Talks and posters by members of the FONTE consortium, incl. abstracts

FONTE has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement No 766115

Vladislav Neskorniuk (Aston University)

ECOC 2021 BORDEAUX

mo1b-ws - Speaker	How machine learning can revolutionize optical fiber communications? Part 1	monday 09:00 - 10:30 Room B

SC4 – Techniques for digitally enhancing optical communication

How machine learning can revolutionize optical fiber communications? 09:00 - 10:30

mo2b-ws - Speaker	How machine learning can revolutionize optical fiber communications? Part 2	monday 11:00 - 12:30 Room B

SC4 – Techniques for digitally enhancing optical communication

How machine learning can revolutionize optical fiber communications? 11:00 - 12:30

tu1c2 - Author	Machine Learning I	tuesday 09:00 - 10:30 Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model 09:30 - 09:45

Vinod Bajaj (TU Delft)

tu1c2 - Author

Machine Learning I

tuesday
09:00 - 10:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model — 09:30 - 09:45

ECOC 2021 BORDEAUX

Darko Zibar (DTU)

ECOC 2021 BORDEAUX

mo1b-ws - Speaker

How machine learning can revolutionize optical fiber communications? Part 1

monday
09:00 - 10:30
Room B

SC4 – Techniques for digitally enhancing optical communication

How machine learning can revolutionize optical fiber communications? 09:00 - 10:30

mo2b-ws - Speaker

How machine learning can revolutionize optical fiber communications? Part 2

monday
11:00 - 12:30
Room B

SC4 – Techniques for digitally enhancing optical communication

How machine learning can revolutionize optical fiber communications? 11:00 - 12:30

tu1c2 - Author

Machine Learning I

tuesday
09:00 - 10:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-end Learning of a Constellation Shape Robust to Variations in SNR and Laser Linewidth 09:00 - 09:30

Francesco Da Ros (DTU)

ECOC 2021 BORDEAUX

mo1d-ws - Speaker — Neuromorphic Computing – Is it going to shift signal processing to a new level? Part 1 — monday 09:00 - 10:30 Room D

SC5 - Optical Transmission systems

Neuromorphic Computing – Is it going to shift signal processing to a new level? 09:00 - 10:30

mo2d-ws - Speaker — Neuromorphic Computing – Is it going to shift signal processing to a new level? Part 2 — monday 11:00 - 12:30 Room D

SC5 - Optical Transmission systems

Neuromorphic Computing – Is it going to shift signal processing to a new level? 11:00 - 12:30

tu1c2 - Author — Machine Learning I — tuesday 09:00 - 10:30 Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-end Learning of a Constellation Shape Robust to Variations in SNR and Laser Linewidth 09:00 - 09:30

Sergei K Turitsyn (Aston University)

tu1c2 - Author

Machine Learning I

tuesday
09:00 - 10:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model 09:30 - 09:45

tu2c2 - Author

Machine Learning II

tuesday
11:00 - 12:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

Neural Networks For Nonlinear Fourier Spectrum Computation 11:00 - 11:15

Sander Wahls (TU Delft)

tu3c2 - Author	Coherent Transceivers	tuesday 14:00 - 15:30 Room C2
SC4 – Techniques for digitally enhancing optical communication		
Experimental Investigation of Nonlinear Fourier Transform Based Fibre Nonlinearity Characterisation		14:30 - 14:45

ECOC 2021 BORDEAUX

Vahid Aref (Nokia Bell Labs)

ECOC 2021 BORDEAUX

tu1c2 - Author	Machine Learning I	tuesday 09:00 - 10:30 Room C2
SC4 – Techniques for digitally enhancing optical communication		
End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model		09:30 - 09:45

tu4c2 - Author	Coherent DSP	tuesday 16:15 - 17:45 Room C2
SC4 – Techniques for digitally enhancing optical communication		
2 Tb/s Single-ended Coherent Receiver		17:15 - 17:30

we1c1 - Author	High speed IM/DD transmission	wednesday 09:00 - 10:30 Room C1
SC5 - Optical Transmission systems		
High-speed IM/DD transmission with analog (de-)multiplexers		09:00 - 09:30

ECOC 2021 BORDEAUX

Jaroslaw E. Prilepsky (Aston University)

tu1c2 - Author

Machine Learning I

tuesday
09:00 - 10:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model — 09:30 - 09:45

tu2c2 - Author

Machine Learning II

tuesday
11:00 - 12:30
Room C2

SC4 – Techniques for digitally enhancing optical communication

Neural Networks For Nonlinear Fourier Spectrum Computation — 11:00 - 11:15

Yves Jaouen (Telecom Paris)

tu4c1 - Author	Amplifier technologies for transmission system	tuesday 16:15 - 17:45 Room C1
SC5 - Optical Transmission systems		
12-Core Erbium/Ytterbium-Doped Fiber Amplifier for 200G/400G Long-Haul, Metro-Regional, DCI Transmission Applications with ROADM		17:15 - 17:30

ECOC 2021 BORDEAUX

Workshops

Monday 13 September
09:00 - 10:30 (Part 1)
11:00 - 12:30 (Part 2)

ROOM B

HOW MACHINE LEARNING CAN REVOLUTIONIZE OPTICAL FIBER COMMUNICATIONS? PART 1 & 2

SC4 - Techniques for digitally enhancing optical communication

ORGANIZERS:

Ezra Ip | *NEC Laboratories America - USA*
Faisal Khan | *Tsinghua University - China*
Christian Häger | *Chalmers University of Technology - Sweden*

Mo1B-WS
How machine learning can revolutionize optical fiber communications?

