ECOC 2013 LONDON

39th European Conference on Optical Communication

PROGRAMME

22-26 September 2013
ICC, ExCeL, London, UK

Organised by:

IET Events
The Institution of Engineering and Technology

Sunday 22 September

	Room A	Room B	Room C	Room D	Room E	Room F
14:00	**WS1:** SDM: How to Migrate from Point-to-Point Transmission to full Optical Networking?	**WS2:** Low-Cost Access to Photonic ICs, 5th European Photonic Integration Forum	**WS3:** Integration of Optical Devices for SDM Transmission	**WS4:** Technologies for Short Reach Optical Interconnects	**WS5:** Architectures and Control for Elastic Optical Networks	**WS6:** SDN Applications for Optical Network Operating System: Challenges and Opportunities
15:30	**Coffee Break**					
16:00	**WS1:** SDM: How to Migrate from Point-to-Point Transmission to full Optical Networking?	**WS2:** Low-Cost Access to Photonic ICs, 5th European Photonic Integration Forum	**WS3:** Integration of Optical Devices for SDM Transmission	**WS4:** Technologies for Short Reach Optical Interconnects	**WS5:** Architectures and Control for Elastic Optical Networks	**WS6:** SDN Applications for Optical Network Operating System: Challenges and Opportunities
17:30	**Get together drinks (Capital Suite, Level 3)**					

Monday 23 September

	Room A	Room B	Room C	Room D	Room E	Room F	Auditorium
09:30							**Plenary session**
11:00	**Coffee Break**						
11:30							**Plenary session**
12:40	**Lunch**						
14:00	**Mo.3.A** Few Mode Fibres & Space Division Multiplexing Session I	**Mo.3.B** Photonic Integration Technologies	**Mo.3.C** Coherent Subsystems	**Mo.3.D** Digital Signal Processing I	**Mo.3.E** Interconnecting Data Centres	**Mo.3.F** Hybrid Fibre Wireless	
15:30	**Coffee Break**						
16:00	**Mo.4.A** Few Mode Fibres and Space Division Multiplexing II	**Mo.4.B** Integrated Devices	**Mo.4.C** Receivers	**Mo.4.D** Digital Signal Processing II	**Mo.4.E** Software Defined Networking and Mulitlayer Networking	**Mo.4.F** High Speed Access Technologies	
17:30	**Welcome Reception (Fox @ ExCeL)**						

Tuesday 24 September

	Room A	Room B	Room C	Room D	Room E	Room F	Room G	Room H
09:00	**Tu.1.A** Infrared Materials and Applications	**Tu.1.B** Components for Access	**Tu.1.C** Optical Signal Processing	**Tu.1.D** Undersea Systems	**Tu.1.E** DSP Algorithms	**Tu.1.F** Integrated Devices	Symposium 1: Nanophotonics & Metamaterials Ideas for Telecoms and Data Processing	Symposium 2: Next Generation Data Centres - Paving the way for the Zettabyte Era
10:30	**Coffee Break**							
11:00	**Exhibition Only**						Symposium 1: Nanophotonics & Metamaterials Ideas for Telecoms and Data Processing	Symposium 2: Next Generation Data Centres - Paving the way for the Zettabyte Era
12:30	**Lunch Break**							
14:00	**Tu.3.A** Advances in Optical Fibres	**Tu.3.B** Interconnects	**Tu.3.C** Transmitter Subsystems		**Tu.3.E** Network Planning and Energy Efficiency	**Tu.3.F** Access Subsystems	Symposium 1: Nanophotonics & Metamaterials Ideas for Telecoms and Data Processing	Symposium 2: Next Generation Data Centres - Paving the way for the Zettabyte Era
15:30	**Coffee Break**							
16:00	**Poster Session (ECOC Exhibition Hall)**						Symposium 1: Nanophotonics & Metamaterials Ideas for Telecoms and Data Processing	Symposium 2: Next Generation Data Centres - Paving the way for the Zettabyte Era

Wednesday 25 September

	Room A	Room B	Room C	Room D	Room E	Room F	Exhibition Hall
09:00	**We.1.A** Metrology	**We.1.B** Modulators I	**We.1.C** Spectrally Shaped Transmission Subsystems	**We.1.D** Beyond WDM	**We.1.E** Elastic Optical Networking	**We.1.F** Flexible Access	09:30-13:00 **UK Photonics Research Showcase*** Workshop Chair: Ian Henning, University of Essex, EPSRC Network UNISON
10:30	**Coffee Break**						
11:00	**We.2.A** Nonlinearity in fibres	**We.2.B** Modulators and Detectors	**We.2.C** Coding & FEC	**We.2.D** Space-Division Multiplexing I	**We.2.E** Flex Grid Networks	**We.2.F** High Availability Access	
12:30	**Lunch**						
14:00	**We.3.A** Phase Sensitive Signal Processing	**We.3.B** Modulators II	**We.3.C** Compensation for Nonlinear Effects	**We.3.D** Space Division Multiplexing II	**We.3.E** Elastic Networks: Control Plane	**We.3.F** Coherent Access	
15:30	**Coffee Break**						
16:00	**We.4.A** Fibre Amplifiers for SDM	**We.4.B** Devices for Switching	**We.4.C** Transmitter Subsystems II	**We.4.D** Nonlinear Fibre Capacity	**We.4.E** Control Plane & PCE	**We.4.F** Field Trials and Experiments	
19:00	**Conference Dinner, Painted Hall, Old Royal Naval College, Greenwich**						

*The event aims to celebrate achievements, highlight the impact and discuss future directions of UK photonics research. Organised by the EPSRC network UNISON and is sponsored by the EPSRC Programme grants HyperHighway and UNLOC

Thursday 26 September

	Room A	Room B	Room C	Room D	Room E	Room F
09:00	**Th.1.A** Optical Packet /Burst Switching I	**Th.1.B** Lasers	**Th.1.C** Subsystems for SDM	**Th.1.D** Coherent Systems Modeling	**Th.1.E** Spectrum Allocation and Defragmentation	**Th.1.F** Short Range Systems
10:30	**Coffee Break**					
11:00	**Th.2.A** Optical Packet /Burst Switching II	**Th.2.B** Devices for Optical Processing	**Th.2.C** SDM Signal Processing	**Th.2.D** Modulation Formats	**Th.2.E** Photonic Node Architecture	**Th.2.F** Data Centre Networking
12:30	**Lunch**					
14:00	**Postdeadline Papers**					
15:30	**Closing Ceremony - Room C**					

WELCOME TO **ECOC 2013**

ECOC is the largest conference on optical communication in Europe, and one of the most respected and long-standing events of its kind in the world. ECOC 2013 is the 39th of the series providing, as it has done every year since its inception, a prime forum to present and discuss the very latest developments and results in optical communication devices, subsystems, transmission systems and networks.

ECOC travels around in Europe from year to year and ECOC 2013 marks a very significant event in that it represents the first return to London, location of the very first ECOC conference held back in 1975. Few of those involved in organising this original conference (which includes the two chairs for 2013!) could have foreseen the important role that the conference they created would play in the future evolution of optical communications, nor indeed the impact the field would go on to have on society itself. After 39 years ECOC remains as relevant and vibrant as ever. The fact that about 50% of the conference delegates typically come from Europe, about 30% from Asia/Pacific and about 20% from North America, highlights that ECOC is a truly global conference. At ECOC 2012, held in Amsterdam, over 1100 delegates attended the conference plus 329 exhibitors with around 4483 visitors to the exhibition, a slight increase in numbers over the ECOCs of previous years. All the indications are that ECOC 2013 will demonstrate yet further growth with paper submissions up by 12.6% and with a slight increase in exhibitor numbers for 2013.

The latest advances in optical communication technologies will be reported at ECOC 2013. Leading-edge technical progress will be presented through a carefully selected blend of keynote addresses, tutorial and invited papers and contributed regular and postdeadline papers.

The plenary session on Monday morning (Monday, 21 September) features talks by: Stephen Baily, General Manager, Research and Development, BBC; Dr Peter Stassar, Technical Director Optical Research, Huawei Technologies; Dr Bernard Barani, Deputy Head of Unit European Commission, DG Connect (Talk Title); Dr Tim Whitley, Managing Director, Research and Innovation, BT Plc; Warren East, Chief Executive Officer, ARM and Professor Eli Yablonovitch, Director of the NSF Center for Energy Efficient Electronics Science, Berkley.

The bulk of the conference programme is built on invited and contributed technical papers, carefully chosen through a rigorous and highly competitive selection process for either oral or poster presentation by an outstanding Technical Programme Committee, comprising around 100 well-known optical communications experts. It is organised into 6 sub-committees: “Fibers, Fiber Devices and Amplifiers”, “Waveguides and Optoelectronic Devices”, “Subsystems for Optical Networks and Datacomms”, “Point to Point Transmission Systems”, “Optical Transport and Large Scale Data Networks” and “Access, Local Area and Data Centre Networks”.

Two full-day special symposia are organised (Tuesday, 24 September) covering two increasingly important topics in the field. These symposia bring together a list of well-known and highly respected speakers and will cover “Nanophotonics and Metamaterials for Telecommunications” and “Next Generation Datacenters”.

The Workshops on Sunday, 22 September provide the opportunity for highly interactive discussions on some of the very hottest research topics.

As a special feature this year, the TPC chairs have organised a half-day workshop aiming to showcase UK photonics research. The workshop will take place on Wednesday, 25 September in the ECOC Exhibition Hall and will celebrate achievements, highlight the impact and discuss future directions of UK photonics research. The event is admission free and is open to ECOC delegates and outside visitors.

The technical programme concludes on Thursday, 26 September with a Postdeadline session, arguably the highlight of the conference, where the very latest and most outstanding results will be presented.

ECOC 2013 provides the ideal opportunity for anyone interested in optical communications, including researchers, product developers, sales managers and telecommunication analysts and market developers, to develop an up-to-date understanding of the field.

The ECOC 2013 conference organisation committee has prepared an exciting social programme to complement the technical programme. These include a conference reception at a traditional British Pub and Restaurant and a Gala dinner at The Painted Hall, Old Royal Naval College at Greenwich which is often described as the ‘finest dining hall in Europe’. Designed by Sir Christopher Wren and Nicholas Hawksmoor, it was originally intended as an eating space for the naval veterans who lived here at the Royal Hospital for Seamen. Its exuberant wall and ceiling decorations pay tribute to British maritime power.

We encourage you to take the opportunity whilst here to visit the city of London, with the immense choice of sightseeing, cultural entertainment and dining experiences that it provides. You might also like to consider extending your stay and experiencing some of the other exciting leisure and business opportunities that the UK has to offer.

Further information on the conference can be found at **www.ecoc2013.org**

Thank you for visiting London and ECOC 2013.

ECOC 2013 Conference General Chairs

Professor Sir David Payne
University of Southampton, UK

Professor Will Stewart
University of Southampton, UK

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Leif Katsuo Oxenløwe, *Technical University of Denmark, Denmark*
Ursula Keller, *ETH Zurich, Switzerland*
Andreas Kirstaedter, *University of Stuttgart, Germany*
Ton Koonen, *COBRA - TU Eindhoven, Netherlands*
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Jean-Claude Simon, *ENSSAT / University of Rennes, France*
Will Stewart, *University of Southampton, UK*
Peter Van Daele, *IMEC - IBBT - Ghent University, Belgium*

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ORC-University of Southampton, UK

Professor Dimitra Simeonidou
University of Bristol, UK

ECOC 2013 Local Organising Committee Chair

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Hideo Kuwahara, *Fujitsu Laboratories Ltd, Japan*
Richard Linke, *IEEE Photonics Society, USA*

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Subcommittee 1 (SC1)

Fibres, Fibre Devices and Amplifiers

This area focuses on optical fibres, their design, fabrication and characterisation, the physics of light propagation in optical fibres, fibre amplifiers and fibre lasers, as well as fibre based devices for telecommunication, data communications and other applications.

Chair:
Periklis Petropoulos, *ORC- University of Southampton, UK*

Members:
Tim Birks, *Bath University, UK*
David DiGiovanni, *OFS Laboratories, USA*
Benjamin Eggleton, *University of Sydney, Australia*
Tommy Geisler, *OFS Denmark, Demark*
Dag Roar Hjelme, *Invivosense, Norway*
Magnus Karlsson, *Chalmers University of Technology (CTH), Sweden*
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Hans Limberger, *EPFL, Switzerland*
Hanne Ludvigsen, *Aalto University, Finland*
Koshiba Masanori, *Hokkaido University, Japan*
Antonio Mecozzi, *University of L'Aquila, Italy*
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Stojan Radic, *UCSD, USA*
Christian G Schaeffer, *Helmut Schmidt Universität, Germany*
Pruneri Valerio, *ICFO - Institut de Ciències Fotòniques, Spain*
Lianshan Yan, *Southwest Jiaotong University, China*

Subcommittee 2 (SC2)

Subsystems for Optical Networks and Datacomms

This area focuses on the design, fabrication, performance testing, and reliability of devices and components used to generate, amplify, detect, switch, or process optical signals for information transport and processing, routing and interconnecting. Technologies include planar waveguides, bulk optics, and photonic bandgap structures based on various material systems.

Chair:
Graeme Maxwell, *CIP Technologies, UK*

Members:
Liam Barry, *Dublin City University, Ireland*
Romain Brenot, *III -V Lab, France*
Joe Campbell, *University of Illinois, USA*
Piero Gambini, *Avago Technologies, Italy*
Christian Lerminiaux, *utt, France*
Geert Morthier, *IMEC – Ghent University, Belgium*
Pascual Muñoz, *VLC Photonics, Spain*
Yoshiaki Nakano, *University of Tokyo, Japan*
Bert Offrein, *IBM, Switzerland*
Min Qiu, *Royal University of Technology (KTH), Sweden*
Marco Romagnoli, *CNIT, Italy*
Leo Spiekman, *Alphion, USA*
Yikai Su, *Shanghai Jiao Tong University, China*
Shinji Tsuji, *Japan Science and Technology Agency, Japan*
Andreas Umbach, *u²t Photonics AG, Germany*

Subcommittee 3 (SC3)

Subsystems for Optical Networks and Datacomms

This area focuses on the modelling, design, and implementation of optical, optoelectronic, or electrical subsystems, including algorithms for digital coherent transceivers, performance monitoring, optical signal processing, add-drop multiplexing, optical switching, and optical packet routing. In addition, the area considers enabling optical interconnects, switching and routing subsystems and integrated interconnection architectures that address the unique challenges of Datacom and Computercom.

Chair:
Seb Savory, *UCL, UK*

Members:
Hercules Avramopoulos, *National TU Athens, Greece*
Johan Bauwelinck, *Ghent University, Belgium*
Laurent Bramerie, *ENSSAT, France*
John Cartledge, *Queens University, Canada*
Ernesto Ciaramella, *Scuola Superiore Sant'Anna, Italy*
Andrew Ellis, *Aston University, UK*
Roberto Gaudino, *Politecnico di Torino, Italy*
Jeurg Leuthold, *ETHZ, Switzerland*
Nakazawa Masataka, *University of Tohoku, Japan*
Werner Rosenkranz, *Universität Kiel, Germany*
Oded Raz, *COBRA - Eindhoven Univ. of Technology, Netherlands*
Namiki Shu, *National Institute of Advanced Industrial Science and Technology, Japan*
Antonio Teixeira, *Universidade de Aveiro Portugal, Portugal*
Moshe Tur, *Tel Aviv University, Israel*
Alan Willner, *UCLA, USA*

Subcommittee 4 (SC4)

Point to Point Transmission Systems

This area focuses on the modelling, design, and implementation of optical transmission links of all scales, highlighting system-level implications of physical impairments and impairment mitigation techniques. Contributions to this area are concerned with aspects such as capacity, reach, flexibility, or energy consumption of optical transmission systems and solutions to overcome the current limitations. Papers illustrating the transmission benefits of novel fibres, devices and subsystems are encouraged but papers focused on fibre, device or subsystem design and/or their more general properties/performance should be submitted elsewhere.

Chair:
Ekaterina Golovchenko, *Tyco, USA*

Members:
Sébastien Bigo, *Alcatel Lucent, France*
Huug De Waardt, *COBRA - Eindhoven Univ. of Technology, Netherlands*
Rene Essiambre, *Alcatel-Lucent, USA*
Fabrizio Forghieri, *Cisco Photonics, Italy*
Yann Frignac, *IT-SudParis, France*
Helmut Griesser, *ADVA Optical Networking, Germany*
Onaka Hiroshi, *Fujitsu, Japan*
Robert Killey, *UCL, UK*
Christophe Peucheret, *Technical University of Denmark, Denmark*
Luca Potì, *CNIT, Italy*
Peter Krummrich, *Technische Universität Dortmund, Germany*
Miyamoto Yutaka, *NTT, Japan*
Wen-De Zhong, *Nanyang Technological University, Singapore*

Subcommittee 5 (SC5)

Optical Transport and Large Scale Data Networks

This area focuses on the modelling, design, architecture, and scaling of optical transport for telecommunications and data networks. This includes circuit- and packet-switched backbone, metro-core and inter datacentre networks as well as the control and management functions and integration with higher layer services. It also covers aspects of successful commercial network deployments and field trials. We particularly encourage submissions that focus on new application areas and cutting-edge network level innovations.

Chair:
Andrew Lord, *BT, UK*

Members:
Achim Autenrieth, *ADVA Optical Networking, Germany*
Carlo Cavazzoni, *Telecom Italia, Italy*
Gabriel Junyent, *Universitat Politécnica de Catalunya, Spain*
Andreas Gladisch, *Deutsche Telekom, Germany*
Jean-Pierre Hamaide, *Alcatel-Lucent, France*
Fernandez-Palacios Juan Pedro, *Telefonica Investigacion y Desarrollo, Spain*
Sato Ken-ichi, *University of Nagoya, Japan*
Fukuchi Kiyoshi, *NEC, Japan*
Suzuki Masatoshi, *KDDI Labs, Japan*
Naoya Wada, *National Institute of Information and Communication Technology, Japan*
Peter Ohlen, *Ericsson, Sweden*
Mario Pickavet, *iMinds – Ghent University, Belgium*
Alexnadros Stavdas, *University of Peloponnese, Greece*
Hidenori Taga, *National Sun Yat-Sen University, Taiwan*
Jarek Turkiewicz, *Warsaw University of Technology, Poland*
Ben Yoo, *UC Davis, USA*

Subcommittee 6 (SC6)

Access, Local Area and Data Center Networks

This area focuses on networking aspects of broadband optical access and local-area networks. It covers FTTx, passive optical networks, radio-over-fibre systems, free space systems, hybrid wireless/optical solutions, in-building and intra data-centre networks. It also comprises aspects of successful commercial mass deployments, field trials, and applications of optical communication technologies in public, private and enterprise networks and computer interconnect networks.

Chair:
Albert Rafel, *BT, UK*

Members:
Ivan Adonovic, *Strathclyde University, UK*
Philippe Chanclou, *Orange, France*
Stefan Dahlfort, *Ericsson, Sweden*
Dirk Breuer, *Deutsche Telekom, Germany*
Bas Huiszoon, *Genexis, Netherlands*
Yuefeng Ji, *Beijing Univ. of Posts and Telecommunications, China*
Christina Lim, *University of Melbourne, Australia*
Idelfonso Monroy, *Technical University of Denmark, Denmark*
Ken Reichmann, *AT&T, USA*
Sales Salvador, *Universitat Politecnica de Valencia, Spain*
Sophie-Camille Bres, *EPFL, Switzerland*
Eduward Tangdiongga, *COBRA - Eindhoven Univ. of Technology, Netherlands*
Ioannis Tomkos, *Athens Information Technology Center, Greece*
Ping-Kong Alex Wai, *Hong Kong Polytechnic University, Hong-Kong*
Naoto Yoshimoto, *NTT, Japan*

Workshop 1 - SDM: How to Migrate from Point-to-Point Transmission to Full Optical Networking?

Room: A

Organised by
Georgios Zervas, *University of Bristol, UK*

Additional organisers
Periklis Petropoulos, *ORC, University of Southampton, UK*
Yoshinari Awaji, *NICT, Japan*
Hidehiko Takara, *NTT, Japan*

Abstract
We experience Internet traffic growth of 100 times every 10 years. The capacity of existing standard single-mode fibre is approaching its limits following significant progress on transmission technologies which allow for high spectral efficiencies to be realised. Space Division Multiplexing (SDM) has emerged as a solution to the problem of saturation of the capacity of optical transmission systems and has effectively achieved a 10-fold increase in the overall fibre capacity within the space of just 2 years. The idea behind SDM is to transmit simultaneously over several different spatial modes of propagation, and the research community is exploring in parallel several different avenues that would allow this to happen; the use of fibres comprising multiple cores, multimode fibres and even the use of optical vortices are the prime examples. In order to fully benefit from the advantages of SDM technologies in a complete network scenario, the corresponding devices for the implementation of optical nodes, transceivers and networks will also need to be developed. However, clearly the relative benefits of the different SDM technologies are not the same and several technical and economic challenges need to be addressed before the wide adoption by service providers.

Part 1 - 14:00-15:30
Introduction Organizers
Recent Progress in SDM Transmission Technologies and Perspectives for Optical Networking - Toshio Morioka, *DTU, Denmark*
High Capacity MCF Transmission Technology for Future Optical Transport Networks - Akihide Sano, *NTT, Japan*
Key Technologies and Requirements for Space Division Multiplexing (SDM) Networks - Takehiro Tsuritani, *KDDI, Japan*
Optical Nodes for SDM Networking: Challenges and Possible Approaches
Norberto Amaya, *University of Bristol, UK*
Multi-dimensional Spatial-spectral Switching Network Nodes
Dan Marom, *The Hebrew University of Jerusalim, Israel*

15:30 Coffee break (ICC Capital Suite Foyer)

Part 2 - 16:00-17:30
IBM SDN-VE: Software Defined Networking for Virtual Environment
Rami Cohen, *IBM, Israel*
Exploiting SDM Benefits in Optical Networks - Jun Sakaguchi, *NICT, Japan*
SDM: What's It Worth to You? – Scenarios for Price-Points of Components of Multi-Core Fiber Systems - Steven Korotky, *Alcatel-Lucent, USA*
Panel Session - *Moderator TBC*

This workshop will discuss the following questions:
- Which is the most suitable SDM technology for networking?
- What are the benefits and challenges of using SDM in networks?
- What is the optimum casting of optical and electronic solutions for SDM networking?
- How do the different SDM alternatives compare when considered for backbone, metro/access and HPC / data-centre networking?
- What are the benefits and challenges of SDM for network virtualization?

Topics:
- SDM networking as well as their associated node, switching and transmission technologies
- Wider audience from Operators to Vendors and research institutes

Target Audience: Wider Audience from Operators to Vendors and research institutes

Workshop 2 - Low-Cost Access to Photonic ICs 5th European Photonic Integration Forum

Room: B

Organised by
Professor Meint Smit, *Eindhoven University of Technology, Netherlands*

Additional organisers
Professor Roel Baets, *University of Ghent, Belgium*
Professor Mike Wale, *Oclaro, UK*

Abstract
In the last few years major progress has been made in the development of a generic foundry infrastructure for low-cost access to design and manufacturing of advanced Photonic ICs, in a similar way to how the microelectronics industry is configured. The approach has been pioneered in European projects like EuroPIC, PhotonFAB, HELIOS and ESSENTIALS. It is further developed in the projects PARADIGM and PLAT4M and it has a prominent place in the roadmap of the Photonics21 platform. The generic photonic foundry approach includes development of standardized fabrication processes, software design kits with component libraries, generic packages and test facilities. This year novel foundry processes with improved capabilities in both InP, Silicon Photonics and TriPleX technology have been announced and will be discussed in the workshop. The workshop will review the roadmap for the generic photonic foundry approach and it will address the business opportunities that are created by the large reduction of the entry costs for application of Photonic ICs in novel or improved products. The present workshop is organized by the integration technology platforms ePIXfab and JePPIX, it is the 5th event of the annual European Photonic Integration Forum.

14:00 Introduction to Generic Photonic IC Technology
Meint Smit, *COBRA TU/e, Netherlands*
14:10 Roadmap for InP and TriPleX-based Photonic Integration
Mike Wale, *Oclaro, UK*
14:30 Silicon Photonics Roadmap - Maurizio Zuffada, *STMicroelectronics, Italy*
14:50 Economics of PICs - Martin Schell, *FhG-HHI, Germany*
15:10 Photonic IC Design - Twan Korthorst, *Phoenix Software BV, Netherlands*
15:30 Coffee break (ICC Capital Suite Foyer)
Part 2: Packaging
16:00 Silicon PIC Packaging - Peter O'Brien, *Tyndall National Institute, Ireland*
16:10 InP PIC Packaging - Bob Musk, *Gooch & Housego, UK*
Application Examples
16:20 The Eastern European Design Hub - Kasia Lawniczuk, *Warsaw University of Technology, Poland*
16:30 Fiber Optic Sensing using Photonic Integrated Circuits
Rolf Evenblij, *Technobis Fibre Technologies, Netherlands*
16:40 Coherence Tomography Applications based on TriPleX Waveguides
Ton van Leeuwen, *Academic Medical Centre, Netherlands*
16:50 Silicon-organic Hybrid Integration
Christian Koos, *IPQ Karlsruhe Institute of Technology, Germany*
Part 3: Capabilities of Coming MPW Foundry Runs
17:00 InP & TriPlex technology / JePPIX - Luc Augustin, *JePPIX, Netherlands*
17:10 Silicon Photonics Technology / ePIXfab - Amit Khanna, *ePIXfab, Belgium*
17:20 Silicon Photonics technology / OPSiS - Michael Hochberg, *OPSiS, US*

Topics:
- Generic InP & TriPleX Roadmap
- STM Silicon Photonics Roadmap
- Economics of PICs
- Present status of Photonic Foundry Design Kits
- Photonic IC Design
- Photonic IC Packaging
- Business examples for low-cost Application-Specific Photonic ICs (ASPICs)
- Capabilities of coming MPW foundry runs in InP, Silicon Photonics and TriPleX Technology

Target Audience: Everybody interested in advanced devices and subsystems for a broad range of applications, including data transport systems and data networks.

Workshop 3 - Integration of Optical Devices for SDM Transmission

Room: C

Organised by
Dr Tetsuya Kawanishi, *NICT, Japan*

Chairs
Brian Corbett, *Tyndall National Institute, Ireland*
Dr Brian Kelly, *Eblana Photonics, Ireland*
Dr Hirotaka Ono, *NTT, Japan*

Abstract
Recently, space division multiplexing (SDM) based on multi-core or multi-mode fibres has attracted a great deal of attention in huge capacity data transmission technologies. Similar to conventional systems, SDM based transmission systems are composed of transmitters, receivers, amplifiers and optical fibres. Large scale integration is recognised as an important step towards reducing costs in conventional systems and in SDM based systems there is the potential to achieve even greater component consolidation. However this requires dramatic improvement of the system components to increase total transmission capacity. The purpose of this workshop is to discuss device requirements for large-scale SDM systems which should have a high number of transmitters and receivers, advanced modulation formats to increase the total capacity and low power consumption to construct sustainable network systems. Crosstalk should be suppressed in SDM systems to avoid degradation of advanced modulation formats. Integration is the key technology for such optoelectronic components and is important for the fibre itself as well as optical components such as connectors, mux/demux devices and amplifiers. This workshop, co-organised and sponsored by EU FP7 project MODEGAP and the EXAT program, Japan, will review and discuss possible new technologies including optoelectronic device integration, amplifiers for SDM, multi-core and few mode fibres. The goal of this workshop is to achieve insights for the future direction of research on components designed for SDM.

Part 1 - 14:00-15:30
Overview of Mode Gap - Dr Ian Giles, *Phoenix Photonics, UK*
Overview of EXAT - Dr Itsuro Morita, *KDDI labs, Japan*
Amplifiers for SDM - Dr Shaiful Alam, ORC – *University of Southampton, UK*
Fibre Splicing - Dr Shoichiro Matsuo, *Fujikura, Japan*
Fibers for Mode Multiplexing - Dr Lars Gruner-Nielsen, *OFS, Denmark*
Photonic Lanterns - Prof Tim Birks, *University of Bath, UK*
Selective Coupling to Higher Order Fibre Modes using Compact Silicon Photonics Grating Devices - Prof Petermann Klaus, *TU Berlin, Germany*
Optical Couplers for SDM - Prof Yasuo Kokubun, *Yokohama National University, Japan*
Photonic Lightwave Circuit - Dr Kenya Suzuki, *NTT, Japan*
Panel Session: Moderator - Dr Shu Namiki, *AIST, Japan*

15:30 Coffee break (ICC Capital Suite Foyer)

Part 2 - 16:00-17:00
Si Photonics Integration - Dr Sylvie Menezo, *LETI, France*
Photonic and RF integration - Dr Toshimasa Umezawa, *NICT, Japan*
High Density RF Connections - Dr Nobuhiro Kikuchi, *NTT, Japan*
Integration Strategies for Mode Mux - Prof Ton Koonen, *TUE, Netherlands*
Power Consumption of SDM Systems - Dr Peter Winzer, *Alcatel-Lucent, USA*
Panel Session: Moderator - *(tbc)*

Topics:
- Large scale integration of optoelectronic devices and component performance criteria for SDM
- Implications of advanced modulation formats for the design of SDM components
- Signal processing for MIMO
- Design and fabrication of multi-core and multi-mode fibres
- Novel optical devices for SDM including optical amplifiers
- Crosstalk reduction using fibre design and signal processing
- Lowering power consumption in transmission systems.

Target Audience: Researchers in optical device or signal processing technologies; transmission system operators; manufacturers of measurement instruments

Workshop 4 - Technologies for Short Reach Optical Interconnects

Room: D

Organised by
Professor Richard Penty, *University of Cambridge, UK*

Additional organisers
Dr Terry Clapp, *Dow Corning, USA*

Abstract
Short-reach optical interconnects have recently attracted significant interest due to the ever increasing demand for bandwidth and reduced energy consumption in large-scale high-performance electronic systems. Optical fibre technologies are now widely deployed in rack-to-rack communications in such systems as they can offer high-capacity low-power interconnections. Next generation supercomputers are expected to require even larger interconnection capacities and reduced power consumption. As a result, optics is increasingly being considered for use in even shorter (<1 m) communication links such as for backplanes and board-to-board, chip-to-chip and on-chip communications owing to the performance advantages it offers with respect to electrical interconnect counterparts when operating at high data rates: larger bandwidth, immunity to electromagnetic interference, reduced power consumption and relaxed thermal management requirements. However, the cost-effective integration of optics into existing electronic systems constitutes a significant technological challenge. Optical technologies need to be compatible with existing electronic system architectures and conventional manufacturing processes of the electronics industry and allow system assembly and packaging at low costs.

This workshop will therefore consider the drivers and optical technologies for next generation very short reach (sub metre) interconnects. This will include guided wave and free space approaches, and will consider length scales for on-chip (~mm), on board (~10cm) and backplane (~1m) communications as well as interconnect architectures for the above applications. Finally barriers to adoption of optical technologies over the existing Cu incumbent technologies will be considered.

Trends in Optical Interconnects for Computing Applications
Dr Bert Offrein, *IBM Zurich*
Standards for Short Reach Optical Interconnect
Dr David Cunningham, *Avago Technologies*
Systems Partitioning for Future Optics on Board Applications
Dr Matt Traverso, *Cisco*
Short Reach Interconnects for Storage Networks
Richard Pitwon, *Xyratex*
Polymer Waveguides for on-board Iinterconnects
Dr Ziyang Zhang, *HHI*
Title TBC
Dr Marika Immonen, *Meadville Group*
Title TBC
Dr Felix Betschon, *Vario-optics*

Topics:
- Guided wave interconnects (including silicon, silica, polymer waveguides)
- 2D and 3D free space interconnects
- Interconnects for optical backplanes
- On-board (chip-to-chip) optical interconnects
- On-chip optical interconnects (including silicon photonics and III-V based PICs)
- Integration of photonics and electronics and hybrid integration
- Reconfigurable optical interconnects

Workshop 5 - Architectures and Control for Elastic Optical Networks

Room: E

Organised by
Juan Pedro Fernández-Palacios, *Telefonica I+D, Spain*

Additional organisers
Dimitrios Klonidis, *AIT, Greece*

Abstract
Wavelength Switched Optical Networks (WSON) were designed with the premise that all channels in a network have the same spectrum needs, based on the ITU-T DWDM grid. However, this rigid grid-based approach is not adapted to the spectrum requirements of the signals that are best candidates for long-reach transmission and high-speed data rates of 400Gbps and beyond. An innovative approach is to evolve the fixed DWDM grid to a flexible grid, in which the optical spectrum is partitioned into fixed-sized spectrum slices. This allows facilitating the required amount of optical bandwidth and spectrum for an elastic optical connection to be dynamically and adaptively allocated by assigning the necessary number of slices of spectrum. Additionally, since optical networks represent the core substrate responsible for inter-carrier data transport, other key research topics addressed in this area include possibly standardized multicarrier and multivendor control solutions to make more effective and open (i.e. vendor-independent) the current implementations. Furthermore new control plane solutions are necessary to introduce dynamicity, elasticity and adaptation in flexi-grid DWDM networks. This workshop aims to provide an overview of the objectives, framework, functional requirements and use cases of elastic optical network architectures and their control architectures. In particular some the topics to be covered in the workshop are: architectural design and use cases for Elastic Optical Networks, metro and core Flexgrid architectures, IP/MPLS and Flexgrid integration, SDN application in elastic optical networks, control architectures for cognitive optical networks, Flexgrid control plane standardization.

14:00 **Introduction**
Juan Fernandez-Palacios, *Telefonica I+D, Spain*
14:05 **Will Flexgrid Networks be worth?**
Akira Hirano, *NTT, Japan*
14:25 **Use Cases for Flexgrid Networking**
Andrew Lord, *BT, UK*
14:45 **IP Over Flexgrid Control Architectures**
Ori Gerstel, *Cisco, Israel*
15:05 **Carrier SDN Transport Networks**
Chris Liou, *Infinera, USA*
15:25 **Standardisation Activities on Flexgrid**
Adrian Farrel, *Juniper, UK*
15:45 **Coffee break (ICC Capital Suite Foyer)**
16:00 **Architecture on Demand**
Norberto Amaya, *University of Bristol, UK*
16:20 **FOX-C Network Architecture**
Erwan Pincemin, *Orange, France*
16:40 **CHRON Network Architecture**
Ioannis Tomkos, *AIT, Greece*
17:00 **Panel Discussion**
17:20 **Close**

Topics:
- Use cases for Elastic Optical Networks
- Metro and core Flexgrid architectures
- IP/MPLS and Flexgrid integration
- SDN application in elastic optical networks
- Control architectures for cognitive optical networks
- Flexgrid control plane standardization.

Target Audience:
- Network operators
- System vendors
- Research groups

Workshop 6 - SDN Applications for Optical Network Operating System: Challenges and Opportunities

Room: F

Organised by
Dr Hiroaki Harai, *NICT, Japan*

Additional organisers
Dr Reza Nejabati, *University of Bristol, UK*
Dr Diego R. Lopez, *Telefónica I+D, Spain*
Dr Inder Monga, *ESnet, USA*

Abstract
Software Defined Network (SDN) is becoming an established trend in operation and management of today's networks from Data Centre to telecomm operators' infrastructures. This trend has been recently reinforced by the evolution of network services by means of Network Functions Virtualisation (NFV) and the consolidation of the OpenFlow protocol that support decoupling of network control and data plane. SDN brings a promising solution to network operators and Data Centre providers for reducing the complexity and costs of deploying and managing their necessarily heterogeneous networks and services. However, a SDN-based network operating system supporting existing and emerging optical network transport that will lay the foundation for true network programmability at all network layers is still missing. This workshop will attempt to shed light on SDN's potentials and benefits as the basis of a network operating system for control and management of optical network for telecom network operators and Data Centre providers. It brings together leading experts from research and industry to discuss solutions for extending SDN frameworks, protocols and technologies to support new advances in optical data plane technologies such as new photonic sub-wavelength or grid-less technologies within context of data centre, access, metro and core networks. Finally, this workshop will also focus on the role and advantage of SDN on supporting large-scale optical infrastructures.

14:00 **Opening Talk**
Dr Hiroaki Harai, *NICT*
14:10 **Supporting IP Services over Virtualized Transport Networks**
Dr Ping Pan, *Infinera*
14:30 **What Can SDN Bring to Transport Networks**
Dr Maarten Vissers, *Huawei*
14:50 **Expectations and Controversies of SDN Technologies in Optical Networks**
Dr Ryutaro Kawamura, *NTT*
15:10 **TBD**
Dr Lyndon Ong, *ONF*
15:30 **Coffee Break (ICC Capital Suite Foyer)**
15:45 **SDN: Typical Operator Use Cases**
Prof. Andrew Lord, *BT*
16:05 **Applicability of SDN Principles for the Control and Management of Optical networks within the STRAUSS EU-Japan Project**
Dr Ramón Casellas, *CTTC*
16:25 **Software Defined Multi-dimentional Optical Networks**
Prof. Dimitra Simeonidou, *University of Bristol*
16:50 **Workshop Panel Discussion**
17:25 **Concluding Talk**
Dr Reza Nejabati, *NICT*

Topics:
- Software defined optical networking for inter and intra Data Center connectivity
- SDN-based network control and management for converged packet over optical networks
- Decoupling of the optical transport from the control plane
- OpenFlow extensions for emerging optical transport technologies
- Coexistence of GMPLS and OpenFlow
- Transport formats, transponder, switching technologies supporting software defined optical network
- Programmable and application-aware optical network enabled by SDN
- SDN role on supporting large scale experimental optical infrastructures

Target Audience:
- Network operators
- Data Centre Providers
- Network and Data centre Vendors
- Researchers and academic

09:45
Fibre Broadband: beginning or end of the journey?

Dr Tim Whitley, *Managing Director, Research and Innovation, BT, UK*

Biography
As MD for Research & Innovation, Tim is accountable for BT's Global research activities

Tim is also MD for Adastral Park, BT's Global Engineering HQ. Prior to his current role Tim was BT's Group Strategy Director, accountable for guiding BT's major strategic and investment choices. He has been at the heart of BT's exciting Next Generation Access plans which will see the next generation of broadband – Fibre Broadband – deployed across the UK since their inception in 2008. Tim joined BT in 1981 as an apprentice engineer and during his 32 year career has held many positions ranging from advanced optical-fibre device and network research, technology consultancy and architecture to Director of techno-economics analysis and Group technology Officer. He has published over 50 papers in the field of optical communications, holds a BSc in Physics and a PhD in Electronic Systems Engineering. Tim is based at BT's Global Engineering and Research HQ, Adastral Park, Ipswich, Suffolk. Tim lives in Felixstowe, England with his wife Teresa and four daughters.

Abstract: Demand for bandwidth rises inexorably, fuelled by over 30 years of innovation and development in communications. This presentation will reprise BT's latest fibre deployment plans and will describe how optical technology, applied to both core and more recently access networks, has played a huge role in delivering a society that enjoys widely available broadband communications and the host of communications, entertainment and transactional services we increasingly rely on for our daily lives. Looking a little further forward as technologists, we can see how exciting concepts such as flexgrid, virtualisation, SDN, and WDM PON will enable the next wave of applications. And as future customers or policy makers, we can envision how fibre communications powered concepts such as eHealth, BigData and Machine to Machine will further revolutionise the very society in which we live. This presentation will describe how we got to this point and provide a few pointers as to where next.

10:10
The Controversial Challenges for Today's Research Towards Next Generation Optical Networks

Dr Peter Stassar, *Technical Director Optical Research, Huawei Technologies, Netherlands*

Biography
MSEE Eindhoven University of Technology (1980)
Since 2011 Technical Director Optical Research at Huawei Technologies. Previously: Senior Optical Product Manager on FTTH CPEs at Genexis in the Netherlands (2004 – 2011) and consulting with Finisar Co. for ITU-T representation (2004 – 2011). Senior Application and System Engineer for optical interface specifications and applications for PDH, SDH, OTN, DWDM, PON equipment, working at Lucent Technologies, AT&T and Philips Telecom (1980 – 2003). Since 2006 Rapporteur of Q.6 in ITU-T SG15, "Characteristics of optical systems for terrestrial transport networks". Since 1989 participating in Q.6. Editor of Recommendations G.664 (optical safety), G.693 (very short distances optical interface specifications), G.695 (CWDM optical interface specifications). Since 2011 participating in IEEE 802.3: 100G and 400G client side optical interface specifications.

10:35
Intelligence Everywhere

Warren East, *Former Chief Executive Officer, ARM, UK*

Biography
Warren East was chief executive officer for ARM Holdings plc from October 2001 to July 2013. Warren joined ARM in 1994 to set up the ARM consulting business. He later held the position of vice president of business operations and was appointed to the board as chief operating officer in October 2000. ARM is a constituent of the FTSE 100. Under Warren's leadership, ARM matured into the world's leading Semiconductor IP licensing company with nearly 1000 Microprocessor licenses sold to over 360 semiconductor companies worldwide, collectively shipping approximately 10 billion ARM chips per year.

Warren is a chartered engineer, a companion of the Chartered Management Institute and a Fellow of both the Institution of Engineering and Technology and the Royal Academy of Engineering. He is also a Distinguished Fellow of the British Computer Society. Warren holds a master's degree in Engineering Science from the University of Oxford and has an honorary doctorate from Cranfield University. In 2007 Warren was named Business Leader of the year at the National Business Awards, and was named in the Barron's list of the world's best 30 CEOs in 2011 and 2013.

He is senior non-executive director and chairman of the audit committee of De La Rue plc, and a non executive director of Micron inc, Dyson limited, and the Connected Digital Economy Catapult. He chairs the ESCO leadership forum and is a member of several advisory boards for venture capital firms and their investee business, and for both Oxford University and Cranfield University.

Abstract: Warren will discuss the business opportunity and wider societal benefits promised by the internet of things and describe ARM's pivotal role in realising these in a sustainable manner. He will examine several key issues which will need to be resolved before this next wave of computing can really take hold, together with some of the approaches ARM is taking to address these, and present an optimistic view of the future awaiting both companies and individuals.

11:30
A New Broadcasting System; how media will change in a highly connected world

Stephen Baily, *General Manager, Research and Development, BBC*

Biography
Stephen Baily was appointed General Manager of BBC Research & Development in March 2011. Stephen is responsible for the overall management of the BBC's research and development department located at sites in London and Manchester, with activities across the media value chain, and its engagement with wider industry and academia.

In recent years, Stephen has worked in a variety of roles in the BBC's Future Media & Technology and Operations divisions, including a period as Head of Distribution Technology, during which he represented the BBC's interests in spectrum planning and Digital Switchover. Previously, Stephen had worked for Research and Development for a number of years, initially in radio frequency design and latterly broadcast system architecture.

During his career, Stephen has played a leading role in system standardisation and launch of a number of key services, including Freeview, Freesat and the BBC's HD television services.

11:55
The Energy Efficient Internet; Searching for the Milli-Volt Switch

Professor Eli Yablonovitch, *Director of the NSF Center for Energy Efficient Electronics Science, Berkley, USA*

Biography
Eli Yablonovitch is the Director of the NSF Center for Energy Efficient Electronics Science (E3S), a multi-University Center based at Berkeley. He received his Ph.d. degree in Applied Physics from Harvard University in 1972. He worked for two years at Bell Telephone Laboratories, and then became a professor of Applied Physics at Harvard. In 1979 he joined Exxon to do research on photovoltaic solar energy. Then in 1984, he joined Bell Communications Research, where he was a Distinguished Member of Staff, and also Director of Solid-State Physics Research. In 1992 he joined the University of California, Los Angeles, where he was the Northrop-Grumman Chair Professor of Electrical Engineering. Then in 2007 he became Professor of Electrical Engineering and Computer Sciences at UC Berkeley, where he holds the James & Katherine Lau Chair in Engineering.

Prof. Yablonovitch is a Fellow of the IEEE, the Optical Society of America and the American Physical Society. He is a Life Member of Eta Kappa Nu, and is elected as a Member of the National Academy of Engineering, the National Academy of Sciences, and the American Academy of Arts & Sciences. He has been awarded the Harvey Prize (Israel), the IEEE Photonics Award, the IET Mountbatten Medal (UK), the Julius Springer Prize, the R.W. Wood Prize, the W. Streifer Scientific Achievement Award, and the Adolf Lomb Medal. He also has an honorary Ph.d. from the Royal Institute of Technology, Stockholm, and from the Hong Kong Univ. of Science & Technology. In his photovoltaic research, Yablonovitch introduced the 4n2 light-trapping factor that is in worldwide use for almost all commercial solar panels. This factor increased the theoretical limits and practical efficiency of solar cells. 4n2 is based on statistical mechanics, and is sometimes called the "Yablonovitch Limit". Yablonovitch introduced the idea that strained semiconductor lasers could have superior performance due to reduced valence band (hole) effective mass. Today, almost all semiconductor lasers use this concept, including telecommunications lasers, DVD players, and red laser pointers. Yablonovitch is regarded as a Father of the Photonic BandGap concept, and he coined the term "Photonic Crystal". The geometrical structure of the first experimentally realized Photonic bandgap, is sometimes called "Yablonovite".

Abstract: Energy efficiency in data centers, and in digital electronics generally, tends to be ~10^6 times worse than theoretical limits. In electronics we need a more sensitive switch that could be controlled by smaller voltages, measured in millivolts. In photonic Data-Comm we need more sensitivity to reduce the number of photons/bit, by orders of magnitude.

The US NSF Center for Energy Efficient Electronics http://www.e3s-center.org/ is taking a multi-faceted approach to these problems that includes research toward a new more sensitive semiconductor switch, nano-mechanical switching, magnetic switching, and new more sensitive photo-receivers.

12:30
European research in Network Technologies: Horizon 2020 perspective

Dr Bernard Barani, *Deputy Head of Unit European Commission, DG, Connect, Belgium*

Biography
Bernard Barani graduated from the École Nationale Supérieure des Télécommunications de Bretagne in 1982. He then served as communications engineer in industry on military infrared systems and then with the European Space Agency on advanced satcom programmes. In 1994, he joined the European Commission Directorate General "Information Society", and was responsible for implementation of research and policy issues of wireless communication, Internet, audio visual systems, Software and Services.

He has been Deputy head of the unit dealing with research and policy in the field of RFID, Internet of Things and networked enterprise systems and is currently Deputy head of the unit in charge of research and innovation on Network Technologies in the CONNECT Directorate General of the European Commission.

Abstract: Research in network technologies has received significant support under the currently running ICT programme of the 7th Framework Programme of research sponsored by the European Union. About €600M have been invested in these technologies, a significant part having been invested to support optical technologies and all optical networks. With the upcoming Horizon 2020 research and innovation programme covering the 2014-2020 financial period, new approaches and topics are being contemplated to support the European network industry. The talk will hence focus on how it is envisaged to cover the sector at large under Horizon 2020, including the optical network technologies, and the retained priority themes for the first work programme.

