A new loading algorithm is proposed to incorporate rate-adaptive coding into water-filling.

The innovations and future needs of WDM transport for inter-data-center interconnections, Bikosh Koley;

Google, USA. Abstract not available

M2F.1 • 13:30 Invited
Ultralow Loss Fiber Advances, Masaaki Hirano; ‘Sumitomo Electric Industries Ltd, Japan. Recent realization of ultralow loss pure-silica-core fibers having 0.15dB/km and their manufacturability will be discussed. The fibers have appropriately enlarged Aeff decided from viewpoint of analytically developed fiber figure-of-merit depending on transmission distances.
M2G • Photodetectors
Presider: Shinji Matsuo; NTT Photonics Laboratories, Japan

M2G.1 • 13:30
A High-Power and High-Linearity 50 GHz Waveguide Photodiode Module, Effimyimos Rouvalis1, Philipp Muller1, Sascha Feddenwitz1, Dirk Trommer1, Jens Stephan1, Andreas Stefan1, Günter Unterb örsch1; 2UTC Photonics AG, Germany. We demonstrate a high-responsivity (0.52 A/W) and high-linearity 50 GHz photodiode module based on an MMI-Splitter and a 4×PD-Array with +3.5 dBm RF-power at 50 GHz.

M2H • Cloud
Presider: Mototyoshi Sekiya; Fujitsu Lab America, USA

M2H.1 • 13:30 Tutorial
Optical Network Requirements for Cloud, Douglas Freimuth1; ‘Cloud Networking, IBM TJ Watson Research Center, USA. The cloud computing model’s acceptance is accelerating and the network is an essential enabler. This tutorial will describe the cloud computing model and relate the requirements of dynamic cloud networks for carrier NFV and large enterprise cloud networks.

M2I • High-Speed Access
Presider: Jorg Elbers; ADVA Optical Networking AG, Germany

M2I.1 • 13:30 Invited
Discrete Multi-Tone for 100 Gb/s Optical Access Networks, Tomyo Takahara1, Toshihisa Tanaka1, Masato Nishihara1, Yutaka Kai1, Lei Li1, Zhenniing Tao2, Jens Rassmussen1; 2Fujitsu Laboratories Ltd, Japan; 1Fujitsu R&D Center, China. Discrete Multi-Tone (DMT) is an attractive technology for short reach optical transmission systems. We have reported several results on transmission experiments using DMT. In this paper we review this technology and these experimental results.

M2J • Amplifiers for SDM I
Presider: Radan Slavik; Optoelectronics Research Centre, University of Southampton, United Kingdom

M2J.1 • 13:30
Design and characterization of Few-Mode Fiber amplifiers, Laurent Bigot1, 2; PhLM/IRCICA, CNRS, France. This tutorial will focus on the modeling and characterization of optical amplifiers based on few-mode erbium-doped fiber. The general equations used to describe multimode amplification will be reviewed and measurement techniques will be revisited.

M2K • Optical Switching
Presider: Milas Popovic; University of Colorado Boulder, USA

M2K.1 • 13:30 Top-Scored
A 204.8 Tbps Throughput 64x64 Optical Cross-Connect Prototype that Allows C/D/C Add/Drop, Kensuke Takaha1, Yojiro Mori1, Hiroshi Hasegawa2, Ken-ichi Sato1, Toshio Watanabe1; 1Department of Electrical Engineering and Computer Science, Nagoya Univ., Japan; 2NTT Photonics Laboratories, NTT Corporation, Japan. We fabricate a subsystem modular 64x64 OXC with C/D/C add/drop capabilities. Its throughput reaches 204.8 Tbps at the channel speed of 40 Gbps. Transmission experiments verify the performance of the prototype.

M2K.2 • 13:45 Top-Scored
Monolithic 50x50 MEMS silicon Photonic Switches with Microsecond Response Time, Sangyoon Han1, 2; Eun-Joon Seok1; Niels Quack1, Byung-Wook You1, Ming C. Wu1; ‘Electrical Engineering and Computer Science, Univ. of California, Berkeley, USA. We report on 50x50 MEMS-actuated silicon photonic switches with 16V switching voltage and microsecond switching time. 2,500 MEMS cantilever 1x2 waveguide switches have been integrated on 9mmx9mm chips.
Monday, 10 March

M2A • QAM—Continued

M2A.3 • 14:00 Top-Scored Generation of a Digitally Shaped 55-Gb/s 64-QAM Single-Carrier Signal Using Novel High-Speed DACs, Sebastian Randel1, Stephen Corteselli1, Peter J. Winzer2, Andrew Adamiecki1, Alan Grauch1, S. Chandrasekhar1, Anna Bielik1, Lars Altenhain1, Tobias Ellermeyer1, Ulrich Dümler1, Henning Langenhagen2, Rolf Schmidt1; 1Bell Laboratories, Alcatel-Lucent, USA; 2TeraXion, Canada. In the Presence of Sinusoidal Tones, rectified Phase Recovery for 64-QAM—Parallel and Pipelined Decision-Diaphragms, Bastian Randel1, Sebastian Randel1, Lars Altenhain1, Tobias Ellermeyer1, Ulrich Dümler1, Henning Langenhagen2, Rolf Schmidt1; 1Bell Laboratories, Alcatel-Lucent, USA; 2TeraXion, Canada. We experimentally investigate the performance of coded-modulation formats based on Nyquist-spectrally-shaped mQAM constellations with spectral efficiencies from 2.4 to 8.0 bits/s/Hz, and demonstrate that the relative performance in uncompensated links depends only on their respective OSNR sensitivity.

M2B • Network Planning—Continued

M2B.3 • 14:00 Simulations of Traffic Growth in a ROADM Network with a Growing Topology, Mark D. Feuer1, Sheryl L. Woodward2, Inwoong Kim3, Paperao Palacharla1, Xi Wang1, Qiong Zhang2, Daniel Bihov1; 1CUNY - College of Staten Island, USA; 2AT&T Labs - Research, USA; 3Fujitsu Laboratories of America, USA; 4Fujitsu Network Communications, USA. We explore the challenges faced when deploying a new technology to serve a large network. Our simulations demonstrate the benefits of having an optical layer that can be reconfigured as the technology’s footprint grows over time.

M2C • Coded Modulation I—Continued

M2C.3 • 14:00 Invited Transmission Performance of Coded Modulation Formats in a Wide Range of Spectral Efficiencies, Jin-King Cai1, Hussam G. Batshon2, Hongbin Zhang2, Matt Mazurczyk2, Oleg Sinkin2, Dmitri Fousra1, Alexei Pilipetskii1; 1TE Sub-Com, USA. We experimentally study the performance of coded-modulation formats based on Nyquist-spectrally-shaped mQAM constellations with spectral efficiencies from 2.4 to 8.0 bits/s/Hz, and demonstrate that the relative performance in uncompensated links depends only on their respective OSNR sensitivity.

M2D • Radio-over-Fiber I—Continued

M2D.2 • 14:00 5-bits/Hz 50-Gbps W-band Optical/Wireless System Employing Single-Sideband Single-Carrier Modulation, Chun-Hung Ho1, Yu-Hsuan Cheng1, Hou-Tzu Huang1, Chun-Ting Lin1, Chia-Chien Wei1, Sien Chi1; 1Inst. of Photonics Technology, National Chiao Tung Univ., Taiwan; 2Department of Photonics, National Sun Yat-sen Univ., Taiwan. We experimentally demonstrate W-band radio-over-fiber system employing single-sideband single-carrier modulation with lower PAPR than OFDM. Up to 50-Gbps wireless transmission with the highest spectral efficiency of 5-bits/Hz at 103GHz can be achieved over 25-km fiber.

M2E • DC 100 Gb/s and Beyond Transmission—Continued

M2E.2 • 14:00 400Gbe Demonstration Utilizing 100Gbe Optical Sub-Assemblies and Cyclic Arranged Waveguide Gratings, Yoshiyuki Doi1, Takaharu Chiyama1, Toshihide Yoshimatsu1, Shunichi Soma1, Manabu Oguma1; 1NTT Photonics Laboratories, NTT Corporation, Japan. We propose a 16 x 25-G/bs WDM configuration with cyclic AWGs as a realistic solution for 400-Gibs Ethernet, which utilizes 100Gbe optical sub-assemblies. A 10-km error-free transmission with our proposed approach demonstrates its technical feasibility.

M2F • Low Loss and Hollow Core Fibers—Continued

M2F.2 • 14:00 Large Aeff Pure-Silica-Core Fiber with Low Similar Splice Loss for Terrestrial Transmission Lines, Yoshinori Yamamoto1, Yuki Kawaguchi1, Masaaki Hirano1; Sumitomo Electric Industries, Ltd., Japan. We demonstrate that pure-silica-core fiber with Aeff of 110 nm2 exhibits low span loss including plural similar splices, which will contribute to high OSNR in hybrid Raman/EDFA-amplified systems.

M2A • QAM—Continued

M2A.4 • 14:15 Parallel and Pipelined Decision-Directed Phase Recovery for 64-QAM in the Presence of Sinusoidal Tones, Wing-Chau Ng1, An T. Nguyen2, Simon Ayotte1, Chul Soo Park1, Leslie Rusch1; 1Universite Laval, Canada; 2TeraXion, Canada. We experimentally investigate the impact of sinusoidal laser phase on parallel and pipelined decision-directed phase recovery in a 5 Gb/s 64-QAM system, including the effects of frequency offset compensation and equalization.

M2B • Network Planning—Continued

M2B.4 • 14:15 Optical Super-Channels in Long-Haul Network Architectures, Steven Clarke1, Serge Asselin1, Arash Vakili1; Network Planning, Ciena Corporation, Canada. Network efficiency is compared for 500Gb/s super-channel and 100Gb/s single-wavelength systems. Results show that exclusively using 500Gb/s systems requires 1.7x to 2.6x more network capacity for the same service demands and introduces network scalability concerns.

M2C • Coded Modulation I—Continued

M2C.3 • 14:15 Seamless W-Band Radio-to-Optical Signal Conversion with Direct IQ Down-Converter, Atsushi Kanno1, Yoshida Kanno1, Pham Tien Dat1, Yoshihideshi Akita1, Iwao Hosaka1, Tetsuya Kawanishi1, Yuki Yoshida1, Ken-ichi Kitayama1; National Inst. of Information and Communications Technology, Japan; 2Osaka Univ., Japan. Seamless conversion from millimeter-wave radio signals to optical baseband signals was demonstrated using a direct IQ down-converter. Hybrid optical and millimeter-wave signal transmission was performed using a conventional digital-coherent receiver, without any special algorithms.

M2D • Radio-over-Fiber I—Continued

M2D.3 • 14:15 100 Gb/s Uncooled DWDM using Orthogonal Coding for Low-cost Data Communication Links, Johannes von Lindern1, Jonathan D. Ingham1, Adrian Warner1, Jiannan Zhu1, Richard V. Penty1, Ian White1; 1Electrical Engineering Division, Univ. of Cambridge, UK. We demonstrate a 10 x 10 Gb/s uncooled DWDM system using orthogonal coding on adjacent carriers, assuming the use of a monolithically integrated sources. A power saving of 72% is expected over traditional WDM.

M2E • DC 100 Gb/s and Beyond Transmission—Continued

M2E.3 • 14:15 Low-Loss Low-Latency Transmission Over Single-Mode Hollow Core Fiber at 10 and 120 Gb/s, Vitaly Mikhailov1, John M. Fini1, Linli Meng1, Brian Morgan1, Jeffrey W. Nicholson1, Robert S. Windeler1, Eric M. Monberg1, Frank V. DiMarcello1, Paul S. Westbrook1; 1OFS Laboratories, USA. We present a single-mode hollow-core fiber with loss of 5.7 dB/km for low latency transmission. We demonstrated penalty-free transmission over 1 and 300 m at 10 Gb/s and 120 Gb/s without optimization of launch conditions.
The demonstrated up to 4-channel TWPDAs show >10GHz 3-dB bandwidths and ~0.75A/W responsivity using 30µm-length PDs.

**M2I • High-Speed Access—Continued**

**M2I.2 • 14:00** Experimental Demonstration of 100 Gbps Optical DMT Transmission Combined with Mobile Data Signal

**M2I.3 • 14:15** 30km Downstream Transmission Using 4×25Gb/s 4-PAM Modulation with Commercial 10Gbps TOSA and ROSA for 100Gb/s-PON, Hong G. Zhang1, Shengmeng Fu1, Jian-gwei Man1, Wei Chen1, Xiaolu Song1, Li Zeng1, Fixed Network Research Department, Huawei Technologies Co., Ltd., China. We proposed a novel 100Gb/s PON scheme using 4-PAM modulation with commercial low-cost 10Gb/s TOSA/ROSA compatible with 40Gb/s TWDM-PON. Experimental results show that with EQ compensating bandwidth limitation and CD, 30km transmission is available.

**M2K • Optical Switching—Continued**

**M2K.3 • 14:00** High-speed and Compact Non-blocking 8×8 InAlGaAs/InAlAs Mach-Zehnder-Type Optical Switch Fabric, Hiroki Kouketsu1, Shoko Kawasaki1, Noriko Koyama1, Akiko Takei1, Taka-fumi Taniguchi1, Yuichi Matsuhashi1, Katsuyuki Utaka1, 1Faculty of Science and Engineering, Waseda Univ., Japan; 2Central Research Laboratory, Hitachi Ltd., Japan; 3Green Computing System Research Organization, Waseda Univ., Japan. A high-speed and compact non-blocking 8×8 InAlGaAs/InAlAs Mach-Zehnder-type optical switch (MZ-OS) fabric consisted of twenty eight 2×2 MZ-OS elements were successfully fabricated. It is expected to operate with switching times of less than 2.5ns.

**M2K.4 • 14:15** Chip-level 10Gbit/s optical interconnects using 1 × 2 polymer vertical splitter on silicon substrate, Chin-Ta Chen1, Po-Kuan Shen1, Teng-Zhang Zhu1, Chia-Chi Chang1, Shu-Shuan Lin1, Mao-Yuan Zeng1, Chien-Yu Chiu1, Hsiu-Liang Hsiao1, Hisao-Chin Lan1, Yun-Chih Lee1, Yo-Shen Lin1, Mount-Learn Wu1, 1Department of Optics and Photonics, National Central Univ., Taiwan; 2Optical Sciences Center, National Central Univ., Taiwan; 3Centera Photonics Inc., Taiwan; 4Department of Electrical Engineering, National Central Univ., Taiwan. The chip-level 10-Gbit/s optical interconnects with the BER better than 10-12 using the 1 × 2 polymer vertical splitter, which is composed of a polymer waveguide and three silicon 45° reflectors is demonstrated.
Room 120

M2A • QAM—Continued

M2A.5 • 14:30
Multicarrier Offset-QAM Modulation for Coherent Optical Communication Systems, Jessica Fickens; Amirhossein Ghaziaiedi, Massimiliano Salsi, François Horlin, Philippe Emplit, Gabriel Charlet; Université libre de Bruxelles, Belgium; Alcatel Lucent Bell Labs, France. We study the performance of multicarrier offset modulation and root-raised-cosine shaped multicarrier modulation with aggregate 32.5 GBd symbol rate and shaped multicarrier modulation with root-raised-cosine constraint abstractions for computing virtual overlay networks.

M2B • Network Planning—Continued

M2B.5 • 14:30
Invited
Network Virtualization, Aihua Guo; ADVA Optical Networking Inc., USA. Network virtualization is introduced to optical networks to enable the offering of logical network resources. This paper examines virtualization practices for optical networks and optical aggregation 32.5 GBd symbol rate and shaped multicarrier modulation with root-raised-cosine modulation and root-raised-cosine performance of multicarrier offset-QAM. Lucent Bell Labs, France. We study the performance of multicarrier offset modulation and root-raised-cosine shaped multicarrier modulation with aggregate 32.5 GBd symbol rate and show that offset modulation is preferable for non-zero rolloff factors.

M2C • Coded Modulation I—Continued

M2C.4 • 14:30
Invited
Four-Dimensional Modulation Formats for Long-Haul Transmission, Pontus Johansson; Martin Spodin; Tobias A. Eriksson; Magnus Karlsson; Photonics Laboratory, Chalmers Univ. of Technology, Sweden. A number of four-dimensional modulation formats are described theoretically and from an implementation point of view. The requirements for digital signal processing and the trade-off between spectral efficiency and receiver sensitivity is discussed.

M2D • Radio-over-Fiber I—Continued

M2D.4 • 14:30
Robust 71–76 GHz Radio-over-Fiber Wireless Link with High-Dynamic Range Photonic Assisted Transmitter and Laser Phase-Noise Insensitive SSB Receiver, Andreas Stohrn; Oleg Cujucari; Frederic van Dyk; Guillermo Carpintero; Tolga Tekin; Stephane Formont; Université Duisburg-Essen, Germany; ACST GmbH, Germany; LET-Lab, France; Technische Universität Berlin, Germany; Thales Systems Aéronautiques, France. A robust radio-over-fiber wireless link system for use in wireless extension and mobile backhaul applications is presented. The wireless link operates at 71–75 GHz E-band carrier frequencies and can transmit up to 2.5 Gbps.

M2E • DC 100 Gb/s and Beyond Transmission—Continued

M2E.4 • 14:30
Top-Scored
O-band 400 Gbit/s Client Side Optical Transmission Link, Tianjian Zhu; Anna Tatarkczak; Miguel Iglesias; Jose Estarain; Jose Bevensee Jensen; Qwen Zhong; Xiaogeng Xu; Idelfonso Taturn; Transmission Technology Research Department, Huawei Technologies Co., China; DTU Fotonic, Department of Photonics Engineering, Technical Univ. of Denmark, Denmark. We present an O-band 400 Gbit/s optical client side Ethernet link with 40 km SMF reach employing four LAN-WOM lanes, MultICAP modulation and direct detection.

M2F • Low Loss and Hollow Core Fibers—Continued

M2F.4 • 14:30
Understanding Wavelength Scaling in 19-Cell Core Hollow-Core Photonic Bandgap Fibers, Yong Chen; Natalie V Wheeler; Naveen Baddela; John Hayes; Seyed Reza Sandoghchi; Eric Numkam Fokuoa; Meng Li; Francesco Poletti; Marco Petrovich; David J. Richardson; Optoelectronics Research Centre, Univ. of Southampton, UK. First experimental wavelength scaling in 19-cell core HC-PBGF indicates that the minimum loss bandwidth occurs at longer wavelengths than previously predicted. Record low loss (2.5 dB/km) fibers operating around 2.5 μm and gas-purging experiments are also reported.

M2A.6 • 14:45
Top-Scored
Experimental Performance of 4D Optimized Constellation Alternatives for PM-8QAM and PM-16QAM, Henning Buelow; Xiaofeng Lu; Laurent Schmalen; Axel Klekamp; Fred Buchali; Bell Labs, Alcatel-Lucent, Germany; LHFI, MAOT, Univ. Erlangen, Germany. Sensitivity and reach of soft-decoded PM-8QAM was improved by 1.2 dB and 35%, respectively, by moving to a 64 point 4D constellation and iterative decoding. Replacing PM-16QAM by 256 4D points led to 0.3-dB gain only.

M2B.5 • 14:45
Top-Scored
Demonstration of 24-Gb/s Carrierless Amplitude and Phase Modulation (CAP) 64QAM Radio-over-Fiber System over 40-GHz Mm-wave Fiber-Wireless Transmission, Junwen Zhang; Xinying Li; Jiangnan Xiao; Gee-Kung Chang; Fan Li; Fudan University, China; ZTE (TX) Inc, USA; Georgia Inst. of Technology, USA. A novel CAP-ROF system based on multi-level carrier-less amplitude and phase modulation (CAP) 64QAM with high spectrum efficiency is demonstrated. The 24-Gb/s CAP-64QAM signal is successfully transmitted over 40-km SMF and 1.5-m 38-GHz wireless link.

M2C.5 • 14:45
Demonstration of 24-Gb/s Carrierless Amplitude and Phase Modulation (CAP) 64QAM Radio-over-Fiber System on 40-GHz Mm-wave Fiber-Wireless Transmission, Junwen Zhang; Xinying Li; Jiangnan Xiao; Gee-Kung Chang; Fan Li; Fudan University, China; ZTE (TX) Inc, USA; Georgia Inst. of Technology, USA. A novel CAP-ROF system based on multi-level carrier-less amplitude and phase modulation (CAP) 64QAM with high spectrum efficiency is demonstrated. The 24-Gb/s CAP-64QAM signal is successfully transmitted over 40-km SMF and 1.5-m 38-GHz wireless link.

M2D.5 • 14:45
Towards 100 Gbps over 100m MMF using a 850nm VCSEL, Miguel Iglesias Olmedo; Anna Tatarkczak; Tianjian Zhu; Jose Estarain; Xiaogeng Xu; Idelfonso Taturn; Transmission Technology Research Department, Huawei Technologies Co., Ltd, China; DTU Fotonic, Department of Photonics Engineering, Technical Univ. of Denmark, Denmark; Transmission Technology Research Department, Huawei Technologies Co., Ltd, China; Optics division, Royal Inst. of Technology (KTH), Sweden. Employing MultiCAP signaling, successful 70.4 Gbps transmission over 100m of OM3 MMF using off-the-shelf 850 nm VCSEL with 10.1 GHz 3-dB bandwidth is experimentally demonstrated indicating the feasibility of achieving 100 Gbps with a single 25 GHz VCSEL.

M2E.5 • 14:45
Accurate Loss and surface mode modeling in Fabricated Hollow-core Photonic Bandgap Fibers, Eric Rodrigue Numkam Fokuoa; Seyed Reza Sandoghchi; Yong Chen; Natalie V Wheeler; Naveen Baddela; John Hayes; Seyed Reza Sandoghchi; Eric Numkam Fokuoa; Meng Li; Francesco Poletti; Marco Petrovich; David J. Richardson; Optoelectronics Research Centre, Univ. of Southampton, UK. We present a method to reconstruct the cross-sectional profile of fabricated hollow-core photonic bandgap fibers from SEM images. For the first time, numerical simulations show a good agreement with measured loss and surface mode position.

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M2G • Photodetectors—Continued

M2G.5 • 14:30
Ultra-Small Butt-Joint Ge Photodetector Featuring Self-Aligned In-situ Doping and CMP-Free Novel CVD Process, Makoto Miura1,2, Junichi Fujikata1,2, Masataka Noguchi1,2, Yasuhiko Anakawa1,2; 1Inst. for Photonics-Electronics Convergence System Technology (PETRA), Japan; 2Inst. of Industrial Science, Univ. of Tokyo, Japan. Ultra-small butt-joint germanium photodetector featuring self-aligned in-situ doping was realized with drastically decreased process number based on novel CVD method. The photodetector showed prominently increased number based on novel CVD method. We report the first experimental demonstration of a cladding pumped FM-EDFA supporting 4 mode groups. The modal gains are measured to be >20dB between 1540nm-1570nm with modal differential gain of ~4dB among the mode groups.

M2G.6 • 14:45
Waveguide Ge/Si Avalanche Photodetector with a Unique Low-Height-Profile Device Structure, Tsung-Yang Liow1,2, Zong Ye1, Philip N. Ji1; 1NIEC Laboratories America Inc., USA. We design network hypervisor applications to embed cloud demands in flexible grid transport networks for the first time. The designed applications can embed at least 15% more cloud demands than the baseline approach.

M2H • Cloud—Continued

M2H.2 • 14:30
Cloud Service Embedding in Software-Defined Flexible Grid Optical Transport Networks, Ankul Kumar Patel1, Zong Ye1, Philip N. Ji1; 1NIEC Laboratories America Inc., USA. We design network hypervisor applications to embed cloud demands in flexible grid transport networks for the first time. The designed applications can embed at least 15% more cloud demands than the baseline approach.

M2H.3 • 14:45
Survivability in Virtualized Networks, Dominic Schupke1,2, Bercu Barla1, Marco Hoffmann1; 1Nokia Siemens Networks, Germany; 2Technische Universität München, Germany. Future highly-reliable cloud and network services demand for survivability architectures covering network and IT infrastructures. We propose corresponding design models and evaluate them.

M2H.5 • 14:45
Experimental Demonstration of 448-Gbps+ DMT Transmission over 30 km SMF, Toshiki Tanaka1, Masato Nishihara1, Tomoo Takahara, Weizhen Yan, Lei Li1, Zhenning Tao1, Manabu Matsuda1, Kazumasa Takabayashi1, Jens Rasmussen2; 1Fujitsu R&D Center, China; 2Fujitsu Laboratories Ltd., Japan. We have experimentally demonstrated 449-Gbps transmission over 30-km SMF using DMT on a LAN-WDM system for 400-Gbps Ethernet. Only four directly modulated lasers and direct detectors as optical devices were necessary to achieve the results.

M2J • Amplifiers for SDM I—Continued

M2J.2 • 14:30
First Demonstration of Cladding-Pumped Few-modal EDFA for Mode Division Multiplexed Transmission, EE Leong Lim, Yongmin Jung, Qiongyue Kang1, Tim C. May-Smith1, Nicholas H. L. Wong1, Robert Standish1, Francesco Poletti1, Jayanta K. Sahu1, Shaiful Alam1, David J. Richardson1; 1Univ. of Southampton, UK. We report the first experimental demonstration of a cladding pumped FM-EDFA supporting 4 mode groups. The modal gains are measured to be >20dB between 1540nm-1570nm with modal differential gain of ~4dB among the mode groups.
M2A • QAM—Continued

M2A.7 • 15:00
Training-Aided PDM 64-QAM Transmission with Enhanced Fiber Nonlinearity Tolerance, Chen Zhu1, Liang B. Du2, An V. Tran1, Arthur J. Lowery2, Elstratos Skafidas3, 1NICTA, Electrical and Electronic Engineering, Univ. of Melbourne, Australia; 2Cisco Optical GmbH, Germany; 3CUDOS, Electrical and Computer Systems Engineering., Monash Univ., Australia. We show that fiber nonlinearity compensation of just the training sequence improves the nonlinearity-limited performance of training-aided m-QAM systems. Experimental results demonstrate transmission performance improvement by 0.4 dB for a 120-Gb/s 64-QAM mission with Enhanced Fiber Nonlinearity Tolerance.

M2A.8 • 15:15
Multi-Stage CPE Algorithms for 64-QAM Constellations, Syed M. Bilal1, Chris R. Fludger1, Gabriella Bosco1, 1DET, Politecnico di Torino, Italy; 2Cisco Optical GmbH, Germany. We propose and analyze a multi-stage architecture for carrier phase-estimation in 64-QAM systems, based on the cascade of several feed-forward elementary blocks. We outline the beneficial effect of increasing the number of elementary blocks.

M2B • Radio-over-Fiber I—Continued

M2B.6 • 15:00
Top-Scored
150-km 103-GHz Direct-Detection OFDM-RoF System Employing Pilot-aided Phase Noise Suppression, Hou-Tzu Huang1, Wan-Ling Liang1, Chia-Chien Wei2, Chun-Ting Lin2, Sien Chi1, 1Inst. of Photonic System, National Chiao-Tung Univ., Taiwan; 2Department of Photonics, National Sun Yat-sen Univ., Taiwan. Pilot-aided phase noise suppression (PPNS) is employed to demonstrate distance- and linewidth-insensitive 103-GHz DD-OFDM-RoF systems. With 10.3-MHz linewidth, PPNS lowers BER of ~6-dBm signal from >10-2 to <10-3 over 150-km fiber and 2-m wireless transmission.

M2B.7 • 15:15
Full-duplex bidirectional transmission of 10-Gb/s millimeter-wave QPSK signal in E-band optical wireless link, Yuan Fang1, Jianjun Yu2, Junwen Zhang2, 1Jiangnan University, China; 2ZTE Corporation, USA. We proposed and experimentally demonstrated full-duplex bidirectional transmission of 10-Gb/s millimeter-wave QPSK signal in E-band optical wireless link with coherent detection and digital signal processing for emergency communication.

M2C • Radio-over-Fiber II—Continued

M2C.6 • 15:00
Real-Time Demonstration of 100Gbps Class Dual-carrier DDO-16QAM-DMT Transmission with Directly Modulated Laser, Xin Xiao1, Fan Li1, 1ZTE (TX) Inc, USA. Real-time 100Gbps dual-carrier DDO-16QAM-DMT transmission and reception is successfully demonstrated at a record line. The measured BER after 20-km LEAF is less than the SD pre-FEC limit of 2×10-2.

M2C.7 • 15:15
A Low-Cost 100GE Optical Transceiver Module for 2km SMF Interconnect with PAM4 Modulation, Jiangwei Man1, Wei Chen1, Xiaolu Song1, Li Zeng1, 1Fixed Network R&D Department, Huawei, China. With the introduction of PAM4 modulation, a novel 100GE optical transceiver module has been proposed using the low-cost 4x10Gbps DML TOSA and PIN ROSA. 4x25Gbps PAM4 signal transmission has been demonstrated over 2km SMF on-line with -11dBm sensitivity and 4dB link margin.

M2D • 15:00
First Investigation of Longitudinal Defects in Hollow Core Photonic Bandgap Fibers, Seyed Reza San doghchi1, Tao Zhang1, John P. Wooler1, 1Optoelectronics Research Centre, Univ. of Southampton, UK. To improve yield in fabricated HC-PBGFs we have studied morphology and longitudinal evolution of occasional, undesired defects causing localized loss. The short spatial and temporal duration of the defects seems indicative of residual preform contaminations.

M2E • DC 100 Gb/s and Beyond Transmission—Continued

M2E.6 • 15:00
Real-Time Demonstration of 100Gbps Class Dual-carrier DDO-16QAM-DMT Transmission with Directly Modulated Laser, Xin Xiao1, Fan Li1, 1ZTE (TX) Inc, USA. Real-time 100Gbps dual-carrier DDO-16QAM-DMT transmission and reception is successfully demonstrated at a record line. The measured BER after 20-km LEAF is less than the SD pre-FEC limit of 2×10-2.

M2F • Low Loss and Hollow Core Fibers—Continued

M2F.6 • 15:00
First Investigation of Longitudinal Defects in Hollow Core Photonic Bandgap Fibers, Seyed Reza San doghchi1, Tao Zhang1, John P. Wooler1, 1Optoelectronics Research Centre, Univ. of Southampton, UK. To improve yield in fabricated HC-PBGFs we have studied morphology and longitudinal evolution of occasional, undesired defects causing localized loss. The short spatial and temporal duration of the defects seems indicative of residual preform contaminations.

Presentations selected for recording are designated with a •. Access these by visiting www.ofcconference.org and clicking on the View Presentations button.

15:30–16:00 Coffee Break, South, Exhibit Halls A, B, C, North, Exhibit Hall D
Disaster-Aware Dynamic Content Placement in Optical Cloud Networks, Sifat Ferdousi, Massimo Tornatore, Biswanath Mukherjee, M. Farhan Habib, Ferhat Dikbiyik. Content placement in cloud networks should be resilient to data loss due to disaster-driven failures. We propose a disaster-aware dynamic content placement scheme to reduce the expected content loss while satisfying resource constraints and QoS.

On-Chip Optical Interconnects Integrated with Laser and Photodetector Using Three-Dimensional Silicon Waveguides, Po-Kuan Shen, Chia-Hao Chang, Chien-Yu Chu, Chia-Chi Chang, Hsiao-Chin Lan, Yun-Chih Lee, Mount-Learn Wu. A whole on-chip optical interconnects integrated with laser, photodetectors, driver IC, and amplifier IC is experimentally demonstrated. A 10-Gbps error-free data transmission is achieved as driving current of laser is 10 mA.

Electronic Two-Dimensional Beam Steering for Integrated Photased Arrays, Behrooz Abiri, Firooz Aflatouni, Angad Rekhi, Ali Hajimiri. This paper presents electrical beam steering in an integrated 4x4 2D optical phased array (OPA) on a silicon on insulator (SOI) process enabling fast and repeatable beam steering for next generation projection, tracking, and imaging.

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Room 102
16:00–18:00
M3A • FEC and Modulation
Presider: Gabriella Bosco; Politecnico di Torino, Italy

M3A.1 • 16:00 • Invited
Energy Efficient FEC for Optical Transmission Systems, Laurent Schmaler1; Bell Laboratories, Alcatel-Lucent, Germany. We give an overview about different options for energy efficient FEC realizations in future optical communication systems. We especially highlight different options for realizing energy efficient decoders for higher order modulation formats.

Room 120
16:00–18:00
M3B • Multi-layer Networks
Presider: Ronald Skoog; Applied Communication Sciences, USA

M3B.1 • 16:00 • Top-Scored
Minimizing resource protection in IP over WDM networks: Multi-layer Shared Backup Router, Arturo Mayoral Lopez de Lema1, Victor Lopez2, Ori Gerstel1, Elef Palkopoulou1, Juan-Pedro Fernandez-Palacios1, Oscar Gonzalez de dias1; Core Networks, Telefonica I+D, Spain; ‘Cisco’, Israel. This work compares two resilience strategies on multi-layer network dimensioning: dual-plane protection and Multi-Layer Shared Backup Router. Latter provides a significant reduction (up to 24%) on the required IP equipment in comparison with current approach.

M3B.2 • 16:15
Optimization of Light-path Configuration Order in IP over WDM Networks using Fast Traffic Matrix Estimation, Shohei Kamaru1, Daisaku Shimazaki1, Hiroki Morii1, Koji Sasakiyama1, Yuki Koizumi2, Shin’ichi Arakawa3, Masayuki Murata3; ‘NTT’, Japan; ‘Osaka Univ., Japan. We propose an algorithm for determining light-path configuration order to minimize the reconfiguration time from a disrupted state to a suboptimal state. It computes a near-optimal solution within one minute on a 1000-node network.

Room 121
16:00–17:45
M3C • Fiber Nonlinearity Mitigation & Compensation
Presider: Fabrizio Forghieri; Cisco, Italy

M3C.1 • 16:00
Exceeding the Nonlinear-Shannon Limit using Raman Laser Based Amplification and Optical Phase Conjugation, Ian Phillips1, Mingmeng Tan1, Marc F. Stephens1, Mary McCarthy2, Elias Giacomides3, Stylianos Sygellos4, Pawel Rosai1, Simon Fabbri2, Son T. Le1, Thavamaran Kanesan2, Sergei K. Turitsyn3, Nick J. Doran1, Paul Harper1, Andrew D. Ellis1; ‘Aston Inst. of Photonics Technologies, Aston Univ., UK. We demonstrate that a combination of Raman laser based amplification and optical phase conjugation enables transmission beyond the nonlinear-Shannon limit. We show nonlinear compensation of 7x114Gbit/s DP-QPSK channels, increasing system reach by 30%.

M3C.2 • 16:15
Fiber Nonlinearity Compensation of an 8-channel WDM PDM-QPSK Signal using Multiple Phase Conjugations, Hao Hu1, Robert M. Jopson2, Alan Gnauck1, Mihaela Dinu1, S. Chandrasekhar1, Xiang Liu1, Chongjin Xie1, Marc Montoliu2, Sebastien Randel1, Colin McKenzie1, ‘Alcatel-Lucent Bell Labs, USA; ‘OTU Fotonic, Technical Univ. of Denmark, Denmark; 2Universitat Politècnica de Catalunya (ETSETB), Spain. We demonstrate compensation of fiber nonlinearities using optical phase conjugation of an 8-channel WDM 32-Gbaud PDM QPSK signal. Conjugating phase every 600 km in a fiber loop enables a 6000 km transmission over TrueWave fiber.

Room 122
16:00–18:00
M3D • Radio-Over-Fiber II
Presider: Andreas Stohr; Universität Duisburg-Essen, Germany

M3D.1 • 16:00
84-Gbps 64-QAM 2 × 2 MIMO RoF System at 60 GHz Employing Single-Sideband Single-Carrier Modulation, Chun-Ting Lin1, Chun-Hung Ho1, Hou-Tzu Huang1, Yu-Hsuan Cheng2; ‘Inst. of Photonics System, National Chiao Tung Univ., Taiwan. 2 × 2 MIMO RoF system employing single-sideband single-carrier modulation is experimentally demonstrated. Compared with OFDM, it has lower PAPR. The highest 84-Gbps data rate within 7-GHz unlicensed band at 60 GHz can be achieved.

M3D.2 • 16:15
LTE Advanced Carrier Aggregation Supporting Fully Standard 3GPP MIMO by Optical Polarization Multiplexing, Maria Morant1, Roberto Llorente1, Josep Prat2, ‘Telecom Technologies, Aston Univ., UK. We review recent developments in multi-mode fiber for high data rate and short reach applications and discuss new trends in multimode fiber to increase system data rate and reach length and for consumer applications.

Room 123
16:00–18:00
M3E • Datacom Switching Architectures
Presider: Odile Loboiron-Ladouceur; McGill Univ., Canada

M3E.1 • 16:00 • Tutorial
Scalable Computing Systems with Silicon Photonic Enabled Data Movement, Keren Bergman1; Columbia Univ., USA. As future computing systems aim to realize Exascale performance the challenge of energy efficient data movement rather than computation is paramount. Silicon photonics has emerged as perhaps the most promising technology to address these challenges by providing ultra-high bandwidth density communication capabilities that is essentially distance independent. This tutorial will explore the design of silicon photonic interconnected architectures and their impact on the system level performance.

Presentations selected for recording are designated with a. Access these by visiting www.ofcconference.org and clicking on the button.

Keren Bergman is the Charles Batchelor Professor and Chair of Electrical Engineering at Columbia University where she also directs the Lightwave Research Laboratory (http://lightwave.ee.columbia.edu/). She leads multiple research programs on optical interconnection networks for advanced computing systems, data centers, optical packet switched routers, and chip multiprocessor nanophotonic networks-on-chip. Dr. Bergman holds a Ph.D. from M.I.T. and is a Fellow of the IEEE and of the OSA. She has authored and co-authored over 350 publications in leading journals and conferences including a current book entitled: Photonic Network-on-Chip

Continued on page 68
16:00–17:45
M3G • High Speed Transmitters and Receivers
Presider: Larry Coldren; Univ. of California Santa Barbara, USA

M3G.1 • 16:00 • Invited
High Density Optical Interconnects for High Performance Computing, Fuad E. Doany1, International Business Machines Corp, USA. High Performance Computing systems with > 105 optical links are deployed today. Chip-scale optical transceivers for next generation systems can simultaneously achieve high bandwidth and high density while minimizing power and cost.

M3H.1 • 16:00 • Survivable Virtual Infrastructure Mapping over Transport Software-Defined Networks (T-SDN), Zilong Ye1,2, Ankitkumar Patel1, Phil Jin1, Chunmung Qiao2, Optical, NEC Labs of America, USA; 2Computer Science, SUNY-Buffalo, USA. An algorithm is proposed to map virtual infrastructures with survivability over T-SDN for the first time. The algorithm improves the traffic-carrying capacity of networks by provisioning at least 13% more demands than the baseline algorithms.

M3H.2 • 16:15 • Heterogeneous Bandwidth Provisioning for Virtual Machine Migration over SDN-Enabled Optical Networks, Uttam Mandal1, M. Farhan Habib1, Shuqiang Zhang1, Pulak Chowdhury1, Massimo Tornatore1,2, Bishwarth Mukherjee1, ‘Computer Science, Univ. of California Davis, USA; ‘Department of Electronics and Information, Politecnico di Milano, Italy. Virtual machine migration in cloud-computing environments is an important operational technique, and requires significant network bandwidth. We demonstrate that heterogeneous bandwidth (vs. homogenous bandwidth) for migration reduces significant resource consumption in SDN-enabled optical networks.

M3I.1 • 16:00 • Invited
Optical Component Technology Options for NG-PON2 Systems, Robert Murano1, ’Photop Aegis, Inc., USA. We review NG-PON2 system architectures and compare the viability of available component technologies to meet challenges at the OLT, ONU and wavelength multiplexing and demultiplexing nodes, and propose an alternative to discrete transceiver/multiplexer OLT architectures.

M3I.1 • 16:00 • Invited
Withdrawn

M3J.1 • 16:00 • Invited
Compact Multi-core Fiber Fan-out with GRIN-lens and Micro-lens Array, Osamu Shimakawa1, Sumitomo Electric Industries, Ltd., Japan. A multi-core fiber fan-out composed of a GRIN-lens and a micro-lens array has been proposed. A seven-core fan-out was fabricated and confirmed the coupling loss between the fan-out and SM-fiber agreed with the optical design.

M3K.1 • 16:00 • All-Fiber Mode Division Multiplexer optimized for GRIN-lens and Micro-lens Array, Tsung-Yang Liow1, Inst. of Microelectronics, Singapore. Compact Multi-core Fiber Fan-out with GRIN-lens and Micro-lens Array, Osamu Shimakawa1, Sumitomo Electric Industries, Ltd., Japan. A multi-core fiber fan-out composed of a GRIN-lens and a micro-lens array has been proposed. A seven-core fan-out was fabricated and confirmed the coupling loss between the fan-out and SM-fiber agreed with the optical design.
Efficiency, Shota Ishimura

Modulation Aiming at Both High Kikuchi limit even when their power efficiencies can approach the Shannon dimension of modulation, their spectral formats. With the increase in the dimension of modulation, their spectral efficiencies can approach the Shannon limit even when their power efficiencies are kept high.

1.05 dB gain even in the presence of frequent cycle slips. With 3% pilot insertion, the FEC decoder can efficiently mitigate decision feedback information from an iterative demodulation with soft-}

Optical Communications, Antonio Napoli

Cycle Slip-Mitigating Turbo Demodulation in LDPC-Coded Coherent Optical Communications, Toshiaki Kake-Akino, Keisuke Kojima, David Millar, Kieran Parsons, Yosshikuni Miyata, Wataru Matsumoto, Takashi Sugihara, Takashi Mizuschi, MERL, USA. We show that an iterative demodulation with soft-decision feedback information from FEC decoder can efficiently mitigate cycle slips. With 3% pilot insertion, the turbo QPSK demodulation achieves 1.05 dB gain even in the presence of frequent cycle slips.

Adaptive Digital Back-Propagation for Optical Communication Systems, Antonio Napoli, Maxim Kuscherov, Chien-Yu Lin, Bernhard Spinnler, Marc Bohn, Danish Rafique, Vincent A. Sieffer, Bernhard Schmauss, R&D, Conant GmbH, Germany; Inst. of Microwave and Photonics (IHF), Univ. of Erlangen (FAU), Germany; COBRA Inst., Eindhoven Univ. of Technology, Netherlands. We propose an adaptive digital back-propagation method (A-DBP) to self-determine unknown fiber nonlinear coefficient gamma. Performance is experimentally verified with 10×224-Gb/s POL-MUX-16QAM over 656km. Optimal DBP performance without knowledge of gamma, is obtained by A-DBP.

M3F.4 • 16:45
Digital Multi-Channel Post-Linearization for Uplink in Multi-Band Radio-Over-Fiber Systems, Yingqing Pei, Jianqiang Li, Kun Xu, Yitang Dai, Ji Yuefeng, Jionglin Lin; Beijing Univ of Posts & Telecom, China. A digital multi-channel post linearization technique is proposed for the uplink of multi-band RoF systems. With all linearization functions located in the central office, >12dB ACLR reduction is demonstrated in a two-band RoF system.

