

Special Symposium on Space Division Multiplexing Technologies (SS SDMT)

Symposium Chair: Yoshinari Awaji, *NICT, Japan*

Space division multiplexing (SDM) is seen as a promising solution to overcome the capacity limit of the single-mode fibers (SMF). Intensive research in this field over the past decade has brought forth sophisticated multi-core fiber designs and multi-mode transmission techniques constantly pushing the limits on achievable data rates and spectral efficiency with regard to a single strand of fiber. At the same time, efforts towards bringing SDM closer to an adoption in real systems also reveal the need for compatibility with standards developed for conventional SMF systems. In this sense, the task of drafting a roadmap towards commercialization is not straightforward and presents us with many options to choose from. Now is the time to discuss and think more carefully about these options. This workshop will try to foster a better understanding on how to bring the most advanced achievements in SDM research in line with commercial viability.

Session: MA1 – Monday, 1 October 2018: 8:30 AM–9:45 AM

Grand Ballroom A

Session Title: Advanced OAM and SDM/WDM

Joint Session: Optical Communications (OC) / Special Symposium on Space Division Multiplexing Technologies (SS SDMT)

Session Chair: Yoshinari Awaji, *NICT, Japan*

MA1.1 8:30 AM–9:00 AM (Invited)

Classical and Quantum Communications with OAM in Fibers

Siddharth Ramachandran, Boston University, Boston, MA, USA

We review advances in, and prospects of, multiplexing data in the classical domain, or achieving high-dimensional keys in the quantum domain, using optical fibers that support Orbital Angular Momentum (OAM) states for scaling mode count in fibers while minimizing intermodal cross-talk.

MA1.2 9:00 AM–9:15 AM

Spatial Quadrature Amplitude Multiplexing Using Coherently Coupled Beams with Orbital Angular Momentum

Kaitlyn Morgan, Clemson University, SC, USA

This paper demonstrates a system for spatial switching of two coherently coupled orbital angular momentum (OAM) modes for a free space optical link based on 32-QAM. In addition, coherent mode detection is accomplished using passive optics in a correlation receiver optical setup.

MA1.3 9:15 AM–9:45 AM (Invited)

Signal Processing for Ultra-Dense WDM/SDM Transmission Systems

Koji Igarashi, Osaka University, Japan

Session: MA2 – Monday, 1 October 2018: 10:30 AM–11:45 AM

Grand Ballroom A

Joint Session: Optical Communications (OC) / Special Symposium on Space Division Multiplexing Technologies (SS SDMT)

Session Title: High Density SDM Transmission

Session Chair: Tetsuya Hayashi, *Sumitomo Electric Industries, Ltd., Japan*

MA2.1 10:30 AM–11:00 AM (Invited)

Mode-selective 45-mode Spatial Multiplexer and recent Applications of Multi-Plane Light Conversion

David Allieux, CAllabs, France

We report the fabrication and characterization of 45 mode space division multiplexers based on Multi-Plane Light Converter. The multiplexers show an average 4 dB insertion loss and -28 dB cross-talk across the C band. Present and future of industrial applications of this technology are exposed.

MA2.2 11:00 AM–11:15 AM

Power Loading in Peak Limited Intensity Modulation Direct Detection Mode Group Division Multiplexing

Nir Sheffi, Ben Gurion University, NY, USA

Data centers experience exponential traffic growth. We suggest an MGDM system based upon IM MZMs coupled to a GI-MMF using Si-photonics and a multi-segment concentric photo-detector. We analyze this system's power loading using convex optimization for two types of closed-loop architectures: the V-BLAST and SVD.

MA2.3 11:15 AM–11:45 AM (Invited)

10 Pbit/s SDM/WDM Transmission

Daiki Soma, KDDI Research, Inc., Fujimino, Japan

Session: MA4 – Monday, 1 October 2018: 3:30 PM–4:45 PM
Special Symposium on Space Division Multiplexing Technologies (SS SDMT)
Session Title: Steps Toward Practicality of SDM
Session Chair: Yoshinari Awaji, *NICT, Japan*

Grand Ballroom A

MA4.1 3:30 PM–4:00 PM (Invited)

Toward the Practical use of the Multi-core Fiber in Optical Communications

Tetsuya Hayashi, *Sumitomo Electric Industries, Ltd., Japan*

The intensive research and development on multi-core and other types of optical fibers for space-division multiplexed transmission has continued already for nearly ten years. This talk will review and discuss recent research and development on the multi-core fiber toward the practical realization.

MA4.2 4:00 PM–4:15 PM

Suppression of Group-Delay Spread in Coupled Two-LP-Mode Four-Core Fiber

Takanori Sato, *Hokkaido University, Japan*

We newly develop the group-delay spread (GDS) analysis for a tight-bent coupled few-mode multicore fiber (FM-MCF) using pseudo guided modes and reveal that the GDS of coupled FM-MCF can be suppressed for the first time.