Key to Session Numbering

Example: Tu.3.C.4

Tu. = day
.3. = The quarter of the day the session is taking place: (1 = first session of the day, 2 = after morning coffee break, 3 = after lunch break, 4 = last session of the day)
.C. = room
.4. = the order the paper is placed in the session

So Tu.3.C.4, is being presented on Tuesday, after the lunch break, in room C and is the 4th paper being presented in the session

Tuesday 24 September 2013

Special Symposia 1 - Nanophotonics & Metamaterials for Telecoms and Data Processing

Room: G

Co-Chairs
- Nikolay Zheludev, *University of Southampton, UK & NTU, Singapore*
- Nader Engheta, *University of Pennslyvania, USA*
- Harry Atwater, *California Institute of Technology, USA*

The fields of metamaterials and nanophotonics are closely interlinked. Nanophotonics is now a major research direction in optical physics and engineering. Driven by the dream of unprecedented device functionality, nanophotonics studies the exciting science of the interaction of light with nanostructures, at the size scale where optical, electronic, structural, thermal and mechanical properties become deeply interdependent. The aim is to control light in a minute device containing just a few layers of atoms using signals carried by only a few photons and to do it very rapidly, within just a few oscillation cycles of the light wave. Metamaterials are artificial electromagnetic media achieved by structuring matter on a sub-wavelength scale. This field of research was catalysed a few years ago by the intriguing opportunity to develop media that refract light in the opposite direction to that of normal media. The field of metamaterials is now a major research direction in photonics. Today its meaning encompasses linear, nonlinear, switchable and artificial gain media offering all manner of unusual and useful functionalities, achieved by artificially structuring matter at sizes smaller than the length scale of the external stimulus. Nanophotonics and metamaterials currently represent two of the most dynamic areas of physics, engineering and materials science and have been facilitated by the recent proliferation of nanofabrication techniques such as high-resolution optical and electron beam lithography, focused ion milling and nanoimprinting. With much of the basic physics now properly understood the new challenge is to develop nanophotonic devices and metadevices and to establish practical applications of the technology. The main purpose of the symposium is to bring together research leaders in the nanophotonics, metamaterials and optical communications communities to foster the exchange of ideas and to identify areas in which these potentially technologies have the potential to have the greatest impact.

Symposia 1 Programme

Tu.1.G
Plasmonics Devices
Chair: Nikolay Zheludev, *University of Southampton, UK & NTU, Singapore*

Tu.1.G.1 • 09:00
Hybrid Plasmonic Photonic Devices for Future Lightwave Circuits
H Atwater[1]; *[1]California Institute of Technology, USA*
We discuss new developments in hybrid plasmonic/photonic device required by future photonic circuit applications including 1) low insertion loss interconnects from Si photonic to plasmonic structures 2) high bandwidth nanoscale conducting oxide modulators and 3) ultracompact CMOS compatible photodetectors.

Tu.1.G.2 • 09:30
Active Plasmonics in True Data Traffic Applications
N Pleros[1,2], K Vyrsokinos[1], D Apostolopoulos[3], D Kalavrouziotis[3], S Papaioannou[1,2], H Avramopoulos[3], F Zacharatos[4], L Markey[4], J-C Weeber4, K Hassan[4], A Dereux[4], A Kumar[5], S I. Bozhevolnyi[5], T Tekin[6], M Waldow[7]; *[1]Information Technologies Institute, Center for Research and Technology Hellas, Thessaloniki, Greece, [2]Dept. of Informatics, Aristotle University of Thessaloniki, Greece, [3]School of Electrical and Computer Engineering, National Technical University of Athens, Greece, [4]Institut Carnot de Bourgogne, University of Burgundy, France, [5]Faculty of Engineering, Institute of Technology and Innovation, University of Southern Denmark, Odense, Denmark, [6]Fraunhofer IZM, Berlin, Germany, [7]AMO GmbH, Gesellschaft für Angewandte Mikro- und Optoelektronik mbH, Aachen, Germany*
We review recent advances in the area of active plasmonics performing with true WDM data traffic. We demonstrate results of a 2x2 Si-plasmonics switching platform and report on the experimentally confirmed energy consumption and speed benefits of thermo-optic plasmonic switches.

Tu.1.G.3 • 10:00
Active Surface Plasmon Photonics
P Berini[1]; *[1]University of Ottawa, Canada*
Active structures enabling the amplification of (or oscillation with) surface plaons are of strong current interest, as are active devices for the detection or surface plasmons. Both types of structures are discussed within the context of optical communications.

10:30-11:00 COFFEE BREAK

Tu.2.G
Metadevices
Chair: David Richardson, *University of Southampton, UK*

Tu.2.G.1 • 11:00
From Photonic Metamaterials to Photonic Metadevices
N Zheludev[1, 2]; *[1]University of Southampton, UK, [2]NTU, Singapore*
We overview the current state of research on metadevices where the exploitation of changing balance of forces the nanoscale allows for reconfigurable nanostructures and the use of liquid crystals, phase changing solids and superconductors offer all-optical and electro-optical switching functionalities.

Tu.2.G.2 • 11:30
Nanoplasmonics: First sensing applications
H Giessen[1]; *[1]University of Stuttgart, Germany*
Nanoplasmonics with its extreme field localization in combination with our ability to detect the scattering spectrum of a single plasmonic nanostructure enables us to sense minute refractive index or absorption changes either in the vicinity or in the nanostructure itself. Plasmonic Fano or perfect absorber geometries, as well as the combination of indirect sensing with hybrid materials, opens up a wide field of novel sensor applications.

Tu.2.G.3 • 12:00
Active Terahertz Metamaterials
A J Taylor[1], H-T Chen[1], A K Azad[1], N K Grady[1], J Heyes[1], D R Chowdhury[1], Y Zeng[1], D A R Dalvit[1], S Trugman[1], Q Jia[1]; *[1]Los Alamos National Laboratory, USA*
We present novel terahertz metamaterials with designed active functionality, enabling dynamic tuning of the amplitude, frequency and polarization state. The dependence of the resonant response on the substrate and/or the fabricated structure enables the creation of active terahertz metamaterial devices.

12:30-14:00 LUNCH

Tu.3.G Computing and Data Processing with Nanophotonics
Chair: Harry Atwater, *California Institute of Technology, USA*

Tu.3.G.1 • 14:00
Computing and Processing with Metatronics and Metamaterials
N Engheta[1]; *[1]University of Pennsylvania, USA*
Properly designed metamaterials and optical metatronics may be exploited to perform signal processing, mathematical operations, and computation. We discuss how various functionalities and operations may be implemented in metamaterial and metatronic blocks, opening possibilities for wave-based ultrafast analog signal processing and computing.

Tuesday 24 September 2013

Special Symposia 1 - Cont.

Tu.3.G.2 • 14:30
Silicon Nanophotonics for Optical Interconnects
J C Rosenberg[1]; [1]*IBM Thomas J. Watson Research Centre, USA*
Silicon nanophotonics enables high-performance optical and electrical components to be combined on a single chip. By monolithically integrating silicon nanophotonic devices within a current 90nm CMOS technology node, compact, high-speed, and low-power elements are demonstrated for wavelength-division-multiplexed optical interconnects.

Tu.3.G.3 • 15:00
Low Power On-chip Light Sources and Quantum Photonic Interfaces
S Buckley[1], K Rivoire[1], B Ellis[1], G Shambat[1], J Vuckovic[1]; [1]*Stanford University, USA*
High quality factor, low mode volume optical microcavities greatly enhance light matter interactions. We demonstrate enhanced $\chi(2)$ nonlinear frequency conversion at nW optical powers, electrically pumped ultralow threshold lasing, and ultrafast direct modulation of an LED, on a photonic crystal cavity platform.

15:30-16:00 COFFEE BREAK

Tu.4.G New Nanophotonic Materials & Applications
Chair: Nader Engheta, *University of Pennsylvania, USA*

Tu.4.G.1 • 16:00
Graphene Nano-photonics and Carrier Dynamics
F Koppens[1]; [1]*ICFO, Spain*
In this talk I will review the new and strongly emerging field of graphene nano-photonics. In particular, I will show how to exploit graphene as a host for guiding, switching and manipulating light and electrons at the nanoscale. Additionally, I will discuss novel types of hybrid graphene photodetectors and new excitating results on carrier dynamics and carrier multiplication in graphene.

Tu.4.G.2 • 16:30
Computing With Fiber Networks
C Soci[1]; [1]*CDTP, Nanyang Technological University, Singapore*
The worldwide optical fiber network already exceeds complexity of brains of primitive living organisms. Could such network implement cognitive functions? We will give examples of optical fiber oracle for solving NP-complete problems, matrix inversion, and other computationally hard tasks.

Tu.4.G.3 • 17:00
Nano Sources and Detectors For Very Short Reach Data Communications
M Orenstein[1]; [1]*Israel Institute of Technology, Israel*
On-chip optical communications was proposed for solving excessive interconnection power. To achieve the goal, ultra power efficient and sensitive miniature sources and detectors should be implemented. Ultrafast LED and nanoscale atto-Farad detector–both relying on nanoplasmonic- metamaterials are described.

18:00-19:30
Round Table: Nanophotonics & Metamaterials Ideas for Telecoms and Data Processing

Special Symposia 2 - Next Generation Data Centres - Paving the way for the Zettabyte Era

Room: H

Co-Chairs
- Juan Pedro Fernandez-Palacios, *Telefónica, Spain*
- Harm J. S. Dorren, *TU Eindhoven, Netherlands*
- Jörg-Peter Elbers, *ADVA Optical Networking, Germany*

The global amount of digital information is growing at a staggering pace of 50% p.a. and will exceed 60 Zettabytes in 2020. While storing and processing of such massive data will offer new business opportunities, it will also require new data centre and data centre networking architectures to provide the necessary scalability, resource sharing, and automation. Scalability is achieved by increasing the number of connected servers and storage devices as well as their interface and processing speeds. Warehouse-size data centres can easily host ten thousands of servers with their associated storage. Using multiple geographically dispersed data centres provides redundancy and further scalability. Server and storage virtualization improve the data centre utilization by resource sharing between multiple tenants or applications. Open source or vendor-specific software frameworks allow an automated control of compute and storage resources. One of the most challenging issues when scaling data centre resources is the attached network infrastructure – inside the data centre, between multiple data centres and between the data centre and the user. A programmatic network control, a flexible allocation of networking functions, and appropriate switching and interface technologies are crucial to facilitate a seamless capacity adaptation and a coordinated orchestration of computing, storage and network resources. This special symposium provides a forum for service & content providers, system integrators, equipment manufacturers, component suppliers and academia to discuss requirements, challenges and solutions for next-generation data centres. Key results from latest research as well as practical findings from commercial deployments will be presented.

Symposia 2 Programme

Tu.1.H
Data Center Role & Applications
Chair: Jorg-Peter Elbers, *ADVA Optical Networking, Germany*

Tu.1.H.1 • 09:00
The Role of Data Centers and Cloud Services in Carrier Networks
M Finnie[1], [1]*Interoute, UK*

Tu.1.H.2 • 09:30
Network Function Virtualization: A Virtual DC Approach for Service Provider Networks
A Reid[1], [1]*British Telecom, UK*

Tu.1.H.3 • 10:00
Cloud Scale Data Centers with Programmable WAN Connectivity
Vijay Vusirikala[1], [1]*Google, USA*

10:30-11:00 COFFEE BREAK

Tu.2.H
Data Center Networking
Chair: Dimitra Simeonidou, *University of Bristol, UK*

Tu.2.H.1 • 11:00
Next-generation Data Center Networks
Chris Liou[1], [1]*Infinera, USA*

Tu.2.H.2 • 11:30
Unifying Software Defined Transport and Datacenter Networking to Deliver Carrier Class Cloud Services
Dominique Verchere, *Alcatel-Lucent Bell Labs, France*
Some challenges for enhancing SDN concepts from datacenter networks to control large scale multi-layer transport networks are presented. These end-to-end connectivity services automatically operated with the delivery of cloud services can improve significantly the global usage of the underlying transport and datacenter networks.

Tu.2.H.3 • 12:00
Network Technologies for Next-generation Data Centers
Rami Cohen[1], [1]*IBM Research, Israel*
The practices of data center network management and configuration, which involve control protocols, addresses, port properties, etc., have significantly grown in complexity over the last few decades. In parallel, emerging workloads present a growing demand for multi tenant network services. Altogether, these two trends present a golden opportunity to revise network management state of the art. In this talk, we present IBM's comprehensive data center network solution: SDN-VE ("Software Defined Network for Virtual Environments"), a network overlay solution that provides a complete implementation framework for network virtualization. This product, based on breakthrough technology developed by IBM Research, consists of an overlay based virtual network platform and a novel intent-based modeling abstraction for specifying the network as a policy-governed service.

12:30-14:00 LUNCH

Tu.3.H Optical switching in Data Centers
Chair: Juan Fernandez Palacios, *Telefonica, Spain*

Tu.3.H.1 • 14:00
Optical Burst Switching in Data Centers
John Dunne[1], [1]*Intune, Ireland*

Tu.3.H.2 • 14:30
On the way to the Photonic Router
Kobi Hasharoni[1], [1]*Compass EOS, Israel*
The bandwidth capacity of telecom and datacom routers is essentially determined by the interconnect bandwidth between chips on different linecards via the backplane. Conventional electrical backplanes are reaching the limit of their ability to handle very high data-rate traffic resulting in high power consumption and large router size and weight. We describe an alternative router design based on an optical chip to chip interconnect in which a large parallel optical transceiver is assembled on a CMOS chip with direct digital to photonic data conversion. This results in drastic reduction of the power consumption and router size, weight and cost enabling significant scalability.

Tu.3.H.3 • 15:00
Opportunities for Photonic Packet/Circuit Switching in Large Scale Data Centers
S Spadaro[1], [1]*Technical University of Catalonia (UPC), Spain*

15:30-16:00 COFFEE BREAK

Tu.4.H Optical Interconnect Technologies
Chair: Harm Dorren

Tu.4.H.1 • 16:00
Prospects of On-board and Intra-board Optical Interconnects
B J Offrein[1], [1]*IBM Research, Switzerland*

Tu.4.H.2 • 16:30
Optical Interconnects for next-generation Data Centers
P De Dobbelaere[1], [1]*Luxtera, USA*

Tu.4.H.3 • 17:00
Photonic Interconnect Technologies in the EU Project Phxtrot
T Tekin[1], [1]*Fraunhofer Institute for Reliability and Microintegration (Fraunhofer IZM), Germany*
PhoxTroT.eu is a large-scale research effort focusing on high-performance, low-energy and cost and small-size optical interconnects across the different hierarchy levels in data center and high-performance computing systems: on-board, board-to-board and rack-to-rack. PhoxTroT tackles optical interconnects in a holistic way, synergizing the different fabrication platforms in order to deploy the optimal "mix&match" technology and tailors this to each interconnect layer.

17:30-18:00
Panel Discussion

Monday 23 September • 14:00 • Room B

SC2: Waveguide and Optoelectronic Devices

Mo.3.B.1 Highly Integrated Monolithic Photonic Integrated Circuits
C R Doerr[1]; [1]*Acacia Communications, USA*

A photonic integrated circuit (PIC) involves a collection of devices on a single substrate that work together to create, guide, mold, or terminate optical photons. Its distant cousin is a high-speed electrical analog (not digital) circuit. PICs find their highest value when integrating many optical components. The technology is finally here to integrate hundreds of optical components together with high yield.

Biography:
Christopher R. Doerr earned a B.S. in aeronautical engineering and a B.S., M.S., and Ph.D. in electrical engineering from the Massachusetts Institute of Technology. Since joining Bell Labs in 1995, Doerr's research has focused on integrated devices for optical communication. He received the OSA Engineering Excellence Award in 2002. He is a Fellow of IEEE and OSA. He was Editor-in-Chief of IEEE Photonics Technology Letters from 2006-2008. He was an Associate Editor for the Journal of Lightwave Technology from 2008-2011. He was awarded the IEEE William Streifer Scientific Achievement Award in 2009. He became a Bell Labs Fellow in 2011. He joined Acacia Communications in 2011.

Tuesday 24 September 2013 • 09:00 • Room A

SC1: Fibres, Fibre Devices and Amplifiers

Tu.1.A.1 Glasses for Infrared Fibre Applications
H Ebendorff-Heidepriem[1]; [1]*Institute for Photonics and Advanced Sensing, The University of Adelaide, Australia*

This paper reviews the optical and thermal properties of glasses transmitting light > 2 microns wavelength. The potential of the glasses for high power and high nonlinearity fibre applications and recent progress in fabrication of fibre from these glasses are also reviewed.

Biography:
Heike Ebendorff-Heidepriem received the Ph.D. degree in chemistry from the University of Jena, Germany, in 1994, where she continued her research on optical glasses until 2000. During 2001-2004 she was with the Optoelectronics Research Centre at the University of Southampton, UK, working on novel photosensitive glasses and soft glass microstructured optical fibres with record high nonlinearity. Since 2005, she has been with the University of Adelaide, Australia. Currently, she is one of the leaders of the Optical Materials & Structures Theme at the Institute for Photonics & Advanced Sensing at The University of Adelaide. Her research focuses on the development of mid-infrared, high-nonlinearity and active glasses; glass, preform and fibre fabrication techniques and surface functionalisation of glass. She was awarded the Woldemar A. Weyl International Glass Science Award in and a prestigious EU Marie Curie Individual Fellowship in 2001. Her research has generated over 100 refereed journal papers and conference proceedings.

Wednesday 25 September 2013 • 09:30 • Room D

SC4 - Point-to-Point Transmission Systems

We.1.D.1 Spatial Multiplexing: The Next Frontier in Network Capacity Scaling
P J Winzer[1]; [1]*Bell Labs, Alcatel-Lucent, USA*

We outline a smooth evolution path of optical networks to spatial multiplexing by complementing deployed fiber infrastructure and existing WDM components with new integrated technologies. We discuss architectural consequences of spatial crosstalk and multiple-input multiple-output (MIMO) signal processing.

Biography:
Peter J. Winzer heads the Optical Transmission Systems and Networks Research Department at Bell Labs, Alcatel-Lucent, in Holmdel, NJ. He received his Ph.D. in electrical engineering from the Vienna University of Technology, Austria, in 1998. Supported by the European Space Agency, he investigated photon-starved space-borne Doppler lidar and laser communications using high-sensitivity digital modulation and detection. At Bell Labs since 2000, he has focused on various aspects of high-bandwidth fiber-optic communication systems, including Raman amplification, advanced optical modulation formats and receiver concepts, digital signal processing and coding, as well as on robust network architectures for dynamic data services. He contributed to several high-speed and high-capacity optical transmission records with interface rates from 10 Gb/s to 1 Tb/s, including the first 100G and the first 400G electronically multiplexed optical transmission systems and the first field trial of live 100G video traffic over an existing carrier network. Since 2008 he has been investigating and promoting spatial multiplexing as a promising option to scale optical transport systems. He has widely published and patented and is actively involved in technical and organizational tasks with the IEEE Photonics Society and the Optical Society of America, currently serving as the Editor-in-Chief of the Journal of Lightwave Technology. Dr. Winzer is a Distinguished Member of Technical Staff at Bell Labs and a Fellow of the IEEE and the OSA.

Wednesday 25 September 2013 • 11:00 • Room C

SC3 - Subsystems for Optical Networks and Datacoms

We.2.C.1 Status and Recent Advances on Forward Error Correction Technologies for Lightwave Systems
A Leven[1], L Schmalen[1]; [1]*Bell Labs, Alcatel-Lucent, Germany*

Since the introduction of coherent transponders, forward error correction based on soft decision is now established in optical communication. In this tutorial, we give a descriptive introduction of one class of commonly used codes, namely LDPC codes. Also we discuss new developments, e.g. convolutional LDPC codes.

Biography:
Andreas Leven is head of the High-Speed Systems and Processing Department at Alcatel-Lucent Bell Labs in Stuttgart, Germany. He received his Ph.D. (Dr.-Ing.) degree from Karlsruhe University, Germany. He spent four years at the Fraunhofer Institute of Applied Solid State Physics, Freiburg, Germany before joining Bell Labs in Murray Hill, New Jersey in 2000 where he worked optoelectronic components for high speed optical communications as well as signal processing for coherent optical systems. From 2008 to 2009, he was on leave with Alcatel-Lucent's Optical Networking Division in Nuremberg, Germany, supporting 100G development activities. In 2009 he moved back to Bell Labs. His current interests include signal processing and coding for high-data rate optical communication systems and SDN for transport networks.

Thursday 26 September 2013 • 09:00 • Room E

SC5 - Optical Transport and Large Scale Data Networks

Th.1.E.1 Solving Routing and Spectrum Allocation Related Optimization Problems
L Velasco[1], A Castro[1], M Ruiz[1]; [1]*Universitat Politècnica de Catalunya (UPC), Spain*

We provide a comprehensible introduction to RSA-related problems in flexgrid networks. Starting from its formulation, we analyze network live cycle and indicate different solving methods for the kind of problems that arise at each network phase: from the initial network planning to network re-optimization, going through network operation.

Biography:
Luis Velasco received the B.Sc. degree in Telecommunications Engineering from Universidad Politecnica de Madrid (UPM) in 1989, the M.Sc. degree in Physics from Universidad Complutense de Madrid (UCM) in 1993, and the PhD degree from Universitat Politecnica de Catalunya (UPC) in 2009.In 1989 he joined Telefonica of Spain and was involved on the specifications and first office application of Telefonica's SDH transport network. In 2004 he joined UPC, where currently he is an associate professor at the Department of Computers Architecture (DAC) and senior researcher at the Advanced Broadband Communications Center (CCABA). He has co-authored more than 80 papers in international journals and peer-reviewed international conferences and is serving in the TPC of several international conferences, as well as reviewer of international journals. He has participated in various IST FP-6 and FP-7 European research projects such as NOBEL 2, e-Photon/ONe+, DICONET, BONE, STRONGEST, IDEALIST, and GÉANT. His interests include both service and network layers, including planning, CAPEX/OPEX issues, routing, and resilience mechanisms, with emphasis on high performance computing for large-scale optimization.

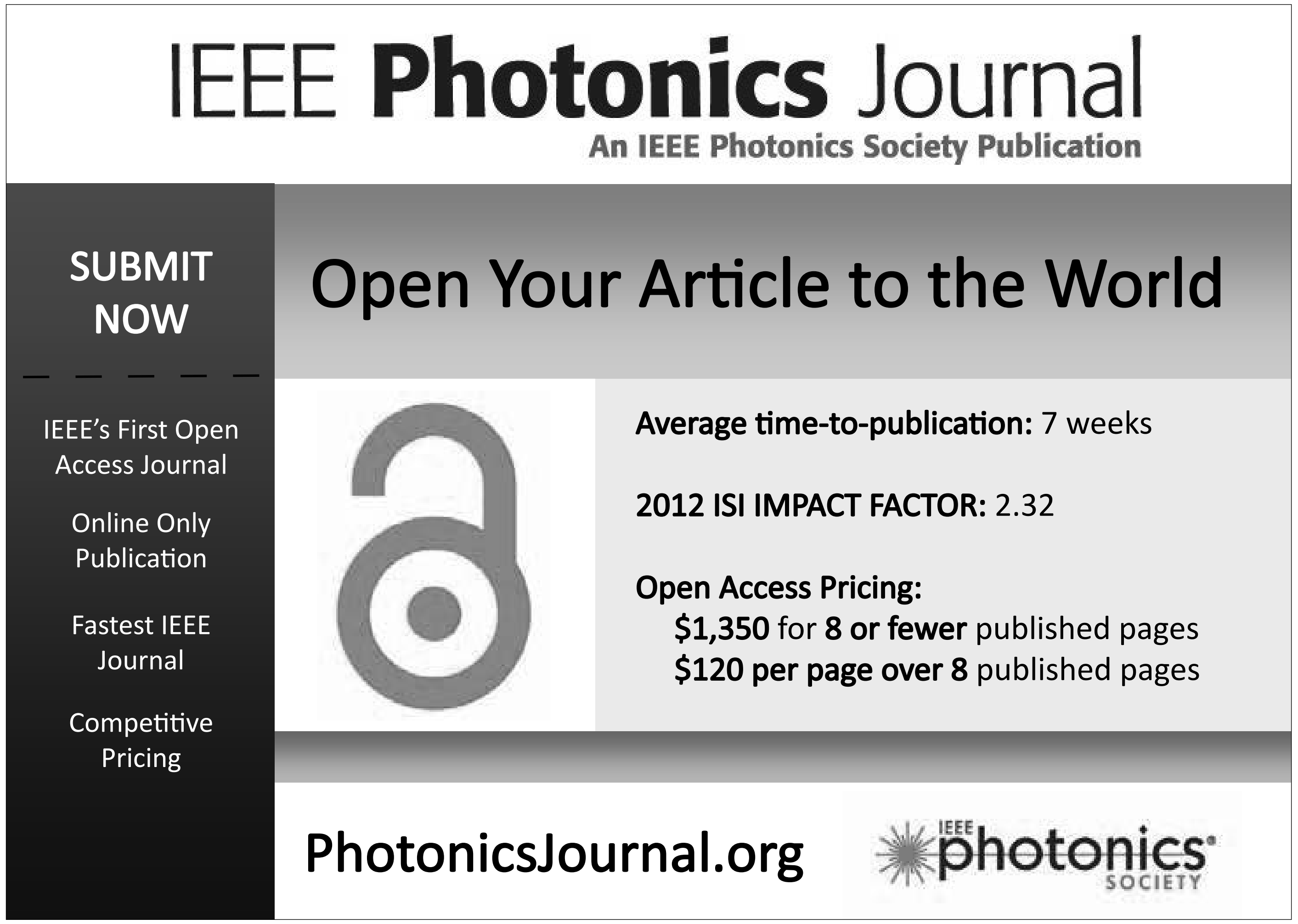
Thursday 26 September 2013 • 11:30 • Room F

SC6 - Access, Local Area and Intra-Data Center Networks

Th.2.F.3 Advancements in Data-Center Networking, and the Importance of Optical Interconnections
L Paraschis[1], [1]*CISCO, USA*

We review innovations in optical technology, system, and network architectures that enable inter, and intra data-centers connectivity to cost-effectively scale to the "cloud-era" requirements for flatter networks, with more flexible provisioning, and higher capacity scaling.

Biography:
Loukas (Lucas) Paraschis is senior solution architect in cisco's Americas next generation network group, primarily responsible for the evolution of converged transport architectures, WAN optimization, routing and optical technologies, business models, and market development efforts in Service Providers, large Enterprise, and Public Sector infrastructure. Prior to his current role, Loukas worked as an R&D engineer, product manager, technical leader, and business development manager for cisco's optical networking and core routing. He has been (co)author in next-generation transport networks of more than 50 peer-reviewed publications, invited, and tutorial presentations, two book chapters, two patents, and was an IEEE Distinguished Lecturer on this topic. Loukas received his Ph.D. from Stanford University, is a senior member of IEEE, and a Fellow of OSA.



Monday 23 September 2013

Mo.3.A.1 • 14:00
A Review of Few-Mode Fibers for Space-Division Multiplexed Transmissions
P Sillard[1], D Molin[1]; [1]*Prysmian Group, France*
A review of the most recent advances on both weakly-coupled and strongly-coupled few-mode fibers is presented. The challenge of increasing the number of LP modes that can actually be used is also discussed.

Mo.3.C.1 • 14:00
Spectrally-Sliced Coherent Receivers for THz Bandwidth Optical Communications
N K Fontaine[1]; [1]*Bell Labs, Alcatel-Lucent, USA*
Spectrally-sliced coherent receivers measure wideband signals in many narrowband slices using efficient optical wavelength demultiplexing, an optical frequency comb (OFC), and an array of coherent receivers. We will show measurements of 214~GBd QPSK after 3200~km transmission.

Mo.3.F.1 • 14:00
Heterogeneous Access Fiber Networks Enabled by Multi-wavelength PONs and Virtualization
R Heron[1], [1]*FTTH Technologies, Alcatel-Lucent, Canada*
Once devoted solely to FTTH, access fiber must increasingly support enterprises, G.FAST nodes, multi-operator uses and mobile backhaul/fronthaul for small cells. These heterogeneous networks will be supported in an operationally efficient way by multi-wavelength PONs and increasing virtualization.

Mo.3.C.2 • 14:30
Progress in InP-based Photonic Components and Sub-systems for Digital Coherent Systems at 100Gbit/s and Beyond
W Forysiak[1]; [1]*Oclaro Technology Ltd, UK*
Digital coherent technology has enabled a new generation of WDM transmission systems with increased capacity and robust performance. We review recent progress in InP-based photonic components and sub-systems to enable cost-effective, compact and scalable new transceiver solutions for 100Gbit/s and beyond, and discuss future directions and challenges.

Mo.3.F.4 • 15:00
Small cell Optical Mobile Backhauling: Architectures, Challenges and Solutions
K Laraqui[1]; [1]*Ericsson Research, Sweden*
Small cell optical backhauling brings forth new challenges and opportunities in connecting radio access to service edge. These relate in particular to macro cells and optical distribution networks, network demarcation, control and management architectures, and convergence with fixed broadband access.

Mo.4.A.1 • 16:00
Orbital Angular Momentum Transmission
A E Willner, *University of South California, USA*
This paper will discuss recent advances in using orbital angular momentum as a domain for multiplexing multiple data channels to increase capacity and spectral efficiency. We will describe Tbit/s transmission results as well as basic demonstrations of switching and networking functions.

Mo.4.B.1 • 16:00
Heterogeneous integration of active semiconductors with silica-based PLC
Y Kurata[1]; [1]*NTT Photonics Labs., Japan*
We review recent advances on the heterogeneous integration of active semiconductors for a silica-based PLC platform. We present the key fabrication techniques and describe the performance of a compact DP-QPSK receiver with heterogeneously integrated high-speed PDs.

Mo.4.B.4 • 17:00
Recent Advances in Electrically Pumped Ge Lasers
J Michel[1]; [1]*Massachusetts Institute of Technology, USA*
Electrically pumped Ge lasers, integrated on a CMOS platform, are promising candidates as integrated lightsources for on-chip photonic systems. The wide gain spectrum from 1520 nm to 1700 nm makes the Ge lasers ideal light sources for WDM applications. There are two main challenges for efficient electrically pumped Ge lasers, high n-type doping concentration and low-loss coupling from Ge waveguides to Si waveguides. The high n-type doping is necessary to overcome the indirect bandgap of Ge and reach gains comparable to other compound semiconductor lasers. We will show that an in-situ delta doping process will yield active Phosphorous concentrations of about 5 x 10^19 cm^-3. The first demonstrated lasers were made from Ge waveguides and did not couple light to Si waveguides, commonly used for on-chip photonic systems. Due to the large refractive index difference between Ge (4.0) and Si (3.5) low loss coupling from a Ge waveguide to a Si waveguide is challenging but a requirement for efficient Ge lasers. We will discuss the different device designs to provide low loss coupling for low threshold lasing.

Mo.4.D.5 • 17:00
Challenges and Opportunities of MIMO Processing for Optical Transport Systems
S Bigo[1], M Salsi[1], O Bertran-Pardo[1], J Renaudier[1], G Charlet[1]; [1]*Alcatel-Lucent Bell Labs, France*
We recall the basics of digital MIMO processing for polarization-division demultiplexing and mode-division demultiplexing and draw some similarities/differences with radio applications. We illustrate the impact of nonlinearities on the mitigation of mode coupling and discuss the challenges of mode-dependent gain in a multimode optical amplifier.

Mo.4.E.1 • 16:00
Optical Packet and Circuit Integrated Networks and SDN Extensions
H Harai[1]; [1]*NICT, Japan*
An optical packet and circuit integrated network (OPCInet) provides high-speed inexpensive service and dedicated bandwidth service to end users. It provides large switching capacity, low energy consumption and high flexibility to network service providers. This paper addresses OPCInet development and extension to GUI-based software-defined network.

Mo.4.F.4 • 16:45
High-Speed Electronics for Short-Link Communication
J Bauwelinck[1], R Vaernewyck[1], J Verbrugghe[1], W Soenen[1], B Moeneclaey[1], C Van Praet[1], A Vyncke[1], G Torfs[1], X Yin[1], X-Z Qiu[1], J Vandewege[1], N Sotiropoulos[2], H De Waardt[2], R Cronin[3], G Maxwell[3], T Tekin[4], P Bakopoulos[5], C P Lai[6], P D Townsend[6]; [1]*INTEC/IMEC, Ghent University, Belgium;* [2]*Eindhoven University of Technology, Netherlands;* [3]*CIP Technologies, UK;* [4]*Fraunhofer IZM, Germany;* [5]*National Technical University of Athens, Greece;* [6]*Tyndall National Institute, Ireland*
High-speed electronic integrated circuits are essential to the development of new fiber-optic communication systems. Close integration and co-design of photonic and electronic devices are becoming more and more a necessity to realize the best performance trade-offs. This paper presents our most recent results and a brief introduction to our research in recently started EU projects.

Tuesday 24 September 2013

Tu.1.B.1 • 09:00
Advanced Optical Components for Access and Datacenters
D Piehler[1]; [1]*NeoPhotonics, USA*
The development of advanced optical technologies for broadband access networks is compared to current development of advanced optical interconnects for datacenter networks. Based on identified parallels and synergies, predictions are made.

Tu.1.D.1 • 09:00
Spectral Shaping for High Spectral Efficiency in Long-Haul Optical Transmission Systems
M Mazurczyk[1]; [1]*TE SubCom, USA*
We transmit 30 Tb/s capacity over 7,200 km and 21 Tb/s capacity over 10,300 km at high spectral efficiency using EDFA only amplification. Advanced digital signal processing including spectral shaping is used to achieve these results.

Tu.1.D.4 • 10:00
Ultra-Long-Haul MCF Transmission Systems
H Takahashi[1], T Tsuritani[1]; [1]*KDDI R&D Laboratories, Japan*
The multicore fiber (MCF) transmission technologies is a promising candidate for next generation optical fiber communication system. In this paper, we review the feasibility of the MCF transmission repeatered by multicore EDFA for ultra-long-haul transmission.

Tu.1.E.3 • 09:30
DSP for High Spectral Efficiency 400G Transmission
X Zhou[1]; [1]*AT&T Labs Research, USA*
This paper presents an overview of several advanced digital signal processing (DSP)- enabled technologies recently demonstrated for high spectral efficiency (SE) 400Gb/s-class transmission, including the SE-adaptable time-domain hybrid QAM, transmitter-side digital spectral shaping, and training-assisted carrier phase recovery.

Tu.1.F.5 • 10:00
Integrated Microwave Photonics for Access Systems
J Capmany[1], P Muñoz[1,2]; [1]*ITEAM Research Institute, Universitat Politecnica de Valencia, Spain;* [2]*VLC Photonics S.L, Universitat Politecnica de Valencia, Spain*
We review the recent advances in integrated microwave photonics. Desired functionalities for access systems and converged fiber-wireless networks are identified. Some of the relevant progress in the principal technology platforms is described.

Tu.3.A.1 • 14:00
Precise Tailoring of Longitudinal Acoustic Property of Optical Fibers by a Hydrogen-loading Technique
Liang Dong[1], Fanting Kong[1], T Hawkins[1]; [1]*ECE/COMSET, Clemson University, USA*
We have demonstrated for the first time a post-processing technique using hydrogen loading and subsequent UV exposure to implement precise longitudinally-tailored acoustic property along a fiber for optimal SBS suppression. Local acoustic velocity can be modified by ~3%, leading to ~500MHz change in Brillouin frequency at ~1micron, equivalent to ~10dB SBS suppression.

Tu.3.B.1 • 14:00
High Performance MEMS-based Micro-optic Assembly for Multi-lane Transceivers
B Pezeshki[1]; [1]*Kaiam Corp., USA*
Advanced transceivers generally require multi-lane approaches, which necessitates the integration of multiple subcomponents. The use of mature, generally available, and low-cost single element components such as EMLs, silica PLCs, and direct-mod DFBs, integrated in a hybrid fashion and optically aligned with MEMS, provides a practical solution.

Tu.3.C.1 • 14:00
Bandwidth-Variable Transceivers Based on 4D Modulation Formats for Future Flexible Networks
J K Fischer[1], S Alreesh[2], R Elschner[1], F Frey[1], M Nöelle[1], C Schubert[1]; [1]*Photonic Networks and Systems, Fraunhofer Heinrich Hertz Institute, Germany;* [2]*Technische Universität Berlin, Fachgebiet Nachrichtentechnik, Germany*
We discuss technology options for bandwidth-variable transceivers which are key components for the realization of flexible software-defined optical networking. In particular, we focus on recent advances in four-dimensional modulation formats and in modulation format transparent data-aided digital signal processing.

Wednesday 25 September 2013

We.1.B.1 • 09:00
Optical Modulators for Advanced Digital Coherent Transmission Systems
H Yamazaki[1], T Goh[1], T Saida[1]; [1]*NTT Photonics Laboratories, Japan*
Advanced optical modulators for future digital coherent transmission systems are being explored. In this paper, a dual-carrier modulator for 400-Gbps transmission, a linear IQ modulator suitable for a DAC-based transmitter, and a simple PS-QPSK modulator are reviewed.

We.1.E.1 • 09:00
Evolution of Traffic Grooming from SDH/SONET to Flexible Grid
S Zhang[1], M Tornatore[2], G Shen[3], B Mukherjee[1]; [1]*University of California, Davis, USA;* [2]*Politecnico di Milano, Italy;* [3]*Soochow University, China*
We review the evolution of traffic grooming from SDH/SONET to evolutionary flexible-grid and elastic-rate technologies and summarize the relevant issues. Sliceable optical transponder is identified as a novel technology that could potentially impact the future grooming paradigm.

We.1.F.1 • 09:00
Access Networks Based on Tunable Transmitters
K Grobe[1]; [1]*ADVA Optical Networking SE, Germany*
State-of-the-art, prospects and problems of access based on tunable lasers are discussed. Potential advantages over competing approaches (seeded reflective transmitters) include higher bit-rate x reach products. Main problem is the lack of availability of low-cost tunables. Here, protection of other tunable-laser markets is required.

We.2.A.1 • 11:00
X3 Processes in High Numerical Optical Fibers and Fiber Tapers
T Lee[1], M I M Abdul Khudus[1], R Ismaeel[1], C A Codemard[2], N G R Broderick[3], G Brambilla[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK;* [2]*Advanced Laser Laboratory, SPI Labs, Optoelectronics Research Centre, University of Southampton, UK;* [3]*Dept. of Physics, University of Auckland, New Zealand*
Intermodally phase matched up- and down-conversion processes based on the third order nonlinearity can be used to efficiently generate UV and mid-IR wavelength regions in solid core silica optical fibers and optical fiber tapers.

We.2.B.1 • 11:00
Monolithic Silicon Photonic Circuits Enable 112-Gb/s PDM-QPSK Transmission over 2560-km SSMF
P Dong[1], X Liu[1], S Chandrasekhar[1], L L Buhl[1], R Aroca[1], Y Baeyens[1], Y K Chen[1]; [1]*Bell Labs, Alcatel-Lucent, USA*;
Using silicon photonic integrated circuits (PICs), we demonstrate the generation, transmission over 2560-km standard single-mode fiber, and detection of 112-Gb/s polarization-division-multiplexed quadrature phase-shift keying signals. These silicon-based PICs promise compact, low-power-consumption, and low-cost coherent transceivers.

We.2.D.3 • 11:30
Multi-core Fiber Transmission Technologies for Peta b/s per Fiber Capacity
H Takara[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan*
Recent development on transmission technologies based on multi-core space-division-multiplexing is described, enabling well over Peta bit/s per fiber link capacity.

We.2.E.1 • 11:00
What is the Benefit of Elastic Superchannel for WDM Network?
T Zami[1]; [1]*Alcatel-Lucent, France*
We discuss the benefits and compromises of elastic spectral efficiency implemented with Nyquist superchannels for the WDM mesh networks featuring static or incremental traffic.

We.3.B.3 • 14:30
High-Speed Silicon-Organic Hybrid (SOH) Modulator with 1.6 fJ/bit and 180 pm/V In-Device Nonlinearity
R Palmer[1], S Koeber[1], W Heni[1], D L Elder[2], D Korn[1], H Yu[3], L Alloatti[1], S Koenig[1], P C Schindler[1], W Bogaerts[3], M Pantouvaki[4], G Lepage[4], P Verheyen[4], J Van Campenhout[4], P Absil[4], R Baets[3], L R Dalton[2], W Freude[1], J Leuthold[5,1], C Koos[1]; [1]*Karlsruhe Institute of Technology, Institutes IPQ and IMT, Germany;* [2]*Dept. of Chemistry, University of Washington, USA;* [3]*IMEC Photonics Research Group, Ghent University, Belgium;* [4]*IMEC vzw., Belgium;* [5]*Electromagnetic Fields & Microwave Electronics Laboratory, ETH-Zurich, Switzerland*
We report on a 40Gbit/s silicon-organic hybrid (SOH) modulator with 11dB extinction ratio. A novel electro-optic chromophore with record in-device nonlinearity of 180pm/V leads to VπL=0.5Vmm and a low energy consumption of 1.6fJ/bit at 12.5Gbit/s.

We.3.B.4 • 15:00
High-speed Silicon Modulators
T Chu[1], X Xiao[1], H Xu[1], X Li[1], Z Li[1], J Yu[1], Y Yu[1]; [1]*Key Laboratory of Integrated Optoelectronics, Institute of Semiconductors, CAS, China*
Several high-speed silicon modulators are demonstrated, including a 60-Gbps MZI modulator with 1.6-dB optical loss, a 25-Gbps microring modulator with misalignment-tolerant interleaved PN junctions, a 60-Gbps microring resonator modulator and a 4x50 Gbps WDM modulator.

We.3.D.3 • 14:30
Nonlinear Equations of Propagation in Multi-Mode Fibers with Random Mode Coupling
A Mecozzi[1], C Antonelli[1], M Shtaif[2]; [1]*University of L'Aquila, Italy;* [2]*Tel Aviv University, Israel*
We review the fundamental equations describing nonlinear propagation in multi-mode fibers in the presence of random mode coupling within quasi-degenerate groups of strongly coupled modes. Our results generalize to the multi-mode propagation regime the Manakov equation describing mode coupling between polarizations in single-mode fibers.

We.3.E.1 • 14:00
Control plane solutions for dynamic and adaptive flexi-grid optical networks
R Muñoz[1], R Casellas[1], R Martínez[1], R Vilalta[1]; [1]*Optical Networks and Systems, Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Spain*
We present an overview of control plane architectures for dynamic and adaptive provisioning and rerouting of elastic optical connections. First, distributed control plane architectures combining GMPLS with stateless and stateful PCEs are discussed. Next, we detail different deployment models of the PCE in the OpenFlow centralized control plane

We.4.A.1 • 16:00
Multicore Erbium Doped Fiber Amplifiers for Space Division Multiplexed System
K Abedin[1], T Thierry[1], J Fini[1], Man F. Yan[1], B Zhu[1], E Monberg[1], F V Dimarcello[1], V R Supradeepa[1], D DiGiovanni[1]; [1]*OFS Laboratories, USA*
We report on recent development of core- and cladding-pumped multicore fiber amplifiers suitable for amplifying space division multiplexed signals. Amplification, noise properties of these amplifiers are shown, and scopes for further development will be discussed.

We.4.C.3 • 16:30
100 Gbit/s Using Intensity Modulation and Direct Detection
J C Cartledge[1], A S Karar[1]; [1]*Dept. of Electrical and Computer Engineering, Queen's University, Canada*
Recent advances in short reach 100 Gbit/s intensity modulation and directed detection systems are reviewed with a focus on 16-QAM half-cycle Nyquist subcarrier modulation, generated using a directly modulated passive feedback laser and polarization multiplexing emulation.

We.4.D.3 • 16:30
Nonlinear Fiber Capacity
E Agrell[1]; [1]*Dept. of Signals and Systems, Chalmers University of Technology, Sweden*
In this semi-tutorial presentation, we review fundamental information theory for links with and without memory, in the linear and nonlinear regimes. A comparison between channel models with long (but finite) memory and infinite memory yields an unexpected result.

We.4.F.3 • 16:30
Photonic-assisted RF transceiver
A Bogoni[1], P Ghelfi[1], F Laghezza[1], F Scotti[1], G Serafino[2], S Pinna[2]; [1]*CNIT, Italy;* [2]*Scuola Superiore Sant'Anna, Italy*
The concept of photonics-assisted RF transceiver will be detailed. It provides extremely stable multiprotocol signals up to the millimeter waveband, and it optically samples directly at RF multiple heterogeneous RF signals, with increased resolution.

Thursday 26 September 2013

Th.1.A.4 • 09:45
Parallel Optical Interconnects for Data Centre Applications
M Fields[1]; [1]*Avago Technologies, USA*
The MicroPOD 12x10G transmitter and receiver board-mounted optical modules were released in 2010. Today, more than 1.5 million units are deployed across a variety of applications. We provide an update on the MicroPOD experience including lessons learned. We introduce a 12x25G board-mounted optics platform that incorporates these lessons.

Th.2.A.1 • 11:00
Multi-Band OFDM Transmission with Sub-band Optical Switching
E Pincemin[1], M Song[1], J Karaki[1], A Poudoulec[2], N Nicolas[2], M Van der Keur[2], Y Jaouen[3], P Gravey[4], M Morvan[4], G Froc[5]; [1]*Orange Labs, France;* [2]*Yenista Optics, France;* [3]*Télécom ParisTech, France;* [4]*Télécom Bretagne, France;* [5]*Mitsubishi Electric Research Center Europe, France*
We demonstrate that optical add-drop of OFDM sub-bands as narrow as 8 GHz inside a 100 Gbps DP-MB-OFDM signal constituted of four sub-bands spaced by 12 GHz is feasible in the middle of a 10x100-km DCF-free G.652 fibre line.

Th.2.C.5 • 12:00
Modal Statistics in Mode-Division-Multiplexed Systems
J M Kahn[1], Keang-Po Ho[2]; [1]*Stanford University, USA;* [2]*Silicon Image, USA*
The performance and complexity of mode-division-multiplexing systems depend on the statistics of modal gains/losses and group delays. Under strong mode coupling, these statistics may be derived from the eigenvalue distributions of random matrices. Strong coupling optimizes performance and minimizes complexity.

Th.2.D.1 • 11:00
1306-km 20x124.8-Gb/s PM-64QAM Transmission over PSCF with Net SEDP 11,300 (b km)/s/Hz using 1.15 samp/symb DAC
A Nespola[1], S Straullu[1], G Bosco[2], A Carena[2], Y Jiang[2], P Poggiolini[2], F Forghieri[3], Y Yamamoto[4], M Hirano[4], T Sasaki[4], J Bauwelinck[5], K Verheyen[5]; [1]*PhotonLab, ISMB, Italy;* [2]*DET, Politecnico di Torino, Italy;* [3]*Cisco Photonics, Italy;* [4]*Sumitomo Electric Industries, Japan;* [5]*INTEC/IMEC, Ghent University, Belgium*
We demonstrated PM-64QAM, 20x124.8-Gb/s Nyquist-WDM over 1306 Km of PSCF in an EDFA-only system configuration. The raw SE was 10.4b/s/Hz, thanks to digital spectral shaping. The Tx DACs operated at a record-low 1.15 sample/symb. The SEDP was 11,327 (b km)/s/Hz.