Recently, there has been a global trend towards using machine learning to improve everyday life. Machine learning models are well suited to problems with no clear analytical solutions, such as image recognition, natural language processing, medical diagnostics, game playing, etc. In telecommunications, there are many problems where analytical solutions are either not obvious, or are computationally difficult to solve. There has been a trend towards using machine learning across all aspects of optical fiber communications from device modeling to transponder impairment compensation to fiber nonlinearity compensation to link modeling to network planning and optimization.

This workshop will be in three parts: part one will focus on how ML can guide the design of optical components and predict their performance; part two will focus on algorithms for link compensation; and part three will focus on the network layer, covering link performance prediction, network optimization & management, and offer a carrier's perspective on how ML can assist the provisioning of services.

In each part, speakers will give 6-minute presentations on a topic targeted by the workshop, followed by 4-minute interactive panel discussion at the end. After all three parts are concluded, there will be an additional 30 minutes for interactive panel discussion with all of the speakers."

Part I: Optical components
1. Darko Zibar: Machine learning for the inverse design of optical amplifiers
2. Maxim Kushnerov: Deep learning applications in coherent optical modems
3. Keisuke Kojima: Machine learning for design and optimization of photonic devices
4. Dan Kilper: Machine learning based optical amplifier gain estimation

Part II: Link compensation
5. Elias Giacoumidis: Unsupervised machine learning for modern transmission systems
6. Berthold Bitachon: Replacing digital backpropagation with neural network
7. Vladislav Neskorniuk: Machine learning methods for nonlinearity mitigation in the physical layer of fiber-optic communication links
8. Shinsuke Fujisawa: Expectations and perspectives from industry on photonic platform for AI-processing in telecommunications

Part III: Network layer applications:
9. Boris Karanov: End-to-end link optimization using deep learning
10. Faisal Nadeem Khan: Comparison of ML and analytical models for lightpaths QoT estimation
11. Marija Furdek: Applications of ML for network security management
12. Luis Velasco: Applications of ML for network control
13. Massimo Tornatore: Routing and spectral assignment using ML-based QoT models
14. Glenn Wellbrock: Carrier's perspective on how ML can assist terrestrial networks
15. Ahmed Triki: Carrier's perspective on how ML can revolutionize terrestrial optical communication networks

SPEAKERS:

Darko Zibar | *DTU - Denmark*
Machine learning for the inverse design of optical amplifiers

Maxim Kuschnerov | *Huawei Munich - Germany*
Deep learning applications in coherent optical modems

Keisuke Kojima | *Mitsubishi - USA*
Machine learning for design and optimization of photonic devices

Dan Kilper | *Trinity College - Ireland*
Machine learning based optical amplifier gain estimation

Elias Giacoumidis | *Dublin City University - Ireland*
Unsupervised machine learning for modern transmission systems

Bertold Ian Bitachon | *ETH Zurich - Switzerland*
Replacing digital backpropagation with neural network

Vladislav NeskorniUK
Aston University - UK
Machine learning methods for nonlinearity mitigation in the physical layer of fiber-optic communication links

Shinsuke Fujisawa | *NEC Corp. - Japan*
Expectations and perspectives from industry on photonic platform for AI-processing in telecommunications

Boris Karanov | *Technology University of Eindhoven - The Netherlands*
End-to-end link optimization using deep learning

Faisal Khan | *Tsinghua University - China*
Comparison of machine learning and analytical models for lightpath QoT estimation

Marija Furdek | *Chalmers University of Technology - Sweden*
Applications of machine learning for network security management

Luis Velasco | *Universitat Politècnica de Catalonia - Spain*
Applications of machine learning for network control

Massimo Tornatore | *Politecnico di Milano - Italy*
Routing and spectral assignment using machine learning based QoT models

Glenn Wellbrock | *Verizon - USA*
Carrier's perspective on how machine learning can assist terrestrial networks

Ahmed Triki | *Orange Labs - France*
Carrier's perspective on how machine learning can revolutionize terrestrial optical communication networks

Workshops

Monday 13 September
11:00 - 12:30

ROOM D

NEUROMORPHIC COMPUTING - IS IT GOING TO SHIFT SIGNAL PROCESSING TO A NEW LEVEL? PART 2

SC5 - Optical Transmission systems

ORGANIZERS:

Stephan Pachnicke
Kiel University - Germany

Peter Bienstman
Ghent University - IMEC - Belgium

Mo2D-WS
Neuromorphic Computing – Is it going to shift signal processing to a new level?

Conventional signal processing in the electrical domain based on binary computing faces various technological and economical limitations. The further scaling of transistors to smaller feature sizes may end soon at about 3nm due to physical, technological and economic constraints. At the same time the exponential growth of physical layer interfaces' bit rates is expected to continue in the foreseeable future leading to an exponential growth of the power dissipation of processors, if no disruptive technology shift is taken.

In the recent past artificial intelligence concepts are being tested for various problems in the optical transmission system environment. It has been shown that problems such as failure prediction, optical performance monitoring and nonlinearity compensation just to name a few can profit from machine learning approaches. Nevertheless, these concepts mostly rely on numerical implementations, which are still being executed in classical (electrical) signal processing hardware.

To be scalable to much higher signal processing speeds (or bandwidths) and significantly lower energy consumption per bit radically new paths have to be followed. In that respect also concepts borrowed (or adapted) from the nature and implemented in the optical or electrical domain are appealing. Potential realizations of neural networks in the optical domain are for example reservoir computing concepts. Also other concepts such as photonic neuron architectures have been investigated in the past and offer radically new ways of information processing. Furthermore, bio inspired neural networks in the electrical domain may offer significant advantages such as much lower power consumption than today's electrical signal processing circuits.

This workshop shall investigate information processing based on neuromorphic circuits in the optical and electrical domain. It shall shed light on how and when such approaches may be ready for implementation into optical transmission systems and what advantages they may offer. Furthermore, current limits and technological hurdles shall be discussed.

