SUMMER TOPICALS

MEETING SERIES

2017

10-12 JULY

SAN JUAN MARRIOTT RESORT
San Juan, Puerto Rico

Zetian Mi, General Chair
University of Michigan, Ann Arbor, USA

Nicolas Fontaine, 2017 Chair-Elect
Nokia Bell Labs, USA

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SUMMER TOPICALS MEETING SERIES 2017
PROGRAM – AT – A – GLANCE

	INTEGRATED PHOTONICS FOR THE ULTRAVIOLET AND VISIBLE SPECTRAL RANGE (IPMI)	INTEGRATED PHOTONICS FOR THE MID-INFRARED (IPUV)	LOW ENERGY INTEGRATED NANOPHOTONICS (LEIN)	OPTICAL SWITCHING TECHNOLOGIES FOR DATACOM AND COMPUTERCOM APPLICATIONS (OSDC)	PHOTONICS RESEARCH FOR 5G AND BEYOND (PR5G)	QUANTUM NETWORKS (QNW)
Room:	**MIRAMAR ATLANTIC I**	**ATLANTIC II**	**BALLROOM I**	**BALLROOM II**	**BALLROOM III**	**BALLROOM IV**
Tuesday, 11 July						
8:00 – 8:30	**CONTINENTAL BREAKFAST – Grand Ballroom Foyer**					
8:30 – 10:00	**TuA1**: GeSn Materials and Devices IV	**TuB1**: III-Nitride Photonics	**TuC1**: Attojoule Photonics *LEIN/OSDC joint session*		**TuE1**: 5G Standards and Field Trials	**TuF1**: Quantum Channels and Decoherence
10:00 – 10:30	**COFFEE BREAK – Grand Ballroom Foyer**					
10:30 – 12:00	**TuA2**: Novel Integration Technology	**TuB2**: Photonic Circuits and Sources for Quantum Information	**TuC2**: Integrated Nanophotonics	**TuD2**: Optically Switched Data Center Network Architectures and Optical Switching Systems I	**TuE2**: 5G Perspectives from Industry and Academia	**TuF2:** Sources of Entangled Photon Pairs
12:00 – 1:30	**LUNCH ON OWN**					
1:30 – 3:00	**TuA3**: Si Based Mid-IR	**TuB3**: Nanobiophotonics and Spectroscopy	**TuC3**: Nanophotonics for High-Speed	**TuD3**: Optically Switched Data Center Network Architectures and Optical Switching Systems II	**TuE3**: High Data Rate Wireless	**TuF3:** Long Distance Quantum Communication
3:00 – 3:30	**COFFEE BREAK – Grand Ballroom Foyer**					
3:30 –5:00	**TuA4**: Novel Si Based Integrated Photonics		**TuC4**: Nanophotonic Devices	**TuD4**: Optically Switched Data Center Network Architectures and Optical Switching Systems III	**TuE4**: Beyond 5G	**TuF4:** Structure of Quantum Network Nodes
Wednesday, 12 July						
8:00 – 8:30	**CONTINENTAL BREAKFAST – Grand Ballroom Foyer**					
8:30 – 10:00	**WA1:** Mid-IR Devices	**WB1:** Novel Photonic Devices and Applications	**WC1:** PLENARY - Integrated Photonics		**WE1:** Test & Measurement for 5G	**WF1:** Quantum Network Theory
10:00 – 10:30	**COFFEE BREAK – Grand Ballroom Foyer**					
10:30 – 12:00			**WC2:** High-Speed Devices	**WD2:** Photonic Integrated Circuits for Advanced Functionalities in Optical Switching I	**WE2:** Photonic/RF Components & FSO for 5G	**WF2:** Quantum Network Constraints – Breakdown Session

Welcome to the
2017 IEEE Photonics Society Summer Topicals Meeting Series

10 - 12 July 2017
San Juan Marriott
San Juan, Puerto Rico

The Summer Topicals Meeting is the premier conference series for exciting, new areas in photonic science, technology, and applications. Experience the opportunity to learn about emerging fields and to interact with the research and technology leaders in an intimate environment.

The 2017 Summer Topical Meetings are focused on **"Integrated Photonics"**.

The following topical meetings will be held:

1. Integrated Photonics for the Ultraviolet and Visible Spectral Range (IPUV)
2. Integrated Photonics for the Mid-Infrared (IPMI)
3. Low Energy Integrated Nanophotonics (LEIN)
4. Optical Switching Technologies for Datacom and Computercom Applications (OSDC)
5. Photonics Research for 5G and beyond (PR5G)
6. Quantum Networks (QNW)

A unique aspect of the Topical Meeting is that IEEE Photonics Society volunteers propose and organize the event. Hence, I would like to thank each of the Topical Chairs and the Program Committee Members who have volunteered and invested their time organizing these conferences over the years. I also want to thank the plenary and invited speakers for giving us their perspectives on the exciting new developments and the challenges in these fields. Finally, I would like to express my sincere appreciation to the IEEE Photonics Society Conference Staff for their professional organization and arrangements.

The topics to be discussed in this year's Summer Topicals span a broad range in emerging and hot areas of research, from materials to devices, integrated photonics, and systems.

- The IPUV topic will cover recent advances in photonic integrated circuits in the UV and visible spectra, with a broad range of applications in biochemical sensing, Raman spectroscopy, photo-ionization, integrated spectrometers, nonlinear optics, LIDAR, and high density optical recording.

- The IPMI topic will bring together photonic engineers, materials scientist, optical physicists, and application experts to present the recent development of mid-infrared (~ 2-20 μm) photonic materials and mid-infrared device design and integration.

- The LEIN topic aims to garner recent advances in nanophotonic devices ranging from nanolasers, detectors to modulators for chip-level optical interconnects and will bring together diverse specialists to estimate bit energies of individual devices with integrated photonics specialists who can look at architectures to utilize such devices.

- The OSDC topic will discuss the latest research and development in optical switching and memory technologies and address a series of challenges with respect to memory bandwidth, energy and speed requirements for the next generation high performance computers.

- The PR5G topic will bring together global participants from both industry and academia and present advances in integrated microwave photonics technology, mm-wave and THz wireless digital/analog radio over fiber systems, radio-optical digital signal processing, and multi-RAT networking.

- The QNW topic aims to provide an interdisciplinary setting to discuss the recent advances of quantum networks, including their novel application and functionalities, architectures and protocols, entanglement creation and manipulation, and quantum nodes and memories.

In addition to the technical presentations, hallway discussions, and other networking, I hope that you have a chance to experience the beautiful beach and many other wonderful attractions in San Juan.

Looking forward to seeing you in San Juan!

Zetian Mi, 2017 General Chair

IEEE Photonics Society
Summer Topicals Meeting Series
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Integrated Photonics For The Mid-infrared (IPMI)

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Photonics Research For 5G And Beyond (PR5G)

Topic Co-Chairs
Andreas Stöhr, University of Duisburg, Germany
Ken-ichi Kitayama, Graduate School for the Creation of New Photonics Industries, Japan
Michael Sauer, Corning Inc., USA

Quantum Networks (QNW)

Topic Co-Chairs
Michael Brodsky, U.S. Army Research Laboratory, USA
Vladimir Malinovsky, U.S. Army Research Laboratory, USA
Paul Alsing, Air Force Research Laboratory, USA

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Final Program

MONDAY, 10 JULY 2017

8:00 am–8:30 am **Grand Ballroom Foyer**

Continental Breakfast

8:30 am–10:00 am **Miramar Atlantic I**
Session MA1 **GeSn Materials and Devices I**
Session Chair Dan Buca, *Forschungszentrum Julich*

8:30 am–9:00 am (*Invited)*

MA1.1 Synthesis of Ge-Sn Alloys by Ion Implantation and Pulsed Laser Melting: Towards a Group IV Direct Band Gap Semiconductor, Jim S. Williams and Tuan T. Tran, *RSPE, Australian National University, Canberra, Australia*

Ion implantation and pulsed laser melting have been used to prepare good quality GeSn alloys with up to 12 at.% Sn on Ge substrates. Both compressively strained and unstrained alloys are obtained and PL emission at 2.15 μm is obtained in the latter case.

9:00 am–9:30 am *(Invited)*

MA1.2 α-Sn and α-$Sn_{1-x}Ge_x$ Film Growth, Characterization & Stability, Arnold M. Kiefer, *Air Force Research Laboratory, Wright-Patterson AFB, OH, USA,* Gordon J. Grzybowski, Stephanie A. Chastang, *Air Force Research Laboratory, Wright-Patterson AFB, OH, and KBRwyle, El Segundo, CA, USA,* and Bruce B. Claflin, *Air Force Research Laboratory, Wright-Patterson AFB, OH, USA*

We report α-Sn and α-SnGe films grown by MBE on various substrates and resulting measured properties. We demonstrate films with Ge compositions beyond the solubility limit for metallic β-Sn and suggest a wide range of Sn-Ge compositions are possible under the proper epitaxial constraints.

9:30 am–10:00 am (*Invited)*

MA1.3 Ge Growth Using Pulsed Laser Solidification, Jifeng Liu, *Dartmouth College*

8:30 am–10:00 am **Atlantic II**
Session MB1 **Emerging UV-Visible Photonic Platforms I**
Session Chair Zetian Mi, *University of Michigan, Ann Arbor, USA*

8:30 am–9:15 am ***(Plenary)***

MB1.1 Advances in GaN-based Quantum Dots for Single Photon Emission, Yasuhiko Arakawa, *University of Tokyo*

We discuss recent progress in growth and physics of GaN quantum dot for single photon emission at the ultraviolet wavelength, including position controlled nanowire quantum dots with a giant biexciton binding energy over 60meV, which enabled single photon sources operating at 350 K.