Th.2.E.1 • 11:00
Synthetic Photonic Nodes for the Future Photonic Network
M Fukui[1], A Hiramatsu[1], T Tsuritani[2], K Kitayama[3]; [1]*NTT, Japan;* [2]*KDDI R&D Laboratories, Japan;* [3]*Osaka University, Japan*
A synthetic photonic node consists of an array of the photonic network processors and reconfigurable optical interconnections. It enables to dynamically synthesize variety of optical node functions by software on the processors. Its concept and some use cases are presented.

UK Photonics Research Showcase

Wednesday 25 September

ECOC Exhibition Hall

Co-located with the internationally leading European Conference on Optical Communications 2013, held in London for the first time since the very first ECOC in 1975, the Photonics Showcase aims to celebrate the recently funded programmes, highlight the impact and discuss future directions of UK photonics research. This event is organised by the ECOC Chairs with the support of the EPSRC network UNISON and is sponsored by the EPSRC HyperHighway and UNLOC Programmes.

The programme of talks represents some of the key UK-funded research programmes. It aims to highlight the key research directions in photonics and communications and explain their importance and potential impact on Government policy and infrastructure planning.

Workshop Chair:
Ian Henning, *University of Essex, EPSRC Network UNISON*

09:35	**Welcome, National Photonics Research Strategy Current and Future** Liam Blackwell, *EPSRC*
09:45	**Photonics for Future Systems** Susan Peacock, *EPSRC*
10:00	**Workshop Plenary** Ian White, *University of Cambridge*
10:30	**EPSRC Programme Grants** David Payne, *University of Southampton: HyperHighway* Polina Bayvel, *UCL: UNLOC* Jaafar Elmirghani, *University of Leeds: INTERNET*
11:30	**Flagship non ICT Photonics Research** Ralph Spencer, *University of Manchester: Square Kilometer Array (SKA)* Patrick Gill, *NPL: Metrology*
12:15	**National Dark Fibre Infrastructure** Alwyn Seeds, *UCL*
12:30	**Photonics 21 and Horizon 2020-UK positioning** Mike Wale, *Oclaro*
12:45	John Lincoln, *Photonics leadership group- group mission, UK academic research and industry, impact*
13:00	**Lunch, Networking, Posters from Relevant UK Research Projects**

09:30-11:00 PLENARY SESSION, Auditorium | 11:00-11:30 COFFEE BREAK | 11:30-12:40 PLENARY SESSION, Auditorium | 12:40-14:00 LUNCH

ROOM A

Mo.3.A
Few Mode Fibres & Space Division Multiplexing Session I
Chair: Pascale Nouch, *Thales, France*

Mo.3.A.1 • 14:00 Invited
A Review of Few-Mode Fibers for Space-Division Multiplexed Transmissions
P Sillard[1], D Molin[1]; [1]*Prysmian Group, France*
A review of the most recent advances on both weakly-coupled and strongly-coupled few-mode fibers is presented. The challenge of increasing the number of LP modes that can actually be used is also discussed.

Mo.3.A.2 • 14:30
Seven-Core Fiber with Enlarged Aeff and Full-C-band Seven-Core EDFA for 100-Tbit/s-Class Transoceanic Transmission
K Igarashi[1], K Takeshima[1], T Tsuritani[1], H Takahashi[1], S Sumita[1], I Morita[1], Y Tsuchida[2], M Tadakuma[2], K Maeda[2], T Saito[2], K Watanabe[2], K Imamura[2], R Sugizaki[2], M Suzuki[1]; [1]*KDDI R&D Laboratories, Japan;* [2]*Furukawa Electric Co., Ltd, Japan*
We report fabrication of a 45.5-km seven-core fiber with enlarged Aeff and a high-power seven-core EDFA with 5-THz bandwidth. Using them, we confirmed the feasibility of 100-Tbit/s-class transoceanic transmission.

Mo.3.A.3 • 14:45
Crosstalk Suppressed Hole-assisted 6-core Fiber with Cladding Diameter of 125 µm
T Sakamoto[1], K Saitoh[2], N Hanzawa[1], K Tsujikawa[1], L Ma[1], M Koshiba[2], F Yamamoto[1]; *1NTT Access Network Service Systems Laboratories, NTT Corporation, Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
We report 125 µm-cladding multi-core fiber with hole-assisted structure for high-density space-division multiplexing transmission. We achieved 125 µm-cladding 6-core fiber experimentally with a low crosstalk of less than -30 dB/100km and a high normalized core multiplicity of 6.0.

ROOM B

Mo.3.B
Photonic Integration Technologies
Chair: Graeme Maxwell, *Hauwei, UK*

Mo.3.B.1 • 14:00 Tutorial
Highly Integrated Monolithic Photonic Integrated Circuits
C R Doerr[1]; [1]*Acacia Communications, USA*
A photonic integrated circuit (PIC) involves a collection of devices on a single substrate that work together to create, guide, mold, or terminate optical photons. Its distant cousin is a high-speed electrical analog (not digital) circuit. PICs find their highest value when integrating many optical components. The technology is finally here to integrate hundreds of optical components together with high yield.

ROOM C

Mo.3.C
Coherent Subsystems
Chair: Shu Namiki, *National Institute of Advanced Industrial Science and Technology, Japan*

Mo.3.C.1 • 14:00 Invited
Spectrally-Sliced Coherent Receivers for THz Bandwidth Optical Communications
N K Fontaine[1]; [1]*Bell Laboratories, Alcatel-Lucent, USA*
Spectrally-sliced coherent receivers measure wideband signals in many narrowband slices using efficient optical wavelength demultiplexing, an optical frequency comb (OFC), and an array of coherent receivers. We will show measurements of 214~GBd QPSK after 3200~km transmission

Mo.3.C.2 • 14:30 Invited
Progress in InP-based Photonic Components and Sub-systems for Digital Coherent Systems at 100Gbit/s and Beyond
W Forysiak[1]; [1]*Oclaro Technology Ltd, UK*
Digital coherent technology has enabled a new generation of WDM transmission systems with increased capacity and robust performance. We review recent progress in InP-based photonic components and sub-systems to enable cost-effective, compact and scalable new transceiver solutions for 100Gbit/s and beyond, and discuss future directions and challenges.

09:30-11:00 PLENARY SESSION, Auditorium | 11:00-11:30 COFFEE BREAK | 11:30-12:40 PLENARY SESSION, Auditorium | 12:40-14:00 LUNCH

ROOM D

Mo.3.D
Digital Signal Processing I
Chair: Miyamoto Yutaka, *NTT, Japan*

Mo.3.D.1 • 14:00
Novel Digital Equalizer for XPM-induced Polarization Crosstalk using Overlapped Fast Independent Component Analysis
K Shibahara[1], M Fukutoku[1]; [1]*Network Innovation Labs., NTT, Japan*
A novel equalization algorithm using overlapped fast independent component analysis (FastICA) is proposed and investigated for nonlinear polarization crosstalk (NPC). The algorithm is shown to provide better Q-factor improvement than conventional algorithms. Also shown are its advantages when used in the step prior to other DSP procedures.

Mo.3.D.2 • 14:15
Digital Nonlinear Noise Cancellation Approach for Optical Long-Haul Transmission Systems
W-R Peng[1], T Tsuritani[1], I Morita[1]; [1]*KDDI R&D Laboratories Inc., Japan*
We propose a practically-implementable nonlinear noise cancellation (NLC) algorithm that effectively removes the "1st-order" fiber nonlinearities. After 6720-km (84x80-km) SSMF transmission, the optimum Q-factor with BPSK is improved by ~1.4 dB with the proposed NLC method.

Mo.3.D.3 • 14:30
Co-operation of Digital Nonlinear Equalizers and Soft-Decision LDPC FEC in Nonlinear Transmission
T Tanimura[1], S Oda[1], T Hoshida[2], Y Aoki[1], Z Tao[3], J C Rasmussen[1]; [1]*Fujitsu Laboratories, Ltd., Japan;* [2]*Fujitsu Ltd, Japan;* [3]*Fujitsu R&D Center, China*
We have experimentally investigated the characteristics of 128 Gb/s DP-QPSK signals received with two types of nonlinear equalizers (NLE) followed by soft-decision (SD) FEC. With experiments, we demonstrate that the optimization of parameters for NLEs enables the successful co-operation of SD-FEC and NLEs after nonlinear transmission.

Mo.3.D.4 • 14:45
Decision Feedback Equalization for Bandwidth-Constrained 28Gbaud Nyquist-WDM PDM-8QAM over 37.5 GHz Grid
J Fickers[1], A Ghazisaeidi[2], M Salsi[2], G Charlet[2], F Horlin[1], P H Emplit[1], S Bigo[2]; [1]*OPERA Dept., Université libre de Bruxelles, Belgium;* [2]*Alcatel-Lucent Bell Labs, France*
We propose to use decision feedback equalization (DFE) for ISI mitigation on 28Gbaud PDM-8QAM bandwidth-constrained Nyquist WDM. We compare DFE and maximum a posteriori (MAP) detection and show that DFE offers a more interesting performance/complexity trade-off than MAP.

ROOM E

Mo.3.E
Interconnecting Data Centres
Chair: Peter Ohlen, *Ericsson, Sweden*

Mo.3.E.1 • 14:00
Towards a Carrier SDN: An Example for Elastic Inter-Datacenter Connectivity
L Velasco[1], A Asensio[1], J L Berral[1,2], A Castro[1], V Lopez[3]; [1]*Universitat Politècnica de Catalunya (UPC), Spain;* [2]*Barcelona Supercomputing Center (BSC), Spain;* [3]*Telefónica Investigación y Desarrollo (TID), Spain*
Abstract We propose a network-driven transfer mode for cloud operations in a step towards a carrier SDN. Inter-datacenter connectivity is requested in terms of volume of data and completion time. The SDN controller translates and forwards requests to an active PCE controlling a flexgrid network.

Mo.3.E.2 • 14:15
Design and Demonstration of Multi-Domain, Multi-Technology Software Defined Networks for High-Performance Cloud Computing Infrastructure
M Channegowda[1], R Nejabati[1], S Peng[1], N Amaya[1], G Zervas[1], Y Shu[1], M Rashidifard[1], D Simeonidou[1]; [1]*High Performance Network Group EEE, University of Bristol, UK*
A novel service on demand (SoD) architecture for data center (DC) is proposed and implemented over a multi-layer multi-technology software defined network. The architecture is demonstrated on an optical DC infrastructure and its performance evaluated with cloud applications.

Mo.3.E.3 • 14:30
Survivable Resource Orchestration for Optically Interconnected Data Center Networks
Q Zhang[1], Q She[2], Y Zhu[3], X Wang[1], P Palacharla[1], M Sekiya[1]; [1]*Fujitsu Labs of America, USA;* [2]*Fujitsu Network Communications, USA;* [3]*Hawaii Pacific University, USA*
We propose resource orchestration schemes in overlay networks enabled by optical network virtualization. Based on the information from underlying optical networks, our proposed schemes provision the fewest data centers to guarantee K-connect survivability, thus maintaining resource availability for cloud applications under any failure.

Mo.3.E.4 • 14:45
A Novel Architecture for Highly Virtualised Software-Defined Optical Clouds
A Stavdas[1], C Matrakidis[1], C (T) Politi[1], T Orphanoudakis[1], J Dunne[2]; [1]*University of Peloponnese, Greece;* [2]*Intune Networks Ltd, Ireland*
We propose a novel optical cloud architecture where IT and Telecom resources are used interchangeably as common infrastructure. Key assets are the MAC controlled passive networks for distributed multiplexing and grooming and a node architecture integrating transmission and switching.

ROOM F

Mo.3.F
Hybrid Fibre Wireless
Chair: Bas Huiszoon, *Genexis, Spain*

Mo.3.F.1 • 14:00 Invited
Heterogeneous Access Fiber Networks Enabled by Multi-wavelength PONs and Virtualization
R Heron[1], [1]*FTTH Technologies, Alcatel-Lucent, Canada*
Once devoted solely to FTTH, access fiber must increasingly support enterprises, G.FAST nodes, multi-operator uses and mobile backhaul/fronthaul for small cells. These heterogeneous networks will be supported in an operationally efficient way by multi-wavelength PONs and increasing virtualization.

Mo.3.F.2 • 14:30
76-Gb/s Highly Spectrally Efficient 2x2 MIMO 60-GHz RoF System Employing I/Q Imbalance Compensation
H-T Huang[1], Y-H Cheng[1], P-T Shih[2], C-T Lin[1], C-H Ho[1], C-C Wei[3], W-L Liang[1], C-S Sun[1], H-H Hsu[1], A Ng'oma[4], S Chi[5]; [1]*Institute of Photonic System, National Chiao-Tung University, Taiwan;* [2]*Corning Research Center, Corning Incorporated, Taiwan;* [3]*Dept. of Photonics, National Sun Yat-sen University, Taiwan;* [4]*Science & Technology, Corning Inc., USA;* [5]*Dept. of Photonics Engineering, Yuan-Ze University, Taiwan*
A 2x2 OFDM-MIMO RoF system with high spectral efficiency is experimentally demonstrated at 60 GHz. 76.4-Gb/s data transmission over 25-km fiber and 3.5-m wireless distance was achieved by using zero-forcing, I/Q-mismatch compensation and bit-loading algorithms.

Mo.3.F.3 • 14:45
Optical Physical-layer Network Coding over Fiber-Wireless
Z Liu[1], L Lu[2], L You[2], C-K Chan[1], S-C Liew[1]; [1]*Dept. of Information Engineering, The Chinese University of Hong Kong, Hong Kong;* [2]*Institute of Network Coding, The Chinese University of Hong Kong, Hong Kong*
We propose and experimentally demonstrate the first optical physical-layer network coding (OPNC) prototype to boost throughput in an OFDM fiber-wireless network. Our technique does not require symbol-level synchronization and only requires moderate modifications of the packet preamble in IEEE 802.11 standard specification.

ROOM A

Mo.3.A.4 • 15:00
Crosstalk Increase in Tightly Bent Multi-Core Fiber due to Power Coupling Mediated by Cladding Modes
T Hayashi[1,2], T Taru[1], T Sasaki[1], K Saitoh[2], M Koshiba[2]; [1]*Optical Communications R&D Laboratories, Sumitomo Electric Industries, Ltd., Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
We developed simplified coupled-power equations including cladding modes, and revealed that crosstalk in tightly bent multi-core fibers can be increased from the existing predictions. The crosstalk increase was proportional to the square of the bend loss coefficient, and validated by experimental results, for the first time.

ROOM B

Mo.3.B.2 • 15:00
Systems and Devices in a 30 GHz Silicon-om-insulator Platform
C Galland[1], A Novack[3,4], Y Liu[1], R Ding[1], M Gould[2], T Baehr-Jones[1], Q Li[5]; Y Yang[1], Y Ma[1], Y Zhang[1], K Padmaraju[5], K Bergman[5], A Eu-Jim Lim[3], G Lo[3], M Hochberg[1,3,4], [1]Dept. of *Electrical and Computer Engineering, University of Delaware, USA;* [2]Dept. of *Electrical Engineering, University of Washington, USA;* [3]*Institute of Microelectronics, A*Star, Singapore,* [4]Dept. of *Electrical and Computer Engineering, University of Singapore, Singapore;* [5]Dept. of *Electrical and Computer Engineering, Columbia University, USA*
We present a 30 GHz silicon photonic platform that includes low-loss passive components, high-speed modulators and photodetectors. The platform is available to the community as part of the OpSIS-IME multi-project-wafer foundry service. We conclude with a proposal for a fully CMOS-compatible optical isolator based on multistage phase modulation.

ROOM C

Mo.3.C.3 • 15:00
Fast Wavelength Switching Digital Coherent OFDM Transceiver
R Maher[1,2], K Shi[1], S J Savory[1], B C Thomsen[1]; [1]*Optical Networks Group, Electronic and Electrical Engineering, University College London, UK;* [2]*The RINCE Institute, School of Electronic Engineering, Dublin City University, Ireland*
Digital dynamic frequency offset removal and DC pilot tone assisted phase noise compensation enables the use of commercially available DS-DBR lasers as both the transmitter and LO in a coherent wavelength switched OFDM transceiver. A 1.5dB penalty relative to low linewidth static lasers is demonstrated under fast wavelength switched operation.

Mo.3.A.5 • 15:15
Trench-assisted Low-crosstalk Few-mode Multicore Fiber
Y Sasaki[1], Y Amma[1], K Takenaga[1], S Matsuo[1], K Saitoh[2], M Koshiba[2]; [1]*Optics and Electronics Laboratory, Fujikura Ltd., Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
Trench-assisted few-mode multicore fiber with high-multiplicity and low-crosstalk characteristics was designed and fabricated. The core supported two-LP-mode transmission over C+L band. The fabricated fiber realized the worst case crosstalk of smaller than -30 dB/100km at 1625 nm with cladding diameter of 195.4 μm.

Mo.3.B.3 • 15:15
CMOS-Compatible Nonuniform Grating Coupler with 86% Coupling Efficiency
W Sfar Zaoui[1], A Kunze[1], W Vogel[1], M Berroth[1], J Butschke[2], F Letzkus[2]; [1]*Institute of Electrical and Optical Communications Engineering, University of Stuttgart, Germany;* [2]*Institut für Mikroelektronik Stuttgart, Germany*
We report a highly efficient grating coupler fabricated using a CMOS-compatible technology process with a record efficiency of -0.64 dB (86.3 %) at a wavelength of 1527 nm and a 1dB-bandwidth of 44 nm. The performance of the structure is enhanced through a backside metal mirror and the use of a nonuniform grating.

Mo.3.C.4 • 15:15
Fixed Point and Power Consumption Analysis of a Coherent Receiver for Optical Access Networks Implemented in FPGA
D Cardenas[1], D Madan[1], S Win[1], D Lavery[1], S Savory[1]; [1]*Optical Networks Group, EE, University College London, UK*
We demonstrate an FPGA implementation of the key DSP blocks required for a 10Gb/s coherent receiver incorporating tunable lasers and evaluate trade-offs between bit resolution, power consumption and performance. We find that a 3dB reduction in power consumption is possible for a 1.8dB sensitivity penalty.

15:30-16:00 COFFEE BREAK (ECOC Exhibition)

Mo.4.A
Few Mode Fibres and Space Division Multiplexing II
Chair: Patrice Megret, *University of Mons, Belgium*

Mo.4.B
Integrated Devices
Chair: Nakano Yoshiaki, *University of Tokyo, Japan*

Mo.4.C
Receivers
Chair: Masataka Nakazawa, *Tohoku University, Japan*

Mo.4.A.1 • 16:00 Invited
Orbital Angular Momentum Transmission
A E Willner[1], [1]*University of South California, USA*
This paper will discuss recent advances in using orbital angular momentum as a domain for multiplexing multiple data channels to increase capacity and spectral efficiency. We will describe Tbit/s transmission results as well as basic demonstrations of switching and networking functions.

Mo.4.B.1 • 16:00 Invited
Heterogeneous Integration of Active Semiconductors with Silica-based PLC
Y Kurata[1]; [1]*NTT Photonics Labs, NTT Corporation, Japan*
We review recent advances on the heterogeneous integration of active semiconductors for a silica-based PLC platform. We present the key fabrication techniques and describe the performance of a compact DP-QPSK receiver with heterogeneously integrated high-speed PDs.

Mo.4.C.1 • 16:00
Stable Costas Loop Homodyne Detection for 20-Gbit/s QPSK Signal Fiber Transmission
A Mizutori[1], S Y Set[2], F Shirazawa[2], M Koga[1]; [1]Oita University, Japan; [2]*Alnair Labs Corporation, Japan*
An experiment confirms stable homodyne detection of a fiber transmitted 20-Gbit/s QPSK signal by a Costas loop circuit. Our low phase noise PLL is shown to compensate E-LD FM response and achieve high sensitivity homodyne detection of the QPSK signal.

Mo.4.C.2 • 16:15
120 Gbit/s, 64 QAM Coherent Transmission Employing an Optical Voltage Controlled Oscillator
Y Wang[1], K Kasai[1], T Omiya[1], M Nakazawa[1]; [1]*Research Institute of Electrical Communication, Tohoku University, Japan*
We demonstrate a polarisation-multiplexed 64 QAM coherent transmission with sub-carrier OPLL based homodyne detection utilising an optical voltage controlled oscillator (OVCO). By using the OVCO, low phase noise OPLL operation was achieved and a 120 Gbit/s data signal was successfully transmitted over 150 km with a low power penalty.

ROOM D

Mo.3.D.5 • 15:00
Fiber Nonlinearity Compensation by Digital Backpropagation of an Entire 1.2-Tb/s Superchannel Using a Full-Field Spectrally-Sliced Receiver
N K Fontaine[1], X Liu[1], S Chandrasekhar[1], R Ryf[1], S Randel[1], P Winzer[1], R Delbue[2], P Pupalaikis[2], A Sureka[2]; [1] *Bell Labs, Alcatel-Lucent, USA;* [2]*LeCroy Corporation, USA*
We receive the full optical field of a 176-GHz wide, 1.2-Tb/s PDM-16QAM superchannel after 960-km TWRS using a spectrally-sliced coherent receiver. Simultaneous compensation of SPM and XPM with digital backpropagation enables 1~dB of Q-factor improvement.

ROOM E

Mo.3.E.5 • 15:00
Bandwidth and Routing Assignment for Virtual Machine Migration in Photonic Cloud Networks
U Mandal[1], M F Habib[1], S Zhang[1], M Tornatore[2], B Mukherjee[1]; [1]*University of California, USA;* [2]*Politecnico di Milano, Italy*
We formulate the bandwidth and routing assignment problem for virtual machine migrations with duration and downtime constraints in photonic cloud networks. Our study shows that optimal bandwidth and routing assignment can reduce network resource utilization by upto 30% at low load and upto 16% at average load while respecting migration constraints.

ROOM F

Mo.3.F.4 • 15:00 Invited
Small Cell Optical Mobile Backhauling: Architectures, Challenges and Solutions
K Laraqui[1]; [1]*Ericsson Research, Sweden*
Small cell optical backhauling brings forth new challenges and opportunities in connecting radio access to service edge. These relate in particular to macro cells and optical distribution networks, network demarcation, control and management architectures, and convergence with fixed broadband access.

Mo.3.E.6 • 15:15
Application-aware and Adaptive Virtual Data Centre Infrastructure Provisioning over Elastic Optical OFDM Networks
S Peng[1], R Nejabati[1], M Channegowda[1], D Simeonidou[1]; [1]*High Performance Network Group, EEE, University of Bristol, UK*
A novel application-aware virtual data centre (VDC) provisioning method for distributed data centres (DCs) enabled by coordinated virtualization of optical OFDM network and DCs is proposed. Furthermore, an adaptive VDC replanning method, supporting virtual topology shifting for accommodating DCs traffic variations, is proposed.

15:30-16:00 COFFEE BREAK (ECOC Exhibition)

Mo.4.D
Digital Signal Processing II
Chair: Helmut Griesser; *ADVA Optical Networking, Germany*

Mo.4.E
Software Defined Networking and Mulitlayer Networking
Chair: Alexnadros Stavdas, *University of Peloponnese, Greece*

Mo.4.F
High Speed Access Technologies
Chair: Albert Rafel, *BT, UK*

Mo.4.D.1 • 16:00
Enhanced Sampling Frequency Offset Compensation Algorithm for PDM CO-OFDM Transmission System
Y Chen[1], N Hanik[1]; [1]*Technische Universität München, Germany*
Sampling frequency offset (SFO) compensation is realized by pilots-based SFO estimation and frame wise interpolation. The algorithm compensates around ±6000 ppm SFO for single channel and ±5000 ppm for WDM-PDM-OFDM transmission system with a Q-factor penalty of less than 0.34 dB.

Mo.4.E.1 • 16:00 Invited
Optical Packet and Circuit Integrated Networks and SDN Extensions
H Harai[1]; [1]*NICT, Japan*
An optical packet and circuit integrated network (OPCInet) provides high-speed inexpensive service and dedicated bandwidth service to end users. It provides large switching capacity, low energy consumption and high flexibility to network service providers. This paper addresses OPCInet development and extension to GUI-based software-defined network.

Mo.4.F.1 • 16:00
10.3Gb/s Burst-mode XFP Transceiver with Emphasis for 10G-EPON Multi-port OLT using RS(255, 223) FEC
S Yoshima[1], M Noda[1], T Suehiro[1], N Suzuki[1], T Nishitani[1], M Nogami[1], J Nakagawa[1]; [1]*Mitsubishi Electric Corporation, Japan*
We propose a 10.3Gb/s burst-mode XFP transceiver with emphasis for 10G-EPON multi-port OLTs. The burst-mode receiver sensitivity of -30.4dBm with FEC was achieved with a 250mm long transmission line to the XFP, peak emphasis gain of 3.5dB and burst-mode CDR.

Mo.4.D.2 • 16:15
Experimental Analysis of Single Carrier POLQAM (6Pol-QPSK) Transmission with Soft-Decoding
H Buelow[1], X Lu[1,2], L Schmalen[1]; [1]*Bell Labs, Alcatel-Lucent, Germany;* [2]*University Erlangen, MAOT, LHFT, Germany*
At 28-Gbaud soft-coded POLQAM exhibits measured coding gain improvements of 1.5dB and 3.1dB for 12.5% and 30% code overhead, respectively, when moving from hard decision to soft decision FEC. Iterative demapping was mandatory to decode the LDPC code which was optimized for POLQAM by EXIT chart technique.

Mo.4.F.2 • 16:15
Experimental Demonstration of C-band Burst-mode Transmission for High Power Budget (64-split with 40km distance) TWDM-PON Systems
S Ihara[1], S Yoshima[1], T Suehiro[1], M Noda[1], E Igawa[1], M Nogami[1], J Nakagawa[1]; [1]*Mitsubishi Electric Corporation, Japan*
We have experimentally demonstrated 2.5Gb/s C-band burst-mode transmission for TWDM-PON. ONU transmitter with 4.0dBm output power and low chirp characteristics giving less than 0.6dB penalty after 50km transmission could achieve NG-PON2 system with a 1:64 split and over 40km transmission.

ROOM A

Mo.4.A.2 • 16:30
Multi-Element Fibre for Space-Division Multiplexed Transmission
S Jain[1], T C May-Smith[1], V J F Rancano[1], P Petropoulos[1], D J Richardson[1], J K Sahu[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We present a multi-element fibre (MEF) as a novel candidate for space-division-multiplexing of optical channels that require high density of data transfer. 3-MEFs, comprising three individual fibres in a common coating, have been fabricated and error-free transmission has been demonstrated.

Mo.4.A.3 • 16:45
Design and Fabrication of Long DMD Maximally Flattened Two-Mode Optical Fibres suitable for MIMO Processing
R Maruyama[1], T Shoji[1], N Kuwaki[1], S Matsuo[1], K Sato[1], M Ohashi[2]; [1]*Fujikura Ltd., Japan;* [2]*Graduate School of Engineering, Osaka Prefecture University, Japan*
We design and fabricate DMD compensation transmission line composed of two mode optical fibres (TMFs) with maximally flattened DMD. The TMFs have low DMD slopes of |0.15| ps/km/nm and 102.6 km line has DMD within |4.0|ps/km in the C+L band.

Mo.4.A.4 • 17:00
Three-Mode Multiplexer in Photonic Crystal Fibre
S Yerolatsitis[1], T A Birks[1]; [1]*Dept. of Physics, University of Bath, UK*
Simple all-fibre mode multiplexers were made by controllably collapsing air holes along a short length of photonic crystal fibre. The LP01 mode and both LP11 modes were excited from three separate input cores, with less than 0.1 dB of loss at the wavelength of 1550 nm.

Mo.4.A.5 • 17:15
Simple Crosstalk Characterization Technique Without Multiple Core Access
K Nakajima[1], C Fukai[1], Y Goto[1], K Saito[1]; [1]*NTT Corporation, Japan*
A simple crosstalk characterization technique is proposed for an uncoupled type multi-core fibre (MCF). Our experimental results show that crosstalk in MCF can be characterized by measuring the output power statistically at one particular core.

ROOM B

Mo.4.B.2 • 16:30
Demonstration of 30-Tbps/cm2 Bandwidth Density by Silicon Optical Interposers Fully Integrated with Optical Components
Y Urino[1,2], S Akiyama[1,2], T Akagawa[1,2], T Baba[1,2], T Usuki[1,2], D Okamoto[1,2], M Miura[1,2], J Fujikata[1,2], T Shimizu[1,2], M Okano[1,3], N Hatori[1,2], M Ishizaka[1,2], T Yamamoto[1,2], H Takahashi[1,2], Y Noguchi[1,3], M Noguchi[1,2], M Imai[1,2], M Yamagishi[1,3], S Saitou[1,3], N Hirayama[1,3], M Takahashi[1,3], E Saito[1,2], D Shimura[1,2], H Okayama[1,2], Y Onawa[1,2], H Yaegashi[1,2], H Nishi[1,2], H Fukuda[1,2], K Yamada[1,2], M Mori[1,3], T Horikawa[1,3], T Nakamura[1,2], Y Arakawa[1,4]; [1]*Institute for Photonics – Electronics Convergence System Technology (PECST), Japan,* [2]*Photonics Electronics Technology Research Association (PETRA), Japan;* [3]*National Institute of Advanced Industrial Science and Technology (AIST), Japan;* [4]*Institute of Industrial Science, The University of Tokyo, Japan*
Silicon optical interposers for inter-chip interconnects, integrated with lasers, optical splitters, modulators, waveguides and photodetectors on a single silicon substrate were demonstrated. They were optically complete and closed systems. We achieved 20-Gbps error-free data transmission and a 30-Tbps/cm2 bandwidth density using these interposers.

Mo.4.B.3 • 16:45
III-V/Silicon First Order Distributed Feedback Lasers Integrated on SOI Waveguide Circuits
S Keyvaninia[1], S Verstuyft[1], L Van Landschoot[1], D Van Thourhout[1], G Roelkens[1], G H Duan[2], F Lelarge[2], J-M Fedeli[4], S Messaoudene[3], T de Vries[4], E-J Geluk[4], B Smalbrugge[4], M Smit[5] ; [1]*Photonics Research Group, INTEC, Ghent University-IMEC, Belgium;* [2]*III-V Lab, a joint lab of 'Alcatel-Lucent Bell Labs France', 'Thales Research and Technology' and 'CEA Leti', France;* [3]*CEA- LETI, France;* [4]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
Heterogeneously integrated III-V-on-silicon first order distributed feedback lasers utilizing an ultra-thin DVS-BCB die-to-wafer bonding process are reported. 5 mW output power coupled to a silicon waveguide, more than 40 dB side mode suppression ratio and continuous wave operation up to 60°C is obtained.

Mo.4.B.4 • 17:00 Invited
Recent Advances in Electrically Pumped Ge Lasers
J Michel[1]; [1]*Massachusetts Institute of Technology, USA*
Electrically pumped Ge lasers, integrated on a CMOS platform, are promising candidates as integrated lightsources for on-chip photonic systems. The wide gain spectrum from 1520 nm to 1700 nm makes the Ge lasers ideal light sources for WDM applications. There are two main challenges for efficient electrically pumped Ge lasers, high n-type doping concentration and low-loss coupling from Ge waveguides to Si waveguides. The high n-type doping is necessary to overcome the indirect bandgap of Ge and reach gains comparable to other compound semiconductor lasers. We will show that an in-situ delta doping process will yield active Phosphorous concentrations of about 5 x 10^19 cm^-3. The first demonstrated lasers were made from Ge waveguides and did not couple light to Si waveguides, commonly used for on-chip photonic systems. Due to the large refractive index difference between Ge (4.0) and Si (3.5) low loss coupling from a Ge waveguide to a Si waveguide is challenging but a requirement for efficient Ge lasers. We will discuss the different device designs to provide low loss coupling for low threshold lasing.

ROOM C

Mo.4.C.3 • 16:30
Integrated Circuits for Wavelength Division De-multiplexing in the Electrical Domain
H-C Park[1], M Piels[1], E Bloch[2], M Lu[1], A Sivananthan[1], Z Griffith[3], L Johansson[1], J Bowers[1], L Coldren[1], M Rodwell[1]; [1]*ECE, University of California, Santa Barbara, USA;* [2]*Dept. of Electrical Engineering, Technion - Israel Institute of Technology, Israel;* [3]*Teledyne Scientific & Imaging Company, USA*
We propose a new concept for a single-chip multi-channel WDM receiver toward Tbps operation. The receiver, consisting of a single photonic IC and a single electrical IC, multiplies data detection capacity by the number of electrical subcarrier channels. In a first demonstration, two BPSK-modulated wavelength channels are successfully demodulated.

Mo.4.C.4 • 16:45
Doubling Direct-detection Data Rate by Polarization Multiplexing of 16-QAM without a Polarization Controller
M Nazarathy[1], A Agmon[1]; [1]*EE, Technion, Israel Institute of Technology, Israel*
Polarization multiplexing (POL-MUX) is precluded in self-coherent direct-detection with remotely transmitted pilot as signal x pilot components fade. We propose and simulate POL-MUX 16-QAM over direct detection, by novel low-complexity photonic integrated optical front-end and adaptive 3x2 MIMO DSP.

Mo.4.C.5 • 17:00
All-Optical OFDM Demultiplexing by Spectral Magnification and Optical Band-Pass Filtering
E Palushani[1], H C Mulvad[1], D Kong[1,2], P Guan[1], M Galili[1], L K Oxenløwe[1]; [1]*DTU Fotonik, Technical University of Denmark, Denmark;* [2]*State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, China*
We propose spectral magnification of optical-OFDM super-channels using time-lenses, enabling reduced inter-carrier-interference in subcarrier detection by simple band-pass filtering. A demonstration on an emulated 100 Gbit/s DPSK optical-OFDM channel shows improved sensitivities after 4-times spectral magnification.

Mo.4.C.6 • 17:15
Wavelength Demultiplexing of Nyquist WDM Signals under Large Frequency Offsets in Digital Coherent Receivers
Y Mori[1], C Han[1], H Lu[1], K Kikuchi[1]; [1]*Dept. of Electrical Engineering and Information Systems, The University of Tokyo, Japan*
We propose a novel wavelength-demultiplexing algorithm applicable to Nyquist WDM systems. The proposed scheme features the ability of perfect wavelength demultiplexing even under the frequency offset half as large as the symbol rate. Through simulations and experiments, effectiveness of our scheme is demonstrated in 16-QAM Nyquist WDM systems.

ROOM D

Mo.4.D.3 • 16:30
Blind Adaptive Equalization for 6PolSK-QPSK Signals
S Alreesh[1], J K Fischer[2], P Wilke-Berenguer[2], C Schubert[2]; [1]*Technische Universität Berlin, Fachgebiet Nachrichtentechnik, Germany;* [2]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany*
We introduce an algorithm for digital equalization of 6PolSK-QPSK signals and present a way to initialize the filter coefficients of a 2×2 adaptive time-domain equalizer in an optimum manner. The proposed algorithm has been found to perform well in both numerical simulations and transmission experiments.

Mo.4.D.4 • 16:45
Joint Frame Synchronization and Frequency Offset Estimation in Coherent Optical Transmission Systems
F Pittalà[1,2], J Qi[1], M Msallem[1,2], J A Nossek[2]; [1]*European Research Center, Huawei Technologies Dusseldorf GmbH, Germany;* [2]*Institute for Circuit Theory and Signal Processing, Technische Universität München, Germany*
A novel method for frame synchronization and frequency offset estimation employing CAZAC sequences is demonstrated in a 256 Gb/s PDM-16QAM transmission system. The proposed algorithm is tolerant to residual CD, PMD, PDL and fast time-varying SOP rotation.

Mo.4.D.5 • 17:00 Invited
Challenges and Opportunities of MIMO Processing for Optical Transport Systems
S Bigo[1], M Salsi[1], O Bertran-Pardo[1], J Renaudier[1], G Charlet[1]; [1]*Alcatel-Lucent Bell Labs, France*
We recall the basics of digital MIMO processing for polarization-division demultiplexing and mode-division demultiplexing and draw some similarities/differences with radio applications. We illustrate the impact of nonlinearities on the mitigation of mode coupling and discuss the challenges of mode-dependent gain in a multimode optical amplifier.

ROOM E

Mo.4.E.2 • 16:30
Traffic Engineering Database Dissemination for Multi-layer SDN Orchestration
O Gonzalez de Dios[1], V Lopez[1], C Haya[1], C Liou[2], P Pan[2], G Grammel[3], J Antich[3], F-P Juan Pedro[1]; [1]*Telefonica I+D, Spain;* [2]*Infinera, USA;* [3]*Juniper Networks, Spain*
Orchestration between multiple layers requires a standard architecture to enable such coordination in multi-vendor scenarios. This work proposes an architecture to solve multi-layer orchestration and experimentally validates topology dissemination in a multi-vendor environment.

Mo.4.E.3 • 16:45
Experimental Demonstration of Adaptive Virtual Network Topology Control Mechanism based on SDTN Architecture
T Miyamura[1], D Shimazaki[1], S Arakawa[2], Y Koizumi[2], S Kamamura[1], K Sasayama[1], K Shiomoto[1], M Murata[2]; [1]*NTT Corporation, Japan;* [2]*Osaka University, Japan*
We designed and developed the first proto-type system of adaptive virtual network topology control based on an SDTN architecture for robust network virtualization. Dynamic resource optimization among multiple virtual networks based on measured traffic was successfully demonstrated on testbed network.

Mo.4.E.4 • 17:00
Novel Approaches for Composition of Online Virtual Optical Networks Utilizing O-OFDM Technology
A Hammad[1], R Nejabati[2], D Simeonidou[2]; [1]*University of Essex, UK;* [2]*University of Bristol, UK*
Optical Orthogonal Frequency Division Multiplexing (O-OFDM) is an attractive transport technology for virtualization of optical networks. In this paper, we propose a novel Integer Linear Programming (ILP) formulation and a scalable efficient heuristic algorithm for online virtualization in an optical network utilizing O-OFDM.

Mo.4.E.5 • 17:15
Dynamic Virtual Network Embedding Scheme based on Network Element Slicing for Elastic Optical Networks
J Zhang[1,2], B Mukherjee[2], J Zhang[1], Y Zhao[1]; [1]*State Key Laboratory of Information Photonics and Optical Communication, Beijing University of Post and Telecommunications, China;* [2]*University of California, Davis, USA*
Dynamic virtual network embedding schemes based on Link Slicing (LS) and Node Slicing (NS) are proposed for elastic optical networks. Simulation results show that both LS and NS achieve better performance than baseline scheme in terms of blocking probability and revenue-to-cost ratio.

ROOM F

Mo.4.F.3 • 16:30
Gigabit SFP Transceiver with Integrated Optical Time Domain Reflectometer for Ethernet Access Services
N Parkin[1], M Bartur[2], D Nesset[1], D Jenkins[2]; [1]*BT, UK;* [2]*Optical Zonu Corp., USA*
An SFP transceiver with integrated OTDR is used with a commercial Ethernet network termination unit and the OTDR functionality evaluated. We show length measurement readings within 90 m of those obtained from a dedicated commercial OTDR tester. The use of OTDR can reduce network downtime by quick reliable location of faults.

Mo.4.F.4 • 16:45 Invited
High-Speed Electronics for Short-Link Communication
J Bauwelinck[1], R Vaernewyck[1], J Verbrugghe[1], W Soenen[1], B Moeneclaey[1], C Van Praet[1], A Vyncke[1], G Torfs[1], X Yin1, X-Z Qiu[1], J Vandewege[1], N Sotiropoulos[2], H De Waardt[2], R Cronin[3], G Maxwell[3], T Tekin[4], P Bakopoulos[5], C P Lai[6], P D Townsend[6]; [1]*INTEC/IMEC, Ghent University, Belgium;* [2]*COBRA, Eindhoven University of Technology, Netherlands;* [3]*CIP Technologies, UK;* [4]*Fraunhofer IZM, Germany;* [5]*National Technical University of Athens, Greece;* [6]*Tyndall National Institute, University College Cork, Ireland*
High-speed electronic integrated circuits are essential to the development of new fiber-optic communication systems. Close integration and co-design of photonic and electronic devices are becoming more and more a necessity to realize the best performance trade-offs. This paper presents our most recent results and a brief introduction to our research in recently started EU projects.

Mo.4.F.5 • 17:15
100-ns λ-selective Burst-Mode Transceiver for 40-km Reach Symmetric 40-Gbit/s WDM/TDM-PON
K Taguchi[1], H Nakamura[1], K Asaka[1], S Nakano[2], S Kimura[1], N Yoshimoto[1]; [1]*NTT Access Network Service System Laboratories, NTT Corporation, Japan;* [2]*NTT Microsystem Integration Laboratories, NTT Corporation, Japan*
We propose a λ-selective burst-mode transceiver with 100-ns wavelength switching for the use in C and L-bands for upstream and downstream signals, respectively. The bidirectional 40-km transmission of symmetric 40-Gbit/s λ-tunable WDM/TDM-PON is demonstrated without a PON repeater.

ECOC 2013 - PROGRAMME TUESDAY 24 SEPTEMBER **PROGRAMME**

ROOM A

Tu.1.A
Infrared Materials and Applications
Chair: Periklis Petropoulos, *University of Southampton, UK*

Tu.1.A.1 • 09:00 Tutorial
Glasses for Infrared Fibre Applications
H Ebendorff-Heidepriem[1]; [1]*Institute for Photonics and Advanced Sensing, The University of Adelaide, Australia*
This paper reviews the optical and thermal properties of glasses transmitting light > 2 microns wavelength. The potential of the glasses for high power and high nonlinearity fibre applications and recent progress in fabrication of fibre from these glasses are also reviewed.

ROOM B

Tu.1.B
Components for Access
Chair: Leo Spiekman, *Aeon Corporation, USA*

Tu.1.B.1 • 09:00 Invited
Advanced Optical Components for Access and Datacenters
D Piehler[1]; [1]*NeoPhotonics, USA*
The development of advanced optical technologies for broadband access networks is compared to current development of advanced optical interconnects for datacenter networks. Based on identified parallels and synergies, predictions are made.

Tu.1.B.2 • 09:30
Multi-Channel 11.3-Gb/s Integrated Reflective Transmitter for WDM-PON
C P Lai[1], R Vaernewyck[2], A Naughton[1], J Bauwelinck[2], X Yin[2], X Z Qiu[2], G Maxwell[3], D W Smith[3], A Borghesani[3], R Cronin[3], K Grobe[4], N Parsons[5], E Kehayas[6], P D Townsend[1]; [1]*Tyndall National Institute, University College Cork, Ireland;* [2]*INTEC/IMEC, Ghent University, Belgium;* [3]*CIP Technologies, UK;* [4]*ADVA Optical Networking SE, Germany;* [5]*Polatis Ltd., UK;* [6]*Constelex Technology Enablers Ltd., Greece*
We present a multi-channel transmitter that employs an arrayed reflective electroabsorption modulator-based photonic integrated circuit and low-power driver array. Error-free 11.3-Gb/s per channel performance is achieved over 96 km of SSMF, with negligible crosstalk (<1-dB penalty) in multi-channel operation.

Tu.1.B.3 • 09:45
Three-mode PLC-type Multi/demultiplexer for Mode-division Multiplexing Transmission
N Hanzawa[1], K Saitoh[2], T Sakamoto[1], K Tsujikawa[1], T Uematsu[2], M Koshiba[2], F Yamamoto[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
We demonstrated a three-mode multi/demultiplexer (MUX/DEMUX) using parallel waveguides with a uniform height for mode division multiplexing transmission. The mode conversion of the LP01 mode to the LP11 and LP21 modes in the C-band was achieved using a fabricated MUX/DEMUX.

ROOM C

Tu.1.C
Optical Signal Processing
Chair: Laurent Bramerie, *CNRS, France*

Tu.1.C.1 • 09:00
Demonstration of 74 GHz Parametric Optical Sampled Analog-to-Digital Conversion
A O J Wiberg[1], D J Esman[1], L Liu[1], Z Tong[1], E Myslivets[1], N Alic[1], S Radic[1]; [1]*University of California San Diego, USA*
We demonstrate a broadband analog parametric optical sampling gate-driven analog-to-digital conversion applicable to high speed signals. A record-fast analog signal of 74 GHz was characterized at 5.4 ENOB for the first time

Tu.1.C.2 • 09:15
Performance Analysis of Simultaneous Multilevel Amplitude and Phase Regeneration
T Roethlingshoefer[1,2,3], G Onishchukov[1,2,3], B Schmauss[3,4], G Leuchs[1,2,3]; [1]*Max Planck Institute for the Science of Light, Germany;* [2]*Institute of Optics, Information and Photonics, University of Erlangen-Nuremburg, Germany;* [3]*Erlangen Graduate School in Advanced Optical Technologies, Germany;* [4]*Institute of Microwaves and Photonics, University of Erlangen-Nuremberg, Germany*
A star-8QAM regeneration was investigated in numerical simulations for two schemes: a combined NALM with a PSA in the loop and a cascade of PSA and NALM. Significant improvements in error vector magnitude and bit error rate are achieved for both schemes in a transmission system limited by amplified spontaneous emission and nonlinear phase noise.

Tu.1.C.3 • 09:30
Mode-Selective Wavelength Conversion Based on Four-Wave Mixing in a Multimode Silicon Waveguide
Y Ding[1], J Xu[1], H Ou[1], C Peucheret[1]; [1]*Dept. of Photonics Engineering, Technical University of Denmark, Denmark*
We report all-optical mode-selective wavelength conversion based on four-wave mixing in a multimode Si waveguide. A two-mode division multiplexing circuit using tapered directional coupler based (de) multiplexers is used for the application. Experimental results show clear eye-diagrams and moderate power penalties for the conversion of both modes.

Tu.1.C.4 • 09:45
All-Optical Pre-Distortion and Fibre Loop Phase Conjugation of POLMUX Signals for Pre-Compensation of Fibre Nonlinearity
M D Pelusi[1]; [1]*CUDOS, The University of Sydney, Australia*
All-optical pre-compensation of nonlinear distortion of polarization-multiplexed 80 Gb/s RZ-DPSK signals by pre-distortion and fibre loop phase-conjugation is evaluated experimentally. The impact of inter-polarization nonlinearity on the bit-error rate improvement for a 728 km dispersion-managed link employing a direct detection receiver is shown.

ROOM D

Tu.1.D
Undersea Systems
Chair: *Valey Kamalov, Google, USA*

Tu.1.D.1 • 09:00 Invited
Spectral Shaping for High Spectral Efficiency in Long-Haul Optical Transmission Systems
M Mazurczyk[1]; [1]*TE SubCom, USA*
We transmit 30 Tb/s capacity over 7,200 km and 21 Tb/s capacity over 10,300 km at high spectral efficiency using EDFA only amplification. Advanced digital signal processing including spectral shaping is used to achieve these results.

