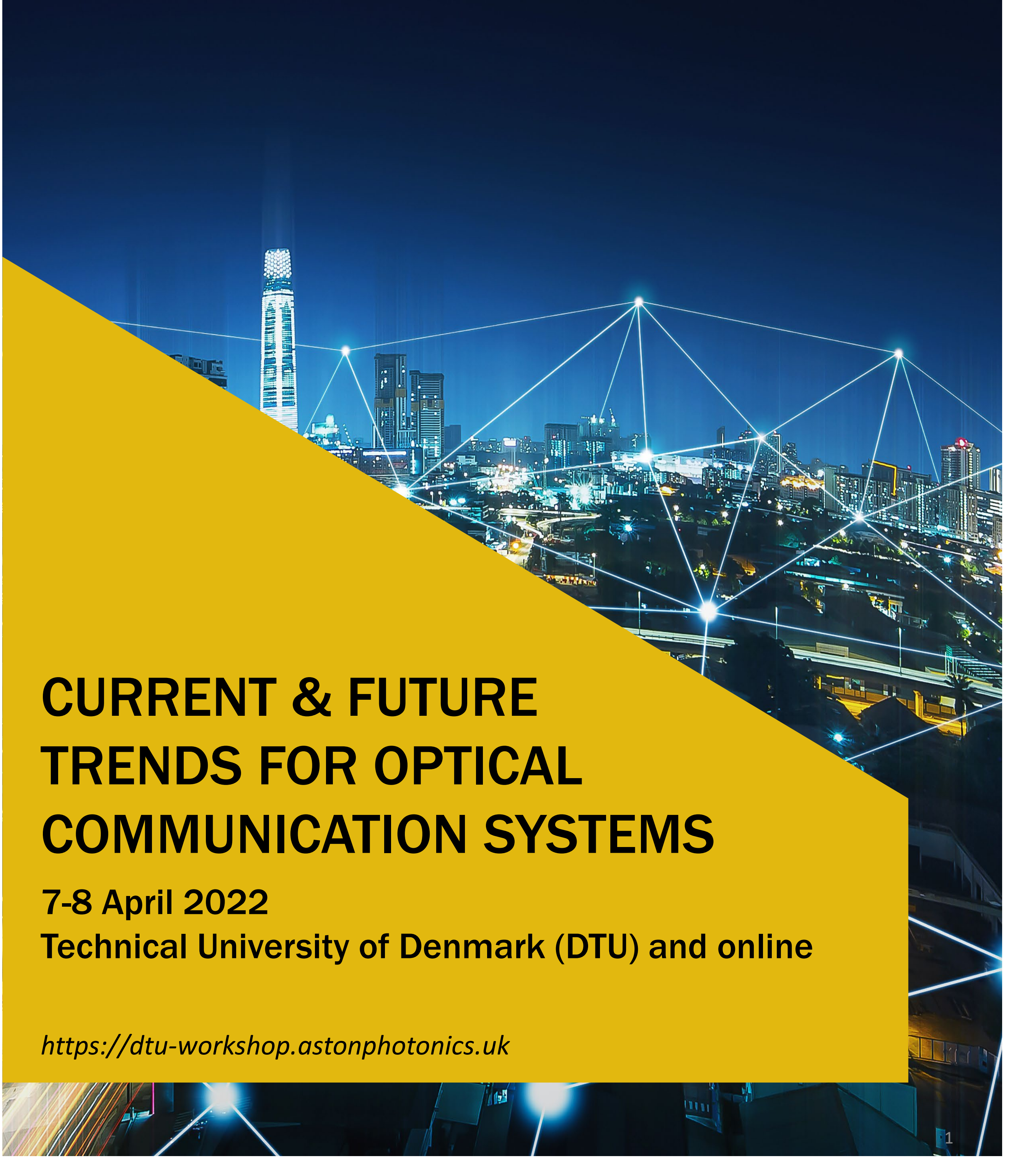
Open to all Workshop

Abstracts and Speakers



CURRENT & FUTURE TRENDS FOR OPTICAL COMMUNICATION SYSTEMS

7-8 April 2022

Technical University of Denmark (DTU) and online

https://dtu-workshop.astonphotonics.uk

The main organisers of this workshop are **Prof. Darko Zibar** & **Dr. Francesco Da Ros** of the Technical University of Denmark and **Prof. Sergei Turitsyn**, director of the Aston Institute of Photonic Technologies at Aston University (UK) together with collaborative research projects they coordinate. These are in particular projects FONTE, WON and MENTOR, who have received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 766115, 814276 and 956713; the European Research Council (H2020-EU CoG FRECOM; 771878) and the Villum Fonden /Villum Young Investigator Project VYI OPTIC-AI (29344).

