ECOC2016
DÜSSELDORF

42nd European Conference on Optical Communication

September 18–22, 2016
Congress Center Düsseldorf (CCD), Germany

FINAL PROGRAMME

www.ecoc-conference.org

ITG INFORMATION TECHNOLOGY SOCIETY IN THE VDE

VDE

Time	Room 18+19	Room 17	Room 16	Room 15	Room 110	Room 112	Room 14
Sunday, September 18							
09:00 – 13:00					Training Course: Laser systems on Photonic Integrated Circuits 10	Training Course: ePIXfab Training cource on the state of the art in Silicon Phonotnics 10	
13:30 – 18:00 15:30 – 16:00 Coffee Break (Foyer CCD)	**WS 1:** Progress and Challenges in Signal Processing and Channel Modelling for Space Division Multiplexed Transmission Systems 12	**WS 2:** Exploring the real value of flexible optical networks 13	**WS 3:** Short range optical transmission for emerging 5G fronthaul, DCI and Metro Networks 14	**WS 4:** Fiber and waveguide based devices for 2 micron, is there the need ? 15	**WS 5:** Next Generation Ultra-Broadband Silicon Photonics Based Integrated Circuits 16	**WS 6:** Extending reach in long-haul WDM systems: What can be achieved with nonlinear mitigation techniques in fully loaded WDM Transmission? 17	4th Optical Interconnect in Data Centers EU-Symposium 11
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nn = page number

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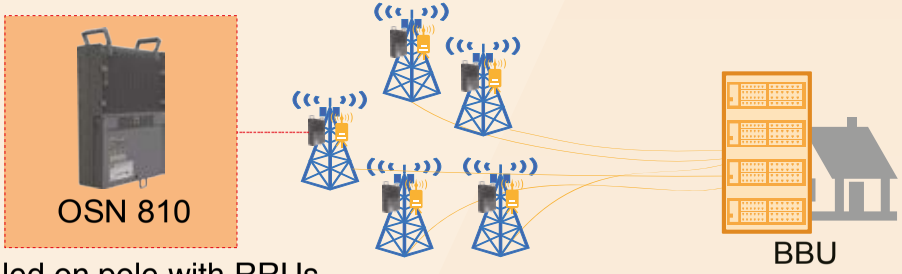
Simplified Network, OTN Everywhere

C-RAN Solution - OSN 810



Installed on pole with RRUs

Support Multi-service

CPRI, OPSI, GE, 10GE, SDH

Large Throughput

15 CPRI Access 120G total capacity

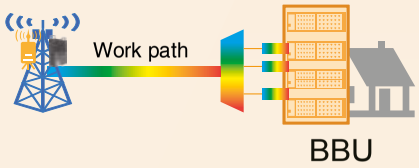
Full Outdoor

"0" site, installation like RRU Satisfy IEC 60529 standard

Easy OAM

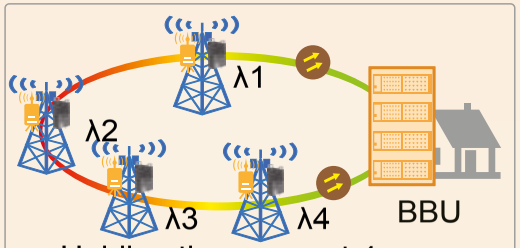
<30min setup, auto-configuration Free of commissioning
Auto detection of power off, error warning, latency and fault location

P2P Network



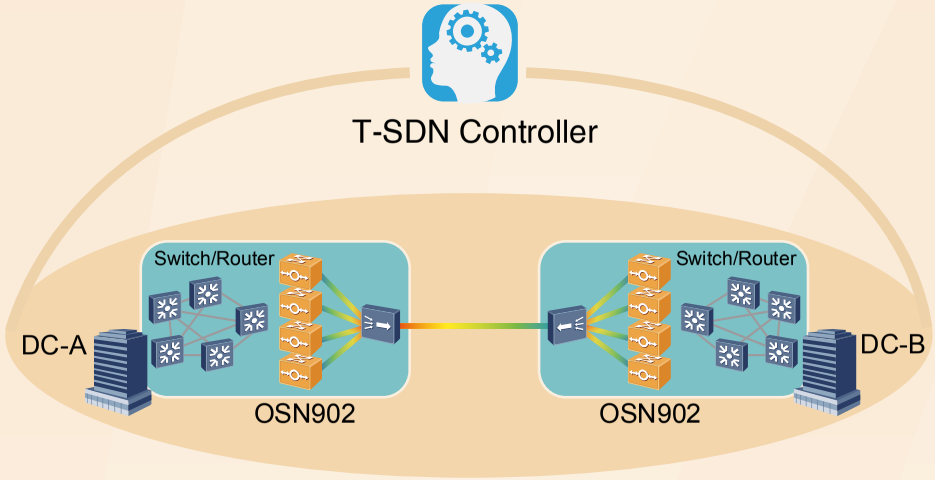
- Bidirection, 100G/50G without protection
- Bidirection, 50G 1+1 protection

Ring /Chain Network



- Unidirection, support 4 access sites
- 50G CPRI bandwidth per access site

DCI Solution - OSN 902



Typical Huawei OSN902 application scenario

HUAWEI OSN902

High Adaptation

- 2 U high, 6 pluggable boards
- Installation in 19-inch cabinets
- Front air inlet and rear air outlet

Green IT

- Self-developed 28nm ASIC chip
- 0.5 W/Gbit
- Ultra low power

Large Capacity

- 400G/slot
- 2.4T/chassis
- Flexible grid

Simplified O&M

- Web GUI
- SNMP
- NETCONF/CORBA /RESTful/CLI

High Security

- Encryption into ODUk

Welcome / Bienvenido / Benvingut / Bienvenu / Willkommen / 欢迎 / **歡迎** / Velkommen / **καλωσόρισμα** / Benvenuto / Welkom / ترحيب / Tervetuloa / Bem-vindo / Powitanie / **добро** / **пожаловать** / Välkommen / **באַגריסן**

Matthias Berger,
Nokia, Nuremberg

Ronald Freund,
Fraunhofer Heinrich Hertz Institute, Berlin

Welcome to ECOC 2016 in Düsseldorf! Following Munich in 2000 and Berlin in 2007, Düsseldorf, Germany will be the next European capital of optical communications, hosting the 42nd edition of the European Conference and Exhibition on Optical Communications held September 18th to 22nd, 2016. This well-established conference will provide another milestone in recent scientific and technical progress on materials, devices, and systems for applications in photonic networks, the basic technology for today's and the future world-wide internet. With attendances and delegates from all over the world, ECOC provides a unique opportunity to stay connected to the latest innovations in the field as well as for networking and interaction that nobody of you should miss.

EOCOC 2016 will start on Sunday, September 18th with six workshops – for warming-up – focusing on hot topics such as elastic optical networking, digital signal processing, architectures for 5G front- and backhaul, nonlinear mitigation techniques, waveguide based devices and ultra-broadband Silicon technology.

The plenary session, open to exhibitors as well, will feature speakers from academia and industry who will share their viewpoints on very relevant topics of present interest and visions on future trends and perspectives. Inspiring talks will be given by Bruno Jacobfeuerborn, CTO of Deutsche Telekom AG and VDE President, Jeffrey Gao, President of the Transmission Network Product Line, Huawei Technologies, Erich Auer, Head of System Engineering, Tesat-Spacecom GmbH & Co.KG and Peter Winzer, Director of Optical Subsystems Research, Nokia Bell Labs.

From student to expert level, from academia to industry, ECOC's special tutorials, invited and contributed papers will analyse the impact and role of photonic technologies in present and future core, metro and converged access networks addressing the major trends and innovations beyond state of the art. From more than 600 submitted papers, the Technical Programme Committee (TPC), composed by world renowned experts and chaired by distinguished scientists, constructed an amazing programme for you addressing continuously ongoing hot topics such as spatial division multiplexing (SDM), data-centre communications, advanced modulation formats, digital signal processing (DSP), super-channel transport and routing, network function virtualization (NFV) as well as rising star topics such as advanced Silicon and InP integrated optics, radio over fibre technologies for emerging 5G mobile communication or visible light communication (VLC). Because of the high interest, free-space optical communication for space and satellite applications was selected as a special topic for this year's ECOC. New developments and trends on emerging and highly forward-looking research in photonics will be addressed in a complementary CLEO (Conference on Lasers and Electro-Optics) focus meeting. The post-deadline paper sessions on Thursday afternoon will give attendees the opportunity to hear new and significant research in rapidly advancing areas at the earliest possible stage.

The conference will be accompanied by an exhibition of leading-edge companies in the photonic system, sub-system and component space. The exhibition is expected to attract more than 300 exhibitors from all over the world. Don't miss the opportunity to meet them!

Please also do not miss the social events, we have especially organised for you: the Get Together, the Welcome Reception and the Conference Dinner for which we selected the Classic Remise, one of the most attractive locations in and around Düsseldorf for a memorable event.

To a very large extent, the success of ECOC 2016 will depend on your active participation.

We are looking forward to seeing you in Düsseldorf!

General Chairs
Matthias Berger, Nokia, Nuremberg
Ronald Freund, Fraunhofer Heinrich Hertz Institute, Berlin


Be there faster
At Nokia, we're transforming connectivity. Our new PSE-2 technology is setting the standard for high capacity optical networking. We are helping service providers effortlessly deliver 100G services and capture the opportunity in every fiber.
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nokia.com/optical-networking
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ECOC 2016 Topics

1 Fibres, Fibre Devices and Fibre Amplifiers

Optical fibres, their design, fabrication and characterisation, physics of light propagation in optical fibres, fibre amplifiers and fibre lasers, as well as fibre based devices and specialty optical fibres for telecommunication and other applications.

2 Waveguide and Optoelectronic Devices

Design, fabrication, testing of performances and reliability of devices and components used to generate, amplify, detect, route, interconnect and process optical signals for information transport and processing, routing and interconnecting. Technologies include planar and 3D waveguides, bulk optics, based on various material systems.

3 Digital and Optical Signal Processing

Modeling, design, and implementation of digital and/or optical techniques, for signal processing for long-haul, Metro or access networks. This area includes digital signal processing algorithms for transmitters and coherent receivers, error correction coding, optical regeneration and any other schemes for impairment mitigation. Analog signal processing subsystems and engines for broadband wireless to fibre segment interfacing and vice-versa are also covered.

4 Subsystems for Optical Networking and Datacoms

Modeling, design, implementation and test of optical, optoelectronic, or electrical subsystems, including line terminals with advanced modulation formats and functionalities, performance monitoring techniques and devices, add-drop multiplexers, optical switches, optical packet routers, optical interconnects, original measurement equipment, and for space applications. In addition, the area considers interconnection devices, subsystems and architectures that address the challenges of Datacom and Computercom.

5 Point-to-Point Transmission Systems

Modeling, design, lab and field implementation of optical transmission fiber links and laser communication in free space, highlighting system level implications of physical impairments and impairment mitigation techniques. Contributions to this area are concerned with aspects such as capacity, reach, flexibility of optical transmission Systems and solutions to overcome the current limitations. Papers illustrating the transmission benefits of novel fibres, devices, subsystems and combined multiplexing techniques are welcome. Quantum communication systems based on optical fibre and free-space optical links are also covered.

6 Core, Metro and Data Center Networks

Modeling, design, architecture, planning, and scaling of optical transport for optical circuit and packet switched core, metro, inter as well as intra data center, and inter satellite networks. This also includes control, orchestration, and management functions, as well as the integration with higher layer network and data center services. It also covers aspects of successful network deployments and field trials.

7 Access, Local Area and Home Networks

Networking aspects of broadband optical access, localarea and home networks. It covers FTTx, passive optical networks, radio-over-fibre systems, optical wireless and free space systems, hybrid wireless/optical solutions, inbuilding networks. It also comprises aspects of cost and energy savings, successful mass deployments and field trials. The topic of optical interconnects is covered within the 4th topical area.

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ECOC 2016 TPC Subcommittees

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SC 5 - Point-to-Point Transmission Systems
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Klaus Petermann, Technische Universität Berlin, Germany
Werner Rosenkranz, Christian-Albrechts-Universität Kiel, Germany
Rob Smets, SURFnet, Netherlands

SC 6 - Core Metro and Data Center Networks
Chair: Sébastien Bigo

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SC 7 - Access, Local Area and Home Networks
Chair: Dirk Breuer

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Eduward Tangdiongga, COBRA - TU Eindhoven, Netherlands
Dora Van Veen, Nokia, USA
Chia-Chien Wei, National Sun Yat-Sen University, Taiwan

09:00 - 13:00 • Room 110
Training Course:
Laser systems on Photonic Integrated Circuits

Training Course Leader: Dr. Erwin Bente (COBRA Institute), (NL)

This training course is an introduction to the fundamentals and the widely varying possibilities and applications of **integrated semiconductor laser systems** that can be realized using **open access photonic integrated circuits based on Indium Phosphide** (InP) substrates. Industrially proven InP technology platforms have in recent years been opened up for use by anyone interested in realizing such photonic integrated circuits.

This course provides a comprehensive introduction to designers wishing to create integrated circuits which include lasers, amplifiers, phase modulators and a range of other important building blocks on the **JePPIX** photonic integration technology platforms. This training course will complement the presentations at the European Photonic Integration Forum 2016 to be held in conjunction with the Exhibition.

In the first part of this course the basics of the integration technology and the fundamental optical circuit components are discussed. Particular emphasis will be on the semiconductor optical amplifier. In the second part, the basic principles and an approach for designing laser cavities are presented. This is followed by a presentation of dynamical modeling and simulation techniques. This will b e illustrated with examples for lasers and photonic circuits. Continuous wave, widely tunable and pulsed laser systems will be described.

Benefits and Learning Objectives

- Understanding the basic principles used in InP based photonic integration technology
- Understanding how to create single chip laser circuits from photonic building blocks
- Insight into the fundamentals and a design methodology for integrated laser cavities
- Understanding how to integrate multiple lasers on the same chip and with other circuits
- Developing an overvew of possible applications through examples of realized circuits
- Learn about open access InP technology platform capabilities

Intended Audience

The course is intended to give an introduction to the possibilities of open access InP photonic integration technology. The course will benefit graduate students as well as industrial and academic researchers who are considering or engaged in the design and application photonic integrated circuits.

Practical Details

Participation is free of charge but registration is required. Registration is made by sending an email to coordinator(at)jeppix.eu. Further information on the training and forum will be avaiable at jeppix.eu

09:00 - 13:00 • Room 112
Training Course:
ePIXfab Training cource on the state of the art in Silicon Phonotnics

Course aim

To provide an insight into the field of Silicon photonics by looking into the recent progres made in this field and challenges associated with it. The course will also provide an understanding on how to enter the field and start prototyping a Silicon photonics IC.

Target audience

Industrial/academic engineers or researchers, with at least a Basic background of photonic Integration, who wish to acquire knowledge about the current art in Silicon photonics.

Course Description

Future developments in the field of datacom/telecom and sensing will require a high level of photonic integration. Silicon Photonics is widely seen as a key enabling technology as it leverages from established CMOS technology allowing low cost manufacturing even for moderate volumes. While the field was predominantly a research field up to a few years ago, we now see the emergence of industrial silicon photonics products ranging from short-reach datacom transceivers to high capacity coherent transceivers and from optical coherence tomography systems to lab-on-a-chip devices.

The science and technology of Silicon Photonics has made tremendous progress since its inception. But has it answered all the challenges associated with it? The main theme of this course is to answer this question by looking into recent progress and breakthroughs associated with Silicon Photonics and open challenges. Specifically the course will address:

- Recent progress made on component level development in Silicon Photonics
- Recent application specific progress made by Silicon Photonics, both in the field of high speed transceivers as well as in the field of sensing
- Recent evolutions in the prototyping and manufacturing platforms for Silicon Photonics as well as the complementing services and tools (design, MPW-service, packaging...)

Program

09:00 - 09:40: **Recent developments in Silicon Photonics components and building blocks**
09:40 - 10:20: **State of the art in Silicon Photonics Transceivers**
10:20 - 10:30: **Short break**
10:30 - 11:00: **State of the art in sensing based on Silicon Photonics**
11:00 - 11:30: **Evolutions in Silicon Photonics Technology platforms, Services and Tools**

Lecturers (provisional)

Prof. Dries Van Thourhout (Ghent University - imec)
Dr. Lars Zimmermann (IHP)
Prof. Roel Baets (Ghent University - imec)
Dr. Abdul Rahim (Ghent University)

Practical Details

The training course is organized by the European Silicon Photonics Alliance ePIXfab (www.epixfab.eu). Participation is free of charge for the ECOC participants, but registration is mandatory. The course will take place at the venue of ECOC2016 on Sunday September 18 from 09:00-11:30. The number of seats is limited. For registration an email should be sent to info@epixfab.eu.

Requests for further details about the training course can also be addressed to the course coordinator Dr. Abdul Rahim (abdul.rahim@intec.ugent.be, phone: +32-9-331 48 43)

09:00 - 18:00 • Room 14
4th Optical Interconnect in Data Centers EU-Symposium

Tolga Tekin (Fraunhofer IZM/TU Berlin, Germany)
Richard Pitwon (Seagate, United Kingdom)
Nikos Pleros (AUTH, Greece)
Emmanouel Varvarigos (CTI 'Diophantus', Greece)
Dimitris Apostolopoulos (ICCS/NTUA, Greece)

Abstract

The symposium is focused on high-performance, low-energy and cost and small-size optical interconnects across the different hierarchy levels in data center. The proliferation of mobile data applications is causing a dramatic shift in the location in which data is stored from client based or mobile storage to Cloud data centres with projections that around 60 % of all data will be stored in the Cloud by 2020.

The projected increase in capacity, processing power and bandwidth density in data centre environments must be addressed by the migration of high density optical interconnect into the data communication enclosures. The conversion point between electrical to optical interconnects will move ever closer to the on-board processing complexes, whether these be CPUs, data storage controllers, FPGAs, routers or switches. This migration is already strongly reflected in the research, development and strategic activities of mainstream organisations in the data centre and broader ICT space and the emergence of a new technology eco-system.

This technology migration is already strongly reflected in the research, development and strategic activities of mainstream organisations in the data centre and broader ICT space and the emergence of a new technology eco-system.

Motivated by recent breakthroughs and emerging technologies in short reach optical interconnect and the evolution of data centre architectures, this symposium aims to highlight the latest achievements on optical system solutions and architectures, that are placing photonics among the key enabling technologies of datacom and computercom evolution.

We intend to draw out and discuss the key technology enablers and inhibitors to widespread commercial proliferation of photonic interconnect in "mega" data centre environments and how the optical interconnect community can collectively help to address these.

The topics addressed will centre on passive and active embedded photonic interconnect technologies including optical circuit boards, polymer and glass waveguides, III-Vs, silicon photonics, photonic crystals and plasmonics in data centers.

Previous Symposia

3rd Optical Interconnect in Data Centers Symposium,
ECOC 2015, Valencia

2nd Optical Interconnect in Data Centers Symposium,
ECOC 2014, Cannes

1st Optical Interconnect in Data Centers Symposium,
Laser Optics Berlin 2014

EU PhoxTrot

PhoxTroT.eu is focusing on on-board, board-to-board and rack-to-rack optical interconnects. The goal of this large-scale EU research effort is the deployment of optimized technologies to tailor dedicated interconnect layers towards high-performance, low-energy and low-cost Data Center and High-Performance Computing Systems. A „mix & match" technology by synergizing the different fabrication platforms such as CMOS electronics, Si-photonics, polymers, glass, III-Vs, and plasmonics will enable generic building blocks (transmitters, modulators, receivers, switches, optochips, multi- and single-mode optical PCBs, chip- and board-to-board connectors) to extend the performance beyond Tb/s and to reduce the energy by more than 50%.

PhoxTroT is a European Union-funded IP project. Grant agreement no: 318240. European Commission, Seventh Framework Program (FP7), ICT - Information and Communication Technologies;

http://cordis.europa.eu/fp7/ict

Introduction

Tolga Tekin (PhoxTroT)

Session 1: The end-user perspective

Bart van Caenegem (European Commission, Belgium)
Richard Pitwon (Seagate, UK)
Katharine Schmidtke (Facebook)
Lê Nguyên Bình (Huawei Technologies Ltd., GER)
Susannah Heck (Kaiam Corporation, USA)

– Round table discussion
– Coffee Break

Session 2: Bringing technology to market I

Elad Mentovich (Mellanox)
Marika Immonen (TTM Mail)
Joni Mellin (ams)
Kobi Hasharoni (Compass EOS)
Kazuhiko Kurata (PETRA)

– Round table discussion
– Lunch Break

Session 3: Bringing technology to market II

Hideyuki Nasu (Furukawa)
Charles Baudot (ST Micro)
Felix Betschon (Variooptics)
Loukas Paraschis (Infinera)
Peter De Dobbelaere (Luxtera)

– Round table discussion
– Coffee Break

Session 4: What comes next?

Harold Haas (University of Edinburgh, UK)
Paraskevas Bakopoulos (National TU Athens, GR)
Takaaki Ishigure (Keio University, JP)
Bert Offrein & Roger Dangel (IBM Research)
Huiyun Liu (UCL, UK)

– Round table discussion

13:30 - 18:00 • Room 18 + 19
WS 1: Progress and Challenges in Signal Processing and Channel Modelling for Space Division Multiplexed Transmission Systems

Organizer: *Benn Thomsen (UCL, UK)*

Content

To date the most impressive single fibre capacity results have utilised Space Division multiplexing either within multiple cores or within a single multimode core or combination thereof. In the 12 years since the Mode Division Multiplexing (MDM) flavour of Space Division Multiplexing (SDM) for coherent systems was first proposed and demonstrated by Hsu et al. we have come a considerable way. From Hsu's first demonstration of 2x2 MIMO at 100Mbit/s per channel over 100m of 62.5um multimode fibre, to the most recently demonstrated 30x30 MIMO at 60Gbit/s per channel over 23 km of specially designed Few Mode Fibre by Fontaine, et al. These impressive results have all used offline MIMO processing to demonstrate the potential capacity of such systems, the challenge now is to develop real-time signal processing technology to show that such systems can outperform conventional single mode fibre approaches and make this a compelling technology to deploy.

This workshop aims to present the state of the art in both receiver and transmitter based signal processing for spatially multiplexed systems, and in channel design/modelling of multimode fibre systems. In particular it will aim to:

- Provide a summary of the state of the art in both fibre design, amplification and signal processing.
- Identify where the key implementation challenges lie.
- Explore solutions to these challenges.

A key question in the design of MDM systems is whether to engineer the channel to minimise or maximise the modal mixing and the implications that this is likely to have on system performance and the MIMO DSP complexity. This workshop will present views from both sides of this design choice.

Session 1: Approaches to DSP free MDM

Optical MIMO Processing (in Modal Basis) for Direct-Detection MDM
Karthik Choutagunta (Stanford University, USA)

Elliptical core fibres MDM without DSP
Ezra Ip (NEC Laboratories America, USA)

OAM fibres for DSP free MDM
Siddharth Ramachandran (Boston University, USA)

Session 2: Channel Modelling and Implementation

Multimode fibre channel modelling in the linear and nonlinear regime
Georg Rademacher (TU Berlin, DE)

Multimode optical amplification performance and implications for channel equalisation
Yongmin Jung (Optoelectronics Research Center, University of Southamption, UK)

Session 3: MIMO-DSP

The challenges of mode division multiplexed transmission with 30+ modes
Nick Fontaine (Nokia Bell Labs, USA)

Optimising MIMO-DSP for different crosstalk and distance regimes
Kai Shi (University College London (UCL), UK)

Taking MIMO-DSP from offline to online implementation
Sebastian Randel (Karlsruhe Institute of Technology, DE)

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

13:30 - 18:00 • Room 17
WS 2: Exploring the real value of flexible optical networks

Organizers: *Dimitrios Apostolopoulos (National Technical University of Athens, GR), Camille Delezoide (Nokia Bell Labs, FR)*

Content

The world's insatiable demand for bandwidth is stretching physical layer capacity; it is only a matter of years before we are faced with throughputs that are beyond the reach of current static optical networks. Moreover, the changing nature of traffic toward more volatile patterns renders the conventional approach of over-provisioning of resources increasingly inefficient. Operators are finding that room for economically viable growth is shrinking. Flexible optical networks are being touted as a means of avoiding the capacity crunch and increasing costefficiency, through the introduction of adaptability in modulation format and elasticity in spectrum utilization, by dropping the fixed grid and allowing dynamic adjustment of throughput and wavelength allocation.

Realizing flexible networks will require a combination of disruptive and cross-layer innovations. In addition to multi-rate, multi-format, malleable-spectrum optical components, also needed are the tools to enable programmability and dynamic operation: Spectrally-efficient modulation formats, novel DSP for linear and nonlinear impairment monitoring and mitigation, enhanced transmission and link-engineering approaches which take physical impairments into consideration, as well as innovative dynamic control plane schemes.

Despite the promises, the challenge remains to precisely quantify the benefit -if any- of flexible deployments. For it to be a worthwhile investment that will encourage market uptake, the additional functionality must ultimately benefit an operator's bottom line, versus static-operation alternatives.

This workshop aims to highlight the latest developments in flexible optical network design, control and operation, focusing on the impact of novel subsystems leveraging coherent technology and software-defined operation. The challenges of design and real-world implementation will be critically explored, and approached from all facets and all layers.

The workshop will include a moderated panel discussion on what it will take to consolidate these emerging technologies into viable, commercial systems, attempting to gauge potential benefits, as well as costs, for telecom operators.

Session 1

Flexible optical networks: Latest concepts and developments
Lena Wosinska (KTH Royal Institute of Technology, SE)

Programmable, multi-rate optical transmission systems enabling flexible optical networks
Antonio Tartaglia (Ericsson Telecomunicazioni, IT)

Advances in DSP-based optical performance monitoring
Maxim Kuschnerov (Coriant, DE)

Quality of Transmission (QoT) modelling and monitoring
Andrea Carena (Politecnico di Torino (PoliTo), IT)

Multiflow transponders for elastic networks
Christos Kouloumentas (NTUA, GR)

Panel Discussion (~20 mins)

Session 2

Network and hardware virtualization towards a smart photonic cloud
Reza Nejabati bati (University of Bristol, UK)

The role of elasticity in the future network
Kevin Sparks (Nokia, USA)

Techno-economic analysis of flexible optical network deployment
David Boertjes (Ciena, USA)

Reaping the benefits of flexibility – A telecom operator's perspective
Matthias Gunkel (DT, DE)

What "flexible" features do we need in optical networks, and why?
Gaya Nagarajan, Giuseppe Rizzelli (Facebook, UK)

Panel Discussion (~20 mins)

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

13:30 - 18:00 • Room 16
WS 3: Short range optical transmission for emerging 5G fronthaul, DCI and Metro Networks

Organizers: *Gordon Ning Liu (Huawei Technologies Co. Ltd., China), Volker Jungnickel (HHI, Germany)*

Content

With the rapidly increasing data traffic in 5G mobile fronthaul, data center interconnect (DCI), and metro networks, the growing bandwidth demand from high speed short range optical transmission will be much more than that from the long-haul optical transmission. Especially, when using conventional digital transmission such as CPRI in CRAN architecture, 5G performance targets would imply a severe capacity crunch. Besides, there are tremendous amounts of optical equipments in short range optical transmission systems compared with the long-haul transmission systems and thus will induce large cost and huge energy consumption. Therefore, the power and cost efficiency should be key considerations for short range optical transmission besides the transmission performance. The workshop aims to bring together internationally recognized experts from network operators, equipment/component vendors and academia in order to provide a comprehensive overview of this important field for next-generation short range optical transmission. Some demands, transmission schemes and optical components technologies which can be shared by 5G fronthaul, DCI and metro networks will be discussed in the first session. Then in the second session, the workshop will be focused on several new concepts, e.g. the Next Generation Fronthaul Interface (NGFI) based on Analog or Ethernet technologies and using a new functional split between BBU and RRH.

Session

Requirements and emerging trends
Xiang Zhou (Google Inc., USA) Data center interconnection

Emerging Technologies for Metro Optical Networking
Xiang Liu (Huawei, USA)

Photonic Integration for Applications from Datacenter to DWDM
Steven Wallace (Lumentum, Canada)

Transmission schemes for future short reach systems
Chao LU (Hong Kong Polytechnic University, Hong Kong)

Advanced modulation formats for 5G fronthaul WDM-PON systems
Annika Dochhan (ADVA Optical Networking SE, Germany)

The required Fixed Access Network evolutions
Philippe Chanclou (Orange Labs, France)

Making fronthaul efficient without killing it
Frank Effenberger (Huawei Technologies, USA)

Converged, Ethernet-based next generation fronthaul
Nathan Gomes (University of Kent, UK)

TBD
Thomas Pfeiffer (Nokia Bell Labs, Germany)

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

13:30 - 18:00 • Room 15
WS 4: Fiber and waveguide based devices for 2 micron, is there the need?

Organizers: *Camille Brés (EPFL, Switzerland), Periklis Petropoulos (University of Southampton, UK)*

Content

The workshop will put forward a discussion on the recent and rapid development of fiber/waveguide based sources and devices for the short wave infrared (2 micron), and will debate whether there is a real need for this technology, especially in the context of telecommunications. Amongst others, we are seeing the emergence of fiberized components, off the shelf sources, high speed modulators, directly modulated sources as well as demonstrations of 2 micron communications in hollow core fibers. Is there a real potential or is it simply interesting physics? What components/technological developments/improvements would be needed to make the technology an implemented reality?

Discussion on non-telecom applications will also be welcome, e.g. on the development and potential of fiber-based supercontinuum sources/combs and, Mid-IR oscillators. While many great and interesting experimental demonstrations have been done, are there the required applications and are fiber/waveguide approaches competitive?

This workshop aims to present the enabling technologies by exploring their strengths, weaknesses and level of maturity, as well as to explore applications and challenges that these technologies can address.

Session

Optical Components for enabling 2um applications
Gary Stevens (Gooch and Housego, UK)

Semiconductor laser diodes and applications in the 2um wavelength region
Brian Kelly (Eblana Photonics, UK)

Rare-earth doped fibre amplifiers in the 2um waveband: Challenges and opportunities
Shaif-Ul Alam (University of Southampton, UK)

III-V-on-silicon photonic integrated circuits for the 2um wavelength range
Gunther Roelkens (University of Gent, Belgium)

Photonic chip–based optical frequency comb for the 2 micron band
Michael Geiselmann (Ecole Polytechnique Fédérale de Lausanne, Switzerland)

Thulium doped fiber femtosecond laser: markets and applications
Nicolas Ducros (Novae, France)

Can the 2 micron window solve the capacity crunch?
Noise MacSuibhne (Aston University, UK)

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

13:30 - 18:00 • Room 110
WS 5: Next Generation Ultra-Broadband Silicon Photonics Based Integrated Circuits

Organizers: *Guang-Hua DUAN (III-V Lab, France)*
Abderrahim Ramdane (CNRS, France)
Johann Peter Reithmaier (University Kassel, Germany)
Jeremy Witzens (RWTH Aachen University, Germany)

Content

Increasing front panel data densities of data center switches as well as increasing reach and data rate of data center state-of-the-art optical interconnects has motivated the emergence of Silicon Photonics based integrated circuits. In parallel, metro and long-haul networks require transceivers with reduced size and power consumption. Silicon photonics is also a candidate for these markets. This Workshop will gather prominent speakers from industry and academia and intends to give an update on the state of the art on Silicon Photonics based integrated circuits, with emphasis on the following two key areas:

- Integration of efficient laser source solutions for silicon photonics with advanced material systems such as quantum dots.
- Silicon based Photonic Integrated Circuits implementing broadband wavelength division multiplexing.

Organization

This workshop is organized in the framework of the EU funded projects BIG PIPES “Broadband Integrated and Green Photonic Interconnects for High Performance Computing and Enterprise Systems” and SEQUOIA “Energy efficient Silicon emitter using heterogeneous integration of III-V quantum dot and quantum dash materials”.

World-wide leading experts will be invited to give talks. The talks, complemented by BIG PIPES and SEQUOIA presentations, will be followed by a Q&A session involving a panel of all the Speakers.

Session 1: Light Sources on Silicon and Comb Laser Based Transceivers

Chair Guang-Hua Duan (III-V Lab, France)

Advances on efficient light sources on silicon
John Bowers (UCSB, USA)

Efficient quantum dot based light sources for silicon photonics
Johann Peter Reithmaier (University Kassel, Germany)

Advances on heterogeneous integration of III-V on silicon
Segolene Olivier (CEA LETI, France)

High capacity silicon photonics based transceivers
Young-Kai Chen (Nokia Bell Labs, USA)

Silicon photonics based high capacity transceivers with hybridly integrated quantum dot lasers
Yasuhiko Arakawa (University Tokyo, Japan)

First panel discussion

Session 2: High Capacity silicon photonics based Transceivers and Super-Channel Architectures

Chair Abderrahim Ramdane (CNRS, France)

Combbased Silicon Photonics transmitters for short reach interconnects
Jeremy Witzens (RWTH Aachen, Germany)

Highly spectrally efficient optical links
Liam Barry (Dublin City University, Ireland)

Scaling datacenter optical interconnects
Elad Mentovich (Mellanox Technologies, Israel)

Super-channel optical interconnects for datacenters
Jörg-Peter Elbers (ADVA Optical Networking SE, Germany)

Silicon photonics based coherent transceivers
Dr. Christopher Doerr (Acacia Communications, USA)

Second panel discussion

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

13:30 - 18:00 • Room 112
WS 6: Extending reach in long-haul WDM systems: What can be achieved with nonlinear mitigation techniques in fully loaded WDM transmission?

Organizers: *Giancarlo Gavioli (Nokia Micro-Electronics Labs, Italy)*
David Millar (Mitsubishi Electric Research Laboratories, USA)
Robert Killey (University College London, UK)

Content

Digital coherent technology has enabled compensation of linear fiber impairments and the introduction advanced error-correction coding in optical transmission systems. Fiber nonlinearity has thus become the dominant obstacle towards achieving the ultimate capacity in optical transmission systems.

Over the recent years, different techniques have been proposed to mitigate for nonlinearities by means of digital and optical signal processing and demonstrated to be effective toward intra-channel nonlinear distortion. This includes both digital and optical techniques for nonlinear channel inversion, or optimization of transmission parameters such as symbol rate and symbol distribution to enable nonlinear tolerant transmission. Digital integrated technology is now expected to be mature enough to enable the implementation of such complex algorithms.

However, recent advancements in fiber propagation modeling have quantified and demonstrated that inter-channel nonlinearities become the dominant effect in fully loaded WDM transmission systems with implication on the effectiveness of intra-channel nonlinear mitigation.

This workshop intends to provide a forum of debate on the effectiveness of nonlinear mitigation techniques in fully loaded WDM transmission and to offer a comparative overview in terms of performance gain and technology complexity of the different solutions for digital and optical nonlinear mitigation in the contest of long-haul dense WDM transmission systems.

Targets:

1) This workshop intends to provide a forum of debate on the effectiveness of nonlinear mitigation techniques in fully loaded long-haul WDM transmission systems.
2) Provide a comparative overview in terms of performance gain and technology complexity of the different solutions for digital and optical nonlinear mitigation.
3) Address the complexity-cost and maturity of digital integrated technology for implementation of nonlinear mitigation algorithms.
4) Provide a theoretical review of the dominant nonlinearities and quantify the impact of intra-channel and inter-channel distortion in the contest of fully loaded WDM transmission Systems.

Session 1

How much should we expect to gain from nonlinear mitigation?
Ronen Dar (Nokia Bell Labs, Holmdel, USA)

Overview of Nonlinearity Mitigation Techniques
Rene-Jean Essiambre (Nokia Bell Labs, Holmdel, USA)

Implementation considerations of digital-domain nonlinear compensation in commercial systems
Qunbi Zhuge (Ciena, Ottawa, Canada)

Digital Nonlinear Compensation for 400G Transceiver with Higher Order Modulation
Zhenning Tao (Fujitsu Labs, Beijing, China)

Nonlinearity compensation benefits in experiments over transoceanic distances using offline processing
Alexei Pilipetskii (TE Subcom, Eatontown, USA)

Commercial use cases of fiber nonlinearity compensation
Danish Rafique (ADVA, Germany)

NLC in Operator Networks - What can it add?
Carsten Behrens (Deutsche Telekom, Germany)

Session 2

Non-Linearity Mitigation by Multi-Subcarrier Transmission and Joint DSP Post-Processing
Pierluigi Poggiolini (Politecnico di Torino, Italy)

Better Compensation with Optical Phase Conjugation?
Andrew Ellis (Aston University, Birmingham, UK)

Nonlinear signal noise interaction in fully loaded systems
Paolo Serena (Università di Parma, Italy)

What else can be done? Inter-channel nonlinear mitigation and optical nonlinear mitigation
Marco Secondini (Scuola Superiore Sant'Anna, Pisa, Italy)

Performance of nonlinearity tolerant constellations in fully loaded WDM systems
John Cartledge (Queen's University, Kingston, Canada)

PMD and wideband nonlinearity compensation: Next bottleneck or fundamental limitation?
Gabriele Liga (University College London, UK)

15:30 - 16:00 Coffee Break | Foyer CCD |

18:00 - 19:30 Get Together | Wintergarden Restaurant CCD |

Matthias Berger, Nokia, Nuremberg; Ronald Freund, Fraunhofer Heinrich Hertz Institute, Berlin

10:15 - 10:45 • Room 1

„Optical Communication – Building the basis for best Customer Experience"

Bruno Jacobfeuerborn
CTO of Deutsche Telekom AG and VDE President

Abstract: The new integrated telecommunications standard 5G will enable communication in real time that is available anywhere and anytime. It will efficiently associate 50 billion „things" and billions of customers, while crating various revolutionary use cases from autonomous driving to ultra HD Virtual Reality applications. Therefore, our industry is facing an tremendous demand regarding bandwidth and latency, that can only be met if we bring two things closer to the customer: The intelligence of the network and fiber lines.

To accelerate the extension of the fiber network and increase the cost efficiency, Deutsche Telekom is driving new cheaper alternatives to standard civil engineering. The aim is to create a portfolio of various installation techniques that can be combined and implemented in the most efficient manner, in consideration of the local basic conditions and customer needs.

As an integrated operator, Deutsche Telekom is well positioned to incorporate the demands of different customer segments into a joint and integrated fiber target architecture. Although boundaries between fixed and mobile access dissolve more and more, a strong fiber-based network will always remain the fundament of providing sustainable telecommunication Services.

Bruno Jacobfeuerborn: Director of Technology Telekom Deutschland GmbH and Chief Technology Officer (CTO) of Deutsche Telekom AG.

Bruno Jacobfeuerborn has been Director of Technology at Telekom Deutschland GmbH since April 2010. In addition, he is Chief Technology Officer (CTO) of Deutsche Telekom AG, a position he has been holding since February 2012.

Since 1989, Bruno Jacobfeuerborn has held various managing positions at Deutsche Telekom AG. From 2002 to 2007, Bruno Jacobfeuerborn was a member of the management team in his capacity as Managing Director of Technology, IT, Procurement and, until 2004, Customer Service at T-Mobile Netherlands in The Hague. At the same time, he headed the International Service Management unit at T-Mobile International. Subsequently, he was a member of the management team and Managing Director of Technology, IT and Procurement at Polska Telefonia Cyfrowa in Warsaw until June 30, 2009. Since July 1, 2009, Bruno Jacobfeuerborn has been responsible for Technology (both mobile and fixed network) in Germany.

10:45 - 11:15 • Room 1

OTN to CO, Key Implementation of Network Simplification

Jeffrey Gao
President, Transmission Network Product Line, Fixed Network Product Line, Huawei Technologies

Abstract: What is main challenges to transport network brought by new service traffic, such as 4K/8K, 5G and cloud service?

How carrier work on their network architecture evolution driven by 3 main factors including new services, new technologies and cost reduction?

Huawei's understanding and strategy on network transformation and latest technologies to face these challenges and fit for the evolution requirement.

Jeffrey Gao is since January 2015 the president of Transmission Network Product Line.

From February 2011 to 2014, he was the Chief Strategy and Marketing Officer of Huawei Western Europe Region. From year 2008 to 2011, he was the Chief Strategy and Marketing Officer of Huawei Fixed Network Business Unit. Jeffrey Gao has lead the innovation cooperation project between VDF and Huawei since 2008, and there are many success case include BBNS, IP MW and PTN project.

From year 2003 to 2008, Mr. Gao was the head of Huawei Datacom PLM, after joined in Huawei Technologies in 1997 Mr. Gao was working in Optical Transport area until 2003, Mr. Gao was also one of the winners of National Science and Technology Achievement Award of China in 2001 and 2002 respectively.

11:15 - 11:45 • Room 1

Optical Communication in Space

Erich Auer
TETS, Head of System Engineering, Tesat-Spacecom GmbH & Co.KG, Backnang

Abstract: The keynote will give an overview on space communication in general and focus specifically on optical communication in space. Todays spacecom is still dominated by radio transmission in all applicable and regulated frequency bands. Optical communication in space opens virtually unlimited capacities without regulations. Comparisons between radio and optical communication in space will be given. The current status of optical communication in space will be outlined, giving some examples of what has already been implemented and demonstrated. An overview of the features and technologies of laser communication terminals for space will be presented. The keynote will conclude with an outlook on future applications of optical communication in space and on the needs for future, space proven technologies in this field.

Erich Auer is an Electrical Engineer graduated and did his PhD at the University of Stuttgart. He works since April 2009 as Chief Technical Officer (CTO) for TESAT-Spacecom, a 100% daughter company of Airbus Defence & Space GmbH. TESAT, located in Backnang/Germany, is one of the leading suppliers of space communication payload equipment for satellites. From 2006 to 2009 he worked for Ericsson as Head of the Fixed Wireless R&D Engineering Germany. In the time frame from 2000 to 2006 he held the position as Head of the R&D Organisation of Marconi Communications in Backnang/Germany. In the years from 1995 to 2000 he was with Bosch Telecom as Head of the R&D Microwave Radio Systems and from 1988 to 1995 he worked for ANT Communications as Division Head in the field of Space Communication. He is married and has two adult daughters.

11:45 - 12:15 • Room 1

From scaling disparities to integrated parallelism: A decathlon for a decade

Peter J. Winzer
Director, Optical Subsystems Research, Nokia Bell Labs, Holmdel, NJ

Abstract: The evolution of network traffic and communication technologies over the past 10+ years and their projections into the coming 10+ years reveal increasingly pronounced scaling disparities between traffic demands, routing capabilities, interface rates, and system capacities. Within a decade, we expect the need for 10+ Terabit/s transponders working over Petabit/s systems and networks. We discuss 10 technology paths to move our industry towards these bold goals.

Peter J. Winzer received his Ph.D. from the Vienna University of Technology, where he worked on space-borne lidar and laser communications for the European Space Agency. At Bell Labs since 2000, he has focused on many aspects of fiber-optic communications, including advanced optical modulation multiplexing, and detection. He has contributed to several high-speed optical transmission records from 100 Gb/s to 1 Tb/s and has been promoting spatial multiplexing to overcome the optical networks capacity crunch. He has widely published and patented and is actively involved with the IEEE Photonics Society and the Optical Society of America (OSA), including service as Editor-in-Chief of the IEEE/OSA Journal of Lightwave Technology, Program Chair of ECOC 2009, and Program/General Chair of OFC 2015/17. Dr. Winzer is a Bell Labs Fellow, a Fellow of the IEEE and the OSA, and a Thomson Reuters Highly Cited Researcher.

Monday, September 19, 2016, 14:00-15:00 Room 18+19
SC 1 - Fibres, Fibre Devices and Fibre Amplifiers

M.1.A.1
High Power Fibre Lasers: Fundamentals, Recent Progress and Challenges
Michalis N. Zervas (Optoelectronics Research Centre, University of Southampton, UK)

Michalis N. Zervas holds a Royal Academy of Engineering Chair in Advanced Fibre Laser Technologies for Future Manufacturing in the Optoelectronics Research Centre, University of Southampton. His research activities include advanced optical fibre amplifier configurations, high power fibre lasers, optical microresonators, and non-linear fibre optics. He was a co-founder of Southampton Photonics Inc. a University of Southampton spin-off, now SPI Lasers, manufacturing high power fibre lasers. He is a Fellow of the Optical Society of America.

Tuesday, September 20, 2016, 11:00-12:00 Room 18+19
SC 3 - Digital and Optical Signal Processing

Tu.2.A.1
Digital Signal Processing for Multilevel Modulation Formats
Seb J. Savory (University of Cambridge, UK)

Seb Savory is a University Lecturer at Cambridge University. Having been sponsored by Nortel through his undergraduate and postgraduate studies at Cambridge, he rejoined the Harlow Laboratories in 2000. In 2005, he moved to UCL where he held a Leverhulme Trust Early Career Fellowship from 2005 to 2007, before being appointed as a Lecturer (2007), Reader (2012) and Professor (2015). In January 2016 he returned to Cambridge as a University Lecturer and Fellow of Churchill College. Dr Savory is the Editor-in-Chief of IEEE Photonics Technology Letters and serves on the Steering Committee of the Optical Fiber Communication conference having previously served as a General Chair (2015) and Program Chair (2013).

Tuesday, September 20, 2016, 09:00-10:00 Room 18+19
SC 2 - Waveguide and Optoelectronic Devices

Tu.1.A.1
Application of photonic crystal and heterogeneous integration to ultra low energy lasers for optical interconnects and data-center networks
Shinji Matsuo (Nippon Telegraph and Telephone Corporation, Japan)

Shinji Matsuo is a Senior Distinguished Researcher in NTT Device Technology Laboratories. He received a B.E. and M.E. in electrical engineering from Hiroshima University in 1986 and 1988 and a Ph.D. in electronics and applied physics from Tokyo Institute of Technology in 2008. In 1988, he joined NTT, where he researched photonic functional devices using VCSELs. Since 2000, he has been researching tunable lasers and low-operating energy directly modulated lasers. He is a member of the JSAP, IEICE, and a Fellow of IEEE.