M3A.2 • 16:30
Multi-dimensional Permutation Modulation Aiming at Both High Spectral Efficiency and High Power Efficiency, Shota Ishimura, Kazuro Kikuchi, Univ of Tokyo, Japan. We analyze the performance of multi-dimensional permutation modulation formats. With the increase in the dimension of modulation, their spectral efficiencies can approach the Shannon limit even when their power efficiencies are kept high.

M3A.3 • 16:30
Invited Metro Transport Architectures for the Future, Wendell Liu, AT&T Services, INC, USA. Metro transport network architectures for the future need to support dynamic connectivity management with switching technologies at different levels that can be controlled via a programmable interface to meet the faster and bigger changes.

M3C.3 • 16:30
WDM Transmission of 3×1.12-Tb/s PDM-16QAM Superchannels with 6.5-b/s/Hz in a 162.5-GHz Flexible-Grid using only Optical Spectral Shaping, Luis Carvalho, Claudio Florida, Carolina Franciscangeli, Victor Parahyba, Edson P. da Silva, Neil G. Gonzalez, Julio Oliveira, CPqD, Brazil. We demonstrated the transmission of 3×1.12-Tb/s superchannels (5×224-Gb/s PDM-16QAM) in 162.5-GHz flexible-grid, 6.5-b/s/Hz SE, using only optical spectral shaping, over 5500-km EDFA link. A maximum reach of 600-km with 3-ROADM passes was obtained employing nonlinear compensation.

M3C.4 • 16:45
Adaptive Digital Back-Propagation for Optical Communication Systems, Antonio Napoli, Maxim Kuscherov, Chien-Yu Lin, Bernhard Spinnler, Marc Bohn, Danish Rafique, Vincent A. Sieffer, Bernhard Schmauss, R&D, Conant GmbH, Germany; Inst. of Microwave and Photonics (IHF), Univ. of Erlangen (FAU), Germany; COBRA Inst., Eindhoven Univ. of Technology, Netherlands. We propose an adaptive digital back-propagation method (A-DBP) to self-determine unknown fiber nonlinear coefficient gamma. Performance is experimentally verified with 10×224-Gb/s POL-MUX-16QAM over 656km. Optimal DBP performance without knowledge of gamma, is obtained by A-DBP.

M3D.3 • 16:30
Centralized Optical Pre-coding for Multi-cell MIMO in Millimeter-wave Radio-over-Fiber System, Lin Cheng, Cheng Liu, Ming Zhu, Jing Wang, Gee-Kung Chang, Georgia Inst. of Technology, USA. We propose a system design for millimeter-wave MIMO communications. Based on centralized optical pre-coding enabled by RoF, multi-cell MIMO is successfully demonstrated to enhance system capacity by exploiting the spatial multiplexing gain.

Low-DMGD 6-LP-Mode Fiber, Pierre Villard, Denis Malin, Marianne Bigot-Astruc, Hélène Maerten, Dennis van Ras, Frank Achtert, R&D, Pysmian Group, France; Pysmian Group, Netherlands. We report the design and the fabrication of a low-DMGD 6-LP-mode fiber adapted to strongly-coupled mode-division-multiplexed systems that allows to multiply the capacity by a tenfold factor.
M3G.2 • 16:30  Invited  Reliability of VCSELs for >25Gb/s, Jim Guenter1, Bobby Hawkins1, Robert Hawthorne1, Gary Landry1; Finisar Corporation, USA. The next individual-channel VCSEL (Vertical Cavity Surface Emitting Laser) node for data communications is 25 Gbps or higher. Providing the required reliability becomes ever more challenging as the speeds increase, but possible with proper design.

M3H.3 • 16:30  Effective Virtual Optical Network Embedding Based on Topology Aggregation in Multi-Domain Optical Networks, Sangjin Hong1, Jason P. Jue1, Qiong Zhang2, Xi Wang2, Hakki C. Cankaya3, Qingya She3, Motoyoshi Sekiya3; 1Computer Science, Univ. of Texas at Dallas, USA; 2Fujitsu Laboratories of America, USA; 3Fujitsu Network Communications, USA. We present an efficient algorithm for mapping a virtual optical network topology onto a physical multi-domain optical network with the objective of minimizing the total network link cost.

M3I.2 • 16:30  Outage probability due to Stimulated Raman Scattering in GPON and TDWM-PON coexistence, Vittorio Cumi1, Stefano Capriata2, Roberto Gaudino1; 1DEI, Politecnico di Torino, Italy; 2Telecom Italia, Italy. TDWM-PON (ITU-T G.989) may induce relevant extra-attenuation on coexistence with GPON due to Raman nonlinearity. We give a compact theoretical framework to study this problem considering polarization statistical effects, leading to outage probability characterization.

M3J.2 • 16:30  Invited  Techniques to detect and stop fiber fuses, Kenji Kurokawa1; 1Electrical and Electronic Engineering, Kitami Inst. of Technology, Japan. The fiber fuse phenomenon will pose a real danger to optical communication systems constructed with conventional single-mode fiber in the future. I describe techniques to actively and/or passively terminate fiber fuses.

M3K.3 • 16:30  Invited  Couplers for Multicore Fibers and 3D Waveguide Technology, Nicholas Psaila1; 1Optoscribe, UK. Components for Space-Division-Multiplexing fabricated using laser inscribed 3D waveguides are presented and discussed. Fan-outs for coupling to multicore fibre, Photonic Lanterns for coupling to multimode fibre, and advanced SDM integration platform capabilities are demonstrated.
M3A • FEC and Modulation—Continued

M3A.4 • 17:00
Comparison of Quaternary Block-Coding and Sphere-Cutting for High-Dimensional Modulation, David Millar1, Toshiaki Koike-Akino2, Sercan O. Arikan1, Kieran Parsons1; 1Mitsubishi Electric Research Labs, USA; 2Department of Electrical Engineering, Stanford Univ., USA. We propose quaternary block coded high-dimensional modulation formats and compare them to spherical lattice-cut and hybrid modulation formats. Noise tolerance and transmission performance are simulated for spectral efficiencies ranging between those of DP-QPSK and DP-8QAM. Similar performance to sphere-cutting is attained with lower DAC resolution.

M3A.5 • 17:15
Top-Scored
Experimental Demonstration of 24-Dimensional Extended Golay Coded Modulation with LDPC, David Millar1, Toshiaki Koike-Akino2, Robert Maher2, Domanic Lavery2, Milen Paskev2, Keisuke Kojima2, Kieran Parsons1, Benn Thorson3, Seb J. Savory2, Polina Bayvel2; 1Mitsubishi Electric Research Labs, USA; 2Department of Computer Engineering, Univ. of California, Santa Barbara, USA. With core networks going up to 1000Gb/s, multiple-layer network protection becomes increasingly important. Optimizing ITU-T G.808.3 Shared Mesh Protection at the transport layer with best effort SLRQ GMPLS protection at L2/L3 and survivability are studied.

M3B • Multi-layer Networks—Continued

M3B.4 • 17:00
Leverage G.808.3 Shared Mesh Protection and Best Effort SLRQ GMPLS Protection in Multi-layer Networks, Yuxun (Eugene) Dai1, Wei Dai2, 1Network Architecture, Cox Communications, USA; 2Department of Electrical Engineering, Stanford Univ., USA. We experimentally demonstrate 256 Gb/s PM-16-QAM Quasi-Single-Mode Transmission over 2600 km using Few-Mode Fiber with Multi-Path Interference Compensation, Sui Qi1, Zhang Hongfu2, John D. Downie2, William A. Wood3, Jason E. Hurley3, Snigdharaj Mishra4, Alan Pak Tao Lau5, Chao Lu1, Hwa-Yew Tam1, Ping-kong Alexander Wai1; 1Electrical Engineering, The Hong Kong Polytechnic Univ., Hong Kong; 2Tyndall National Inst., Univ. College cork, Ireland; 3Cornell Incorporated, USA; 4Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong. We experimentally demonstrate 256 Gb/s PM-16-QAM transmission up to 2600 km by using 100-km spans of few-mode fibers (FMF) operating in quasi-single-mode (QSM) transmission and using a DD-LMS algorithm to compensate multi-path interference (MPI).

M3C • Fiber Nonlinearity Mitigation & Compensation—Continued

M3C.5 • 17:00
Experimental Investigation on Multi-Dimensional Digital Predistortion for Multi-Band Directly-Modulated Radio-Over-Fiber Systems, Hao Chen1, Jianqiang Li2, Kun Xu3, Yitang Dai4, Fei Fei Yin1, Jintong Lin1; 1Beijing Univ of Posts & Telecom, China; 2Tyndall National Inst., Eindhoven Univ of Technology, Netherlands. The control plane is implemented for the first time to allow scheduling and power leveling in a monolithic 8×8 space and wavelength selective cross-connect. 16 dynamic data connections are established within 16μs.

M3D • Radio-Over-Fiber II—Continued

M3D.6 • 17:15
Ultra-High-Speed Fiber-Wireless Fiber Link for Emergency Communication System, Xinying Li1, Ziheng Cao1, Junwen Zhang1, Fan Li1, Gao Jingtao1, Fudan Univ., China; 2Eindhoven Univ. of Technology, Netherlands; 3ZTE (TX) Inc, USA; 4Georgia Inst. of Technology, USA. We propose and experimentally demonstrate fiber-wireless-fiber link suited for emergency situation. The proposed system has throughput comparable with fiber-optic communication. Capacity of 109.6 Gb/s over two spans of 80-km SMF and 2x2 MIMO is demonstrated.

M3E • Datacom Switching Architectures—Continued

M3E.3 • 17:15
OPTOPUS: Optical Backplane for Data Center Switches, Michael R. Tan1, Paul Rosenberg2, Georgios Pano-topoulos3, Moray McLaren4, Wayne So-nin5, SAGI MATHAI6, Jen niee Kiyama7, Joseph Straznicky1, David Warren1; 1Hewlett Packard Labs, USA; 2Hewlett Packard Company, USA; 3Hewlett Packard Labs, UK. An all optically connected data center switch with a Multi-Bus Optical Backplane is demonstrated. The broadcast bus is based on a multimode zig-zag star coupler capable of 1.6 optical broadcast on 12 multimode GI fiber channels.
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<td><strong>M3G</strong> • High Speed Transmitters and Receivers—Continued</td>
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**M3G.3 • 17:00**

*Up to 64-QAM Modulation of a Silicon-Ring-Resonator-Modulator*, Giovanni Benincasa de Farias¹, Sylvie Menezes¹, Olivier Dubray¹, Delphine Marois-Morini², Laurent Vivien², Andre Myko³, Benjamin Blampey³, CEA-Leti, France; ²Institut d’Electronique Fondamentale, France. The multi-level modulation of a Silicon-Ring-Resonator-Modulator (Si-RRM) is demonstrated for the first time: an up-to-64-Quadrature Amplitude Modulation (QAM) linear modulation span. This is made possible due to the use of a highly linear Si-RRM is demonstrated for the first time: an up-to-64-Quadrature Amplitude Modulation (QAM).

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<td><strong>M3H</strong> • Optical Networks and Virtualization—Continued</td>
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**M3H.5 • 17:00**

*Towards Software Defined Autonomic Terabit Optical Networks*, Julio Oliveira¹, Juliano Oliveira¹, Marcos Siqueira¹, Rafael Scarafaggi¹, Marcos Salvador¹, Leonardo Mariani¹, Neil G. Gonzalez¹, Luis Carvalho¹, Fabian Van’t Hoof¹, Giovanni Santos¹, Eduardo C. Magalhaès¹, João Januario¹, CPGD, Brazil. This paper presents an Optical SDN architecture and implementation enabled for virtual optical networks, supporting adaptive and cognitive algorithms to enhance QoT. The paper also shows experimental results of a software-defined autonomic flexible transponder.

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<td><strong>M3I</strong> • NG-PON2 Technologies—Continued</td>
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**M3I.4 • 17:00**

*Burst-mode Electronic Dispersion Compensation*, Peter Osseur¹, Stefano Porta¹, Clement Antony¹, Arul Jain¹, Denis Kelly¹, Nasir Quadri¹, Giuseppe Talli¹, Paul Townsend², ³Photonic Systems Group, Tyndall National Inst., Univ. College Cork, Ireland. We demonstrate burst-mode electronic dispersion compensation to support the upstream transmission in hybrid DWDM-TDMA PONs. It is shown how fast tap adaptation is feasible within the short preamble at the start of each burst.

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<td><strong>M3J</strong> • High Power Lasers, Components and Sensors—Continued</td>
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**M3J.4 • 17:15**

*128km fully-distributed high-sensitivity fiber-optic intrusion sensor with 15m spatial resolution*, Fei Peng¹, ²UECTC, China. An ultra-long phase-sensitive optical time domain reflectometry (OTDR) that can achieve high-sensitivity intrusion detection over 128 km fiber with high spatial resolution of 15 m is presented, which is the longest F-OTDR reported to date.

**M3K.5 • 17:15**

*57 Channel (19x3) Spatial Multiplexer Fabricated using Direct Laser Inscription*, Paul Mitchell¹, Graeme Brown¹, Robert R. Thomson¹, Nicholas Psaila¹, Ajoy Kar¹, ²Optoscribe Ltd., UK; ¹Inst. of Photonics and Quantum Sciences, Heriot Watt Univ., UK. We present a 57 channel spatial multiplexer consisting of 19 separate 3-port photonic lanterns arranged in a hexagonal array. An average insertion loss of 0.92 dB was measured across all ports with 0.1 dB uniformity.

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Room 102

M3A • FEC and Modulation—Continued

M3A.6 • 17:30
Staircase Rate-Adaptive LDPC-Coded Modulation for High-Speed Intelligent Optical Transmission, Yequn Zhang1, Ivan B. Djordjevic1; ‘Univ. of Arizona, USA. We propose staircase rate-adaptive LDPC-coded modulation that is suitable for high-speed intelligent optical transmission. Compared with shortening of LDPC codes, larger coding gain can be obtained and error floor can also be effectively mitigated.

M3A.7 • 17:45
A Simple and High-Performance Method for Combining Soft-Decision FEC with Differential Encoding in 100 Gbps Dual-Polarization QPSK System, Julie Karaki1, Raphael Le Bidan1, Erwan Pincemin1; ‘France Telecom, France; ‘Signal & Communications Department, Telecom Bretagne, France. By a joint design of FEC and modulation, we demonstrate that it is possible to associate strong soft-FEC and differentially-encoded QPSK systems with negligible coding gain penalty and minor modifications in existing transceivers. The resulting system is robust to cycle slips.

Room 120

M3B • Multi-layer Networks—Continued

M3B.6 • 17:30
Invited
Considerations for multi-layer network optimization, John Leddy1; ‘Comcast Corporation, USA. Abstract Not Available

Room 121

M3C • Fiber Nonlinearity Mitigation & Compensation—Continued

M3C.6 • 17:30
Spectrally-efficient Dual Phase-Conjugate Twin Waves with Orthogonally Multiplexed Quadrature Pulse-Shaped Signals, Tsuyoshi Yoshida1, Takashi Sugihara1, Kazuyuki Ishida1, Takashi Mizuochi1; ‘Mitsubishi Electric Corporation, Japan. We propose a novel nonlinearity mitigation technique which can double the spectral efficiency of a phase-conjugate twin wave by diplexing the twin waves. Simulation shows a Q improvement of 1.2 dB from conventional DP-QPSK transmission.

Room 122

M3D • Radio-Over-Fiber II—Continued

M3D.7 • 17:30
Top-Scored
Antenna Polarization Diversity for 146Gb/s Polarization Multiplexing QPSK Wireless Signal Delivery at W-band, Xinying Li1, Junwen Zhang1, Fan Li1, Jiangnan Xiao1; ‘Fudan Univ., China; ‘ZTE (TX) Inc, USA. We experimentally demonstrate a novel W-band integrated optical-wireless system based on antenna polarization diversity, which can realize 80-km SMF-28 transmission and 2-m × 2 MIMO wirelessly for up to 39-Gb/d (146 Gb/s) PDM-QPSK signal at W-band.

Room 123

M3E • Datacom Switching Architectures—Continued

M3E.5 • 17:30
Gain Effect on the Scalability of SOA-based Optical Space Switches, Peicheng Liao1, Chunshu Zhang1, Xi Lu1, Mehrdad Mir Shafiei1, Cesaretti Isabella1, Nicola Andrioli2; ‘Odele Liborion-Ladouceur1; ‘Dept. of Electrical and Computer Eng., McGill Univ., Canada; ‘Scuola Superiore Sant’Anna, Italy. Scalability is assessed by propagating WDM packets through multiple SOAs using a loop. Experimental results show that high SOA gain is more energy-efficient for single-stage space switch while low gain enhances the scalability of multi-stage architectures.

Room 124

M3F • Multimode and Few-Mode Fibers—Continued

M3F.5 • 17:30
Effect of random linear mode coupling on intermodal four-wave mixing in few-mode fibers, Yuhe Xiao1,2; Sami Muntaz1, Rene-Jean Essiambre1; ‘Govind P. Agrawal1; ‘The Inst. of Optics, Univ. of Rochester, USA; ‘Bell Laboratories, Alcatel-Lucent, USA. We study numerically intermodal four-wave mixing (IM-FWM) in few-mode fibers including both birefringence fluctuations and random linear coupling. We find that linear mode coupling reduces idler power by 3.5 dB for non-degenerate IM-FWM.
M3G • High Speed Transmitters and Receivers—Continued

M3G.5 • 17:30
Exploring the limits of high-speed receivers for multimode VCSEL-based optical links, Nicolas Dupuis1, Daniel Kuchta1, Fuad E. Doany1, Alexander V. Rlyakov1, Jonathan Proesel1, Christian Baks1, Clint L. Schow2, Sarah Luong1, Chuan Xie1, Li Wang1, Shenghong Huang1, Kenneth Jackson1, Neinyi Li1, IBM T.J. Watson Research Center, USA; 2Sumitomo Electric Device Innovations USA, USA. We present complete characterizations of multimode GaAs photodetectors for high-speed VCSEL-based optical links and compare SiGe receiver IC performances in a 62Gbps back-to-back link for different photodiode designs.

M3H • Optical Networks and Virtualization—Continued

M3H.6 • 17:30
Wireless-DataCenter Backhaul over Hardware Virtualized Flexible Optical Network, Bijan Rahimzadeh-Roofee1, Georgios S. Zervas1, Yan Yan1, Shuping Peng1, Reza Nejabati2, Anna Tzanakaki2, Dimitra E. Simeonidou1,1, 2Electrical and Electronic, Univ. of Bristol, UK; 1Network Design and Services Group, Athens Information Technology, Greece. Architecture design extensions for Time Shared Optical Network (TSO) are proposed for mobile backhaul. It introduces higher rates, flexible sub-lambda or lambda modes of operation, and dynamic memory allocation facilitating infrastructure virtualization and reprogramming.

M3I • NG-PON2 Technologies—Continued

M3I.5 • 17:30
Top-Scored
Demonstration of 10Gb/s burst-mode transmission using a linear burst-mode receiver and burst-mode electronic equalization, Stefan Port1, Cleitus Antony1, Giuseppe Talli1, Daniel Carey1, Peter Osseir1, Paul Townsend1, Tyndall National Inst., Univ. College Cork, Ireland. Using burst-mode electronic dispersion compensation and a linear burst-mode receiver, we achieved >100km reach at 15dB loud/soft ratio. Gear shifted least mean squares adaptation limit the number of training bits in the preamble to 250.

M3J • High Power Lasers, Components and Sensors—Continued

M3J.5 • 17:30
Fast Pump-Power-Independent Brillouin Fiber Optic Sensor, Avi Most1, On Danon1, Yar Peled1, Moshe Turi1, Tel Aviv Univ., Israel. A fast and distributed Brillouin sensor, which is immune to pump power variations is presented. 120Hz strain vibrations are measured over 50m fiber with >1kHz sampling rate, demonstrating immunity to >5dB pump power variations.

M3K • Multiplexer for Space-Division Multiplexing—Continued

M3K.6 • 17:30
Orbital-Angular-Momentum Mode (De)Multiplexer: A Single Optical Element for MIMO-based and non-MIMO-based Multimode Fiber Systems, Giovanni Milione1,2, Hao Huang1, Martin Laverry3, Alan Willner1, Robert R. Alfano1, 3Electrical Engineering, Univ. of Southern California, USA; 1New York State Center for Complex Light, USA. A mode (de)multiplexer in a basis of OAM modes for MIMO-based and non-MIMO-based multimode fiber systems is experimentally demonstrated which via a single optical element can (de)multiplex and generate individual modes with potential scalability.

M3K.7 • 17:45
Experimental Demonstration of Basic Functionalities for 0.1THz Orbital Angular Momentum (OAM) Communications, Long Zhu1, Xuli Wei1, Jian Wang1, Zongyi Zhang1, Shuhui Li1, Kejia Wang1, Jinsong Liu1, Wuhan National Laboratory for Optoelectronics, China. By designing and fabricating 3D printed spiral phase plates (SPPs), we demonstrate basic functionalities for terahertz (THz) orbital angular momentum (OAM) communications, including the generation, detection, conversion, multicasting and manipulation of OAM at 0.1 THz.
Room 102  Room 120  Room 121  Room 122  Room 123  Room 124

08:00–10:00  Tu1A • Plenary Session

10:00–17:00  Exhibition and Show Floor, Exhibit Halls A, B, C (South) & Hall D (North) (coffee service from 10:00–10:30)

11:00–14:00  Unopposed Exhibit-Only Time, Exhibit Halls A, B, C (South) & Hall D (North) (concessions available)

12:00–14:00  Poster Preview, Exhibit Hall South

14:00–16:00  Tu2A • RF Photonic Devices
               President: Leif Johansson; Univ. of California Santa Barbara, USA

14:00–16:00  Tu2B • Field Trial Demonstrations and Modulation Formats
               President: Richard Younce; Tellabs, USA

14:00–15:45  Tu2C • New Devices in NGPON Networks
               President: Susumu Kinoshita; Fujitsu Laboratories Ltd., Japan

14:00–16:00  Tu2D • Amplifiers for SDM - II
               President: Peter Krummrich; Universitat Dortmund, Germany

14:00–16:00  Tu2E • Ring Resonators
               President: Jurgen Michel; Massachusetts Inst. of Technology, USA

14:00–16:00  Tu2F • DSP-Based Optical Access
               President: Jun-ichi Kani; NTT Access Service Systems Laboratories, Japan

Tu2A 14:00  Integrated Silicon-Organic Hybrid (SOH) Frequency Shifter, Matthias Lauermann1, Claudius Weimann1, Alexander Knopp2, Delwin L. Elder3, Wolfgang Heni1, Robert Palmer1, Dietmar Korn1, Philipp Schindler1, Sebastian Koeber1, Luca Alleotti1, Hui Yu1, Wim Bogaarts1, Larry R. Dalton1, Christian Rembe1, Juerg Leuthold1, Wolfgang Freude1, Christian Koos1, ’Inst. of Photonic and IMT, Karlsruhe Inst. of Technology (KIT), Germany; 2Polytec GmbH, Germany; 3Department of Chemistry, Univ. of Washington, USA; 4IMEC, Photonics Research Group, Ghent Univ., Belgium; 5Department of Information Science and Electronic Engineering, Zhejiang Univ., China; 6Electromagnetic Fields Laboratory, Swiss Federal Inst. of Technology (ETH), Switzerland. We demonstrate a waveguide-based frequency shifter on the silicon-organic hybrid (SOH) platform, enabling frequency shifts up to 10 GHz. Spurious side-modes are suppressed by more than 23 dB using temporal shaping of the drive signal.

Tu2B 14:00  Transmission of 400G PM-16QAM Channels over Long-Haul Distance with Commercial All-Distributed Raman Amplification System and Aged Standard SMF in Field, Tiejun J. Xia1, Glenn A. Wellbrock2, Ming-Fang Huang3, Shaoliang Zhang4, Yue-Kai Huang4, DO-IL CHANG4, Sergey Burshtev5, Wayne Pelouch6, Edwin Zak2, Hector dePedro2, William Szeto2, Herve Février2, ’Verizon Communications, Inc., USA; 2NEC Laboratories, Inc., USA; 3Xtera Communications, Inc., USA; 4Tellabs, USA; 5’Xtera Communications, Inc., USA. Transmission of eight dual-carrier 400G PM-16QAM channels over 1,504-km aged SSMF in field is demonstrated with high-coding-gain FEC and commercial all-distributed-Raman amplification system. The result shows 16QAM can be used for Raman amplification system. The newly demonstrated 400G PM-16QAM platform, enabling frequency shifts up to 10 GHz. Spurious side-modes are suppressed by more than 23 dB using temporal shaping of the drive signal.

Tu2C 14:00  Multi-service OFDM Uplink Transmission in Full-Duplex FTtx Systems Using RSOA-based WDM-PON Architecture, Truong An Nguyen, Kim Lefebvre, Leslie Rusch, ’Electrical and Computer Engineering, Center d’Optique, Photonique et Laser, Canada. We experimentally demonstrate, for the first time, the transmission of multi-service analog OFDM WiFi uplink signal along with OOK downlink signal over 20 km of single mode fiber in a full-duplex SOA-based WDM-PON fiber-to-the-x system.

Tu2D 14:00  Experimental Demonstration of Silicon-Based Metallic Whispering Gallery Mode Disk Resonators and Their Thermo-Tuning, Fe Lou1, Lars Thylen1, Lech Wosinski1, ’Kungliga Tekniska Hogskolan, Sweden; 2Hewlett-Packard Laboratories, USA; 3Si-based metallic whispering gallery mode disks with 0.5 μm and 1 μm radii are theoretically analyzed and experimentally demonstrated. Estimated Purcell factor is around 127±42. Thermo-tuning of the device is also presented.

Tu2E 14:00  Digital Coherent Technology for Long-Reach Optical Access, Domanic Laverty1, Seb J. Savory1, ’Univ. College London, UK. This semi-tutorial paper outlines the potential advantages afforded by digital coherent receivers in long-reach optical access networks. Low complexity DSP algorithms are discussed which relax the optical complexity requirements of a coherent receiver.
14:00–16:00 Tu2G • OFDM I
Presider: William Shieh; Univ. of Melbourne, Australia

Tu2G.1 • 14:00
Experimental Study of Weighted Inter-frame Averaging Based Channel Estimation for CO-OFDM System, Paikun Zhu1, Juhao Li1, Hui Zhao1, Cheng Zhang1, Yue Liu1, Yeping Zhao1, Yongji He1, Zhangyuan Chen1, State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking Univ., China. We propose an efficient channel estimation method based on weighted inter-frame averaging for CO-OFDM system. Up to 2.4 dB error vector magnitude improvement compared with traditional methods is shown by a magnitude improvement compared with traditional methods.

Michael C. Larson is an R&D manager at JDSU in Milpitas, CA, overseeing source laser development. He holds a bachelor of engineering from Harvey Mudd College, and M.S. and Ph.D. in electrical engineering from Stanford.

12:00–14:00 Poster Preview, Exhibit Hall South

Room 125 Room 130 Room 131 Room 132 Room 133

08:00–10:00 Tu1A • Plenary Session

10:00–17:00 Exhibition and Show Floor, Exhibit Halls A, B, C (South) & Hall D (North) (coffee service from 10:00–10:30)

11:00–14:00 Unopposed Exhibit-Only Time, Exhibit Halls A, B, C (South) & Hall D (North) (concessions available)

11:00–12:00 Network Components in FTTX Systems, Expo Theater Programming III
For more details, see page 43

11:00–12:30 OIDA Review of Roadmaps for the Optical Communications Market and NPI Overview, Expo Theater II Programming
For more details, see page 41

12:00–14:00 Panel I: State of the Industry, Expo Theater I Programming
For more details, see page 37

12:30–14:00 Advancing Optical Solutions in Cloud Computing, Communications and Networking, Expo Theater III Programming
For more details, see page 43

13:30–16:30 The Future of the Metro Core: A New and Innovative Approach to Delivering a Scalable, Yet Simplified, Approach to Delivering a Scalable, Yet Simplified, Metro Core Network, Expo Theater II Programming
For more details, see page 41

14:30–15:15 Panel: 100G Single Lambda Optics, Expo Theater III Programming
For more details, see page 43

15:15–16:00 Snapshot on 400GE Standardization, Expo Theater III Programming
For more details, see page 43

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For more details, see page 43
Tu2A • RF Photonic Devices—Continued

Tu2A.2 • 14:15
Rapidly Reconfigurable RF Arbitrary Waveform Synthesis using a CMOS Silicon Photonic Chip, Jian Wang1, Fuwan Gan1, Ben Ni1, Hao Shen1; Daniel E. Leaird1, Andrew M. Weiner1, Minghao Qi1,2; ‘Electrical and Computer Engineering, Purdue Univ., USA; 2Shanghai Inst. of Microsystem and Information Technology, Chinese Academy of Sciences, China. We demonstrate nanosecond-reconfigurable RF waveforms with a time-domain synthesis method using a silicon photonic chip. The waveform is modulated by a synchronized silicon electro-optic intensity modulator embedded in the pulse shaper.

Tu2A.3 • 14:30
A Compact Optically Driven Traveling-Wave Radiating Source, Steven Bowers1; Belhooz Abrin1; Firooz Aghuy Burtsev1, Daniel E. Leaird1, Andrew M. Weiner1; ‘Electrical and Computer Engineering, Purdue Univ., USA. A compact silicon-photonic optically driven mm-wave radiator uses a multi-port driven travelling-wave antenna driven by 8 silicon photodiodes with -3dB bandwidth of 25GHz to produce -9.7dBm EIRP at 180GHz.

Tu2B • Field Trial Demonstrations and Modulation Formats—Continued

Tu2B.2 • 14:15
150 x 120 Gb/s Field Trial over 1,504 km using All-Distributed Raman Amplification, DO-IL CHANG1, Sergey Burtshev1, Wayne Pelouch1, Edwin Zak1, Hector dePedro1, William Sztolc1, Herve Ferrier1, Tiejun J. Xia1, Glenn A. Wellbrock1; ‘Xtera Communications, USA; ‘Verizon, USA. An all-distributed Raman system is demonstrated to support high order modulation formats with coherent digital processing. We report the transmission of 150 channels x 120 Gb/s over 1,504 km field fiber with 5 dB Q margin.

Tu2C • New Devices in NGPON Networks—Continued

Tu2C.2 • 14:15
Development of Si photonics technology: Ge/Si avalanche photodiode for PON applications, Mengyuan Huang1, Pengfei Cai1, Liangbo Wang1, Tuo Shu1, Wang Chen1, Su Li1, Guanghui Hou1, Ching-yin Hong1, Dong Pan1; ‘SiFotonics Technologies Co., Ltd., USA. We accomplished the first mass-production of Ge/Si avalanche photodiode (APD) for FTTH applications in a standard CMOS foundry. Our APDs satisfy sensitivity requirements of 10G PON (both OLT and ONU sides) applications within -9°C–75°C.

Tu2D • Amplifiers for SDM - II—Continued

Tu2D.2 • 14:30
Invited Challenges of Few Mode Amplifiers, Massimiliano Salsi1; ‘Alcatel-Lucent Bell Labs, France. We review recent experimental demonstrations of amplifiers for spatial division multiplexed optical transmission systems. We present an analysis of the existing and of the future few-mode erbium doped fiber amplifiers for an increasingly larger number of modes.

Tu2E • Ring Resonators—Continued

Tu2E.2 • 14:15
Air-suspended High-Q Ring Microparticles with Scatterer-Avoiding “Wiggler” Supermode Fields, Yang-yang Liu1, Milos Popovic1; ‘Department of Electrical, Computer, and Energy Engineering, Univ. of Colorado at Boulder, USA. We demonstrate air-suspended high-Q ring resonators based on multimode Bloch matching and resultant scatterer-avoiding “wiggler” supermode field. Device designs are fabricated in silicon-on-insulator and undercut to form air-suspended structures with measured Qs up to 139,000.

Tu2F • DSP-Based Optical Access—Continued

Tu2F.2 • 14:30
Extended TWDM-PON demonstration up to 100 km and 35 dB ODN loss on Burst-Mode Coherent Reflective PON, Stefano Straullu1, Fabrizio Forghieri1, Gabriella Bosco1, Valter Ferrero1, Roberto Gaudino1; Istituto Superiore Mario Boella, Italy; 2Electronics and Telecommunications, Politecnico di Torino, Italy; 3CISCO Photonics, Italy. We demonstrate the upstream path for a TWDM-PON on up to 100 km installed fibers, 35 dB ODN loss and 4 wavelengths, using burst-mode self-coherent OLT receiver and reflective ONU transmitters without tunable lasers.
Tu2G • OFDM I—Continued

Tu2G.2 • 14:15
Enhanced Dispersion Tolerance of Coherent Offset-QAM OFDM over Conventional OFDM, Jian Zhao1, Andrew D. Ellis2; 1Tyndall National Inst., Ireland; 2Aston Inst. of Photonic Technology, Aston Univ., UK. We experimentally demonstrate 38-Gbit/s offset-16QAM OFDM over 840km without guard interval, and numerically show that 112-Gbit/s PDM offset-QPSK OFDM achieves 23% increase in net capacity over conventional OFDM under the same transmission reach.

Tu2G.3 • 14:30
Top-Scored
Demonstration of Software-defined Multiband OFDM with Low-complexity Phase Noise Compensation, Xi Chen1, Jiayuan He1, Di Che1, William Shieh1; 1Univ. of Melbourne, Australia. We demonstrate low-complexity phase noise compensation for a software-defined multiband OFDM system. Experimental results show that laser phase noise up to 1 MHz can be compensated for 114.8-Gb/s 16-QAM signals after 480-km SSMF transmission.

Tu2H • Tunable Lasers & Comb Sources—Continued

Tu2I • Symposium on Enabling the Cloud: Datacenter as a Network I—Continued

Tu2J • High Capacity Transmission Using SDM—Continued

Tu2K • Nonlinear Effects in Optical Fibers—Continued

Tu2H.2 • 14:15
Invited
Data Center Networking: A Brave New World, Dinesh Dutt, Cumulus Networks, USA. Data centers are changing the way networking is done. When the revolution is over, the landscape will be as altered as the server landscape was when the Intel tsunami swept aside the vertically integrated server market of the late 90s. In this talk, we’ll explore the ideas that underpin these changes, ideas that include modern network architectures, network overlays and network management.

Tu2I.2 • 14:30
Invited
Long-Haul Transmission Using Multicore Fibers, Hidenori Takahashi1, Koji Igarashi2, Takehiro Tsuritani3; 1KDDI R&D Laboratories Inc., Japan. We review recent progress of long-haul transmission over 6,000 km using multicore fiber (MCF) repeatered with multicore (MCI)-EDFA. The capacity-distance product has been increased from 177 Pbit/km to 1.03 Ebit/km/km.

Tu2J.2 • 14:30
Invited
Modeling of Software-defined Multiband OFDM with Low-complexity Phase Noise Compensation, Xi Chen1, Jiayuan He1, Di Che1, William Shieh1; 1Univ. of Melbourne, Australia. We demonstrate low-complexity phase noise compensation for a software-defined multiband OFDM system. Experimental results show that laser phase noise up to 1 MHz can be compensated for 114.8-Gb/s 16-QAM signals after 480-km SSMF transmission.
Tu2A • RF Photonic Devices—Continued

Tu2A.4 • 14:45 Invited High-Power Microwave Photodiodes, Andreas Beling1, Electrical and Computer Engineering, Univ. of Virginia, USA. The talk reviews modified uni-traveling carrier photodiodes that are capable of delivering high RF output power levels of >1 Watt. Discrete photodiodes, balanced detectors, photodiode arrays, and waveguide photodiodes are discussed.

Tu2B • Field Trial Demonstrations and Modulation Formats—Continued

Tu2B.4 • 14:45 Top-Scored 400Gb/s Real-time Trial Using Rate-adaptive Transponders for Next Generation Flexible-grid Networks, ANNACHIARA PAGANO1, Emilio Riccardi2, Marco Bertolini1, Vitaliano Farelli1, Tony Van De Velde1. TELECOM ITALIA, Italy; 2ALCATEL-LUCENT ITALY, Italy; ALCATEL-LUCENT FRANCE, France. We demonstrate real-time transmission using a 400G rate-adaptive transponder in metro regional Telecom Italia multivendor legacy environment. Transmission over G.652 and G.655 fibers was successfully achieved with 5.33 b/s/Hz of spectral efficiency.

Tu2C • New Devices in NGPON Networks—Continued

Tu2C.4 • 15:00 Comparison of Downstream Transmitters for High Loss Budget of Long-Reach 10G-PON, Zhengxuan Li1, Lulin Yi1, Weisheng Hu1, Shanghai Jiao Tong Univ., China. A comparison among different transmitters was made by evaluating the sensitivities under various launch powers and reaches. Experimental results indicate that directly-modulated laser based transmitters provide higher loss budget for long reach 10G-PON.

Tu2D • Amplifiers for SDM - II—Continued

Tu2D.3 • 15:00 1.7 μm Band Optical Fiber Amplifier, Makoto Yamada1, Hirotsuka Chiu2, Jun Ono2. 1Department of Electrical & Information Systems, Osaka Prefecture Univ., Japan; 2NTT Photonics Laboratories, Japan. We realize for the first time a 1.7 μm band fiber amplifier. The maximum gain of 22.5 dB and the noise figure of 6.2 dB were achieved at the signal wavelength of 1700 nm.

Tu2E • Ring Resonators—Continued

Tu2E.4 • 14:45 Wavelength Locking of a WDM Silicon Microring Demultiplexer using Dithering Signals, Kishore Padma-raju1, Lian-Wee Luo2, Xiaoqiang Zhu3, Madeleine Glick1, Raj Dutta4, Michal Lipson5, Keren Bergman5, Columbia Univ., USA; 2Cornell Univ., USA; 3APIC Corporation, USA. A control system utilizing dithering signals is used to demonstrate wavelength locking of WDM channels by a microring filter array. Data measurements verify that the dithering mechanism has a negligible effect on filtered data channels.

Tu2F • DSP-Based Optical Access—Continued

Tu2F.3 • 14:45 A Long Reach IM/DD OFDM-PON Using Super-Nyquist Image Induced Aliasing and Code-Division Multiplexing, Changjian Guo1, Longling Dai1, South China Normal Univ., China. An 83.2-km, 20-Gb/s QPSK CDM-OFDM-PON is experimentally demonstrated. The reachable distance is extended from less than 40 km to 90 km using super-Nyquist image induced aliasing. CDM-OFDM is shown to outperform conventional OFDM signals in IM/DD systems.
Tu2G.4 • 14:45
Fast Wavelength Switching DP-OFDM Transceiver in a 5-Node 800km Coherent OBS Network, Robert Maher1, Hou-Man Chin1, Manoj Thakur2, Dorian Lavery3, Polina Bayvel1, Seb J. Savory1, Benn C. Thorsen1; 1Electrical and Electronic Engineering, Univ. College London, UK. Fast wavelength switching OFDM transceiver enables the coherent reception of 2-burst channels within a 1dB penalty after 800km transmission. Burst detection and variable path-history compensation are performed using inherent OFDM synchronization symbols and cyclic prefix.

Tu2G.5 • 15:00
Pre-Amplified 64-QAM-OFDM Modulation of a Colorless Laser Diode for 30 Gbit/s Transmission with Enhanced SNR, Cheng-Ting Tsai1, Min-Chi Cheng1, Gong-Ru Lin1; 1National Taiwan Univ., Taiwan. A directly-modulated colorless laser diode based pre-amplified 64-QAM-OFDM transmission at 30Gbit/s is demonstrated with optimized SNR of 21.6 dB and EVM of 8.3 % to provide spectral efficiency of 6 bit/sec/Hz and BER of <2.5×10^-3.

Tu2H.2 • 15:00
Narrow Linewidth Tunable Light Source Integrated with Distributed Reflector Laser Array, Go Kobayashi1, Kazuaki Kiyota1, Tatsuya Kimoto1, Toshikazu Mukaihara1; 1Optical Devices Dept, Fitel Photonics Laboratory, Furukawa Electric Co., Ltd., Japan. We demonstrated tunable light source integrated with 12 DR laser array and SOA, for the first time. We could report single-mode operation (SMSR>43dB) and narrow linewidth less than 185kHz over 40nm C-band range.

Tu2I.3 • 15:00
Invited
The State of OpenFlow, Guido Apopenzeller; Big Switch Networks, USA. OpenFlow is a protocol that has risen to prominence in a very short period of time. However despite the tremendous interest, few OpenFlow production deployments in the data center exist today. In this talk, we review OpenFlow deployments, examine the challenges of the current OpenFlow development model, and present our perspective and what needs to change for OpenFlow to become ubiquitous.

Tu2J.3 • 15:00
Invited
Ultra-high Capacity Transmission with Few-mode Silica and Hollow-core Photonic Bandgap Fibers, Vincent A. Sleiffer1, Paolo Leoni2, Yong-min Jung3, Haoshuo Chen1, Maxim Kuschnerov1, Shaiful Alam3; 1Technische Universität Eindhoven, Netherlands; 2Universität der Bundeswehr München, Germany; 3Optoelectronics Research Centre, UK; 4Coriant R&D GmbH, Germany; 5OFS, Denmark. We review the capacity records achieved using mode division multiplexing in few mode fiber and hollow core photonic bandgap fibers. Currently the MDM capacity record for both fiber types is 73.7 Tb/s, whereas per wavelength 960 Gb/s is achieved.
Tu2A.5 • 15:15
Strong Enhancement in Saturation Power of Sub-THz Photodiode by Using Photonic Millimeter-Wave Femtosecond Pulse Generator, Jih-Hsin Wu, Yi-shiu Chen, Cheng-Hung Lai, Hao-Yun Liu, Chen-Bin Huang, Ci-Ling Pan, Ji-Wei Shi, Dept. of Electrical Engineering, National Central Univ., Taiwan; Inst. of Photonics Technologies, National Tsing-Hua Univ., Taiwan; Dept. of Physics, National Tsing-Hua Univ., Taiwan. A photonic MMW femtosecond pulse-generator has been demonstrated. Using it, we achieve strong (6.4 dB) saturation-power enhancements, which result in +3.9 dBm maximum output of UTC-PD at 160 GHz, as compared to that under sinusoidal excitation.

Tu2A.6 • 15:30
A Photonic Integrated Fractional Hilbert Transformer With Continuous Tunability, Jianping Yao, Weilin Liu, Ming Li, Robert Guzzon, Erik Norberg, Larry A. Coldren, Univ. of Ottawa, Canada; ECE, UCSB, USA. A continuously tunable fractional Hilbert transformer based on a photonic integrated chip in an InP-InGaAsP material system consisting of semiconductor optical amplifiers and current injection phase modulators is proposed and experimentally demonstrated.