MA4.3 4:15 PM–4:45 PM (Invited)

Switching Paradigms for SDM-WDM Networks

Dan Marom, *Hebrew University of Jerusalem, Israel*

We newly develop the group-delay spread (GDS) analysis for a tight-bent coupled few-mode multicore fiber (FM-MCF) using pseudo guided modes and reveal that the GDS of coupled FM-MCF can be suppressed for the first time.

Special Symposium on Microwave Photonics in Defense (SS MPD)

Symposium Co-Chairs: Thas A. Nirmalathas, *University of Melbourne, Australia*
 Richard De Salvo, *Harris, USA*
 Maurizio Burla, *ETH, Switzerland*

Session: MG1 – Monday, 1 October 2018: 8:30 AM – 10:00 AM

Lake Audubon

Session Title: Microwave Photonics Technologies for Defense
Session Chair: Thas A. Nirmalathas, *University of Melbourne, Australia*

MG1.1 8:30 AM–9:00 AM (Invited)

Microwave Photonics in Future Military Systems

Edward I. Ackerman, *Photonic Systems Inc., USA*

Since the late 1980s, when fiber-optic links were first shown to enable high-fidelity transport of analog signals between distant locations, additional capabilities enabled by microwave photonic technology have evolved. This paper provides an overview of the technology's contributions to the electronics industry as a whole.

MG1.2 9:00 AM–9:30 AM (Invited)

Microwave Photonics in Radar

Paul Matthews, *Northrop Grumman Corporation, VA, USA*

Recent technological innovations in electronic devices are resulting in dramatic changes in military sensor architectures and design. These trends and their impact on architectures and the system design process will be discussed in order highlight potential insertion opportunities for photonic techniques in future military systems.

MG1.3 9:30 AM–10:00 AM (Invited)

Antennas and Signal Processing with Photonics

Rodney Waterhouse, *Pharad Inc., USA*

Efficient, integrated antenna/microwave/photonic modules are critical for communications, signal intelligence and radar signal processing applications. We present a model that enables the electromagnetic properties of the antenna (input impedance, antenna efficiency) to be readily incorporated into system simulation tools to enable full link optimization.

Session: MG2 – Monday, 1 October 2018: 10:30 AM–12:00 PM**Lake Audubon****Special Symposium on Microwave Photonics in Defense (SS MPD)****Session Title:** Microwave Photonics Technologies for Radar**Session Chair:** Christina Lim, *University of Melbourne, Australia***MG2.1 10:30 AM–11:00 AM (Invited)****Microwave Photonics in Radar****Leonardo Lembo**, *Scuola Superiore Sant'Anna & Italian Navy, Naval Research Center CSSN, Vallauri Institute, Italy*

An overview on the trend and main issues of radars and the potential of introducing photonics will be presented. The advantages in terms of frequency-agility, multi-band operation and performance on a single radar apparatus and on multiple input-multiple output radar systems will be detailed.

MG2.2 11:00 AM–11:30 AM (Invited)**Millimeter-Wave Radars Using Radio-Over-Fibers****Tetsuya Kawanishi**, *Waseda University / National Institute of Information and Communications Technology (NICT), Japan*

This paper describes concept of sensor-over-fiber and its application to millimeter-wave radar systems with many antenna units connected through radio-over-fiber networks, where the radar range resolution can be a few centimeters.

MG2.3 11:30 AM–12:00 PM (Invited)**Universal MWP Signal Processors – Architectures and Technologies****Jose Capmany**, *Valencia University, Spain***Special Symposium on Integrated Photonics and Information Security (SS IPIS)****Symposium Chair:** Amy Foster, *Johns Hopkins University, MD, USA*

The speed and information capacity of light waves provide potential benefits for information security devices and systems. In this symposium, we would like to highlight work in the area of optics for information security, in particular, the integration of such tools into on-chip photonic devices.

Session: WC3 – Wednesday, 3 October 2018: 1:30 PM–2:45 PM**Grand Ballroom C****Special Symposium on Integrated Photonics and Information Security (SS IPIS)****Session Title:** SS Integrated Photonics & Information Security**Session Chair:** Amy Foster, *Johns Hopkins, MD, USA*

The speed and information capacity of light waves provide potential benefits for information security devices and systems. In this symposium, we would like to highlight work in the area of optics for information security, in particular, the integration of such tools into on-chip photonic devices.

WC3.1 1:30 PM–2:00 PM (Invited)**Silicon-based All-optical Logic Gates and Memories for Low-latency, High-speed Cryptography****Imad Agha**, *University of Dayton, Ohio, USA*

While cryptographic protocols run efficiently on general computers, there has been a push towards deployment on smaller scales. Achieving high-throughput on devices with limited resources makes an all-optical approach an attractive prospect. All-optical logic gates and all-optical memories form the backbone of such a platform.

WC3.2 2:00 PM–2:15 PM**Silicon Photonic Cryptographic Engines****Bryan Bosworth**, *Johns Hopkins University, MD, USA*

We present nonlinear chaotic silicon micro-cavities as unclonable physical keys to solve multiple problems in applied cryptography, particularly secure authentication and encryption.