Tu.1.D.2 • 09:30
401 km Unrepeatered Transmission of Dual-Carrier 400 Gb/s PDM 16 QAM mixed with 100 Gb/s Channels
D Mongardien[1], C Bastide[1], B Lavigne[1], S Etienne[1], H Bissessur[1]; [1]*Alcatel-Lucent Submarine Networks, France*
We present the unrepeatered transmission of a dual carrier 400 Gb/s PDM-16QAM channel over 401 km, mixed with 100 Gb/s PDM-QPSK channels. We show that pre-emphasis of the 400 Gb/s channel results in equalized channel margins at the link output.

Tu.1.D.3 • 09:45
Transmission of 256 Gb/s PM-16QAM and 128 Gb/s PM-QPSK Signals over Long-Haul and Submarine Systems with Span Lengths Greater than 100 km
J D Downie[1], J Hurley[1], D Pikula[1]; [1]*Corning Incorporated, USA*
Transmission systems with span lengths averaging 112.3 km using ultra-low loss, large effective area fiber are used to demonstrate transmission of 20 PM-16QAM signals over more than 2,300 km and 20 PM-QPSK signals more than 14,400 km. For 40 channels, the 128 Gb/s PM-QPSK system has a reach > 7,400 km with 3 dB margin over the FEC threshold.

ROOM E

Tu.1.E
DSP Algorithms
Chair: John Cartledge, *Queen's University, Canada*

Tu.1.E.1 • 09:00
Constellation Expansion and Iterative Demapping and Decoding for 100G Systems
P Leoni[1], V Sleiffer[2], S Calabrò[3], B Lankl[1]; [1]*Institut Für Informationstechnik, Universität der Bundeswehr München, Germany;* [2]*COBRA institute, Eindhoven University of Technology, Netherlands;* [3]*Nokia Siemens Networks Optical GmbH, Germany*
We investigate theoretically and experimentally the use of large constellations and low-rate FEC codes in 100G systems, improving both spectral efficiency and OSNR performance over conventional systems based on QPSK and high rate codes.

Tu.1.E.2 • 09:15
Simplified Transmitter-Side DSP Implementation for Optical Multilevel Signaling with Delay Detection
N Kikuchi[1], T Yano[1]; [1]*Central Reseach Lab., Hitachi, Japan*
We propose a new DSP configuration for optical higher-order multilevel signaling with chromatic dispersion pre-distortion both for optical delay-detection and for coherent detection with digital delay detection, which is effective to significantly reduce hardware size.

Tu.1.E.3 • 09:30 Invited
DSP for High Spectral Efficiency 400G Transmission
X Zhou[1]; [1]*AT&T Labs Research, USA*
This paper presents an overview of several advanced digital signal processing (DSP)- enabled technologies recently demonstrated for high spectral efficiency (SE) 400Gb/s-class transmission, including the SE-adaptable time-domain hybrid QAM, transmitter-side digital spectral shaping, and training-assisted carrier phase recovery.

ROOM F

Tu.1.F
Integrated Devices
Chair: Philippe Chanclou, *Orange Labs, France*

Tu.1.F.1 • 09:00
Hybrid InP/Polymer Optical Line Terminals for 40-Channel 100-GHz spectrum-sliced WDM-PON
D De Felipe[1], C Zawadzki[1], Z Zhang[1], A Maese[1], M Wenzel[1], H Li[1], G Przyrembel[1], A Sigmund[1], M Möhrle[1], N Keil[1], N Grote[1], M Schell[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute, Germany*
40-channel optical line terminals with 100-GHz channel spacing based on a polymer integration platform are introduced. Transmitter and receiver components are presented, consisting on polymer AWGs integrated with InP-based multi-wavelength lasers and planar photodetectors, respectively.

Tu.1.F.2 • 09:15
Optical True-Time-Delay Microwave Beam-Steering with 1 Gb/s Wireless Transmission for In-Building Networks
Z Cao[1], F Li[2,3], H P A Van de Boom[1], E Tangdiongga[1], A M J Koonen[1]; [1]*COBRA, Eindhoven University of Technology, Netherlands;* [2]*ZTE USA, USA;* [3]*Hunan University, China*
An optical true time delay based microwave beam-steering (OTTD-MBS) scheme integrated with a radio-over-fibre system is demonstrated. Properties of 1Gb/s data wireless transmission with OTTD-MBS are studied.

Tu.1.F.3 • 09:30
16-Channel Tunable VCSEL Array with 50-GHz Channel Spacing for TWDM-PON ONUs
E-G Lee[1], J C Lee[1], S-G Mun[1], E-S Jung[1], J H Lee[1], S S Lee[1]; [1]*ETRI, Republic of Korea*
A tunable VCSEL array which has tunability of 50-GHz spaced 16 channels without mode hopping is successfully emonstrated. The tunable laser shows low power consumption for wavelength tuning of 0.01 W and error-free transmission with 20-km SMF and 64-way splitter.

Tu.1.F.4 • 09:45
Low-Cost Transmitter for Flexible-Format Generation up to 16-QAM for Spectral-Efficiency Conscious PONs
B Schrenk[1], I Lazarou[2], S Dris[2], P Bakopoulos[2], H Avramopoulos[2], M Stierle[1], H Leopold[1]; [1]*Dept. Safety & Security, AIT Austrian Institute of Technology, Austria;* [2]*School of Electrical and Computer Engineering, National Technical University of Athens, Greece*
A flexible-format EAM/SOA-transmitter for coherent PONs with spectral efficiencies of up to 4 bits/symbol, delivering up to 4 Gb/s per-user bandwidth over 34-49dB loss budget, is demonstrated. We show that its constellational multiplicity can be exploited for energy-aware throughput optimization.

ROOM A

Tu.1.A.2 • 10:00
Diode-pumped Wideband Thulium-doped Fiber Amplifiers for Optical Communications in the 1800 - 2050 nm Window
Z Li[1], A M Heidt[1], S U Alam[1], N Simakov[1], Y Jung[1], J M O Daniel[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We present the first in-band diode-pumped TDFAs operating in the 2 µm wavelength region and test their application as high performance amplifiers in potential future telecommunication networks. We demonstrate amplification over a 240 nm wide window in the range 1810 - 2050 nm with up to 36 dB gain and noise figure as low as 4.5 dB.

Tu.1.A.3 • 10:15
Demonstration of a 2µm-OTDR
M Belal[1], S U Alam[1], J K Sahu[1], D J Richardson[1], T P Newson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We report the development of an OTDR operating at the emerging wavelength band of 2 µm. A 30dB dynamic range and spatial resolution of 10m is achieved.

ROOM B

Tu.1.B.4 • 10:00
Employing an Integrated Mode Multiplexer on Silicon-on-Insulator for Few-mode Fiber Transmission
H Chen[1], R van Uden[1], C Okonkwo[1], B Snyder[2], O Raz[1], P O'Brien[2], H van den Boom[1], H de Waardt[1], T Koonen[1]; [1]*COBRA, Eindhoven University of Technology, Netherlands;* [2]*Tyndall National Institute, University College Cork, Ireland*
An integrated Silicon-on-Insulator mode multiplexer is experimentally verified by mode-multiplexed 2 x 10Gbaud QPSK transmission over 1km Few-mode Fiber guiding LP01 and LP11 modes. Robust transmission is demonstrated over C-band with high mode crosstalk suppression

Tu.1.B.5 • 10:15
40 nm Tuneable Source for Colourless ONUs based on Dual Hybridly Integrated Polymer Waveguide Grating Lasers
D De Felipe[1], C Zawadzki[1], Z Zhang[1], W Brinker[1], H N Klein[1], M Möhrle[1], N Keil[1], N Grote[1], M Schell[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institute, Germany*
A dual-laser tuneable source based on a polymer integration platform is proposed as a low-cost light source for WDM-PON. A tunability of 40 nm along the C-band using a maximum electrical power of 82 mW was achieved. Direct modulation at 2.5 Gb/s through 20 km standard single-mode fibre and a 100 GHz-AWG has been successfully demonstrated.

ROOM C

Tu.1.C.5 • 10:00
Tunable Optical Correlator using an Optical Frequency Comb for Generating Multiple Taps in a Tapped-Delay-Line Composed of a Single Nonlinear Element
M Ziyadi[1], M R Chitgarha[1], S Khaleghi[1], A Mohajerin-Ariaei[1], A Almaiman[1], J D Touch[2], M Tur[3], C Langrock[4], M M Fejer[4], A E Willner[1]; [1]*Dept. of Electrical Engineering, University of Southern California (USC), USA;* [2]*Information Sciences Institute, University of Southern California, USA;* [3]*School of Electrical Engineering, Tel Aviv University, Israel;* [4]*Edward L. Ginzton Laboratory, Stanford University, USA*
We experimentally demonstrate a tunable optical correlator to search for multiple patterns among QPSK symbols in 20 Gbuad stream. We use an optical frequency comb to generate coherent signals and add them coherently using a single PPLN waveguide. Multiple patterns with different lengths are successfully searched on QPSK signals.

Tu.1.C.6 • 10:15
Reconfigurable 2-D WDM Optical Tapped-Delay-Line to Correlate 20-Gbaud QPSK Data
M R Chitgarha[1], M Ziyadi[1], S Khaleghi[1], A Mohajerin-Ariaei[1], A Almaiman[1], J D Touch[2], M Tur[3], C Langrock[4], M M Fejer[4], A E Willner[1]; [1]Ming Hsien, *Dept. of Electrical Engineering, University of Southern California, USA;* [2]*Information Sciences Institute, University of Southern California, USA,* [3]*Tel Aviv University, Israel;* [4]*Edward L. Ginzton Laboratory, Stanford University, USA*
We demonstrate a 2-D optical tapped-delay-line that exploits nonlinearities and chromatic dispersion to perform 2-D correlation on 20-Gbaud QPSK data with correlator results with average EVM ~7.8%. We successfully recognize different 2×2 target patterns in an image with 961 pixels.

10:30-11:00 COFFEE BREAK (ECOC Exhibition) | 11:00-12:30 EXHIBITION ONLY | 12:30-14:00 LUNCH BREAK

Tu.3.A
Advances in Optical Fibres
Chair: Tim Birks, *University of Bath, UK*

Tu.3.A.1 • 14:00 Invited
Precise Tailoring of Longitudinal Acoustic Property of Optical Fibers by a Hydrogen-loading Technique
L Dong[1], F Kong[1], T Hawkins[1]; [1]*COMSET/ECE, Clemson University, USA*
We have demonstrated for the first time a post-processing technique using hydrogen loading and subsequent UV exposure to implement precise longitudinally-tailored acoustic property along a fiber for optimal SBS suppression. Local acoustic velocity can be modified by ~3%, leading to ~500MHz change in Brillouin frequency at ~1micron, equivalent to ~10dB SBS suppression.

Tu.3.B
Interconnects
Chair: Christian Lerminiaux, *UTT, France*

Tu.3.B.1 • 14:00 Invited
High Performance MEMS-based Micro-optic Assembly for Multi-lane Transceivers
B Pezeshki[1]; [1]*Kaiam Corp., USA*
Advanced transceivers generally require multi-lane approaches, which necessitates the integration of multiple subcomponents. The use of mature, generally available, and low-cost single element components such as EMLs, silica PLCs, and direct-mod DFBs, integrated in a hybrid fashion and optically aligned with MEMS, provides a practical solution.

Tu.3.C
Transmitter Subsystems
Chair: Jeurg Leuthold, *ETHZ, Switzerland*

Tu.3.C.1 • 14:00 Invited
Bandwidth-Variable Transceivers Based on 4D Modulation Formats for Future Flexible Networks
J K Fischer[1], S Alreesh[2], R Elschner[1], F Frey[1], M Nölle[1], C Schubert[1]; [1]*Fraunhofer Heinrich Hertz Institute, Germany;* [2]*Technische Universität Berlin, Fachgebiet Nachrichtentechnik, Germany*
We discuss technology options for bandwidth-variable transceivers which are key components for the realization of flexible software-defined optical networking. In particular, we focus on recent advances in four-dimensional modulation formats and in modulation format transparent data-aided digital signal processing.

ROOM D

Tu.1.D.4 • 10:00 Invited
Ultra-Long-Haul MCF Transmission Systems
H Takahashi[1], T Tsuritani[1]; [1]*KDDI R&D Laboratories, Japan*
The multicore fiber (MCF) transmission technologies is a promising candidate for next generation optical fiber communication system. In this paper, we review the feasibility of the MCF transmission repeatered by multicore EDFA for ultra-long-haul transmission.

ROOM E

Tu.1.E.4 • 10:00
Experimental Investigation of Training Sequence for Adaptive Equalizer Initialization in DP-16QAM System
M Yan[1], Z Tao[1], T Tanimura[2], S Oda[2], Y Cao[1], Y Zhao[1], T Hoshida[3], J C Rasmussen[3]; [1]*Fujitsu R&D Center, China;* [2]*Fujitsu Laboratories, Japan;* [3]*Fujitsu Ltd, Japan*
A training sequence which realizes frame synchronization, frequency offset estimation and channel estimation simultaneously at the initial capturing stage is proposed and verified in a 32Gbaud DP-16QAM system. Experiment shows that it tolerates various linear distortions, such as CD, PMD and PDL, and avoids the singularity problem.

Tu.1.E.5 • 10:15
Fully-Blind Cycle Slip Compensation with Time-Interleaved Polarisation Coding in Two Dimensional Phase Domain
T Yoshida[1], T Sugihara[1], T Fujimori[1], K Ishida[1], T Mizuochi[1]; [1]*Information Technology R&D Center, Mitsubishi Electric Corporation, Japan*
Alternating the polarisation coded symbol mapping rules between 2 symbols provides fully-blind cycle slip compensation. Simulation shows that the proposed method achieves performance only 0.2 dB below the theoretical limit for dual-polarised binary phase-shift keying.

ROOM F

Tu.1.F.5 • 10:00 Invited
Integrated Microwave Photonics for Access Systems
J Capmany[1], P Muñoz[1,2]; [1]*ITEAM Research Institute, Universitat Politecnica de Valencia, Spain;* [2]*VLC Photonics S.L, Universitat Politecnica de Valencia, Spain*
We review the recent advances in integrated microwave photonics. Desired functionalities for access systems and converged fiber-wireless networks are identified. Some of the relevant progress in the principal technology platforms is described

10:30-11:00 COFFEE BREAK (ECOC Exhibition) | 11:00-12:30 EXHIBITION ONLY | 12:30-14:00 LUNCH BREAK

Tu.3.E
Network Planning and Energy Efficiency
Chair: Jarek Turkiewicz, *Warsaw University of Technology, Poland*

Tu.3.E.1 • 14:00
Realistic Energy-Saving Potential of Load-Adaptive Operation in Conventional and Platform-Consolidated Operator Networks
C Lange[1], D Kosiankowski[1], A Gladisch[1]; [1]*Deutsche Telekom, Telekom Innovation Laboratories, Germany*
The energy-saving potential of load-adaptive operation principles for fixed operator networks is evaluated based on realistic network data for current and all-IP network equipment distributions. Overall energy savings with support of load-adaptive operation of below 10% for current and of around 50% for platform-consolidated networks are obtained.

Tu.3.E.2 • 14:15
Adaptive Power Efficiency for Chromatic Dispersion Compensation
C Dorize[1], Y Pointurier[1], F Vacondio[1], J-C Antona[1], S Bigo[1]; [1]*Alcatel-Lucent Bell Labs, France*
When digitally compensating for chromatic dispersion in coherent systems, we propose to adjust the number of operations according to each lightpath requirement so as to save energy through DSP power scaling. We achieve energy savings up to 77% (resp. 57%) into the compensation stage, when considering a core network scenario at 100 (resp. 200) Gb/s.

Tu.3.F
Access Subsystems
Chair: Stefan Dahlfort, *Ericsson, USA*

Tu.3.F.1 • 14:00
Single-Fibre Operation of a Metro Access System with Network Based Wavelength Control
M Roppelt[1], M Lawin[1], M Eiselt[1]; [1]*ADVA Optical Networking, Germany*
The operation of a tree-type WDM access system with low-cost tuneable terminals is demonstrated. Wavelength control is based on a central wavelength locker with laser tuning information being transmitted to the distributed terminal via a tone-based overhead channel. The wavelength evolution of turn-up and in-service operation is demonstrated.

Tu.3.F.2 • 14:15
Burst Frame Power Equalizer that Controlling Gains of Cascaded SOAs for Long-Reach WDM/TDM PON Systems
M Fujiwara[1,2], R Koma[1], N Yoshimoto[1,2]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan;* [2]*Graduate School of Information Science and Technology, Hokkaido University, Japan*
Proposed gain control scheme for cascaded SOAs avoids triggering pattern effect and improves output power equalization accuracy, which yields long-reach WDM/TDM-PON systems with wide operating ranges; input dynamic range is 19.0 dB.

ROOM A

Tu.3.A.2 • 14:30
Photosensitivity and Luminescence Induced by ArF-Irradiation of Hydrogen Loaded Bi-SiO2 Fiber
G Violakis[1], H G Limberger[1], A S Zlenko[2], S L Semjonov[2], V M Mashinsky[2], E M Dianov[2]; [1]*Ecole Polytechnique Fédérale de Lausanne (EPFL), School of Engineering, Switzerland;* [2]*Fiber Optics Research Center RAS, Russian Federation*
Bi:SiO2 fiber drawn under oxidizing conditions shows ultra-low photosensitivity and no NIR luminescence under 1064 nm pumping. Hydrogen loading followed by ArF irradiation induced both. The increase of photosensitivity and the creation of luminescence centers seem to be linked to the reduction of Bi3+.

Tu.3.A.3 • 14:45
Data Transmission Over 1km HC-PBGF Arranged With Microstructured Fiber Spliced to Both Itself and SMF
J P Wooler[1], F Parmigiani[1], S R Sandoghchi[1], N V Wheeler[1], D R Gray[1], F Poletti[1], M N Petrovich[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
Validation of novel splicing strategy enabling integration of hollow-core photonic band gap fiber with both itself and conventional SMF is presented. Self-splices are robust and low loss (0.16dB). Penalty-free 40Gbit/s data transmission is demonstrated in 1km arrangement of spliced HC-PBGF.

Tu.3.A.4 • 15:00
Understanding the Physical Origin of Surface Modes and Practical Rules for their Suppression
F Poletti[1], E Numkam Fokoua[1]; [1]*Optoelectronics Research, University of Southampton, UK*
We present a model explaining the physical origin of surface modes in hollow core photonic bandgap fibres. We discuss the existence of two families of surface modes, strut and rod localised, and propose practical rules to avoid them both. Based on this understanding, we propose a novel realistic design for large core, surface mode free fibres.

Tu.3.A.5 • 15:15
Fabrication and Properties of Lead-Germanate Glasses for High Nonlinearity Fibre Applications
H Tilanka Munasinghe[1], A Winterstein-Beckmann[2], C Schiele[3], L Wondraczek[2], D Manzani[1], S Afshar V[1], T M Monro[1], H Ebendorff-Heidepriem[1]; [1]*Institute for Photonics and Advanced Sensing, University of Adelaide, Australia;* [2]*Otto-Schott-Institute, University of Jena, Germany;* [3]*Dept. of Materials Science, University of Erlangen, Germany*
We report on the fabrication of novel germanate glasses and fibres. We have characterised the glasses in terms of their thermal properties, Raman spectra and refractive indices (both linear and nonlinear) and present them as viable alternatives to tellurite glasses for soft glass optical fiber applications.

ROOM B

Tu.3.B.2 • 14:30
Free-Space Coherent Optical Communication Demonstration using a 3D Photonic Integrated Circuit Device for Orbital Angular Momentum Multiplexing/ Demultiplexing
R P Scott[1], B Guan[1], C Qin[1], N K Fontaine[2], T Su[1], C Ferrari[2], M Cappuzzo[2], F Klemens[2], B Keller[2], M Earnshaw[2], S J Ben Yoo[1]; [1]*Electrical and Computer Engineering, University of California, Davis, USA;* [2]*Bell Laboratories, Alcatel-Lucent, USA*
We show error-free 10GBd DQPSK data transmission performance using orbital angular momentum (OAM) modes that are multiplexed and demultiplexed by a low-loss, hybrid-integrated device based on a silica planar lightwave circuit (PLC) coupled to a 3-D photonic integrated circuit.

Tu.3.B.3 • 14:45
40-Gb/s Cost-Effective FPC-Based Optical Engine for Optical Interconnect Using Novel High-Speed FPC Connector
T Yagisawa[1], T Shiraishi[1], M Sugawara[1], Y Miki[2], M Kaybayashi[2], K Tanaka[1]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fujitsu Component Ltd., Japan*
40-Gb/s error-free operation was successfully demonstrated for the first time as an optical engine (OE) using VCSEL. The OE with a cost-effective FPC-based structure realized 40-Gb/s operation by using our newly developed high-speed FPC connector between PCB and FPC-OE substrate.

Tu.3.B.4 • 15:00
Lambda-Scale Embedded Active-Region Photonic Crystal Lasers for Off-Chip Interconnect
S Matsuo[1,3], K Takeda[1,3], T Sato[1,3], T Fujii[1,3], A Shinya[2,3], E Kuramochi[2,3], M Notomi[2,3], K Hasebe[1,3], T Kakitsuka[1,3]; [1]*NTT Photonics Laboratories, Japan;* [2]*NTT Basic Research Laboratories, Japan;* [3]*Nanophotonics Center, NTT Corporation, Japan*
We successfully increase the output power of an electrically driven photonic crystal laser. By using a six-quantum-well structure and decreasing the series resistance, the device, having 32-µA threshold current, exhibits 39.3-µW output power. We also demonstrate bit-error rate measurements with 10-Gbit/s signal without using optical amplifier.

ROOM C

Tu.3.C.2 • 14:30
Transmitter Mask Testing for 28 GBaud PM-QPSK
H Eliasson[1], P Johannisson[1], H Sunnerud[2], M Westlund[2], M Karlsson[1], P Andrekson[1]; [1]*Photonics Laboratory, Dept. of Microtechnology and Nanoscience, Chalmers University of Technology, Sweden;* [2]*EXFO Sweden AB, Sweden*
We suggest a method for pass/fail testing of PM-QPSK transmitters. The test is based on mask testing with time-resolved EVM and accepts transmitters where individual impairments cause less than 0.5 dB OSNR penalty. The design of the test is performed by computer simulations followed by experimental verification of some key results.

Tu.3.C.3 - 14:45
Eight-Dimensional Modulation for Coherent Optical Communications
T Koike-Akino[1], D S Millar[1], K Kojima[1], K Parsons[1]; [1]*Mitsubishi Electric Research Laboratories, USA*
We propose several 8-dimensional modulation formats for coherent fiber-optic communications. For spectral efficiencies of 1.75 and 2 b/s/Hz/pol, the proposed modulations offer up to 1 dB gain over DP-QPSK.

Tu.3.C.4 • 15:00
Spectrally-Efficient Single-Sideband Subcarrier-Multiplexed Quasi-Nyquist QPSK with Direct Detection
S M Erkilinc[1], R Maher[1], M Paskov[1], S Kilmurray[1], S Pachnicke[2], H Griesser[2], B C Thomsen[1], P Bayvel[1], R I Killey[1]; [1]*Optical Networks Group, Dept. of Electronic and Electrical Engineering, University College London, UK;* [2]*ADVA, Optical Networking SE, Germany*
We propose and experimentally assess SSB SCM quasi-Nyquist QPSK for spectrally-efficient direct detection links. Nine channel 10.7 GHz-spaced WDM signal generation at 14 Gb/s per channel is demonstrated with a subcarrier frequency of 5.25 GHz.

16:00-17:30 POSTER SESSION, Exhibition Hall (See page 54)

ROOM D

ROOM E

Tu.3.E.3 • 14:30
Capacity Planning for Dynamic Inter-Data Center Networking via Erlang Modeling
A Nikolaidis[1], S Asselin[1], M Auster[2], N Bragg[3]; [1]*Network Planning, CTO, Ciena Corporation, Canada;* [2]*Market Development, Ciena Corporation, Canada;* [3]*Network Architecture, CTO, Ciena Corporation, Canada*
Data center virtualization and cloud service delivery models are driving the need for Network-as-a-Service offerings. This paper proposes a method for dimensioning networks for such services via Erlang modeling. Dynamic service adjustment and network orchestration are shown to achieve a major reduction in transport capacity requirements.

Tu.3.E.4 • 14:45
Planning of Converged Optical Wireless Network and DC Infrastructures in Support of Mobile Cloud Services
K N Georgakilas[1], M P Anastasopoulos[1], A Tzanakaki[1], G Zervas[2], D Simeonidou[2]; [1]*Athens Information Technology, Greece;* [2]*University of Brtistol, UK*
This paper focuses on converged optical/wireless network and DC infrastructures supporting mobile Cloud services. Planning these infrastructures using stochastic optimization approaches and allowing virtual machine migration to address end-user mobility, facilitates significant resource efficiency improvement.

Tu.3.E.5 • 15:00
Novel Design of G.ODUSMP to Achieve Sub-50 ms Performance with Shared Mesh Protection in Carrier Networks
W Wauford[1], S Roy[1], O Turckcu[1], S Ahuja[1], S Hand[1], A Sadasivarao[1], B Lu[1]; [1]*Infinera, USA*
This paper describes the first practical implementation of shared mesh protection with <50 ms performance using the emerging standards G.808.3 & G.ODUSMP. It also presents the performance benefits of this implementation demonstrating 20-26% network cost savings vs. 1+1 protection and a maximum protection switch time substantially less than 50 ms.

Tu.3.E.6 • 15:15
Techno-Economic Advantages of Cognitive Virtual Topology Design
N Fernandez[1], R J Durán[1], E Palkopoulou[2], I de Miguel[1], I Stiakogiannakis[2], N Merayo[1], I Tomkos[2], R M Lorenzo[1]; [1]*Universidad de Valladolid, Spain;* [2]*Athens Information Technology Center, Greece*
We demonstrate that the introduction of cognitive techniques in virtual topology design leads to significant savings in terms of the total cost of ownership compared to conventional methods. Case study results indicate that capital and operational expenditures can be respectively reduced by up to 20% and 25% via a genetic algorithm-based method.

ROOM F

Tu.3.F.3 • 14:30
Multi System Next-Generation PONs Impact on Video Overlay
A Shahpari[1], J D Reis[1], S Ziaie[1], R Ferreira[1], M Lima[1], A N Pinto[1], A Teixeira[1,2]; [1]*Dept. of Electronics, Telecommunications and Informatics, University of Aveiro, Instituto de Telecomunicações, Portugal;* [2]*Nokia Siemens Networks Portugal S.A., IE WSM, Portugal*
In this paper we validate a model to be used in multi system next generation PONs to estimate the impact of Raman crosstalk in video overlay. We have considered G.98X ITU-T series and Coherent multi-wavelength systems.

Tu.3.F.4 • 14:45
Reach Extension of RSOA-Self Seeded Transmitters for DWDM Metropolitan Networks with a Single EDFA
F Saliou[1], S Dat Le[1], Q Deniel[1], P Chanclou[1]; [1]*Orange Labs, France*
DWDM sources based on self seeded-RSOAs (SFP packaged) are experimented to bring easier usage in metropolitan networks. An optical budget of 26.5dB is realized with 50km of fiber and is further extended up to 60dB and 120km with an EDFA.

Tu.3.F.5 • 15:00
Experimental Demonstration of a 10 Gb/s 16-QAM SCM WDM PON with Bandwidth-limited RSOA and IM/DD Transceivers
J M Buset[1], Z A El-Sahn[1,2], D V Plant[1]; [1]*Photonic Systems Group, Dept. of Electrical and Computer Engineering, McGill University, Canada;* [2]*Electrical Engineering Department, Alexandria University, Egypt*
We demonstrate 10 Gb/s/λ full-duplex transmission over a 20 km single feeder WDM PON. DSP enables spectrally efficient 16-QAM modulation and RF subcarrier multiplexing (SCM) for both uplink and downlink channels using low cost optoelectronics. BER performance below the RS(255,223) FEC threshold is verified.

Tu.3.F.6 • 15:15
Simultaneous Optical Routing and Millimeter-Wave Generation Exploiting High-Order Resonant Switch for In-Building Networks
S Zou[1], P DasMahapatra[1], K A Williams[1], R Stabile[1], E Tangdiongga[1], A M J Koonen[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
To effectively generate and convey the millimeter-wave radio signal for future in-building networks, the IF signal is up-converted and routed to the respective antenna unit simultaneously. Both the amplitude and phase transfer functions of the integrated switch enable the PM-to-IM conversion in the optical frequency multiplication scheme.

16:00-17:30 POSTER SESSION, Exhibition Hall (See page 54)

ROOM A

We.1.A
Metrology
Chair: Magnus Karlsson, *Chalmers University of Technology (CTH), Sweden*

We.1.A.1 • 09:00
Fiber Raman Amplification for Metrological Transfer of Phase-coherent Optical Frequencies
G Bolognini[1], C Clivati[2,3], D Calonico[2], S Faralli[4], F Levi[2], A Mura[2], N Poli[5]; [1]*Consiglio Nazionale delle Ricerche, IMM Institute, Italy;* [2]*Istituto Nazionale di Ricerca Metrologica INRIM, Italy;* [3]*Politecnico di Torino, Italy;* [4]*Scuola Superiore Sant'Anna, TeCIP Institute, Italy;* [5] *Dip. Fiscia e Astronomia INFN and LENS, Università di Firenze, Italy*
We analyze the benefits of distributed Raman amplification in metrology transfer of phase-coherent ultra-narrowband optical frequencies in a long fiber link (200 km with additional 16 dB loss), providing high-gain bi-directional amplification with limited impact on phase noise, attaining a fractional frequency instability of 3×10–19 over 1000 s.

We.1.A.2 • 09:15
Fast and Broadband Fiber Dispersion Measurement with Dense Wavelength Sampling
G M Ponzo[1], M V Petrovich[1], X Feng[1], P Horak[1], F Poletti[1], P Petropoulos[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We report on a method to obtain accurate dispersion measurements from low-coherence interferograms. This novel phase extraction method enables high accuracy, broadband measurements and very dense (20points/nm over 500nm) datasets for both dispersion and dispersion slope.

We.1.A.3 • 09:30
Fast Polarimetry of Multipulse Vector Soliton Operation
V Tsatourian[1,2,3], S V Sergeyev[1], C Mou[1], A Rozhin[1], V Mikhailov[4], B Rabin[4]; P S Westbrook[4], S K Turitsyn[1], [1]*Aston Institute of Photonic Technologies, Aston University, UK;* [2]*National Physical Laboratory, UK;* [3]*School of Engineering and Physical Sciences, Heriot-Watt University, UK;* [4]*OFS Fitel, USA*
Applying high-speed polarimetery we experimentally demonstrate new types of vector solitons for multipulse operation in an erbium doped carbon nanotube mode-locked laser. The observed states of polarisation reveal either fast pulse-to-pulse polarisation switching between cross-polarised modes or slow cyclic evolution.

We.1.A.4 • 09:45
Environmental Perturbation Tracking in Coherent OTDR for Recovering Detection Sensitivity
H Iida[1], K Toge[1], F Ito[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan*
The effect of environmental perturbations applied to long-haul submarine cables on the C-OTDR performance is demonstrated. Perturbation-tracking compensation experiment based on software processing reveals that we can compensate for SNR degradation caused by a Doppler frequency shift in backscattering.

ROOM B

We.1.B
Modulators I
Chair: Liam Barry, *DCU, Ireland*

We.1.B.1 • 09:00 Invited
Optical Modulators for Advanced Digital Coherent Transmission Systems
H Yamazaki[1], T Goh[1], T Saida[1]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan*
Advanced optical modulators for future digital coherent transmission systems are being explored. In this paper, a dual-carrier modulator for 400-Gbps transmission, a linear IQ modulator suitable for a DAC-based transmitter, and a simple PS-QPSK modulator are reviewed.

We.1.B.2 • 09:30
Very-Low-Voltage Operation of Mach-Zehnder Interferometer-Type Electroabsorption Modulator
Y Ueda[1], T Fujisawa[1], S Kanazawa[1], W Kobayashi[1], K Takahata[1], H Ishii[1]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan*
We have developed a new interferometer-type electroabsorption modulator. It operates at a very-low voltage of 0.2 V at 25.8-Gbit/s modulation, which can reduce optical transmitter power consumption and allows the adoption of cost-effective CMOS drivers.

We.1.B.3 • 09:45
Performance Improvement of Silicon Micro-Cavity Modulators by Iteration of the p-i-n Intrinsic Region Width
A Al-Saadi[1], B A Franke[1], S Kupijai[1], C Theiss[1], H Rhee[1], S Mahdi[1], L Zimmermann[2], D Stolarek[2], H H Richter[2], H J Eichler[1], U Woggon[1], S Meister[1]; [1]*Technische Universität Berlin, Institut für Optik und Atomare Physik, Germany;* [2]*IHP Microelectronics, Germany*
The distance between the p+- and n+-doped regions of the p-i-n diode in micro-cavity modulators represents a compromise between speed and loss. We varied the intrinsic region width to determine the influence on the modulator properties through simulations and experiments. A width of 0.7 μm was found to be the optimal value for modulation operation.

ROOM C

We.1.C
Spectrally Shaped Transmission Subsystems
Chair: Andrew Ellis, *Aston University, UK*

We.1.C.1 • 09:00
Transmission of a 1.1 Tb/s Super Channel in 100 GHz Optical Bandwidth Based on PM-256 QAM and Spatially Coupled FEC
R Dischler[1], L Schmalen[1]; [1]*Alcatel-Lucent Bell Labs, Germany*
We demonstrate generation and transmission of PM-256 QAM signals at a symbol rate of 14.1 GBd in a 20-GHz channel grid WDM scheme as a 1.1 Tb/s super channel. Application of spatially coupled LDPC coding with iterative demodulation reduces the required FEC overhead down to 21 % compared to non-iterative schemes.

We.1.C.2 • 09:15
Three-carrier 1 Tbit/s Dual Polarization 16-QAM Superchannel Using Look-Up Table Correction and Optical Pulse Shaping
J H Ke[1], Y Gao[1], J C Cartledge[1]; [1]*Dept. of Electrical and Computer Engineering, Queen's University, Canada*
By using look-up table correction for pattern-dependent distortion and optical pulse shaping for enhancing the spectral efficiency, a three-carrier 1.206 Tbit/s dual-polarization 16-QAM superchannel exhibits a back-to-back OSNR sensitivity of 25.9 dB (BER = 10-3), a net spectral efficiency of 4.47 b/s/Hz, and transmission over 1500 km of SMF.

We.1.C.3 • 09:30
Experimental Comparison of 32-Gbaud Electrical-OFDM and Nyquist-WDM Transmission with 64GSa/s DAC
Y Lu[1], Y Fang[1], B Wu[1], K Wang[1], W Wan[1], F Yu[1], L Li[1], X Shi[1], Q Xiong[1]; [1]*Huawei Technologies Co. Ltd., Transmission Technology Research Dept., China*
The transmission performances of Electrical-OFDM and Nyquist-WDM systems using 32GBaud PDM-QPSK and PDM-16QAM modulations generated by a 64GSa/s DAC, were compared experimentally for the first time. The results show that both of the Nyquist-WDM and OFDM systems achieve same transmission distance and have similar nonlinear transmission performance.

We.1.C.4 • 09:45
Detection of 320 Gb/s Nyquist OTDM Received by Polarization-insensitive Time-domain Optical Fourier Transformation
H Hu[1], D Kong[1,2], E Palushani[1], M Galili[1], H C H Mulvad[1], L K Oxenløwe[1]; [1]*DTU Fotonik, Dept. of Photonics Engineering, Technical University of Denmark, Denmark;* [2]*State Key Laboratory of Information Photonics & Optical Communications, Beijing University of Posts and Telecommunications, China*
320 Gb/s Nyquist-OTDM is generated by rectangular filtering with a bandwidth of 320 GHz and received by polarization-insensitive time-domain optical Fourier transformation (TD-OFT) followed by passive filtering. After the time-to-frequency mapping in the TD-OFT, the Nyquist-OTDM is converted into a waveform similar to an OFDM signal.

ROOM D

We.1.D
Beyond WDM
Chair: Fabrizio Forghieri, *Cisco Photonics, Italy*

We.1.D.1 • 09:30 Tutorial
Spatial Multiplexing: The Next Frontier in Network Capacity Scaling
P J Winzer[1]; [1]*Bell Labs, Alcatel-Lucent, USA*
We outline a smooth evolution path of optical networks to spatial multiplexing by complementing deployed fiber infrastructure and existing WDM components with new integrated technologies. We discuss architectural consequences of spatial crosstalk and multiple-input multiple-output (MIMO) signal processing.

ROOM E

We.1.E
Elastic Optical Networking
Chair: Naoya Wada, *National Institute of Information and Communication Technology, Japan*

We.1.E.1 • 09:00 Invited
Evolution of Traffic Grooming from SDH/SONET to Flexible Grid
S Zhang[1], M Tornatore[2], G Shen[3], B Mukherjee[1]; [1]*University of California, Davis, USA;* [2]*Politecnico di Milano, Italy;* [3]*Soochow University, China*
We review the evolution of traffic grooming from SDH/SONET to evolutionary flexible-grid and elastic-rate technologies and summarize the relevant issues. Sliceable optical transponder is identified as a novel technology that could potentially impact the future grooming paradigm.

We.1.E.2 • 09:30
Moving Boundary between Wavelength Resources in Optical Packet and Circuit Integrated Ring Network
H Furukawa[1], T Miyazawa[1], N Wada[1], H Harai[1]; [1]*National Institute of Information and Communications Technology, Japan*
We present an optical packet and circuit integrated ring network which can move a boundary between wavelength resources of optical packets and paths for flexible resource usage. Using a hybrid optical packet/circuit switch and transponder, an optical packet link is automatically changed to optical path links on one waveband.

We.1.E.3 • 09:45
Impact of Multi-flow Transponder on Equipment Requirements in IP over Elastic Optical Networks
T Tanaka[1], A Hirano[1], M Jinno[2]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan;* [2]*Kagawa University, Japan*
We evaluate the elastic optical network performance from the network to node component level using a multi-layer network design scheme. Results show that the multi-flow optical transponderbased network model reduces equipment requirements such as router interfaces and wavelength selective switch parameters.

ROOM F

We.1.F
Flexible Access
Chair: Naoto Yoshimoto, *NTT, Japan*

We.1.F.1 • 09:00 Invited
Access Networks Based on Tunable Transmitters
K Grobe[1]; [1]*ADVA Optical Networking SE, Germany*
State-of-the-art, prospects and problems of access based on tunable lasers are discussed. Potential advantages over competing approaches (seeded reflective transmitters) include higher bit-rate x reach products. Main problem is the lack of availability of low-cost tunables. Here, protection of other tunable-laser markets is required.

We.1.F.2 • 09:30
Flexible TDMA Access Optical Networks Enabled by Burst-mode Software Defined Coherent Transponders
F Vacondio[1], O Bertran-Pardo[1], Y Pointurier[1], J Fickers[1], A Ghazisaeidi[1], G de Valicourt[1], J C Antona[1], P Chanclou[2], S Bigo[1]; [1]*Alcatel-Lucent Bell Labs, France;* [2]*Orange Labs, France*
We propose a concept of flexible PON and show with experiments and network dimensioning how burst-mode, software-defined coherent transponders can more than double the average capacity per user in TDMA access networks.

We.1.F.3 • 09:45
Low Complexity Transmitter-side Compensation for Optical Device Nonlinearities in 100Gb/s Transmission over 500m SMF
B Liu[1], W Yan[1], L Li[1], H Chen[1], Z Tao[1], T Takahara[2], J C Rasmussen[2], T Drenski[3]; [1]*Fujitsu R&D Center, China;* [2]*Fujitsu Laboratories Ltd, Japan;* [3]*Fujitsu Semiconductor Europe GmbH, Germany*
The device nonlinearity by laser diode and photo detector is identified as one of the major distortions in a 100Gb/s-class transmission over 500m SMF using discrete multi-tone technology. A novel transmitter-side DSP algorithm is proposed and 20% capacity improvement is achieved by a simple structure without usage of any feedback iterations.

ROOM A

ROOM B

We.1.B.4 • 10:00
Generation of Dual-Carrier QPSK Signals with Mixed Electronics-Optics Modulator
K Kikuchi[1], T Saida[1], H Nosaka[1], H Yamazaki[1], M Nagatani[1], T Goh[1], K Kurishima[1], K Murata[1]; [1]*NTT Photonics Labratories, NTT Corporation, Japan*
We devised a dual-carrier QPSK modulator that uses both analogue electrical and optical modulation, which simplifies the optical circuit configuration and reduces the power consumption of a transmitter. We demonstrated the generation of dual-carrier 14-Gbaud QPSK signals with the devised modulator.

We.1.B.5 • 10:15
High-Speed Direct-Modulation of InP Microdisk Lasers
J Hofrichter[1], O Raz[2], S Keyvaninia[3], T de Vries[2], H J S Dorren[2], T Morf[1], B J Offrein[1]; [1]*IBM Research - Zurich, Switzerland;* [2]*Eindhoven University of Technology, Netherlands;* [3]*Photonics Research Group, Gent University/IMEC, Belgium*
We demonstrate for the first time high-speed direct-modulation of InP microdisk lasers by exploiting longitudinal mode competition. High-speed operation is demonstrated by means of S21 and PRBS modulation. We show open eye diagrams and bit-error rates up to 10 Gb/s.

ROOM C

We.1.C.5 • 10:00
Seamless Spectral Defragmentation of Nyquist OTDM-WDM Signals in Add-Drop Node for All-Optical Elastic Network
H N Tan[1], K Tanizawa[1], T Inoue[1], T Kurosu[1], S Namiki[1]; [1]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*
We demonstrate a seamless frequency translation of Nyquist OTDM-WDM signals using a dual-stage polarization-diversity FWM-based wavelength converter for all-optical elastic network. A 172-Gbaud Nyquist OTDM signal is elastically frequency-shifted at an add-drop node and successfully transmitted over 80-km fiber link.

We.1.C.6 • 10:15
Precise Remote Optical Carrier Addition Into 200-Gb/s CO-OFDM Channel Using Fiber Frequency Conversion
T Kato[1], R Okabe[1], T Richter[2], R Elschner[2], C Schmidt-Langhorst[2], C Schubert[2], S Watanabe[1]; [1]*Fujitsu Labotratories Ltd., Japan;* [2]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany*
We propose a locally defined precise subcarrier addition into an orthogonal frequency-division multiplexed signal using fiber-frequency conversion. A 12.5-GBd QPSK-signal is added into an exact frequency grid to generate 200-Gb/s CO-OFDM at a free-running remote node without additional OSNR penalty.

10:30-11:00 COFFEE BREAK (ECOC Exhibition)

We.2.A
Nonlinearity in Fibres
Chair: Dag Hjelme, *HiST, Norway*

We.2.A.1 • 11:00 Invited
X3 Processes in High Numerical Optical Fibers and Fiber Tapers
T Lee[1], M I M Abdul Khudus[1], R Ismaeel[1], C A Codemard[2], N G R Broderick[3], G Brambilla[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK;* [2]*Advanced Laser Laboratory, SPI Labs, Optoelectronics Research Centre, University of Southampton, UK;* [3]*Dept. of Physics, University of Auckland, New Zealand*
Intermodally phase matched up- and down-conversion processes based on the third order nonlinearity can be used to efficiently generate UV and mid-IR wavelength regions in solid core silica optical fibers and optical fiber tapers

We.2.B
Modulators and Detectors
Chair: Joe Campbell, *University of Illinois, USA*

We.2.B.1 • 11:00 Invited
Monolithic Silicon Photonic Circuits Enable 112-Gb/s PDM-QPSK Transmission over 2560-km SSMF
P Dong[1], X Liu[1], S Chandrasekhar[1], L L Buhl[1], R Aroca[1], Y Baeyens[1], Y-K Chen[1]; [1]*Bell Labs, Alcatel-Lucent, USA*
Using silicon photonic integrated circuits (PICs), we demonstrate the generation, transmission over 2560-km standard single-mode fiber, and detection of 112-Gb/s polarization-division-multiplexed quadrature phase-shift keying signals. These silicon-based PICs promise compact, low-power-consumption, and low-cost coherent transceivers.

We.2.C
Coding & FEC
Chair: Werner Rosenkranz, *Universität Kiel, Germany*

We.2.C.1 • 11:00 Tutorial
Status and Recent Advances on Forward Error Correction Technologies for Lightwave Systems
A Leven[1], L Schmalen[1]; [1]*Bell Labs, Alcatel-Lucent, Germany*
Since the introduction of coherent transponders, forward error correction based on soft decision is now established in optical communication. In this tutorial, we give a descriptive introduction of one class of commonly used codes, namely LDPC codes. Also we discuss new developments, e.g. convolutional LDPC codes.

ROOM D

ROOM E

We.1.E.4 • 10:00
OpenFlow-Controlled Elastic Optical Networks with Direct-Detection Optical OFDM (DDO-OFDM) Transmission
L Liu[1], W-R Peng[2], R Casellas[3], T Tsuritani[2], I Morita[2], R Martínez[3], R Muñoz[3], S J Ben Yoo[1]; [1]*University of California, Davis, USA;* [2]*KDDI R&D Laboratories Inc., Japan;* [3]*Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Spain*
We design and deploy an extended OpenFlow-based control plane for elastic optical networks with DDO-OFDM transmission, detailing the network architecture, the two-phase routing and spectrum assignment algorithm, OpenFlow protocol extensions and the experimental validation.

We.1.E.5 • 10:15
Experimental Validation of an Elastic Low-Complex OFDM-Based BVT for Flexi-Grid Metro Networks
M S Moreolo[1], J M Fabrega[1], F J Vílchez[1], L Nadal[1], V López[2], G Junyent[1]; [1]*Centre Tecnològic de Telecomunicacions de Catalunya, Spain;* [2]*Telefonica I+D, Spain*
Cost-effective rate/bandwidth variable transponder (BVT) based on DSB DD-OFDM using low-complexity DSP is proposed for flexi-grid MAN. Elastic capabilities are experimentally evaluated, for transmitting 12.5GHz channels at variable rate between 5Gb/s and 10Gb/s along optical path from 45km to 195km.

ROOM F

We.1.F.4 • 10:00
Cost-effective Broadband GaAs IQ Modulator Array for Long-Reach OFDM-PONs
L Stampoulidis[1], E Giacoumidis[2], M F O'Keefe[3], I Aldaya[4], R G Walker[3], Y Zhou[3], N Cameron[3], E Kehayas[1], A Tsokanos[5], I Tomkos[6], N J Doran[2], L Zimmermann[7]; [1]*Constelex Technology Enablers Ltd, Greece;* [2]*Aston Institute of Photonic Technologies (AIPT), Aston University, UK;* [3]*u[2]t Photonics UK Ltd, UK; 4Tecnológico de Monterrey, Mexico;* [5]*Plymouth University, UK;* [6]*Athens Information Technology (AIT) Center, Greece;* [7]*IHP Microelectronics, Germany*
A novel modulator array integrating eight GaAs electro-optic IQ modulators is characterized and tested over long-reach direct-detected multi-band OFDM-PONs. The GaAs IQ modulators present > 22 GHz bandwidth with 3V Vpi, being suitable for a 100-km 40-Gb/s OOFDM-PON supporting up to 1024 users.