Tu2B.6 • 15:30
Cost-effective Next Generation Mobile Fronthaul Architecture with Multi-IF Carrier Transmission Scheme, Seung-Hyun Choi, Heuk Park, Hwan Seok Chung, Kyeong-Hwan Doo, Sang Soo Lee, Jjong Hyun Lee, Optical Internet Department, Electronics and Telecommunications Research Inst., Republic of Korea. We proposed a cost-effective next generation mobile fronthaul architecture with multi-IF carrier transmission scheme and investigated the system performance under various IF carrier operating conditions.

Tu2B.6 • 15:30 Top-Scored
Measurement and Mitigation of Wave-length Drift due to Self-Heating of Tunable Burst-Mode DML for TWDM-PON, Yong Guo, Xin Liu, Songlin Zhu, Guohua Melkumov, Igor A. Bufetov, Fiber Optics Research Center of RAS, Russia; Southeastern University, China; College of Optical Sciences, The Univ. of Arizona; Univ. of Southern California, USA; EECS, University of California Berkeley, USA. Based on a novel, “spoked-ring” active microcavity, we demonstrate optical modulators in an unmodified 45nm SOI CMOS process at 5Gb/s with <5J/bit energy consumption; and filters with record thermal tuning efficiency of 2μW/GHz.

Tu2C.5 • 15:15
Increasing Splitting Ratio of 10Gb/s Class PONs by Using FW-DMF that Acts as Low Loss Splitter for Upstream and Conventional Splitter for Downstream, Masamichi Fujimura, Ken-Ichi Suzuki, Naoto Yoshimoto, Manabu Oguama, Shunichi Soma, NTT Access Network Service Systems Laboratories, NTT Corporation, Japan; NTT Photonics Laboratories, NTT Corporation, Japan. A simple optical splitter, a dual-mode fiber (DMF) is connected to a funnel-shaped waveguide (FW), is proposed and the feasibility of a 128-way 10G-EPON system using a 1 x 16 prototype is experimentally demonstrated.

Tu2C.5 • 15:15
S-band Thulium-doped Fiber Amplifier Enhancement using ASE Suppression, Sulaiman Wadi Harun, Siamak Dawazadah emami, Harith Ahmad, Hainul Azhar Abdul Rashid, Ahmad Razil Muhammed, Universiti Malaya, Malaysia; Multimedia Univ., Malaysia. A new method for gain enhancement in S-band Thulium-doped fiber amplifier (TDFA) co-doped with Aluminum is demonstrated using a photonic crystal fiber and macro-bending approach to suppresses both amplified spontaneous emissions at 800 nm and 1800 nm.

Tu2C.5 • 15:15 Top-Scored
Excited State Absorption in Bismuth-doped Fibers with Various Glass Compositions, Evgeny M. Dianov, Konstantin E. Riiumkin, Mikhail A. Melkumov, Igor A. Bufetov, Fiber Optics Research Center of RAS, Russia; Southeastern University, China; College of Optical Sciences, The Univ. of Arizona; EECS, University of California Berkeley, USA. Based on a novel, “spoked-ring” active microcavity, we demonstrate optical modulators in an unmodified 45nm SOI CMOS process at 5Gb/s with <5J/bit energy consumption; and filters with record thermal tuning efficiency of 2μW/GHz.

Tu2D.4 • 15:15
High-speed on-chip photonic link based on ultralow-power microring modulator, Xi Xiao, Hao Xu, Xiaoyao Li, Zhiyong Liu, Yude Yu, Jinzhong Yu, State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts & Telecommunications, China; Chinese Acad Sci Inst of Semiconductor, China. We present an 15 GHz silicon-based on-chip photonic link composed of a 0.5 V-Vpp, 25 Gb/s tunable microring modulator and a ~40 GHz Ge-on-Si photodetector. Low-Vpp data transmissions of 12.5-20 Gb/s are experimentally demonstrated.

Tu2D.6 • 15:30 Top-Scored
Energy-Efficient Active Photonics in a Zero-Change, State-Of-The-Art CMOS Process, Mark T. Wade, Jeffrey M. Shainline, Jason S. Orcutt, Chen Sun, Rajesh Kumar, Ben Moss, Michael Georgas, Rajeev J. Ram, Vladimir Stoianovic, Milos Popovic, ECE, Univ. of Colorado at Boulder, USA; EECS, Massachusetts Inst. of Technology, USA; EECS, Univ. of California Berkeley, USA. Based on a novel, “spoked-ring” active microcavity, we demonstrate optical modulators in an unmodified 45nm SOI CMOS process at 5Gb/s with <5J/bit energy consumption; and filters with record thermal tuning efficiency of 2μW/GHz.

Tu2F.5 • 15:15
Real-Time Software-Defined Dynamic Resource Allocation using OpenFlow for Next-Generation OFDM-based Optical Access Networks, Stanley Johnson, Weiyang Ma, Milorad Cvijetic, Jun He, John Wisssinger, Alan Willner, College of Optical Sciences, The Univ. of Arizona, USA; Univ. of Southern California, USA. We demonstrate the first software-defined dynamic resource allocation of OFDM subcarriers and modulation formats using the OpenFlow protocol and real-time DSP. Dynamic resource allocation for HD video and text is achieved for 20km SMF transmission.
Room 130

Tu2G • OFDM I—Continued

Tu2G.6 • 15:15
40Gbps 100-km SSMF VSB-IMDD OFDM Transmission Experiment Based on SSII Cancellation and FBG-Filtering, Cheng Ju1, Xue Chen1, Zhiqiu Zhang1, 2, Beijing Univ. of Posts and Telecommunications, China. We propose and experimentally demonstrate a 40Gbps FBG-based VSB-IMDD OFDM scheme with SSII cancellation that extends the available bandwidth up to 10GHz over 100-km SSMF transmission.

Tu2G.7 • 15:30
Experimental Investigation of Discrete Multitone Transmission in the Presence of Optical Noise and Chromatic Dispersion, Annika Dochhadi1, Helmut Griesser1, Helmut Griesser1, Laia Nadal Reixats3, Michela Svaluto Moreolo3, Jorg P. Elbers2, 3CTTC, Spain.

Room 131

Tu2H • Tunable Lasers & Comb Sources—Continued

Tu2H.3 • 15:15
A Wide Bandwidth Coherent Optical Comb Source Based on a Monolithically Integrated Mode-Locked Ring Laser, Valentina Moskalenko1, Sylwester Latkowski1, Tijbbe de Vries1, Luc M. Augustin1, Kaveer Leijtens1, Meint Smul1, Erwin Bente1, Eindhoven Univ. of Technology, Netherlands. A ring mode-locked laser fabricated as a monolithic photonic integrated circuit using a LP based integration technology is presented. It generates an optical coherent comb around 1546 nm with a record 11.5 nm 3 dB bandwidth.

Room 132

Tu2J • High Capacity Transmission Using SDM—Continued

Tu2J.4 • 15:30
Enabling Autonomic Provisioning in SDN Cloud Networks with NFV Service Chaining, Casimer DeCusatis, IBM, USA and Robert Cannistra, Marist College, USA. Experimental results are presented from an SDN/NFV testbed with automated, dynamically provisioned, 125 km optical/WAN. Live VM migration for NFV video serving is demonstrated, along with Layer 0-3 orchestration using Open Daylight, OpenFlow, and DOVE.

Room 133

Tu2K • Nonlinear Effects in Optical Fibers—Continued

Tu2K.3 • 15:30
Highly Nonlinear Tellurite Glass Fiber for Broadband Applications, Mohamed A. Eltabib1, Kamal Hammani1, Xian Peng1, Mohammad Belal1, Jindan Shi1, Adonis Bogris2,3, Alex Amynta4, Dimitris Syvridis4, David J. Richardson5, Periklis Petropoulos1, 1Optoelectronics Research Centre, Univ. of Southampton, UK; 2National and Kapodistrian Univ. of Athens, Greece; 3Department of Informatics, Technological Educational Inst. of Athens, Greece. We report the characterization of loss and nonlinearity of a broadband tellurite glass fiber both at 1.55µm and 2µm wavelengths. The study is accompanied by a demonstration of wavelength conversion at both of these wavelengths.
Tu2A.7 • 15:45
First Demonstration of a Tunable Single-Bandpass Photonic Radiofrequency Filter Based on Optical Frequency Comb from a Microring, Xiaoxiao Xue¹, Hyoung-Jun Kim¹, Yi Xuan¹,² Jian Wang¹,² Daniel E. Leaird¹, Minghao Qi¹,² Andrew M. Weiner¹; ¹School of Electrical and Computer Engineering, Purdue Univ., USA; ²Birck Nanotechnology Center, Purdue Univ., USA. We demonstrate a photonic radiofrequency filter with greatly reduced complexity based on an optical frequency comb from a SiN microring. A novel structure is proposed to suppress unwanted passbands and achieve a widely tunable single passband.

Tu2F.7 • 15:45
N:1 Protection Design for Minimizing OLTs in Resilient Dual-Homed Long-Reach Passive Optical Network, Avishek Nag¹, David B. Payne¹, Marco Ruffini¹; ¹Trinity College Dublin, Ireland. An N:1 protection mechanism is proposed to reduce backup OLTs in a resilient dual-homed LR-PON deployment. We model the problem as an Integer Linear Program and solve it for an Irish network deployment.
Tu2G.8 • 15:45
Experimental Demonstration of Elastic Optical Networking utilizing Time-Sliceable Bitrate Variable OFDM Transceiver, Josep M. Fabrega¹, Michela Svaluto Moreolo¹, F. Javier Vilchez¹, Bijan R. Rofoee¹, Yenni Ou², Norberto Amaya², Georgios S. Zervas³, Dimitra E. Simeonidou⁴, Yuki Yoshida⁴, Ken-ichi Kitayama⁵; ¹Ctr Tecnològic de Telecom de Catalunya, Spain; ²High-Performance Networks Group, Univ. of Bristol, UK; ³Osaka Univ., Japan. A cost-effective time-sliceable IM/DD OFDM transceiver using low-complex DSP is experimentally investigated. Slicing capabilities are tested for concurrently serving 12.5GHz channels running at up to 10Gb/s variable bandwidth optical routes covering up to 185km.

Tu2H.5 • 15:45
Single Quantum Dash Mode-Locked Laser as a Comb-Generator in Four-Channel 112 Gbit/s WDM Transmission, Mathilde Gay¹, Arthur O’Hare¹, Laurent Bramerie¹, Zhenyu Hao¹, Schadac Fresnel¹, Christophe Peucheret¹, Pascal Besnard¹, Siddharth Joshi¹, Sophie Barbet², Francois Lelarge²; ¹CNRS Foton, Université Européenne de Bretagne, Ensai, France; ²Ill-Vlab, France. We demonstrate 100 km transmission at 28 Gbit/s/channel of 4 DWDM channels using a single quantum-dash mode-locked laser. The amplitude noise of each filtered laser line is improved using limiting amplification in an SOA.

Tu2K.4 • 15:45
Conversion Efficiency and Crosstalk Optimization in Four-mode Phase-Sensitive Multicasting Mixer by Vectorial Phase Manipulation, Lan Liu¹, Zhi Tong¹, Andreas O. Wiberg¹, Yauheni Myslivets¹, Ping Piu Kuo¹, Nikola Alic², Stojan Radic²; ¹Univ. of California San Diego, USA. The input phases in a four-mode phase-sensitive multicasting, is manipulated yielding a 12-dB gain improvement compared with the phase-insensitive case. Additionally, up to 13-dB crosstalk reduction for arbitrary spectral region is achieved with phase management.

16:00–16:30 Coffee Break, South, Exhibit Halls A, B, C, North, Exhibit Hall D

NOTES
Room 120
16:30–18:30 Tu3A • Fiber Nonlinearity Mitigation
Presider: Gernot Goeger; Huawei, USA

Tu3A.2 • 16:45 Time-Division Hybrid Modulation Formats: Tx Operation Strategies and Countermeasures to Nonlinear Propagation, Vittorio Curri, Andrea Carera, Pier Luigi Poggiolini, Roberto Cigliuti, Fabrizio Forghieri, Chris R. Fludger, Theo Kuper, DET, Politecnico di Torino, Italy; Cisco Photonics, Italy; Cisco Optical GmbH, Germany. We propose four strategies for TDHMF Tx operation. BER minimization permits PM-QPSK/PM-16QAM performance similar to PM-8QAM's. In TDHMF nonlinear propagation, predistortion and/or polarization interleaving enables the maximum reach predicted by GN-model.

Room 121
16:30–18:30 Tu3C • Protection & Other Practical Considerations in PONs
Presider: Denis Khotimsky; Verizon Communications Inc, USA
Tu3C.1 • 16:30 Invited PON Resilience, Frank Effenberger; Access R&D, Futurewei Technologies, USA. Passive Optical Networks are being applied to a wider set of applications, including those that are outage sensitive. Protection or resilience techniques address this need. This paper reviews these techniques, focusing on active research areas.

Tu3C.1 • 16:30 Invited Fiber Based Multiplexing and Demultiplexing devices for Few Mode Fiber Space Division Multiplexed Communications, Ian Giles, Rong-sheng Chen, Victor Garcia-Munoz; Phoenix Photonics, UK. All-fiber components offer an effective technology option for passive multiplexers and demultiplexers for few mode fiber transmission systems. New component options to meet the requirements are being explored for individual and mode group transmission.

Room 122
16:30–18:00 Tu3D • Components for SDM
Presider: Shu Namiki; NTT DOCOMO, INC., Japan
Tu3D.1 • 16:30 Invited Spot Size Converter with Cross-Vertical Taper for Low-Loss Coupling between ZrO₂-SiO₂ PLC and SMF, Shintaro Yamasaki, Yasuyoshi Uchida, Masanori Takahashi, Tatsuo Yamasaki, Junichi Hasegawa, Takeshi Yagi, Furukawa Electric Co., Ltd., Japan. We developed a novel spot size converter with cross-vertical taper. Connection loss between ZrO₂-SiO₂ PLC with 5.5% Δ and SMF was reduced to 0.2 dB/facet at 1550 nm, and less than 0.4 dB/facet in C-band.

Tu3D.2 • 16:45 Invited Ultra-Small Coherent Mixer Consists of 5.5%-Δ ZrO₂-SiO₂-Based Low Loss PLC, Masanori Takahashi, Yasuyoshi Uchida, Shintaro Yamasaki, Junichi Hasegawa, Takeshi Yagi, Furukawa Electric Co., Ltd., Japan. We developed a novel spot size converter with cross-vertical taper. Connection loss between ZrO₂-SiO₂ PLC with 5.5% Δ and SMF was reduced to 0.2 dB/facet at 1550 nm, and less than 0.4 dB/facet in C-band.

Room 123
16:30–18:15 Tu3E • Novel Materials
Presider: Jun-ichi Kani; ETH Zurich, Switzerland
Tu3E.1 • 16:30 Invited Optical Access for Mobile Front/Back Haul
Presider: Peter Vetter; Alcatel-Lucent, USA
Tu3E.1 • 16:30 Top-Scored Optical Network Technologies and Architectures for Backhaul/Fronthaul of Future Radio Access supporting Big Mobile Data, Yukihiko Okumura, Jun Terada; NTT DoCoMo, Japan. As a new scheme of dense cells deployment in future cellular network, “Phantom cell concept” has been proposed that overlays multiple cell layers. In this tutorial, future radio access/mobile optical network (FRAMON) that realizes the concept and its requirements and challenging issues are explained.

Yukihiko Okumura joined NTT Radio Communications Systems Laboratories, Japan, in 1991, and since 1992, he has been engaged in the research, standardization and development of wideband/broadband mobile radio communication technologies, terminals and systems, at NTT Mobile Communications Network, Inc. (now NTT DOCOMO, INC.). He is a senior member of IEEE. Jun Terada joined the NTT LSI Laboratories in 1995, where he was engaged in research and development of low-voltage analog circuits. From 2006, he was engaged in high-speed front-end circuits for optical transceivers. Since 2012, he has engaged in optical and wireless converged access networks at the NTT Access Network Service Systems Laboratories.
Tu3G • OFDM II
16:30–18:30
Presider: Lianshan Yan;
Southwest Jiaotong Univ.,
China

Digital Sub-banded Coherent Optical OFDM Transmission, Moshe Nazareth1, Alex Tolmachev1; 1Technion
Israel Inst of Technology, Israel. OFDM is much more efficiently processed digitally slicing received channel spectrum by under-decimated filter banks, decoding the spectral slices in an array of lower speed sub-band OFDM receivers. Low-complexity FPGA real-time implementation will be presented.

Tu3H • InP-based Optoelectronic Devices
16:30–18:30
Presider: Lars Zimmermann;
IHP, Germany

InP modulators with linear accelerator like segmented electrode structure, Tomoaki Kato1; 1Green Platform Research Laboratories, NEC Corporation, Japan. Quasi-traveling-wave type InP modulators with accelerator like segmented electrode structure directly driven by CMOS IC were reviewed. Their potential for low-power, multi-level modulation and waveform equalizing performances were discussed.

Tu3I • Symposium on Enabling the Cloud: Datacenter as a Network II
16:30–19:00
Presider: Dirk van den Borne; Juniper Networks Inc., Germany

Extending SDN beyond the Data Center Walls, Stuart Elby, Verizon, USA. The service and economic benefits of extending virtualization and software defined networking across geographically dispersed data centers (aka The Cloud) will be discussed. A specific example pertaining to video distribution services will be explored, and gaps in what is currently available in the marketplace to achieve success will be highlighted.

Tu3J • Spectral Shaping
16:30–18:30
Presider: Misha Brodsky;
AT&T Labs, USA

High capacity transport: 100G and beyond, Kim Roberts1; 1Ciena, Canada. For excellent cost and performance, modern high capacity transport systems use digital coherent processing. Coherent methods will be explained, and measured performance will be shown for factory production coherent systems at 100 to 400 Gb/s.

Kim Roberts has innovated in the areas of optical transmission and high capacity packet connections since 1984. His creations are at the heart of much of Ciena’s (Formerly Nortel’s) optical transmission portfolio from the first OC-48 to the 40-400 Gb/s DSP-assisted coherent transceivers. He has been granted over 120 US patents while at labs in Edmonton, Harlow UK, and Ottawa. He was named a Nortel Fellow and received the Outstanding Engineer medal in 2008 from IEEE Canada.

Tu3K • Specialty Fiber and Fiber Optic Sensors
16:30–18:30
Presider: Kay Schuster1, Hartmut Lehmann1, Tino Elsmann1, Tobias Habisreuther1, Sebastian Dochow1; 1Fiber optics, IPHT Jena, Germany.
The paper describes optical fibers due to evanescent field and interferometric sensing, advanced temperature measuring and Raman sensors. Fiber applications will be combined with a focus on technology efforts for the fiber and sensor fabrication.

Tu3G.1 • 16:30 Invited
Digitally Sub-banded Coherent Optical OFDM Transmission, Moshe Nazareth, Alex Tolmachev; 1Technion
Israel Inst of Technology, Israel.

Tu3H.1 • 16:30 Invited
InP modulators with linear accelerator like segmented electrode structure, Tomoaki Kato; 1Green Platform Research Laboratories, NEC Corporation, Japan.

Tu3I.1 • 16:30 Invited
Extending SDN beyond the Data Center Walls, Stuart Elby, Verizon, USA.

Tu3J.1 • 16:30 Tutorial
High capacity transport: 100G and beyond, Kim Roberts; 1Ciena, Canada.

Tu3K.1 • 16:30 Invited
Specialty Fibers for Fiber-optic Sensors, Kay Schuster1, Hartmut Lehmann1, Tino Elsmann1, Tobias Habisreuther1, Sebastian Dochow1; 1Fiber optics, IPHT Jena, Germany.
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**Tu3A.3 • 17:00 Top-Scored**
Robust and Efficient Receiver-side Compensation Method for Intra-channel Nonlinear Effects, Tomofumi Oyama¹, Hisao Nakashima², Shoichiro Oda¹, Tomohiro Yamauchi¹, Zhennig Tao¹, Takeshi Hoshida¹, Jens Rasmusser²; ¹Fujitsu Laboratories Ltd., Japan; ²Fujitsu Limited, Japan; ³Fujitsu R&D Center, Japan. We propose a decision-aided intra-channel nonlinear equalizer based on a perturbation method, which offers one-stage compensation and symbol rate operation. It tolerates errors in decision-aided data and shows fine performance in 128Gbit/s DP-QPSK transmission experiment.

**Tu3C.2 • 17:00**
Experimental Study of Type B Protection for TWDM-PON System, Takashi Nishitani¹, Jun Mizuguchi¹, Hiroaki Muki¹, ¹Mitsubishi Electric Corporation, Japan. Protection switching time is important factors in TWDM-PON system for business application because it defines the service outage time when failure occurs. An experiment using TWDM-PON assumed 40G-PON system shows that the protection switching time is 25.7 ms.

**Tu3D.2 • 17:00 Invited**
How To Connect Multicore and Multimode Fibers, Ryo Nagase¹; ¹Faculty of Engineering, Chiba Inst. of Technology, Japan. Multicore and multimode fibers are proposed for use in space-division multiplexing for ultra-wide-band optical transmission systems. This paper introduces recent progress on multicore and multimode fiber connection technologies.

**Tu3E.3 • 17:00 Invited**
Graphene and Beyond for Ultrafast Optical Communications and Interconnects, Fengnian Xia¹; ¹Electrical Engineering, Yale Univ., USA. We discuss the potential role of graphene in future optical communications. High speed graphene photodetectors, modulators and graphene plasmons are presented. Other two dimensional materials with a direct band gap for light emitting are covered.

**Tu3A.4 • 17:15**
Dynamics of Intra Super-channel Fiber Nonlinearity Compensation in Flex-grid Optical Networks, Danish Rafique¹, Talha Rahman¹, Antonio Napoli¹, Bernhard Spinnler¹; ¹Research and Technology, Coriant GmbH, Germany. The benefit of intra super-channel nonlinearity mitigation reduces with increasing sub-carrier count within the super-channel (higher net data-rate), with the maximum reach improvement, compared to linear compensation, of 150% for single-carrier 240Gb/s PM-16QAM.

**Tu3C.3 • 17:15 Invited**
FTTdp: ONU Complexity Reduction, Michael P. McGary¹, Elliott Gumola¹; ¹Department of Electrical and Computer Engineering, Univ. of Texas at El Paso, USA. We define and evaluate two strategies for reducing the complexity of an optical network unit deployed in a hybrid PON/DSL access network. This complexity reduction will result in reduced energy consumption and cost.

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Thank you for attending OFC. Look for your post-conference survey via email and let us know your thoughts on the program.
Tu3G.2 • 17:00
Channel Equalization Based on Independent Component Analysis for Coherent Optical PDM-OFDM, Xiang Li1, Wen-De Zhang1, Alphones Arakiaaswami1, Changyuan Yu1,2, School of Electrical and Electronic Engineer, Nanyang Technological University, Singapore, 1Department of Electrical and Computer Engineering, National Univ. of Singapore, Singapore, 2A*STAR Inst. for Infocomm Research (I2R), Singapore. We propose an independent component analysis based channel equalizer for coherent optical PDM-OFDM without using training symbols. The proposed scheme achieves transmission performance better than or as good as the conventional equalizer using training symbols.

Tu3G.3 • 17:15
Top-Scored Nonlinear-Tolerant Adaptive Zero-Guard-Interval CO-OFDM for Highly Spectral Efficient Optical Transmission, Wei Wang1, Gunbi Zhuge1, Xian Xu1, Mohamed Morsy-Osman1, Mathieu Chagnon1, Meng Qiu1, David V. Plant1, 1Department of Electrical and Computer Engineering, McGill Univ., Canada. An adaptive channel estimation method is proposed for zero-guard-interval CO-OFDM. The improvement in nonlinear tolerance, SOP tracking ability and residual CD tolerance compared to intra-frequency domain averaging is numerically and experimentally demonstrated.

Tu3H.2 • 17:00
AWG-DBR-based WDM Transmitter fabricated in an InP Generic Foundry Platform, Katarzyna Lawniczuk1,2, Christophe Kazmierski1, Mike Wale1, Pawel Szczepanski1, Ryszard Pramidowicz2, Mantis Smit1, Xaveer Leijtens1, 1Technische Universiteit Eindhoven, Netherlands, 2Warsaw Univ. of Technology, Poland, 3III-V lab, Common laboratory of Alcatel/Lucent Bell Labs France, Thales Research and Technology, France. Oclaro Technology Ltd., UK, 4National Inst. of Telecommunications, Poland. We report a novel narrow-linewidth WDM transmitter operating at 10Gbps per transmission channel with 275kHz optical linewidth. The device was fabricated in generic InP-based foundry process and integrates AWG/laser with selective DBR-mirrors and Mach-Zehnder modulators.

Tu3H.3 • 17:15
An InP Monolithically Integrated Multi-Frequency Wavelength Converter, Francesca Bonetti1, Nicola Andriulli1, Stefano Faralli1, Jonathan Klamkin2, Emil Kleijn1, Tjibbe de Vries2, Giampiero Contestabile1, 1Scuola Superiore Sant Anna, Italy; 2Boston Univ., USA; 3Technische Universiteit Eindhoven, Netherlands. We demonstrate a novel InP-PIC for all-optical wavelength conversion that monolithically integrates a digitally tunable 4-channel multi-wavelength laser and a SOA-MZI. Operations up to 5 Gba/s are shown by BER-measurement with moderate power penalty.

Tu3I.2 • 17:00
Invited Enabling High Performance Cloud Services through Optical Layer Programmability and Virtualisation, Dimitra Simeonidou1, University of Bristol, United Kingdom. We report new research targeting optical layer programmability and virtualisation for advanced DC and Cloud infrastructures. We focus on novel coordinated software-hardware solutions to unlock flexibility, programmability and resource sharing in the optical layer.

Tu3J.2 • 17:00
Invited Plastic Optical Fibers for Sensing Applications, Francis Berghmans1, Hugo Thienpont2, Vrije Universiteit Brussel, Belgium. We review recent developments in polymer optical fiber sensor technology and how such “POF” sensors may extend the capabilities of the existing silica fiber sensors.
Tu3A • Fiber Nonlinearity Mitigation—Continued

Tu3A.5 • 17:30 Top-Scored
Multi-channel Nonlinearity Compensation of 128-Gb/s PDM-QPSK Signals in Dispersion-Managed Transmission Using Dispersion-Folded Digital Backward Propagation, Can Xua1, Xiang Liub1, S. Chandrasekharb1, Nicolas K. Fontaine1, Lika Zhub1, Guang-fang Li1, (Bell Labs, Alcatel-Lucent, USA; 1Univ. of Central Florida, CREOL, USA). We demonstrate nonlinearity compensation of 37.5-GHz-spaced 128-Gb/s PDM-QPSK signals using dispersion-folded digital-backward-propagation and a spectrally-sliced receiver that simultaneously receives three WDM-signals, showing mitigation of intra-channel and inter-channel nonlinear effects in a 2560-km dispersion-managed TWR5-fiber link.

Tu3A.6 • 17:45 Top-Scored
Simplified Nonlinearity Pre-compensation Using a Modified Summation Criteria and Non-Uniform Power Profile, Ying Gaoa1, Abdullah S. Karab1, John C. Cartledge1, Scott Yama1, Maurice O’Sullivan1, Charles Laperle1, Andrezej Borowicza1, Kim Roberts1, (Electrical and Computer Engineering, Queen’s Univ., Canada; 1Ciena, Canada; 2Mathematics and Statistics, Queen’s Univ., Canada). By modifying the summation selection criteria and using the non-uniform power distribution profile, a further reduction in the complexity of implementing the perturbation-based nonlinear pre-compensation algorithm for a 128 Gb/s DP 16-GAM signal is demonstrated.

Tu3B • Panel: Energy-efficiency in Telecommunication Operator Networks: a Reality Check—Continued

Tu3C • Protection & Other Practical Considerations in PONs—Continued

Tu3D • Components for SDM—Continued

Tu3E • Novel Materials—Continued

Tu3F • Optical Access for Mobile Front/Backhaul—Continued

Tu3D.3 • 17:30
Mode Multiplexer/Demultiplexer Based on a Partially Elongated Multi-Core Fiber, Hitoshi Uemuraa1, Yusuken Sascal1, Shoko Nishimotob1, Takui Uematsuc1, Katsumi Takenagaa1, Koji Omiich1, Ryuchiro Goto1, Shiochirou Matsumoa1, Kunimasa Saitohb1, (Optics and Electronics Laboratory, Fujikura Ltd., Japan; 1Graduate School of Information Science and Technology, Hokkaido Univ., Japan). A mode multiplexer/demultiplexer based on a partially elongated multi-core fiber is designed and fabricated. The mode conversion from the LP01 mode to the LP11 mode at two wavelengths is demonstrated by changing the elongating condition.

Tu3E.4 • 17:30
High-Efficiency Thermal-Tunable Microring Resonators Made of Cu-Dielectric-Si Hybrid Plasmonic Waveguides, Shiyang Zhub1, Patrick Guo-Qiang La2, Dm Lee Kwong1, (1Inst. of Microelectronics, Singapore; 2NTT Access Network Service Systems Laboratories, NTT Corporation, Japan). We propose and experimentally verify novel low-complexity clock distribution and recovery for high-speed UDWDM-OFDMA-based mobile backhaul. 30Gbps UDWDM-OFDMA transmission with synchronous 50MHz clock distribution over 40km SSMF is achieved.

Tu3E.5 • 17:45
A Novel DBA Scheme for TDM-PON Based Mobile Fronthaul, Takayoshi Tashiro1, Shigenu Kawan1, Jun Teras1, Tomaaki Kawamura1, Nobuyuki Tanaka1, Satoshi Shigematsu2, Naoto Yoshimoto1, (1NICT, Japan; 2NTT Access Network Service Systems Laboratories, NTT Corporation, Japan). We propose a mobile-DBA with low-latency for a TDM-PON based mobile fronthaul. It utilizes mobile-scheduling information and reduces the latency to about 1/20 of conventional one. Measured latencies (< 50 μs) are enough for LTE.
Room 125

Tu3G • OFDM II—Continued

Tu3H • InP-based Optoelectronic Devices—Continued

Room 130

Room 131

Tu3J • Symposium on Enabling the Cloud: Datacenter as a Network II—Continued

Tu3K • Specialty Fiber and Fiber Optic Sensors—Continued

Room 132

Room 133

Tu3G.4 • 17:30 Top-Scored Experimental Demonstration of Data-dependent Pilot-aided Phase Noise Estimation for CO-OFDM, Son T. Le1, Thavamaran Kanesan1, Mary McCarthy1, Elias Giacoumidis1, Ian Phillips1, Marc F. Stephens1, Mingming Tan1, Nick J. Doran1, Andrew D. Ellis1, Sergei K. Tutyavin1; 1Photons research group, Aston Univ., UK. We demonstrate a novel phase noise estimation scheme for CO-OFDM, in which pilot subcarriers are deliberately correlated to the data subcarriers. This technique reduces the overhead by a factor of 2.

Tu3G.5 • 17:45 Top-Scored Direct-Detection Multi-Band OFDM Metro Networks Employing Virtual Carriers and Low Receiver Bandwidth, Tiago F. Alves1, André Alberto1, Adolfo Cartaxo1; 1IST/Instituto de Telecomunicações, Portugal. A metro network using a novel multi-band (MB) OFDM signal is proposed to reduce the receiver bandwidth. A required OSNR for a BER=10^-3 of 28 dB is demonstrated in a 240-km long 7-band MB-OFDM system.

Tu3H.3 • 17:30 Top-Scored Nonlinearity Mitigation with Spectral Shaping Greater than Nyquist, Oleg Smirnov1, Dmitri Foursz2, Matt Mazurczyk1, Hangbin Zhang3, Ji-Xing Cai4, Yu Sun4, Alexei Pilipetskii1, 1TE SubCom, USA. We experimentally and theoretically investigate digital spectral shaping for nonlinearity mitigation. We use transmitter digital-to-analog converter to shape channel spectrum to match the channel spacing and optimize linear and nonlinear performance. Theoretical calculations agree well with experiment.

Tu3J.4 • 17:45 Top-Scored Nonlinearity Mitigation Using DACs and demonstrate the improved nonlinearity tolerance over single carrier signals in long-haul coherent optical transmission systems.

Tu3J.5 • 17:45 Top-Scored A Compact Low-Power 224-Gb/s DP-16QAM Modulator Module with InP-based Modulator and Linear Driver ICs, Taizo Tatsumi1, Naoki Itabashi1, Tomoko Ikagawa1, Naoya Kono1, Morinori Seki1, Keiji Tanaka1, Kazuhiro Yamaji1, Yasushi Fujimura1, Katsumi Uesaka1, Takashi Nakabayashi1, Hajime Shoji1, Shiochi Ogita1; 1 Transmission Devices R & D Labs., Sumitomo Electric Industries, Ltd., Japan. A compact 224-Gb/s DP-16QAM InP-based modulator module including linear driver ICs and polarization multiplexing micro-optics is demonstrated. A power dissipation is 3.2 W with compatible performance with LiNbO3-based modulator in back-to-back operation.

Room 125

Tu3H • InP-based Optoelectronic Devices—Continued

Tu3I • Symposium on Enabling the Cloud: Datacenter as a Network II—Continued

Tu3J • Spectral Shaping—Continued

Room 131

Room 132

Room 133

Tu3K • Specialty Fiber and Fiber Optic Sensors—Continued

Tu3J.3 • 17:45 Top-Scored Subcarrier Multiplexing Using DACs for Fiber Nonlinearity Mitigation in Coherent Optical Communication Systems, Meng Qiu1, Qunbi Shen1, Mohamed Moray-Asman1, David V. Plant1; 1McGill Univ., Canada. We experimentally generate subcarrier multiplexed signals using high-speed DACs and demonstrate the improved nonlinearity tolerance over single carrier signals in long-haul coherent optical transmission systems.

Tu3J.2 • 17:30 Electrical Current-driven Dual-core Optical Fiber with Embedded Metal Electrodes, Zhenggang Lian1, Martha Segura1, Nina Podoliak1, Xin Feng1, Nicolas White1, Peter Horak1, Wei Loh1; 1’Optoelectronics Research Centre, UK. A dual suspended-core optical fiber with four embedded metal electrodes was fabricated by fiber drawing from a composite preform. Heating the fiber by running watt-level electrical power through the electrodes produced optical switching between cores.

Tu3J.4 • 17:45 Top-Scored Nonlinearity Mitigation with Spectral Shaping Greater than Nyquist, Oleg Smirnov1, Dmitri Foursz2, Matt Mazurczyk1, Hangbin Zhang3, Ji-Xing Cai4, Yu Sun4, Alexei Pilipetskii1, 1TE SubCom, USA. We experimentally and theoretically investigate digital spectral shaping for nonlinearity mitigation. We use transmitter digital-to-analog converter to shape channel spectrum to match the channel spacing and optimize linear and nonlinear performance. Theoretical calculations agree well with experiment.

Tu3K.4 • 17:45 Top-Scored Inverse-parabolic Graded-index Profile for Transmission of Cylindrical Vector Modes in Optical Fibers, Bora Ung1, Lixian Wang1, Charles Brunet1, Pravin Varty1, Cang Jin1, Leslie Rusch1, Younes Messaddeq1, Sophie LaRochelle1, Center for Optics, Photonics and Lasers, Universite Laval, Canada. We propose and fabricate a novel few-mode optical fiber for transmission of cylindrical vector modes. Effective index separations larger than 2.1E-4, even with strong fiber bends, are achievable in the C-band.
Tu3A • Fiber Nonlinearity Mitigation—Continued

Tu3A.7 • 18:00
Mitigating Intra-channel Nonlinearity in Coherent Optical Communications Using ISI-free Polynomial Pulses, Abdullah S. Karar1, Ying Gao2, John C. Cartledge1, Saeed Gazor3,1, Maurice O’Sullivan3, Charles Laperle2, Andrzej Borowiec1, Kim Roberts2; 1Electrical and Computer Engineering, Queen’s Univ., Canada; 2Ciena, Canada; 3Mathematics and Statistics, Queen’s Univ., Canada. ISI-free polynomial pulses are considered for mitigating intra-channel nonlinearity for a 128 Gb/s DP 16-QAM system. A maximum transmission distance of 4500 km is achieved offering a 25% reach extension relative to root-raised-cosine pulses.

Tu3A.8 • 18:15
Efficient Fiber Nonlinearity Mitigation in 50-GHz-DWDM Transmission of 256-Gb/s PDM-16QAM Signals by Folded Digital-Back-Propagation and Channelized FBG-DCMs, Xiang Liu1, S. Chandrasekhar1, Peter J. Winzer1, Benoit Maheux-Laureau2, Francois Trepanier2; 1Alcatel-Lucent Bell Labs, USA; 2TerXion, Canada. We demonstrate DSP-efficient mitigation of intrachannel and interchannel nonlinear impairments in dispersion-managed DWDM transmission by using channelized-FBG-DCMs and dispersion-folded digital-back-propagation, showing similar nonlinearity tolerance as dispersion-unmanaged transmission for 256-Gb/s PDM-16QAM signals over 12×100-km SSMF spans.

Tu3B • Panel: Energy-efficiency in Telecommunication Operator Networks: a Reality Check—Continued

Tu3B.6 • 18:00
Optical Network Unit (ONU) Power Saving in Time Division Multiplexed Passive Optical Networks (TDM-PONs), Yuanqi Luo1, Frank Effenberger1, 1Huawei Technologies Co Ltd, USA. We review power saving in TDM-PONs and propose a mechanism to save the ONU power consumption with backward compatibility. Evaluation results show our proposal reduces ONU receiver power consumption as compared with G-PON and BIPON.

Tu3C • Protection & Other Practical Considerations in PONs—Continued

Tu3C.5 • 18:00
Correlation-based End-reflection-assisted Brillouin Analysis for Discriminating Small Branch Length Difference, Hiroshi Takahashi1, Chihiro Kito1, Fumihiko Ito1, Kazuo Hotate1; 1NTT, Japan; 2The Univ. of Tokyo, Japan. A novel end-reflection-assisted Brillouin analysis is proposed and demonstrated for discriminating branches of PON with similar lengths, employing correlation domain Brillouin gain analysis and correlation based branch discrimination technique.

Tu3C.6 • 18:15
Silicon Waveguides and Filters in Hyperuniform Disordered Photonic Solids for the Near-infrared, Milan Milosevic1, Marian Florescu1, Weiming Man1, Paul Steinhardt1, Salvatore Torquato1, Paul Chaikin1, Timothy Amos1, Gev Nakhla2, Ruth Ann Muller3; 1Electronic Engineering, Univ. of Surrey, UK; 2Physics and Astronomy, San Francisco State Univ., USA; 3Physics, Princeton Univ., USA. We demonstrate DSP-efficient mitigation of intrachannel and interchannel nonlinear impairments in hyperuniform disordered photonic solids. Temperature sensitivity of resonant defects is more than 500 times lower than that of the standard silicon microring resonators.

Tu3E • Novel Materials—Continued

Tu3E.6 • 18:00
Dynamic Compression Method Using Wireless Resource Allocation for Digitized Radio over TDM-PON System, Naotaka Shibata1, Shigeru Kuwano2, Jun Terada1, Naoto Yoshimoto1, 1NTT, Japan. We developed a prototype of a network adapter that implements the dynamic compression method for digitized radio over TDM-PON systems. Experimental results show that the required PON bandwidth can be reduced to 1/8.

Tu3F • Optical Access for Mobile Front/Back Haul—Continued

Tu3F.5 • 18:15
Joint Bandwidth Provisioning and Cache Management for Video Distribution in Software-Defined Passive Optical Networks, Xin Li1, Konstantinos Karanakis1, Neda Covietic2, Akhiro Tanaka1, Chunming Gao1, Ting Weng1; 1NEC Lab America, USA; 2The State Univ. of New York at Buffalo, USA. We propose joint bandwidth provisioning and base station caching for video delivery in software-defined PON. Performance evaluation via custom simulation models reveals 30% increase in served video requests and 90% reduction in service response delays.
Tu3G • OFDM II—Continued

Experimental Demonstration of Digital Coherent Superposition of Optical OFDM Subcarrier Pairs for Mitigation of Linear and Nonlinear Phase Noise, Xingwen Yi1, Xuemei Chen1, Chao Li2, Ming Luo1, Qi Yang3, Zhaohui Li4, Kun Qiu1; 1Key Laboratory of Optical Fiber Sensing and Communications, Ministry of Education, Uni of Elec Science & Tech of China, China; 2State Key Lab of Optical Com- munication Technology and Networks, China; 3Inst. of Photonics Technology, Jinan Univ., China. We experimentally demonstrate digital coherent superposition of optical OFDM subcarrier pairs with Hermitian symmetry to mitigate phase noise, including laser phase noise, and cross-phase modulation. Optical OFDM subcarrier pairs are used to demonstrate digital coherent superposition of optical OFDM subcarrier pairs for mitigation of linear and nonlinear phase noise.

Tu3H • InP-based Optoelectronic Devices—Continued

Opto-electronic integrated circuits (OEICs), for 100G Ethernet and Coherent Networks Based on Multi-Guide Vertical Integration Platform, Sasa Ristic1, Miroslaw Flajsarczak2, Michael Lebby3,4, OneChip Photonics, Canada; 2McGill Univ., Canada; 3Univ., Australia. We present monolithically integrated InP-based optoelectronic circuits, using our cost-efficient, multi-guide vertical integration platform, for the following applications: 100G Ethernet transmitters (100GBASE-PSM4 and 100GBASE-LR4), Ethernet receivers (100GBASE-PMS4, 100GBASE-LR4, and 40GBASE-LR4), and 112Gbps DP-QPSK coherent receivers.

Tu3I • Symposium on Enabling the Cloud: Datacenter as a Network II—Continued

Infrastruc- ture Architecture for Network Functions Virtualization with SLA Guarantee, Hideyuki Shimono; 1NEC, Japan. Infrastructure Architecture for Network Functions Virtualization with SLA Guarantee, This presentation covers a discussion on infrastructure architecture of a NFV system and how it differs from datacenter infrastructure in terms of traffic patterns, topology, SLAs, and controls on VM allocation and network routing.

Tu3J • Spectral Shaping—Continued

Optical Spectral Shaping and High Spectral Efficiency in Long Haul Systems, Matt Mazurczyk1, 2TE SubCom, USA. Spectral shaping implemented with digital-to-analog converters is a powerful technique for increasing spectral efficiency. We review both its background and experimental demonstrations including a record single core result of 44.1 Tb/s over 9,100 km.

Tu3K • Specialty Fiber and Fiber Optic Sensors—Continued

Flat-top Beam from a 50µm-Core Yb-doped Leakage Channel Fiber, Fanting Kong1, 2, Guancheng Gu1, 2, Thomas W. Hawkins1, 2, Joshua Parsons1, 2, Maxwell Jones1, 2, Christopher Dunn1, 2, Monica T. Kalichvsky-Dong1, Kanxian Wei1, Bryce Sams1, Liang Dong1, 2, ECE, Clemson Univ., USA; 2COMSET, Clemson Univ., USA; 3Nufern, USA. Flat-top beam is demonstrated in a 50µm-core leakage channel fiber using a central ytterbium-doped area with an index depression of ~2x10^-4, resulting in an effective mode area of ~1880µm², i.e. >50% increase from uniform core.