SPEAKERS:

Apostolos Argyris
UIB-IFISC - Spain
Fiber-based reservoir computing for processing PAM-4 encoded signals

Charis Mesaritakis
University of Athens - Greece
Neuromorphic schemes for next generation telecomunication and security applications

Kambiz Jamshidi
TU Dresden - Germany
Silicon ring resonators for reservoir computing-based transmission impairment compensation

Ripalta Stabile
Tu Eindhoven - The Netherlands
All-Optical Neural Networks through InP Photonic Integrated Cross-Connects

Francesco Da Ros
DTU - Denmark
Extending the transmission reach of IM/DD links through reservoir computing

Tuesday 14 September

ROOM C2

MACHINE LEARNING I

10:00 - 10:15

Tu1C1.5
Estimating Network Components Polarization-Dependent Loss Using Performance Statistical Measurements

We propose a novel approach to estimate reconfigurable optical add-drop multiplexers (ROADM) polarization-dependent loss (PDL) using the signal-to-noise ratio distribution induced by PDL. We show an uncertainty cut between 40% and 80% compared to datasheet in several configurations.

Joana Girard-Jollet* | *Presenter | *Alcatel Submarine Networks, Nozay - France, Télécom Paris, Institut Polytechnique de Paris - France*
Matteo Lonardi | *Nokia Bell Labs - France*
Petros Ramantanis | *Nokia Bell Labs - France*
Paolo Serena | *University of Parma, Department of Engineering and Architecture - Italy*
Chiara Lasagni | *University of Parma, Department of Engineering and Architecture - Italy*
Patricia Layec | *Nokia Bell Labs - France*
Jean-Christophe Antona | *Alcatel Submarine Networks, Nozay - France*

09:00 - 10:30

Chair: Darko Zibar DTU Fotonik - Denmark
SC4 - Techniques for digitally enhancing optical communication

Tu1C2.1
End-to-end Learning of a Constellation Shape Robust to Variations in SNR and Laser Linewidth

We propose an autoencoder-based geometric shaping that learns a constellation robust to SNR and laser linewidth estimation errors. This constellation maintains shaping gain in mutual information (up to 0.3 bits/symbol) with respect to QAM over various SNR and laser linewidth values.

Ognjen Jovanovic* | *Presenter
Technical University of Denmark - Denmark
Francesco Da Ros | *Technical University of Denmark - Denmark*
Metodi P. Yankov | *Technical University of Denmark - Denmark*
Darko Zibar | *Technical University of Denmark - Denmark*

09:30 - 09:45

Tu1C2.3
End-to-End Deep Learning of Long-Haul Coherent Optical Fiber Communications via Regular Perturbation Model

We present a novel end-to-end autoencoder-based learning for coherent optical communications using a -parallelizable" perturbative channel model. We jointly optimized constellation shaping and nonlinear pre-emphasis achieving mutual information gain of 0.18 bits/sym./pol. simulating 64GBd dual-polarization single-channel transmission over 30x80 km G.652 SMF link with EDFAs.

Vladislav NeskorniUK* | *Presenter | *Aston Institute of Photonic Technology - UK, Nokia, 70435 Stuttgart - Germany*
Andrea Carnio | *Nokia, Vimercate 20871 - Italy*
Vinod Bajaj | *Delft Center for Systems and Control, Delft University of Technology, 2628 CD Delft - The Netherlands, Nokia, 70435 Stuttgart - Germany*
Domenico Marsella | *Nokia, Vimercate 20871 - Italy*
Sergei K. Turitsyn | *Aston Institute of Photonic Technology - UK*
Jaroslaw E. Prilepsky | *Aston Institute of Photonic Technology - UK*
Vahid Aref | *Nokia, 70435 Stuttgart - Germany*

09:45 - 10:00

Tu1C2.4
Over-the-fiber Digital Predistortion Using Reinforcement Learning

We demonstrate, for the first time, experimental over-the-fiber training of transmitter neural networks (NNs) using reinforcement learning. Optical back-to-back training of a novel NN-based digital predistorter outperforms arcsine-based predistortion with up to 60% bit-error-rate reduction.

Jinxiang Song* | *Presenter | *Chalmers University of Technology - Sweden*
Zonglong He | *Chalmers University of Technology - Sweden*
Christian Häger | *Chalmers University of Technology - Sweden*
Magnus Karlsson | *Chalmers University of Technology - Sweden*
Alexandre Graell I Amat | *Chalmers University of Technology - Sweden*
Henk Wymeersch | *Chalmers University of Technology - Sweden*
Jochen Schröder | *Chalmers University of Technology - Sweden*

ROOM D

NONLINEAR FIBER CHANNEL MODELLING

09:30 - 09:45

Chair: Helmut Grießer ADVA Optical Networking SE - Germany
SC6 - Theory of Optical Communications and Quantum Communications

Tu1D.3
Power Allocation Optimization in the Presence of Stimulated Raman Scatterin

We leverage the simplicity of closed-form expressions of the nonlinear interference variance in the presence of stimulated Raman scattering (SRS) for fast pre-emphasis optimization in wideband wavelength division multiplexing (WDM) terrestrial systems with sparse dynamic gain equalizers.

Chiara Lasagni* | *Presenter | *University of Parma - Italy*
Paolo Serena | *University of Parma - Italy*
Alberto Bononi | *University of Parma - Italy*
Jean-Christophe Antona | *Alcatel Submarine Networks, Nozay - France*

09:45 - 10:00

Tu1D.4
Machine Learning for Power Profiles Prediction in Presence of Inter-channel Stimulated Raman Scattering

Two artificial neural network (ANN) models are presented to predict power profiles over C+L-band in presence of inter-channel stimulated Raman scattering (ISRS) and to support non-linear interference (NLI) modeling. High prediction accuracy is obtained with maximum errors ≤ 0.1 dB over thousands different partial loads.