Additional co-organisers of the event are projects REAL-NET, POST-DIGITAL, MOCCA, MEFISTA and MULTIPLY, who have received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement 813144, 860360, 814147, 861152 and 713694 respectively.

Session 1: Practical implementation and network applications of Nonlinear Fourier Transform	
Time (CET)	**Chair: Vinod Bajaj,** TU Delft
09:00 – 09:05	**Darko Zibar**; Technical University of Denmark ***Welcome and Opening Remarks***
09:05 – 09:40	**Sander Wahls**; Delft University of Technology **Title:** ***Pulse shaping in the nonlinear Fourier domain***
09:40 – 10:15	**Marco Secondini**; Scuola Superiore Sant'Anna **Title:** ***To NFT, or not to NFT, different ways of dealing with fiber nonlinearity***
10:15 – 10:50	**Alan Pak Tao Lau**; The Hong Kong Polytechnic University **Title:** ***Multi-symbol DSP techniques for discrete eigenvalue transmissions based on NFT***
10:50 – 11:05	Break
11:05 – 11:40	**Stas Derevyanko**; Ben Gurion University of the Negev **Title:** ***Channel models and spectral efficiency limits for optical fiber transmission systems employing the Nonlinear Fourier Transform***
11:40 – 12:15	**Morteza Kamalian-Kopae**' Aston University **Title:** ***Noise in the nonlinear Fourier domain***
12:15 – 13:30	Lunch

Session 2: ML methods for Ultra-Wide Band systems	
Time (CET)	Chair: Uiara Celine de Moura, Technical University of Denmark
13:30 – 14:05	Antonio Napoli; Infinera Germany Title: *Coherent-based point-to-multipoint optical networks: potentialities, challenges and benefits.*
14:05 – 14:40	Cristian Antonelli; University of L'Aquila Title: *Modeling of Multiple-Mode Propagation in Fibers for Space-Division Multiplexing*
14:40 – 15:15	Michael Galili; Technical University of Denmark Title: *Compensation of Nonlinear Signal Distortion using Optical Phase Conjugation*
15:15 – 15:30	Break
15:30 – 16:05	Andrea Carena; Politecnico di Torino Title: *ML models for the abstraction of photonic components in UWB systems*
16:05 – 16:40	Thomas Bradley; Eindhoven University of Technology Title: *High Capacity Data Transmission with Space Division Multiplexing*
16:40 – 17:15	Anastasiia Vasylchenkova; University College London Title: *Analytical models for quality of information estimation in the ultrawideband transmission*
18:00 – 21:00	Dinner, drinks and networking Dinner and Beer tasting at Noerrebro Bryghus (transport will be arranged)

Schedule Fri 8 April 2022

Session 3: ML and AI applied to MB optical communication	
Time (CET)	**Chair: Vladislav Neskorniuk; Aston University**
09:00-09:35	**Jelena Pesic**; Nokia France **Title:** ***Will Machine Learning mitigate the extra cost of increase in capacity?***
09:35 – 10:10	**Marija Furdek**; Chalmers University of Technology **Title:** ***Monitoring optical network security with machine learning***
10:10 – 10:45	**Marc Ruiz**; Universitat Politècnica de Catalunya **Title:** ***Opportunities and challenges of AI-based autonomous operation in MB scenarios***
10:45 – 11:00	Break
11:00 – 11:35	**Laurent Schmalen**; Karlsruhe Institute of Technology **Title:** ***Autoencoders in Optical Communications – From Modulation Format Optimization to Blind Equalization***
11:35 – 12:10	**Boris Karanov**; Eindhoven University of Technology **Title:** ***End-to-end deep learning for communication over dispersive nonlinear channels***
12:10 – 12:45	**Mehran Soltani**; Technical University of Denmark **Title:** ***Spatial and spectral power evolution design using machine learning-enabled Raman amplification***
12:45 – 14:00	Lunch
14:00-17:00	**Guided tour of the DTU Laboratories Facilities** Building 343, download map here, and further networking opportunities with workshop participants and DTU members of staff. In parallel: FONTE Project Networking and Management Meeting (closed event)
18:00-21:00	**Informal networking opportunity**