18:30–20:00 Conference Reception, South, Rooms 103 & 104

19:30–21:30 Rump Session — Will Traffic Growth Break the Internet — And Can Optical Communications Help?, North, Room 130
W1A.1 • 08:00
5 x 50 Gb/s WDM Transmission of 32 Gbaud DP-3-PSK over 36,000 km Fiber with Spatially Coupled LDPC Coding, Fred Buchali, Laurent Schmalen, Axel Klein, Karsten Schuh, Andreas Leven, Alcatel-Lucent Bell Labs, Germany: A novel 3-PSK modulation format with 2 dB SNR gain over BPSK is implemented for ultra long haul transmission with spatially coupled LDPC coding. 50% reach extension is achieved leading to 36,000 km transmission distance.

Organizer: Maarten Vissers, Huawei, The Netherlands

The Optical Transport Network (OTN) is becoming the main technology in provider transport networks worldwide to interconnect wireline and wireless service nodes in access, metro, core and backbone networks as well as small, medium and large enterprises and data centers regionally and globally. This panel addresses the evolution of the OTN over the past 15 years (OTN’s 1st era) and the expected evolution for the next 15 years (OTN’s 2nd era). Topics include flexible rate OTU network applications, beyond 100G OTU structure, service mappings and ODU grooming, forecast of the time line for beyond 100G OTU bit rates, standardization and market demand and necessary progress in electronic and photonic integration. Panel members represent network and data centre providers, IP and transport vendors and analysts.

Speakers:
The Need for FlexMAC and Flexible Framing in a Software Defined Coherent Modulation World, Tad Hofmeister, Google, USA

The Operator’s view of Flexible Elastic Optical Networks, Takuya Chara, NTT Group, Japan

Three Dimensions of Flexibility for Beyond 100G Transmission, Geoff Bennett, Infinera, USA; Andrew Schmit, Infortechnics, USA

W1C.2 • 08:15
Flexibility of Programmable Add/ Drop Architecture for ROADMs, Miqael Garnich Alarbac, Juliano Oliveira, Marcos Siqueira, Norberto Amaya, Georgios S. Zervas, Dimitra E. Simeonidou, Univ. of Bristol, UK

Field Demonstration of Datacenter Resource Migration via Multi-Domain Software Defined Transport Networks with Multi-Controller Collaboration, Yiming Yu, Yi Lin, Xiaofeng Li, Yongli Zhao, Jianrui Han, Haomian Zheng, Yadi Cui, Mingju Xiao, Hui Li, Yang Peng, Ji Yang, Masahiro Hayashitani, Yohei Hasegawa, Kazuya Suzuki, Yasuhiro Maakushi, NEC Corporation, Japan

Single Optical Source for Next-Generation Data Communication Links, Jonathan D. Ingham, Richard V. Penty, Ian White, David G. Cunningham, Univ. of Cambridge, UK; Avago Technologies, UK

Novel High-Resolution OTDR Technology for Next-Generation Optical Networking, Charlie Kuznia, Joe Ahadian, Dick Pommeren, Rich Hagan, Paul Bachta, Man Wong, Kris Kusumoto, Sandra Skendzic, Chuck Tabbert, Mark Beranek, USA; Naval Air Systems Command, USA. We present high-resolution optical time domain reflectometer (ODTR) integration into fiber optic transceivers. Transceivers with built-in test (BIT) ODTR can characterize the fiber plant and isolate faults to reduce network installation and maintenance costs.
Room 130

08:00–10:00
W1H • Advanced Integrated Transceiver Technologies
Presider: Jonathan Klamkin; Boston Univ., USA

W1H.1 • 08:00 • Invited
Experiment Turbulence Compensat
Low Noise and Regenerative Phase Sensitive Amplifier based on PPLN Waveguides, Takeshi Umeki1, Masaki Asobe1, Hidetsuha Takeda1, Osamu Tadanaga1, Koji Enbutsu1, Yutaka Miyamoto1, Hirokazu Takenouchi1; 2NTT Photonics Labs, Japan; 3NTT Network Innovation Labs, Japan. We review the capabilities of phase sensitive amplifiers based on PPLN waveguides for optical communication. Specifically, we discuss their unique low noise amplification, phase and amplitude regeneration in multi-span transmissions, and multilevel phase coding signal amplification.

W1H.2 • 08:15 • Invited
Degenerate Mode-Group Division Multiplexing using Delayed Adaptive Frequency-Domain Equalization, Kai Shi1, George Gordon1, Benn C. Thomson1; Electronic and Electrical Engineering, Univ. College London, UK; Engineering, Univ. of Cambridge, UK. A reduced complexity delayed adaptive frequency-domain equalizer is proposed for MIMO equalization in degenerate mode-group multiplexed systems. A factor of 2.8 reduction of the DSP complexity is obtained compared to the optimized delayed time-domain equalizer.

W1J.1 • 08:00 • Invited
Adaptive Photonic-Assisted M-ary ASK/M-QAM Millimeter-Wave Synthesis in Multi-Antenna Radio-over-Fiber System, Ming Zhu1, Lin Cheng1, Jing Wang1, Cheng Liu1, Ghee-Kung Chang1; Georgia Inst. of Technology, USA. We propose and experimentally verify novel photonic-assisted multi-antenna RoF system to achieve multiplexing gain by synthesizing two 1/0.5-Gb/s OOK/4-QAM mm-wave signals into a 2/1-Gb/s 4-ary ASK/M-QAM signal, or SNR gain by combining two identical channels.

W1J.2 • 08:15 • Invited
Frequency-Hopping Microwave Waveform Generation Based on a Frequency-Tunable Optoelectronic Oscillator, Jianping Yao1, Wangxiao Li1, Weifeng Zhang1, Weifeng Zhang1; Univ. of Ottawa, Canada. High-speed and wideband frequency-hopping microwave waveform generation based on a frequency-tunable optoelectronic oscillator using a polarization modulator and a polarization-maintaining phase-shifted fiber Bragg grating is demonstrated.

W1K.1 • 08:00
Analysis and Implementation of a 3-Way Handshake Signaling Protocol for Highly Dynamic Transport Networks, Ronald Skoog1, Joel Gannett1, Keith Kim1, Haim Kibrinski1, Michael Rauch1; Ann C. Von Lehmen1, Brian Wilson1; Optical Network Research, Applied Communication Sciences, USA. A 3-Way handshake signaling protocol was previously developed that meets DARPA CORONET program requirements for highly dynamic transport networks. Presented here are extensions to OTN-based networks, and protocol validation in a 100-node emulation testbed.

Show Floor Programming

08:30–09:15
■ Service Provider Summit
Keynote: Packet Optical vs. OTN, Expo Theater I Programming
For more details, see page 39
09:15–10:45
■ Service Provider Summit
Panel I: Packet Optical Convergence, Expo Theater I Programming
For more details, see page 39
W1A.3 • 08:30
Transoceanic Transmission of Dual-Carrier 400G DP-8QAM at 121.2km Span Length with EDFA-Only, Shao-liang Zhang\textsuperscript{1}, Fatih Yaman\textsuperscript{1}, Ting Wang\textsuperscript{1}, Eduardo Mateo\textsuperscript{2}, Takanori Inoue\textsuperscript{1}, Yoshioh Inada\textsuperscript{1}, Takaaki Ogata\textsuperscript{1}; \textsuperscript{1}NEC Laboratories America Inc, USA; \textsuperscript{2}Submarine Network Division, NEC Corporation, Japan. 400-Gb/s dual-carrier DP-8QAM transmission over 6,787 km is reported at 121.2km span length, the longest to date with EDFA only. Spectral efficiency of 4.54 bits/Hz is achieved thanks to Nyquist shaping and nonlinear compensation techniques.

W1C.3 • 08:30
Experimental Demonstration and Benefits of Self-Healing Hard-Wired and Synthetic ROADMs, Matija Dzanko\textsuperscript{1}, Marija Furdek\textsuperscript{1,2}, Norberto Amaya\textsuperscript{1}, Georgios S. Zervas\textsuperscript{1}, Branko Mikac\textsuperscript{1}, Dimitra E. Simeonidou\textsuperscript{1}; \textsuperscript{1}Department of Telecommunications, Univ. of Zagreb, Faculty of Electrical Engineering and Computing, Croatia; \textsuperscript{2}Department of Electrical and Electronic Engineering, Univ. of Bristol, Faculty of Engineering, UK; \textsuperscript{3}Royal Inst. of Technology KTH, ICT School, Sweden. Novel hard-wired and synthetic ROADM architectures with self-healing capabilities are experimentally demonstrated. Simulation results show significant improvements of availability and recovery time due to node-level restoration, with reduced mean down time and operator revenue losses.

W1C.4 • 08:45
1.92 Tbit/s, 64 QAM Coherent Nyquist Pulse Transmission over 150 km with a Spectral Efficiency of 7.5 bits/Hz, David O. Otuya\textsuperscript{1}, Keisuke Kasai\textsuperscript{1}, Toshihiko Hirooka\textsuperscript{1}, Masato Yoshida\textsuperscript{1}, Masataka Nakazawa\textsuperscript{1}; \textsuperscript{1}Tohoku Univ., Japan. We demonstrate, for the first time, a polarization-multiplexed 160 Gsymbol/s, 64 QAM coherent optical Nyquist pulse transmission. 1.92 Tbit/s data were successfully transmitted over 150 km with a spectral efficiency of 7.5 bits/Hz.

W1D.2 • 08:30 • Invited
Flexible TWDM PONs, Ning Cheng\textsuperscript{1}; \textsuperscript{1}Huawei Technologies USA, USA. A flexible TWDM PON is demonstrated with error-free performance using enhanced CFP transceiver for OLT and tunable SFP+ transceiver for ONUs. Such PON system allows pay-as-you-grow deployment, supports load balancing and achieves significant power saving.

W1E.3 • 08:30 • Invited
SDN Concept: From Theory to Network Implementation, Ljudmila Tanevski\textsuperscript{1}; \textsuperscript{1}Alcatel-Lucent, USA. A CDC ROADM architecture compatible with emerging DWDM super-channel technology. A real world network model is used to quantify that this architecture requires fewer network components leading to less capital and operational costs.

W1F.3 • 08:30
60-Gb/s CAP-64QAM Transmission Using DML with Direct Detection and Digital Equalization, Junwen Zhang\textsuperscript{1,2}, Xinying Li\textsuperscript{1}, Yan Xia\textsuperscript{1}, Yufei Chen\textsuperscript{1}, Xue Chen\textsuperscript{1}, Jianguo Yu\textsuperscript{1}, Jiangan Xiao\textsuperscript{1}, ZTE (TX) Inc, USA; \textsuperscript{2}Fudan Univ., China; \textsuperscript{3}ZTE Corp., China; \textsuperscript{4}Beijing Univ. of Posts and Telecommunications, China. Digital equalization based on modified DD-LMS algorithm is used to equalize the CAP-64QAM with reduced complexity and improved performances. A record 60-Gb/s CAP-64QAM over 20-km SSMF based on the DML and direct detection is demonstrated.
W1G • Advanced Signal Generation—Continued

W1G.2 • 08:30
**Experimental Demonstration of Optical Nyquist Generation of 32-Gb/s QPSK using a Comb-based Tunable Optical Tapped-Delay-Line FIR Filter**, Morteza Ziyadi1, Mohammad Reza Chitgarha1, Amirhossein Mohammadian1, Salman Khaleghi1, Ahmed Almaimani1, Y. Akasaka2, J.-Y. Yang1, M. Sekiya1, Moshe Willner1, Joe Touch1, Moshe Tur1, Loukas Paraschis1, Carsten Langrock2, Martin Fejer1, Alan Willner1, 1Ming Hsieh Department of Electrical Engineering, Univ. of Southern California, USA; 2School of Electrical engineering, Tel Aviv Univ., Israel; 3Cisco Systems, USA; 4Edward L. Ginzton Laboratory, Stanford Univ., USA. We experimentally demonstrate tunable optical Nyquist generation of 32Gbaud QPSK signals using optical tapped-delay line. Optical Nyquist spectra for different number of taps are shown, and 20% EVM and 2.8 dB OSNR penalty at BER of 1e-3 are measured.

W1G.3 • 08:45
**Nonlinearity-Tolerant Frequency Domain Root M-shaped Pulse for Spectrally Efficient Coherent Transmissions**, Xian Xu1, Qunbi Zhuge2,1, Mohammad Reza Chitgarha1, Meng Qiu1, Qunbi Zhuge1,1, Mohammad Reza Chitgarha1,2,1Electrical Engineering, Tel Aviv Univ., Canada; 2Ciena Corporation, USA; 1Information Science Inst., Univ. of Southern California, USA. We measured a 64-QAM signal over a 10-km standard single-mode fiber (SSMF) with an EVM of 1.1% and a spectral efficiency of 230 bit/s/Hz.

W1H • Advanced Multiplexing—Continued

W1H.3 • 08:30
**First Experimental Demonstration of a Time Domain Multiplexed SDM Receiver for MIMO Transmission Systems**, Roy van Uden1, Chigo Okonkwo1, Haoshuo Chen1, Frans Huijskens2, Huug Waardt1, A. Koonen1, 1Cobra Research Inst., Eindhoven Univ. of Technology, Netherlands. Conventionally, an SDM system requires a 4-port oscilloscope for each dual polarization mode. Using a novel and cheaper 2×4-port oscilloscope SDM receiver, 3-mode 28GBaud DP-32QAM is experimentally verified after 41.7km few-mode fiber transmission.

W1H.4 • 08:45
**Top-Scored Ultra-High 230-bit/s/Hz Spectral Efficiency using OFDM/OQAM 64-QAM Signals over Pol-Muxed 22 Orbital Angular Momentum (OAM) Modes**, Jian Wang1, Shuhui Li1, Chao Li1, Long Zhu1, Chengcheng Gui1, Dequan Xie1, Ying Qiu1, Qi Yang1, Shaohua Yu1, 1Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; 2State Key Laboratory of Optical Comm. Technologies and Networks, China. We demonstrate the multiplexing/demultiplexing of 22 orbital angular momentum (OAM) modes. Using 17 9-Gbit/s OFDM/OQAM 64-QAM signals over pol-muxed 22 OAM modes (44 channels in total), we achieve an ultra-high spectral efficiency of 230 bit/s/Hz.

W1I • Coherent Integrated Transceiver Technologies—Continued

W1I.3 • 08:45
**Simple Three-dimensional Simplex Modulator**, Hiroshi Yamazaki1, Yasuaki Hashizume1, Takashi Saida1, 1NTT Photonics Laboratories, Japan. We devised a simple 3D simplex modulator containing only two Mach-Zehnder sub-modulators. The modulator has smaller intrinsic modulation loss than that with the conventional configuration. It operated at 43 Gb/s.

W1J • Signal Generation—Continued

W1J.3 • 08:30
**Invited Tunable QAM Transmitter Based on Direct Modulation Laser**, Joseph Kakande1, Radan Slavik2, Richard Phelan1, Brian Kelly1, David J. Richardson1, 1Bell Labs, Alcatel-Lucent, USA; 2Optoelectronics Research Center, Univ. of Southampton, UK; 3Eblana Photonics, Ireland. We discuss a technique that allows for flexible synthesis of square QAM constellations via the direct modulation of tunable, injection locked, semiconductor lasers. The approach uses optical coherent multiplexing and we demonstrate full C-band tuning.

W1K • Network Control—Continued

W1K.3 • 08:45
**E2E Traffic Engineering Routing for Transport SDN**, fabio ubaldi1, Paola Iovanna2, Francesco Di Michele2, Juan-Pedro Fernández-Palacios2, Vicente Pascual-Castro2, 1Ericsson, Italy; 2Telefonica R+D, Spain. The article proposes a hierarchical routing approach, validated by simulation on real network operator, based on a novel adaptive virtualization scheme, suitable for transport SDN, allowing dynamic configuration of heterogeneous multi-domain packet-optical networks.
Coherent Optical Transmission over 150 km with a Potential SE of 15.3 QAM transmission (66 Gbit/s) with a 15.3% increased transmission distance.

W1A.6 • 09:15
2048 QAM (66 Gbit/s) Single-Carrier Coherent Optical Transmission over 150 km with a Potential SE of 15.3 bit/s/Hz, Shokei Beppu, Masato Yoshida, Keisuke Kasai, Tohoku University, Japan. We have successfully achieved a 2048 QAM transmission (66 Gbit/s) with a potential spectral efficiency of 15.3 bit/s/Hz in a single carrier coherent transmission over 150 km.

W1C.5 • 09:00
QoS of Optical Metro Networks, Philippe Gravelyn, Michel Morvan, Bogdan Uscumlic, Lida Sadeghian, Computer Science Department, Telecom Bretagne, France; Optics Department, Telecom Bretagne, France; IIRSA, France. Metro networks support increasing traffic volumes and evolving traffic profiles. Revisiting metro networks architecture, this paper shows that both optical transparency and sub-wavelength granularity can be achieved, while still ensuring transport network QoS levels.

W1D.3 • 09:00
Delay Modulation for TWDM PONs, Ning Cheng, Min Zhou, Kerry Litvin, Frank Effenberger, American Research Center, Huawei Technologies USA, USA; Steven Hand, Onur Turkcu, Steven Hand, Infinera, USA. OTN switching enables high network efficiency and operational ease-of-use. This paper evaluates several real-world network and traffic models and concludes that OTN switching benefits are maximized more by traffic patterns rather than by physical topology.

W1D.4 • 09:15
Automatic ONU Wavelength Control in TWDM PONs, Ning Cheng, Frank Effenberger, American Research Center, Huawei Technologies USA, USA. Low cost and effective approaches for automatic ONU wavelength control in TWDM PONs are proposed by using low-power and low-frequency low-data-rate signal from the tunable ONU transmitter. Experimental results validate the proposed approaches.

W1E.4 • 09:00
Variation of OTN Switching Benefits in Real-World Networks Based on Network and Traffic Connectivity, Soumya Roy, Chalmers Univ. of Technology, Sweden; Onur Turkcu, Infinera, USA. OTN switching enables high network efficiency and operational ease-of-use. This paper evaluates several real-world network and traffic models and concludes that OTN switching benefits are maximized more by traffic patterns rather than by physical topology.

W1E.5 • 09:15
Comparison of Converged Packet-Optical Core Network Architecture Options, Serge Melle, Srijayet Alhusaini, Ericsson, Sweden; Bogdan Uscumlic, Infinera, USA. Two architectural approaches for converged packet-optical core networks are compared in a North American network: IP over WDM and IP over OTN. Results show a converged OTN/WDM layer reduces IP/MPLS and total packet-optical network costs.
W1G • Advanced Signal Generation & Monitoring—Continued

W1G.4 • 09:00
A Highly-Integrated Optical Frequency Synthesizer Based on Phase-locked Loops, Minghui Lu1, Hyun-chul Park1, Eli Bloch1, Leif Johansson1, Mark Rodwell2, Larry A. Coldren1,2; 1Electrical and Computer Engineering, Univ. of California Santa Barbara, USA; 2Electrical Engineering, Technion - Israel Inst. of Technology, Israel; 3Materials, Univ. of California Santa Barbara, USA. The first highly-integrated optical synthesizer is realized by photonic integration and optical phase-locking technique. Preliminary results show >160 GHz output frequency range and a relative frequency accuracy as defined by the RF signal.

W1G.5 • 09:15
Cost-effective Optical Nyquist Pulse Generator with Ultra-flat Optical Spectrum Using Dual-parallel Mach-Zehnder Modulators, Xiang Liu1,2,3, Eli Bloch1, Yanfei Xing1, Caiyun Lou1,1, Bingkun Zhou1,1, Tsinghua Univ, China. Rectangular-shaped optical frequency comb generation with Nyquist temporal waveforms using dual-parallel Mach-Zehnder modulators is proposed. Nyquist pulse with 3.66% duty cycle and 25-tone frequency combs with flatness within 0.5 dB is generated.

W1H.5 Tutorial
Superchannel for Next-Generation Optical Networks, Xiang Liu1, S. Chandrasekhar1; 1Alcatel-Lucent Bell Labs, USA. We review recent advances in the generation, detection, transmission, and networking of Tb/s-class optical superchannels. Enabling technologies such as advanced digital signal processing, bandwidth-flexible optical network elements, and large-scale photonic and electronic integration are discussed.

W1I • Advanced Multiplexing—Continued

W1I.4 • 09:00 Invited
Integrated photonic coherent receiver, Milan L. Maksanovic1; 1Freedom Photonics, USA. Nyquist generation of arbitrary radio-frequency arbitrary waveforms is reviewed, with an emphasis on ultrabroadband signal generation. Recent progress towards increased time aperture and time-bandwidth product and applications to wireless transmission are discussed.

W1J Tutorial
Arbitrary Waveform Generation—Continued

W1J.4 • 09:00
Photonics-based Radio-Frequency Arbitary Waveform Generation, Andrew M. Weiner1,2; 1Purdue Univ., USA; 2Purdue University. Optical generation of arbitrary radio-frequency arbitrary waveforms is reviewed, with an emphasis on ultrabroadband signal generation. Recent progress towards increased time aperture and time-bandwidth product and applications to wireless transmission are discussed.

W1K • Network Control—Continued

W1K.4 • 09:00
Impact of IP Layer Routing Policy on Multi-Layer Design, Eleni Palkopoulou1,2, On Gerstel3, Ioannis Stiakogiannakis1,2, Thomas Telkamp1, Victor Lopez3, Ioannis Tomkos4; 1Cisco, Greece; 2Cisco, Israel; 3Foundation for Research and Technology, Greece; 4Telefonica I+D, Spain; 5Athens Information Technology Center, Greece; 6Cisco, Netherlands. We evaluate the impact of the IP layer routing policy (Hop-Based and Distance-Based) on the cost and latency of a multi-layer network design. We find that the optical network’s regeneration requirements affect the optimal policy.
W1A.7 • 09:30
On the Emulation of High Spectral Efficiency System in Laboratories Experiments, Gabriel Charlet1, Patrice Brindel1, Rafael Ros-Müller1; 1Alcatel-Lucent Bell Labs, France. The impact of channel multiplexing on system performance is investigated in case of high spectral efficiency systems emulation. Implications of band edge filtering, guard bands and passive coupler loss are studied.

W1C.6 • 09:30
Enhancement of Fiber Frequency Utilization by Employing Grouped Optical Path Routing, Yuki Terada1, Yojiro Mori1, Hiroshi Hasegawa1, Ken-ichi Sato1; 1Department of Electrical Engineering and Computer Science, Nagoya Univ., Japan. Optical path grouped routing not only simplifies the node’s architecture, but also mitigates the signal degradation due to optical filtering at each node. It can improve frequency utilization of fibers or mitigate WSS requirements.

W1D.5 • 09:30
Beneficial OLT Transmitter and Receiver Concepts for NG-PON2 Using Semiconductor Optical Amplifiers, Rene Bonk1, Harald Schmuck1, Wolfgang Poehlmann1, Thomas Pfeiffer1; Bell Labs Germany, Alcatel-Lucent Germany, Germany. OLT transmitter and receiver concepts using SOA for NG-PON2 are experimentally compared. A single SOA per wavelength channel at the Tx and a configuration comprising linear SOA followed by APDs at the Rx are beneficial.

W1E.6 • 09:30
Using SDN Technology to Enable Cost-effective Bandwidth-on-Demand for Cloud Services, Robert D. Doverspike1, George Clapp1, Pierre Doyou2, Douglas Freimuth3, Krishna Gullapalli3, Jeffrey Hartley2, Emmanuel Mavragiorgis1, James O’Connor4, Jorge Pastor1, K. Ramakrishnan1, Michael Rauch1, Mark Stallner5, Ann C. Von Lehmen4, Brian Wilson1, Sheryl L. Woodward1; 1AT&T Labs, USA; 2Brocade, USA; 3Ciena, USA; 4Applied Communication Sciences, USA; 5IBM TJ Watson Research Center, USA. We describe bandwidth-on-demand in an evolved multi-layer, SDN-based Cloud Services model. We also show an initial proof-of-concept demonstration of this capability.

W1F.7 • 09:30
The Role of Optical Interconnections in Future Data Centers of Large Enterprises, Brad Spiers1; 1Bank of America, USA. Abstract not available
W1G.6 • 09:30
Accurate Bit Error Ratio Monitor by Spectral Filtering and Optical Power Measurements, Shoichiro Oda1, Tomohiro Yamauchi1, Jeng-Yuan Yang2, Yoichi Akasaka3, Olga Vassilev4a, Yasuhiko Aoki1, Mototoshi Sekiya1, Jens Rasmussen5, 1Fujitsu Laboratories Ltd., Japan; 2Fujitsu Laboratories of America, Inc, USA. We propose a novel bit error ratio monitoring method by optical bandpass filter and optical power measurements and experimentally demonstrate its sufficient accuracy with various fiber launched powers and wavelengths in WDM dispersion-uncompensated transmission link.

W1G.7 • 09:45
Robust Autonomous Software-Defined Coherent Optical Receiver, Pierre Issautier1, Jie Pan1, Stephen Ralph1, 1ECE, Georgia Inst. of Technology, USA. A new robust Stokes space based modulation format recognition scheme using advanced statistical methods is demonstrated for autonomous software-defined coherent optical receiver applications. Experimental 1056km transmission signals are successfully identified among OOK/BPSK/QPSK/16-QAM and decoded with minimum BER at 16 or 32 Gbaud.

W1H • Advanced Multiplexing—Continued

W1I • Advanced Signal Generation & Monitoring—Continued

W1J • Network Control—Continued

W1K • Coherent Integrated Transceiver Technologies—Continued

W1L • Signal Generation—Continued

Papers are available online for download. Visit www.ofcconference.org and click on the Download Digest Papers button.
We propose a 100 Gbit/s real-time digital coherent transmission over a 32-km GI-MMF with a 62.5 μm core diameter. The DSP enables the optical channel to be switched from SMF to G.652 within 70 ms.

W2A.1
100 Gbit/s DP-QPSK Transmission over a 32 km Legacy Multi-Mode Fiber Using a Real-Time Digital Coherent Transceiver, Yoshikazu Hirooka1, Masatake Nakazawa1, Tetsuro Komukai2, Toshikazu Sakano2; 1Research Inst. of Electrical Communication, Tohoku Univ., Japan; 2NTT Network Innovation Laboratories, Japan. We demonstrate a 100 Gbit/s real-time digital coherent transmission over a 32-km GI-MMF with a 62.5 μm core diameter. The DSP enables the optical channel to be switched from SMF to G.652 within 70 ms.

W2A.2
10-Gb/s, 20-km VCSEL Optical Access Link at 1.3 μm with 23-dB Power Budget, Jingjing Zhou1, Changyuan Yu1, Hoon Kim1, 1National Univ. of Singapore, Singapore. We demonstrate 23-dB power budget of a 20-km unamplified optical access system using a 1.3-μm, 10-Gb/s VCSEL. It is enabled by using continuous-phase frequency-shift keying/amplitude-shift keying format, DC-balanced line coding, and avalanche photo-detector.

W2A.3
20 Gb/s Mode-Group-Division Multiplexing employing Hermite-Gaussian Launches over Worst-Case Multimode Fiber Links, Yunni Li1, Jennifer D. Ingham1, Shibunji Amaya1, Wouter Tavernier2, Didier Grot2, 1Ericsson Research Silicon Valley, USA; 2France Telecom, France. We propose and experimentally demonstrate a full-duplex bi-directional transmission optical wireless-over-fiber integration system at W-band with the speed up to 15 Gb/s for both 95.4 GHz link and 88.6 GHz link for the first time.

W2A.4
A 30 Gb/s full-duplex bi-directional transmission optical wireless-over-fiber integration system at W-band, Chuanjuan Tang1, Fan Li1, Junwen Zhang2, Xinying Li1, Jiangnan Xiao1, 1Fudan Univ., China; 2ZTE Corporation, USA. We propose and experimentally demonstrate a full-duplex bi-directional transmission optical wireless-over-fiber integration system at W-band with the speed up to 15 Gb/s for both 95.4 GHz link and 88.6 GHz link for the first time.

W2A.5
A Data-Aided Amplitude and Phase Equalizer for Direct-Detection Optical OFDM, Chenxi Hao1, Xuelin Yang1, Wenzhen Hu1, Chenglin Bai1, 1State Key Lab of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong Univ., China; 2Shandong Key Laboratory of Optical Communication Science and Technology, Liao Cheng Univ., China. A data-aided equalizer is proposed and demonstrated to compensate for the amplitude and phase fluctuations in direct-detection optical OFDM. Significant improvement in error vector magnitude is achieved, using time-domain averaging on amplitude and phase independently.

W2A.6
A Software-Defined Time Synchronization Solution in Transport Networks, Liuyan Han1, Han Li1, Lei Wang1, Nan Hua1, 1China Mobile Research Inst., China; 2Department of Electronic Engineering, Tsinghua Univ., China. We propose the first software-defined time synchronization network solution by introducing programmable synchronization state transition matrix and output matrix. Experimental results show that it could effectively meet the multi-time-domain requirements and enhance flexibility.

W2A.7
All-Optical Tree-based Greedy Router, sahel sahaf1, Abhishek Dixit, Wouter Tavernier2, Didier Grot2, 1Ericsson Research Silicon Valley, USA; 2France Telecom, France. We propose an approach to differentially encoded 100G systems, demonstrating a computational-efficient CapEx model capturing key cost factors to analyze packet- and DWDM-based metro networks. Study on a real network using market cost figures supports evolution towards DWDM under fast traffic growth.

W2A.8
Analysis of extended range variable gain hybrid Raman-EDFAs in systems using Nyquist-WDM 100/200G PM-QPSK/16QAM, Wladek Forysiak1,3, Nobuo Kuwaki1, Yuichi Nakaya2, Gabriella Cincotti4, Ken-ichi Kitayama1, 1Department of Electrical, Electronics and Information Engineering, Osaka Univ., Japan; 2Optics and Electronics Laboratory, Fujikura Ltd., Japan; 3National Inst. of Information and Communications Technology (NICT), Japan; 4Department of Applied Electronics, Univ. Roma Tre, Italy. A 30 Gb/s full-duplex bi-directional transmission optical wireless-over-fiber integration system at W-band with the speed up to 15 Gb/s for both 95.4 GHz link and 88.6 GHz link for the first time.

W2A.9
Asynchronous MDM-OCMD-based 10G-PON over 40km-SMF and 2km-TMF Using Mode MUX/DeMUX at Remote Node and OLT, Takahiro Kodama1, Tomoko Isoda1, Kaji Morita1, Akhiro Maruta1, Ryo Maruyama1, Nobuo Kuwaki2, Shoichiro Matsuo2, Naoya Wada3, Gabriella Cincotti4, Ken-ichi Kitayama1, 1Department of Electrical, Electronics and Information Engineering, Osaka Univ., Japan; 2Optics and Electronics Laboratory, Fujikura Ltd., Japan; 3National Inst. of Information and Communications Technology (NICT), Japan; 4Department of Applied Electronics, Univ. Roma Tre, Italy. A 30 Gb/s full-duplex bi-directional transmission optical wireless-over-fiber integration system at W-band with the speed up to 15 Gb/s for both 95.4 GHz link and 88.6 GHz link for the first time.

W2A.10
Broadband Predistortion Circuit Design for Electro-Absorption Modulator in Radio over Fiber System, Xupu Zhang1, Ran Zhu2, 1Electrical and Computer Engineering, Concordia Univ., Canada. A broadband predistortion circuit is designed to remove 3rd order inter-modulation distortion of electro-absorption modulator in radio-over-fiber system, resulting in spurless free dynamic range improvement of ~9 dB from 7 to 14 GHz.

W2A.11
Calculating Availability Bounds in Complex Systems and IP Network Topologies, Jonathan Weston-Dawkes1, 1The MITRE Corporation, USA. A bounding algorithm, including resource consolidation, for high-precision estimation of connection availability is derived. Resource mincuts in a sample core IP network are generated to estimate the connection availability under different diversity assumptions.

W2A.12
CapEx Model and Analysis for Metro Networks: DWDM vs. Packet, Ming Xia1, Stefan Dahlholt2, Lynn Luo1, Guangquan Wang1, Shikui Shen1, 1Ericsson Research Silicon Valley, USA; 2Ericsson Region North East Asia, China; 3China Unicorn Design Inst., China. We propose a computational-efficient CapEx model capturing key cost factors to analyze packet- and DWDM-based metro networks. Study on a real network using market cost figures supports evolution towards DWDM under fast traffic growth.

W2A.13
Channelized Chromatic Dispersion Compensation for XPM Suppression and Simplified Digital OSM Compensation, Liang B. Du1, Arthur J. Lowery1, 1Manash Univ., Australia. Channelized dispersion compensation strongly suppresses inter-channel non-linearities. We show that it also supports folded digital backpropagation, which can compensate for the intra-channel nonlinearity at a computational cost of only 1.8 times that of CD compensation alone.

W2A.14
Coherent Optical Transmission at 40 and 100 Gbps over 1000 km of DCF-free G.652 and G.655 Fibre Infrastructure, Erwan Pincemin1, Omid Zia-Chahabi2, Didier Grot2, Thierry Guillouloss2, 1France Telecom, France. We experimentally compare the performances of 40 Gbps DP-QPSK, 40 Gbps DP-QPSK and 100 Gbps DP-QPSK modulation formats over 10x100 km of DCF-free trans-mission lines using either G.652 or G.655 fibres.

W2A.15
Constellation Expansion and Multi-Symbol Detection for Differentially Encoded 100G Systems, Paolo Leonardi1, Vincent A. Sleiffer2, Stefano Calabro1, Berthold Lankl1, 1University of the Bundeswehr Muenchen, Germany; 2COBRA Inst., Eindhoven Univ. of Technology, Netherlands; 3Coriant R&D GmbH, Germany. We propose an approach to differentially encoded 100G transmission that improves both spectral efficiency and OSNR performance over conventional DQPSK-based systems, demonstrating a practical performance beyond the theoretical limit of the conventional approach.

W2A.16
Cost Tradeoffs in Converged Metro Networks Designs, Enrique Hernandez-Vilacencio1, 1Alicatel-Lucent, USA. The cost structure of converged packet-oriented metro aggregation networks is evaluated. Hierarchical Layer-2/Layer-3 architectures are shown to have better CAPEX structure than hierarchical Layer-2 architectures. Layer-3 CAPEX and traffic volumes may justly other point solutions.

W2A.17
Cost-Efficient Design of Flexible Optical Networks Implemented by Architecture on Demand, Aymal Munir Ahmad1, Georgios S. Zervas1, Norberto Amaya1, Dimitra E. Simeonidou1, 1Linköpings Universitet, Sweden; 2High-Performance Networks Group, Bristol Univ., UK. Architecture on demand (AoD) node offers considerable flexibility against traditional ROADMs. The paper presents a cost-efficient network planning strategy that exploits the flexibility inherent in AoD. Results show that AoD can save significantly in node modules through a proper network design.
W2A.18 Delayed Self-homodyne Detection for OFDM-PON Downstream, Qi Yang1, Rong Hu1, Tao Gu2, Zhaohui Li1, Xi Chen2, William Shieh3, Hao Bi4, Chao Li1, Cai Li1, Xiao Xiao1, Shaohua Yu1, State Key Laboratory of Optical Comm, China; Inst. of Electron. and Inf. Techn., China; 2Dep. of Electrical and Electronic Engineering, The Univ. of Melbourne, Australia. We propose a novel OFDM-PON using the delayed self-homodyne detection technique. A cost/spectrum efficient 10.94 Gbps downstream transmission is experimentally demonstrated over 20-km SSF and 1:64 splitter without any optical amplifiers on ONUs.

W2A.19 Demonstration and Network Scalability Analysis of 8-Fiber-Delay-Line SOA-Based Optical Buffer Embedded Optical Packet Switching, Hideaki Furukawa1, Satoshi Shinada1, Takayo Miyazawa1, Naoya Wada1, Hironori Hara1, Naohiro Aono1, State Key Laboratory of Optical Fibre and Cable Manufacture Technology, Yangtze Optical Fibre and Cable Co., Ltd., China; 2National Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We demonstrate a 1.2 Tbps real-time transmission over 4 types of fiber with 120G PDM-QPSK Nyquist WDM prototype systems. Performance of different fiber is compared and 3200km transmission is achieved without Raman amplification.

W2A.20 Demonstration of OpenFlow-Enabled Traffic and Network Adaptive Transport SDN, Philip N. Ji1, Tiejun Qian2, Ming-Fang Huang1, Yoshihiko Aono1, Tsutomu Tajima1, Glenn A. Wellbrock1, Ting Wang1, NEC Laboratories America Inc, USA; Verizon, USA; Converged Network Division, NEC Corporation, Japan. We experimentally demonstrate the first OpenFlow-enabled transport SDN that performs multi-flow switching by cross-layer optimization and configuring all major hardware elements, including adaptive EDFA-Raman amplifier, multi-degree superchannel transponder, and flexible grid switching node.

W2A.21 Demonstration of Real-time 1.2 Tbps Transmission over 4 Types of Fiber with Nyquist WDM Prototype System, Chengliang Zhang1, Yufei Chen1, Runran Wang1, Xue Chen1, Junjie Li1, Yuan Ma1, Qi Zhang2, Hongyan Zou2, Zheng yan3, Bailin Shen1, Qinmin Zhou1, Dongdong Shang1, Chao Ge2, Beijing Research Inst., China Telecom Corporation Limited, China; 2ZTE Corporation, China; 3State Key Laboratory of Optical Fiber and Cable Manufacture Technology, Yangtze Optical Fibre and Cable Co., Ltd., China. We demonstrate a 1.2 Tbps real-time transmission over 4 types of optical fiber with 120G PDM-QPSK Nyquist WDM prototype systems. Performance of different fiber is compared and 3200km transmission is achieved without Raman amplification.

W2A.22 Development of LC Type Optical Visual Connection Identifier (V.C.I) For Multimode Fiber, Kanako Suzuki1, Yoshinori Nakatani1, Seiji Kojima1, Takahiro Sato1, Tetsuya Sueoka1, Takao Nishikawa2, Hitachi Metals Ltd., Japan; 2NTT communications Corp, Japan. We developed the dual LC type optical visual connection identifier for multimode fibers to be able to confirm the on/off status of a certain line for decreasing the risk of disconnecting important live lines.

W2A.23 Digital Back-Propagation for High Spectral-Efficiency Terabit/s Superchannels, Gabriele Liga1, UC, UK. We assess the effectiveness of digital backpropagation algorithm for a 1.2 Tbps high spectral efficiency superchannel when the input digital bandwidth is varied around the channel center. It is shown that the single channel case gives the best performance.

W2A.24 Digital Orthogonal Filtered Optical OFDM for FTTH PONs, Jianming Tang1, Mario Boles1, Roger Giddings2, Bangor Univ., UK. To perform self-protected, bandwidth-variable and analogue-hardware-free channel add/drop networking functions, optical OFDM employing DSP-based orthogonal filters is proposed, optimized and evaluated for the first time, which overcomes all fundamental limitations associated with conventional CAP modulation.

W2A.25 Downstream and Upstream Nyquist Band Optimization for Heterodyne Coherent PON, Jacklyn D. Reis1, Ali Shahpari1, Ricardo M. Ferreira1, Darlene M. Neves1, Mario Lima1, Antonio L. Teixeira1, Department of Electronics, Telecommunications and Informatics, Univ. of Aveiro, Institute of Information and Communications Technology, Japan. We demonstrate a 1.2 Tbps real-time transmission over 4 types of fiber with Nyquist bands in coherent PON with self-heterodyne detection. Both power and frequency offset coefficients are found for symmetric Nyquist shaped 10 Gbps per user.

W2A.26 Dual-Wavelength Clock Recovery with Simultaneous Fourfold Demultiplexing Using an Opto-electronic Oscillator, Qiang Wang1, Li Huo1, Yanfei Xing1, Dong Wang1, Xin Chen1, Caizun Lou1, Bingkun Zhou1, Qiang-hua Univ, China. Dual-wavelength Gaussian-like clock recovery with simultaneous error-free fourfold demultiplexing of a 100-Gbps OTDM-DPSK signal are demonstrated with an improved opto-electronic oscillator. Frequency-doubled clock recovery is also achieved.

W2A.27 Energy and Spectrum Efficiency with Multi-Flow Transponders and Elastic Regenerators in Survivable Flexible Bandwidth Virtual Optical Networks, Bowen Chen1, Weisheng Xie1, Jie Zhang1, Jason P. Jue1, Yongli Zhao1, Shangqiu Huang1, Wanli Gu1, State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts & Telecom, China; 2Erik Jonsson School of Engineering and Computer Science, The Univ. of Texas at Dallas, USA. Survivable energy-aware and spectrum-aware approaches (SEA/SSA) are developed to minimize energy and spectrum consumption in flexible bandwidth virtual optical networks. Simulation results show that SEA and SSA can efficiently reduce energy and spectrum consumption, respectively.

W2A.28 Experimental Demonstration of a Cognitive Optical Network for Protection of Restoration Time, Christoforos Kachris1, Dimitris Klonis2, Antonio Francescon2, Domenico Siracusa2, Elia Salvador2, Ramón D. Durán Baz2, Santiago de Madrid1, Robert Borkowski1, Antonio Caballero1, Idelfonso Tafur1, Yabin Ye1, Andrez Tymeczko1, Ioannis Tomkos4, Athens Information Technology, Greece; 1CREATE-NT, Italy; 2Univ. of Valladolid, Spain; 3Technical Univ. of Denmark, Denmark; 4Orange Polska, Poland. This work presents the implementation and performance evaluation of a cognitive heterogeneous optical network testbed. The testbed integrates the CMP, the data plane and the cognitive system and reduces by 48% the link restoration time.

W2A.29 Experimental Demonstration of Reconfigurable Long-Reach Software-Defined Dual-Mode Networks, Thomas Shun Rong Shen1, Shuang Yin2, Ahmad R. Dhaimi3, Leonid G. Kazovsky3, Stanford Univ, USA. We propose and experimentally demonstrate a novel reconfigurable long-reach software-defined UltraFlow access network that provides flexible, robust and energy efficient optical Flow switched and legacy IP services to end-users in wide areas.

W2A.30 Experimental Demonstration of Robustness and Accuracy of an MZI-based OSNR Monitor under Transmitter Drift and Reconfigurable Networking Conditions for Pol-Muxed 25 Gbaud QPSK and 16-QAM Channels, heard alnaiman1, Mohammad Reza Chitgarha2, Wahy Daab1, Morteza Zayadi1, Amirhossein Mohajerin Ariaei1, Salman Khaledi1, Moshe Willner1, Vijay Yurusurilak1, Wendy Zhao1, Dan Kilper1, Loukas Parasha1, Atiyah Alsh1, Michael Wang2, Keren Bergman1, Moshe Tur1, Joe Touch1, Alan Willner1, Ming Hsieh Department of Electrical Engineering, Univ. of Southern California, USA; 2Google Inc., USA; 3College of Optical Sciences, Univ. of Arizona, USA; 4Cisco Systems, Inc., USA; 5De-
**W2A.31** Exploiting Degraded-Service Tolerance to Improve Performance of Telecom Networks, S. Sedef Savaş 1, M. Farhan Habib 1, Massimo Tornatore 1, Biswanath Mukherjee 1, 2,1 Department of Computer Science, Univ. of California, Davis, USA, 1 Dipartimento di Elettronica Informazione e Bioingegneria, Politecnico di Milano, Italy. Degraded-service-tolerant connections can operate over a reduced bandwidth under failure conditions. We propose a provisioning scheme that accepts degraded services not only during failures but also during admission process to increase service acceptance and/or availability.

