kong

W4D.1 • 15:30 Invited
Optical Performance Monitoring in DSP-based Coherent Optical Systems, Zhenhua Dong[1], Qi Sui[1], Alan Pak Tao Lau[1], Kangping Zhong[1], Liangchuan Li[2], Zhaohui Li[3], Chao Lu[1]; [1]*Hong Kong Polytechnic Univ., Hong Kong;* [2]*Network Research Department, Huawei Technologies Co. Ltd, China;* [3]*Institute of Photonics Technology, Jinan Univ., China.* We review the requirements for optical performance monitoring in high capacity DSP based coherent optical transmission systems. Recent proposed schemes for OSNR and CD monitoring for coherent systems are summarized.

Room 406AB

15:30–17:30
W4E • Unrepeatered and Raman-Assisted Transmission
Presider: Benyuan Zhu; OFS Laboratories, USA

W4E.1 • 15:30
Extended Reach of 116 Gb/s DP-QPSK Transmission using Random DFB Fiber Laser Based Raman Amplification and Bidirectional Second-order Pumping, Mingming Tan[1], Pawel Rosa[1], Ianlan Phillips[1], Paul Harper[1]; [1]*AIPT, Aston Univ., UK.* We propose a novel random DFB fiber laser based Raman amplification using bidirectional second-order pumping. This extends the reach of 116 Gb/s DP-QPSK WDM transmission up to 7915 km, compared with other Raman amplification techniques.

W4E.2 • 15:45
80 x 200 Gb/s 16-QAM unrepeatered transmission over 321 km with third order Raman amplification, Hans Bissessur[1], Christian Bastide[1], Suwimol Dubost[1], Sophie Etienne[1]; [1]*Alcatel-Lucent Submarine Networks, France.* We show 80 x 200 Gb/s transmission over 321 km of low-loss fiber with third order Raman amplification without ROPA. We investigate narrow channel spacing down to 37.5 GHz, targeting a capacity of 21 Tb/s.

Room 407

15:30–17:30
W4F • Quantum Communications
Presider: Milorad Cvijetic; Univ. of Arizona, USA

W4F.1 • 15:30
Quantum Secured Gigabit Passive Optical Networks, Bernd Fröhlich[1], James F. Dynes[1], Marco Lucamarini[1], Andrew W. Sharpe[1], Simon W. Tam[1], Zhiliang Yuan[1], Andrew J. Shields[1]; [1]*Toshiba Research Europe Ltd., UK.* We report transmission of a quantum signal alongside conventional Gigabit Passive Optical Network traffic in the same optical distribution network. Encryption keys generated from quantum signals enable provable secure communication in optical access networks.

W4F.2 • 15:45
Impairment Evaluation toward QKD Integration in a Conventional 20-Channel Metro Network, Slavisa Aleksic[1], Florian Hipp[2], Dominic Winkler[1], Andreas Poppe[2], Bernhard Schrenk[2], Gerald Franzl[1]; [1]*Institute of Telecommunications, Vienna Univ. of Technology, Austria;* [2]*AIT Austrian Institute of Technology, Austria.* Integration of QKD in telecom infrastructures raises noise issues not present in systems using dedicated fibers. Experiments on a 3-node metro network indicate that integration is possible when allocating broadband quantum channels in the O-band.

Room 408A

15:30–17:30
W4G • High Speed Fiber-Wireless Links
Presider: Andreas Stohr; Universität Duisburg-Essen, Germany

W4G.1 • 15:30
Laser-Phase-Fluctuation-Insensitive Optical Coherent Transmission of 16-QAM Radio-over-Fiber Signal with Offset-Frequency-Spaced Two-Tone Local Light, Toshiaki Kuri[1], Takahide Sakamoto[1], Tetsuya Kawanishi[1]; [1]*National Institute of Information and Communications Technology, Japan.* A digital-signal-processing-assisted and laser-phase-fluctuation-insensitive optical coherent transmission of a 10-Gbaud 16-quadrture-amplitude-modulation radio-over-fiber signal with an offset-frequency-spaced two-tone local light is experimentally demonstrated. Error-free symbol recovery after the 20-km-long fiber-optic transmission is shown.

W4G.2 • 15:45
Mode-Division Multiplexed W-Band RoF Transmission for Higher-order Spatial Multiplexing, Nikolaos Panteleimon Diamantopoulos[1], Shohei Inudo[1], Yuki Yoshida[1], Akihiro Maruta[1], Atsushi Kanno[2], Pham Tien Dat[2], Tetsuya Kawanishi[2], Ryo Maruyama[3], Nobuo Kuwaki[3], Shoichiro Matsuo[3], Ken-ichi Kitayama[1]; [1]*Graduate School of Engineering, Osaka Univ., Japan;* [2]*National Institute of Information and Communications Technology (NICT), Japan;* [3]*Optics and Electronics Laboratory, Fujikura Ltd., Japan.* 20Gb/s seamless 2×2 MIMO transmission of W-Band millimeter-wave signals over a 30-km modal-dispersion-compensated mode-division multiplexed link and a 2.5-m wireless path, is demonstrated for enhancing the transmission capacity in radio-over-fiber systems.

Room 408B

15:30–17:30
W4H • Beyond the Gold Box: The Future of Integrated Optics III
Presider: Christopher Cole; Finisar Corporation, USA

W4H.1 • 15:30 Invited
Circuit Design Techniques For High Bit Rate and High Density Optical Interconnects, The'Linh Nguyen[1]; [1]*Finisar Corporation, USA.* High density and high bit rate optical interconnects require higher level of integration and complexity. These solutions require circuits design techniques that result in low power and low crosstalk penalty which will be discussed in this paper.

W4H.2 • 15:50
Withdrawn

Room 409AB

15:30–17:30
W4I • Fiber Characterization
Presider: Thierry Taunay; OFS Laboratories, USA

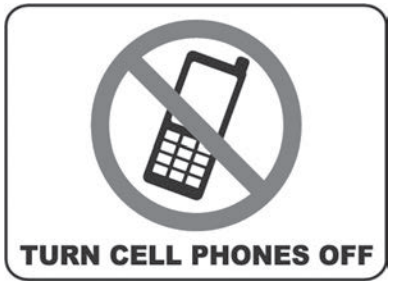
W4I.1 • 15:30
Identification of Loss Factors by Evaluating Backscattered Modal Loss Ratio Obtained with 1-μm-band Mode-detection OTDR, Atsushi Nakamura[1], Keiji Okamoto[1], Yusuke Koshikiya[1], Tetsuya Manabe[1], Manabu Oguma[2], Toshikazu Hashimoto[2], Mikitaka Itoh[2]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan;* [2]*NTT Device Technology Laboratories, NTT Corporation, Japan.* We propose a novel diagnostic technique for identifying loss factors using 1-μm-band mode-detection OTDR. The loss ratio between the LP_{01} and LP_{11} modes of backscattered light determines the macrobending or fusion splicing state.

W4I.2 • 15:45
Digitally Enhanced Optical Frequency Domain Reflectometry with Long Measurement Range, Qingwen Liu[1], Li Liu[1], Xinyu Fan[1], Jiangbing Du[1], Lin Ma[1], Zuyuan He[1]; [1]*Shanghai Jiao Tong Univ., China.* A digitally enhanced optical frequency domain reflectometry technique is proposed, in which the frequency-to-distance mapping is realized in digital domain. A spatial resolution of 1 m over 56 km was obtained in demonstrational experiments.

Room 410

15:30–17:30
W4J • SDN Transport and NFV
Presider: Loukas Paraschis; Cisco Systems, Inc., USA

W4J.1 • 15:30 Invited
SDN Transport Architecture and Challenges, Vishnu S. Shukla[1]; [1]*Verizon Communications Inc, USA.* SDN architecture based on separation of control and data functions enables realization of programmability and application aware networking. High level reference architecture components are discussed and potential challenges are outlined for implementation.



Room 411

15:30–17:30
W4K • Coding and Modulation Format Design
Presider: Takashi Sugihara; Mitsubishi Electric Corporation, Japan

W4K.1 • 15:30 Invited
Coded Modulation Design for Finite-Iteration Decoding and High-Dimensional Modulation, Toshiaki Koike-Akino[1], David Millar[1], Keisuke Kojima[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Labs, USA.* We show how to design capacity-approaching LDPC codes under different mod- ulation formats and different decoding methods. With EXIT chart analysis for finite-iteration BICM-ID of various HDM, we achieve 2dB gain from a code optimized for 1D modulation.

Show Floor Programming

■ **Market Watch**

15:30–17:00
Panel V: Intra-Data Center Interconnection Architectures and Challenges
For more details, see page 40

Room 402AB

W4A • Advanced Photonic Integration Platforms—Continued

W4A.2 • 16:00
Polarization Insensitive Variable Optical Attenuator Based on Field Induced Waveguides with a Liquid Crystal Core, Martin Blasl[1], Kirstin Bornhorst[1], Florenta Costache[1]; [1]*Fraunhofer Institute Photonic Microsyst., Germany.* A VOA based on field induced waveguides with isotropic liquid crystal core is fabricated on silicon backplane. Low loss and 0.1 dB PDL is ensured for 0-20 dB attenuation range by a special electrode design.

W4A.3 • 16:15
Grating coupled low loss Ge-on-Si waveguides and multimode interferometers for the mid-infrared, Milos Nedeljkovic[1], Jordi Soler Penadés[1], Ali Z. Khokhar[1], Colin J. Mitchell[1], Stevan Stanković[1], Thalia Dominguez Bucio[1], Callum G. Littlejohns[1], Frederic Y. Gardes[1], Goran Z. Mashanovich[1]; [1]*Univ. of Southampton, UK.* Germanium-on-silicon is a promising platform for planar photonics over the entire mid-infrared range. We report here grating coupled Ge-on-Si waveguides with record low losses of 0.6dB/cm, multimode interferometers and Mach-Zehnder interferometers.

Room 403A

W4B • Advances in Optical Connectors—Continued

W4B.2 • 16:00
Single-mode 24-fiber connector with GI fiber lens array, Osamu Shimakawa[1], Hajime Arao[1], Naoki Matsushita[1], Yuichi Mitose[1], Dai Sasaki[1], Masaki Ohmura[1], Hiroshi Kohda[1]; [1]*Sumitomo Electric Industries, Ltd., Japan.* A Single-mode 24-fiber connector with GI fiber-lenses is developed. The lenses make it possible to adopt MT-connector based guide-pin-alignment. Insertion loss of 0.54dB on average and loss variation less than 0.08dB under temperature cycling is achieved.

W4B.3 • 16:15
Development of MPO type 8-multicore fiber connector, Kengo Watanabe[1], Tsunetoshi Saito[1], Kohei Kawasaki[1], Mitsuhiro Iwaya[1], Takayuki Ando[1], Katsuki Suematsu[1], Masato Shiino[1]; [1]*Furukawa Electric Co., Ltd., Japan.* We developed MPO type 8-MCF (56-core) connector. Rotational alignment with alignment member and absorption of protrusion difference using compressive strain were adopted. Fabricated 8-MCF connector demonstrated all core PC and connection loss < 0.7 dB.

Room 403B

W4C • Phase Sensitive Amplifiers—Continued

Room 404AB

W4D • Performance Monitoring—Continued

W4D.2 • 16:00
Nonlinearity-Tolerant OSNR Estimation Technique for Coherent Optical Systems, Hyeokgyu Choi[1], Jun Ho Chang[1], Hoon Kim[1], Yun Chur Chung[1]; [1]*Korea Advanced Inst of Science & Tech, Korea (the Republic of).* We demonstrate a novel technique capable of accurately monitoring OSNR even under the influences of fiber nonlinearities. We show that this technique can monitor the OSNR of 112-Gb/s PDM-QPSK signals with accuracy of 1.3 dB.

W4D.3 • 16:15
Differential Pilots Aided In-Band OSNR Monitor with Large Nonlinear Tolerance, Liang Dou[2], Zhenning Tao[2], Ying Zhao[2], Shoichiro Oda[1], Yasuhiko Aoki[1], Takeshi Hoshida[3], Jens C. Rasmussen[1]; [1]*Fujitsu Laboratories Ltd., China;* [2]*Fujitsu R&D Center, China;* [3]*Fujitsu Limited, Japan.* Differential pilots aided in-band OSNR monitor is proposed and verified under 32GBaud WDM experiments. High accuracy (<0.5dB error), no dependency on pulse shapes, and large nonlinear tolerance (1dB error after 4dBm 2700km transmission) are proved.

Room 406AB

W4E • Unrepeatered and Raman-Assisted Transmission—Continued

W4E.3 • 16:00 Invited
Unrepeatered High-speed Transmission Systems, Do-Il Chang[1], Wayne S. Pelouch[1], Sergey Burtsev[1], Philippe Perrier[1], Herve Fevrier[1]; [1]*Xtera Communications Inc USA, USA.* We review recent advances in the technologies required for high-speed unrepeatered transmission systems, with a specific focus on distributed Raman amplification. We also report several experimental demonstrations with record capacity and reach combinations.

Room 407

W4F • Quantum Communications—Continued

W4F.3 • 16:00 Invited
High-speed Quantum Communications in Telecom-fibers using Overlapping Temporal Modes, Vesselin Velev[1], Julia Larikova[1,3], Prem Kumar[1], Yuping Huang[1,2]; [1]*Northwestern Univ., USA;* [2]*Physics and Engineering Physics, Stevens Institute of Technology, USA;* [3]*Coriant, USA.* We analyze an efficient quantum-communications architecture over telecom fibers using overlapping time-frequency modes and optimal receivers based on nonlinear processing.

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

Room 408A

W4G • High Speed Fiber-Wireless Links—Continued

W4G.3 • 16:00 Invited

Photonics for Gigabit Wireless, Ampalavanapilla T. Nirmalathas[1], Chathurika Ranaweera[1], Ke Wang[1], Yizhuo Yang[1], Ishita Akhtar[1], Christina Lim[1], Elaine Wong[1], Efstratios Skafidas[1]; [1]*Univ. of Melbourne, Australia.* Wireless dominates among our future connectivity requirements, moving towards speeds greater than gigabits/second. Photonics can provide energy-efficient, scalable and high-speed front- and back-haul, cost-effective network integration as well as competitive optical wireless connectivity options.

Room 408B

W4H • Beyond the Gold Box: The Future of Integrated Optics III—Continued

W4H.3 • 16:10 Invited

Low-Power MOS-Capacitor Based Silicon Photonic Modulators and CMOS Drivers, Mark A. Webster[1], Kumar Lakshmikumar[1], Craig Appel[1], Cristiana Muzio[1], Bipin Dama[1], Kal Shastri[1]; [1]*Cisco Systems, Inc., USA.* We present efficient MOS-capacitor based silicon photonic modulators driven by low-power CMOS inverter based driver ICs. Operating under the lumped-element approximation, modulation formats of NRZ, PAM, and QAM are demonstrated.

Room 409AB

W4I • Fiber Characterization—Continued

W4I.3 • 16:00

Experimental Evaluation of the Time and Frequency Crosstalk Dependency in a 7-Core Multi-Core Fiber, Ruben S. Luis[1], Benjamin Puttnam[1], Werner Klaus[1], Jose M. Mendinueta[1], Yoshinari Awaji[1], Naoya Wada[1], Atsushi Kanno[2], Tetsuya Kawanishi[2], Testuya Nakanishi[3], Tetsuya Hayashi[3], Takashi Sasaki[3]; [1]*Photon. Network System Laboratory, National Inst Information & Comm Tech, Japan;* [2]*Lightwave Devices Laboratory, National Institute of Information and Communications Technology, Japan;* [3]*Sumitomo Electric Industries, Japan.* We experimentally evaluate the time-varying crosstalk frequency response of a multicore fiber. Our findings suggest that dynamically adaptive transmission would be able to exploit this behavior, to improve the performance of crosstalk-limited links.

W4I.4 • 16:15

Analysis of Inter-core Crosstalk in Homogeneous Multi-core Two-mode Fiber under Bent Condition, Jun Ho Chang[1], Hyeokgyu Choi[1], Sung Hyun Bae[1], Dong Hoon Sim[1], Hoon Kim[1], Yun Chur Chung[1]; [1]*Korea Advanced Inst of Science & Tech, Korea (the Republic of).* We analyze the inter-core crosstalk in a homogeneous multi-core two-mode fiber under bent condition by using coupled-mode equations. The effects of the intra-core mode coupling on the inter-core crosstalk are investigated for various bending radii.

Room 410

W4J • SDN Transport and NFV—Continued

W4J.2 • 16:00

Active Probing assisted Monitoring for Software Defined Networks, Hon-Tung Luk[1], Lian-Kuan Chen[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong.* Efficient and agile control-plane design is crucial for emerging flexible, on-demand optical networks. Active probing assisted monitoring is proposed and shown to reduce monitoring time by around 75% to achieve rapid monitoring in optical networks.

W4J.3 • 16:15

Consideration of Control Entity Failure in Distributed Controlled Multi-domain Multi-vendor Optical Networks, Wangyang Liu[1,2], Nan Hua[1,2], Xiaoping Zheng[1,2], Bingkun Zhou[1,2], Xiaohui Chen[3,4]; [1]*Tsinghua National Laboratory for Information Science and Technology (TNList), China;* [2]*Department of Electronic Engineering, Tsinghua Univ., China;* [3]*School of Communication and Information Engineering, Univ. of Electronic Science and Technology of China, China;* [4]*Fiberhome Telecommunication Technologies Co, Ltd, China.* We study on the problems caused by single control entity failure in the distributed controlled network architecture and then propose a novel scheme to improve network performance in terms of blocking probability and actual load.

Room 411

W4K • Coding and Modulation Format Design—Continued

W4K.2 • 16:00 Invited

On the Use of Factor Graphs in Optical Communications, Henk Wymeersch[1], Naga V. Irukulapati[1], Domenico Marsella[2], Pontus Johannisson[1], Erik Agrell[1], Marco Secondini[2]; [1]*Chalmers Univ. of Technology, Sweden;* [2]*Scuola Superiore Sant'Anna, Italy.* Factor graphs and message passing allow the near-automated development of algorithms in many engineering disciplines, including digital communications. This paper gives an overview of their possible use in optical communications.

Show Floor Programming

■ **Market Watch**

15:30–17:00

Panel V: Intra-Data Center Interconnection Architectures and Challenges

For more details, see page 40

Room 402AB

W4A • Advanced Photonic Integration Platforms—Continued

W4A.4 • 16:30 Invited
Mid-Infrared Photonics, Richard A. Soref[1]; [1]*The Engineering Program, The Univ. of Massachusetts at Boston, USA.* Silicon-based SiGeSn hetero-device technology is very well suited for manufacturable, low-cost, OEIC-chip applications at 1.8 to 5 micron wavelengths: IR camera chips, 2-micron fiber-optic transceivers and smartphone sensor chips for the "internet of things".

Room 403A

W4B • Advances in Optical Connectors—Continued

W4B.4 • 16:30 Invited
Multi-fiber Connector Technologies, Mike Hughes[1], Darrell Childers[1], Joe Graham[1], Sharon Lutz[1], Toshiaki Satake[1]; [1]*US Conec Ltd, USA.* This paper describes the advancement of high density optical interconnect components which is enabling high bandwidth, low cost, single-mode and multimode optical communication between IC's for on-card, optical backplane and chassis to chassis applications.

Room 403B

W4C • Phase Sensitive Amplifiers—Continued

W4C.2 • 16:30
A Novel Phase-Locking-Free Phase Sensitive Amplifier based Regenerator, Niels-Kristian Kjøller[1], Kasper Røge[1], Pengyu Guan[1], Hans Christian Mulvad[1], Michael Galili[1], Leif K. Oxenlowe[1]; [1]*DTU Fotonik, Denmark.* We propose and demonstrate a novel PSK regenerator based on phase sensitive amplification without active phase-locking. The scheme is applied to regenerate a phase noise degraded 10-Gbit/s DPSK signal, improving receiver sensitivity by 3.5 dB.

W4C.3 • 16:45
FWM-based, Idler-free Phase Quantiser with Flexible Operating Power, Kyle R. Bottrill[1], L Jones[1], Francesca Parmigiani[1], David J. Richardson[1], Periklis Petropoulos[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK.* Coherently adding a signal's conjugate and third harmonic at the latter's wavelength enables phase quantisation across a large operating power range. With broadband phase noise, a 5.6dB QPSK receiver sensitivity improvement is achieved with BER=10^{-4}.

Room 404AB

W4D • Performance Monitoring—Continued

W4D.4 • 16:30
Low optical power embedded OTDR, Deepak Devicharan[1], Timothy Zahnley[1], Scott Dahl[1], Aravanan Gurusami[2], Ian McClean[3]; [1]*II-VI Photonics Inc, USA;* [2]*II-VI Photonics Inc, USA;* [3]*II-VI Photonics, UK.* A live fiber loss measurement technique with 0dBm laser source accurately identifies losses over 100km fiber with no change to distance resolution. Multiple levels of length and resolution analysis are obtained from a single dataset.

W4D.5 • 16:45
In-Band OSNR Monitoring of PM-QPSK Using the Stokes Parameters, Lars Lundberg[1], Henrik Sunnerud[2], Pontus Johannisson[1]; [1]*Photonics Laboratory, Department of Microtechnology and Nanoscience, Chalmers Univ. of Technology, Sweden;* [2]*EXFO Sweden AB, currently with Evidente AB, Sweden.* We discuss OSNR monitoring using low bandwidth Stokes parameter analysis. OSNR levels reaching 23dB are experimentally estimated within ±1dB. Simulations show resilience to chromatic dispersion, corresponding to 1000km of SMF for the experimental setup.

Room 406AB

W4E • Unrepeatered and Raman-Assisted Transmission—Continued

W4E.4 • 16:30 Invited
HFA Optimization for NyWDM Tranmission, Vittorio Curri[1], Andrea Carena[1]; [1]*DET, Politecnico di Torino, Italy.* We propose optimization rules for HFA in NyWDM transmission over uniform uncompensated links and for moderate pumping regime we introduce a fiber Raman merit parameters showing that noise reduction is always dominant on NLI enhancement.

Room 407

W4F • Quantum Communications—Continued

W4F.4 • 16:30
Real-time 10 Gbit/s-16 QAM Quantum Stream Cipher Transmission over 320 km with FPGA-based Transmitter and Receiver, Masato Yoshida[1], Toshihiko Hirooka[1], Keisuke Kasai[1], Masataka Nakazawa[1]; [1]*Tohoku Univ., Japan.* We demonstrate the first real-time 10 Gbit/s-16 QAM quantum stream cipher transmission over 320 km with an FPGA-based transmitter and receiver. The random number sequence pattern was changed on-line to increase the encryption security.

Networking • 16:45

Room 408A

W4G • High Speed Fiber-Wireless Links—Continued

W4G.4 • 16:30
20-Gb/s PDM-QPSK Signal Delivery over 1.7-km Wireless Distance at W-Band, Jiangnan Xiao[1], Jianjun Yu[1,2], Xinying Li[1], Yuming Xu[1], Ziran Zhang[1], Long Chen[1]; *[1]Department of Communication Science and Engineering, and Key Laboratory for Information Science of Electromagnetic Waves (MoE), Fudan Uni., China; [2]ZTE (TX) Inc, USA*. We experimentally demonstrate 1.7-km wireless delivery of 20-Gb/s@85.5-GHz PDM-QPSK signal with a BER less than 3.8×10^{-3}, which, to the best of our knowledge, is the longest wireless transmission distance at W-band up to now.