9:15 am–9:30 am

MB1.2 A New Architecture for Fabrication of On-Chip Arrays of Nanoscale Light Sources in the UV-Visible, Babak Nikoobakht, *National Institutes of Standards and Technology, Gaithersburg, MD, USA*

The current state-of-the-art methodologies for on-chip light sources rely on traditional microfabrication and thin film growth that lose their efficiency for creating optical sources with sub-100 nm dimensions. We present a platform for in-situ formation/integration of semiconductors for realization of arrays of nanoscale light sources.

9:30 am–10:00 am ***(Invited)***

MB1.3 Applications of Aluminum Nitride and Lithium Niobate to Visible Photonics, Matt Eichenfield, *Sandia National Labs*

We will discuss recent progress at Sandia National Laboratories in photonic devices made from or in conjunction with lithium niobate and aluminum nitride. Topics discussed will include nonlinear frequency conversion, modulation, switching, and tunability of photonic devices.

8:30 am–10:00 am **Ballroom I**
Session MC1 **Platforms for Nanophotonic Integration**
Session Chair Michael Gerhold, *US Army Research Laboratory, USA*

8:30 am–9:00 am ***(Invited)***

MC1.1 First-Priniciple Computational Simulation Techniques for Active Nanophotonic Devices, Shanhui Fan, *Stanford*

9:00 am–9:30 am ***(Invited)***

MC1.2 Nanophotonic Devices for Power-Efficient Computing and Optical Interconnects, Zheng Wang, Zhoufeng Ying, Shounak Dhar, Zheng Zhao, David Pan and Ray T. Chen, *University of Texas, Austin, Austin, TX, USA*

To solve the problem in huge power consumption of the data centers and cloud computing, we design an extreme optical adder architecture suitable for ultra-high bit count. n-bit full adder are full implementable on a silicon platform using guided wave optics.

9:30 am–10:00 am ***(Invited)***

MC1.3 Recent Progress in Monolithic Silicon Electronics-Photonics Integration in Advanced CMOS, Milos Popovic, C. Sun, M. Wade, M. Georgas, S. Lin, A. Atabaki, F. Pavanello, J. Shainline, L. Alloatti, J. Orcutt, R. Ram, V. Stojanovic, S. Moazeni, and N. Mehta

We present recent progress in silicon electronics-photonics integration in unmodified 45nm SOI CMOS technology including various photonic devices, and systems including the first single-chip microprocessor with photonic I/O, low energy 40Gbps transmitters and receivers, and applications to optical switching.

8:30 am–10:00 am **Ballroom III**

Session ME1 **5G Architectures**

Session Chair Ken-ichi Kitayama, *Graduate School for the Creation of New Photonics Industries, Japan*

8:30 am–9:00 am ***(Invited)***

ME1.1 TBD, Roberto Sabella Ericsson, *Italy*

9:00 am–9:30 am ***(Invited)***

ME1.2 Elastic Optical Technologies and SDN/NFV Control for 5G Mobile X-Haul, Raul Muñoz, Josep Maria Fàbrega, Ramon Casellas, Michela Svaluto Moreolo, Ricard Vilalta, Laia Nadal and Ricardo Martínez, *Centre Tecnològic de Telecomunicacions de Catalunya (CTTC/CERCA), Castelldefels (Barcelona), Spain*

This paper presents a 5G mobile x-haul architecture composed of central offices with OLT programmable S-BVTs, small-DC and Ethernet switching, and edge nodes located in the 5G cell-site cabinets with cloudlet, Ethernet aggregation and elastic ONT to meet the specific 5G mobile x-hauling requirements.

8:30 am–10:00 am **Ballroom IV**
Session MF1 **QNW Plenary**
Session Chair Michael Brodsky, *US Army Research Laboratory, USA*

8:30 am–9:15 am ***(Plenary)***

MF1.1 Quantum Networking: From Today's QKD Links to Tomorrow's Quantum Internet, William Munro, *NTT Basic Research Labs., Atsugi, Japan*

The development of quantum technologies allows for completely new ways to create, manipulate and store information. Quantum communication, the ability to transmit such information, is a primitive for tomorrows quantum Internet. Here we discuss how starting with QKD we can realize this future internet.

9:15 am–10:00 am ***(Plenary)***

MF1.2 Reminiscences on 25 Years of DoD Investments Leading to Quantum Information, Peter Reynolds, *Army Research Office, Research Triangle Park, NC, USA*

I trace my DoD program management history from 1980's laser cooling and trapping, to Bose Einstein condensation, atom lasers, Fermi degenerate gases, and atomtronics, to the beginnings of QIS in the form of trapped ion qubits, optical lattices, and quantum emulation of condensed matter.

10:00 am–10:30 am **Grand Ballroom Foyer**

Coffee Break

10:30 am–12:00 pm **Miramar Atlantic I**
Session MA2 **GeSn Materials and Devices II**
Session Chair Jifeng Liu, *Dartmouth College, USA*

10:30 am–11:00 am ***(Invited)***

MA2.1 GeSn-based Light Sources and Photoconductors towards Integrated Photonics for the Mid-Infrared, Joe Margetis, John Tolle, *ASM, Phoenix, AZ, USA,* Sattar Al-Kabi, Yiyin Zhou, Huong Tran, Thach Pham, Wei Dou, Perry Grant, Shui-Qing Yu, *University of Arkansas, Fayetteville, AR, USA,* Wei Du, Seyed Ghetmiri, Mansour Mortazavi, *University of Arkansas at Pine Bluff, Pine Bluff, AR, USA,* Greg Sun, Richard Soref, *University of Massachusetts at Boston, Boston, MA, USA*, Yiyin Zhou, Perry Grant and Baohua Li, *Arktonics LLC, Fayetteville, AR, USA*

GeSn-based optically pumped lasers and photoconductors have been systematically investigated. The operation wavelength of these devices covers 2–3 μm. Since GeSn technique is fully compatible with current CMOS process, the GeSn-based devices can be widely used in the area of Si integrated photonics.

11:00 am–11:30 am ***(Invited)***

MA2.2 (Si)GeSn Plasmonics, Inga Anita Fischer, Lion Augel, Audrey Berrier, Michael Oehme, Jörg Schulze, *University of Stuttgart, Stuttgart, Germany*

Based on experimental results for the permittivity of highly doped GeSn layers we discuss the use of (Si)GeSn as tunable plasmonic materials at wavelengths > 5 um.

11:30 am–12:00 pm ***(Invited)***

MA2.3 SiGeSn/GeSn Heterostructures for Group IV Lasers, Dan Buca

10:30 am–12:00 pm **Atlantic II**
Session MB2 **Nonlinear and Quantum Photonics**
Session Chair Matt Eichenfield, *Sandia National Laboratories, USA*

10:30 am–11:00 am ***(Invited)***

MB2.1 Connecting Visible and Telecommunication Band Spectra with Silicon Nitride Quantum Photonics, Xiyuan Lu, Qing Li, Daron Westly and Kartik Srinivasan, *NIST, Gaithersburg, MD, USA*

We describe our recent development of silicon nitride nanophotonic devices for connecting quantum states in the visible and telecommunication band spectra. Device design, simulation, fabrication, and measurement results will be presented. Future directions and applications for integrated quantum photonics will also be discussed.

11:00 am–11:30 am ***(Invited)***

MB2.2 Wide Band Parametric Optical Processes in Crystalline Microresonators, Wei Liang, Anatoliy A. Savchenkov, Vladimir S. Ilchenko, Danny Eliyahu, Andrey B. Matsko and Lute Maleki, *OEwaves Inc., Pasadena, CA, USA*

We study several kinds of low-threshold crystalline whispering gallery mode resonator-based OPOs emitting broadband optical spectra. The parametric process is phase matched due to interaction of different mode families, as well as contribution from the interplay of second- and higher-order group velocity dispersion.

11:30 am–12:00 pm ***(Invited)***

MB2.3 Integrated Nonlinear Photonics at Visible Wavelengths, Marko Loncar, *Harvard University*

10:30 am–12:00 pm **Ballroom II**

Session MD2 **Optical Signal Processing and Optical Memories & Buffering**

Session Chair George T. Kanellos, *Aristotle University of Thessaloniki, Greece*

10:30 am–11:00 am ***(Invited)***

MD2.1 Polarization Bistable VCSELs and Their Applications to All-Optical Signal Processing, Hitoshi Kawaguchi, *Nara Institute of Science and Technology, Kizugawa, Japan*

We review recent progress in research of polarization bistable VCSELs and their applications to optical signal processing. Low power-consumption operation and reliable operation with BER better than 1×10^{-9} of all-optical flip-flops, high speed memory operation, and header recognition are discussed.

11:00 am–11:30 am ***(Invited)***

MD2.2 Optical Memory and Optical logic for Ultralow Latency Processing Based on Integrated Nanophotonics, Masaya Notomi, A. Shinya, K. Nozaki, *NTT Basic Research Laboratories, NTT Nanophotonics Center*, T. Ishihara and K. Inoue, *Kyushu University*

We review recent progress in various photonic functional components, such as optical switches and memories, based on advanced nanophotonic technologies including photonic crystals, and discuss possible applications for logic processing with ultralow latency.

11:30 am–12:00 pm ***(Invited)***

MD2.3 Electrically Driven Hybrid InP-on-SOI Nanocavities for Lasers, Switches and Memories, Fabrice Raineri

The convergence of microelectronics and photonics currently triggers large technological and scientific efforts with the view to develop novel optoelectronic nanodevices. We demonstrate InP-on-SOI-based nanolaser diodes that can also be used for fast switches and memories operating with low activation energies.