**W2A.32** FEC Overhead and Fiber-Nonlinearity Mitigation: Performance and Power Consumption Tradeoffs, Daniush Rafique 1, Taha Rahman 1, Antonio Napoli 1, Bernhard Spinnler 1, Stefano Calabro 1, 2,1 Research and Technology, Coriant GmbH, Germany. Increasing the FEC overhead overestimates substantial power-consumption requirements, alternatively, super-channel nonlinear mitigation ensures 30% reduction in power consumption, for a fixed distance at a lower overhead, and up to 35% improved reach, at a fixed FEC overhead.

**W2A.33** Fiber-Nonlinearity Limitation of Transmission Distances in Ultra-Dense Gridless Photonic Networks, Yojiro Mori 1, Hiroshi Hasegawa 1, 2,1 Department of Electrical Engineering and Computer Science, Nagoya Univ., Japan. We investigate the maximum transmission distance of the multilevel-modulation formats for ultra-dense gridless photonic networks based on distance-adaptive modulation. Simulation results show the relationships among the transmission distance, the guard band, and the optical-filter design.

**W2A.34** First demonstration of a wavelength-swept discovery process for λ-tunable WDM/TDM-PON system, Masahiro Sarashina 1, Hideaki Tami 1, Satoshi Furusito 1, Akuya Suzuki 1, Masayuki Kashima 1, Yoshiaki Mukojima 1, Shin Kaneko 1, Tomaaki Yoshida 1, Shunji Kumasra 1, Naota Yoshimoto 1, 2,1 Oki Electric Industry Co., Ltd., Japan, 2 NTT Access Network Service Systems Laboratories, NTT Corporation, Japan. We propose a wavelength-swept discovery process for λ-tunable WDM/TDM-PON system. Our discovery process is successfully demonstrated on the λ-tunable WDM/TDM-PON prototype. We also confirmed that the ONU can receive the discovery message at any wavelength.

**W2A.35** Global ROADM-Based Spectrum Equalizer in SDN Architecture for QoS Optimization at DWDM Networks, Eduardo C. Magalhães 1, 2,1, Juliano Oliveira 1, 2,1, Heitor Carvalho 1, 2,1, Matheus Magalhães 1, 2,1, Miguel Garrich Albarace 1, 2,1, Marcos Siqueira 1, 2,1, Aldário Bordondini 1, 2,1, Julio Oliveira 1, 2,1, 1 Sao Paulo - Optical Communication Division, 2 ECE, UNM, USA. We propose a practical modified continuous-variable quantum key distribution system to improve the secret key rate over long transmission distance by inserting a practical noiseless optical amplifier at the output of quantum channel.

**W2A.36** High degree optical cross-connect based on multicast switch, Thierry Zami 1, 2,1 Alcatel-Lucent, France. 8×16 multicast switches enable contentionless WDM Optical Cross-Connect (OXC) as long as the node connectivity is smaller than 8. This study examines to what extent they can also suit 2D-degree OXC featuring low intra-node contention.

**W2A.37** High Linearity Downconverting Analog Photonic Link Based on Digital Signal Post-Compensation, Niu Zhongjie 1, Hongdeye Yang 1, Ming Zhu 1, Jing Wang 1, 2,1 Giga-Kung Chang 1, 2,1 Geonomics Inst. of Technology, USA. We propose and experimentally demonstrate a prototype of local centralized optical coordinated multipoint (CoMP) that targets beamforming applications in future-proof millimeter wave small cells based on radio-over-fiber fronthauls.

**W2A.38** Improvement of Continuous-variable Quantum Key Distribution System by Using a Practical Noiseless Amplifier, Yi-Chen Liang 1, Song Yu 1, Wenji Gu 1, 1 Beijing Univ. of Posts and Telecommunications, China. We propose a practical modified continuous-variable quantum key distribution system to improve the secret key rate over long transmission distance by inserting a practical noiseless optical amplifier at the output of quantum channel.

**W2A.39** Improving the Robustness to Timing Errors with Windowing Technique for 40GHz 64-QAM OFDM-RoF System, Fan Li 1, 2,1, Junwen Zhang 1, 2,1, Song Yu 1, 2,1, Junwen Zhang 1, 2,1, Song Yu 1, 2,1, 1 Beijing Univ. of Posts and Telecommunications, China; 2 Beijing Univ. of Posts and Telecommunications, China. The pilot tone enables direct detection, at -20dBm. Tests have been carried out on an operating LTE fronthaul link introduced. Tests have been carried out on an operating LTE fronthaul link. Tests have been carried out on an operating LTE fronthaul link.

**W2A.40** Investigation on Burst-mode Inter-channel Crosstalk in XG-PON and TWDM-PON, Han Hyub Lee 1, Hee Yeol Ryu 1, Gwang Yong Yi 1, Jong Hyun Lee 1, Sang Soo Lee 1, 1 Electronics and Telecommunications Research Inst., Republic of Korea, 1 Ericsson-LE, Republic of Korea. Inter-channel crosstalk of burst-mode upstream in XG-PON and TWDM-PON are investigated. Differential optical pulse loss and ASE noise from 256 ONUs contribute to increasing power penalty. ASE noise filtering mitigates the impairment and ensures negligible penalty.

**W2A.41** Jitter impact on mobile fronthaul links, Thierno Diallo 1, Anna Pizzinat 1, Philippe Champiou 1, Fabienne Salion 1, Fabrice Detele 1, Christelle Aupetit-Berthelomart 1, Orange Labs Networks, France; 1 Laboratory XLIM, France. An innovative setup for thorough jitter characterization in fronthaul links is introduced. Tests have been carried out on an operational LTE fronthaul link measuring jitter impact on BER, EVM and frequency deviation.

**W2A.42** Long Reach UDWM PON with SCM-QPSK Modulation and Direct Detection, Prince M. Anandarajah 1, 2,1, Rui Zhou 1, 2,1, Vidyak Jyotsna 1, 2,1, Gutierrez Pascual 1, 2,1, Eamonn Martin 1, 2,1, LEO, Dublin City Univ., Ireland; 1 Pilot Photonics, Ireland. We demonstrate a 100km un-repeated downstream transmission based on a 12.5GHz wavelength tunable comb source with 1.25Gbs SSB-SCM-QPSK data. The pilot tone enables direct detection and phase noise independence with error free performance at -20dbm.

**W2A.43** Optical CoMP Transmission in Millimeter-Wave Small Cells for Mobile Fronthaul, Lin Cheng 1, Cheng Liu 1, Ming Zhu 1, Jing Wang 1, 2,1 Giga-Kung Chang 1, 2,1 Geonomics Inst. of Technology, USA. We propose and experimentally demonstrate a prototype of local centralized optical coordinated multipoint (CoMP) that targets beamforming applications in future-proof millimeter wave small cells based on radio-over-fiber fronthauls.

**W2A.44** Optical FlowBroker: Load-Balancing in Software-Defined Multi-Domain Optical Networks, Dan Marconetti 1, Lei Liu 1, S.J.Ben Yoo 1, UC Davis, USA. We present a new Openflow control architecture, referred to as Optical FlowBroker, for multi-domain software-defined optical networks. The hierarchical brokers improve scalability and inter-domain global coordination, while allowing domain controllers to manage intra-domain forwarding decisions.

**W2A.45** Optical Multiplexing of Asynchronous OOK and DPSK Signals in PPLN Waveguide, Antonio Malacarne 1, Sergio Pinna 1, Antonella Bogon 1, National Laboratory of Photonic Networks, CNIT, Italy; 1 Technische Universitaet Darmstadt, Germany. A scheme for aggregating asynchronous OOK and DPSK optical data flows by generating an 8-APSK signal at the original DPSK signal wavelength, is demonstrated. The scheme is based on second-order nonlinear interaction in PPLN waveguide.

**W2A.46** Optimization Design for Multi-Domain Optical Network Protection, Kaile Liang 1, Hao Bai 1, Mahshid Rahnamay-Naemi 1, Fang Xu 1, Marwan Batayneh 1, Majeed Hayat 1, Nasir Ghani 1, ECE, UNM, USA; 2 Home, USA; 3 Cisco Systems, USA; 4 Viasat, USA. This paper develops a novel hierarchical optimization model for lightpath protection in multi-domain optical networks. The proposed formulation is then solved and its results compared with some advanced distributed heuristic protection strategies.

**W2A.47** Optimized Design of Fixed/Flex-Rate Line-Cards and Transceivers over Multiple Planning Cycles, Antonio Eira 1, 2,1, João Pedro 1, 2,1, João Pires 1, 2,1, Coriant Portugal, Portugal; 1 Instituto de Telecomunicacões, Portugal. We present a comparison between line-card and transceiver designs based on single and multi-rate technology over multiple planning cycles. The results suggest multi-rate hardware is most suited to networks without significant regeneration requirements.

**W2A.48** Performance Analysis of GA, ROA, and TSA for Solving the Max-RWA Problem in Optical Networks, Eamonn Martin 1, 2,1, 1 School of Information Science and Engineering, University of Electro-Communications, Japan; 1 National Laboratory of Photonic Networks, CNIT, Italy; 1 Technische Universitaet Darmstadt, Germany. A scheme for aggregating asynchronous OOK and DPSK optical data flows by generating an 8-APSK signal at the original DPSK signal wavelength, is demonstrated. The scheme is based on second-order nonlinear interaction in PPLN waveguide.
Room 102
13:00–15:00 W3A • Flex
Presider: Darli Mello; Universidade de Brasilia, Brazil

Room 120
13:00–15:00 W3B • Novel Network Elements
Presider: Chris Fludger; Cisco Optical GmbH, Germany

Room 121
13:00–15:00 W3C • Panel: How Can Residential Broadband Networks Support the Small Cell Backhaul of the Future?
Presider: Alexey Turukhin; TE Subcom, USA

Room 122
13:00–15:00 W3D • Fiber Measurements and Characterization
Presider: Lutz Rapp; Coriant, Germany

Room 123
13:00–14:30 W3E • Fiber Ampliers: Design and Characterization
Presider: Marco Presi; Scuola Superiore di Studi Universitari di Perfezionamento Sant’ Anna di Pisa, Italy

Room 124
13:00–15:00 W3F • Signal Processing I (Regeneration)
Presider: Alexey Turukhin; TE Subcom, USA

W3A.1 • 13:00 Invited Complexity and Flexible Grid Networks, Massimo Tomatore1, Cristina Rotondi1, Annalisa Morea1, Giuseppe Rizzelli2, ‘Department of Electronics, Information and Bioengineering, Politecnico di Milano, Italy; 1Alcatel-Lucent Bell Labs, France; 2Network Rail Telecom, UK. For the optimization of routing and spectrum allocation in a FlexiGrid Networks, we explore the tradeoff between network cost and problem complexity according to the following aspects: traffic grooming, regeneration, modulation/baud-rate assignment.

W3B.2 • 13:15 Performance Comparison of Different 8QAM Constellations for the Use in Flexible Optical Networks, Markus Noelle1, Felix Frey1, Robert Etschner1, Carsten Schmidt-Langhorst1, Antonio Napoli1, Colja Schubert1; Photonic Networks and Systems, FhG-HHI, Germany; 1Coriant R&D GmbH, Germany. We investigate the influence of DAC resolution and pulse shaping on the system performance of different 8QAM constellations. Furthermore, we experimentally show that a circular constellation outperforms the commonly used 8QAM constellation by 0.7 dB in terms of OSNR sensitivity at a BER of 3.8*10^-3.

W3C.1 • 13:00 Invited Crosstalk Analysis of FSK Light Label on 112 Gbps DP-QPSK Signal in CNCG ROADM Network, Goji Nakagawa1, Shoichiro Oda1, Kyosuke Sone1, Yasuhiro Aoki1, Kazuo Hiroishi1, Takaahito Tanimura1, Takeshi Hoshida1, Jens Rasmussen2; 1Fujitsu Laboratories Limited, Japan; 2Fujitsu Limited, Japan. We investigated crosstalk of FSK supervisory channel superimposed on a 112 Gbps DP-QPSK caused by pass-band narrowing effect in CNCG ROADM network. We estimated maximum number of ROADM nodes and frequency mis-alignment tolerance between main signal and center frequency of WSS pass-band that the FSK light label technique could support.

W3D.1 • 13:00 Invited New OTDR Measurement and Monitoring Techniques, Andre CHAMPA1,2, ‘Department of Photonics Engineering, Technical Univ. of Denmark, Denmark. We present the theory of Raman amplification in multimode and multicore fibers, Cristian Antonelli1, Antonio Mecozzi1, Mark Shtaif1; 1Universita degli Studi dell’Aquila, Italy; 2Tel Aviv Univ., Israel. We present the theory of Raman amplification in multi-mode fiber structures in the framework of space-division multiplexed transmission. Random linear coupling between the various fiber modes plays a critical role in the process of amplification by equalizing the Raman gain within quasi-degenerate mode groups.

W3E.1 • 13:00 Invited Modeling Raman amplification of multimode and multicore fibers, Carsten Schmidt-Langhorst1, Antonio Mecozzi1, Mark Shtaif1, ‘ Universita degli Studi dell’Aquila, Italy; 2Tel Aviv Univ., Israel. We report a novel all-optical clock recovery technique for a BPSK OFDM superchannel. Four-wave mixing in SOAs strips the modulation from the superchannel sub-carriers, two of which beat in a photodiode to recover the clock.

W3F.1 • 13:00 Clock Recovery of Phase Modulated Optical OFDM Superchannel, Mark Power1,2, Wei Jia1,2, Roderick P. Webb2, Robert J. Manning1,3, Fatima C. Garcia Gunning1,3; 1Photonic Systems Group, Tyndall National Inst., UCC, Ireland; 2Department of Electrical and Electronic Engineering, Univ. College Cork, Ireland; 3Department of Physics, Univ. College Cork, Ireland. We report a novel all-optical clock recovery technique for a BPSK OFDM superchannel. Four-wave mixing in SOAs strips the modulation from the superchannel sub-carriers, two of which beat in a photodiode to recover the clock.

W3F.2 • 13:15 Ultrafast All-Optical Clock Recovery Based on Phase-Only Linear Optical Filtering, Reza Marandi1, Deming Kong2, Michael Galli1, Leif Katsuo Oxenløwe1, José Azaña1; 1INRS-Energie Materiaux et Telecom, Canada; 2Department of Photonics Engineering, Technical Univ. of Denmark, Denmark. We report on a novel technique for all-optical clock recovery from RZ OOK data based on phase-only filtering, significantly enhancing the recovered clock quality and energy-efficiency compared to the use of a Fabry-Perot filter.

TURN CELL PHONES OFF
W3G.1 • 13:00
First Demonstration of a Full C-Band WDM-PON System with Novel High-Temperature DS-DBR Lasers, Stephan Pachnicke1, Jiannan Zhu1, Mirko Lawin2, Adrian Wonfor2, Richard V. Penty2, Rosie Cush1, Richard Turner1, Paul Firth1, Mike Wale1, Ian White1, Jörg P. Elbers3; ADVA Optical Networking AG, Germany; 2Centre for Photonic Systems, Univ. of Cambridge, UK; 3ADVA Optical Networking SE, Germany.

We demonstrate automatic operation of a cooler-less tunable-laser based WDM-PON system. Using a pilot-tone based overhead channel and centralized wavelength locking scheme, 1 Gb/s and 10 Gb/s data transmission is demonstrated in a multi-user set-up.

W3J.1 • 13:00
Pilot-aided Log-likelihood Ratio for LDPC coded M-QAM CO-OFDM System, shengjiao cao1, Pooi-Yuen Kam1, Changyuan Yu1,2; 1Electrical and Computer Engineering, National Univ. of Singapore, Singapore; 2*STAR Inst. for Infocomm Research (I2R), Singapore. Pilot-aided log-likelihood ratio as well as its approximation are derived for LDPC coded M-QAM CO-OFDM system with consideration of laser phase noise. Our metric performs better than the conventional metric in 16QAM and 64QAM simulation.

Advances in C and L band Self-seeded WDM-PON Links using Injection-locked Fabry-Perot Lasers and Modulation Averaging, Tim Komjenovic1, Dubravko Babic1, Zvanimir Sipus1; 1Faculty of Electrical Engineering and Computing, Univ. of Zagreb, Croatia. Self-seeded colorless WDM-PON optical links employing modulation averaging are demonstrated using commercially available matched Fabry-Perot laser and receiver pairs in C and L bands over 60 km at 1.25 Gbaud line rate.

W3J.2 • 13:15
20x224Gbps (56Gbaud) PDM-QPSK Transmission in 50GHz grid over 3040km G.652 fiber and EDFA-only link. Using Soft Output Faster than Nyquist Technology, Liangchuan Li1, Yanhao Liu1, Ling Liu1, Deyuan Chang1, Zhiyu Xiao1, Yiya Wei1; 1Huawei Technologies Co., Ltd., China. We report 20x224Gbps PDM-QPSK in 50GHz grid over G.652 fiber and EDFA-only link. Using Soft Output Faster than Nyquist and 7% SDFEC, 4bit/s/Hz net spectral efficiency transmission over 3040km with 21dB span loss is achieved.

W3K.1 • 13:00
High-speed ASIC for Optical Communications, Jon Stanley1; Fujitsu Semiconductor Europe GmbH, UK. Delivering continuous high performance at lower power presents a challenge to system and ASIC developers alike. Efficient DSP design is essential but the underlying technology has a significant role to play in an optimized solution.

Room 131

13:00–15:00
W3I • Symposium on Advanced Electro-optic Packaging and Assembly Technologies I and Panel Discussion
Presider: Nicholas Iyadis; Univ. of Arizona, USA

13:00–14:45
W3J • Coded Modulation II
Presider: Milorad Cvijetic; Univ. of Arizona, USA

Room 132

13:00–15:00
W3K • DSP Hardware
Presider: Chris F judger; Cisco Optical GmbH, Germany

Room 133

13:00–15:00
W3L • Network Function Virtualization
Presider: Dave Culler; University of California, Berkeley, USA

12:30–15:00
SDN 2.0 is Here - What Have We Learned?, Expo Theater II Programming
For more details, see page 42
13:00–15:00
MarketWatch Panel III: Data Center Architecture and Content Delivery Strategies, Expo Theater I Programming
For more details, see page 38
14:00–15:00
OIF Networking & Operation Session, Expo Theater III Programming
For more details, see page 44

Dr Diego Lopez is responsible for Technology Exploration within the TPI/GCTO Unit in Telefonica I+D, Diego Lopez is responsible for Technology Exploration within the TPI/GCTO Unit in Telefonica I+D. Diego Lopez is responsible for Technology Exploration within the TPI/GCTO Unit in Telefonica I+D.
Dynamic Differential Delay Aware RMSA for Elastic Multi-path Provisioning in GMPLS Flexi-grid DWDM Networks, Raul Muñoz1, Ramon Casellas1, Ricardo Martinez1, Silvano Frigerio1, Alberto Lometti2,1 ‘Optical Networks and Systems, CTTIC, Spain; 2Alcatel Lucent Italia, Italy. We experimentally evaluate multi-path RMSA algorithms that minimize the differential delay and the required buffer capacity. A proof-of-concept of multi-path routing, provisioning and transmission with a GMPLS-controlled Flexi-grid DWDM setup using 5-BYVs is also presented.

Over 10-Tb/s/port Optical Packet Switching using Polarization-Multiplexed DWDM/16-QAM packets, Satoshi Shinada1, Jose D. Mendaro1, Naoya Wada1,1 National Inst. of Information and Communications Technology, Japan. We demonstrated a 10.24-Tb/s/port (20 Gbaud 16-QAM × 64) × 2-Polarizations) optical packet switching system using add and drop of multi-level modulated, wideband optical packets.

Spatio-Temporal Gain Dispersion Neutralization in a Flexible DWDM System, Shigehiro Takasaka1, Yuko Taniguchi1,2, Masanori Takahashi1,2, Hiroshi Matsumura1,2, Kohei Doi1, Ryuchi Sugizaki1,1 FITEL Photonics Lab., Furukawa Electric Co., Ltd., Japan; 2Department of Electrical Engineering, Tohoku Gakuen Univ., Japan. Fabricated dispersion stable HNLFs enable a quasi-phase-matched FOPA with only 2-stage configuration to have flat gain more than 22 dB with bandwidth of 50 nm. NF is less than 4.4 dB in C-band.

High-Dimensional Stokes-Space Analysis for Monitoring Fast Change of Mode Dispersion in Few-Mode Fibers, Qian Hu1, Xi Chen1, An Li1, William Sheil1, Department of Electrical and Electronic Engineering, The Univ. of Melbourne, Australia. We adopt high-dimensional Stokes-space analysis to measure the time evolution of the mode dispersion in few-mode fibers. One advantage of the method is that the laser phase noise is intrinsically cancelled.

Characterization of a Fiber-Optical Parametric Amplifier in a 5 x 28-Gb/s 16-QAM DWDM System, Isaac Sackey1,2, Robert Elschner1, Markus Nölle1, Thomas Richter1,2, Jiro Hiroichi1, Miyake Tadakuma1, Masanori Takahashi1, Masanori Takahashi1, Hiroshi Matsumura1, Kohei Doi1, Ryuchi Sugizaki1, FITEL Photonics Lab., Furukawa Electric Co., Ltd., Japan. We demonstrate counter-dithering of pumps between two cascaded FWM processes for highly-efficient format-independent wavelength conversion. Up to 1.28Tb/s FWM conversion efficiency is obtained over 32 nm. 86-Gbps DP-QPSK are converted with OSNR penalty below 0.3dB at 10^{-3} BER.
is currently focused on identifying and evaluating new opportunities in technologies applicable to network infrastructures, and the coordination of national and international collaboration activities. His current interests are related to network infrastructural services (with special emphasis on security and AAA), new network architectures, and network programmability and virtualization. Diego is actively participating in the ETSI ISG on Network Function Virtualization (acting as Technical Manager of the group), the ONF, and the IETF WGs connected to these activities.

A Nyquist signaling technology application to future optical access networks is discussed. Implementation issues regarding low symbol rates are characterized. The potential benefits of Nyquist in symmetric/bi-directional PON are presented by means of parameter optimization.

Advanced coded-modulation for ultra-high-speed optical transmission, Ivan B. Djordjevic1, Department of Electrical and Computer Engineering, Univ. of Arizona, USA. This tutorial represents an overview of advanced coded-modulation for optical communications. It describes the following ultra-high-speed optical transport enabling techniques: codes on graphs, adaptive coded-modulation, and turbo equalization.

Challenges with Pluggable Optical Modules for Coherent Optical Communication Systems, Thomas Duthel1, Peter Hermanns1, Timo Winkler von Mohrenfels1, James E. Whiteaway1, Theo Kupfer1, Cisco Optical GmbH, Germany. Coherent pluggable modules will separate the DSP chip from optics. Challenges of such architecture are exemplarily discussed for the transmitter side based on simulations. Measurements show state-of-the-art performance for a Nyquist 16QAM integrated InP transmitter.

Performance Analysis of Pre- and Post-compensation for Bandwidth-constrained Signal in High-Spectral-Efficiency Optical Coherent Systems, Zhensheng Jia1, Hung-Chang Chien1, Junwen Zhang1, Ze Dong1, Yi Cai1, 1Optics Lab, ZTE (TX), USA. We present and analyze several pre- and post-compensation algorithms for bandwidth-limited optical signal on mitigation towards inter-symbol-interference (ISI) or joint ISI and inter-channel-interference (ICI) impairments. Experimental results and support to higher-order format are also demonstrated.
W3A • Flex—Continued

W3B • Novel Network Elements—Continued

W3C • Panel: How Can residential Broadband Networks Support the Small Cell Backhaul of the Future?—Continued

W3D • Fiber Measurements and Characterization—Continued

W3E • Fiber Amplifiers: Design and Characterization—Continued

W3F • Signal Processing I (Regeneration)—Continued

W3A.4 • 14:00 Energy Efficiency of IP-over-Elastic Optical Networks with Sliceable Optical Transponders, Jiawei Zhang1,2, Yonli Zhao1, Jie Zhang1, Bishwanath Mukherjee1,2, Beijing Univ. of Posts and Telecommunications, China; 1Univ. of California, Davis, USA. We study power consumption of IP-over-Elastic optical networks with different elastic optical transponders. The results show that significant energy saving is achievable using sliceable transponder; and also show how transponder slicability can influence energy saving.

W3B.5 • 14:00 Optical Comb-enabled Cost-effective ROADM Scheme for Elastic Optical Networks, Paikun Zhu1,2, Juhan Li1, Luoping Niu1, Yingying Xu1, Yuanxiang Chen1, Xiaopeng Xie1, Xin Chen1, Bingli Guo1, Zhangyuan Chen1, Yongqi He1; 1State Key Laboratory of Advanced Optical Communication Systems and Networks, Peking Univ., China. We propose a ROADAM Add/Drop scheme based on optical comb for elastic optical networks and experimentally demonstrates the feasibility. The scheme supports wide-range subband to superchannel Add/Drop functionality, while greatly saves network devices.

W3C.4 • 14:00 Measurement of Distributed Modal Birefringence in a Few-Mode Fiber Based on Brillouin Dynamic Grating, An Li1, William Sheih1; 1The Univ. of Melbourne, Australia. We report efficient generation and measurement of Brillouin dynamic grating in a few-mode fiber (FMF). By using a three-wave pump-probe setup combined with heterodyne coherent detection, distributed modal birefringence in a FMF has been characterized.

W3D.4 • 14:00 Wavelength Assignment Dependency of AGC EDFA Gain Offset under Dynamic Optical Circuit Switching, Kiyoa Ishii1, Junya Kurumida1, Shu Namiki2; 1AIST, Japan; 2NTT Network Innovation Laboratories, Japan. Dynamic gain offsets in WDM AGC EDFAs caused by optical circuit switching are experimentally evaluated. A simple wavelength assignment policy can reduce the gain offsets by up to 0.7 dB after five cascaded EDFAs.

W3E.4 • 14:00 Top-Scored Simultaneous Phase Regeneration of CoWDM BPSK Signals by Hybrid Optical Phase Squeezer, Takayuki Kuros1, Shu Namiki1, Mengyu Gao2; 1Photonic Networks Research Center, Natl Inst of Adv Industrial Sci & Tech, Japan; 2School of Electronics and Information Engineering, Soochow Univ., China. We propose a new concept of hybrid optical phase squeezer and demonstrate simultaneous phase regeneration of two CoWDM BPSK signals. A gain extinction ratio of 20dB is achieved with a pump power of only 3dBm.
Continued

W3G • WDM Access—Continued

W3G.4 • 14:00
Operation of a RSOA WDM PON Self-seeded Transmitter Over More than 50 km of SSMF up to 10 Gb/s, Paolo Parolari, I, Lucia Marazzi, I, Marco Brunero, I, Mario Martinelli, I, Anaëlle Maha, I, Sophie Barbet, I, Francois Lelarge, I, Romain Brenot, I, Giancarlo Gavioli, I, Gael Simon, I, Fabienne Saliou, I, Gian Denis, I, Philippe Chanclou, I, DEIB, Politecnico di Milano, Italy; II-V Lab, France; Alcatel-Lucent Italia, Italy; Orange Labs, France. For the first time we present operation of a WDM PON self-seeded transmitter in the O-band achieving more than 50-km SSMF transmission up to 10 Gb/s over 8 channels.

W3G.5 • 14:15
70km external cavity DWDM sources based on O-band Self Seeded RSOAs for transmissions at 2.5Gbit/s, Gael Simon, I, Fabienne Saliou, I, Philippe Chanclou, I, Qian Deniel, I, Didier Erasme, I, Romain Brenot, I, Orange Labs, France; Télécom ParisTech, France; II-V Lab, France. A DWDM self-seeded source achieves transmission in the O-band up to 90km SSMF at 2.5Gbps. Moreover, a “face-to-face” self-seeded architecture permits to realize transmissions at 2.5Gbps with extra-long optical cavities reaching 70km of SSMF.

W3H • Network Virtualization—Continued

W3H.4 • 14:05 Invited
Integrating 3D-TSV and Photonics in System in Package Products: Challenges and Opportunities, Bill Bottoms, JITRS, USA. The new challenges which must be overcome to achieve this vision and the potential solutions will be discussed.

This Symposium will be followed by a panel discussion.

W3I • Symposium on Advanced Electro-optic Packaging and Assembly Technologies I and Panel Discussion—Continued

W3I.4 • 14:15 Top-Scored
Flexible Virtual Network Provisioning over Distance-Adaptive Flex-Grid Optical Networks, Xi Wang, Qiong Zhang, Inwoong Kim, Paparoa Palcharla, Motoyoshi Sekiya, Fujitsu Laboratories of America, USA. We present an adaptive virtual optical network provisioning procedure for distance-adaptive flex-grid optical networks. Simulations show ~3 times increase in effective network capacity by leveraging the combined effect of flexible node mapping and distance-adaptive modulation.

W3J • Coded Modulation II—Continued

W3J.4 • 14:00 Invited
A Novel Adaptive Digital Pre-equalization Scheme for Bandwidth Limited Optical Coherent System with DAC for Signal Generation, Junwen Zhang, I, Hung-chang Chien, I, ZTE (TX) Inc, USA; Fudan Univ, China. We propose and experimentally demonstrated a novel adaptive pre-equalization scheme for bandwidth limited optical coherent system using DAC for signal generation. System performance improvements are demonstrated by the results of 40-GBaud QPSK/8QAM/16QAM with adaptive pre-equalization.

W3K • DSP Hardware—Continued

W3K.4 • 14:00
Linear Optical Modulator, Akimasa Kaneko, Hiroshi Yamazaki, Yurika Miyamoto, NTT Photonics Laboratories, Japan; NTT Network Innovation Laboratories, Japan. The nonlinear (sinusoidal) response of a conventional Mach-Zehnder modulator is an obstacle to achieving low-loss and low-distortion electro-optic signal conversion in a DAC-based optical transmitter. Our linear optical modulator solves this problem.
W3A.6 • 14:30
Effect of Link Margins and Frequency Granularity on the Performance and Modulation Format Sweet Spot of Multiple Flexgrid Optical Networks, Abhijit Mitra1, Andrew Lord1, Subrat Kar2, Paul Wright1; 1British Telecom Laboratories, British Telecom, UK; 2Department of Electrical Engineering, Indian Inst. of Technology, Delhi, India.
We consider range of modulation formats for small, medium and large networks as a function of line margin and frequency granularity. Capacity increases by 80%, 65% and 46.5% with 12.5GHz granularity at the OSNR limit.

W3B.7 • 14:30
Invited
InP-based high-speed transponder, Robert A. Griffin1; 1Caswell, Oclaro plc, UK. A new generation of line-side pluggable transponders and transceivers capable of flexible 100 and 200 Gba/s transmission will be underpinned by developments in InP PICs, which offer high performance, compact footprint and low power dissipation.

W3C.6 • 14:30
Top-Scored
Measurement of Intramodal and Intermodal Brillouin Gain Spectra in a Few-mode Fiber, Kwang Yong Song1, Yong Hyun Kim2; 1Physics, Chung-Ang Univ., Republic of Korea. Brillouin gain spectra of intramodal and intermodal SBS for different pump-probe pairs of four LP modes (LP01, LP11, LP21, and LP02 modes) in a few-mode fiber are analyzed using mode-division multiplexer composed of mode-selective couplers.

W3D.7 • 14:30
Measurement of Mode Coupling Distribution Along a Few-Mode Fiber Using a Synchronous Multi-channel OTDR, Masataka Nakazawa1, Masato Yoshida2, Toshihiko Hirooka1; 1Research Inst. of Electrical Communication, Tohoku Univ., Japan. We demonstrate the nondestructive measurement of mode coupling along a few-mode fiber using a synchronous multi-channel OTDR. The mode coupling distribution between the LP_{01} and LP_{m,n} modes is successfully obtained with a 10-m spatial resolution.

W3E.6 • 14:30
An Optical Phase Quantiser Exhibiting Suppressed Phase Dependent Gain Variation, Kyle R. Bottrill1, Graham D. Hesketh1, Francesca Parmigiani1, Peter Horak1, David J. Richardson1, Periklis Petropoulos1; 1Optoelectronics Research Centre, Univ. of Southampton, UK. We experimentally demonstrate an all-optical phase quantiser based on phase-sensitive amplification which alleviates phase noise to amplitude noise conversion. Phase transfer functions are measured for the very first time using a novel scheme.

Presentations selected for recording are designated with a . Access these by visiting www.ofcconference.org and clicking on the View Presentations button.
W3G.6 • 14:30
First System Demonstration of Hitless λ-Tuning Sequence for Dynamic Wavelength Allocation in WDM/TDM-PON, Shin Kaneko1, Tomoaki Yoshida1, Satoshi Furusawa1, Masa-hiro Sarashina2, Hideaki Tana1, Akoya Suzuki1, Toshiaki Mukojima1, Shunji Kimura1, Naoto Yoshimoto1; 1NTT Access Network Service Systems Labs., Japan; 2Oki Electric Industry Co. Ltd, Japan. We propose hitless λ-tuning sequence for dynamic wavelength allocation in WDM/TDM-PONs and demonstrate highly frequent wavelength tunings in 100-ms intervals without data-frame loss using MAC boards. Pay-as-you-grow operation based on the proposed sequence is also shown.

W3G.7 • 14:45
High Output Power and Burst Extinction Ratio ONU Using a Simple Configuration Booster SOA with Gain Peak Detuning for WDM/TDM-PON, Katsuhisa Taguchi1, Kota Asaka1, Shunji Kimura1, Naoto Yoshimoto1, NTT, Japan. We propose a high-output power λ-selective transmitter utilizing a simple configuration burst-mode booster SOA with gain peak detuning that achieve pattern effect mitigation. We successfully demonstrate over 40-dB loss budget and 40-km reach WDM/TDM-PON.

W3H.4 • 14:30
Optical Grooming with Spectrum Engineering (OG-SE) in Flexi-Grid Networks, Xiaosong Yu1, Yongli Zhao1, Jie Zhang1; 1Beijing Univ of Posts & Telecom, China. This paper introduces the concept of Spectrum Engineering in flexi-grid optical networks, and proposes an Optical Grooming algorithm with Spectrum Engineering (OG-SE). Simulation results show it performs well in blocking rate.

W3H.5 • 14:45
Experimental Evaluation of Virtual Topology Design and Reconfiguration in Optical Networks by means of Cognition, Domenico Siracusa1, Antonio Francesconi1, Natalia Fernández2, Ignacio de Miguel2, Ramón J. Durán Barroso2, Juan Carlos Agudo2, Elío Salvadori1; 1CREATE-NET, Italy; 2Universidad de Valladolid, Spain. The effectiveness of a multi-objective virtual topology design algorithm and a reconfiguration policy supported by cognitive techniques is demonstrated in an emulated testbed deploying a centralized control and management architecture.

W3K.6 • 14:45
DSP-Implementable Block Processing of Carrier-phase Recovery for M-QAM Signals, Takashi Inoue1, Shu Namiki1; 1Natl Inst. of Adv. Industr. Sci. & Tech., Japan. We propose a novel carrier-phase recovery scheme for M-QAM signals, which has DSP-implementable structure and is capable of carrier-frequency offset more than 10% of symbol rate. We demonstrate its operation for 16 and 64QAM signals.
Avoid Spectrum Defragmentation.

Kyosuke Sone, Effective Utilization of Network by Spectrum Defragmentation, OFC 2014 • 9–13 March 2014

W4A.1 • 15:30 Invited Effective Utilization of Network by Spectrum Defragmentation, Kyosuke Sone1, Xi Wang1, Shinji Yamashita1, Yasuhiko Aoki1, Fujitsu Laboratories Ltd., Japan; 2Fujitsu Laboratories of America, Inc., USA. We experimentally demonstrate hitless spectrum defragmentation and show the effectiveness of spectrum defragmentation through network simulations. In addition, we implement the OpenFlow extensions for spectrum defragmentation.

W4A.1 • 15:30 Invited CORONET: Testbeds, Cloud Computing, and Lessons Learned, Ann C. von Lehmen1, Robert D. Dover2, spike2, George Clapp2, Douglass M. Freimuth1, Joel Gannett1, Keith Kim1, Hai Mavrogenis1, Jorge Pastor1, Michael Rauch1, K. Ramakrishnan1, Ron Skoog1, Brian Wilson1, Sheryl L. Woodward1; Applied Communication Sciences, USA; 2AT&T Labs - Research, USA; 3Applied Communications Sciences, IBM TJ Watson Research Center, USA. We summarize the DARPA CORONET program approach to bandwidth-on-demand, and implementation and demonstration of Cloud Computing applications in network testbeds.

W4C.1 • 15:30 Invited Long wavelength vertical cavity surface emitting lasers for data communications, Eli Kapon1; Ecole Polytechnique Federale de Lausanne, Switzerland. Low power consumption, integrability and recent progress in industrialization of long wavelength (>1.2μm) vertical cavity surface emitting lasers make them the light source of choice for data center communication links and integration with silicon photonics.

W4D.1 • 15:30 Invited Dispersionless Low-loss Miniature Slow Light Delay Lines Based on Optical Fibers, Misha Smetsky1; Aston Univ., UK. A miniature slow light delay line with the record large delay time, small transmission loss, dispersion, and effective speed of light is proposed and demonstrated using the SNAP (Surface Nanoscale Axial Photonics) technology.

W4E.1 • 15:30 Top-Scored 1.9 μm Coherent Source Generation in Hydrogen-Filled Hollow Core Fiber by Stimulated Raman Scattering, Zefeng Wang1, Fei Yi1, William Wadsworth2, Jonathan C. Knight2; 1Physics, Univ. of Bath, UK; 2National Univ of Defense Technology, China. A 1.9 μm fiber gas Raman converter is reported for the first time. A low loss hydrogen-filled hollow-core negative curvature fiber is pumped with a 1064 nm microchip laser, generating a 1907 nm output with quantum conversion efficiency >48%.

W4E.2 • 15:45 Broadly Time-Dispersion-Tuned Narrow Linewidth All-Fiber-Integrated Optical Parametric Oscillator, Lei Zhang1, Sigang Yang1, Hongwei Chen2, Minghua Chen2, Shihong Xie1; 1Tsinghua Univ., China. A highly efficient, narrow linewidth, time-dispersion-tuned all-fiber-integrated optical parametric oscillator is demonstrated. The output wavelength can be continuously tuned in the ranges from 960 to 1048 nm and from 1076 to 1180 nm.

W4F.1 • 15:30 Real-time All-optical OFDM Transmission System Based on Time-Domain Optical Fourier Transformation, Pengyu Guan1; 1Communication, Tohoku Univ., Japan; 2State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China. We propose a novel simple all-optical OFDM transmission system based on time-domain OFT using time-lenses. A real-time 16 Gbit/s DPSK OFDM transmission with 16 decorrelated data subcarriers is successfully demonstrated over 100 km.

W4F.2 • 15:45 All-optical High-performance Demultiplexing Using Optical Nyquist Pulse Sampling, Daiki Seya1; 1Research Inst. of Electrical Communication, Tohoku Univ., Japan. We propose all-optical Nyquist demultiplexing using an optical Nyquist pulse as a sampling pulse. Crosstalk between data and sampling pulses is greatly reduced by the narrow spectral width, resulting in a 3-dB receiver sensitivity improvement.
W4G.1 • 15:30
Fully Coherent Self-Homodyne Bi-directional Enhanced Performance PON, Ali Shahpari1, Ruben S. Luis2, Jacklyn D. Reis1, Ricardo M. Ferreira1, Zoran Vujicic1, Jose D. Mendinueta2, Mario Lima1, Naoya Wada2, Antonio L. Texeira1, 1Department of Electronics, Telecommunications and Informatics, Instituto de Telecomunicacoes of Aveiro, Aveiro, Portugal, Photonic Network Research Institute Group, 2National Institute of Information and Communications Technology, Tokyo, Japan. We present a coherent-PON employing partial overlap of downstream/upstream Nyquist spectra, allowing bi-directional operation and enhanced spectral efficiency (2×120Gb/s@50GHz). Additionally, frequency shifting of Nyquist bands from the carrier allowed reduced RBS and dynamic SRS.

W4G.2 • 15:45
Simplified Polarization Diversity Heterodyne Receiver for 1.25Gb/s Cost-Effective uWDM-PON, Iván Canó1, Adolfo Liner1, Victor Polo1, Josep Pratt1, Universitat Politècnica de Catalunya, Barcelona, CAT, Spain. We propose a heterodyne receiver with a single-photodiode per polarization for ONU receiver in low-cost uWDM-PON. This grants polarization diversity operation showing a penalty of 6dB in sensitivity compared to a balanced detector.

W4H.1 • 15:30
Energy Saving Through Traffic Profiling and Prediction in Self-Optimizing Optical Networks, Domenico Siracusa1, Federico Pederzoli1, Renato Lo Cigno1, Elio Salvadori1, 1CREATE-NET, Italy; 2DIIS, Univ of Trento, Italy. A method that automatically learns and predicts the traffic behavior to save energy by adjusting the number of active optical carriers is presented. Simulations prove it provides large savings and ensures low traffic loss probability.

W4H.1 • 15:35
Invited Presentation
Taking Optics to the Chip: From Board-mounted Optical Assemblies to Chip-level Optical Interconnects, Catharina E. Schmidtke1, Frank Flens1, Daniel Mahgarefah1, 1Finsar Corporation, USA. Board-mounted optical assemblies (BOAs) enable significant bandwidth density increase relative to pluggable optics at the card edge. We discuss the challenges for the next step in this evolution as optics moves towards the chip.

W4H.2 • 15:45
Joint Optimization of Transmission Performance and Bandwidth Utilization Based on Software Defined Network, Wei Guo1, Wang Bin1, Yaohui Jin1, Weisheng Hu1, Ming Xia1, 1Shanghai Jiao Tong Univ, China; 2Ericsson Research, USA. We propose an extended Software Defined Networks (SDN) controller to improve bandwidth utilization with guaranteed transmission performance. An experimental implementation shows reduced bandwidth waste without impacting transmission delay and packet loss for designated applications.

W4J.1 • 15:30
High-Dimensional Modulation for Mode-Division Multiplexing, Sercan O. Arık1,2, David Millar1, Toshiaki Koke-Akino1, Keisuke Kojima1, Kieran Parsons2, 1Mitsubishi Electric Research Laboratories, USA; 2Department of Electrical Engineering, Stanford Univ., USA. We explore high-dimensional modulation for mode-division multiplexed optical fiber communication systems, focusing on an optimized 24-D modulation formats in six-mode fiber transmission. Compared with conventional formats, our simulations demonstrate up to 8.7 dB span loss budget improvement for 6 b/s/Hz intra-channel spectral efficiency.