Pulse shaping in the nonlinear Fourier domain

Sander Wahls

Delft University of Technology

Sander Wahls received a Diplom degree in mathematics from TU Berlin in 2007, and a doctorate in electrical engineering (summa cum laude) from the same university in 2011. He is currently an associate professor with ius promovendi at the Delft Center for Systems & Control at TU Delft. Before joining TU Delft in 2014, Sander spent two years as a Postdoctoral Research Fellow in the Department of Electrical Engineering at Princeton University. His research is focused on system theory and signal processing for nonlinear systems, currently in the areas of integrable systems, nonlinear Fourier transforms and their application in engineering problems. He received the 2015 Johann-Philipp-Reis Award for his work on fast nonlinear Fourier transforms. In 2016, the European Research Council (ERC) awarded him a Starting Grant on the same topic. Since 2021, he is serving on the ECOC Subcommittee “Techniques for digitally enhancing optical communication”. He is a Senior Member of the IEEE.

Abstract:

In recent years, many new fiber-optic transmission schemes based on nonlinear Fourier transforms (NFT) have been proposed. The time domain characteristics of the pulses generated by these schemes can differ significantly. Pulse shapes have a considerable impact on spectral efficiency. We therefore survey existing NFT-based transmission schemes in this talk, and discuss the different possibilities to control the pulse shapes that they offer.

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To NFT, or not to NFT, different ways of dealing with fiber nonlinearity

Marco Secondini

Scuola Superiore Sant'Anna

Marco SECONDINI received the M.S. degree in Electrical Engineering from the University of Roma Tre, Rome, Italy, in 2000, and the Ph.D. degree from Scuola Superiore Sant'Anna, Pisa, Italy, in 2006. In 2005, he was a Visiting Faculty Research Assistant with the Photonics Group, University of Maryland Baltimore County, Baltimore, USA. Since 2007, he has been with Scuola Superiore Sant'Anna, where he currently serves as an Associate Professor of Telecommunications. He also collaborates with the Photonic Networks & Technologies National Lab of the CNIT in Pisa. He served in the technical program committees of the Optical Fiber Communication Conference (OFC), the European Conference of Optical Communication (ECOC), the Asia Communications and Photonics Conference (ACP), the Global Communications Conference (GLOBECOM), and the International Conference on Communications (ICC). He currently serves as an Associate Editor for IEEE Transactions on Communications. His research interests are in the area of optical fiber communications, with a special focus on information theoretical aspects, modulation and detection techniques, and fiber nonlinearity modelling. In this area, he has coauthored more than 120 papers in leading journals and conferences.

Abstract:

Fiber nonlinearity limits the performance of current optical fiber communication systems. In this talk, we review different approaches that can be followed to mitigate the impact of fiber nonlinearity. In particular, we focus on the idea that fiber nonlinearity can be avoided, or at least reduced, by properly shaping the waveforms that are transmitted through the optical fiber. To this aim, we consider two rather different approaches, namely, constellation shaping and nonlinear frequency division multiplexing. The former acts at a symbol level, optimizing the constellation in a high-dimensional space to minimize fiber nonlinearity. The latter acts at a waveform level, using the nonlinear Fourier transform to perform modulation and demodulation in the nonlinear spectrum domain, where fiber propagation is linear. Pros and cons of the two techniques are discussed, exploring their potential and limits.

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Multi-symbol DSP techniques for discrete eigenvalue transmissions based on NFT

Alan Pak Tau Lau

The Hong Kong Polytechnic University

Alan PT LAU received his B.A.Sc in Engineering Science (Electrical Option) and M.A.Sc. in Electrical and Computer Engineering from University of Toronto in 2003 and 2004 respectively. He obtained his Ph.D. in Electrical Engineering at Stanford University in 2008 and has joined the Hong Kong Polytechnic University where he is now an Associate Professor. His research covers system characterization, performance monitoring, digital signal processing and machine learning applications of various optical communication systems and networks. He collaborates extensively with Industry and serves in technical program committees of major conferences in Optical Communications.