We.1.F.5 • 10:15
Amplified RSOA Self-Tuning Laser for WDM PON Using Saturated SOA for Noise Reduction and Data Cancellation
Q Deniel[1,2], F Saliou[1], S D Le[1], P Chanclou[1], D Erasme[2], R Brenot[3]; [1]*Orange Labs, France;* [2]*Telecom ParisTech, France;* [3]*III-V Labs, France*
We evaluated different km-long WDM PON laser sources based on amplified self-tuning solution. RIN reduction and data cancellation is demonstrated by using saturated SOA inside the cavity. The BER performance at 2.5Gb/s was enhanced with up to 50km cavity length.

10:30-11:00 COFFEE BREAK (ECOC Exhibition)

We.2.D
Space-Division Multiplexing I
Chair: Peter Krummrich, *Technische Universität Dortmund, Germany*

We.2.D.1 • 11:00
708-km Combined WDM/SDM Transmission over Few-Mode Fiber Supporting 12 Spatial and Polarization Modes
R Ryf[1], S Randel[1], N K Fontaine[1], X Palou[1,2], E Burrows[1], S Corteselli[1], S Chandrasekhar[1], A H Gnauck[1], C Xie[1], R-J Essiambre[1], P J Winzer[1], R Delbue[3], P Pupalaikis[3], A Sureka[3], Y Sun[4], L Grüner-Nielsen[5], R V Jensen[5], R Lingle Jnr[4]; [1]*Bell Laboratories, Alcatel-Lucent, USA;* [2]*Universitat Politecnica de Catalunya (ETSETB), Spain;* [3]*Teledyne LeCroy, USA;* [4]*OFS, USA;* [5]*OFS Fitel Denmark, Denmark*
We transmit 16 WDM channels using 20-Gbd QPSK over 12 spatial and polarization modes of 708-km few-mode fiber at a spectral-efficiency-distance product of 11328 km bit/s/Hz.The transmitted signals are recovered using off-line 12 x 12 multiple-input multiple-output digital signal processing.

We.2.E
Flex Grid Networks
Chair: Achim Autenrieth, *ADVA Optical Networking, Germany*

We.2.E.1 • 11:00 Invited
What is the Benefit of Elastic Superchannel for WDM Network?
T Zami[1]; [1]*Alcatel-Lucent, France*
We discuss the benefits and compromises of elastic spectral efficiency implemented with Nyquist superchannels for the WDM mesh networks featuring static or incremental traffic

We.2.F
High Availability Access
Chair: Dirk Breuer, *Deutsche Telekom AG, Germany*

We.2.F.1 • 11:00
Automatic Restoration over a Type B Dual Parented PON Using VLAN Switching
A Rafel[1], N Parkin[1], K Farrow[1], P Wright[1], D Nesset[1]; [1]*BT Research and Innovation, UK*
We propose an automated solution for end-to-end traffic restoration based on Ethernet OAM and VLAN switching over a type B dual parented PON. A prototype based on a commercial GPON is used to report results obtained in a lab configuration.

ROOM A

We.2.A.2 • 11:30
High-Peak-Power Femtosecond Pulse Generation using Graphene as Saturated Absorber and Dispersion Compensator
L Yi[1], Z Li[1], R Zheng[1], Z Ni[2], H Nan[2], Z Liang[3], R Ding[3], W Hu[1]; [1]*The State Key Lab of Advanced Optical Communication Systems and Networks, Shanghai Jiao Tong University, China;* [2]*Dept. of Physics, Southeast University, China;* [3]*Graphene Research and Characterize Center, Taizhou Sunano New Energy Corporation, China*
We demonstrate a passively mode-locked Erbium-doped fibre laser by using CVD fabricated graphene as both saturated absorber and dispersion compensator to achieve a 12-nJ energy pulse with 303-fs width, resulting in a 40-kW peak power, which is the highest value for graphene-based Erbium-doped passively mode-locked all-fibre laser.

We.2.A.3 • 11:45
Narrow Linewidth Brillouin Laser based on Chalcogenide Chip
I V Kabakova[1,2], R Pant[1,2], D-Y Choi[2,3], S Debbarma[2,3], S J Madden[2,3], B Luther-Davies[2,3], B J Eggleton[1,2]; [1]*Institute of Photonics and Optical Sciences (IPOS), School of Physics, University of Sydney, Australia;* [2]*Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Australia;* [3]*Laser Physics Centre, Australian National University, Australia*
We demonstrate a narrow-linewidth Brillouin laser based on chalcogenide photonic chip. We show that the laser linewidth is 15 times smaller compared to the pump. This is due to the optical feedback and acoustic damping of the pump noise.

We.2.A.4 • 12:00
Wavelength Conversion of Optical 64QAM and its Performance Optimization by Constellation Monitoring
G-W Lu[1], T Sakamoto[1], T Kawanishi[1]; [1]*NICT, Japan*
We experimentally demonstrate for the first time to our best knowledge, the wavelength conversion of 64QAM through four-wave mixing in highly-nonlinear fiber. In order to eliminate the extra nonlinear distortions such as SPM and SBS, it is suggested to optimize the operation condition by monitoring the constellations, rather than BER.

ROOM B

We.2.B.2 • 11:30
A Compact Silicon-on-Insulator Optical Hybrid for Low Loss Integration with Balanced Photodetectors
M S Hai[1], M N Sakib[1], O Liboiron-Ladouceur[1]; [1]*Dept. of Electrical and Computer Engineering, McGill University, Canada*
An optical hybrid design based on paired multimode interference couplers in silicon-on-insulator process is investigated. The device exhibits greater than 20 dB CMRR and low phase deviation (<10) over 30 nm in the C-band. The design eliminates the use of optical cross waveguides for integration with balanced photodetectors.

We.2.B.3 • 11:45
Compact 100Gb/s DP-QPSK Integrated Receiver Module Employing Three-dimensional Assembly Technology
H Tanobe[1], Y Kurata[1], Y Nakanishi[1], H Fukuyama[1], M Itoh[1], E Yoshida[1]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan*
We demonstrate a compact 100 Gbit/s DP-QPSK receiver module as small as 18 mm (W) x 16 mm (D) x 2.8 mm (H). The module size is reduced by using a ball grid array (BGA) package with three-dimensional assembly technology and applying a heterogeneous integrated PLC. Error-free DP-QPSK signal demodulation is successfully demonstrated.

We.2.B.4 • 12:00
25-Gbit/s Burst-mode Optical Receiver using High-speed Avalanche Photodiode for 100-Gbit/s Optical Packet Switching
M Nada[1], M Nakamura[2], H Matsuzaki[1]; [1]*NTT Photonics Laboratories, Japan;* [2]*Dept. of Electrical, Electronic and Computer Engineering, Gifu University, Japan*
25-Gbit/s error-free operation of an optical receiver is demonstrated against burst signal without preambles. The receiver with a high-sensitivity avalanche photodiode and burst-mode transimpedance amplifier successfully exhibits sufficient receiver sensitivity and a short rise time for burstmode operation in 100-Gbit/s optical packet switching.

ROOM C

We.2.C.2 • 12:00
Tomlinson-Harashima Precoding for Fiber-Optic Communication Systems
R Rath[1], W Rosenkranz[1]; [1]*Christian-Albrechts-Universität zu Kiel, Germany*
The performance of Tomlinson-Harashima precoding (THP) is investigated for a 12.5 GBaud 16QAM transmission. THP is shown to reduce significantly the computational load compared with linear equalization and to eliminate the error propagation phenomenon associated with decision-feedback equalization.

ROOM D

We.2.D.2 • 11:15
20 x 960 Gb/s MDM-DP-32QAM Transmission over 60km FMF with inline MM-EDFA
V A J M Sleiffer[1,5], P Leoni[2], Y Jung[3], J Surof[4], M Kuschnerov[5], V Veljanovski[5], D J Richardson[3], S U Alam[3], L Grüner-Nielsen[6], Y Sun[7], B Corbett[8], R Winfield[8], S Calabro[5], B Sommerkorn-Krombholz[5], H von Kirchbauer[5], H De Waardt[1]; [1]*COBRA institute, Eindhoven University of Technology, Netherlands;* [2]*Universität der Bundeswehr München, Germany;* [3]*Optoelectronics Research Centre, University of Southampton, UK;* [4]*Technische Universität München, Germany;* [5]*Nokia Siemens Networks Optical GmbH, Germany;* [6]*OFS, Denmark;* [7]*OFS, USA;* [8]*Tyndall National Institute, University College Cork, Ireland*
We show transmission of 20 wavelength-division-multiplexed (WDM) x 3 mode-division-multiplexed (MDM) x 320-Gb/s DP-32QAM modulated channels (spectral efficiency (SE) of 15 bits/s/Hz) over 60km of few-mode fiber (FMF) with inline multi-mode EDFA (MM-EDFA).

We.2.D.3 • 11:30 Invited
Multi-core Fiber Transmission Technologies for Peta b/s per Fiber Capacity
H Takara[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan*
Recent development on transmission technologies based on multi-core space-division-multiplexing is described, enabling well over Peta bit/s per fiber link capacity.

We.2.D.4 • 12:00
DWDM Transmission of 128Gb/s PM-16QAM Signal over 1815km of 7-core MCF Using Shared Carrier Reception for Improving the Received Signal Quality
E Le Taillandier de Gabory[1], M Arikawa[1], T Ito[1], K Fukuchi[1]; [1]*Green Platform Research Laboratories, NEC Corporation, Japan*
We demonstrate SCR method with 1815km transmission of 128Gb/s PM-16QAM over 7-core MCF using ECL. Frequency offset compensation of SCR enables demodulation and tolerates more than 10% path difference. Phase noise compensation of SCR enables to extend the transmitted distance, when using DFB, up to 1650km provided precise skew adjustment.

ROOM E

We.2.E.2 • 11:30
A Novel Semi-flexible Grid Optical Path Network That Utilizes Aligned Frequency Slot Arrangement
Z-S Shen[1], H Hasegawa[1], K-I Sato[1], T Tanaka[2], A Hirano[2]; [1]*Nagoya University, Japan;* [2]*NTT Network Innovation Laboratories, NTT Corporation, Japan*
We propose a novel elastic optical path network where each specific bitrate signal uses its own dedicated fixed grid and a slot-width-edge anchor frequency. Numerical evaluations verify that the proposed networks can almost match the performance of conventional flexible grid networks, while allowing tunable filters to be used in a fixed grid system.

We.2.E.3 • 11:45
Effect of Link Margin and Frequency Granularity on the Performance of a Flexgrid Optical Network
A Mitra[1], A Lord[2], S Kar[3], P Wright[2]; [1]*Dept. of Electrical Engineering, Indian Institute of Technology, India;* [2]*British Telecom Laboratories, British Telecom (BT), UK;* [3]*Dept. of Electrical Engineering and BSTM, Indian Institute of Technology, India*
We show how dynamically adjustable modulation formats can be used to reduce optical path operating margins in Flexgrid networks, reverting to lower order reduced OSNR QAM if ageing occurs. Spectral savings amount to as much as 63% across a network but due to use of 64QAM, a fine frequency granularity of 6.25GHz is required.

We.2.E.4 • 12:00
Simulation Results of Shannon Entropy based Flexgrid Routing and Spectrum Assignment on a Real Network Topology
P Wright[1], M C Parker[2], A Lord[1]; [1]*British Telecom, UK;* [2]*Lexden Technologies Ltd, UK*
We present a novel RSA algorithm that uses a quantitative fragmentation metric using the concept of Shannon entropy in Flexgrid networks. By applying this metric to a representative network, support for almost 10% more demands in a static growth scenario is shown.

ROOM F

We.2.F.2 • 11:15
Centralized Monitoring of True Splice Loss in PON Including MFD Mismatched Fibres
H Takahashi[1], K Toge[1], F Ito[1]; [1]*NTT Access Network Service System Laboratories, Japan*
We present a technique for the centralized monitoring of true splice loss in branched fibres, even when G.652 and G.657 fibres are combined, using end-reflection-assisted Brillouin-analysis. And we realize a splice loss accuracy of better than 0.1-dB in 8-branched PON.

We.2.F.3 • 11:30
Frequency-Code Multiplexed End Reflection Assisted Brillouin Analysis for Monitoring PONs
C Kito[1], F Ito[1], H Takahashi[1], K Toge[1]; [1]*NTT Access Networks Service Systems, Japan*
We use frequency-code multiplexing in dynamic range enhancement technique for end reflection assisted Brillouin analysis that can monitor PON branches individually. 12-frequency code multiplexing is used for monitoring 8-branched fibres, and signal to noise ratio is improved by 4.5 dB.

We.2.F.4 • 11:45
Simple ONU Transmitter Based on Direct-Phase Modulated DFB Laser with Heterodyne Detection for udWDM-PON
I N Cano[1], A Lerín[1], V Polo[1], J Tabares[1], J Prat[1]; [1]*Universitat Politecnica de Catalunya, Spain*
A direct phased modulated DFB laser with a simple equalizer is proposed for cost-effective ONU implementation in udWDM-PON. DBPSK data is successfully transmitted at 1.25Gb/s achieving a receiver sensitivity of -42dBm at a BER=10-3 with heterodyne detection while a penalty of less than 1dB is observed with 75km when compared with btb.

We.2.F.5 • 12:00
An Automatic Load-balancing DWBA Algorithm Considering Long-time Tuning Devices for λ-tunable WDM/TDM-PON
T Yoshida[1], S Kaneko[1], S Kimura[1], N Yoshimoto[1]; [1]*NTT Access Network Service Systems Laboratories, NTT Corporation, Japan*
We propose an automatic load-balancing DWBA algorithm for λ-tunable WDM/TDM-PONs. The algorithm is widely applicable despite the use of long-time tuning devices. We have confirmed with simulations that the proposed algorithm properly activates λ-tuning when the load-balancing is needed although the λ-tuning period is much longer than the DBA cycle.

ROOM A

ROOM B

We.2.B.5 • 12:15
A High-Power and High-Linearity Photodetector Module with 25 dBm RF Output Power at 10 GHz
E Rouvalis[1], Q Zhou[2], A Beling[2], A S Cross[2], A G Steffan[1], J C Campbell[2]; [1]*u²t Photonics AG, Germany;* [2]*University of Virginia, Dept. of ECE, USA*
We have developed a packaged photodetector module with an RF output power of almost 25 dBm at 10 GHz and more than 23 dBm at 15 GHz. To the best of our knowledge, these are the highest RF power levels ever reported from fully packaged 1.55 µm photodetectors without electrical amplification.

ROOM C

We.2.C.3 • 12:15
Hybrid Soft/Hard Decision Multilevel Coded Modulation for Beyond 100Gbps Optical Transmission
F Yu[1], D Chang[1], N Stojanovic[2], C Xie[2], M Li[1], L Jin[1], Z Xiao[1], X Shi[1], L Li[1]; [1]*Huawei Technologies Co., Ltd., Network Research Dept., China;* [2]*Huawei Technologies Duesseldorf GmbH, European Research Center, Germany*
We propose a hybrid soft/hard decision multilevel coded modulation scheme (HMLC) which improves the performance-complexity ratio compared with conventional single LDPC scheme. An iterative multi-stage decoding algorithm between LDPC and BCH codes is presented.

12:30-14:00 LUNCH

We.3.A
Phase Sensitive Signal Processing
Chair: Michele Midrio, *Università di Udine, Italy*

We.3.B
Modulators II
Chair: Marco Romagnoli, *CNIT, Italy*

We.3.C
Compensation for Nonlinear Effects
Chair: Ernesto Ciaramella, *Scuola Superiore Sant'Anna, Italy*

We.3.A.1 • 14:00
Mitigation of Nonlinear Impairments on QPSK Data in Phase-Sensitive Amplified Links
B Corcoran[1], S L I Olsson[1], C Lundström[1], M Karlsson[1], P A Andrekson[1]; [1]*Fiber Optic Communications Research Center (FORCE), Photonics Laboratory, Dept. Microtechnology and Nanoscience, Chlamers University of Technology, Sweden*
We investigate the mitigation of nonlinear impairments via phase-sensitive amplification. We show in simulation and experiment that this effect can be optimized through engineering link dispersion. A phase-sensitive amplified link is measured to reduce nonlinear penalties by over 3dB compared to a phase-insensitive amplified link.

We.3.B.1 • 14:00
Monolithically Integrated 10Gbit/sec Silicon Modulator with Driver in 0.25µm SiGe:C BiCMOS
L Zimmermann[1], D J Thomson[2], B Goll[3], D Knoll[1], S Lischke[1], F Y Gardes[2], Y Hu[2], G T Reed[2], H Zimmermann[3], H Porte[4]; [1]*IHP, Germany;* [2]*Optoelectronics Research Centre, University of Southampton, UK;* [3]*Vienna University of Technology, Austria;* [4]*PHOTLINE Technologies, France*
We present the first monolithic photonic integration in the electronic frontend of a high-performance BiCMOS technology. 10Gbit/sec operation of a Silicon Mach-Zehnder modulator device with 8dB extinction in dual-drive is demonstrated.

We.3.C.1 • 14:00
Efficient Transmitter-side Nonlinear Equalizer for 16QAM
T Oyama[1], H Nakashima[2], T Hoshida[2], Z Tao[3], C Ohshima[1], J C Rasmussen[2]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fujitsu Ltd, Japan;* [3]*Fujitsu R&D Center, China*
We propose and numerically evaluate a simplified pre-distortion algorithm to compensate intra-channel nonlinearity for 16QAM, which provides gate-count reduction through multiplier-free implementation. We confirm the tolerance to chromatic dispersion uncertainty and the applicability to different pulse formats.

We.3.A.2 • 14:15
QAM Phase-Regeneration in a Phase-Sensitive Fiber-Amplifier
T Richter[1], R Elschner[1], C Schubert[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany*
We demonstrate the use of a four-level phase-regenerator for QAM regeneration. The regenerator is based on a black-box fiber-based phase-sensitive amplifier. General conclusions are derived from investigations with 25-GBd star-8QAM.

We.3.B.2 • 14:15
20Gb/s Silicon Ring Modulator Co-Integrated with a Ge Monitor Photodetector
M Pantouvaki[1], P Verheyen[1], G Lepage[1], J De Coster[1], H Yu[2], P De Heyn[2], P Absil[1], J Van Campenhout[1]; [1]*Imec, Belgium;* [2]*Dept. of Information Technology, Ghent University, Belgium*
We demonstrate the monolithic integration of a 20Gb/s silicon ring modulator with low dark-current Ge monitor photodetectors. The wavelength exhibiting optimum modulation performance can be tracked by measuring the photocurrent of monitor photodetectors implemented at the through and drop port of the ring modulator.

We.3.C.2 • 14:15
Simple Optimization Method for Nonlinear Compensation by Filtered Backpropagation-based Equalization Utilizing Intra-stage Dispersion
W Maeda[1], D Ogasahara[1], J Abe[1], T Ito[1], M Arikawa[1], H Noguchi[1], K Fukuchi[1]; [1]*Green Platform Research Laboratories, NEC Corporation, Japan*
We propose a simple optimization method based on the relation between the filter configuration and the dispersion compensated at each stage in order to maximize filtered backpropagation performance. We validate our method with the transmission of 127-Gb/s PM-QPSK signal over all SMF 2400 km line in nonlinear regime.

ROOM D

We.2.D.5 • 12:15
Interleaved Core Assignment for Bidirectional Transmission in Multi-Core Fibers
F Ye[1], T Morioka[1]; [1]*DTU Fotonik, Dept. of Photonics Engineering, Technical University of Denmark, Denmark*
We study interleaved core assignment for bidirectional transmission in multi-core fibers. By combining it with heterogeneous core structure in an 18-core fiber, the transmission distance is extended by 10 times compared to homogeneous core structure with unidirectional transmission, achieving a total capacity of 1 Pb/s per direction.

ROOM E

We.2.E.5 • 12:15
Is Flexi-grid Needed Anymore with Spectrally Efficient Time Frequency Packing Terabit Superchannel Technology?
G Meloni[1], G Berrettini[2], F Fresi[2], R Magri[3], F Cavaliere[3], L Potì[1]; [1]*Photonic Networks National Laboratory, CNIT, Italy;* [2]*Scuola Superiore Sant'Anna, Italy;* [3]*Ericsson Telecomunicazioni S.p.A, Italy*
We demonstrate that frequency packing technology breathes new life into existing optical networks by allowing terabit super-channel transport against common opinion that expensive flex-grid infrastructure upgrade is required. 4.2 to 5.69 b/s/Hz spectral efficiency is obtained over ULH reach

ROOM F

12:30-14:00 LUNCH

We.3.D
Space Division Multiplexing II
Chair: Huug De Waardt, *COBRA - Eindhoven University of Technology, Netherlands*

We.3.E
Elastic Networks: Control Plane
Chair: Jean-Pierre Hamaide, *Alcatel-Lucent, France*

We.3.F
Coherent Access
Chair: Albert Rafel, *BT, UK*

We.3.D.1 • 14:00
Simultaneous Turbulence Compensation of Multiple Orbital-Angular-Momentum 100-Gbit/s Data Channels using a Gaussian Probe Beam for Wavefront Sensing
Y Ren[1], G Xie[1], H Huang[1], C Bao[1], Y Yan[1], N Ahmed[1], M P J Lavery[2], B Erkmen[3], S J Dolinar[3], M Tur[4], M Neifeld[5], M J Padgett[2], R Boyd[6], J H Shapiro[7], A E Willner[1]; [1]*Dept. of Electrical Engineering, University of Southern California, USA;* [2]*School of Physics and Astronomy, University of Glasgow, UK;* [3]*Jet Propulsion Laboratory, California Institute of Technology, USA;* [4]*School of Electrical Engineering, Tel Aviv University, Israel;* [5]*Dept. of Electrical and Computer Engineering, University of Arizona, USA;* [6]*Dept. of Physics and Astronomy, The Institute of Optics, University of Rochester, USA;* [7]*Research Laboratory of Electronics, Massachusetts Institute of Technology, USA*
The simultaneous compensation of OAM modes propagating through turbulent channel is experimentally demonstrated by using a Gaussian probe beam for wavefront sensing. The experiment results indicate that the turbulence-induced crosstalk and power penalty could be efficiently mitigated by ~12.5 dB and ~11 dB respectively.

We.3.E.1 • 14:00 Invited
Control Plane Solutions for Dynamic and Adaptive Flexi-grid Optical Networks
R Muñoz[1], R Casellas[1], R Martínez[1], R Vilalta[1]; [1]*CTTC, Spain*
We present an overview of control plane architectures for dynamic and adaptive provisioning and rerouting of elastic optical connections. First, distributed control plane architectures combining GMPLS with stateless and stateful PCEs are discussed. Next, we detail different deployment models of the PCE in the OpenFlow centralized control plane

We.3.F.1 • 14:00
Coherent Reflective PON Architecture: Can it be Made Compatible with TWDM-PON?
S Straullu[2], F Forghieri[3], G Bosco[1], V Ferrero[1], R Gaudino[1]; [1]*Istituto Superiore Mario Boella, Italy;* [2]*Politecnico di Torino, Italy;* [3]*CISCO Photonics, Italy*
We discuss the compatibility between reflective PON architectures and the recently defined TWDM-PON for NG-PON2. Focusing on the upstream, we experimentally demonstrate that, by using burst-mode coherent detection at OLT, reflective PON can achieve the specification target set for TWDM-PON, without requiring precise wavelength accuracy at ONU.

We.3.D.2 • 14:15
2.576Tb/s (23×2×56Gb/s) Mode Division Multiplexed 4PAM over 11.8 km Differential Mode Delay Uncompensated Few-Mode Fiber using Direct Detection
R G H van Uden[1], C M Okonkwo[1], H S Chen[1], F M Huijskens[1], B Corbett[2], R Winfield[2], H De Waardt[1], A M J Koonen[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands;* [2]*Tyndall National Institute, University College Cork, Ireland*
2.576Tb/s (23×2×56Gb/s) mode division multiplexed transmission over 11.8km differential mode delay uncompensated few-mode fiber is experimentally demonstrated using direct-detection and 28GBaud 4-level pulse amplitude modulation (4PAM). Assuming 27.5% (training sequence, framing, and error correcting) overhead, the net bit-rate is 1.87Tb/s.

We.3.F.2 • 14:15
System Demonstration of a Time and Wavelength-Set Division Multiplexing PON
D van Veen[1], W Pöhlmann[2], J Galaro[1], B Deppisch[2], A Duque[1], M F Lau[1], B Farah[1], T Pfeiffer[2], P Vetter[1]; [1]*Alcatel-Lucent, USA;* [2]*Alcatel-Lucent, Germany*
We present a full system implementation of TWSDM-PON based on a low cost tunable laser in the ONU and featuring automated wavelength initialization and tracking processes that are seamlessly added to the existing XGPON1 ONU activation protocol.

ROOM A

We.3.A.3 • 14:30
Demonstration of Degenerate Vector Phase-Sensitive Amplification
A L Riesgo[1], C Lundström[1], M Karlsson[1], P A Andrekson[1]; [1]*Photonics Laboratory, Dept. of Microtechnology and Nanoscience, Chalmers University of Technology, Sweden*
The performance of a degenerate vector (dual cross-polarized pump) phase-sensitive amplifier (PSA) is characterized and compared to a degenerate scalar (dual co-polarized pump) PSA. In both schemes, we assess the gain as a function of the signal state of polarization, verifying its compliance with theory, and the phase transfer function.

We.3.A.4 • 14:45
Digital Phase-Locked Loop-Stabilized Four-Mode Phase-Sensitive Parametric Multicasting
L Liu[1], Z Tong[1], A O J Wiberg[1], E Myslivets[1], B P Kuo[1], N Alic[1], S Radic[1]; [1]*University of California San Diego, USA*
Digital phase-locked loop was implemented for stabilization of dual-pump driven, four-mode phase-sensitive multicasting. A stable operation of more than 20-copy-count multicast with a 12-dB conversion efficiency improvement over the phase-insensitive case is demonstrated for the first time.

We.3.A.5 • 15:00
Low-penalty Phase De-multiplexing of QPSK Signal by Dual Pump Phase Sensitive Amplifiers
M Gao[1], T Kurosu[1], T Inoue[1], S Namiki[1]; [1]*National Institute of Advanced Industrial Science and Technology (ASTI), Network Photonics Research Centre, Japan*
We demonstrate phase de-multiplexing of QPSK signal to BPSK signals based on dual-pump phase sensitive amplifiers by controlling and stabilizing the gain axis. The de-multiplexed BPSK signals have an OSNR penalty less than 1-dB compared to the back-to-back BPSK signals.

We.3.A.6 • 15:15
All-optical Signal Processing for 16-QAM Using Four-Level Optical Phase Quantizers Based on Phase Sensitive Amplifiers
A Bogris[1], D Syvridis[2]; [1]*Dept. of Informatics, Technological Educational Institute of Athens, Greece;* [2]*Optical Communications Laboratory Dept. of Informatics and Telecommunications, University of Athens, Greece*
The potential of four-level optical phase quantizers towards coherent processing of advanced modulation formats such as 16-QAM is proposed and numerically demonstrated. The work shows that phase quantization can demultiplex 16-QAM into two QPSK signals enabling sub-channel switching and optical regeneration of 16-QAM modulation formats.

ROOM B

We.3.B.3 • 14:30 Invited
High-Speed Silicon-Organic Hybrid (SOH) Modulator with 1.6 fJ/bit and 180 pm/V In-Device Nonlinearity
R Palmer[1], S Koeber[1], W Heni[1], D L Elder[2], D Korn[1], H Yu[3], L Alloatti[1], S Koenig[1], P C Schindler[1], W Bogaerts[3], M Pantouvaki[4], G Lepege[4], P Verheyen[4], J Van Campenhout[4], P Absil[4], R Baets[3], L R Dalton[2], W Freude[1], J Leuthold[1,5], C Koos[1]; [1]*Karlsruhe Institute of Technology, Institutes IPQ and IMT, Germany;* [2]*University of Washington, Dept. of Chemistry, USA;* [3]*IMEC Photonics Research Group, Ghent University, Belgium;* [4]*IMEC vzw., Belgium;* [5]*Electromagnetic Fields & Microwave Electronics Laboratory, ETH-Zurich, Switzerland*
We report on a 40Gbit/s silicon-organic hybrid (SOH) modulator with 11dB extinction ratio. A novel electro-optic chromophore with record in-device nonlinearity of 180pm/V leads to $V_\pi L$=0.5Vmm and a low energy consumption of 1.6fJ/bit at 12.5Gbit/s.

We.3.B.4 • 15:00 Invited
High-speed Silicon Modulators
T Chu[1], X Xiao[1], H Xu[1], X Li[1], Z Li[1], J Yu[1], Y Yu[1]; [1]*Key Laboratory of Integrated Optoelectronics, Institute of Semiconductors, Chinese Academy of Sciences, China*
Several high-speed silicon modulators are demonstrated, including a 60-Gbps MZI modulator with 1.6-dB optical loss, a 25-Gbps microring modulator with misalignment-tolerant interleaved PN junctions, a 60-Gbps microring resonator modulator and a 4x50 Gbps WDM modulator.

ROOM C

We.3.C.3 • 14:30
Novel Polarization-diversity Scheme Based on Mutual Phase Conjugation for Fiber-nonlinearity Mitigation in Ultra-long Coherent Optical Transmission Systems
H Lu[1], Y Mori[1,2], C Han[1,3], K Kikuchi[1]; [1]*Dept. of Electrical Engineering and Information Systems, The University of Tokyo, Japan;* [2]*Nagoya University, Japan;* [3]*Electronics and Telecommunications Research Institute (ETRI), Republic of Korea*
We propose a novel method of fiber-nonlinearity mitigation for ultra-long optical transmission systems, which employs two polarization modes mutually phase-conjugated. Simulations and experiments show that in the nonlinear region, this diversity method significantly outperforms both of the single- and dual-polarization schemes at the same bit rate.

We.3.C.4 • 14:45
Extending Digital Backpropagation to Account for Noise
N V Irukulapati[1], H Wymeersch[1], P Johannisson[2], E Agrell[1]; [1]*Dept. of Signals and Systems, Chalmers University of Technology, Sweden;* [2]*Dept. of Microtechnology and Nanoscience, Chalmers University of Technology, Sweden*
We propose a maximum a posteriori-based scheme that extends digital backpropagation (DBP) by accounting for the nonlinear signal-noise interaction. With periodic dispersion compensation we find up to 20% reach improvement over DBP. For uncompensated links DBP is close to optimal.

We.3.C.5 • 15:00
Coherent Intradyne Opto-Electro-Optic Spectral Inverter and its Application for SPM Mitigation and Wavelength Conversion
A Klekamp[1], F Buchali[1]; [1]*Alcatel-Lucent, Bell Labs, Germany*
We report on a new joint coherent intradyne o/e/o spectral inverter and wavelength converter applied for midspan spectral inversion (MSI). MSI leads to an increase in nonlinear threshold for 16QAM 200 Gb/s signals of 2.4 and 1.6 dB in single channel and DWDM experiment, respectively, and is used to double the transmission distance.

We.3.C.6 • 15:15
Simplified Volterra Series Nonlinear Equalizer by Intra-Channel Cross-Phase Modulation Oriented Pruning
F P Guiomar[1], S B Amado[1], N J Muga[1], J D Reis[1], A L Teixeira[1,2], A N Pinto[1]; [1]*Dept. of Electronics, Telecommunications and Informatics, University of Aveiro, Instituto de Telecomunicações, Portugal;* [2]*Nokia Siemens Networks Portugal S.A., ON WSM, Portugal*
We propose a simplified Volterra series nonlinear equalizer (VSNE) based on a pruned symmetric reconstruction of the third-order kernel. In a 224 Gb/s PM-16QAM transmission system with 1600 km, the number of complex multiplications has been reduced by 3 orders of magnitude relatively to the full VSNE, at the expense of 1.3 dB performance penalty.

ROOM D

We.3.D.3 • 14:30 Invited
Nonlinear Equations of Propagation in Multi-Mode Fibers with Random Mode Coupling
A Mecozzi[1], C Antonelli[1], M Shtaif[2]; [1]*University of L'Aquila, Italy;* [2]*Tel Aviv University, Israel*
We review the fundamental equations describing nonlinear propagation in multi-mode fibers in the presence of random mode coupling within quasi-degenerate groups of strongly coupled modes. Our results generalize to the multi-mode propagation regime the Manakov equation describing mode coupling between polarizations in single-mode fibers.

We.3.D.4 • 15:00
Splice Induced Nonlinear Performance Penalty in Mode-Division Multiplexed Transmission Systems
G Rademacher[1], S Warm[1], K Petermann[1]; [1]*Technische Universität Berlin, FB Hochfrequenztechnik, Germany*
We investigate mode-division multiplexed transmission systems that employ several spans of few-mode fibers regarding the influence of splice-induced mode coupling on the transmission performance. We show that the combination of nonlinearities splice-induced coupling leads to a strongly impaired transmission performance.

ROOM E

We.3.E.2 • 14:30
Software-Defined Fragmentation-Aware Elastic Optical Networks Enabled by OpenFlow
L Liu[1], Y Yin[1], M Xia[2], M Shirazipour[3], Z Zhu[4], R Proietti[1], Q Xu[3], S Dahlfort[2], S J Ben Yoo[1]; [1]*University of California, Davis, USA;* [2]*Ericsson Research Silicon Valley, USA;* [3]*Ericsson Research, Canada;* [4]*University of Science and Technology of China, China*
We present a software-defined fragmentation-aware elastic optical network, in which an extended OpenFlow-based control plane intelligently routes connection requests to avoid spectrum fragmentation. The overall feasibility and efficiency of the proposed scenario is validated by using both numerical simulation and experimental demonstration.

We.3.E.3 • 14:45
Experimental Evaluation of Delay-Sensitive Traffic Routing in Multi-Layer (Packet-Optical) Aggregation Networks for Fixed Mobile Convergence
R Martínez[1], R Casellas[1], R Muñoz[1], R Vilalta[1]; [1]*CTTC, Spain*
An experimental evaluation of delay-sensitive traffic routing within GMPLS multi-layer (MPLS-TP/WSON) aggregation networks for fixed mobile convergence is presented. We compare the performance of two novel routing algorithms designed to fulfill both the delay and bandwidth service requirements while exploiting the multi-layer (grooming) objectives.

We.3.E.4 • 15:00
Optical Control Plane Based on an Analytical Model of Non-Linear Transmission Effects in a Self-Optimized Network
R Pastorelli[1], S Piciaccia[1], G Galimberti[1], E Self[1], M Brunella[1], G Calabretta[1], F Forghieri[1], D Siracusa[2], A Zanardi[2], E Salvadori[2], G Bosco[3], A Carena[3], V Curri[3], P Poggiolini[3]; [1]*Cisco Photonics Italy srl, Italy;* [2]*CREATE-NET, Italy;* [3]*Dip di Electronica e Telecomunicazioni, Politecnico di Torino, Italy*
In pure coherent networks, the real time application of a recently proposed analytical non-linear model allows network performance optimization. Control Plane circuit restoration based on this approach intrinsically avoids crank-back processes. An experiment demonstrates the optimum routing process in a self-configured network.

We.3.E.5 • 15:15
Evaluation of Strategies for Dynamic Routing Algorithms in Support of Flex-Grid based GMPLS Elastic Optical Networks
I Turus[1,2], J Kleist[1], A Manolova Fagertun[2], L Dittmann[2]; [1]*NORDUnet A/S, Denmark;* [2]*Dept. of Photonics Engineering, Technical University of Denmark, Denmark*
We evaluate OSPF-TE extensions within GMPLS framework in support of flex-grid optical networks. Based on OSPF-TE LSAs, two routing strategies are proposed achieving up to 15% and 70% respectively improved blocking ratio for low loaded network (10-30 Erlangs) compared to the shortest path scenario.

ROOM F

We.3.F.3 • 14:30
A Novel Flexible Optical Remote Node Architecture for Dynamic Wavelength Allocation over Hybrid WDM/TDM PON Systems
M-F Huang[1], D Qian[1], N Cvijetic[1], P N Ji[1], T Wang[1]; [1]*NEC Laboratories America, USA*
We demonstrate a flexible optical remote node architecture enabled dynamic wavelength allocation for converged optical access and mobile backhaul applications. Source-free and colorless ONUs have been realized in a bidirectional long-reach 80km hybrid WDM/TDM PON with a 1:32 passive split.

We.3.F.4 • 14:45
Coherent SCM-WDM-PON System using OFDM or Single Carrier with SSB Modulation and Wavelength Reuse
C Kottke[1], J von Hoyningen-Huene[2], M Eiselt[3], H Grießer[3], J P Elbers[3], K Habel[1], W Rosenkranz[2]; [1]*Heinrich-Hertz Institute, Fraunhofer Institute for Telecommunications, Germany;* [2]*Chair for Communications, University of Kiel, Germany;* [3]*ADVA Optical Networking SE, Germany*
We propose a SCM-WDM-PON system, suitable for up to 320 users at 1 Gb/s, using SSB modulation and wavelength reuse for colorless ONUs. The experimental results demonstrate the feasibility of this concept, showing increased spectral efficiency at cost of a small penalty for the OFDM case as compared to single carrier DQPSK modulation.

We.3.F.5 • 15:00
A 1.25 Gb/s Low-Cost Coherent PON
M Presi[1], G Cossu[1], R Corsini[1], F Bottoni[1], E Ciaramella[1]; [1]*Instituto TeCIP Scuola Superiore Sant'Anna, Italy*
We demonstrate a 1.25 Gb/s long reach PON (66 km+1:128 split) based on a simplified phase-diversity homodyne coherent receiver, which uses a common DFB as local oscillator, has simple processing and needs no frequency locking. -48 dBm sensitivity and good channel selectivity (6.25 GHz) are achieved.

We.3.F.6 • 15:15
Flexible TWDM PON with Load Balancing and Power Saving
N Cheng[1], L Wang[2], D Liu[2], B Gao[2], J Gao[2], X Zhou[2], H Lin[2], F Effenberger[1]; [1]*American Research Centre, Huawei Technologies, USA;* [2]*Advanced Technology Dept., Huawei Technologies, China*
A flexible TWDM PON system is proposed which allows pay-as-you-grow deployment of OLT transceiver modules, supports load balancing among different ODNs and achieves significant power saving at OLT. A proof-of-concept experimental testbed confirms the feasibility of the proposed system with 40Gb/s symmetric capacity and more than 38 dB power budget.

ROOM A **ROOM B** **ROOM C**

15:30-16:00 COFFEE BREAK (ECOC Exhibition)

We.4.A
Fibre Amplifiers for SDM
Chair: Tommy Geisler, *OFS Denmark*

We.4.A.1 • 16:00 Invited
Multicore Erbium Doped Fiber Amplifiers for Space Division Multiplexed System
K Abedin[1], T Thierry[1], J Fini[1], M Yan[1], B Zhu[1], E Monberg[1], F Dimarcello[1], V R Supradeepa[1], D DiGiovanni[1]; [1]*OFS Laboratories, USA*
We report on recent development of core- and cladding-pumped multicore fiber amplifiers suitable for amplifying space division multiplexed signals. Amplification, noise properties of these amplifiers are shown, and scopes for further development will be discussed

We.4.A.2 • 16:30
Few-mode EDFA Supporting 5 Spatial Modes with Reconfigurable Differential Modal Gain Control
Y Jung[1], Q Kang[1], J K Sahu[1], B Corbett[2], R Winfield[2], F Poletti[1], S U Alam[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK;* [2]*Tyndall National Institute, University of College Cork, Ireland*
We experimentally demonstrate a FM-EDFA supporting 5 spatial modes with reconfigurable differential gain control and excellent gain-flatness obtained through mode-selective bi-directional pumping of a custom fiber with a radially-profiled erbium dopant distribution.

We.4.B
Devices for Switching
Chair: Bert Offrein, *IBM Research GmbH, Switzerland*

We.4.B.1 • 16:00
An 8×8 Broadcast-and-Select Optical Switch Based on Monolithically Integrated EAM-Gate Array
T Segawa[1], M Nada[1], M Nakamura[1,2], Y Suzaki[1], R Takahashi[1]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan;* [2]*Dept. of Electrical, Electronic and Computer Engineering, Gifu University, Japan*
A compact, low-power 8×8 broadcast-and-select optical switch is developed based on a high-speed EAM-gate array supporting a wide flat wavelength band. The switch is free from optical/electrical crosstalk and undesirable nonlinear effects observed in SOA-based switches. Error-free switching is demonstrated for 25-Gbps burst-mode optical packets.

We.4.B.2 • 16:15
Dynamic Multi-Path WDM Routing in a Monolithically Integrated 8x8 Cross-Connect
R Stabile[1], A Rohit[1], K A Williams[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
We demonstrate for the first time WDM multi-path routing through a monolithically integrated 8x8 cross-connect. Sixteen WDM data channels are dynamically routed from four inputs with excellent OSNR of 27.0-31.1 dB and nanosecond switch time.

We.4.B.3 • 16:30
Silica-Based 100-GHz-Spacing Integrated 40-λ 1×4 Wavelength Selective Switch
T Yoshida[1], H Asakura[1], T Mizuno[2], H Takahashi[2], H Tsuda[1]; [1]*Graduate School of Science and Technology, Keio University, Japan;* [2]*NTT Photonics Laboratories, NTT Corporation, Japan*
A densely integrated 1×4 wavelength selective switch (WSS) is designed and fabricated. The channel spacing is 100 GHz and the number of channels is 40. The transmission losses and the crosstalk are less than 8.8 dB and -19.4 dB, respectively.

We.4.C
Transmitter Subsystems II
Chair: Johan Bauwelinck, *Ghent University, Belgium*

We.4.C.1 • 16:00
5.3 GHz Modulation Passband for Fiber Lengths Up to 100 km Using a Directly Modulated Passive Feedback Laser
A S Karar[1], M A Rezania[1], N Deb[1], J C Cartledge[1]; [1]*Dept. of Electrical and Computer Engineering, Queen's University, Canada*
The chirp and bandwidth tuneability of a passive feedback laser are used to obtain a modulation passband that is void of power fading dips and allows the transmission of 21.418 Gbit/s and 10.709 Gbit/s SCM signals over 61 km and 102 km of SMF, respectively.

We.4.C.2 • 16:15
Single-channel 1.28 Tbit/s Transmission over 58 km in the 1.1 μm Band with Wideband GVD and Dispersion Slope Compensation
K Koizumi[1], T Hirooka[1], M Yoshida[1], M Nakazawa[1]; [1]*Research Institute of Electrical Communication, Tohoku University, Japan*
We demonstrate a single-channel 1.28 Tbit/s subpicosecond pulse transmission at 1.1 μm using a high-Δ single-mode step index fiber and ytterbium-doped fiber amplifiers. With a chirped fiber Bragg grating and pre-chirping technique for wideband GVD and dispersion slope compensation, 58 km transmission was successfully achieved.

We.4.C.3 • 16:30 Invited
100 Gbit/s Using Intensity Modulation and Direct Detection
J C Cartledge[1], A S Karar[1]; [1]*Dept. of Electrical and Computer Engineering, Queen's University, Canada*
Recent advances in short reach 100 Gbit/s intensity modulation and directed detection systems are reviewed with a focus on 16-QAM half-cycle Nyquist subcarrier modulation, generated using a directly modulated passive feedback laser and polarization multiplexing emulation.

ROOM D **ROOM E** **ROOM F**

15:30-16:00 COFFEE BREAK (ECOC Exhibition)

We.4.D
Nonlinear Fibre Capacity
Chair: Rene-Jean Essiambre, *Alcatel-Lucent, USA*

We.4.D.1 • 16:00
Reach Comparison of Next Generation Optical Fibers with EDFA/Raman Amplification
K Balemarthy[1], R Lingle Jnr[2]; [1]*OFS, India;* [2]*OFS, USA*
Using the Gaussian Noise model for nonlinearities, we show that larger effective area fibers are more beneficial compared to lower loss fibers with EDFA/Raman amplification even with realistic pump power and EDFA output power limits.

We.4.D.2 • 16:15
Nonlinearity Compensation Benefit in High Capacity Ultra-Long Haul Transmission Systems
J-X Cai[1], O V Sinkin[1], H Zhang[1], H G Batshon[1], M Mazurczyk[1], D G Foursa[1], A Pilipetskii[1], G Mohs[1]; [1]*TE SubCom, USA*
We experimentally investigate digital back propagation (DBP) benefit versus channel pre-emphasis, average launch power per channel, and transmission distance. We find the DBP benefit scales monotonically with channel power and transmission distance. Measurement results match well with theory.

We.4.D.3 • 16:30 Invited
Nonlinear Fiber Capacity
E Agrell[1]; [1] *Dept. of Signals and Systems, Chalmers University of Technology, Sweden*
In this semi-tutorial presentation, we review fundamental information theory for links with and without memory, in the linear and nonlinear regimes. A comparison between channel models with long (but finite) memory and infinite memory yields an unexpected result.

We.4.E
Control Plane & PCE
Chair: Suzuki Masatoshi, *KDDI Labs, Japan*

We.4.E.1 • 16:00
Experimental Demonstration of an Active Stateful PCE Performing Elastic Operations and Hitless Defragmentation
A Castro[1], F Paolucci[2], F Fresi[2], M Imran[2], B Brata Bhowmik[3], G Berrettini[2], G Meloni[4], A Giorgetti[2], F Cugini[4], L Velasco[1], L Potì[4], P Castoldi[2]; [1]*Universitat Politècnica de Catalunya, Spain;* [2]*TeCIP, Scuola Superiore Sant'Anna, Italy;* [3]*Electrical Engineering Department, Indian Institute of Technology, India;* [4]*CNIT, Italy*
An experimental demonstration of active stateful PCE for flexgrid networks is presented. The PCE enables elastic operations on established connections and, when required, performs hitless defragmentation of spectrum resources. Experimental assessment, including shifting of 400Gbps four sub-carrier superchannel is shown.

We.4.E.2 • 16:15
Minimization of the Impact of the TED Inaccuracy Problem in PCE-Based Networks by Means of Cognition
I Rodríguez[1], R J Durán Barroso[1], D Siracusa[2], I de Miguel[1], A Francescon[2], J C Aguado[1], E Salvadori[2], R M Lorenzo[1]; [1]*Universidad de Valladolid, Spain;* [2]*CREATE-NET, Italy*
We propose and demonstrate the benefits of a simple yet effective cognitive technique to enhance stateless Path Computation Element (PCE) algorithms with the aim of reducing the connection blocking probability when relying on a potentially non up-to-date Traffic Engineering Database (TED).

We.4.E.3 • 16:30
Experimental Demonstration of H-PCE with BPG-LS in Elastic Optical Networks
M Cuaresma[1], F Muñoz del Nuevo[1], S Martinez[1], A Mayoral[1], O Gonzalez de Dios[1], V Lopez[1], J P Fernandez-Palacios[1]; [1]*Core Network Evolution, Global CTO, Telefonica I+D ACTO, Spain*
In the H-PCE architecture the mechanism to build the Traffic Engineering Database of the Parent PCE is not defined. This work validates the use of BGP-LS to feed the TED and compares two algorithms that use different amount of information.