Ann Margareth Rosa Brusin* | *Presenter | *Politecnico di Torino - Italy*
Mahdi Ranjbar Zefreh | *Politecnico di Torino - Italy*
Pierluigi Poggiolini | *Politecnico di Torino - Italy*
Stefano Piciaccia | *Cisco Photonics - Italy*
Fabrizio Forghieri | *Cisco Photonics - Italy*
Andrea Carena | *Politecnico di Torino - Italy*

Tuesday 14 September

ROOM C2

MACHINE LEARNING II

11:00 - 11:15

Chair: Sander Wahls Delft University of Technology - The Netherlands
SC4 - Techniques for digitally enhancing optical communication

Tu2C2.1 EXTENDED
Neural Networks For Nonlinear Fourier Spectrum Computation

We demonstrate that neural networks can outperform conventional numerical nonlinear Fourier transform algorithms for processing the noise-corrupted optical signal. Applying the Bayesian hyper-parameters optimisation, we design the architecture of neural networks capable to compute nonlinear signal spectrum at low SNR more accurately than conventional algorithms.

Egor Sedov **| *Presenter*** | *Aston Institute of Photonic Technology - UK, Novosibirsk State University The Russian Federation*
Pedro Jorge Freire da Carvalho Souza | *Aston Institute of Photonic Technology - UK*
Igor Chekhovskoy | *Novosibirsk State University The Russian Federation*
Sergei K. Turitsyn | *Aston Institute of Photonic Technology - UK, Novosibirsk State University The Russian Federation*
Jaroslaw E. Prilepsky | *Aston Institute of Photonic Technology - UK*

11:15 - 11:30

Tu2C2.2
Gated Recurrent Unit based Autoencoder for Optical Link Fault Diagnosis in Passive Optical Networks

We propose a deep learning approach based on an autoencoder for identifying and localizing fiber faults in passive optical networks. The experimental results show that the proposed method detects faults with 97% accuracy, pinpoints them with an RMSE of 0.18 m and outperforms conventional techniques.

Khouloud Abdelli **| *Presenter*** | *ADVA Optical Networking SE - Germany*
Florian Azendorf | *ADVA Optical Networking SE - Germany*
Helmut Grießer | *ADVA Optical Networking SE - Germany*
Carsten Tropschug | *ADVA Optical Networking SE - Germany*
Stephan Pachnicke | *Kiel University - Germany*

11:30 - 11:45

Tu2C2.3
Symbol-Based Supervised Learning Predistortion for Compensating Transmitter Nonlinearity

We experimentally demonstrate a symbol-based nonlinear digital pre-distortion (DPD) technique utilizing supervised learning, which is robust against a change of modulation format. Back-to-back

transmission of 30 Gbaud 32, 64, and 256QAM confirms that our scheme significantly outperforms the baseline of arcsine-based pre-distortion.

Zonglong He **| *Presenter*** | *Chalmers University of Technology - Sweden*
Jinxiang Song | *Chalmers University of Technology - Sweden*
Christian Häger | *Chalmers University of Technology - Sweden*
Kovendhan Vijayan | *Chalmers University of Technology - Sweden*
Peter Andrekson | *Chalmers University of Technology - Sweden*
Magnus Karlsson | *Chalmers University of Technology - Sweden*
Alexandre Graell I Amat | *Chalmers University of Technology - Sweden*
Henk Wymeersch | *Chalmers University of Technology - Sweden*
Jochen Schröder | *Chalmers University of Technology - Sweden*

11:45 - 12:00

Tu2C2.4
Zero-Multiplier Sparse DNN Equalization for Fiber-Optic QAM Systems with Probabilistic Amplitude Shaping

We propose a multiplier-less deep neural network (DNN) to mitigate fiber-nonlinear distortion of shaped constellations. Our DNN achieves an excellent performance-complexity trade-off with progressive lottery ticket hypothesis (LHT) weight pruning and additive powers-of-two (APoT) quantization.

Toshiaki Koike-Akino **| *Presenter*** | *MERL - USA*
Ye Wang | *MERL - USA*
Keisuke Kojima | *MERL - USA*
Kieran Parsons | *MERL - USA*
Tsuyoshi Yoshida | *Mitsubishi Electric Corporation - Japan*

12:00 - 12:15

Tu2C2.5
Fiber Link Anomaly Detection and Estimation Based on Signal Nonlinearity

A fiber link anomaly detection and estimation approach is proposed. Using signal nonlinear distortion, signal power profile anomaly and passband narrowing anomaly can be recognized with high quantitative and position accuracy. Such approach does not require additional equipment and can support online working.

Gleb Sidelnikov **| *Presenter*** **|** ***Huawei Moscow Research Center - The Russian Federation***
Konstantin Pestov | *Huawei Moscow Research Center - The Russian Federation*
Ji Luo | *Huawei Moscow Research Center - The Russian Federation*
Bofang Zheng | *Huawei Technologies Co. Ltd. - China*

ROOM D

FIBER NONLINEARITY MITIGATION AND SPACE-DIVISION MULTIPLEXING

11:30 - 12:00

Chair: Cristian Antonelli University of L'Aquila - Italy
SC6 - Theory of Optical Communications and Quantum Communications

Tu2D.3 EXTENDED
A Model of the Nonlinear Interference in Space-Division Multiplexed Systems with Arbitrary Modal Dispersion

We show how to include modal dispersion in the Gaussian noise model extended to space-division multiplexed systems with strongly-coupled modes. The proposed model enables fast and accurate design of SDM links. Here we use it to reveal a considerable dependence of cross-nonlinearities on modal dispersion.