Abstract:

For discrete eigenvalue transmissions (or soliton transmissions), one seeks to encode as much information as possible in each degree of freedom and shorten the distance between neighboring pulses to increase the overall bit rate. However, such attempts would result in nonlinear inter-symbol interference (ISI) across multiple symbols and significantly degrade transmission performance. We hereby demonstrate analytically and experimentally that one can considerably improve soliton transmission performance by intentionally allowing neighboring solitons to interact and collide during propagation and exchange positions at the receiver followed by standard NFT processing. This can be achieved by designing neighboring solitons' eigenvalues $\boldsymbol{\lambda}$ to have opposite signs in the real part while the magnitude $|\Re(\boldsymbol{\lambda})|$ is optimized for a given transmission distance so that neighboring transmitted pulses would have swapped their timing positions at the receiver. We further investigated joint modulation of discrete eigenvalue $\boldsymbol{\lambda}$ and $\boldsymbol{b}$ -coefficents $\boldsymbol{b}(\boldsymbol{\lambda})$ and developed a suite of multi-symbol digital signal processing (DSP) techniques to exploit the statistical correlations between the continuous and discrete eigenvalues and $\boldsymbol{b}$ -coefficents to mitigate nonlinear distortions and improve detection performance. We jointly modulate $\boldsymbol{\lambda}$ with 16-QAM and $\boldsymbol{b}(\boldsymbol{\lambda})$ with 16-APSK and experimentally demonstrate 64 Gb/s (net 54 Gb/s) over 1200 km with the proposed multi-symbol DSP algorithms.

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Channel models and spectral efficiency limits for optical fiber transmission systems employing the Nonlinear Fourier Transform

Stas Derevyanko

Ben Gurion University of the Negev

Stanislav (Stas) DEREVYANKO is a theoretical physicist by training and has spent most of his career looking at nonlinear and/or disordered systems. From high energy beams scattering in a disordered medium to Shannon informational capacity of the modern day optical fibre communications scientists and engineers have to look at and describe the systems that are affected both by nonlinearity and noise. While the area of high power and high signal-to-noise ratio is studied by the nonlinear physics (with many achievements to its credit) the opposite limit deals with fully disordered systems and/or incoherent pulses and is the subject of the general theory of disordered systems. The grey area in between, when both signal and noise contribute equally to the dynamics of the system remains one of the main challenges for both physicists and engineers.
Most of his current research activities deal with the interplay of nonlinearity and disorder in one way or another. From optical telecommunications to thermalization in coupled waveguides and from information theory to machine learning – they all have one thing in common: they are enormous fun!.

Abstract:

In this talk I will outline recent developments in the field of theoretical modelling of NFT-channels limited by the amplifier spontaneous emission. The two main problems currently facing NFT-based transmission are signal-noise interaction due to the loss of integrability and low spectral efficiency due to the need for the burst mode transmission. With respect to the former I will show that the sources of signal distortion at the receiver are twofold: a direct ASE noise component and the so-called processing noise of purely deterministic nature. For the popular b-modulation NFT scheme the developed theory of the ASE noise component shows that the noise power spectral density goes to zero at high values of input power so the dominating signal distortion at high power is the processing noise.

With regard to the ways of increasing the spectral efficiency I will show that by using more efficient nonlinear spectral carriers (like Gauss-Hermit waveforms) one can significantly improve the time-bandwidth product of the NFT bursts and reach spectral efficiencies that are competitive with the conventional values at the same propagation distances.

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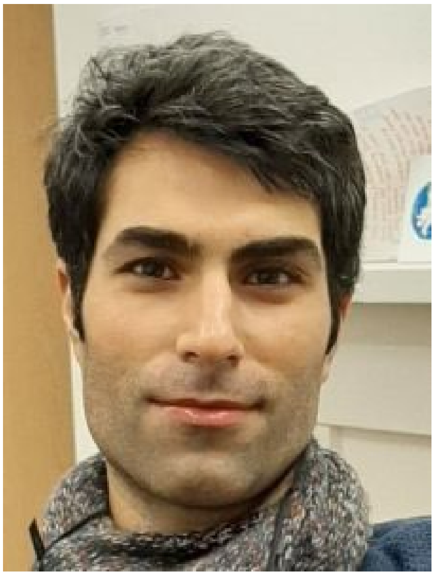
Noise reduction techniques in the nonlinear Fourier domain

Morteza Kamalian-Kopae
Aston University

Morteza KAMALIAN-KOPAE received his BSc in electrical engineering from Isfahan University of Technology, Isfahan, Iran, his MSc in communication engineering from Yazd University, Yazd, Iran, and his PhD in electrical engineering from Aston University, Birmingham, UK. Since graduation, he has been with Aston Institute of Photonic Technologies (AIPT) as a research fellow working on nonlinear Fourier transform, in particular, for periodic solutions of the nonlinear Schrödinger equation. His research interests include signal processing in optical communication, analysis of nonlinear dynamics, and wireless communication systems.