W4G.5 • 16:45
On the MIMO Channel Rank Deficiency in W-band MIMO RoF transmissions, Shohei Inudo[1], Yuki Yoshida[1], Atsushi Kanno[2], Pham Tien Dat[2], Tetsuya Kawanishi[2], Ken-ichi Kitayama[1]; *[1]Graduate School of Engineering, Osaka Univ., Japan; [2]National Institute of Information and Communications Technology, Japan*. Spatial multiplexing gain degradation due to millimeter-order antenna misalignments in W-band MIMO-RoF systems is investigated in 40-Gbps-class 2×2 MIMO-OFDM RoF transmissions.The advantage of space-time block coding there is also demonstrated.

Room 408B

W4H • Beyond the Gold Box: The Future of Integrated Optics III—Continued

W4H.4 • 16:30 Invited
Deploying DSP in Optical Transceiver Modules, Vipul Bhatt[1]; *[1]Inphi Corporation, USA*. Application of specific digital signal processing techniques can ease the bandwidth and SNR limitations of optical links. This can lead to flexible layout and packaging options as well as improved performance.

W4H.5 • 16:50 Invited
Can Discrete Multi-Tone Reduce the Cost for Short Reach Systems?, Tomoo Takahara[1], Toshiki Tanaka[1], Masato Nishihara[1], Zhenning Tao[2], Lei Li[2], Jens C. Rasmussen[1]; *[1]Fujitsu Laboratories Ltd., Japan; [2]Fujitsu R&D Center, Ocean International Center, China*. Digital Signal processing is going on spreading from long reach systems to short reach systems like inter-/intra-data center systems. The cost requirements for short reach systems are more stringent than requirements for long reach systems. And digital signal processing is attractive for cost reduction of optical and electrical components. In this paper, digital signal processing, especially Discrete Multi-Tone, are discussed from the viewpoint of cost reduction.

Room 409AB

W4I • Fiber Characterization—Continued

W4I.5 • 16:30
Fiber fuse propagation in LP_{11} mode in few-mode fiber, Nobutomo Hanzawa[1], Kenji Kurokawa[2], Kyozo Tsujikawa[1], Takayoshi Mori[1], Masaki Wada[1], Fumihiko Yamamoto[1]; *[1]NTT Corporation, Japan; [2]Kitami Institute of technology, Japan*. We observed fiber fuse propagation in the LP_{11} mode in few-mode fiber. We report that the propagation threshold of the fiber fuse in the LP_{11} mode was higher than that in the LP_{01} mode.

W4I.6 • 16:45
Mitigating Spectral Leakage and Sampling Errors in Spatial and Spectral (S^2) Imaging, David R. Gray[1], Seyad R. Sandoghchi[1], Natalie V. Wheeler[1], Naveen K. Baddela[1], Gregory T. Jasion[1], Marco N. Petrovich[1], Francesco Poletti[1], David J. Richardson[1]; *[1]Univ. of Southampton, UK*. We present a novel method for validating the relative power value (MPI) of the Spatial and Spectral (S^2) imaging technique. By applying corrections for spectral leakage and sampling errors we found the MPI determinations to be accurate within 1dB.

Room 410

W4J • SDN Transport and NFV—Continued

W4J.4 • 16:30 DEMO
Experimental Demonstration of Hierarchical Control over Multi-Domain OTN Networks Based on Extended Openflow Protocol, Ruiquan Jing[1], Chengliang Zhang[1], Yongli Zhao[2], Yiran Ma[1], Junjie Li[1], Xiaoli Huo[1], Jianrui Han[3], Jiayu Wang[4], Shengbo Fu[5]; *[1]China Telecom Beijing Research Institute, China; [2]Beijing Univ. of Posts and Telecommunications, China; [3]Huawei, China; [4]ZTE, China; [5]Fiberhome, China*. We demonstrate a control mechanism for multi-domain optical networks with commercial OTN equipments by using hierarchical SDN controllers. A solution based on extended OpenFlow was proposed to support Control Virtual Network Interface in OTN network.

W4J.5 • 16:45
SDN/NFV orchestration for dynamic deployment of virtual SDN controllers as VNF for multi-tenant optical networks, Raul Muñoz[1], Ricard Vilalta[1], Ramon Casellas[1], Ricardo Martínez [1], Thomas Szyrkowiec[2], Achim Autenrieth[2], Victor López[3], Diego López[3]; *[1]CTTC, Spain; [2]ADVA Optical Networking, Germany; [3]Telefónica I+D, Spain*. We propose to virtualize the SDN control functions and move them to the cloud. We experimentally evaluate the first SDN/NFV orchestration architecture to dynamically deploy independent SDN controller instances for each deployed virtual optical network.

Room 411

W4K • Coding and Modulation Format Design—Continued

W4K.3 • 16:30
Experimental Investigation of a Four-Dimensional 256-ary Lattice-based Modulation Format, Tobias A. Eriksson[1], Saleem Alreesh[2,3], Carsten Schmidt-Langhorst[3], Felix Frey[3], Pablo Wilke Berenguer[3], Colja Schubert[3], Johannes K. Fischer[3], Peter A. Andrekson[1], Magnus Karlsson[1], Erik Agrell[4]; *[1]Department of Microtechnology and Nanoscience, Chalmers Univ. of Technology, Sweden; [2]Fachgebiet Nachrichtentechnik, Technische Universität Berlin, Germany; [3]Fraunhofer Institute for Telecommunications Heinrich Hertz Institute, Germany; [4]Department of Signals and Systems, Chalmers Univ. of Technology, Sweden*. A four-dimensional modulation format with 256 point from the D_4-lattice (256-D_4) is compared to PM-16QAM in experiments. 256-D_4 is more sensitive at high OSNR but with a 21.3% overhead turbo product code, PM-16QAM outperforms 256-D_4.

W4K.4 • 16:45
Pairwise Coding to Mitigate Polarization Dependent Loss, Chen Zhu[1], Binhuang Song[1], Leimeng Zhuang[1], Bill Corcoran[1], Arthur Lowery[1]; *[1]Monash Univ., Australia*. By pre-coding data across polarizations, the performance degradation due to PDL can be largely mitigated without any coding overhead. Experimentally, this technique shows more than 2-dB Q^2 improvement for PDM-QPSK with 6-dB worst-case PDL.

Show Floor Programming

■ **Market Watch**

15:30–17:00
Panel V: Intra-Data Center Interconnection Architectures and Challenges
For more details, see page 40

Room 402AB

W4A • Advanced Photonic Integration Platforms—Continued

W4A.5 • 17:00
Ultra-low Loss CMOS Compatible Multi-Layer Si_3N_4-on-SOI Platform for 1310nm Wavelength , Ying Huang[1], Xiaoguang Tu[1], Eu-Jin Lim[1], Junfeng Song[1], Tsung-Yang Liow[1], Guoqiang Lo[1]; [1]*Institute of Microelectronics, A*STAR, Singapore*. We demonstrated the applications of our Si_3N_4-on-SOI platform for O-band operation with propagation and interlayer transition loss of ~0.24dB/cm and ~0.2dB, respectively. We also characterized our SOI-based Ge photo-detector and silicon modulator at λ= 1310nm.

W4A.6 • 17:15
3D Sparse Finite-Difference Time-Domain Simulation of Silicon Photonic Integrated Circuits, Christopher R. Doerr[1]; [1]*Acacia Communications, Inc., USA*. Silicon photonic circuits are growing in size yet designing them often requires full-vectorial 3D simulation. Simulation times can be impractical with today's tools. We propose a new simulation tool that is significantly faster.

Room 403A

W4B • Advances in Optical Connectors—Continued

W4B.5 • 17:00
Reliable Expanded Beam Connector Compliant with Single-mode Fiber Transmission at 10 Gbit/s, Sy Dat LE[1], Michel Gadonna[2], Monique . Thual[1], Lionel Quetel[3], Jean-Francois Riboulet[3], Vincent Metzger[4], Douglas Parker[4], Alain Philippe[4], Sebastien Claudot[4]; [1]*CNRS UMR Foton, France;* [2]*IMT, Télécom Bretagne, France;* [3]*IDIL Fibres Optiques, France;* [4]*Souriau - Esterline, France*. A new microlens design brings together benefits of physical contact and expanded beam technologies resulting in a reliable single-mode fiber connection requiring low maintenance for 10 Gbit/s networks as the Fiber-To-The-Home.

W4B.6 • 17:15
Controlling Fiber Geometry to Improve Optical Performance of Low-Cost 12-fiber MTP Connectors, Esteban Marin[1], Hieu Tran[1], Andrey Kobyakov[1]; [1]*Corning Optical Communications, USA*. We study the effect of fiber tip shape and height distribution on fiber physical contact in the MTP connector. We identify a new polishing process that results in <0.17dB of mean insertion loss per fiber.

Room 403B

W4C • Phase Sensitive Amplifiers—Continued

W4C.4 • 17:00
Phase-Sensitive Amplification of 28 GBaud DP-QPSK Signal, Abel Lorences-Riesgo[1], Tobias A. Eriksson[1], Carl Lundström[1], Magnus Karlsson[1], Peter A. Andrekson[1]; [1]*Chalmers Tekniska Hogskola, Sweden*. We demonstrate, for the first time, amplification of a DP-QPSK signal using a vector phase-sensitive amplifier (PSA). The PSA-based receiver shows an about 0.7 dB sensitivity improvement compared to an EDFA-based receiver.

Networking • 17:15

Room 404AB

W4D • Performance Monitoring—Continued

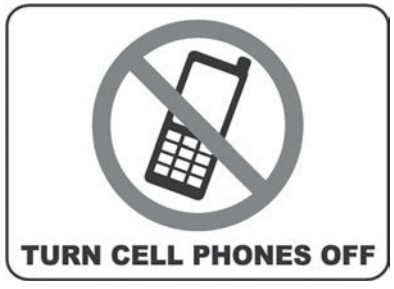
W4D.6 • 17:00
Non-intrusive In-band OSNR Measurement of Polarization Multiplexed Signals Operating in the Non-Linear Regime, Daniel Gariepy[1], Steven Searcy[2], Gang He[1], Sorin Tibuleac[2]; [1]*EXFO, Canada;* [2]*ADVA Optical Networking, USA*. We introduce a non-intrusive OSNR measurement technique relying on spectral deformation analysis which is suitable for densely provisioned polarization-multiplexed signals operated in the nonlinear regime. We demonstrate its performance over a wide range of conditions.

W4D.7 • 17:15 Top Scored DEMO
Miniaturized Heterodyne Channel Monitor with Tone Detection, Harald Rosenfeldt[1], Ian Grainge Clarke[1], Steve Frisken[1], Greg Dash[1], Xinhua Huang[1], Huiping Li[1], Weilong Cui[1], Jiangtao Zhang[1], Junjie Chen[1], Zhengwei Kong[1], Simon Poole[1]; [1]*Finisar Corporation, China*. We present a miniaturized heterodyne optical channel monitor with 300 MHz frequency resolution, 0.5 GHz absolute frequency accuracy and tone detection ability. The compact optical package size of 19x27x7mm makes it suitable for integration into next-generation ROADMs.

Room 406AB

W4E • Unrepeatered and Raman-Assisted Transmission—Continued

Networking • 17:00



Room 407

W4F • Quantum Communications—Continued

Room 408A

W4G • High Speed Fiber-Wireless Links—Continued

W4G.6 • 17:00
W-band OFDM RoF System with Simple Envelope Detector Down-Conversion, Che-Hao Li[1], Meng-Fan Wu[1], Chi-Hsiang Lin[1], Chun-Ting Lin[1]; [1]*National Chiao Tung Univ., Taiwan.* This article proposes W-band OFDM RoF system at 103.5 GHz employing ED down-conversion structure. Compared with traditional Mixer down-conversion, ED has simpler receiver structure, and no local oscillator is needed. The data rate of W-band OFDM signals with 10-GHz bandwidth can achieve 40 Gbps over 25-km fiber and 2-m wireless transmission.

W4G.7 • 17:15
Demonstration of 120 Gbit/s Full-duplex Signal Transmission over Fiber-Wireless-Fiber Network at W-band, Yuming Xu[1], Jianjun Yu[1,2], Xinying Li[1], Jiangnan xiao[1], Gee-Kung Chang[3]; [1]*Fudan Uni., China;* [2]*ZTE Corporation, China;* [3]*Georgia Institute of Technology, Georgia.* We demonstrate full-duplex transmission of 120-Gb/s PDM-QPSK signal over simplified fiber-wireless-fiber network at W-band for the first time. The network is realized by photonic generation and demodulation techniques with a BER less than 2×10^{-2}.

Room 408B

W4H • Beyond the Gold Box: The Future of Integrated Optics III—Continued

W4H.6 • 17:10 Invited
Investigation of 50 GBd PAM-4 Electrical Interfaces for 2km Data Center Interconnects, Edward Frlan[1], Alan Tipper[1]; [1]*Semtech, Canada.* This paper investigates the packaging options and electrical TOSA/ROSA interconnects within next-generation 400G data center optical modules.

Room 409AB

W4I • Fiber Characterization—Continued

W4I.7 • 17:00 Invited
Characterization of Space-Division Multiplexing Fibers Using Swept-wavelength Interferometry, Nicolas K. Fontaine[1]; [1]*Alcatel-Lucent Bell Labs, USA.* Swept-wavelength interferometry can rapidly characterize the amplitude and phase transfer matrices of multi-mode fibers and components. We will show measurements of short (meter) and long (kilometer) few-mode, multi-mode, and coupled multi-core fibers.

Room 410

W4J • SDN Transport and NFV—Continued

W4J.6 • 17:00 Invited
SDN and NFV Convergence a Technology Enabler for Abstracting and Virtualising Hardware and Control of Optical Networks, Reza Nejabati [1], Shuping Peng[1], Mayur Channegowda[1], Bingli Guo[1], Dimitra E. Simeonidou[1]; [1]*Univ. of Bristol, UK.* A new architecture utilizing combination of SDN and NFV for deeply programmable optical Internet infrastructure is proposed where network devices can be sliced, interconnected and programmed on demand for specific transport and network computing tasks.

Room 411

W4K • Coding and Modulation Format Design—Continued

W4K.5 • 17:00
Design of Constant Modulus Modulation Considering Envelopes, Keisuke Kojima[1], Toshiaki Koike-Akino[1], David Millar[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Laboratories, USA.* We propose a method of designing modulation schemes for increasing Euclidean distance white minimizing power fluctuations during transitions. Simulations show that this has 0.8 ~ 1.0 dB higher loss budget than DP-BPSK and 4D Simplex modulation over 6,000 km links.

W4K.6 • 17:15
Quadrature Duobinary Modulation and Detection, Chongjin Xie[1], Sai Chen[2]; [1]*Alcatel-Lucent Bell Labs, USA;* [2]*Beijing Univ. of Posts and Telecommunications, China.* We investigate the performance of quadrature-duobinary (QDB) modulation with both maximum-likelihood-sequence-estimation and symbol-by-symbol detection and show that QDB can achieve better performance than 8-ary quadrature-amplitude modulation (8QAM) and 16QAM at a 4-b/s/Hz spectral efficiency.

Room 402AB

08:00–10:00
Th1A • SDN – Transport
Presider: Hans-Juergen Schmidtke; Juniper Networks Inc., USA

Th1A.1 • 08:00 Invited
SDN Multi-layer Transport Benefits, Deployment Opportunities, and Requirements, Mazen Khaddam[1], Loukas Paraschis[2], Jeff Finkelstein[1]; [1]*Cox Communications, Inc., USA;* [2]*Cisco, USA*. IP+WDM transport benefits significantly from advancements in SDN automation, and traffic-engineering central-"PCE"-control optimization, potentially >30%. We discuss adoption opportunities in planning/engineering and operations/maintenance, trade-offs, and requirements for multi-phased evolution to a programmable multi-layer SDN architecture.

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

Room 403A

08:00–10:00
Th1B • Practical ASIC Implementation
Presider: Masahito Tomizawa; Nippon Telegraph & Telephone Corp, Japan

Th1B.1 • 08:00 Invited
Practical Implementation of Higher Order Modulation Beyond 16-QAM, Jonas Geyer[1], Christopher R. Doerr[1], M Aydinlik[1], N Nadarajah[1], A Caballero[1], C Rasmussen[1], B Mikkelsen[1]; [1]*Acacia Communications, Inc., USA*. We review practical aspects of higher order QAM modulation for optical coherent transmission systems. Measurements of 64-QAM with a silicon-photonics based integrated transmitter show only minor degradation, when compared to a discrete components setup.

Room 403B

08:00–10:00
Th1C • Sensors and Applications
Presider: Rogerio Nogueira; Instituto De Telecomunicacoes, Portugal

Th1C.1 • 08:00 Tutorial
Biomedical Fiber Optic Sensor Applications, Alexis Mendez[1]; [1]*MCH Engineering, LLC, USA*. This tutorial will describe the needs for bio-medical sensing and illustrate—through several real-life application examples—the benefits brought by optical fibers and fiberoptic sensors and their ongoing development. Key technical challenges and industry trends will be identified.

Alexis Mendez received a Ph.D. degree in Electrical Engineering from Brown University, in 1992. He is president of MCH Engineering LLC—a consulting firm specializing in optical fiber sensing technology. Dr. Mendez was the former Group Leader of the Fiber Optic Sensors Lab within ABB Corporate Research (USA). He has written 60 technical publications, co-authored 2 books, taught several short courses, received 5 US patents, and a R&D100 award. Dr. Mendez is a member of the OFS International Steering Committee, a Fellow of SPIE and was past Chairman of the 2006 International Optical Fiber Sensors Conference (OFS-18).

Room 404AB

08:00–10:00
Th1D • SDM
Presider: Robert Killey; Univ. College London, UK

Th1D.1 • 08:00 Invited
MIMO DSP Complexity in Mode-Division Multiplexing, Sercan O. Arik[1], Daulet Askarov[1], Joseph M. Kahn[1]; [1]*Stanford Univ., USA*. We review group delay management techniques and multi-input multi-output (MIMO) digital signal processing (DSP) architectures for mode-division multiplexing systems. We demonstrate long-period fiber grating devices for introduction of strong mode coupling to obtain fast and low complexity MIMO DSP.

Room 406AB

08:00–10:00
Th1E • Stokes Vector and Direct Detection Transceivers
Presider: Gernot Goeger; Huawei, Germany

Th1E.1 • 08:00
Direct-Detection Receiver for PDM Signals, Dong Hoon Sim[1], Hoon Kim[1], Yun Chur Chung[1]; [1]*KAIST, Korea (the Republic of)*. We propose a novel direct-detection receiver for polarization-multiplexed signal. For a demonstration, the proposed receiver is used for the detection of 20-Gb/s PDM-OOK signal while the polarizations of these signals are scrambled at 3 Mrad/s.

Th1E.2 • 08:15
PMD induced impairment mitigation in Stokes vector direct detection systems, Qian Hu[1], Di Che[1], Yifei Wang[1], William Shieh[1]; [1]*The Univ. of Melbourne, Australia*. We present the first measurement of PMD mitigation in Stokes vector direct detection (SV-DD) systems. By applying two novel algorithms, PMD tolerance has been improved from 3.5 to 9 ps for a 93-Gb/s SV-DD system.

Room 407

08:00–10:00
Th1F • Functional Photonic Circuits
Presider: Joris Campenhout; Interuniversity Microelectronics Center, Belgium

Th1F.1 • 08:00
Back-End Integration of Multilayer Photonics on Silicon, Shiyang Zhu[1], Guoqiang Lo[1]; [1]*Institute of Microelectronics, Singapore*. We present vertically-stacked a-Si:H and AlN photonic circuits using back-end CMOS technology, which exhibit low propagation losses of ~3.8 and ~1.4 dB/cm respectively. Various passive devices with high-performance are demonstrated on these two photonic layers.

Th1F.2 • 08:15
Widely Bandwidth-Tunable Broadband Optical Filter on Silicon, Jonathan St-Yves[1], Hadi Bahrami[1], Sophie LaRochelle[1], Wei Shi[1]; [1]*Université Laval, Canada*. We demonstrate an integrated tunable silicon band-pass filter with low in-band ripples of 0.3 dB, a high contrast of 55 dB, and no free-spectral range. A record bandwidth tuning over 670 GHz was achieved.

Room 408A

08:00–10:00
Th1G • Optical Transceiver Technologies for Data Com
Presider: Xuezhe Zheng; Oracle Corporation, USA

Th1G.1 • 08:00 Top Scored
5 mW/Gbps hybrid-integrated Si-photonics-based optical I/O cores and their 25-Gbps/ch error-free operation with over 300-m MMF, Kenichiro Yashiki[1], Yasuyuki Suzuki[1], Yasuhiko Hagihara[1], Mitsuru Kurihara[1], Masatoshi Tokushima[1], Junichi Fujikata[1], Akio Ukita[1], Koichi Takemura[1], Takanori Shimizu[1], Daisuke Okamoto[1], Jun Ushida[1], Shigeki Takahashi[1], Toshinori Uemura[1], Makoto Okano[1], Junichi Tsuchida[1], Takaaki Nedachi[1], Makoto Fushimi[1], Ichiro Ogura[1], Jun Inasaka[1], Kazuhiko Kurata[1]; *[1]PETRA, Japan.* We developed 5 mm square Si-photonics-based chip-scale optical transmitters/receivers called "optical I/O cores". The power consumption of their hybrid-integrated ICs is 5 mW/Gbps. We demonstrated 25-Gbps/ch error-free operation over 300-m MMF in the O band.

Th1G.2 • 08:15
A 25 Gbps silicon photonic transmitter and receiver with a bridge structure for CPU interconnects, Akinori Hayakawa[1,2], Masaya Kibune[1], Asako Toda[3], Shinsuke Tanaka[4], Takasi Simoyama[4], Yanfei Chen[1], Tomoyuki Akiyama[1,2], Shigekazu Okumura[4], Takeshi Baba[4], Tomoyuki Akahoshi[1], Seiji Ueno[5], Maruyama Kazunori[1], Masahiko Imai[4], Jian H. Jiang[3], Pradip Thachile[3], Tamer Riad[3], Shigeaki Sekiguchi[1,2], Suguru Akiyama[4], Yu Tanaka[4], Ken Morito[1,2], Daisuke Mizutani[1], Toshihiko Mori[1], Takuji Yamamoto[3], Hiroji Ebe[1,2]; *[1]Fujitsu Laboratories Limited, Japan; [2]Fujitsu Limited, Japan; [3]Fujitsu Laboratories of America, USA; [4]Photonics Electronics Technology Research Association, Japan; [5]Fujitsu Semiconductor Limited, Japan.* We present a novel configuration of hybrid-integrated silicon photonic interconnects employing a bridge structure, and demonstrate 25 Gbps error-free operation between transmitter and receiver with power efficiency of 9.6 mW/Gbps including a serializer chip.