We.4.F
Field Trials and Experiments
Chair: Camille-Sophie Bres, *EPFL, Switzerland*

We.4.F.1 • 16:00
On-the-Field Demonstration of Quintuple-Play Service Provision in Long-Reach OFDM-based WDM-PON Access Networks
R Llorente[1], M Morant[1], E Pellicer[1], M Herman[2], Z Nagy[2], T Alves[3], A Cartaxo[3], J Herrera[4], J Correcher[5], T Quinlan[6], S Walker[6], C E Rodrigues[7], P Cluzeaud[8], A Schmidt[9], R Piesiewicz[10], R Sambaraju[11]; [1]*Nanophotonics Technology Centre, Universitat Politècnica de València, Spain;* [2]*Towercom a.s., Slovakia;* [3]*Instituto de Telecomunicações, Instituto Superior Técnico, Portugal;* [4]*Fibernova Systems S.L., Spain;* [5]*DAS Photonics S.L., Spain;* [6]*School of Computer Science and Electronic Engineering, University of Essex, UK;* [7]*PT Inovaçao, Portugal;* [8]*THALES Communications, France;* [9]*Hochschule für Technik und Wirtschaft Dresden, Germany;* [10]*Wroclawskie Centrum Badan EIT+ sp., Poland;* [11]*CORNING Incorporated, USA*
A multi-user 4-wavelength OFDM WDM-PON providing quintuple-play services is demonstrated on-the-field in a long reach FTTH network in Bratislava (Towercom, Slovakia) achieving 60.8km. An OFDM signal bundle is transmitted in coexistence (LTE, WiMAX, UWB, DVB T and ad hoc OFDM GbE) providing 1.45Gbit/s per user.

We.4.F.2 • 16:15
Demonstration of SOA-assisted Open Metro-Access Infrastructure for Heterogeneous Services
H Schmuck[1], R Bonk[1], W Poehlmann[1], C Haslach[1], W Kuebart[1], D Karnick[2], J Meyer[2], D Fritzsche[3], E Weis[3], J Becker[2], W Freude[2], T Pfeiffer[1]; [1]*Alcatel-Lucent AG, Bell Labs, Germany;* [2]*Karlsruhe Institute of Technology, Germany;* [3]*Deutsche Telekom AG, Germany*
Simultaneous operation of multiple services showing different modulation formats, multiplexing techniques and bitrates is experimentally demonstrated in an open converged metro-access infrastructure. Signal performance impact of SOA-induced penalties is studied along the chain.

We.4.F.3 • 16:30 Invited
Photonic-assisted RF Transceiver
A Bogoni[1], P Ghelfi[1], F Laghezza[1], F Scotti[1], G Serafino[2], S Pinna[2]; [1]*CNIT, Italy;* [2]*Scuola Superiore Sant'Anna, Italy*
The concept of photonics-assisted RF transceiver will be detailed. It provides extremely stable multiprotocol signals up to the millimeter waveband, and it optically samples directly at RF multiple heterogeneous RF signals, with increased resolution.

ROOM A

We.4.A.3 • 16:45
Few Mode Er^{3+}-Doped Fiber with Microstructured Core Enabling Spectral and Modal Gain Equalization for Spatial Division Multiplexing
G Le Cocq[1], L Bigot[1], A Le Rouge[1], G Bouwmans[1], H El Hamzaoui[1], K Delplace[1], M Bouazaoui[1], Y Quiquempois[1]; [1]*PhLAM/IRCICA Université de Lille[1], France*
Simulations and experimental results on Er3+-doped fibers that amplify 6 modes over the C-band are reported. It is shown that complex Er3+-doping profile can hardly be achieved by MCVD process and that microstructuring the core could be an alternative to tailor the Er3+ doping profile. As a proof of concept, such a fiber is modeled and realized.

We.4.A.4 • 17:00
12-Core Double-Clad Er/Yb-Doped Fiber Amplifier Employing Free-space Coupling Pump/Signal Combiner Module
H Ono[1], K Takenaga[2], K Ichii[2], S Matsuo[2], T Takahashi[1], H Masuda[3], M Yamada[4]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan;* [2]*Optics and Electronics Laboratory, Fujikura Ltd., Japan;* [3]*Interdisciplinary Faculty of Sci. and Eng., Shimane University, Japan;* [4]*Graduate School of Engineering, Osaka Prefecture University, Japan*
We demonstrate the simultaneous 12-core amplification of a double-clad Er/Yb-doped fiber amplifier by using newly developed free-space coupling pump/signal combiner modules equipped with multi-core fiber pigtails. C-band amplification is successfully achieved using a 5-m long double-clad Er/Yb-doped fiber.

We.4.A.5 • 17:15
Cladding-Pumped Seven-Core EDFA Using a Multimode Pump Light Coupler
S Takasaka[1], H Matsuura[2], W Kumagai[2], M Tadakuma[1], Y Mimura[1], Y Tsuchida[1], K Maeda[1], R Miyabe[1], K Aiso[1], K Doi[2], R Sugizaki[1]; [1]*FITEL Photonics Lab., Furukawa Electric Co., Ltd., Japan;* [2]*Dept. of Mechanical Engineering, Tohoku Gakuin University, Japan*
We demonstrate a cladding-pumped seven-core erbium-doped fibre amplifier. A developed multimode pump light coupler enables the cladding pump. We measure amplification characteristics of all the seven cores and obtain gain of >14dB, noise figure of <9dB in C-band. Total crosstalk for the centre core is -32.7 dB.

ROOM B

We.4.B.4 • 16:45
Dynamic Multi-Path Routing in a Fifth-Order Resonant Switch Matrix
P Dasmahapatra[1], R Stabile[1], A Rohit[1], K A Williams[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
Dynamic multi-path routing is studied for the first time in a cross-point switch matrix comprising fifth order resonant switch elements. Connections are made between eight inputs and two outputs with on-chip losses of up to 9.5dB and 35μs guard times between the configured paths.

We.4.B.5 • 17:00
Polarization Diversity 2×2 Switch with Silicon-Wire Waveguide
S H Kim[1], Y Shoji[1], G Cong[1], H Kawashima[1], T Hasama[1], H Ishikawa[1]; [1]*National Institute of Advanced Industrial Science and Technology, Japan*
A polarization independent 2×2 switch based on silicon wire waveguide was fabricated. We built a diversity circuit consists of polarization splitters/combiners, TE-TM intersections, and TE- and TM-switches. Polarization-independent operation was demonstrated. Extinction ratio achieved 30 dB at wavelength of 1550 nm.

We.4.B.6 • 17:15
Fiber-Port-Count in Wavelength Selective Switches for Space-Division Multiplexing
N K Fontaine[1], R Ryf[1], D T Neilson[1]; [1]*Bell Labs/Alcatel-Lucent, USA*
We show that the fiber count of a space-division multiplexed (SDM) wavelength selective switch can match an equivalent single-mode WSS using a mode-remapper at the switch input and a proportional increase in spectral-resolution. Otherwise, the fiber count decreases proportional to the number of modes in the steering dimension.

ROOM C

We.4.C.4 • 17:00
Pulse-Carver-Free RZ-64 QAM Transmitter with Electronic CD Pre-Compensation and Auto Bias Control
H Kawakami[1], T Kobayashi[1], K Yonenaga[1], Y Miyamoto[1]; [1]*NTT Network Innovation Laboratories, NTT Corporation, Japan*
We propose a simple optical return to zero quadrature amplitude modulation (RZ-QAM) transmitter with Auto Bias Control (ABC) circuit. This transmitter is pulse carver free and offers electronic pre-compensation for chromatic dispersion (CD). Measured penalty induced by ABC was less than 0.2 dB, with and without CD pre-compensation.

19:30 GALA DINNER, Painted Hall, Old Royal Naval College, Greenwich

ROOM D

We.4.D.4 • 17:00
System Benefits of Digital Dispersion Pre-Compensation for Non-Dispersion-Managed PDM-WDM Transmission
A Ghazisaeidi[1], J Renaudier[1], M Salsi[1], P Tran[1], G Charlet[1], S Bigo[1]; [1]*Alcatel-Lucent Bell Labs, France*
We studied the system benefits of applying dispersion pre-compensation using programmable DAC, on the performance of 32.5 Gbaud root-raised-cosine pulse-shaped PDM-WDM BPSK, QPSK, and 16QAM. With 50% dispersion pre-compensation, for BPSK 1.5 dB improvemement of optimum Q2-factor is observed while for QPSK and 16QAM no improvement was observed.

We.4.D.5 • 17:15
Experimental Demonstration of Capacity-Achieving Phase-Shifted Superposition Modulation
J Estaran[1], D Zibar[1], A Caballero[1], C Peucheret[1], I T Monroy[1]; [1]*DTU Fotonik, Technical University of Denmark, Denmark*
We report on the first experimental demonstration of phase-shifted superposition modulation (PSM) for optical links. Successful demodulation and decoding is obtained after 240 km transmission for 16-, 32- and 64-PSM.

ROOM E

We.4.E.4 • 16:45
Resilient Provisioning for Multi-Flow Elastic Optical Networking
M Xia[1], S Dahlfort[1]; [1]*Ericsson Research, USA*
We propose a resilient provisioning scheme for multi-flow elastic optical networking by exploiting elastic traffic assignment and path diversity. Our scheme requires no link-disjoint routing, and significantly reduces resource overbuild from Virtual Concatenation in two sample core networks.

We.4.E.5 • 17:00
Data Center Interconnection Orchestration with Virtual GMPLS-controlled MPLS-TP Networks over a Shared Wavelength Switched Optical Network
R Vilalta[1], R Muñoz[1], R Casellas[1], R Martínez[1]; [1]*Optical Networks and Systems, CTTC, Spain*
We present an Orchestrator architecture to dynamically configure and deploy virtual GMPLS-controlled MPLS-TP networks for data center interconnection over a shared WSON. We evaluate its performance in the ADRENALINE Testbed, in terms of the service setup delay.

We.4.E.6 • 17:15
Emergent Optical Network Integration and Control of Multi-Vendor Optical Networks for Quick Disaster Recovery
S Xu[1], N Yoshikane[2], M Shiraiwa[1], H Furukawa[1], T Tsuritani[2], Y Awaji[1], N Wada[1]; [1]*Photonic Network Research Institute, National Institute of Information and Communications Technology (NICT), Japan;* [2]*KDDI R&D Laboratories Inc., Japan*
For quick and cost-efficient recovery of backbone network from huge disasters, the emergent optical network integration with the survived multi-vendor optical systems are investigated. Both the data-plane and the control-plane are successfully demonstrated in a two-vendor prototype test-bed.

ROOM F

We.4.F.4 • 17:00
Frequency-Reconfigurable Optical-to-Radio Signal Converter Based on Radio-over-Fiber Technology with Optical Frequency Comb
A Kanno[1], T Kuri[1], I Morohashi[1], I Hosako[1], T Kawanishi[1], Y Yoshida[2], K Kitayama[2]; [1]*NICT, Japan;* [2]*Osaka University, Japan*
A frequency-reconfigurable radio-over-fiber (RoF) signal convertor based on an optical frequency comb is proposed for application to a millimeter-wave/terahertz/optical hybrid system. The frequency transition from the RoF signal at 83 GHz to the higher millimeter-wave and terahertz signals is successfully demonstrated.

We.4.F.5 • 17:15
First Demonstration of Energy Efficient IM-DD OFDM-PON using Dynamic SNR Management and Adaptive Modulation
H Kimura[1], K Asaka[1], H Nakamura[1], S Kimura[1], N Yoshimoto[1]; [1]*NTT Access Network Service System Laboratories, NTT Corporation, Japan*
This paper describes the first demonstration of an energy efficient OFDM-PON using the dynamic SNR management. The controlling calculation precision and modulation format optimizes the DSP energy consumption while satisfying the BER requirements. We realize a 58.7% effective energy efficiency per bit in an FPGA-based receiver experimentally.

19:30 GALA DINNER, Painted Hall, Old Royal Naval College, Greenwich

ROOM A

Th.1.A
Optical Packet/Burst Switching I
Chair: Oded Raz, *COBRA - Eindhoven University of Technology, Netherlands*

Th.1.A.1 • 09:00
Investigation of Optical Buffer Capacity using Large-scale Fiber Delay Lines for Variable-length Optical Packet Switching
S Shinada[1], H Furukawa[1], N Wada[1]; [1]*National Institute of Information & Communications Technology, Japan*
We investigate an actual capacity of optical buffer using fiber delay lines (FDLs) and a prioritized buffer management for variable-length optical packets. From tests of Nx1 packet contention, we confirm the 31-FDLs buffer can resolve the contentions while keeping packet loss less than 10-3 until a total packet rate of inputs reaches about 60%.

Th.1.A.2 • 09:15
Low Latency and Efficient Optical Flow Control for Intra Data Center Networks
W Miao[1], S Di Lucente[1], J Luo[1], H Dorren[1], N Calabretta[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
We demonstrate a highly spectral efficient optical bidirectional system based on reusing the label wavelength to implement an optical flow control for intra-data center networks. Experimental results show error free operation and an effective reduction of the system complexity.

Th.1.A.3 • 09:30
A 40 Gb/s Scalable Optical Polymer Backplane Using a Regenerative Shared Bus Architecture
N Bamiedakis[1], A Hashim[1], R V Penty[1], I H White[1]; [1]*Centre for Advanced Photonics and Electronics, Dept. of Engineering, University of Cambridge, UK*
The first multi-channel optical backplane demonstrator using on-board multimode polymer waveguides and a scalable shared-bus regenerative architecture is reported. The system allows bus extension by cascading multiple polymeric bus modules, and enables error-free 4×10 Gb/s interconnection between any two card interfaces on the bus.

Th.1.A.4 • 09:45 Invited
Parallel Optical Interconnects for Data Center Applications
M Fields[1]; [1]*Avago Technologies, USA*
The MicroPOD 12x10G transmitter and receiver board-mounted optical modules were released in 2010. Today, more than 1.5 million units are deployed across a variety of applications. We provide an update on the MicroPOD experience including lessons learned. We introduce a 12x25G board-mounted optics platform that incorporates these lessons.

ROOM B

Th.1.B
Lasers
Chair: Romain Brenot, *III-V Lab, France*

Th.1.B.1 • 09:00
Ten-Channel Wavelength Tunable Single-Mode Laser Array Based on Slots
Q Lu[1], W Guo[2], A Abdullaev[1], M Nawrocka[1], J O'Callaghan[3], J F Donegan[1]; [1] School of Physics *Trinity College Dublin, School of Physics, Ireland;* [2]*Dept. of Electrical and Computer Engineering, University of California, Santa Barbara, USA;* [3]*Tyndall National Institute, University College Cork, Ireland*
We present a re-growth free 10-channel wavelength-tunable single-mode laser array based on slots. Stable single-mode operation is observed with the output-power >37mW and side-mode-suppression-ratio >50dB. A quasi-continuous tuning range >31nm is obtained from 3°C to 45°C. A typical linewidth of about 1.4MHz is achieved for the fabricated lasers.

Th.1.B.2 • 09:15
Heterogeneously Integrated III-V/Si Distributed Bragg Reflector Laser with Adiabatic Coupling
A Descos[1], C Jany[2], D Bordel[1], H Duprez[1], G Beninca de Farias[1], P Brianceau[1], S Menezo[1], B Ben Bakir[1]; [1]*CEA, LETI, Minatec Campus, France;* [2]*III-V Lab, Joint Lab of "Alcatel-Lucent, Bell Labs", "Thales Research and Technology" and "CEA Leti", France*
We report on an III-V on Silicon distributed Bragg reflector laser with adiabatic coupling operating continuous wave at 1547 nm. The lasing threshold at 20 °C and the maximum output power are 17 mA and 15 mW, respectively. The fiber-coupled power is higher than 4 mW. The device is directly modulated and generates open eye-diagram up to 12.5 Gb/s.

Th.1.B.3 • 09:30
Narrow Linewidth, High Power, High Operating Temperature Digital Supermode Distributed Bragg Reflector Laser
S C Davies[1], R A Griffin[1], A J Ward[1], N D Whitbread[1], I Davies[1], L Langley[1], S Fourte[1], J Mo[2], Y Xu[2], A Carter[1]; [1]*Oclaro Technology LTD, UK;* [2]*Oclaro Technology LTD, China*
We demonstrate a hybrid electronic and thermally tuned digital supermode distributed Bragg reflector (DSDBR) laser operating at 50OC submount temperature with <200kHz Lorentzian linewidth, >16dBm fiber-coupled output power, >40dB SMSR and full C-band capability. Module power dissipation is <3W for 75OC ambient operation.

Th.1.B.4 • 09:45
6.25 GHz Flexible Grid Tuning of Fully Heater-tuned CSG-DR Lasers with Sub-millisecond Wavelength Switching
H Matsuura[1], T Kaneko[2], K Tanizawa[1], E Banno[2], K Uesaka[2], H Kuwatsuka[1], S Namiki[1], H Shoji[2]; [1]*National Institute of Advanced Industrial Science and Technology (AIST), Japan;* [2]*Sumitomo Electric Industries Ltd., Japan*
A TDA-CSG DR laser with a narrow linewidth of 300 kHz has been controlled to lock on 6.25 GHz resolution flexible grid using two compact 50 GHz-FSR Fably-Perot etalon filters. Fast wavelength switching time of less than 1 msec including feedback control time is also ensured for whole C-band wavelength range.

ROOM C

Th.1.C
Subsystems for SDM
Chair: Roberto Gaudino, *Politecnico di Torino, Italy*

Th.1.C.1 • 09:00
110x110 Optical Mode Transfer Matrix Inversion
J Carpenter[1], B J Eggleton[1], J Schröder[1]; [1]*Centre for Ultra High Bandwidth Devices for Optical Systems (CUDOS), Institute of Photonics and optical Sciences (IPOS), University of Sydney, Australia*
The largest complete mode transfer matrix of a fibre is measured with 110 spatial and polarization modes. This matrix is then inverted and the pattern required to produce specified modes at the receiver are launched at the transmitter.

Th.1.C.2 • 09:15
Spatial Light Modulator-based Few-Mode Fiber Switches for Space-Division Multiplexing Applications
E Ip[1], N Cvijetic[1], T Wang[1]; [1]*NEC Laboratories America, USA*
We propose a spatial light modulator-based architecture for few-mode fiber switches, investigate its mode coupling properties, and introduce a phase dithering method for inducing uniform insertion loss across modes with low mode coupling.

Th.1.C.3 • 09:30
Reconfigurable 2×2 Orbital-Angular-Momentum-Based Optical Switching of 50-Gbaud QPSK Channels
N Ahmed[1], H Huang[1], Y Ren[1], Y Yan[1], G Xie[1], A E Willner[1]; [1]*Ming Hseih Dept. of Electrical Engineering, University of Southern California, USA*
We experimentally demonstrate a reconfigurable 2×2 switch for four OAM-multiplexed beams carrying 50-Gbaud QPSK data channels. The performance of the switch is measured for different switch configurations. An OSNR penalty of < 2.5 dB is observed for the switched channels.

Th.1.C.4 • 09:45
4×4 MIMO Equalization to Mitigate Crosstalk Degradation in a Four-Channel Free-Space Orbital-Angular-Momentum-Multiplexed System using Heterodyne Detection
H Huang[1], G Xie[2], Y Ren[3], Y Yan[1], C Bao[1], N Ahmed[1], M Ziyadi[1], M Chitgarha[1], M Neifeld[2], S Dolinar[3], A E Willner[1]; [1]*Dept. of Electrical Engineering, University of Southern California, USA;* [2]*Electrical and Computer Engineering, University of Arizona, USA;* [3]*Jet Propulsion Lab, USA*
We demonstrate crosstalk degradation mitigation using 4×4 MIMO equalization on an orbital-angular-momentum-multiplexed free-space data link with heterodyne detection. 20-Gbit/s QPSK signal with up to -4.8 dB crosstalk is recovered and the BER is reduced by two orders of magnitude.

ROOM D

Th.1.D
Coherent Systems Modeling
Chair: Sébastien Bigo, *Alcatel-Lucent, France*

Th.1.D.1 • 09:00
Design Rules for Reach Maximization in Uncompensated Nyquist-WDM Links
V Curri[1], A Carena[1], G Bosco[1], P Poggiolini[1], A Nespola[2], F Forghieri[3]; [1]*DET-Politecnico di Torino, Italy;* [2]*Istituto Superiore Mario Boella, Italy;* [3]*Cisco Photonics, Italy*
We propose analytical design rules to predict relative maximum reach variations in NyWDM uncompensated links. Tradeoffs among system parameters are shown. Validation is demonstrated using experimental data. The method can be used also for comparison of different modulation formats.

Th.1.D.2 • 09:15
Semi-Analytical Model for the Performance Estimation of 100Gb/s PDM-QPSK Optical Transmission Systems without Inline Dispersion Compensation and Mixed Fiber Types
E Seve[1], P Ramantanis[1], J-C Antona[1], E Grellier[1], O Rival[1], F Vacondio[1], S Bigo[1]; [1]*Alcatel-Lucent Bell Labs, France*
We propose a simple semi-analytical model to predict the performance of transmission systems without in-line dispersion compensation and mixed fiber types. Comparing with numerical simulations we show that our model predicts the Q^2 factor with an accuracy of 0.2 dB.

Th.1.D.3 • 09:30
On the Accuracy of the Gaussian Nonlinear Model for Dispersion-unmanaged Coherent Links
P Serena[1], A Bononi[1]; [1]*Università degli Studi di Parma, Dept. Ingegneria dell'Informazione, Italy*
We discuss the reasons why the Gaussian nonlinear model provides accurate bit error rate predictions in dispersion unmanaged PDM-QPSK coherent links.

Th.1.D.4 • 09:45
Impact of the Transmitted Signal Initial Dispersion Transient on the Accuracy of the GN-Model of Non-Linear Propagation
A Carena[1], G Bosco[1], V Curri[1], P Poggiolini[1], F Forghieri[2]; [1]*Politecnico di Torino, DET, Italy;* [2]*Cisco Photonics Italy srl, Italy*
The GN-model neglects the initial signal dispersion transient in the fiber. We show that this circumstance causes the coherent-accumulation GN-model to provide a lower-bound to system performance estimation, typically less than 0.5 dB away from actual, while the simpler incoherent GN-model typically incurs lower performance estimation errors.

ROOM E

Th.1.E
Spectrum Allocation and Defragmentation
Chair: Gabriel Junyent, *Universitat Politécnica de Catalunya, Spain*

Th.1.E.1 • 09:00 Tutorial
Solving Routing and Spectrum Allocation Related Optimization Problems
L Velasco[1], A Castro[1], M Ruiz[1]; [1]*Universitat Politècnica de Catalunya (UPC), Spain*
We provide a comprehensible introduction to RSA-related problems in flexgrid networks. Starting from its formulation, we analyze network live cycle and indicate different solving methods for the kind of problems that arise at each network phase: from the initial network planning to network re-optimization, going through network operation.

ROOM F

Th.1.F
Short Range Systems
Chair: Idelfonso Monroy, *Technical University of Denmark*

Th.1.F.1 • 09:00
35.2 Gbps 8-PAM Transmission Over 100 m of MMF Using an 850 nm VCSEL
K Szczerba[1], M Karlsson[1], P Andrekson[1], A Larsson[1], E Agrell[2]; [1]*Dept. of Microtechnology and Nanoscience, Chalmers University of Technology, Sweden;* [2]*Dept. of Signals and Systems, Chalmers University of Technology, Sweden*
We report experimental demonstration of 8-PAM transmission using an 850 nm VCSEL and 100 m of OM4-type MMF. The 8-level driving signal was generated using a 3-bit DAC, the error rates were measured in real time using a conventional error analyzer. Maximum uncoded bit rate was 37.5 Gbps, which corresponds to 35.2 Gbps with 7% FEC overhead.

Th.1.F.2 • 09:15
Comparison of 100 Gb/s Ethernet Links using PAM-8, Multi-pulse, and Hybrid CAP-16/QAM-16 Modulation Schemes
J L Wei[1], J D Ingham[1], D G Cunningham[2], R V Penty[1], I H White[1]; [1]*Centre of Photonic Systems, Electrical Engineering Division, Dept. of Engineering, University of Cambridge, UK;* [2]*Avago Technologies, UK*
A theoretical study compares 100 Gb/s Ethernet links and finds that multi-pulse and hybrid CAP-16/QAM-16 (PAM-8) schemes support transmission over 10 km (2 km) SMF. Multi-pulse and CAP-16/QAM-16 need 2× the number of arithmetic operations and 7× or 3× the number of filter taps respectively but exhibit reduced power dissipation compared with PAM-8.

Th.1.F.3 • 09:30
Experimental Comparison of Pulse Amplitude Modulation (PAM) and Discrete Multi-tone (DMT) for Short-Reach 400-Gbps Data Communication
Y Kai[1], M Nishihara[1], T Tanaka[1], T Takahara[1], L Li[2], Z Tao[2], B Liu[2], J C Rasmussen[1], T Drenski[3]; [1]*Fujitsu Laboratories Ltd., Japan;* [2]*Fujitsu R&D Center, China;* [3]*Fujitsu Semiconductor Europe, Germany*
We simulated and experimentally measured the transmission characteristics of PAM and DMT by using the same simulation model and the same experimental setup. Consequently, we have confirmed that DMT has an advantage over PAM.

Th.1.F.4 • 09:45
11×5×10Gb/s WDM-CAP-PON Based on Optical Single-side Band Multi-level Multi-band Carrier-less Amplitude and Phase Modulation with Direct Detection
J Zhang[1,2,4], J Yu[1],F Li[1,3,4], H-C Chien[1], X Li[2], Z Dong[1,4]; [1]*ZTE USA, USA;* [2]*Fudan University, China;* [3]*Hunan University, China;* [4]*Georgia Institute of Technology, USA*
We propose and demonstrate a novel WDM-CAP-PON based on optical single-side band multi-level multi-band carrier-less amplitude and phase modulation (MM-CAP). We successfully transmit 11 WDM-channels for 55 users with 10-Gb/s downstream data rate per user over 40-km SMF.

ROOM A

ROOM B

Th.1.B.5 • 10:00
56 Gbit/s InGaAlAs-MQW 1300 nm Electroabsorption-Modulated DFB-Lasers with Impedance Matching Circuit
H Klein[1], C Bornholdt[1], G Przyrembel[1], A Sigmund[1], W-D Molzow[1], H-G Bach[1], Martin Moehrle[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany*
We have developed electroabsorption modulated DFB Lasers at 1305 nm using an identical InGaAlAs MQW core in the DFB and the EAM section. A 50Ω matching circuit is realized on-chip giving an f3dB of 39.4 GHz. We present 56 Gbit/s eyes with a dynamic extinction ratio of 9.5 dB. The fiber coupled output power under modulation is +5 dBm at 45°C.

ROOM C

Th.1.C.5 • 10:00
698.5-Gb/s PDM-2048QAM Transmission over 3km Multicore Fiber
D Qian[1], E Ip[1], M-F Huang[1], M-J Li[2], T Wang[1]; [1]*NEC Laboratories America, Inc., USA;* [2]*Corning Inc, USA*
We demonstrate the largest constellation output transmission of 58.67Gb/s PDM-2048QAM using twelve single-mode cores of a 3km multicore fiber. As a result, 698.5-Gb/s transmission is achieved within an optical bandwidth of 3.4GHz.

Th.1.C.6 • 10:15
19-core MCF Transmission System using EDFA with Shared Core Pumping Coupled in Free-space Optics
J Sakaguchi[1], W Klaus[1], B J Puttnam[1], J M D Mendinueta[1], Y Awaji[1], N Wada[1], Y Tsuchida[2], K Maeda[2], M Tadakuma[2], K Imamura[2], R Sugizaki[2], T Kobayashi[3], Y Tottori[3], M Watanabe[3], R V Jensen[4]; [1]*National Institute of Information and Communications Technology, Japan;* [2]*Fitel Photonics Laboratory, Furukawa Electric Co., Ltd., Japan;* [3]*Optoquest Co., Ltd., Japan;* [4]*OFS, Denmark*
We have developed a 19-SDM transmission system consisting of a new low-crosstalk 19-core fiber and a prototype 19-core EDFA. The EDFA uses shared free-space optics to couple pump light into cores and thus is SDM transparent. Recirculating loop experiment with PDM-QPSK signals shows the system feasibility for long-haul transmission over 900 km.

10:30-11:00 COFFEE BREAK (ICC Capital Suite Foyer)

Th.2.A
Optical Packet/Burst Switching II
Chair: Antonio Teixeira, *Universidade de Aveiro Portugal*

Th.2.A.1 • 11:00 Invited
Multi-Band OFDM Transmission with Sub-band Optical Switching
E Pincemin[1], M Song[1], J Karaki[1], A Poudoulec[2], N Nicolas[2], M Van der Keur[2], Y Jaouen[3], P Gravey[4], M Morvan[4], G Froc[5]; [1]*France Telecom Orange Labs Networks, France;* [2]*Yenista Optics, France;* [3]*Institut Télécom, Télécom ParisTech, France;* [4]*Institut Télécom, Télécom Bretagne, France;* [5]*Mitsubishi Electric Research Center Europe, France*
We demonstrate that optical add-drop of OFDM sub-bands as narrow as 8 GHz inside a 100 Gbps DP-MB-OFDM signal constituted of four sub-bands spaced by 12 GHz is feasible in the middle of a 10x100-km DCF-free G.652 fibre line.

Th.2.B
Devices for Optical Processing
Chair: Piero Gambini, *Avago Technologies, Italy*

Th.2.B.1 • 11:00
Silicon-Organic Hybrid (SOH) Frequency Comb Source for Data Transmission at 784 Gbit/s
C Weimann[1], S Wolf[1], D Korn[1], R Palmer[1], S Koeber[1], R Schmogrow[1], P C Schindler[1], L Alloatti[1], A Ludwig[1], W Heni[1], D Bekele[1], D L Elder[2], H Yu[3], W Bogaerts[3], L R Dalton[2], W Freude[1], J Leuthold[1,4], C Koos[1]; [1]*Karlsruhe Institute of Technology (KIT), Institutes IPQ and IMT, Germany;* [2]*Dept. of Chemistry, University of Washington, USA;* [3]*Ghent University, IMEC, Photonics Research Group, Belgium;* [4]*Electromagnetic Fields & Microwave Electronics Laboratory (IFH), ETH-Zurich, Switzerland*
We demonstrate a frequency comb generator using silicon-organic hybrid (SOH) electro-optic modulators to obtain flat-top comb spectra. This is the first demonstration of a modulator-based frequency comb generator on silicon. The viability of the device is confirmed in a data transmission experiment achieving an aggregate data rate of 784 Gbit/s.

Th.2.B.2 • 11:15
A Novel Optoelectronic Serial-to-Parallel Converter for 25-Gb/s Burst-mode Optical Packets
S Ibrahim[1], H Ishikawa[1], T Nakahara[1], R Takahashi[1]; [1]*NTT Photonics Labs, NTT Corporation, Japan*
An optoelectronic serial-to-parallel converter is realized for the first time to interface 25-Gb/s asynchronous optical packets to CMOS. A single chip can interface either single or dual packets. The device exhibits a pattern-effect-free response and tolerance to trigger pulse energy. Dual 1:16 packet conversion with a 640ps period is demonstrated/

Th.2.C
SDM Signal Processing
Chair: Seb Savory, *UCL, UK*

Th.2.C.1 • 11:00
Frequency Diversity MIMO Detection for Coherent Optical Transmission
N Kaneda[1], T Pfau[1], J Lee[1]; [1]*Bell Labs, Alcatel-Lucent, USA*
The concept of frequency diversity multiple-input and multiple-output (MIMO) detection is explained, and the digital signal processing technique to utilize this concept is proposed. The proposed technique is successfully applied in experiments to separate 10-Gbaud polarization division multiplexed QPSK signals with 6-GHz carrier spacing.

Th.2.C.2 • 11:15
Adaptive Step Size MIMO Equalization for Few-Mode Fiber Transmission Systems
R G H van Uden[1], C M Okonkwo[1], V A J M Sleiffer[1], H De Waardt[1], A M J Koonen[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands*
The multiple-input multiple-output (MIMO) weight matrix is separated into row vectors to adaptively control the step size per output. Using an experimental 3-moded dual polarization coherent transmission setup, we show that the convergence time can be reduced by 50%.

ROOM D

Th.1.D.5 • 10:00
Performance Dependence on Channel Baud-Rate of Coherent Single-carrier WDM Systems
A Bononi[1], N Rossi[1], P Serena[1]; [1]*Università degli Studi di Parma, Dept. Ingegneria dell'Informazione, Italy*
The nonlinear threshold versus baudrate is simulated for dual-polarization BPSK, QPSK and 16QAM over 20x100km SMF dispersion-managed (DM) and unmanaged (DU) links. The best baudrate is discussed, and comparisons with DU theory are provided.

Th.1.D.6 • 10:15
Stratified-Sampling Estimation of Outage Probability in Nonlinear Coherent Systems with Polarization Dependent Loss
N Rossi[1], P Serena[1], A Bononi[1]; [1]*Università degli Studi di Parma, Dept. Ingegneria dell'Informazione, Italy*
A novel Stratified-Sampling algorithm is used to estimate the outage probability due to nonlinearity, PDL and PMD in a 15-channel 32Gbaud PDM-QPSK system over a 30x100km dispersion managed NZDSF link.

ROOM E

Th.1.E.2 • 10:00
Adaptive Spectrum Defragmentation with Intelligent Timing and Object Selection for Elastic Optical Networks with Time-Varying Traffic
M Zhang[1], C You[1], H Jiang[1], Z Zhu[1], Y Yin[2], L Liu[2], S J Ben Yoo[2]; [1]*University of Science and Technology of China, China;* [2]*University of California, Davis, USA*
We propose intelligent timing and object selection algorithms for adaptive spectrum defragmentation in EONs with time-varying traffic. The simulation results show that the algorithms can stabilize and reduce bandwidth blocking probability (BBP) effectively with the minimum number of connection reconfigurations.

Th.1.E.3 • 10:15
Defragmentation-Based Capacity Enhancement for Fixed to Flexible-Grid Migration Scenarios in DWDM Networks
A Eira[1,2], J Pedro[1,2], J Pires[2], D Fonseca[1,2], J Fernández-Palacios[3], V López[3], S Spaelter[4]; [1]*Nokia Siemens Networks S.A.R, Portugal;* [2]*Instituto de Telecomunicações, Instituto Superior Técnico, Portugal;* [3]*Telefonica I+D, Spain;* [4]*Nokia Siemens Networks Optical, Germany*
This paper investigates the most favorable conditions for a full defragmentation procedure when evolving from a fixed to a flexible-grid scenario. Results show that migrating legacy channels to flexible-grid formats can yield up to 50% more capacity for future traffic, provided these legacy channels are also spectrally re-planned.

ROOM F

Th.1.F.5 • 10:00
1.5 Gbps PN-ZP-DMT Transmission System for 1-mm Core Diameter SI-POF with RC-LED
L Peng[1], S Haese[1], M Hélard[1], M Liu[1]; [1]*Electronics and Telecommunications Institute of Rennes (IETR), National Institute of Applied Sciences (INSA), Université Européene de Bretagne, France*
A novel PN-ZP-DMT transmission scheme without requiring dedicated pilots for channel estimation is proposed. Hardware experiments on 50 m SI-POF with RC-LED show that the proposed scheme achieves a transmission rate of 1.5 Gbps with low cost off the shelf components.

Th.1.F.6 • 10:15
Reach Extensions with Chromatic Dispersion Compensated Multimode Fibers
D Molin[1], M Bigot-Astruc[1], P Sillard[1]; [1]*Prysmian Group, France*
We show how chromatic-dispersion-compensated MMFs allow to extend the reach of 40/100GbE links up to 400m and to bridge 150m distance at 25Gbps without equalization or forward error correction.

10:30-11:00 COFFEE BREAK (ICC Capital Suite Foyer)

Th.2.D
Modulation Formats
Chair: *Onaka Hiroshi, Fujitsu, Japan*

Th.2.D.1 • 11:00 Invited
1306-km 20x124.8-Gb/s PM-64QAM Transmission over PSCF with Net SEDP 11,300 (b km)/s/Hz using 1.15 samp/symb DAC
A Nespola[1], S Straullu[1], G Bosco[2], A Carena[2], Y Jiang[2], P Poggiolini[2], F Forghieri[3], Y Yamamoto[4], M Hirano[4], T Sasaki[4], J Bauwelinck[5], K Verheyen[5]; [1]*PhotonLab, Instituto Superiore Mario Boella, Italy;* [2]*Politecnico di Torino, DET, Italy;* [3]*Cisco Photonics srl, Italy;* [4]*Sumitomo Electric Industries Ltd., Japan;* [5]*INTEC/IMEC, Ghent University, Belgium*
We demonstrated PM-64QAM, 20x124.8-Gb/s Nyquist-WDM over 1306 Km of PSCF in an EDFA-only system configuration. The raw SE was 10.4b/s/Hz, thanks to digital spectral shaping. The Tx DACs operated at a record-low 1.15 sample/symb. The SEDP was 11,327 (b km)/s/Hz.

Th.2.E
Photonic Node Architecture
Chair: Emmanuel Le Taillandier de Gabory, *NEC Corporation, Green Platform Research Laboratories*

Th.2.E.1 • 11:00 Invited
Synthetic Photonic Nodes for the Future Photonic Network
M Fukui[1], A Hiramatsu[1], T Tsuritani[2], K Kitayama[3] [1]*NTT, Japan;* [2]*KDDI R&D Laboratories, Japan;* [3]*Osaka University, Japan*
A synthetic photonic node consists of an array of the photonic network processors and reconfigurable optical interconnections. It enables to dynamically synthesize variety of optical node functions by software on the processors. Its concept and some use cases are presented.

Th.2.F
Data Centre Networking
Chair: Eduward Tangdiongga, *COBRA Research Institute, Eindhiven University Technology, Netherlands*

Th.2.F.1 • 11:00
Low Latency, Rack Scale Optical Interconnection Network for Data Center Applications
S Rumley[1], M Glick[2], G Dongaonkar[1,3], R Hendry[1], K Bergman[1], R Dutt[2,3]; [1]*Dept. of Electrical Engineering, Columbia University, USA;* [2]*APIC Corporation, USA;* [3]*PhotonIC Corporation, USA*
Warehouse scale data centers running complex applications involving large numbers of servers require low latency interconnects to avoid excessive delays to the user. The SPINet (Scalable Photonic Interconnection Network) architecture can be used in packet mode at low load for ultra- low latency or TDM mode for long flows or periods of congestion.

Th.2.F.2 • 11:15
A 64.4 Gbps.km Optical Interconnect Employing a High-Power High-Speed Single-Mode 850-nm VCSELs and OFDM Format
I-C Lu[1], C-C Wei[2], J-W Shi[3], H-Y Chen[1,4], S-F Tsai[1], Z-R Wei[3], J-M Wun[3], J-X Wu[2], J Chen[1]; [1]*Dept. of Photonics, National Chiao Tung University, Taiwan;* [2]*Dept. of Photonics, National Sun Yat-sen University, Taiwan;* [3]*Dept. of Electrical Engineering, National Central University, Taiwan;* [4]*Information and Communication Research Labs, Industrial Technology Research Institute, Taiwan*
We demonstrate a high-power (6.7 mW) high-speed (3-dB bandwidth of 12-GHz) small-linewidth (0.08 nm) single-mode (SMSR of > 30 dB) 850-nm VCSEL for optical interconnects application, and a record-high bit-rate-distance product (28 Gbps 2.3 km) for OM4 MMF transmission under OFDM modulation formats is presented.

ROOM A

Th.2.A.2 • 11:30
40G Burst Mode Optical Clock Recovery after 52 km Transmission Enabled by a Dynamically Switched Quantum Dash Mode-Locked Laser
J Luo[1], J Parra-Cetina[2], P Landais[2], H J S Dorren[1], N Calabretta[1]; [1]*COBRA Research Institute, Eindhoven University of Technology, Netherlands;* [2]*School of Electronic Engineering, Dublin City University, Ireland*
We demonstrate for the first time 40 Gb/s burst mode optical clock recovery after 52 km transmission which is enabled by injection locking a dynamically switched quantum dash mode-locked laser diode. 40 GHz packet clock is recovered with ~25 ns locking time, 46 dB signal to noise floor suppression and 64 fs timing jitter.

Th.2.A.3 • 11:45
Wavelength-Tunable Burst-Mode Receiver with Correlation-Based Polarization Separation
J Gripp[1], J E Simsarian[1], S Corteselli[1], T Pfau[1]; [1]*Alcatel-Lucent, Bell Laboratories, USA*
We demonstrate a fast wavelength-tunable burst-mode receiver for DP-QPSK optical packets. Training symbols are used for frequency offset recovery, packet alignment, and rapid polarization separation using 64-bit cross correlations.

Th.2.A.4 • 12:00
Demonstration of FSK Light Label Receiver Prototype for Light Path Tracing of 112 Gbps DP-QPSK Signal
G Nakagawa[1], S Oda[1], K Sone[1], Y Aoki[1], K Hironishi[1], T Tanimura[1], T Hoshida[2], J C Rasmussen[1]; [1]*Fujitsu Laboratories Ltd, Japan;* [2]*Fujitsu Ltd, Japan*
We developed a frequency shift keying (FSK) light label receiver prototype that enables to detect a Path-ID superimposed on 112 Gbps DP-QPSK signal, and demonstrated the light path tracing capabilities in color-less, non-directional, contention-less and grid-less (CNCG) ROADM network.

Th.2.A.5 • 12:15
A Compact Integrated 40Gb/s Packet Demultiplexer and Label Extractor on Silicon-on-Insulator for an Optical Packet Switch
P De Heyn[1], J Luo[2], A Trita[1], S Pathak[1], S Di Lucente[2], H Dorren[2], N Calabretta[2], D Van Thourhout[1]; [1]*Photonics Research Group, Dept. of Information Technology, Ghent University - imec, Belgium;* [2]*Dept. of Electrical Engineering, Eindhoven University of Technology, Netherlands*
We demonstrate a compact 40Gb/s 32-channel packet demultiplexer and in-band label extractor based on photonic integrated AWG followed by a narrow-band microring resonator at each AWG output. Error free operation with ≤0.5dB penalty was measured.

ROOM B

Th.2.B.3 • 11:30
Silicon Photonic Optical Serial-to-Parallel Converter with Phase Operation
H Kusano[1], H Uenohara[1]; [1]*Precision and Intelligence Laboratory, Tokyo Institute of Technology, Japan*
A silicon photonic optical serial-to-parallel converter (OSPC) with phase operation consisting of Mach-Zehnder delay interferometers (MZDIs) with 1 to 8-bit delay lengths has been fabricated for 8-bit processing at 40 Gbps. Preliminary results of the OSPC operation have been successfully obtained.

Th.2.B.4 • 11:45
Terahertz Bandwidth Photonic Hilbert Transformers and Implementations in Ultra Wideband Single-sideband Filters
C Sima[1], J C Gates[1], C Holmes[1], M N Zervas[1], P G R Smith[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
Planar Bragg grating based photonic Hilbert transformers (PHTs) with THz bandwidths are proposed and practically demonstrated. An X-coupler, PHT, and a flat-top reflector are incorporated, demonstrating 2THz all-optical single-sideband filters. Devices are fabricated via a direct UV grating writing technique on a silica-on-silicon platform.

Th.2.B.5 • 12:00
Flexible True-Time-Delay Beamforming in a Photonics-Based RF Broadband Signals Generator
F Scotti[1], P Ghelfi[1], F Laghezza[2], G Serafino[3], S Pinna[3], A Bogoni[1]; [1]*CNIT, National Lab of Photonics Networks, Italy;* [2]*CNIT, National Lab of Radar and Surveillance Systems, Italy;* [3]*Scuola Superiore Sant'Anna, TeCIP Institute, Italy*
A novel architecture is proposed generating and independently delaying multiple wideband RF signals for phased arrayed antennas. Experimental results show independent controlled delays up to 200ps for broadband signals at 10GHz and 40GHz simultaneously.

ROOM C

Th.2.C.3 • 11:30
Mode Scramblers and Reduced-Search Maximum-Likelihood Detection for Mode-Dependent-Loss-Impaired Transmission
A Lobato[1], F Ferreira[2], J Rabe[3], M Kuschnerov[4], B Spinnler[4], B Lankl[1]; [1]*University of Federal Armed Forces, Germany;* [2]*Nokia Siemens Networks Portugal S. A., Portugal;* [3]*Technische Universität München, Germany;* [4]*Nokia Siemens Networks Optical GmbH, Germany*
We propose mode scrambling in combination with reduced-search maximum-likelihood detection for performance enhancement of few-mode fiber transmission systems impaired by mode-dependent loss. Significant reach improvements are demonstrated for 3x- and 6x158-Gb/s MDM QPSK-OFDM transmission.

Th.2.C.4 • 11:45
Complexity Analysis of Adaptive Frequency-Domain Equalization for MIMO-SDM Transmission
S Randel[1], P J Winzer[1], M Montoliu[1,2], R Ryf[1]; [1]*Bell Laboratories, Alcatel-Lucent, USA;* [2]*Universitat Politecnica de Catalunia, ETSETB, Spain*
We describe a low-complexity frequency-domain equalizer enabling MIMO-SDM transmission. We find that an unconstrained implementation can lead to a considerably reduced complexity with a Q-factor penalty of 0.2 dB. We further discuss complexity scaling of a 1-Tb/s MIMO-SDM interface.

Th.2.C.5 • 12:00 Invited
Modal Statistics in Mode-Division-Multiplexed Systems
J M Kahn[1], K-P Ho[2]; [1]*E. L Ginzton Laboratory, Stanford University, USA;* [2]*Silicon Image, USA*
The performance and complexity of mode-division-multiplexing systems depend on the statistics of modal gains/losses and group delays. Under strong mode coupling, these statistics may be derived from the eigenvalue distributions of random matrices. Strong coupling optimizes performance and minimizes complexity.

12:30-14:00 LUNCH

14:00-15:30 POSTDEADLINE PAPERS

15:30-16:00 CLOSING CEREMONY - Room C

ROOM D

Th.2.D.2 • 11:30
Experimental Comparison between Hybrid-QPSK/8QAM and 4D-32SP-16QAM Formats at 31.2 GBaud using Nyquist Pulse Shaping
R Rios-Muller[1], J Renaudier[1], O Bertran-Pardo[1], A Ghazisaeidi[1], P Tran[1], G Charlet[1], S Bigo[1]; [1]*Bell Labs Alcatel-Lucent, France*
We report on the performance comparison between two modulation formats carrying each 2.5 bits per transmitted 2D-symbol. Using Nyquist pulse shaping and a 33-GHz spacing grid, we show that the 4D-32SP-16QAM format outperforms the Hybrid-QPSK/8QAM format over a transmission link made of standard single mode fiber.