Paolo Serena **| *Presenter*** | *University of Parma - Italy*
Chiara Lasagni | *University of Parma - Italy*
Alberto Bononi | *University of Parma - Italy*
Cristian Antonelli | *University of L'Aquila - Italy*
Antonio Mecozzi | *University of L'Aquila - Italy*

12:00 - 12:15

Tu2D.5
Mode Vector Modulation

We propose a new energy-efficient, short-haul, multidimensional modulation using spatial degrees of freedom in SDM fibers to create well-separated points in the generalized Stokes space. We study the transceiver architecture, geometric constellation shaping, bit-to-symbol mapping, and the performance of the optically-preamplified direct-detection receiver.

Ioannis Roudas **| *Presenter*** | *Montana State University - USA*
Jaroslaw Kwapisz | *Montana State University - USA*
Eric Fink | *Montana State University - USA*

Tuesday 14 September

ROOM C2

COHERENT TRANSCEIVERS

14:30 - 14:45

Chair: Sebastian Randel Karlsruhe Institute of Technology (KIT), Institute of Photonics - Germany and Quantum Electronics (IPQ)
SC4 - Techniques for digitally enhancing optical communication

Tu3C2.3
Experimental Investigation of Nonlinear Fourier Transform Based Fibre Nonlinearity Characterisation

First experimental results on the characterisation of the nonlinear fibre coefficient using nonlinear Fourier transforms are reported for a 1000 km NZDSF fibre link. No special training signals were used. Instead, conventional pulse-shaped QPSK symbols were transmitted.

***Pascal de Koste* | *Presenter* |** *Delft University of Technology - The Netherlands*
Jonas Koch | *Kiel University - Germany*
Stephan Pachnicke | *Kiel University - Germany*
Sander Wahls | *Delft University of Technology - The Netherland*

14:45 - 15:00

Tu3C2.4
The Interaction Between Pilot Based Linear Equalizer and Device Nonlinearity in Optical Coherent Communication

The interaction between QPSK pilot based linear equalizer and device nonlinearity and the corresponding penalty are demonstrated experimentally. By setting proper amplitude probabilistic distribution, new pilot design mitigates it and improves Q more than 1dB.

Xiaofei Su* | *Presenter | *Fujitsu Ltd. - China*
Ke Zhang | *Fujitsu Ltd. - China*
Tong Ye | *Fujitsu Ltd. - China*
Zhenning Tao | *Fujitsu Ltd. - China*
Hisao Nakashima | *Fujitsu Ltd. - Japan*
Takeshi Hoshida | *Fujitsu Ltd. - Japan*

15:00 - 15:15

Tu3C2.5
Polarization Change Monitor Based on Geometrical Analysis in Stokes Space

We propose a novel polarization change monitor by analyzing geometrical relation of pilot symbols in Stokes space. The proposed monitor is experimentally verified and result shows that the polarization change in the range of quasi static to 3MHz can be captured.

Jingnan Li* | *Presenter | *Fujitsu Ltd. - China*
Yangyang Fan | *Fujitsu Ltd. - China*
Zhenning Tao | *Fujitsu Ltd. - China*
Hisao Nakashima | *Fujitsu Ltd. - Japan*
Takeshi Hoshida | *Fujitsu Ltd. - Japan*

15:15 - 15:30

Tu3C2.6
Overcoming WSS Filtering with Bandwidth-Variable Probabilistic Constellation Shaping

Employing probabilistic constellation shaping with jointly optimized entropy and symbol-rate, we demonstrate that the tolerance towards WSS filtering can be significantly enhanced. Compared with standard uniform modulation, OSNR gains in the range of 1–3 dB are experimentally demonstrated for 400G–600G systems, after 5–10 WSS passes.

Fernando P. Guiomar* | *Presenter | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal*
Marco A. Fernandes | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal, University of Aveiro - Portugal*
Adriano Messias | *Idea! Electronic Systems - Brazil*
Tomaz Vilela | *Idea! Electronic Systems - Brazil*
Daniel Formiga | *Idea! Electronic Systems - Brazil*
Jacklyn Reis | *Idea! Electronic Systems - Brazil*
Paulo P. Monteiro | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal, University of Aveiro - Portugal*

ROOM D

DIRECTLY MODULATED LASERS

14:30 - 15:00

Chair: Romain Brenot Huawei - France
SC2 - Optoelectronic devices and technologies

Tu3D.3 EXTENDED
2-channel 112-Gbps NRZ Short-Reach Transmission Based on 60-GHz-Bandwidth Directly-Modulated Membrane Laser Array on Si

Directly-modulated membrane lasers on SiO2/Si with ~60-GHz bandwidths are fabricated using an optimized longitudinal design for photon-photon resonance. A fabricated two-channel array exhibits 2×112 Gbps NRZ modulation over 2-km transmissions, consuming <0.3 pJ/bit operating energy.

Nikolaos Panteleimon Diamantopoulos* | *Presenter | *NTT Access Network Service Systems Laboratories - Japan*
Takuro Fuji | *NTT Access Network Service Systems Laboratories - Japan*
Suguru Yamaoka | *NTT Access Network Service Systems Laboratories - Japan*
Hidetaka Nishi | *NTT Access Network Service Systems Laboratories - Japan*
Takaaki Kakitsuka | *NTT Access Network Service Systems Laboratories - Japan •Waseda University - Japan*
Tai Tsuchizawa | *NTT Access Network Service Systems Laboratories - Japan*
Matsuo Shinji | *NTT Access Network Service Systems Laboratories - Japan*
Koji Takeda | *NTT Access Network Service Systems Laboratories - Japan*
Toru Segawa | *NTT Access Network Service Systems Laboratories - Japan*

15:00 - 15:15

Tu3D.5
1060nm Single-mode Metal-aperture VCSEL Array with Transverse Resonance and Low Power Consumption below 50 fJ/bit

We present 1060nm intracavity metal-aperture VCSELs array toward high-speed and single-mode operation with record low power consumption. The intracavity metal-aperture causes the transverse resonance which provides the modulation bandwidth-enhancement. We demonstrated 60Gbps PAM4 and 40Gbps NRZ modulations with energy efficiency of 48fJ/bit and 50fJ/bit, respectively.