12:00 pm–12:15 pm

MD2.4 Optical Time-Slot Interchanger and Si-Based Delay Lines Towards Integrated Feed-Forward Buffers, Miltiadis Moralis-Pegios, George Mourgias-Alexandris, Theonitsa Alexoudi, *Aristotle University of Thessaloniki, Thessaloniki, Greece,* Matteo Cherchi, Mikko Harjanne, Timo Aalto, *VTT Technical Research Centre of Finland, Espoo Finland,* Nikos Pleros and Konstantinos Vyrsokinos, *Aristotle University of Thessaloniki, Thessaloniki, Greece*

We demonstrate a time-slot interchanger unit utilizing differentially biased SOA-MZI wavelength converters. Replacement of the fiber delay lines with integrated waveguides is also investigated. We report error-free rearrangement of three 10Gbps data packets for the fiber case and error-free transmission through the integrated delays.

10:30 am–12:00 pm **Ballroom III**

Session ME2 **5G Fiber Wireless Covergence**

Session Chair Michael Sauer, *Corning Inc., USA*

9:30 am–10:00 am ***(Invited)***

ME2.2 **The Impact of 5G on the Optical Network,** Michael Frankel, *Ciena, Hanover, MD, USA* and Nigel Bragg, *Ciena, London, United Kingdom*

5G impact on optical network starts in 2019 in advanced economies. It becomes another service on Metro and Long Haul networks. Growth occurs in point-point connectivity from wireline edge to antenna sites demanding large bandwidth, low cost and power, and reach targets of <20 km.

10:00 am–10:30 am ***(Invited)***

ME2.3 **End-to-End Quality of Service Over Advanced Heterogeneous 5G Networks,** Halina Tarasiuk, *Warsaw University of Technology, Warsaw, Poland*

In this talk, I will show an impact of new use cases and new network technologies as network virtualization and SDN on end-to-end quality of service guarantees over advanced heterogeneous 5G network. Current research topics in this area will be discussed.

10:30 am–12:00 pm **Ballroom IV**

Session MF2 **Entangling Protocol and Entanglement Manipulation**

Session Chair Janos Bergou, *Hunter College, USA*

10:30 am–11:00 am ***(Invited)***

MF2.1 **Challenges for Realizing Ubiquitous Quantum Networks; Quantum Digital Signatures,** Nicholas Peters, *Oak Ridge*

11:00 am–11:15 am

MF2.2 **Entanglement Swapping with Two Imperfect States,** Brian T. Kirby, Siddhartha Santra, Vladimir S. Malinovsky and Michael Brodsky, *US Army Research Laboratory, Adelphi, MD, USA*

We present a formal description of entanglement swapping of any two, arbitrarily mixed, density matrices. Application of this result reveals bounds on the rank and concurrence of the final state for several classes of input states.

11:15 am–11:30 am

MF2.3 Quantum-Scheme for Improving Interferometric Visibility with Imperfect Distributed Entangled-States, Siddhartha Santra, Brian T. Kirby, Vladimir S. Malinovsky, Michael Brodsky, *US Army Research Laboratory, Adelphi, MD, USA*

We analyze a quantum-scheme for measuring interferometric visibility for telescopic applications with imperfectly entangled states as a resource. The scheme overcomes photon loss thus permitting measurement with larger baseline leading to finer resolution of angular intensity distribution of remote sources of light.

11:30 am–12:00 pm *(Invited)*

MF2.4 Quantum Computation and the Entanglement of Photons by Photons, Barry M. Garraway, *University of Sussex, Brighton, United Kingdom*

The quantum processing of cavity photons by photons can be achieved in theory by utilising a multi-mode cavity interacting with a multi-state system. The theory presented is based on an effective Hamiltonian approach, and by selecting configurations which are less sensitive to decoherence.

12:00 pm–1:30 pm

Lunch Break (on own)

1:30 pm–3:00 pm **Miramar Atlantic I**
Session MA3 **IPMI Plenary**
Session Chair Shui-Qing Yu, *University of Arkansas, USA*

1:30 pm–2:00 pm *(Invited)*

MA3.1 Will Ge and GeSn Lasers Enable Si Photonics in the Mid-Infrared?, Alexei Chelnokov, Nicolas Pauc, Alban Gassenq, Joris Aubin, Quang Minh Thai, Laurent Milord, Mathieu Bertrand, Kevin Guilloy, Johan Rothman, *University Grenoble Alpes, Grenoble, France,* Thomas Zabel, Hans Sigg, *Paul Scherrer Institute, Villigen, Switzerland,* Jean-Michel Hartmann, Vincent Calvo and Vincent Reboud, *University Grenoble Alpes, Grenoble, France*

Already mature in the near-IR, silicon photonics now moves into mid-IR for gas sensing. Here also, monolithically-integrated laser sources are desperately needed. We demonstrate optically pumped mid-IR GeSn-on-Si lasers in several cavity configurations. How far are we from CMOS-integrated electrically-pumped room-temperature lasers?

2:00 pm–2:30 pm *(Invited)*

MA3.2 Nanoheteroepitaxy as a Viable Route to Integrate III-V Compounds on Si Substrates: The Cases for InP and GaAs, *Giovanni Capellini, IHP, Frankfurt (Oder), Germany*

We show how nanoheteroepitaxy (NHE) can be exploited to integrate different semiconductors (Ge, GeSn, InP, GaAs) on suitably patterned Silicon substrates. As a first application, we demonstrate two hybrid photodetectors featuring Ge o InP NHE and a SL graphene top electrode.

1:30 pm–3:00 pm **Atlantic II**

Session MB3 **Emerging UV-Visible Photonics Platforms II**

Session Chair Hongxing Jian, *Texas Tech University, USA*

1:30 pm–2:00 pm ***(Invited)***

MB3.1 Visible-Wavelength Photonic Integrated Circuits for Trapped-Ion Quantum Computing, Karan K. Mehta, Gavin N. West and Rajeev J. Ram, *Massachusetts Institute of Technology, Cambridge, MA, USA*

We report on work using visible integrated photonics to control trapped ions for quantum information processing. Planar radio frequency traps confine the ions while light is routed via visible waveguides and modulators and delivered to the ion by focusing grating couplers.

2:00 pm–2:30 pm ***(Invited)***

MB3.2 AIN Integrated Quantum Photonics Circuits, Stefan Preble, *Rochester Institute of Tech.*

2:30 pm–3:00 pm ***(Invited)***

MB3.3 Single Crystal AlN Substrates for AlGaN-Based UV Optoelectronics, Rafael Dalmau, Baxter Moody, H. Spalding Craft and Raoul Schlesser, *HexaTech, Inc., Morrisville, NC, USA*

Wide bandgap nitride semiconductors have attracted interest for next-generation optoelectronic and power handling devices. Performance gains are enabled by lattice–matched, native substrates, which are experiencing steadily increasing demand. Prospects for AlGaN-based UVC emitters developed on native, single crystal AlN substrates will be presented.

1:30 pm–3:00 pm **Ballroom II**

Session MD3 **Silicon Photonic Switches/Electro-Optic Switches/Electronic-Photonic Cointegration I**

Session Chair Paraskevas Bakopoulos, *National Technical University of Athens (NTUA), Greece*

1:30 pm–2:00 pm ***(Invited)***

MD3.1 Silicon Photonic Switch with Spot Size Converters for Low-Loss, Polarization-Insensitive Optical Coupling to Fibers, Shigeru Nakamura, Shigeyuki Yanagimachi, *NEC Corp., Tsukuba, Ibaraki, Japan,* Hitoshi Takeshita and Akio Tajima, *NEC Corp., Kawasaki, Kanagawa, Japan*

We demonstrate compact 8×8 silicon photonic switch modules with low loss, low polarization sensitivity, and low cross-talk properties. Port count extensibility using multiple compact modules and faster switching based on thermo-optical effect of silicon are useful also for datacenter applications.

2:00 pm–2:30 pm ***(Invited)***

MD3.2 Silicon 16x16 Switch Matrix Based on Dual-Ring Assisted MZI Structures with Fast and Energy Efficient Switching, Linjie Zhou, Liangjun Lu, Zhanzhi Guo and Jianping Chen, *Shanghai Jiao Tong University, Shanghai, China*

We review our recent progress on silicon photonic switches based on dual-ring assisted MZI switch elements. The ring resonances are aligned using thermal tuning to set the initial switching state. Nano-second switching is realized upon free-carrier injection with PIN diodes in the ring resonators.

1:30 pm–3:00 pm **Ballroom III**

Session ME3 **5G Fronthaul/Backhaul**

Session Chair Takeshi Nakamura, *NTT DoCoMo, Japan*

1:30 pm–2:00 pm ***(Invited)***

ME3.1 Optical Access Network Technologies for Future Radio Access Networks, Jun Terada, Tatsuya Shimada and Akihiro Otaka, *NTT Corp., Yokosuka, Japan*

This paper describes optical access network technologies that support future radio access networks. Packet-based BBU is expected to accommodate multiple services and PON with low-latency scheme is a promising candidate to for MFH transmission in future radio access networks.

2:00 pm–2:30 pm ***(Invited)***

ME3.2 Optical Access Technologies for 5G Mobile Communication Networks, Hwan Seok Chung, Han Hyub Lee, Keong-Hwan Doo, Kwangok Kim, Seoug-Hwan Kim,Seung-Hyun Cho, Jun Ki Lee and Jong Hyun Lee, *ETRI, Daejon, South Korea*

We reviews optical access technologies for 5G mobile communication networks such as mobile data compression, high-speed passive optical network (PON), and analog radio over fiber (RoF) technologies. Recent feasibility studies for future optical access network with optical mobile convergence are discussed.