WC3.3 2:15 PM–2:30 PM**Physical-Layer Security in Free-Space Optical Communications Using Bessel-Gaussian Beams****Tyan-Lin Wang**, *University of Arizona, AZ, USA*

Physical-layer security in free-space optical communications channels is compromised when eavesdroppers perform optical beam-splitting attacks. Previous simulations showed that Laguerre-Gaussian beams carrying orbital angular momentum provide increased secrecy capacity compared to Gaussian beams. We extend those studies by simulating Bessel-Gaussian beams and obtain further improvement.

WC3.4 2:30 PM–2:45 PM**Photonic Physical Unclonable Functions using Silicon Nitride Spiral Waveguides**Hongcheng Sun, *Johns Hopkins University, MD, USA*

Silicon nitride spiral physical unclonable functions provide unique spectral fingerprints in a compact, integrated platform and have potential for use in IC authentication.

Special Symposium on Constellation Shaping (SS CS)Symposium Chair: Ivan Djordjevic, *University of Arizona, USA***Session: WF3 – Wednesday, 3 October 2018: 1:30 PM–3:00 PM**

Lake Anne A/B

Special Symposium on Constellation Shaping (SS CS)

Session Title: Constellation Shaping

Session Chair: Ivan B. Djordjevic, *University of Arizona, AZ, USA*

Progress in constellation shaping: design metrics, implementation techniques, limitations and interaction with forward error correction.

WF3.1 1:30 PM–2:00 PM (Invited)**Low-Complexity Distribution Matcher Based on Hadamard Matrix Combined with Geometrical Shaping for PAM-4 IM-DD Transmission Systems**Nebojsa Stojanovic, *Huawei Technologies Duesseldorf GmbH, Munich, Germany*

We propose a simple algorithm for controlling PAM-4 level probabilities in IM-DD optical systems. Probabilistic shaping is combined with a level optimization procedure in systems dominated by optical noise. The OSNR gain of 1.5 dB is achieved in simulations by using an EML with ER = 8 dB.

WF3.2 2:00 PM–2:30 PM (Invited)**Hybrid Probabilistic-geometric Shaping in Optical Communication Systems**Zhen Qu, *University of Arizona, AZ, USA*

We propose a universal distribution matcher applicable to any two-dimensional signal constellation. We experimentally demonstrate that the performance of the proposed 32-ary quadrature amplitude modulation (QAM), based on hybrid probabilistic-geometric shaping, is superior to probabilistically shaped (PS)-32 QAM and regular 32 QAM, and comparable to PS-64 QAM.

WF3.3 2:30 PM–3:00 PM (Invited)**Optimizing the Achievable Data Rates of Tricky Channels: a Probabilistic Shaping for OPC Channel Example**Metodi Yankov, *Technical University of Denmark, Denmark*

A method is presented for online probabilistic shaping parameter optimization for channels, which are non-trivial to model and are thus difficult to optimize offline. An example is provided for a mid-link optical phase conjugation based nonlinearity compensation channel with inline dispersion compensation.

Session: ThC1 – Thursday, 4 October 2018: 8:30 AM–10:00 AM

Grand Ballroom C

Joint Session: Optical Communications (OC) / Special Symposium on Integrated Photonics and Information Security (SS IPIS)

Session Title: Secure Communications

Session Chair: Eduardo Temprana, *University of California, CA, USA***ThC1.1 8:30 AM–9:00 AM (Invited)**Chris Erven, *University of Bristol, England***ThC1.2 9:00 AM–9:15 AM****Feasibility of Quantum Communications in Aquatic Scenario**Silvia Tarantino, *Technical University of Denmark, Denmark*

Security in underwater communications is a very sensitive topic due to its great interest in scientific, industrial and military applications. We present a feasibility analysis of different types of quantum communications protocols in aquatic scenario.

ThC1.3 9:15 AM–9:30 AM**Toward the Integration of CV Quantum Key Distribution in Deployed Optical Networks**Fotini Karinou, *Huawei Technologies Duesseldorf GmbH, Germany*

We report on the advances toward the integration of our developed CV-QKD system in existing optical infrastructure and (WDM) networks. We demonstrate for first time the use of the aforementioned CV-QKD system to encrypt a 10GE client service over deployable OTN legacy equipment over 20-km.

ThC1.4 9:30 AM–9:45 AM

Polarization Entanglement Quantum Key Distribution with Covert Classical Communications

John Gariano, *University of Arizona, AZ, USA*

By using a covert classical communication channel for error reconciliation in QKD systems, higher SKRs are capable of being achieved. Assuming transmission over a 30km maritime channel, our previous results for the selection of optimum wavelength for use are re-examined.

ThC1.5 9:45 AM–10:00 AM

Slepian-FBGs-based Optical Covert Communications

Ivan B. Djordjevic, *University of Arizona, AZ, USA*

Various optical encryption/physical-layer security schemes are able to protect the content of the message, but are not able to protect user's privacy by preventing the detection of transmission attempt. To solve for this problem, we propose a Slepian-FBGs-based scheme enabling positive rate optical covert communications.