W4J.2 • 15:45
Photonic-Lantern-Based Mode Multiplexers for Few-Mode Fiber Transmission, Roland Ryf1,2, Nicolas K. Fontaine1, Marc Montoliu1,2, Sebastian Randell1, Burcu Ercan1, Haoshuo Chen1,2, S. Chandrasekar1, Alan Gnauck2, Sergio G. Leon-Saval2, Joss Bland-Hawthorn1, Joel R. Salazar Gil1, Yi Sun1, Robert Lingle1, 1Bell Labs, Alcatel-Lucent, USA; 2Universitat Politècnica de Catalunya (ETSETB), Spain; 3COBRA Inst., Eindhoven Univ. of Technol., Netherlands; 4Inst. of Photonics and Optical Science (IPOSI), The Univ of Sydney, Australia; 5OFFS, USA. We report transmission experiments in few-mode fibers supporting 6 spatial- and polarization modes, where low-loss photonic lanterns are used as mode-multiplexers. We measured a transmission distance of 900–km for 32 WDM channels with a 100–GHz channel spacing and a distance of 1500–km for a single wavelength channel experiment.

Timo Pfau received the Dr.-Ing. degree in electrical engineering from the University of Paderborn, Germany, in 2009. He is currently a Member of Technical Staff in the Enabling Physical Technologies domain at Bell Laboratories, Alcatel-Lucent in Murray Hill, NJ. His research interests include advanced modulation formats, digital signal processing, and real-time implementation of high-speed communication systems.
Wednesday, 12 March

Room 102
W4A • Defragmentation Control—Continued

Room 120
W4B • Optical Network Optimization I—Continued

Room 121
W4C • Long Wavelength VCSELs and Quantum Dot Lasers—Continued

Room 122
W4D • Slow Light and Multicore Fiber—Continued

Room 123
W4E • Novel Optical Schemes—Continued

Room 124
W4F • Signal Processing II—Continued

W4A.2 • 16:00 Demonstration of Online Spectrum Defragmentation Enabled by OpenFlow in Software-defined Elastic Optical Networks, Shoujiang Ma1, Cen Chen, Shengru Li1, Mingyang Zhang1, Suoheng Li1, Yan Shao1, Zuqiang Zhu1, Lei Liu1, S. J. Ben Yoo1, 1School of Information Science and Technology, Univ. of Science and Technology of China, China; 2Department of Electrical and Computer Engineering, Univ. of California, Davis, USA. We propose and experimentally demonstrate a control-plane framework to realize online spectrum defragmentation (DF) in software-defined elastic optical networks. Experimental results show that the spectrum DF enabled by OpenFlow reduces the blocking probability effectively.

W4C.2 • 16:00 Comparative cost analysis of optical networks with shared mesh protection in the beyond-100-Gb/s networks era, Noboru Yoshikane1, Takehiro Tsuiritani1, KDDI R&D Labs., Fujimino, Japan. This paper shows a comparison of the number of network equipment, network cost and required fiber resource between the flexible-bitrate networks using 100/400-Gb/s signals with the conventional dedicated protection and the emerging shared mesh protection.

W4A.3 • 16:15 Experimental Assessment of a High Performance Back-end PCE for Flexgrid Optical Network Re-optimization, Lluís Gifre Renom1,2, Luis Velasco1, Nacho Navarro1, Gabriel Junyent1; 1Optical Communications Group (GCO), Universitat Politécnica de Catalunya (UPC), Spain; 2Barcelona Supercomputing Center (BSC), Spain; 3High Performance Computing Group, Universitat Politécnica de Catalunya (UPC), Spain. A specialized high performance Graphics Processing Unit (GPU)-based back-end Path Computation Element (PCE) to compute re-optimization in Flexgrid networks is presented. Experimental results show 6x speedups compared to single centralized PCE.

W4A.3 • 16:15 Withdrawn.

W4D.3 • 16:15 Top-Scored Multicore-fiber Cable with Core Density of 6 cores/mm², Itaru Ishida1, Yoshimichi Amma1, Keisuke Hirakawa1, Hitoshi Uemura1, Yussuke Sasaki1, Katsuhira Takenaga2, Naoto Ito1, Ken Osato1, Shoichiro Matsuo1; 1Optics and Electronics Laboratory, Fujikura Limited, Japan; 2Optical Fiber Cables R&D Dept., Fujikura Limited, Japan. An Ultra-high density cable with 12-core MCF was presented. A fabricated cable realized core density of 6 cores/mm². The change of crosstalk behavior before and after cabling was moderate thanks to adequate cable design.

W4E.4 • 16:15 Invited Optical Frequency Combs for Telecom and Datacom Applications, Nikola Alic1, Stojan Radic1; Qualcomm Inst. of Telecommunications, Univ. of California San Diego, USA. We demonstrate compliance with and applicability of the new generation comb sources to telecom and datacom applications. The new sources are characterized by OSNRs surpassing 40 dB, encompassing C and L telecom bands.
W4G • Coherent PON—Continued

W4G.3 • 16:00
Experimental demonstration of a novel polarization-independent coherent receiver for PONs, Marco Presi1, Raffaele Corsini1, Ernesto Ciarapella1; ‘TeCIP Institute, Scuola Superiore di Studi Universitarie di Perfezionamento Sant’Anna di Pisa, Pisa, PI, Italy. We experimentally demonstrate a novel polarization-independent coherent receiver for low-cost PONs using intensity-modulation and low-cost components. The receiver is successfully tested in a 1.25 Gb/s long reach (66 km, 48 dB ODN loss) system.

W4G.4 • 16:15
Demonstration of 3-ONU Multiplexed Coherent IFDMA-PON Uplink System using Real-Time Prototypes, Kenji Ishii1, Yuki Yoshida1, Kiyoshi Onohara1, Masaki Noda1, Masamichi Nogami1, Akihiko Murata1, Takashi Mizuochi1, Ken-ichi Kitayama1; ‘Optical Communication Technology Dept., Mitsubishi Electric Corporation Information Technology R&D center, Kamakura, Kanagawa, Japan; ‘Department of Electrical, Electronic and Information Eng., Osaka University, Suita, Osaka, Japan. Coherent IFDMA-PON uplink system with 3 multiplexed ONU transmitters, almost no penalty and OLT receiver and two offline ONU transmitters, almost no penalty between all of subcarrier assignments was confirmed.

W4H • Network Design Challenges and Implementations—Continued

W4H.3 • 16:00
The Equinix Network, Lane Patterson1; ‘Equinix, USA. Abstract not available

W4H.2 • 15:55
Invited
Packaging Challenges in Next Generation Coherent Line Sides Components, Robert Blum1; ‘Oclaro, USA. Starting from lessons learned in the 10G and 40G space we’ll present different packaging approaches for these new 100G coherent modules and sub-components and discuss packaging design trade-offs based on thermal and RF simulations.

W4I • Symposium on Advanced Electro-optic Packaging and Assembly Technologies II—Continued

W4I.3 • 16:00
Invited
8.96Tb/s (32x28GBaudx32QAM) Transmission over 0.95 km 19 cell Hollow-Core Photonic Bandgap Fiber, Roy van Udend1, Chigo Okonkwo1, Haoshuo Chen1, Natalie V. Wheeler2, Francesco Peletti2, Marco Petrovich1, David J. Richardson1, Huug Waardt, de1, A. Koonen1; ‘Cobra Research Inst., Eindhoven Univ. of Technology, Netherlands; ‘Optoelectronics Research Centre, Univ. of Southampton, UK. The longest coherent transmission distance of 0.95km, and highest distance×bandwidth product 19cell hollow-core photonic bandgap fiber (HC-PBGF) are demonstrated, indicating the potential for longer distance HC-PBGF high capacity coherent transmission applications.

W4I.4 • 16:15
6x28GBaud 128-SP-QAM Transmission over 41.75 km Few Mode Fiber with a 6x6 MIMO FDE, Roy van Udend1, Chigo Okonkwo1, Haoshuo Chen1, Huug Waardt, de1, A. Koonen1; ‘Cobra Research Inst., Eindhoven Univ. of Technology, Netherlands. By exploiting 4D constellations, 6x28GBaud 128-SP-QAM transmission over 41.75 km few mode fiber with 6x6 multiple-input multiple-output (MIMO) frequency domain equalization (FDE) is demonstrated to perform better than 8QAM, whilst carrying 0.5bit/symbol more information.

Papers are available online for download. Visit www.ofcconference.org and click on the Download Digest Papers button.
Room 102
W4A • Defragmentation Control—Continued

Room 120
W4B • Top-Scored SDN Control of All-Optical Frequency Conversion and Defragmentation for Super-channels, Francesco Paolucci1, Nicola Sambò1, Gianluca Meloni2, Gianluca Berrettini2, Francesco Fresi1, Luca Pott1, Piero Castoldi1; 1TeCIP, Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna di Pisa, Italy; 2CNIT, Italy. Frequency conversion and a novel hitless defragmentation technique (based on PPLN waveguide) suitable for super-channels are demonstrated and automatically controlled. Extended OpenFlow sets power and frequency of the pumps responsible for conversion and defragmentation.

Room 121
W4C • Long Wavelength VCSELs and Quantum Dot Lasers—Continued

Room 122
W4D • Slow Light and Multicore Fiber—Continued

Room 123
W4E • Novel Optical Schemes—Continued

Room 124
W4F • Signal Processing II—Continued

W4A.4 • 16:30 Top-Scored SDN Control of All-Optical Frequency Conversion and Defragmentation for Super-channels, Francesco Paolucci1, Nicola Sambò1, Gianluca Meloni2, Gianluca Berrettini2, Francesco Fresi1, Luca Pott1, Piero Castoldi1; 1TeCIP, Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna di Pisa, Italy; 2CNIT, Italy. Frequency conversion and a novel hitless defragmentation technique (based on PPLN waveguide) suitable for super-channels are demonstrated and automatically controlled. Extended OpenFlow sets power and frequency of the pumps responsible for conversion and defragmentation.

W4B.4 • 16:30 Impact of transponders and regenerators wake-up time on sleep-mode enabled transparent optical networks, Albert Pagès1, Massimo Tomarone1, Jordi Perelló1, Salvatore Spadaro2, Annalisa Morea2, 1Universitat Politècnica de Catalunya (UPC), Barcelona, CAT, Spain; 2Politecnico di Milano, Milano, Italy. Frequency conversion and a novel hitless defragmentation technique (based on PPLN waveguide) suitable for super-channels are demonstrated and automatically controlled. Extended OpenFlow sets power and frequency of the pumps responsible for conversion and defragmentation.

W4C.3 • 16:30 Low Driving Voltage (< 400mVpp) Electro-absorption Modulator Laterally Integrated with VCSEL, Hamed Dalir1, Yuta Takahashi1, Fumio Koyama1, 1Electronics and Applied Physics, Tokyo Inst. of Technology, Japan. A compact (8μm long) electro-absorption slow-light modulator is laterally integrated with a 980nm InGaAs VCSEL incorporating a bow-tie shape oxide aperture. We demonstrate a low driving voltage below 400mVpp and large signal modulation up to 25Gbps.

W4D.4 • 16:30 Dependence of Crosstalk Increase due to Tight Bend on Core Layout of Multi-Core Fiber, Tetsuya Hayashi1, Testuya Nakamichi1, Takashi Sasaki1, Kunimasa Saitoh2, Masanori Koshiba2, 1Optical Communications R&D Laboratories, Sumitomo Electric Industries Ltd, Japan; 2Graduate School of Information Science and Technology, Hokkaido Univ., Japan; 3Hokkaido Univ. Career Center, Japan. Dependence of the tight-bend-induced crosstalk increase on the core layout is experimentally investigated. The crosstalk increase exponentially decreases with the core-to-core distance increase, and depends on the positions of excited and coupled cores.

W4E.5 • 16:45 Erbium-Doped Laser with Multi-segmented Silicon Nitride Structure, Pumawiman Pumawiman1, Ehsan S. Hosseini1, Jae Sun2, Thomas A. Badl2, Gery Leake2, Douglas D. Coolbaugh2, Michael R. Watts1; 1Univ. of Sydney, Australia; 2Bandwidth Communications, USA. We present a spatially-diversive optical vector network analyzer which is capable of measuring some or all of the mode transfer matrix of a system in an arbitrary mode basis using single or multiple sweeps.

W4F.4 • 16:30 Enhanced Tunable Parametric Delay Assisted by Gain-Transparent Stimulated Brillouin Scattering, liang wang1, Chaoran Huang1, Xiaofei Cheng1, Chester Shu2, 1Inst. for Infocomm Research, A*STAR, Singapore; 2Chinese Univ. of Hong Kong, Hong Kong. We demonstrate extension of optical parametric delay by enhancing the wavelength conversion bandwidth through dynamic phase-matching control in fiber-based four-wave mixing. The delay range has been increased by 37% from 248 to 340 ps.

W4A.5 • 16:45 Invited: Adaptive Reconfiguration of Sub-lambda and Wavelength Paths for Unpredictable Traffic Demands, Akihiro Kadohata1,2; 1Innovation Laboratories, Japan; 2Verizon, Waltham, MA. Regional Networks, Richard Younce1, Christopher Chase2, Geoffrey Gerke1, Li Zhu2, Connie Chang-Hasnain2, UC Berkeley, USA; 2Bandwidth Communications, USA. We present a spatially-diversive optical vector network analyzer which is capable of measuring some or all of the mode transfer matrix of a system in an arbitrary mode basis using single or multiple sweeps.

W4B.5 • 16:45 Low Driving Voltage (< 400mVpp) Electro-absorption Modulator Laterally Integrated with VCSEL, Hamed Dalir1, Yuta Takahashi1, Fumio Koyama1, 1Electronics and Applied Physics, Tokyo Inst. of Technology, Japan. A compact (8μm long) electro-absorption slow-light modulator is laterally integrated with a 980nm InGaAs VCSEL incorporating a bow-tie shape oxide aperture. We demonstrate a low driving voltage below 400mVpp and large signal modulation up to 25Gbps.

W4C.4 • 16:45 Laterally Integrated with VCSEL, Michal Dymalkov1,2, Albert Pagès1, Jordi Perelló1, Massimo Tomarone1, Ricard Riba2, 1TeCIP, Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna di Pisa, Italy; 2Politecnica Catalunya (UPC), Barcelona, CAT, Spain. We report on a high-speed bifunctional device is demonstrated as tunable resonant cavity detector and VCSEL by simultaneously integrated with a 980nm InGaAs VCSEL incorporating a bow-tie shape oxide aperture. We demonstrate a low driving voltage below 400mVpp and large signal modulation up to 25Gbps.

W4D.5 • 16:45 Reconfigurable SDM Optical Vector Network Analyzer, Joel A. Carpenter1,2, Benjamin J. Eggleton1, Jochen Schröder1,2, 1Univ. of Sydney, Australia; 2Bandwidth Communications, USA. We present a spatially-diversive optical vector network analyzer which is capable of measuring some or all of the mode transfer matrix of a system in an arbitrary mode basis using single or multiple sweeps.

W4E.5 • 16:45 Erbium-Doped Laser with Multi-segmented Silicon Nitride Structure, Pumawiman Pumawiman1, Ehsan S. Hosseini1, Jae Sun2, Thomas A. Badl2, Gery Leake2, Douglas D. Coolbaugh2, Michael R. Watts1; 1Univ. of Sydney, Australia; 2Bandwidth Communications, USA. We present a spatially-diversive optical vector network analyzer which is capable of measuring some or all of the mode transfer matrix of a system in an arbitrary mode basis using single or multiple sweeps.

W4F.5 • 16:45 A Bandwidth-Tunable Narrowband Rectangular Optical Filter Based on Stimulated Brillouin Scattering, linyang li1, Wei Wei2, Lihong Fan2, Cunfei Hu1, 1Inst. for Infocomm Research, A*STAR, Singapore; 2Chinese Univ. of Hong Kong, Hong Kong. We demonstrate extension of optical parametric delay by enhancing the wavelength conversion bandwidth through dynamic phase-matching control in fiber-based four-wave mixing. The delay range has been increased by 37% from 248 to 340 ps.
Dayou Qian received the B.S. degree in physics from Tsinghua University, China, the M.S. degree in electrical engineering from the University of California, Los Angeles, and the Ph.D. degree in electrical engineering from Florida International University, Miami, in 2000, 2002, and 2006, respectively. From May 2006 to August 2013, he was a Technical Staff Senior Member at NEC Laboratories America, Princeton, NJ. He is currently a Product Line Manager at Juniper Networks in Sunnyvale, CA. His research interests include optical line/client side interface design and transmission technologies. He has authored more than 100 papers for prestigious journals and conferences. He holds 6 U.S. patents with 38 others pending.

Dayou Qian • Coherent PON—Continued

Integrated Packets/Circuit Hybrid Network Field-Trial Demonstrating Sub-Wavelength Aggregation, Steinar Bjornstad1; Ramina Veilani1, Jan P. Braut1, Kourosh Bozorgebrahimi1, 1Telematics, Norwegian Univ. of Science and Technology, Norway; 2TransPacket, Norway; 3UNINETT, Norway. We report aggregation of sub-wavelengths in an integrated packet/circuit hybrid optical network. Aggregation of packet streams with circuit quality of service combined with statistical multiplexing enables packet delay variation of only 15ns at 82.4% throughput.

This Symposium will be followed by a panel discussion.

Dayou Qian • Coherent PON—Continued

Integrated Packets/Circuit Hybrid Network Field-Trial Demonstrating Sub-Wavelength Aggregation, Steinar Bjornstad1; Ramina Veilani1, Jan P. Braut1, Kourosh Bozorgebrahimi1, 1Telematics, Norwegian Univ. of Science and Technology, Norway; 2TransPacket, Norway; 3UNINETT, Norway. We report aggregation of sub-wavelengths in an integrated packet/circuit hybrid optical network. Aggregation of packet streams with circuit quality of service combined with statistical multiplexing enables packet delay variation of only 15ns at 82.4% throughput.

This Symposium will be followed by a panel discussion.

Wi4G.5 • 16:30 Tutorial
Coherent Solution in Optical Access Networks, Dayou Qian1, Juniper Networks, Sunnyvale, CA, United States. Coherent technologies have been introduced to optical access networks because of its outstanding performance, spectrum efficiency, dispersion tolerance, burst-mode support, etc. This tutorial will review some coherent solutions for the next generation PON.

Wi4H • Network Design Challenges and Implementations—Continued

W4I • Symposium on Advanced Electro-optic Packaging and Assembly Technologies II—Continued

W4J • Few-Mode Fiber Transmission—Continued

W4K • Carrier Recovery and Phase Noise—Continued

W4K.2 • 16:30 Invited
Carrier Phase Estimation for DP-16QAM Using QPSK Partitioning and Quasi-Multiplier-Free Algorithms, Kang Ping Zhong1; Jian Hong Ke1; Ying Gao1; John C. Cartledge1; Alan Pak Tao Lou1; Chao Lu1; Photonics Research Center, Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong; 1Department of Electrical and Computer Engineering, Queen’s Univ., Canada; 2Photonics Research Center, Department of Electrical Engineering, The Hong Kong Polytechnic Univ., Hong Kong. A low complexity and linewidth tolerant two-stage carrier phase estimation (CPE) by using QPSK partitioning and quasi-multiplier free algorithm is proposed for DP-16QAM signal. The performance, linewidth tolerance the algorithm are numerically and experimentally demonstrated.

W4K.3 • 16:45 Invited
Homodyne OFDM using Simple Optical Carrier Recovery, Zhixin Liu1; David S. Wu1; David J. Richardson1; Radan Slavik2; Univ. of Southampton, UK. We use optical injection locking for carrier recovery in RF-pilot aided OFDM. Any need for optical pre-filtering is eliminated and only narrow guard bands are required. Improved performance with respect to heterodyne detection is demonstrated.
Wednesday, 12 March

**W4A.6 • 17:15**
Reduce Spectrum Defragmentation Latency in EONs with Effective Parallelization of Connection Reconfigurations, Changsheng You¹, Mingyang Zhang¹, Zuqing Zhu¹; ¹School of Information Science and Technology, Univ. of Science and Technology of China, China. We investigate parallel defragmentation and propose a novel algorithm to achieve effective parallelization of the connection reconfigurations with a conflict graph. Simulation results show that the algorithm can effectively reduce the latency of traffic migrations.

**W4C.5 • 17:00**
Top-Scored
High Performance 1.3μm InAs Quantum Dot Lasers Epitaxially Grown on Silicon, Alan Y. Liu¹, Chong Zhang², Andrew Snyder¹, Dimitri Lubyshev¹, Joel M. Fastenau¹, Amy Liu¹, Arthur C. Gossard¹; ¹John E. Bowers²; ²Materials, Univ. of California Santa Barbara, USA; ³Electrical and Computer Engineering, Univ. of California Santa Barbara, USA; ⁴IQE Inc., USA. We demonstrate 1.3 μm InAs quantum dot lasers on silicon by molecular beam epitaxial growth with low thresholds (16 mA), high output power (>50 mW), high T0 (>200 K), and high temperature lasing (115 °C).

**W4C.6 • 17:15**
Modular Hybrid Dilated Mach-Zehnder Switch with Integrated SOAs for Large Port Count Switches, Qixiang Cheng¹, Adrian Wonfor¹, JinLong Wei¹, Richard V. Penty¹, Ian White¹; ¹Engineering Department, Univ. of Cambridge, UK. A modular dilated MZI based optical switch with integrated SOAs is demonstrated with excellent -40dB crosstalk/extinction ratio, 3ns switching time and nearly penalty-free operation. Studies show an 8x8 switch with 14dB IPDR for 0.5dB penalty.

**W4D.6 • 17:00**
Development of Small MT Type 2-multicore Fiber Connector, Kengo Watanabe¹, Tsunetoshi Saito¹, Katsumi Suematsu¹, Ryo Nagase¹, Masato Shinoh¹; ¹Furukawa Electric Co., Ltd., Japan; ²Chiba Inst. of Technology, Japan. We developed small MT type 2-MCF connector. PC condition for MT type MCF connector was studied theoretically and experimentally. Fabricated 2-MCF connector demonstrated return loss more than 46dB and connection loss less than 0.3dB. Demonstration of 10G Burst-Mode DML and EDC in Symmetric 40Gb/s TWDM-PON over 40km Passive Reach.

**W4F.6 • 17:00**
Invited
All Optical Processing in QD-SOAs, Giampiero Contestabile¹; ¹Scuola Superiore Sant Anna di Pisa, Italy. High-gain InAs QD-SOAs are promising active devices for efficient, broadband and high-speed signal processing. Recent results about wavelength conversion of intensity modulated and coherent signals are reviewed.
W4H 6 • 17:00 Invited Optical Networking Applications in the Mobile Backhaul and Fronthaul (geared toward Reliance Infotel), Anuj Jain; Reliance Infotel, India. Abstract Not Available

W4K 4 • 17:00 A Study of Laser White and Brownian FM Noise in Coherent QPSK Signals, Keisuke Matsuda1, Hiroshi Bessho1, Ki-yotomo Hasegawa1, Tsuyoshi Yoshida1, Kazuyuki Ishida1; Information Technology R&D Center, Mitsubishi Electric Corporation, Japan. We studied laser noise numerically and experimentally in terms of frequency variance within frequency estimation response time, and showed that a normalized variance below $1 \times 10^{-6}$ is required to limit the penalty to 0.5 dB.

W4K 5 • 17:15 Overcoming the Effect of Cycle Slips Caused by Low Frequency Noise from Monolithic Tunable Lasers, Tam N. Huynh1, Liam P. Barry1; ‘School of Electronic Engineering, Dublin City Univ., Ireland. We investigate cycle slip effects of monolithic tunable lasers in a 10.7 Gbaud QPSK system employing feedback or feed-forward phase tracking algorithms. Experimental results demonstrate an increased probability of cycle slip due to low frequency noise in SGDBR lasers.
Room 120

08:00–10:00
Th1A • Silicon Nitride and Liquid Crystal Devices
Presider: Takashi Saida; NTT Corporation, Japan

Th1A.1 • 08:00
Low Loss (<0.2dB per transition) CMOS Compatible Multi-Layer Si3N4-on-SOI Platform with Thermal-Optics Device Integration for Silicon Photonics, Ying Huang1, Rianshu Luo1, Junfeng Song1, Tsung-Yang Liow1, Patrick Guo-Qiang Lo1; 1Inst. of Microelectronics, A*STAR, Singapore. A multi-layer Si3N4-on-SOI platform is demonstrated, achieving <0.2dB transition loss between layers over 70nm bandwidth. 0.8dB/cm propagation loss is measured for PECVD Si3N4 waveguide at λ=1580nm. Thermal-optic micro-ring filter is also integrated on the platform.

Th1A.2 • 08:15
Integrated Single and Multi-layer Si3N4 Platform for Ultra-low Loss Propagation and Small Bending Radii, Daryl T. Spencer1, Arne Leinse2, Renan Moreira1, Jock T. Bovington1, John E. Bowers1, Arne Leinse1, H.H. van den Vlekkert1, Rene G. Heideman1, Marcel Hoekman2, Theo T. Veenstra2; 1Electrical and Computer Engineering, Univ. of California Santa Barbara, USA; 2LioniX BV, Netherlands. A combination of low loss and small bend radius Si3N4 waveguide regions are integrated with one etch step. Propagation losses of 1.5 dB/m and 7 dB/m are measured with a transition loss of ≤0.5 dB taper.

NOTES

Room 121

08:00–10:00
Th1C • Silicon Photonics I
Presider: Huapu Pan; FutureWei Technologies, Inc., USA

Th1C.1 • 08:00
A Path to 300 mm Hybrid Silicon Photononic Integrated Circuits, John E. Bowers1, Jock T. Bovington1, Alan Y. Liu1, Arthur C. Gossard1, 1Univ. of California Santa Barbara, USA. We describe recent advances in hybrid silicon components and photonic integrated circuits. We present a path towards scalable, ultralow cost photonic integrated circuits (PICs) on 300 mm silicon substrates.

Th1C.2 • 08:15
Optic Micro-ring Filter is Also Integrated
hu Luo

Room 122

08:00–10:00
Th1D • Network Subsystem
Presider: Nicola Calabretta; Technische Universiteit Eindhoven, Netherlands

Th1D.1 • 08:00
Invited
Integrated Silicon Photonics Links for High Bandwidth Data Transport, Hai-Feng Liu1, Intel Corporation, USA. We review the technology development of integrated silicon photonics CWDM links, and demonstrate the transmission of 25Gb/s signals from integrated silicon photonics transceivers over a record 820m MMF optimized for high modal bandwidth at 1310 nm.

NOTES
Bi-directional 400 Mbit/s LED-based Optical Wireless communication for Non directed Line of Sight Transmission, Amir M. Khalid\textsuperscript{1}, Ernesto Ciaramella\textsuperscript{1}, Scuola Superiore Sant Anna di Pisa, Italy We experimentally demonstrated a 400 Mbit/s bi-directional optical wireless transmission operating in non-directed line-of-sight configuration, based on visible/infrared LEDs for downlink/uplink, exploiting adaptive Discrete Multi-Tone technique and optimized optical filters.

Optical Fiber Runs through “In-Unit” with 0.9mm Drop, Clear Clips and Epoxy with Invisible Tracks, Christopher D. Levendos\textsuperscript{1}, Chalmers Inst. of Technology, USA; 2ADVA Optical Systems, ADVA Optical Networks SE, Germany. We investigated the causes of the difficulty in implementing a larger FTTH network in LATAM region, challenges & issues will be analyzed in this paper.

A 3.25-Gbps VLC-communication Science and Engineering, Wang Yuanquan\textsuperscript{1}; Rongling Li\textsuperscript{1}, 1Department of Communication Science and Engineering, Fudan Univ., China. A 3.25-Gbps VLC system applying 512QAM SC-FDE is experimentally demonstrated for the first time using an RGB-LED with 3-dB bandwidth of 10MHz. The BERs for all first time using an RGB-LED with 3-dB system applying 512QAM SC-FDE is already a reality in the LATAM region. We investigated the causes of the difficulty of implementing a larger FTTH network in LATAM region, challenges & issues will be analyzed in this paper.

Georgia Institute of Technology, USA; 2ADVA Optical Systems, ADVA Optical Networks SE, Germany. We investigated the causes of the difficulty of implementing a larger FTTH network in LATAM region, challenges & issues will be analyzed in this paper.

Andrekson is Professor of Photonics and previously spent several years in the US (Bell Labs, Cenix Inc., Lehigh University). His research interests include amplifiers, all-optical functionalities, and high spectral efficiency transmission. He co-founded Picosolve, now part of EXFO where he is a Director. Andrekson is a Fellow of the OSA and the IEEE and author of four-hundred scientific publications. He was member of the Board of Governors for the IEEE Photonics Society and has served as an expert for the evaluation of the Nobel Prize in Physics. Currently he holds an ERC Advanced Grant for work on phase-sensitive optical amplifiers.

Amir M. Khalid\textsuperscript{1}, Ernesto Ciaramella\textsuperscript{1}, Scuola Superiore Sant Anna di Pisa, Italy We experimentally demonstrated a 400 Mbit/s bi-directional optical wireless transmission operating in non-directed line-of-sight configuration, based on visible/infrared LEDs for downlink/uplink, exploiting adaptive Discrete Multi-Tone technique and optimized optical filters.

Christopher D. Levendos\textsuperscript{1}, Chalmers Inst. of Technology, USA; 2ADVA Optical Systems, ADVA Optical Networks SE, Germany. We investigated the causes of the difficulty in implementing a larger FTTH network in LATAM region, challenges & issues will be analyzed in this paper.

The BERs for all first time using an RGB-LED with 3-dB system applying 512QAM SC-FDE is already a reality in the LATAM region. We investigated the causes of the difficulty of implementing a larger FTTH network in LATAM region, challenges & issues will be analyzed in this paper.

Amir M. Khalid\textsuperscript{1}, Ernesto Ciaramella\textsuperscript{1}, Scuola Superiore Sant Anna di Pisa, Italy We experimentally demonstrated a 400 Mbit/s bi-directional optical wireless transmission operating in non-directed line-of-sight configuration, based on visible/infrared LEDs for downlink/uplink, exploiting adaptive Discrete Multi-Tone technique and optimized optical filters.
Room 102

Th1A • Silicon Nitride and Liquid Crystal Devices—Continued

Th1A.3 • 08:30
Si3N4-on-SOI Polarization Rotator-Splitter Based on TM0-TE1 Mode Conversion, Wesley D. Sacher1, Ying Huang2, Ding Liang2, Tymon Barwicz3, Jared C. Mikkelson1, Benjamin J. Taylor1, Patrick Guo-Qiang Lo1, Joyce Poon1, 1Univ. of Toronto, Canada; 2Inst. of Microelectronics, A*STAR, Singapore; 3IBM Thomas J. Watson Research Center, USA. A polarization rotator-splitter is demonstrated using a Si3N4 waveguide atop a silicon waveguide. The device exhibits polarization crosstalk < -19 dB, loss < 1.5 dB, and PDL < 1.0 dB over an 80 nm bandwidth.

Th1A.4 • 08:45
High Efficiency Silicon Nitride Grating Coupler with DBR, Huijuan Zhang1, Chao Li1, Xiaoguang Yu1, Haifeng Zhou1, Xianshu Luo1, Mingbin Yu1, Patrick Guo-Qiang Lo1, 1Inst. of Microelectronics, Singapore. We have designed and demonstrated high efficiency Silicon nitride grating couplers with two periods of distributed Bragg reflectors at 1490 nm. The peak coupling efficiency is ~2.6 dB and the 1-dB bandwidth is ~53 nm.

Room 120

Th1B • Panel: 100G Deployment on Submarine Links—Continued

Room 121

Th1C • Silicon Photonics I—Continued

Th1C.2 • 08:30 Invited
A CMOS Wafer-Scale, Monolithically Integrated WDM Platform for TB/s Optical Interconnects, Guoliang Li1, Timothy Creazzo1, Elton Marchena1, Paul K. L. Yu1, Stephen Krassikl1, 1Skorpios Technologies Inc., USA. We present a unique Si photonics platform with butt-coupled III-V and SOI waveguides fabricated in a wafer-scale CMOS process. This enables high-efficiency lasers, modulators, photodetectors, and tuning-free Mux/Demux, which is ideal for TB/s optical interconnects.

Room 122

Th1D • Network Subsystem—Continued

Th1D.2 • 08:30
Demonstration of 1-to-13 PDM-8QAM SCFDM Superchannel Multicasting in HNLF, Paikun Zhu1, Jiahao Li1, Yuanxiao Chen1, Yingying Xu1, Nan Zhang1, Bingli Guo1, Zhangqian Chen1, Yongqi He2, 1State Key Laboratory of Advanced Optical Communications Systems and Networks, Peking Univ., China. All-optical superchannel multicasting is promising for flexible data grooming in future optical networks. In this work, we experimentally demonstrate 1-to-13 multicasting of 240 Gb/s PDM-8QAM SCFDM superchannel in HNLF.

Room 123

Th1E • Planning I—Continued

Th1E.2 • 08:30
Network-Efficient Superchannel Transmission by the Multichannel Compensation of Nonlinearities, Tiago Lima1, Valery Rozental1, André Barretto1, Darli Mello1, 1Department of Electrical Engineering, Univ. of Brasilia, Brazil. We investigate potential network-cost savings due to the multichannel compensation of nonlinearities generated by subcarriers within the same superchannel. Two case studies (European and German networks) demonstrated tangible cost reductions (6-11%) using 5 adjacent subcarriers.
**Room 125**

**Th1F** • Visible Light Communications—Continued

**Th1F.3 • 08:30**

LED-based Visible Light Communication in a Practical Indoor Interfered Environment Employing DMT and STBC, Chia Chien Wei¹, Fang-Ming Wu¹, Zhen-Yu Chen¹, Chun-Ting Lin², Yung-Jui Chen¹, Sien Chi¹;¹Department of Photonics, National Sun Yat-sen Univ., Taiwan; ²Inst. of Photonic System, National Chiao Tung Univ., Taiwan. We demonstrate practical indoor VLC of 3.2-m transmission, and investigate multipath interference between LEDs. Employing repetition coding, 161–266-Mbps DMT-signals are achieved depending on interference severity. Employing STBC, about fixed 220-Mbps data rate could be achieved.

**Th1F.4 • 08:45**

Next Generation Visible Light Communications: 10 Mb/s with Polymer Light-Emitting Diodes, Paul A. Haigh¹,², Francesco Bausi³,⁴, Zabih Ghassemlooy¹, Ioannis Papakonstantinou⁵, Hoo Le Minh¹, Charlotte Flechon¹,², Franco Cacialli³,⁴;¹Faculty of Engineering and Environment, Northumbria Univ., UK; ²Department of Electronic and Electrical Engineering, Univ. College London, UK; ³Department of Physics, Univ. College London, UK; ⁴London Centre of Nanotechnology, Univ. College London, UK. The first 10 Mb/s real-time organic visible light communications system based on polymer light-emitting diodes is demonstrated using a Virtex-6 FPGA-based LMS equalizer, with an improvement rate of 7 Mb/s compared to the current state-of-the-art.

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**Room 130**

**Th1G** • Applications & Deployments of FTTx—Continued

**Th1G.3 • 08:30**

The Impact of Inter-platform Competition on the Economic Viability of Municipal Fiber Networks, Matthieu Tahon¹, Marlies Van der Wee¹, Sofie Verbruggje², Didier Colle¹, Mario Pickavet¹;¹Ghent Univ. - iMinds, Belgium. Local authorities investing in fiber broadband networks must meet the market investor principle. We apply a game theoretic approach to model the impact of inter-platform competition on the viability of the fiber business case.

**Th1G.4 • 08:45**

SDN and Potential Applicability to Access Networks, Nabil Bitar¹;¹Verizon, USA. This paper explores the applicability of the Software Defined Networking (SDN) paradigm to access networks. In particular, it describes Broadband and Enterprise use cases where SDN can play a role in enabling new network services.

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**Room 131**

**Th1H** • Novel Amplification Technologies & Signal Processors—Continued

**Th1H.3 • 08:30**

Next Generation Photonic Node Architecture Using Software-defined Universal Transceivers, Yasuhiro Aoki¹, Xi Wang¹, Goji Nakagawa¹, Shoichiro Oda¹, Kyosuke Sone¹, Taka-hito Tanimura¹, Takeshi Hoshida², Paparoa Palacharla³, Motoyoshi Sekiya², Jens Rasmussen⁴;¹Fujitsu Laboratories Ltd., Japan; ²Fujitsu Laboratories of America, Inc., USA; ³Fujitsu Ltd., Japan. Flexible and dynamic photonic node architecture for next generation software defined photonic network is described. The pooling architecture of universal transceivers provides the better utilization of network element.

**Th1I** • Next Generation ROADM and Photonic Switch Architectures—Continued

**Th1I.3 • 08:30**

Invited Next Generation Photonic Node Architecture Using Software-defined Universal Transceivers, Yasuhiro Aoki¹, Xi Wang¹, Goji Nakagawa¹, Shoichiro Oda¹, Kyosuke Sone¹, Taka-hito Tanimura¹, Takeshi Hoshida², Paparoa Palacharla³, Motoyoshi Sekiya², Jens Rasmussen⁴;¹Fujitsu Laboratories Ltd., Japan; ²Fujitsu Laboratories of America, Inc., USA; ³Fujitsu Ltd., Japan. Flexible and dynamic photonic node architecture for next generation software defined photonic network is described. The pooling architecture of universal transceivers provides the better utilization of network element.
Thursday, 13 March

**Room 102**

**Th1A** • Silicon Nitride and Liquid Crystal Devices—Continued

**Th1A.5** • 09:00
Low-loss/Large-tolerance Mode Converter Between SiN Waveguide and Cleaved Single Fiber, Li-anxi Jia1, Junfeng Song1,2, Tsung-Yang Liow1, Xianshu Luo1, Xiaoguang Tu1, Qing Fang1, Edward Koh Sing Chen1, Mingbin Yu1, Patrick Guo-Qiang Lo1, 1Inst. of Microelectronics, Singapore; 2State Key Laboratory on Integrated opto-electronics, China. A mode converter is fabricated with SiON to reduce coupling loss between SiN waveguide and cleaved single-mode fiber. The coupling loss is 1.2 and 1.4dB/facet for TE and TM mode with 3dB alignment tolerance of ±3.5µm.

**Th1A.6** • 09:15
Transmission of a 1.44 Tbit/s Data Stream using a Feedback-Stabilized SiN Kerr Frequency Comb Source, Joerg Pfeifle1, Yomin Yu1, Philipp Schindler1, Victor Brash2, Tobias Herr1, Claudius Weimann1, Klaus Hartinger1, Ronald Holzwarth1, 1Institute of Technology, Germany. We have developed quarter-wave shifted laser arrays with embedded bare patch regions. As cw-light sources in 40-Gb/s links, these lasers show over 10 dB improvement in back reflection tolerance compared to a standard DFB reference design.

**Room 121**

**Th1C** • Silicon Photonics I—Continued

**Th1C.3** • 09:00
An 8-Wavelength Laser Array with High Back Reflection Tolerance for High-Speed Silicon Photonic Transmitters, Laurent Schares1, Yoon H. Lee1,2, Daniel Kuchta1, Urs Koren1, Len Kateshni1, 1IBM TJ Watson Research Center, USA; 2Avago Technologies, USA; 3Cornell Univ., USA. We have developed quarter-wave shifted laser arrays with embedded bare patch regions. As cw-light sources in 40-Gb/s links, these lasers show over 10 dB improvement in back reflection tolerance compared to a standard DFB reference design.

**Th1C.4** • 09:15
Strain-induced Enhancement of Free-carrier Effects in SiGe for Optical Modulator and VOA Applications, Younghyun Kim1,2, Mitsuru Takenaka1, Takenori Osada1, Masahiko Hata1, Shinichi Takagi1, 1Univ. of Tokyo, Japan; 2Sumitomo Chemical Co. Ltd, Japan. Enhanced free-carrier effects in strained SiGe enable high-efficiency VOA, exhibiting 1/3 of power consumption of Si. The broadband operation from 1.34 to 1.64 µm and error-free operation for 18-dBm 12.5 Gb/s optical signal are obtained.

**Th1C.5** • 09:15
Dynamic Routing of Millimeter-Wave Signal for In-Building Networks Using Integrated Resonant Switch Matrix, Jim (Shihuan) Zou1, Prometheus DasMahapatra1, Patty Stabile1, Kevin Williams1, E. Tong-dingga2, A. Koonen1; 1COBRA, Eindhoven Univ. of Technology, Netherlands. We demonstrate dynamic routing between millimeter-wave pico-cells for in-building networks by using an integrated resonant switch matrix. The 128-QAM mm-wave signal exhibits an EVM of only 2.3% in the dynamic operation.

**Room 122**

**Th1D** • Network Subsystem—Continued

**Th1D.4** • 09:00
640 Gbit/s Optical Packet Switching using a Novel In-Band Optical Notch-Filter Labeling Scheme, Ashenafi Kiros Medhin1, Lei Katsuo Oxenløwe1, Michael Galli1, 1Department of Photonics Engineering, Technical Univ. of Denmark, Denmark. Optical packet switching of 640 Gbit/s data packets is reported using an in-band optical labeling technique based on notch-filters of the data spectrum and extracting the label using a bandpass filter. BER 10-9 is achieved.

**Th1D.5** • 09:15
Impact of Reducing Channel Spacing from 50GHz to 37.5GHz in Fully Transparent Meshed Networks, Annalisa Morea1, Jérémy Renaudier1, Aminhossein Ghazisaeidi1, Oniro Bertrand Pandol1, Thierry Zami1, 1Alcatel-Lucent France, France. Accounting for tight filtering impairments, we show why the ideal extra capacity of 33% brought by 37.5GHz channel spacing (compared to 50GHz) may be significantly reduced under physical constraints of fully transparent meshed networks.

**Room 123**

**Th1E** • Planning I—Continued

**Th1E.5** • 09:15
Optimized Amplifier Placements for Improved Energy and Spectral Efficiency in Protected Mixed-Line-Rate Networks, Jorge Lopez Vizcaino1,2, Yabin Ye1, Felipe Jimenez2, Andres Macho2, Peter Krummrich2, 1Huawei Technologies District of GmbH, Germany; 2Technische Universität Dortmund, Germany. We propose the selective placement of additional amplifiers to augment the energy and spectral efficiency of protected mixed-line-rate WDM scenarios. Significant energy efficiency per GHz improvements, network capacity enlargements and blocking reduction are achieved.
VOLKER JUNGNICKEL received a Dr. rer. nat. (Ph.D.) degree in physics from Humboldt University in Berlin in 1995. He worked on semiconductor quantum dots and laser medicine and joined Fraunhofer HHI in 1997. Since 2003, he is an adjunct lecturer at TU Berlin and project leader at HHI. He has contributed to high-speed indoor optical wireless links, first 1 Gb/s MIMO-OFDM mobile radio transmission experiments, a first real-time implementation and field trials for the LTE standard and using joint transmission coordinated multipoint (JCoMP). He has authored and co-authored more than 160 conference and journal papers, book chapters and patents.
Th1A • Panel: 100G Deployment on Submarine Links—Continued

Th1A.7 • 09:30 Variable Optical Power Splitter with Field-Induced Waveguides in Liquid Crystals in Paranematic Phase, Florenta Costache1, Haldor Hartwig1, Kirstin Bornhart2, Martin Blasl1; ‘Smart Micro-Optics SMO/AMS, Fraunhofer Inst. for Photonic Microsystems, Germany. A novel 1×2 variable optical power splitter based on field-induced waveguides in paranematic phase liquid crystals is reported. Continuously, voltage adjustable splitting with sub-microsecond response time is demonstrated on a device fabricated on silicon backplane.