2:30 pm–3:00 pm ***(Invited)***

ME3.3 Concepts and Requirements for the Ethernet-Based Evolved Fronthaul, Nathan J. Gomes, Philippos Assimakopoulos, *University of Kent, Canterbury, United Kingdom,* Philippe Chanclou, *Orange Labs, Lannion, France,* Jörg-Peter Elbers, Daniel Münch, *ADVA Optical Networking, Munich, Germany* and Volker Jungnickel, Fraunhofer-HHI, Berlin, Germany

The use of Ethernet in the fronthaul permits convergence and exploitation of statistical multiplexing gains of the new interfaces, but minimum latency and latency variation requirements may become challenging. The techniques proposed to meet these challenges are summarized.

1:30 pm–3:00 pm **Ballroom IV**

Session MF3 **Qubit Encoding-Exploiting Photonic Degrees of Freedom**

Session Chair Zhiliang Yuan, *Toshiba, UK*

1:30 pm–2:00 pm ***(Invited)***

MF3.1 **Manipulation of Broadband Time-Frequency Entangled Photons,** Anrew Weiner, *Purdue University*

2:00 pm–2:30 pm ***(Invited)***

MF3.2 **Quantum Information Processing and Networking with Polychromatic Photons,** Pavel Lougovski, Joseph M. Lukens and Nicholas A. Peters, *Oak Ridge National Laboratory, Oak Ridge, TN, USA*

Quantum information processing (QIP) with the spectral degree of freedom of a photon offers an immense parallelization capability. We discuss how to unlock this power using classical telecom equipment such as pulse shapers and electro-optic modulators and implement QIP natively over a quantum network.

2:30 pm–3:00 pm ***(Invited)***

MF3.3 **Photon Orthogonal Temporal Modes as a Complete Quantum Information Framework,** Michael Raymer, *Univesity of Oregon, Eugene, OR, USA*

Quantum information can be encoded in the temporal shape (temporal mode) of single photons. Field-orthogonal temporal modes provide a new framework for quantum information science. They span a high-dimensional quantum state space and lend themselves to integration into existing single-mode fiber communication networks.

3:00 pm–3:30 pm **Grand Ballroom Foyer**

Coffee Break

3:30 pm–5:00 pm **Miramar Atlantic I**
Session MA4 **GeSn Materials and Devices III**
Session Chair Arnold Kiefer, *Air Force Research Labs, USA*

3:30 pm–4:00 pm ***(Invited)***

MA4.1 **Novel Group IV Nano- and Micro- Structures for Light Sources on Silicon,** Y. Y. Li, *Chinese Academy of Sciences, Shanghai, China,* Y. Han, *Chinese Academy of Sciences, Shanghai, China and University of Chinese Academy of Sciences, Beijing, China,* Y. X. Song, *Chinese Academy of Sciences, Shanghai, China*, Z. P. Zhang, Z. Y. S. Zhu, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China,* Q. M. Chen, J. J. Liu, *Chinese Academy of Sciences, Shanghai, China and University of Chinese Academy of Sciences, Beijing, China,* and S. M. Wang, *Chinese Academy of Sciences, Shanghai, China, ShanghaiTech University, Shanghai, China and Chalmers University of Technology, Gothenburg, Sweden*

We present our researches on novel group IV nano- and micro- structures on Si. Tensile-strained Ge QDs were grown and photoluminescence was achieved. The GeSn thin films were demonstrated, and partially suspended GeSn microstructures were fabricated for relaxing the compressive strain.

4:00 pm–4:30 pm ***(Invited)***

MA4.2 **GeSn/SiGeSn Ordering Alloys,** Oussama Moutanabbir, *Polytechnic of Montreal*

4:30 pm–5:00 pm ***(Invited)***

MA4.3 **Spin-optoelectronic Functionalities of Group IV Materials,** Fabio Pezzoli, Sebastiano De Cesari, Elisa Vitiello, *LNESS and Università di Milano-Bicocca, Milano, Italy* and Maksym Myronov, *The University of Warwick, Coventry, United Kingdom*

We address the convergence of spintronics and photonics on group IV semiconductors, with a special focus on Ge and GeSn alloys. By leveraging optical investigations, we will gather insights into a rich spin physics and explore prospects for the exploitation of advanced spin-optoelectronic functionalities.

3:30 pm–5:00 pm **Atlantic II**
Session MB4 **Emerging UV-Visible Photonic Platforms III**
Session Chair Wolfram Pernice, *University of Muenster, Germany*

3:30 pm–4:00 pm ***(Invited)***

MB4.1 **Hexagonal Boron Nitride Epilayers for Deep UV Photonics,** Hongxing Jiang and Jingyu Lin, *Texas Tech University, Lubbock, TX, USA*

Hexagonal BN (h-BN) possesses extraordinary properties including large bandgap (~6.5 eV) as well as high optical absorption and emission. We provide a briefly overview of MOCVD growth and exploration of the basic properties and applications of h-BN epilayers.

4:00 pm–4:30 pm ***(Invited)***

MB4.2 III-Nitride on Silicon Photonic Circuits, P. Boucaud, I. Roland, Y. Zeng, F. Tabataba-Vakili, M. El Kurdi, S. Sauvage, X. Checoury, *Université Paris-Saclay, Orsay, France,* M. Gromovyi, S. Rennesson, F. Semond, J.-Y. Duboz, *Université Côte d'Azur, Valbonne, France,* M. de Micheli, *Université de Nice-Sophia Antipolis, Nice, France,* J. Selles, C. Brimont, T. Guillet, *CNRS-Université de Montpellier, Montpellier, France* and B. Gayral, *CEA, Grenoble, France and University Grenoble Alpes, Grenoble, France*

We present recent progress achieved with III-nitride photonic circuits epitaxially grown on silicon(111). The photonic circuits embed two-dimensional photonic crystals and microdisk resonators coupled to suspended waveguides. We discuss the linear and nonlinear response of the resonators through second and third harmonic generation.

4:30 pm–5:00 pm ***(Invited)***

MB4.3 Fin Photonics: A New Architecture for Photonic Integrated Circuits on Unconventional Substrates, Lee Bassett, *University of Pennslyvania, PA, USA*

Single-mode fin waveguides can be fabricated directly on bulk, high-refractive-index substrates using standard lithography. This CMOS-compatible architecture facilitates electronic-photonic co-integration in silicon, as well as scalable photonic circuits in wide-bandgap materials like diamond and SiC for nonlinear and quantum photonics.

3:30 pm–5:00 pm **Ballroom I**

Session MC4 **Low Energy Approaches**

Session Chair David Miller, *Stanford University, USA*

10:00 am–10:30 am ***(Invited)***

MC4.2 Photonic Interconnect with Superconducting Electronics for Large-Scale Neuromorphic Computing, Sonia M. Buckley, Jeff Chiles, Adam N. McCaughan, Richard P. Mirin, Sae Woo Nam and Jeffrey M. Shainline, *National Institute of Standards and Technology, Boulder, CO, USA*

Advanced neuromorphic systems require massive interconnectivity, extreme energy efficiency, and complex signaling mechanisms. Here we propose an integrated optoelectronic platform utilizing superconducting electronics with photonic signaling to enable neuromorphic computing beyond the scale of the human brain.

10:30 am–11:00 am ***(Invited)***

MC4.3 Photonic Crystal and Inverse-Designed Devices for Low Energy Integrated Nanophotonics, Tomas Sarmiento and Jelena Vuckovic, *Standford University, CA, USA*

We have demonstrated fast light sources and modulators with record low energy consumption by leveraging the moderate Q factor and small mode volume of photonic crystal cavities. We are also investigating nanophotonics engineered using an inverse design algorithm to further improve the device performance.

3:30 pm–5:00 pm **Ballroom II**

Session MD4 **Silicon Photonic Switches/Electro-Optic Switches/Electronic-Photonic Cointegration II**

Session Chair Theoni Alexoudi, *Aristotle University of Thessaloniki, Greece*

3:30 pm–4:00 pm *(Invited)*

MD4.1 Devices and Architectures for Rapidly Reconfigurable Photonic Switching Systems, Benjamin G. Lee, *IBM Thomas J. Watson Research Center, Yorktown Heights, NY, USA*

This talk will review recent work developing a scalable photonic switching platform that enables reconfiguration at the nanosecond scale, addressing innovations in device design, packaging, and architecture that can overcome scaling limitations imposed by the physical layer.

4:00 pm–4:30 pm *(Invited)*

MD4.2 Loss and Crosstalk Solutions in Fast Silicon Photonic Switch Systems, Dominic J. Goodwill, Hamid Mehrvar and Eric Bernier, *Huawei Technologies Canada, Ottawa, ON, Canada*

Silicon photonic carrier-injection switches can enable Petabits/s packet switch cores. These switches are compatible with 100GigE and future 400GigE link budgets, using crosstalk suppression topology, aggressive loss reduction including 0.001dB crossings, polarization control and rapid auto-calibration, and removing self-heating transients to prevent dynamic crosstalk.