Wednesday, September 21, 2016, 09:00-10:00 Room 18+19
SC 4 - Subsystems for Optical Networking and for Datacoms

W.1.A.1
Advanced Silicon Photonics for Post-Moore Era
Koji Yamada (National Institute of Advanced Industrial Science and Technology, Japan)

Koji Yamada received his B.E., M.E. and Ph.D. degrees in nuclear engineering from Kyushu University, Japan, in 1986, 1988 and 2003, respectively. Currently, he is a group leader of Silicon Photonics Group in in National Institute of Advanced Industrial Science and Technology (AIST), Japan. From 1988 to 2015, in NTT laboratories, he was engaged in studies on accelerator physics/engineering for synchrotron light sources and studies on silicon photonic platform. Since joining AIST in 2015, he continues studying silicon photonic platform.

Thursday, September 22, 2016, 09:00-10:00 Room 18+19
SC 5 - Point-to-Point Transmission Systems

Th.1.A.1
Mitigation of Nonlinear Propagation Impairments by Digital Signal Processing
Takeshi Hoshida (Fujitsu Laboratories, Japan)

Takeshi Hoshida is a Project Director at Network Systems Laboratory in Fujitsu Laboratories Ltd., in Kawasaki, Japan. He received the B.E., M.E., and Ph.D. degrees in electronic engineering from the University of Tokyo, Tokyo, Japan, in 1993, 1995, and 1998, respectively. Since 1998, when he joined Fujitsu Laboratories Ltd., Kawasaki, Japan, he has been engaged in the research and development of dense wavelength-division multiplexing optical transmission systems. From 2000 to 2002, he was with Fujitsu Network Communications, Inc., Richardson, TX. Since 2007, he has also been with Fujitsu Limited, Kawasaki, Japan.

He has authored or co-authored more than 150 conference and journal contributions, and has been serving as a member of technical program committee in conferences such as OFC and OECC.

Wednesday, September 21, 2016, 14:00-15:00 Room 18+19
SC 6 - Core Metro and Data Center Networks

W.3.A.1
Roles and Benefits of Elastic Optical Networks in Beyond 100-Gb/s Era
Masahiko Jinno (Kagawa University, Japan)

Masahiko Jinno is a Professor of Electronics and Information Engineering at Kagawa University. Prior to joining Kagawa University in October 2012, he was a Senior Research Engineer, Supervisor at Network Innovation Laboratories, Nippon Telegraph and Telephone Corporation (NTT). Prof. Jinno is a Fellow of the Institute of Electronics, Information and Communication Engineers (IEICE) and a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE).

Wednesday, September 21, 2016, 11:00-12:00 Room 18+19
SC 7 - Access, Local Area and Home Networks

W.2.A.1
Industrial Trends and Roadmap of Access
Frank Effenberger (Huawei - Futurewei Technologies, USA)

Frank Effenberger has worked in the optical access field at Bellcore, Quantum Bridge Communications (Motorola), and Futurewei Technologies, where he is now the Vice President of the fixed access network lab. His team works on forward-looking fiber, copper, and coax access technologies, with several “world’s first” prototypes and trials. Frank is a Fellow of the OSA, the IEEE, and Huawei, and holds 77 US patents.

SC 1 - Fibres, Fibre Devices and Fibre Amplifiers

Monday, September 19, 2016, 17:00 – 17:30 Room 18+19

Design and characterization of multicore Erbium-doped fibers
Sophie Larochelle (Université Laval, Canada)

Tuesday, September 20, 2016, 11:00 – 11:30 Room 112

Optical Fibre Technologies for Future Communication Networks
Perikles Petropoulous (University Southampton, USA)

Wednesday, September 21, 2016, 09:30 – 10:00 Room 17

Multicore optical fiber grating arrays for sensing applications
Paul Westbrook (OFS Fitel, LLC, USA)

Wednesday, September 21, 2016, 11:30 – 12:00 Room 17

Coupled Few-mode Multi-core Fibre for Ultra-high Spatial Density Space Division Multiplexing
Taiji Sakamoto (Nippon Telegraph and Telephone Corporation, Japan)

Wednesday, September 21, 2016, 14:00 – 14:30 Room 17

Linear and Nonlinear Properties of OAM in Fibers
Siddarth Ramachandran (University of Boston, USA)

SC 2 - Waveguide and Optoelectronic Devices

Monday, September 19, 2016, 16:00 – 16:30 Room 110

High-Speed Directly Modulated Heterogeneously Integrated InP/Si DFB Laser
Geert Morthier (Ghent University, Belgium)

Tuesday, September 20, 2016, 10:00 – 10:30 Room 18+19

Higher Speed VCSEL Links using Equalization
Daniel Kuchta (IBM - T. J. Watson Research Center, USA)

Tuesday, September 20, 2016, 16:30 – 17:00 Room 18+19

High Speed Silicon Organic Hybrid (SOH) Modulators
Stefan Wolf (Karlsruhe Institute of Technology - KIT, Germany)

Wednesday, September 21, 2016, 11:00 – 11:30 Room 110

Quantum-Dot Lasers Monolithically Grown on Silicon Substrates
Huiyun Liu (University College London, UK)

Wednesday, September 21, 2016, 15:00 – 15:30 Room 112

Monolithic Electronic-Photonic Co-Integration in Photonic BiCMOS
Lars Zimmermann (Leibniz-Institute - IHP, Germany)

Thursday, September 22, 2016, 10:00 – 10:30 Room 17

Ultrafast laser inscription of 3D waveguides for SDM applications
Robert Thomson (Heriot-Watt University, UK)

SC 3 - Digital and Optical Signal Processing

Monday, September 19, 2016, 14:00 – 14:30 Room 17

Adaptive Transceivers in Nonlinear Flexible Networks
David Ives (University of Cambridge, UK)

Monday, September 19, 2016, 16:30 – 17:00 Room 17

Power Efficient Coherent Transceivers
Jonas Geyer (Acacia Communications, USA)

Tuesday, September 20, 2016, 10:00 – 10:30 Room 110

Joint Modulation and Coding Optimization for Long-Haul Nyquist-WDM Transmissions
Rafael Rios-Muller (Bell Labs Nokia, France)

Tuesday, September 20, 2016, 16:00 – 16:30 Room 17

Prospects for Real-Time Compensation of Fiber Non-linearities
Michael Reimer (Ciena, USA)

Wednesday, September 21, 2016, 09:00 – 09:30 Room 16

Probabilistically Shaped QAM for Independent Reach, Spectral Efficiency and Bit-rate Adaptation
Fred Buchali (Nokia Bell Labs, Germany)

Wednesday, September 21, 2016, 11:30 – 12:00 Room 16

Scalable SD-FEC for Efficient Next-Generation Optical Networks
Kenya Sugihara (Mitsubishi Electric Corporation, Japan)

SC 4 - Subsystems for Optical Networking and for Datacoms

Monday, September 19, 2016, 14:30 – 15:00 Room 16

Injection-locked Homodyne Detection System for Higher-order QAM Digital Coherent Transmission
Keisuke Kasai (Tohoku University, Japan)

Wednesday, September 21, 2016, 10:00 – 10:30 Room 18+19

High-Speed Photonics for Side-by-Side Integration with Billion Transistor Circuits in Unmodified CMOS Processes
Luca Alloatti (ETH, Switzerland)

Wednesday, September 21, 2016, 11:00 – 11:30 Room 112

High radix all-optical switches for software-defined data-centre networks
Nick Parsons (Polatis, USA)

Wednesday, September 21, 2016, 12:00 – 12:30 Room 112

Coherent Optical Subcarrier Processing and Add/Drop Multiplexing
Carsten Schmidt-Langhorst (Fraunhofer Heinrich Hertz Institute, Germany)

Thursday, September 22, 2016, 09:30 – 10:00 Room 16

High-Speed VCSELs for Datacom
Anders Larsson (Chalmers University of Technology, Sweden)

SC 5 - Point-to-Point Transmission Systems

Monday, September 19, 2016, 15:00 – 15:30 Room 15

Mutual information characterization of nonlinear fiber channels
Tobias Eriksson (Chalmers University of Technology, Sweden)

Tuesday, September 20, 2016, 09:00 – 09:30 Room 15

Ultra-high capacity SDM/WDM transmission over multicore and multimode fibers
Takehiro Tsuritani (KDDI R&D Laboratories Inc., Japan)

Tuesday, September 20, 2016, 09:30 – 10:00 Room 15

Pb/s, Homogeneous, Single-mode Multi-Core Fiber Systems
Ben J. Puttnam (NICT Photonic Network Laboratory, Japan)

Wednesday, September 21, 2016, 10:00 – 10:30 Room 15

Analytical and Semi-Analytical Models for Nonlinear Transmission
Ronen Dar (Nokia Bell Labs, USA)

Wednesday, September 21, 2016, 15:00 – 15:30 Room 15

Solutions for 400Gbit/s Inter Data Center WDM Transmission
Annika Dochhan (ADVA Optical Networking, Germany)

SC 6 - Core Metro and Data Center Networks

Monday, September 19, 2016, 15:00 – 15:30 Room 112

Building a Programmable Testbed Infrastructure in the UK to Support Network R&D
David Salmon (JISC, UK)

Monday, September 19, 2016, 16:00 – 16:30 Room 112

A roadmap for evolving towards optical intra-data-center Networks
Lars Ditmann (Danish Technical University, Denmark)

Tuesday, September 20, 2016, 09:00 – 09:30 Room 17

Operator use cases that benefit from multi-layer optimization and application awareness
Victor Lopez (Telefonica, Spain); Domenico Siracusa (CREATE-NET, Italy); Dimitrios Klonidis (AIT, Greece); Juan Pedro Fernández-Palacios (Telefónica I+D, Spain)

Tuesday, September 20, 2016, 12:00 – 12:30 Room 17

Elastic all-optical networks: a new paradigm enabled by the physical layer. How to optimize network Performances?
Vittorio Curri (Politecnico di Torino, Italy)

Tuesday, September 20, 2016, 16:00 – 16:30 Room 15

Adaptive and Efficient Multilayer Elastic Optical Network Planning
Takafumi Tanaka, (NTT, Japan)

Thursday, September 22, 2016, 09:00 – 09:30 Room 110

Can Metro Networks be the Next Playground for (true) Elastic Networks
Patricia Layec (Nokia Bell Labs, France)

SC 7 - Access, Local Area and Home Networks

Monday, September 19, 2016, 14:30 – 15:00 Room 110

Protection Systems for optical access Networks
Takashi Nishitani (Mitsubishi Electric Corporation, Japan)

Tuesday, September 20, 2016, 09:15 – 09:45 Room 112

Optical Network Technologies for Wireless Communication Network
Jun Terada (NTT Access Service Network System Laboratories, Japan)

Tuesday, September 20, 2016, 10:00 – 10:30 Room 112

Optics For 5G: How Can We Combine Low Cost With Demanding Requirements?
Antonio Tartaglia (BUCI DUIP PDU OM Systems & Technology Ericsson Telecomunicazioni S.p.A., Italy)

Tuesday, September 20, 2016, 17:00 – 17:30 Room 18+19

Recent Progress on 25G EPON and beyond
Vincent Houtsma (Bell Labs - Nokia, USA)

Wednesday, September 21, 2016, 12:00 – 12:30 Room 18+19

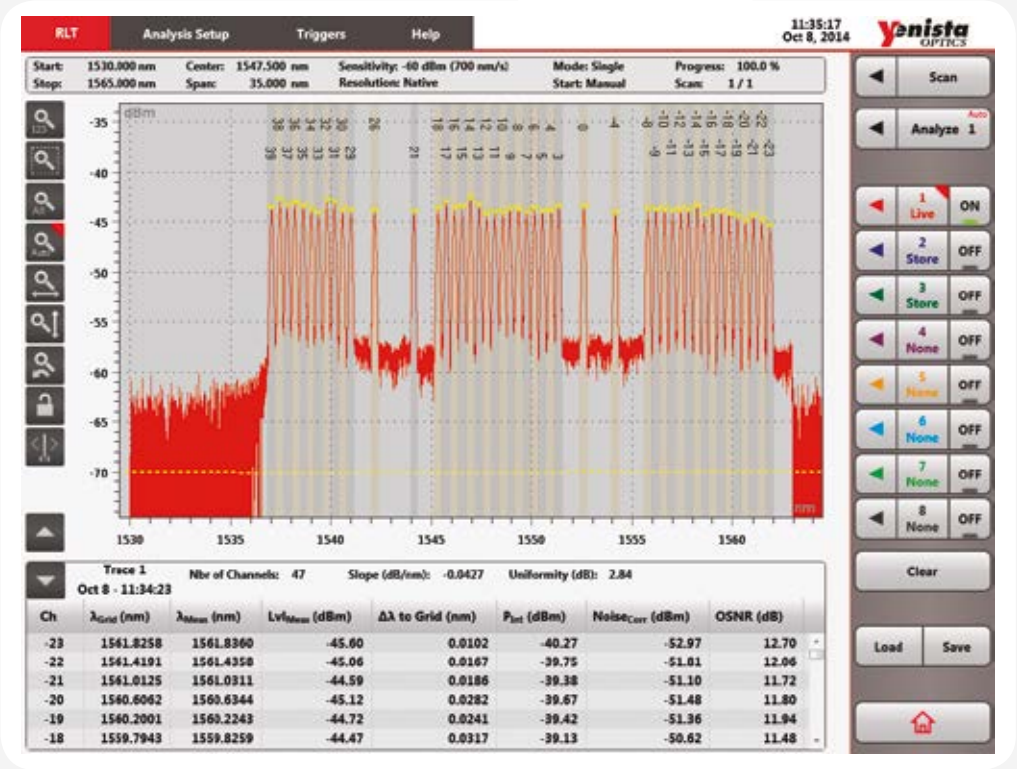
Cost effective 25 Gbps Optical Access Technology
Dora van Veen (Nokia, USA)

Wednesday, September 21, 2016, 14:30 – 15:00 Room 110

Burst-Mode Optical Amplifier Technologies for TWDM-PON
Masamichi Fujiwara (NTT Access Service Network System Laboratories, Japan)

Optical Spectrum Analyzer

Recirculating Loop Experiments
OSA20 > 10x faster at RBW of 20 pm*



Screen shot of the OSA20 for a recirculating loop transmission experiment of 100 Gb/s QPSK - Spectrum after 10 loops of 560 km = 5600 km -

***Bench mark test:**

- Test set-up:
  - 17 x 560 km = 9520 km
  - Gate = 1 ms
  - Sweep span = 35 nm

- Measurement time:
  - OSA20 = 27 seconds against 6317B = 830 seconds

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CLEO FOCUS MEETING
FUNDAMENTAL PHOTONICS FOR FUTURE TELECOMMUNICATIONS

Following on from successful conferences held since 2006, the European Physical Society and CLEO Europe-EQEC in collaboration with the Chairs of ECOC 2016 are delighted to announce the organisation of a special CLEO Focus Meeting on Fundamental Photonics for Future Telecommunications, to be held as part of ECOC 2016.

New developments and trends on emerging and highly forward-looking research in photonics will be at the heart of this special CLEO Focus Meeting, complementary to the regular ECOC sessions. The meeting will showcase state-of-the-art results which bridge the gap between basic science and applications.

The scope includes, but is not limited to, digital and optical signal processing, nanophotonics, plasmonics, nonlinear optics, novel materials including metamaterials, novel devices, spatio-temporal complex nonlinear dynamics, optical angular momentum research, quantum optics, emerging ultrafast technologies, new concepts in optical generation including supercontinuum sources, optical rogue waves and frequency combs, multimode systems, beam manipulation and wave-guiding, and other optical communication and processing related topics.

Tuesday, September 20, 2016

CLEO 1: Spatiotemporal Control • Room 14

Chair: Sergei K. Turitsyn (Aston University & Photonics Research Group, UK)

09:00 **Frequency Stability in Optical Networks: Challenges, Implementation and Implications (invited)**
Stojan Radic (University of California, San Diego, USA)
♦ The role of frequency carrier stability in optical networks is discussed. We show that so-called nonlinear capacity limit for fiber transmission was established erroneously and has no physical basis in any optical network of practical interest.

09:30 **Pulse Combining and Compression in Multi-core Fibers**
Igor Chekhovskoy (Novosibirsk State University & Institute of Computational Technologies, RU); Alexander Rubenchik (Lawrence Livermore National Laboratory, USA); Olga Shtyrina (Novosibirsk State University & Institute of Computational Technologies, RU); Sergei K. Turitsyn (Aston University & Photonics Research Group, UK); Mikhail Fedoruk (Novosibirsk State University & Institute of Computational Technologies, RU)
♦ We investigate pulse compression and combining efficiency for multi-core fibers of different structures. Coherent combining in one core with efficiency over 80% and pulse compression few hundreds times are demonstrated. We analyse the influence of perturbations of input pulses.

09:45 **Spatiotemporal Nonlinear Interactions in Multimode Fibers**
Katarzyna Krupa (ICB UMR CNRS 6303 Université de Bourgogne Franche-Comté & XLIM UMR CNRS 7252 Université de Limoges, FR); Alessandro Tonello (XLIM UMR CNRS 7252 Université de Limoges, FR); Abdelkrim Bendahmane (Université de Bourgogne, FR); Richard Dupiol (ICB UMR CNRS 6303 Université de Bourgogne Franche-Comté, FR); Badr Shalaby, Marc Fabert (XLIM UMR CNRS 7252 Université de Limoges, FR); Alain Barthelemy (XLIM Institut de Recherche, FR); Guy Millot (CNRS/Université de Bourgogne, FR); Stefan Wabnitz (University of Brescia, IT); Vincent Couderc (Université de Limoges, FR)
♦ We observe experimentally a novel spatiotemporal dynamics of multimode fibers allowing for a new type of parametric instability and an original phenomenon of light self-organisation. Our experiments agree well with theoretical predictions and numerical simulations based on the Gross-Pitaevskii equation.

10:00 **Ultra-Stable Optical Frequency and Accurate Timing Signal Dissemination Using Telecommunication Network (Invited)**
Olivier Lopez (LPL - CNRS - Paris 13 University, FR); Nicolas Quintin (LPL - Paris 13 University - CNRS, FR); Fabio Stefani (SYRTE - PARIS Observatory - CNRS - UPMC, FR); Anthony Bercy (LPL - CNRS - Paris 13 University, FR); Nicolas Chiodo (LPL - Paris 13 University - CNRS, FR); Fabrice Wiotte (LPL - CNRS - Paris 13 University, FR); Emilie Camisard (RENATER, FR); Chriistian Chardonnet (LPL - CNRS - Paris 13 University, FR); Giorgio Santarelli (LP2N - CNRS - Bordeaux University, FR); Paul-Eric Pottie (SYRTE - CNRS - Observatoire de Paris - UPMC, FR); Anne Amy-Klein (LPL - Paris 13 University - CNRS, FR)
♦ Optical fibre links have been developed to transfer an ultrastable optical frequency between distant laboratories for time and frequency metrology and high-precision measurements. We will review the specificity of this technique, its performance and a few applications.

10:30 - 11:00 Coffee Break

CLEO 2: Optical Information Processing • Room 14

Chair: Stefan Wabnitz (University of Brescia, Italy)

11:00 **Photonic Reservoir Computing for Ultra-Fast Information Processing Using Semiconductor Lasers (Invited)**
Ingo Fischer, Julian Bueno, Daniel Brunner, Miguel Soriano and Claudio Mirasso (IFISC (UIB-CSIC), ES)
♦ Neuro-inspired computational concepts like reservoir computing can now be implemented in telecommunication-compatible hardware, with high hardware and energy efficiency and exhibiting excellent computing performance. This provides interesting perspectives for applications in telecommunication.

11:30 **Enhanced nonlinear spectral compression in fibre by sinusoidal phase modulation**
Christophe Finot (University of Burgundy, FR); Sonia Boscolo (Aston University, UK)
♦ We propose a simple approach to enhance the spectral compression arising from nonlinear pulse propagation in a Kerr medium. We numerically show that an additional sinusoidal temporal phase modulation enables efficient reduction of the intensity level of spectral side lobes.

11:45 **Linear and Nonlinear Frequency-Division Multiplexing**
Mansoor Isvand Yousefi (Telecom ParisTech, FR); Xianhe Yangzhang (Technical University of Munich, DE)
♦ Achievable rates of WDM and nonlinear frequency-division multiplexing (NFDM) are computed as a function of transmit power. The NFDM rate increases monotonically with power, in contrast to the WDM rate which characteristically vanishes at high powers. The improvement results from nonlinear signal multiplexing.

12:00 **Periodic Nonlinear Fourier Transform Based Transmissions with High Order QAM Formats**
Morteza Kamalian, Kopae (Aston University & Aston Institute of Photonic Technologies, UK); Jaroslaw Prilepsky (Aston University & Aston Institute of Photonic Technologies, UK); Son Le (Aston University, UK); Sergei K. Turitsyn (Aston University & Photonics Research Group, UK)
♦ We propose, for the first time, a technique of constructing signals with high order QAM formats (128--512 QAM) for periodic nonlinear Fourier transform based systems. The proposed method effectively eliminates the inverse transformation stage reducing significantly the system‘s complexity.

12:15 **Programmable single-photon to single-atom quantum interface**
Juergen Eschner, Christoph Kurz, Pascal Eich, Michael Schug and Philipp Müller (Saarland University, DE)
♦ Integration of quantum photonic systems into future telecommunication technologies, for example for quantum cryptography, requires interfacing single photons as quantum information carriers with single atoms as quantum memories. We demonstrate a programmable interface for bi-directional quantum state conversion between single photons and single trapped atomic ions.

12:30 **Sources for Integrated Quantum Information Processing (Invited)**
Christine Silberhorn, Benjamin Brecht, Christof Eigner, Harald Hermann, Stephan Krapick, Kai-Hong Luo, Regina Kruse, Raimund Ricken and Linda Sansoni (University of Paderborn & Faculty of Sciences, DE); Viktor Quiring (Universitaet Paderborn, DE)
♦ Integrated optics provides a promising platform for the implementation of highly complex and compact circuits for quantum information applications. Integrated waveguide sources feature high brightness and interferometric stability. Here we present our work on advanced multi-channel devices.

13:00 - 14:00 Lunch Break

14:00 - 16:00 Exhibition Only

CLEO 3: Optoelectronics • Room 14

Chair: Stojan Radic (University of California, San Diego, USA)

16:00 **Subwavelength Index Engineered Structures: Fundamental Building Blocks for the Next Generation Photonic Integrated Circuits (Invited)**
Pavel Cheben (NRC Institute for Microstructural Sciences, CA); Danxia Xu (NRC Institute for Microstructural Sciences, DE)
♦ Subwavelength engineered all-dielectric metamaterial structures are likely to become key building blocks for the next generation of integrated photonic circuits. This unique technology allows synthesis of an effective photonic medium with an unprecedented control of material properties. We present an overview of emerging implementations, including high-efficiency broadband fibre-chip surface grating couplers and edge couplers, ultra-broadband splitters, sensors and mid-infrared waveguide components, to name a few.

16:30 **New Ultrafast Laser Sources and Nonlinear Devices Based on TM:II-VI Semiconductors**
Sergey Vasilyev, Igor Moskalev, Mike Mirov, Viktor Smolski and Sergey Mirov (IPG Photonics Mid-IR Lasers, USA); Valentin Gapontsev (IPG Photonics Corporation, USA)
♦ Transition-metal-doped II-VI semiconductors possess a unique blend of physical, spectroscopic, optical, and technological parameters. These materials enable high power lasers in important middle-infrared range; they are also well suited for generation and efficient nonlinear frequency conversion of ultra-short optical pulses.

16:45 **Fundamental and Applied Aspects of Submonolayer Quantum Dots as Active Medium in Opto-electronics**
Bastian Herzog, Mirco Kolarczik, Yücel Kaptan, Benjamin Lingnau, Kathy Lüdge, Jan-Hindrik Schulze and Ricardo Rosales (Technische Universität Berlin, DE); Dieter Bimberg (Technical University of Berlin, DE); Andre Strittmatter (Technische Universität Berlin, DE); Udo Pohl, Ulrike Woggon and Nina Owschimikow (Technische Universität Berlin, DE)
♦ Submonolayers promise to combine the high gain of quantum wells with the stability of quantum dots. We investigate the carrier dynamics by phase sensitive heterodyne pump-probe experiments and find a fast <2ps relaxation and high gain, accompanied by large nonlinearities.

17:00 **Realization of Arbitrary Complex Apodization Profiles in Integrated Waveguide Bragg Gratings on SOI**
Hamed Pishvaibazargani (Institut National de la Recherche Scientifique (INRS), CA); Jose Azana (INRS, CA)
♦ We implement waveguide Bragg gratings (BGs) with misaligned sidewall corrugations in order to realize profiles. In particular a very challenging grating design, namely photonic Hilbert transformer, has user-defined complex apodization been successfully demonstrated on SOI.

17:15 **Nonlinear Integrated Photonics in Lithium Niobate by Direct Femtosecond Laser Writing**
Sebastian Kroesen, Lukas Wesemann, Kemal Tekce and Jörg Imbrock (Institute of Applied Physics, University of Münster, DE); Cornelia Denz (Institute of Applied Physics, University of Münster, DE)
♦ We report on the monolithic fabrication of integrated optical elements in lithium niobate by direct femtosecond laser writing. Advanced designs and processing schemes enable a novel synthesis of complex refractive index structures and tailored nonlinearity.

Wednesday, September 21, 2016

CLEO 4: Nonlinear Cavities • Room 14

Chair: Bertrand Kibler (C NRS / Université Bourgogne Franche-Comté, FR)

09:00 **Using Kerr combs for coherent optical communications (Invited)**
Yanne Chembo (FEMTO-ST Institute, FR)
♦ Kerr optical frequency combs can be used as multi-wavelength sources for coherent optical fiber telecommunication networks. We here discuss some results perspectives and challenges in this emerging field.

09:30 **Chipscale Frequency combs: From soliton physics to coherent telecommunication**
Michael Geiselmann, Victor Brasch, Martin Pfeiffer and Karpov Maxim (Ecole Polytechnique Federale de Lausanne, CH); Junqiu Liu and Hairun Guo (EPFL, CH); Grigoriy Lihachev (Lomonosov Moscow State University, RU); Michael Gorodetsky (M. V. Lomonosov Moscow State University, RU); Tobias Kippenberg (Ecole Polytechnique Federale de Lausanne, CH)
♦ We generate soliton Kerr frequency combs in a silicon nitride microresonator. These combs are fully coherent and are used as channel generator for coherent telecommunication. With the right dispersion engineering we can broaden the spectrum to 75THz span around 1550nm.

09:45 **Seeding of Modulation Instability in a Nonlinear Fiber Ring Cavity**
Abdelkrim Bendahmane (Université de Bourgogne, FR); Julien Fatome (CNRS/Université de Bourgogne, FR); Christophe Finot (University of Burgundy, FR); Guy Millot (CNRS/Université de Bourgogne, FR); Bertrand Kibler (CNRS / Université Bourgogne Franche-Comté, FR)
♦ We experimentally and numerically investigate the impact of coherent and incoherent seeding of the modulation instability process in a nonlinear fiber ring cavity. Our results highlight the sensitivity of the nonlinear dynamics in term of sideband bandwidth and temporal coherence.

10:00 **Comb Peculiarities of the Dispersion-managed Soliton in the Hybrid Mode-locked Erbium-doped All-fiber Ring Laser**
Dmitriy Dvoretskiy, Stanislav Sazonkin, Maxim Negin, Dmitry Shelestov, Alexey Pniov and Valery Karasik (Bauman Moscow State Technical University, RU); Alexander Krylov (Fiber Optics Research Center of the RAS, RU); Elena Obraztsova (A M Prokhorov General Physics Institute of the RAS, RU)
♦ We studied optical comb peculiarities of the ultra-short dispersion-managed soliton generation in the erbium-doped all-fiber ring laser hybrid mode-locked with Carbon: Boron Nitride Single-Walled Nanotubes in the co-action with a nonlinear polarization evolution.

10:15 **Kerr Frequency Combs in a Bichromatically Pumped Nonlinear Fiber Ring Cavity**
Abdelkrim Bendahmane (Université de Bourgogne, FR); Davide Ceoldo (Università di Brescia, Brescia, IT); Julien Fatome and Guy Millot (CNRS/Université de Bourgogne, FR); Tobias Hansson and Daniele Modotto (Università di Brescia, Brescia, IT); Stefan Wabnitz (University of Brescia, Italy); Bertrand Kibler (CNRS / Université Bourgogne Franche-Comté, FR)
♦ We report numerical and experimental studies of four-wave mixing processes emerging from dual-frequency pumping of a passive fibre ring cavity. We observe the emission of a periodic train of nearly-background-free soliton pulses associated with Kerr frequency combs.

10:30 - 11:00 Coffee Break

CLEO 5: Lasers and instabilities • Room 14

Chair: Yanne Chembo (FEMTO-ST Institute, FR)

11:00 **Real-Time Single-Shot Diagnostics of Mode-Locked Lasers (invited)**
Georg Herink (University of Goettingen & UCLA, DE); Felix Kurtz (University of Goettingen, DE); Bahram Jalali (University of California, Los Angeles, USA); Claus Ropers (University of Goettingen, DE); Daniel Solli (UCLA, USA)
♦ The combination of photonic time-stretch techniques and real-time electronics enables rapid single-shot spectral acquisition over millions of consecutive laser pulses. We present the first real-time spectral view onto the evolution of femtosecond-pulses from noise, onto stable and meta-stable multi-pulse operation.

11:30 **Real Time Measurements of Noise-induced Rogue Waves Generated by Modulation Instability in Optical Fibre**
Mikko Närhi (Tampere University of Technology, FI); Benjamin Wetzel (INRS-EMT, CA); Cyril Billet (Université de Franche-Comté, FR); Thibaut Sylvestre (Femto-ST Institute & CNRS, FR); Shanti Toenger and Jean-Marc Merolla (FEMTO-ST Institute, FR); Roberto Morandotti (INRS-EMT, CA); Frederic Dias (University College Dublin, IR); Goëry Genty (Tampere University of Technology, FI); John Dudley (Université de Franche-Comté, FR)
♦ Using a parametric temporal magnifier system, we report for the first time on the direct temporal measurement of rogue waves and breather-like structures arising from spontaneous modulation instability.

11:45 **FBG Reflectivity Impact on RIN in Ultralong Laser Amplifiers**
Giuseppe Rizzelli Martella (CSIC - Instituto de Optica, ES); Md Asif Iqbal (Aston University, UK); FRsca Gallazzi and Paweł Rosa (CSIC - Instituto de Optica, ES); Mingming Tan (Aston University & AIPT, UK); Pedro Corredera (CSIC - Instituto de Optica, ES); Juan Diego Ania-Castanon (CSIC - Instituto de Optica, ES); Paul Harper (Aston University, UK)
♦ We analyse, both numerically and experimentally, the Relative Intensity Noise transfer in ultra-long Raman laser amplifiers isolating the combined effect of front-FBG reflectivity and pump power split and quantitatively showing their impact on a 100 km, 2nd-order, bidirectionally pumped configuration.

12:00 **Extremely Pulsating Solitons in a Mode-locked Fiber Laser**
Junsong Peng (AstonUniversity, UK); Nikita Tarasov, Srikanth Sugavanam and Dmitry Churkin (Aston University, UK)
♦ Extremely pulsating solitons were observed experimentally in a mode-locked fiber laser. The solitons changed their intensity by an order of magnitude and exhibited time shift with a period of 1100 cavity roundtrips; meanwhile their optical spectrum breathed and compressed periodically.

12:15 **High-order linearly-polarized random Raman fiber laser for telecom applications**
Ekaterina Zlobina and Sergey Kablukov (Institute for Automation and Electrometry SB RAS, RU); Sergey Babin (Institute for Automation and Electrometry SB RAS & Novosibirsk State University, RU)
♦ We demonstrate an efficient linearly polarized random lasing in a 1.8-km PM fiber up to the 5th order Stokes component at ~1360 nm. Potential applications and problems of further expansion to longer wavelengths are discussed.

M.1.A: High Power Fiber Lasers — Room 18+19

Chair: Hans G. Limberger (EPFL & Gr-Sci-HL, CH)

M.1.A.1 • 14:00 *Tutorial*
High Power Fibre Lasers: Fundamentals, Recent Progress and Challenges
Michael Zervas (University of Southampton & SPI Lasers, UK); Christophe Codemard (SPI Lasers, UK)
♦ We review the fundamental properties and latest power scaling in fibre lasers, including limitations imposed by fibre nonlinearities, transverse modal instabilities and other parasitic effects. Their impact on the industrial applications space is also considered.

M.1.B: DSP for Receiver Subsystems — Room 17

Chair: Naoya Wada (NICT, JP)

M.1.B.1 • 14:00 *Invited*
Adaptive Transceivers in Nonlinear Flexible Networks
David Ives (University of Cambridge, UK); Alex Alvarado (University College London, UK); Seb J Savory (University of Cambridge, UK)
♦ Transceiver adaptation is essential within an optical network to make effective use of the physical layer resources. We investigate the types of a daptation, the granularity of control and its effect on network data throughput.

M.1.B.2 • 14:30
Accurate and Robust Channel Spacing Estimation Based on Periodic Training Sequence in Denser Nyquist-WDM System
Ying Zhao, Huihui Li, Xiaofei Su, Liang Dou and Zhenning Tao (Fujitsu R&D Center Ltd., PRC); Shoichiro Oda (Fujitsu Laboratories Ltd., JP); Yasuhiko Aoki (Fujitsu Limited, JP); Takeshi Hoshida and Jens C. Rasmussen (Fujitsu Laboratories Limited, JP)
♦ We propose an accurate and robust channel spacing estimation method based on a designed periodic training sequence. Experiment results show that estimation error is less than 50MHz and the method is immune to chromatic dispersion, polarization effects and fiber nonlinearity.

M.1.B.3 • 14:45
Linewidth-Tolerant Carrier Phase Estimation for N-PSK Based on Pilot-Assisted N/2th-power Method
Tomofumi Oyama (Fujitsu Laboratories Ltd, JP); Takeshi Hoshida, Hisao Nakashima (Fujitsu Limited, JP); Takahito Tanimura (Fujitsu Laboratories Ltd., JP); Yuichi Akiyama (Fujitsu Limited, JP); Jens C. Rasmussen (Fujitsu Laboratories Ltd., JP)
♦ We propose a novel pilot-assisted carrier phase estimation method to reduce cycle slips. We numerically confirm that carrier phase recovery based on proposed method outperforms conventional V&V method in BER performance in large linewidth condition without causing any cycle slips.

M.1.B.4 • 15:00
Time Recovery for Spectrally-Sliced Optical Receivers
Valery Nobl Rozental, André Souza, Sandro M. Rossi, Andrea Chiuchiarelli, Juliano Rodrigues Fernandes de Oliveira and Jacklyn D. Reis (CPqD, Division of Optical Technologies, BR)
♦ We propose and experimentally demonstrate a symbol synchronization method for spectrally-sliced optical receivers with MIMO equalizer signal reconstruction in a PM-16QAM 56-GBd 20x400G testbed. A novel timing error detector extracts sampling phase information from equalizer coefficients.

M.1.B.5 • 15:15
Widely Linear Blind Adaptive Equalization for Transmitter IQ-Imbalance/Skew Compensation in Multicarrier Systems
Edson Porto da Silva (Technical University of Denmark, DK); Darko Zibar (DTU Fotonik, department of Photonic Engineering, Technical University of Denmark, DK)
♦ Simple analytical widely linear complex-valued models for IQ-imbalance and IQ-skew effects in multicarrier transmitters are presented. To compensate for such effects, a 4$\times$4 MIMO widely linear adaptive equalizer is proposed and experimentally validated.

M.1.C: High Speed Subsystems — Room 16

Chair: Laurent Bramerie (Foton CNRS UMR & ENSSAT / Université de Rennes 1, FR)

M.1.C.1 • 14:00
On Single-Carrier 400G Line Side Optics Using PM-256QAM
Hung-Chang Chien, Jianjun Yu (ZTE (TX) Inc., USA)
♦ For the first time, 400G line side interface based on single-carrier PM-256QAM is proposed and experimentally demonstrated, reaching 1.04-dBQ BTB system margin to the SD pre-FEC limit through fast-converging polarization-tracking blind equalization and LUT nonlinearity compensation.

M.1.C.2 • 14:15
180-Gb/s (90-GBd QPSK) Single Carrier Transmitter Using a Thin Film Polymer on Silicon I/Q Modulator
Gregory Raybon, Junho Cho,and Andrew Adamiecki (Nokia Bell Labs, USA); Peter Winzer (Bell Labs, USA); Luis Carvalho, Julio Cesar Oliveira (BrPhotonics, BR); Agnieszka Konczykowska and Jean-Yves Dupuy (III-V Lab, FR); Filipe Jorge (Nokia Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR)
♦ We demonstrate high-speed (90-GBd) modulation of a thin film polymer on Silicon (TFPS) I/Q modulator achieving single-polarization quadrature phase shift keyed (QPSK) data rates of 180 Gb/s.

M.1.C.3 • 14:30 *Invited*
Injection-locked Homodyne Detection System for Higher-order QAM Digital Coherent Transmission
Keisuke Kasai, Masato Yoshida, Toshihiko Hirooka, Masataka Nakazawa (Tohoku University, JP)
♦ We describe recent advances in a homodyne-detection system with injection locking and its application for higher-order QAM coherent transmission. Injection locking enables precise optical carrier-phase synchronisation with a simple receiver configuration. We demonstrate a 320 Gbit/s, 256QAM-160 km transmission.

M.1.C.4 • 15:00
100 GSa/s BiCMOS DAC Supporting 400 Gb/s Dual Channel Transmission
Karsten Schuh, Fred Buchali, Wilfried Idler, Qian Hu, Wolfgang Templ (Nokia, Bell Labs, DE); Anna Bielik, Lars Altenhain, Henning Langenhagen, Jörg Rupeter, Ulrich Dümler, Tobias Ellermeyer, Rolf Schmid and Michael Möller (MICRAM Microelectronic GmbH, DE)
♦ We demonstrate generation of a 32Gbaud 16QAM dual polarization dual channel signal from one laser utilizing novel 100GSa/s BiCMOS digital-to-analog converters. Fiber transmission over 2200 km of SSMF is also demonstrated outperforming a 64 GBaud system by 25% in reach.

M.1.C.5 • 15:15
Single-Detector, Single-ADC, Switched Coherent Optical Receiver for High Symbol Rate Systems Experiments
Gregory Raybon, Junho Cho and Andrew Adamiecki (Nokia Bell Labs, USA); Peter Winzer (Lucent Technologies, USA); Nicolas K Fontaine (Bell Labs/Nokia, USA); Jean-Yves Dupuy and Agnieszka Konczykowska (III-V Lab, FR); Filipe Jorge (Nokia Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR); Peter Pupalaikis (LeCroy Corporation, USA); Roger Delbue, B Bhat and Patrick Connally (Teledyne Lecroy, USA); Roland Ryf (Bell Labs, Nokia, USA); Ellsworth C. Burrows (Bell Labs, Nokia, USA)
♦ We demonstrate a polarization-diversity coherent receiver with 100-GHz electrical bandwidth using only a single photodetector and a single high-speed analog-to-digital converter (ADC). We verify receiver performance using 90-GBd polarization-multiplexed QPSK test signals.

15:30 - 16:00 Coffee Break | Exhibition Hall |

M.1.D: Probabilistic Shaping — Room 15

Chair: Gabriel Charlet (Nokia Bell Labs, FR)

M.1.D.1 • 14:00
Experimental Comparison of Gains in Achievable Information Rates from Probabilistic Shaping and Digital Backpropagation for DP-256QAM/1024QAM WDM Systems
Edson Porto da Silva, Metodi Yankov, Francesco Da Ros, Soren Forchhammer, Michael Galili, Leif Oxenløwe (Technical University of Denmark, DK); Darko Zibar (DTU Fotonik, department of Photonic Engineering, Technical University of Denmark, DK)
♦ Gains in achievable information rates from probabilistic shaping and digital backpropagation are compared for WDM transmission of 5x10-GBd DP-256QAM/1024QAM up to 1700 km reach. The combination of both techniques its shown to provide gains of up to 0.5 bits/QAM symbol.

M.1.D.2 • 14:15
Field Demonstration of 1 Tbit/s Super-Channel Network Using Probabilistically Shaped Constellations
Wilfried Idler, Fred Buchali, Laurent Schmalen and Eugen Lach (Nokia Bell Labs, DE); Ralf-Peter Braun (Deutsche Telekom T-Labs, DE); Georg Böcherer, Patrick Schulte and Fabian Steiner (Technische Universität München, DE)
♦ We successfully tested the suitability of probabilistically shaped constellations in field environment. We performed 1 Tbit/s 4-carriers super-channel transmission in the German nationwide backbone network with an extended family of probabilistically shaped constellations using 16QAM, 36QAM and 64QAM.

M.1.D.3 • 14:30
Study of electrical subband multiplexing at 54 GHz modulation bandwidth for 16QAM and probabilistically shaped 64QAM
Fred Buchali, Wilfried Idler, Karsten Schuh and Laurent Schmalen (Nokia Bell Labs, DE); Georg Böcherer, Fabian Steiner and Patrick Schulte (Technische Universität München, DE); Tobias A. Eriksson (Nokia Bell Labs, DE)
♦ We showed 14% and 9% reach gain for electrical subband multiplexed 16QAM and PS-64QAM signals at 54GHz modulation bandwidth. A detailed analysis exhibits up to 40% gain for best subbands.

M.1.D.4 • 14:45
Capacity Approaching Transmission using Probabilistic Shaping and DBP for PFE Constrained Submarine Optical Links
Robert Maher, Domanic Lavery, Gabriele Liga, Milen Paskov and Alex Alvarado (University College London, UK); Tobias Fehenberger (Technical University of Munich (TUM), DE); Polina Bayvel (UCL, UK)
♦ Probabilistic constellation shaping and DBP enables the reduction in per-channel launch power by 2.2 dB, in a 150 channel 11000 km submarine link. For a fixed PFE voltage of 12 kV, the total system throughput is increased by 64%.

M.1.D.5 • 15:00 *Invited*
Mutual information characterization of nonlinear fiber channels
Tobias A. Eriksson (Nokia Bell Labs, DE); Tobias Fehenberger (Technical University of Munich (TUM), DE)
♦ Achievable information rates are investigated for different coherent transmission scenarios. By using four-dimensional channel statistics, taken over two polarizations or two consecutive time slots, gains compared to conventional two-dimensional demappers are found, even for links without inline dispersion compensation.

M.1.E: Coherent PON — Room 110

Chair: Roberto Gaudino (Politecnico di Torino, IT)

M.1.E.1 • 14:00
Demonstration of 100 Gb/s/λ-based Coherent PON System Using New Automatic Gain Controlled EDFA with ASE Compensation Function for Upstream Pre-Amplification
Naoki Suzuki, Hiroshi Miura, Kenichi Uto (Mitsubishi Electric Corporation, JP)
♦ We demonstrate the first prototype real-time 100 Gb/s/λ-based Coherent-PON. With an improved upstream received sensitivity of -38.1 dBm, a large loss budget of 39.1 dB over 80 km was achieved by a new AGC-EDFA with ACF and a simplified DSP.

M.1.E.2 • 14:15
Bidirectional symmetric 8 x 10.7 Gb/s WDM-PON over 108 km installed fiber using low complexity polarization-insensitive coherent ONUs
M. Sezer Erkilinc, Domanic Lavery, Kai Shi, Benn C Thomsen, Polina Bayvel, Robert I Killey (University College London, UK); Seb J Savory (University of Cambridge, UK)
♦ Polarization-time block-coded OFDM-QPSK downstream channels are robustly detected using a polarization-insensitive coherent receiver, consisting of only a 3-dB coupler and single balanced PD. 8x10.7 Gb/s channels are bidirectionally transmitted over 108km installed fiber achieving a 1:16-way passive split.

M.1.E.3 • 14:30 *Invited*
Protection Systems for optical access networks
Takashi Nishitani (Mitsubishi Electric Corporation, JP)
♦ A PON needs a protection scheme to ensure the system's reliability. Fast protection switching is important for outage-free maintenance and rapid recovery from failure. This paper introduces two PON protection systems for fast protection switching in under 50ms.

M.1.E.4 • 15:00
22-dB Dynamic Range, Real-Time Burst-Mode Reception of Digital Coherent 20-Gb/s QPSK PON Upstream Signals
Ryo Koma (NTT Access Network Service Systems Laboratories, NTT Corporation, JP); Masamichi Fujiwara (NTT Access Network Service Systems Laboratories, JP); Jun-ichi Kani (NTT, JP); Sang-Yuep Kim (NTT Access Network Service Systems Laboratories, JP); Takahiro Suzuki (NTT & NTT Access Network Service Systems Laboratory, JP); Hideki Mori and Tomoyuki Wada (NTT Advanced Technology Corp., JP); Ken-Ichi Suzuki (NTT, JP); Akihiro Otaka (NTT Corporation, JP)
♦ We report, for the first time, real-time burst-mode digital coherent reception wherein frame power differences are considered. 20-Gb/s QPSK burst signals with 22-dB dynamic range are successfully received by SOA-based optical power equalizer and burst-mode DSP.