Room 408B

08:00–10:00
Th1H • OFDM-based Optical Access
Presider: Jianming TANG; Bangor Univ., UK

Th1H.1 • 08:00 Tutorial
OFDM for Optical Access, Johannes von Hoyningen-Huene[1], Christian Ruprecht[1]; *[1]Christian-Albrechts Universität zu Kiel, Germany.* This tutorial discusses the principles and characteristic features of orthogonal frequency division multiple access (OFDMA) in next generation optical access networks. The advances of recent years and the future challenges are discussed.

Johannes von Hoyningen-Huene received the Dipl.-Ing. degree in Electrical Engineering at the University of Kiel, Germany. He is currently a research assistant at the Chair for Communications at the University of Kiel, Germany and is working towards his Ph.D. degree. His research interests include digital signal processing of single carrier and OFDMA systems for optical access networks.

Christian Ruprecht received the M.Sc. in Electrical Engineering from the Technical University of Hamburg-Harburg, Germany. He is currently employed as a research assistant at the Chair for Communication at the University of Kiel, Germany, where he is working towards his Ph.D. degree. The main focus of his Ph.D. work is OFDM for next generation optical access networks.

Room 409AB

08:00–10:00
Th1I • Grooming and Traffic Asymmetry
Presider: Luis Velasco; Universitat Politecnica de Catalunya, Spain

Th1I.1 • 08:00
Cost benefits of asymmetric IP-over-DWDM networks with elastic transceivers, Annalisa Morea[1], Andrew Lord[2], Dominique Verchere[1]; *[1]Alcatel-Lucent, France; [2]British Telecom, UK.* Asymmetric bidirectional routing based on IP-over-WDM architectures, leveraging elastic optoelectronic devices, is proposed for more cost-efficient optical networks. This new routing paradigm saves up to 25% overall (add/drop and regeneration) optoelectronic devices.

Th1I.2 • 08:15
Evaluation of Impact of Traffic Asymmetry on Performance of Elastic Optical Networks, Krzysztof Walkowiak[1], Roza Goscien[1], Miroslaw Klinkowski[2]; *[1]Wroclaw Univ. of Technology, Poland; [2]National Institute of Telecommunications, Poland.* The impact of traffic asymmetry on performance of Elastic Optical Networks (EONs) is studied. Results of experiments are presented to show how both symmetric and asymmetric lightpath provisioning scenarios influence spectrum usage and network CAPEX cost.

Room 411

08:00–10:00
Th1J • Panel: FTTH Indoor Optical Fiber Installation Technologies

Moderator: John George; *Solutions and Professional Services, OFS, USA*

Organizer: Robert Lingle; *OFS, USA*

Fiber is moving inside both homes and office buildings in the current wave of Gigabit PON roll out. The conflicting goals of fast installation for labor savings and aesthetics inside the home or office have brought indoor installation technologies to the forefront of practical fiber optics technology. This panel will explore both carrier experience and requirements as well as available solutions.

David Chen; *Verizon, USA*

Robert Mapes; *AT&T, USA*

Philippe Chanclou; *Orange Labs, France*

Kiyoshi Omoto; *NTT Access Service Systems Laboratories, Japan*

Room 402AB

Th1A • SDN – Transport—Continued

Th1A.2 • 08:30
WAN Virtualization and Dynamic End-to-End Bandwidth Provisioning Using SDN, Adrian Lara[1], Byrav Ramamurthy[1], Eric Pouyoul[2], Inder Monga[2]; [1]*Univ. of Nebraska-Lincoln, USA;* [2]*Energy Science Network, USA.* We evaluate a WAN-virtualization framework in terms of delay and scalability and demonstrate that adding a virtual layer between the physical network and the end-user brings significant advantages and tolerable delays.

Th1A.3 • 08:45 Top Scored
Proactive Hierarchical PCE based on BGP-LS for Elastic Optical Networks, Alessio Giorgetti[1], Francesco Paolucci[1], Filippo Cugini[2], Piero Castoldi[1]; [1]*Scuola Superiore Sant'Anna, Italy;* [2]*CNIT, Italy.* Hierarchical PCE architecture is considered in multi-domain EONs. A novel scheme is proposed to proactively update the parent PCE using BGP-LS. Simulations show that the proposed scheme reduces blocking probability and parent PCE control load.

Th1A.4 • 09:00 Top Scored
First Multi-partner Demonstration of BGP-LS enabled Inter-domain EON control with H-PCE, Oscar Gonzalez de dios[1], Ramon Casellas[2], Roberto Morro[3], Francesco Paolucci[4], Victor Lopez[1], Ricardo Martínez [2], Raul Muñoz[2], Ricard Vilalta[2], Piero Castoldi[4]; [1]*Telefonica, Spain;* [2]*CTTC, Spain;* [3]*Telecom Italia, Italy;* [4]*CNIT-Scuola Superiore Sant'Anna, Italy.* The control of Multi-domain Elastic Optical Networks (EON) is possible by combining H-PCE based computation, BGP-LS topology discovery, remote Instantiation via PCEP, and signaling via RSVP-TE. This paper presents the first multi-platform demonstration that fully validates such control architecture achieving multi-protocol interoperability.

Room 403A

Th1B • Practical ASIC Implementation—Continued

Th1B.2 • 08:30 Invited
Challenges in Implementing High-speed, Low-power ADCs, Lukas Kull[1]; [1]*IBM Research - Zurich, Switzerland.* Challenges of CMOS ADC implementations for 100 Gb/s optical communication systems and beyond are highlighted. Limitations and opportunities of architectures and circuits are discussed based on a 56–90 GS/s 8 bit ADC in 32 nm SOI CMOS.

Th1B.3 • 09:00 Tutorial
Design Trade-offs in Practical ASIC Implementations, Oscar E. Agazzi[1]; [1]*ClariPhy Communication, Inc., USA.* This tutorial will present tradeoffs in the practical implementation of coherent optical transceivers. Power versus performance, testability, floor planning and layout, signal and power integrity and other relevant aspects of practical design will be discussed.

Room 403B

Th1C • Sensors and Applications—Continued

Th1C.2 • 09:00 Invited
Shape Sensing using Multi-core Fiber, Jason Moore[1]; [1]*NASA Langley Research Center, USA.* A method of converting multi-core fiber strain and twist measurements into three dimensional shape measurements using Frenet-Serret equations adapted to the treatment of a multi-core optical fiber as a Kirchhoff elastic rod is presented.

Room 404AB

Th1D • SDM—Continued

Th1D.2 • 08:30 Invited
Dense Space Division Multiplexed Transmission over Multi-core and Multi-mode Fiber, Takayuki Mizuno[1], Hidehiko Takara[1], Akihide Sano[1], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Laboratories, Japan.* We review recent progress in space division multiplexed (SDM) transmission, and examine our experimental demonstration of dense SDM (DSDM) using both multi-core and multi-mode, which provides a key advance to ultra-high capacity transmission.

Th1D.3 • 09:00
Mode Selection and Larger Set Equalization for Mode-Multiplexed Fiber Transmission Systems, El Mehdi Amhoud[1], Elie Awwad[1], Ghaya Rekaya-Ben Othman[1], Yves Jaouen[1]; [1]*Telecom Paristech, France.* We study the performance of six-mode and ten-mode fiber-based SDM systems impaired by mode-dependent-loss when selecting an appropriate set of modes for multiplexing at the transmitter, and detecting more modes at the receiver.

Room 406AB

Th1E • Stokes Vector and Direct Detection Transceivers—Continued

Th1E.3 • 08:30
Simple and Efficient Algorithm for Polarization Tracking and Demultiplexing in Dual-polarization IM/DD Systems, Kazuro Kikuchi[1]; [1]*Univ. of Tokyo, Japan.* We propose a simple and efficient DSP algorithm, which enables to demodulate dual-polarization PAM signals in direct-detection receivers. Simulation results show that the power penalty stemming from digital polarization tracking and demultiplexing is negligibly small.

Th1E.4 • 08:45
Implementing Simplified Stokes Vector Receiver for Phase Diverse Direct Detection, Di Che[2,1], An Li[1], Qian Hu[1], Xi Chen[1], William Shieh[1]; [1]*Univ. of Melbourne, Australia;* [2]*National ICT Australia - Victoria Research Laboratory, Australia.* We propose a novel Stokes vector receiver (SV-R) with phase diversity based on 4 single-ended photo-detectors and demonstrate 80-Gb/s direct detection (DD) over 160-km SSMF transmission. OSNR sensitivity is compared among different SV-R DD schemes.

Th1E.5 • 09:00 Invited
Linearization of Optical Channels with Stokes Vector Direct Detection, William Shieh[1], Di Che[1,2], Qian Hu[1], An Li[1]; [1]*Univ. of Melbourne, Australia;* [2]*National ICT Australia - Victoria Research Laboratory (NICTA-VRL), Australia.* Aiming to improve the performance of short-reach optical communications, Stokes-vector direct detection (SV-DD) is proposed to realize linear complex optical channels. In this paper, we present the principle and discuss the performance of SV-DD modulation format.

Room 407

Th1F • Functional Photonic Circuits—Continued

Th1F.3 • 08:30
Colorless, Dual-Polarization 90° Hybrid with Integrated VOAs and Local Oscillator on Polymer Platform, Ziyang Zhang[1], Alejandro M. Novo[1], Andrzej Polatynski[1], Tim Mueller[1], Gelani Irmscher[1], David Felipe[1], Moritz Kleinert[1], Walter Brinker[1], Crispin Zawadzki[1], Norbert Keil[1]; [1]*Fraunhofer Heinrich Heritz Institute, Germany.* Colorless and polarization-multiplexed 90° hybrid is demonstrated on polymer platform with vertically inserted thin-film elements as efficient polarization splitter and rotator, on-chip VOAs, and integrated 22-nm wavelength-tunable high-power local oscillator for coherent WDM detection.

Th1F.4 • 08:45
Compact Programmable Monolithically Integrated 10-Stage Multi-Channel WDM Dispersion Equalizer on Low-Loss Silicon Nitride Planar Waveguide Platform, Renan Moreira[1], Sarat Gundavarapu[1], Daniel J. Blumenthal[1]; [1]*Electrical and Computer Engineering, Univ. of California Santa Barbara, USA.* We demonstrate a tunable dispersion equalizer on a low loss Si_3N_4/SiO_2 planar waveguide platform. The equalizer has a tuning range of ±550 ps/nm, a footprint of 222.5 mm^2, and can compensate multiple WDM channels simultaneously.

Th1F.5 • 09:00
Silicon hybrid wavelength/mode-division-demultiplexer with 64 channels for on-chip optical interconnects, Jian Wang[1], Sitao Chen[1], Shipeng Wang[1], Daoxin Dai[1]; [1]*Zhejiang Univ., China.* A novel 64-channel silicon hybrid demultiplexer is proposed and demonstrated by utilizing a 1×4 ADC-type mode demultiplexer and two 17×17 bi-directional AWGs. The measured insertion loss and crosstalk are around -5dB and -14dB, respectively.

Room 408A

Th1G • Optical Transceiver Technologies for Data Com—Continued

Th1G.3 • 08:30 Invited

Intel®'s Silicon Photonics on an Advanced Manufacturing Platform, Matthew N. Sysak[1]; [1]*Intel Corporation, USA.* We discuss Intel®'s Silicon Photonics advanced fabrication advantages, highlighting the transition from 200mm to 300mm manufacturing. We use specific examples of the optical technologies to illustrate the advantages.

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

Th1G.4 • 09:00 Invited ▶

Fiber Optics Packaging, Frank Flens[1]; [1]*Finisar Corporation, USA.* A discussion of upcoming trends in multimode fiber optics module styles, product architecture and product usage. Emphasis is given to high speed, high density applications (e.g. supercomputing and core routing).

Room 408B

Th1H • OFDM-based Optical Access—Continued

Th1H.2 • 09:00 ▶

A 200-Gbps OFDM Long-Reach PON over 60-km Transmission without Inline and Pre-Amplifier, Hsing Yu Chen[1,2], Chia-Chien Wei[3], Che-Yu Lin[1], Li-Wei Chen[1], I-Cheng Lu[1], Jason (Jyehong) Chen[1]; [1]*National Chiao Tung Univ., Taiwan;* [2]*Industrial Technology Research Institute, Taiwan;* [3]*National Sun Yat-sen Univ., Taiwan.* 200-Gbps 60-km OFDM transmission in a 4-channel WDM system is demonstrated with 29-dB loss budget per channel without inline and pre-amplifier. Employing 10-GHz EAM and PIN, the LR-PON can support 64 ONUs with >2.5-Gbps/ONU capacity.

Room 409AB

Th1I • Grooming and Traffic Asymmetry—Continued

Th1I.3 • 08:30 Invited

Elastic Black Link for Future Vendor Independent Optical Networks, Matthias Gunkel[1], Arnold Mattheus[1], Antonio Napoli[2], Gianluca Meloni[3], Francesco Fresi[3], Talha Rahman[4]; [1]*Optical Packet Transport, Deutsche Telekom AG Laboratories, Germany;* [2]*Coriant R&D GmbH, Germany;* [3]*CNIT, Italy;* [4]*COBRA Research Institute, Netherlands.* We review the status of Black Link standardization activities, prospects and challenges on possible elastic-optical extensions, and report on the latest experimental achievements on DSP technology compatibility for next generation 1.28 Tb/s PM-16QAM super-channel.

Th1I.4 • 09:00

Impact of Adaptive Modulation on Cost Efficient Traffic Grooming in Elastic Optical Networks, Yutaka -. Takita[1], Kazuyuki Tajima[1], Tomohiro Hashiguchi[1], Toru Katagiri[1], Takao Naito[1]; [1]*Fujitsu Limited, Japan.* We evaluate the contribution of "adaptive modulation" to cost reduction in traffic grooming-capable optical networks. We demonstrate up to 25% optical line reduction with adaptive modulation for large networks carrying traffic of hundreds of terabits/s.

Room 411

Th1J • Panel: FTTH Indoor Optical Fiber Installation Technologies —Continued

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

Room 402AB

Th1A • SDN – Transport—Continued

Th1A.5 • 09:15
First Demonstration of SDN-based Segment Routing in Multi-layer Networks, Andrea Sgambelluri[1], Alessio Giorgetti[1], Filippo Cugini[2], Gianmarco Bruno[3], Francesco Lazzeri[3], Piero Castoldi[1]; *[1]Scuola Superiore Sant Anna di Pisa, USA; [2]CNIT, Italy; [3]Ericsson, Italy.* Segment Routing enabling dynamic optical bypass in a multi-layer network is experimentally demonstrated. Edge nodes are efficiently configured by an enhanced SDN controller, showing effective scalability performance under different label stacking conditions.

Th1A.6 • 09:30 **Invited**
Autonomic Agent for Transport Networks, Dean Bogdanovic[1]; *[1]Juniper Networks Inc., USA.* An autonomic agent example that controls forwarding behavior across heterogeneous transport networks, based on performance metrics calculated across L1 to L3.

Room 403A

Th1B • Practical ASIC Implementation—Continued

Dr. Oscar Agazzi is the Senior Vice President and Chief Systems Architect at ClariPhy Communications, Inc. He is the chief architect of the ClariPhy family of coherent as well as direct detection optical transceivers. Prior to joining ClariPhy, he worked at Broadcom Corporation and at Lucent Technologies Bell Laboratories. Dr. Agazzi holds a Ph.D. in Electronic Engineering from the University of California at Berkeley. He has over 150 patents issued or pending, and has published more than 60 technical papers in journals and conferences. He is a Lucent Technologies Bell Labs Fellow and a Fellow of the IEEE.

Room 403B

Th1C • Sensors and Applications—Continued

Th1C.3 • 09:30
Optical Electric Field Sensor using Push-Pull for Vibration Noise Reduction, Frederick Seng[1], Nikola Stan[1], Spencer Chadderdon[2], Chad Josephson[1], Rex King[1], Legrand Shumway[1], Richard Selfridge[1], Stephen Schultz[1]; *[1]Brigham Young, USA; [2]Harris Corporation, USA.* The push-pull slab-coupled optical sensor measures a localized single electric field component with the advantage of reducing adverse strain effects for sensing in harsh vibrating environments. Its miniature size makes it ideal for compact environments.

Room 404AB

Th1D • SDM—Continued

Th1D.4 • 09:15
Optical Diversity Transmission with Signal and its Phase-conjugate Lights through Multi-core Fiber, Masafumi Koga[1,2], Akira Mizutori, Teppei Ohata, Hidehiko Takara; *[1]Oita Univ., Japan; [2]Electrical and electronics Engineerings, Faculty of Engineerings, Japan.* This paper demonstrated a 4.5dB Q-value improvement by realizing maximum-ratio combining in phase-conjugate light pair diversity transmission through a multi-core fiber. Simulations confirm cancellation of the spatial correlation component in the enhanced amplified-spontaneouse emission noise.

Th1D.5 • 09:30
Long Distance Transmission in a Multi-Core Fiber with Self-Homodyne Detection, Benjamin J. Puttnam[1], Ruben S. Luis[1], Jose Manuel Delgado Mendinueta[1], Jun Sakaguchi[1], Werner Klaus[1], Yoshinari Awaji[1], Naoya Wada[1], Atsushi Kanno[1], Tetsuya Kawanishi[1]; *[1]National Inst Info & Comm Tech (NICT), Japan.* We investigate long-distance space-division multiplexed self-homodyne transmission in two synchronized recirculating loops. Compared to intradyne detection, PDM-64QAM transmission distance with DFB lasers is doubled and 6800km PDM-QPSK transmission, within 1dB of intradyne detection, is achieved.

Room 406AB

Th1E • Stokes Vector and Direct Detection Transceivers—Continued

Th1E.6 • 09:30
52.6 Gbit/s Single-Channel Directly-Modulated Optical Transmitter for 2-μm Spectral Region, Zhixin Liu[1], Zhihong Li[1], Yong Chen[1], Brian Kelly[2], Richard Phelan[2], John O'Carroll[2], John P. Wooler[1], Natalie V. Wheeler[1], Alexander M. Heidt[1], Thomas Richter[3], Colja Schubert[3], Martin Becker[4], Francesco Poletti[1], Marco N. Petrovich[1], Shaif-Ul Alam[1], David J. Richardson[1], Radan Slavík[1]; *[1]Optoelectronics Research Centre, Univ. of Southampton, UK; [2]Eblana Photonics, Ireland; [3]Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany; [4]IPHT, Germany.* Optical injection locking is used to increase the modulation bandwidth and suppress chirp in a single-channel, single-polarization discrete multi-tone bit-loading-optimized transmitter. Transmission through a hollow-core photonic bandgap fiber with negligible signal degradation and distortion is demonstrated.

Room 407

Th1F • Functional Photonic Circuits—Continued

Th1F.6 • 09:15
Ultra-Low Loss Vertical Optical Couplers for 3D Photonic Integrated Circuits, Kuanping Shang[1], Shibnath Pathak[1], Guangyao Liu[1], S. J. B. Yoo[1]; *[1]Univ. of California, Davis, USA.* We design, fabricate, and demonstrate ultra-low loss Si3N4 vertical couplers for multilayer photonic integrated circuits. We achieve 0.05 dB coupling loss, 100×2 μm2 footprint, and vertical coupling tolerant to lateral misalignment up to 1.2 μm.

Th1F.7 • 09:30 **Invited**
Diamond-integrated Optomechanical Circuits, Wolfram H. Pernice; Diamond integrated photonic devices are promising candidates for applications in nanophotonics and optomechanics. Here I present active modulation of diamond-based devices by exploiting mechanical degrees of freedom in free-standing electro-optomechanical resonators.

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Room 408A

Th1G • Optical Transceiver Technologies for Data Com—Continued

Th1G.5 • 09:30

Bidirectional 400-Gb/s transmission by 100GbE Optical Sub-Assemblies and a Cyclic Arrayed Waveguide Grating, Yoshiyuki Doi[1], Takaharu Ohyama[1], Yasuhiko Nakanishi[1], Toshihide Yoshimatsu[1], Shunichi Soma[1], Hiroshi Yamazaki[1], Manabu Oguma[1]; *[1]NTT Corporation, Japan*. We propose a bidirectional 400-Gb/s configuration that uses optical subassemblies for 100-Gb/s Ethernet and a cyclic arrayed waveguide grating. The feasibility of a 10-km fiber transmission of 28-Gbaud 8λ-PAM4 and a compact transceiver are shown.

Room 408B

Th1H • OFDM-based Optical Access—Continued

Th1H.3 • 09:15 Top Scored

Demonstration of No-guard-band Coherent IFDMA/OFDMA/SC-FDMA-PON Coexistence Uplink System using Real-time IFDMA Transmitter, Kenji Ishii[1], Yuki Yoshida[2], Kiyoshi Onohara[1], Masaki Noda[1], Masamichi Nogami[1], Akihiro Maruta[2], Ken-ichi Kitayama[2]; *[1]Mitsubishi Electric Corporation, Japan; [2]Osaka Univ., Japan*. We demonstrated multiple-FDMA co-coexisted PON uplink transmission using the real-time ONU transmitter prototype. Flexible bandwidth assignment to multiplexed 3-ONU and the distance-adaptive capability is successfully indicated.

Th1H.4 • 09:30

OFDM PON Downstream Scheme with Symbol Pre-distortion and Scalable Receiver Frontend, Cheng Ju[1], xue chen[1], Na Liu[1], Qi Zhang[2], Huitao Wang[2]; *[1]Beijing Univ Posts & Telecommunications, USA; [2]ZTE Corporation, China*. We propose and experimentally demonstrate a 40-Gbps A-RF-tone-based VSSB-DD OFDM PON downstream scheme with symbol pre-distortion and scalable receiver frontend to reduce the SSBI and the computational complexity of ONUs, respectively.

Room 409AB

Th1I • Grooming and Traffic Asymmetry—Continued

Th1I.5 • 09:15

Impact of Grooming Architecture of Transport Nodes in Line Interface Count for Multi-Period Planning, Rui M. Morais[1,3], João Pedro[1,4], Paulo Monteiro[2,3], Armando N. Pinto[2,3]; *[1]Coriant Portugal, Portugal; [2]Department of Electronic, Telecommunications and Informatics, Univ. of Aveiro, Portugal; [3]Instituto de Telecomunicações, Portugal; [4]Instituto de Telecomunicações, Instituro Superior Técnico, Portugal*. We analyze the impact of the node architecture flexibility in the number of line interfaces required, for multi-period planning with and without traffic churn. The line interface savings from enforcing hitless traffic re-grooming are highlighted.

Th1I.6 • 09:30

Residual Capacity Aware Dynamic Control of GRE-based Routing Optical Path Networks under Traffic Growth Model, Yuki Terada[1], Yojiro Mori[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; *[1]Nagoya Univ., Japan*. We propose a novel control algorithm for Grouped Routing networks that utilize a metric for residual capacity estimation. Numerical experiments under growing traffic scenarios confirm that it can maximize the fiber frequency utilization.