4:30 pm–5:00 pm *(Invited)*

MD4.3 Large-Scale Silicon Photonic Switches with MEMS, Tae Joon Seok, *Gwangju Institute of Science*

3:30 pm–5:00 pm **Ballroom III**

Session ME4 **Integrated Photonics for 5G**

Session Chair Hiroshi Murata, *Osaka University, Japan*

3:30 pm–4:00 pm ***(Invited)***

ME4.1 **Photonic Integration Technology for the Interface between the Optical and Wireless Part in 5G Networks: The H2020-ICT-HAMLET Approach,** Panos Groumas, *National Technical University of Athens, Athens, Greece and Optagon Photonics, Athens, Greece,* Christos Tsokos, *National Technical University of Athens, Athens, Greece*, Moritz Kleinert, *Fraunhofer Institute for Telecommunications, Berlin, Germany,* Denys Marchenko, *LioniX B.V, Enschede, The Netherlands,* Vasilis Katopodis, *National Technical University of Athens, Athens, Greece,* Matthijn Dekkers, *SolMateS, Enschede, The Netherlands,* Matteo Falcucci, *Linkra Srl, Agrate Brianza (MB), Italy,* Roelof Bernardus Timens, *LioniX B.V, Enschede, The Netherlands and SATRAX B.V, Enschede, The Netherlands,* Lefteris Gounaridis, *National Technical University of Athens, Athens, Greece,* Chris G. Roeloffzen, *LioniX B.V, Enschede, The Netherlands and SATRAX B.V, Enschede, The Netherlands,* Antonello Vannucci, *Linkra Srl, Agrate Brianza (MB), Italy,* Rene G. Heideman, *LioniX B.V, Enschede, The Netherlands,* Norbert Keil, *Fraunhofer Institute for Telecommunications, Berlin, Germany,* Christos Kouloumentas, *National Technical University of Athens, Athens, Greece and Optagon Photonics, Athens, Greece* and Hercules Avramopoulos, *National Technical University of Athens, Athens, Greece*

Photonic integration technology that will enable the development of transceivers interfacing the optical and wireless interfaces in future 5G networks, along with preliminary results from our system testbeds are presented. The technology is developed within the framework of H2020-ICT-HAMLET project.

4:00 pm–4:30 pm ***(Invited)***

ME4.2 **Integrated Photonic Devices for Analog Photonic Systems,** Leif Johanson, *UCSB*

4:30 pm–5:00 pm ***(Invited)***

ME4.3 **100G Solution Tailored for 5G Based Upon CAPS3,** Luca Poti, Gianluca Meloni, *CNIT, Pisa, Italy,* Francesco Fresi, Marco Secondini, Enrico Forestieri, *Scuola Superiore Sant'Anna, Pisa, Italy,* Fabio Cavaliere, *Ericsson, Pisa, Italy* and Giancarlo Prati, *Scuola Superiore Sant'Anna, Pisa, Italy*

CAPS-3 modulation format is used in 100G system for 5G applications. CAPS-3 is simple to generate, can be direct detected, and is able to defeat any significant amount of chromatic dispersion, without the need of digital signal processing in a distance range between 10 and 20 km.

3:30 pm–5:00 pm **Ballroom IV**

Session MF4 **Single Photon Sources, Switches, Detectors**

Session Chair Michael Fanto, *Air Force Research Labs, USA*

3:30 pm–4:00 pm ***(Invited)***

MF4.1 **Manipulation of Quantum Light Pulses by Electro-Optic Phase Modulation,** Brian John Smith, *University of Oregon, Eugene, OR, USA,* Michal Karpinski, *University of Warsaw, Warsaw, Poland,* Laura J. Wright, *University of Oxford, Oxford, United Kingdom,* Michal Jachura, *University of Warsaw, Warsaw, Poland,* Christoph Soeller, Valerian Thiel and Alexander Davis, *University of Oxford, Oxford, United Kingdom*

We report an experimental demonstration of deterministic pulse-mode manipulation of single photons achieved by application of controlled spectral and temporal phases. These techniques enable quantum wavelength- and time-division multiplexing applications, realization of multimode unitary transformations, and facilitate interfacing of different physical platforms.

4:00 pm–4:30 pm ***(Invited)***

MF4.2 **All-Optical Switching for Photonic Quantum Networks,** Prem Kumar, *Northwestern University*

4:30 pm–5:00 pm ***(Invited)***

MF4.3 **Pushing Single Photon Detection to the Limits (And Perhaps Beyond),** Alan Migdal, *NIST*

5:15 pm–6:30 pm **Ballroom IV**

Panel Session **Integrated Photonics**

David Miller, *Stanford University, USA*
Mo Soltani, *Raytheon BBN Technologies, USA*
Vladimir Stojanovich, *UC-Berkeley, USA*
Milos Popovic, *Boston University, USA*
Scott Diddams, *NIST, USA*
Fisher Yu, *University of Arkansas, USA*

7:00 pm–9:00 pm **Tuscany**

Session MP **Welcome Reception/Poster Session**

Session Chair Zetian Mi, *University of Michigan, Ann Arbor, USA*

7:00 pm–9:00 pm

MP1 **Structural and Electrical Characterization of Silicon Supersaturated with Gold by Pulsed Laser Melting of Nanometer-Thick Gold Films,** Philippe K. Chow, Quentin Hudspeth and Jeffrey Warrender, *US Army ARDEC – Benet Laboratories, Watervliet, NY, USA*

Raman spectroscopy and Rutherford backscattering spectrometry reveal that the thickness of a gold film deposited on silicon influences resolidification after pulsed-laser melting, giving rise to surface morphologies not observed with ion-implanted and laser-melted silicon. As film thickness approaches 5nm, the morphology dominates electrical behavior.

MP2 **Intrinsic Damping in Silicon Slab Waveguides in the Mid-Infrared,** Christian Ranacher, Andreas Tortschanoff, Cristina Consani, Nithin Ravi Kumar, Mohssen Moridi, *Carinthian Tech Research AG, Villach, Austria,* Thomas Grille, *Infineon Technologies Austria , Villach, Austria,* and Bernhard Jakoby, *Johannes Kepler University, Linz, Austria*

The mid-infrared region is prominent for gas sensing due to the unique footprint of various volatile organic compounds. We investigated the intrinsic damping in silicon slab waveguides in the mid-infrared region in order to provide a platform for evanescent-field sensing using silicon waveguides.

MP3 **Material Gain for Bi-Containing III-V Quantum Wells Grown on GaAs, InP, and GaSb Substrates: Towards Longer Wavelengths,** Marta Gladysiewicz and R. Kudrawiec, *Wroclaw University of Science and Technology, Wroclaw, Poland*

The 8-band kp Hamiltonian is applied to calculate the electronic band structure and material gain for Bi-containing III-V quantum wells grown on GaAs, InP, and GaSb substrate. It is shown that the gain peak strongly shifts to longer wavelengths due to Bi incorporation.

MP4 **Suspended GeSn Microstructure for Light Source on Si,** Yi Han, *Chinese Academy of Sciences, Shanghai, China and University of Chinese Academy of Sciences, Beijing, China,* Yaoyao Li, Yuxin Song, *Chinese Academy of Sciences, Shanghai, China,* Zhenpu Zhang, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China,* Juanjuan Liu, *Chinese Academy of Sciences, Shanghai, China and University of Chinese Academy of Sciences, Beijing, China,* Zhongyunshen Zhu, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China* and Shumin Wang, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China and Chalmers University of Technology, Gothenburg, Sweden*

A novel suspended GeSn microstructure is demonstrated by selective etching of GeSn thin film on Ge. XRD and μ-Raman measurements show that the compressive strain in the GeSn thin film is effectively relaxed, and furthermore, unexpected tensile strain was introduced in the suspended GeSn.

MP5 **GeSn/Ge Dual-Nanowire Heterostructure,** Zhongyunshen Zhu, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China,* Yuxin Song, *Chinese Academy of Sciences, Shanghai, China,* Yi Han, *Chinese Academy of Sciences, Shanghai, China and University of Chinese Academy of Sciences, Beijing, China,* Yaoyao Li, *Chinese Academy of Sciences, Shanghai, China,* Zhenpu Zhang, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China,* Liyao Zhang, *Chinese Academy of Sciences, Shanghai, China* and Shumin Wang, *Chinese Academy of Sciences, Shanghai, China and ShanghaiTech University, Shanghai, China and Chalmers University of Technology, Gothenburg, Sweden*

A dual-nanowire heterostructure with a GeSn layer laterally laying on Ge nanowires is demonstrated by MBE. The strain field analyzed by FEM shows that this structure can significantly release the compressive strain in GeSn for potential direct bandgap conversion as a Si-based light source.

MP6 **Tunable HMM-Based Devices for Integrated Photonics,** Bartosz Janaszek, Anna Tyszka-Zawadzka, *Institute of Microelectronics and Optoelectronics WUT, Warsaw, Poland* and Pawel Szczepański, *Institute of Microelectronics and Optoelectronics WUT, Warsaw, Poland and National Institute of Telecommunications, Warsaw, Poland*

This paper demonstrates the functionality of Tunable Hyperbolic Metamaterials (HMMs) based on stimulus-sensitive materials in the context of potential applications. Special emphasis was laid on possible implementation within integrated systems as e.g. optical delays/buffers, reflection modulators, or selective amplifiers with controllable gain spectrum.

MP7 **100Gb/s Ultra Wide Misalignment Tolerance WDM Transmitter with Novel Vertical Grating Coupler,** Beiju Huang, *Chinese Academy of Sciences, Beijing, China,* Zan Zhang, *Chang'an University, Xi'an, China,* Zanyun Zhang, *Tianjin Polytechnic University, Tianjin, China,* Chuantong Cheng, *Chinese Academy of Sciences, Beijing, China* and Hongda Chen, *Chinese Academy of Sciences, Beijing, China and University of Chinese Academy of Sciences, Beijing, China*

A 4×25Gb/s ultra wide misalignment tolerance WDM transmitter with novel vertical grating coupler has been demonstrated on CMOS-compatible SOI Platform. The misalignment tolerance along the horizontal direction of grating coupler is as high as ±4μm.