M.1.E.5 • 15:15
Field-Trial of Low-Cost Coherent UDWDM-PON with Real-Time Processing, λ-Monitoring and EPON Coexistence
Ivan Cano, Josep Prat, Jeison Tabares, Juan Camilo Velásquez Micolta, Saeed Ghasemi, Victor Polo and Guang Yong Chu (Universitat Politècnica de Catalunya, ES); Marco Presi, Ernesto Ciaramella, Mario Rannello, Fabio Bottoni, Massimo Artiglia and Giulio Cossu (Scuola Superiore Sant'Anna University, IT); Robert Pous, Gregorio Azcárate and Chantal Vila (Promax, ES); Helen Debregeas-Sillard (III-V Lab, FR); Gemma Vall-llosera (Ericsson Research, SE); Albert Rafel (BT, UK)
♦ An UDWDM-PON with simple real-time ASK and DPSK transceivers is validated in a field-trial with deployed fibre achieving -47 dBm sensitivity at BER=2e-3 with 1.25 Gbit/s effective user bitrate. Real data traffic transmission and EPON coexistence are also demonstrated.

M.1.F: Advanced Optical Networking — Room 112

Chair: Lena Wosinska (KTH Royal Institute of Technology, SE)

M.1.F.1 • 14:00
Impact of Traffic Profile on the Performance of Spatial Superchannel Switching in SDM Networks
Behnam Shariati and Dimitrios Klonidis (Athens Information Technology, GR); Domenico Siracusa and Federico Pederzolli (CREATE-NET, IT); Jose Manuel Rivas (Athens Information Technology, GR); Luis Velasco (Universitat Politècnica de Catalunya (UPC), ES); I Tomkos (AIT Greece, GR)
♦ We compare the performance of three SDM switching paradigms under different traffic profiles. We show that their performance is highly traffic dependent. We also show that increasing the spectral switching granularity, significantly improves the performance of spatial group switching.

M.1.F.2 • 14:15
Comparison of SDM and WDM on Direct and Indirect Optical Data Center Networks
Yifan Liu, Hui Yuan, Adaranijo Peters and Georgios Zervas (University of Bristol, UK)
♦ We benchmark Data Centre topologies under SDM and WDM transport in terms of network capacity, utilization, blocking probability, cost and power consumption. SDM offers cost and power benefits than WDM while Spine-Leaf demonstrates all-round best performance among all topologies.

M.1.F.3 • 14:30
Experimental Demonstration of a Flexible Filterless and Bidirectional SDM Optical Metro/Inter-DC Network
George M. Saridis (University of Bristol, UK); Benjamin J Puttnam (National Institute of Information and Communications Technology, JP); Ruben S Luís (NICT, USA); Werner Klaus, Takaya Miyazawa and Yoshinari Awaji (National Institute of Information and Communications Technology (NICT), JP); Georgios Zervas and Dimitra Simeonidou (University of Bristol, UK); Naoya Wada (NICT, JP)
♦ We experimentally evaluate a filterless, all-optical network using architecture-on-demand nodes and MCF-based links for metro and inter-data centre communication. We demonstrate that bidirectional SDM networking with elastic super-channels can eliminate drop-and-waste while supporting hitless dynamic bandwidth allocation.

M.1.F.4 • 14:45
Cost Benefit Quantification of SDM Network Implementations based on Spatially Integrated Network Elements
Jose Manuel Rivas and Behnam Shariati (Athens Information Technology, GR); Antonia Mastropaolo (Scuola Superiore Sant'Anna, IT); Dimitrios Klonidis, I Tomkos (AIT Greece, GR)
♦ We perform a techno-economic analysis of different SDM network implementations considering spatially-integrated transceivers, amplifiers and switches. We quantify the cost reduction of the SDM schemes compared to conventional approaches based on parallel-fiber systems.

M.1.F.5 • 15:00 *Invited*
Building a Programmable Testbed Infrastructure in the UK to Support Network R&D
David Salmon (Jisc, UK)
♦ Availability of network testbed infrastructures for the UK academic network research communities is currently at a scale never previously realised. These infrastructures will be described, together with some of the project work being undertaken and the prospects for future developments.

15:30 - 16:00 Coffee Break | Exhibition Hall |

M.2.A: Fiber Amplifiers for SDM — Room 18+19

Chair: Pierre Sillard (Prysmian, FR)

M.2.A.1 • 16:00
Efficient pumping scheme for amplifier arrays with shared pump laser
Alan Gnauck (Nokia Bell Labs, USA); Peter Winzer (Bell Labs, USA); Robert Jopson, Ellsworth Burrows (Nokia Bell Labs, USA)
♦ tbd

M.2.A.2 • 16:15
Cladding Pumped Seven-Core EDFA Using an Absorption-Enhanced Erbium Doped Fibre
Yukihiro Tsuchida, Koichi Maeda and Kengo Watanabe (Furukawa Electric co., Ltd., JP); Koki Takeshima (KDDI R&D Laboratories Inc., JP); Toru Sasa, Tsunetoshi Saito and Shigehiro Takasaka (Furukawa Electric co., Ltd., JP); Yu Kawaguchi and Takehiro Tsuritani (KDDI R&D Laboratories, Inc., JP); Ryuichi Sugizaki (Furukawa Electric co., Ltd., JP)
♦ We fabricate a seven-core erbium doped fibre that has enhanced absorption cores. We demonstrate C-band cladding-pumped amplification with 20 dB gain, 6 dB NF, 15 dBm output power, and -53 dB core-to-core averaged crosstalk.

M.2.A.3 • 16:30
Novel 6-Mode Fibre Amplifier with Large Erbium-Doped Area for Differential Modal Gain Minimization
Yuta Wakayama (KDDI R&D, JP); Koji Igarashi (Osaka University, JP); Daiki Soma, Hidenori Taga and Takehiro Tsuritani (KDDI R&D Laboratories, Inc., JP)
♦ We demonstrate a cladding-pumped six-mode fibre amplifier with a widely erbium-doped distribution over the core for uniform overlap between spatial modes and the gain medium. The differential modal gain of less than 3.3 dB was achieved in the entire C-band.

M.2.A.4 • 16:45
Core-pumped 10-mode EDFA with Cascaded EDF Configuration
Masaki Wada and Taiji Sakamoto (NTT Corporation, JP); Shinichi Aozasa (NTT Corporation & NTT Access Network Service Systems Laboratories, JP); Takayoshi Mori, Takashi Yamamoto and Kazuhide Nakajima (NTT Corporation, JP)
♦ We experimentally demonstrate a 10-mode fibre amplifier consisting of EDFs with a step-and-ring erbium concentration profile. We achieve a low differential modal gain below 3.5 dB and a low noise figure (4.5-7.0 dB) with a core-pumped configuration in the C-band.

M.2.A.5 • 17:00 *Invited*
Design and characterization of multicore erbium-doped fibers
Sophie LaRochelle, Cang Jin and Younes Messaddeq (Université Laval, CA)
♦ We discuss the design and performance of double-cladding multicore erbium-doped fibers for space-division multiplexing. We describe optimization of signal core and pump annular-cladding to improve pumping efficiency and demonstrate designs leading to gain >19 dB and noise figure <6 dB.

M.2.B: DSP for Short Reach — Room 17

Chair: Dimitrios Apostolopoulos (National Technical University of Athens & Institute of Communication and Computer Systems, GR)

M.2.B.1 • 16:00
Reach Enhancement for WDM Direct-Detection Subcarrier Modulation using Low-Complexity Two-Stage Signal-Signal Beat Interference Cancellation
Zhe Li, M. Sezer Erkilinc and Robert Maher (University College London, UK); Lidia Galdino (Optical Networks Group, University College London, UK); Kai Shi, Benn C Thomsen, Polina Bayvel and Robert I Killey (University College London, UK)
♦ We describe a novel low-complexity SSBI cancellation scheme, and experimentally investigate its performance in a 7×25 Gb/s WDM direct-detection single-sideband 16QAM Nyquist-subcarrier modulation system. The scheme achieves a doubling of the transmission reach.

M.2.B.2 • 16:15
Artificial Neural Networks for Linear and Non-Linear Impairment Mitigation in High-Baudrate IM/DD Systems
Jose Manuel Estaran, Rafael Rios-Müller, Miquel A. Mestre (Nokia Bell Labs, FR); Filipe Jorge (Alcatel Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR); Haik Mardoyan (Nokia Bell Labs, FR); Agnieszka Konczykowska and Jean-Yves Dupuy (III-V Lab, FR); Sebastien Bigo (Bell Labs, Alcatel-Lucent, FR)
♦ We propose using artificial neural networks onto IM/DD optical links to infer simultaneously linear and non-linear channel response. We experimentally exploit this information on an 84-GBd 4-PAM system, proving up to 10x BER improvement over FFE after 1.5-km SSMF.

M.2.B.3 • 16:30 *Invited*
Power Efficient Coherent Transceivers
Jonas C Geyer, Christian Rasmussen, Bhupen Shah, Torben Nielsen and Mehrdad Givehchi (Acacia Communications, Inc., USA)
♦ We review critical areas in the design process of power efficient coherent transceivers, and we highlight the achievable power saving by designing for a particular application as well as power and cost savings when using higher order modulation.

M.2.B.4 • 17:00
Non-linearity Compensation of High-Speed PAM4 Signals from Directly-Modulated Laser at High Extinction Ratio
Nobuhiko Kikuchi and Riu Hirai (Center for Technology Innovation, Hitachi Ltd., JP); Takayoshi Fukui (Oclaro Japan, JP)
♦ We propose a new non-linear waveform compensation scheme for DML-based PAM signals applicable either at transmitter or receiver-side, and its effectiveness is verified with 56-Gbit/s PAM4 experiments with less than 0.1-dB sensitivity penalties up to 8.9-dB extinction ratio.

M.2.B.5 • 17:15
Experimental Investigation of Impulse Response Shortening for Low-Complexity MLSE of a 112-Gbit/s PAM-4 Transceiver
Sjoerd van der Heide (Eindhoven University of Technology & ADVA Optical Networking SE, NL); Nicklas Eiselt (Technical University of Denmark, DK); Helmut Griesser (ADVA Optical Networking SE, DE); Juan Jose Vegas Olmos (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU); Chigo Okonkwo (Eindhoven University of Technology, NL)
♦ An optimized channel shortening method for reduced complexity MLSE detection enables the compensation of severe inter-symbol interference. Experimental investigations demonstrate the benefit on the performance for a severely bandwidth limited 112-Gbit/s PAM-4 transmission system with residual chromatic dispersion.

M.2.C: Pulse Amplitude Modalation I — Room 16

Chair: Michael Galili (Technical University of Denmark, DK)

M.2.C.1 • 16:00 *Upgraded*
100-Gbaud PAM-4 intensity-modulation direct-detection transceiver for datacenter interconnect
Miquel A. Mestre (Nokia Bell Labs, FR); Filipe Jorge (Alcatel Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR); Haik Mardoyan and Jose Manuel Estaran (Nokia Bell Labs, FR); Fabrice Blache (Alcatel-Thales III-V Lab, FR); Philippe Angelini and Agnieszka Konczykowska (III-V Lab, FR); Muriel Riet (Alcatel Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR); Virginie Nodjiadjim (Alcatel-Thales 3-5 Lab, FR); Jean-Yves Dupuy (III-V Lab, FR); Sebastien Bigo (Nokia Bell Labs, FR)
♦ We demonstrate an IM/DD PAM-4 optical transceiver operating at 84 and 100 Gbaud, and achieve successful demodulation after 1 km and 500 m of standard single mode fiber, respectively. Electrical generation is enabled by an integrated high-speed selector power DAC.

M.2.C.2 • 16:30
112 Gb/s PAM-4 Using a Directly Modulated Laser with Linear Pre-Compensation and Nonlinear Post-Compensation
Yuliang Gao, John C Cartledge, Scott Yam and Ali Rezania (Queen's University, CA); Yasuhiro Matsui (Finisar Corp, USA)
♦ For 112 Gb/s PAM-4 short reach transmission using a directly modulated laser, the end-to-end frequency response is used to pre-compensate bandwidth limitations and a Volterra equalizer is used to post-compensate nonlinear signal distortion.

M.2.C.3 • 16:45
112 Gb/s PAM-4 Optical Signal Transmission over 100-m OM4 Multimode Fiber for High-Capacity Data-Center Interconnects
Fotini Karinou, Nebojsa Stojanovic, Cristian Prodaniuc and Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Thomas Dippon (Keysight Technologies Deutschland GmbH, DE)
♦ 112 Gb/s PAM-4 transmissions over 100-m OM4 MMF is demonstrated using a multi-mode 850-nm VCSEL. Results show that BER below the FEC limit can be achieved when employing equalization (FFE/MLSE) at the receiver. MLSE complexity vs. performance is also investigated.

M.2.C.4 • 17:00 *Upgraded*
100 GHz EML for High Speed Optical Interconnect Applications
Oskars Ozolins (Acreo Swedish ICT, SE); Miguel Olmedo (Royal Institute of Technology, SE); Xiaodan Pang (Acreo Swedish ICT AB, SE); Simone Gaiarin (Technical University of Denmark, DK); Aditya Kakkar and Aleksejs Udalcovs (KTH Royal Institute of Techology, SE); Klaus Engenhardt and Tadeusz Asyngier (Tektronix GmbH, PL); Richard Schatz (Kista Photonic Research Centre (KPRC), Royal Institute of Technology (KTH), SE); Jie Li (Acreo Swedish ICT AB, SE); Fredrik Nordwall (Tektronix GmbH, SE); Urban Westergren (Kista Photonic Research Centre (KPRC), Royal Institute of Technology (KTH), SE); Darko Zibar (DTU Fotonik, depertment of Photonic Engineering, Technical University of Denmark, DK); Sergei Popov (Royal Institute of Technology, SE); Gunnar Jacobsen (Acreo AB, SE)
♦ We report on a 116 Gbit/s OOK, 4PAM and 105 Gbit/s 8PAM optical transmitter using InP-based integrated EML for interconnect applications with up to 30 dB static extinction ratio and over 100 GHz 3-dB bandwidth with 2 dB ripple.

18:00 - 20:30 Welcome Reception | Foyer CCD |

M.2.D: Short Distance Direct Detection Systems — Room 15

Chair: Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)

M.2.D.1 • 16:00
Experimental Demonstration of 112-Gbit/s PAM-4 over up to 80 km SSMF at 1550 nm for Inter-DCI Applications
Nicklas Eiselt (Technical University of Denmark, DK); Sjoerd van der Heide (Eindhoven University of Technology & ADVA Optical Networking SE, NL); Helmut Griesser (ADVA Optical Networking SE, DE); Michael Eiselt (ADVA, DE); Chigo Okonkwo (Eindhoven University of Technology, NL); Juan Jose Vegas Olmos (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU)
♦ We experimentally demonstrate 112-Gbit/s PAM-4 over 80 km SSMF at 1550 nm. It is shown, that a channel shortening filter (CSF) matched to the memory of a subsequent MLSE significantly improves the performance while keeping complexity manageable.

M.2.D.2 • 16:15
Single Wavelength 248-Gb/s transmission over 80-km SMF Based on Twin-SSB-DMT and Direct Detection
Liang Zhang and Tianjian Zuo (Huawei, PRC); Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Jie Zhou, Enbo Zhou and Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)
♦ We propose a single-polarization direct-detection twin-SSB-DMT system. Enabled by MIMO-array DSP, transmissions of 248-Gb/s over 80-km SMF with a BER of 1.8e-2 (<SD-FEC) and 224-Gb/s over 60-km SMF with a BER of 4.2e-3 (<HD-FEC) are successfully demonstrated.

M.2.D.3 • 16:30
112-Gbit/s Intensity-Modulated Direct-Detect Vestigial-Sideband PAM4 Transmission over an 80-km SSMF Link
Jeffrey Lee, Noriaki Kaneda and Young-Kai Chen (Nokia Bell Labs, USA)
♦ Employing vestigial-sideband 4-level pulse amplitude modulation (VSB-PAM4), single-channel as well as five-channel DWDM 112-Gbit/s per wavelength transmission is experimentally demonstrated over an 80-km standard single-mode fiber. Chromatic dispersion is compensated using digital signal processing at the receiver.

M.2.D.4 • 16:45
Improvement in Bandwidth-Limitation Tolerance and Achievement of 1-Sps Chromatic-Dispersion Pre-compensation Using Polarization-Interleaved 4-Level/7-Level Coding PAM
Shuto Yamamoto, Akira Masuda, Hiroki Kawahara, Shingo Kawai and Mitsunori Fukutoku (NTT, JP)
♦ We have achieved polarization-interleaved 4-level/7-level coding PAM transmission using 1-Sps pre-compensation for chromatic dispersion with a narrow-electrical-bandwidth limitation based on numerical simulations. We experimentally confirm the scheme feasibility using 112-Gb/s signal and 20-GHz bandwidth limitation in a conventional direct-detection system.

M.2.D.5 • 17:00
Transmission and Direct Detection of 300-Gbps DFT-S OFDM Signals Based on O-ISB Modulation with Joint Image-Cancellation and Nonlinearity-Mitigation
Yuanquan Wang (Fudan University, PRC); Jianjun Yu and Hungchang Chien (ZTE (TX) Inc, USA); Xinying Li and Nan Chi (Fudan University, PRC)
♦ By utilizing joint image-cancellation and nonlinearity-mitigation algorithms, we experimentally demonstrate record 300-Gbps and 240-Gbps direct-detection optical independent-sideband DFT-S OFDM signals at BTB and transmission over 160-km SSMF with the BER less than 2×10-2, respectively.

M.2.D.6 • 17:15
49 Gbit/s Direct-Modulation and Direct-Detection Transmission over 80 km SMF-28 without Optical Amplification or Filtering
Zhixin Liu (University of Southampton, UK); M. Sezer Erkilinc (University College London, UK); Brian Kelly (Eblana Photonics, IR); John Carroll (Dublin City University, IR); Richard Phelan (Eblana Photonics, IR); Benn Thomsen and Robert Killey (University College London, UK); David J Richardson (University of Southampton, UK); Polina Bayvel (University College London, UK); Radan Slavík (ORC, University of Southampton, UK)
♦ We demonstrate direct-modulation of a discrete mode laser using Discrete Multi-Tone modulation for transmission distances up to 100 km in the 1550 nm band. A large operational temperature range (0-65degC) is also demonstrated.

M.2.E: Transmitters I — Room 110

Chair: Romain Brenot (III-V Lab & Nokia Bell Labs, FR)

M.2.E.1 • 16:00 *Invited*
High-Speed Directly Modulated Heterogeneously Integrated InP/Si DFB Laser
Geert Morthier and Amin Abbasi (Ghent University, BE); Jochem Verbist, Shahram Keyvaninia and Xin Yin (Ghent University - IMEC, BE); Johan Bauwelinck (Ghent University - iMinds, BE); Gunther Roelkens (Ghent University - IMEC, BE); Francois Lelarge (Alcatel Thales III-V Lab, FR); Guang-Hua Duan (III-V Lab, FR)
♦ We discuss how InP membrane laser diodes, heterogeneously integrated on SOI can be designed for high speed operation. This is illustrated with several static and dynamic characteristics of fabricated lasers. We finally report link experiments with the modulated lasers.

M.2.E.2 • 16:30
10-40 Gbit/s Hybrid III-V/Si wavelength-tunable transmitter for short- and long-reach communications
Guilhem de Valicourt, Chia-Ming Chang, Young-Kai Chen and Sethumadhavan Chandrasekhar (Nokia Bell Labs, USA); Anaelle Maho (III-V Lab, FR); Romain Brenot (III-V Lab & Nokia Bell Labs, FR); Po Dong (Nokia Bell Labs, USA)
♦ We demonstrate an ultra-compact hybrid tunable III-V/Si transmitter with more than 28 nm tuning range. We successfully achieved modulation up to 40 Gbit/s and transmission over 20 (100) km at 25 (10) Gbit/s.

M.2.E.3 • 16:45
50km Error Free Transmission at 10Gb/s with an Integrated Hybrid III-V on Silicon Directly Modulated DFB Laser and Ring Resonator
Antonin Gallet (III-V lab, a joint lab of Nokia, Thales and CEA, FR); Alexandre Shen and Dalila Make (Alcatel Thales III-V Lab, FR); Guang-Hua Duan (III-V Lab, FR); Ségolène Olivier (CEA-Leti, FR); Guillaume Levaufre (III-V lab, a joint lab of Nokia, Thales and CEA Leti, FR); Stéphane Malhouitre (CEA-Leti, FR); Nils Girard (III-V lab, a joint lab of Nokia, Thales and CEA Leti, FR); Francois Lelarge (Alcatel Thales III-V Lab, FR); Romain Brenot (III-V Lab & Nokia Bell Labs, FR); Jean-Guy Provost (Alcatel Thales III-V Lab, FR)
♦ A directly-modulated Hybrid III-V/SOI DFB laser and a ring resonator are integrated on a single chip. Thanks to the ring resonator filter which provides extinction ratio enhancement, error free transmission at 10Gb/s over 50 km single mode fibre is demonstrated.

M.2.E.4 • 17:00
Two-Section RSOA with Enhanced Modulation-Cancelling Effect for Self-Seeded Colorless WDM Transmitter
Peng Zhou, Wenhui Zhan and Takuo Tanemura (University of Tokyo, JP); Masaru Mukaikubo (Oclaro Japan, Inc., JP); Yoshiaki Nakano (University of Tokyo, JP)
♦ We propose and demonstrate novel RSOA design with segmented electrodes to enhance the modulation cancelling effect without sacrificing the bandwidth for self-seeded colorless WDM transmitter applications. Optimal driving condition is derived numerically and confirmed experimentally at 10 Gb/s.

M.2.E.5 • 17:15
Novel Approach for Self-Seeded Cavity based on Reflective Electro Absorption Modulator Semiconductor Optical Amplifier
Anaelle Maho (III-V Lab, FR); Sophie Barbet (Alcatel-Thales III-V Lab, IT); Karim Mekhazni (III-V Lab, FR); Romain Brenot (III-V Lab & Nokia Bell Labs, FR)
♦ We propose a novel approach for self-seeded cavities by replacing the usual RSOA by a REAMSOA. With discrete components, we only achieved transmission on 50km at 2.5Gbit/s, although each device can operate up to 20Gbit/s.

M.2.F: Data Center Networks — Room 112

Chair: Steinar Bjørnstad (NTNU, NO)

M.2.F.1 • 16:00 *Invited*
A roadmap for evolving towards optical intra-data-center networks
Lars Dittmann (Technical University of Denmark, DK); Anna Manolova Fagertun (Telia Denmark, DK); Valerija Kamchevska, Michael Galili, Leif Oxenløwe, Sarah Ruepp and Michael S. Berger (Technical University of Denmark, DK)
♦ The paper focuses on presenting an updated view on the state of the art in data centre networks. The EU project COSIGN has provided optical DCN roadmaps, strategies and a techno-economic analysis of the involved industrial partners' value proposition.

M.2.F.2 • 16:30 *Upgraded*
Flexible Architecture and Control Strategy for Metro-Scale Networking of Geographically Distributed Data Centers
Matteo Fiorani (KTH Royal Institute of Technology, SE); Payman Samadi and Yiwen Shen (Columbia University, USA); Lena Wosinska (KTH Royal Institute of Technology, SE); Keren Bergman (Columbia University, USA)
♦ This paper proposes a flexible architecture and control strategy to enable adaptive resource allocation in metro-scale inter data center networks. Experimental implementation and numerical evaluations are presented, proving substantial benefits in terms of transmission time and resource usage.

M.2.F.3 • 17:00
ARON: Application-Driven Reconfigurable Optical Networking for HPC Data Centers
Guojun Yuan (Institute of Computing Technology & Chinese Academy of Sciences, PRC); Roberto Proietti (University of California, Davis, USA); Xiaoli Liu (Institute of Computing Technology, Chinese Academy of Sciences, PRC); Alberto Castro Casales (University of California, Davis, USA); Dawei Zang and Ninghui Sun (Institute of Computing Technology, Chinese Academy of Sciences, PRC); CheYu Liu (University of California, San Diego, USA); Cao Zheng (ECE University of California Davis, PRC); S. J. Ben Yoo (University of California, Davis, USA)
♦ We designed and experimentally demonstrated an application-driven adaptive network that supports fast topology reconfiguration by wavelength routing to match applications' communication characteristics. Even in a small-scale system, 1.25× performance improvement is achieved by performing network reconfiguration.

M.2.F.4 • 17:15
Scalability Assessment of the OPSquare Architecture for High-capacity and Large-connectivity Data Center Networks
Wang Miao (Eindhoven University of Technology, NL); Fulong Yan (Eindhoven University of Technology & TU/e, PRC); Nicola Calabretta (COBRA Research Institute, NL)
♦ The OPSquare data center network performance are investigated for different modulation format and high-capacity 4×25Gb/s waveband, 28Gb/s PAM4 and 40Gb/s DMT traffic. Results show >8 dB dynamic range with <3 dB penalty for optical switches at scale of 64×64.

18:00 - 19:30 Welcome Reception | Foyer CCD |

Tu.1.A: Light Sources for Interconnects — Room 18+19

Chair: Sylvie Menezo (CEA-LETI, FR)

Tu.1.A.1 • 09:00 *Tutorial*
Applications of photonic crystal and heterogeneous integration to ultra-low-energy lasers for optical interconnects and datacenter networks
Shinji Matsuo (NTT Corporation, JP)
♦ This tutorial reviews the latest developments in membrane lasers, including photonic crystal lasers and heterogeneously integrated lasers on Si. These devices are directly modulated with low operating energy. Heterogeneous integration technologies enable us to fabricate large-scale photonic integrated circuits.

Tu.1.A.2 • 10:00 *Invited*
Higher Speed VCSEL Links using Equalization
Daniel Kuchta (IBM T.J. Watson Research Center, USA)
♦ With FFE Equalization, VCSEL-based links using NRZ modulation have been demonstrated error-free to 71Gb/s at 850nm, 56Gb/s at 1530nm, and 50Gb/s to 90C. This paper will review this progress and speculate on the realization of 100Gb/s serial links.

Tu.1.B: Multi-Layer SDN — Room 17

Chair: Raul Muñoz (CTTC, ES)

Tu.1.B.1 • 09:00 *Invited*
Operator use cases that benefit from multi-layer optimization and application awareness
Victor Lopez (Telefonica, ES); Domenico Siracusa (CREATE-NET, IT); Dimitrios Klonidis (AIT, GR); Juan Pedro Fernández-Palacios (Telefónica I+D, ES)
♦ Multi-layer optimization enables the operators to optimize their packet and transport resources. The application awareness will provide potential savings as well as will offer a better adaptation to the network services to the applications.

Tu.1.B.2 • 09:30
Peer SDN Orchestration: End-to-End Connectivity Service Provisioning Through Multiple Administrative Domains
Ricard Vilalta and Arturo Mayoral (CTTC, ES); Victor Lopez and Victor Uceda (Telefónica, ES); Ramon Casellas, Ricardo Martinez and Raul Muñoz (Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), ES); Alejandro Aguado, Jaume Marhuenda, Reza Nejabati and Dimitra Simeonidou (University of Bristol, UK); Noboru Yoshikane, Takehiro Tsuritani and Itsuro Morita (KDDI R&D Laboratories, JP); Thomas Szyrkowiec (ADVA Optical Networking & Technische Universität München, DE); Achim Autenrieth (ADVA Optical Networking, DE)
♦ This papers proposes the usage of Control Orchestration Protocol (COP) as an East-West interface in order to interconnect different SDN controllers (peer model) through multiple administrative domains. An experimental validation of network connectivity provisioning is presented in an international testbed.

Tu.1.B.3 • 09:45
First demonstration of SDN-controlled Multi-Layer Restoration and its advantage over Optical Restoration
Itay Maor, Ori Gerstel (Sedona Systems Ltd., IL); Victor Lopez (Telefonica, ES); Thomas Szyrkowiec (ADVA Optical Networking & Technische Universität München, DE); Achim Autenrieth (ADVA Optical Networking, DE); Bernd Pruessing, Nuno Borges (Coriant GmbH, DE); Fisher FU (Huawei Technologies, PRC); Guiu Fabregas (Nokia, ES); Juan P. Fernández-Palacios (Telefónica I+D, ES)
♦ We demonstrate a full implementation of centrally orchestrated multi-layer restoration over commercial optical and IP gear. The process considers the behavior of the IP layer. Compared to optical restoration, the packet loss is 54% lower.

Tu.1.B.4 • 10:00
Interoperable Multi-Domain Delay-aware Provisioning using Segment Routing Monitoring and BGP-LS Advertisement
Francesco Paolucci (Scuola Superiore Sant'Anna, IT); Víctor Uceda (Telefonica, ES); Andrea Sgambelluri (KTH Royal Institute of Technology, SE); Filippo Cugini (CNIT, IT); Oscar González de Dios (Telefonica I+D, ES); Victor Lopez and Luis M. Contreras (Telefonica, ES); Paolo Monti (KTH Royal Institute of Technology, SE); Paola Iovanna, Fabio Ubaldi and Teresa Pepe (Ericsson, IT); Piero Castoldi (Scuola Superiore Sant'Anna, IT)
♦ This paper demonstrates a multi-domain SDN orchestrator using delay information to provision network services using BGP-LS and a novel monitoring system enabled by Segment Routing. Moreover, it is the first implementation and interoperability of the BGP-LS extensions for TE metrics.

Tu.1.B.5 • 10:15
Experimental Demonstration of Policy-based Dynamic End-to-End Provisioning over Multi-Layer Network using SDN
Jaume Marhuenda, Alejandro Aguado, Sarvesh Sanjay Bidkar, Emilio Hugues-Salas, Reza Nejabati and Dimitra Simeonidou (University of Bristol, UK)
♦ Contemporary transport networks require dynamic multi-layer service provisioning to support ever-growing application traffic. We present a software platform architecture based on SDN principles combined with a network policy engine to experimentally demonstrate dynamic multi-layer provisioning over a national dark-fibre network.

Tu.1.C: Advanced Modulation — Room 16

Chair: David Hillerkuss (ETH Zurich, CH)

Tu.1.C.1 • 9:00
Duobinary Pulse-Shaped Complex Modulation of Directly Modulated Lasers
Di Che (The University of Melbourne & National ICT Australia, AU); Feng Yuan (University of Melbourne, AU); Hamid Khodakarami (University of Tehran, IR); William Shieh (University of Melbourne, USA)
♦ We propose duobinary pulse shaping for the complex modulation of directly modulated lasers, which significantly relieves the optical spectrum expansion induced by frequency chirp. The newly designed 3-tap MLSE decoder is verified via both simulation and 10-Gbaud PAM-4 experiment.

Tu.1.C.2 • 09:15
Eight Dimensional Optimized Modulation for IM-DD 56 Gbit/s Optical Interconnections Using 850 nm VCSELs
Xiaofeng Lu and Anna Tatarczak (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU)
♦ A novel 8-dimensional optimized modulation format is designed and compared with PAM-n in a 28-GBd 850 nm VCSEL based IM-DD system, enabling the transmission on 100GBASE-SR4 FEC threshold over various 100 m MMF links.

Tu.1.C.3 • 09:30
Stable WDM-Signal-and-LO-frequency Synchronisation and Transmission Employing Multi-Carrier Light Sources and a Multi-Core Fibre for Coherent Photonic Networks
Kunihiko Mori, Fukutaro Hamaoka, Kengo Horikoshi (NTT Corporation, JP); Mitsunori Fukutoku (NTT Innovation Laboratories, JP)
♦ We successfully demonstrate a novel technique for synchronising optical frequencies in WDM signals and LO lights. We can simultaneously stabilise the polarisations of multi-carrier LO lights, which are transmitted with SDM-WDM signals via a multi-core fibre for digital coherent detection.

Tu.1.C.4 • 09:45
64-Gb/s Optical Transmission Using DFB-EAM Transmitter and SOA-PIN-TIA Receiver with -23.5-dBm Record Sensitivity
Philippe Angelini (III-V Lab, FR); Fabrice Blache (Alcatel-Thales III-V Lab, FR); Filipe Jorge (Alcatel Thales III-V Lab, joint la: Bell Labs and Thales Research and Technology, FR); Christophe Caillaud (Alcatel-Thales III-V Lab, FR); Michel Goix, Karim Mekhazni, Bernadette Duval (III-V Lab, FR); Franck Mallécot (Alcatel-Thales III-V Lab, FR); Philippe Charbonnier, Jean-Yves Dupuy (III-V Lab, FR); Mohand Achouche (Alcatel-Thales III-V Lab, FR)
♦ This paper reports a transmission system for next generation short-reach high-speed optical communications. It consists of a 63-GHz DFB-EAM transmitter and a SOA-PIN-TIA receiver with -23.5-dBm sensitivity (BER=10-9) at 64 Gb/s in NRZ-OOK operation, yielding penalty<0.5 dB over 2-km transmission.

10:30 - 11:00 Coffee Break | Exhibition Hall |

Tu.1.D: SDM Transmission I — Room 15

Chair: Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)

Tu.1.D.1 • 09:00 *Invited*
Ultra-high capacity SDM/WDM transmission over multicore and multimode fibers
Takehiro Tsuritani (KDDI R&D Laboratories, Inc., JP)
♦ Recent progress and future challenges on high-capacity spatial division multiplexing (SDM) transmission technologies using multi-core and multimode fibers are reviewed and discussed.

Tu.1.D.2 • 09:30 *Invited*
Pb/s, Homogeneous, Single-mode Multi-Core Fiber Systems
Benjamin J Puttnam (National Institute of Information and Communications Technology, JP); Ruben S Luís (NICT, USA); Jun Sakaguchi, Werner Klaus, Jose Manuel Delgado Mendinueta, Yoshinari Awaji and Naoya Wada (National Institute of Information and Communications Technology (NICT), JP); Erik Agrell (Chalmers University of Technology, SE)
♦ We discuss multi Pb/s transmission using homogeneous, single-mode, multi-core fibers. We outline the key components of a recent high capacity demonstration, the consequences of fiber properties and the potential for enhanced efficiency from spatial-super-channel transmission.

Tu.1.D.3 • 10:00
Demonstration of 0.52 Pb/s Potential Transmission Capacity over 8,830 km using Multicore Fiber
Alexey Turukhin, Hussam G. Batshon, Matthew Mazurczyk and Yu Sun (TE Subcom, USA); Carl Davidson (Tyco Telecommunications, USA); Jin-Xing Cai (TE SubCom, USA); Oleg Sinkin (Tyco Telecom, USA); William Patterson (Tyco Electronics Subsea Communications, USA); Gregory Wolter and Maxim Bolshtyansky (TE Subcom, USA); Dmitri Foursa (Tyco Telecommunications, USA); Alexei Pilipetskii (Tyco Electronics Subsea Communications, USA)
♦ We demonstrate feasibility of 0.52Pb/s transmission over 8,830km using a 12-core fiber, C+L band EDFAs, and a new coded modulation format. Compared to optimal 8QAM with the same 4.86b/s/Hz spectral efficiency, our modulation scheme achieves 1.0dB improvement in receiver sensitivity.

Tu.1.E: Coding and Receivers — Room 110

Chair: Yves Jaouën (Telecom ParisTech, FR)

Tu.1.E.1 • 09:00
A Low-complexity Implementation of Full-rate Polarization-Time Codes for PDL Mitigation in Single-Carrier Optical Transmissions using the Constant Modulus Algorithm
Elie Awwad, Patrice Tran (Nokia Bell Labs, FR); Gabriel Charlet (Bell Labs, Alcatel-Lucent, FR)
♦ We demonstrate through simulations and experimental measurements a low-complexity implementation of the 2x2 Silver code to mitigate PDL in a single-carrier PDM system using CMA equalization. The obtained gains are compared to the optimal ones achieved by an ML decoder.

Tu.1.E.2 • 09:15
Full-Channel Parallel Measurement of 4x20-Gb/s All-Optical OFDM Signals by Using Loop-Assisted Coherent Matched Detector
Takahide Sakamoto (National Institution of Information and Communications Technology, JP); Guo-Wei LU (Institute of Innovative Science and Technology, Tokai University & National Institute of Information and Communications Technology (NICT), JP); Naokatsu Yamamoto (National Institute of Information and Communications Technology, JP)
♦ We demonstrate measurement of 4x20-Gb/s all-optical OFDM signals by using loop-assisted coherent matched detector. All-optical OFDM signal is projected onto the time-frequency domain first; then, all sub-channels are restored through digital matrix processing, without relying on optical FFT.

Tu.1.E.3 • 09:30
Quadrature Decomposition of a 20 Gbaud 16-QAM Signal into 2×4-PAM Signals
Abel Lorences-Riesgo (Chalmers University of Technology, SE); Tobias A. Eriksson (Nokia Bell Labs, DE); Mikael Mazur and Peter A Andrekson (Chalmers University of Technology, SE); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE)
♦ We propose a novel phase-sensitive processor capable of operating at low nonlinear phase shifts. With a nonlinear phase shift of 2×15 rad, quadrature decomposition is demonstrated with penalty of 0.5 dB at BER=10e-3.

Tu.1.E.4 • 09:45
Receiver Memory Requirement in Mode Delay Compensated Few-Mode Fibre Spans with Intermediate Coupling
Christian Sanchez, Filipe M. Ferreira, Naoise Mac Suibhne, Stylianos Sygletos and Andrew Ellis (Aston University, UK)
♦ The required receiver time window after propagation through few-mode fibre is studied for a broad range of coupling and mode delay span configurations. Under intermediate coupling, effective mode delay compensation is observed for a compensation period of 25km.

Tu.1.E.5 • 10:00 *Invited*
Joint Modulation and Coding Optimization for Long-Haul Nyquist WDM Transmissions
Rafael Rios-Müller, Jeremie Renaudier, Gabriel Charlet (Nokia Bell Labs, FR)
♦ We review modulation format choice and optimization for long-haul optical communications systems taking into account channel coding implementation constraints such as overhead and decoder architecture as well as transmitter impairments.

Tu.1.F: Optical Access for 5G — Room 112

Chair: Yan Shi (Genexis, NL)

Tu.1.F.1 • 09:00
5G Transport in Future Access Network
Dirk Breuer (Deutsche Telekom T-Labs, DE); Erik Weis (Deutsche Telekom, Laboratories, DE); Klaus Grobe (ADVA, DE); Sandro Krauss (Deutsche Telekom AG, DE); Francesco Musumeci (Politecnico di Milano, IT); Jose Alfonso Torrijos Gijon (Telefonica I+D, ES); Björn Skubic (Ericsson AB, SE)
♦ Techno-economic results for 5G back/fronthaul based NG-PON2 with PtP-WDM-PON overlay and WR-WDM-PON for different RAN splits are presented for an urban area. It is shown that the convergence benefit with residential access decreases significantly for high bit rate interfaces.

Tu.1.F.2 • 09:15 *Invited*
Optical Network Technologies for Wireless Communication Network
Jun Terada, Tatsuya Shimada, Tatsuya Shimizu and Akihiro Otaka (NTT Corporation, JP)
♦ This paper describes trends of 5G mobile networks and RAN technologies. The Ethernet-based vBBU is expected to support several types of BBU and PON with low-latency scheme is a good candidate for MFH transmission in 5G networks.

Tu.1.F.3 • 09:45
Performance Demonstration of Real Time Compressed CPRI Transport
Zakaria Tayq, Antoine Quere, Luiz Anet Neto, Philippe Chanclou, Fabienne Saliou and Kamil Grzybowski (Orange Labs, FR); Christelle Aupetit-Berthelemot (XLIM - University of Limoges, FR); Sun Yoo and Sung Hong (Solid, KR)
♦ A real time CPRI compression solution is experimentally investigated. Tests have been performed on a LTE fronthaul link measuring its impact on EVM and latency. The obtained results show a 73% compression compliant with 3GPP specifications.

Tu.1.F.4 • 10:00 *Invited*
Optics For 5G: How Can We Combine Low Cost With Demanding Requirements?
Antonio Tartaglia (Ericsson Telecomunicazioni S.p.A., IT)
♦ 5G is the opportunity for optical technologies to become increasingly relevant across all networking domains. We will review how state-of-the-art industrial technologies are evolving to meet its most demanding requirements and discuss the challenge of finding the best cost structures.

10:30 - 11:00 Coffee Break | Exhibition Hall |

Tu.2.A: Digital Signal Processing — Room 18+19

Chair: Benn C Thomsen (University College London, UK)

Tu.2.A.1 • 11:00 *Tutorial*
Digital Signal Processing for Multilevel Modulation Formats
Seb J Savory (University of Cambridge, UK)
♦ In this tutorial we explore digital signal processing (DSP) techniques for multilevel modulation formats. We detail both transmitter DSP (encoding, modulation, equalisation and filtering) and receiver DSP (equalisation, filtering, synchronisation, demodulation and decoding) after which we discuss current research challenges.

Tu.2.A.2 • 12:00
Transmitter Impairment Mitigation and Monitoring for High Baud-Rate, High Order Modulation Systems
Chris Fludger, Theo Kupfer (Cisco Optical GmbH, DE)
♦ Receiver-based compensation algorithms for transmitter impairments such as timing skew, gain and offset imbalance and quadrature error are presented. We demonstrate monitoring and diagnosis functions based on signal processing coefficients.

Tu.2.A.3 • 12:15
Sequential MAP Detection for High Baud-Rate Systems with Pattern-Dependent Distortions
Ali Bakhshali (Queens University, CA); Wai-Yip Geoffrey Chan, Ali Rezania, John C Cartledge (Queen's University, CA)
♦ A sequential MAP detection strategy with a wide range in its performance-complexity trade-off is proposed to ameliorate pattern-dependent distortions due to transmitter and receiver limitations. A complexity reduction by a factor of 7 is reported based on the experimental results.

Tu.2.B: Network Automation — Room 17

Chair: Sebastien Bigo (Bell Labs, Alcatel-Lucent, FR)

Tu.2.B.1 • 11:00
A Learning Living Network for Open ROADM Networks
Shoichiro Oda, Masatake Miyabe and Setsuo Yoshida (Fujitsu Laboratories Ltd., JP); Toru Katagiri and Yasuhiko Aoki (Fujitsu Limited, JP); Jens C. Rasmussen (Fujitsu Laboratories Limited, JP); Martin Birk and Kathy Tse (AT&T Laboratories, USA)
♦ We experimentally demonstrate a "living network" that autonomously keeps record of its path-level performance. The more services are added, the more accurate the performance of a newly to be established service is estimated which enables operation close to performance limits.

Tu.2.B.2 • 11:15
Bringing Data Analytics to the Network Nodes
Alba Vela, Anna Via, Marc Ruiz and Luis Velasco (Universitat Politècnica de Catalunya (UPC), ES)
♦ Monitoring every 15 minutes imposes long traffic anomaly detection times and thus, the monitoring frequency needs to be increased to reduce those times, which entails large amount of monitoring data collected. Consequently, we propose bringing data analytics to the nodes.

Tu.2.B.3 • 11:30
A Machine Learning Approach for Dynamic Optical Channel Add/Drop Strategies that Minimize EDFA Power Excursions
Yishen Huang (Columbia University, USA); Wiem Samoud (Institut Mines Telecom, Telecom ParisTech, CNRS LTCI, FR); Craig Gutterman (Columbia University, USA); Cedric Ware (Institut Mines-Télécom, Télécom ParisTech, CNRS LTCI, FR); Mounia Lourdiane (TELECOM SudParis, FR); Gil Zussman, Payman Samadi and Keren Bergman (Columbia University, USA)
♦ We demonstrate a machine learning approach to characterize channel dependence of power excursions in multi-span EDFA networks. This technique can determine accurate recommendations for channel add/drop with minimal excursions and is applicable to different network designs.

Tu.2.B.4 • 11:45
Adaptive Guard-band Assignment with Adaptive Spectral Profile Equalizer to Improve Spectral Usage of Impairment-Aware Elastic Optical Network
Hitoshi Takeshita, Hidemi Noguchi, Jun-ichi Abe, Shinsuke Fujisawa, Akio Tajima (NEC Corporation, JP)
♦ We propose an adaptive guard-band assignment method that solves its over-assignment problem and an adaptive spectral profile equalizer to enhance its capability. Simulation and experimental results demonstrate a 12.5% spectral usage improvement and feasibility for application to actual networks.

Tu.2.B.5 • 12:00 *Invited*
Elastic all-optical networks: a new paradigm enabled by the physical layer. How to optimize network performances?
Vittorio Curri, Mattia Cantono, Roberto Gaudino (Politecnico di Torino, IT)
♦ Physical layer equipment is the enabling technology for the elastic use of networks. We propose the statistical network assessment process as benchmarking method. As an example we compare PM-mQAM vs. TDHMF transceivers on a Pan-EU network topology, considering three fibers.

Tu.2.C: Measurement and Control — Room 16

Chair: Toshihiko Hirooka (Tohoku University, JP)

Tu.2.C.1 • 11:00
OSNR System Margin Estimation by Nonlinear Noise Insensitive OSNR Monitor
Tomohiro Yamauchi and Shoichiro Oda (Fujitsu Laboratories Ltd., JP); Liang Dou and Xiaofei Su (Fujitsu R&D Center, PRC); Takeshi Hoshida (Fujitsu Laboratories Limited, JP); Yasuhiko Aoki (Fujitsu Limited, JP); Zhenning Tao (Fujitsu R&D Center Ltd., PRC); Jens C. Rasmussen (Fujitsu Laboratories Limited, JP)
♦ We propose an OSNR system margin estimation technique based on nonlinear noise insensitive OSNR monitoring. We experimentally demonstrate its accuracy less than 0.3dB estimation error for five-subcarrier DP-16QAM superchannel in dispersion-uncompensated transmission with various fiber launched power and various reaches.

Tu.2.C.2 • 11:15
Deep Learning Based OSNR Monitoring Independent of Modulation Format, Symbol Rate, Chromatic Dispersion
Takahito Tanimura (The University of Tokyo & Fujitsu Laboratories Ltd., JP); Takeshi Hoshida, Tomoyuki Kato, Shigeki Watanabe and Jens C. Rasmussen (Fujitsu Laboratories Limited, JP); Makoto Suzuki and Hiroyuki Morikawa (The University of Tokyo, JP)
♦ A deep neural network (DNN) is employed for optical performance monitoring. We show that DNN-based monitor successfully estimates OSNR of signals modulated in different formats and symbol rates in the presence of chromatic dispersion and polarization rotation without prior knowledge.