Room 411

Th1J • Panel: FTTH Indoor Optical Fiber Installation Technologies —Continued

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Room 402AB	Room 403A	Room 403B	Room 404AB	Room 406AB	Room 407
Th1A • SDN – Transport—Continued	**Th1B • Practical ASIC Implementation—Continued**	**Th1C • Sensors and Applications—Continued**	**Th1D • SDM—Continued**	**Th1E • Stokes Vector and Direct Detection Transceivers—Continued**	**Th1F • Functional Photonic Circuits—Continued**
		Networking • 09:45	Networking • 09:45	Th1E.7 • 09:45 **Direct modulation of 56 Gbps duobinary-4-PAM,** Lau Suhr[1], Juan Jose . Vegas Olmos[1], Bangning Mao[2], xiaogeng xu[3], Gordon Ning Liu[3], Idelfonso Tafur Monroy[1]; *[1]Department of Photonics Engineering, Technical Univ. of Denmark, Denmark; [2]European Research Center, Huawei, Germany; [3]Transmission Technology Research Department, Huawei, China*. This paper reports on the direct modulation of externally modulated laser and transmission through single mode fiber of a 56 Gbps duobinary-4-pulse amplitude modulation signal through 10 GHz class optics.	

10:00–12:00 Th2A • Interactive Demo and Poster Session II, *Exhibit Hall K*

10:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall (concessions available)*

10:00–15:00 Exhibition and Show Floor, *Exhibit Hall (coffee service from 10:00–10:30)*

NOTES

Room 408A

Th1G • Optical Transceiver Technologies for Data Com—Continued

Th1G.6 • 09:45

25.8 Gbps Error Free Transmission over 10 km at Wavelengths from 1271 to 1331nm by Uncooled (25 to 85°C) Directly Modulated DFB Lasers for 100G-CWDM4, Takayuki Nakajima[1], Toshihiko Fukamachi[1], Mitsuo Akashi[1], Atsushi Nakamura[1], Yasushi Sakuma[1], Shigenori Hayakawa[1], Ryu Washino[1], Masaru Mukaikubo[1], Kaoru Okamoto[1], Katsuya Motoda[1], Kazuhiko Naoe[1], Kouji Nakahara[1], Shigehisa Tanaka[1], Kazuhisa Uomi[1]; [1]*Oclaro Japan, inc., Japan*. We successfully demonstrated 25.8 Gbps error free transmission through an 11.4km-long fiber using 1.3 μm directly modulated DFB lasers at the CWDM wavelengths for temperatures as high as 85°C.

Room 408B

Th1H • OFDM-based Optical Access—Continued

Th1H.5 • 09:45

42-Gbit/s directly modulated 64-QAM OFDM with 10-GHz TO-can packaged colorless laser diode, Yu-Chieh Chi[1], Chung-Yu Lin[1], Min-Chi Cheng[1], Cheng-Ting Tsai[1], Gong-Ru . Lin[1]; [1]*Graduate Institute of Photonics and Optoelectronics, National Taiwan Univ., Taiwan*. A 10-GHz TO-can packaged colorless laser diode under coherent injection-locking for 42-Gbit/s 64-QAM OFDM transmission over 25-km SMF is demonstrated to achieve the lowest BER of 4.2E-4 at a receiving power of -2 dBm.

Room 409AB

Th1I • Grooming and Traffic Asymmetry—Continued

Networking • 09:45

Room 411

Th1J • Panel: FTTH Indoor Optical Fiber Installation Technologies —Continued

10:00–12:00 Th2A • Interactive Demo and Poster Session II, *Exhibit Hall K*

10:00–13:00 Unopposed Exhibit-Only Time, *Exhibit Hall (concessions available)*

10:00–15:00 Exhibition and Show Floor, *Exhibit Hall (coffee service from 10:00–10:30)*

NOTES

10:00–12:00
Th2A • Interactive Demo & Poster II

M3A.5	W3C.2	Th3J.6
Tu2G.1	W4J.4	Th4A.2
Tu3E.2	Th2A.1	

For the full list of Interactive Demo Posters, please refer to page 18.

Th2A.1 DEMO
The Manipulated Rotating BPSK Technique Compatible with Conventional CMA Algorithm, Tao Zeng[1,2], Yong Pan[1], Ming Luo[1], Yuanxiang Wang[1], Rong Hu[1], Qi Yang[1], Shaohua Yu[1,2]; *[1]Wuhan Res. Inst Post & Telecommnication, China; [2]School of Optical and Electronic Information, Huazhong Uni. of Science and Technology, China.* This paper proposes a manipulated rotating binary phase shift keying (MR-BPSK) technique, which can use conventional constant modulus algorithm (CMA) to update the adaptive filter coefficient. This technique inherits the robust nonlinear tolerance of conventional BPSK, which is proved in 420/440km real time unrepeatered transmission experiment.

Th2A.2
On the SOA cascadability and design rules for optical packet-switched networks, Miquel A. Mestre[1], Philippe Jennevé[1], Haik Mardoyan[1], Amirhossein Ghazisaeidi[1], Sébastien Bigo[1], Guilhem de Valicourt[1]; *[1]Alcatel-Lucent Bell Labs, France.* We experimentally evaluate performances of QPSK, 8- and 16-QAM signals after traversing a long cascade of up to 50 SOAs and assess system design rules for an optical packet-switched SOA-based network.

Th2A.3
Multi-Wavelength In-band OSNR Monitoring based on Lyot-Sagnac Interferometer, Na An[1], Jifang Qiu[1], Zhuili Huang[1], Bo Yuan[1], Deming Kong[1], Jian Wu[1]; *[1]Beijing Univ of Posts & Telecom, China.* An in-band OSNR monitor based on Lyot-Sagnac interferometer is experimentally demonstrated for 4×40GBaud NRZ-QPSK WDM signal without requirement for prior knowledge of the noise-free coherence properties of the signal. OSNR from 7.5~25dB was realized.

Th2A.4
Demonstration of multi-hop optical packet switching and transmission using SOA-based optical packet switches, Satoshi Shinada[1], Ruben S. Luis[1], Hideaki Furukawa[1], Naoya Wada[1]; *[1]National Inst Information & Comm Tech, Japan.* We demonstrate a multi-hop optical packet switching using SOA-based broadband optical switches and burst-mode EDFAs. Over 450 km all-optical packet transmission was achieved by 10-hops of the optical packet switch for the first time.

Th2A.5
Multifunctional All-optical Signal Processing Scheme for Simultaneous Multichannel WDM Multicast and XOR Logic Gates Based on FWM in QD-SOA, Danshi Wang[1,2], Ming Zhang[1], Guo-Wei Lu[2,3], Jun Qin[1], Takahide Sakamoto[2], Kouichi Akahane[2], Naokatsu Yamamoto[2], Tetsuya Kawanishi[2]; *[1]Beijing Univ Posts & Telecommunications, China; [2]National Institute of Information and Communications Technology (NICT), Japan; [3]Institute of Innovation Science and Technology, Tokai Univ., Japan.* Through FWM in our fabricated QD-SOA and without additional pumps, three 1-to-3 WDM multicasts and three XOR logic gates are simultaneously realized for three 10 Gbps NRZ-DPSK signals. The error-free performance is achieved for all of the signals and the power penalties are < 1.3 dB at BER of 10^{-9}.

Th2A.6
Optical Comb-based Versatile Wavelength Division Multicasting Add-drop Node for Efficient WDM Networks, Jun Sakaguchi[1], Takahide Sakamoto[1], Atsushi Kanno[1], Yoshinari Awaji[1], Naoya Wada[1], Tetsuya Kawanishi[1]; *[1]NICT, Japan.* We demonstrate a robust and modulation-format-transparent multicasting wavelength converter based on a Mach-Zehnder optical comb generator. All the wavelength-converted channels show maximum 0.6 dB and 1.1 dB penalties for QPSK and 16QAM signals, respectively.

Th2A.7
Simple Receiving Scheme in 100-GHz DD OFDM RoF Systems Employing Low-Sampling-Rate ADCs and Digital Preprocess, Huan-Ching Liu[2], Chi-Hsiang Lin[2], Chun-Ting Lin[2], Chia Chien Wei[1], Hou-Tzu Huang[2], Hsun-Hao Hsu[2], Meng-Fan Wu[2], Sien Chi[2]; *[1]National Sun Yat-sen Univ., Taiwan; [2]National Chiao Tung Univ., Taiwan.* A simple low-sampling-rate receiving scheme is proposed for W-band OFDM-RoF systems. Using the proposed preprocess, aliasing-free subcarriers can be received, and employing the optimized delays to ADCs can achieve the performance insensitive to sampling rate.

Th2A.8
Impact of WDM Channel Spacing on Millimeter-wave Wireless Access using Wireless Coherent Radio-over-Fiber (CRoF) channels, Rattana Chuenchom[1], Sebastian Babiel[1], Matthias Steeg[1], Andreas Stohr[1]; *[1]Univ. Duisburg-Essen, USA.* Impact of channel spacing in a WDM network on the performance of wireless channels selected by the coherent optical heterodyne radio-over-fiber approach. Experimental demonstration shows a penalty of about ~1 dB per 5 GHz decreased channel spacing down to a channel spacing of 15 GHz and a penalty of ~2 dB between 15 GHz and 10 GHz channel spacing.

Th2A.9
100~200-GHz Optical Mm-wave Generation by One Modulator and Its Application in 64QAM W-band Signal Transmission System, Xinying Li[1], Jianjun Yu[1,2], Jiangnan Xiao[1], Yuming Xu[1], Ziran Zhang[1], Long Chen[1]; *[1]Fudan Univ., China; [2]ZTE (TX) Inc., USA.* We experimentally demonstrate 100~200-GHz mm-wave generated by only one intensity modulator driven by a 100-GHz RF signal can carry 10-Gbaud 64QAM signal to realize 2-m wireless delivery with a BER under 2×10^{-2}.

Th2A.10
Carrier Recovery Techniques for Semiconductor Laser Frequency Noise for 28 Gbd DP-16QAM, Miguel Iglesias Olmedo[1,2], Xiaodan Pang[3], Molly Piels[2], Richard Schatz[1], Gunnar Jacobsen[3], Sergei Popov[1], Idelfonso Tafur Monroy[2], Darko Zibar[2]; *[1]Optics division, Royal Institute of Technology (KTH), Sweden; [2]Technical Univ. of Denmark, Denmark; [3]Networking and Transmission Laboratory, Acreo AB, Sweden.* We report on the first experimental comparison of DD-PLL, two-stage feed forward, and two variations of extended Kalman filtering for tracking semiconductor laser frequency noise. We identify which carrier phase recovery technique works best depending on the carrier induced frequency noise profile.

Th2A.11
Advanced Detection of Super-Nyquist WDM QPSK Signals with 5-bit/s/Hz Spectral Efficiency, Sai Chen[1], Chongjin Xie[2], Jie Zhang[1]; *[1]Beijing Univ of Posts & Telecom, China; [2]Bell Laboratories, Alcatel-Lucent, USA.* We show that using a quadrature 4-level polybinary detection scheme together with maximum-likelihood-sequence estimation, we can achieve a 5-bit/s/Hz spectral efficiency for super-Nyquist WDM quadrature-phase-shift-keyed signals, with performance comparable to 16-ary quadrature-amplitude modulation.

Th2A.12
Linearity Requirements of QAM Transmitters, Stuart Hughes[1], Jie Pan[1], Jerrod Langston[1], Pierre Isautier[1], Hari Shankar[2], Stephen Ralph[1]; *[1]Georgia Tech, USA; [2]Inphi Corporation, USA.* 16, 64QAM, and higher-modulation formats impose strict linearity requirements on the modulator-driver response. We experimentally demonstrate the relation between transmitter nonlinearity and constellation distortion. Simulations confirm experimental data for a wide range of harmonic distortion.

Th2A.13
Transceiver-Limited High Spectral Efficiency Nyquist-WDM Systems, David Millar[1], Robert Maher[2], Domanic Lavery[2], Toshiaki Koike-Akino[1], Alex Alvarado[2], Milen Paskov[2], Keisuke Kojima[1], Kieran Parsons[1], Benn C. Thomsen[2], Seb J. Savory[2], Polina Bayvel[2]; *[1]Mitsubishi Electric Research Labs, USA; [2]Univ. College London (UCL), UK.* We experimentally examine the maximum achievable transmission performance of a 7 channel Nyquist-WDM system with 10GBd per carrier. Back-to-back, a maximum of 11.9 bit/sym and 13.8 bit/sym can be transmitted for DP-64QAM and DP-256QAM respectively, while after 2 spans of transmission, a maximum of 12.4 bit/sym and 11.6 bit/sym can be achieved.

Th2A.14
PDL-Tolerant Signal Generation by Digital Spectrum Slicing and Polarization Control, Takahito Tanimura[1], Tomofumi Oyama[1], Hisao Nakashima[1], Jens C. Rasmussen[1]; *[1]Fujitsu Laboratories Ltd., Japan.* We propose a novel PDL-tolerant signal generation and reception method without additional optical devices and numerically demonstrate its efficiency for a 128 Gbit/s 2 subcarrier Nyquist-FDM DP-QPSK signal.

Th2A.15
4D-CMA: Enabling Separation of Channel Compensation and Polarization Demultiplex, Fred Buchali[1], Henning Buelow[1], Karsten Schuh[1], Wilfried Idler[1]; *[1]Alcatel-Lucent Bell Labs, Germany.* We propose a 4D-CMA feedback for butterfly filter adaptation enabling separation of channel compensation and polarization demultiplex. Using a digital polarization controller for demultiplex we demonstrate feasibility and ~10-fold speed increase compared to standard CMA.

Th2A.16
Performance and Advantages of 100 Gb/s QPSK/8QAM Hybrid Modulation Formats, Fred Buchali[1], Wilfried Idler[1], Laurent Schmalen[1], Karsten Schuh[1]; *[1]Alcatel-Lucent Bell Labs, Germany.* We designed and compared time-domain hybrid-modulation formats with adaptive symbolrates and adaptive code rates to optimize the reach of variable grid 100 Gb/s systems. Experimental comparisons quantify linear, non-linear and coding gain of various schemes.

Th2A.17
Comparative Digital Mitigations of DAC Clock Tone Leakage in a Single-Carrier 400G System, Yanjun Zhu[1], Wei-Ren Peng[1], Yan Cui[1], Clarence Kan[1], Fei Zhu[1], Yusheng Bai[1]; *[1]Huawei Technologies (USA), USA.* We investigate performances of two digital methods for suppression of clock tone leakages of an 80GS/s high-speed DAC supporting single-carrier 400G. A novel clock leakage mitigation technique is experimentally demonstrated for the first time.

Th2A.18
Generation of 448-Gbps OTDM-PDM-16QAM Signal with an Integrated Modulator Using Orthogonal CSRZ Pulse, Hiroshi Yamazaki[1,2], Takashi Goh[1], Toshikazu Hashimoto[1], Akihide Sano[2], Yutaka Miyamoto[2]; *[1]NTT Device Technology Laboratories, Japan; [2]NTT Network Innovation Laboratories, Japan.* We generated a 56-Gbaud single-carrier PDM-16QAM signal using a single integrated modulator driven with 28-Gbaud electronic signals. Two orthogonal CSRZ pulses generated in the modulator are used for spectrally efficient OTDM.

Th2A.19
Enhancing Clock Tone via Polarization Pre-rotation: A Low-complexity, Extended Kalman Filter-based Approach, Wing-Chau Ng[1], An T. Nguyen[1], Chul Soo Park[1], Leslie A. Rusch[1]; *[1]Universite Laval, Canada.* We experimentally verified that our proposed low-complexity extended Kalman filter-based polarization pre-rotation at ASIC rates enhances the clock tone of polarization-multiplexed signals.

Th2A • Interactive Demo & Poster II—Continued

Th2A.20
Performance of Joint Iterative Detection and Decoding in Coherent Optical Channels, Mario A. Castrillón[1], Damian A. Morero[1,3], Oscar E. Agazzi[2], Mario R. Hueda[1]; [1]*Laboratorio de Comunicaciones Digitales, Universidad Nacional de Córdoba, Argentina;* [2]*ClariPhy Communications, Inc. , USA;* [3] *ClariPhy Argentina S.A., Argentina.* We show that a joint iterative detection and decoding algorithm compensates phase noise and laser frequency fluctuations in a 100 Gb/s coherent optical receiver with non-differential 16-QAM modulation, achieving 1 dB gain over existing solutions.

Th2A.21
Agnostic Software-Defined Coherent Optical Receiver Performing Time-Domain Hybrid Modulation Format Recognition, Pierre Isautier[1], Jerrod Langston[1], Jie Pan[1], Stephen Ralph[1]; [1]*Georgia Institute of Technology, USA.* We present a novel DSP architecture for coherent optical receivers that identifies time-domain hybrid modulation formats without any prior knowledge of the received signal. Experimental investigation demonstrates successful identification of 31.5GBaud TDHMF signals composed with BPSK/QPSK/8QAM/16QAM after 810km transmission.

Th2A.22
Addition of In-band Crosstalk to the Gaussian Noise Model, Jie Pan[1], pierre isautier[1], Mark Filer[2], Sorin Tibuleac[2], Stephen Ralph[1]; [1]*Georgia Institute of Technology, USA;* [2]*Adva optical Networking, USA.* The combination of a spectral weighting metric and a colored-to-white noise weighting factor incorporates crosstalk into the Gaussian noise model providing a performance prediction tool requiring no direct measurement of crosstalk impact on system sensitivity.

Th2A.23
LDPC Coded Modulation with Probabilistic Shaping for Optical Fiber Systems, Tobias Fehenberger[1], Georg Böcherer[1], Alex Alvarado[2], Norbert Hanik[1]; [1]*Institute for Communications Engineering, Technische Universität München, Germany;* [2]*Optical Networks Group, Univ. College London (UCL), UK.* An LDPC coded modulation scheme with probabilistic shaping, optimized interleavers and noniterative demapping is proposed. Full-field simulations show an increase in transmission distance by 8% compared to uniformly distributed input.

Th2A.24
Optoelectronic method for distributed compensation of XPM in long haul WDM systems, Benjamin Foo[1], Bill Corcoran[1,2], Arthur Lowery[1,2]; [1]*Electrical and Computer Systems Engineering, Monash Univ., Australia;* [2]*Centre for Ultrahigh bandwidth Devices for Optical Systems, Australia.* We propose an optoelectronic method for distributed compensation of XPM based on power-dependent phase rotation. Simulations show 2.7-dB improvement in peak Q for a 28-Gbaud QPSK channel with 14-Gbit/s NRZ-OOK neighbors after 3200-km transmission.

Th2A.25
Two Orthogonal Carriers Assisted 82-Gb/s Dual-band DDO-OFDM Transmission over 320-km SSMF, Rong Hu[2], Qi Yang[2], Ming Luo[2], Shaohua Yu[2], Zhang Zhang[1], Junbo Xu[1]; [1]*Fiberhome, China;* [2]*State Key Laboratory of Optical Comm. Technologies and Networks, China.* We propose a fading-free direct detection method for transmission of complex-value OFDM signal in metro distances. By using two orthogonal optical carriers, an 82-Gb/s dual-band transmission is demonstrated over 320-km SSMF within only 30-GHz electrical bandwidth.

Th2A.26
Design of Enhanced Channel Equalizers for Adaptive Zero-Guard-Interval CO-OFDM Systems, Wei Wang[1], Qunbi Zhuge[1,2], Yuliang Gao[1,3], David Plant[1]; [1]*Mcgill Univ., Canada;* [2]*Ciena corporation, Canada;* [3]*The Hong Kong Polytechnic Univ., Hong Kong.* We propose the design of frequency domain block least-mean-square and recursive-least-square equalizers for adaptive zero-guard-interval CO-OFDM systems. Improvements in the channel estimation accuracy and channel tracking speed are experimentally and numerically demonstrated.

Th2A.27
Performance Optimization in ROADM-Enabled DWDM Systems Using Flexible Modulation Formats, Wei Wang[1], Qunbi Zhuge[1,2], Yuliang Gao[1,3], Xian Xu[1], David Plant[1]; [1]*Mcgill Univ., Canada;* [2]*Ciena Corporation, Canada;* [3]*The Hong Kong Polytechnic Univ., Hong Kong.* The time domain hybrid QAM enabled flexible transceiver is proposed to adaptively optimize the transmission performance in DWDM systems with cascaded ROADMs. Comprehensive performance investigations are conducted for both fixed and flexible grid systems.

Th2A.28
Parallel Split-Step Method for Digital Backpropagation, Fernando P. Guiomar[2,1], Sofia B. Amado[2,1], Celestino S. Martins[1], Armando N. Pinto[2,1]; [1]*Instituto de Telecomunicações, Portugal;* [2]*Univ. of Aveiro, Department of Electronics, Telecommunications and Informatics, Portugal.* We propose a novel split-step method for digital backpropagation in which the linear and nonlinear steps are applied in parallel, favouring hardware implementation. Numerical results show significant performance advantage over the classic split-step Fourier method.

Th2A.29
Adaptive Pre-equalization using Bidirectional Pilot Sequences to Estimate and Feed Back Amplitude Transfer Function and Chromatic Dispersion, Seiji Okamoto[1], Mitsuteru Yoshida[1], Kazushige Yonenaga[1], Tomoyoshi Kataoka[1]; [1]*NTT corporation, USA.* We propose an adaptive pre-equalization system that compensates the amplitude transfer function and chromatic dispersion using estimates transmitted from the receiver. Two kinds of pilot sequences are used for estimation and mutual communication.

Th2A.30
6.27 bit/s/Hz Spectral Efficiency VCSEL-based Coherent Communication over 800km of SMF, Gianluca Meloni[1], Antonio Malacarne[1], Francesco Fresi[2], Luca Poti[1]; [1]*National Laboratory of Photonic Networks, CNIT, Italy;* [2]*TeCIP, Scuola Superiore Sant'Anna, Italy.* 125.5Gbps dual-polarization QPSK coherent transmission with sub-Nyquist 6.27bit/s/Hz-spectral efficiency is demonstrated in regional flex-grid WDM scenario up to 800km of SMF. Two commercial VCSELs are used at the transmitter and as local oscillator respectively.

Th2A.31
Noise Characterization and Transmission Evaluation of Unrepeated Raman Amplified DP-16QAM Link, Atalla El-Taher[2], Xiaodan Pang[1], Richard Schatz[3], Gunnar Jacobsen[1], Sergei Popov[3], Sergey Sergeyev[2]; [1]*Acreo AB, Sweden;* [2]*Aston Univ., UK;* [3]*Optics division, Royal Institute of Technology (KTH), Sweden.* Impairments characterization and performance evaluation of Raman amplified unrepeated DP-16QAM transmissions are conducted. Experimental results indicate that small gain in forward direction enhance the system signal-to-noise ratio for longer reach without introducing noticeable penalty.

Th2A.32
Comparison between Square and Stepped-Square QAM for Optical Transmission, Ahmed Awadalla[1], Kuang-Tsan Wu[1], David Yevick[2]; [1]*Infinera, Canada;* [2]*Univ. of Waterloo, Canada.* We present a comparison of QAM and stepped-square QAM (SS-QAM) for optical transmission. While offering lower average power and 2D peak-to-average power ratio (PAPR), SS-QAM suffers a penalty in baseband due to higher 1D-PAPR.

Th2A.33
Experimental Investigation on Crosstalk of FSK Supervisory Signal in ROADM networks, Guoxiu Huang[1], Goji Nakagawa[1], Shoichiro Oda[1], Kyosuke Sone[1], Setsuo Yoshida[1], Yasuhiko Aoki[1], Jens C. Rasmussen[1]; [1]*Fujitsu Laboratories Ltd., Japan.* The crosstalk of FSK supervisory signal encoded on 80×128Gbit/s DP-QPSK WDM channels in CNCG-ROADM networks was experimentally and theoretically estimated. The simulation results confirm that 30-cascaded ROADM could be supported with proper FSK signal decoder parameters.