Th1A.8 • 09:45 Bistable Switching Operation in a Si Sampled Grating Waveguide with Ferroelectric Liquid Crystals Cladding, Katsumi Nakatsuha1, Akifumi Kato1, Yoshiki Hayama1, Kanagawa Inst. of Technology, Japan; ‘The National Inst. of Advanced Industrial Science and Technology, Japan. A Si sampled grating waveguide with a ferro-electric liquid crystal cladding was proposed and fabricated. The bistable switching operation of the fabricated device, which was latched without state-sustaining power, was demonstrated.

Th1B • 100G Deployment on Submarine Links—Continued

Th1B • Panel: 100G Deployment on Submarine Links—Continued

Th1B.3 • 09:45 On the Usage of Multiflow Transponders under Anycast and Unicast Traffic in Elastic Optical Networks, Krzysztof Walkowiak1,2, Miroslaw Klinkowski3; ‘Systems and Computer Networks, Wroclaw Univ. of Technology, Poland, ‘National Inst. of Telecommunications, Poland. The impact of anycast and unicast traffic on transponder usage in both symmetric and asymmetric lightpath provisioning scenarios in Elastic Optical Networks is studied. Acceptable costs of multiflow transponders, with respect to 100G WDM transponders, are evaluated.

Th1C • Silicon Photonics I—Continued

Th1C.6 • 09:45 Demonstration of over 1000-Channel Hybrid Integrated Light Source for Ultra-High Bandwidth Interchip Optical Interconnection, Takanori Shimizu1,2, Makoto Okano1, Hirokiyuki Takahashi2, Nobuaki Hatani2, Masaishige Ishizaka1, Tsuyoshi Yamamoto1,2, Masahiko Morii1,2, Tsuyoshi Horikawa1,2, Yutaka Urino1,2, Takahiro Nakamura1,2, Yasuhiro Arakawa1,2; ‘PECST, Japan, ‘PETRA, Japan, ‘IAIST, Japan; ‘The Univ. Tokyo, Japan. An over 1000-channel hybrid integrated light source has been demonstrated by novel spot-size converters with a SiOx slab layer and by optimization considering thermal interference of multiple LD arrays for low power consumption.

Th1D • Network Subsystem—Continued

Th1D.6 • 09:30 Invited Photonic Interconnects for Data Centers, Tolga Tekin1,2, Nikos Piers2, Dimitris Apostolopoulos1; ‘System Integration and Interconnection Technologies, Fraunhofer IZM, Germany; ‘Research Center of Micropenephic Technologies, Technische Universität Berlin, Germany; ‘Centre for Research and Technology Hellas, Greece; ‘Inst. of Communications & Computer Systems / National Technical Univ. of Athens, Greece. Power consumption and size appear as the main set of barriers in next-generation Data Center. PhoxToT has been conceived to address optical interconnects at a holistic way among all hierarchy levels: chip-to-chip, board-to-board, rack-to-rack.

Th1E • Planning I—Continued

Th1E.6 • 09:30 Demonstration of All-optical Inverse Multiplexing in Elastic Optical Networks, Yingying Xu1, Junhao Li1, Paikun Zhu1, Bingli Guo1, Yuanxiang Chen1, Yucheng Zhang1, Yan Wang1, Zhangyan Chen1, Yangji He1; Peking Univ., China. We propose all-optical inverse multiplexing in elastic optical networks using superchannel multicasting to achieve efficient spectrum utilization. We show the benefit by simulation and demonstrate the feasibility by experiment on OFDM superchannel.

10:00–12:00 Th2A • Poster Session II, North, Exhibit Hall C

10:00–16:00 Exhibition and Show Floor, Exhibit Halls A, B, C, North, Exhibit Hall D

10:00–13:00 Unopposed Exhibit-Only Time, Exhibit Halls A, B, C, North, Exhibit Hall D
A Practical Approach For Excess Bandwidth Distribution for EPONs, Amr Elrasad1, Basem Shihada1; 1CEMSE, KAUST, Saudi Arabia. This paper introduces a novel approach called Delayed Excess Scheduling (DES), which practically reuse the excess bandwidth in EPONs system. DES is suitable for the industrial deployment as it requires no timing constraint and achieves better performance compared to the previously reported schemes.

Distributed Measurement of Signal Power Evolution in a Phase Sensitive Parametric Amplifier, Fatemeh alishahi1, Armand Vedadi1, Marcelo Soto1, Andrey Denisov1, Khashayar Mehrany2, Luc Thevenaz2, Camille-Sophie Bres1; 1Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland; 2Sharif Univ. of Technology, Islamic Republic of Iran. A method to measure the signal power evolution along phase-sensitive parametric amplifiers is proposed using Brillouin optical time-domain analysis. Different evolutions along the fiber are reported by varying input wave phases, including amplification and de-amplification.

Invited Flexibility in Submarine Fiber Optic Networks, Bruce Nyman; 1TE Sub-Com, USA. Submarine networks are migrating from static to reconfigurable configurations, and are adopting OADM technology similar to that being deployed in terrestrial networks. We will examine the different technology and operating issues involved in implementing flexibility in terrestrial versus submarine networks.
A High Efficiency Nonlinear Compensation Algorithm with Reduced Complexity Based on XPM Model, Yangyang Fan, AIMIE of A*Star, Singapore, Singapore; 2State Key Laboratory of Electronic Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts & Telecommunications, China. We present an analysis procedure for the high-speed silicon depletion-mode Mach-Zehnder modulator. The bandwidth performances, including electrical scattering parameters, electro-optic modulation responses and modulated optical signals at different frequencies, were characterized and verified by measurements.

A Unibroadband Fiber Grating Coupler with Focused Curved Subwavelength Structures, Qiangqiang Zhang, Wei Yang, Ziyu Wang, Xingjun Wang, Xianjun Cai, Xingjun Wang, Peking Univ., China; 2State Key Laboratory of Optical Communication Technologies and Networks, Wuhan Research Inst. of Posts & Telecommunications, China. We present an analysis procedure for the high-speed silicon depletion-mode Mach-Zehnder modulator. The bandwidth performances, including electrical scattering parameters, electro-optic modulation responses and modulated optical signals at different frequencies, were characterized and verified by measurements.

Adiabatically Widened Silicon Microring Resonators with Improved Tolerance to Wafer-scale Variations, Jerec C. Mikkelsen1, Department of Electrical and Computer Engineering, Univ. of Toronto, Canada. Silicon microrings with adiabatically widened bends are more tolerant to dimension-al variations than standard designs. Improvements in the intra-die and wafer-scale variation of the resonance wavelength are demonstrated in the IMEC passive processes.

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Th2A.35 High-speed Silicon Modulators with Slow-wave Electrodes, Ran Ding, Yingyan Ma, Yang Liu, You Yang, Andy L. Lim, Patrick Guo-Giang Lo, Tom Baehr-Jones, Michael Hochberg, Electrical and Computer Engineering, Univ. of Delaware, USA; *Inst. of Microelectronics, A*STAR (Agency for Science, Technology and Research), Singapore, *Inst. of Electrical and Computer Engineering, Nanyang Technological University, Singapore, *Inst. of Electrical and Computer Engineering, National Univ. of Singapore, Singapore. We demonstrate a high-speed dual-drive silicon traveling-wave modulator with slow-wave, periodically phase-shifted mismatched-line electrodes and discuss the design aspects of such an approach. Our design also ensures true single-RF-mode operation independent of signaling schemes.

Th2A.36 IFIT Stage-dependent Minimum Bit Maps for Real-time Optics, Jianming Yang1,2, Tingfang Tang1, Junjie Zhang1, Wenyuan Yuan1,2, Roger Giddings,3 Min Wang1, School of Electronic Engineering, Bangor Univ., UK; *Key Laboratory of Spectral Fiber Optics and Optical Access Networks, Shanghai Univ., China. To significantly reduce the FPGAASIC resource consumption, we numerically identify and experimentally verify that, for the first time, an optimum map of minimum bit-resolutions of different IFIT stages against DAC resolutions.

Th2A.37 Impact of Fabrication Non-Uniformity on Chip-Scale Silicon Photonic Integrated Circuits, Lukas Chrostowski, Xu Wang, Jonas Flueckiger, Yichen Wu1, Yun Wang, Sahba Talebi Farid, *Electrical and Computer Engineering, Univ. of British Columbia, Canada. This study of 371 identical resonators on a 16x16 chip fabricated by a silicon photonics foundry reveals a strong linear correlation between the physical distance between devices and the variance in their wavelength mismatch.

Th2A.38 Improvement of Signal Quality after Long-Haul Transmission over Multi-Core Fiber with Adaptive MIMO-FDE Using Time-Domain Coefficient Selection, Manabu Ankawa,1,2,3, Emmanuel Le Taillandier de Gabory,1 Toshiharu Ichihara,1,2, Kiyoshi Fukuchi,1,2, Green Platform Research Laboratories, NEC Corporation, Japan. We show numerically signal degradation due to excess noise in adaptive MIMO-FDE used on transmission over MCF. We propose coefficient selection in time domain with an up to 2.9 dB of Q factor improvement.

Th2A.39 Inverse Dispersion Design in Silicon Waveguides, David Castello-Lurbe1, Victor Torres-Company2, Enrique Silvestre1,1 Department of Optica, Universidad de Valéncia, Spain; *Microwave and Nanoscience Department (M2C), Chalmers Univ. of Technology, Sweden. We present a numerical tool to find the cross-section geometry of silicon-on-insulator waveguides that leads to a target dispersion profile. In <10 iterations, we achieve geometries leading to a target dispersion profile. We present a numerical tool to find the cross-section geometry of silicon-on-insulator waveguides that leads to a target dispersion profile. In <10 iterations, we achieve geometries leading to a target dispersion profile.

Th2A.40 Inverse Mode Area Hybrid Multi-trench Fiber for Anomalous Dispersion, Deepak Jain1,2, Catherine Baskiotis1, Jayanta K. Sahu1,2, Jonathan C. Knight1; 1Department of Physics, University of Southampton, UK; 2National Physical Laboratory, Teddington, National Inst. of Ireland. *Irish Centre for High-End Research, Ireland. High performance laser is integrated on Si substrates with monolithically coupled polymer waveguides. The design allows 2μm misalignment, consistent with CMOS fabrication. 16x4 mm gap and 8dB loss were demonstrated with improvement paths to <2dB loss.

Th2A.41 Laser Integration with CMOS Assemble Process for Si Photonics, Ricky Tseng,1 James O’Callaghan1, Feras Eid1, Michael Gleeson1, Brandon Rawlings1, Mauro Kobrinsky1, Ibrahim Ban1, Roger Nagle1, Brian Corbett1, Peter Chang1, Components Research, Technology Manufacturing Group, Intel Corporation, USA; *Institute of Science, Technology and Innovation, Linköping University, Sweden. We present a numerical tool for the first time, of an optimum map of numerical identifications and experimental validation by Combination of an EDFA and a SBS Laser Ring cavity, Dinhuan Wang, Wengang Gao, Zhongshuo Duan,1, Tonglei Cheng,1, Takenobu Suzuki2, Yasutake Ohishi1, *Research Center for Advanced Photon Technology, RCAST, The University of Tokyo, Japan. Large negative group velocity propagation of optical pulse was demonstrated by the combined fast light effects and thermal suppression in an EDFA and a stimulated Brillouin scattering laser ring cavity.

Th2A.42 Low-Complexity Training-Aided 2x2 MIMO Frequency Domain Fractional Spaced-Antenna Using Intrinsic Faraday Effect, Jayanta K. Sahu1,2, Jonathan C. Knight1; 1Department of Physics, University of Southampton, UK; 2National Physical Laboratory, Teddington, National Inst. of Ireland. *Irish Centre for High-End Research, Ireland. We propose to monitor OSNR by using an optical phase portrait that is depicted by single low-speed sampler with software synchronization technique. This method reduces moni- toring setup cost, and increases tolerance to the aliased clock frequency estimation offset.

Th2A.43 Magnetooptic Nonlinear Optical Loop Mirror for All-optical 3R Signal Regeneration, Feng Wen1,2, Bao-Jian Wu1, Xing-Yu Zhou1, Hao Yuan1, Kun Qiu1, Key Lab of Optical Fabrication and Communications, Ministry of Education, Univ. of Electronic Science and Technology of China, China. A magnetooptic nonlinear optical loop mirror using intrinsic Faraday Effect of fibers is proposed. Magnetically controllable regeneration control is implemented with the output and the receiver sensitivity im- provement is further improved by 1.7dB under 200Gs magnetic field.

Th2A.44 Multi-function Demonstration for Multi Core Fiber Fan-in/Fan-out Module and Evanescent Free Space Optics, Yu-saku Totton1, Hiroshi Itozou1, Tetsuya Kobayashi2; *OPTOQUEST CO., LTD, Japan. Multi-functionality is demonstrated for multi core fiber fan-in/fan-out device using free space optics by an isolator at the beam intersection. Insertion loss and isolation are below 0.7 dB and over 50 dB, respectively.

Th2A.45 Negative Curvature Fibers with Reduced Loss, Yuki Takeyama, Jonathan C. Knight1; Physics, Univ. of Bath, UK. We describe improved designs for “negative curvature” hollow core anti-resonant fibers. Numerical simulations show that introducing additional silica rings into the cladding results in a major reduction in the fiber leakage losses, for realizable fiber structures.

Th2A.46 Negative Group Velocity Propagation by Combination of an EDFA and a SBS Laser Ring cavity, Jinghuan Wang, Wengang Gao, Zhongshuo Duan1, Tonglei Cheng,1 Takenobu Suzuki2, Yasutake Ohishi1; *Research Center for Advanced Photon Technology, RCAST, The University of Tokyo, Japan. Large negative group velocity propagation of optical pulse was demonstrated by the combined fast light effects and thermal suppression in an EDFA and a stimulated Brillouin scattering laser ring cavity.

Th2A.47 Novel Design of Large-Mode-Area Rod-Type Fibers with Negative Curvature Trenches at 1 μm, Jitthapan J1,2, Jian Sun1,2,3, Johan Nilsson1,2, Seong-woo Yoo1,2,3; EEE, Nanyang Technological University, Singapore; *IORC, Univ. of Southampton, UK; *Inst. of Lightwave Technologies, Beijing Jiaotong Univ., China. A novel large-mode-area fiber with negative curvature is proposed. A fundamental mode effective area is over 5000 μm^2 with only 10.6 μm. Higher-order modes can be effectively suppressed by 100 times higher losses.

Th2A.48 On-Chip Demultiplexing of Polarization and Wavelength Multiplexed OFDM/QAM Signals using Silicon 2D Grating Coupler and Microring Resonators, Jian Wang, Chengcheng Gu1, Chao Li, Qin Yang1, Xinliang Zhu1; "Wuhan National Laboratory for Optoelectronics, Huazhong Univ. of Science and Technology, China; *State Key Laboratory of Optical Comm. Technologies and Networks, China. We design and fabricate an on-chip polarization and wavelength multiplexing demultiplexer incorporating silicon 2D grating coupler and microring resonators. Moreover, we experimentally demonstrate the demultiplexing of polarization and wavelength multiplexed OFDM/QAM signals.

Th2A.49 OSNR Monitoring by Using Single Sampling Channel Generated 2-D Phase Portrait, Yi Yu1,2, Changhai Yu1;1 National Univ. of Singapore, Singapore; *A*STAR Inst. for Info- comm Research (I2R), Singapore. We propose to monitor OSNR by using a 2-D phase portrait that is depicted by single low-speed sampler with software synchronization technique. This method reduces monitoring setup cost, and increases tolerance to the aliased clock frequency estimation offset.

Th2A.50 Over 300 Channels Uncoupled Few-mode Multi-core Fiber for Space Division Multiplexing, Tatsuhiko Watanabe1, Yasuo Kokubun1; Graduate school of engineering, Yokohama National Univ., Japan. Over 350 channels can be theoretically accom- modated in a 1×200μm diameter of a fiber.

Th2A.51 Path to Silicon Photonics Commercialization: 25 Gb/s Platform Development in a CMOS Manufac- turing Foundry Line, Andy E. Lim1, Tsung-Yang Liou1; Junfeng Song1, Chao Li1, Qing Fang1, Xiaoqiang Tu1, Ning Duan1, Kok Kiong Chen1, Roger Poh Cher Ten1, Chuan Peng1, Bong woo Mung1, Mohd Nurul Islam2, Jee Soo Park1, Chivukula Subbu1, Patrick Guo-Giang Lo1; *Inst. of Microelectronics, Singapore; *Globalfoundries, Singapore. Silicon photonics platform in a commercial 0.18 μm CMOS foundry line is described. Low-loss Si passives and high speed germa- nium photodetectors (>20GHz) with low dark current (<11A) and high responsivity (1.06A/W) at 1550nm are presented.

Th2A.52 PLC-type LP11 Mode Rotator with Single-trench Waveguide for Mode-division Multiplexing Transmission, Takashimata1, Nobuteru Hansatani1, Kunimasa Saitoh1, Yuhei Ishizaka1, Kouhei Masumoto1, Taji Sakamoto2, Takanishi Matsui1, Kyoju Tujiwaka1, Fumiaki Yamamoto1; School of Information Science and Technology, Hokkaido Univ., Japan; *NTT Access Network Service Sys- tems Laboratories, NTT Corporation, Japan. PLC-type LP11 mode rotator with a single-trench waveguide is designed and fabricated. Converting LP11a (LP11b) mode into LP11b (LP11a) mode is achieved with high conversion efficiency over a wide wavelength range.

Th2A.53 Pulse Design Trade-Offs for Spectrument-Efficient PDM-WDM Coher- ent Optical Transmission Systems, Amirhossein Ghaziaseheid1, Jessica Fickers1, Gabriel Charlet1; *Bell Labs, France; *Université Libre de Brux- elles, Belgium. We study the joint effect of pulse spectral rolloff and impulse-response truncation length on the performance of densely packed root-raised cosine pulse-shaped 32 Gbaud PDM-QPSK and 16QAM, through extensive bit-error-rate and spectrum measurements.
Th2A.54 Record-high Sensitivity Receiver Using Phase Sensitive Fiber Optical Parametric Amplification, Rohit Malik; Samuel Olsson; Peter A. Androck; Carl Lundstrom; Magnus Karlsson; Chalmers Univ. of Technology, Sweden. We demonstrate record sensitivity (55 photons/bit) for on-off keying modulation at 10 Gb/s using a phase sensitive amplifier as preamplifier. Experimental results depicting the effects of pump phase modulation on the sensitivity are reported.

Th2A.55 Reduced Wafer-Scale Frequency Variation in Adiabatic Microring Resonators, Zhan Su, Ehsan S. Hosseini, Erman Timurdogan, Jie Sun, Gerald Leake, Douglas D. Coobaugh; Michael R. Watts. Research Laboratory of Electronics, Massachusetts Inst. of Technology, USA; College of Nanoscale Science & Engineering, Univ. at Albany, USA. We experimentally demonstrate that adiabatic microring resonators not only achieve high quality factors in the presence of electrical contacts but, importantly, exhibit reduced susceptibility to wafer-scale fabrication induced resonant frequency variations compared to standard microrings.

Th2A.56 Reducing Cabling Complexity in Large Flattened Butterfly Networks by an Order of Magnitude, Marton Cserna1, Florin Ciucu1, Ralf-Peter Braun1, András Gulyás1,2, Budapest Univ. of Technology and Economics, Hungary; Univ. of Warwick, UK; Deutsche Telekom AG, Germany; Hungarian Academy of Science, Information System Research Group, Hungary. We show that cabling complexity in large flattened butterfly networks can be reduced by an order of magnitude, without increasing capital costs or control plane complexity, by employing DWDM transceivers and arrayed waveguide grating routers.

Th2A.57 Robust and Controllable Generation of Frequency Combos in Microresonators with Selected Sideband Feedback, Yufeng Jiang, Xin Zhao, Jian Wang, Ben Niu, Ya Li, Guoping Hu, Pei-Hsun Wang, Minghao Qi, Andrew M. Weiner, Zheng Zheng; School of Electronic and Information Engineering, Beijing Univ., China; School of Electrical and Computer Engineering & Birck Nanotechnology Center, Purdue, USA. With feedback and amplification at selected sidebands of a SiN microring spectrum, we achieve controllable line spacing in the generated comb under relaxed pumping conditions. Such reduced pump power requirement is beneficial for many applications.

Th2A.58 Design of 3-dB Directional Coupler with Weak Gap Sensitivity for Silicon Wire Waveguide, Guang-Wei Cong, Keijiro Suzuki, Sanghun Kim, Ken Tanizawa, Shu Namiki, Hitoshi Kawashima; AIST, Japan. We designed a robust 3-dB directional coupler which has a narrow silicon core and a wide gap. Performance insensitivity is improved by more than 10 times from the conventional coupler. Better stability was experimentally verified.

Th2A.59 Scalable and Distributed Optical Network Architecture based on AWGR for HPC and Data Centers, Roberto Proietti, Zheng Cao, Yuliang Li, S.J. Ben Yoo; Univ. of California Davis, USA. We propose an AWGR-based scalable optical direct interconnect architecture exploiting a flat distributed Thin-CLOS topology at the core-layer. The architecture scales beyond 100,000 nodes with a diameter of 7, low latency, high degree and throughput.

Th2A.60 Scalable and Topology Adaptive Intra-data Center Networking Enabled by Wavelength Selective Switching, Zhonghua Zhu1, Shan Zhong1, CoAdra Photonics Inc, USA. We present an enhanced n-ary, 2 flat distributed optical switching architecture for intra-DC interconnection which using existing WSS components. The proposed architecture is highly scalable, topology adaptive and suitable for dynamic and diverse traffic pattern.

Th2A.61 Silicon Ridge Waveguide Directional Couplers with Improved Tolerance to Wafer-scale Variations, Jared C. Mikkelsen, Wesley Sacher, Joyce Poon1; Department of Electrical and Computer Engineering, Univ. of Toronto, Canada. Silicon directional couplers are designed to be tolerant to width, height, coupling gap, and etch depth variations. Improvements in the wafer-scale variation of the splitting ratio are demonstrated in the IMEC Standard Passives process.

Th2A.62 Stability of Fiber Bragg Gratings Fabricated Using UV Ar+ and ArF Excimer in Bismuth-aluminum-doped Silica Fibers, Georgios Violakis, Hans G. Limpert1, Valery M. Mashinsky, Evgeny M. Dianov; Ecole Polytechnique Federale de Lausanne, Switzerland; Fiber Optics Research Center, Russian Federation. Continuous annealing of fiber Bragg gratings fabricated using cw and pulsed laser irradiation in Bi-Al fibers of different concentrations show activation energy spectra linked to Bi-Al. Thermal stability maps were obtained by their analytical representation.

Th2A.63 Time-interleaved Carrier-suppressed Return-to-Zero QPSK for Filter-less Dual-carrier Transmission, Takahide Sakamoto1, Guo-Wei Lu1, Tetsuya Kawanishi1; NICET, Japan. We demonstrate time-interleaved carrier-suppressed return-to-zero (Th-CSRZ) signaling, aiming for high-spectral-efficiency dual-carrier transmission. Optical filter-less modulation and demodulation schemes are proposed, achieving 40-Gb/s Th-CSIRZ-QPSK.

Th2A.64 Transmission and Reception of Quad-Carrier QPSK-OFDM Signal with Blind Equalization, Fan Li1, Jianwen Zhang1, Jiangnan Xiao2, Xinying Li2; ZTE Corporation, USA; Hunan Univ., China; Fudan Univ., China; Georgia Inst. of Technology, USA. Quad-Carrier QPSK-OFDM signal transmission and reception is successfully demonstrated with blind equalization like a 25-QAM signal with CMMA equalization. The phase recovery can be realized with simple Viterbi algorithm and the FFE should be done after 4 subcarriers are separated with FFT.

Th2A.65 Tunable Third-harmonic Generation in a Novel Chalcogenide-tellurite Hybrid Optical Fiber, Tonglie Cheng, Tinghun Deng, Weiqing Gao, Zhongchao Duan, Takenedu Suzuki, Yasutake Ohishi; NICT, Japan. A novel chalcogenide-tellurite hybrid optical fiber was fabricated. And Tunable third-harmonic generation from 568 nm to 869 nm is observed with the phase wavelength changing from 1700 to 2600 nm.

Th2A.66 Ultra-small, Low-crosstalk, Electrically-driven InGaAsP Photonic-wire Optical Switches on III-V CMOS Photonics Platform, Yuki Ikku1, Masafumi Yokoyama1, Osamu Ichikawa2, Takenori Osada3, Masahiko Hata4, Mitsuaki Takenaka1, Shinichi Takagi1; Univ. of Tokyo, Japan; Sumitomo Chemical Company Ltd., Japan. Ultra-small, electrically-driven InGaAsP photonic-wire optical switches are demonstrated. Large carrier-induced index change in InGaAsP enables low crosstalk of -29 dB even with 50-μm-long phase shifters. 50-Gb/s WDM signals are successfully transmitted within 2-db power penalty.
Room 102
13:00–15:00
Th3A • Semiconductor Lasers
Presider: Liming Zhang; Alcatel-Lucent Bell Labs, USA

Room 120
13:00–15:00
Th3B • Resilient Networks
Presider: Ron Johnson; Cisco Systems, Inc., USA

Room 121
13:00–15:00
Th3C • Low Power VCSEL Interconnect
Presider: Ali Ghiassi; Ghiassi Quantum LLC, USA

Room 122
13:00–14:45
TH3D • RF Photonic Processing
Presider: Periklis Petropoulos; Optoelectronics Research Centre, UK

Room 123
13:00–15:00
TH3E • DSP Algorithms I
Presider: Noriaki Kaneda; Bell labs, USA

Room 124
13:00–15:00
Th3F • Demultiplexers and Switches
Presider: Joris Van Campenhout; InterUniv. Microelectronics Center, Belgium

Th3A.1 • 13:00 Invited
56-Gb/s Direct Modulation in InGaAlAs BH-DFB Lasers at 55°C, Kouji Nakahara1, Yuki Wakayama1, Takeshi Kitada1, Takafumi Taniguchi1, Toshikiro Fujimaki2, Yasushi Kama3, Shigehisa Tanaka1; Hitachi,Ltd, Japan; 2Oclaro Japan, Inc., Japan. Direct modulation at 56 Gb/s of 1.3-µm InGaAlAs-MQW DFB laser, incorporating a ridge-shaped buried heterostructure (RS-BH), operating at 55°C, is experimentally demonstrated for the first time.

Th3B.1 • 13:00 Invited
Multi-layer Restoration - The Impact on the Optical Layer, Matthias Gunkel1; ‘Optical Packet Transport, Deutsche Telekom, Germany. Multi-layer resilience including optical restoration against optical failures and backup interfaces provisioned against port failures is considered from an operator’s perspective. This approach saves 25%-30% of the IP links in Deutsche Telekom’s core network.

Th3C.1 • 13:00 Invited
The Evolution of 850nm VCSELS from 100Gb/s to 25 and 56Gb/s, Jim Tatum1; Finisar Corporation, USA; VCSELS are now being commercially deployed in applications up to 28Gbps. This paper will present a review of current VCSEL and PD capability and explore the technology development required to extend operation to even higher data rates.

TH3D.1 • 13:00
High-resolution, Photonically-sampled, Analog-to-Digital Conversion Employing Spatial Oversampling, Ori Golan1, Luca Mauri1, Fabiano Pasinato1, Cristian Cattaneo1, Guido Consanomi2, Stefano Balsamo2, Dan Maram1; ‘Applied Physics, Hebrew Univ., Israel; 2Oclaro Corporation, Italy. Photonically-Sampled analog-to-digital conversion utilizing a spatial oversampling technique is described and experimentally demonstrated. Spatial oversampling’s ability to boost the ADC’s resolution is verified. Digitization of a 13GHz signal with 6.3 ENOB is demonstrated.

TH3E.1 • 13:00
Noise Power Directed Adaptive Frequency Domain Least Mean Square Algorithm with Fast Convergence for DMGD Compensation in Few-Mode Fiber Transmission Systems, Xuan He1, Yi Weng1, Junyi Wang1, Zhongqi Pan1; ‘Electrical and Computer Engineering, Univ. of Louisiana at Lafayette, USA; ‘LinkQuest Inc, USA. We investigate a fast convergence adaptive FD-LMS algorithm for compensating DMGD in few-mode fiber systems. The new algorithm increases the convergence speed by 54% over conventional adaptive FD-LMS method with 8.1% hardware complexity increase.

TH3F.1 • 13:00 Top-Scored
Compact Wavelength Selective Switch Based on High-density Bragg Reflector Waveguide Array with 120 Output Ports, Xiaodong Gu1, Fumi Koyama2; ‘Photonics Integration System Research Center, P&I Lab., Tokyo Inst. of Technology, Japan. A wavelength selective switch based on a Bragg reflector waveguide array is proposed with 120 output ports, exhibiting switching to arbitrary ports. The dense waveguide array with giant angular-dispersion enables large-scalability in small footprint.

TH3F.2 • 13:15 Top-Scored
Output Ports, Christian G. Schäffer1,2, Abdul Rahim1,3, Stefan Schwarz1, Jürgen Bruhn1, Lars Zimmermann1, Sheikh Jalil Ahmed1, Christian G. Schäffer2, Klaus Petermann1; ‘Fachgebiet Hochfrequenztechnik, Technische Universität Berlin, Germany; ‘Department of High-Frequency Engineering and Optoelectronics, Helmut-Schmidt-Universität, Germany; ‘Institute 16 channel DFT filter based on 4×4 MMI couplers is designed and fabricated in SOI. The characterization of device has shown that it can demultiplex 16×36.5 Gbaud QPSK modulated sub-carriers of an O-OFDM super-channel.

PAPERS ARE AVAILABLE ONLINE FOR DOWNLOAD. VISIT WWW.OFCONFERENCE.ORG AND CLICKING ON THE "DOWNLOAD DIGEST PAPERS" BUTTON.
Th3G.1 • 13:00  
32-dB Loss Budget High-Capacity OFDM Long-Reach PON over 60-km Transmission without Optical Amplifiers, Chia-Chien Wei1, Hsing Yu Chen2,3, Hsuan-Hao Chu1, Yu-Chao Chen3, Chih-Yuan Song3, I-Cheng Lu1, JyeHong Chen1; 1National Sun Yat-sen Univ., Taiwan; 2National Chiao Tung Univ., Taiwan; 3Industrial Technology Research Inst., Taiwan. For the first time, 33-Gbps 60-km OFDM transmission is demonstrated to show 32-dB loss budget without inline and pre-amplifier. Employing 10-GHz EAM and PIN, the long-reach PON can economically support 32 ONUs with >1-Gbps/ONU capacity.

Th3I.1 • 13:00  
Benefits of Active Stateful PCE for Flexgrid Networks, Filippo Cugini1, Francesco Paolucci1, Francesco Presi1, Gianluca Meloni1, Gianluca Berretti1, Nicola Sambo2, Alessio Giorgetti1, Tommaso Foggi1, Luca Poti1, Piero Castoldi1, 1CNIT, Italy; 2Scuola Superiore Sant’Anna, Italy. Relevant benefits of the active stateful PCE architecture are experimentally demonstrated on a flexgrid network testbed. Two experiments are reported, including a first demo on PCE-controlled code-adaptation applied to a 1Tb/s super-channel.

Th3K.1 • 13:00  
10 Gb/s CAP128 System Using Directly Modulated Laser for Short Reach Optical Communications, Li Tao1, 2, Yiguang Wang1, Yuliang Gao1, Alan Pak Tao Lau1, Chao Lu1, 1Department of Communication Science and Engineering, Fudan Univ., China; 2Photonics Research Center, Department of Electronic and Information Engineering, The Hong Kong Polytechnic Univ., Hong Kong. We experimentally demonstrate a 10.5 Gb/s CAP128 system over 40 km SSMF using DML and direct-detection, with a hybrid MMA/DD-LMS equalization scheme. The influences of RIN and laser linewidths of the DML are also investigated.

Th3J.1 • 13:00  
Top-Scored  
Generation and Transmission of 100-Gb/s PDM 4-PAM Using Directly Modulated VCSELs and Coherent Detection, Chongjin Xie1, Silvia Spiga2, Po Dong3, Peter J. Winzer4, Alan Gnauck1, Christoph Gréus2, Christian Neumeyer2, Markus Ortsiefer2, Michael Müller2, Markus Amann2, 1Alcatel-Lucent Bell Labs, USA; 2Walter Schottky Institut, TU München, Germany; 3VERTILAS GmbH, Germany. We generate a 100-Gb/s polarization-division-multiplexed 4-level pulse-amplitude-modulation signal with two directly modulated 1.5-µm single-mode VCSELs. Coherent detection and digital signal processing enable the transmission over 400-km standard single-mode-fiber (SSMF) with 20% overhead hard-decision forward-error-correction.
Th3A • Semiconductor Lasers—Continued

Th3A.2 • 13:30 Tunable 16 DFB Laser Array with Unequally Spaced Passive Waveguides for Backside Wavelength Monitor, Yoshifumi Sasahata1, Keisuke Matsumoto1, Takashi Nagira1, Hitoshi Sakuma1, Kazumasa Kishimoto1, Masato Suzuki1, Daikuke Suzuki1, Yuichiro Horiguchi1, Masakazu Takabayashi2, Keita Mochizuki1, Mitsunobu Gotoda2, Hiroshi Aruga3, Eitaro Ishimura1, High Frequency & Optical Device Works, Mitsubishi Electric Corporation, Japan; 2Advanced Technology R & D Center, Mitsubishi Electric Corporation, Japan; 3Information Technology R & D Center, Mitsubishi Electric Corporation, Japan.

Th3B • Resilient Networks—Continued

Th3B.2 • 13:30 Fast Restoration in SDN-based Flexible Optical Networks, Alessio Giorgetti1, Francesco Paolucci1, Filippo Cugini1, Piero Castoldi1, 2TeCIP, Scuola Superiore di Studi Universitari e di Perfezionamento Sant’Anna di Pisa, Italy; 3CNIT, Italy. The benefits of the SDN control plane to drive fast restoration are demonstrated on Flexible Optical Networks. Required OpenFlow extensions are detailed. Simulations report improved recovery time with respect to GMPLS/PCE restoration.

Th3C • Low Power VCSEL Interconnect—Continued

Th3C.2 • 13:30 Top-Scored 64Gb/s Transmission over 57m MMF using an NRZ Modulated 850nm VCSEL, Daniel Kuchta1, Alexander V. Rylaykov1, Clint L. Chown2, Johan Thorsen3, Johan S. Gustavsson1, Anders Larsson1, 1IBM T.J. Watson Research Center, USA; 2Dept. of Microelectronics and Nanoscience, Photonics Laboratory, Chalmers Univ. of Technology, Sweden. We report a directly modulated 850nm VCSEL-based optical link operating error free (BER < 1E-12) at 64Gb/s over 57m of OM4 multimode fiber. At 60Gb/s, the error free distance increases to 107m.

Th3D • RF Photonic Processing—Continued

Th3D.3 • 13:30 Tunable Frequency-doubling Brillouin Optoelectronic Oscillator Using Single-sideband Suppressed-carrier Modulation, Jiuhao Zang1, Yan Li1, Zhisheng Yang1, Qiang Wu1, Wei Li1, Rongqing Hui1, Jintang Lin1, 1Beijing Univ. of Posts and Telecommunications, China. A tunable frequency-doubling Brillouin optoelectronic oscillator pumped by a single-sideband suppressed-carrier modulated light is demonstrated. Microwave signal with a frequency range of 21.8-41.8GHz is generated using a RF source lower than 10GHz.

Th3E • DSP Algorithms I—Continued

Th3E.3 • 13:30 Feed-Forward and Feedback Timing Recovery for Nyquist and Faster than Nyquist Systems, Nebojsha Stojanovic1, Yu Zhao1, Changsong Xie1, Huawei, Germany. We present a novel timing recovery architecture for Nyquist systems having their performance independent of the Nyquist filter and modulation formats. Excellent performance is demonstrated even in extremely bandlimited systems, called faster than Nyquist systems.

Th3F • Demultiplexers and Switches—Continued

Th3F.3 • 13:30 Fine Resolution Arbitrary Optical Filtering with a Hybrid Guided-Wave/Free-Space Optics Platform, David Snelfield1, Ray Rudnick1, Oni Golani1, Noam Goldstein1, 1Hebrew Univ. of Jerusalem, Israel. We apply a spatial light modulator to spectrally dispersed light at extremely fine resolution to realize an optical filter with the ability to set any spectral amplitude and phase modulation, subject to the optical resolution limit.
Th3G • OFDM-based Optical Access—Continued

Th3G.3 • 13:30
50-Gbps 100-km EAM-based OFDM-IMDD Transmission Employing Novel SS1 Cancellation, Hisung Yu Chen1, Chia-Chien Wei2, Yu-Chao Chen3, Hsuan-Hao Chu4, Chih-Yuan Song5, I-Cheng Lui1, Jiehong Chen7, Industrial Technology Research Inst., Taiwan; 2National Chiao Tung Univ., Taiwan; 3National Sun Yat-sen Univ., Taiwan. We build a new SS1 cancellation technique to compensate both modulator nonlinearity and dispersion-induced nonlinear distortion. Employing the SS1 cancellation to optimize EAM operation, superior 50-Gbps EAM-based OFDM-IMDD transmission over 100-km SSMF is successfully demonstrated.

Ken-Ichi Suzuki, Ph.D. Senior Research Engineer, Supervisor, NTT Access Network Service Systems Laboratories, Taiwan. This tutorial presents activities of conformance and interoperability testing for EPON systems, especially SIOPP compliant ones, in IEEE 1901.4 WG and related organizations. I also show activities for interoperability tests and events in Japan.

Th3H • Access Networks—Continued

Th3H.2 • 13:30 Top-Scored
Activities for Conformance and Interoperability Testing in EPON Standardization, Ken-Ichi Suzuki1, NTT Access Network Service Systems Laboratories, Japan. This tutorial presentation introduces activities of conformance and interoperability testing for EPON systems, especially SIOPP compliant ones, in IEEE 1901.4 WG and related organizations. I also show activities for interoperability tests and events in Japan.

Th3I • SDN and PCE—Continued

Th3I.3 • 13:45
Flexible-Client: The Missing Piece Towards Transport Software-Defined Networks, Ankikumar Patel1, Konstantinos Kanakasis1, Philip N. Ji2, Junqiang Hu1; 1NEC Laboratories America Inc, USA; 2Huawei Technologies Co., Ltd., China. We report the experimental testbed evaluation of connectivity provisioning in which OpenFlow and GMPLS control planes interwork by means of an orchestrating stateful PCE. The hierarchical nature of the PCE allows seamless multi-domain operation.

Th3J • Advanced Optical Transceivers—Continued

Th3J.3 • 13:45
448 Gbit/s DP-16QAM Transmission Using Integrated Tunable CMOS Laser Sources, Elton Marchena1, Marco Camera1, Gianmarco Bruno2, Hacene Chaouch1, Sam Albanna1, Hong Cai3, Chris Bliss1, Lina He2, John Zyskind1, Stephen Krasulick1, Antonio Tartaglia2, Amit Mizrahi2, Rob Stone4; 1Skorpios Technologies, Inc., USA; 2Skorpios Technologies, Inc., USA; 3KDDI R&D Laboratories America Inc, USA; 4ELDIS, Republic of Korea. We demonstrate 448 Gbit/s transmission using CMOS silicon photonic, hybrid-integrated, full-band tunable lasers as transmit and local oscillator for 28 GBaud DP-16QAM. Marginal system performance differences were measured when compared with conventional commercially available lasers, proving suitability for coherent applications.

Th3K • Direct Detection—Continued

Th3K.3 • 13:30 Top-Scored
First Experimental Demonstration of Coherent CAP for 300-Gb/s Metropolitan Optical Networks, Jose Estaran1, Miguel Iglesias1, Darko Zibar2, Xiaogeng Xu3, Idefonso Tafur2, 1Danmarks Tekniske Universitet, Denmark; 2Huawei Technologies Co., Ltd., China. We report on high-capacity coherent links employing dual polarization 2D-CPM modulation, allowing for signal design in 8-dimensional space. Successful demodulation of 221 Gb/s (7.5 b/s/Hz) and 336 Gb/s (7.8 b/s/Hz) after 225 km and 451 km of standard single-mode fiber (SSMF) is achieved.

Ken-Ichi Suzuki, Ph.D. Senior Research Engineer, Supervisor, NTT Access Network Service Systems Laboratories, Japan. For the uplink in a statistical OFDM-allocation scheme is demonstrated. We build a new SS1 cancellation technique to compensate both modulator nonlinearity and dispersion-induced nonlinear distortion. Employing the SS1 cancellation to optimize EAM operation, superior 50-Gbps EAM-based OFDM-IMDD transmission over 100-km SSMF is successfully demonstrated.

Th3K.4 • 13:45
Nyquist-shaped Dispersion-precompensated Subcarrier Modulated optical OFDM transmission with Direct Detection, Sezer Erklin1, Sean Kilmurray1, Stephen Pachnicke1, Helmut Griesser2, Ben Thomsen2, Robert I. Killey3; 1Electronic and Electrical Engineering, Univ. College London, UK; 2Optical Networking SE, ADVA, Germany; 3Optical Networking SE, ADVA, Germany. We report on the first experimental demonstration of 14 Gb/s direct-detection single-sideband subcarrier modulated quasi-Nyquist OFDM transmission. Using electronic pre-compensation, error-free transmission was achieved over 800 km of dispersion-uncompensated standard single-mode fiber.
**Th3A.4 • 14:00**

**Invited**

Sudharsanan Srinivasan, Alais Arrighi¹, Martijn J. R. Heck¹, John Hutchinson¹, Erik Norberg¹, Gregory Fish¹, John E. Bowers¹. We present results from two hybrid silicon mode-locked lasers each with a 2GHz cavity and one with an intra-cavity filter, which allows for 29GHz operation and 55dB super-mode noise suppression compared to harmonic mode-locking.