Tu.2.C.3 • 11:30
Nonlinear Spatially Resolved Interferometer for Distance Resolved Power and Gain Tilt Measurement
Andrew D. Shiner, Andrzej Borowiec, Michael Reimer, Douglas W Charlton and Maurice O'Sullivan (Ciena Corporation, CA)
♦ A new experimental technique for making distance resolved measurements of the wavelength dependent power profile and gain evolution in multi-span telecommunications fiber links is demonstrated. Results for a 10x80km span link agree with directly measured powers to within 0.3 dB.

Tu.2.C.4 • 11:45
Polarization Controller for Si photonic integrated circuits with an active closed loop control
Vito Sorianello (CNIT-Laboratory of Photonic Networks, IT); Gabriele De Angelis, Philippe Velha, Tommasso Cassese and Valerio Preite (Scuola Superiore Sant'Anna, IT); Alberto Bianchi (Ericsson Telecomunicazioni, IT); Francesco Testa (Ericsson Lab Italy, IT); Marco Romagnoli (PGT Photonics, IT)
♦ A polarization insensitive silicon photonic circuit for the management of any arbitrary polarization state of light coming from a fiber linked to a remote source is demonstrated. WDM channels with a common arbitrary polarization at the input are automatically equalized.

Tu.2.C.5 • 12:00
2D Passive Optical Beam-steering Module with 7 Scan Lines within 12.2°×5.6° for Free-space Indoor Communication
Chin Wan Oh (Eindhoven University of Technology, NL); Robbert van der Linden (Eindhoven University of Technology & Genexis BV., NL); Gustaaf Sutorius (Keysight Technologies, NL); Eduward Tangdiongga (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ We experimentally demonstrate a two-dimensional (2D) passive optical beam-steering module constructed using reflection and transmission gratings for angular coverage of 12.2°×5.6° with seven scanning lines. We vigorously evaluate the 2D beam-steered system with OOK, 4-PAM and DMT transmission.

12:30 - 14:00 Lunch Break | Exhibition Hall |

14:00 - 16:00 Exhibition Only

Tu.2.D: SDM Transmission II — Room 15

Chair: Rene Essiambre (Nokia, USA)

Tu.2.D.1 • 11:00
Exploiting Selective Excitation of Strongly Coupled Modes to Reduce DMGD in Multi-mode Transmission Systems
John van Weerdenburg (Eindhoven University of Technology, NL); Jose Antonio-Lopez and Juan Alvarado-Zacarias (CREOL, USA); Denis Molin (Prysmian Group, FR); Marianne Bigot-Astruc (Draka Communications, FR); Roy van Uden and Huug de Waardt (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL); Rodrigo Anezcua-Correa (CREOL, USA); Pierre Sillard (Prysmian, FR); Chigo Okonkwo (Eindhoven University of Technology, NL)
♦ By exploiting strong coupling in higher-order modes, we experimentally demonstrate reduced differential mode group delay by a factor of 3. Comparing LP02+LP21 with respect to LP01+LP11 3-mode transmission, a 27% reduction in equalizer length is shown after 53.4km MMF transmission.

Tu.2.D.2 • 11:15
Nonlinear Distortion in Mode Delay Compensated Few-Mode Fibre Spans with Intermediate Coupling
Filipe M. Ferreira, Christian Sanchez, Naoise Mac Suibhne, Stylianos Sygletos and Andrew Ellis (Aston University, UK)
♦ Nonlinear distortion in delay-compensated spans for intermediate coupling is studied for the first time. Coupling strengths under -30dB/100m allow distortion reduction using shorter compensation lengths and higher delays. For higher coupling strengths no significant penalty results from shorter compensation lengths.

Tu.2.D.3 • 11:30 *Upgraded*
10-Mode Mode-Multiplexed Transmission with Inline Amplification
Roland Ryf, Haoshuo Chen, Nicolas K Fontaine, Amado and Velázquez-Benítez (Nokia Bell Labs, USA); Jose Antonio-Lopez, Juan Alvarado-Zacarias and Zeinab Sanjabi Eznaveh (CREOL, USA); Cang Jin (Université Laval & COPL, CA); Bin Huang (Nokia Bell Labs, USA); Sun Hyok Chang (ETRI, KR); Burcu Ercan (UC Davis, USA); Cedric Gonnet (Prysmian Group, FR); Marianne Bigot-Astruc and Denis Molin (Draka Communications, FR); Frank Achten (Prysmian Group, NL); Pierre Sillard (Prysmian, FR); Rodrigo Anezcua-Correa (CREOL, USA)
♦ We demonstrate combined wavelength- and mode-multiplexed transmission over a fiber with 10 spatial modes using all multimode components including an erbium-doped amplifier, an acousto-optics switch and a splitter arranged as a recirculating loop.

Tu.2.D.4 • 12:00
Study of Inter-Modal Four Wave Mixing in Two Few-Mode Fibres with Different Phase Matching Properties
Francesca Parmigiani, Yongmin Jung (Optoelectronics Research Centre, University of Southampton, Southampton, UK); Søren M. M. Friis (Technical University of Denmark, DK); Qiongyue Kang and Ioannis Begleris (Optoelectronics Research Centre, University of Southampton, Southampton, UK); Peter Horak and Periklis Petropoulos (University of Southampton, UK); Karsten Rottwitt (Technical University of Denmark, DK); David J Richardson (University of Southampton, UK)
♦ We experimentally study inter-modal four-wave mixing (FWM) in few-mode fibres with different phase matching properties. The possibility of transmitting two spatial modes without inter-modal FWM cross-talk in the C-band is presented.

Tu.2.E: MM-Wave Devices — Room 110

Chair: Pascual Muñoz (VLC Photonics, ES)

Tu.2.E.1 • 11:00
40 dB-Rejection Sharp-Edge Integrated SOI Phase-Shifted Bragg Grating Filter for Microwave Photonics
Giovanni Serafino (Scuola Superiore Sant'Anna, IT); Claudio Porzi (Consorzio Nazionale Interuniversitario per le Telecomunicazioni, IT); Philippe Velha and Nicola Andriolli (Scuola Superiore Sant'Anna, IT); Paolo Ghelfi (CNIT, IT); Antonella Bogoni (Scuola Superiore Sant'Anna, IT)
♦ An integrated, high-order phase-shifted Bragg-grating realizing steep-sloped optical passband filter with measured 41.5 dB out-of-band rejection and a transition bandwidth roll-off of 288 GHz/nm is demonstrated in passive Silicon-on-Insulator technology and verified in two different microwave photonics applications.

Tu.2.E.2 • 11:15
Wavelength-tunable True Time Delay for Multi-beam Radio Beamformer in Multi-Gbps Satellite Communication
Netsanet Tessema (University of Eindhoven & COBRA Research Institute, NL); Zizheng Cao (Eindhoven University of Technology, NL); J. H. C. (Johan) van Zantvoort (University of Eindhoven, NL); Eduward Tangdiongga and A. B. (Bart) Smolders (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ We present a Si3N4 photonic integrated chip providing wavelength-dependent true time delay for forming multiple radio beams: a number of multi-Gbps connections from home-to-multiple satellites can be supported simultaneously.

Tu.2.E.3 • 11:30
Fully-Packaged 71-76 GHz Coherent Photonic Mixer featuring WR-12 Output for CRoF Backhauling
Besher Khani and Vitaly Rymanov (University of Duisburg-Essen, DE); Jörg Honecker (u2t Photonics AG, DE); Andreas Gerhard Steffan (Finisar Berlin, DE); Andreas Stöhr (University of Duisburg-Essen, DE)
♦ Here, we report on a novel fully-integrated 70 GHz band (71-76 GHz) rectangular-waveguide-type coherent photonic mixer (WR12-CPX) module for coherent radio-over-fiber (CRoF) backhaul links, featuring a high-speed balanced photodetector and a rectangular waveguide output (WR-12) for direct fiber-to-the-antenna connectivity.

Tu.2.E.4 • 11:45
Optoelectronic comb generation and cross-injection locking of photonic integrated circuit for millimetre-wave generation
Andrzej Jankowski (III-V Lab Thales Research & Technology and CEA-LETI, FR); Gael Kervella (III-V Lab, FR); Mourad Chtioui (Thales Air Systems, FR); Marco Lamponi (Huawei Technologies, FR); Frédéric Van Dijk (Alcatel Thales III-V Lab, FR)
♦ We demonstrate how a monolithically integrated heterodyne source was used for a 33.6 GHz signal generation using an optical solution by a combination of cross-optical injection locking inside the chip and electrical injection locking at the RF signal 7th sub-harmonic.

Tu.2.E.5 • 12:00
Narrow Linewidth Operation (<10 kHz) in Self-injection-locked Tunable DFB Laser Array (SIL-TLA) Integrated with Optical Feedback Planar Lightwave Circuit (PLC)
Hiroyuki Ishii, Naoki Fujiwara and Kei Watanabe (NTT Corporation, JP); Shigeru Kanazawa (NTT Photonics Laboratories, NTT Corporation, JP); Mikitaka Itoh, Hirokazu Takenouchi and Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)
♦ A novel self-injection-locked tunable DFB laser array (SIL-TLA) integrated with an optical feedback planar lightwave circuit (PLC) is proposed. The fabricated device operates with a stable single mode and a narrow linewidth of <10 kHz over the full C-band.

Tu.2.E.6 • 12:15
Mitigation of Mode Partition Noise in Quantum-Dash Fabry-Perot Mode-Locked Lasers using Manchester Encoding
Mohamed Essghair Chaibi (University of Rennes 1, FR); Laurent Bramerie and Sebastien Lobo (ENSSAT / Université de Rennes 1, FR); Christophe Peucheret (University of Rennes 1, FR)
♦ The use of Manchester encoding with balanced detection is proposed in order to overcome the mode partition noise (MPN) limit of quantum-dash mode-locked lasers used as multi wavelength sources. Successful MPN mitigation is demonstrated for a 10-mode laser at 10Gbit/s

Tu.2.F: Novel Fibre Technologies — Room 112

Chair: Camille-Sophie Bres (EDFL, CH)

Tu.2.F.1 • 11:00 *Invited*
Optical Fibre Technologies for Future Communication Networks
Periklis Petropoulos (University of Southampton, UK)
♦ New transmission technologies need to be developed to satisfy the ever increasing demand for communication traffic. This paper reviews some recent research on optical fibre technology that aims at addressing this challenge.

Tu.2.F.2 • 11:30
Experimental demonstration of Compact and Robust All-Fiber Orbital Angular Momentum Generator
Xinglin Zeng, Yan Li, Jian Wu and Yongjie Tian (Beijing University of Posts and Telecommunications, PRC); Q Mo (Fiberhome Telecommunication Technologies Co. Ltd, PRC); Wei Li (Beijing University of Posts and Telecommunications, PRC)
♦ An all-fiber scalar orbital angular momentum generator is demonstrated by cascading mode selective coupler and few mode-polarization maintaining fiber. With the compactness and robustness, this generator may play a key role in space division multiplexing systems.

Tu.2.F.3 • 11:45
Microbending effects in hollow-core photonic bandgap fibers
Eric Numkam Fokoua, Yong Chen, David J Richardson and Francesco Poletti (University of Southampton, UK)
♦ We developed a model for the study of how microbends affect the operation of hollow-core photonic bandgap fibers. Increased loss due to intermodal coupling is predicted. Preliminary experimental observations are in good agreement with the model's predictions.

Tu.2.F.4 • 12:00
Dispersion-Flattened Composite Highly Nonlinear Fibre Optimised for Broadband Pulsed Four-Wave Mixing
Mads Lillieholm, Michael Galili and Leif Oxenløwe (Technical University of Denmark, DK)
♦ We present a segmented composite HNLF optimised for mitigation of dispersion-fluctuation impairments for broadband pulsed four-wave mixing. The HNLF-segmentation allows for pulsed FWM-processing of a 13-nm wide input WDM-signal with -4.6-dB conversion efficiency

Tu.2.F.5 • 12:15
Mode-Selective Fiber Laser Using a Photonic Lantern
Ning Wang (University of Central Florida, USA); Jose Antonio-Lopez, Juan Alvarado-Zacarias and Zeinab Sanjabi Eznaveh (CREOL, USA); He Wen (Tsinghua University, PRC); Pierre Sillard (Prysmian, FR); Sergio Leon-Saval (University of Sydney & Sydney Astrophotonic Instrumentation Laboratory (SAIL), AU); Axel Schulzgen (University of Central Florida, USA); Rodrigo Anezcua-Correa (CREOL, USA); Guifang Li (University of Central Florida, USA)
♦ We experimentally demonstrate a transverse mode-selective fiber laser using a photonic lantern. The output modes of laser are switchable among the 6 LP modes supported by the gain fiber. Their slope efficiency, optical spectra, and mode profiles are measured.

12:30 - 14:00 Lunch Break | Exhibition Hall |

14:00 - 16:00 Exhibition Only

Tu.3.A: Modulators — Room 18+19

Chair: Andreas Umbach (Finisar, DE)

Tu.3.A.1 • 16:00
Multi-level Optical Signal Generation Using a Segmented-Electrode InP IQ-MZM with Integrated CMOS Binary Drivers
Michael Vanhoecke (Ghent University, BE); Nikolaos Argyris (National Technical University of Athens, GR); Alessandro Aimone (Fraunhofer HHI, DE); Stefanos Dris (National Technical University of Athens, GR); Dimitrios Apostolopoulos (National Technical University of Athens & Institute of Communication and Computer Systems, GR); Koen Verheyen, Renato Vaernewyck (Ghent University, BE); Guy Torfs, Xin Yin, Erwin Bosman (Ghent University - IMEC, BE); Gerrit Fiol, Marko Gruner, Robert Klötzer (Fraunhofer Institut für Nachrichtentechnik, Heinrich-Hertz-Institut, DE); Johan Bauwelinck (Ghent University - iMinds, BE); Hercules Avramopoulos (National Technical University of Athens, GR)
♦ We present a segmented-electrode InP IQ-MZM, capable of multi-level optical signal generation (5-bit per I/Q arm) by employing direct digital drive from integrated, low-power (1W) CMOS binary drivers. Programmable, multi-level operation is demonstrated experimentally on one MZM of the device.

Tu.3.A.2 • 16:15
Ultra-High Bandwidth InP IQ Modulator with 1.5 V Vπ
Yoshihiro Ogiso (NTT Device Innovation Center, NTT Corporation, JP); Takashi Yamada, Josuke Ozaki and Yuta Ueda (NTT, JP); Norihide Kashio (NTT Device Innovation Center, NTT Corporation, JP); Nobuhiro Kikuchi, Eiichi Yamada (NTT Corporation, JP); Hiroyasu Mawatari and Hiromasa Tanobe (NTT, JP); Shigeru Kanazawa (NTT Photonics Laboratories, NTT Corporation, JP); Hiroshi Yamazaki (NTT Corporation, JP); Yoshitaka Ohiso (NTT Photonics Laboratories, NTT Corporation, JP); Takuro Fujii, Mitsuteru Ishikawa and Masaki Kohtoku (NTT Corporation, JP)
♦ We propose a new high-bandwidth (> 67 GHz) and low-Vπ (< 1.5 V) InP-based IQ modulator for more flexible modulation formats, and demonstrate the first up to 120-Gbaud IQ modulations without optical pre-equalization.

Tu.3.A.3 • 16:30 *Invited*
High-Speed Silicon-Organic Hybrid (SOH) Modulators
Stefan Wolf, Wladislaw Hartmann, Matthias Lauermann, Heiner Zwickel, Yasar Kutuvantavida, Clemens Kieninger, Wolfgang Freude, Christian Koos (Karlsruhe Institute of Technology (KIT), DE)
♦ We report on recent progress in high-speed SOH modulators. We demonstrate generation of 100 Gbit/s on-off-keying (OOK) and 252 Gbit/s 16QAM signals, as well as amplifier-less, DAC-less 16QAM signaling at peak-to-peak voltages 0.4 Vpp. Thermal stability at 80°C was shown.

Tu.3.A.4 • 17:00
Record-high Modulation-efficiency Depletion-type Si-based Optical Modulator with In-situ B Doped Strained SiGe Layer on Si Waveguide for 1.3 um Wavelength
JJunichi Fujikata, Masataka Noguchi (Photonics Electronics Technology Research Association, JP); Jaehoon Han (The University of Tokyo, JP); Shigeki Takahashi (Photonics Electronics Technology Research Association, JP); Mitsuru Takenaka (The University of Tokyo, JP); Takahiro Nakamura (Photonics Electronics Technology Research Association, JP)
♦ We develop depletion-type Si optical modulator with strained SiGe on lateral Si pn junction. Owing to in-situ B doping for SiGe, we achieve high modulation efficiency of 0.6-0.67 Vcm at 1.3 um wavelength with clear eye opeing at 28 Gbps.

Tu.3.A.5 • 17:15
Characterization and Digital Pre-compensation of Electro-optic Crosstalk in Silicon Photonics I/Q Modulators
Xi Chen, Po Dong, Sethumadhavan Chandrasekhar, Kwangwoong Kim, Borui Li, Haoshuo Chen, Andrew Adamiecki, Alan Gnauck and Peter Winzer (Nokia Bell Labs, USA)
♦ Electro-optic crosstalk in Silicon Photonics I/Q modulators is characterized and up to -19 dB crosstalk is found. Digital pre-compensation is performed which shows up to 3.7 dB Q2 factor improvement or 64-QAM signals.

Tu.3.B: DSP for Nonlinearity Mitigation — Room 17

Chair: John C Cartledge (Queen's University, CA)

Tu.3.B.1 • 16:00 *Invited*
Prospects for Real-Time Compensation of Fiber Nonlinearities
Michael Reimer, Maurice O'Sullivan, Qunbi Zhuge, Shahab Oveis Gharan, Andrzej Borowiec, Loren Berg and Priyanth Mehta (Ciena Corporation, CA)
♦ We estimate limits on capacity and reach improvements achievable through nonlinear compensation for realizable coherent transceivers over a range of network applications. Methods for low-complexity electronic nonlinear compensation on regional long-haul and ultra-long-haul submarine applications are considered.

Tu.3.B.2 • 16:30
Equalization-Enhanced Phase Noise in Nonlinear Inverse Synthesis Transmissions
Son Le and Ian Phillips (Aston University, UK); Jaroslaw Prilepsky, Morteza Kamalian, Kopae (Aston University & Aston Institute of Photonic Technologies, UK); Andrew Ellis and Paul Harper (Aston University, UK); Sergei K. Turitsyn (Aston University & Photonics Research Group, UK)
♦ We experimentally investigate, for the first time, the performance penalty due to equalization-enhanced phase noise in nonlinear inverse synthesis transmissions with QPSK and 16QAM OFDM modulation formats.

Tu.3.B.3 • 16:45
Blind Adaptive XPM Model Based Digital Backpropagation for Subcarrier-Multiplexing Systems
Fangyuan Zhang (McGill University, CA); Qunbi Zhuge (Ciena Corporation, CA); Meng Qiu, Mathieu Chagnon and David Plant (McGill University, CA)
♦ We propose a low complexity blind adaptive digital back-propagation (DBP) scheme for subcarrier multiplexing (SCM) systems and experimentally demonstrate its fast convergence to the optimal performance without any prior knowledge of the link parameters.

Tu.3.B.4 • 17:00
Demonstration of Coherent Transmission Reach Tripling by Frequency-Referenced Nonlinearity Pre-compensation in EDFA-only SMF Link
Eduardo Temprana, Evgeny Myslivets, Vahid Ataie, Bill Ping Piu Kuo and Nikola Alic (University of California San Diego, USA); Vijay Vusirikala and Vinayak Dangui (Google Inc, USA); Stojan Radic (University of California, San Diego, USA)
♦ A 200% reach extension in a coherent WDM link is demonstrated for the first time by relying on mutually referenced frequency carriers. The reach tripling was achieved by transmitter-side nonlinear impairment cancellation.

Tu.3.B.5 • 17:15
Polarization Effects in Nonlinearity Compensated Links
Ivan Fernandez de Jauregui Ruiz, Amirhossein Ghazisaeidi, Elie Awwad, Patrice Tran and Gabriel Charlet (Nokia Bell Labs, FR)
♦ We experimentally assess the impact of PDL and PMD on the performance of nonlinear compensation algorithms in dispersion unmanaged links. We show that perturbative nonlinear compensation is more robust to PDL, but more sensitive to PMD compared to filtered digital-backpropagation.

Tu.3.C: Multicarier Modulation — Room 16

Chair: Mario Martinelli (Politecnico di Milano, IT)

Tu.3.C.1 • 16:00
400 Gbit/s Real-Time All-Analogue FBMC/OFDM based on a Mode Locked Laser
Fernando Gutiérrez and Eamonn Martin (Dublin City University, IR); Philip A Perry (University College Dublin, IR); Andrew Ellis (Aston University, UK); Aravind Anthur (IIT Madras, India); Vivek Panapakkam (CNRS Laboratory for Photonics and Nanostructures, FR); Quentin Gaimard (CNRS, FR); Kamel Merghem (CNRS Laboratory for Photonics and Nanostructures, FR); Francois Lelarge (Alcatel Thales III-V Lab, FR); Abderrahim Ramdane (CNRS/LPN & Institut National des Télécommunications, FR); Liam Barry (Dublin City University, IR)
♦ A real-time 20x21.6 Gbit/s WDM electro-optical transceiver is presented. Optical carriers were spaced by 37 GHz and each one transmitted four orthogonally overlapping broadband subchannels. Only analogue electronics were employed for the OFDM (de) modulation and subcarrier synchronization.

Tu.3.C.2 • 16:15
Discrete Multi-tone Transmitter at Net Data Rate of 200 Gbps Using a Digital-Preprocessed Analog-Multiplexed DAC
Hiroshi Yamazaki, Munehiko Nagatani, Shigeru Kanazawa, Hideyuki Nosaka, Toshikazu Hashimoto and Fukutaro Hamaoka (NTT Corporation, JP); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)
♦ We demonstrated 214-Gbps/λ single-polarization discrete multi-tone optical transmission using a digital-preprocessed analog-multiplexed DAC based on two CMOS sub-DACs. Diversity synthesis utilizing image signal was introduced to enhance the performance. A bit error rate below 3.8x10-3 was obtained.

Tu.3.C.3 • 16:30
Real-Time Hardware Demonstration of 180 Gbps DFT-S OFDM Receiver Based on Digital Sub-banding
Alex Tolmachev, Maxim Meltsin, Rolf Hilgendorf and Mordechay Orbah (Technion - Israel Institute of Technology, IL); Yitzhak Birk (Technion, IL); Shalva Ben Ezra (Finisar, IL); Moshe Nazarathy (Technion, Israel Institute of Technology, IL)
♦ In just 3 FPGAs we realize fastest (180 Gbps) real-time filter-bank based DFT-S CO-OFDM 16-QAM 25 GHz Rx, at record 1.06 samples/symbol (7.3 b/Hz), demonstrating dual polarization SMF transmission. Extrapolated ASIC would save <50% power.

Tu.3.C.4 • 16:45
56 Gb/s DMT Transmission with VCSELs in 1.5 um Wavelength Range over up to 12 km for DWDM Intra-Data Center Connects
Annika Dochhan (ADVA Optical Networking SE, DE); Nicklas Eiselt (Technical University of Denmark, DK); Robert Hohenleitner (Vertilas GmbH, DE); Helmut Griesser (ADVA Optical Networking SE, DE); Michael Eiselt (ADVA, DE); Markus Ortsiefer (VERTILAS GmbH, c/o GATE Garching, DE); Christian Neumeyr (VERTILAS, GmbH, DE); Juan Jose Vegas Olmos (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU); Jörg-Peter Elbers (ADVA AG Optical Networking, DE)
♦ We demonstrate up to 12 km, 56 Gb/s DMT transmission using high-speed VCSELs in the 1.5 um wavelength range for future 400Gb/s intra-data center connects, enabled by vestigial sideband filtering of the transmit signal.

Tu.3.D: Elastic Optical Networks III — Room 15

Chair: Piero Castoldi (Scuola Superiore Sant'Anna, IT)

Tu.3.D.1 • 16:00 *Invited*
Adaptive and Efficient Multilayer Elastic Optical Network Planning
Takafumi Tanaka, Tetsuro Inui, Akihiro Kadohata and Akira Hirano (NTT, JP); Wataru Imajuku (Kindai University, JP)
♦ We overview our current works on the heuristic IP-over-elastic optical network (EON) planning algorithms including modulation-aware virtual topology planning in the planning phase and multiperiod multilayer network planning which adapts to dynamic traffic conditions in the operational phase.

Tu.3.D.2 • 16:30
Broker-based Cooperative Game in Multi-Domain SD-EONs: Nash Bargaining for Agreement on Market-Share Partition
Lu Sun (University of Science and Technology of China, PRC); Xiaoliang Chen (University of California, Davis & University of Science and Technology of China, USA); Shilin Zhu, Zuqing Zhu (University of Science and Technology of China, PRC); Alberto Castro Casales, S. J. Ben Yoo (University of California, Davis, USA)
♦ We model the cross-domain lightpath provisioning in multi-broker based multi-domain SD-EONs as a cooperative game, propose to obtain Pareto-efficient market-share partition for the brokers with Nash bargaining, and design the system framework to realize the proposal.

Tu.3.D.3 • 16:45
Time and Spectrum Aggregation in Metropolitan Network for Heterogeneous Traffic Profile
Ion Popescu (KDDI R&D Laboratories, Inc., JP); Ahmed Triki (Institut mines Télécom, Télécom Bretagne, FR); Xiaoyuan Cao (KDDI R&D Laboratories, Inc., JP); Annie Gravey (Institut Mines Telecom - Telecom Bretagne & UMR CNRS 6074 IRISA, FR); Takehiro Tsuritani (KDDI R&D Laboratories, Inc., JP); Philippe Gravey (Télécom Bretagne, FR); Noboru Yoshikane (KDDI R&D Laboratories, JP); Michel Morvan (Telecom Bretagne, FR)
♦ We propose a new optical transport solution, TSAN, based on variable bit rate packet transmission and passive switching. The expected CAPEX and OPEX savings in TSAN are assessed using scenarios based on current and next generation network architectures.

Tu.3.D.4 • 17:00
Comparing Networking Benefits of Digital Back-Propagation vs. Lightpath Regeneration
Mattia Cantono, Roberto Gaudino, Pierluigi Poggiolini, Vittorio Curri (Politecnico di Torino, IT)
♦ We compare the networking benefits of Ideal-Single-Channel Digital-Back-Propagation (ISC- DBP) vs. Lightpath Regeneration as Quality-of-Transmission enhancing techniques. By analyzing three different topologies, we show that ISC-DBP has the potential to substantially reduce the number of required regenerators in all-optical networks.

Tu.3.D.5 • 17:15
Latency-aware Multi-layer Network Optimization in IP-over-WDM Core Networks
Ćiril Rožić, I Tomkos and Dimitrios Klonidis (Athens Information Technology, GR)
♦ We study the handling of latency-sensitive traffic in a IP/optical core network. We show the superiority of our proposed latency-aware multi-layer network optimization approach, and evaluate the impact of propagation and electronic processing delays.

Tu.3.E: Nonlinear and Quantum Techniques — Room 110

Chair: Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE)

Tu.3.E.1 • 16:00
Design of 2-Soliton Spectral Phase Modulated Pulses Over Lumped Amplified Link
Vahid Aref, Henning Buelow (Nokia Bell Labs, DE)
♦ Over a lumped amplified link, we explain numerically how to design solitonic pulses keeping the same breathing period. We demonstrate experimentally the transmission of 2-Solitonic pulses with QPSK spectral amplitude modulation over 1600 km with a low error rate.

Tu.3.E.2 • 16:15
Transmission of Waveforms Determined by 7 Eigenvalues with PSK-Modulated Spectral Amplitudes
Henning Buelow, Vahid Aref, Wilfried Idler (Nokia Bell Labs, DE)
♦ 2-ns waveforms with 7 eigenvalues and their QPSK-modulated spectral amplitudes were optimized by taking constraints of link, transmitter, and receiver into account. In experiment these signals were transmitted with a BER of 3.2E-3 over 1440-km of NZ-DSF fiber spans.

Tu.3.E.3 • 16:30
34.6 Tbit/s WDM Transmission Using Soliton Kerr Frequency Combs as Optical Source and Local Oscillator
Pablo Marin, Juned N Kemal, Philipp Trocha and Stefan Wolf (Karlsruhe Institute of Technology, DE); Arne Kordts, Karpov Maxim, Martin Pfeiffer and Victor Brasch (Ecole Polytechnique Federale de Lausanne, CH); Wolfgang Freude (Karlsruhe Institute of Technology (KIT), DE); Tobias Kippenberg (Ecole Polytechnique Federale de Lausanne, CH); Christian Koos (Karlsruhe Institute of Technology (KIT), DE)
♦ We demonstrate massively parallel WDM transmission using Soliton Kerr frequency combs both as multi-wavelength source at the transmitter and as multi-wavelength local oscillator at the receiver. The viability of the concept is proven by transmitting 34.6Tbit/s over 75km.

Tu.3.E.4 • 16:45
Heterodyne Coherent Scheme for Long Distance Quantum Key Distribution Using a Real Local Oscillator
Sebastian Kleis, Christian Schaeffer (Helmut-Schmidt-University, DE)
♦ We present a novel heterodyne coherent scheme for secure key distribution. In contrast to most other QKD schemes it is very practical because it works with a real free running LO at the receiver side.

Tu.3.F: Advanced Modulation for Access — Room 112

Chair: Dirk Breuer (Deutsche Telekom T-Labs, DE)

Tu.3.F.1 • 16:00
Transmission of 100-Gb/s DSB-DMT over 80-km SMF Using 10-G class TTA and Direct-Detection
Jie Zhou, Liang Zhang and Tianjian Zuo (Huawei, PRC); Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Sen Zhang, Enbo Zhou and Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)
♦ We experimentally demonstrate 100-Gb/s DSB-DMT transmission over 80-km SMF using 10-GHz TTA and Direct-Detection technique. Maximum capacities up to 125 Gb/s, 106 Gb/s and 103 Gb/s are achieved with BER at 4.5×10-3 for BTB, 40-km and 80-km SMF transmissions, respectively.

Tu.3.F.2 • 16:15
25Gb/s PAM4 Adaptive Receiver Equalisation Requirements for Burst-Mode Transmission Systems
Marco Dalla Santa (Tyndall National Institute, University College Cork, IR); Cleitus Antony (Tyndall National Institute, IR); Giuseppe Talli (Tyndall National Institute & Tyndall National Institute, IR); Paul Townsend (Tyndall National Institute, IR)
♦ Requirements for burst-mode equalisation in a 25Gb/s PAM4 system for passive optical network upstream traffic are analysed for different linear equaliser solutions, with transmission over 40km of fibre. The impact of chromatic dispersion, transmitter bandwidth restriction and non-linearities is considered.

Tu.3.F.3 • 16:30
Demonstration and Analysis on PAM-4/8, DB-PAM-2/4 and DMT Formatted TDM-PON with 25Gbps, 40Gbps, 50Gbps Capacity per Lane using Economical 10Gbps Transceivers
Chenhui Ye, Xiaofeng Hu, Kaibin Zhang (Alcatel-Lucent Bell Labs, PRC)
♦ We demonstrate 25Gbps/40Gbps/50Gbps TDM-PONs using PAM-2/4/8, duo-binary PAM-2/4, and DMT formats on economical 10Gbps transceivers. Based on the performance/cost analysis and comparison, we also introduce a general guidance on format choice for 25Gbps+ PONs.

Tu.3.F.4 • 16:45
Demonstration of Upstream Flexible 2-/4-PAM Formats for Practical PON Deployments
Robbert van der Linden (Eindhoven University of Technology & Genexis BV., NL); Xin Yin (Ghent University - IMEC, BE); Nguyen-Cac Tran (Genexis B.V., Eindhoven, NL); Johan Bauwelinck (Ghent University - iMinds, BE); Eduward Tangdiongga (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ Adaptive 2-/4-PAM modulation in PONs leverages the distribution of optical path losses to increase capacity. Upstream 2-/4-PAM burst transmission is demonstrated with a selectable fixed 4-tap FIR-filter, improving the performance of each gain mode of the burst-mode receiver.

Tu.3.F.5 • 17:00 *Invited*
Recent Progress on 25G EPON and beyond
Vincent Houtsma, Dora van Veen (Nokia Bell Labs, USA); Ed Harstead (Alcatel-Lucent, BE)
♦ An overview of recent developments in next generation high speed PON and the progress being made in IEEE P802.3ca working group on 25G EPON and beyond is given.

W.1.A: Advanced Silicon Photonics — Room 18+19

Chair: Richard Pitwon (Seagate, UK)

W.1.A.1 • 09:00 *Tutorial*
Advanced Silicon Photonics for Post-Moore Era
Koji Yamada (National Institute of Advanced Industrial Science and Technology, JP)
♦ Telecom/Datacom traffic is growing explosively as device technology development guided by Moore's law nears it end. Although silicon photonics technology offers immediate solutions, much further evolution is needed in order to cope with the continual growth expected in the future.

W.1.A.2 • 10:00 *Invited*
High-Speed Photonics for Side-by-Side Integration with Billion Transistor Circuits in Unmodified CMOS Processes
Luca Alloatti (ETH Zurich, CH)
♦ Monolithic integration of photonics and electronics is key to chip-to-chip optical interconnects. However, high-yield CMOS nodes impose strict constraints on materials and design rules. We review high-responsivity photodiodes and low-voltage modulators for 12.5Gbaud links in an unmodified 45nm CMOS node.

W.1.B: Fiber Sensing and Measurement — Room 17

Chair: Patrice Mégret (University of Mons (UMONS) & Faculté Polytechnique, BE)

W.1.B.1 • 09:00
High Dynamic Range Linear Optical Sampling with Coherence Recovery for Measuring Fibre Impulse Response
Fumihiko Ito and Naoto Kono (Shimane University, JP); Daisuke Iida and Tetsuya Manabe (NTT Corporation, JP)
♦ Impulse responses of 2-mode fibres are measured by a method based on linear optical sampling with newly developed amplitude averaging technique with phase noise compensation. The intermodal coupling is observed with 10-ps time resolution and 80 dB dynamic range.

W.1.B.2 • 09:15
Measurement of Temperature-Induced Polarization Drift and Correlation in a 7-Core Fiber
Mikael Mazur (Chalmers University of Technology, SE); Thierry Taunay (OFS Laboratories, USA); Tommy Geisler and Lars Grüner-Nielsen (OFS Fitel Denmark, DK); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE); Peter A Andrekson (Chalmers University of Technology, SE)
♦ We study the correlation in polarization drift between different cores of a 7-core fiber subjected to temperature fluctuations. We present a method to quantify these changes and show that the drift in different cores is correlated to 98%.

W.1.B.3 • 09:30 *Invited*
Multicore optical fiber grating arrays for sensing applications
Paul Westbrook, Tristan Kremp, Kenneth Feder, Thierry Taunay , Eric Monberg, Hongchao Wu, Debra Simoff and Roy Ortiz (OFS Labs, USA)
♦ We review recent advances in optical fiber sensor array technology aimed at next generation applications such as shape sensing and enhanced scatter enabled distributed sensing.

W.1.C: Signal Shaping — Room 16

Chair: Andrew Ellis (Aston University, UK)

W.1.C.1 • 09:00 *Invited*
Probabilistically Shaped QAM for Independent Reach, Spectral Efficiency and Bit-rate Adaptation
Fred Buchali, Wilfried Idler and Laurent Schmalen (Nokia Bell Labs, DE); Georg Böcherer, Patrick Schulte and Fabian Steiner (Technical University of Munich, DE)
♦ In this paper we review probabilistically shaped constellations and experimentally investigate probabilistically shaped QAM systems operated at both high bit-rate and high reach requiring high baudrate transmission. We demonstrate up to 29% reach increase by probabilistic shaping.

W.1.C.2 • 09:30
Low-Complexity Shaping for Enhanced Nonlinearity Tolerance
Junho Cho, Sethumadhavan Chandrasekhar, Ronen Dar, Peter Winzer (Nokia Bell Labs, USA)
♦ We present a novel low-complexity signal shaping method which offers significant linear and nonlinear gains. The shaping gain exceeds the coding gain, and the data rate can be easily adapted by shaping.

W.1.C.3 • 09:45
Implicit Constellation Shaping in Regenerative Optical Networks
Laurent Schmalen, Fred Buchali (Nokia Bell Labs, DE)
♦ In this paper, we consider optical coherent networks with regenerative nodes. We show that by properly optimizing the regenerators, we can improve the network's spectral efficiency with minor receiver modifications. This method automatically includes a fall-back to lower-order modulation formats.

W.1.C.4 • 10:00
Four-Dimensional Trellis Coded Modulation for Flexible Optical Transponders
Saleem Alreesh (Technische Universität Berlin, DE); Carsten Schmidt-Langhorst, Robert Emmerich, Pablo Wilke Berenguer, Colja Schubert and Johannes K. Fischer (Fraunhofer Heinrich Hertz Institute, DE)
♦ We experimentally demonstrate 4-D TCM based on PDM-16QAM, PDM-32QAM and PDM-64QAM formats . A multi-rate optical transponder is enabled by only a single encoder/decoder structure. The scheme is resilient to cycle-slip events due to its 90° phase rotation invariant property.

W.1.C.5 • 10:15
Temporal Probabilistic Constellation Shaping for WDM Optical Communication Systems
Metodi Yankov, Soren Forchhammer (Technical University of Denmark, DK)
♦ Finite state machine sources transmitting QPSK are studied as input to WDM optical fiber systems with ideal distributed Raman amplification. The probabilities of successive constellation symbols are shaped for nonlinear transmission and gains of around 500km (5-10%) are demonstrated.

10:30 - 11:00 Coffee Break | Exhibition Hall |

W.1.D: Nonlinear Distortions — Room 15

Chair: Yann Frignac (Institut Mines-Télécom, FR)

W.1.D.1 • 09:00
Experimental Study of Nonlinear Phase Noise and its Impact on WDM Systems with DP-256QAM
Metodi Yankov, Francesco Da Ros, Edson Porto da Silva (Technical University of Denmark, DK); Tobias Fehenberger (Technical University of Munich (TUM), DE); Luca Barletta (Politecnico di Milano, IT); Darko Zibar (DTU Fotonik, department of Photonic Engineering, Technical University of Denmark, DK); Leif Oxenløwe, Michael Galili, Soren Forchhammer (Technical University of Denmark, DK)
♦ A probabilistic method for mitigating the phase noise component of the non-linear interference in WDM systems with Raman amplification is experimentally demonstrated. The achieved gains increase with distance and are comparable to the gains of single-channel digital back-propagation.

W.1.D.2 • 09:15
Impact of WDM Channel Correlations on Nonlinear Transmission
Ronen Dar, Sethumadhavan Chandrasekhar, Alan Gnauck, Borui Li, Junho Cho, Ellsworth Burrows and Peter Winzer (Nokia Bell Labs, USA)
♦ We study the impact of channel correlations on the accumulation of nonlinear interference noise in WDM transmission experiments. Theoretical predictions, split-step simulations and experimental measurements indicate negligible impact for QPSK transmission, but notably strong artifacts for high-order QAM formats.

W.1.D.3 • 09:30
Independence of the Impact of Inter-Channel Non-Linear Effects on Modulation Format and System Implications
Antonino Nespola and Luca Bertignono (Istituto Superiore Mario Boella, IT); Gabriella Bosco, Andrea Carena and Pierluigi Poggiolini (Politecnico di Torino, IT); Fabrizio Forghieri (Cisco Photonics Italy srl, IT)
♦ We show by simulation that the impact of inter-channel non-linear effects is independent of modulation format in long-haul systems, once long-correlated non-linear phase-noise has been removed. We back-up the finding experimentally and investigate the system implications.

W.1.D.4 • 09:45
Experimental Analysis of Correlations in the Nonlinear Phase Noise in Optical Fiber Systems
Tobias Fehenberger (Technical University of Munich (TUM), DE); Mikael Mazur (Chalmers University of Technology, SE); Tobias A. Eriksson (Nokia Bell Labs, DE); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE); Norbert Hanik (Munich University of Technology, DE)
♦ A dual-link self-homodyne receiver is used to measure the phase correlations introduced by the interplay of dispersion and fiber nonlinearities. The dependence of the memory on the WDM setup, signal power and transmission distance is experimentally demonstrated.

W.1.D.5 • 10:00 *Invited*
Analytical and Semi-Analytical Models for Nonlinear Transmission
Ronen Dar (Nokia Bell Labs, USA)
♦ We review recent advances in modeling nonlinear interference noise (NLIN) in WDM systems. We explore the time-domain and frequency-domain representations of NLIN and discuss techniques for evaluating its statistical properties and impact on system performance.

W.1.E: Photonics-Based Wireless Access — Room 110

Chair: Guillermo Carpintero (Universidad Carlos III de Madrid, ES)

W.1.E.1 • 09:00 *Upgraded*
Demonstration of a Real-Time FPGA-Based CPRI-Compatible Efficient Mobile Fronthaul Transceiver Supporting 53 Gb/s CPRI-Equivalent Data Rate Using 2.5-GHz-Class Optics
Huaiyu Zeng and Xiang Liu (Futurewei Technologies, USA); Sharief Megeed (Futurewei Technologies, Huawei R&D USA, USA); Naresh Chand (Futurewei Technologies, USA); Frank Effenberger (Huawei Technologies, USA)
♦ We experimentally demonstrate a real-time CPRI-compatible mobile fronthaul transceiver using 5-GSa/s DAC/ADC, Xilinx Virtex 7 FPGA, and 2.5-GHz-class DML and APD. A CPRI-equivalent aggregated throughput of 53 Gb/s is achieved with an one-way processing latency as low as 1.8 ms.

W.1.E.2 • 09:30
Full-Duplex Mobile Backhaul Transportation based on Fiber-Wireless Integrated FSO and MMW Hybrid Links with Adaptive Signal Processing to Combat Diverse Weather Conditions
Junwen Zhang, Gk Chang, Jing Wang and Mu Xu (Georgia Institute of Technology, USA); Jianjun Yu (Fudan Univerisity, PRC); Lin Cheng (Georgia Institute of Technology, USA)
♦ We propose and experimentally demonstrate a novel full-duplex mobile backhaul network based on fiber-wireless integrated MMW and FSO hybrid links using adaptive diversity combining technique. Performance improvements and enhanced reliability are validated under diverse weather conditions at 11.25-/8.4-Gb/s for down-/up-links.

W.1.E.3 • 09:45
PIC-enabled Dynamic Bidirectional Indoor Network Employing Optical Wireless and Millimeter-wave Radio Techniques
Ketamaw Mekonnen, Chin Wan Oh, Zizheng Cao and Amir Masood Khalid (Eindhoven University of Technology, NL); Nicola Calabretta (COBRA Research Institute, NL); Eduward Tangdiongga (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ We propose a hybrid radio-optical wireless system using a photonic integrated chip to realize highly reconfigurable indoor networks which provide ultimate capacities per user. Bidirectional transmission rates of >35Gb/s are demonstrated using discrete-multitone modulation.

W.1.E.4 • 10:00
Photonics-Aided over 100-Gbaud All-Band (D-, W- and V-Band) Wireless Delivery
Xinying Li (Fudan University, PRC); Jianjun Yu (ZTE (TX) Inc., USA); Jiangnan Xiao, Yuming Xu and Long Chen (Fudan University, PRC)
♦ We experimentally demonstrate photonics-aided D-band (110GHz-170GHz) wireless mm-wave signal delivery with a record baud rate of 46Gbaud and photonics-aided all-band (D-, W- and V-band) wireless mm-wave signal delivery with a record baud rate of over 100Gbaud (400Gbps).

W.1.E.5 • 10:15
80 Gbit/s 16-QAM Multicarrier THz Wireless Communication Link in the 400 GHz Band
Shi Jia (Tianjin University, DK); Xianbin Yu (Zhejiang University, PRC); Hao Hu (Technical University of Denmark, DK); Jinlong Yu (Tianjin University, PRC); Toshio Morioka (Technical University of Denmark, DK); Peter Uhd Jepsen (Denmark Technical University, DK); Leif Oxenløwe (Technical University of Denmark, DK)
♦ We experimentally demonstrate a high-speed multicarrier THz wireless communication system operating in the 400 GHz band. The use of spectrally efficient 16-QAM modulation and broadband THz transceivers enable link data rates up to 80 Gbit/s.

W.1.F: SDN and NFV — Room 112

Chair: Achim Autenrieth (ADVA Optical Networking, DE)

W.1.F.1 • 09:00
Multi-tenant 5G Network Slicing Architecture with Dynamic Deployment of Virtualized Tenant Management and Orchestration (MANO) Instances
Arturo Mayoral, Raul Muñoz, Ricard Vilalta, Ramon Casellas and Ricardo Martinez (Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), ES)
♦ We present and experimentally assess a multi-tenant network slicing architecture that dynamically provides 5G slices (virtual network and cloud resources, and virtualized network functions) and SDN/NFV control instances for a full control of allocated resources as if they were real.

W.1.F.2 • 09:15
First Experimental Demonstration of Secure NFV Orchestration over an SDN-Controlled Optical Network with Time-Shared Quantum Key Distribution Resources
Alejandro Aguado, Emilio Hugues-Salas, Paul Anthony Haigh, Jaume Marhuenda, Alasdair Price, Phil Sibson, Jake Kennard, Christopher Erven, John Rarity and Mark Thompson (University of Bristol, UK); Andrew Lord (British Telecom, UK); Reza Nejabati and Dimitra Simeonidou (University of Bristol, UK)
♦ We demonstrate, for the first time, a secure optical network architecture that combines NFV orchestration and SDN control with quantum key distribution (QKD) technology. A novel time-shared QKD network design is presented as a cost-effective solution for practical networks.