Th2A.34
Field transmission of uncompressed ultra-high definition video signals through dynamic optical path network, Takayuki Kurosu[1], Satoshi Suda[1], Takashi Inoue[1], Junya Kurumida[1], Junishiro Kawamoto[2], Tsuyoshi Nakatogawa[2], Shu Namiki[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan;* [2]*Japan Broadcasting Corporation, Japan.* We demonstrate, for the first time, transmission of 86-Gb/s ultra-high definition video signals from Tokyo to Tsukuba over 173 km. Successful operation was confirmed through bit-error-rate < 10^{-9} and noise-free videos displayed on the screen.

Show Floor Programming

■ **Market Watch**

10:30–12:30
Panel VI: Do Carriers really want Network Convergence or Maintain Equipment Divergence?
For more details, see page 40

Th2A • Interactive Demo & Poster II—Continued

Th2A.35
First Demonstration of Service-Differentiated Converged Optical Sub-Wavelength and LTE/WiFi Networks over GEANT, Bijan Rahimzadeh Rofoee[1], kostas katsalis[2], Yan Yan[1], Yi Shu[1], Thanasis Korakis[2], Leandros Tassiulas[2], Anna Tzanakaki[1], Georgios S. Zervas[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]Univeristy of Thessaly, Greece.* A converged optical-wireless testbed is formed integrating TSON sub-wavelength networking in UK and the NITOS wireless solution in Greece. End-to-end service provisioning and flow differentiation are demonstrated across two networks communicating over the GEANT.

Th2A.36
FlowBroker: Market-Driven Multi-Domain SDN With Heterogeneous Brokers, Dan Marconett[1], S. J. B. Yoo[1]; *[1]UC Davis, USA.* We present an enhanced market-driven multi-broker architecture for multi-domain SDN forwarding, in which heterogeneous brokers compete for domain customers and can peer with one another to provide enhanced services if economically beneficial.

Th2A.37
Scalable Virtual Network Provisioning over Distance-Adaptive Flexible Grid Optical Networks, Yi Zhu[1], Kevin K. Goo[1], Yan Liang[1], Qiong Zhang[2], Xi Wang[2], Paparao Palacharla[2], Motoyoshi Sekiya[2]; *[1]Hawaii Pacific Univ., USA; [2]Fujitsu Laboratories of America, Inc., USA.* We propose a game theory based heuristic for provisioning virtual networks over distance-adaptive flexible grid optical networks. Our approach obtains close-to-optimal solutions with scalable and fast computation, which is critical for handling on-demand requests.

Th2A.38
Reliability-Constrained Resource Allocation with Weighted SRLG for Distributed Clouds, Yi Zhu[1], Yan Liang[1], Kevin K. Goo[1], Qiong Zhang[2], Xi Wang[2], Paparao Palacharla[2], Motoyoshi Sekiya[2]; *[1]Hawaii Pacific Univ., USA; [2]Fujitsu Laboratories of America, Inc., USA.* We propose heuristics to allocate virtual machines among distributed data centers for a cloud request. Our objective is to minimize the maximum delay between selected data centers, while considering the reliability and computing resource constraints.

Th2A.39
Distributed Control Plane with Spectral Fragmentation-aware RMSA and Flexible Reservation for Dynamic Multi-domain Software-defined Elastic Optical Networks, Hai-Chau Le[1], Lei Liu[1], S. J. B. Yoo[1]; *[1]Univ. of California, Davis, USA.* We propose a distributed control scheme utilizing spectral fragmentation-aware RMSA and flexible active/passive reservation mechanism for dynamic multi-domain software-defined elastic optical networks. Our proposed scheme offers significant blocking probability reduction compared to conventional GMPLS/PCE architecture.

Th2A.40
Experimental Seamless Virtual Machine Migration Using an Integrated SDN IT and Network Orchestrator, Arturo Mayoral López de Lerma[1], Ricard Vilalta[1], Raul Muñoz[1], Ramon Casellas[1], Ricardo Martínez [1]; *[1]CTTC, Spain*. This paper demonstrates an experimental Virtual Machine (VM) migration across several network domains (intra/inter-datacenter) while the VM network connection state is maintained. A SDN IT and Network Orchestrator is responsible for the VM seamless migration.

Th2A.41
Demonstration of SDN orchestration in optical multi-vendor scenarios, Victor Lopez[1], Oscar Gonzalez de dios[1], Louis Miguel[1], Joshua Foster[2], Hector Silva[2], Loudon Blair[2], Joseph Marsella[2], Thomas Szyrkowiec[3], Achim Autenrieth[3], Chris Liou[4], Abhinava Sadasivarao[4], Sharfuddin Syed[4], John Sunjun[5], Baoquan Rao[5], Fatai Zhang[5]; *[1]Telefonica I+D, Spain; [2]Ciena, USA; [3]ADVA, Germany; [4]Infinera, USA; [5]Huawei, China*. SDN brings automation to network operation and abstracts the complexity of optical networks. An orchestration layer is required to support multivendor interoperability scenarios. This work demonstrates that an ABNO architecture enables SDN controlled domain interoperability.

Th2A.42
Best Effort Multi-Rate Optical Networks, Yamini Jayabal[1], Yue Fei[1], Andrea Fumagalli[1], Rosanna Pastorelli[2], Gabriele Galimberti[2], Giovanni Martinelli[2]; *[1]Univ. of Texas at Dallas, USA; [2]Cisco Photonics Italy srl, Italy.* Load-aware signal power selection strategies are applied while planning multi-rate optical networks intended to carry best effort traffic. Network fiber spans are carefully classified as either full-load or odd-only, trading wavelengths for improved OSNR.

Th2A.43
CapEx Advantages of Few-Mode Fiber Networks, Yao Li[1,2], Nan Hua[1,2], Xiaoping Zheng[1,2], Guifang Li[3,4]; *[1]1. National Laboratory for Tsinghua Information Science and Technology, China; [2]2. Department of Electronic Engineering, Tsinghua Univ., China; [3]3. CREOL, The College of Optics & Photonics , Univ. of Central Florida, USA; [4]4. College of Precision Instrument and Opto-Electronic Engineering, Tianjin Univ., China*. CapEx minimization for few-mode fiber networks is studied for different traffic patterns for the first time. FMF networks can have significant CapEx advantages for bulk data transfer and for fine-granularity switching by deploying MDM-compatible WSSs.

Th2A.44
Impact of Fanout and Transmission Reach on Performance of Multicasting in Elastic Optical Networks, Krzysztof Walkowiak[1], Roza Goscien[1], Massimo Tornatore[2], Michal Wozniak[1]; *[1]Wroclaw Univ. of Technology, Poland; [2]Politecnico di Milano, Italy, Italy.* The impact of fanout and transmission reach on provisioning of static multicast traffic in Elastic Optical Networks is studied. Result of numerical experiments are presented to show the impact in terms of spectrum and regenerator usage.

Th2A.45
Utilization of Spectrum Slot Fragmentation to Improve Network Resource Efficiency on Elastic Optical Network, Shinsuke Fujisawa[1], HItoshi Takeshita[1], Tomoyuki Hino[1], Akio Tajima[1], Kiyoshi. Fukuchi[1]; *[1]NEC Corporation, Japan*. A novel utilization technique of spectrum slot fragmentation is proposed for elastic optical network. By network simulation, we have confirmed the advantage of our technique and its performance improvement becomes larger for optical nodes without wavelength contention.

Th2A.46
On the Cost of Protection in Optical Slot Switching Rings with Elastic Transponders, Bogdan Uščumlić[1], Yvan Pointurier[1], Annalisa Morea[1], Sébastien Bigo[1]; *[1]Alcatel-Lucent Bell Labs France, France*. We propose an optimal network dimensioning model for different configurations of optical slot switching metropolitan rings with elastic-rate transponders. Sharing transponders across the two ring directions along with standard "shared protection" minimizes protection cost.

Th2A.47
Highly Scalable Subsystem Modular OXC Nodes that Host Tailored Add/drop Mechanism, Hiroto Ishida[1], Hiroshi Hasegawa[1], Ken-ichi Sato[1]; *[1]Nagoya Univ., Japan*. We propose and optimize as a complete entity, a novel highly scalable subsystem modular OXC architecture that employs an efficient add/drop part. Numerical experiments prove significant hardware scale reduction compared to the conventional architecture.

Th2A.48
A comparison study of joint and sequential multi-layer planning for IP over flexible optical networks, Vasileios Gkamas[1,2], Konstantinos Christodoulopoulos[1,2], Emmanouel Varvarigos[1,2]; *[1]Univ. of Patras, Greece; [2]Computer Technology Institute and Press "Diophantus", Greece.* We propose a joint multi-layer planning algorithm for IP over flexible optical networks, and use it, to compare the performance of joint as opposed to sequential multi-layer network planning in terms of spectrum and cost.

Th2A.49
Renewable-Energy-Aware Data Center Placement in Optical Cloud Networks, Yu Wu[1], Massimo Tornatore[2], Saigopal Thota[3], Biswanath Mukherjee[3]; *[1]Electrical & Computer Engineering, Univ. of California, Davis, USA; [2]Computer Science, Politecnico di Milano, Italy; [3]Computer Science, Univ. of California, Davis, USA.* We solve the problem of datacenter placement in optical cloud networks with the aim of jointly minimizing the non-renewable datacenter energy consumption and the number of DCs. Lexicographic optimization is utilized to balance the two objectives.

Th2A.50
New ROADMs with DSP-Enabled Dynamic and Flexible Operations for Elastic Optical Networks, Jianming TANG[1], Wei Jin[1], Xiao Duan[1], Mario Bolea[1], Roger Giddings[1], Ning Jiang[1], chongfu Zhang[2], Kun Qiu[2]; *[1]Bangor Univ., UK; [2]UESTC, China*. Flexible ROADMs for architecture on demand are proposed and investigated, for the first time, which offer DSP-enabled dynamic operations at wavelength, sub-wavelength and orthogonal sub-band levels, continuous add-channel frequency tuneablility, and10dB drop-channel sensitivity improvements.

Th2A.51
Intra-Cavity Dispersion-Induced Performance Degradations of Dual-RSOA-Based Self-Seeded PON Systems, Jianming Tang[1], Mingliang Deng[1], Bingyao Cao[1], Roger Giddings[1], Yixian Dong[1], Ning Jiang[2], Derek Nesset[3], Kun Qiu[2]; *[1]Bangor Univ., UK; [2]Key Laboratory of Optical Fiber Sensing and Communications, Univ. of Electronic Science and Technology of China, China; [3]British Telecommunications Laboratories, UK.* Experiments show that, compared to 10m-long dual-RSOA self-seeded cavities, 1km-long cavity's chromatic dispersions considerably broaden signal spectral widths, increase RINs by 4.8dB, and cause 2.2dB power penalty degradations for 10Gb/s@25km adaptive OOFDM self-seeded PON systems.

Th2A.52
Stimulated Raman Scattering Impairments Induced by NGPON2 Introduction in Co-existing PONs, Gael Simon[1,2], Fabienne Saliou[1], Philippe Chanclou[1], Bertrand Le Guyader[1], Laurent Guillo[1]; *[1]Orange Labs, France; [2]Telecom ParisTech, France.* We investigate on NG-PON2 introduction effects in a coexisting PON topology. Simple optical power measurements permit to demonstrate that stimulated Raman scattering brings up to 3.9dB extra-losses on GPON. No other significant impairments were observed.

Th2A.53
AMO-FBMC for Reduction of Multiple Access Interference between Asynchronous ONUs in PON, Sun-Young Jung[1], Sang-Min Jung[1], Sang-Kook Han[1]; *[1]Yonsei Univ., Korea (the Republic of)*. OFDM has interference problem due to sidelobes, which hinders OFDM-based multiple access in optical uplink. By employing filter bank-based multicarrier (FBMC), we experimentally verified relaxation of multiple access interference and improvements of performance and capacity.

Th2A • Interactive Demo & Poster II—Continued

Th2A.54
1.5-µm, 21.4-Gbps 4-PAM VCSEL Link for Optical Access Applications , Jingjing Zhou[1], Changyuan Yu[1,3], Hoon Kim[2]; *[1]National Univ. of Singapore, Singapore; [2]Electrical Engineering, Korea Advanced Institute of Science & Technology, Korea (the Republic of); [3]A*STAR Institute for Infocomm Research (I2R), Singapore.* We investigate the transmission performance of 21.4-Gbps 4-PAM signals generated by using a 1.54-µm VCSEL. We achieve >8-dB power budget after 15-km transmission over SSMF by optimizing the extinction ratio and utilizing electronic equalization.

Th2A.55
Application-Aware Software-Defined EPON Upstream Resource Allocation, Divya Chitimalla[1], Saigopal Thota[1], S. Sedef Savas[1], Sang-Soo Lee[2], Han-Hyub Lee[2], Soomyung Park[2], Biswanath Mukherjee[1]; *[1]Univ. of California Davis, USA; [2]Electronics and Telecommunications Research Institute, Korea (the Republic of).* We study an SDN-enabled EPON architecture that utilizes application information from clients to achieve superior upstream resource allocation. This leads to better quality of experience of video-conferencing clients which are high consumers of upstream bandwidth.

Th2A.56
Photonics-Assisted Microwave Mixing and Direct Detection for Dual-Polarization and SCM based UDWDM-PON, Jianyu Zheng[1,2], Feng Lu[2], Mu Xu[2], Ming Zhu[2], Ibrahim Khalil[2], Jianguo Liu[1], Ninghua Zhu[1], Gee-Kung Chang[2]; *[1]Chinese Academy of Sciences, China; [2]School of Electrical and Computer Engineering, Georgia Institute of Technology, USA.* A novel photonics-assisted unconventional double-sideband sub-carrier modulation is proposed for dual-polarization UDWDM-PON with direct detection. High spectral-efficiency is achieved by removing the band-limited electrical mixing components.

Th2A.57
Extension of Self-Seeding to 10/2.5Gb/s T(W)DM PONs through Remotely Pumped ODN Extenders, Josep Prat[1], Bernhard Schrenk[2,1], Francesc Bonada[1], Guilhem de Valicourt[3], Jose A. Lazaro[1], Romain Brenot[4]; *[1]Universitat Politecnica de Catalunya, Spain; [2]Safety&Security, Austrian Institute of Technology, Austria; [3]Alcatel-Lucent Bell Labs, USA; [4]III-V labs, France.* Self-seeded upstream transmission is applied to power-splitting PONs through remote amplification at extender boxes. Tree splits up to 1:16 are found to be compatible for full-duplex 10/2.5Gb/s PONs with fully passive optical distribution network.

Th2A.58
UDWDM PON with 6 X 2.5GBaud 16-QAM Multicarrier Transmitter and Phase Noise Tolerant Direct Detection, Prince M. Anandarajah[1], Tam N. Huynh[1], Vidak Vujicic[1], Rui Zhou[1], Liam P. Barry[1]; *[1]Dublin City Univ., Ireland.* We demonstrate a 50km un-repeated downstream transmission based on a 12.5GHz comb source with 6 channels, each carrying 2.5GBd 16-QAM data. The pilot tone enables direct detection and phase noise independence delivering 10Gb/s per user.

Th2A.59
Real-Time Coherent ONU for λ-to-the-user Based on Fully Analogue Processing of OOK Signals, fabio bottoni[1], Marco Presi[1], Massimo Artiglia[1], Josep Prat[2], Ernesto Ciaramella[1]; *[1]scuola superiore sant'anna, Italy; [2]Universitat Politecnica de Catalunya, Spain.* Using fully-analogue and commercially available electronics, we realize a real-time coherent ONU receiver for Ultra-Dense WDM-PON based on intensity-modulated signals. The receiver also requires common photonic components and has -47dBm sensitivity at FEC level.

Th2A.60
Optimal Polarization Launch for Raman Depletion Minimization in GPON and TWDM-PON Coexistence, Mattia Cantono[1], Vittorio Curri[1], Antonio Mecozzi[2], Roberto Gaudino[1]; *[1]Politecnico di Torino, Italy; [2]Università dell'Aquila, Italy.* TWDM-PON (ITU-T G.989) will induce relevant extra-attenuation when operating in full coexistence with GPON due to Raman nonlinearity. We give a detailed analysis of optimal polarization launch options.

Th2A.61
Measurement of Direct Modulated Laser Frequency-Drift in Burst-Mode and Impact on Narrowly Filtered Receivers, Wolfgang Poehlmann[1], Doutje van Veen[2], Harald Schmuck[1], Bernhard Deppisch[1], Rene Bonk[1], Thomas Pfeiffer[1]; *[1]Alcatel-Lucent Deutschland AG, Bell Labs , Germany; [2]Alcatel-Lucent USA Inc., Bell Labs , USA.* The frequency-drift under burst-mode operation is evaluated. A fast drift at start of burst is found that has inverted sign compared to thermal drift. The impact on narrowly filtered receivers is studied by BER measurements.

Th2A.62
An SDN-based Integration of Green TWDM-PONs and Metro Networks Preserving End-to-End Delay, Koteswararao Kondepu[2], Andrea Sgambelluri[2], Luca Valcarenghi[2], Filippo Cugini[1], Piero Castoldi[2]; *[1]CNIT, Italy; [2]Scuola Superiore Sant Anna di Pisa, Italy.* A novel latency-aware aggregation node architecture supporting TWDM-PONs is successfully demonstrated. The node, performing traffic scheduling according to sleep-mode operations, includes a lightweight SDN solution, scaled to operate as intra-node controller.

Th2A.63
Experimental Demonstration of Passive Optical Network Based on Mode-Division-Multiplexing, Tao Hu[1], Juhao Li[1], Paikun Zhu[1], Qi Mo[2], Yili Ke[2], Cheng Du[2], Zhijian Liu[2], Yongqi He[1], Zhengbin Li[1], Zhangyuan Chen[1]; *[1]Peking Univ., China; [2]Wuhan Research Institute of Posts and Telecommunications, China.* We propose and experimentally demonstrate passive optical network based on mode-division-multiplexing. Two individual linearly polarized (LP) modes are successfully transmitted over 1.8-km low-modal-crosstalk few-mode optical fiber and demultiplexed with error-free performance.

Th2A.64
Experimental Demonstration of Optical Labeled Superchannel Switching for Elastic Optical Network, Zhongying Wu[1], Juhao Li[1], Paikun Zhu[1], Xin Chen[1], Jing Guan[1], Yingying Xu[1], Zhangyuan Chen[1], Yongqi He[1]; *[1]Peking Univ., China.* We propose a node architecture supporting optical labeled superchannel switching scheme for elastic optical network. Flexible superchannel/label generation and detection based on optical comb, label swapping with extraction, erasure, re-add are experimentally demonstrated.

Th2A.65
High Performance 400 Gigabit Ethernet Links using Hybrid Multiband CAP/QAM Scheme, Jinlong Wei[1], Qixiang Cheng[2], David Cunningham[3], Richard V. Penty[2], Ian White[2], Helmut Griesser[1]; *[1]ADVA Optical Networking SE, Germany; [2]Univ. of Cambridge, UK; [3]AVAGO Technologies , UK.* We propose the first combined 4×100Gb/s hybrid multiband CAP-16 transmitter and QAM-16 receiver system and simulations show that it has 0.7 dBo (2.2 dBo) more power margin than 8×50Gb/s (4×100Gb/s) PAM-4 over DML (EML) SMF link.

Th2A.66
1.3 µm SDN-enabled Optical Packet Switch Architecture for High Performance and Programmable Data Center Network, Wang Miao[1], Fernando Agraz[2], Huug de Waardt[1], Salvatore Spadaro[2], Harm J. Dorren[1], Nicola Calabretta[1]; *[1]Eindhoven Univ. of Technology, Netherlands; [2]Universitat Politècnica de Catalunya, Spain.* We demonstrate a 1.3 µm port-count scalable SDN-enabled optical packet switch architecture for programmable data-center networks. Experimental assessments of a 40Gb/s 4x4 switch system with SDN-control show $<10^{-5}$ packet-loss and <430ns latency for 0.5 load.

Th2A.67
Single channel 112Gbit/sec PAM4 at 56Gbaud with digital signal processing for data centers applications , Dan Sadot[1,2], Guy Dorman[2], Albert Gorshtein[2], Eduard Sonkin[2], Or Vidal[2]; *[1]Ben Gurion Univ. of the Negev , Israel; [2]MultiPhy, Israel.* 112Gbit/sec DSP-based single channel PAM4 at 56Gbaud that fits into QSFP is experimentally demonstrated. The DSP enables use of mature 25G optoelectronics for 2-10km datacenter intra-connections, and 8Tbit/sec over 80km interconnections between data centers.

■ **Market Watch**

10:30–12:30
Panel VI: Do Carriers really want Network Convergence or Maintain Equipment Divergence?
For more details, see page 40

Room 402AB

13:00–15:00
Th3A • Short Reach
Presider: Christopher Cole; Finisar Corporation, USA

Th3A.1 • 13:00 Invited
Solutions for 80km DWDM Systems, Annika Dochhan[1], Helmut Griesser[1], Michael . Eiselt[1], Joerg-Peter Elbers[1]; [1]*ADVA Optical Networking SE, Germany.* We review currently discussed solutions for 80 km DWDM transmission targeting inter data-center connections at 100G and 400G line rates. PDM-64QAM, PAM4 and DMT are investigated, while the focus lies on directly detected solutions.

Room 403A

13:00–15:00
Th3B • Future of Broadband Access I: Trends and Drivers
Presiders: Neda Cvijetic; NEC Laboratories America Inc., USA and Junichi Kani; NTT Access Service Systems Laboratories, Japan

Th3B.1 • 13:00 Invited
Application Drivers and Trends for Future Broadband Access, Tomoaki Yoshida[1], Tomohiro Taniguchi[1], Akihiro Otaka[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan.* We address the future access service and system requirements in Japan. We must ensure that sufficient bandwidth is available for future mobile and IP-TV services. We propose an optical access platform to meet these different requirements.

Room 403B

13:00–15:00
Th3C • Exploring Fiber Limits
Presider: Oleg Sinkin; TE SubCom, USA

Th3C.1 • 13:00 Invited
Low Loss and Low Nonlinearity Fibers for Long Haul Transmission, Yoshinori Yamamoto[1], Yuki Kawaguchi[1], Masaaki Hirano[1]; [1]*Sumitomo Electric Industries Ltd, Japan.* We review advance of pure-silica-core fiber with ultra-low loss of 0.15dB/km and large Aeff of 130μm^2. This fiber is applicable for C+L-band broadband transmission in submarine ultra-long links, exhibiting sufficiently low macro- and micro-bending losses.

Room 404AB

13:00–15:00
Th3D • Nonlinear Interference: Modeling and Mitigation I
Presider: Cristian Antonelli; Universita degli Studi dell'Aquila, Italy

Th3D.1 • 13:00
A Multi-stage Perturbation Technique for Intra-channel Nonlinearity Compensation, Xiaojun Liang[1], Shiva Kumar[1]; [1]*Department of Electrical and Computer Engineering, McMaster Univ., Canada.* Using a multi-stage perturbation technique to compensate intra-channel nonlinearities, the computational complexity is reduced by a factor up to 9.3 and the Q-factor improvement over linear compensation is increased from 1.7 dBQ to 2.7 dBQ.