Abstract:
Nonlinear Fourier transform provides us with the analytical relation between the input and output of the optical fibre link. This is what is required to find the capacity of fibre as the most important communication channel of modern data networks. An important part of this analytical model is the stochastic distribution of the received signal which is corrupted by random noise. In this talk, I will discuss some mathematical tools to explore noise and its representation in the Fourier domain and how we can quantify its impact in the NFT framework.

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Coherent-based point-to-multipoint optical networks: potentialities, challenges and benefits.

Antonio Napoli

Infinera Germany

Antonio NAPOLI received his Ph.D. degree from the Politecnico di Torino with a thesis on “Electronic equalization for advanced modulation formats”. Since 2006 he joined the R&D of Siemens COM, where he was initially working on EDFA transient suppression for long and ultra-long-haul optical networks. In 2007, he became a member of the established joint venture between Nokia and Siemens, named Nokia Siemens Networks, where he was working on cutting-edge projects on robust and tolerant design of optical communications systems at 100 Gb/s and 400 Gb/s. In particular, he was involved in the design and development of future DSP-based coherent receivers for next-generation optical communication systems. In 2013, he joined Coriant, where he has been involved in EU project working on data plane activities, such as for example in the EU FP-7 IDEALIST project. From Oct. 1st 2018, he is with Infinera. His research interests include DSP for optical bandwidth variable transponders from metro to long-haul network receivers, advanced modulation techniques, and wideband optical system design and modelling.

Abstract:

A paradigm shift in optical communication networks is proposed, with the introduction of a new ecosystem of devices and components with the capability of transforming current point-to-point optical networks (with their entailed, limiting, electrical aggregation) into flexible, scalable and cost-effective point-to-multipoint networks. In the new architecture, which better aligns with the hub-and-spoke traffic patterns observed in today’s metro and access network segments, interoperability across a variety of transceivers operating at different speeds is achieved using individually routed, digitally generated subcarriers. The first comprehensive demonstration of the technical feasibility of the proposed point-to-multipoint architecture based on digital subcarrier multiplexing is presented, along with the remarkable cost savings and simplification of the network it enables.

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Infinera®

Modeling of Multiple-Mode Propagation in Fibers for Space-Division.

Cristian Antonelli

University of L'Aquila

CV here

Abstract:

This talk will review the main concepts involved in the modelling of propagation in fibers for space-division multiplexed transmission, with focus on modal dispersion and nonlinear interference, as well as the interplay between them.

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Compensation of Nonlinear Signal Distortion using Optical Phase Conjugation.

Michael Galili

Technical University of Denmark

Michael GALILI (Member, IEEE) was born in Aabenraa, Denmark, in 1977. He received the M.Sc. degree (Eng.) in applied physics from the Technical University of Denmark (DTU), Kgs. Lyngby, Denmark, in 2003 and the Ph.D. degree in optical communications and signal processing from DTU Fotonik in 2007. He is currently an Associate Professor and Scientific Coordinator with the Research Center Silicon Photonics for Optical Communication (SPOC). He is the author or coauthor of more than 300 peer-reviewed journal and conference publications and he is teaching and supervising students at bachelor's, master's, and Ph.D. level. His research interests include optical transmission and signal processing for telecommunication, nonlinear integrated devices for optical processing and advanced optical switches for datacom systems.

Abstract:

We will discuss our recent work on compensation of fibre nonlinearity using optical phase conjugation. This technique allows for some degree of compensation of optical nonlinearities accumulated during fibre transmission by implementing optical phase conjugation at a symmetric position with respect to the accumulation of nonlinearities. In this way nonlinear phase rotation accumulated during one part of the propagation may be compensated by nonlinear phase rotation affecting the conjugated field in a later part of the propagation.
We will discuss span configurations in transmission links to improve the performance of compensation. We will also discuss optical pre- or post-compensation using lumped compensation schemes as well as efforts to achieve compensation in few-mode fibre transmission.