Hameeda Ibrahim* | *Presenter | *Minia university - Egypt, Tokyo Institute of Technology - Japan*
Ahmed Hassan | *Department of Physics, Faculty of Science, Al-Azhar University, Assuit, Egypt - Egypt, Tokyo Institute of Technology - Japan*
Xiaodong Gu | *Ambition Photonics Inc. - Japan •Tokyo Institute of Technology - Japan*
Satoshi Shinada | *National Institute of Information and Communications Technology - Japan*
Mostafa Farghal | *Minia university - Egypt*
Fumio Koyama | *Tokyo Institute of Technology - Japan*

Tuesday 14 September

ROOM A

OAM AND NEW GUIDING MECHANISMS

16:45 - 17:00

Chair: Luca Palmieri University of Padova - Italy
SC1 - Novel Fibres, Fibre Devices and Fibre Amplifiers

Tu4A.3 HIGHLY SCORED
Record (60) Uncoupled Modes in A Step-Index Fiber due to A New Light Guidance Mechanism: Topological Confinement

We exploit a recently discovered, so-called, topological confinement effect, to achieve mode-mixing resistant (inter-mode purity > 15 dB) propagation of a record 60 modes over 90 meters of a simple step-index fiber.

Zelin Ma | ***Presenter*** | *Boston University - USA*
Poul Kristensen | *OFS-Fitel - Denmark*
Siddharth Ramachandran | *Boston University - USA*

17:00 - 17:15

Tu4A.4
Experimental Demonstration of Amplifying 14 Orbital Angular Momentum Modes in Ring-Core Erbium-Doped Fiber with High Modal Gain

We propose and experimentally demonstrate an orbital angular momentum (OAM) fiber amplifier supporting 14 OAM modes based on a fabricated ring-core erbium-doped fiber with a core pump configuration acquiring a high modal gain up to 30.32 dB at 1550 nm.

Xi Zhang | ***Presenter*** | *Huazhong University of Science and Technology - China*
Jun Liu | *Huazhong University of Science and Technology - China*
Cheng Du | *Fiberhome Telecommunication Technologies Co. Ltd - China*
Wei Li | *Fiberhome Telecommunication Technologies Co. Ltd - China*
Jian Wang | *Huazhong University of Science and Technology - China*

ROOM C1

AMPLIFIER TECHNOLOGIES FOR TRANSMISSION SYSTEM

16:45 - 17:00

Chair: Gabriel Charlet Huawei Technologies - France
SC5 - Optical Transmission systems

Tu4C1.3 HIGHLY SCORED
13.4-Tb/s WDM Transmission over 1,280 km Repeated only with PPLN-based Optical Parametric Inline Amplifier

Inline-amplified 2.1-THz WDM transmission with the longest transmission distance of 1,280 km using OPA-based repeater only is demonstrated. Two-stage PPLN-based OPA offers sufficient gain to compensate losses of standard 80-km fibre span and optical gain equalizer for 640-Gb/s PDM-PS36QAM signals with 100-GHz-spaced 21-ch WDM configuration.

Takayuki Kobayashi | ***Presenter*** | *NTT Access Network Service Systems Laboratories - Japan*
Shimpei Shimizu | *NTT Access Network Service Systems Laboratories - Japan*
Masanori Nakamura | *NTT Access Network Service Systems Laboratories - Japan*
Takushi Kazama | *NTT Access Network Service Systems Laboratories - Japan*
Takeshi Umeki | *NTT Access Network Service Systems Laboratories - Japan*
Ryoichi Kasahara | *NTT Access Network Service Systems Laboratories - Japan*
Fukutaro Hamaoka | *NTT Access Network Service Systems Laboratories - Japan*
Yutaka Miyamoto | *NTT Access Network Service Systems Laboratories - Japan*

17:00 - 17:15

Tu4C1.4
8-Tbps (20 × 400 Gbps) Unrepeated Transmission over 80 km with 2-THz PPLN-Based Phase-Sensitive Amplification Using Precise Chromatic Dispersion Pre-Compensation

We demonstrate an 80-km unrepeated transmission of a 20-ch. 96-Gbaud PS-64QAM WDM signal with 100-GHz spacing using a periodically poled LiNbO3-based phase-sensitive amplifier. We achieve widest-band simultaneous phase-sensitive amplification over 2 THz (4 THz including an idler band) by precise chromatic dispersion pre-compensation.

Shimpei Shimizu | ***Presenter*** | *NTT Corporation - Japan*
Takayuki Kobayashi | *NTT Corporation - Japan*
Masanori Nakamura | *NTT Corporation - Japan*
Takushi Kazama | *NTT Corporation - Japan*
Takeshi Umeki | *NTT Corporation - Japan*
Ryoichi Kasahara | *NTT Corporation - Japan*
Yutaka Miyamoto | *NTT Corporation - Japan*
Koji Enbutsu | *NTT Corporation - Japan*

17:15 - 17:30

Tu4C1.5
12-Core Erbium/Ytterbium-Doped Fiber Amplifier for 200G/400G Long-Haul, Metro-Regional, DCI Transmission Applications with ROADM

A 12-core Er/Yb-doped fiber amplifier with 21-dBm/core output power and 5.3-Watts multimode pump is used to address various transmission applications with ROADM. 1200-km with 200G DP-QPSK and 300-km with 400G DP-16QAM are achieved in serial configuration at 1550-nm. Parallel 12x100-km transport with 400-ZR+ transceiver is also implemented.