Th3D.2 • 13:15
Training-based Determination of Perturbation Coefficients for Fiber Nonlinearity Mitigation, Wei-Ren Peng[1], Zhihong Li[1], Fei Zhu[1], Yusheng Bai[1]; [1]*Futurewei Technologies Inc., USA.* A new training method to determine perturbation coefficients for fiber nonlinearity mitigation is proposed and experimentally demonstrated. This method can deliver reliable coefficients for arbitrary pulse shapes, CD and power profiles without the full knowledge of system parameters.

Room 406AB

13:00–15:00
Th3E • Forward Error Correction Codes
Presider: David Millar; Mitsubishi Electric Research Labs, USA

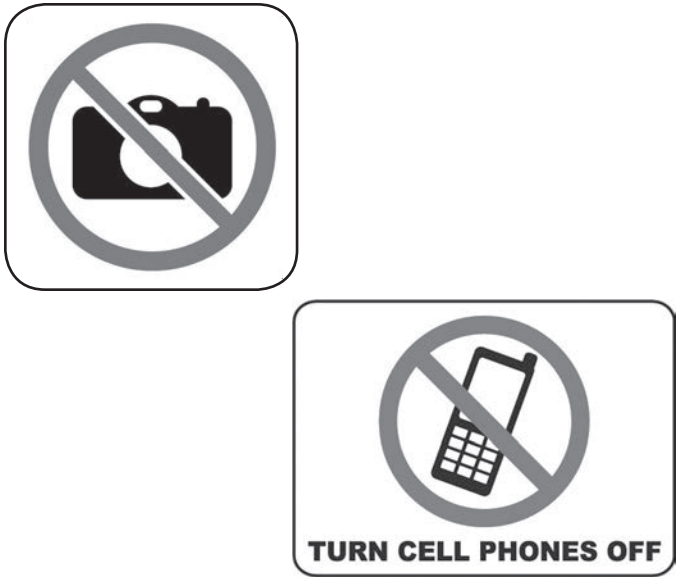
Th3E.1 • 13:00
On Optimal Modulation and FEC Overhead for Future Optical Networks, Alex Alvarado[1], David J. Ives[1], Seb J. Savory[1], Polina Bayvel[1]; [1]*Univ. College London, UK.* Transceivers employing square PM-QAM with up to two FEC overheads are optimized based on the SNR distribution. For NSFNET two FEC overheads with PM-16QAM give an 82% throughput increase compared with PM-QPSK with 7% overhead.

Th3E.2 • 13:15
Low-Overhead Low-Power-Consumption LDPC-Based FEC Solution for Next-Generation High-Speed Optical Systems, Mo Li[1], Zhiyu Xiao[1], Fan Yu[1], Nebojsa Stojanovic[2], Ivan B. Djordjevic[3], Xiaozhong Shi[1], Liangchuan Li[1]; [1]*Network Research Department, Huawei Technologies Co., Ltd., China;* [2]*European Research Center, Huawei Technologies Duesseldorf GmbH, Germany;* [3]*Department of electrical and Computer Engineering, Univ. of Arizona, USA.* A low-overhead low-power-consumption LDPC-based FEC solution for next-generation high-speed optical systems is proposed. The novel concept provides 10.2-dB NCG with 12% total overhead and less than 2-W power consumption for 100-Gbps throughput.

Room 407

13:00–15:00
Th3F • Photonic Coupling
Presider: Takashi Saida; NTT Corporation, Japan

Th3F.1 • 13:00 Invited
Integrated Photonic Devices and Circuits in Multilayer Silicon Nitride-on-Silicon Platforms, Joyce K. Poon[1], Wesley D. Sacher[1], Ying Huang[2], Guo-Qiang Lo[2]; [1]*Univ. of Toronto, Canada;* [2]*Institute of Microelectronics, Singapore.* Low-loss silicon nitride waveguides integrated onto silicon photonic platforms enable the scaling to large-area photonic circuits. Properties of a multilayer silicon nitride-on-silicon platform and a variety of photonic devices and circuits will be described.



Room 408A

13:00–15:00
Th3G • DSP in Coherent Transceiver
Presider: Etsushi Yamazaki; NTT Network Innovation Laboratories, Japan

Th3G.1 • 13:00
Novel digital pre-distortion techniques for low-extinction ratio Mach-Zehnder modulators, Antonio Napoli[1], Mahdi Mezghanni[2], Danish Rafique[1], Vincent Sleiffer[3], Bernhard Spinnler[1], Marc Bohn[1]; *[1]Coriant GmbH & Co. KG, Germany; [2]TUM, Germany; [3]TU/e, Netherlands*. A novel digital pre-distortion technique for low-extinction ratio modulators is presented. Penalty-free transmission in back-to-back system configuration is reported for 16- and 64QAM at 32GBaud with modulator extinction ratios as low as 14dB.

Th3G.2 • 13:15
Investigation of CAZAC Sequences for Data-Aided Channel Estimation Considering Nonlinear Optical Transmission, Markus Nölle[1], Felix Frey[1], Robert Elschner[1], Carsten Schmidt-Langhorst[1], Colja Schubert[1], Johannes K. Fischer[1]; *[1]Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany*. We investigate CAZAC sequences with positive and negative chirp for the use as training sequences in data-aided channel estimation. While both sequences show the same linear performance, the right choice of chirp is critical in case of nonlinear transmission. A performance difference of up to 2 dBQ was experimentally verified.

Room 408B

13:00–15:00
Th3H • Standard and Networks Convergence
Presider: Annalisa Morea; Alcatel-Lucent, France

Th3H.1 • 13:00 **Tutorial**
Ethernet and OTN: 400G and Beyond, Steve Trowbridge[1]; *[1]Alcatel-Lucent, USA*. This session reviews key aspects of 100G standardization including the relationships of Ethernet and Optical Transport Network standards, describing major proposals and "state of play" as standards these technologies are evolved to 400G and beyond.

Dr. Stephen Trowbridge (Alcatel-Lucent) joined Bell Laboratories over 30 years ago and has been involved in standards since 1995 in the areas of optical networking and high speed Ethernet. He is currently Chairman of ITU-T Study Group 15 which is responsible for Networks, Technologies and Infrastructures for Transport, Access and Home. He was a member of the IEEE 802.3ba editorial team during the development of 40 Gb/s and 100 Gb/s Ethernet and a key contributor to other Ethernet projects. He works in the IP Transport business unit of Alcatel-Lucent. He received his Ph.D. from the University of Colorado at Boulder.

Room 409AB

13:00–15:00
Th3I • Coherent Access
Presider: Domanic Lavery; Univ. College London, UK

Th3I.1 • 13:00
Low-Cost 6.25 GHz UDWDM-PON based on Direct Intensity-Modulated Transmitters, Marco Presi[1], Raffaele Corsini[1], Massimo Artiglia[2], Fabio Bottoni[1], Giulio Cossu[1], Ernesto Ciaramella[1]; *[1]TeCIP Institute, Scuola Superiore Sant'Anna, Italy; [2]Photonics Network Labs, CNIT, Italy*. We experimentally demostrate a 6.25 GHz grid WDM-PON based on commercially available directly-modulated DFB transmitters driven by 650mVpp signals and simplified coherent receivers. The system can support 35 dB ODN losses and allows the lambda-to-the-user approach.

Th3I.2 • 13:15
Optimization Criteria for Coherent PONs with Video Overlay and Hybrid ODN, Ali Shahpari[1], Ricardo M. Ferreira[1], Artur Sousa[1], Vitor Ribeiro[1], Jacklyn D. Reis[2], Mario Lima[1], Antonio L. Teixeira[1]; *[1]Instituto de Telecomunicações, Portugal; [2]Division of Optical Technologies,, CPqD, Brazil*. Based on a test bed of hybrid point-to-multipoint optical distribution network, in coexistence of UDWDM with video overlay, we derive a set of optimum parameters and their impact on the network operation.

Room 410

13:00–15:00
Th3J • Virtualization
Presider: Georgios Zervas; Univ. of Bristol, UK

Th3J.1 • 13:00
Survivable Virtual Optical Network Mapping in Spectrum and Modulation Format Convertible Flexible Grid Optical Networks, Fahim Khandaker[1], Weisheng Xie[1], Jason Jue[1], Xi Wang[2], Qiong Zhang[2], Qingya She[3], Hakki Cankaya[3], Paparao Palacharla[2], Motoyoshi Sekiya[2]; *[1]Univ. of Texas at Dallas, USA; [2]Fujitsu Laboratories of America, USA; [3]Fujitsu Network Communications, USA*. We study the problem of survivable Virtual Optical Network (VON) mapping in a flexible grid optical network with tunable programmable regenerators that are capable of converting spectrum and modulation format. We propose heuristic algorithms to address the problem with the objective of minimizing blocking probability for dynamic VON requests.

Th3J.2 • 13:15
Minimal Virtualized-Elastic-Regenerator Placement and Least Congestion Resources Assignment for Translucent Elastic Optical Networks, Masahiko Jinno[1], Tomohiko Takagi[1], Kosuke Kiyokawa[1]; *[1]Kagawa Univ., Japan*. A virtualized-elastic-regenerator (VER) is a promising solution for efficiently regenerating various superchannels in elastic optical networks. We propose an effective heuristic for calculating minimal VER placement, routing, and least congestion resources assignment.

Room 411

13:00–15:00
Th3K • Special Session on The Societal, Business, and Technical Impact of Net Neutrality

Moderators and Organizers: Pat Iannone; *Bell Labs, USA;* Rich Linke; *Aluben Research LLC, USA*

Network neutrality-related regulatory decisions, or the lack thereof, will impact not only the business landscape for internet service providers (ISPs), content providers, and application innovators, but will have a profound effect on the user experience. Less widely publicized is the impact these decisions will have on optical network technologies and architectures. This symposium will illuminate the fundamental issues around net neutrality and the potential impact of various proposals.

Speaker:

Kurt Opsahl; *Electronic Frontier Foundation, USA*

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel VII: Are CDNs Lightening the Load on the Core and Metro Networks
For more details, see page 40

Room 402AB

Th3A • Short Reach—Continued

Th3A.2 • 13:30
Practical Implementation of 100-Gbit/s/Lambda Optical Short-Reach Transceiver with Nyquist PAM4 Signaling using Electroabsorptive Modulated Laser (EML), Nobuhiko Kikuchi[1], Riu Hirai[1], Takayoshi Fukui[2]; *[1]Hitachi Ltd, Japan; [2]Oclaro Japan, Japan.* We investigate practical equalizing filter requirement and temperature range of EML-base 102.4-Gbit/s Nyquist-PAM4 transceivers and demonstrate its wide-temperature operation (20 degree) and a 40-km SMF transmission at 1.3 mm using commercial EMLs experimentally.

Th3A.3 • 13:45
Experimental Demonstration of 500Gbit/s Short Reach Transmission Employing PAM4 Signal and Direct Detection with 25Gbps Device, Kang Ping Zhong[1], Wei Chen[2], Qi Sui[1], Jiangwei Man[2], Alan P. Lau[1], Chao Lu[1], Li Zeng[2]; *[1]The Hong Kong Polytechnic Univ., Hong Kong; [2]Fixed Network R&D Department,Huawei Technologies Co, Ltd, China.* In this paper, we experimentally demonstrate single channel 128Gbit/s and four lanes transmission with a total capacity of 500Gbit/s for short reach applications employing PAM4 format and direct detection with commercial 25Gbps devices.

Room 403A

Th3B • Future of Broadband Access I: Trends and Drivers—Continued

Th3B.2 • 13:30 Invited
Internet Connectivity for the World's 60% Unconnected Population, Hamid Hemmati[1]; *[1]Facebook Inc., USA.* Due to three orders of magnitude global population density distribution, advanced telecom payload technologies located on earth, air and space are required to meet the challenge of providing Internet service to the unconnected world population.

Room 403B

Th3C • Exploring Fiber Limits—Continued

Th3C.2 • 13:30 Top Scored
Transmission Optimized Impairment Mitigation by 12 Stage Phase Conjugation of WDM 24x48 Gb/s DP-QPSK Signals, Karen Solis-Trapala[1], Mark D. Pelusi[2], Hung Nguyen Tan[1], Takashi Inoue[1], Shu Namiki[1]; *[1]National Institute of Advanced Industrial Science and Technology (AIST), Japan; [2]Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS), Australia.* Fiber impairment mitigation of an unprecedented 24 WDM channel count is demonstrated in a transmission optimized fiber link using 12 phase conjugations. An 8dB higher nonlinearity threshold is measured for WDM 1.1Tb/s DP-QPSK signals.

Th3C.3 • 13:45
Spatial-Spectral-Efficiency-enhanced Multi-Core Fiber, Testuya Nakanishi[1], Tetsuya Hayashi[1], Osamu Shimakawa[1], Takashi Sasaki[1]; *[1]Sumitomo Electric Industries Ltd, Japan.* A spatial-spectral-efficiency (SSE)-enhanced multi-core fiber (MCF) is designed by considering splicing loss, transmission distance, attenuation, and nonlinearity. Proposed MCF achieves highest SSE ever-fabricated single-mode MCFs with transmission distance up to 4,000 km.

Room 404AB

Th3D • Nonlinear Interference: Modeling and Mitigation I—Continued

Th3D.3 • 13:30
Perturbative Nonlinear Pre-Compensation in Presence of Optical Filtering, Amirhossein Ghazisaeidi[1], Jérémie Renaudier[1], Patrice Tran[1], Gabriel Charlet[1]; *[1]Bell Labs, France.* We study the performance of perturbative nonlinear pre-compensation algorithm in presence of in-line optical filtering, by numerical and experimental investigations. We show that optical filtering can severely degrade the performance of perturbative nonlinear pre-compensation.

Th3D.4 • 13:45
Advanced and Low-Complexity Digital Backpropagation for Subcarrier-Multiplexing Systems, Fangyuan Zhang[1], Qunbi Zhuge[1,2], Meng Qiu[1], Xian Xu[1], Wei Wang[1], Yuliang Gao[1,3], Mathieu Chagnon[1], David Plant[1]; *[1]Department of Electrical and Computer Engineering, McGill Univ., Canada; [2]Ciena Corporation, Canada; [3]Photonics Research Centre, Department of Electrical Engineering, The Hong Kong Polytechnic Univ., Hong Kong.* An advanced digital backpropagation algorithm is proposed for subcarrier-multiplexing systems. Efficient intra-channel nonlinear compensation is experimentally demonstrated using this algorithm with 40 spans/step and 16 spans/step for QPSK and 16QAM formats, respectively.

Room 406AB

Th3E • Forward Error Correction Codes—Continued

Th3E.3 • 13:30
On Parameter Optimization for Staircase Codes, Christian Häger[1], Alexandre Graell i Amat[1], Henry D. Pfister[2], Alex Alvarado[3], Fredrik Brännström[1], Erik Agrell[1]; *[1]Chalmers Univ. of Technology, Sweden; [2]Duke Univ., USA; [3]Univ. College London, UK.* We discuss the optimization of staircase code parameters based on density evolution. An extension of the original code construction is proposed, leading to codes with steeper waterfall performance.

Th3E.4 • 13:45
Dynamic Window Decoding for LDPC Convolutional Codes in Low-Latency Optical Communications, Tian Xia[2,1], Toshiaki Koike-Akino[1], David Millar[1], Keisuke Kojima[1], Kieran Parsons[1], Yoshikuni Miyata[3], Kenya Sugihara[3], Wataru Matsumoto[3]; *[1]Mitsubishi Electric Research Labs, USA; [2]School of Electrical Engineering and Computer Science, Louisiana State Univ., USA; [3]Information Technology R&D Center, Mitsubishi Electric Corporation, Japan.* We propose a dynamic window decoding scheme for LDPC convolutional codes to reduce the latency compared to the belief propagation decoding. The BER performance of our proposed memory-efficient decoding scheme is verified by simulations.

Room 407

Th3F • Photonic Coupling—Continued

Th3F.2 • 13:30
Band-Structure Approach to Synthesis of Grating Couplers with Ultra-High Coupling Efficiency and Directivity, Jelena Notaros[1], Milos Popović[1]; *[1]Univ. of Colorado Boulder, USA.* We propose a complex-wavevector band-structure approach to synthesis of fiber-to-chip grating couplers, and show apodized bi-level designs with 95% coupling efficiency and 99% directivity using only two device layers of a monolithic SOI CMOS process.

Th3F.3 • 13:45 Top Scored
An O-band Metamaterial Converter Interfacing Standard Optical Fibers to Silicon Nanophotonic Waveguides, Tymon . Barwicz[1], Alexander Janta-Polczynski[2], Marwan Khater[1], Yan Thibodeau[2], Robert Leidy[3], Jeffrey Maling[3], Stephan Martel[2], Sebastian Engelmann[1], Jason S. Orcutt[1], Paul Fortier[2], William M. Green[1]; *[1]IBM TJ Watson Research Center, USA; [2]IBM Bromont, Canada; [3]IBM Microelectronics Division, USA.* A metamaterial interface between standard optical fibers and silicon waveguides was fabricated in a CMOS production facility and shows -1.3dB peak efficiency with 0.8dB penalty over a 100 nm bandwidth and all polarizations.

INTERNATIONAL YEAR OF LIGHT 2015

Room 408A

Th3G • DSP in Coherent Transceiver—Continued

Th3G.3 • 13:30 Invited

Advanced Digital Nonlinear Distortion Compensation, Liang Dou[2], Ying Zhao[2], Zhenning Tao[2], Yangyang Fan[2], Takeshi Hoshida[3], Jens C. Rasmussen[1]; [1]*Fujitsu Laboratories Ltd., China;* [2]*Fujitsu R&D Center, China;* [3]*Fujitsu Limited, Japan.* We review the recent progresses on the nonlinear perturbation pre-distortion including the modified nonlinear model for performance improvement and nonlinear terms combination for complexity reduction. With Nyquist nonlinear model, the performance shows even more improvement.

Room 408B

Th3H • Standard and Networks Convergence—Continued

Room 409AB

Th3I • Coherent Access—Continued

Th3I.3 • 13:30 Invited

Technologies for a Cost-effective Coherent udWDM-PON, Josep Prat[1]; [1]*Universitat Politecnica de Catalunya, Spain.* A new ultra-dense WDM-PON with coherent techniques and low cost devices is developed for an efficient utilization of the optical spectrum, showing that the "Wavelength-to-the-User" concept can be feasible with 6.25 GHz channel spacing in a splitter-based PON.

Room 410

Th3J • Virtualization—Continued

Th3J.3 • 13:30 Invited

Programmable Hardware for High Performance SDN, Gordon Brebner[1]; [1]*Xilinx, USA.* There is a significant speed mismatch between optical transmission and the current data center. The Field Programmable Gate Array offers a flexible bridge between emergent photonic technologies and next-generation data center servers, via programmable hardware.

Room 411

Th3K • Special Session on The Societal, Business, and Technical Impact of Net Neutrality—Continued

NOTES

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel VII: Are CDNs Lightening the Load on the Core and Metro Networks
For more details, see page 40

Room 402AB

Th3A • Short Reach—Continued

Th3A.4 • 14:00
112 Gb/s PAM4 Transmission Over 40km SSMF Using 1.3 µm Gain-Clamped Semiconductor Optical Amplifier, Trevor Chan[1], Winston I. Way[1]; [1]*NEOPhotonics Corp, USA.* By using a gain-clamped 1.3µm semiconductor optical pre-amplifier, we experimentally demonstrated that both single- and dual-wavelength 112Gb/s 4-level pulse-amplitude-modulation (PAM4) signals can be transported over 40km standard single-mode fiber with >3dB power margin.

Networking • 14:15

Room 403A

Th3B • Future of Broadband Access I: Trends and Drivers—Continued

Th3B.3 • 14:00 Invited
Operational Issues in Access Networks: Past, Present, and Future, David B. Payne[1,2]; [1]*Trinity College Dublin, Ireland;* [2]*Aston Univ., UK.* Future network operation will be influenced by business and ownership models and the regulatory environment as future superfast and flexible broadband networks emerge. This paper discusses the issues affecting operators and network operations as network evolution progresses.

Room 403B

Th3C • Exploring Fiber Limits—Continued

Th3C.4 • 14:00 Tutorial
Propagation Effects in SDM Fibers, Antonio Mecozzi[1]; [1]*Universita degli Studi dell'Aquila, Italy.* We discuss the modeling of linear and nonlinear propagation in fibers for space-division multiplexed transmission. The equations governing the nonlinear propagation in such fibers, generalizing the equations for single mode propagation, will be presented.

Antonio Mecozzi is a Professor and the Director of Department of Physical and Chemical Sciences of the University of L'Aquila, Italy. Previously, he worked for 15 years at Fondazione Ugo Bordoni in Rome. He was a visiting scientist at the Research Laboratory of Electronics of MIT from 1991 to 1992 and a visiting scientist at AT&T Labs in 1999 and 2000. His areas of interest include nonlinear propagation in fiber, polarization mode dispersion, spatial division multiplexed transmission, physics and applications of semiconductor optical amplifiers, optical amplification and noise. He holds numerous patents and over 170 publications in refereed scientific journals. He is a Fellow of the Optical Society of America and of the IEEE.

Room 404AB

Th3D • Nonlinear Interference: Modeling and Mitigation I—Continued

Th3D.5 • 14:00 Invited
Fiber Nonlinearity Compensation: Practical Use Cases and Complexity Analysis, Danish Rafique[1], Bernhard Spinnler[1]; [1]*Coriant R&D GmbH, Germany.* We review the applications of fiber nonlinearity compensation (NLC) in homogeneous and heterogeneous networks, (non)dispersion-managed links, and terabit transmission systems. Practically viable intra-channel NLC is shown to allow ~3.7dB gains, well beyond conventionally acknowledged bounds.

Room 406AB

Th3E • Forward Error Correction Codes—Continued

Th3E.5 • 14:00
LDPC Codes for Optical Channels: Is the "FEC Limit" a Good Predictor of Post-FEC BER?, Alex Alvarado[1], Erik Agrell[2], Domanic Lavery[1], Polina Bayvel[1]; [1]*Univ. College London, UK;* [2]*Chalmers Univ. of Technology, Sweden.* We answer the question in the title negatively. More precisely, the FEC limit is invalid for soft decision decoding and low to medium code rates. A better predictor is the generalized mutual information.

Th3E.6 • 14:15 Top Scored
Spatially-Coupled LDPC Protograph Codes for Universal Phase Slip-Tolerant Differential Decoding, Laurent Schmalen[1], Stephan ten Brink[2], Andreas Leven[1]; [1]*Alcatel Lucent Bell Labs, Germany;* [2]*Institute of Telecommunications, Univ. of Stuttgart, Germany.* We show how a single spatially coupled LDPC code constructed from an optimized protograph with optimized windowed decoding outperforms different conventional LDPC codes in iterative differential decoding with significantly lower error floors and identical complexity.

Room 407

Th3F • Photonic Coupling—Continued

Th3F.4 • 14:00
Flexible Polymer Optical Waveguide for Si Photonics Interface, Shotaro Takenobu[1], Toshihisa Okada[1], Seiki Ohara[1], Tymon . Barwicz[2], Yoichi Taira[3], Takashi Sayama[1], Nobuhiko Imajyo[1]; [1]*Asahi Glass CO.,LTD., Japan;* [2]*IBM T.J. Watson Research Center, USA;* [3]*IBM Research – Tokyo, Japan.* We realize a technology of single mode polymer optical waveguide with precise alignment structures suitable for silicon photonic component assembly. The propagation loss is 0.5 dB/cm at 1550 nm.