Th.2.D.3 • 11:45
Comparison of Two Modulation Formats at Spectral Efficiency of 5 Bits/Dual-Pol Symbol
H Sun[1], R Egorov[2], B E Basch[2], J McNicol[1], K-T Wu[1]; [1]*Infinera, Canada;* [2]*Verizon Laboratories, USA*
Two modulation formats at spectral efficiency of 5 bits/dual-pol symbol are compared. Linewidth tolerances and feed-forward carrier recovery methods are discussed. Performances over uncompensated SMF and LEAF fibers are shown. The 4-D optimized format is found to be modestly better than a hybrid combination of PM-QPSK and PM-8QAM.

Th.2.D.4 • 12:00
Frequency and Polarization Switched QPSK
T A Eriksson[1], P Johannisson[1], M Sjödin[1], E Agrell[2], P A Andrekson[1], M Karlsson[1]; [1]*Dept. of Microtechnology and Nanoscience, Chalmers University of Technology, Sweden;* [2]*Dept. of Signals and Systems, Chalmers University of Technology, Sweden*
We propose 8-dimensional biorthogonal modulation as a format with 3 dB increased asymptotic power efficiency over PM-QPSK. We demonstrate one possible experimental implementation of this format based on frequency and polarization switching and compare with dual-carrier PM-QPSK and PS-QPSK.

Th.2.D.5 • 12:15
Long-Haul Transmission of 1-Tb/s Superchannels, 175-GHz Spaced, over SSMF using Nyquist Pulse Shaping and Flex-Grid WDM Architecture
J Renaudier[1], A Ghazisaeidi[1], P Tran[1], O Bertran-Pardo[1], G Charlet[1], S Bigo[1]; [1]*Bell Labs, Alcatel-Lucent, France*
We report on the long-haul transmission of 1-Tb/s superchannels using PDM-16QAM modulation and Nyquist pulse shaping. Based on flexible grid wavelength selective switch technology, we transmit three 1-Tb/s superchannels spaced by 175-GHz over 1600 km of SSMF and four ROADM, with a spectral efficiency of 5.7 bit/s/Hz.

ROOM E

Th.2.E.2 • 11:30
Dynamic Path Bandwidth Allocation for 1000x10-Scale Optical Layer-2 Switch Network based on Hierarchical Timeslot Allocation Algorithm and Timeslot Converter
K Hattori[1], M Nakagawa[1], N Kimishima[1], M Katayama[1], A Misawa[1]; [1]*NTT Network Service Systems Laboratories, NTT Corporation, Japan*
We are developing optical layer-2 switch network that achieves dynamic path bandwidth allocation (DPBA) for efficient aggregation in metro NWs. We show the experimental results of DPBA cycle according to variations in traffic on NW scale of 1000x10.

Th.2.E.3 • 11:45
Performance Evaluation of Large-scale OXCs that Employ Multi-stage Hetero-granular Optical Path Switching
H-C Le[1], H Hasegawa[1], K Sato[1]; [1]*Nagoya University, Japan*
We evaluate the performance of large-scale two-stage-routing OXC architectures that can be based on small-degree WSSs and simple optical devices, 1xn switches or WBSSs. They are shown to reduce necessary hardware scale substantially at the cost of few additional fibers.

Th.2.E.4 • 12:00
Subsystem Modular OXC Architecture that Achieves Disruption Free Port Count Expansion
Y Tanaka[1], Y Iwai[1], H Hasegawa[1], K Sato[1]; [1]*Nagoya University, Japan*
We propose a novel interconnection approach for our subsystem modular OXC node that achieves graceful modular growth without any service disruption and only marginal routing performance offset. We analyze the origins of blocking and demonstrate the necessity of jointly optimizing intra/inter-node routing and wavelength assignment.

Th.2.E.5 • 12:15
Optical Cross-connect with Adaptive Intra-node Contention
T Zami[1]; [1]*Alcatel-Lucent, France*
Within the context of colorless and multidirectional wavelength routing node, this study illustrates the trade-off in terms of connectivity, total add/drop capacity, and intra-node contention

ROOM F

Th.2.F.3 • 11:30 Tutorial
Advancements in Data-Center Networking, and the importance of Optical Interconnections
L Paraschis[1], [1]*CISCO, USA*
We review innovations in optical technology, system, and network architectures that enable inter, and intra data-centers connectivity to cost-effectively scale to the "cloud-era" requirements for flatter networks, with more flexible provisioning, and higher capacity scaling.

12:30-14:00 LUNCH

14:00-15:30 POSTDEADLINE PAPERS

15:30-16:00 CLOSING CEREMONY - Room C

P.1 • Poster - Fibre, Fibre Devices and Amplifiers

P.1.1 • Significant Noise Reduction in Multimode Fiber Links Using Graded-index Plastic Optical Fiber with Microscopic Heterogeneous Core
A Inoue[1], R Furukawa[2], M Matsuura[2], Y Koike[1]; [1]*Keio Photonics Research Institute, Keio University, Japan;* [2]*Centre for Frontier Science & Engineering, University of Electro-Communications, Japan*
We show that the reflection noises in multimode fiber links can be significantly reduced by using graded-index plastic optical fiber with microscopic heterogeneous core. It is suggested that the intrinsic mode coupling due to the microscopic heterogeneities can result in the noise reduction without optical isolator and fiber end-face polishing.

P.1.2 • Experimental Observation of Third-Harmonic Generation in a ZBLAN Fluoride Fiber with Elliptical Core
W Gao[1], K Ogawa[2], X Xue[1], M Liao[1], D Deng[1], T Cheng[1], T Suzuki[1], Y Ohishi[1]; [1]*Research Center for Advanced Photon Technology, Toyota Technological Institute, Japan;* [2]*FiberLabs Inc., Japan*
We demonstrate third harmonic generation (THG) in an elliptical-core ZBLAN fluoride fiber. Linearly polarized THG around 523 nm is obtained. The extinction ratios are higher than 10 dB in 35 cm fiber. Tunable THG from 605 to 740 nm is observed when pumped by an optical parametric oscillator with the pump wavelength from1800 to 2200 nm.

P.1.3 • A Preliminary Analysis of Spin in Few-Mode Optical Fibers
L Palmieri[1], A Galtarossa[1,2]; [1]*Dept. of Information Engineering, University of Padova, Italy;* [2]*International Institute for Urban Systems Engineering, Southeast University, China*
The effect that spin has on modal dispersion of few-mode fibers is qualitatively studied. The analysis shows that spin may indeed reduce modal dispersion within the LP(1,1) manifold, although reduction may be not as effective as in single-mode fibers.

P.1.4 • Fibre Grating Filters for Suppression of Near Infrared OH Emission Lines
A Gbadebo[1], E Turitsyna[1], X Shu[1], J Williams[1], S Turitsyn[1]; [1]*Aston Institute of Photonics Technology, Aston University, UK*
Here we present the design and fabrication of multi-notch optical fibre Bragg gratings for suppressing OH emission lines in the near infrared spectra of the night sky for astrophysical applications. We demonstrate a novel approach of fabricating 2, 3 and 5-notch filters using the phase mask technology, which show a good match with the model.

P.1.5 • Reconfigurable Fiber Optical Parametric Amplifier Gain Profile by Phase Matching Control with Gain-Transparent SBS
L Wang[1], C Shu[1]; [1]*Dept. of Electronic Engineering and Centre for Advanced Research in Photonics, The Chinese University of Hong Kong, Hong Kong*
Reconfigurable gain profile has been demonstrated in a single-pump FOPA under SBS control. The scheme offers the capability of randomly synthesizing profiles to satisfy different system requirements. Dynamic gain flattening within 0.05 dB variation is achieved over a 24-nm bandwidth.

P.1.6 • Brillouin Optical Correlation Domain Analysis in Linear Configuration based on Differential Lock-in Detection
J H Jeong[1], K H Chung[1,3], K Lee[1], K Y Song[3], J-H Lee[1], J-M Jeong[2], S-B Lee[1]; [1]*Centre for Opto-Electronic Convergence Systems, Korea Institute of Science and Technology (KIST), Republic of Korea;* [2]*Dept. of Electrical & Computer Engineering, Hanyang University, Republic of Korea;* [3]*Dept. of Physics, Chung-Ang University, Republic of Korea*
Brillouin optical correlation domain analysis (BOCDA) in linear configuration is demonstrated newly based on differential lock-in detection. Three-fold enhancement in the spatial resolution is achieved compared to the former system based on beat-lock-in detection, as well as the simpler configuration for the signal processing.

P.1.7 • Low-loss Physical-Contact-Type Fan-out Device for 12-core Multicore Fiber
Y Abe[1], K Shikama[1], S Yanagi[1], T Takahashi[1]; [1]*NTT Photonics Laboratories, NTT Corporation, Japan*
We propose a low-loss fan-out for 12-core multicore fiber, which achieves physical-contact connection between coupled cores by accurately arranging fibers and optimizing the conditions for physical contact, and demonstrate a physical contact connection with a low average insertion loss of 0.64 dB and a high return loss of over 55 dB for 12 cores.

P.1.8 • All-fiber, Ultra-wide Band Tunable Laser Source at 2 µm
Z Li[1], S U Alam[1], Y Jung[1], A M Heidt[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We report a direct diode pumped all-fiber tunable laser source at 2 µm with over 250 nm of tuning range. A 3 dB power flatness of 200 nm with a maximum output power of 30 mW at 1930 nm was achieved. The laser has high OSNR of over 50 dB across the whole tuning range.

P.1.9 • 300-mW Average Output Power Hybrid Mode-Locked Thulium-Doped Fiber Laser
M Chernysheva[1,2], A A Krylov[1], C Mou[2], R N Arif[2], A Rozhin[2], M H Rümmeli[3,4], S K Turitsyn[2], E M Dianov[1]; [1]*Fiber Optics Research Center of Russian Academy of Science, Russian Federation;* [2]*Aston Institute of Photonics Technologies, Aston University, UK;* [3]*IFW Dresden, Germany;* [4]*Center for Integrated Nanostructure Physics IBS Sungkyunkwan University, Republic of Korea*
We report on ring thulium-doped fiber laser hybrid mode-locked by single-walled carbon nanotubes and nonlinear polarization evolution generating 600-fs pulses at 1910-1980nm wavelength band with 72.5MHz repetition rate. Average output power reached 300mW in single-pulse operation regime, corresponding to 4.88kW peak power and 2.93nJ pulse energy.

P.1.10 • Virtual Delay Line Interferometer by a Transmissive Phase-modulated Fiber Bragg Grating
M A Preciado[1], X Shu[1], K Sugden[1]; [1]*Aston Institute of Photonic Technologies, Aston University, UK*
A novel approach based on transmissive phase-modulated fiber Bragg grating (FBG) to implement a virtual delay line interferometer (DLI) is proposed, designed, numerically simulated and fabricated. The resulting devices provide the functionality of a Mach-Zehnder interferometer (MZI), or equivalently a Michelson-Morley interferometer (MMI).

P.1.11 • Wideband Uniform Generation of Shape-Adjustable Pulses in Two-Pump Fiber Optic Parametric Amplifier
M A Shoaie[1], A Vedadi[1], C-S Bres[1]; [1]*PHOSL STI-IEL, EPFL, Switzerland*
A tunable, stable pulse generation technique based on two-pump fiber optic parametric amplifier is theoretically analyzed and experimentally demonstrated to generate uniform near-Gaussian pulses over 32 nm. It is shown that pulse shape can also be tuned and that a specific phase matching case enables Nyquist pulse generation over a wide bandwidth.

P.1.12 • Laser Spectral Linewidth Suppression Scheme for Coherent Detection
D Pan[1,2], C Ke[1,2], S Fu[1,2], Y Liu[2], D Liu[1,2], A E Willner[3]; [1]*National Engineering Laboratory for Next Generation Internet Access System, Huazhong University of Science and Technology, China;* [2]*School of Optical and Electronic Information, Huazhong University of Science and Technology, China;* [3]*Dept. of Electrical Engineering, University of Southern California, USA*
We demonstrate an effective spectral linewidth suppression of commercial TLS using long cavity, narrow bandwidth SBS filter and multi frequency-selection mechanism. Measured linewidth suppression from ~3MHz to <20kHz is achieved with a SMSR improvement of ~20dB over the C-band.

P.1.13 • Modeling of Micro-bending in Multimode Fibers with Parabolic Index Profile using Discrete Coupling Points
A A Juarez[1], E Krune[1], C-A Bunge[2], S Warm[1], K Petermann[1]; [1]*Technische Universität Berlin, Germany;* [2]*University of Applied Sciences, Germany*
A discrete coupling model is presented which describes accurately mode coupling effects induced by splices and micro-bending in MMF and their effect on amplitude and phase of the field. It is shown that the MMF transmission characteristics and power distribution is completely governed by the power coupling losses induced by modal coupling.

P.1.14 • Experimental Verification of Four Wave Mixing Efficiency Characteristics in a Few Mode Fiber
N Mac Suibhne[1], A Ellis[2], F C Garcia Gunning[3], S Sygletos[2]; [1] *Tyndall National Institute and Dept. of Electronic Engineering, University College Cork, Ireland;* [2]*Aston Institute of Photonic Technologies, Aston University, UK;* [3]*Tyndall National Institute and Dept. of Physics, University College Cork, Ireland*
We introduce simple techniques to measure the efficiency of inter-mode four-wave mixing with respect to intra-mode four-wave mixing. We demonstrate experimentally that the inter-mode nonlinearity increases the nonlinear noise by approximately 2dB for the fibre studied.

P.1.15 • The Impact of Fiber Core Ellipticity and Modal Coherency on Few Moded Erbium Doped Fiber Amplifiers
E-L Lim[1], S Dasgupta[1], Q Kang[1], J M O Daniel[1], F Poletti[1], S Alam[1], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*
We numerically demonstrate that the few moded erbium doped fiber amplifier models based on linearly polarized and vector modes are equivalent when the fiber core exhibits slight ellipticity and the signals in the guided modes are incoherent. These conditions are fulfilled in a practical mode division multiplexed system.

P.2 • Waveguide and Optoelectronic Devices

P.2.1 • Highly Alignment Tolerant 4 x 25 Gb/s ROSA Module for 100G Ethernet Optical Transceiver
J Ki Lee[1,2], S-K Kang[1], J Y Huh[1], Y-S Jang[2]; [1]*Electronics and Telecommunications Research Institute, Republic of Korea;* [2]*Dept. of Electronics Engineering, Chungnam National University, Republic of Korea*
In the development of a compact 4 x 25 Gb/s ROSA (receiver optical sub-assembly) for 100G Ethernet transceivers, we have investigated alignment tolerance between an optical demultiplexer and a four-channel PD array. The module exhibited very large lateral alignment tolerance of more than ± 250 µm.

P.2.2 • 60-Gb/s Mode Division Multiplexing and Wavelength Division Multiplexing in Si Multimode Waveguides
C P Chen[1], J B Driscoll[1], R R Grote[1], Y Liu[1], R M Osgood Jnr[1], K Bergman[1]; [1]*Dept. of Electrical Engineering, Columbia University, USA*
A silicon photonic waveguide system with mode-division and wavelength-division-multiplexing capabilities is demonstrated. Error-free (BER<10^-12) data transmission of 2 modal channels and 3-wavelengths operating with aggregate bandwidth of 60-Gb/s is realized. This work motivates future bandwidth scalability of silicon photonic interconnects.

P.2.3 • Wavelength Locking of Microring Resonators and Modulators using a Dithering Signal
K Padmaraju[1], D F Logan[2,3], J J Ackert[2], A P Knights[2], K Bergman[2]; [1]*Dept. of Electrical Engineering, Columbia University, USA;* [2]*Dept. of Engineering Physics, McMaster University, Canada;* [3]*Dept. of Electrical & Computer Engineering, University of Toronto, Canada*
We present a scalable, energy-efficient method to automatically align microring resonators and modulators with laser wavelengths, as well as provide thermal stabilization. The method utilizes a dithering signal to generate error signals that are immune to fluctuations in laser power.

P.2.4 • Bit Error Rate Performance Evaluation of a Silicon-on-Insulator Optical-Network-on-Chip Router in a WDM Configuration
A Parini[1,2], G Bellanca[1,2], A Annoni[3], F Morichetti[3], A Melloni[3], M J Strain[4], M Sorel[4], C Pareige[5], M Gay[5], L Bramerie[5], M Thual[5]; [1]*Laboratory for Micro and Submicro Enabling Technologies of the Emilia-Romagna Region, (MIST E-R), Italy;* [2]*Dipartimento di Ingegneria, Università di Ferrara, Italy;* [3]*Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano, Italy;* [4]*School of Engineering, University of Glasgow, UK;* [5]*CNRS Foton Laboratory, Enssat, Université Européenne de Bretagne, France*
We present a microring-based integrated router in Silicon-on-Insulator technology suitable for optical networking at chip level. The switching functionalities in a 3-channels 10 Gbit/s WDM configuration are evaluated through the BER curves.

P.2.5 • Effective Phase Noise Suppression in Externally Injected Gain Switched Comb Source for Coherent Optical Communications
R Zhou[1], V Vujicic[1], T N Huynh[1], P M Anandarajah[1], L P Barry[1]; [1]*The RINCE Institute, Dublin City University, Ireland*
We investigate the residual phase noise in an injected gain switched comb source with FM-noise spectrum analysis, and examine the impact of this noise on the performance of a DQPSK system at 10.7GBaud. A 2dB penalty exists for the 10 line comb source due to the excess phase noise, and the penalty can be eliminated by optimized injection.

P.2.6 • A Prototype Multicore-fiber Optical Switch Unit for a Large-capacity and High-Reliability Network
Y Lee[1], K Tanaka[1], K Hiruma[1], E Nomoto[1], H Arimoto[1]; [1]*Central Research Laboratory, Hitachi, Ltd., Japan*
A prototype optical switch unit with multi-core fibers (MCFs) was fabricated. Using an MCF link, the prototype succesfully demonstrated automatic switching of optical routes when line failure occurred. Its recovery time was 25 ms, which is less than the time specified in the ITU-T standard (50 ms).

P.2.7 • Comparison of InP and Silicon Mach-Zehnder Modulators in Terms of Chirp
D Petousi[1,2], L Zimmermann[2], K Voigt[1], J Kreissl[2], K Petermann[1]; [1]*Technische Universitaet, Germany;* [2]*IHP, Germany*
We analyze the impact of nonlinear InP-based and Silicon-based phase shifters on Mach Zehnder modulator chirp. To identify performance limits, we compare state-of-the-art InP modulators with existing and numerically optimized Silicon modulators. We show that similar performance characteristics can be expected for both technologies.

P.2.8 • Compact 100G Coherent Receiver Using InP-based 90° Hybrid Integrated with Photodiodes
M Takechi[1]; Y Taeiwa[1], S Ogita[1]; [1]*Transmission Devices R&D Labs., Sumitomo Electric Industries, Ltd, Japan*
A compact 100G coherent receiver using InP-based 90° hybrid integrated with photodiodes is reported. The package body size, at 13.6 x 25.2 x 5.5 mm, is the smallest ever reported. The device demonstrates bandwidth of 24 GHz and responsivity of 64 mA/W at 1550 nm. 128 Gbit/s DP-QPSK transmission tests have been successfully conducted.

P.2.9 • 3D Stacked Transmitter and Receiver Chips for High Bandwidth Density Optical Interconnects
P Duan[1], O Raz[1], B E Smalbrugge[1], K L Plassche, van de[1], S Dorrestein[2], J Duis[2], H G S Dorren[1]; [1]*COBRA Research School, Eindhoven University of Technology, Netherlands;* [2]*TE connectivity, Netherlands*
A receiver chip based on 3D stacking a photodiode chip directly on top of TIA CMOS IC is demonstrated. Open eye patterns are demonstrated for both 3D stacked receiver and transmitter chips and BER measurements of the transmitter show penalty free operation under uniform biasing conditions proving that the interconnecting technology is robust.

P.2.10 • Single-Pump, Tunable Wavelength Conversion of 8×12.5 Gsymbol/s QPSK Channels in a Quasi-Rectangular PPLN
A Albuquerque[1], B J Puttnam[2], M Drummond[1], S Shinada[2], R Nogueira[1], N Wada[2]; [1]*Instituto de Telecomunicacoes, Portugal;* [2]*National Institute of Information and Communications Technology, Japan*
We use a layer peeling algorithm to design and produce a PPLN with a 400GHz quasi-rectangular conversion response. Single-pump, tunable wavelength conversion of 8×12.5 Gsymbols/s QPSK channels in a 50GHz WDM grid is achieved with a 3dB maximum OSNR penalty.

P.2.11 • Continuous Wave Phase-Sensitive Four-Wave Mixing in Silicon Waveguides With Reverse-Biased p-i-n Junctions
F Da Ros[1], D Vukovic[1], A Gajda[2,3], L Zimmermann[3], K Petermann[2], C Peucheret[1]; [1]*Dept. of Photonics Engineering, Technical University of Denmark, Denmark;* [2]*Institut für Hochfrequenz- und Halbleiter-Systemtechnologien, TU Berlin, Germany;* [3]*IHP, Germany*
Phase-sensitive four-wave mixing is experimentally demonstrated using continuous wave pumps in silicon waveguides with p-i-n junctions. The reverse biasing allows decreasing the free carrier lifetime, enabling a phase-sensitive extinction ratio in excess of 15 dB.

P.2.12 • Tunable Two-Stage 6th order FIR-Filter for Residual Dispersion Compensation
S Schwarz[1], A Rahim[2], J Bruns[2], K Petermann[2], C G Schaeffer[1]; [1]*Helmut Schmidt University, Chair of High-Frequency Engineering, Germany;* [2]*Berlin Institute of Technology, Hochfrequenztechnik-Photonics, Germany*
We show the performance of a tunable dispersion compensator realized in SOI using a parallel-serial approach. The measured transmission response for positive and negative dispersion was used to improve the dispersion tolerance of a 28 GBaud QPSK transmission system by 44%.

P.2.13 • Scalable Multi-segment Phase Mask for Spatial Power Splitting and Mode Division Demultiplexing
H Chen[1], T Koonen[1]; [1] *COBRA Institute, Eindhoven University of Technology, Netherlands*
Multi-segment Phase Mask (MSPM) designs for spatial power splitting and mode division demultiplexing are verified through simulation and experiments. Coupler insertion loss and mode dependent loss are calculated. A spatial light modulator is used to emulate the proposed MSPMs.

P.2.14 • Monolithic Integration of AlInGaAs DS-DBR Tunable Laser and AlInGaAs MZ Modulator with Small Footprint, Low Power Dissipation and Long-Haul 10Gb/s Performance
A J Ward[1], V Hill[1], R Cush[1], S C Heck[1], P Firth[1], Y Honzawa[2], Y Uchida[2]; [1]*Oclaro Technology Ltd, UK;* [2]*Oclaro Japan Inc, Japan*
A monolithically integrated tunable ILMZ device is presented which uses AlInGaAs in both the laser and MZ regions. This allows high temperature operation and low Vπ giving power dissipation of less than 1.6W at a levelled power output of 0.5dBm. Transmission performance at 10Gb/s consistent with long-haul operation is also presented.

P.2.15 • Single Mach-Zehnder Modulator with Active Y-branch for Higher than 60 dB Extinction-Ratio Operation
Y Yamaguchi[1], S Nakajima[2], A Kanno[2], T Kawanishi[2], M Izutsu[1], H Nakajima[1]; [1]*Graduate School of Advanced Science and Engineering, Waseda University, Japan;* [2]*National Institute of Information and Communications Technology, Japan*
We investigated a lithium niobate (LiNbO3) single Mach-Zehnder modulator (MZM) with an active Y-branch, which is similar to an optical Y-branch switch. Using the modulator, we demonstrated high extinction-ratio operation (>60 dB) and confirmed the function and the useful of the active Y-branch MZM.

P.2.16 • Tunable 1550-nm High Contrast Grating VCSEL Detector

W Yang[1], L Zhu[1], Y Rao[2], C Chase[2], M Huang[2], C J Chang-Hasnain[1]; [1]*Dept. of Electrical Engineering and Computer Sciences, University of California at Berkeley, USA;* [2]*Bandwidth10 Inc., USA*

We report a 1550-nm tunable transceiver using a monolithic high contrast grating VCSEL, functioning as both a laser and detector. A 1A/W responsivity, 33.5 nm tuning range, 1.2 nm spectrum width and 2.5 Gb/s detection speed are achieved at its detector mode. An error-free 1 Gb/s link between two such VCSEL detectors is experimentally demonstrated.

P.2.17 • Thin-Film Mach-Zehnder Lithium Niobate Optical Modulator on Silicon Substrates with VπL of 4·V-cm

P Rabiei[1], J Ma[1], J Chiles[1], S Khan[1,2], S Fathpour[1,2]; [1]*CREOL, The College of Optics and Photonics, University of Central Florida, USA;* [2]*Dept. of Electrical and Computer Engineering, University of Central Florida, USA*

Y-cut lithium niobate Mach-Zehnder optical modulators with record-low half-voltage length-product of 4 V-cm are demonstrated. A novel fabrication method that allows low-loss, high-index-contrast waveguides of lithium niobate on silicon substrate is used.

P.2.18 • Hybrid Integration of Lens-Integrated Surface-Emitting Laser for Silicon Photonics Light Source

T Suzuki[1], K Adachi[1], T Okumura[1], H Arimoto[1], S Tanaka[1]; [1]*Central Research Laboratory, Hitachi Ltd., Japan*

As a silicon photonics light source, a lens-integrated surface-emitting laser (LISEL) was integrated on a silicon-waveguide platform for the first time. Excess loss due to misalignment of +/- 5 µm between the LISEL and silicon waveguide is only 1.5 dB.

P.2.19 • Low-crosstalk 2 × 2 InGaAsP Photonic-wire Optical Switches using III-V CMOS Photonics Platform

Y Ikku[1], M Yokoyama[1], M Noguchi[1], O Ichikawa[2], T Osada[2], M Hata[2], M Takenaka[1], S Takagi[1]; [1]*Dept. of Electrical Engineering and Information Systems, The University of Tokyo, Japan;* [2]*Sumitomo Chemical Company Ltd., Japan*

Low-crosstalk electrically-driven 2 × 2 InGaAsP photonic-wire Mach-Zehnder interferometer optical switches are demonstrated on the III-V CMOS photonics platform. The low carrier-induced loss in InGaAsP enables crosstalk as low as -30 dB. The error-free switching of 12.5 Gb/s optical signals is also achieved with power penalty of less than 2 dB.

P.2.20 • 100Gb/s Multi-Guide Vertical Integration Transmitter PIC in InP for Fiber-Optics Interconnects

V Tolstikhin[1], S Ristic[1], K Pimenov[1], C Watson[1], M Florjanczyk[1]; [1]*OneChip Photonics Inc., Canada*

Regrowth-free monolithic transmitter PIC in InP, which comprises a distributed feedback laser, a laser monitor, a 1x4 beam splitter, four 25Gb/s electro-absorption modulators and four spot-size converters, is reported. With 1mm x 4.4mm footprint, it is among the most compact and power efficient transmitter optics solutions to 100Gb/s interconnects.

P.3 • Subsystems for Optical Networks and Datacoms

P.3.1 • Novel Baud-Rate Estimation Technique for M-PSK and QAM Signals based on the Standard Deviation of the Spectrum

M V Ionescu[1], M S Erkilinc[1], M Paskov[1], S J Savory[1], B C Thomsen[1]; [1]*Optical Networks Group, Dept. of Electronic & Electrical Engineering, University College London, UK*

A robust baud-rate estimation technique that is integrated into a coherent receiver prior to digital equalization and intermediate frequency estimation based on the standard deviation of the signal spectrum is presented. It is shown to operate from 4 to 25 GBaud QPSK signals with a maximum estimation error of 2% at the FEC limit of 3.8x10-3.

P.3.2 • Chromatic Dispersion Monitoring and Adaptive Compensation in an 8 x 12.5 Gb/s All-Optical OFDM System

S Shimizu[1], G Cincotti[2], N Wada[1]; [1]*National Institute of Information and Communications Technology, Japan;* [2]*Engineering Dept., University Roma Tre, Italy*

We propose and experimentally demonstrate a novel technique for chromatic dispersion (CD) monitoring and adaptive compensation in all-optical OFDM systems by using pilot symbols and a virtually imaged phased array. The adaptive CD compensation drastically improves the bit-error-rate from over 10^-5 to under 10^-9.

P.3.3 • SSMI Cancellation in Direct-detection Optical OFDM with Novel Half-cycled OFDM

F Li[1,2,3], Z Cao[5], X Li[4], L Chen[2]; [1]*ZTE, USA;* [2]*Hunan University, China;* [3]*Georgia Institute of Technology, USA;* [4]*Fudan University, China;* [5]*Eindhoven University of Technology, Netherlands*

Half-cycled DDO-OFDM transmission and reception was successfully demonstrated to resist SSMI without spectra efficiency reduction for the first time. The receiver sensitivity was improved by 2 and 1.5 dB in QPSK and 16QAM OFDM with 40-km SSMF-28 transmission, respectively.

P.3.4 • Polarization-Time Coded OFDM for PDL Mitigation in Long-Haul Optical Transmission Systems

E Awwad[1], Y Jaouën[1], G R-B Othman[1], E Pincemin[2]; [1]*Institute Telecom/Télécom ParisTech, France;* [2]*France Telecom, Orange Labs, France*

We experimentally demonstrate the potential of Polarization-Time codes in mitigating PDL in long-haul transmissions. The Silver code exhibits the best performance (2dB Q-penalty reduction at a PDL of 6dB). Moreover, for inline PDL, it improves the mean Q-factor by 0.6dB while significantly narrowing the variance of the corresponding distribution.

P.3.5 • Modified Walsh-Hadamard Transform for PDL Mitigation

W-R Peng[1], T Tsuritani[1], I Morita[1]; [1]*KDDI R&D Laboratories Inc., Japan*

We propose a modified Walsh-Hadamard transform (MWHT) that reduces the PDL penalty by equalizing the performance of both polarization tributaries. The realization of MWHT requires just one piece of PMF and therefore exhibits a very low-cost PDL solution.

P.3.6 • A Low-Complexity Carrier Phase and Frequency Offset Estimator with Adaptive Filter Length for Coherent Receivers

A Meiyappan[1], P-Y Kam[1], H Kim[1]; [1]*Dept. of Electrical and Computer Engineering, National University of Singapore, Singapore*

We present a low-complexity joint carrier phase and frequency offset estimator, with adaptive sample averaging length according to the modulation format, signal-to-noise ratio, and laser linewidth. No preset parameters are required. It also achieves complete frequency estimation range.

P.3.7 • Low-Complexity Linewidth-Tolerant Carrier Phase Estimation for 64-QAM Systems Based on Constellation Transformation

S M Bilal[1], G Bosco1, P Poggiolini1, C R S Fludger[2]; [1]*DET, Politecnico di Torino, Italy;* [2]*Cisco Optical GmbH, Germany*

A novel three-stage digital feed-forward carrier recovery algorithm based on the transformation of 64-QAM constellation into QPSK is proposed. For 1 dB penalty at BER=10-2, it can tolerate a linewidth-times-symbol-rate product of 4.5x10-5, making it possible to operate 32-Gbaud optical 64-QAM systems with current commercial tunable lasers.

P.3.8 • Enhanced Performance for Implicit Training-Aided Coherent Optical Systems by Self-Interference Removal

C Zhu[1], A V Tran[1], T Anderson[1], E Skafidas[1]; [1]*Victoria Research Laboratory, NICTA Ltd, University of Melbourne, Australia*

We present an approach to eliminate the data-induced interference to the channel estimation of implicit training-aided coherent optical systems by removing the cyclic mean of the transmitted signal. The proposed method shows large improvement in both QPSK and 16-QAM experiments, and can achieve comparable performance as the blind adaptation scheme.

P.3.9 • Investigation of Polarization-Insensitive Phase Regeneration using Polarization-Diversity Phase-Sensitive Amplifier

J-Y Yang[1], M Ziyadi[2], Y Akasaka[1], S Khaleghi[2], M R Chitgarha[2], J Touch[2,3], M Sekiya[1]; [1]*Fujitsu Laboratories of America, USA;* [2]*Dept. of Electrical Engineering, University of Southern California, USA;* [3]*Dept. of Computer Science, University of Southern California, USA*

We investigate a polarization-diversity PSA for polarization-insensitive phase regeneration of single- and dual-polarization phase modulation formats. We show effective reduction on phase noise insensitive to signal's polarization by simulations and preliminarily verify this PSA by experiments.

P.3.10 • DFT-based Offset-QAM OFDM with Arbitrary Orthogonal Waveform Generation

J Zhao[1]; [1]*Photonics Systems Group, Tyndall National Institute, University College Cork, Ireland*

We propose and experimentally demonstrate DFT-based offset-QAM OFDM which can achieve sub-channel orthogonality using various signal spectral profiles, in contrast to sinc-function based conventional OFDM and rectangular-function based Nyquist frequency division multiplexing.

P.3.11 • Improved Performance of Optical F-OFDM over Conventional OFDM for Residual Frequency Offset Compensation

J Zhao[1]; [1]*Photonics Systems Group, Tyndall National Institute, University College Cork, Ireland*

We experimentally show that the tolerance of residual frequency offset (RFO) to subcarrier spacing ratio of optical fast OFDM is four times greater than that of conventional OFDM, when multi-tap equalizers are applied for the RFO compensation.

P.3.12 • In-band OSNR Monitor using an Optical Bandpass Filter and Optical Power Measurements for Superchannel Signals

S Oda[1], J-Y Yang[2], Y Akasaka[2], K Sone[1], Y Aoki[1], M Sekiya[2], J C Rasmussen[1]; [1]*Fujitsu Laboratories, Ltd., Japan;* [2]*Fujitsu Laboratories of America, Inc., USA*

We propose a novel in-band OSNR monitor using an optical bandpass filter and power measurements for superchannel signals and experimentally demonstrate accurate OSNR monitoring of two-subcarrier DP-16QAM signal and higher tolerance to spectral narrowing.

P.3.13 • Tunable Optical Code Converter using Two Linear-Slope Pulse Streams and Cross Phase Modulation

T Kodama[1], N Wada[2], G Cincotti[3], K Kitayama[1]; [1]*Dept. of Electrical, Electronics and Information Engineering, Osaka University, Japan;* [2]*National Institute of Information and Communications Technology, Japan;* [3]*Engineering Department, University Roma Tre, Italy*

A tunable multiple optical code converter for flexible OCDM-based networks is demonstrated for the first time, that allows dynamic code (bandwidth) allocation. The proposed scheme uses two linear-slope control pulse streams in the C-band.

P.3.14 • A Direct Sequence Coherent OCDMA Proposal Employing a Code-Tunable SOI Intregrated Encoder and a Multi-band & Multi-code SSFBG Decoder

R Baños[1], D Pastor[1], D Domenech[1,2]; [1]*Instituto de Telecomunicaciones y Aplicaciones Multimedia, Universidad Politécnica de Valencia, Spain;* [2]*VLC Photonics S.L., Universidad Politécnica de Valencia, Spain*

We present, to the best of our knowledge, a Code-Tunable Direct Sequence Coherent OCDMA integrated device based on Silicon On Insulator. Moreover to perform the En-Decoding process a novel design of Super Structured Fibre Bragg Gratings with multiple en-decoding bands asigged to different codes is demonstrated.

P.3.15 • WDM-PDM Signal Processing based on a Silicon Polarization Insensitive Filter

Y Qin[1], Y Yu[1], L Xiang[1], J Zou[1], B Zou[1], X Zhang[1]; [1]*Wuhan National Laboratory for Optoelectronics & School of Optoelectronic Science and Engineering, Huazhong University of Science and Technology, China*

We propose and fabricate a silicon based polarization insensitive scheme consisting of a micro ring resonator and two 2-dimensional grating couplers. For demonstration, simultaneous demodulation for WDM-PDM NRZ-DPSK signals has been achieved successfully with error free, reflecting the good performance and the practicability of the proposed scheme.

P.3.16 • Blind Cycle-Slip Detection and Correction for Coherent Communication Systems

Y Gao[1], A P T Lau[1], C Lu[2], Y Dai[3], X Xu[3]; [1]*Photonics Research Center, Dept. of Electrical Engineering, The Hong Kong Polytechnic University, Hong Kong;* [2]*Photonics Research Center, Dept. of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hong Kong;* [3]*Huawei Technologies Co., Ltd., China*

We propose a blind cycle-slip detection and correction(CS-DC) technique based on locating the minimum of the sliding average of twice estimated phase noise ej2φ. Simulation results demonstrate a residual CS probability of 2x10-7 even in highly nonlinear systems.

P.3.17 • Employing DDBPSK in Optical Burst Switched Systems to Enhance Throughput

A J Walsh[1], T N Huynh[1], J Mountjoy[2], A Fagan[2], A D Ellis[3,1], L P Barry[1]; [1]*Rince Institute, Dublin City University, Ireland;* [2]*School of Electrical, Electronic and Communications Engineering, University College Dublin, Ireland;* [3]*Aston Institute of Photonic Technologies, School of Engineering and Applied Science, Aston University, UK*

We demonstrate that doubly differential decoding can demodulate phase shift keyed data much faster after the switching event of a tunable laser than usual mth power single differential decoding. This technique can significantly improve throughput of optical burst switched networks.

P.3.18 • Joint Iterative Carrier Synchronization and Signal Detection for Dual Carrier 448 Gb/s PDM 16-QAM

D Zibar[1], L Carvalho[2], J Estaran[2], E Silva[2], C Franciscangelis[2], V Ribeiro[2], R Borkowski[2], J Oliveira[2], I T Monroy[1]; [1]*Technical University of Denmark, Denmark;* [2]*CPqD Centro de Pesquisa e Desenvolvimento em Telecomunicações, Brazil*

Soft decision driven joint carrier synchronization and signal detection, employing expectation maximization, is experimentally demonstrated. Employing soft decisions offers an improvement of 0.5 dB compared to hard decision, digital PLL based, carrier synchronization and demodulation.

P.3.19 • Wideband Wavelength Conversion of 5 Gbaud 64-QAM Signals in a Semiconductor Optical Amplifier

B Filion[1], W C Ng[1], A Nguyen[1], L A Rusch[1], S LaRochelle[1]; [1]*Dept. of Electrical and Computer Engineering, COPL, Université Laval, Canada*

We demonstrate wideband wavelength conversion of 64-QAM signals with BER below the forward error correction threshold (2x10-3) over the entire C-band using two co-polarized pumps. We also investigate the dependence of the power penalty on input optical-signal-to-noise-ratio with a single pump configuration.

P.3.20 • TONAK: A Distributed Low-latency and Scalable Optical Switch Architecture

R Proietti[1], C J Nitta[1], Y Yin[1], V Akella[1], S J B Yoo[1]; [1]*Dept. of Electrical and Computer Engineering, University of California, Davis, USA*

This paper proposes TONAK, an AWGR-based optical switch with distributed control plane. Simulations results for a 128-port switch show high throughput and low average packet latency for offered loads of up to 75%, while achieving an energy efficiency of ≈ 50pJ/bit.

P.3.21 • Optical Grooming of OOK and DQPSK Signals by 8 APSK Signal Generation in PPLN Waveguide

S Pinna[1], A Malacarne[2], A Bogoni[2]; [1]*Scuola Superiore Sant'Anna, TeCIP, Italy;* [2]*National Laboratory of Photonic Networks, CNIT, Italy*

We experimentally implement and characterize a novel integrable and wavelength preserving PPLN-based scheme, for optical grooming of a 20Gbps OOK and a 40Gbps DQPSK signals into a 20Gbaud 8-APSK one. Device performance are evaluated by BER and OSNR penalty measurements.

P.3.22 • Optical and RF Power Requirements for a new Injection-locked Semiconductor Laser Diode Method Compared with Conventional Approaches for QPSK and QAM Modulations

R Slavik[1], B Kelly[2], R Phelan[2], J O'Carroll[2], D J Richardson[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK;* [2]*Eblana Photonics Ltd., Ireland*

Our recently-developed QAM synthesis using direct modulation of injection locked semiconductor lasers is analysed in terms of the optical and RF power requirements and compared with IQ modulation and multiple binary modulator schemes.

P.3.23 • Fast Optical Spectrum Estimation using a Digital Coherent Receiver

H-M Chin[1], K Shi[1], R Maher[1], M Paskov[1], B Thomsen[1], S Savory[1]; [1]*Optical Networks Group, Dept. of Electronic & Electrical Engineering, University College London, UK*

We investigate the use of a fast switching DSDBR tunable laser in a coherent receiver to enable microsecond sweeping time over the C-band. Thomson's Multitaper method is used to estimate spectral slices which are then digitally stitched to form the complete scanned spectrum.

P.3.24 • All-Optical Phase-Preserving Amplitude Regeneration of a 640 Gbit/s RZ-DPSK Signal

Z Lali-Dastjerdi[1], M Galili[1], H C Hansen Mulvad[1], H Hu[1], L K Oxenløwe[1], K Rottwitt[1], C Peucheret[1]; [1]*DTU Fotonik, Technical University of Denmark, Denmark*

Phase-preserving amplitude regeneration based on optical parametric amplification has been experimentally demonstrated for a 640 Gbit/s RZ-DPSK signal. Improvement of 2.2 dB in receiver sensitivity at a BER of 10^{-9} together with 13.3 dB net gain have been successfully achieved.

P.3.25 • Receiver Sensitivity Enhancement by Using Subcarrier Reliability Aware Soft LDPC in CO-OFDM Systems

D Che[1,2], H Khodakarami[2], A Li[2], X Chen[2], T Anderson[1,2], W Shieh[2]; [1]*Victoria research laboratory, NICTA Ltd., Australia;* [2]*Electrical and Electronic Engineering, University of Melbourne, Australia*

We propose a concatenated LDPC and Reed-Solomon coding scheme for CO-OFDM systems taking consideration of varying reliability among different subcarriers. BER performance measurement shows that such reliability-aware soft LDPC is effective in combating near-DC noise for CO-OFDM systems.

P.3.26 • Time-lens Based Optoelectronic Oscillator for Simultaneous Clock Recovery and Demultiplexing of OTDM Signal

Y Xing[1], L Huo[1], Q Wang[1], X Jiang[1], H Li[1], C Lou[1]; [1]*Dept. of Electronic Engineering, Tsinghua University, China*

Time-lens base optoelectronic oscillator was proposed. Simultaneous clock recovery and demultiplexing were demonstrated with 100-Gb/s OTDM signal. 25-GHz tributary clock with 122-fs timing jitter was obtained and error-free demultiplexing with a power penalty of 1.7 dB was achieved.

P.3.27 • Method for Determining the Low-Pass Filter Bandwidth for the Low-Pass Filter Assisted Digital Back Propagation Algorithm

Y Gao[1], J H Ke[1], J C Cartledge[1], S S-H Yam[1]; [1]*Dept. of Electrical and Computer Engineering, Queen's University, Canada*

A methodology is presented for estimating the bandwidth of the low-pass filter (LPF) used in the LPF assisted digital back propagation algorithm for mitigating the effects of intra-channel fiber nonlinearities. The usefulness of the methodology is demonstrated for an experimental 112 Gb/s dual-polarization 16-QAM system.

P.3.28 • A Novel Single-Input Multiple-Output Encoder/Decoder and its Application to Optical Packet Switching

B Dai[1], X Wang[1], S Shimizu[2], N Wada[2]; [1]*Heriot-Watt University, UK;* [2]*National Institute of Information and Communications Technology, Japan*

We propose a single-input multiple-output en/decoder, which can simultaneously and flexibly generate and separate a group of independent optical codes in the different optical paths with a specific permutation and combination of code patterns. We demonstrate the en/decoder for all-optical label processing in an optical packet switching system.

P.3.29 • Self-pumping Wavelength Conversion of Mixed Order PSK Signals by FWM to Realise Band Conversion

K R Bottrill[1], F Parmigiani[1], D J Richardson[1], P Petropoulos[1]; [1]*Optoelectronics Research Centre, University of Southampton, UK*

We present an FWM based wavelength conversion that differs from the typical approach in requiring no additional pump sources; two PSK signals are mixed in an HNLF, effectively pumping each other to facilitate wavelength conversion. The approach enables us to demonstrate band conversion as well as conversion of PSK signals of differing order.

P.3.30 • Autonomous Software-Defined Coherent Optical Receivers Performing Modulation Format Recognition in Stokes-Space

P P Isautier[1], A Stark[2], J Pan[1], K Mehta[3], S E Ralph[1]; [1]*School of Electrical and Computer Engineering, Georgia Institute of Technology, USA;* [2]*Georgia Tech Research Institute, USA;* [3]*Qualcomm, USA*

We present a hybrid modulation format recognition method combining Stokes-space analysis/higher-order-statistics, robust in lower OSNR conditions that successfully identifies OOK/BPSK/QPSK/16-QAM. The new architecture's blind demodulation performance is compared to our previous one using experimental 1056km transmission data at 16/32Gbaud.

P.3.31 • Statistical Properties of Broadband Chaotic Signals for Ultrafast True Random Bit Sequence Generation

A Argyris[1], M Bourmpos[1], A Bogris[1,2], D Syvridis[1]; [1]*Informatics and Telecommunications, National and Kapodistrian University of Athens, Greece;* [2]*Dept. of Informatics, Technological Educational Institute of Athens, Greece*

Optical chaotic carriers can be exploited as sources for true random bit sequence (TRBS) generation at ultrafast rates for securing data transmission. An experimental investigation on the statistical properties of such signals is performed and associated to TRBS generation performance.

P.3.32 • First All-optical Alamouti Coding Demonstration for Polarization Diversity Transmissions via Optical Phase Conjugation

S Inudo[1], Y Yoshida[1], A Maruta[1], K Kitayama[1]; [1]*Graduate School of Engineering, Osaka University, Japan*

An all-optical space-time coding technique for polarization diversity transmissions is proposed and experimentally demonstrated for the first time. Based on the wavelength-shift-free optical phase conjugation technique, the Alamouti-type polarization-time coding is realized in the optical domain without additional electro-optic modulation circuits.

P.4 • Point-to-Point Transmission Systems

P.4.1 • High Spectral Efficiency for Long-haul Optical Links: Time-Frequency Packing vs High-order Constellations

G Colavolpe[1], T Foggi[2]; [1]*Dipartimento di Ingegneria dell'Informazione, Università degli Studi di Parma, Italy;* [2]*CNIT, University of Parma, Italy*

We investigate the time-frequency packing technique on long-haul optical links in order to increase the spectral efficiency. This solution is compared to high-order formats at equal bit or baud rate, demonstrating that higher spectral efficiency can be more effectively reached.

P.4.2 • Self-Homodyne Detection of Polarization-Multiplexed Pilot Tone Signals Using a Polarization Diversity Coherent Receiver

R S Luis[1], B J Puttnam[1], J-M D Mendinueta[1], J Sakaguchi[1], S Shinada[1], M Nakamura[2], Y Kamio[1], N Wada[1]; [1]*National Institute of Information and Communications Technology, Japan;* [2]*Dept. of Electronics and Bioinformatics, School of Science and Technology, Meiji University, Japan*

We report a new detection scheme for self-homodyne receivers using a polarization diversity receiver and a prototype pilot tone vector modulator. We show superior performance comparing with intradyne detection using MHz-linewidth lasers, low baud rate QPSK and 16QAM signals and demonstrate 0.9dB improvement in resilience to fiber nonlinearities.