MP8 **Photonic Crystal Surface-Emitting Lasers on Silicon Substrates,** Shih-Chia Liu, Deyin Zhao, Yonghao Liu, Hongjun Yang, *University of Texas at Arlington, TX, USA,* Carl Reuterskiöld-Hedlund, Mattias Hammar, *KTH-Royal Institute of Technology, Kista, Sweden,* Zhenqiang Ma, *University of Wisconsin-Madison, WI, USA* and Weidong Zhou, *University of Texas at Arlington, TX, USA*

We report here photonic crystal surface emitting lasers on bulk silicon substrates. Optically pumped lasers were demonstrated with single mode operation. Thermal resistance of such oxide-free cavity was investigated to evaluate the heat dissipation and lasing characteristics.

TUESDAY, 11 JULY 2017

8:00 am–8:30 am **Grand Ballroom Foyer**

Continental Breakfast

8:30 am–10:00 am **Miramar Atlantic I**
Session TuA1 **GeSn Materials and Devices IV**
Session Chair Stephan Wirths, *IBM, USA*

8:30 am–9:00 am ***(Invited)***

TuA1.1 Material Analysis of GeSn/SiGeSn Quantum Wells Based on Many-Body Theory, Takeshi Fujisawa and Kunimasa Saitoh, *Hokkaido University, Sapporo, Japan*

Material characteristics (optical gain/absorption, refractive index change) of GeSn/SiGeSn quantum wells in mid-IR region is theoretically investigated based on many-body theory. The strategies for designing quantum wells having large material gain or absorption under applied electric field are discussed.

9:00 am–9:30 am ***(Invited)***

TuA1.2 Modeling of the Electronic Band Structure and the Material Gain in GeSn-Based Quantum Wells, R. Kudrawiec, H. S. Mączko, and M. Gladysiewicz, *Wroclaw University of Science and Technology, Wrocław, Poland*

It is shown that the emission wavelength from GaSn-based quantum wells grown on GeSn/Si virtual substrate can be controlled by the content of virtual substrate while the light polarization can be controlled via the built-in strain from 100% TE to 80% TM mode.

9:30 am–10:00 am ***(Invited)***

TuA1.3 Analysis of Direct Transition in GeSn/Ge Quantum Well Systems for Photonic Applications, Guo-En Chang, *National Chung Cheng University, Chiayi County, Taiwan*

We present a variational study of direct transitions in GeSn/Ge quantum well system for photonic applications. The exciton radiuses, binding energies, and oscillator strengths are calculated for various Sn contents are calculated and discussed.

8:30 am–10:00 am **Atlantic II**

Session TuB1 **III-Nitride Photonics**

Session Chair Philippe Boucaud, *University of Paris-Saclay, France*

8:30 am–9:00 am ***(Invited)***

TuB1.1 Top-Down Fabrication for III-Nitride Nanophotonics, George T. Wang, Benjamin Leung, *Sandia National Laboratories, Albuquerque, NM, USA,* Changyi Li, Miao-Chan Tsai, *University of New Mexico, Albuquerque, NM, USA,* Sheng Liu, Jeremy B. Wright, Daniel D. Koleske, Ping Lu, Jeffrey J. Figiel, Ting S. Luk, Igal Brener, Arthur J. Fischer, Xiaoyin Xiao, Jeffrey Y. Tsao, Michael E. Coltrin, *Sandia National Laboratories, Albuquerque, NM, USA,* Ganesh Balakrishnan and Steven R. J. Brueck, *University of New Mexico, Albuquerque, NM, USA*

New top-down approaches for realizing high aspect ratio III-nitride (GaN-based) photonic nanostructures with controlled dimensions, including nanowires and quantum dots are presented. Approaches to controlling the lasing properties of these structures are highlighted.

9:00 am–9:30 am ***(Invited)***

TuB1.2 Photonic Engineering of III-Nitride Active and Passive Devices, Jung Han, *Yale University*

III nitride semiconductors are promising yet challenging for visible and UV photonics. One of the main challenges is the formation of waveguide and cavity within epitaxial constraints. We will discuss the use of electrochemical method to produce active (lasers) and passive photonic devices (waveguides).

9:30 am–10:00 am ***(Invited)***

TuB1.3 AlGaN Nanowire Deep Ultraviolet Optoelectronics, Songrui Zhao, Sharif Sadaf, *McGill University, Montreal, Quebec, Canada,* Xianhe Liu and Zetian Mi, *McGill University, Montreal, Quebec, Canada and University of Michigan, Ann Arbor, MI, USA*

We have investigated the epitaxy and properties of AlGaN nanowires on a Si platform. We have demonstrated electrically pumped semiconductor lasers in the UV-B and UV-C bands. With the use of Al-tunnel junction, we have further achieved high efficiency LEDs in the UV-C band.

8:30 am–10:00 am **Ballroom I**

Session TuC1 **Attojoule Photonics**

Session Chair Michael Gerhold, *US Army Research Laboratory, USA*

8:30 am–8:45 am ***(Tutorial)***

TuC1.1 Attojoule Optoelectronics – Saving Even More Energy with Optics, David A. B. Miller, *Stanford University, Stanford, CA, USA*

Sub-micron optoelectronics promises sub-fJ/bit operating energies. Efficient device mechanisms, tight integration, low-loss nanophotonics, and new approaches to eliminate most link circuitry, including 2D array communications enabled by silicon photonics, could enable us to take full advantage of such devices for low-energy processing and communication.

8:45 am–9:30 am ***(Plenary)***

TuC1.2 Opportunities for Integrated Nanophotonics: From Across Data-Centers to Connecting Logic Gates, Vladimir Stojanovic, *UC Berkeley*

8:30 am–10:00 am **Ballroom III**

Session TuE1 5G Standards and Field Trials

Session Chair Tetsuya Kawanishi, *Waseda University, Japan*

8:30 am–9:00 am ***(Invited)***

TuE1.1 5G Trials Toward 2020 and Beyond, Tekashi Nakamura, *NTT DoCoMo, Japan*

9:00 am–9:30 am ***(Invited)***

TuE1.2 Advanced Photonic Devices for 5G Network in Dense User Enviroment, Hiroshi Murata, *Osaka University, Japan*

Millimeter-wave (MMW) wireless technology is promising for fifth generation (5G) mobile communication systems owing to the outstanding characteristics for high-speed data transfer and massive connection capability by frequency and spatial multiplexing. Therefore, photonic links for MMW wireless networks are becoming more important.

8:30 am–10:00 am **Ballroom IV**

Session TuF1 Quantum Channels and Decoherence

Session Chair Paul Kwiat, *University of Illinois at Urbana–Champaign, USA*

8:30 am–9:00 am ***(Invited)***

TuF1.1 Complementarity in Multipath Interferometers, Janos Bergou, *Hunter College, CUNY*

9:00 am–9:30 am ***(Invited)***

TuF1.2 Entanglement and Decoherence in Optical Amplifiers, James D. Franson, *University of Maryland Baltimore County, Baltimore, MD, USA*

An ideal optical amplifier is generally considered to be a linear device. We show that entanglement between the signal and idler modes can produce nonlinear behavior and decoherence even for small gains where the added noise is negligible.

9:30 am–9:45 am

TuF1.3 A Cold-Atom Quantum Memory for Long Distance Quantum Networks, Paul D. Kunz, Neal E. Solmeyer, Kevin C. Cox, David H. Meyer, *Army Research Laboratory, Adelphi, MD, USA*

The primary limitation of current state-of-the-art quantum memories, that prevents them from enabling long distance quantum networking, is inefficiency in the write-in and read-out processes. We present our work addressing these processes respectively using Rydberg blockade and high cooperativity cavity coupling.

9:45 am–10:00 am

TuF1.4 On-Chip Quantum Optical Networks Comprising Co-Designed Spectrally Uniform Single Photon Source Array and Dielectric Light Manipulating Elements, Swarnabha Chattaraj, Jiefei Zhang, *University of Southern California, Los Angeles, CA, USA,* Siyuan Lu, *University of Southern California, Los Angeles, CA, USA and IBM Thomas J. Watson Research Center, Yorktown Heights, New York, USA* and Anupam Madhukar, *University of Southern California, Los Angeles, CA, USA*

We present an approach to quantum optical networks comprising spectrally uniform ordered array of single quantum dots as on-chip single photon sources integrated with dielectric light manipulating multifunctional units that guide, propagate and create interference of the emitted photons aimed at quantum information processing.

10:00 am–10:30 am **Grand Ballroom Foyer**

Coffee Break

10:30 am–12:00 pm **Miramar Atlantic I**
Session TuA2 **Novel Integration Technology**
Session Chair Bruce Claflin, *USA Air Force, USA*

10:30 am–11:00 am ***(Invited)***

TuA2.1 Integration of Silicon Carbide on Silicon for Its Application in Ultraviolet Photodetectors, Maksym Myronov and Gerard Colston, *University of Warwick, Coventry, United Kingdom*

Cubic silicon carbide (3C-SiC) offers an alternative wide bandgap semiconductor to conventional materials such as hexagonal silicon carbide (4H-SiC) or gallium nitride (GaN) for the detection of UV light. Novel low-temperature epitaxy technology, leading to the invention of state of the art wafer scale.