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ML models for the abstraction of photonic components in UWB systems

Andrea Carena

Politecnico di Torino

Andrea CARENA is Full Professor in the Optical Communication Group of Dipartimento di Elettronica e Telecomunicazioni at Politecnico di Torino, Italy. He received the M.Sc. and Ph.D. degrees in electronic engineering from Politecnico di Torino, Torino, Italy, in 1995 and 1998, respectively. He is currently an Associate Professor at the Optical Communication Group, Dipartimento di Elettronica e Telecomunicazioni, Politecnico di Torino. His research interests include physical layer design optical communication systems: coherently detected systems, digital coherent receiver design, digital signal processing techniques for advanced modulation formats, digital nonlinearity mitigation, Nyquist-WDM for Terabit Superchannel implementation, algorithm for computer simulation of fiber propagation, and a particular emphasis on fiber nonlinearities modeling. He co-authored more than 200 scientific publications. In 2014 and 2015, he received the IEEE/OSA “JOURNAL OF LIGHTWAVE TECHNOLOGY” Best Paper Award.

Abstract:

In recent years data traffic has seen an extraordinary growth driven by a continuous increase in the number of connected devices and the development of new bandwidth hungry applications. To improve the capacity of optical networks, a promising solution is the adoption of Ultra-Wide-Band (UWB) systems expanding the fiber bandwidth beyond the standard C-band. In this context, the introduction of a software-defined networking (SDN) paradigm is a viable solution to deliver flexibility and dynamic reconfigurability to the network. To implement SDN in UWB networks it is required the full abstraction and virtualization of each network element as it allows operations coordinated by a centralized network controller. This objective can be reached by defining simple but accurate models for all components. This talk presents an approach based on the application of Machine Learning (ML) techniques and it focus on two network elements: the photonic switch and the Raman amplifier.

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High Capacity Data Transmission with Space Division Multiplexing.

Thomas Bradley

Eindhoven University of Technology

Thomas BRADLEY is a senior researcher in the High Capacity Optical Transmission Lab of the Electro-Optical Communications Group at the Institute for Photonics Integration, TU/e. His current research lies in two key areas of fibre optic sensing and quantum communications. The development of novel optical fibres and fibre post processing techniques can be exploited to support novel optical fibre sensors and advances in quantum communications. He has authored and co-authored several high impact publications in Nature Photonics, Optics Express and has several prestigious post deadline papers at leading optical communications conferences

Abstract:

There is current and ongoing exponential growth in internet traffic. Such scaling requires an exponential increase in the amount of single mode fibre deployed to support this traffic and which combined with the approach of the Shannon capacity limit requires the development of novel technology to address this challenge. Space division multiplexing (SDM) using few mode, multi-core and/or few mode multi-core fibres have potential for ultra-high capacity data transmission. Here, I present our work in developing SDM technology and characterisation tools for ultra-high capacity data transmission. In addition, I present an emerging technology, Hollow Core Fibres as a potential revolutionary technology for low latency high-capacity data transmission.

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Analytical models for quality of information estimation in the ultrawideband transmission.

Anastasiia Vasylchenkova

University College London

Anastasiia Vasylchenkova is currently a Leverhulme Trust Research Fellow in Optical Networks Group at University College London, running a research project on the analytical modelling of ultrawideband optical communication. She received her BSc and MSc in nuclear physics from Kharkiv National University, and a PhD from Aston University, Birmingham, UK, for her research within the nonlinear Fourier transform approach for optical communications. Her research interests include fibre optics, nonlinearity mitigation, analytical modelling and transmission system design.

Anastasiia is an experienced educator in STEM, educational events manager and designer, Fellow of the Higher Educational Academy. She is holding the role of the President International Physicists' Tournament, leading the work of the executive team. Beyond this, she has 10 years of volunteering experience for STEM and photonics communities, including engagement through SPIE, IEEE, and OSA. She is a Committee Member and Publicity Officer of the IEEE Photonics UK and Ireland Photonics Chapter, and a Chair-elect of the OSA Optical Communication Technical Group.

Abstract:

The optimisation and design of optical transmission systems involve multiple factors and interplay between noise sources, fibre nonlinearity and dispersions. For ultrawideband systems, the total number of parameters scales with the number of channels, and the optimisation appears to be computationally challenging. To compensate for it, one can apply analytical models for the quality of transmission estimation. Those can give the statistically averaged value of the signal to noise ratio, being an effective and accurate tool instead of full-scale signal transmission simulations. In the talk, I will cover the advantage that the Gaussian noise model and its generalisation to account for interchannel Raman scattering can bring to the analysis and optimisation of the transmission systems.

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Will Machine Learning mitigate the extra cost of increase in capacity?