W.1.F.3 • 09:30
On-Demand Allocation of Control Plane Functions via SDN/NFV for Monitoring-enabled Flexi-grid Optical Networks with Programmable BVTs
Ramon Casellas, Josep M. Fabrega, Raul Muñoz, Laia Nadal Reixats, Ricard Vilalta, Michela Svaluto Moreolo and Ricardo Martinez (Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), ES)
♦ A modular SDN architecture for flexi-grid networks, relying on the NFV framework, allows on-demand allocation and composition of virtualized control plane functions into instances, in a cost effective way. We demonstrate its use in the adaptive control of BVTs

W.1.F.4 • 09:45
Experimental Assessment of VDC Provisioning in SDN/OpenStack-based DC infrastructures with optical DCN
Albert Pagès, Fernando Agraz, Rafael Montero (Universitat Politècnica de Catalunya (UPC), ES); Giada Landi and Roberto Monno (Nextworks, IT); José I Aznar (I2cat, ES); Albert Viñés (Fundació i2CAT, Internet i Innovació Digital a Catalunya, ES); Chris Jackson and Dimitra Simeonidou (University of Bristol, UK); Salvatore Spadaro (Universitat Politecnica de Catalunya (UPC), ES)
♦ VDC provisioning requires the coordinated configuration of several types of resources. We present a DC architecture for the orchestration and provisioning of VDC instances on top of DCs with optical DCN and experimentally validate the proposed architecture.

W.1.F.5 • 10:00
Experimental Evaluation of YAMATO, a SDN Control Plane for Joint and Fractional-Joint Switched SDM Optical Networks
Federico Pederzolli, Matteo Gerola and Andrea Zanardi (Create-Net, IT); Xavier Forns and J. Ferran (W-Onesys, Barcelona, ES); Domenico Siracusa (CREATE-NET, IT)
♦ Managing (Fractional) Joint Switching will enable the deployment of cost-effective SDM networks. This paper describes a network model and the first control plane implementation handling these paradigms. We show, using an emulated testbed, that the system is responsive and scalable.

W.1.F.6 • 10:15
Virtualized Routing and Frequency Allocation Functions in Elastic Optical Networks
Quan Pham Van (Telecom Sudparis & Nokia Bell Labs, FR); Dominique G. Verchere (Nokia Bell Labs & France, FR); Selma Khebbache (Télécom SudParis, Institut Mines-Télécom, FR); Djamal Zeghlache (Institut Mines-Telecom, Telecom SudParis & UMR 5157 CNRS - Samovar, FR); Patricia Layec and Arnaud Dupas (Nokia Bell-Labs, FR); Sebastien Bigo (Bell Labs, Alcatel-Lucent, FR)
♦ Optical channels are configured according to changing data traffic demands through virtualized routing and frequency allocation (VRFA) functions executed as SDN applications. Two algorithms are evaluated considering the trade-off between allocated DWDM frequency grid ranges and execution time.

10:30 - 11:00 Coffee Break | Exhibition Hall |

W.2.A: Trends on Passive Optical Network — Room 18+19

Chair: Philippe Chanclou (Orange Labs, FR)

W.2.A.1 • 11:00 *Tutorial*
Industrial Trends and Roadmap of Access
Frank Effenberger (Huawei Technologies, USA)
♦ Optical access has grown in speed, from 50 Mb/s pi-PON to 10 Gb/s XG-PON. Further capacity increases are envisioned to employ multiple wavelengths and advanced line coding. This paper reviews the current trends in access, and predicts a likely roadmap.

W.2.A.2 • 12:00 *Invited*
Cost Effective 25 Gbps Optical Access Technology
Dora van Veen, Vincent Houtsma (Nokia Bell Labs, USA)
♦ Overview and discussion of cost effective 25 Gb/s TDM-PON based on 10G optical components using electrical duobinary signalling and electronic equalization methods is presented.

W.2.B: Multicore Fibers — Room 17

Chair: Kunimasa Saitoh (Hokkaido University, JP)

W.2.B.1 • 11:00
125 µm 5-core fibre with heterogeneous design suitable for migration from single-core system to multi-core system
Tomohiro Gonda, Katsunori Imamura and Ryuichi Sugizaki (Furukawa Electric co., Ltd., JP); Yu Kawaguchi and Takehiro Tsuritani (KDDI R&D Laboratories, Inc., JP)
♦ 125 µm 5-core fibre with heterogeneous core design suitable for the migration from single-core system to multi-core system was designed and fabricated. This fibre has high space division multiplexing factor comparable to 19-core fibres.

W.2.B.2 • 11:15
Crosstalk-Managed Heterogeneous Single-Mode 32-Core Fibre
Yusuke Sasaki, Ryohei Fukumoto, Katsuhiro Takenaga and Kazuhiko Aikawa (Fujikura Ltd., JP); Kunimasa Saitoh (Hokkaido University, JP); Toshio Morioka (Technical University of Denmark, DK); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)
♦ A heterogeneous single-mode 32-core fibre with a cladding diameter of 243 µm is designed and fabricated. The highest core count in single-mode multi-core fibres and low worst-case crosstalk of less than –24 dB/1000 km in C-band are achieved simultaneously.

W.2.B.3 • 11:30 *Invited*
Coupled Few-mode Multi-core Fibre for Ultra-high Spatial Density Space Division Multiplexing
Taiji Sakamoto, Takayoshi Mori, Masaki Wada, Takashi Yamamoto, Fumihiko Yamamoto, Kazuhide Nakajima (NTT Corporation, JP)
♦ We review our recent work on coupled few-mode multi-core fibre and describe a super-mode-based MCF design for suppressing MIMO processing complexity. We also report 125 um-cladding strongly coupled 3-mode 7-core fibre for reducing inter-core non-uniformity induced differential mode delay.

W.2.B.4 • 12:00
Compact 32-Core Multicore Fibre Isolator for High-Density Spatial Division Multiplexed Transmission
Yongmin Jung (Optoelectronics Research Centre, University of Southampton, Southampton, UK); Shaif-ul Alam (University of Southampton, UK); Yusuke Sasaki (Fujikura Ltd., JP); David J Richardson (University of Southampton, UK)
♦ We present a fully integrated 32-core multicore fibre isolator with low insertion loss (average loss <0.8dB, core-to-core variation <2dB) and low inter-core crosstalk (<-40dB).

W.2.B.5 • 12:15
Effects of Core Count/Layout and Twisting Condition on Spatial Mode Dispersion in Coupled Multi-Core Fibers
Tetsuya Hayashi (Sumitomo Electric Industries, Ltd., JP); Haoshuo Chen and Nicolas K Fontaine (Nokia Bell Labs, USA); Takuji Nagashima (Sumitomo Electric Industries, Ltd., JP); Roland Ryf and Rene Essiambre (Nokia Bell Labs, USA); Toshiki Taru (Sumitomo Electric Industries, Ltd., JP)
♦ We investigated the dependence of the spatial-mode dispersion (SMD) of coupled-core fibers on core count/layout and twisting conditions. The results indicate the importance of the core count/layout design optimization taking account of the twisting conditions.

W.2.C: Error Correction — Room 16

Chair: Helmut Griesser (ADVA Optical Networking SE, DE)

W.2.C.1 • 11:00
Experimental Demonstration of Nonbinary LDPC Convolutional Codes for DP-64QAM/256QAM
Toshiaki Koike-Akino (Mitsubishi Electric Research Laboratories (MERL), USA); Kenya Sugihara (Mitsubishi Electric Corporation, JP); David Millar, Milutin Pajovic (Mitsubishi Electric Research Laboratories (MERL), USA); Wataru Matsumoto (Mitsubishi Electric Corporation, JP); Alex Alvarado, Robert Maher, Domanic Lavery and Milen Paskov (University College London, UK); Keisuke Kojima and Kieran Parsons (Mitsubishi Electric Research Laboratories, USA); Benn C Thomsen (University College London, UK); Seb J Savory (University of Cambridge, UK); Polina Bayvel (UCL, UK)
♦ We show the great potential of nonbinary LDPC convolutional codes (NB-LDPC-CC) with low-latency windowed decoding. It is experimentally demonstrated that NB-LDPC-CC can offer a performance improvement of up to 5 dB compared with binary coding.

W.2.C.2 • 11:15
Optimal Layered Scheduling for Hardware-Efficient Windowed Decoding of LDPC Convolutional Codes
Toshiaki Koike-Akino (Mitsubishi Electric Research Laboratories (MERL), USA); Stark Draper (University of Toronto, CA); Ye Wang (Mitsubishi Electric Research Laboratories, USA); Kenya Sugihara and Wataru Matsumoto (Mitsubishi Electric Corporation, JP); David Millar and Kieran Parsons, Valeria Arlunno and Keisuke Kojima (Mitsubishi Electric Research Laboratories, USA)
♦ We propose an optimal design method for layered scheduling in low-power windowed decoding of LDPC convolutional codes. Our optimal scheduling achieves up to a 70% complexity reduction and a 1 dB gain over conventional scheduling for limited decoding iterations.

W.2.C.3 • 11:30 *Invited*
Scalable SD-FEC for Efficient Next-generation Optical Networks
Kenya Sugihara, Keisuke Dohi, Kazuo Kubo, Takashi Sugihara, Wataru Matsumoto, Kenji Ishii (Mitsubishi Electric Corporation, JP)
♦ An SD-FEC has an even potential of a further optimization of a spectral efficiency and a power consumption in optical networks. A scalable SD-FEC is the key idea that improves efficiency of next-generation optical networks.

W.2.C.4 • 12:00
Improvement on FEC performance by Turbo Equalization for Super-Nyquist WDM systems
Shuai Yuan and Koji Igarashi (Osaka University, JP); Takehiro Tsuritani; Itsuro Morita (KDDI R&D Laboratories, Inc., JP)
vIn Super-Nyquist WDM systems, maximum likelihood decoder for duobinary shaping degrades the post-FEC BER performance.
♦ We experimentally confirm that degradation of post-FEC BER characteristics can be remarkably suppressed by introducing turbo equalization.

W.2.C.5 • 12:15
Improved Soft-Decision Forward Error Correction via Post-Processing of Mismatched Log-Likelihood Ratios
Alex Alvarado (University College London, UK); Leszek Szczecinski (INRS-EMT, CA); Tobias Fehenberger (Technical University of Munich (TUM), DE); Polina Bayvel and Milen Paskov (University College London, UK)
♦ Correction of soft information based on achievable information rates for SD-FEC is discussed. Linear scaling of LLRs is shown to offer gains of up to 0.75 dB for a rate 0.8 LDPC code in a channel dominated by phase noise.

12:30 - 14:00 Lunch Break

W.2.D: Advanced Modulation Formats I — Room 15

Chair: Giancarlo Gavioli (Nokia, IT)

W.2.D.1 • 11:00
5 and 7 bit/symbol 4D Modulation Formats Based on 2A8PSK
Keisuke Kojima (Mitsubishi Electric Research Laboratories, USA); Tsuyoshi Yoshida (Mitsubishi Electric Corporation, JP); Toshiaki Koike-Akino, David Millar, Kieran Parsons and Valeria Arlunno (Mitsubishi Electric Research Laboratories (MERL), USA)
♦ We propose 5 and 7 bit/symbol 4D modulation formats based on 2A8PSK, which outperform previously known modulation formats for each spectral efficiency. Combined with the recently reported 6 bit/symbol 2A8PSK, the 2A8PSK family covers 5-7 bits without significant hardware modifications.

W.2.D.2 • 11:15
Digital Subcarrier Multiplexing 4-D Set-Partitioning QAM Signals
Xiang Meng (Huazhong University of Science and Technology, PRC); Qunbi Zhuge (Ciena Corporation, CA); Meng Qiu and Thang Hoang (McGill University, CA); Mohammad Sowailem (McGill University, Egypt); Xingyu Zhou (UESTC, PRC); Fangyuan Zhang (McGill University, CA); Ming Tang, Changjian Ke, Deming Liu and Songnian Fu (Huazhong University of Science and Technology, PRC); David Plant (McGill University, CA)
♦ We experimentally investigate 4-D set-partitioning formats in digital subcarrier multiplexing systems. The proposed 4-D set-partitioning of signals across two subcarriers outperforms the conventional approach implemented across two polarizations in terms of both nonlinearity and optical filtering tolerance.

W.2.D.3 • 11:30
96-GBaud Coded 8-Dimensional 16QAM Transmission over 5,252 km Using Iterative Soft-Output Decoding
Masanori Nakamura, Fukutaro Hamaoka, Asuka Matsushita, Kengo Horikoshi, Hiroshi Yamazaki and Munehiko Nagatani (NTT Corporation, JP); Akihide Sano (NTT Network Innovation Laboratories, JP); Akira Hirano (NTT, JP); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)
♦ We propose novel coded 8-dimensional 16QAM demonstrating 576-Gbps transmission over 5,252km. At the same spectral efficiency, 8D-16QAM using iterative soft output decoding can expand the transmission reach by 1,212km compared to conventional PDM-8QAM.

W.2.D.4 • 11:45
Folded Orthogonal Frequency Division Multiplexing for Super-Channel Sub-Banding
Bill Corcoran, Chen Zhu, Arthur Lowery and Binhuang Song (Monash University, AU)
♦ Orthogonal, periodic-sinc-shaped sub-carrier spectra allow multi-carrier bands with the precise, rectangular frequency definition of Nyquist-WDM. Experimental demonstration of these 'folded' OFDM bands shows a 0.5-1.7-dB implementation penalty, allowing 520-Gb/s super-channel transmission over 4160 km.

W.2.D.5 • 12:00
Improved Flexibility in Rate and Reach by Time-Frequency Packed QPSK
Qian Hu, Fred Buchali, Laurent Schmalen, Wilfried Idler, Roman Dischler and Henning Buelow (Nokia Bell Labs, DE)
♦ We experimentally demonstrate a transmission system with adaptable rate and reach based on time-frequency-packing technique. Packed by a digital filter, the DP-QPSK signal is transmitted at various baud rates in a sub-Nyquist channel with fixed bandwidth.

W.2.E: Transmitters II — Room 110

Chair: Leo Spiekman (Aeon Corp., USA)

W.2.E.1 • 11:00 *Invited*
Quantum-dot lasers monolithically grown on silicon substrates
Huiyun Liu (University College London & Torrington Place, UK)
♦ Monolithically integrating III-V lasers on Si is the most promising solution to overcome the issue of lack of efficient light sources on Si. We demonstrated the first practical silicon-based telecommunications-wavelength quantum-dot laser with high output power and long lifetime.

W.2.E.2 • 11:30
Polymer-based Integrated Tuneable laser with On-Chip Wavelength Locker
David De Felipe, Magnus Happach, Moritz Kleinert, Crispin Zawadzki, Walter Brinker, Wolfgang Rehbein, Martin Moehrle and Norbert Keil (Fraunhofer Heinrich-Hertz-Institute, DE); Werner Hofmann (Technische Universität Berlin, DE); Martin Schell (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, DE)
♦ A polymer-based integrated tuneable laser with on-chip wavelength locker is presented. The device incorporates a free-space-based 100-GHz etalon, and monitor planar photodiodes coupled by means of 45° mirrors. Wavelength stabilization with a resolution of ±4 GHz has been demonstrated.

W.2.E.3 • 11:45
Wavelength Stabilized Silicon/III-V Hybrid Laser
Argishti Melikyan, Guilhem de Valicourt, Po Dong, Nicolas K Fontaine, Kwangwoong Kim, Chia-Ming Chang and Young-Kai Chen (Nokia Bell Labs, USA)
♦ We demonstrate wavelength stabilized hybrid silicon/III-V laser. The on-chip silicon diode temperature sensor integrated with the laser cavity allows sub-10pm wavelength stabilization in temperature fluctuation of 2 C around pre-set temperature.

W.2.E.4 • 12:00
Transmission Characteristics of 32-Gbaud PDM IQ Monolithic Silicon Modulator Operating with 2-VPPD Drive Voltage
Norihiro Ishikura, Kazuhiro Goi, Haike Zhu, Mikhail Illarionov, Hiroki Ishihara, Akira Oka, Takuya Oda, Koichiro Masuko, Teijiro Ori and Kensuke Ogawa (Fujikura Ltd., JP); Yuki Yoshida (National Institute of Information and Communications Technology, JP); Ken'ichi Kitayama (The Graduate School for the Creation of New Photonics Industries, JP); Tsung-Yang Liow, Xiaoguang Tu, Patrick Lo and Dim-Lee Kwong (Institute of Microelectronics, SG)
♦ Monolithic silicon PDM IQ modulator having vertical PN-junction rib-waveguide phase shifters in a ceramic-based metal package operating with RF drive voltage as low as 2 VPPD is characterized in 32-Gbaud optical-fibre transmission. Signal-to-noise ratio penalty is obtained as 5.5 dB.

W.2.E.5 • 12:15
High-Speed Monolithically Integrated Silicon Photonic Transmitters in 0.25 µm BiCMOS Platform
Despoina Petousi, Iria Garcia Lopez (IHP GmbH, DE); Stefan Lischke (IHP Frankfurt/Oder, DE); Dieter Knoll, Pedro Rito, Marcel Kroh and Georg Winzer (IHP GmbH, DE); Christian Mai (IHP Frankfurt/Oder, DE); Karsten Voigt (Technical University of Berlin, DE); Ahmet Cagri Ulusoy and Dietmar Kissinger (IHP GmbH, DE); Lars Zimmermann (IHP & Technical University of Berlin, DE); Klaus Petermann (Technical University of Berlin, DE)
♦ Monolithically integrated Si depletion-type transmitters in 0.25 µm photonic BiCMOS platform with different driving approaches are discussed. A power efficient implementation featuring integrated 4-bit DAC functionality is presented, from which PAM-4 eye diagrams up to 40 Gb/s are demonstrated.

W.2.F: Switching and Routing — Room 112

Chair: Oded Raz (Eindhoven University of Technology, NL)

W.2.F.1 • 11:00 *Invited*
High radix all-optical switches for software-defined data-centre networks
Nick Parsons (Polatis, UK); Rich Jensen (Polatis, USA); Adam Hughes (Polatis, UK)
♦ We review use cases for optical circuit switching (OCS) in datacentre networks, together with results for a 384x384 port dark fibre OCS with median loss of 1.5dB. Challenges of scaling SDN-enabled OCS fabrics to greater than 50,000 endpoints are discussed.

W.2.F.2 • 11:30
Large-Scale Optical Circuit Switch for Intra-Datacenter Networking Using Silicon-Photonic Multicast Switch and Tunable Filter
Koh Ueda, Yojiro Mori and Hiroshi Hasegawa (Nagoya University, JP); Ken-Ichi Sato (School of Engineering - Nagoya University, JP); Keijiro Suzuki, Hiroyuki Matsuura, Ken Tanizawa, Satoshi Suda, Kazuhiro Ikeda, Shu Namiki and Hitoshi Kawashima (National Institute of Advanced Industrial Science and Technology, JP); Shigeru Nakamura, Shigeyuki Yanagimachi and Akio Tajima (NEC Corporation, JP)
♦ We propose a novel optical circuit switch architecture for intra-datacenter networking. The key components, optical multicast switches and tunable filters are fabricated using silicon photonics. Proof-of-concept transmission experiments are performed using newly developed silicon-photonic devices.

W.2.F.3 • 11:45
System Performance Assessment of a Monolithically Integrated WDM Cross-Connect Switch for Optical Data Centre Networks
Nicola Calabretta (COBRA Research Institute, NL); Wang Miao, Kristif Prifti and Kevin Williams (Eindhoven University of Technology, NL)
♦ We assess the system performance of a photonic integrated 4x4x4lamba WDM cross-connect switch with nanoseconds wavelength, space, time switching operation. Experimental results show error-free dynamic switching of 10 Gb/s, 20 Gb/s, and 40 Gb/s data packets with <2dB penalty.

W.2.F.4 • 12:00 *Invited*
Coherent Optical Subcarrier Processing and Add/Drop Multiplexing
Carsten Schmidt-Langhorst, Thomas Richter and Robert Elschner (Fraunhofer Heinrich Hertz Institute, DE); Tomoyuki Kato, Takahito Tanimura, Shigeki Watanabe and Takeshi Hoshida (Fujitsu Laboratories Ltd., JP); Colja Schubert (Fraunhofer Heinrich Hertz Institute, DE)
♦ Frequency conversion in optical fiber allows for coherent optical processing of densely multiplexed subcarriers in spatially separated nodes. Proof-of-concept experiments show the applicability to up to 32QAM subcarriers, broadband operation (400 GHz) and selective processing of PDM subcarrier tributaries.

12:30 - 14:00 Lunch Break

W.3.A: Elastic Optical Networks I — Room 18+19

Chair: Ioannis Tomkos (Athens Information Technology, GR)

W.3.A.1 • 14:00 *Tutorial*
Roles and Benefits of Elastic Optical Networks in Beyond 100-Gb/s Era
Masahiko Jinno (Kagawa University, JP)
♦ This tutorial reviews elastic optical networking technology and presents its roles and benefits in a new era where major line rates in metro/core optical networks are 100 Gb/s and beyond.

W.3.A.2 • 15:00
How deploying elastic and fixed 100 Gb/s transponders can further optimize cost per Gb/s during ageing of WDM networks
Thierry Zami (Nokia, FR); Jelena Pesic and Petros Ramantanis (Nokia Bell Labs, FR)
♦ This study illustrates how jointly deploying relatively low cost 100 Gb/s optical transponders and elastic optical transponders fitting the ageing of margins can further improve return on investment for the operators of WDM networks

W.3.A.3 • 15:15
Low-cost CD-ROADMs Based Elastic Optical Networks Employing Wavelength Defragmentation
Yutaka Takita, Kazuyuki Tajima, Tomohiro Hashiguchi and Toru Katagiri (Fujitsu Limited, JP)
♦ We evaluate low-cost CD-ROADMs (L-CD-ROADMs) based elastic optical networks where wavelength defragmentation is applied. Through simulations, we confirm that such networks can save close to 50% of ROADM cost in the add/drop part with negligible impact on wavelength utilization efficiency.

W.3.B: Fibres for Mode Division Multilexing — Room 17

Chair: Francesco Poletti (University of Southampton, UK)

W.3.B.1 • 14:00 *Invited*
Linear and Nonlinear Properties of OAM in Fibers
Siddharth Ramachandran (Boston University, USA)
♦ Stable propagation of OAM in fibers has opened up a new design space with applications ranging from telecommunications to biomedical imaging. This talk will review progress in the field, elucidating the unique linear and nonlinear properties of OAM fiber modes.

W.3.B.2 • 14:30
Low-Loss 25.3km Few-Mode Ring-Core Fibre for Mode-Division Multiplexed Transmission
Yongmin Jung and Qiongyue Kang (Optoelectronics Research Centre, University of Southampton, UK); Hongyan Zhou (State Key Laboratory of Optical Fiber and Cable Manufacture Technology, PRC); Rui Zhang, Su Chen, Honghai Wang and Yucheng Yang (Yangtze Optical Fibre and Cable Joint Stock Limited Company, PRC); Xianqing Jin (USTC, PRC); Frank Payne (University of Oxford, UK); Shaif-ul Alam and David J Richardson (University of Southampton, UK)
♦ We report the design, fabrication and characterisation of a few-mode ring-core fibre supporting 4 mode groups. The low loss (~0.3dB/km) and length (25.3km) are both records for a ring-core fibre.

W.3.B.3 • 14:45
Group Delay Spread in Graded-Index 10-Spatial-Mode Fibers
Carmen Castineiras (Prysmian Group & University Lille 1, FR); Denis Molin and Marianne Bigot (Prysmian Group, FR); Laurent Bigot (University of Lille - CNRS, FR); Yves Quiquempois (Université de lille, FR); Pierre Sillard (Prysmian, FR)
♦ We theoretically investigate the group delay spread (GDS) of 10-spatial-mode fibers.The strongly-coupled regime leading to the increase of GDS with the square root of distance is only achieved for high perturbations and below a certain effective index difference value.

W.3.B.4 • 15:00
Fibers with High Numbers of Modes and Low DMGDs
Pierre Sillard, Marianne Bigot and Denis Molin (Prysmian Group, FR); Koen de Jongh and Frank Achten (Prysmian Group, NL)
♦ Fibers with high numbers of spatial modes (≥15) and low DMGDs (<90ps/km) are designed and fabricated. In such fibers, the highest-order modes are not used to reduce the impacts of cladding and DMGD sensitivity to process variability.

W.3.B.5 • 15:15
Demonstration of a Thin-Ring Air Core Fiber Supporting 22 Stable Angular Momentum Modes
Patrick Gregg (Boston University, USA); Poul Kristensen (OFS Fitel, DK); Steven Golowich (MIT-Lincoln Laboratory, USA); Siddharth Ramachandran (Boston University, USA)
♦ A thin-ring air-core fiber design suppressing higher radial-order modes enables supporting a record number (22) of stable spin-orbit coupled angular momentum modes over 10m. Output projection measurements of all non-degenerate modes reveal >18dB purity relative to nearest neighbours.

W.3.C: Nonlinear Optical Signal Processing — Room 16

Chair: Leif Oxenløwe (Technical University of Denmark, DK)

W.3.C.1 • 14:00 *Upgraded*
THz-Range Optical Frequency Shifter for Dual Polarization WDM Signals Using Frequency Conversion in Fibre
Tomoyuki Kato and Shigeki Watanabe (Fujitsu Laboratories Ltd., JP); Takahito Tanimura (The University of Tokyo & Fujitsu Laboratories Ltd., JP); Thomas Richter, Robert Elschner, Carsten Schmidt-Langhorst and Colja Schubert (Fraunhofer Heinrich-Hertz-Institut, DE); Takeshi Hoshida (Fujitsu Laboratories Ltd., JP)
♦ We propose an optical frequency shifter for dual-polarization signals using frequency conversion in fibre. We achieve THz-range frequency shift with the original signal suppression without an optical filter and demonstrate combining of two dual-polarization 400-Gb/s superchannels with acceptable in-band crosstalk.

W.3.C.2 • 14:30 *Upgraded*
QPSK Phase-Regeneration in a Silicon Waveguide Using Phase-Sensitive Processing
Isaac Sackey and Erik Liebig (Technical University of Berlin, DE); Thomas Richter (Fraunhofer Heinrich-Hertz-Institut, DE); Andrzej Gajda (IHP GmbH, DE); Lars Zimmermann (IHP & Technical University of Berlin, DE); Klaus Petermann (Technical University of Berlin, DE); Colja Schubert (Fraunhofer Heinrich-Hertz-Institut, DE)
♦ We present an in-line 4-level phase-regenerator which utilizes phase-sensitive amplification in a silicon waveguide with reverse-biased p-i-n junction. Phase noise reduction is investigated for a QPSK signal in a 1,040-km dispersion-managed link.

W.3.C.3 • 15:00
Characterization of a Wavelength Converter for 256-QAM Signals Based on an AlGaAs-On-Insulator Nano-waveguide
Francesco Da Ros, Metodi Yankov, Edson Porto da Silva, Minhao Pu, Luisa Ottaviano and Hao Hu (Technical University of Denmark, DK); Elizaveta Semenova (Department of Photonics Engineering, Technical University of Denmark, DK); Soren Forchhammer (Technical University of Denmark, DK); Darko Zibar (DTU Fotonik, department of Photonic Engineering, Technical University of Denmark, DK); Michael Galili, Kresten Yvind and Leif Oxenløwe (Technical University of Denmark, DK)
♦ High efficiency and broadband wavelength conversion in a 9-mm AlGaAs-On-Insulator waveguide is shown to provide high-quality (OSNR > 30 dB) idler generation over a 28-nm bandwidth enabling error-free conversion of 10-GBd 256-QAM with OSNR penalty below 2.5 dB.

W.3.C.4 • 15:15
Experimental Demonstration of Phase-Sensitive Regeneration of a 20-40 Gb/s QPSK Channel without Phase-Locked Loop using Brillouin Amplification
Ahmed Almainman, Yinwen Cao, Morteza Ziyadi, Amirhossein Mohajerin-Ariaei, Peicheng Liao, Changjing Bao, Fatemeh Alishahi, Ahmad Fallahpour, Bishara Shamee (University of Southern California, USA); Joe Touch (USC/ISI, USA); Youichi Akasaka and Tadashi Ikeuchi (Fujitsu Laboratories of America, Inc., USA); Steven Wilkinson (Raytheon, USA); Moshe Tur (Tel-Aviv University, IL); Alan Willner (University of Southern California, USA)
♦ We experimentally demonstrate all-optical phase-sensitive regeneration of a 20-40Gb/s QPSK signal without a phase-locked loop by amplifying the fourth harmonic using Brillouin amplification. We observe up to 65% reduction in phase noise and 3.4 dB gain at BER of 10-4.

15:30 - 16:00 Coffee Break | Exhibition Hall |

16:00 - 17:30 W.4.P: Poster Session I

W.3.D: Advanced Modulation Formats II — Room 15

Chair: Hiroshi Onaka (Fujitsu Limited, JP)

W.3.D.1 • 14:00
82.29-Tb/s (182×560-Gb/s) Transmission of 42GHz-Spaced WDM PDM-128-QAM OFDM Signals over 100-km SMF
Fan Li and Jianjun Yu (ZTE (TX) Inc., USA); Yuanquan Wang, Junwen Zhang and Xinying Li (Fudan University, PRC); Hung-Chang Chien (ZTE (TX) Inc., USA)
♦ Transmission of 42GHz-spaced 182×560-Gb/s PDM-128QAM-OFDM over 2×50-km SMF with DFT-S PAPR suppression and DD-LMS post-equalization is successfully demonstrated for the first time to enable large-capacity systems on 400G wavelengths.

W.3.D.2 • 14:15
Super-Nyquist 9-WDM 126-GBaud PDM-QPSK Transmission over 7878km using Digital-Preprocessed Analog-Multiplexed DAC for Long-Haul Applications
Asuka Matsushita, Fukutaro Hamaoka, Masanori Nakamura, Kengo Horikoshi, Hiroshi Yamazaki and Munehiko Nagatani (NTT Corporation, JP); Akihide Sano (NTT Network Innovation Laboratories, JP); Akira Hirano (NTT, JP); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP)
♦ We successfully demonstrate 400Gbps/carrier data transmission (504Gbps line-rate assuming 25.5% FEC) over 7878km using 126-GBaud PDM-QPSK signal generated by a digital pre-processed analog multiplexed DAC. Spectral efficiency of 3.21bit/s/Hz is achieved with super-Nyquist 125-GHz WDM spacing and optical pre-filtering.

W.3.D.3 • 14:30
Comparison of Single Carrier 200G 4QAM, 8QAM and 16QAM in a WDM Field Trial Demonstration over 612 km SSMF
Ginni Khanna (Technical University of Munich, DE); Talha Rahman (Eindhoven University of Technology, Eindhoven, NL); Erik Man (Coriant R&D GmbH, DE); Emilio Riccardi (Telecom Italia Lab, IT); Annachiara Pagano, Anna Chiado'Piat (Telecom Italia, IT); Bernhard Spinnler, Stefano Calabro, Danish Rafique, Uwe Feiste (Coriant R&D GmbH, DE); Huug de Waardt (Eindhoven University of Technology, NL); Bernd Krombholz (Coriant R&D GmbH, DE); Tomislav Drenksi (Socionext Europe GmbH, UK); Marc Bohn, Antonio Napoli (Coriant R&D GmbH, DE); Norbert Hanik (Munich University of Technology, DE)
♦ We present results of a field trial carried on Telecom Italia EDFA-only legacy link with 0.3 dB/km average fiber attenuation. Single carrier 200G WDM DP-4QAM, DP-8QAM and DP-16QAM were successfully transmitted with system margin of 4.1dB, 4.3dB and 2.6dB respectively.

W.3.D.4 • 14:45
Experimental Study of Subcarrier Multiplexing Benefit in 74 nm Bandwidth Transmission up to 20,450 km
Jin-Xing Cai, Matthew Mazurczyk (TE SubCom, USA); Oleg Sinkin (Tyco Telecom, USA); Maxim Bolshtyansky (TE Subcom, USA); Dmitri Foursa (Tyco Telecommunications, USA); Alexei Pilipetskii (Tyco Electronics Subsea Communications, USA)
♦ We experimentally demonstrate 0.8dB subcarrier-multiplexing benefit for QPSK signals transmitted in 74nm bandwidth over 20,450km, and only 0.2dB benefit is achieved for 16QAM signals. We observe subcarrier index performance dependence due to the transmitter RF noise spectrum.

W.3.D.5 • 15:00 *Invited*
Solutions for 400 Gbit/s Inter Data Center WDM Transmission
Annika Dochhan (ADVA Optical Networking SE, DE); Nicklas Eiselt (Technical University of Denmark, DK); Helmut Griesser (ADVA Optical Networking SE, DE); Michael Eiselt (ADVA, DE); Juan Jose Vegas Olmos (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU); Jörg-Peter Elbers (ADVA AG Optical Networking, DE)
♦ We review some currently discussed solutions for 400 Gbit/s inter-data center WDM transmission for up to 100 km. We focus on direct detected solutions, namely PAM4 and DMT, and present two WDM systems based on these formats.

W.3.E: TWDM PON — Room 110

Chair: Derek Nesset (BT plc, UK)

W.3.E.1 • 14:00
Field-Trial of a Real-Time 100 Gb/s TWDM-PON Based on 10G-Class Optical Devices
Lilin Yi, Honglin Ji and Zhengxuan Li (Shanghai Jiao Tong University, PRC); Xiang Li, Cai Li (Wuhan Research Institute of Post & Telecommunication, PRC); Qi Yang (FiberHome, PRC); Lei Xue and Xiaodong Wang (Shanghai Jiao Tong University, PRC); Suyi Wang, Ying Yang and Junbo Xu (Fiberhome, PRC); Shaohua Yu (Huazhong University of Science&Technology, PRC); Weisheng Hu (Shanghai Jiao Tong University, PRC)
♦ We show the first field trial of 100G-PON with downstream/upstream data rates of 25/10Gb/s/λ based on 10G-class optical devices supporting 40-km reach and 33-dB loss budget. The system stability is verified by 67-hour real-time BER measurement.

W.3.E.2 • 14:15
Experimental Demonstration of Low Cost Wavelength Drift Mitigation for TWDM Systems
Gael Simon and Fabienne Saliou (Orange, FR); Philippe Chanclou and Luiz Anet Neto (Orange Labs, FR); Didier Erasme (Telecom ParisTech, FR)
♦ We experimentally proved that a harmful wavelength drift of tunable DMLs under burst mode is induced by adiabatic and thermal chirp. We demonstrate the possibility to compensate one phenomenon by the other. The wavelength drift can be reduced by 50%.

W.3.E.3 • 14:30 *Invited*
Burst-Mode Optical Amplifier Technologies for TWDM-PON
Masamichi Fujiwara (NTT Access Network Service Systems Laboratories, JP)
♦ We introduce our burst-mode optical amplifier technologies for TWDM-PONs that support E2 class power budget, allow service providers to flexibly locate optically-amplified repeaters in long-reach systems, and also accommodate many more users through higher splitting ratios.

W.3.E.4 • 15:00
Dynamically Reconfigurable TDM-DWDM PON Ring Architecture for Efficient Rural Deployment
Daniel Carey, Nicola Brandonisio, Stefano Porto, Alan Naughton, Peter Ossieur (Tyndall National Institute, IR); Nick Parsons (Polatis Ltd., UK); Giuseppe Talli and Paul Townsend (Tyndall National Institute, IR)
♦ A novel chained amplifier node access architecture for rural areas has been demonstrated for the first time using FEC in burst mode operation at 10Gb/s implemented on FPGAs supporting 40 channels and 1024 users with a reach of 120k.

W.3.E.5 • 15:15
User/Service Group Separation in Optical Domain Using Overlayed Modulation Technique for 40 Gbit/s Single Wavelength TDM PON
Robert Borkowski (Nokia, DE); Rene Bonk (Alcatel-Lucent, DE); Wolfgang Poehlmann (Nokia, DE); Thomas Pfeiffer (Alcatel-Lucent, DE)
♦ We experimentally demonstrate optical layer separation between user/service groups in burst-mode upstream of 40 Gbit/s TDM PON using overlayed modulation technique. Loss budget exceeding 29 dB and C-band transmission up to 40 km with 12 km differential reach is achieved.

W.3.F: Silicon Photonics and Integration — Room 112

Chair: Antonio Fincato (STMicroelectronics, IT)

W.3.F.1 • 14:00
Optimization of Integrated Silicon Doped Heaters for Optical Microring Resonators
Paolo Pintus, Costanza Manganelli, Fabrizio Gambini and Fabrizio Di Pasquale (Scuola Superiore Sant'Anna, IT); Maryse Fournier and Olivier Lemonnier (CEA LETI, FR); Christophe Kopp (CEA, LETI, MINATEC DOPT Grenoble, FR); Claudio Oton (Scuola Superiore Sant'Anna, IT)
♦ We present the design, the fabrication and the characterization of thermally tunable integrated silicon-doped heaters for optical switches. Their performance, with focus on Reconfigurable Optical Add/Drop Multiplexer, has been investigated in term of power consumption and time response.

W.3.F.2 • 14:15
Ge Waveguide Photodetector on Wafer-Bonded Ge-on-Insulator Substrate Monolithically Integrated with Amorphous Si Waveguide
Jian Kang, Mitsuru Takenaka and Shinichi Takagi (University of Tokyo, JP)
♦ We demonstrate the proof-of-concept of Ge/a-Si hybrid photonic integrated circuits on Ge-on-insulator (GeOI) substrate fabricated by wafer bonding. We successfully demonstrate waveguide Ge PIN photodetector with low-dark-current operation on GeOI wafer monolithically integrated with a-Si passive waveguide.

W.3.F.3 • 14:30
Novel Nonreciprocal Devices with Integrated Electromagnet for Silicon Photonics
Paolo Pintus (Scuola Superiore Sant'Anna, IT); Duanni Huang and Chong Zhang (University of California, Santa Barbara, USA); Yuya Shoji and Tetsuya Mizumoto (Tokio Institute of Technology, JP); John Bowers (University of California, USA)
♦ We present a novel approach to construct integrated isolators and circulators based on magneto-optical materials. An integrated electromagnet is designed and fabricated, eliminating the need for a permanent magnet. The fabricated devices exhibit high performance and can be easily integrated/packaged.

W.3.F.4 • 14:45
Hybrid 2D/3D Photonic Integration for Non-Planar Circuit Topologies
Aleksandar Nesic, Matthias Blaicher and Tobias Hoose (Karlsruhe Institute of Technology (KIT), DE); Matthias Lauermann (Infinera Corporation, USA); Yasar Kutuvantavida, Wolfgang Freude and Christian Koos (Karlsruhe Institute of Technology (KIT), DE)
♦ We present a concept for realizing crossing-free photonic integrated circuits (PIC) using 3D freeform waveguides. We prove the viability of the approach using a silicon photonic 4x4 switch-and-select device. The method is applicable to a wide range of PIC technologies.

W.3.F.5 • 15:00 *Invited*
Monolithic Electronic-Photonic Co-Integration in Photonic BiCMOS
Lars Zimmermann (IHP & Technical University of Berlin, DE)
♦ Monolithic co-integration of silicon photonics with high-performance BiCMOS is a new technology for implementing efficient sub-systems in high-speed optical communications. Present status of the technology will be reviewed, pros and cons in comparison to other integration technologies will be discussed.

15:30 - 16:00 Coffee Break | Exhibition Hall |

16:00 - 17:30 W.4.P: Poster Session I

SC 1 - Fibres, Fibre Devices and Fibre Amplifiers

W.4.P1.SC1.1 Experimental Observation of Mid-infrared Supercontinuum Generation in an As2Se3- AsSe2 Fiber
Tonglei Cheng, Kenshiro Nagasaka, Hoang Tuan Tong and Xiaojie Xue (Toyota Technological Institute, JP); Morio Matsumoto and Hiroshige Tezuka (Furukawa Denshi Co., Ltd., JP); Takenobu Suzuki and Yasutake Ohishi (Toyota Technological Institute, JP)
♦ We experimentally investigate supercontinuum generation spanning 2.0 to 15.1 µm in a 3 mm-long As2Se3-AsSe2 fiber with the mid-infrared femtosecond pulse pump source.

W.4.P1.SC1.2 Low-loss and Low-nonlinearity Few-mode Fibre for LP21 Mode Transmission with Low DSP Complexity
Takayoshi Mori, Taiji Sakamoto, Masaki Wada, Azusa Urushibara, Takashi Yamamoto and Kazuhide Nakajima (NTT Corporation, JP)
♦ A few-mode fibre with a low-loss (0.180 dB/km) and large-Aeff (366 um2) at 1550 nm in the LP21 mode is presented. We demonstrate a low-DSP-complexity transmission over 100 km few-mode fibre and reveal high nonlinear tolerance using the LP21 mode.

W.4.P1.SC1.3 Theoretical study of mode coupling via the gain medium in FM-EDFA including mode beating effects
Jean-Baptiste Trinel, Guillaume Le Cocq, Olivier Vanvincq, Yves Quiquempois, Esben Andresen (Université de Lille, FR); Laurent Bigot (University of Lille - CNRS, FR)
♦ A field-propagating model for active optical fibers is applied to the particular case of Few-Mode EDFA. Mode coupling through the amplifying medium is analyzed and results show significant differences compared to usual intensity models.

W.4.P1.SC1.4 Bi/Er Co-doped Fibers as an Active Medium for Optical Amplifiers for the C-, L- and U- Telecommunication Bands
Sergei Firstov (Fiber Optics Research Center, RAS, RU); Vladimir F. Khopin (Institute of Chemistry of High Purity Substances of RAS, RU); Konstantin Riumkin and Sergey Alyshev (Fiber Optics Research Center, RAS, RU); Mikhail Melkumov (Fiber Optics Research Center of the Russian Academy of Sciences, RU); Aleksey N. Guryanov (Institute of Chemistry of High Purity Substances of RAS, RU); Evgeny M. Dianov (Fiber Optics Research Center of the Russian Academy of Sciences, RU)
♦ We report the first results on the fabrication of Bi/Er co-doped fibers with the gain bandwidth over 200 nm ranging from 1530 to 1770 nm. The main fiber characteristics affecting the amplification are discussed.

W.4.P1.SC1.5 Angular Momentum Dependence of the Twist-Induced Effect in Few-Mode Fibres
Paolo Martelli, Annalaura Fasiello, Oriana Soccali, Pierpaolo Boffi and Mario Martinelli (Politecnico di Milano, IT)
♦ The twist-induced effect on fibre modes has been recognized as a phase shift depending on the total angular momentum. The amount of this phase shift has been measured through an interference experiment in a few-mode fibre, confirming the theoretical predictions.

W.4.P1.SC1.6 Improved Method for Measuring Inter-Core Crosstalk in Multi-Core Fibres Using a Near-Infrared Camera
Shota Saitoh, Yoshimichi Amma, Yusuke Sasaki, Katsuhiro Takenaga and Kazuhiko Aikawa (Fujikura Ltd., JP)
♦ We present an improved method that enables measurement of crosstalk as low as approximately –50 dB using a near-infrared camera. Measured results of a 32-core fibre are in good agreement with those by the conventional method using a power meter.

W.4.P1.SC1.7 Highly Nonlinear Few-Mode Fiber for Optical Parametric Amplification
Elham Nazemosadat, Abel Lorences-Riesgo, Magnus Karlsson, Peter A Andrekson (Chalmers University of Technology, SE)
♦ A highly nonlinear dispersion-shifted few-mode fiber is designed. The dispersion properties and high nonlinearity of this fiber allow simultaneous single-pump parametric amplification of four spatial modes (LP01, LP11, LP02, LP21), with high gain and low cross-talk, over the C-band.

SC 2 - Waveguide and Optoelectronic Devices

W.4.P1.SC2.8 Low Operating-Energy Directly Modulated Membrane Distributed-Reflector Lasers on Si
Takuro Fujii, Koji Takeda, Erina Kanno, Koichi Hasebe, Hidetaka Nishi, Ryo Nakao, Tsuyoshi Yamamoto, Takaaki Kakitsuka , Shinji Matsuo (NTT Corporation, JP)
♦ We achieve a low operating energy and high modulation speed in a directly modulated membrane laser on Si. A relatively thick (350 nm) membrane structure enables us to reduce the series resistance, which reduces the operating energy to 97 fJ/bit.

W.4.P1.SC2.9 8-channel InP OFDM Transmitter PIC with Integrated Optical Fourier Transform
Braulio Gomez Saavedra, Ronald Kaiser, Johannes Beyer, Marko Rausch, Marko Gruner, Walter Fürst and Martin Schell (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, DE)
♦ An InP-based 8-channel 1550 nm OFDM transmitter PICs is demonstrated for the first time. The PIC integrates a 1x8 splitter/combiner, eight TWE Mach-Zehnder IQ modulators, an 8-port AWG, 50-Ohms termination resistors, and CPW/CPS transmission line connections/transitions.

W.4.P1.SC2.10 Integrated 8-Channel Mode and Wavelength Demultiplexer for MDM and WDM Transmission over Few-Mode Fibers
Daniele Melati, Andrea Alippi, Andrea Annoni, Nicola Peserico and Andrea Melloni (Politecnico di Milano, IT)
♦ We demonstrate a photonic integrated circuit for simultaneous demultiplexing of two fiber modes and four wavelength channels. Combined with integrated MDM multiplexer the circuit is successfully exploited for the transmission of 10Gbit/s channels with cross-talk lower than -15 dB.