11:00 am–11:30 am *(Invited)*

TuA2.2 Rhombohedral Super Hetero Epitaxy of Cubic SiGe on Trigonal c-Plane Sapphire, Sang H. Choi and Adam J. Duzik, *NASA Langley Research Center, Hampton, VA, USA*

New rhombohedral super-hetero-epitaxy technology was developed at NASA. This epitaxy technology enables the growth of unprecedented cubic-trigonal hybrid single crystal structures with lattice match on sapphire (Al_2O_3) substrates, hence with little strain and very few defects at the interface.

11:30 am–12:00 pm *(Invited)*

TuA2.3 Monolithic Integration of III-V Materials on Si for Solar Cell, Nano- and Optoelectronic Applications, Stephan Wirths, *IBM*

10:30 am–12:00 pm **Atlantic II**
Session TuB2 **Photonic Circuits and Sources for Quantum Information**
Session Chair George Wang, *Sandia National Laboratories, USA*

10:30 am–11:00 am *(Invited)*

TuB2.1 Carbon Nanotube Single Photon Circuits, Wofram Pernice, *Karlsruhe Institute of Tech.*

11:00 am–11:30 am *(Invited)*

TuB2.2 Quantum Emission from Atomic Defects in Wide-Bandgap Semiconductors, Gabriele Grosso, Benjamin Lienhard, Hyowon Moon, *MIT, USA,* Diego Scarabell, *Columbia University, New York, NY, USA,* Tim Schroeder, Kwang-Yong Jeong, Tsung-Ju Lu, *MIT, USA,* Amanuel M. Berhane, *University of Technology Sydney, New South Wales, Australia*, Shalom Wind, *Columbia University, New York, NY, USA,* Igor Aharanovich, *University of Technology Sydney, New South Wales, Australia* and Dirk Englund, *MIT, MA, USA*

Non-classical light sources, such as atoms and atom-like emitters play central roles in many areas of quantum information processing with applications as single photon generators, sources for nonlinearity and quantum memories.

11:30 am–12:00 pm *(Invited)*

TuB2.3 Multi-Level Photonics for Trapped-Ion Quantum Computing, Dave Kharas, Cheryl Sorace-Agaskar, Suraj Bramhavar, William Loh, Jeremy M. Sage, Paul W. Juodawlkis and John Chiaverini, *Massachusetts Institute of Technology, Lexington, MA, USA*

A scalable trapped-ion-based quantum-computing architecture requires the capability to optically address individual ions at several wavelengths. We demonstrate a dual-layered silicon nitride photonic platform for integration into planar ion traps designed for trapped-ion control in a 400 to 1100 nm wavelength range.

10:30 am–12:00 pm **Ballroom I**

Session TuC2 **Integrated Nanophotonics**

Session Chair Weidong Zhou, *University of Texas at Arlington, USA*

10:30 am–11:00 am ***(Invited)***

TuC2.1 Optical Antennas; LED's Faster Than Lasers, Eli Yablonovitch, *University of California, Berkeley*

The US National Science Foundation–Science & Technology Center for Energy Efficient Electronics Science (E3S) is searching for low energy communication devices to replace the transistor. 10^4 reduction in electronics power consumption is possible. This talk will try to answer: What's standing in the way?

11:00 am–11:30 am ***(Invited)***

TuC2.2 Nanoscale Light Emitters and Their Dynamics for Chip-Scale Integration, Y. Fainman, S. H. Pan, Q. Gu, A. El Amili and F. Vallini, *University of California, San Diego, La Jolla, CA, USA*

This paper discusses nanoscale engineered metal-dielectric-semiconductor resonant gain geometries confined in all three dimensions used to create a new type of nanolasers and light emitters. When these emitters are driven in a pulsed regime, dynamic hysteresis is observed and characterized.

11:30 am–12:00 pm ***(Invited)***

TuC2.3 Ultra-Small Capacitance and Ultral-Low Energy Integrated Nanophotonics by Photonic Crystals Toward Optical Computing, Masaya Notomi, *NTT*

Photonic crystal technologies enable miniaturized OE/EO converters with extremely small capacitance. We demonstrate our recent achievement of these devices for very efficient OE/EO conversions in a chip. Furthermore, we discuss their potential to optoelectronic computing in a chip with ultrasmall latency.

10:30 am–12:00 pm **Ballroom II**

Session TuD2 **Optically Switched Data Center Network Architectures and Optical Switching Systems I**

Session Chair George T. Kanellos, *Aristotle University of Thessaloniki, Greece*

10:30 am–11:00 am ***(Invited)***

TuD2.1 Optical Network Architectures and Technologies for Datacenters, Lena Wosinska, Rui Lin, Yuxin Cheng and Jiajia Chen, *KTH Royal Institute of Technology, Kista, Sweden*

The paper highlights the challenges related to the increasing importance of datacenter services, leading to dramatically growing datacenter traffic. The advantages of using photonic technology in intra-datacenter networks are discussed and a cross-layer view for network architecture design is presented.

11:00 am–11:30 am ***(Invited)***

TuD2.2 Harnessing Path Diversity for Laser Control in Data Center Optical Networks, Yigit Demir, *Intel, Hillsboro, OR, USA,* Nikolaos Terzenidis, *Aristotle University of Thessaloniki, Thessaloniki, Greece,* Haiyang Han, *Northwestern University, Evanston, IL, USA,* Dimitris Syrivelis, *Center for Research and Technology – Hellas (CERTH), Thessaloniki, Greece,* George T. Kanellos, *Aristotle University of Thessaloniki, Thessaloniki, Greece*, Nikos Hardavellas, *Northwestern University, Evanston, IL, USA,* Nikolaos Pleros, *Aristotle University of Thessaloniki, Thessaloniki, Greece,* Srikanth Kandula, *Microsoft Research, Redmond, WA, USA* and Fabian Bustamante, *Northwestern University, Evanston, IL, USA*

We present a datacenter optical network architecture for energy proportionality. The network turns off underutilized redundant paths to save energy by power-gating the optical transceivers. The system monitors network traffic and adaptively turns on the optical transceivers when bandwidth demands exceed a programmable threshold.

11:30 am–12:00 pm ***(Invited)***

TuD2.3 Scheduling and Control in Hybrid Data Centers, Madeleine Glick and Houman Rastegarfar, *University of Arizona, Tucson, AZ, USA*

We examine the scheduling issues in hybrid electrical/optical data center (DC) networks, considering several implementation requirements. For flexible and programmable resource provisioning, centralized software-defined network (SDN) control can be best complemented with distributed, fast, and accurate flow classification based on machine learning (ML).

10:30 am–12:00 pm **Ballroom III**

Session TuE2 **5G Perspectives from Industry and Academia**

Session Chair Andreas Stohr, *University Duisburg-Essen, Germany*

10:30 am–11:15 am ***(Plenary)***

TuE2.1 The Revolutionary Evolution Towards 5G, Chih-Lin I, *China Mobile Research Institute*

11:15 am–12:00 pm ***(Plenary)***

TuE2.2 Fiber-Wireless Convergence for Next Generation Heterogeneous Mobile Data Communications, Gee-Kung Chang, Mu Xu and Feng Lu, *Georgia Institute of Technology, Atlanta, GA, USA*

A leading-edge radio access network empowered by fiber-wireless integration is envisioned. Recent research progress is discussed in aspects of advanced waveforms, digital/analog radio-over-fiber interface, coordinated multi-point transmissions, and all-band multi-tier networking, which are key enabling technologies for the future 5G heterogeneous network.

10:30 am–12:00 pm **Ballroom IV**

Session TuF2 **Sources of Entangled Photon Pairs**

Session Chair Alan Migdal, *National Institute of Standards and Technology, USA*

10:30 am–11:00 am ***(Invited)***

TuF2.1 Integrated Photon Sources for Quantum Information Science, Michael Fanto, *Air Force Research Lab*

11:00 am–11:15 am

TuF2.2 Multi-Wavelength Photon Pair Source Assisted by a Silicon-on-Insulator Micro-Ring Resonator, Bernhard Schrenk, Fabian Laudenbach, Paul Müllner, Winfried Boxleitner, *Austrian Institute of Technology, Vienna, Austria,* Daivid Fowler, *CEA-LETI, Grenoble, France,* Rainer Hainberger and Hannes Hübel, *Austrian Institute of Technology, Vienna, Austria*

An integrated photon pair source in the 1550nm wavelength region is demonstrated. Spontaneous four-wave mixing is facilitated through a silicon-on-insulator micro-ring filter with 125GHz spaced resonances. Coincidences in pair emission are observed with a 95% visibility at spectral channels equidistant to the pump wavelength.

11:15 am–11:45 am ***(Invited)***

TuF2.3 Generation, Characterization, and Manipulation of Fiber-Coupled Entangled Photons, Kim F. Lee and Gregory S. Kanter, *NuCrypt, LLC, Evanston, IL, USA*

Systems for generating, manipulating, and measuring entangled photons are described. Quantum state tomographies are recorded with the entangled photons distributed over fiber. A high speed, low loss quantum switch for 1550 nm photons is demonstrated which can manipulate photons for processing or multiplexing.

11:45 am–12:00 pm

TuF2.4 In-Situ Calibration of Fiber-Optics Entangled Photon Distribution System, Daniel E. Jones, Brian T. Kirby and Michael Brodsky, *US Army Research Laboratory, Adelphi, MD, USA*

A source of entangled photons is connected via optical fibers to two single photon detectors. By simultaneously measuring pump power dependencies of the detection probabilities at each detector, as well as the probability of coincidence counts, we reliably extract all relevant system parameters.