P.4.3 • Feasibility Study of Wide-Band In-line SOA Amplification for PDM-MQAM Long-haul WDM Transmission Systems

D F Bendimerad[1], A Ghazisaeidi[2], J Vuong[1], P Ramantanis[1], A Seck[1], J Renaudier[2], Y Frignac[1]; [1]*Mines-Télécom/Telecom SudParis, France;* [2]*Alcatel-Lucent Bell Labs, France*

We present a numerical investigation for the use of semiconductor optical amplifiers (SOA) as broadband amplifiers in a context of quasi-Nyquist WDM long-haul transmission using PDM-QPSK, 8-QAM and 16-QAM modulation formats. The SOAs nonlinear behavior is assessed for each format considering different numbers of channels and cumulative dispersion.

P.4.4 • Transmission of a DAC-Free 1.12-Tb/s Superchannel with 6-b/s/Hz over 1000 km with Hybrid Raman-EDFA Amplification and 10 Cascaded 175-GHz Flexible ROADMs

L H H Carvalho[1,2], C Franciscangelis[1], E p Silva[1], S H Linakis[1], V E Parahyba[1], J R F Oliveira[1], G E R Paiva[1], N G Gonzalez[1], A C Bordonalli[2], J C R F Oliveira[1]; [1]*CPqD Foundation, Brazil;* [2]*Unicamp, School of Electrical Engineering & Computer Engineering, Brazil*

We investigated the performance of a 1.12-Tb/s (5x224-Gb/s PDM-16QAM) superchannel with 6-b/s/Hz, using optical prefiltering, over hybrid LongLine-SSMF link with hybrid Raman-EDFA amplification and cascaded 175-GHz ROADMs. A maximum reach of 1000-km with 10-ROADM passes was obtained employing nonlinear compensation.

P.4.5 • System Performance of Long-Haul 112-Gb/s PDM-QPSK DWDM Transmission over Large-area Fiber and SSMF Spans

B Zhu[1], D W Peckham[2], X Jiang[2], R Lingle Jnr[2]; [1]*OFS Labs, USA;* [2]*OFS, USA;* [3]*City University of New York, USA*

We experimentally compare the system performance of 80x112-Gb/s DWDM transmission over large-area-fiber and SSMF spans. The large-area-fiber offers ~2.6 dBm higher optimum launch power with about 1.5dB Q-factor improvement than SSMF at 32x100-km, and about 63% longer reach than SSMF.

P.4.6 • 48.8-Gb/s 16-QAM Direct-Detection Optical OFDM Based on Block-wise Signal Phase Switching

A Li[1], D Che[1], X Chen[1], Q Hu[1], Y Wang[1], W Shieh[1]; [1]*Dept. of Electrical & Electronic Engineering, The University of Melbourne, Australia*

We propose a novel scheme of direct-detection optical OFDM system based on block-wise signal-phase-switching (SPS). Experimental demonstration of 48.8-Gb/s SPS-DDO-OFDM signal transmission over 80-km SSMF was achieved with single polarization and photo-detector.

P.4.7 • Optimization Method for PSA-based Multi-Level Regenerators

M Sorokina[1], S Sygletos[1], S Turitsyn[1]; [1]*Aston Institute of Photonics Technologies, Aston University, UK*

We develop an analytical methodology for optimizing phase regeneration based on phase sensitive amplification. The results demonstrate the scalability of the scheme and show the significance of simultaneous optimization of transfer function and the signal alphabet.

P.4.8 • Nonlinear Compensation for 1.76Tbit/s PDM-16QAM Nyquist-SCFDE Superchannel Transmission

R Ding[1], Z Zheng[1], Z Huang[1], F Zhang[1], Z Chen[1], C Yang[1]; [1] *State Key Laboratory of Advanced Optical Communications and Networks, Peking University, China*

We present several nonlinear compensation algorithms and demonstrate their performance on both 44.1Gbit/s single channel and 1.76Tbit/s superchannel Nyquist-SCFDE PDM-16QAM transmission systems. Up to 1.6dB Q improvement for single channel and 0.66 dB for superchannel can be achieved by nonlinear compensation.

P.4.9 • Optical Link Design for Minimum Power Consumption and Maximum Capacity

N J Doran[1], A D Ellis[1]; [1]*AIPT, Aston University, UK*

Using a well-established analytic nonlinear signal-to-noise ratio noise model we show that there are very simple, fibre independent, amplifier gains which minimize the total energy requirement for amplified systems. Power savings of over 50% are shown to be possible by choosing appropriate amplifier gain and output power.

P.4.10 • Optimum Design for Compensation Method of Intra-channel Nonlinear Distortions based on Digital Backpropagation assisted by Mitigation with CD pre-compensation

D Ogasahara[1], W Maeda[1], M Arikawa[1], T Ito[1], H Noguchi[1], J Abe[1], F Kiyoshi[1]; [1]*Green Platform Research Laboratories, NEC Corporation, Japan*

We propose an optimum design of nonlinear compensation based on digital backpropagation assisted by mitigation with CD pre-compensation in order to reduce circuit resources. Transmission experiment with a 127Gbps PM-QPSK signal over a 2,400km SSMF line exhibits Q improvement with small stage number backpropagation and -20% CD pre-compensation.

P.4.11 • Nonlinear Performance Limits in Highly Dispersive Transmission Systems

F Matera[1]; [1]*Fondazione Ugo Bordoni, Italy*

This paper shows how to evaluate the performance of long haul optical transmission systems operating in high dispersed pulse propagation regimes by means of a simple Q factor formula valid also for polarization multiplexing and extended to WDM systems.

P.4.12 • Information Quality (IQ) Factor as Soft-Decision Decoding Threshold for Optical Communications

T Fehenberger[1], N Hanik[1]; [1]*Institute for Communications Engineering, Technische Universität München, Germany*

A novel quantity called IQ-factor is proposed that facilitates the analysis of soft-decision decoding. The IQ-factor is based on mutual information and naturally relates to the Q-factor. We use IQ to define decoding thresholds. Simulations show that IQ is an accurate estimate of the system performance.

P.4.13 • Iterative Bit and Power Loading for Coherent Optical OFDM to Account for Fiber Nonlinearities

F Wäckerle[1], S Stern[1], R Fischer[1]; [1]*Institut für Nachrichtentechnik, Universität Ulm, Germany*

We assess adaptive modulation techniques for bandwidth-elastic, continuously spaced CO-OFDM systems. An iterative loading algorithm employing an FWM-based nonlinear interference model is proposed. Increased tolerance to fiber nonlinearities compared to conventional loading schemes and significant improvements over non-loaded schemes are obtained.

P.4.14 • Comparison of Numerical Bit Error Rate Estimation Methods in 112Gbs QPSK CO-OFDM Transmission

S T Le[1], K J Blow[1], V R Menzentsev[1], S K Turitsyn[1]; [1]*Aston Institute of Photonics Technologies, Aston University, UK*

We demonstrate an accurate BER estimation method for QPSK CO-OFDM transmission based on the probability density function of the received QPSK symbols. Using a 112Gbs QPSK CO-OFDM transmission as an example, we show that this method offers the most accurate estimate of the system's performance in comparison with other known approaches.

P.4.15 • Improved Analytical Model for Intra-Channel Nonlinear Distortion by Relaxing the Lossless Assumption

Y Zhao[1], L Dou[1], Z Tao[1], M Yan[1], S Oda[2], T Tanimura[2], T Hoshida[3], J C Rasmussen[2]; [1]*Fujitsu R&D, China;* [2]*Fujitsu Laboratories Ltd., Japan;* [3]*Fujitsu Ltd, Japan*

We present an analytical solution for intra-channel nonlinearity based on perturbation theory. By relaxing the unrealistic lossless assumption in the conventional method, the model accuracy is improved by 20% for 1500km CD-managed link. Further application of the model shows a 0.6dB Q improvement under a 128Gb/s DP-QPSK pre-distortion experiment.

P.4.16 • Improved Bounds on the Nonlinear Fiber-Channel Capacity

R Dar[1], M Shtaif[1], M Feder[1]; [1]*School of Electrical Engineering, Tel Aviv University, Israel*

By taking advantage of the temporal correlations of nonlinear phase noise in WDM systems we show that the capacity of a nonlinear fiber link is notably higher than what is currently assumed. This advantage is translated into the doubling of the link distance for a fixed transmission rate.

P.4.17 • Experimental Study of the Impact of Dispersion Pre-Compensation on PDM-QPSK and PDM-16QAM Performance in Inhomogeneous Fiber Transmission

X Liu[1], S Chandrasekhar[1]; [1]*Alcatel-Lucent, Bell Labs, USA*

We show experimentally that the nonlinear transmission performance of Nyquist-filtered 128-Gb/s PDM-QPSK and 256-Gb/s PDM-16QAM signals is direction-dependent in inhomogeneous fiber links. We further study the impact of electronic dispersion pre-compensation on the performance in the underperforming direction for superchannel transmission.

P.4.18 • Extending 100G Transatlantic Optical Transmission over Legacy DMF Fibers using Time-Domain Four-Dimensional Nonbinary LDPC-Coded Modulation

Y Zhang[1], S Zhang[2], I B Djordjevic[1], F Yaman[2], T Wang[2]; [1]*Dept. of Electrical and Computer Engineering, University of Arizona, USA;* [2]*NEC Laboratories America, USA*

The transmission reach of 102.4 Gb/s Nyquist-shaped signal has been experimentally improved to 7,680 km by employing time-domain four-dimensional nonbinary LDPC-coded modulation scheme, resulting in 1,440 km extended distance compared to the counterpart nonbinary LDPC-coded PDM-QPSK.

P.5 • Optical Transport and Large Scale Data Networks

P.5.1 • Optimization of Subcarrier Spacing of 400 Gb/s Dual-Carrier Nyquist PDM-16QAM in a Flexgrid Scenario
C Schmidt-Langhorst[1], F Frey[1], M Noelle[1], R Elschner[1], C Meuer[2], P Wilke-Berenguer[1], C Schubert[1]; [1]*Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Germany;* [2]*Technical University Berlin, Hochfrequenztechnik - Photonics, Germany*
For a 448 Gb/s dual-carrier 28-GBd Nyquist PDM-16QAM data signal we investigate experimentally the trade-off between inter-subcarrier crosstalk and tight optical filtering after passing through a wavelength selective switch at Flexgrid channel bandwidths of 75, 63 and 50 GHz.

P.5.2 • Online Repurposing and Dimensioning of a Programmable Fixed-Grid and Flex-Grid Optical Network
B R Rofoee[1], G Zervas[1], Y Yan[1], D Simeonidou[1]; [1]*High Performance Networks, University of Bristol, UK*
This paper reports on architectural and performance analysis of online re-purposed networks built with programmable data and control plane for Fixed and Flex-Grid communication. The studies demonstrate the effect of node placement strategies on performance and the corresponding trade offs.

P.5.3 • Dynamic Provisioning via a Stateful PCE with Instantiation Capabilities in GMPLS-Controlled Flexi-grid DWDM Networks
R Casellas[1], R Martínez[1], R Muñoz[1], L Liu[2], T Tsuritani[3], I Morita[3]; [1]*CTTC, Spain;* [2]*University of California, Davis, USA;* [3]*KDDI R&D Laboratories, Inc., Japan*
We report the implementation and performance evaluation of an active stateful PCE that relies on a GMPLS control plane for the actual provisioning of elastic connections in a flexi-grid DWDM network. It is based on experimental extensions to the PCEP protocol and enables more advanced and concurrent path computations.

P.5.4 • Energy- and Cost-Efficient Protection in Core Networks by a Differentiated Quality of Protection Scheme
J Lopez[1,3], Y Ye[1], F Jimenez[2], P M Krummrich[3]; [1]*Huawei Technologies Duesseldorf GmbH, Germany;* [2]*Telefónica I+D, Spain;* [3]*Techniche Universitaet Dortmund, Germany*
A differentiated quality of protection scheme is proposed as an energy-and cost-efficient protection strategy for long-haul optical networks. Significant energy efficiency per GHz improvements and CapEx reductions can be achieved for both fixed-grid WDM and flexible-grid networks.

P.5.5 • Interest of the MIXGRID Setup for Elastic Spectral Efficiency
T Zami[1]; [1]*Alcatel-Lucent, France*
We quantify the benefit of elastic WDM networks aligning channels on one irregular grid of optical frequencies on all their transmission links to mitigate the routing constraints. The channels are modulated at constant baud rate with variable bit rate.

P.5.6 • Unified Approach of Top-down and Bottom-up Methods for Estimating Network Energy Consumption
K Ishii[1], F Okazaki[1], J Kurumida[1], K Mizutani[2], H Takeshita[2], K Kobayashi[1], D Mochinaga[3], S Namiki[1], K Sato[4], T Kudoh[1]; [1]*National Intitute of Advanced Industrial Science and Technology, Japan;* [2]*Green Platform Research Laboratories, NEC Corporation, Japan;* [3]*Mitsubishi Research Institute, Inc., Japan;* [4]*Nagoya University, Japan*
We present a unified approach of top-down and bottom-up methods for estimating network energy consumption by introducing weighting factors for network areas, which allows accurate estimation of the absolute value and scaling at the same time. Applying this approach to Japan shows introduction of optical cut-through will save energy by 20% in 2030.

P.5.7 • Design and Experimental Evaluation of Dynamic Inverse-Multiplexing Provisioning in GMPLS-controlled Flexi-Grid DWDM Networks with Sliceable OTN BVTs
R Muñoz[1], R Vilalta[1], R Casellas[1], R Martínez[1], S Frigerio[2], A Lometti[2]; [1]*Centre Tecnològic de Telecomunicacions de Catalunya, Spain;* [2]*Alcatel Lucent Italia, Italy*
We present and experimentally evaluate a GMPLS/PCE control architecture for dynamic provisioning of inverse-multiplexed elastic optical connections in flexi-grid DWDM networks, combining sliceable bandwidth-variable transponders (BVTs) and OTN signals.

P.5.8 • Open Virtual Infrastructure: Implementation Framework for Integrated Provisioning of Virtualized Network and Application Resources based on Software Defined Networking (SDN)
Y Yu[1], J Zhang[1], Y Zhao[1], S Wang[1], H Yang[1], H Li[1], Y Ji[1], Y Lin[2], J Han[2], S Qiu[2]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, China;* [2]*Huawei Technologies Co., Ltd., China*
We propose an hourglass-model-based control framework named Open Virtual Infrastructure (OVI) for integrated virtualization of ICT infrastructure including optical/IP networks and data centers, which can provide heterogeneous virtualized resources for different customers. Experimental demonstration is conducted with results of 20% cost reduction.

P.5.9 • Influence of Embodied Energy in the Energy Efficiency of Optical Transport Networks
J Mata[1,2], Y Ye[1], J Lopez[1], I T Monroy[2]; [1]*Huawei Technologies Duesseldorf GmbH, Germany;* [2]*DTU Fotonik Technical University of Denmark, Denmark*
An energy model including both operational and embodied energy is proposed to evaluate the performance evolution of optical transport networks in a multi-period study up to 15 years. Significant improvements in energy efficiency per GHz and energy reductions can be achieved for flexi-grid OFDM-based networks with respect to fixed-grid WDM ones.

P.5.10 • Fiber Routing, Wavelength Assignment and Multiplexing for DWDM-Centric Converged Metro/Aggregation Networks
S Zhang[1], M Xia[2], S Dahlfort[2]; [1]*University of California, Davis, USA;* [2]*Ericsson Research, USA*
The planning problem of novel DWDM-centric converged metro/aggregation networks is solved by algorithms based on intelligent wavelength assignment and an auxiliary-graph approach that exploits load-balanced routing and the optical-multiplexing capability of WSSes.

P.5.11 • Fixed versus Flex Grid with Route Optimised Modulation Formats and Channel Data Rates of 400 Gbits and Above
D J Ives[1], S J Savory[1]; [1]*Optical Networks Group, Dept. of Electronic and Electrical Engineering, University College London, UK*
We optimise a 5-node resource limited mesh network with data rates of 400 Gbits and above. We show that by optimising the modulation format as part of the routing algorithm the network throughput can be increased. Fixed and flex grid solutions were compared showing similar throughput however a fixed 75 GHz grid required fewer transceivers.

P.5.12 • Dynamic Advance Reservation Multicast in Data Center Networks over Elastic Optical Infrastructure
S Shen[1], W Lu[1], X Liu[1], L Gong[1], Z Zhu[1]; [1]*University of Science and Technology of China, China*
We investigate dynamic advanced reservation (AR) multicast in data center networks over elastic optical infrastructure, and propose several algorithms to realize all-optical AR multicasting for data center backup and migration by considering request scheduling and RSA jointly.

P.5.13 • Experimental Demonstration of a Contentionless GMPLS-based Light Path Setup using Colourless and Directionless ROADMs
A Frikha[1], M D Mbaye[1], J Meuric[1], E Le Rouzic[1]; [1]*Orange Labs, France*
We implement a GMPLS-based control plane that solves the contention problem of Colourless and Directionless (CD) ROADMs. The method is simpler than implementing CD & Contentionless (CD&C) ROADMs and avoids the complex extension of OSPF-TE.

P.5.14 • An Efficient Model for the Multilayer Network Planning of IP-over-WDM Networks
M Nikolayev[1], A Morea[1], Y Pointurier[1], J-C Antona[1]; [1]*Alcatel-Lucent Bell Labs, France*
We present for the first time "the stair function", a characteristic function corresponding to a routing and grooming (RG) algorithm and a topology. It allows to estimate the results of network planning over a vast scope of traffic matrixes, to evaluate in detail and to compare RG algorithms independently from a traffic scenario.

P.5.15 • Dynamic Resource Allocation with Virtual Grid for Space Division Multiplexed Elastic Optical Network
S Fujii[1], Y Hirota[1], H Tode[2]; [1]*Dept. of Information Networking, Graduate School of Information and Technology, Osaka University, Japan;* [2]*Dept. of Computer Science and Intelligent Systems, Graduate School of Engineering, Osaka Prefecture University, Japan*
We proposed on-demand spectrum and core allocation method which constructs virtual grid for space division multiplexed elastic optical network. Virtual grid requires relatively simple switch configuration. Simulation result shows that virtual grid can improve both blocking probability and inter-core crosstalk.

P.5.16 • Reachability Matrix-based Path Computation using Matrix Self-Multiplication
X Wang[1], C Gao[2], Q Zhang[1], M Bouda[1], P Palacharla[1], M Sekiya[1]; [1]*Fujitsu Labs of America, USA;* [2]*The University of Texas at Dallas, USA*
We present a novel all-optical reachability matrix-based path computation procedure that calculates end-to-end reachable paths with either minimum or specified number of regenerators using simple matrix multiplications, as well as satisfying constraints such as latency/cost. We demonstrate practical computation times for real-world networks.

P.5.17 • Hitless Network Re-Optimization to Reduce Spectrum Fragmentation in Distributed GMPLS Flexible Optical Networks
D Siracusa[1], A Broglio[1], A Zanardi[1], E Salvadori[1], G Galimberti[2], D La Fauci[2]; [1]*CREATE-NET, Italy;* [2]*Cisco Photonics, Italy*
This paper presents a network re-optimization procedure moving the spectrum allocation of connections in a distributed fashion to defragment flexible optical networks, according to the proposed policies. Without changes to GMPLS standards, it improves network performance without traffic disruptions or excessive burdens for the control plane.

P.5.18 • Self-Healing Optical Networks with Architecture on Demand Nodes
M Dzanko[1], M Furdek[1], N A Gonzalez[2], G Zervas[2], B Mikac[1], D Simeonidou[2]; [1]*Dept. of Telecommunications, University of Zagreb, Faculty of Electrical Engineering and Computing, Croatia;* [2]*Dept. of Electrical and Electronic Engineering, University of Bristol, UK*
Architecture on Demand (AoD) can provide self-healing at the optical node level due to its flexibility and the ability to employ idle components for failure recovery. We study the impact of AoD to network availability at different traffic switching granularities, showing significant improvements compared to traditional static node architecture.

P.6 • Access, Local Area and Data Center Networks

P.6.1 • Demonstration of WDM/TDM-PON Prototype Transceiver Employing SOA to Suppress Beat Noise
H Iwamura[1];M Sarashina[1], H Saito[1], H Tamai[1], S Kobayashi[1], M Minato[1], M Kashima[1]; [1]*Oki Electric Industry Co. Ltd., Japan*
We investigated the requirement of the extinction characteristic for WDM/TDM-PON transceiver to split over 128 on single wavelength. The prototype transceiver integrating SOA with high extinction capability around 50dB was developed and demonstrated the suppression of beat noise.

P.6.2 • Real-Time Demonstration of DMT-based DDO-OFDM Transmission and Reception at 50Gb/s
F Li[1,2], X Xiao[1], X Li[3], Z Dong[1]; [1]*ZTE, USA;* [2]*Hunan University, China;* [3]*Fudan University, China*
Real-time DMT-based DDO-OFDM transmission and reception is successfully demonstrated at a record line rate of 50Gbps. The measured BER after 20-km LEAF is less than the SD pre-FEC limit of 2.7×10-2.

P.6.3 • Modal Noise Impact in Plastic Optical Fiber Links for Radio-over-Fiber Systems
M Matsuura[1], R Furukawa[1], A Inoue[2], Y Koike[2]; [1]*The Center for Frontier Science and Engineering, University of Electro-Communications, Japan;* [2]*Keio Photonics Research Institute, Keio University, Japan*
We evaluate and compare the modal noise impacts in silica-based multimode fibers (MMFs) and plastic optical fibers (POFs) with same core diameters of 50-μm. In this experiment, we show that POFs fundamentally have higher tolerance to offset connection and lower modal noise than MMFs in terms of error-vector magnitude and speckle pattern.

P.6.4 • 4.64-bit/s/Hz 46.4-Gbps W-band Direct-Detection OFDM-RoF System Employing Two Cascaded Single-Drive MZMs
H-T Huang[1], W-L Liang[1], C-T Lin[1], C-C Wei[2], Y-H Cheng[1], C-H Ho[1], H-C Liu[1], M-F Wu[1], S Chi[3]; [1]*Institute of Photonic System, National Chiao-Tung University, Taiwan;* [2]*Dept .of Photonics, National Sun Yat-sen University, Taiwan;* [3]*Dept. of Photonics Engineering, Yuan-Ze University, Taiwan*
A W-band direct-detection OFDM-RoF system with two cascaded single-drive MZM was experimentally demonstrated. With bit-loading algorithm, 46.4-Gb/s data-rate and 4.64-bit/s/Hz spectral efficiency transmission over 25-km fiber and 2-m wireless transmission was achieved.

P.6.5 • Energy Demand of High-Speed Connectivity Services in NG-PON Massive Deployments
S Lambert[1], J Montalvo[2], J A Torrijos[2], B Lannoo[1], D Colle[1], M Pickavet[1]; [1]*Ghent University-iMinds, Belgium;* [2]*Telefonica I+D, Spain*
Energy consumption of Next-Generation PONs is estimated in a major European city deployment scenario. For a fair comparison, Dynamic Bandwidth Allocation and Quality of Service are considered when comparing the energy demand of high speed access for the different technologies.

P.6.6 • Performance Enhancement of a Hybrid Wired/Wireless OFDM Based PON Infrastructure Using an Integrated Device with Optical Injection
A Saljoghei[1], C Browning[1], L Barry[1]; [1]*The RINCE Institute, Dublin City University, Ireland*
We study the use of monolithically integrated Discrete Mode lasers employing optical injection as a cost effective approach for improving the performance of a hybrid wired/wireless OFDM PON using direct modulation, with transmission through 50 km of SSMF. The Baseband signal operated at 12.5 Gb/s and a 16 QAM LTE was used for the wireless signal.

P.6.7 • 30Gb/s Real-Time Triple Sub-band OFDM Transceivers for Future PONs Beyond 10Gb/s/λ
R P Giddings[1], E Hugues-Salas[1], J M Tang[1]; [1]*School of Electronic Engineering, Bangor University, UK*
30Gb/s real-time OFDM transceivers are experimentally demonstrated, for the first time, incorporating an 11.25Gb/s baseband and a 2×9.375Gb/s IQ modulated passband. The adaptive bit/power-loaded, independently power-optimised triple sub-bands are sampled at 4GS/s. Key factors limiting the maximum transceiver performance are identified.

P.6.8 • Electrical Splitting OEO G-PON Reach Extender Demonstration
B Le Guyader[1], W Poehlmann[2], F Saliou[1], L Jentsch[2], L Guillo[1], P Chanclou[1], T Pfeiffer[2]; [1]*Orange Labs, France;* [2]*Alcatel-Lucent Bell Labs, Germany*
A new generation of low cost G-PON OEO Reach Extender (RE) based on a 1:16 electrical splitting is demonstrated. It gives the opportunity to cover total optical budget between Central Office and home equipments up to 58dB.

P.6.9 • 140 km Long-Reach WDM-PON Experiment for Ring-based Access Network Architectures
E In de Betou[1], C-A Bunge[2], H Åhlfeldt[1], M Olson[1]; [1]*Transmode Systems AB, Sweden;* [2]*Deutsche Telekom AG, Hochschule für Telekommunikation Leipzig, Germany*
We have investigated the effects of using WDM-PON based on ASE-seeded injection-locked transmitters in a ring-based network architecture with cascaded OADM nodes. Transmission at 1.25 Gb/s over 140 km SMF using a booster amplifier and dispersion compensation was demonstrated.

P.6.10 • Novel DBA Algorithm for Energy Efficiency in TWDM-PONs
A Dixit[1], B Lannoo[1], D Colle[1], M Pickavet[1], P Demeester[1]; [1]*Dept. of Information Technology, Ghent University-iMinds, Belgium*
Time and wavelength division multiplexed passive optical networks (TWDM-PONs) have been widely accepted as a next generation optical access (NGOA) solution. We propose a novel dynamic bandwidth allocation (DBA) algorithm for energy efficiency in TWDM-PONs.

P.6.11 • A Multi-gigabit W-Band Bidirectional Seamless Fiber-Wireless Transmission System with Simple Structured Access Point
X Pang[1], J J V Olmos[1], A Lebedev[1], I T Monroy[1]; [1]*Dept. of Photonics Engineering, Technical University of Denmark, Denmark*
We propose a simple wireless access point for hybrid access networks and experimentally demonstrate bidirectional operation in W-Band. Photonic up-conversion and electrical down-conversion are used in the downlink, while in the uplink both up- and down-conversion are conducted by electrical means.

P.6.12 • Power Reduction by Adaptively Optimizing Optical Power using Actual BER for 10G-EPON Systems
N Ikeda[1], H Uzawa[1], K Terada[1], S Shigematsu[1], H Koizumi[1], M Urano[1]; [1]*Microsystem Integration Laboratories, NTT Corporation, Japan*
The OLT calculates the pre-FEC BER using the number of corrected error bits, and decides the optical power of the ONU transmitter. The ONU adaptively adjusts the optical power according to the decision during the discovery window. The power consumption is reduced by 250 mW without any additional devices and without degrading throughput.

P.6.13 • Experimental Demonstration of Remote Unified Control for OpenFlow-based Software Defined Access Optical Networks
H Yang[1], Y Zhao[1], J Zhang[1], R Gu[1], J Wu[1], J Han[2], Y Yao[3], Y Lin[2], Y Lee[2], Y Ji[1]; [1]*State Key Laboratory of Information Photonics and Optical Communications, Beijing University of Posts and Telecommunications, China;* [2]*Huawei Technologies Co., Ltd, China;* [3]*China Telecom Corporation Ltd Beijing Research Institute, China*
We propose a software defined access optical network (SDAON) architecture for remote unified control with service-aware flow scheduling based on OpenFlow-enabled passive optical network. The overall feasibility and efficiency of the proposed architecture are experimentally verified on our testbed.

P.6.14 • Inter-channel Crosstalk Impairment of Time and Wavelength Division Multiplexing Passive Optical Network
H Y Rhy[1], G Y Yi[1], H-H Lee[2], S S Lee[2]; [1]*Ericsson-LG, Republic of Korea;* [2]*ETRI, Republic of Korea*
Inter-channel crosstalk impairment of time and wavelength division multiplexing passive optical network is investigated. A method to overcome the crosstalk impairment by controlling ONU transmit signal power is also proposed.

P.6.15 • 15-Gbit/s Slow Adaptive Uplink OFDMA-PON Employing Channel Stabilization Technique Using Low Frequency Seed Carrier Modulation and Gain Saturated SOA at OLT
S-M Jung[1], M-K Hong[1], S-Y Jung[1], S-M Yang[1], S-K Han[1]; [1]*Dept. of Electrical and Electronic Engineering, Yonsei University, Republic of Korea*
We demonstrated a slow adaptive OFDMA-PON scheme that can support 15-Gbit/s uplink based on 1-GHz RSOAs employing channel stabilization. A low frequency seed carrier modulation and gain-saturated SOA were applied to realize the proposed scheme.

P.6.16 • Comparative Analysis of M-PAM vs OOK for Multimode Fiber Links with Intersymbol Interference
K Balemarthy[1], R Lingle Jnr[2]; [1]*OFS, India;* [2]*OFS, USA*
We determine a closed-form expression for the bit error rate of MMF links with intersymbol interference using M-PAM modulation. We investigate the reach at which 4-PAM is advantageous compared to OOK for various bit rates.

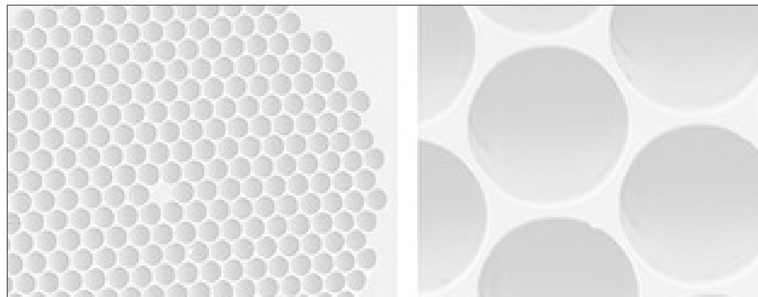
P.6.17 • Experimental Demonstration of 39Gbps for FDM PON
A Lebreton[1,2], B Charbonnier[1], J Le Masson[2,3], R Dong[2], P Chanclou[1]; [1]*Orange Labs, France;* [2]*LAB-STICC Université de Bretagne-Sud, France;* [3]*Ecoles de Saint Cyr Coëtquidan, France*
We demonstrate experimentally a downstream capacity of 39Gbps based on FDM PON architecture using a new resources allocation algorithm with 11.5GHz electrical bandwidth.

P.6.18 • Ultra-fast 1+1 Protection in 10 Gb/s Symmetric Long Reach PON
S McGettrick[1], L Guan[1], A Hill[1], D B Payne[1], M Ruffini[1]; [1]*CTVR, University of Dublin, Trinity College, Ireland*
In this paper we evaluate PON protection switching times using our FPGA-based hardware implementation of a Long-Reach PON protocol based on the XGPON standard. We first compare reactivation times of different 1+1 protection scenario, and then we propose hardware modifications to reduce PON protection times.

P.6.19 • Propagation Impairments due to Raman Effect on the Coexistence of GPON, XG-PON, RF-video and TWDM-PON
R Gaudino[1], V Curri[1], S Capriata[2]; [1]*Politecnico di Torino, Italy;* [2]*Telecom Italia, Italy*
We analyze propagation effects in the coexistence of GPON, XG-PON, RF-Video and TWDM-PON. We show that high power TWDM-PON channels excite Stimulated Raman Scattering inducing extra-loss on GPON due to power depletion. We address the problem through simulations and propose and validate a simple analytical model for the effect.

P.6.20 • Upper Bound for Energy Efficiency in Multi-Cell Fibre-Wireless Access Systems
A M J Koonen[1], M Popov[2], H Wessing[3]; [1]*COBRA Institute - Eindhoven University of Technology, Netherlands;* [2]*Acreo Swedish ICT AB, Sweden;* [3]*DTU Fotonik, Technical University Denmark, Denmark*
Bringing radio access points closer to the end-users improves radio energy efficiency. However, taking into account both the radio and the optical parts of a fibre-wireless access system, the overall system energy efficiency has an upper bound determined by the relation between the energy consumption of the optical and wireless parts.

P.6.21 • Simplified Wavelength Control of Uncooled Widely Tuneable DSDBR Laser for Optical Access Networks
L Ponnampalam[1], C C Renaud[1], R Cush[2], R Turner[2], M J Wale[2], A J Seeds[1]; [1]*Dept. of Electronic and Electrical Engineering, University College London, UK;* [2]*Oclaro, UK*
A simplified control system is described which uses only three point calibration to maintain the wavelength of the ITU channels of an uncooled DS-DBR laser, spaced at 50GHz, over the full C-band. Wavelength is controlled mode-hop free over a temperature range of 15°C to 40°C.



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Conference and Venue Information

Registration Desk Opening Hours
The ECOC 2013 registration desk is located on Level 3 of the ICC Capital Suite.

Sunday, 22 September	12:30-18:00
Monday, 23 September	08:30-17:30
Tuesday, 24 September	08:30-17:30
Wednesday, 25 September	08:30-17:30
Thursday, 26 September	08:30-16:00

Speaker Upload Area
All presenting authors are requested to report to the speaker upload area at least 90 minutes before their allocated presentation time to upload their PowerPoint presentation.

The speaker upload area is located in the ICC Capital Lounge on Level 2. Speakers are not permitted to present from their own laptops and presentations will not be accepted in the presenting rooms.

Cloakroom
The cloakroom is located on Level 0 (next to the Capital Hall) at the east end of the venue.

Insurance
The Organisers cannot be held responsible for accidents to registrants or for damage to or loss of their personal property howsoever caused. Registrants should therefore make their own insurance arrangements.

IEEE Internet Cafe
The ECOC 2013 Internet Cafe has been sponsored by IEEE Photonics Society. It will be available to conference participants and located in the ICC Capital Lounge (Level 2) beside the speaker preview area.

Refreshments
Monday - Wednesday: Coffee vouchers can be redeemed at the two delegate coffee areas within the ECOC Exhibition Hall on level 1 at the times indicated on the programme. Sunday & Thursday: Coffee will be available in the ICC Capital Suite

Lunch
Lunch is NOT included in registration fees however there are a variety of shops, cafes and restaurants along the boulevard beside the ECOC exhibition hall.

Name Badges
To gain access to the conference, social events and exhibition halls your ECOC name badge must be worn at all times. Lost badges will not be replaced.

Non-Smoking Policy
To comply with UK law smoking is prohibited inside and is only permitted within designated areas outside the conference building.

Post-Deadline Papers
The Post-Deadline Papers will be available for download on Wednesday via the website and the mobile app. Programmes will be available at the registration desk.

Poster Area
The poster area is located within the ECOC 2013 Exhibition. Each poster will be allocated a specific poster board. Authors should hang posters from Monday, 23 September and remove them before the close of the exhibition at 16:00 on Wednesday 25 September. Dedicated poster session: Tuesday, 24 September 16:00-17:30.

Conference Proceedings
A USB copy of the proceedings is available to all ECOC 2013 delegates upon registration.

Social Events

All delegates are reminded to wear their name badges to all social events. Attendance at the Get Together Drinks on Sunday and the Welcome Reception at the Fox@ExCeL is included in the conference registration fee.

If you have purchased extra tickets for a social event please visit the ECOC 2013 Conference Registration desk to collect a name badge/ticket

Additional tickets for the Welcome Reception and the Gala Dinner can be purchased onsite from the ECOC 2013 Conference Registration desk.

Get Together Drinks - ICC Capital Suite

17:30-18:30
Sunday, 22 September 2013

Meet your colleagues and socialise with your friends during the "Get-Together-Drinks". Access is free to all registered conference participants.

Welcome Reception - The Fox@ExCeL

17:30- 20:00
Monday, 23 September 2013

Come and enjoy our British themed night at the Fox@ExCeL. Greeted by her majesty's Royal Guards, guests will be able to taste a range of British cuisine including fish'n'chips, traditional British Ale tasting and cheese tasting. There's even a live caricaturist and the chance to meet Charlie Chaplain so after a hard day's night, why not unwind with a refreshing glass of pimms at what is sure to be a fantastic networking event at ECOC 2013. Additional tickets can be purchased onsite from the registration desk for £20+VAT each.

Directions to the Fox@ExCeL
The Fox is located outside the west entrance to ExCeL (opposite end to ICC Capital Suite and ECOC Exhibition). Walk along the boulevard and the Fox is on your right.

Gala Dinner - The Painted Hall

19:30
Wednesday, 25 September 2013

The Painted Hall is often described as the 'finest dining hall in Europe'. Designed by Sir Christopher Wren and Nicholas Hawksmoor, it was originally intended as an eating space for the naval veterans who lived here at the Royal Hospital for Seamen. Its exuberant wall and ceiling decorations are by James Thornhill and pay tribute to British maritime power. Join us for a sumptuous dinner in luxurious historic surroundings.

Pre-dinner entertainment will be provided by The English String Band who use a combination of fiddles, violas, cellos and double bass to create a full and exciting sound playing traditional English tunes from around the country.

After dinner sit back and relax and enjoy the sounds of Gwalia Male Choir who with their broad repertoire with entertain with some surprising pieces that will not only move but also delight.

Tickets are £85+ VAT and include pre-dinner drinks, a sumptuous 3 course dinner with wine in the luxurious surroundings of the Painted Hall. Additional dinner tickets can be purchased at the conference registration desk.

Directions to Gala Dinner

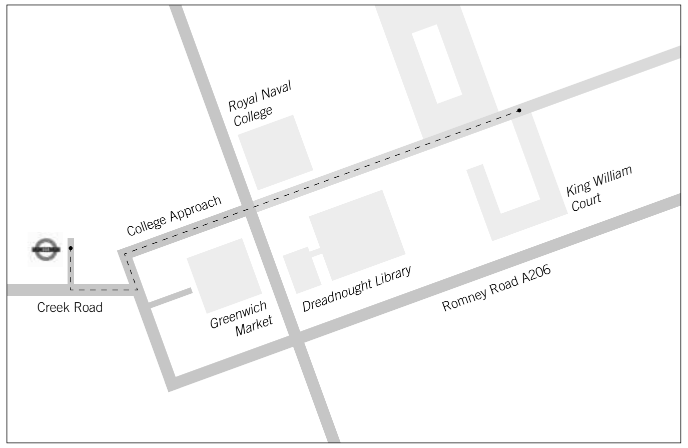
- **Docklands Light Rail (DLR)**
  Approximate journey time - 35mins
  At Prince Regent DLR station, take the DLR towards Tower Gateway. Alight / change at Westferry. At Westferry take the DLR towards Lewisham and alight at Cutty Sark (for Maritime Greenwhich) DLR Station.

Directions from Cutty Sark (for Maritime Greenwich) DLR Station to Old Royal Navy College:

Walking time: 3-5mins

Follow signs at Cutty Sark DLR station to Maritime Greenwhich. Leaving the station turn left and follow College Approach straight up to the Greewhich Campus.

Once you are in the grounds of the Old Royal Navy College continue straight and the Painted Hall is in the King William Court on the right.



Hotel Reservations
Brief2Events will be providing onsite assistance with hotel bookings and queries on Sunday, 22 September from 08:00-15:00 and on Monday, 23 September from 08:00 -15:00 outside of these times they can be contacted on

Email: reservations@brief2event.com
Phone: + 44 (0) 1202 400850
Website: http://www.brief2event.com/e/ecoc2013

General Information

Travelling Around London
The most economical way to travel around London is by using an Oyster Card. Each delegate will be provided with a free Oyster card with a top up value of £10.

You can increase the value on your card at any Underground, DLR and train station using the automated machine or by visiting ticket booth. You can also top up your card at any shop displaying the Oyster symbol.

How to use your Oyster Card
Tube, DLR, London Overground and National Rail
What to do: Touch your Oyster card on the yellow card reader at the start and end of your journey. If you're at a station without gates or the gates are already open you must still touch in and out. If you don't touch in and out you may pay a maximum pay as you go fare of up to £8.30.

What happens: If you've enough pay as you go credit you'll see a green light. If there are gates, they'll open. If you don't have enough credit a 'seek assistance' message will be displayed and the gates will not open. You can't travel until you top up your Oyster card or buy a paper ticket. Please seek assistance from a station attendant..

Buses
What to do: Touch your Oyster card on a yellow card reader inside the bus when you board, only at the start of the journey.

Don't touch it again when you get off.

For further information on travelling around London using your Oyster Card please visit www.tfl.gov.uk

Taxis
There is a taxi rank located at the East side entrance, level 0.

Printing / Business Services
There is a business service centre at ExCeL including photocopying / printing, faxing and Bureau De Change. Located on the boulevard (level 1) at the west side of ExCeL between halls N4 and S4. All services are chargeable.

Banking
The currency in the UK is Pounds Sterling. There is a Bureau De Change at the business centre at ExCeL and most hotels offer this service. There are also ATM machines located throughout the boulevard at the ExCeL.

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Wi-Fi

Before Connecting
Before starting to use the ExCeL London WLAN, your wireless settings should be;

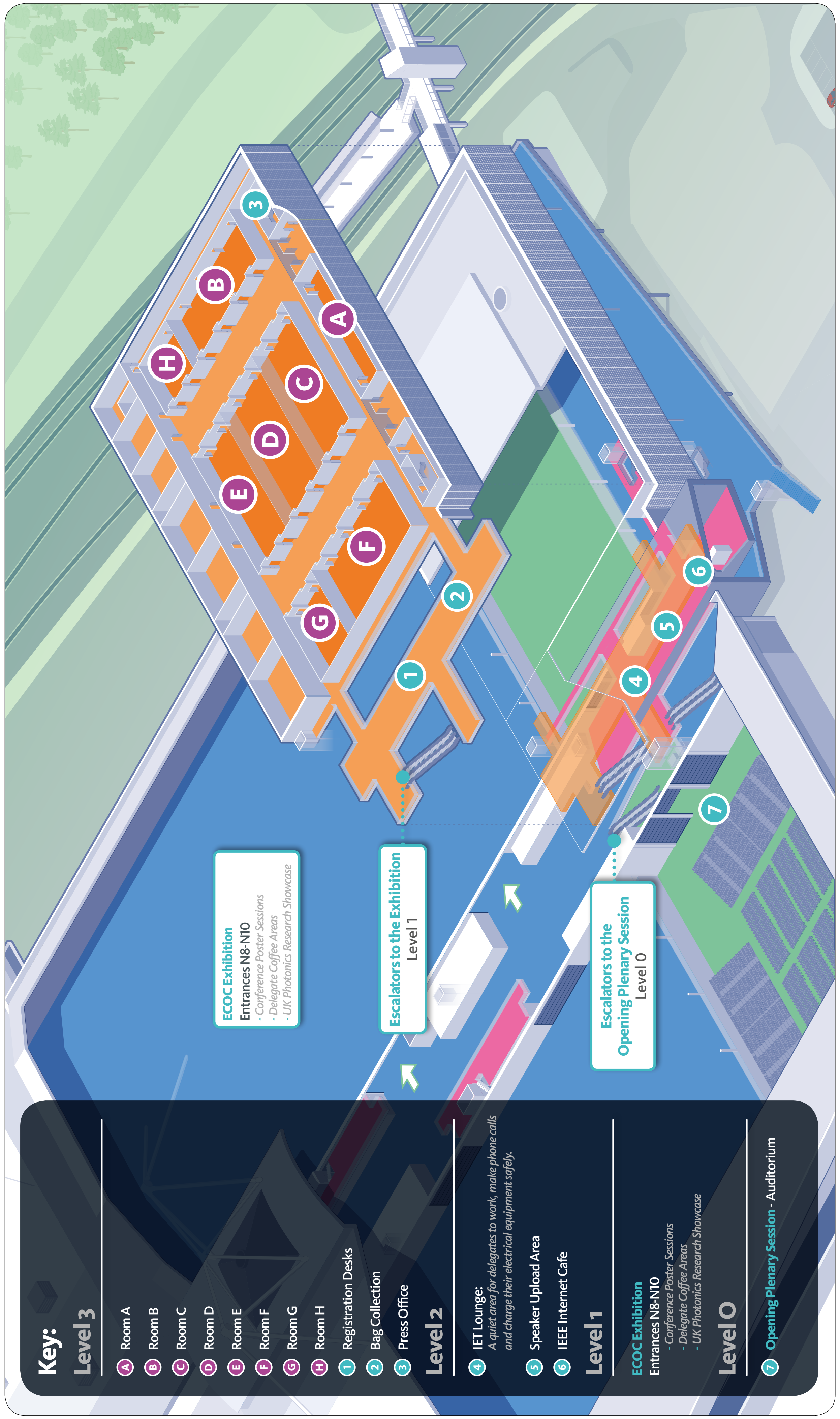
- Service Set Identifier (SSID) set to ECOC_Conference_WiFi (case sensitive and no spaces)
- Network type set to 'infrastructure'
- Wireless network key (WEP) disabled

If you access a company network using your laptop, you may have to disable your web browser's proxy settings and Intranet homepage (change to another valid web address, Google for example)
Make sure your wireless adapter is turned on.

Connecting
Network: ECOC_Conference_WiFi
Password: theiet

All wireless services, regardless of location or service provider, are susceptible to interference. This can lead to loss of connectivity, slow network traffic and poor performance. By using this service you have acknowledged your understanding of this. The wireless system is compatible with 802.11a/g/n, however to ensure you have the best and most efficient experience with our wireless network please make sure you use a device that operates on the 5GHz frequency (802.11n/a), as this is less affected by the type of interference found in a conference/ exhibition space.


Connection at 2,900 Meters Under the Sea
What a moment! When Huawei engineers completed the 1,127 kilometers of fiber optic cable, with some of it running at depths of 2,900 meters under the Caribbean sea - they knew that the people of Suriname and Guyana could expect to enjoy 3,000 times higher bandwidth than before.
As a leading global ICT solutions provider, we develop the technologies that help you share your dreams and let your inspiration travel. Huawei. Building a connected world of endless possibilities.
Photo by Huawei staff: Bao Pengyun at Norway Network Checking Centre
HUAWEI



ECOC Exhibition
Entrances N8-N10
- Conference Poster Sessions
- Delegate Coffee Areas
- UK Photonics Research Showcase
Escalators to the Exhibition
Level 1
Escalators to the Opening Plenary Session
Level 0
Key:
Level 3
A Room A
B Room B
C Room C
D Room D
E Room E
F Room F
G Room G
H Room H
1 Registration Desks
2 Bag Collection
3 Press Office
Level 2
4 IET Lounge:
A quiet area for delegates to work, make phone calls and charge their electrical equipment safely.
5 Speaker Upload Area
6 IEEE Internet Cafe
Level 1
ECOC Exhibition
Entrances N8-N10
- Conference Poster Sessions
- Delegate Coffee Areas
- UK Photonics Research Showcase
Level 0
7 Opening Plenary Session - Auditorium

Organised by:

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The Institution of Engineering and Technology

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Cannes 2014

See you next year in
Cannes, France
21 - 25 September 2014