Jelena Pesic

Nokia France

Jelena PESIC received a Ph.D. in Optical Networks from the University of South Brittany in collaboration with France Telecom–Orange Labs, France, in 2012. She received a best paper award at the IEEE ONDM conference in 2011. After her PhD Jelena joint Telecom Bretange as Post-doctoral Research Engineer and later INRIA, where she worked on the European project SASER. After moving to Alcatel–Lucent (now Nokia) Bell Labs in 2014, she focused on dynamic elastic networks dimensioning and techno-economic studies. Her main areas of research interest include intelligent optical networks, including core and metro networks. Jelena was selected OSA Ambassador in 2018.
She is currently working at Nokia as Systems Integration Specialist, with ION IP Optical Networks WDM technical expertise on the basis of the Nokia IP Transport product portfolio.

Abstract:

Machine learning has become an exciting subject in optical networks for both industry and academia. Its success reflects the growing need for network adaptation to changing circumstances (e.g., traffic, topology, or even user preferences). Moreover, challenges in optical networ ks are becoming more critical as we think about their evolution towards future scenarios with more data traffic, such as 5G networks, IoT, and others. Tomorrow's optical networks are a complex domain asking for very high capacity networks that also need to save the cost per bit. In this talk, we will try to explore machine learning for optical networks in light of its enormous technical capabilities as well as its potential to reduce costs.

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Monitoring optical network security with machine learning

Marija Furdek

Chalmers University of Technology

Marija Furdek works in the research unit Optical Networks. Her expertise lies in optical network design and optimization, with an emphasis on physical-layer security and resilience. She strives to develop secure, cognitive and autonomous communication networks. As (co)PI and WP/task leader, Marija participated in several Swedish and international scientific projects with collaborators from industry and academia. She co-authored 90+ scientific publications in international journals and conferences, 5 of which received best paper awards. She is a Senior Member of IEEE and OSA

Abstract:

Optical networks are critical infrastructure vulnerable to a range of physical layer attacks that can degrade a multitude of services in the upper network layers. Despite recent progress, a framework for cognitive security management is not established yet. In this talk, we will discuss the challenges related to attack prevention, detection, and recovery. The focus will be placed on supervised, unsupervised and semi-supervised learning techniques that have promising performance in detecting known as well as novel attack types. The main challenges related to accuracy, scalability, interpretability and practical deployment of ML-based security diagnostics procedures will be reviewed, and ways of addressing these challenges will be examined.

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Opportunities and challenges of AI-based autonomous operation in MB scenarios

Marc Ruiz

Universitat Politècnica de Catalunya

Marc RUIZ received the M.Sc. degree in Statistics and Operations Research in 2009 from the Universitat Politecnica de Catalunya (UPC). In 2009 he joined the Advanced Broadband Communications Center (CCABA) to start his pre-doctoral research, receiving the PhD degree (with honors) in Computer Science in 2012 from the Computers Architecture Department (DAC) at UPC. He is currently working as a post doctoral researcher with the CCABA. His research interests include optimization and data analytics for next generation 5G networks. He has developed part of his work in the framework of past FP-7 European research projects such as DICONET, STRONGEST, IDEALIST, and GÉANT. Currently, he is working on the H2020 5G-PPP METRO-HAUL project, covering several topics on network planning and data analytics for metro optical networks. Moreover, he has participated in various national funded projects.

Abstract:

After the success of the first focused and standalone 5G trials, the beyond 5G (B5G) era already started, becoming the mainstream of academic and industry-driven research for next-generation networks. Future B5G networks must be able to operate with massive small-cell deployments and end-to-end connectivity in support of heterogeneous use cases with very different requirements in terms of bandwidth, latency and reliability. The availability of Multi-Band transmission, as well as other key technologies such as pluggable optics, will also lead to a complete redesign of the optical transport network. This also includes the control and management planes, that need to fully support autonomous network operation based on AI/ML algorithms, zero-touch networking and intent-based networking paradigms.

In this talk, we will review recent research contributions focused on AI/ML-based autonomous networking for several use cases including real time and near-real time operation. In addtion, analysis of the challenges and opportunities for future research applied to the foreseen optical transport technologies and networking paradigms will be introduced.