Erwan PINCEMIN | *Presenter* | *Orange Labs - France*
Jérémie Jauffrit | *Ekinops - France*
Pierre-Yves Disez | *Ekinops - France*
Yann Loussouarn | *Orange Labs - France*
Claude Le Bouëtté | *Ekinops - France*
Romain Kerampran | *Lumibird - France*
Sylvain Bordais | *Lumibird - France*
Gilles Melin | *iXBlue - France*
Thierry Taunay | *Photonics Bretagne - France*
Yves Jaouen | *Telecom Paris - France*
Michel Morvan | *IMT Atlantique - France*

Technical Sessions Tuesday 14 September

ROOM C2

COHERENT DSP

17:15 - 17:30

Chair: Sander Wahls Delft University of Technology - The Netherlands
SC4 - Techniques for digitally enhancing optical communication

Tu4C2.5 HIGHLY SCORED
2 Tb/s Single-ended Coherent Receiver

We demonstrate a single-ended coherent receiver with a record net data rate of 2 Tb/s in B2B, showing 3 dB OSNR advantage compared to the conventional coherent receiver at a LOSPR of 10 dB. Over 80 km, a net data rate of 1.872 Tb/s is achieved

Son Le* | *Presenter | *Nokia Bell Labs - USA*
Vahid Aref | *Nokia - Germany*
Xi Chen | *Nokia Bell Labs - USA*

17:30 - 17:45

Tu4C2.6
Maximizing the Performance of Digital Multi-Carrier Systems with Transmission-Aware Joint Carrier Phase Recovery

Theoretical gains of digital multi-carrier systems are hindered by the use of sub-optimal conventional phase recovery, especially after fiber transmission. We experimentally validate an advanced, dispersion-aware algorithm that addresses this issue, achieving SNR gains up to ~0.5dB with 800G 125Gbaud 16-carrier PCS-64QAM, transmitted over 1800km.

Celestino S. Martins* | *Presenter | *Huawei Technologies France - France*
Abel Lorences-Riesgo | *Huawei Technologies France - France*
Manuel Neves | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal*
Sami Mumtaz | *Huawei Technologies France - France*
Yann Frignac | *Huawei Technologies France - France*
Trung Hien Nguyen | *Huawei Technologies France - France*
Paulo P. Monteiro | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal*
Gabriel Charlet | *Huawei Technologies France - France*
Fernando P. Guiomar | *Instituto de Telecomunicações, Universidade de Aveiro - Portugal*
Stefanos Dris | *Huawei Technologies France - France*

ROOM D

MODULATORS AND TRANSMITTERS

16:15 - 17:45

Chair: Hélène Debrégeas Almae Techologies - France
SC2 - Optoelectronic devices and technologies

Tu4D.1
A 260 Gb/s/λ PDM Link with Silicon Photonic Dual-Polarization Transmitter and Polarization Demultiplexer

We demonstrate a silicon-photonic dual-polarization transmitter with an integrated on-chip laser, transmitting 260 Gb/s PAM-4 data on a single wavelength carrier, and a single-chip polarization demultiplexer, recovering the polarization multiplexed signals with a TDECQ of 3.0 dB for both polarizations.

Meer Sakib* | *Presenter | *Intel Corporation - USA*
Peicheng Liao | *Intel Corporation - USA*
Duanni Huang | *Intel Corporation - USA*
Ranjeet Kumar | *Intel Corporation - USA*
Xinru Wu | *Intel Corporation - USA*
Chaoxuan Ma | *Intel Corporation - USA*
Guan-Lin Su | *Intel Corporation - USA*
Haisheng Rong | *Intel Corporation - USA*

16:45 - 17:00

Tu4D.3
Silicon IQ Modulator for 120 Gbaud QAM

We experimentally demonstrate an all-silicon IQ modulator with a segmented design operating at 120 Gbaud 32QAM. We achieve BER below the 25% FEC-threshold for a line-rate of 600 Gb/s (net 480 Gb/s) on a single polarization.

Zibo Zheng* | *Presenter | *COPL, Universite Laval - Canada, State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecо - China*
Abdolkhalegh Mohammadi | *COPL, Universite Laval - Canada*
Omid Jafari | *COPL, Universite Laval - Canada*
Hassan Sepehrian | *COPL, Universite Laval - Canada*
Jiachuan Lin | *Huawei Technologies - Canada*
Xiaoguang Zhang | *State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecо - China*
Leslie Rusch | *Presenter* | *COPL, Universite Laval - Canada*
Wei Shi | *COPL, Universite Laval - Canada*

17:00 - 17:15

Tu4D.4
Ge Ring Modulator Based on Carrier-injection Phaser Shifter Operating at Two Micrometer Band

We demonstrated proof-of-concept Ge ring modulator by carrier injection on the Ge-on-insulator (GeOI) platform. Owing to the strong optical confinement in Ge rib waveguide, the optical modulation with 13 dB extinction ratio was obtained by optical phase shift induced by 1 mA current injection.