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**Th3A.5 • 14:15**

**Top-Scored**

Michael L. Davenport¹, Gregory Carrier, Sweden. Abstract not available

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**Th3B • Resilient Networks—Continued**

**Th3B.4 • 14:00**

Benefits and challenges of Telisone-ra’s PanEuropean Network, Mattias Fridstrom¹; TeliaSonera International Carrier, Sweden. Abstract not available

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**Th3C • Low Power VCSEL Interconnect—Continued**

**Th3C.4 • 14:00**

High Speed Temperature Insensitive Optical Data Transmission with Compact 850nm TO-can Assemblies, Jaroslaw Turkiewicz², Jörg Kropp², Nikolay Ledentsov², Vitaly Shchukin², George Schaefer²; Inst. of Telecommunications, Warsaw University of Technology, Poland; Vl-Systems, Germany. Error-free operation at and above 28 Gbit/s is demonstrated for fully integrated TO-can based 850 nm transmitter and receiver subassemblies in a broad range of driving conditions and temperatures.

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**Th3C.5 • 14:15**

40-Gb/s FPC-based Optical Transceiver with Integrated-lens on Small Active Area Diameter of Photodiode, Manko Sugawara¹, Takashi Shirasaki¹, Takashi Yagisawa¹, Yukito Tsunoda¹, Hideki Oku¹, Satoshi Ide¹; Kaozuiku Tanaka¹; Fujitsu Laboratories, Japan. We demonstrated a high-speed FPC-based optical receiver above 40-Gb/s using novel lens-integrated technique on a small-active-area-diameter PD. The integrated-lens allows us to use high-bandwidth small-diameter photodiodes with low coupling loss.

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**Th3D • RF Photonic Processing—Continued**

**Th3D.4 • 14:00**

The First Fully Photonic-based Radar Demonstrator: Concept and Field Trial, Paolo Ghelli¹, Francesco Laghezza¹, Filippo Scotti¹, Giovanni Serafino¹, Amoregino Capra¹, Sergio Pirná¹, Antonella Bogan¹; National Laboratory of Photonic Networks, CNIT, Italy; TECIP, Scuola Superiore Sant’Anna, Italy; Laboratory of Radar & Surveillance Systems, CNIT, Italy. We report the first fully photons-based radar demonstrator. Photons enables flexibility, wide bandwidth, precision, leading to a fully digital radar paradigm. Field trial results targeting commercial airplanes prove its effectiveness as a proof of concept.

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**Th3D.5 • 14:15**

An Novel Update Algorithm in Stokes Space for Adaptive Equalization in Coherent Receivers, Gabriella Bosco¹, Monica Viainin¹, Piauigi Poggiani¹, Fabrizio Forgieri¹; DET, Politecnico di Torino, Italy; Cisco Photonics, Italy. We propose a novel update algorithm based on error signals evaluated in Stokes space, independent of both phase-noise and frequency-offset. We compare its performance to standard CMA for PM-16QAM modulation, showing 0.5-dB gain at BER=10⁻³.

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**Th3E • DSP Algorithms I—Continued**

**Th3E.5 • 14:00**

Blind and Universal DSP for Arbitrary Modulation Formats and Time Domain Hybrid QAM Transmissions, Yuliang Gao¹, Qunbi Zhuge¹, David V. Plant¹, Chao Lu¹, Alan Pak Tao Lau¹; Electrical Engineering, The Hong Kong Polytechnic University, Hong Kong; Electrical and Computer Engineering, McGill University, Canada; Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong. We propose a blind and universal DSP platform containing a new joint timing and frequency offset estimation technique. The quick convergence speed enables fast receiver initializations for flexible transmissions with arbitrary modulation formats.

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**Th3E.6 • 14:15**

Analog and Digital Photonics for Future Military Systems, Paul J. Matthews¹; Northrop Grumman Corp, USA. Due to their unique capabilities, fiber-optics and photonics are key enabling technologies for many military sensors and systems. The influence of fiber-optics on current and future trends in military sensors will be presented.

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**Th3F • Demultiplexers and Switches—Continued**

**Th3F.4 • 14:00**

Optimized 90° Hybrid with Side-wall Grating in Silicon on Insulator, Thomas Fähn¹, Wolfgang Vogel¹, Martin Schmidt¹, Manfred Berrath¹, Jörg Butschke¹, Florian Leitzkus¹; Inst. of Electrical and Optical Communications Engineering, Univ. of Stuttgart, Germany; Instytut Mikrotechniki Stuttgart, Germany. MMI-based 90° hybrids are optimized with sidewall gratings acting as effective index medium, notably increasing the usable bandwidth. Optimum grating parameters are determined with eigenmode expansion and Floquet-Bloch theory.
Room 125

Th3G • OFDM-based Optical Access—Continued

Th3G.5 • 14:00
37.5 km Urban Field Trial of OFDMA-PON Using Colorless ONUs with Dynamic Bandwidth Allocation and TCM, Christian Ruprecht¹, Yingkan Chen¹, Daniel Fintsche², Johannes von Hoyningen-Huene¹, Norbert Hanik², Erik Weis³, Dirk Breuer¹, Werner Rosenkranz²; “Chair for Communications, Univ. of Kiel, Germany; ¹Inst. of Communications Engineering, Technische Universität München, Germany; ²EICT GmbH, Germany; ³Labs, Deutsche Telekom AG, Germany. An OFDMA-PON field trial using coherent detection in upstream and direct detection in downstream on 37.5 km feeder fiber is demonstrated. A power budget supporting 32 cost-effective colorless ONUs with dynamic bandwidth allocation is reported.

Th3G.6 • 14:15
17.125 Gb/s over 25 km Transmissions of Real-time Dual-band Optical OFDM Signals Modulated by 1 GHz RSOAs, Jianming Tang¹, Qianwu Chen¹, Min Wang¹, Jaume Marhuenda¹, Vicente López¹, Alejandro Aguado¹, Oscar Gonzalez de Dios¹, Juan-Pedro Fernández-Palacios¹, Vicente Rivera¹, Lydia C. L. Yu¹, Takahiro Imai¹, Hiroshi Onaka¹, Fujitsu Laboratories, Japan. The novel superfilter technique for flexgrid optical networks is proposed to compact spectrum-continuous lightpaths. The technique is applied in a specifically extended SDN architecture, showing significant gains in terms of spectral efficiency.

Room 130

Th3H • Access Networks—Continued

Th3H.4 • 14:10
Filter Optimization in SDN-based Flexgrid Networks, Francesco Paolucci², Francesco Fresi², Alberto Castro³, Luis Velasco³, Filippo Cugini³, Nicola Sambo³, Alessio Giorgetti³, Luca Poti¹, Piero Castoldi¹; “CNIT, Italy; ³Scuola Superiore Sant’Anna, Italy. Utilizing 1 GHz RSOAs at 17.125 Gb/s real-time dual-band and 4 GS/s DACs/ADCs, record-high powers. Variations in RSOA-injected optical powers show excellent robustness to 20 dB receiver sensitivity improvements over IMDD-based 25 km 55Mfs which are experimentally demonstrated, which show excellent robustness to 20 dB variations in RSOA-injected optical powers.

Room 131

Th3I • SDN and PCE—Continued

Th3I.4 • 14:00
ABNO: A Feasible SDN Approach for Multi-vendor IP and Optical Networks, Alejandro Aguado¹, Victor Lopez¹, Jaime Marhuenda¹, Oscar Gonzalez de Dios¹, Juan-Pedro Fernández-Palacios¹, Lydia C. L. Yu¹, Takahiro Imai¹, Hiroshi Onaka¹, Fujitsu Laboratories, Japan. The proposed scheme exhibits low complexity and does not have any bandwidth overhead.

Room 132

Th3J • Advanced Optical Transceivers—Continued

Th3J.4 • 14:00
100G/400G Project in Japan, Hiroshi Onaka¹, Fujitsu Laboratories, Japan. Invited. The 100G/400G Project in Japan has been progressing in the field trials, and the results of the project will be demonstrated.

Room 133

Th3K • Direct Detection—Continued

Th3K.5 • 14:00
Blind Symbol Synchronisation in Direct-detection Optical OFDM Using Virtual Subcarriers, Rachid Bouziane¹, Peter A. Milder², Sean Killmurray¹, Benn C. Thomsen¹, Stephan Pachnicke¹, Polina Bayvel¹, Robert I. Killey¹; “Department of Electrical and Computer Engineering, Stony Brook Univ., USA; ²ADVA Optical Networking SE, Germany. The performance of a novel blind symbol synchronisation technique using a 30.65 Gb/s real-time 16-QAM OFDM transmitter with direct detection is reported. The proposed scheme exhibits low complexity and does not have any bandwidth overhead.

Th3K.6 • 14:15
16-ary Stokes-vector Modulation Enabling DSP-based Direct Detection at 100 Gbit/s Kazuo Kikuchi¹, Shojiro Kawakami¹, The Univ. of Tokyo, Japan; ¹Photonic Lattice, Inc., Japan. Multi-level optical signals designed in the three-dimensional Stokes space can be demodulated by a direct-detection receiver using low-complexity DSP. Simulation results demonstrate that the 16-ary signal can achieve the bit rate of 100 Gbit/s.
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<td><strong>Th3A • Semiconductor Lasers—Continued</strong></td>
<td><strong>Th3B • Resilient Networks—Continued</strong></td>
<td><strong>Th3C • Low Power VCSEL Interconnection—Continued</strong></td>
<td><strong>TH3D • RF Photonic Processing—Continued</strong></td>
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<td><strong>Th3A.6 • 14:30</strong></td>
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<td>Monolithic Buried Heterostructure DFB Laser Array for Integrated Optical Interconnects and WDM Systems, Jingsi Li¹, Song Tang², Jeffery Wang³, Yue Liu⁴, Haiming Xu⁵, Qi Tang⁶, Xiangfei Chen⁷, Julian Cheng⁸, ¹Univ. of Texas at Austin, USA, ²Nanjing Univ., China; ³ATG Technologies, Inc., USA, ⁴Wuhan Huagong Genuine Optics Tech Co., Ltd. China. We report a monolithic buried heterostructure DFB laser array by reconstruction equivalent chirp (REC) technique. Using interference lithography and photolithography, an integrated laser array with accurate wavelength control and good performance has been demonstrated.</td>
<td>Network Cost Savings and Service Differentiation using Priority-driven sub-50ms Shared Mesh Protection, Soumya Roy¹, Sudhindra Kota¹, Onur Turkcu¹, Steven Hand¹, Krish Verma¹, Rajan Rao¹, Infinea, USA. This paper shows how shared mesh protection with prioritization of services and pre-emption of low-priority services, as defined in standards, G.808.3 and G.ODUSMP provide high network cost savings while enabling &lt;50 ms recovery.</td>
<td>Low Power CMOS-driven 1060 nm Multimode Optical Link, Jean Benoit Heroux¹, Tomofumi Kise¹, Masaki Funabashi², Toyohiro Aoki², Clint L. Schow³, Alexander V. Rylyakov³, Shigeru Nakagawa², ¹IBM Research - Tokyo, IBM Japan, Japan; ²COE Team, FITELO Products division, Furukawa Electric Co., Ltd., Japan; ³IBM Research - T.J. Watson Center, IBM, USA. A high speed, low power 1060nm optical link with 90-nm CMOS chips is demonstrated using a VCSEL bias as low as 2 mA. A 4 Gb/s bit efficiency is obtained at 20 Gbps.</td>
<td>Energy Efficient Digital Signal Processing, Maxim Kuschnerov¹, Thomas Bex², Peter Kanzmaier³, ¹Conant R&amp;D GmbH, Germany. We discuss the major power reduction trends for DSP-ASICs used in coherent optical interfaces that target line card and pluggable applications. Optimization measures are shown for the digital and physical design of such integrated circuits.</td>
<td>Low Crosstalk Wavelength Tunable Filter that Utilizes Symmetric and Asymmetric Mach-Zehnder Interferometers, Shoichi Takashina¹, Yojiro Mori¹, Hiroshi Hasegawa¹, Ken-ichi Sato¹, Toshihiko Watanabe¹, ¹Department of Electrical Engineering and Computer Science, Nagoya Univ., Japan; ²NTT Photonics Laboratories, NTT Corporation, Japan. We propose a novel AWG-based wavelength tunable filter architecture that utilizes symmetric and asymmetric Mach-Zehnder interferometers for switching and filtering functions. A prototype is fabricated as a PLC and its good performance is experimentally confirmed.</td>
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<td><strong>Th3A.7 • 14:45</strong></td>
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<td><strong>Th3C.7 • 14:45</strong></td>
<td><strong>Th3D.6 • 14:30</strong></td>
<td><strong>Th3E.6 • 14:30</strong></td>
<td><strong>Th3F.5 • 14:30</strong></td>
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<td>Uncooled Clear-Eye-Opening Operation (25 to 95°C) of 25.8/28-Gb/s 1.3-µm InGaAlAs-MQW Directly Modulated DFB Lasers, Toshihiko Fukumachi¹, Atsushi Nakamura¹, Yasushi Sakuma¹, Shigemori Hayakawa¹, Ryu Washino¹, Masanobu Mukaikubo¹, Kooru Okamoto¹, Takayuki Nakajima¹, Yuki Wakayama¹, ¹Applied Physics, Hebrew Univ., Israel. We demonstrate 25.8-Gb/s mask margins of more than 20% up to 85°C. Moreover, clear 28.0-Gb/s eye diagram was obtained at 95°C.</td>
<td>Highly Survivable Software Defined Synergistic IP+Optical Transport Networks, Dongyu Zhang¹, Xuefei Song¹, Songtao Mai¹, Shuang Hao¹, Hongxiong Guo¹, Yinben Xia¹, ¹Beijing Univ. of Posts and Telecommunications, China; ²Huaen Technologies, China. A hierarchically controlled IP+Optical multilayer Transport SDN architecture is proposed, which highlights flexible resource provisioning and dynamic cross-layer restorations. The propositions are also demonstrated via an implemented testbed prototype.</td>
<td>New MMF and VCSEL Metrics for System Reach Predictions, Denis Molin¹, Marianne Bigot-Astruc², Pierre Sillard¹, ¹Prismian Group, France. We propose new MMF and VCSEL metrics derived from standard measurements procedures and we demonstrate how to combine them to predict system performance.</td>
<td>Invited One GHz Resolution Arrayed Waveguide Grating Filter with LCoS Phase Compensation, Roy Rudick¹, David Sinefield¹, Oni Golani¹, Dan Marom¹, ¹Applied Physics, Hebrew Univ., Israel. We correct fabrication phase errors of 63-μm, 50GHz FSR AWG to achieve 1GHz resolution, by imaging the waveguides onto a phase spatial light modulator. Variable bandwidth and center frequency tuning is achieved by spatial filtering.</td>
<td>One GHz Resolution Arrayed Waveguide Grating Filter with LCoS Phase Compensation, Roy Rudick¹, David Sinefield¹, Oni Golani¹, Dan Marom¹, ¹Applied Physics, Hebrew Univ., Israel. We correct fabrication phase errors of 63-μm, 50GHz FSR AWG to achieve 1GHz resolution, by imaging the waveguides onto a phase spatial light modulator. Variable bandwidth and center frequency tuning is achieved by spatial filtering.</td>
<td></td>
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**Th3G • OFDM-based Optical Access—Continued**

*Th3G.7 • 14:30*

P-OFDM: Spectrally Efficient Unipolar OFDM, Hany Elgala¹, Thomas D. C. Little²; Boston Univ., USA. A novel OFDM signal format, polar-OFDM (P-OFDM), is proposed. P-OFDM offers twice as much spectral efficiency as state-of-the-art real-value unipolar OFDM formats. Inherently, the high PAPR is reduced and the numerical evaluation of the BER performance under dynamic-range constraint of optical sources demonstrates superior results.

**Th3I • SDN and PCE—Continued**

*Th3I.6 • 14:30 Invited*

Towards a Network Operating System, Victor Lopez¹, Oscar Gonzalez de Dios¹, Beatriz Fuentes¹, Marcelo Yannuzzi¹, Juan-Pedro Fernández-Palacios¹, Diego Lopez¹; Telefonica I+D, Spain; ²Technical Univ. of Catalonia, Spain. A Network Operating System (NetOS) is a novel paradigm for developing a next-generation network management and operation platform. As we shall describe, NetOS not only goes far beyond the SDN concepts but also constitutes a fundamental enabler for NFV.

**Th3K • Direct Detection—Continued**

*Th3K.7 • 14:30 Invited*

Direct Detection Optical OFDM, Wei R. Peng¹; Futurewei Technologies Inc., USA. In this paper we review the prior works on DDO-OFDM systems, including the traditional DDO-OFDM that utilizes single band and single polarization, the multiband DDOOFDM superchannel, and the dual-polarization (PDM) DDO-OFDM.

**Th3G.8 • 14:45**

Up to 60 km Bidirectional Transmission of a 16 Channels × 10 Gb/s FDM-WDM PON Based on Self-Seeded Reflective Semiconductor Optical Amplifiers, Sy Dat Le¹, Aurélien Lebreton¹, Fabienne Saliou¹, Qian Deniel¹, Benoît Charbonnier¹, Philippe Chancou¹; ²Orange R&D, France; ³Université de Bretagne Sud, France; ⁴Telecom ParisTech, France. We experimentally demonstrate for the first time a bidirectional transmission up to 60-km of a 16-channel-WDM-PON at 10-Gb/s. An optical-budget over 30-dB was obtained. This was based on self-seeded RSOAs and multi-level-modulation of RF signals.

Join the conversation.
Follow @ofcconference on Twitter.
Use hashtag #OFC2014.

15:00–15:30 Coffee Break, Exhibit Halls A, B, C, North, Exhibit Hall D
Th4A.1 • 15:30
Demonstration of Orbital Angular Momentum State Conversion Using Two Hybrid 3D Photonic Integrated Circuits, Chuan Qin1, Binbin Guan1, Ryan P. Scott2, Roberto Proietti1, Nicolas K. Fontaine3, Tiejun Su4, Carlo Ferranti1, Mark Capuzzo3, Fred Clemens5, Bob Keller5, Mark Eamshaw4, S.J. Ben Yoo6; 1Univ. of California Davis, USA; 2Bell Laboratories, Alcatel-Lucent, USA; 3Bell Laboratories, Alcatel-Lucent, USA; 4Bell Laboratories, Alcatel-Lucent, USA; 5Univ. of California Davis; 6Andreas K. Fontaine, USA. We will demonstrate an 11 port count single-mode WSS.

Room 120
16:30-17:15
Th4B • Panel: SDN for Transport Networks
Presider: Roland Ruy; Alcatel-Lucent, USA

Room 121
16:30-17:15
Th4C • Silicon Photonics II
Presider: Po Dong; Alcatel-Lucent Bell Labs, USA

Room 122
16:30-17:15
Th4D • DSP Algorithms II
Presider: Gabriella Bosco; Politecnico di Torino, Italy

Room 123
16:30-17:15
Th4E • Planning II
Presider: Annalisa Morea; Alcatel-Lucent, France

Turn Cell Phones Off

Thursday, 13 March
15:30–17:15
Th4F • High-Speed Transmission
Presider: Michael Eiselt; ADVA Optical Networking SE, Germany

Th4G • Emerging Data Center Interconnect
Presider: Andrew Alduino; Intel Corporation, USA

Th4H • Wideband Communications & Sensing
Presider: Guifang Li; Univ. of Central Florida, USA

15:30–17:30
Th4F.1 • 15:30 Invited
Single-carrier and Dual-carrier 400-Gb/s and 1-Tb/s Transmission Systems, Gregory Raybon; Alcatel-Lucent Bell Labs, USA. Abstract not available

Th4G.1 • 15:30 Invited
“CMOS Photonics” Main Innovations and Value in Data-centers, Kal Shastri; Cisco, USA. Abstract not available

Th4H.1 • 15:30 Tutorial
Terahertz Photonics for Communications, Alwyn J. Seeds; Electronic and Electrical Engineering, Univ. College London, UK. Extending the high data-rate capacity of optical fibre transmission to wireless devices, requires greatly increased carrier frequencies. This tutorial will describe how photonic techniques can enable ultra-high capacity data transmission using signals at Terahertz frequencies.

15:30–17:00
Th4J • Architectures & Technologies for Computing Systems
Presider: George Papen; Univ. of California San Diego, USA

Th4J.1 • 15:30 Invited
Large Scale Data Warehouse Build Out Based on Commodity Ethernet Fabrics, Ariel Hendel; Broadcom Corporation, USA. Abstract not available

13:00–16:00
POF Symposium, Expo Theater II Programming
For more details, see page 42

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

Alwyn Seeds received the Ph.D. and D.Sc. degrees from the University of London. After working as a Staff Member at MIT Lincoln Laboratory he moved to University College London, where he is Professor of Opto-electronics and Head of the Department of Electronic and Electrical Engineering. He has published over 400 papers and filed some 15 patents on microwave and opto-electronic devices and their systems applications. Professor Seeds has been elected a Fellow of the Royal Academy of Engineering (UK) and an IEEE Fellow (USA). He has served as Vice-President for Technical Affairs of the IEEE Photonics Society (USA).
ard M. Osgood, Jr.

40-Gb/s data rate are demonstrated, of power penalty at an aggregate 2-mode mode-division-multiplexed data is transmitted jointly with on-chip 

Yan P. Chen

1, Yu Yu, Weili Yang, 1

1, Xinliang Zhang, 1

2, John C. Cartledge, 2

3, Andrew P. Knights, 3

1, Richard R. Grote, 1

1, Abdullah S. Karari, 1

1, John C. Cartledge, 1

1, Bill Corcoran, 1

1, Trevor Anderson, 1

1, Arthur J. Lowery, 1

1, Efstratios Skafidas, 1

1, Victoria Research Lab, NICTA, Electrical and Electronic Engineering, Univ. of Melbourne, Australia; 2, CUDOS, Electrical and Computer Systems Engineering, Monash Univ., Australia; 3, Center for Technology Infusion, La Trobe Univ., Australia. We experimentally demonstrate 18×64-Gb/s Nyquist PDM-16QAM signal transmission over 800-km single-mode fiber. The receiver matched filtering and channel’s linear impairment compensation are jointly processed with a single linear filter, greatly reducing the computational complexity.

Noam Ophir

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Room 102

Th4A • Space Division Multiplexing—Continued

First Demonstration of Polarization-multiplexing Combined with On-chip Mode-Division-Multiplexing, Christine P. Chen, Jeffrey B. Driscoll, Noam Ophir, Richard R. Grote, Richard M. Osgood, Jr., Keren Bergman, Electrical Engineering, Columbia Univ., USA. Polarization-multiplexed data is transmitted jointly with on-chip 2-mode mode-division-multiplexed data. Error-free operation and 5 dB of power penalty at an aggregate 40-Gb/s data rate are demonstrated, showing potential for pol-mux and mode-division-multiplexing networks on chip.

Mengyuan 1, Yu Yu1, Weili Yang, 1, Xinliang Zhang, 1, Richard R. Grote, 1, Abdullah S. Karari, 1, John C. Cartledge, 1, Bill Corcoran, 1, Trevor Anderson, 1, Arthur J. Lowery, 1, Efstratios Skafidas, 1, Victoria Research Lab, NICTA, Electrical and Electronic Engineering, Univ. of Melbourne, Australia; 2, CUDOS, Electrical and Computer Systems Engineering, Monash Univ., Australia; 3, Center for Technology Infusion, La Trobe Univ., Australia. We experimentally demonstrate 18×64-Gb/s Nyquist PDM-16QAM signal transmission over 800-km single-mode fiber. The receiver matched filtering and channel’s linear impairment compensation are jointly processed with a single linear filter, greatly reducing the computational complexity.

Christine P. Chen

1

Room 120

Th4B • Panel: SDN for Transport Networks—Continued

On-chip Multiplexing Conversion between PDM and MDM, Mengyuan Ye, Yu Yu, Weili Yang, Jinghui Zou, Yaguang Qin, Xiniang Zhang, Wuhan National Lab for Optoelectronics, China. A compact SOI device used for the conversions between PDM and MDM is proposed and demonstrated successfully. The proposed on-chip circuit can be used for accommodating the interface of systems utilizing different multiplexing techniques.

Room 121

Th4C • Silicon Photonics II—Continued

On-chip Multiplexing Conversion between PDM and MDM, Mengyuan Ye, Yu Yu, Weili Yang, Jinghui Zou, Yaguang Qin, Xiniang Zhang, Wuhan National Lab for Optoelectronics, China. A compact SOI device used for the conversions between PDM and MDM is proposed and demonstrated successfully. The proposed on-chip circuit can be used for accommodating the interface of systems utilizing different multiplexing techniques.

Room 122

Th4D • DSP Algorithms II—Continued

10 Gb/s Bit Error Free Performance of a Monolithic Silicon Avalanche Waveguide Integrated Photodetector, Jason J. Ackert, Abdullah S. Karari, John C. Cartledge, Paul E. Jessep, Andrew P. Knights, Engineering Physics, McMaster Univ., Canada; Electrical and Computer Engineering, Queen’s Univ., Canada; 1Physics and Computer Science, Wilfrid Laurier Univ., Canada. Bit error free operation of a waveguide-integrated monolithic silicon avalanche photodiode is obtained for 10 Gb/s. The infrared photosresponse is enabled by the 1.8 µm absorption peak of the silicon divacancy defect, introduced via ion implantation.

Room 123

Th4E • Planning II—Continued

Energy Efficiency and Reliability Trade-off in Optical Core Networks, Pawel Wiatr, Jiajia Chen, Paolo Monti, Lena Wosinska, School of ICT, Optical Networks Lab, KTH Royal Inst. of Technology, Sweden. We assess the highest allowable reliability performance degradation of active components caused by applying energy-efficient mechanisms. EDFA are identified as the most critical devices where energy saving might not cover the potential additional repairation cost.

Room 124

Th4E • Planning II—Continued

After Failure Repair Optimization in Dynamic Flexgrid Optical Networks, Marc Ruiz, Mateusz Zatkiewicz, Alberto Castro, Miroslaw Klinkowski, Luis Velasco, Michal Pioro, Optical Communications Group, Universität Politecnicale de Catalunya, Spain; 2Inst. of Telecommunications, Warsaw Univ. of Technology, Poland; 3Dept. Transmission and Optical Technologies, National Inst. of Telecommunications, Poland. We introduce the problem of reoptimizing the network after a link failure has been repaired as an effective way for reducing capacity usage and improving network performance. Numerical results show gains higher than 42%.
A 1 Tb/s option Lengths Greater than 200 km, Long-Haul Distances with Span QPSK Signals over Regional and DP-16QAM and Multi-Carrier DP-QPSK signals with 37.5-GHz carrier spacing. The transmission system with span length greater than 200-km SSF with 44-dB loss and standard EDFA/RA amplification is employed.

3.16:15 High-contrast, All-silicon Waveguiding Platform for Multi-octave Integrated Photonics, Jeff Chiles1, Saeed Khan2, Jichi Ma2, Sasan Fathpour2, Creel1, The College of Optics and Photonics, Univ. of Central Florida, USA; 2Department of Electrical and Computer Engineering, Univ. of Central Florida, USA. A novel all-silicon optical platform (ASOP) is demonstrated, enabling low-loss propagation in wavelengths of 1.2-8.5 μm. The robust platform offers enhanced CMOS compatibility for electronic-photonic integration in the broadest possible transparency range of silicon.

3.16:15 A Low Latency Optical Top of Rack Switch for Data Centre Networks with Minimized Processor Energy Load, Shiyan Liu1, Qixiang Cheng2, Adrian Wonfor1, Richard V. Penty2, Ian White1, Philip M. Watts1, Electronic and Electrical Engineering, Univ. College London, UK; 2Centre for Advanced Photonics and Electronics, Univ. of Cambridge, UK. We propose a low latency optical data center top of rack switch using recirculation buffering and a hybrid M2/SOA switch architecture to reduce the network power dissipated on future optically connected server chips by 53%.
Room 120
Th4A • Space Division Multiplexing—Continued

Room 121
Th4B • Panel: SDN for Transport Networks—Continued

Room 122
Th4C • Silicon Photonics II—Continued

Room 123
Th4D • DSP Algorithms II—Continued

Room 124
Th4E • Planning II—Continued

Th4A.5 • 16:30
Experimental Demonstration of a Gain-flattening Filter for Few-mode Fiber Based on a Spatial Light Modulator, Ezra Ip1, Yu Gu Ruo2, Ming-Jun Li1, Yee-Kai Huang1, Joseph Kahn1
1NEC Laboratories America Inc, USA; 2Stanford University, USA. We demonstrate a spatial light modulator-based few-mode fiber gain-flattening filter (FM-GFF). Arbitrary insertion loss is induced by a phase scattering function. We use the FM-GFF to flatten the output of a few-mode erbium-doped fiber amplifier.

Th4A.6 • 16:45
A Two-mode Division Multiplexing Filter Demonstrated Using a SOI Ring Resonator, Bryce Dorin1, Winnie N. Ye1, 1Electronics, Carleton Univ., Canada. We present experimentally a two-mode ring resonator add/drop filter which exhibits distinct resonances for each mode. This device demonstrates strong potential for channel selective filtering in mode-division multiplexing systems.

Th4C.5 • 16:30
Monolithically Integrated 25Gbps/sec Receiver for 1.55um in Photonic BiCMOS Technology, Dieter Knoll1, Stefan Lischke1, Lars Zimmermann1, Bernd Heinemann1, Daniel Micsik1, Pylyp Ostrovsky2, Georg Winzer3, Marcel Kroh1, Rainer Barth3, Thomas Grabolla1, Katrin Schulz1, Mirko Fraschke1, Marco Lisker2, Jürgen Drews3, Andreas Trusch1, Andreas Krüger1, Steffen Marschmeyer1, Harald Richter3, Oksana Fursenko1, Yuji Yamamoto1, Benjamin Wohlfel1, Klaus Petermann1, Andreas Beling1, Bernd Tillack1, 1IHP, Germany; 2TU Berlin, Germany; 3Univ. of Virginia, USA. A monolithically integrated 25Gbps receiver is shown as a demonstrator for a novel photonic BiCMOS process which allows for dense co-integration of 200GHz bipolar transistors and CMOS devices with waveguides, couplers, and Ge photodiodes.

Th4C.6 • 16:45
Polarization-insensitive 5x20Gb/s WDM Ge Receiver using Compact Si Ring Filters with Collective Thermal Tuning, Peter De Heyn1, Jeroen De Coster2, Peter Verheyen1, Guy Lepage1, Marianna Pantouvaki2, Philippe Absi3, Wim Bogaerts1, Dries Van Thourhout1, Jos Van Campenhout1, 1Information Technology, Universiteit Gent, Belgium; 2InterUniv. Microelectronics Center (imec), Belgium. A 5x20Gb/s WDM Ge receiver with 300GHz channel spacing is presented. Uniform flat-top channel responses result in a 0.1A/W fiber-referenced responsivity and crosstalk better than -15dB for all channels and polarization states.

Th4D.5 • 16:30
Reducing the Power Consumption of the CMA Equalizer Update for a Digital Coherent Receiver, Daniel Cardenas1, Domanic Lavery1, Philip Watts1, Seb J. Savory1, Electric and Electronic Engineering, Univ. College of London, UK. A reduced complexity multiplier-free CMA equalizer update is proposed and synthesized for a 10 Gb/s receiver using a 45-nm CMOS process. The proposed algorithm allows up to 52% power consumption reduction without penalty in performance.

Th4D.6 • 16:45
Novel Equalizer Architecture for Hitless Rate Switching in Energy-Efficient Optical Systems, Valery Rozental1, Gianmarco Bruno2, Marco Camerá3, Darli Mello3, 1IHP, Germany; 2Univesidade de Brasilia, Brazil; 3Ericsson Telecommunications, Italy. We propose a novel equalizer architecture for hitless rate switching in energy-efficient optical systems. Power savings are achieved by rate reduction under low client traffic. The equalizer architecture is experimentally validated in a 100G system.

Th4E.5 • 16:45
Physical Layer Characteristics and Design of Long Haul Fast Turn-on/off’s and Flow Switched All-optical Networks, Vincent W. Chan1, 1Massachusetts Inst. of Technology, USA. Adiabatic switching will quench EDFA transients at fast lightpath turn-on/off’s. A new metric determines lightpath performance. The worst case occurs when there is only one channel present with non-decreasing performance as more wavelengths are added.
Room 125
Th4F • High-Speed Transmission—Continued

Th4F.4 • 16:30
Over 2000-km Transmission of 60-Gbaud PDM-QPSK Signal with Heterodyne Detection and SE of 4b/s/Hz, Xinying Li, Junwen Zhang, Fan Li, Jiangnan Xiao, 2Fudan Univ., China; 2ZTE (TX) Inc, USA. We experimentally demonstrate 8×240-Gb/s WDM-PDM-QPSK signal transmission on 50-GHz grid over 5×420-km SMF-28 with 4-b/s/Hz net SE adopting simplified heterodyne detection and 9QAM-like procession. 9QAM-like procession is more efficient than digital-post-filtering for this heterodyne system.

Th4F.5 • 16:45
Transmission of 128-Gb/s PDM-4PAM Generated with Electroabsorption Modulators over 960-km Standard Single-Mode Fiber, Changjin Xie1; 1Alcatel-Lucent Bell Labs, USA. We generate a 128-Gb/s polarization-division-multiplexed 4-level amplitude-pulse modulation (PDM-4PAM) signal with electroabsorption modulators and transmit it over 960-km standard single-mode fiber (SSMF) using digital coherent detection with 20% overhead soft-decision forward-error-correction.

Room 130
Th4G • Emerging Data Center Interconnect—Continued

Th4G.4 • 16:30 Invited
Hybrid Silicon Photonics Integration, Ashok Krishnamoorthy1; 1Oracle, USA. Abstract not available

Th4G.5 • 16:45 Top-Scored
Photonic Ultra-wideband Software-defined RF Receiver for Electronic Spectrum Measurements, Daniel Onori1, Francesco Laghezza1, Paolo Ghezzi1, Sergio Pirro1, Filippo Scotti1, Giovanni Serafino1, Antonella Bogoni2, 1TeCiP, Scuola Superiore Sant’Anna, Italy; 2NLPN, CNIT, Italy. The architecture of an innovative photonic assisted RF receiver for simultaneously filter, down-convert, and digitize received signals is presented. It allows the reception and analysis of RF signals up the mm-waves.

Room 131
Th4H • Wideband Communications & Sensing—Continued

Th4H.2 • 16:30
Passive Approach for Phase Fluctuation Cancellation of Anonymous Microwave Signal Transmission, Zongle Li1, Lianshan Yan1, Yulan Peng1, Wei Pan1, Bin Luo1, LiYang Shao1; 1Southwest Jiaotong Univ., China. A passive approach for phase fluctuation cancellation of anonymous microwave signal transmission is proposed and experimentally demonstrated. Phase drift of 54-ps for 2.45-GHz signals is reduced to 3.8-ps after 10-km SMF transmission.

Th4H.3 • 16:45
Dr. William Green is a Research Staff Member and Manager of the Silicon Integrated Nanophotonics Group at the IBM Thomas J. Watson Research Center. His research activities encompass the design of devices and systems for terabit-per-second-class silicon optical interconnects. In addition, Dr. Green's work has extended the silicon photonic integrated circuit platform to the generation and processing of mid-infrared optical signals, for applications utilizing molecular spectroscopy. His work has been recognized through the 2012 IBM Corporate Award and the 2012 IEEE Photonics Society Young Investigator Award. Dr. Green is a Senior Member of the IEEE and the OSA.

Room 132
Th4I • Silicon Sources & New Wavelengths—Continued

Th4I.4 • 16:30
Highly Reliable Silicone Based Optical Waveguides Embedded in PCBs, Tobias Lamprecht1, Markus Halter1, Ranjith John1, Chad Amb1, Brandon Swatowski1, Stefan Beyer1, Daniel Meier1, Ken Weidner1, Felix Betschon1, 1vario-optics ag, Switzerland; 2Dow Corning Corporation, USA. Photopatterned silicone optical waveguides are overcoming major hurdles towards their integration in electro-optical printed circuit boards (EOCB) for optical interconnects. They show good optical performance after lamination and reflow soldering.

Room 133
Th4J • Architectures & Technologies for Computing Systems—Continued

Th4J.4 • 16:30
Connector Performance Analysis for D-Shaped Multi-Core Multi Mode Fiber, Petar Pepeljugoski1, Fuad E. Doany1, Daniel Kuchta1, Benjamin Lee1, Clint L. Schow1, Laurent Schavers1; 1International Business Machines Corp, USA. Investigation of connector performance for D-shaped multi-core MMF found that worst case equivalent connector offset >5.5m is possible with >2dB loss. Statistical simulations indicate that with proper launch conditions less than 0.75dB loss is possible.

Show Floor Programming

Thursday, 13 March

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Th4A.7 • 17:00
Few-mode Fiber Wavelength Selective Switch with Spatial-diversity and Reduced-steering Angle, Nicolas K. Fontaine1, Roland Ryf1, Chang Liu1, Burcu Ercan1, Joel R. Salazar Gil2, Sergio G. Leon-Saval1, Joss Bland-Hawthorn1, David T. Neilson1, 1Alcatel-Lucent Bell Labs, USA; 2School of Physics, Univ. of Sydney, Australia. We demonstrated an LCoS based 1×2 wavelength selective switch with few-mode fiber inputs. A 3D waveguide that contains mode-demultiplexers with a restuffling network enables mode-independent passbands and a reduced steering angle requirement.

Th4A.8 • 17:15
Dynamic Mode Group Equalization Filter and Variable Optical Attenuator for Few Mode Fibers, Israel Weiss1, Jonathan Genuth1, David Smedfel1, Meni Blau1, Moran Bin Nun1, R. Benjamin Lingle2, Lars E. Gruner-Nielsen1, Dan Marom1; 1Applied Physics, Hebrew Univ. of Jerusalem, Israel; 2OFS, USA; 3OFS Fitel Denmark, Denmark. Variable optical attenuation for few-mode fibers is presented, utilizing an amplitude spatial light modulator. -28dB uniform attenuation and 10dB differential mode equalization is demonstrated, potentially gain-balancing mode dependent amplification.

Th4B.7 • 17:00
Monolithic Integration of Si-silica Waveguide Delay Line Interferometer and Germanium Photodetectors for 25-Gbit/s DPSK Demodulator, Tatsuro Hiraki1, Hiroshi Fukuda2, Tai Tsuchizawa1, Rai Kou1, Hidetaka Nishi1,2, Kataro Takeda1,2, Tsuyoshi Yamamoto2, Yasuhiko Ishikawa2, Kazumi Wada1, Koji Yamada1,2, 1NTT Nanophotonics Center, Japan; 2NTT Microsystem Integration Laboratories, Japan; 3Univ. of Tokyo, Japan. A straight-shape Si-silica waveguide delay-line interferometer and Ge photodetectors (PD) are monolithically integrated for a DPSK demodulator. The device with a footprint of 0.49 mm² and a fiber-to-PD responsivity of 0.29 A/W successfully demodulates 25-Gbit/s DPSK signals.

Th4B.8 • 17:15
Reduced OSNR Penalty for Frequency Drift Tolerant Coherent Packet Switched Systems Using Doubly Differential Decoding, Anthony J. Walsh1,2, James Mountjoy1, Anthony Fagan1, Colin Browning1, Andrew D. Ellis1, Liam P. Barry1, 1Rince Inst., Dublin City Univ., Ireland; 2Tyndall National Inst., Ireland. We experimentally demonstrate a 2.4 dB improvement in 200G DP-16QAM maximum system margin over 800 km of TrueWave Classic fiber using only 3 distinct perturbation coefficients in nonlinear pre-distortion with 50% chromatic dispersion pre-compensation.

Th4C.7 • 17:00
Aggressive Quantization on Perturbation Coefficients for Nonlinear Pre-Distortion, Qunbi Zhuge1, Michael Reimer1, Andrzej Borowiec2, Maurice O’Sullivan1, David V. Plant1, 1McGill Univ., Canada; 2Ciena Corporation, Canada. We experimentally demonstrated a 2.4 dB improvement in 200G DP-16QAM maximum system margin over 800 km of TrueWave Classic fiber using only 3 distinct perturbation coefficients in nonlinear pre-distortion with 50% chromatic dispersion pre-compensation.

Th4C.8 • 17:15
Maximum Entropy (MaxEnt) Routing and Spectrum Assignment for Flexgrid-based Elastic Optical Networking, Paul Wright1, Michael C. Parker2, Andrew Lord1, 1British Telecom, UK; 2Lexden Technologies Ltd, UK. A maximum entropy approach to routing and spectral allocation in elastic optical networks is implemented using a genetic algorithm and operated on a real network topology. This approach avoids fragmentation problems and increases network utilization.
Th4F.6 • 17:00
Transmission of 480-Gb/s Dual-carrier PM-8QAM over 2550km SMF-28 Using Adaptive Pre-equalization, Junwen Zhang1,2, Hung-chang Chien1, Ze Dong1, Jiangnan Xiao1, ZTE (TX) Inc, USA; 2ZTE (TX) Inc., China. With a novel adaptive pre-equalization scheme based on DD-LMS, four 100-GHz channels, each carrying a 480-Gb/s dual-carrier PM-8QAM signal, are successfully transmitted over 2550-km SSMF with EDFA-only amplification.

Th4G.5 • 17:00
Nonlinear Compensation for 980 nm High Power, Single-Mode VCSELs for Energy Efficient OM 4 Fiber Transmission, I-Cheng Lu1, Chia-Chen Wei2, Hsing-Yu Chen1, Pei-Yu Chung1, Peng-Hao Huang1, Jia-Wei Jiang1, Kai-Lun Chiu1, Jin-Wei Shi1, Jyehong Chen1; 1National Chiao Tung Univ., Taiwan; 2National Sun Yat-sen Univ., Taiwan; RIndustrial Technology Research Inst., Taiwan; 3National Central Univ., Taiwan. A nonlinear compensation method is demonstrated to boost the launch power for optical interconnects employing OFDM format. A 1.5 dB sensitivity improvement is obtained for a 2-km OM4 fiber transmission system at 15 Gbit/sec.

Th4G.6 • 17:15
Ultra-compact 320 Gb/s and 160 Gb/s WDM Transmitters Based on Silicon Microrings, Yang Liu1, Ran Ding1, Qi Li1, Xuan Zhe1, Yunchu Li1, Yisu Yang1, Andy E. Lim2, Patrick Guo-Qiang Lo1, Keren Bergman1, Tom Baehr-Jones1,5, Michael Hochberg1,2; 1Department of Electrical & Computer Engineering, Univ. of Delaware, USA; 2Department of Electrical Engineering, Columbia Univ., USA; 3Inst. of Microelectronics, A*STAR (Agency for Science, Technology and Research), Singapore; 4Department of Electrical & Computer Engineering, National Univ. of Singapore, Singapore; 5EastWest Photonics PTE LTD, Singapore. We demonstrated 320Gb/s 8-channel and 160Gb/s 4-channel WDM transmitter using silicon microrings based on conventional common-bus architecture and a new “Mod-MUX” architecture respectively. We discuss and compare the two designs and highlight their complementary merits.

18:00–20:00 Postdeadline Paper Sessions