Th3F.5 • 14:15
Optical Demonstration of a Compliant Polymer Interface between Standard Fibers and Nanophotonic Waveguides, Tymon Barwicz[1], Yoichi Taira[2], Shotaro Takenobu[3], Nicolas Boyer[4], Alexander Janta-Polczynski[4], Yan Thibodeau[4], Swetha Kamlapurkar[1], Sebastian Engelmann[1], Hidetoshi Numata[2], Robert L. Bruce[1], Simon Laflamme[4], Paul Fortier[4], Yurii A. Vlasov[1]; [1]*IBM TJ Watson Research Center, USA;* [2]*IBM Research – Tokyo, Japan;* [3]*Asahi Glass Co, Japan;* [4]*IBM Bromont, Canada.* We demonstrate a peak transmission efficiency of -2.4dB between a standard optical fiber and a nanophotonic waveguide using a mechanically compliant polymer interface. We find a 1.5dB penalty over a 100nm bandwidth and all polarizations.

Room 408A

Th3G • DSP in Coherent Transceiver—Continued

Th3G.4 • 14:00 Invited

Clock Recovery in Coherent Optical Receivers, Nebojsa Stojanovic[1]; Hu Chuan[1]; [1]*Huawei Technologies Co., Ltd., China*. We investigated symbol timing in coherent systems. Several non-data-aided phase detector candidates are listed for specific excess bandwidth-dependent applications. Parallel implementation including clock recovery delay and hardware limitations are studied.

Thank you for attending OFC. Look for your post-conference survey via email and let us know your thoughts on the program.

Room 408B

Th3H • Standard and Networks Convergence—Continued

Th3H.2 • 14:00 Invited

Fixed and Mobile Convergence: Which Role for Optical Networks?, Stéphane Gosselin[1], Anna Pizzinat[1], Xavier Grall[1], Dirk Breuer[2], Eckard Bogenfeld[2], Jose Torrijos Gijón[3], Ali Hamidian[4], Neiva Fonseca[4]; [1]*Orange Labs, France;* [2]*Deutsche Telekom AG, Germany;* [3]*Telefonica Investigacion y Desarrollo SA, Spain;* [4]*Ericsson AB, Sweden*. Fixed and Mobile Convergence (FMC) is a key stake for operators in the perspective of 5G networks. This paper analyzes the expected role of optical networks for convergence and integration of fixed and mobile infrastructures.

Room 409AB

Th3I • Coherent Access—Continued

Th3I.4 • 14:00 Top Scored

Demonstration of Nyquist UDWDM-PON with Digital Signal Processing in Real-Time, Ricardo Ferreira[1], Jacklyn D. Reis[2], Sandro M. Rossi[2], Sofia B. Amado[1], Ali Shahpari[1], Neil G. Gonzalez[2], Juliano R. Oliveira[2], Armando N. Pinto[1], Antonio L. Teixeira[1]; [1]*Department of Electronics, Telecommunications and Informatics, Univ. of Aveiro, Instituto de Telecomunicações, Portugal;* [2]*CPqD, Division of Optical Technologies, Brazil*. This paper reports the first coherent WDM-PON (16×2.5 Gb/s QPSK) experimental demonstration with real-time Nyquist OLT transmitters and real-time ONU receivers. Both transmitters/receivers implemented in FPGA use a simple 8-bit DSP architecture. An optimal transmitted power of -7 dBm per channel is achieved for 50 km, 1:16 split and 2.5 GHz grid.

Th3I.5 • 14:15

Bidirectional Coherent WDM-PON Performance with Real-Time Nyquist 16QAM Transmitter, Jacklyn D. Reis[1], Ricardo M. Ferreira[2], Sandro M. Rossi[1], Thyago M. Pinto[1], Gabriel J. Suzigan[1], Ali Shahpari[2], Antonio L. Teixeira[2], Neil G. Gonzalez[1], Juliano R. Oliveira[1]; [1]*Division of Optical Technologies, CPqD, Brazil;* [2]*DETI, Univ. of Aveiro, Instituto de Telecomunicações, Portugal*. This paper experimentally investigates the nonlinear performance and backscattering tolerance for a full-duplex bidirectional coherent WDM-PON with real-time Nyquist 16QAM transmitter. With 2x8x10 Gb/s over 50 km, the performance is evaluated for various pulse roll-off factors.

Room 410

Th3J • Virtualization—Continued

Th3J.4 • 14:00

SDN Dual-optimization Application for EDFAs and WSS-based ROADMs, Heitor Carvalho[1,2], Eduardo C. Magalhães[1,2], Miquel G. Alabarce[1], Neil G. Gonzalez[1], Marcelo Nascimento[1], Fabio Margarido[1], Leonardo Mariote[1], Aldario Bordonalli[2], Juliano R. Oliveira[1]; [1]*CPqD, Brazil;* [2]*School of Electrical and Computer Engineering, Univ. of Campinas, Brazil*. A novel SDN dual-optimization application based on EDFA adaptive gain control and WSS-based spectrum equalization is proposed. OSNR 5.7 dB gains for 80 DWDM 128-Gb/s channels are experimentally demonstrated in our metropolitan optical network test-bed.

Th3J.5 • 14:15

Field Trial of Broker-based Multi-domain Software-Defined Heterogeneous Wireline-Wireless-Optical Networks, Lei Liu[1], Zuqing Zhu[2], Xiong Wang[1,3], Guanghua Song[1,4], Cen Chen[2], Xiaoliang Chen[2], Shoujiang Ma[2], Xiaotao Feng[1], Roberto Proietti[1], S. J. B. Yoo[1]; [1]*Univ. of California, Davis, USA;* [2]*Univ. of Science and Technology of China , China;* [3]*Univ. of Electronic Science and Technology of China, China;* [4]*Zhejiang Univ., China*. Driven by a broker-based OpenFlow control plane, we report the first field trial of software-defined heterogeneous wireline-wireless-optical multi-domain networks connecting UC Davis Campus, USTC, California OpenFlow Testbed Network (COTN) and Energy Sciences Network (ESNet).

Room 411

Th3K • Special Session on The Societal, Business, and Technical Impact of Net Neutrality—Continued

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel VII: Are CDNs Lightening the Load on the Core and Metro Networks
For more details, see page 40

Room 402AB

Th3A • Short Reach—Continued

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

Room 403A

Th3B • Future of Broadband Access I: Trends and Drivers—Continued

Th3B.4 • 14:30 Invited ▶

FTTx Migration Challenges to Gigabps Hyper-connectivity Networking Infrastructure, Bongtae Kim[1]; *[1]Electronics and Telecommunications Research Institute (ETRI), Korea (the Republic of).* By upgrading current 100Mbps class FTTx to 1Gbps, commercial nationwide 'Giga Internet' service has launched in 2014 in Korea. Including government, big four operator's (KT, SKB, LGU+, MSOs) efforts for network evolution will be presented.

Room 403B

Th3C • Exploring Fiber Limits—Continued

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

Room 404AB

Th3D • Nonlinear Interference: Modeling and Mitigation I—Continued

Th3D.6 • 14:30

Analytical results on system maximum reach increase through symbol rate optimization, Pierluigi Poggiolini[1], Yanchao Jiang[1], Andrea Carena[1], Gabriella Bosco[1], Fabrizio Forghieri[2]; *[1]Politecnico di Torino, Italy; [2]Cisco Photonics Italy, Italy.* We investigate the dependence of maximum system reach on symbol rate. We identify a suitable modeling framework and derive a closed-form formula for the optimum rate, typically 2-to-10 GBaud. Maximum reach gains are between 5% and 20%.

Th3D.7 • 14:45

Complexity Reduction of Perturbation-based Nonlinear Compensator by Sub-band Processing, Tomofumi Oyama[1], Hisao Nakashima[2], Takeshi Hoshida[2], Takahito Tanimura[1], Yuichi Akiyama[2], Zhenning Tao[3], Jens C. Rasmussen[2]; *[1]Fujitsu Laboartories Ltd., Japan; [2]Fujitsu Limited, Japan; [3]Fujitsu R&D Center, China.* We propose and numerically evaluate a novel sub-band processing architecture for computational complexity reduction of the perturbation-based nonlinear compensator. The complexity is reduced by a factor of 12.4 in 3000-km transmission with 0.1 dB penalty.

Room 406AB

Th3E • Forward Error Correction Codes—Continued

Th3E.7 • 14:30

Experimental Investigation of Polar Code Performance for Coherent UDWDM PONs, Zifeng Wu[1], Johannes K. Fischer[2], Berthold Lankl[1]; *[1]Institute for Communications Engineering, Univ. of the Federal Armed Forces Munich, Germany; [2]Photonic Networks and Systems, Fraunhofer Heinrich Hertz Institute, Germany.* We report on the experimental investigation of Polar codes with 7% overhead for forward-error-correction (FEC) in a coherent UDWDM PON scenario. The measured post-FEC bit error ratio vs. the signal-to-noise ratio is compared with results from simulations.

Th3E.8 • 14:45

Tomlinson-Harashima Precoding with Soft Detection for Faster than Nyquist DP-16QAM Coherent Optical Systems, Deyuan Chang[1], Oluyemi Omomukuyo[1], Octavia Dobtre[1], Ramachandran Venkatesan[1], Paul Gillard[1], Chuck Rumbolt[2]; *[1]Memorial Univ. of Newfoundland, Canada; [2]Newfoundland Technology Center, Altera Corporation, Canada.* We demonstrate the feasibility of transmitting 5×32 Gbaud DP-16QAM faster-than-Nyquist signals within 30 GHz spaced channels, which is enabled by the Tomlinson-Harashima precoding (THP) combined with soft-decision forward error correction (SD-FEC).

Room 407

Th3F • Photonic Coupling—Continued

Th3F.6 • 14:30 DEMO

Effect of Waveguide Surface Roughness on the Fiber Coupling Efficiency of Inverse Tapers, Min TENG[1], Ben Niu[1], Kyunghun Han[1], Minghao Qi[1]; *[1]Purdue Univ., USA.* We investigate the effect of waveguide surface roughness on the coupling efficiency between silicon inverse tapers and lensed fibers. Short taper lengths of 30-50 micrometers are shown to achieve minimum coupling loss.

Th3F.7 • 14:45

Silicon Photonic Dual-Polarization Nanotaper for Chip-to-Fiber Coupling, Sean P. Anderson[1], Mark A. Webster[1]; *[1]Cisco Systems, Inc., USA.* We present a dual-polarization nanotaper that operates as an integrated silicon photonic beam cube, having low PDL and superior polarization extinction over 130 nm of bandwidth, and tightly-controlled NA for coupling to fiber.

15:00–15:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

Room 408A

Th3G • DSP in Coherent Transceiver—Continued

Th3G.5 • 14:30
Faster-than-Nyquist DFT-S-OFDM using Overlapping Sub-Bands and Duobinary Filtering, Chen Zhu[1], Bill Corcoran[1], Monir Morshed[1], Leimeng Zhuang[1], Arthur Lowery[1]; *[1]Monash Univ., Australia.* We propose a novel single-channel Faster-than-Nyquist-DFT-S-OFDM transmitter that allows the sub-bands' spectra overlap flexibly. By combing duobinary filtering to mitigate intersub-band interference, 12% more spectral efficiency is demonstrated in a super-channel experiment over 3360-km transmission.

Th3G.6 • 14:45
Novel DAC digital pre-emphasis algorithm for next-generation flexible optical transponders, Antonio Napoli[1], Mahdi Mezghanni[2], Danish Rafique[1], Vincent Sleiffer[3], Talha Rahman[3], Bernhard Spinnler[1], Stefano Calabrò[1], Marc Bohn[1]; *[1]Coriant GmbH & Co. KG, Germany; [2]TUM, Germany; [3]TU/e, Netherlands.* We present a novel digital pre-emphasis algorithm based on the mean-square-error. We numerically demonstrate a significant increase of the maximum transmittable symbol rate for 4- up to 64QAM and experimentally, a ~0.7dBQ-gain for 40GBaud-16QAM.

Room 408B

Th3H • Standard and Networks Convergence—Continued

Th3H.3 • 14:30
Scalable Service Provisioning in Converged Optical/Wireless Clouds using Compression Techniques, Markos P. Anastasopoulos[1], Anna Tzanakaki[1,2], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol , Greece; [2]Physics, Univ. of Athens, Greece.* To support scalable service provisioning in converged optical/wireless clouds we adopt for the first time compressive sensing (CS) techniques. CS achieves optimal service provisioning with significantly reduced control and management information and computational complexity.

Th3H.4 • 14:45
Experimental validation of MTU-BRAS connectivity with DMT transmission and coherent detection in flexgrid metro networks using sliceable transceivers, Josep M. Fabrega[1], Michela Svaluto Moreolo[1], Javier Vilchez[1], Konstantinos Christodoulopoulos[3], Emmanouel Varvarigos[3], Juan Fernandez-Palacios[2]; *[1]Ctr Tecnològic de Telecom de Catalunya, Spain; [2]Telefonica I+D, Spain; [3]Univ. of Patras, Greece.* Simple and cost-effective DMT transmission in combination with shared coherent detection is proposed for evolutionary flexgrid metro/regional networks. Network testbed experiments show successful 10Gb/s connections from MTUs to the sliceable transceiver at the virtual BRAS farm, covering up to 150km.

Room 409AB

Th3I • Coherent Access—Continued

Th3I.6 • 14:30 Invited
VCSELs for Coherent PON, Jesper B. Jensen[1,2], Roberto Rodes[3], Ning Cheng[4], Idelfonso Tafur Monroy[1]; *[1]DTU Fotonik, Denmark; [2]Bifrost Communications, Denmark; [3]Finisar Corporation, USA; [4]Huawei Technologies, USA.* Recent advances and research on coherent technologies for access networks are discussed and put into context of user demands and standardization work.

Room 410

Th3J • Virtualization—Continued

Th3J.6 • 14:30
Network Virtualization Controller for Abstraction and Control of OpenFlow-enabled Multi-tenant Multi-technology Transport Networks, Ricard Vilalta[1], Raül Muñoz[1], Ramon Casellas[1], Ricardo Martínez[1], Frederic Francois[2], Shuping Peng[2], Reza Nejabati [2], Dimitra E. Simeonidou[2], Noboru Yoshikane[3], Takehiro Tsuritani[3], Itsuro Morita[3], Victor López[4], Thomas Szyrkowiec[5], Achim Autenrieth[5]; *[1]CTTC, Spain; [2]High-Performance Networks Group, Univ. of Bristol, UK; [3]KDDI R&D Laboratories, Japan; [4]Telefónica I+D, Spain; [5]ADVA Optical Networking SE, Germany.* A network hypervisor is introduced to dynamically deploy multi-tenant virtual networks on top of multi-technology optical networks. It provides an abstract view of each virtual network and enables its control through an independent SDN controller.

Networking • 14:45

Room 411

Th3K • Special Session on The Societal, Business, and Technical Impact of Net Neutrality—Continued

15:00–15:30 Coffee Break, *Exhibit Hall & 400 Rooms Foyer*

Show Floor Programming

■ **Market Watch**

13:00–15:00
Panel VII: Are CDNs Lightening the Load on the Core and Metro Networks
For more details, see page 40

Room 402AB

15:30–17:30
Th4A • DMT and PAM Transceivers
Presider: Sebastian Randel; Alcatel-Lucent Bell Labs, USA

Th4A.1 • 15:30 Top Scored
130-Gbps DMT Transmission using Silicon Mach-Zehnder Modulator with Chirp Control at 1.55-µm, Yutaka Kai[1], Masato Nishihara[1], Toshiki Tanaka[1], Ryo Okabe[1], Tomoo Takahara[1], Jens C. Rasmussen[1], Hiroki Ishihara[2], Kazuhiro Goi[2], Kensuke Ogawa[2]; [1]*Fijitsu Laboratories ltd., Japan;* [2]*Optics and Electronics Laboratory, Fijikura ltd., Japan*. We evaluated the transmission performance of discrete multi-tone (DMT) modulation with 10-Gbps SiP MZ modulator at 1550-nm region. We achieved a transmission of 130-Gb/s over 2-km SMF with BER of $3.0x10^{-03}$.

Th4A.2 • 15:45 Top Scored DEMO
C-band Single Wavelength 100-Gb/s IM-DD Transmission over 80-km SMF without CD compensation using SSB-DMT, Liang Zhang[1], Enbo Zhou[1], Qiang Zhang[1], Xiaogeng Xu[1], Gordon Ning Liu[1], Tianjian Zuo[1]; [1]*Huawei Company, China*. C-band 100-Gb/s discrete multi-tone modulation transmission over 80-km single mode fiber without CD compensation is experimentally demonstrated. By using dual-drive Mach-Zehnder modulator-assisted single-sideband modulation, CD induced power fading is eliminated after direct detection.

Room 403A

15:30–17:30
Th4B • Future of Broadband Access II: Technologies
Presiders: Neda Cvijetic; NEC Laboratories America Inc., USA and Antonio L. J. Teixeira; DETI, Instituto de Telecomunicacoes, Portugal

Th4B.1 • 15:30 Invited
DOCSIS 3.1® Technology and Hybrid Fiber Coax for Multi-Gbps Broadband, Dan Rice[1]; [1]*SVP Network Technologies, CableLabs, USA*. DOCSIS 3.1 technologies over HFC networks will continue to support the best-in-market speeds delivered to the broadest population of consumers with the best customer experience. This paper describes the trends of broadband demand and how cable technology will evolve leveraging fiber deep technologies.

Room 403B

15:30–17:30
Th4C • Multicore Fibers
Presider: Kazuhide Nakajima; Nippon Telegraph & Telephone Corp, Japan

Th4C.1 • 15:30 Tutorial
Multicore Fiber Technology, Kunimasa Saitoh[1]; [1]*Hokkaido Univ., Japan*. Multicore fibers (MCFs) are expected as a good candidate for overcoming the capacity limit of current optical communication system. This tutorial will describe technical challenges and prospect of MCFs for space-division multiplexing (SDM).

Kunimasa Saitoh is a Professor at Graduate School of Information Science and Technology, Hokkaido University, Japan. He received his Ph.D. degree in electronic engineering from Hokkaido University in 2001. His research interests include optical fiber communications, fiber optics, nanophotonics, and integrated optical devices. He is an author or coauthor of more than 150 research papers in refereed international journals. Prof. Saitoh is a member of IEEE, OSA, and IEICE. In 2008, he was awarded the Young Scientists' Prize of the Commendation for Science and Technology from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Government of Japan.

Room 404AB

15:30–17:30
Th4D • Nonlinear Interference: Modeling and Mitigation II
Presider: Fabrizio Forghieri; Cisco, Italy

Th4D.1 • 15:30 Invited
Bi-directional Transmission to Reduce Linear and Nonlinear Crosstalk, Fatih Yaman[1]; [1]*NEC Laboratories America, Inc, USA*. Interleaved bi-directional transmission is shown to be a forward-looking system architecture benefiting from reduced nonlinear penalty. Although its performance is limited by Rayleigh scattering it is more suitable for systems designed for high spectral efficiency.

Room 406AB

15:30–17:30
Th4E • Modulators & Switches
Presider: Takuo Tanemura; Univ. of Tokyo, Japan

Th4E.1 • 15:30 Top Scored
Low Switching Voltage InP-Based Travelling Wave Electrode Mach-Zehnder Modulator Monolithically Integrated with DFB-Laser for 60 Gb/s NRZ, Sophie Lange[1], Ronald Kaiser[1], Marko Gruner[1], Michael Hamacher[1], Karl-Otto Velthaus[1], Martin Schell[1]; [1]*Photonic Components, Fraunhofer Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, Germany.* We present a transmitter consisting of a travelling wave electrode InP-based Mach-Zehnder modulator monolithically integrated with a DFB laser. For the first time, 60Gb/s NRZ at low $1.5V_{pp}$ modulation voltage and zero chirp is demonstrated.

Th4E.2 • 15:45 Top Scored
InP Coherent Optical Modulator with Integrated Amplification for High Capacity Transmission, Robert A. Griffin[1], Neil D. Whitbread[1], Stephen Jones[1], Susannah C. Heck[1], Paul Firth[2], Donald Govan[2], Thomas Goodall[2]; [1]*Oclaro, UK;* [2]*Oclaro, UK*. We report the design and characterization of an InP-based coherent optical transmitter integrating optical gain together with modulator, monitor and control elements to provide enhanced performance for high spectral efficiency 100Gb/s transmission.

Room 408A

15:30–17:30
Th4F • Coherent Transceiver
Presider: Ronald Freund; Fraunhofer Inst Nachricht Heinrich-Hertz, Germany

Th4F.1 • 15:30
InP Integrated Coherent Transmitter for 100 Gb/s DP-QPSK transmission , Maxime Poirier[1], Marcel Boudreau[1], Yu-Min Lin[1], Raghuram Narayan[1], Chengkun Chen[1], Xiaoyu Hong[1], Rad Olson[1], Xu Liu[1], Milind Gokhale[1], Jerry Young Ma[1], Mark Eshelman[1], Yu-Min Lin[2], Raghuram Narayan[2], Chengkun Chen[1], Xiaoyu Hong[2], Rad Olson[2], Xu Liu[2], Milind Gokhale[2], Yong Ma[2], Mark Eshelman[2]; [1]*Neophotonics, Canada;* [2]*Neophotonics, USA.* We demonstrate an integrated coherent transmitter (ICT) comprised of a co-packaged narrow linewidth BH-DFB laser and InP-based high performance modulator suitable for 100 Gb/s DP-QPSK coherent transmission. This ICT provides a signal output power > 0dBm and an independent 10 dBm local oscillator (LO) port.

Th4F.2 • 15:45
Fast Polarization-State Tracking Based on Radius-Directed Linear Kalman Filter, Guoliang Cao[1], Yanfu Yang[1], Kangping Zhong[2], Xian Zhou[2], Yong Yao[1], Alan Pak Tao Lau[2], Chao Lu[2]; [1]*Electronic and Information Engineering, Shenzhen Graduate School, Harbin Institute of Technology, China;* [2]*Electronic and Information Engineering, Hong Kong Polytechnic Univ., China.* We propose and experimentally demonstrate a blind polarization tracking scheme based on radius-directed linear Kalman filter. It has the advantages of fast convergence and is inherently insensitive to phase noise and frequency offset effects.

Room 408B

15:30–17:30
Th4G • Network Virtualization
Presider: Inder Monga; ESnet, USA

Th4G.1 • 15:30 Invited
Software-Defined, Virtualized Networking and Beyond 100G, Atsushi Takahara[1]; [1]*NTT Network Innovation Laboratories, Japan.* Network Virtualization is important in network architecture. In this paper, we describe state-of-the-art challenges in implementing network virtualization functions and several use cases of utilizing network virtualization in the Beyond 100G Era.