W.4.P1.SC2.11 PDM-QPSK WDM Signal Amplification Using PPLN-Based Polarization-Independent In-Line Phase-Sensitive Amplifier
Masashi Abe, Takushi Kazama, Takeshi Umeki and Koji Enbutsu (NTT Device Technology Laboratories, JP); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP); Hirokazu Takenouchi (NTT Photonics Laboratories, JP)
♦ We demonstrate the in-line phase-sensitive amplification of PDM-QPSK WDM signals. The amplifier consists of PPLN waveguides and has a net gain of 12 dB. These signals are transmitted over 80 km by recovering the pilot tone.

W.4.P1.SC2.12 Broadband Frequency Comb Generation in Aluminum Nitride Microring Resonators
Xianwen Liu, Changzheng Sun, Bing Xiong, Jian Wang, Lai Wang, Yanjun Han, Zhibiao Hao, Hongtao Li and Yi Luo (Tsinghua University, PRC); Jianchang Yan, Tongbo Wei, Yun Zhang and Junxi Wang (Institute of Semiconductors, Chinese Academy of Sciences, PRC)
♦ Nearly octave frequency comb spanning from 1075 to 2075 nm is generated in epitaxial aluminum nitride microring resonator with intrinsic quality factor as high as ~1.6 million. Blue-shifted dispersive-wave emission is observed, which helps extend the frequency comb coverage.

W.4.P1.SC2.13 Broadband 8 × 8 Si-Wire PILOSS Switch with Double Mach-Zehnder Switch Elements
Keijiro Suzuki, Ken Tanizawa, Satoshi Suda, Hiroyuki Matsuura, Kazuhiro Ikeda, Shu Namiki and Hitoshi Kawashima (National Institute of Advanced Industrial Science and Technology, JP)
♦ We report a broadband 8×8 Si-wire optical switch based on a double Mach-Zehnder element switch. An operating bandwidth of 20 nm for -20 dB crosstalk is obtained, which is 2.7-times broader than that with single Mach-Zehnder element switches.

W.4.P1.SC2.14 Route-and-Select Type Wavelength Cross Connect for Core-Shuffling of 7-Core MCFs with Spatial and Planar Optical Circuit
Keita Yamaguchi (NTT Corporation & NTT Device Technology Labs, JP); Mitsumasa Nakajima, Yuichiro Ikuma, Kazunori Seno and Osamu Moriwaki (NTT Corporation, JP); Kenya Suzuki (NTT Device Technology Laboratories, NTT Corporation, JP); Mikitaka Itoh (NTT Photonics Laboratories, JP); Mitsunori Fukutoku (NTT Innovation Laboratories, JP); Yutaka Miyamoto (NTT Network Innovation Laboratories, JP); Toshikazu Hashimoto (NTT Corporation, JP)
♦ We demonstrated a route-and-select type 7×7 core-shuffle wavelength cross connect switch based on a spatial and planar optical circuit. The spatial beam transformer enables us to integrate 14-in-1 WSSs in the same optical system as the conventional 1×N WSS.

W.4.P1.SC2.15 Flexible, Multi-channel, Ultra-dense Optical Interface for Silicon Photonics
Victor I. Kopp, Jongchul Park, Mitch Wlodawski, Jonathan Singer and Dan Neugroschl (Chiral Photonics Inc., USA); Peter De Heyn, Brad Snyder and Joris Van Campenhout (IMEC, BE); Philippe Absil (IMEC, BE)
♦ We demonstrate an all-glass, 61-channel, flexible, two-dimensional optical fiber array with 37 inner channels matched to an array of vertical grating couplers of a multi-channel (16 Tx and 16 Rx) transceiver prototype occupying a chip area of only 0.16 mm2.

W.4.P1.SC2.16 On-chip Optical Sampling using an Integrated SOA-based Nonlinear Optical Loop Mirror
Leimeng Zhuang, Chen Zhu, Bill Corcoran, Zihan Geng, Binhuang Song and Arthur Lowery (Monash University, AU)
♦ We report the first demonstration of on-chip optical sampling using an integrated SOA-based nonlinear optical loop mirror. The device implements a compact design featuring a size of 2 x 1.2 mm2 and a sampling window of about 30 ps.

W.4.P1.SC2.17 Experimental Demonstration of On-Chip Orbital Angular Momentum Carrying Twisted Light Generation Using Dielectric Metasurfaces on Silicon Platform
Hongya Wang (Huazhong University of Science and Technology & Wuhan National Laboratory for Optoelectronics, PRC); Jun Liu, Jing Du and Jian Wang (Huazhong University of Science and Technology, PRC)
♦ We demonstrate a method of generating twisted lights OAM whose topological number ranges from l = 1 to 4 at the wavelength of 980 nanometer using dielectric metasurfaces array on silicon-on-insulator platform.

W.4.P1.SC2.18 Integrated Switchable Mode Exchange for Reconfigurable Mode-Multiplexing Optical Networks
Chunlei Sun, Yu Yu, Guanyu Chen and Xinliang Zhang (Huazhong University of Science and Technology, PRC)
♦ We propose and demonstrate an on-chip switchable mode exchange utilizing a mode dependent Mach-Zehnder interferometer assisting by a phase shifter. By controlling the phase difference, the data carried on different modes can be exchanged with power penalty less than 1dB.

W.4.P1.SC2.19 Integrated-optic Demultiplexer for Variable Capacity Optical OFDM Signals Composed of Slab Star Coupler-type Optical DFT Circuit and Variable Optical Attenuators
Koichi Takiguchi (Ritsumeikan University, JP)
♦ I report a novel waveguide-type OFDM filter that can adaptively demultiplex 10 to 50 Gbaud symbol rate sub-carrier channels. It was fabricated with silica waveguide technology and the adoption of variable attenuators reduced loss variation when changing the filter characteristics.

SC 3 - Digital and Optical Signal Processing

W.4.P1.SC3.20 Experimental Demonstration of All-Optical FEC Coding Scheme with Convolutional Code using Single Signal Source
Yohei Aikawa and Hiroyuki Uenohara (Tokyo Institute of Technology, JP)
♦ We experimentally demonstrate all-optical FEC coding scheme consisting of all-optical HNLF-based wavelength converters and XOR gates with (7,5)_8 convolutional code. The proposed scheme offers 3.5 dB net coding gain at BER=10^{-9} with DPSK-modulated RZ-format signals at 10 Gbps.

W.4.P1.SC3.21 Sidelobe Suppression using Cancellation Sub-Carriers for OFDM Superchannels
Yiwei Xie, Chen Zhu, Binhuang Song and Arthur Lowery (Monash University, AU)
♦ We mitigate the inter-channel-interference (ICI) in orthogonal frequency division multiplexing (OFDM) superchannel by adding cancellation sub-carriers (CCs). We experimentally show that CC-OFDM outperforms conventional OFDM by 0.4-dB in a dual-polarization 400-Gbps 3360-km OFDM superchannel.

W.4.P1.SC3.22 Real-Time Flexible Heterogeneous UDWDM System for Coherent PON
Ricardo Ferreira (Instituto de Telecomunicações, PRT); Ali Shahpari (University of Aveiro, PRT); Sofia Amado (University of Aveiro & Instituto de Telecomunicações, Aveiro, PRT); Jacklyn D. Reis (CPqD, BR); Armando Pinto, Antonio Teixeira (DETI, University of Aveiro & Insitituto de Telecomunicações, PRT)
♦ We demonstrate the first reconfigurable real-time receiver DSP in a flexible heterogeneous UDWDM system for coherent PON applying different modulation formats. The evaluation reports the ODN power budget for multiple UDWDM configurations using QPSK, 8PSK and 8QAM signals.

W.4.P1.SC3.23 Cluster Analysis of Received Constellations for Optical Performance Monitoring
John van Weerdenburg, Roy van Uden, Eric Sillekens and Huug de Waardt (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL); Chigo Okonkwo (Eindhoven University of Technology, NL)
♦ Performance monitoring based on centroid clustering to investigate constellation generation offsets. The tool allows flexibility in constellation generation tolerances by forwarding centroids to the demapper. The relation of fibre nonlinearities and singular value decomposition of intra-cluster noise is experimentally demonstrated.

W.4.P1.SC3.24 Embedded In-Band DQPSK Signaling within n-QAM Data Transmission
Roman Dischler, Fred Buchali and Laurent Schmalen (Nokia Bell Labs, DE)
♦ We propose embedded sequences of DQPSK-symbols in a n-QAM data stream for independent signaling on transponder level. Experimentally we demonstrate a simplified processing chain with low additional processing effort obtaining a BER margin of factor 10 vs. data-BER.

W.4.P1.SC3.25 Characterization and Pre-Distortion of Linear and Non-Linear Transmitter Impairments for PM-64QAM Applications
Thomas Duthel, Peter Hermann, Johann Schießl, Chris Fludger, Andreas Bisplinghoff and Theodor Kupfer (Cisco Optical GmbH, DE)
♦ A characterization approach for optical IQ transmitter's skew, frequency response and non-linear properties is presented. Its effectiveness is proven by performance measurements of digitally pre-distorted PM-64QAM at 384Gbit/s. Special attention is given to the optical loss induced by modulation.

W.4.P1.SC3.26 A Novel Fixed Throughput Nonlinear Cross-Polarization Compensation: Flexible k-Best GML
Patricia Layec (Nokia Bell Labs France, FR); Nicola Rossi (Nokia Bell Labs, FR); Sebastien Bigo (Bell Labs, Alcatel-Lucent, FR)
♦ We propose a novel blind nonlinear cross-polarization compensation method based on Generalized Maximum Likelihood. It offers a fixed throughput implementation easing the hardware logic integration thanks to a breadth-first search. Simulations show a 1dB gain in nonlinear tolerance.

W.4.P1.SC3.27 A Trellis-Based Phase Correction for Mitigating Nonlinear Effects
Mahdi Zamani, Hossein Najafi and Jeebak Mitra, Chuandong Li and Zhuhong Zhang (Huawei Technologies Canada, CA)
♦ A hardware-efficient trellis-based algorithm is proposed for fiber nonlinearity mitigation in coherent systems, especially for high order modulations. Experimental results, in 200 Gb/s DP-16QAM co-propagated with 10-G channels, demonstrate significant performance improvement over other existing methods of comparable complexity.

W.4.P1.SC3.28 Ultra-Wideband Nonlinearity Compensation Performance in the Presence of PMD
Gabriele Liga (University College London, UK); Cristian B. Czegledi (Chalmers University of Technology, SE); Tianhua Xu (Optical Networks Group, University College London, UK); Erik Agrell (Chalmers University of Technology, SE); Robert I Killey and Polina Bayvel (University College London, UK)
♦ We numerically investigate the performance of multi-channel digital backpropagation for 1 THz optical fibre transmission in the presence of polarisation-mode dispersion. We show that the average SNR performance rapidly saturates as a function of the compensation bandwidth.

W.4.P1.SC3.29 Novel IM/DD Single-Sideband OFDM Generation Featuring Tolerance to Dispersion-Related Fading and Distortion
Yi-Hsiang Wang and Chia-Chien Wei (National Sun Yat-Sen University, TW); Hidenori Taga Takehiro Tsuritani (KDDI R&D Laboratories Inc., JP)
♦ Based on a cascaded DML/EAM, we proposed a novel IM/DD scheme to generate SSB-OFDM signals, featuring tolerance to dispersion-related fading and distortion. Without compensation for dispersion and nonlinear distortion, 5-GHz SSB-OFDM signal can achieve 12.8 Gbps after 250 km.

W.4.P1.SC3.30 Precoded Faster-than-Nyquist Coherent Optical Transmission
Mrinmoy Jana, Ahmed Medra and Lutz Lampe (University of British Columbia, CA); Jeebak Mitra (Huawei Technologies Canada, CA)
♦ In this paper we propose a novel symbol-by-symbol memoryless soft demapping method for coded coherent optical systems that employ Faster-than-Nyquist (FTN) transmission for improved spectral efficiency and Tomlinson-Harashima precoding for low-complexity equalization of FTN.

W.4.P1.SC3.31 Electro-Optic Frequency Offset Estimator for Optical OFDM
Jokhakar Jignesh, Bill Corcoran and Chen Zhu (Monash University, AU); Arthur Lowery (Monash Univ, AU)
♦ We present a new design for an electro-optic carrier frequency offset (CFO) estimator for optical OFDM systems, and experimentally demonstrate CFO estimation using off-the-shelf components, capable of tracking up to ±500 MHz offsets from a 28-Gbaud OFDM signal.

SC 4 - Subsystems for Optical Networking and Datacoms

W.4.P1.SC4.32 Adaptive RF Signal Stability Distribution Over Remote Optical Fiber Transfer Based on Photonic Phase Shifter
Shanguo Huang, Wensheng ZHai, Xinlu Gao, Mutong Xie, Mingyang Zhao and Wenjing Xu (Beijing University of Posts and Telecommunications, PRC); Wanyi Gu (Key Laboratory of Optical Communication and Lightwave Technologies, Ministry of Education, Beijing U, PRC)
♦ We demonstrate adaptive RF signal distribution stability over 50 km optical fiber using phase pre-compensation technology. The experimental results implement 360° phase shift over 20 GHz to 30 GHz with Allan deviation approximate 8.35×10-17 at average time of 1000 s.

W.4.P1.SC4.33 Techno-Economic Analysis of Carrier Sources in Slice-able Bandwidth Variable Transponders
Muhammad Imran (Scuola Superiore Sant'Anna, IT); Antonio D'Errico (Ericsson, IT); Andrew Lord (British Telecom, UK); Luca Potì (Consorzio Nazionale Interuniversitario per le Telecomunicazioni, IT)
♦ Different carrier source implementation strategies in sliceable bandwidth variable transponders have been compared in terms of cost and power consumption. A reduction factor up to 4 has been obtained through novel centralized carrier source schemes.

W.4.P1.SC4.34 Experimental Validation of Scalability Improvement for Passive Optical Interconnect by Implementing Digital Equalization
Rui Lin (KTH Royal Institute of Technology & Huazhong University of Science and Technology, PRC); Xiaodan Pang (Swedish ICT AB, SE); Oskars Ozolins (Acreo Swedish ICT, SE); Zhenhua Feng (Huazhong University of Science and Technology, PRC); Anders Djupsjöbacka (Acreo, SE); Urban Westergren and Richard Schatz (Kista Photonic Research Centre (KPRC), Royal Institute of Technology (KTH), SE); Gunnar Jacobsen (Acreo AB, SE); Ming Tang, Songnian Fu and Deming Liu (Huazhong University of Science and Technology, PRC); Sergei Popov, Jiajia Chen (KTH Royal Institute of Technology, SE)
♦ We experimentally investigate scalability of a coupler-based passive optical interconnect (POI) employing cost-efficient modulation formats, pulse amplitude modulation and discrete multi-tone. Results reveal that digital equalization significantly boosts the POI scalability, particularly for the cases requiring higher transmission performance.

W.4.P1.SC4.35 Drive-amplitude-independent Auto Bias Control Circuit for QAM Signals and Its Demonstration with an InP-based IQ Modulator
Hiroto Kawakami and Shoichiro Kuwahara (NTT Corporation, JP); Akira Hirano (NTT, JP)
♦ A novel auto bias control technique for various types of IQ modulators is proposed. The technique can generate any order quadrature amplitude modulation signals with no dependence on drive amplitude. The measured penalty was found to be almost negligible.

W.4.P1.SC4.36 Direct Measurement on Frequency Response of Common Mode Rejection Ratio in Coherent Receiver
Keizo Inagaki (National Institute of Information and Communications Technology, JP); Tetsuya Kawanishi (Waseda University & National Institute of Information and Communications Technology, JP); Atsushi Kanno and Naokatsu Yamamoto (National Institute of Information and Communications Technology, JP)
♦ We propose a direct measurement method of CMRR frequency response in coherent receivers. Measured CMRR frequency response is drastically improved over 2 to 40 GHz frequency range by tuning the amplitude and skew balance in a coherent receiver under test.

W.4.P1.SC4.37 SDN-enabled Backpropagation Correction for OSNR Estimation and Optimization in Under-Monitored EDFA-based Optical Links
Juliano Assine, Anderson Bravalheri and Heitor Carvalho (CPqD, BR); Miquel Garrich (Politecnico di Torino, BR); Yue Fei, Xue Wang (The University of Texas at Dallas, USA); Andrea Fumagalli (UTD, USA); Jacklyn D. Reis (CPqD, BR); Juliano Rodrigues Fernandes de Oliveira (CPqD Foundation & University of Sao Paulo, BR)
♦ SDN is a key technology to address the challenges in quasi-static and over-provisioned undermonitored EDFA-based optical links. We propose and experimentally demonstrate a SDN-enabled backpropagation correction technique to efficiently estimate and increase OSNR while minimizing remote network operations.

W.4.P1.SC4.38 MxM WSS Based ROADM Architecture with Topology-Insensitive Routing Performance
Masaki Niwa, Yojiro Mori and Hiroshi Hasegawa (Nagoya University, JP); Ken-Ichi Sato (School of Engineering - Nagoya University, JP)
♦ We propose MxM WSS based ROADM architecture that employs main/junction subsystem OXCs and OXC-assisted transponder-bank add/drop. Extensive computer simulations verify that the proposed architecture offers high routing performance regardless of the physical network topology cost-effectively.

W.4.P1.SC4.39 SEFDM Based Spectrum Compressed VLC System Using RLS Time-domain Channel Estimation and ID-FSD Hybrid Decoder
Yiguang Wang and Yingjun Zhou (Fudan University, PRC); Tao Gui, Kangping Zhong, Xian Zhou, Liang Wang, Alan Pak Tao Lau and Chao Lu (The Hong Kong Polytechnic University, HK); Nan Chi (Fudan University, PRC)
♦ For the first time we experimentally demonstrate an 800Mb/s SEFDM based VLC system over 3m free-space transmission for 20% bandwidth saving. RLS time-do-main equalizer is proposed for channel estimation, and an ID-FSD hybrid decoder is utilized for ICI elimination.

W.4.P1.SC4.40 Real Time 10Gb-Ethernet Transmission over 2D Indoor Passive Beam Steered Optical Wireless System based on High Port Arrayed Waveguide Gratings
Amir Masood Khalid, Maria Torres Vega, Ketamaw Mekonnen, Zizheng Cao and Antonio Liotta (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ We demonstrate the real-time 10Gb-Ethernet data delivery to multiple users simultaneously over an indoor optical wireless system based on 2D passive optical beam-steering using high-port count arrayed waveguide gratings. The transmitted optical power is kept below eye safety limit

W.4.P1.SC4.41 Multi-Wavelength Multiplexer with Independent Mode Control Based on Multi-Plane Light Conversion
Guillaume Labroille, Nicolas Barré, Pu Jian and Jean-François Morizur (CAILabs SAS, FR)
♦ We report dual wavelength spatial multiplexers based on the technique of Multi-Plane Light Conversion, which have the capability of independently multiplexing signals at different wavelengths with high mode selectivity, enabling applications to FM-EDFA and PON over multi-mode fibers.

W.4.P1.SC4.42 Capacity Improvement Using Bandwidth-Variable Transceiver in Meshed Optical Networks with Cascaded ROADMs
Xingyu Zhou (University of Electronic Science and Technology of China, PRC); Qunbi Zhuge (Ciena Corporation, CA); Meng Qiu (McGill University, Montreal, CA); Xiang Meng (Huazhong University of Science and Technology, PRC); Fangyuan Zhang (McGill University, CA); Baojian Wu (University of Electronic Science and Technology of China, PRC); David Plant (McGill University, CA)
♦ We experimentally demonstrate the capacity improvement achieved by bandwidth-variable transceivers (BVT) in fiber links with cascaded ROADMs. Compared with a fixed symbol rate transceiver with standard QAMs, the BVT increases capacity by up to 17%.

W.4.P1.SC4.43 Up to 108 Gb/s PAM 850 nm Multi and Single Mode VCSEL Transmission over 100 m of Multi Mode Fiber
Grzegorz Stepniak (Warsaw University of Technology, PL); Lukasz Chorchos (Warsaw University of Technology & Institute of Telecommunications, PL); Mikel Agustin, Joerg Kropp, Nikolai Ledentsov, Vitaly Shchukin, Nikolai Ledentsov, Jr (VI Systems GmbH, DE); Jarosław P. Turkiewicz (Warsaw University of Technology & Institute of Telecommunications, PL)
♦ Studies on ultra-high speed 850 nm VCSEL transmission are presented. Various system configurations regarding fibre length, VCSEL type and uncoded and coded PAM modulation schemes are investigated. Successful record 108 Gb/s PAM-4 transmission over 100 m MMF is shown.

W.4.P1.SC4.44 PAM-n Solutions for Low-Cost Implementations of 100 Gbps/Lambda Transmissions
Cristian Prodaniuc, Nebojsa Stojanovic, Fotini Karinou and Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Thomas Dippon (Keysight Technologies Deutschland GmbH, DE); Roberto Llorente (Universidad Politecnica de Valencia, ES)
♦ We experimentally demonstrate 112 Gbps PAM-4 and 126 Gbps PAM-8 BTB transmissions using bandlimited setups with less than 12 GHz 3-dB bandwidth. 4D-PAM-5 TCM is also implemented, showing power sensitivity gains over PAM-4 at rates of up to 88 Gbps.

W.4.P1.SC4.45 Low Latency Optical Label Switched Add-Drop Node for Multi-Tb/s Data Center Interconnect Metro Networks
Wang Miao, John van Weerdenburg, Roy van Uden and Huug de Waardt (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL); Chigo Okonkwo (Eindhoven University of Technology, NL); Nicola Calabretta (COBRA Research Institute, NL)
♦ We demonstrate an optical label-switched add-drop node with Terabit/s channels and sub-microsecond switching for data center interconnect metro networks. Experiments show excellent scalability with limited performance degradation up to 15 nodes and 2.688 Tb/s capacity.

SC 5 - Point-to-Point Transmission Systems

W.4.P1.SC5.46 Cascadability Investigation of High Granular Optical Channel Defragmentation Node for Flexible Optical Networks
Satoshi Shimizu (National Institute of Information and Communications Technology, JP); Gabriella Cincotti (University Roma Tre, IT); Naoya Wada (NICT, JP)
♦ Two different node configurations are testes: no-guard-interval (No-GI) and inter-band guard-interval (IB-GI) configuration. The bit-error-rate of No-GI exceeds 10^-3 after 8-hop, whereas 16-hop was achieved in IB-GI configuration with BER~10^-3, owing to the elimination of tight filtering.

W.4.P1.SC5.47 Inter-Island Demonstration of an FSO High Speed Laser Ethernet Transceiver for Telerobotic Space-Surface Control
Amita Shrestha, Julio César Ramírez Molina, Dirk Giggenbach and Jorge Pacheco-Labrador , Christopher Schmidt (German Aerospace Center (DLR), DE)
♦ This paper presents the experimental results of 100Mbps Laser Ethernet Transceivers for high-speed communications in a 142 Km free-space optical inter-island link. Round-trip times below 1.6 ms and error free transmission at full throughput during several time intervals were demonstrated.

W.4.P1.SC5.48 Quantum-limited Measurements of Signals from Geostationary Earth Orbit
Dominique Elser, Kevin Günthner, Imran Khan, Birgit Stiller, Ömer Bayraktar and Christian Müller (Max Planck Institute for the Science of Light, DE); Karen Saucke, Daniel Troendle, Frank F Heine, Stefan Seel, Peter Greulich and Herwig Zech (Tesat Spacecom, DE); Bjorn Guetlich, Ines Richter and Rolf Meyer (DLR, DE); Christoph Marquardt (Max Planck Institute for the Science of Light, DE); Gerd Leuchs (University Erlangen-Nuremberg, DE)
♦ Quantum key distribution (QKD) has been implemented in metropolitan area networks around the world. Optical satellite communication is seen as suitable to provide the missing long-haul interconnections. We validate this approach by quantum measurements of optical signals from space.

W.4.P1.SC5.49 Single-channel 5.12 Tbit/s (1.28 Tbaud) DQPSK Transmission over 300 km Using Non-coherent Nyquist Pulses
Daiki Suzuki, Koudai Harako, Toshihiko Hirooka and Masataka Nakazawa (Tohoku University, JP)
♦ We demonstrate a single-channel 5.12-Tbit/s, 300-km transmission using non-coherent Nyquist pulses with polarization-multiplexed DQPSK at 1.28 Tbaud. Despite this ultrahigh baud rate, we achieved a record distance at 5.12 Tbit/s thanks to the high PMD tolerance of the Nyquist pulse.

W.4.P1.SC5.50 56 Gb/s 20-km Transmission of PAM-4 Signal Employing an EML in C-band without in-line Chromatic Dispersion Compensation
Fotini Karinou, Nebojsa Stojanovic and Cristian Prodaniuc (Huawei Technologies Duesseldorf GmbH, DE)
♦ We experimentally demonstrate 56 Gb/s PAM-4 transmission using a 1.55-μm EML over a 20-km SMF maximum reported distance without employing DCFs in the link, for low-cost metro and short-reach WDM applications. Performance is optimized and compared for various DSP schemes

W.4.P1.SC5.51 552 Gbit/s, 46 Gbaud, 64 QAM Coherent Transmission over 160 km with Simple LD-based Injection-locked Homodyne Detection
Keisuke Kasai, Masato Yoshida and Masataka Nakazawa (Tohoku University, JP)
♦ We describe a single-carrier, polarisation-multiplexed 46 Gbaud 64 QAM coherent transmission. Using an LD-based injection-locked local oscillator for homodyne detection, we transmitted 552-Gbit/s data over 160 km with a bit-error rate of 6×10^-4. The potential spectral efficiency reached 9.2 bit/s/Hz.

W.4.P1.SC5.52 178 Gb/s Short-Range Optical Transmission Based on OFDM, Electrical Up-Conversion and Signal Combining
Christoph Kottke (Fraunhofer Heinrich Hertz Institute, DE); Christian Schmidt (Technical University of Berlin & Fraunhofer Heinrich Hertz Institute, DE); Kai Habel (Fraunhofer HHI, DE); Volker Jungnickel (Fraunhofer Heinrich Hertz Institute & Technical University of Berlin, DE)
♦ We demonstrate our improved wideband OFDM transmission system, using electrical up-conversion and signal combining. Transmission rates of 178 Gb/s over 2 km of SSMF were achieved with an IM/DD system on a single wavelength and single polarization.

W.4.P1.SC5.53 High Resolution Characterization of the Spectral Broadening Due to Inter-Channel Fiber Nonlinearities
Aazar Kashi, John C Cartledge and Ali Rezania (Queen's University, CA); Ali Bakhshali (Queens University, CA); Maurice O'Sullivan, Charles Laperle, Andrzej Borowiec and Kim Roberts (Ciena Corporation, CA)
♦ The spectral broadening due to inter-channel fiber nonlinearities is quantified in terms of the spectral edge power for 256 Gb/s dual-polarization 16-QAM signals in a 9-channel system with 37.5 GHz channel spacing.

W.4.P1.SC5.54 Evaluation of High-Speed EML-based IM/DD links with PAM Modulations and Low-Complexity Equalization
Xiaodan Pang (Swedish ICT AB, SE); Oskars Ozolins (Acreo Swedish ICT, SE); Simone Gaiarin (Technical University of Denmark, DK); Miguel Olmedo (Royal Institute of Technology, SE); Richard Schatz and Urban Westergren (Kista Photonic Research Centre (KPRC), Royal Institute of Technology (KTH), SE); Darko Zibar (DTU Fotonik, depertment of Photonic Engineering, Technical University of Denmark, DK); Sergei Popov (Royal Institute of Technology, SE); Gunnar Jacobsen (Acreo AB, SE)
♦ We experimentally evaluated up to 96 Gb/s/λ PAM IM/DD transmissions with an EML and digital equalizations. Symbol-spaced FFE/DFEs with fewer than 10 taps are shown being sufficient for a high and stable performance over a 4 km SMF link.

W.4.P1.SC5.55 Experimental Demonstration of Physical-Layer Security in a Fiber-Optic Link by Information Scrambling
Junho Cho, Kyle C Guan, Sethumadhavan Chandrasekhar, Peter Winzer (Nokia Bell Labs, USA)
♦ We experimentally demonstrate a physical-layer secure optical fiber communication link that prohibits an eavesdropper from detecting any useful information. Our classical approach is based on a simple linear feedback shift register, thus scaling to multi-Terabits/s of secure bit rates.

W.4.P1.SC5.56 Achievable Information Rates Estimation for 100-nm Raman-Amplified Optical Transmission System
Nikita A. Shevchenko (University College London, UK); Tianhua Xu (Optical Networks Group, University College London, UK); Daniel Semrau, Gabriel Saavedra, Gabriele Liga, Milen Paskov, Lidia Galdino, Alex Alvarado, Robert I Killey and Polina Bayvel (University College London, UK)
♦ The achievable information rates of optical communication system using ultra-wide bandwidth 100-nm distributed Raman amplification have been investigated for each individual sub-channels, based on the first-order perturbative analysis of nonlinear distortions.

W.4.P1.SC5.57 Seed Lightwave Distribution over 1600 km for 64QAM-based Coherent WDM Optical Networks with Low DSP-complexity
Jun Sakaguchi, Yoshinari Awaji (National Institute of Information and Communications Technology (NICT), JP); Naoya Wada (NICT, JP)
♦ Seed lightwave distribution eliminates degradation of coherent signals by phase noise and frequency offset. Seed lightwave was distributed over 1600 km, which amounts to factor five or ten improvement from previous results, while maintaining sufficient quality for DP-64QAM transmission.

W.4.P1.SC5.58 Effect of Statistical Variations in the Response of Cascaded ROADMs on 100 Gb/s DP QPSK System Performance
John C Cartledge and Clay Doggart (Queen's University, CA); Maurice O'Sullivan, Charles Laperle, Andrzej Borowiec and Kim Roberts (Ciena Corporation, CA)
♦ Using a real-time transceiver, the performance implications of passband impairments and bandwidth narrowing resulting from the cascading of ROADMs are assessed using a programmable optical filter and variable bandwidth optical filter to emulate the overall response.

W.4.P1.SC5.59 Real-time 70 Gbit/s, 128 QAM Quantum Noise Stream Cipher Transmission over 100 km with Secret Keys Delivered by Continuous Variable Quantum Key Distribution System
Masataka Nakazawa, Masato Yoshida, Toshihiko Hirooka and Keisuke Kasai (Tohoku University, JP); Takuya Hirano (Gakushuin University, JP)
♦ We demonstrate a real-time quantum noise stream cipher transmission with a continuous variable quantum key distribution system to greatly increase encryption security. 70 Gbit/s, 128 QAM encrypted data have been successfully transmitted over 100 km.

W.4.P1.SC5.60 Experimental Investigation of the Impact of Distributed Link PDL on a Coherent Transmission System
Hou-Man Chin (Orange Polska & University College London, PL); Douglas W Charlton (Ciena Corperation, CA); Andrzej Borowiec, Charles Laperle, Michael Reimer and Maurice O'Sullivan (Ciena Corporation, CA); Seb J Savory (University of Cambridge, UK)
♦ We experimentally investigate the impact of distributed PDL in a 35 Gbaud PM-QPSK optical coherent transmission system implemented by commercially available transceivers over 800 km dispersion uncompensated SMF. 60,000 random instances of distributed link PDL were realized for performance measurements.

SC 6 - Core, Metro and Data Center Networks

W.4.P1.SC6.61 Filterless Networks Based on Optical White Boxes and SDM
Ajmal Muhammad (Royal Institute of Technology (KTH), Stockholm & Linköping University, SE); Marija Furdek (KTH Royal Institute of Technology, SE); Georgios Zervas (University of Bristol, UK); Lena Wosinska (KTH Royal Institute of Technology, SE)
♦ We propose an agile and programmable multicore fiber (MCF)-based filterless network that exploits the flexibility offered by spatial domain multiplexing and programmable optical switches to eliminate the waste of spectrum due to unfiltered transmission.

W.4.P1.SC6.62 Experimental Assessment of Seamless Interconnection of OPS and EPS Networks with IP Addressing and Routing Control
Sugang Xu, Kenji Fujikawa, Hideaki Furukawa, Hiroaki Harai, Yoshinari Awaji and Naoya Wada (National Institute of Information and Communications Technology (NICT), JP)
♦ We demonstrate the OPS network which is empowered with the fully distributed and automated control capabilities of IP addressing and routing. Seamless interconnection of OPS and EPS networks is achieved with the IP-layer protocols HANA/HQLIP as the unified C-Plane mechanism.

W.4.P1.SC6.63 Optical Networking Utilizing Virtual Direct Links
Yusaku Ito, Yojiro Mori and Hiroshi Hasegawa (Nagoya University, JP); Ken-Ichi Sato (School of Engineering - Nagoya University, JP)
♦ We propose efficient optical networking technology employing virtual direct links that offer coarse/fine hybrid granular routing. We compare the effectiveness of the proposal to different networking technologies that employ coarse granular routing.

W.4.P1.SC6.64 Passive Optical Metro Network based on NG-PON2 with Sharing Burst-mode Receiver between Continuous-mode and Burst-mode Transmitters to Support Cloud Edges
Kyota Hattori and Masahiro Nakagawa (NTT Corporation, JP); Toshiya Matsuda (NTT, JP); Masaru Katayama (NTT Network Service Systems Labs, JP); Katsutoshi Koda (NTT, JP)
♦ We propose a future metro network architecture based on NG-PON2 to achieve high-reliability and cost-effectiveness for the VM migration of cloud edges. Experimental results showed the feasibility of reducing the number of receivers and unavailability could be reduced by half.

W.4.P1.SC6.65 Spectrum sharing for elastic transmission parameter adaptation
Nicola Sambo (Scuola Superiore Sant'Anna, IT); Kostas Christodoulopoulos (University of Patras, Greece); Piero Castoldi (Scuola Superiore Sant'Anna, IT); Emmanouel Varvarigos (University of Patras & Computer Technology Institute, Greece)
♦ We propose spectrum sharing between different service classes: part of spectrum used by low-priority traffic can be reconfigured and used by high-priority traffic, enabling adaptation to more robust transmission. Even 70% of high-priority traffic is recovered from soft-failures without rerouting.

W.4.P1.SC6.66 Methods of Designing Green Optical Networks with Parallel Integration of Optical Components
Onur Turkcu, Abishek Gopalan, Biao Lu, Abhijit Chitambar, Pravin Mahajan and Parthiban Kandappan (Infinera, USA)
♦ We study the effects of network designs using Discrete and Integrated models into network energy consumption. We evaluate both models on three different network architectures with optical and/or digital switching capabilities. We demonstrate the power efficiency of the Hybrid architecture.

W.4.P1.SC6.67 Techno-Economic Evaluation of Optical Transport Network in Metropolitan Deployments
Tamara Jiménez (University of Valladolid, ES); Victor Lopez (Telefonica, ES); Felipe Jiménez, Oscar González de Dios, Juan P. Fernández-Palacios (Telefónica I+D, ES)
♦ Optical Transport Network (OTN) technology provides multiple benefits to the network operator in backbone networks. This paper presents a techno-economic comparison of optical solutions for metropolitan scenarios to assess when OTN must be deployed.

SC 7 - Access, Local Area and Home Networks

W.4.P1.SC7.68 10-Gbaud OOK / PAM4 Digital Mobile Fronthaul based on One-Bit / Two-bit Delta-Sigma Modulation Supporting Carrier Aggregation of 32 LTE-A Signals with up to 256 and 1024QAM
Jing Wang (Georgia Institute of Technology, USA); Zhenhua Yu (Texas Instruments, USA); Kai Ying, Junwen Zhang, Feng Lu, Mu Xu, Lin Cheng and Xiaoli Ma (Georgia Institute of Technology, USA); Gee-Kung Chang (Georgia Tech, USA)
♦ 10-Gbaud OOK/PAM4 digital mobile fronthaul was experimentally demonstrated by using one-bit/two-bit delta-sigma modulation supporting 32 LTE-A carrier aggregation for 3GPP release 13 with up to 256 and 1024QAM. Compared with CPRI, the mobile fronthaul capacity is increased by 4 times.

W.4.P1.SC7.69 Analysis of Performance Degradations Induced by Multipath Interferences in RoF-based Mobile Fronthaul Network Implemented by Using Directly Modulated Lasers
Byung Gon Kim (KAIST(Korea Advanced Institute of Science and Technology), KR); Hoon Kim (KAIST, KR); Kazuki Tanaka, Takashi Kobayashi, (KDDI R&D Laboratories, JP); Kosuke Nishimura (KDDI R&D Laboratories Inc. & Optical Access Network Laboratory, JP); Masatoshi Suzuki (KDDI R&D Laboratories, JP); Yun C. Chung (KAIST, KR)
♦ We investigate the effects of multipath interferences on the performance of a radio-over-fiber-based mobile fronthaul network using directly modulated lasers. Our theoretical model obtained without using the quasi-static approximation agrees well with the measured data.

W.4.P1.SC7.70 Experimental Demonstration of 25/30/40-Gb/s Flexible-PON Downstream Transmission by Using Pre-Compensated DMT with Adaptive Modulation/Bandwidth and 10G EML/APD
Minghui Tao (Advanced Access Network Research Center, Huawei Technologies, Wuhan, PRC); Huaiyu Zeng (Futurewei Technologies, USA); Lei Zhou (Huawei Technologies & Advanced Access Network Research D, PRC); Shuchang Yao (Huawei Technologies, PRC); Shengping Li (Huawei Technologies Co., Ltd., PRC); Xiang Liu (Futurewei Technologies, USA)
♦ We demonstrate the downstream transmission of a flexible-PON at 25/30/40-Gb/s data rates by using low-cost 10G EML/APD and pre-compensated variable-bandwidth DMT with 8/16-QAM subcarrier formats, respectively achieving -24/-22/-15.5dBm receiver sensitivities at BER=10-3 after 20-km SSMF transmission in the C-band.

W.4.P1.SC7.71 Demonstration of NG-PON2 Coexisting with Other Systems on Same ODN by Using WDM filter with Low Power Penalty of under 1.0 dB
Yuki Sakaue (NTT Corporation, JP); Katsuhisa Taguchi (NTT, JP); Kazutaka Hara (NTT Access Network Service Systems Laboratories, JP); Toshiaki Shitaba and Tomohiro Taniguchi (NTT Corporation, JP); Susumu Nishihara and Kota Asaka (NTT Access Network Service Systems Laboratories, JP); Ken-Ichi Suzuki, Akihiro Otaka (NTT Corporation, JP)
♦ We demonstrate the coexistence of TWDM-PON, GE/10G-EPONs, and video service system on the same ODN by using a WDM-filter based coexistence element. Thanks to a sufficient isolation at the filter, a power penalty of <1.0dB in all PONs is achieved.

W.4.P1.SC7.72 190-Gb/s CPRI-Equivalent Rate Fiber-Wireless Mobile Fronthaul for Simultaneous Transmission of LTE-A and F-OFDM Signals
Tien Dat Pham, Atsushi Kanno and Naokatsu Yamamoto (National Institute of Information and Communications Technology, JP); Tetsuya Kawanishi (Waseda University & National Institute of Information and Communications Technology, JP)
♦ We propose an efficient, flexible fiber-wireless mobile fronthaul for simultaneous transmission of different RATs. We successfully transmit 2×20-MHz LTE-A and 4×800-MHz F-OFDM signals with a CPRI-equivalent data rate of 190 Gb/s over a converged 20-km fiber and 1-m 90 GHz.

W.4.P1.SC7.73 Experimental Optimization of DSP-Aggregated Front-hauling Transmission for up to 4x96 LTE radio waveforms
Stefano Straullu and Silvio Abrate (Istituto Superiore Mario Boella, IT); Roberto Gaudino and Mengesha Befekadu (Politecnico di Torino, IT)
♦ In this paper we demonstrate the transmission of up to 384 LTE channels with the DSP-based channel aggregation, for fronthauling applications, over a conventional PON infrastructure. An analysis on the impact of the optical link on the EVM is shown.

W.4.P1.SC7.74 10 Gbit/s Phase Time Diversity Directly Modulated DFB with Single-PD Intradyne Receiver for Coherent WDM-PON
Ivan Cano, Juan Camilo Velásquez Micolta, Victor Polo and Josep Prat (Universitat Politècnica de Catalunya, ES)
♦ A 10 Gbit/s directly modulated DFB laser with phase diversity in time is experimentally tested with polarization independent intradyne detection. Rx sensitivity of -34 dBm at BER=10e-3 is achieved in a 40 GHz channel spaced WDM-PON.

W.4.P1.SC7.75 Transmission Experiment of LTE Signals by IF-over-Fiber Using Commercial Base Station and Deployed Optical Fibers
Byung Gon Kim (KAIST(Korea Advanced Institute of Science and Technology), KR); Kazuki Tanaka, Takashi Kobayashi, Abdelmoula Bekkali (KDDI R&D Laboratories Inc., JP); Kosuke Nishimura (KDDI R&D Laboratories Inc. & Optical Access Network Laboratory, JP); Hoon Kim (KAIST, KR); Masatoshi Suzuki (KDDI R&D Laboratories, JP); Yun Chur Chung (KAIST, KR)
♦ We experimentally verify the practicality of the IF-over-Fiber (IFoF) transmission scheme by using commercial base stations and deployed optical fibers. No significant degradation is observed under this realistic condition similar to commercial LTE systems.

W.4.P1.SC7.76 A Techno-Economic Outlook to Optical-Interface Requirements for Midhauling of 5G Small Cells
Francesco Musumeci (Politecnico di Milano, IT); Massimo Tornatore (Politecnico di Milano & University of California, Davis, IT); Achille Pattavina (Politecnico di Milano, IT)
♦ We estimate the amount of optical interfaces to support fronthaul of Small Cells under aggressive 5G traffic forecasts, considering different functional splits (midhaul) and cell configurations. Cost of interfaces can be minimized by properly selecting functional split and radio configuration.

W.4.P1.SC7.77 Flexible 2/4-PAM-Modulation 25-Gb/s PON for Next Generation Access Network
Jianhe Gao and Huafeng Lin (Huawei Technologies, PRC); Xiang Liu (Futurewei Technologies, USA); Xuming Wu (Huawei Technologies, PRC); Lei Zhou (Huawei Technologies & Advanced Access Network Research D, PRC); Shuchang Yao (Huawei Technologies, PRC)
♦ A novel low-cost 2/4-PAM dual-mode 25-Gb/s PON is proposed based on commercial 10-Gb/s TOSA/ROSA. By introducing the rate-detector, dual-modes with different DSP algorithms could adaptively work. This scheme could meet the requirements of different ODNs.

W.4.P1.SC7.78 Improving the CoMP Performance through Wavelength Reconfiguration in Cloud Radio and Optical Access Networks
Jiawei Zhang, Ji Yuefeng, Songhao Jia, Hui Li, Xiaosong Yu, Yongli Zhao and Jie Zhang (Beijing University of Posts and Telecommunications, PRC)
♦ A minimum-cut graph based wavelength reconfiguration scheme (MCG-WR) is proposed to improve coordinated multipoint (CoMP) performance in a TWDM-PON based cloud radio access network. Simulation results show that MCG-WR can effectively reduce the inter-BBU CoMP traffic through dynamic wavelength reconfiguration.

Th.1.A: Nonlinear Mitigation — Room 18+19

Chair: Rob Smets (SURFnet, NL)

Th.1.A.1 • 09:00 *Tutorial*
Mitigation of Nonlinear Propagation Impairments by Digital Signal Processing
Takeshi Hoshida (Fujitsu Laboratories Ltd., JP)
♦ Various digital signal processing algorithms have been studied in order to offset the nonlinear Shannon limit dominated by the optical Kerr effect. This tutorial attempts to overview the operation principles, implementation challenges and achievement, and future outlook on those techniques.

Th.1.A.2 • 10:00
Experimental Demonstration of Modulation-Dependent Nonlinear Interference in Optical Fibre Communication
Lídia Galdino, Gabriele Liga and Gabriel Saavedra (University College London, UK); David Ives (University of Cambridge, UK); Robert Maher and Alex Alvarado (University College London, UK); Seb J Savory (University of Cambridge, UK); Robert I Killey and Polina Bayvel (University College London, UK)
♦ For the first time the modulation format dependence of nonlinear interference in long-haul optical fibre transmission is experimentally demonstrated for polarisation-division multiplexed 4, 16, 64 and 256-QAM.

Th.1.A.3 • 10:15
Dispersion Map Optimization for Nonlinearity Mitigation in Two-Span Phase-Sensitive Amplifier Links
Egon Astra (Tallinn University of Technology, EST); Samuel L. I. Olsson and Henrik Eliasson (Chalmers University of Technology, SE); Taavi Laadung (Tallinn University of Technology, EST); Peter A Andrekson (Chalmers University of Technology, SE)
♦ The first investigation of dispersion map optimization in two-span PSA-amplified links is presented. We show numerically and experimentally, that the nonlinearity mitigation improves by 1.4dB if different dispersion maps are applied in each span, compared to single-span optimized maps.

Th.1.B: Multiplexing and Switching Devices — Room 17

Chair: Takuo Tanemura (University of Tokyo, JP)

Th.1.B.1 • 09:00
Wavelength Selective Switch for Commercial Multimode Fiber Supporting 576 Spatial C hannel
Haoshuo Chen, Nicolas K Fontaine, Roland Ryf, Bin Huang and Amado Velázquez-Benítez (Nokia Bell Labs, USA); Cang Jin (Université Laval & COPL, CA); Burcu Ercan (UC Davis, USA); David Neilson (Bell Labs, USA)
♦ We demonstrate a 1 x 16 wavelength selective switch with commercial multimode fibers (OM3) supporting 36 spatial modes. It provides a switch throughput of 576 spatial channels with a mode-dependent loss below 5.5 dB.