Ziqiang Zhao* | *Presenter | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*
Chong Pei Ho | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*
Qiang Li | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*
Kasidit Toprasertpong | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*
Shinichi Takagi | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*
Mitsuru Takenaka | *Department of Electrical Engineering and Information Systems, The University of Tokyo - Japan*

17:15 - 17:30

Tu4D.5
Novel Single-Sideband Modulator in Silicon on Insulator Technology with Widely Tunable Carrier-to-Sideband Ratio for Broadband RF Signals

A compact silicon photonics single-sideband modulator with continuously tunable carrier-to-sideband ratio and large spurious sideband rejection of 40 dB is demonstrated using a single phase modulator, sideband selection through photonic integrated filter, and carrier re-insertion. Operation with a 5 Gbps ASK-modulated 16.5 GHz carrier is reported

Claudio Porzi* | *Presenter | *Scuola Superiore Sant'Anna, TeCIP Institute - Italy*
Fabio Falconi | *Scuola Superiore Sant'Anna, TeCIP Institute - Italy*
Antonella Bogoni | *Scuola Superiore Sant'Anna, TeCIP Institute - Italy*
Marc Sorel | *School of Engineering, University of Glasgow - UK, Scuola Superiore Sant'Anna, TeCIP Institute - Italy*

17:30 - 17:45

Tu4D.6
Silicon Microring Modulator with Polarization Insensitivity

We propose a polarization-insensitive silicon IQ microring modulator. We show theoretically and experimentally that the symmetric circular paths from the polarization splitter-rotator achieve polarization independence. We demonstrate our modulator is effective for single sideband modulation.

Xun Guan* | *Presenter | *Center of Optics, Photonics and Laser, Laval University - Canada*
Wei Shi | *Center of Optics, Photonics and Laser, Laval University - Canada*
Leslie Rusch | *Center of Optics, Photonics and Laser, Laval University - Canada*
Mingyang Lyu | *Center of Optics, Photonics and Laser, Laval University - Canada*

Wednesday 15 September

ROOM B

NOVEL RADIO-OVER-FIBER DEVICES AND SYSTEMS

16:15 - 16:45

Chair: Leif Katsuo Oxenløwe Technical University of Denmark - Denmark
SC7 - Photonics for RF and Free Space Optics applications

We4B.1
Power-over-Fiber for Radio-over-Fiber Links

This paper introduces simultaneous data and power transmission by power-over-fiber using a single optical fiber for driving a remote antenna unit in radio-over-fiber-based mobile communication networks. This paper also discusses the future prospects of power-over-fiber.

Motoharu Matsuura | Presenter
University of Electro-Communications - Japan

ROOM C1

HIGH SPEED IM/DD TRANSMISSION

09:00 - 09:30

Chair: Norbert Hanik TU Munich - Germany
SC5 - Optical Transmission systems

We1C1.1
High-speed IM/DD transmission with analog (de-)multiplexers

In this paper we give an overview on the status of devices for analog multiplexing and demultiplexing and experimental results in general and on the results achieved within the ECSEL Taranto project.

Karsten Schuh | Presenter
Nokia - Germany

Qian Hu
Nokia - Germany
Roman Dischler
Nokia - Germany
Vahid Aref
Nokia - Germany
Fred Buchali
Nokia - Germany
Son Le
Nokia Bell Labs - USA
Michael Collisi
Chair of Electronics and Circuits, Saarland University, Saarbrücken - Germany
Michael Möller
Chair of Electronics and Circuits, Saarland University, Saarbrücken - Germany
Horst Hettrich
Micram Microelectronic GmbH, Bochum - Germany
Rolf Schmid
Micram Microelectronic GmbH, Bochum - Germany
Xuan-Quang Du
Institute of Electrical and Optical Communications Engineering, University of Stuttgart - Germany
Markus Grözing
Institute of Electrical and Optical Communications Engineering, University of Stuttgart - Germany
Manfred Berroth
Institute of Electrical and Optical Communications Engineering, University of Stuttgart - Germany

HIGH CAPACITY TRANSMISSION

14:00 - 14:30

Chair: Jochen Schröder Chalmers University of Technology - Sweden
SC5 - Optical Transmission systems

We3C1.1
High Symbol-Rate Signal Optimization for Long-Haul Transmission Systems over 1-Tbps/λ Net-Data Rate

We discuss the theoretical and practical aspects of high symbol-rate signal optimization techniques for realizing a >1-Tbps/λ long-haul transmission system. We also review the key technologies for transmitting the high symbol-rate signal such as modulation format design, bandwidth extension techniques, and equalization schemes.

Masanori Nakamura | Presenter
NTT Network Innovation Laboratories - Japan

Fukutaro Hamaoka
NTT Network Innovation Laboratories - Japan
Takayuki Kobayashi
NTT Network Innovation Laboratories - Japan
Hiroshi Yamazaki
NTT Device Technology Laboratories - Japan
NTT Network Innovation Laboratories - Japan
Munehiko Nagatani
NTT Device Technology Laboratories - Japan
NTT Network Innovation Laboratories - Japan
Yoshihiro Ogiso
NTT Device Innovation Center - Japan
Hitoshi Wakita
NTT Device Technology Laboratories - Japan
Yutaka Miyamoto
NTT Network Innovation Laboratories - Japan

SPACE DIVISION MULTIPLEXING

16:15 - 16:45

Chair: Norbert Hanik TU Munich - Germany
SC5 - Optical Transmission systems

We4C1.1
Ultra-wide band transmission in few-mode fibers

Space-division multiplexing (SDM) enables the transmission of independent data channels over different fiber modes of multi-mode fibers. In this talk, we review key characteristics of devices and fibers for SDM transmission and summarize recent SDM transmission demonstrations, including 1.01 peta-bit/s transmission in a 15-mode fiber.

Georg Rademacher | Presenter
NICT - Japan

Benjamin Puttnam
NICT - Japan
Ruben S Luis
NICT - Japan
Tobias Eriksson
Infinera - Sweden
Nicolas Fontaine
Nokia Bell Labs - USA
Mikael Mazur
Nokia Bell Labs - USA
Haoshuo Chen
Nokia Bell Labs - USA
Roland Ryf
Nokia Bell Labs - USA
David Neilson
Nokia Bell Labs - USA
Pierre Sillard
Prysmian Group - France
Frank Achten
Prysmian - The Netherlands
Yoshinari Awaji
NICT - Japan
Hideaki Furukawa
NICT - Japan