Room 409AB

15:30–17:30
Th4H • Advances in TDM-PON and FTTx Deployment
Presider: David Piehler; Fields and Waves, USA

Th4H.1 • 15:30
APD-Based DuoBinary Direct Detection Receivers for 40 Gbps TDM-PON, Vincent Houtsma[1], Doutje van Veen[1], Alan Gnauck[2], Patrick Iannone[1]; [1]*Bell Labs, Alcatel-Lucent, USA;* [2]*Bell-Labs, Alcatel-Lucent, USA.* We report on the feasibility of using 25 Gbps APDs as 3-level electrical duobinary direct detection receivers for use in low cost 40 Gbps TDM-PON.

Th4H.2 • 15:45 Top Scored
25Gb/s 3-level Burst-Mode Receiver for High Serial Rate TDM-PONs, Xin Yin[1], Jochem Verbist[1], Timothy De Keulenaer[1], Bart Moeneclaey[1], Jochen Verbrugghe[1], Xing Zhi Qiu[1], Johan Bauwelinck[1]; [1]*IIMEC/INTEC, Ghent Univ., Belgium.* We report the first 25Gb/s 3-level modulated BM-RX employing a ¼-rate linear BM APD-TIA and a custom decoder IC. We successfully demonstrated burst-mode sensitivity of 20.4dBm with 18dB dynamic burst-to-burst for 25Gb/s upstream links.

Room 411

15:30–17:30
Th4I • Special Symposium on Fiber Optic Parametric Amplifiers: A Tribute to the Research of Prof. Michel Marhic

Moderator: Leonid G. Kazovsky; *Stanford Univ., USA*

Organizer: Periklis Petropoulos; *Univ. of Southampton, UK;* Kenneth K. Y. Wong; *Univ. of Hong Kong, Hong Kong;* Shu Namiki, *AIST, Japan*

Prof. Michel Marhic was one of the most dedicated researchers in the theory and applications of fiber optical parametric amplifiers. After learning that Prof. Marhic passed away suddenly and unexpectedly in August 2014, we were honored to organize a special session in recognition of his world-leading work in this area. Anyone, especially those who knew Prof. Marhic, are cordially asked to join this session and share their memories and research works. The session will celebrate the progress on fiber optic parametric amplifiers, a field that has benefitted so much from Prof. Michel Marhic's contributions.

Speakers:

Kenneth K. Y. Wong; *The Univ. of Hong Kong, Hong Kong*

Prem Kumar; *Northwestern Univ., USA*

Colin McKinstrie; *Applied Communication Sciences, USA*

Youichi Akasaka; *Fujitsu Laboratories of America, USA*

Stojan Radic; *UCSD, USA*

Peter Andrekson; *Chalmers Univ. of Technology, Sweden*

Periklis Petropoulos; *Univ. of Southampton, UK*

Shu Namiki; *AIST, Japan*

Nick Doran; *Aston Univ., UK*

Room 402AB

Th4A • DMT and PAM Transceivers—Continued

Th4A.3 • 16:00 Top Scored

56 Gb/s Direct Detected Single-Sideband DMT Transmission over 320-km SMF Using Silicon IQ Modulator, Chi Yan Wong[1], Sen Zhang[1], Lei Liu[1], Tao Wang[1], Qiang Zhang[1], Yuanyuan Fang[1], Shupeng Deng[1], Gordon Ning Liu[1], Xiaogeng Xu[1]; [1]*Huawei Technology Ltd., China.* High performance silicon IQ modulator is fabricated and used to demonstrate the first 56 Gb/s direct detected single-sideband DMT transmission over 320-km SMF. The required OSNR of 26.3 dB at BER of 3.7×10^{-3} was achieved.

Th4A.4 • 16:15

Dispersion-Tolerant Single-Sideband OFDM Transmission in IM/DD Systems Using a Single Cascaded EAM, Hsuan-Lin Cheng[1], Wei-Hung Chen[1], Chia Chien Wei[1], Yi-Jen Chiu[1]; [1]*National Sun Yat-sen Univ., Taiwan.* Using a single cascaded EAM, we demonstrate 13.5-Gbps IM/DD-OFDM transmission over 0~200-km without distance-dependent bit-loading. Dispersion-induced fading and nonlinear distortion in conventional IM/DD systems are settled by novel single-sideband modulation and SSII cancellation schemes, respectively.

Th4A.5 • 16:30

Transmission of 56-Gb/s PAM-4 over 26-km Single Mode Fiber Using Maximum Likelihood Sequence Estimation, Chen Chen[1], Xuefeng Tang[1], Zhuhong Zhang[1]; [1]*Huawei Technologies Canada, Canada.* We experimentally demonstrated a transmission of 56-Gb/s PAM-4 over a 26.4-km single mode fiber (SMF) at 1550nm using maximum likelihood sequence estimation (MLSE). We discuss the transmitter and receiver DSP that can improve PAM-4 performance.

Room 403A

Th4B • Future of Broadband Access II: Technologies—Continued

Th4B.2 • 16:00 Invited

Copper is the New Black for Ultra Broadband Networks, David Eckard[1], Michael Timmers[1]; [1]*Alcatel-Lucent Fixed Networks Division CTO, Belgium.* G.fast, the newest ITU protocol for copper access, will deliver anywhere from hundreds of Mb/s to close to 1Gb/s. Operators have an additional tool at their disposal to provide fiber like speeds over existing copper.

Networking • 16:30

Room 403B

Th4C • Multicore Fibers—Continued

Th4C.2 • 16:30

Delay spread in strongly coupled multi-core fibers for SDM transmission, Cristian Antonelli[1], Antonio Mecozzi[1], Mark Shtaif[2]; [1]*Universita degli Studi dell'Aquila, Italy;* [2]*School of Electrical Engineering, Tel Aviv Univ., Israel.* The mean square delay spread in strongly coupled multi-core fibers increases linearly with propagation distance. We quantify the coefficient of this linear growth and characterize its dependence on the fiber parameters. We show that the mean delay spread increases with the coupling coefficient between cores, while it reduces with its fluctuations.

Room 404AB

Th4D • Nonlinear Interference: Modeling and Mitigation II—Continued

Th4D.2 • 16:00

Experimental validation of the EGN-model in uncompensated optical links, Antonino Nespola[2], Mathieu Huchard[2], Gabriella Bosco[1], Andrea Carena[1], Yanchao Jiang[1], Pierluigi Poggiolini[1], Fabrizio Forghieri[3]; [1]*DET, Politecnico di Torino, Italy;* [2]*Istituto Superiore Mario Boella, Italy;* [3]*Cisco Photonics Italy srl, Italy.* We report the first experimental validation of the EGN-model. Using a PM-QPSK Nyquist-WDM transmission we confirm the enhanced accuracy of the EGN-model comparing maximum reach prediction with those of GN-model.

Th4D.3 • 16:15

A Simple Strategy for Mitigating XPM in Nonlinear WDM Optical Systems, Domenico Marsella[1], Marco Secondini[1], Erik Agrell[2], Enrico Forestieri[1]; [1]*TeCIP Institute, Scuola Superiore Sant Anna, Italy;* [2]*Department of Signals and Systems, Chalmers Univ. of Technology, Sweden.* Resilience to cross-phase modulation (XPM) can be improved by employing multicarrier modulation formats. The impact of the number of subcarriers on the achievable information rate is discussed and a possible XPM compensation strategy is suggested.

Th4D.4 • 16:30

Experimental Study of the Limits of Digital Nonlinearity Compensation in DWDM Systems, ChangYu Lin[2], Sethumadhavan Chandrasekhar[1], Peter J. Winzer[1]; [1]*Alcatel-Lucent Bell Labs, USA;* [2]*Department of Electrical and Computer Engineering, Univ. of Arizona, USA.* We experimentally investigate idealized digital nonlinearity compensation in a 9-channel DWDM system. A Q^2-factor gain of 2-dB for single-channel transmission is reduced to 0.1-dB in DWDM operation and recovers to 0.8-dB for nonlinearity compensation across all channels.

Room 406AB

Th4E • Modulators & Switches—Continued

Th4E.3 • 16:00

Low Loss InP C-Band IQ Modulator with 40GHz Bandwidth and 1.5V Vπ, Gregory Letal[1], Kelvin Prosyk[1], Ron Millett[1], David Macquistan[1], Stéphane Paquet[2], Olivier Thibault-Maheu[2], Jean-Frédéric Gagné[2], Pierre-Louis Fortin[2], Reza Dowlatshahi[3], Brian Rioux[3], Tony SpringThorpe[3], Matt Hisko[3], Rubin Ma[3], Ian Woods[1]; [1]*TeraXion, Canada;* [2]*TeraXion, Canada;* [3]*Canadian Photonics Fabrication Centre, Canada.* Design and fabrication improvements to InP optical IQ modulators resulted in a reduced Vπ of 1.5V while maintaining 40GHz bandwidth and loss <7.5dB over C-band. Dual polarization QPSK constellations using 3Vpp drive are presented.

Th4E.4 • 16:15

First 105 Gb/s Low Power, Small Footprint PAM-8 Impedance-engineered TOSA with InP MZ-Modulator and Customized Driver IC using Predistortion, Braulio Gomez Saavedra[1], Norman Wolf[1], Lei Yan[1], Christian Meuer[1,2], Jung Han Choi[1], Karl-Otto Velthaus[1], Marko Gruner[1], Colja Schubert[1], Heinz-Gunther Bach[1], Martin Schell[1]; [1]*Fraunhofer-Institut für Nachrichtentechnik, Germany;* [2]*Institut für Telekommunikationssysteme, Technische Universität Berlin, Germany.* A small footprint, low power 105Gb/s PAM-8 TOSA with InP-based/Mach-Zehnder modulator and a customized SiGe differential driver with a modulation power of 3.23pJ/bit is demonstrated. Predistortion is applied to compensate for non-linearities of both devices.

Th4E.5 • 16:30 Invited

BiCMOS Silicon Photonics Platform, Lars Zimmermann[1],D. Knoll[1], M. Kroh[1], S. Lischke[1], D. Petousi[1], G. Winzer[1], Y. Yamamoto[1]; [1]*IHP, Germany.* Photonic BiCMOS is a new monolithic electronic-photonic integration technology, offering high-speed bipolar transistors together with broadband silicon photonics devices such as germanium detectors and depletion-type modulators. Integration aspects and first demonstrator examples shall be reviewed.

Room 408A

Th4F • Coherent Transceiver—Continued

Th4F.3 • 16:00 Invited

Compact InP-based Optical Modulator for 100-Gb/s Coherent Pluggable Transceivers, Masaki Kotoku[1]; [1]*Nippon Telegraph & Telephone Corp, Japan.* InP-based MZ modulators are suitable for realizing coherent pluggable transceivers. They offer compact size, low driving voltage and high performance. Targeting lower power consumption, we employed a reduced driving voltage and an athermal twin-IQ modulator.

Th4F.4 • 16:30 Tutorial

Coherent Optical Communication Technology, Kazuro Kikuchi[1]; [1]*The Univ. of Tokyo, Japan.* This tutorial lecture discusses fundamentals of the coherent optical communication technology. It covers quantum mechanical understanding of coherent (heterodyne and homodyne) detection, optical circuits for coherent receivers, and digital signal processing for coherent communications.

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Room 408B

Th4G • Network Virtualization—Continued

Th4G.2 • 16:00

Orchestrating Virtual Machine Migrations in Telecom Clouds, Joaquim Barrera[1], Marc Ruiz[1], Luis Velasco[1]; [1]*Universitat Politecnica de Catalunya, Spain.* A throughput model is experimentally assessed and then used to compare non-orchestrated against orchestration when multiple VMs are migrated among datacenters in a telecom cloud. Numerical results show migration time reductions as high as 71%.

Th4G.3 • 16:15

Heterogeneous Multi-domain Network Virtualization with End-to-end Differentiated Service Provisioning and Virtual Network Organization, Xiaoyuan Cao[1], Noboru Yoshikane[1], Takehiro Tsuritani[1], Itsuro Morita[1]; [1]*KDDI R&D Laboratories, Japan.* Hierarchical network virtualization is demonstrated on a heterogeneous multi-domain network testbed, based on SDN/Openflow and two-level Flowvisor. Differentiated services with various sets of QoS requirements are provisioned in the end-to-end optimally organized virtual networks.

Th4G.4 • 16:30

Data Center Service Localization based on Virtual Resource Migration in Software Defined Elastic Optical Network, Hui Yang[1], Yongli Zhao[1], Jie Zhang[1], Yuanlong Tan[1], Yuefeng Ji[1], Jianrui Han[2], Yi Lin[2], Young Lee[2]; [1]*Beijing Univ of Posts & Telecom, China;* [2]*Huawei Technologies Co., Ltd., China.* We present a data center service localization architecture based on virtual resource migration in software defined elastic optical network. The overall feasibility and efficiency of the proposed architecture are experimentally verified on our testbed.

Room 409AB

Th4H • Advances in TDM-PON and FTTx Deployment—Continued

Th4H.3 • 16:00 Top Scored

Analysis of Forward Error Correction in the Upstream Channel of 10Gb/s Optically Amplified TDM-PONs, Daniel Brunina[1], Stefano Porto[1], Anil Jain[1], Caroline P. Lai[1], Cleitus Antony[1], Nicola Pavarelli[1], Marc Rensing[1], Giuseppe Talli[1], Peter Ossieur[1], Peter O'Brien[1], Paul Townsend[1]; [1]*Photonic Systems Group, Tyndall National Institute, Univ. College Cork, Ireland.* We experimentally investigate the performance of forward error correction operated in burst-mode using a burst-mode receiver. We show reduced error correction capability due to transients from the burst-mode receiver at the start of each burst.

Th4H.4 • 16:15

Efficient Monitoring for Ring-based Long-Reach Passive Optical Networks, Min Cen[1], Jiajia Chen[2], Véronique Moeyaert[1], Patrice Mégret[1], Marc Wuilpart[1]; [1]*Electromagnetism and Telecommunication Department, Université de Mons, Belgium;* [2]*Optical Networks Lab, KTH Royal Institute of Technology, Sweden.* An efficient monitoring scheme based on transmission-reflection analysis is proposed for long-reach passive optical networks. Both experimental and simulation results have demonstrated that the proposed scheme provides better localization functionality than the conventional methods.

Th4H.5 • 16:30 Invited

The Latest Fusion Splicing Technologies and Applications to FTTx Deployment, Akio Tanabe[1]; [1]*Furukawa Electric, Japan.* Fusion splicing in FTTH deployment is part of the final process to link the network. Here we examine the latest fusion splicing technologies used worldwide and the challenges they present.

Room 411

Th4I • Special Symposium on Fiber Optic Parametric Amplifiers: A Tribute to the Research of Prof. Michel Marhic—Continued

Room 402AB

Th4A • DMT and PAM Transceivers—Continued

Th4A.6 • 16:45
Experimental Demonstration of 100G/lambda Nyquist-PAM4 Transmission with Digital Pre-Equalization of Chromatic Dispersion for Extended-Reach 400GbE, Riu Hirai[1], Nobuhiko Kikuchi[1]; [1]*Hitachi, Japan*. 40-km NZ-DSF and SSMF transmission of 100 Gbit/s/lambda Nyquist-PAM4 with the help of digital pre-equalization is demonstrated, achieving BER less than Super FEC limit (BER 2E-3).

Th4A.7 • 17:00
Dispersion Pre-Compensation for PAM Transmission System Using 1-sample/symbol DAC and IQ Modulator, Takashi Inoue[1], Shu Namiki[1]; [1]*Natl Inst of Adv Industrial Sci & Tech, Japan*. We propose a systematic scheme for flexible dispersion pre-compensation using 1-sample/symbol digital-to-analog converter and IQ modulator for PAM transmission system. Transmission of dispersion-pre-compensated 12-Gbaud 4-PAM signal over SSMF links up to 120km is successfully demonstrated.

Networking • 17:15

Room 403A

Th4B • Future of Broadband Access II: Technologies—Continued

Room 403B

Th4C • Multicore Fibers—Continued

Th4C.3 • 16:45
High-count Multi-Core Fibers for Space-Division Multiplexing with Propagation-Direction Interleaving, Feihong Ye[1], Kunimasa . Saitoh[2], Hidehiko Takara[3], Rameez Asif[1], Toshio Morioka[1]; [1]*Technical Univ. of Denmark, Denmark;* [2]*Hokkaido Univ., Japan;* [3]*NTT Network Innovation Laboratories, Japan*. By introducing a square lattice structure for bidirectional core assignments in multi-core fibers, the effectiveness of propagation-direction interleaving for crosstalk reduction can be increased, realizing a 24-core fiber with − 30.6 dB crosstalk over 100 km.

Th4C.4 • 17:00
High-density Multicore Fiber with Heterogeneous Core Arrangement, Yoshimichi Amma[1], Yusuke Sasaki[1], Katsuhiro Takenaga[1], Shoichiro Matsuo[1], Jiajing Tu[2], Kunimasa Saitoh[2], Masanori Koshiba[2], Toshio Morioka[3], Yutaka Miyamoto[4]; [1]*Optics and Electronics Laboratory, Fujikura Ltd., Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido Univ., Japan;* [3]*Department of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [4]*NTT Network Innovation Laboratories, NTT Corporation, Japan*. A 30-core fiber with heterogeneous cores that achieved large spatial multiplicity and low crosstalk of less than -40 dB at 100 km was demonstrated. The correlation lengths were estimated to be more than 1 m.

Networking • 17:15

Room 404AB

Th4D • Nonlinear Interference: Modeling and Mitigation II—Continued

Th4D.5 • 16:45
Reach Enhancement of 100% for a DP-64QAM Super-Channel using MC-DBP, Robert Maher[1], Domanic Lavery[1], David Millar[2], Alex Alvarado[1], Kieran Parsons[2], Robert Killey[1], Polina Bayvel[1]; [1]*Univ. College London, UK;* [2]*Mitsubishi Electric Research Laboratories, USA*. A digital coherent super-receiver enables the reception and demodulation of a 7x10GBd DP-64QAM Nyquist spaced super-channel. Multi-channel DBP provides a 100% improvement in reach from 640km to 1280km of SSMF, with an ISD of 9.15b/s/Hz.

Th4D.6 • 17:00 Invited
The Dynamics of Inter-channel Nonlinear Distortions in Fiber-Transmission System, Mark Shtaif[1], Ronen Dar[1], Meir Feder[1], Antonio Mecozzi[2]; [1]*Tel-Aviv Univ., Israel;* [2]*Univ. of L'Aquila, Italy*. The properties of nonlinear interference noise (NLIN) in fiber optic transmission are explained and predicted by considering pulse-collisions occurring during propagation. The pulse-collision picture explains all previously unexplained phenomena and suggests paths for NLIN cancelation.

Room 406AB

Th4E • Modulators & Switches—Continued

Th4E.6 • 17:00
Low-Energy, High-Performance Lossless 8×8 SOA Switch, Qixiang Cheng[1], Adrian Wonfor[1], Jinlong Wei[1], Richard V. Penty[1], Ian White[1]; [1]*Univ. of Cambridge, UK*. We demonstrate the first monolithically-integrated active-passive lossless 8×8 SOA switch. A wide IPDR of 14.5dB for penalty <1dB is achieved. The switch paths through the device exhibit excellent uniformity.

Th4E.7 • 17:15
Sixteen-Channel Monolithically Integrated InP Wavelength Selector Based on a Chain of Passband-Flattened Cyclic AWG and Optical Switches, Ripalta Stabile[1], Nicola Calabretta[1], Kevin A. Williams[1], Harm J. Dorren[1]; [1]*Technische Universiteit Eindhoven, Netherlands*. An integrated wavelength selector based on combinations of integrated AWGs and SOAs selects one-out-of-sixteen input channels. Loss-compensated, error-free 16 WDM channel selection operation with <2.3dB penalty is reported with an OSNR of up to 32.5dB/0.1nm.

17:30–18:00 Beverage Break, *400 Rooms Foyer*

18:00–20:00 Postdeadline Papers, *Location will be announced in the Postdeadline Paper Digest*

Room 408A

Th4F • Coherent Transceiver—Continued

Kazuro Kikuchi received his Ph.D. degree in electronic engineering from the University of Tokyo. In 1979, he joined the Department of Electronic Engineering of the University of Tokyo and is currently a professor. He also serves on the board of directors for Alnair Labs Corporation, Japan. Throughout his career, his research has focused on optical fiber communications, and he is currently involved in coherent optical communication systems. He is a Fellow of the IEEE Photonics Society, a member of OSA, and a Fellow of IEICE. He is the recipient of awards including C&C Prize (2013) and John Tyndall Award (2014).

Room 408B

Th4G • Network Virtualization—Continued

Th4G.5 • 16:45
SDN-enabled Programmable Optical Packet/ Circuit Switched Intra Data Centre Network, Bingli Guo[1], Shuping Peng[1], Chris Jackson[1], Yan Yan[1], Yi Shu[1], Wang Miao[3], Harm J. Dorren[3], Nicola Calabretta[3], Fernando Agraz[2], Salvatore Spadaro[2], Jordi P. Muntan[2], Giacomo Bernini[4], Roberto Monno[4], Nicola Ciulli[4], Reza Nejabati [1], Georgios Zervas[1], Dimitra E. Simeonidou[1]; *[1]Univ. of Bristol, UK; [2]Universitat Politècnica de Catalunya, Spain; [3]Eindhoven Univ. of Technology, Netherlands; [4]Nextworks, Italy.* We demonstrated an SDN-enabled optical DCN leveraging AoD, OPS, FPGA-based ToR with extended OpenDayLight controller and extended OF protocol. Experimental results show application-aware OCS/OPS connection provisioning (753/214ms), OPS end-to-end connections latency (252μs), and OCS/OPS switchover.

Th4G.6 • 17:00
Virtual Machine Migration over Optical Circuit Switching Network in a Converged Inter/Intra Data Center Architecture, Payman Samadi[1], Junjie Xu[1], Keren Bergman[1]; *[1]Columbia Univ., USA.* We present a novel converged inter/intra data center architecture using optical-circuit-switching over metro-scale distances. A Software Defined Network (SDN) control-plane provides connectivity between the application and data-plane layers. Virtual-machine migration over 50km is experimentally demonstrated.

Th4G.7 • 17:15
SDN-Controlled Routing of Elephants and Mice over a Hybrid Optical/Electrical DCN Testbed, Konstantinos Kanonakis[1], Yawei Yin[1], Philip Ji[1], Ting Wang[1]; *[1]NEC Laboratories America, Inc., USA.* We propose an SDN-controlled hybrid optical/electrical intra-DCN framework allowing differentiated routing of diverse flow types. Experimental results demonstrate flow completion time reduction of up to 60% and 40% for elephants and mice respectively.

Room 409AB

Th4H • Advances in TDM-PON and FTTx Deployment—Continued

Th4H.6 • 17:00 Invited
Field Reliability of Silica-based PLC Splitter for FTTH, Atsushi Aratake[1]; *[1]NTT Device Innovation Center, Japan.* Silica-based planar lightwave circuits (PLCs) are widely used as the key components in fiber-to-the-home (FTTH) systems because of their various advantages. This paper reviews the reliability of the PLC-type 8-branch optical splitter for outdoor plant.

17:30–18:00 Beverage Break, *400 Rooms Foyer*

18:00–20:00 Postdeadline Papers,
Location will be announced in the Postdeadline Paper Digest

Room 411

Th4I • Special Symposium on Fiber Optic Parametric Amplifiers: A Tribute to the Research of Prof. Michel Marhic—Continued