Th.1.B.2 • 09:15
Waveguide-Frontend with Integrated Polarization Diversity Optics for Wavelength Selective Switch Array
Hiroshi Kudo, Yuichiro Ikuma, Kota Shikama, Yohei Sakamaki and Mitsumasa Nakajima (NTT Corporation, JP); Keita Yamaguchi (NTT Corporation & NTT Device Technology Labs, JP); Kazunori Seno (NTT Corporation, JP); Kenya Suzuki (NTT Device Technology Laboratories, NTT Corporation, JP); Mikitaka Itoh (NTT Photonics Laboratories, JP); Toshikazu Hashimoto (NTT Corporation, JP)
♦ We propose a waveguide-frontend with integrated polarization diversity optics for a wavelength selective switch (WSS) with a spatial and planar optical circuit. We demonstrate a 2-in-1 1×20 WSS and confirmed operation with a polarization dependent loss of <0.43 dB.

Th.1.B.3 • 09:30
Compact Silicon Photonic Interleaver Using an Interfering Loop Containing a Fabry-Perot Cavity Formed by Sagnac Loop Mirrors
Xinhong Jiang, Yuxing Yang, Boyu Liu, Yong Zhang, Ciyuan Qiu and Yikai Su (Shanghai Jiao Tong University, PRC)
♦ A compact (106.4 × 55.1 μm2) silicon photonic interleaver is proposed and experimentally demonstrated. The 3-dB and 20-dB bandwidths of the passband are ~1.09 nm and ~1.585 nm, respectively. The central wavelength can be changed by tuning only one waveguide.

Th.1.B.4 • 09:45
Ultra-compact and Highly Efficient Polarization Splitter and Rotator Based on a Silicon Bent Directional Coupler
Yong Zhang, Yu He, Xinhong Jiang, Boyu Liu, Ciyuan Qiu and Yikai Su (Shanghai Jiao Tong University, PRC)
♦ An ultra-compact (coupling length ~ 8.77 micrometer) silicon polarization splitter and rotator is demonstrated based on a bent directional-coupler. The peak TM-TE coupling efficiency reaches 96.6%. The crosstalk values are < -10 dB over a wavelength range of 40 nm.

Th.1.B.5 • 10:00 *Invited*
Ultrafast laser inscription of 3D waveguides for SDM applications
Robert R. Thomson (Heriot Watt University, UK)
♦ I will present the work that has been conducted on the application of ultrafast laser inscription to the fabrication of three-dimensional components, such as 3D fan-outs and photonic lanterns, for future applications in space division multiplexing (SDM).

Th.1.C: Pulse Amplitude Modulation II — Room 16

Chair: Xin Yin (Ghent University - IMEC, BE)

Th.1.C.1 • 09:00
Experimental Demonstration of 56 Gbit/s PAM-4 over 15 km and 84 Gbit/s PAM-4 over 1 km SSMF at 1525 nm using a 25G VCSEL
Nicklas Eiselt (Technical University of Denmark, DK); Helmut Griesser (ADVA Optical Networking SE, DE); Jinlong Wei (ADVA Optical Networking SE); Annika Dochhan (ADVA Optical Networking SE, DE); Robert Hohenleitner (Vertilas GmbH, DE); Markus Ortsiefer (VERTILAS GmbH, c/o GATE Garching, DE); Michael Eiselt (ADVA, DE); Christian Neumeyr (VERTILAS, GmbH, DE); Juan Jose Vegas Olmos (Technical University of Denmark, DK); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU)
♦ Record 28-GBd PAM-4 transmission over 15 km SSMF and 42-GBd PAM-4 over 1 km SSMF using a low-power 25G VCSEL are demonstrated at 1525 nm without optical dispersion compensation and only simple transceiver DSPs.

Th.1.C.2 • 09:15
Single Lane 150-Gb/s, 100-Gb/s and 70-Gb/s 4-PAM Transmission over 100-m, 300-m and 500-m MMF Using 25-G Class 850nm VCSEL
Tianjian Zuo, Liang Zhang and Jie Zhou (Huawei, PRC); Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Enbo Zhou and Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)
♦ We experimentally demonstrated a record transmission with bit-rates of 150-Gb/s, 100-Gb/s and 70-Gb/s over 100-m, 300-m and 500-m MMFs. More than 2-dB performance gain has been observed employing a 13-level duobinary 4-PAM format for bandwidth limited system.

Th.1.C.3 • 09:30 *Invited*
High-Speed VCSELs for Datacom
Anders Larsson and Johan Gustavsson (Chalmers University of Technology, SE); Petter Westbergh (Finisar, USA); Erik Haglund, Emanuel Haglund and Ewa Simpanen (Chalmers University of Technology, SE)
♦ VCSEL-MMF is the dominating technology for short-reach optical interconnects in datacenters and high performance computing systems at current serial rates of up to 25-28 Gb/s. This is likely to continue at 50-56 Gb/s. The technology shows potential for 100 Gb/s.

Th.1.C.4 • 10:00
56 Gb/s PAM-4 Driver IC for Long-Wavelength VCSEL Transmitters
Wouter Soenen (Ghent University & iMinds-imec, BE); Renato Vaernewyck (Ghent University, BE); Xin Yin (Ghent University - IMEC, BE); Silvia Spiga (Walter Schottky Institut, Technical University of Munich, DE); Markus-Christian Amann (Technical University of Munich, DE); Geert Van Steenberge (Ghent University - IMEC, BE); Elad Mentovich (Mellanox Technologies, IL); Paraskevas Bakopoulos (National Technical University of Athens, GR); Johan Bauwelinck (Ghent University - iMinds, BE)
♦ We present the first 56 Gb/s PAM-4 driver IC, developed in 130 nm SiGe BiCMOS, for long-wavelength VCSEL transmitters. Efficiency of the integrated 4-tap FFE driving a state-of-the-art 1.5 um VCSEL is verified, showing back-to-back BER below 1E-6.

Th.1.C.5 • 10:15
100 Gbps PAM-4 Transmission over 100m OM4 and Wideband Fiber using 850nm VCSELs
Justin Lavrencik, Siddharth J Varughese, Varghese A. Thomas (Georgia Institute of Technology, USA); Gary Landry (Finisar Corp, USA); Yi Sun, Roman Shubochkin and Kasyapa Balemarthy, Balemarthy (OFS, USA); Jim Tatum (Finisar Corp, USA); Stephen Ralph (Georgia Institute of Technology, USA)
♦ We experimentally demonstrate 100 Gbps PAM-4 transmission over 105m of OM4 and wideband MMF fibers. The 107Gbps line rates allow 100Gbps user rates with FEC. The link included unpackaged 850nm VCSELs designed for 25G operation and offline equalization and decoding.

10:30 - 11:00 Coffee Break | Foyer CCD |

11:00 - 12:30 Th.2.P: Poster Session II

12:30 - 14:00 Lunch Break

14:00 - 14:30 Post Deadline Paper Sessions

15:30 - 16:00 Awards and Closing Ceremony | Room 1 |

Th.1.D: Auxiliary Managementand Control Channel Technologies for Mobile Fronthaul — Room 15

Chair: Kota Asaka (NTT Access Network Service Systems Laboratories, JP)

Th.1.D.1 • 09:00
Experimental Investigation of an Optically-superimposed AMCC in 100 Gb/s Coherent WDM-PON for 5G Mobile Fronthaul
Satoshi Yoshima, Takaaki Katsumata, Hiroshi Miura, Yuita Noguchi, Akiko Nagasawa, Naoki Suzuki and Masaki Noda (Mitsubishi Electric Corporation, JP)
♦ We experimentally demonstrated a 100 Gb/s coherent WDM-PON for 5G mobile fronthaul controlled by an AMCC superimposed on the DP-QPSK signal. The required receiver sensitivity of -26dBm was achieved when the modulation index was set to between 5% and 40%.

Th.1.D.2 • 09:15
Experimental Investigation of AMCC Superimposition Impact on CPRI Signal Transmission in DWDM-PON Network
Goji Nakagawa and Kyosuke Sone (Fujitsu Ltd., JP); Shoichiro Oda and Setsuo Yoshida (Fujitsu Laboratories Ltd.); Yasuhiko Aoki and Motoyuki Takizawa (Fujitsu Ltd., JP); Jens C. Rasmussen (Fujitsu Laboratories Ltd., JP)
♦ We have investigated and clarified the impact of AMCC superimposition on CPRI signal transmission, and confirmed that the impact of message channel was negligibly small for CPRI option 8 client signal. We demonstrated AMCC signal detection with DWDM-PON network.

Th.1.D.3 • 09:30
Low-frequency Pilot Tone Management for WDM-PON toward Future Mobile Fronthaul employing 64B/66B Line Coding
Kazuaki Honda (NTT Corporation, JP); Takayuki Kobayashi (NTT, JP); Susumu Nishihara (NTT Access Network Service Systems Laboratories, JP); Tatsuya Shimada (NTT, JP); Jun Terada and Akihiro Otaka (NTT Corporation, JP)
♦ Low frequency embedded pilot tone can provide protocol-free management channels for WDM-PON-based mobile fronthaul systems. Experiments show modulation index control enables 128 kb/s pilot tones to be inserted into 64B/66B-line-coded CPRI option 8 signals, which have a low frequency component.

Th.1.D.4 • 09:45
Experimental Real Time AMCC Implementation for Fronthaul in PtP WDM-PON
Zakaria Tayq, Luiz Anet Neto and Philippe Chanclou (Orange Labs, FR); Christelle Aupetit-Berthelemot (XLIM - University of Limoges, FR)
♦ A real-time pilot tone implementation allowing fronthaul monitoring and wavelength tunability in WDM-PON systems is experimentally demonstrated. The obtained results show transmission of a 128 kb/s control signal with minor impact on CPRI.

Th.1.D.5 • 10:00
Experimental Demonstration of Accommodation of TDD-based Mobile Fronthaul and Secondary Services in a TDM-PON
Daisuke Hisano and Takayuki Kobayashi (NTT, JP); Hiroshi Ou (NTT Corporation, JP); Tatsuya Shimada (NTT, JP); Jun Terada and Akihiro Otaka (NTT Corporation, JP)
♦ We experimentally demonstrate a novel bandwidth allocation scheme using a TDD frame monitor. We confirm that the average throughput of the secondary system is increased over ninefold and a mobile fronthaul is transmitted with a less than 50 μs latency.

Th.1.D.6 • 10:15
Dynamic Resource Sharing for C-RANs with Joint Orchestration of Radio and Transport
Muhammad Rehan Raza and Matteo Fiorani (KTH Royal Institute of Technology, SE); Ahmad Rostami (Ericsson Research, SE); Björn Skubic and Peter Öhlen (Ericsson AB, SE); Lena Wosinska and Paolo Monti (KTH Royal Institute of Technology, SE)
♦ We present a resource allocation strategy for centralized radio access network architectures able to adapt to the wireless network capacity requirements. Both simulation and emulation results show that it is possible to reuse up to 33.3% of the transport resources.

Th.1.E: Elastic Optical Networks II — Room 112

Chair: Dimitra Simeonidou (University of Bristol, UK)

Th.1.E.1 • 09:00 *Invited*
Can Metro Networks Be the Next Playground for (True) Elastic Networks
Patricia Layec, Arnaud Dupas, Dominique G. Verchere and Sebastien Bigo (Nokia Bell-Labs, FR);
♦ We review elastic optical networks experiments and associated use cases. Metro networks are particularly well-suited to the introduction of some level of dynamics in the optical networks, leveraging elastic building blocks such as transponders and optical nodes.

Th.1.E.2 • 09:30
Demonstration of Bandwidth Maximization between Flexi/Fixed Grid Optical Networks with Real-Time BVTs
Shuangyi Yan, Emilio Hugues-Salas, Ali Hammad, Yan Yan, George M. Saridis, Sarvesh Sanjay Bidkar, Reza Nejabati and Dimitra Simeonidou (University of Bristol, UK); Arnaud Dupas and Patricia Layec (Nokia Bell Labs, FR)
♦ Real-Time SDN-based BVT enables baud-rate tunability to combat the filtering effect of the legacy filters for interoperability between fixed-grid/flexigrid. Based on the passed filters and link-distance, SDN controller configures BVTs to maximize the link capacity.

Th.1.E.3 • 09:45
Spectral-Efficiency Maximization with Subcarrier-Multiplexed Hybrid-QAM Signals Adaptive to Distance and Hop Count
YYuma Isono, Masaki Niwa, Yojiro Mori and Hiroshi Hasegawa (Nagoya University, JP); Ken-Ichi Sato (School of Engineering - Nagoya University, JP)
♦ We propose a novel spectral efficiency maximization method adaptive to distance and hop count for subcarrier-multiplexed hybrid-QAM signals. Simulation results show that the proposed scheme substantially improves spectral efficiency in all the networks topologies tested.

Th.1.E.4 • 10:00
Energy Efficiency of General-Purpose Systems Employing Virtualization Concepts in Operator Networks
Christoph Lange and Dirk Kosiankowski (Deutsche Telekom AG, DE); Michael Schlosser (Berlin Institute for Software Defined Networks, DE); Andreas Gladisch (Deutsche Telekom AG & Innovation Labs, DE)
♦ The energy efficiency of purpose-built and virtualization-aided general-purpose telecom equipment is compared based on power measurements, traffic observations and network modelling. The results show improved energy efficiency of software realizations based on general-purpose systems originating from finer-granular capacity provisioning.

Th.1.E.5 • 10:15
Software Defined Contention in Wavelength Cross-Connects
Thierry Zami (Nokia, FR); Colin Kelly (Nokia, CA)
♦ We assess the paradoxical benefit of lightly degrading by software restriction the blocking ratio of an initially contentionless add/drop stage in a wavelength routing cross-connect, to maximize its capacity and keep as much as possible efficient transponders and internal amplification

10:30 - 11:00 Coffee Break | Foyer CCD |

11:00 - 12:30 Th.2.P: Poster Session II

12:30 - 14:00 Lunch Break

14:00 - 14:30 Post Deadline Papers Sessions

15:30 - 16:00 Awards and Closing Ceremony | Room 1 |

SC 1 - Fibres, Fibre Devices and Fibre Amplifiers

Th.2.P2.SC1.1 Demonstration of an Ultra-Flat Raman-Enhanced Fibre Optical Parametric Amplifier (FOPA) with >110nm Gain-Bandwidth
Vladimir Gordienko and Marc Stephens (Aston University, UK); Shigehiro Takasaka *(Furukawa Electric co., Ltd., JP); Atalla El-Taher, Ian Phillips and Wladek Forysiak (Aston University, UK); Ryuichi Sugizaki (Furukawa Electric co., Ltd., JP); Nick Doran (Aston University, UK)*
♦ We demonstrate a Raman-enhanced FOPA achieving record unfiltered gain variation of only ±0.5dB over 111nm bandwidth and 9.6dB gain. We amplify a 60Gb/s QPSK signal error-free across the L-band with maximum Q2 penalty of 0.9±0.3dB.

Th.2.P2.SC1.2 Millimeter-Resolution Long Range Optical Frequency Domain Reflectometry for Health Monitoring of Access Network
Bin Wang, Xinyu Fan, Guangyao Yang, Qingwen Liu and Zuyuan He (Shanghai Jiao Tong University, PRC)
♦ We greatly improve the performance of optical frequency domain reflectometry by using high-order sideband modulation and injection-locking technique. A spatial resolution of 4.2 mm over 10 km measurement range is obtained, and polarization beat length of 10.5 cm is measured.

Th.2.P2.SC1.3 High-speed Dynamic Strain Measurement Based on Frequency-swept Pulsed BOTDA
Chihiro Kito, Hiroshi Takahashi and Kunihiro Toge, Tetsuya Manabe (NTT Corporation, JP)
♦ We propose a high-speed, dynamic strain measurement based on real-time Brillouin time-domain analysis of correlated gain measured with an oscilloscope. We achieved the highest recorded speed of 97 kilo-points/s over 1 km fibre, which is close to the repetition limit.

Th.2.P2.SC1.4 Experimental Evaluation of RF crosstalk in Multicore Fibers for Radio over fiber Applications
Jose Manuel Galve Higon, Jose Capmany and Ivana Gasulla (Universidad Politecnica de Valencia, ES); Tiago Alves (Instituto de Telecomunicações, PRT); Adolfo Cartaxo (IST-TUL, PRT); Salvador Sales (Universidad Politecnica de Valencia, ES)
♦ We present a simple theoretical formalism and experimental characterization of RF-crosstalk due to inter-core coupling in homogeneous Multicore Fibers. Measurements confirm the behaviour predicted by the model. The results are relevant for the design of radio over fiber systems.

Th.2.P2.SC1.5 Dependence of Kerr Comb Linewidth and Coherent System Performance on the Pump Linewidth
Peicheng Liao and Changjing Bao (University of Southern California, USA); Arne Kordts, Karpov Maxim and Martin Pfeiffer (Ecole Polytechnique Federale de Lausanne, CH); Lin Zhang (Tianjin University, PRC); Amirhossein Mohajerin-Ariaei, Yinwen Cao, Ahmed Almainman and Morteza Ziyadi (University of Southern California, USA); Youichi Akasaka (Fujitsu Laboratories of America, Inc., USA); Tomer Yeminy (Ben Gurion University, IRL); Moshe Tur (Tel-Aviv University, IRL); Tobias Kippenberg (Ecole Polytechnique Federale de Lausanne, CH); Alan Willner (University of Southern California, USA)
♦ We experimentally investigate the dependence of Kerr comb linewidth, generation and coherent system performance on the pump linewidth. The linewidth of generated combs could be determined by the pump demonstrating the pump-limited system performance of Kerr combs.

Th.2.P2.SC1.6 Optimizing the Curvature of Elliptical Cladding Elements to Reduce Leakage Loss in Antiresonant Hollow Core Fibres
Lieke van Putten, Eric Numkam Fokoua, Seyedmohammad Abokhamis mousavi, Walter Belardi and Francesco Poletti (University of Southampton, UK)
♦ We study systematically the effect of the curvature of glass membranes on the confinement loss of an antiresonant negative curvature hollow core fibre. Optimum curvatures are found that can reduce the fibre loss by orders of magnitude.

Th.2.P2.SC1.7 A Crosstalk Analysis of Heterogeneous 30-Core Fibre
Takeshi Fujisawa (Hokkaido University, JP); Yoshimichi Amma (Fujikura Ltd., PRC); Shoichiro Matsuo and Kazuhiko Aikawa (Fujikura Ltd., JP); Kunimasa Saitoh and Masanori Koshiba (Hokkaido University, JP)
♦ Intercore crosstalk of heterogeneously arranged 30-core fibre having four kinds of cores is investigated. Measured crosstalk for all the combinations of cores are in good agreement with calculated values by coupled-mode theory with single correlation length, assuming longitudinal random twist.

SC 2 - Waveguide and Optoelectronic Devices

Th.2.P2.SC2.8 Monolithically Integrated 40 Gbit/s Tunable Transmitter in an Experimental Generic Foundry Process for Large-Scale Integration
Weiming Yao (Eindhoven University of Technology & COBRA Research Institute, NL); Meint K Smit (Technical University Eindhoven, NL); Michael J. Wale (Oclaro, UK)
♦ We present a tunable transmitter photonic integrated circuit fabricated on an experimental generic III-V foundry platform, consisting of a DBR-laser with 10 nm continuous tuning range, monolithically integrated with a traveling-wave Mach-Zehnder modulator capable of 40 Gbit/s operation.

Th.2.P2.SC2.9 Simultaneous Two-Wavelength Hybrid III/V-Si Laser Based on Single-Section Quantum Dot Gain
Michael Eggleston, Guilhem de Valicourt, Jeffrey Lee and Kwangwoong Kim (Nokia Bell Labs, USA); Ting-Chen Hu (Nokia Bell Labs, USA); Vitalii Sichkovskyi and Johann Peter Reithmaier (University of Kassel, DE); Young-Kai Chen (Nokia Bell Labs, USA)
♦ We demonstrate a novel selectable multi-wavelength hybrid III-V/Si laser using in-homogeneously broadened quantum dot gain material. Simultaneous stable lasing on two wavelengths is achieved while maintaining low RIN one order of magnitude better than previously demonstrated with mode-locked lasers.

Th.2.P2.SC2.10 Ultra-broadband Integrated Four-Channel Mode-Division-Multiplexing Based on Tapered Mode-Evolution Couplers
Jing Wang (Huawei Technologies Co., Ltd., PRC); Yi Xuan (Purdue University, USA); Minghao Qi (Purdue University, PRC); Lei Liu, Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)
♦ We reported an ultra-broadband integrated four-channel mode-division multiplexing (MDM) scheme based on tapered mode-evolution couplers. This MDM link exhibits a very large –1 dB bandwidth of >180 nm, which is considerably larger than most of the previously reported MDM links.

Th.2.P2.SC2.11 Experimental Study of Phase and Intensity Noise in a Monolithically Integrated DFB Laser IQ Modulator PIC at QPSK operation
Sophie Lange, Ronald Kaiser, Marko Gruner, Martin Schell (Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, DE)
♦ Phase noise in monolithic optical laser-modulator PICs influences QPSK performance depending on laser bias current and internal optical feedback. The phase noise was most significant at lower symbol rates and minimized at high symbol rates at selected bias points.

Th.2.P2.SC2.12 Emission Beam Engineering of 1.3-µm High-power DFB Laser Using Monolithically-integrated Mirror and Lens for Silicon Photonics
Koichiro Adachi, Takanori Suzuki, Kouji Nakahara, Akira Nakanishi, Kazuhiko Naoe and Shigehisa Tanaka (Oclaro Japan, Inc., JP)
♦ A beam-angle control of 1.3-µm high-power DFB laser without mode-profile degradation was demonstrated using monolithically-integrated mirror and lens. By tuning the mirror angle and lens position, wide-range angled beam (up to 20º) without degradation in mode profile was successfully achieved.

Th.2.P2.SC2.13 Optical Amplitude Modulator Linearized by Integration of Optical Interferometric Waveguides
Yuya Yamaguchi, Atsushi Kanno, Tetsuya Kawanishi, Masayuki Izutsu and Hirochika Nakajima (Waseda University & National Institute of Information and Communications Technology, JP)
♦ We propose an optical amplitude modulator with tailored transfer function by integration of Mach-Zehnder-interferometer-based waveguides. The fabricated modulator designed to enhance the linearity showed a unique transfer function in good agreement with the theoretical one.

Th.2.P2.SC2.14 120 Gbit/s PAM-4 Signaling Using a Silicon-Organic Hybrid (SOH) Mach-Zehnder Modulator
Heiner Zwickel, Stefan Wolf, Yasar Kutuvantavida, Clemens Kieninger , Matthias Lauermann, Wolfgang Freude and Christian Koos (Karlsruhe Institute of Technology (KIT), DE)
♦ Four-level pulse amplitude modulation (PAM-4) signals are generated using a silicon-organic hybrid (SOH) push-pull Mach-Zehnder modulator. We demonstrate data rates (symbol rates) of 120 Gbit/s (60 GBd) with a 500 µm long device fabricated through a commercial silicon photonic foundry.

Th.2.P2.SC2.15 Differential Microring Binary Phase-shift Keying Modulators
Chia-Ming Chang, Guilhem de Valicourt , Sethumadhavan Chandrasekhar, Po Dong (Nokia Bell Labs, USA)
♦ We experimentally demonstrate a nested microring modulator in a Mach-Zehnder interferometer for BPSK at 10 Gbps. Differential drive of such a modulator facilitates BSPK modulation and offers several advantages such as cancellation of imperfection from single ring modulator.

Th.2.P2.SC2.16 Femtosecond Laser Written Integrated Spatial Multiplexers for Few-Mode Multicore Fibre
Nicolas Riesen (University of Adelaide, AU); Simon Gross (Macquarie University, AU); John Love (The Australian National University, AU); Yusuke Sasaki (Fujikura Ltd., JP); Michael Withford (Macquarie University, AU)
♦ We demonstrate compact femtosecond laser written 3D spatial multiplexers for few-mode multicore fibre operating across the C+L bands. The integrated tapered mode couplers feature direct mode-selectivity, excellent mode extinction ratios (up to 25 dB) and low insertion loss (~2 dB).

Th.2.P2.SC2.17 Ultra-efficient interleaved depletion modulators by using advanced fabrication technology
Anna Lena Giesecke, Andreas Prinzen, Heiko Füser, Caroline Porschatis, Holger Lerch, Jens Bolten, Stephan Suckow, Bartos Chmielak and Thorsten Wahlbrink (AMO GmbH, DE)
♦ We fabricated highly efficient silicon photonic depletion modulators utilizing interdigitated pn-junctions with critical dimensions <200 nm. With this concept, record low values <2VdB of ($V_\pi L\alpha$)_2V as key figure of merit for the efficiency of such modulators have been achieved.

Th.2.P2.SC2.18 50-GHz+ Thin-Film Polymer on Silicon Modulator for PAM4 100G-per-wavelength Long-Reach Data Center Interconnects
Andrea Chiuchiarelli (CPqD, BR); Sandro M. Rossi (CPqD Telecom & IT Solutions, BR); Valery Nobl Rozental (CPqD, Division of Optical Technologies, BR); Glauco Simões (CPqD, BR); Luis Carvalho, Julio Cesar Oliveira (BrPhotonics, BR); Juliano Rodrigues Fernandes de Oliveira (CPqD Foundation & University of Sao Paulo, BR); Jacklyn D. Reis (CPqD, BR)
♦ This paper demonstrates 50-GHz+ Mach-Zehnder modulator based on thin-film Polymer on Silicon platform for Data Center Interconnects. System level demonstration is successfully carried out for 40x112 Gb/s, 56-GBd PAM4 optical channels in 100-GHz WDM grid over record 140-km link distance.

Th.2.P2.SC2.19 Physical Layer Compact Models for Ring Resonators based Dense WDM Optical Interconnects
Sébastien Rumley, Meisam Bahadori, Dessislava Nikolova and Keren Bergman (Columbia University, USA)
♦ Two compact models relating the coupling and attenuation coefficient of ring resonators to their physical dimensions are introduced. We leverage these models to delimit the capabilities of ring resonators for dense WDM optical interconnects.

Th.2.P2.SC2.20 Back-Reflection Free Grating Couplers on Silicon-on-Insulator
Jeong Hwan Song and Xavier Rottenberg (IMEC, BE)
♦ We propose a design of novel grating couplers having low back-reflections on silicon-on-insulator (SOI) where grating trenches are asymmetrically etched. 3D-FDTD simulations show that the average back-reflection of 1dB bandwidth in the proposed grating coupler is -41dB.

SC 3 - Digital and Optical Signal Processing

Th.2.P2.SC3.21 Nonlinear Blind Equalization for 16-QAM Coherent Optical OFDM using Support Vector Machines
Elias Giacoumidis (University of Sydney, CUDOS, IPOS, AU); Mhatli Sofien (ENIT, TUN); Son Le (Aston University, UK); Ivan A Aldaya (University of Campinas, BR); Mary McCarthy and Andrew Ellis (Aston University, UK); Benjamin Eggleton (University of Sydney, AU)
♦ A novel blind nonlinear equalizer (BNLE) based on support vector machines is experimentally demonstrated for ~41-Gb/s 16-QAM CO-OFDM at 2000 km. For 2 dBm launched optical power, BNLE reduces the fiber nonlinearity penalty by ~1 dB compared to Volterra-based NLE.

Th.2.P2.SC3.22 Machine Learning for Optical Performance Monitoring from Directly Detected PDM-QAM Signals
Jesper Wass, Jakob Thrane, Molly Piels, Júlio C. M. Diniz and Rasmus Jones (Technical University of Denmark, DK); Darko Zibar (DTU Fotonik, Depertment of Photonic Engineering, Technical University of Denmark, DK)
♦ Supervised machine learning methods are applied and demonstrated experimentally for inband OSNR estimation and modulation format classification in optical communication systems. The proposed methods accurately evaluate coherent signals up to 64QAM using only intensity information.

Th.2.P2.SC3.23 Experimental Investigation of Compression with Fixed-length Code Quantization for Convergent Access-Mobile Networks
Luiz Anet Neto, Philippe Chanclou, Zakaria Tayq and Bidossessi Charlyse Zabada (Orange Labs, FR); Fabienne Saliou and Gael Simon (Orange, FR)
♦ We experimentally assess compression with scalar and vector quantization for fixed-mobile convergent networks. We show that four-dimensional vector quantization allows 73% compression compliant with 3GPP EVM recommendations for transmissions over 25 km SSMF with 1:16 split ratio.

Th.2.P2.SC3.24 Timing Jitter Impact on QAM Modulation of Frequency Combs Obtained by Cross Phase Modulation of Mode-locked Lasers
Mark Pelusi (University of Sydney, AU); Karen Solis-Trapala (EFFECT Photonics, NL); Takashi Inoue (National Institute of Advanced Industrial Science and Technology, JP); Hung Nguyen Tan (Danang University of Science & Technology, VN); Shu Namiki (National Institute of Advanced Industrial Science and Technology, JP)
♦ Lower noise frequency combs obtained from mode-locked semiconductor and mode-locked fiber lasers by cross-phase modulation of output pulses in nonlinear fiber are compared. The importance of low timing jitter for enabling comb-line modulation with 96-Gb/s-DP-16QAM and 64QAM signals is shown.

Th.2.P2.SC3.25 Polarization-Mode Dispersion Aware Digital Backpropagation
Cristian B. Czegledi (Chalmers University of Technology, SE); Gabriele Liga and Domanic Lavery (University College London, UK); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE); Erik Agrell (Chalmers University of Technology, SE); Seb J Savory (University of Cambridge, UK); Polina Bayvel (University College London, UK)
♦ We study a modified DBP algorithm that accounts for PMD. Based on the accumulated PMD at the receiver, the algorithm distributively compensates for PMD in the reverse propagation and outperforms the conventional approach by up to 2.1 dB.

Th.2.P2.SC3.26 On the Design of Capacity-Approaching Unit-Memory Spatially Coupled LDPC Codes for Optical Communications
Laurent Schmalen, Detlef Suikat, Vahid Aref and Detlef Rösener (Nokia Bell Labs, DE)
♦ We consider unit-memory spatially coupled LDPC codes for optical communications. We analyze the region of wave-like convergence using an FPGA-based windowed decoding emulator. We show that the post-FEC errors occur in long bursts and highlight some design guidelines.

Th.2.P2.SC3.27 Hardware-efficient Precise and Flexible Soft-demapping for Multi-Dimensional Complementary APSK Signals
Tsuyoshi Yoshida and Keisuke Matsuda (Mitsubishi Electric Corporation, JP); Keisuke Kojima (Mitsubishi Electric Research Laboratories, USA); Hiroshi Miura and Keisuke Dohi (Mitsubishi Electric Corporation, JP); Milutin Pajovic and Toshiaki Koike-Akino, David Millar and Kieran Parsons (Mitsubishi Electric Research Laboratories, USA); Takashi Sugihara (Mitsubishi Electric Corporation, JP)
♦ We propose the combination of log-likelihood ratio (LLR) table and min-sum algorithm-based LLR updates for simple, precise, and flexible soft-demapping of multi-dimensional complementary APSK signals. Transmission experiment verifies the demapping loss is limited to 0.15 dB in Q-factor.

Th.2.P2.SC3.28 Sub-Symbol-Rate Sampling of Super-Nyquist Signals
Cheng Xu, Guanjun Gao and Jie Zhang (Beijing University of Posts and Telecommunications, PRC); Sai Chen (Beijing University of Posts and Telecommunications & Bell Labs, Alcatel-Lucent, USA); Ming Luo (FiberHome, PRC); Rong Hu (State Key Lab. of Optical Comm. Technologies and Networks, PRC)
♦ We demonstrate 12-Gbaud WDM PDM-QPSK transmission with 10GHz channel spacing and only 9.6-GSa/s ADC sampling rate. By using 4PB shaping with MLSE, the sampling rate can be reduced to 0.8-times symbol-rate without OSNR penalty, compared with that of 2-times symbol-rate.

Th.2.P2.SC3.29 Efficient SDM-MIMO Stokes-Space Equalization
Francisco Javier Vaquero Caballero (Technical University of Denmark, DE); Abdullah Zanaty (University of Kiel, DE); Fabio Pittalá, Gernot Goeger and Yabin Ye (Huawei Technologies Duesseldorf GmbH, DE); Idelfonso Tafur Monroy (Technical University of Denmark, Denmark & ITMO University, RU); Werner Rosenkranz (University of Kiel, DE)
♦ We propose a novel frequency-domain 6x6 MIMO Stokes-space equalizer and compare its performance to a 6x6 MIMO LMS architecture. This method is suited to overcome DSP complexity and laser linewidth issues in SDM transmission systems.

Th.2.P2.SC3.30 Short-Reach Distance Extension through CAPS Coding and DSP-free Direct Detection Receiver
Francesco Fresi and Gianluca Meloni (CNIT, IT); Marco Secondini (Scuola Superiore Sant'Anna, IT); Fabio Cavaliere (Ericsson Telecomunicazioni, IT); Luca Potì (Consorzio Nazionale Interuniversitario per le Telecomunicazioni, IT); Enrico Forestieri (Scuola Superiore Sant'Anna, IT)
♦ Order-3 CAPS coding for short-reach direct-detection systems is experimentally demonstrated. Chromatic dispersion tolerance is compared to that of OOK and PAM-4 modulations, with respect to which transmission distance can be increased by a factor of 4 and 1.5, respectively.

Th.2.P2.SC3.31 Comparison of Multi-Channel Nonlinear Equalization using Inverse Volterra Series versus Digital Backpropagation in 400 Gb/s Coherent Superchannel
Vassiliki Vgenopoulou (Athens Information Technology, GR); M. Sezer Erkilinc and Robert I Killey (University College London, UK); Yves Jaouën (Telecom ParisTech, FR); Ioannis Roudas (Corning Inc., USA); Ioannis Tomkos (Athens Information Technology, GR)
♦ We investigate the performance of a Volterra-based nonlinear equalizer and the digital backpropagation (DBP) method in multi-channel nonlinear equalization after 20×80 km transmission distance. The Volterra equalizer, which operates with single-step-per-span, performs similarly compared to DBP with 40 steps-per-span

Th.2.P2.SC3.32 Experimental Investigation of GF(3 2) Nonbinary LDPC-coded Non-uniform 9-QAM Modulation Format
Zhen Qu, Changyu Lin, Tao Liu and Ivan B. Djordjevic (University of Arizona, USA)
♦ A specially designed GF(3^2) nonbinary LDPC-coded non-uniform 9-quadrature amplitude modulation (QAM) is proposed. The experimental and numerical results show that the proposed scheme outperforms nonbinary GF(2^3) LDPC-coded uniform 8-QAM by ~0.8-dB.

Th.2.P2.SC3.33 Selective wavelength conversion of multi-channel 16-QAM signal in a graphene-silicon microring resonator
Yun Long, Xiao Hu, Mengxi Ji, Li Shen and Andong Wang (Huazhong University of Science and Technology, PRC); Yi Wang (Wuhan National Laboratory for Optoelectronics & Huazhong University of Science and Technology, PRC); Jian Wang (Huazhong University of Science and Technology, PRC)
♦ By exploiting graphene-enhanced FWM in a graphene-silicon microring, we propose and experimentally demonstrate selective wavelength conversion of multi-channel 16-QAM signal. Efficient wavelength conversion and low crosstalk are observed when the channel spacing is 100 GHz and 50 GHz, respectively.

SC 4 - Subsystems for Optical Networking and Datacoms

Th.2.P2.SC4.34 Optical DAC for Generation of PAM4 Using Parallel Electro-Absorption Modulators
Wan-Jou Huang and Chia-Chien Wei (National Sun Yat-Sen University, TW); Jyehong Chen (National Chiao Tung University, TW)
♦ Employing a proposed optical 2-bit DAC based on parallel EAMs, we experimentally demonstrated 50- and 64-Gbps optical 4-PAM signals. Compared to using an electrical DAC, the optical DAC has better performance and higher tolerance to the operation conditions of modulators.

Th.2.P2.SC4.35 Hexagonal Reconfigurable Lattice Mesh for Programmable Photonic Processors
Daniel Pérez (Universidad Politécnica de Valencia, ES); Ivana Gasulla and Jose Capmany (Universidad Politecnica de Valencia, ES); Richard Soref (University of Massachusetts Boston, USA)
♦ We propose a hexagonal tuneable-coupler-based mesh design, for the implementation of reconfigurable optical cores in programmable processors. This hexagonal mesh outperforms the previously proposed square mesh topology in on-chip integration metrics and performance. We provide application examples and robustness simulations.

Th.2.P2.SC4.36 Single-Ended In-Service Hybrid Monitoring of Fibre-Extended Copper Lines
Gustavo Amaral, Andrea Baldivieso and Joaquim Dias Garcia (Pontifical Catholic University of Rio de Janeiro, BR); Patryk Urban (Ericsson AB, SE); Jean Pierre von der Weid (Pontifical Catholic University of Rio de Janeiro, BR)
♦ We report on the simultaneous monitoring of both fibre and copper links in a fibre-extended copper mobile fronthaul network. The monitoring signal, which is allocated to an optical subcarrier channel, is used to determine both the fibre's and copper's characteristics.

Th.2.P2.SC4.37 A Self-Optimizing 4-Channel 30 Gbaud/s PAM-4 Packaged Silicon Photonics Subsystem with Binary Driving Signals
Nathan Abrams, David M Calhoun, Christine Chen and Keren Bergman (Columbia University, USA)
♦ We demonstrate four channel PAM-4 modulation in a silicon-photonic platform driven by push-pull binary electrical signals. The subsystem self-optimizes through a gradient descent algorithm across the full range of starting voltages.

Th.2.P2.SC4.38 Overall Frequency Response Measurement of DSP-based Optical Transmitter Using Built-in Monitor Photodiode
Yangyang Fan, Zhenning Tao, Liang Dou, Ying Zhao, Hao Chen (Fujitsu Research and Development Center Company Limited, PRC); Saito Taku and Komaki Kousuke (Fujitsu Ltd., JP); Takeshi Hoshida and Jens C. Rasmussen (Fujitsu Laboratories Ltd., JP)
♦ To pre-equalize the bandwidth limitation at the transmitter side, the overall response of the transmitter is required. An accurate response measurement assisted by the photodiode built in Mach-Zehnder modulator is proposed and experimentally demonstrated.

Th.2.P2.SC4.39 Demonstration of a 71.8 Gbps 4-PAM 850 nm VCSEL-based Link with a Pre-emphasizing Passive Filter
Tamás Lengyel and Krzysztof Szczerba (Chalmers University of Technology, SE); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE); Anders Larsson and Peter A Andrekson (Chalmers University of Technology, SE)
♦ We present 71.8 Gbps 4-PAM back-to-back transmission in an 850 nm VCSEL-based link using a passive pre-emphasis filter and FEC with no post-equalization. Bit error rates below 10-8 are demonstrated with 72 Gbps uncoded data.

Th.2.P2.SC4.40 Service-triggered failure identification/localization through monitoring of multiple parameters
Marc Ruiz (Universitat Politècnica de Catalunya, ES); Francesco Fresi (CNIT, IT); Alba Vela (Universitat Politècnica de Catalunya (UPC), ES); Gianluca Meloni (CNIT, IT); Nicola Sambo (Scuola Superiore Sant'Anna, IT); Filippo Cugini (CNIT, IT); Luca Potì (Consorzio Nazionale Interuniversitario per le Telecomunicazioni, IT); Luis Velasco (Universitat Politècnica de Catalunya (UPC), ES); Piero Castoldi (Scuola Superiore Sant'Anna, IT)
♦ Failures in the optical layer might impact the quality of supported services. We experimentally characterize several failure causes and propose an effective machine learning-based algorithm to localize and identify the most probable cause of failure impacting a given service.

Th.2.P2.SC4.41 Cascadability Performance of a High-speed Electro-absorption Optical Switch for DP-16QAM and DP-QPSK Optical Signals
Hideaki Furukawa (NICT, JP); Jose Manuel Delgado Mendinueta (National Institute of Information and Communications Technology, JP); Toru Segawa (NTT Corporation & NTT Device Technology Laboratories, JP); Ryo Takahashi (NTT Device Technology Laboratories, JP); Satoshi Shinada (National Institute of Information and Communications Technology, JP); Naoya Wada (NICT, JP)
♦ We experimentally investigate the cascadability of electro-absorption optical switches for optical packet switched networks. Dual-polarization QPSK and 16QAM optical signals can cascade more than 50 and 10 EA optical switches, respectively, which is 1.6 times greater compared to SOA switches.

Th.2.P2.SC4.42 Direct Modulation of a Hybrid III-V/Si DFB Laser with MRR Filtering for 22.5-Gb/s Error-Free Dispersion-Uncompensated Transmission over 2.5-km SSMF
Valentina Cristofori, Francesco Da Ros and Yunhong Ding (Technical University of Denmark, DK); Alexandre Shen (Alcatel-Thales III-V Lab, FR); Antonin Gallet (III-V lab, a joint lab of Nokia, Thales and CEA, FR); Dalila Make (Alcatel Thales III-V Lab, FR); Guang-Hua Duan (III-V Lab, FR); Leif Oxenløwe (Technical University of Denmark, DK); Christophe Peucheret (University of Rennes 1, FR)
♦ Error-free and penalty-free transmission over 2.5 km SSMF of a 22.5 Gb/s data signal from a directly modulated hybrid III-V/Si DFB laser is achieved by enhancing the dispersion tolerance using a silicon micro-ring resonator.

Th.2.P2.SC4.43 Characterization of a Packaged Network on Chip based on Multi-Microrings
Stefano Faralli, Isabella Cerutti, Fabrizio Gambini and Paolo Pintus (Scuola Superiore Sant'Anna, IT); Giovan Battista Preve (CNIT, IT); Marco Chiesa (Scuola Superiore Sant'Anna, IT); Rubén Ortuño (Universidad Politécnica de Valencia & Nanophotonics Technology Center, ES); Nicola Andriolli (Scuola Superiore Sant'Anna, IT)
♦ A multi microring network on chip with 6 ports has been fabricated in SOI, packaged and characterized. The BER penalty for two simultaneous 10Gb/s transmissions of up to 5 hops is below 1 dB at BER of 10-9.

Th.2.P2.SC4.44 Single-Lane 112Gbps Transmission over 300m OM4 Multimode Fiber Based on A Single-Transverse-Mode 850nm VCSEL
Bo Wu (Huawei Technologies Co. Ltd, *PRC*); Xian Zhou (The Hong Kong *Polytechnic University, PRC); Yanan Ma, Jun Luo, Shaofeng Qiu (Huawei Technologies Co., Ltd, PRC); Kangping Zhong (The Hong Kong Polytechnic University, HK); Feng Zhiyong (Huawei Technologies Co., PRC); Chao Lu (The Hong Kong Polytechnic University, HK); Vitaly Shchukin and Joerg Kropp, Nikolay Ledentosov (VI Systems GmbH, DE)*
♦ Single-lane 120Gbps-BtB, 118Gbps-100m, 117Gbps-200m and 112Gbps-300m discrete multi-tone transmission based on a single-transverse-mode 850nm band VCSEL is investigated respectively over standard OM4 multimode fiber. This proves our previous conclusion of single-lane capacity beyond 100G by more optical coupling power

Th.2.P2.SC4.45 Precise Sub-carrier Frequency Monitor and Control Method for Superchannel Transmission in Cascaded ROADM Network
Guoxiu Huang, Shoichiro Oda (Fujitsu Laboratories Ltd., JP); Ying Zhao (Fujitsu Research and Development Center, PRC); Huihui Li (Fujitsu R&D Centre Co., Ltd., PRC); Tomohiro Yamauchi (Fujitsu Laboratories Ltd., JP); Setsuo Yoshida and Yasuhiko Aoki (Fujitsu Ltd., JP); Zhenning Tao (Fujitsu R&D Center Ltd., PRC); Jens C. Rasmussen (Fujitsu Laboratories Ltd., JP)
♦ We proposed precise sub-carrier frequency monitor and control method to eliminate laser frequency uncertainness in super-channel transmission. Based on digital signal processing without additional hardware, the relative frequency accuracy reached 10 times higher than ITLA specification.

Th.2.P2.SC4.46 End-to-end Optical 25Gb/s Link Demonstrator with Embedded Waveguides, 90°Out-of-Plane Connector and On-board Optical Transceivers
Marika Immonen (TTM Technologies, FN); Ruiyong Zhang (FCI Deutschland GmbH, DE); Marie Press, Hong Tang and Wanlu Lei (Ericsson AB, SE); Jinhua Wu and Hui Juan Yan (TTM Technologies, PRC); Long Xiu Zhu (TTM Technologies, FN); Murat Serbay (FCI Deutschland GmbH, DE)
♦ We present optical/electrical demonstrator with 96-optical channels totalling 2.4Tb/s aggregate capacity tested with 300Gb/s on-board transceivers, embedded waveguides, and connectors with 90° reflectors in a standard PCB. Results show BER 1E-12at 25Gb/s, <0.1dB/cm transmission loss and 2.5dB connector loss.

Th.2.P2.SC4.47 Monolithic Photonic-Electronic Linear Direct Detection Receiver for 56Gbps OOK
Marcel Kroh, Ahmed Awny (IHP Microelectronics, DE); Georg Winzer (IHP, DE); Rajasekhar Nagulapalli (Inphi, UK); Stefan Lischke (IHP Frankfurt/Oder, DE); Dieter Knoll and Anna Peczek (IHP GmbH, DE); Daniel Micusik (Rohde & Schwarz, DE); Ahmet Cagri Ulusoy and Dietmar Kissinger (IHP, DE); Lars Zimmermann (IHP & Technical University of Berlin, DE); Klaus Petermann (Technical University of Berlin, DE)
♦ A monolithic photonic-electronic direct detection single pol linear receiver chip is presented. Electro-optical bandwidth and BER measurements reveal state-of-the-art performance of the integrated receiver.