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Autoencoders in Optical Communications – From Modulation Format Optimization to Blind Equalization

Laurent Schmalen

Karlsruhe Institute of Technology

Laurent SCHMALEN is a full professor at Karlsruhe Institute of Technology (KIT) in Karlsruhe, Germany, where he heads the Communications Engineering Lab (CEL). From 2011 to 2019, he was a member of technical staff and department head at Nokia Bell Labs in Stuttgart, Germany. He joined Bell Labs after receiving his Ph.D. from RWTH Aachen University in Aachen, Germany. His research topics include forward error correction algorithms and digital coded modulation schemes for high-speed optical communications. He received multiple awards for his research work, including the 2016 Journal of Lightwave Technology Best Paper Award, has more than 120 publications in journal and conference papers, has co-authored 4 book chapters and holds several patents.

Abstract:

In the recent years, machine learning techniques have proven to be indispensable tools for designing communication systems. One particularly popular technique is the concept of auto-encoders. In this talk, we will introduce the concept of auto-encoders and show how they can be used in two distinct ways to optimize the physical layer of optical communication systems. In particular, we show how to design higher order constellations that are tailored to channels exhibiting laser phase noise by using a novel differentiable blind phase search algorithm. As a second application, we use the concept of variational auto-encoders to design novel blind equalizers for coherent optical communications compensating linear impairments. The proposed algorithm jointly carries out equalization and performs a channel estimation, which is useful for providing information to higher network layers.

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End-to-end deep learning for communication over dispersive nonlinear channels

Boris Karanov

Eindhoven University of Technology

Boris KARANOV is a post-doctoral research member of the Signal Processing Systems Group at the Eindhoven University of Technology with research focused on the application of deep learning for digital signal processing in optical fibre communications. He received his PhD from University College London, London, U.K., and Nokia Bell Labs, Stuttgart, Germany His Ph.D. research focused on developing new coding and detection methods for communication over the nonlinear dispersive optical fibre channel using deep learning. In 2018, Boris was a recepient of the Nokia “Most innovative AI solution” award for pioneering work in the field of machine learning applications to communication systems.

Abstract:

Deep learning, allowing the approximation of any nonlinear function, finds an increasing application in the digital signal processing modules of communication systems. Often, a specific transmitter or receiver function, such as coding, modulation or equalization, is optimized using deep learning. Moreover, deep learning and neural networks allow to design a complete communication system by carrying out the optimization in a single process spanning from the transmitter input to the receiver output. Such systems, implemented as a single deep neural network, have the potential to achieve the optimal end-to-end performance and recently gained popularity in communication scenarios, where the optimum pair of transmitter and receiver or optimum processing modules are not known or prohibitive because of complexity. In low-cost optical fiber systems based on intensity modulation and direct detection (IM/DD), the joint effects of chromatic dispersion and square-law photodiode detection render the communication channel nonlinear with memory. Such systems are particularly suitable for deep learning-based signal processing due to absence of optimal algorithms as well as complexity constraints. We discuss how end-to-end deep learning can be implemented in the low-cost fiber system and compare their performance and complexity with classical designs.

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Spatial and spectral power evolution design using machine learning-enabled Raman amplification

Mehran Soltani

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Mehran SOLTANI received his B.Sc. and M.Sc. degrees in electrical engineering, communications systems from Amirkabir University of Technology; Tehran, Iran. His M.Sc. thesis (2020) was entitled “Learning-based Estimation and Detection in OFDM Systems”, addressing deep learning methods for channel estimation and signal detection in OFDM systems. He joined the *Machine Learning in Photonic systems* group at the Department of Photonics Engineering, DTU, in July 2020. His PhD, under the supervision of Prof. Darko Zibar, focuses on signal power evolution design using machine learning-based Raman amplification. His research interests include machine learning and signal processing applied to optical and wireless communication systems.

Abstract:

Raman amplification is one of the key technologies in improving the performance of fiber optic communication systems. In this talk, I will present our machine learning framework on Raman amplifier design for shaping the signal power evolution over the frequency and fiber distance. The proposed framework adjusts the Raman pump power values to obtain the desired two-dimensional (2D) profiles using a convolutional neural network (CNN) followed by the differential evolution (DE) technique. The CNN learns the mapping between the 2D profiles and their corresponding pump power values. Nonetheless, its performance is not accurate for designing 2D profiles of practical interest, such as a 2D flat or a 2D symmetric (with respect to the middle point in fiber distance). To adjust the pump power values more accurately, the DE fine-tunes the power values initialized by the CNN to design the proposed 2D profile with a lower cost value. The results assert the very good performance of the proposed CNN-assisted DE framework utilized in designing 2D flat and symmetric power profiles defined over the whole C-band. Furthermore, the proposed DE with the CNN initialization provides higher accuracy with lower variance compared to the randomly initialized DE optimization.

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