Th.2.P2.SC4.48 Experimental Demonstration of Full-Duplex Data Transmission Link using Twisted Lights Multiplexing over 1.1-km Orbital Angular Momentum (OAM) Fiber
Shi Chen and Jun Liu (Huazhong University of Science and Technology, PRC); Yifan Zhao (Huazhong University of Science and Technology & Wuhan National Laboratory for Optoelectronics, PRC); Long Zhu, Andong Wang, Jing Du, Shuhui Li and Jian Wang (Huazhong University of Science and Technology, PRC)
♦ We propose and demonstrate a full-duplex data transmission link using twisted light multiplexing over 1.1-km OAM fiber. The measured full-duplex OSNR penalties at BER of 2×10-3 for uplink and downlink are about 2.3 dB.

SC 5 - Point-to-Point Transmission Systems

Th.2.P2.SC5.49 Experimental Studies on Characteristics of Polarization Parameters over Atmospheric Turbulence
Jiankun Zhang, Ruijie Li and Anhong Dang (Peking University, PRC)
♦ We report an investigation on turbulence-induced changes for overall polarization parameters of light beams, with different wavelength and under different Rytov indexes. Experimental results show strong correlations between state of polarization and turbulent strength, which is consistent with theoretical predictions.

Th.2.P2.SC5.50 Investigation of Potential MPI Effects on Supervisory Channel Transmission Below Cable Cut-off in G.654 Fibres
John D Downie, Jason Hurley and Hector DePedro, Steven Garner, Jeremy Blaker, Aramais Zakharian, Sergey Ten and Greg Mills (Corning Incorporated, USA)
♦ We examine supervisory channel transmission at wavelengths below cable cut-off in G.654 fibres via modelling and cabled fibre tests. We find negligible MPI and no penalty for 2.5 Gb/s transmission in a worst-case configuration up to 40 nm below cut-off.

Th.2.P2.SC5.51 Experimental Investigation of Quasi-Periodic Power Spectrum in Raman-Assisted Phase Sensitive Amplifier for 10/20/50-Gbaud QPSK and 10-Gbaud 16QAM Signals
Yinwen Cao, Fatemeh Alishahi (University of Southern Californi, USA); Youichi Akasaka (Fujitsu Laboratories of America, Inc., USA); Morteza Ziyadi, Ahmed Almainman, Amirhossein Mohajerin-Ariaei, Changjing Bao and Peicheng Liao, Ahmad Fallahpour, Bishara Shamee (University of Southern California, USA); Tadashi Ikeuchi (Fujitsu Laboratories of America, Inc., USA); Shigehiro Takasaka and Ryuichi Sugizaki (Furukawa Electric co., Ltd., JP); Joe Touch (USC/ISI, USA); Moshe Tur (Tel-Aviv University, ISR); Alan Willner (University of Southern California, USA)
♦ Raman-assisted PSA without phase-stabilization-loop is experimentally evaluated by placing signals at different locations in a quasi-periodic PSA power spectrum. With phase adjustment, an 18dB peak-dip gain-extinction-ratio difference is observed. Improved performance is demonstrated using 10/20/50-Gbaud QPSK and 10-Gbaud 16QAM signals.

Th.2.P2.SC5.52 5-band (O, E, S, C, and L) WDM Transmission with Wavelength Adaptive Modulation Format Allocation
Seiji Okamoto, Kengo Horikoshi, Fukutaro Hamaoka, Kyo Minoguchi and Akira Hirano (NTT Corporation, JP)
♦ We propose wavelength adaptive modulation format allocation method for extremely wide WDM system. We successfully demonstrated 5-band WDM transmission for the first time, and showed potential capacity achieves 106.77 Tbit/s within 23.5 THz or 173.83 nm using proposed method.

Th.2.P2.SC5.53 A Digital Coherent Optical Code Division Multiplexing Network with 16-Tb/s (2560×6.25-Gb/s) Capacity
Xie Wang, Yuanda Huang, Yanzhao Lu, Yi Yu and Liangchuan Li (Huawei Technologies Co., Ltd., PRC)
♦ We experimentally demonstrate a digital coherent optical code division multiplexing network with total capacity of 16-Tb/s (80×32×6.25-Gb/s) in C-band featuring 6.25-Gb/s per node for 2560 supported nodes over 300-km standard-single-mode-fiber.

Th.2.P2.SC5.54 150-Gb/s DMT over 80-km SMF transmission based on Spectrally Efficient SSBI cancellation using guard-band Twin-SSB Technique
Liang Zhang and Tianjian Zuo (Huawei, PRC); Qiang Zhang (Huawei Technologies Duesseldorf GmbH, DE); Jie Zhou, Enbo Zhou, Gordon Ning Liu (Huawei Technologies Co. Ltd., PRC)
♦ We propose a spectrally efficient SSBI cancellation scheme based on guard-band twin-SSB technique. 112-Gb/s DMT transmission over 80-km SMF is experimentally demonstrated with an ROSNR of 30.7 dB and the highest achieved capacity is up to 150 Gb/s.

Th.2.P2.SC5.55 Advanced Receiver Design enables PDM-16QAM DWDM Transmission over 2660 km of SSMF with Only EDFA
Xiaozhou Wang (Universität der Bundeswehr München & Coriant GmbH, DE); Stefano Calabro and Bernhard Spinnler (Coriant R&D GmbH, DE); Ginni Khanna (Technical University of Munich, DE); Berthold Lankl (University of Federal Armed Forces Munich, DE)
♦ We demonstrate experimental DWDM PDM-16QAM transmission at 200 Gb/s over 2660 km of SSMF, using EDFA-only amplification and advanced DSP techniques, including powerful digital pre-distortion, iterative carrier recovery and decoding using 50% OH soft-decision FEC.

Th.2.P2.SC5.56 Experimental Nonlinear Frequency Division Multiplexed Transmission using Eigenvalues with Symmetric Real Part
Alexander Geisler and Christian Schaeffer (Helmut-Schmidt-University, DE)
♦ We demonstrate the nonlinear transmission of a PSK modulated discrete spectrum consisting of up to 3 eigenvalues, 2 of them having non-zero symmetric real parts. A low error rate using NFT detection at 4Gbps is shown.

Th.2.P2.SC5.57 Correlation Between Modulated and Probe Signals for Superchannel Inter-Subcarrier Nonlinear Phase Perturbations
Ali Rezania, John C Cartledge and Aazar Kashi, Ali Bakhshali, Ahmed Abd El-Rahman (Queen's University, CA)
♦ For a 1 Tb/s dual-polarization 16-QAM Nyquist-superchannel, the degree of correlation for the inter-subcarrier nonlinearity induced phase perturbation is assessed between a modulated center subcarrier and a CW probe center subcarrier.

Th.2.P2.SC5.58 Power Consumption of a Minimal-DSP Coherent Link with a Polarization Multiplexed Pilot-Tone
Lars Lundberg, Christoffer Fougstedt, Per Larsson-Edefors and Peter A Andrekson (Chalmers University of Technology, SE); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE)
♦ We experimentally study the trade-off between performance and DSP power consumption. While minimal DSP allows transmission of 16QAM at 5GBaud, the symbol rate can be increased if an extra equalizer is added, leading to energy savings in optical components.

Th.2.P2.SC5.59 Cross Polarization Modulation (XPolM) Compensation for Submarine Upgrade Links using DP-8QAM
Milutin Pajovic, David Millar, Kieran Parsons (Mitsubishi Electric Research Laboratories, USA); Keisuke Matsuda and Hiroshi Miura (Mitsubishi Electric Corporation, JP); Keisuke Kojima Toshiaki Koike-Akino (Mitsubishi Electric Research Laboratories, USA); Tsuyoshi Yoshida (Mitsubishi Electric Corporation, JP)
♦ We propose a method of XPolM compensation suitable for submarine upgrade systems, and experimentally validate performance for a 70 × 192 Gb/s DP-8QAM system. The method improves the Q-factor by 0.16dB and outperforms the conventional NPCC by 0.12dB.

Th.2.P2.SC5.60 Stochastic Nonlinear Interference in Dispersion Managed Coherent Optical Links
Nicola Rossi (Nokia Bell Labs, FR); Amirhossein Ghazisaeidi (Université Laval, CA); Petros Ramantanis (Nokia Bell Labs, FR)
♦ We numerically investigate the stochastic nature of nonlinear interference in dispersion managed links. We show deviation of signal statistics from Gaussian assumption and significant performance variability due to interaction between nonlinearity and polarization mode dispersion.

Th.2.P2.SC5.61 Improving 100-Gb/s Transmission Performance in a 1250-km Legacy Dispersion-Managed Link with Co-Propagating 10-Gb/s OOK Channels via Modified Phase-Conjugated Twin Waves
Xuefeng Tang, Zhuhong Zhang and Zhiping Jiang (Huawei Technologies (Canada), CA); Xiang Liu (Futurewei Technologies, USA); Chuandong Li (Huawei Technologies (Canada), CA)
♦ We experimentally demonstrate the improved nonlinear transmission performance of a 100-Gb/s channel using modified phase-conjugated twin waves in a 1250-km legacy dispersion-managed SSMF link and 50-GHz-spaced co-propagating 10-Gb/s OOK channels, achieving 0.7dB improved performance over a common 100-Gb/s DP-QPSK channel.

Th.2.P2.SC5.62 Optimum Capacity Utilization in Space-Division Multiplexed Transmission Systems with Multimode Fibers
Georg Rademacher and Friederike Schmidt, Klaus Petermann (Technical University of Berlin, DE)
♦ For maximum capacity utilization, all spatial channels in space-division multiplexed transmission systems are desired to perform equally. We show that an optimized per-mode power is capable of increasing the overall system OSNR.

Th.2.P2.SC5.63 Mitigation of Fading Caused by Atmospheric Turbulence with FMF Coupling and Maximum Ratio Combining Used in 320-m Free-Space Optical Transmission of 10 Gb/s BPSK
Manabu Arikawa, Takashi Ishikawa, Kohei Hosokawa, Seigo Takahashi, Yoshimasa Ono and Toshiharu Ito (NEC Corporation, JP)
♦ We experimentally demonstrated the sum of the six modes of FMF improved coupling efficiency by 6.5 dB for the optical beam impaired by 320-m open-air free-space transmission, and fading was suppressed by digital maximum ratio combining for 10 Gb/s BPSK.

Th.2.P2.SC5.64 Achievable Information Rate of Nonlinear Inverse Synthesis Based 16QAM OFDM Transmission
Son Le and Ian Phillips (Aston University, UK); Jaroslaw Prilepsky , Morteza Kamalian, Kopae (Aston University & Aston Institute of Photonic Technologies, UK); Andrew Ellis and Paul Harper (Aston University, UK); Sergei K. Turitsyn (Aston University & Photonics Research Group, UK)
♦ We experimentally investigate, for the first time, the achievable information rate of the nonlinear inverse synthesis system with 16QAM OFDM format employing hard and soft FEC, showing that 3 bits/symbol can be achieved over a distance of 1632 km.

SC 6 - Core, Metro and Data Center Networks

Th.2.P2.SC6.65 Demonstration of a Hybrid SDN/GMPLS Control Plane for Optical Virtual Private Networks with Restoration Capabilities
Domenico Siracusa, Federico Pederzolli , Matteo Gerola and Andrea Zanardi (Create-Net, IT); Domenico La Fauci and Gabriele Maria Galimberti (Cisco Photonics, IT)
♦ Creating Optical Virtual Private Networks (OVPNs) over existing deployments is becoming an operator concern. This paper describes the first hybrid SDN/GMPLS implementation addressing this problem and demonstrates, through an emulated testbed, that the system is responsive and provides OVPN-specific restoration.

Th.2.P2.SC6.66 Crosstalk-aware Virtual Optical Network Embedding (VONE) in Spatial Division Multiplexing Enabled Elastic Optical Networks with Multi-core Fibers
Ruijie Zhu and Yongli Zhao, Hui Yang, Yuanlong Tan, Xiaosong Yu, Guanjun Gao and Jie Zhang (Beijing University of Posts and Telecommunications, PRC); Nannan Wang and Jason P. Jue (University of Texas at Dallas, USA)
♦ A crosstalk-aware VONE (CA-VONE) algorithm is proposed for spatial division multiplexing enabled elastic optical networks with multi-core fibers. Simulation results show that CA-VONE can achieve better performance than the previous algorithms in terms of blocking probability and resource utilization.

Th.2.P2.SC6.67 Experimental Demonstration of a Programmable S-BVT with PDM Capability for Flexible Optical Metro Networks
Laia Nadal Reixats and Michela Svaluto Moreolo, Josep M. Fabrega, Francisco Javier Vilchez (Centre Tecnològic de Telecomunicacions de Catalunya, ES)
♦ We experimentally demonstrate a programmable sliceable-BVT with PDM capability and adaptive FEC selection based on DD-OFDM, achieving 40G-100G transmission rates. PDM slice-ability is also assessed within the ADRENALINE network nodes enabling up to 50\% spectral saving.

Th.2.P2.SC6.68 Transport API: A Solution for SDN in Carriers Networks
Victor Lopez (Telefonica, ES); Ricard Vilalta (CTTC, ES); Víctor Uceda (Universidad Autónoma de Madrid, ES); Arturo Mayoral (CTTC, ES); Ramon Casellas (Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), ES); Ricardo Martinez and Raul Muñoz (CTTC, ES); Juan P. Fernández-Palacios (Telefónica I+D, ES)
♦ The ONF Transport API is an interface to enable control of Transport networks, including services such as topology, or connectivity setup. We present the first demonstration of a connectivity service over a DWDM network using the ONF Transport API.

Th.2.P2.SC6.69 Nonlinear-impairments- and crosstalk-aware resource allocation schemes for multicore-fiber-based flexgrid networks
Madushanka Nishan Dharmaweera and Li Yan (Chalmers University of Technology, SE); Magnus Karlsson (Chalmers University of Technology & Photonics Laboratory, SE); Erik Agrell (Chalmers University of Technology, SE)
♦ In this study, we propose a novel spectrum and core allocation scheme that incorporates both intra-core physical layer impairments and inter-core crosstalk. We demonstrate that accounting for the latter increases spectral efficiency by at least 50% when crosstalk is significant.

Th.2.P2.SC6.70 On Deploying Encryption Solutions to Provide Secure Transport-as-a-Service (TaaS) in Core and Metro Networks
Kyle C Guan and Joseph Kakande (Bell Labs, Nokia, USA); Junho Cho (Nokia Bell Labs, USA)
♦ We study different architectural options of deploying OTN encryption solutions for the core or metro transport networks, by evaluating the equipment cost, bandwidth utilization, and complexity of key management under different traffic patterns.

Th.2.P2.SC6.71 Results of Empirical Searches for k-Connected Minimum-Mean-Hop Network Topologies
Joseph Kakande and Steve Korotky (Nokia Bell Labs, USA)
♦ We identify members of the sets of non-degenerate k-connected Minimum-Mean-Hop topologies for a given number of nodes and links using empirical searches and substantiate the accuracy of an approximation for the minimum average hops for 2-connected graphs.

SC 7 - Access, Local Area and Home Networks

Th.2.P2.SC7.72 Unified Evolution-Ready 25 Gbps NG-PON Architecture
Vincent Houtsma (Nokia Bell Labs, USA); Dora van Veen (Nokia Bell Labs, USA); Ed Harstead (Alcatel-Lucent, BE)
♦ First experimental proof of a unique evolution-ready 25G TDM-PON architecture featuring dual-rate 10 and 25 Gbps upstream. The architecture supports a novel black-box approach taking into account future optical and electronic component cost evolutions.

Th.2.P2.SC7.73 Multi-Core Based 94-GHz Radio and Power over Fiber Transmission Using 100-GHz Analog Photoreceiver
Toshimasa Umezawa, Atsushi Kanno, Tien Dat Pham, Kouichi Akahane, Yoshinari Awaji, Naokatsu Yamamoto and Tetsuya Kawanishi (National Institute of Information and Communications Technology (NICT), JP)
♦ We propose a multi-core-based radio and power over fiber transmission using a 100 GHz photoreceiver, and demonstrate 1 m photonic wireless transmission at 10 Gbps (OFDM, 16QAM, 3 GHz) through a photonic power supply via cores in a multi-core fiber.

Th.2.P2.SC7.74 Ultrahigh-Fidelity Mobile Fronthaul Using Analog Angle Modulation
Di Che (The University of Melbourne & National ICT Australia, AU); Feng Yuan and William Shieh (University of Melbourne, AU)
♦ We propose angle modulation to remarkably enhance the SNR of channel-aggregation-based analog fronthaul link. Experiments show >27-dB SNR improvement using CPRI-equivalent bandwidth and >5 dB advantage of nonlinearity tolerance, compared with amplitude modulation.

Th.2.P2.SC7.75 TWDM-PON ONUs Optical Frequency Drift versus Tuning
Gael Simon and Fabienne Saliou (Orange, FR); Philippe Chanclou (Orange Labs, FR); Bertrand Le Guyader (Orange, FR); Laurent Guillo (France Telecom R&D, FR); Luiz Anet Neto (Orange Labs, FR); Didier Erasme (Telecom ParisTech, FR)
♦ A vendor's TWDM-PON system and a commercial laser permit to demonstrate that reaching optical budget requirements for all NG-P ON2 capable channels signifies failing upstream spectral excursion requirements, and reciprocally.

Th.2.P2.SC7.76 Multi-Dimensional Resources Integration for Service Provisioning in 5G Cloud Radio over Fiber Network
Hui Yang, Wei Bai, Yuanlong Tan, Ao Yu, Jie Zhang (Beijing University of Posts and Telecommunications, PRC); Young Lee (Huawei Technologies Co., Ltd, USA); Yuefeng Ji (Beijing University of Posts and Telecommunications, P.R. China)
♦ We propose a multi-dimensional resources integration (MDRI) architecture for services provisioning with resources integrated provisioning (RIP) scheme in software defined cloud radio over fiber network of 5G. The feasibility and efficiency are verified on OpenFlow-based enhanced SDN testbed.

Th.2.P2.SC7.77 Feasibility Study on In-Band Unidirectional ONU Control of the 10G-class WDM Overlaid Digital Baseband UHD Video Distribution System
Toshiaki Shitaba, Tomohiro Taniguchi and Hidekazu Shimizu (NTT Corporation, JP); Toshihito Fujiwara (NTT & NTT Access Network Service Systems Laboratories, JP); Hisao Yoshinaga and Tomoki Sugawa (NTT Corporation, JP)
♦ This paper describes a downlink digital baseband video distribution system using WDM-overlay technology. An experiment confirms the feasibility of in-band carousel ONU control, a key technology of the system.

Th.2.P2.SC7.78 Direct Detection OFDM PON using Ge-on-Si Photodetector Employing Volterra Filtering for Nonlinear Compensation
Yung Hsu, Jun-jie Liu (National Chiao Tung University, TW); Xinru Wu (The Chinese University of Hong Kong, HK); Hsin-Yu Wu (National Chiao Tung University, TW); Chien-Hung Yeh (Industrial Technology Research Institute, TW); Hon Tsang (The Chinese University of Hong Kong, HK); Jyehong Chen and Chi-Wai Chow (National Chiao Tung University, TW)
♦ We propose and demonstrate a Ge-on-Si photodetector-based direct-detection orthogonal-frequency-division-multiplexing passive-optical-network (OFDM-PON) employing Volterra-filtering for nonlinear compensation. Capacity is enhanced by 49.55% to data-rate of 53.8Gbit/s after 20-km standard-single-mode-fiber (SSMF).

Th.2.P2.SC7.79 LTE-A Multiband and Ethernet over Large-core Diameter GI POF for Wired and Wireless In-home Networks
Federico Forni (Eindhoven University of Technology & Genexis B. V., NL); Yan Shi (Genexis, NL); Henrie van den Boom, Eduward Tangdiongga (Eindhoven University of Technology, NL); Ton Koonen (COBRA, Eindhoven University of Technology, NL)
♦ We demonstrate the successful co-transmission of 7 standard-compliant 64-QAM LTE-A bands and 2Gb/s 4-PAM over 35m of 1mm core diameter GI-POF and 3.5m LOS and NLOS wireless links. This demonstrates the suitability of POF for the next-generation home-appliance wireless-wired services.

Th.2.P2.SC7.80 Optical Beating Interference Reduction by Using Optical Pulse Division Multiplexing in IM/DD based OFDMA-PON Uplink
Sun-Young Jung, Chang-Hun Kim, Sang-Min Jung and Sang-Kook Han (Yonsei University, KR)
♦ Optical beating interference (OBI) hinders signal detection in IM/DD based multiple access with single nominal wavelength. Optical pulse division multiplexing based OBI reduction is proposed and experimentally demonstrated in OFDMA-PON uplink by considering spectrum broadening and near-orthogonality.

Th.2.P2.SC7.81 Real-Time Demonstration of an Optically Powered Radio Head for Low-Power Small Cells with 94 dB End-to-End Budget
Bernhard Schrenk, Thomas Zemen (AIT Austrian Institute of Technology GmbH, AUT)
♦ End-to-end analogue down- and uplink radio transmission with real-time signal processing is experimentally demonstrated using a technologically lean and energy-conscious remote radio head. Powering through the fronthaul at an optical feed of 290 mW enables a centralised power supply.

Th.2.P2.SC7.82 Multilevel Pulse Width Modulation Fibre Optic Transmission for Next Generation Mobile Fronthaul
Paola Parolari and Alberto Gatto (Politecnico di Milano, IT); Lorenzo Combi (DEIB Politecnico di Milano, IT); Pierpaolo Boffi, Mario Martinelli and Umberto Spagnolini (Politecnico di Milano, IT)
♦ Multilevel pulse width modulation for optical C-RAN fronthaul is proved and compared with standard pulse width modulation for aggregated LTE channels. Transmission over 7.5-km SSMF in a WDM PON fronthaul network is experimentally demonstrated for 16 LTE-64QAM aggregated channels.

Th.2.P2.SC7.83 Energy-Efficient Cycle Length Compressing Scheme for TDM based Passive Optical Network
Yunxin Lv, Ning Jiang and Chenpeng Xue, Kun Qiu (University of Electronic Science and Technology of China, PRC)
♦ An energy-efficient scheme based on cycle length compressing is proposed and analysed. By periodically compressing polling cycle length, longer sleeping time as well as substantial energy saving are obtained at ONU.

Author List

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Fraunhofer
Heinrich Hertz Institute

LED BASED OPTICAL WIRELESS BACKHAUL LINK

Robust, low latency infrared LED link for mobile backhaul

Specifications

- Infrared LED based
- Easy alignment:
  500 Mbps over 100 m
  250 Mbps over 200 m
- Bidirectional data exchange
- Dynamic rate adaptation
- Latency: < 2 ms
- 1 GbE chipset and interface
- Footprint and weight:
  240 mm x 230 mm x 130 mm, 3 kg

Benefits

- Low cost optical wireless link based on infrared LEDs

Applications

- Wireless point-to-point communication in industrial environments
- Backhauling for WiFi and LTE
- Building to building connectivity
- Redundancy for fixed line connection

Distributed by:

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E-Mail: products-pn@hhi.fraunhofer.de
Web: www.hhi.fraunhofer.de/LED-Backhaul

General Informations

ECOC 2016 Conference Venue

Congress Center Düsseldorf (CCD)

Stockumer Kirchstraße 61
40474 Düsseldorf, Germany
www.d-cse.de

ECOC 2016 Organization Office

VDE-Conference Services
Ms Hatice Altintas

Phone: +49-(0)69-63 08-477
Fax: +49-(0)69-63 08-144

Stresemannallee 15
60596 Frankfurt, Germany

E-mail: hatice.altintas@vde.com
Internet: www.ecoc-conference.org

ECOC 2016 Website and App

All the information concerning the ECOC 2016 Conference can be found at: www.ecoc-conference.org

The Conference app ECOC 2016 is available to download for Android devices (https://play.google.com/store/apps) and Apple devices (https://www.apple.com/itunes/)

Wi-Fi

There will be free WIFI access available in the conference venue including the conference rooms, the foyers as well as the Exhibition Hall.

Search for network name: **ECOC2016**

Enter Password: **pam4keysight**

How to get to Düsseldorf & the Venue

By Public Transport

The U78/U79 underground lines and the 722 bus will take you quickly and conveniently to the CCD Congress Center Düsseldorf.

Take the U78 (from the direction of the city centre) or the U79 (from the direction of the city centre, Kaiserswerth, Wittlaer and Duisburg) to the **Messe Ost/Stockumer Kirchstrasse** stop. From there it is a roughly 15-minutes' walk, across Stockumer Kirchstrasse, to the CCD Congress Center Düsseldorf.

Alternatively you can take the 722 bus (from the main train station) to the last stop CCD Stadthalle (entrance to the ECOC venue).

Shuttle Busses

Shuttle busses will be available from the underground station "Messe Ost/Stockumer Kirchstrasse" to the CCD Stadthalle.

Free Public Transportation Ticket

All the registered conference delegates will receive a 5 day **"KombiTicket"** giving access to all the public transportations (Bus, Underground, S-Bahn) within and in the surroundings of Düsseldorf including the Düsseldorf Airport.

Taxi from Airport

The airport is just three kilometres from the CCD Congress Center Düsseldorf.

Düsseldorf taxi switchboard: +49 (0)211 333-33
or: +49 (0)211 999-99

Rhein-Taxi: +49 (0)211 212121

The basic charge is 4.50 EUR, each additional kilometre will cost 2 EUR. For credit card payments, a surcharge of 2 EUR will apply.

For taxi rides from Düsseldorf Airport to all of the entrances of Messe Düsseldorf or vice versa, a special price of 20,00 EUR for each ride applies day and night.

By Car

Just follow the signs to Messe Düsseldorf. When you reach the immediate congress centre environs, follow the special signs CCD Stadthalle, CCD Süd or CCD Ost and the parking signs P3, P4 or P5. If necessary, the big car parks at Messe Düsseldorf can also be used.

Input data for your GPS:

Rotterdamerstrasse 144
40474 Düsseldorf

Parking (Fee: 3 € per hour/max. 15 €)

More than 1,200 parking spaces are available right by the CCD Congress Center Düsseldorf. The Düsseldorf fair is easily reached by car and around the CCD Congress Center Düsseldorf are several parking areas, which provides many and close parking options.

Parking space 1:
CCD 4: Address: Stockumer Kirchstraße, 40474 Düsseldorf

Parking space 2:
CCD 3: Address: Stockumer Kirchstraße, 40474 Düsseldorf

Parking space 3:
CCD 5: Address: Rotterdamer Straße, 40474 Düsseldorf

Parking space 4:
P7 Messe Ltu-Arena /
Esprit Arena: Address: Ltu-Arena-Straße 1, 40474 Düsseldorf

Travelling from the north

Follow the A52 in the direction of Düsseldorf. Change to the A44 in the direction of the airport (Düsseldorf Flughafen). Leave the motorway at the Düsseldorf Stockum exit and follow the signs CCD Süd / CCD Stadthalle.

Travelling from the south

Follow the A57. At Meerbusch switch to the A44 in the direction of the airport (Flughafen). After the tunnel leave the motorway at the Messe / Arena exit and follow the signs CCD Süd / CCD Stadthalle.

Travelling from the east

Follow the A3. At Velbert take the A44 in the direction of the airport (Flughafen). Leave the motorway at the Düsseldorf Stockum exit and follow the signs CCD Süd / CCD Stadthalle.

Travelling from the west

Follow the A57. At Meerbusch switch to the A44 in the direction of the airport (Flughafen). After the tunnel leave the motorway at the Messe / Arena exit and follow the signs CCD Süd / CCD Stadthalle.

Accommodation

During the conference you can contact the hotels agencies below for room changes or any other questions concerning your room reservation.

Business Travel & Convention Service Team

Phone: +49 (0)211 17 202-839 Fax: +49 (0)211 17 202-3221

E-mail: messe@duesseldorf-tourismus.de
Website: www.duesseldorf-tourismus.de/en/conference/ecoc

Smart and More Service Team

Phone: +49 (0)40 88 171 240

E-mail: smartfairs@smartandmore.de
Website: www.tms.smartandmore.de/ecoc/2016

Onsite Registration

The Conference Registration desk is located in the Foyer of the Stadthalle (see map on page 79)

Please note that the Exhibition registration desk will also be located at the Congress Centre Stadthalle. You do not need to register for the exhibition as the Conference badge gives you full access to it. The Exhibition will be located in Hall 3 (see map on page 78, 79).

Conference Registration Opening Times

Sunday, September 18. . . . . 08:00 – 18:00
Monday, September 19 . . . . . 08:00 – 18:00
Tuesday, September 20 . . . . . 08:00 – 18:00
Wednesday, September 21 . . 08:00 – 18:00
Thursday, September 22 . . . . 08:00 – 16:00

Name Badges

Delegate badges must be worn at all times to gain access to the conference sessions, exhibition and social events.

Baggage Room and Cloakroom for Delegates

There are cloakroom facilities at the CCD within the Conference and Exhibition registration area. The Organizers cannot be held responsible for damage to or loss of their personal property howsoever caused.

Opening Times

Sunday, September 18. . . . . 08:00 – 20:00
Monday, September 19 . . . . . 08:30 – 22:00
Tuesday, September 20 . . . . . 08:00 – 18:30
Wednesday, September 21 . . 08:00 – 18:00
Thursday, September 22 . . . . 08:00 – 17:00

Social Events

Get Together Drink

Sunday, September 18, 18:00 - 19:30

Location: Conference Venue CCD, Wintergarden Restaurant South

Attendance to the Get Together is included in the Conference registration fee. Conference delegates will not be issued an extra ticket, the Conference badge will grant you access to the Get Togehter.Join your colleagues for a pre-conference drink. Access is free to all registered conference delegates.

Welcome Reception

Monday, September 19, 18:00 - 20:30

Location: Conference Venue CCD, Big Foyer Stadthalle

Attendance to the Welcome Reception is included in the Conference registration fee. Conference delegates will not be issued an extra ticket, the Conference badge will grant you access to the Welcome Reception. Additional Welcome Reception tickets can be booked at the Conference registration desk.

Conference Dinner

Wednesday, September 21, 19:30 - 22:30

Location: **The Classic Remise** (a center for vintage cars in a historic roundhouse for locomotives.)

The Conference Dinner is NOT included in the conference registration fees.

Conference delegates who have registered and paid for the conference dinner will get a ticket together with their conference badge at the Conference Registration desk.

A limited number of tickets are still available to purchase at the Conference registration desk.

The transfert to the location Classic Remise will be done by Oldtimer busses:

Meeting point and departure: In front of the Conference Registration desk at 18:00 h.

Return bus services will be provided from the Classic Remise to the Congress Centre.

Classic Remise Düsseldorf
Harffstr. 110a
D – 40591 Düsseldorf
Phone: +49 (0)211 22950570
Fax: +49 (0)211 22950579
E-Mail: duesseldorf@remise.de

Coffee Breaks and Lunch

Coffee breaks: Coffee breaks are included in the conference registration and will be held in the following places and times:

Day	Location	Time
Sunday, September 18	Foyer CCD close to the conference rooms	15:30 – 16:00
Monday, September 19	Exhibition Hall	15:30 – 16:00
Tuesday, September 20	Exhibition Hall	10:30 – 11:00
Wednesday, September 21	Exhibition Hall	10:30 – 11:00 + 15:30 – 16:00
Thursday, September 22	Foyer CCD close to the conference rooms	10:30 – 11:00

General Informations

Lunch: Lunch is NOT included in conference registration fees. However there are a variety of "Food Beverage selling points" and Restaurants in the CCD as well as inside the Exhibition Hall, where the coffee breaks will be served from Monday to Wednesday.

Restaurant / Refreshment Opening Days and Times

Sunday, September 18		
CCD Süd Restaurant	10:00 – 17:00	
Monday, September 19		
Exhibition Hall - Pick up One	09:00 – 16:30	
Exhibition Hall - Pick up Two	09:00 – 16:30	
Main Foyer Bar	08:00 – 18:00	
Exhibition Hall Delegate Coffee Point 1	09.30 – 16:30	When delegate coffee is not being served.
Exhibition Hall Delegate Coffee Point 2	09.30 – 16:30	When delegate coffee is not being served.
Exhibition Hall Restaurant	11:00 – 15:00	Sit down. Hot and cold food served.
CCD Süd Restaurant	11:00 – 15:00	Sit down. Hot and cold food served.
Tuesday, September 20		
Exhibition Hall Pick up One	09:00 – 16:30	
Exhibition Hall Pick up Two	09:00 – 16:30	
Main Foyer Bar	08:00 – 18:00	
Exhibition Hall Delegate Coffee Point 1	09.30 – 16:30	When delegate coffee is not being served.
Exhibition Hall Delegate Coffee Point 2	09.30 – 16:30	When delegate coffee is not being served.
Exhibition Hall Restaurant	11:00 – 15:00	Sit down. Hot and cold food served.
CCD Süd Restaurant	11:00 – 15:00	Sit down. Hot and cold food served.
Wednesday, September 21		
Exhibition Hall Pick up One	09.30 – 16:00	
Exhibition Hall Pick up Two	09.30 – 16:00	
Main Foyer Bar	08:00 – 18:00	
Exhibition Hall Delegate Coffee Point 1	09.30 – 16:00	When delegate coffee is not being served.
Exhibition Hall Delegate Coffee Point 2	09.30 – 16:00	When delegate coffee is not being served.
Exhibition Hall Restaurant	11:00 – 15:00	
CCD Süd Restaurant	11:00 – 15:00	
Thursday, September 22		
CCD Süd Restaurant	10:00 - 17:00	

ECOC Exhibition

The Exhibition will take place in Hall 3 of the CCD. The conference participants have automatically access to the exhibition. On Tuesday, September 20, the conference will stop from 14:00–16:00 to allow the Conference participants to visit the Exhibition. www.ecocexhibition.com

Exhibition opening hours:

Monday, September 19 . . . . . 09.30 – 17:00

Tuesday, September 20 . . . . . 09:30 – 17:00

Wednesday, September 21 . . 09:30 – 16:00

ECOC 2016 Programme

Details of times and technical sessions can be found on the ECOC website:

www.ecoc-conference.org/Programme

A printed copy of the programme will be included in the conference bags upon registration.

A digital copy of the programme and papers will be also included on the USB memory stick (proceedings) as well as in the conference app.

Workshops

Sunday, September 18, 13:30 – 18:00

Conference Venue (CCD)

See details in your printed copy of the programme or on the website or in the conference app ECOC 2016 which is available to download for Android devices (https://play.google.com/store/apps) and Apple devices (https://www.apple.com/itunes/). The 6 workshops are open to all conference delegates.

Opening and Plenary Session

Monday, September 19, 10:00 – 12:00

Auditorium (Room 1), Conference Venue (CCD Stadthalle)

The plenary session is open to delegates, exhibitors / exhibition visitors and the general public.

Poster Sessions

The poster area will be located in the Big Foyer of the CCD Stadthalle.

Poster presenting authors can display their poster starting from Tuesday, September 20, from 09:00 h and they may remain until the end of the Conference on September 22, 2016, 16:00 h.

Posters not withdrawn after that time will be destroyed.

Poster Session I: Wednesday, September 21, 16:00 – 17:30.

Poster Session II: Thursday, September 22, 11:00 – 12:30.

Oral Sessions

All oral, contributed, invited, tutorial, symposia and post-deadline sessions will be presented at the Conference Venue (CCD Stadthalle).

From Monday, September 19 to Thursday, September 22.

See details in your printed copy of the programme or on the website or conference app.

Media Check

The media check room is located in the CCD Room 10.

Authors are asked to upload their PowerPoint Presentation in the media check room at least 30 min. prior to their sessions begin.

For authors scheduled on Sunday, September 18 during a workshop, they should bring their memory stick at least 1 hour before the beginning of the workshop, directly to their workshop room.

Media Check Room opening hours

Sunday, September 18 . . . . . 14:00 – 18:00

Monday, September 19 . . . . . 08:00 – 18:00

Tuesday, September 20 . . . . . 08:00 – 18:00

Wednesday, September 21 . . 08:00 – 18:00

Thursday, September 22 . . . . 08:00 – 15:00

Closing Ceremony

Thursday, September 22, 15:30 – 16:00.

The closing ceremony, including the Best Student Paper Award sponsored by ADVA will take place in Room 1 (Auditorium). The closing ceremony is open to all registered participants.

Post Deadline Papers Proceedings

ECOC 2016 printed proceedings of post-deadline papers will be available starting Tuesday, September 20, morning on the message board and at the Confverence Registration desk.

Currency & ATM Machine

The currency in Germany is Euros €.

The venue has an ATM Machine located at the south entrance.

Electrical Charging Points

There will be electrical charging points in the CCD (voltage is 220 v.). Depending on your device, a plug adaptor may be necessary; please check in advance.

Press Room

The Press Room is located in the Exhibition Hall.

Only press representatives correctly identified will be allowed to use this room.

Messages

A board is at the disposal of delegates in the Conference Registration area to leave messages to their colleagues and friends.

First Aid

The venue medical centre is located within the south entrance of the CCD. Please also come to the organizers office and report any medical instances.

In case of medical emergency or unexpected need, please come to the onsite registration desk located in the CCD Stadthalle, ground floor.

No smoking policy

According to German law smoking is prohibited inside any building, venue, hotels, busses, etc. Smoking is only allowed at open air zones.

Lost-and-Found

Lost-and-Found will be collected in room 12, located at the first floor of the CCD Stadthalle.

Insurance

The Organizers cannot be held responsible for accidents to participants or for damage to or loss of their personal property howsoever caused.

Shopping

Düsseldorf is one of the most elegant shopping metropolises worldwide.

Visit the exclusive boulevard “Königsallee”, with its variety of luxury stores and of course the trendy boutiques of the Altstadt. This is shopping at its best! More and more renowned labels are attracted to Königsallee. The names of fashion designers having shops in Düsseldorf read like the Who‘s Who of the trade – Armani, Dior, Gucci, Strenesse, Prada, Miu Miu, JOOP, Jil Sander, Zegna, Féraud and many more.

43rd European Conference on Optical Communication

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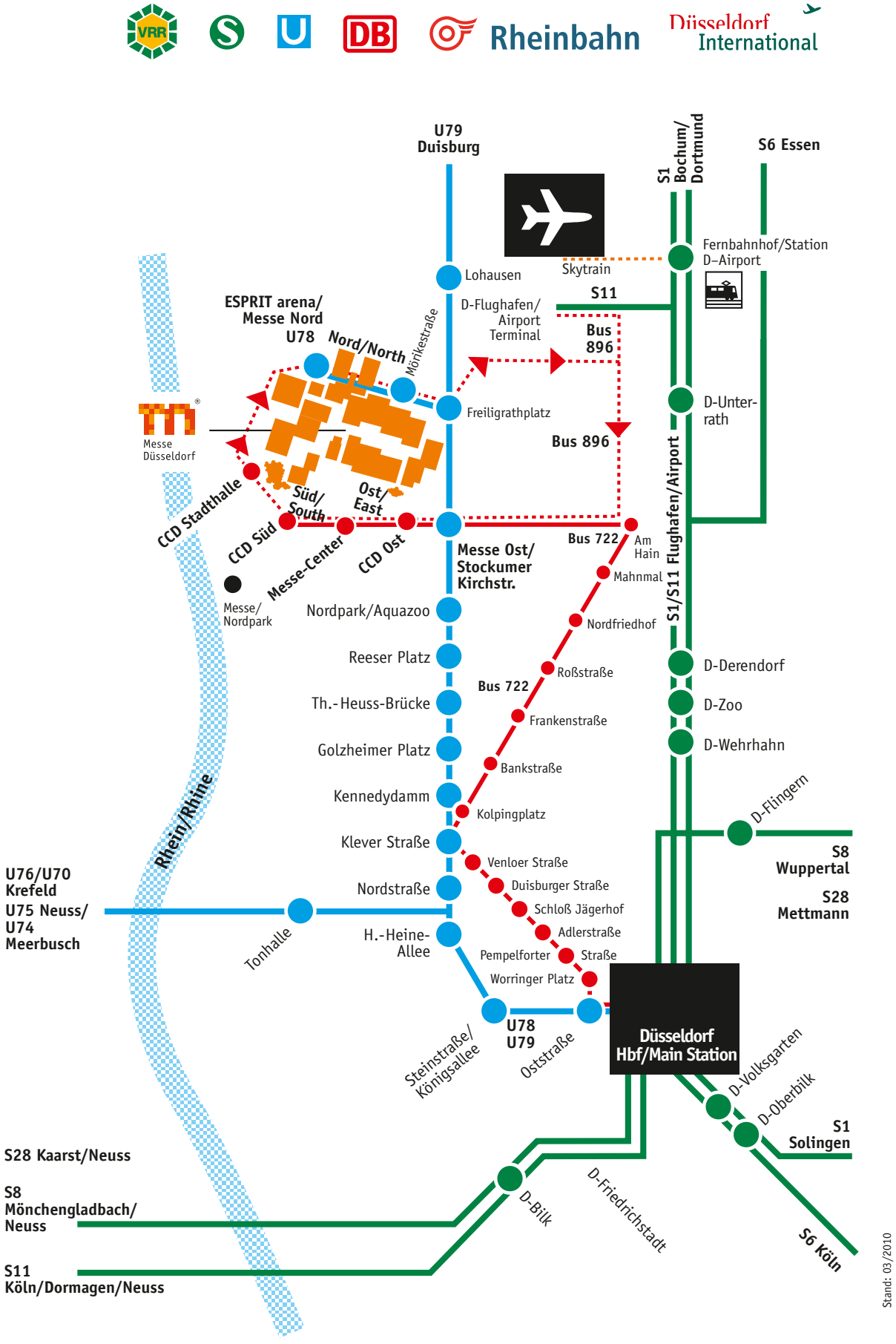


DÜSSELDORF
Congress | Sport | Event

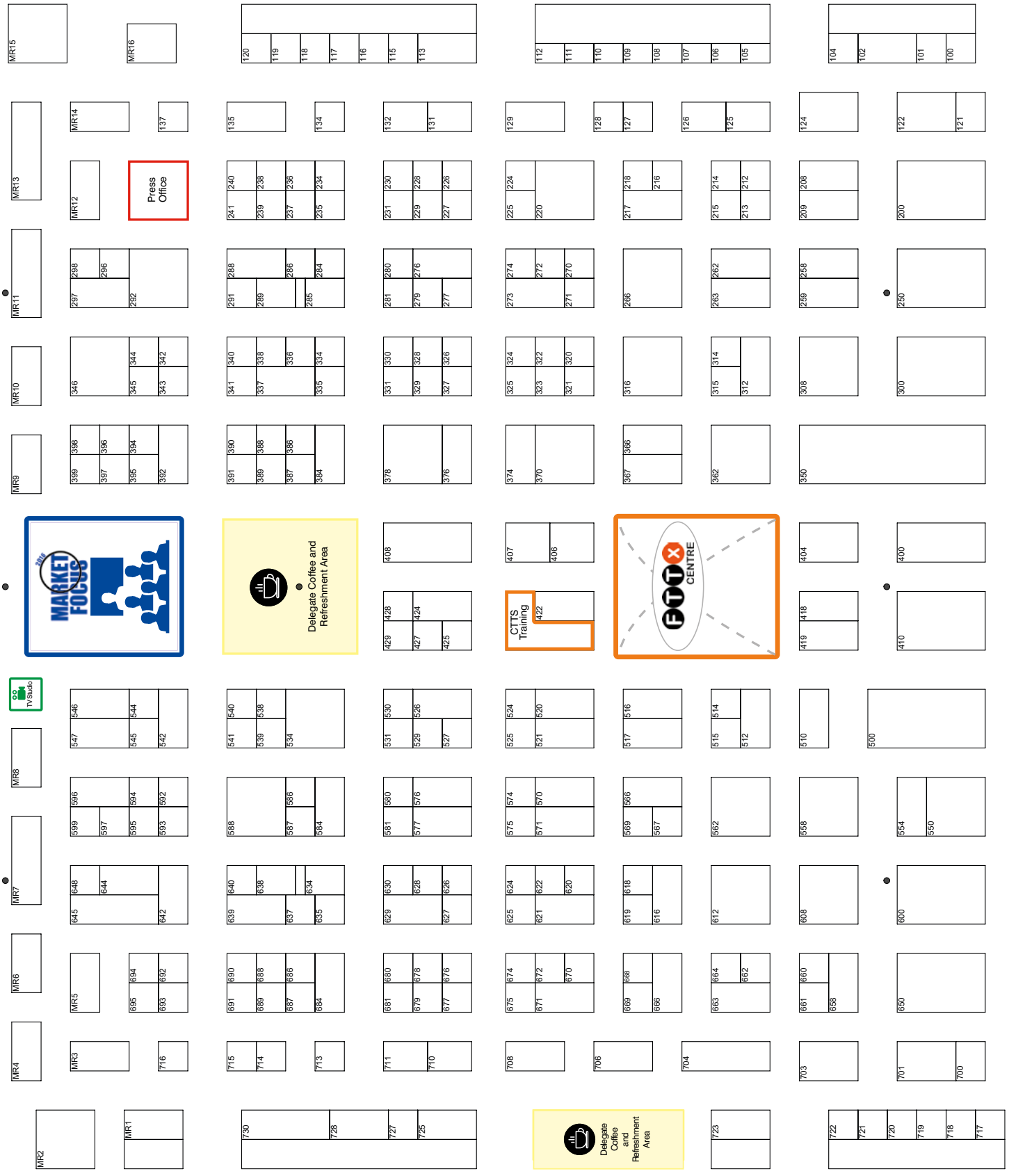
Exhibitor Index

Exhibitor Index

ECOC2016 DÜSSELDORF

Exhibition Floorplan

19 - 21 Sept 2016



Ground Floor

1st Floor

Exhibition Organisers Office

- Conference Rooms
- Restaurants/Bars
- Exhibitor Meeting Rooms
- Exhibition Organisers Office

ECOC 2016

42nd European Conference
on Optical Communication

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