12:00 pm–1:30 pm

Lunch Break (on own)

1:30 pm–3:00 pm **Miramar Atlantic I**
Session TuA3 **Si Based Mid-IR**
Session Chair Jay Mathews, *University of Dayton, USA*

1:30 pm–2:00 pm ***(Invited)***

TuA3.1 n-Ge on Si for Mid-Infrared Plasmonic Sensors, Douglas J. Paul, Kevin Gallacher, Ross W. Millar, *University of Glasgow, Glasgow, United Kingdom,* Valeria Giliberti, Eugenio Calandrini, Leonetta Baldassarre, *Sapienza Universit di Roma, Rome, Italy,* Marco P. Fischer, *University of Konstanz, Konstanz, Germany,* Jacopo Frigerio, Andrea Ballabio, *Politecnico di Milano, Como, Italy,* Emilie Sakat, Giovanni Pellegrini, *Politecnico di Milano, Milano, Italy,* Daniele Brida, *University of Konstanz, Konstanz, Germany,* Giovanni Isella, *Politecnico di Milano, Como, Italy*, Michele Ortolani, *Sapienza Universit di Roma, Rome, Italy,* and Paolo Biagioni, *Politecnico di Milano, Milano, Italy*

The detection and amplification of molecular absorption lines from a mustard gas simulant is demonstrated using plasmonic antennas fabricated from n-Ge epitaxially grown on Si. Approaches to integrated sensors will be presented along with a review of n-Ge compared to other mid-infrared plasmonic materials.

2:00 pm–2:30 pm ***(Invited)***

TuA3.2 Hyperdoping Silicon Beyond Sulfur: Structural and Electronic Properties with Metal Dopants, Jeffrey M. Warrender, *US Army ARDEC – Benet Labs, Watervliet, NY, USA,* Jay Mathews, *University of Dayton, Dayton, OH, USA,* Quentin Hudspeth, Philippe K. Chow, *US Army ARDEC – Benet Labs, Watervliet, NY, USA,* Wenjie Yang, *Australian National University, Canberra, Australia,* Austin J. Akey, *Harvard University, Cambridge, MA, USA* and James S. Williams, *Australian National University, Canberra, Australia*

Hyperdoping silicon with transition metals offers the potential of subbandgap photodetection, but metal impurities can be difficult to kinetically trap. Instabilities during solidification introduce large length-scale defects. We present guidelines for avoiding these instabilities, and electronic properties for layers that do not exhibit them.

2:30 pm–3:00 pm ***(Invited)***

TuA3.3 Figures of Merit for Hyperdoped IR Photodetectors, Jacob J. Krich, *University of Ottawa, Ottawa, ON, Canada*

Hyperdoping – doping far above the solid solubility limit – can produce intermediate bands, which provide one route to potentially make highly effective IR photodetectors and solar cells. We will discuss device modeling and figures of merit for such intermediate band absorbers and devices.

1:30 pm–3:00 pm **Atlantic II**

Session TuB3 **Emerging UV-Visible Photonic Platforms and Applications**

Session Chair Andrea Armani, *University of Southern California, USA*

1:30 pm–2:00 pm ***(Invited)***

TuB3.1 Full Spectrum Visible Integrated Photonics in Scaled Microelectronic CMOS, Amir H. Atabaki, Gavin N. West, Karan K. Mehta, Daniel Kramnik and Rajeev J. Ram, *Massachusetts Institute of Technology, Cambridge, MA, USA*

In this work, we demonstrate an integrated electronic-photonic platform in a standard 65 nm microelectronic CMOS 300 mm foundry. Alongside electronics, we monolithically integrate silicon avalanche photodiodes and optical waveguides that operate from violet to NIR through a mask-less post-CMOS-compatible fabrication process.

2:00 pm–2:30 pm ***(Invited)***

TuB3.2 Silicon Nitride Photonic Integrated Circuits for Multi-Color Optical Engine with Application in Microscopy and Flow Cytometry, Florian Merget, *Aachen University, Aachen, Germany*

We are developing a silicon nitride photonic integrated circuit to replace dichroic mirrors, acousto-optic tunable filters and fiber switches inside a multi-color laser engine aimed towards fluorescent microscopy and flow cytometry. Both the application space and design aspects will be discussed.

2:30 pm–2:45 pm

TuB3.3 Integrated Al_2O_3 Waveguide for Ultraviolet Spectroscopy, Xiaochuan Xu, *Omega Optics Inc., Austin, TX, USA,* Elham Heidari, Lijun Huang, *University of Texas at Austin, Austin, TX, USA,* Naimei Tang, *Omega Optics Inc., Austin, TX, USA* and Ray T. Chen, *Omega Optics Inc., Austin, TX, USA and University of Texas at Austin, Austin, TX, USA*

Integrated photonic waveguides on Al_2O_3/SiO_2 platform are proposed to cover the 220 ~ 320nm wavelength-range, which is of paramount significance in protein and nuclei acid quantification. The proposed system requires 500x less volume of solutions compared to conventional NanoDrop.

2:45 pm–3:00 pm

TuB3.4 Alumina Waveguides for Full-Spectrum Integrated Photonics, Gavin N. West, Karan K. Mehta, Rajeev J. Ram, *Massachusetts Institute of Technology, Cambridge, MA, USA*

We demonstrate fully confined waveguides in the ultraviolet spectrum, and present amorphous aluminum oxide as a viable waveguide platform for broad-spectrum integrated photonics with transmission from the infrared to the ultraviolet. Fabrication of aluminum oxide photonic structures and experimental results are discussed.

1:30 pm–3:00 pm **Ballroom I**

Session TuC3 **Nanophotonics for High-Speed**

Session Chair Shaya Fainman, *University of California, San Diego, USA*

1:30 pm–2:00 pm ***(Invited)***

TuC3.1 Photonic Integrated Chips for Low-Power, High-Bandwidth Communications, Tin Komljenovic, Chong Zhang, Shangjian Zhang, John E. Bowers, University of California, Santa Barbara, CA, USA

We demonstrate a fully integrated photonic network-on-chip (NoC) circuit comprising of more than 400 components realized in heterogeneous silicon photonic process offering 2.56 Tbps transmission capacity.

2:00 pm–2:20 pm ***(Invited)***

TuC3.3 Collective Behaviors in Arrays of Coupled Metallic Nanolasers, Mercedeh Khajavikhan, *UCF*

2:20 pm–2:40 pm ***(Invited)***

TuC3.4 InGaN Nanowire Integrated Nanophotonics, Zetian Mi, *University of Michigan, Ann Arbor, MI, USA and McGill University, Montreal, Quebec, Canada,* Yong-Ho Ra, Roksana Rashid, Renjie Wang and Ishiang Shih, *McGill University, Montreal, Quebec, Canada*

We propose to develop a GaN nanowire based platform on Si substrate for integrated nanophotonics. We have demonstrated the epitaxy of InGaN nanostructures with controlled shape, composition, and morphology, which will serve as the building block for the emerging GaN integrated nanophotonics.

1:30 pm–3:00 pm **Ballroom II**

Session TuD3 **Optically Switched Data Center Network Architectures and Optical Switching Systems II**

Session Chair Maria Anagnosti, *Infinera*

1:30 pm–2:00 pm ***(Invited)***

TuD3.1 Board Level Interconnection with WDM Routing Functionality, George Kanellos, Theoni Alexoudi, Charoula Mitsolidou, Stelios Pitris, *Aristotle University of Thessa, Thessaloniki, Greece,* Tobias Lamprecht, *Vario-Optics, Switzerland,* Roger Dangel, Herwig Hahn, Bert J. Offrein, *IBM, Switzerland,* Peter De Heyn, Joris Van Campenhout, *IMEC, Belgium,* Hannes Ramon, Joris Lambrecht, Johan Bauwelinck, Xin Yin, *UGent, Belgium,* Fabrice Raineri, Dorian Sanchez, *CNRS, France,* Ruiyong Zhang, *FCI, Germany,* Marco Sampietro, Andrea Melloni, Emanuele Guglielmi, *Politechnico Di Milano, Italy,* Guido Chiaretti, *STMicroelectronics, Italy* and Nikos Pleros, *Aristotle University of Thessa, Thessaloniki, Greece*

In the present communication, we review recent advances of the European project ICT-STREAMS platform that employs AWGR-based WDM routing concepts with key- silicon photonics technologies and polymer based electro-optical circuit boards, towards enabling on-board wavelength routing architecture for multiple chip-to-chip interconnection.

2:00 pm–2:30 pm ***(Invited)***

TuD3.2 TBD, Reza Nejabati, *Uni Bristol*

2:30 pm–3:00 pm ***(Invited)***

TuD3.3 Combining Optics and SDN to Enable True Hybrid Integration of Electronic and Photonic Switching Solutions, Gonzalo de Villota, Wang Miao, *TU/e, Eindhoven, The Netherlands,* Yaniv Ben-Itzhak, *IBM Research Lab, Haifa, Israel,* Cosmin Caba, *DTU Fotonik, Lyngby, Denmark,* Liran Schour, *IBM Research Lab, Haifa, Israel,* Shay Vargaftik, *IBM Research Lab, Haifa, Israel and Technion, Israel Institute of Technology, Haifa, Israel,* Karel van de Plassche, Nicola Calabretta and Oded Raz, *TU/e, Eindhoven, The Netherlands*

We demonstrate how combining optical and electronic switches with a Software Defined Network control plane paves the way to the introduction of optical switching solutions in data centers. Two different architectures: C-Share and OpSquare are discussed and analyzed using simulation, emulation and experiment.

1:30 pm–3:00 pm **Ballroom III**

Session TuE3 High Data Rate Wireless

Session Chair Nathan Gomes, *University of Kent, England*

1:30 pm–2:00 pm ***(Invited)***

TuE3.1 Backhaul Communications at 10's of Gbps Data-Rate, Hamid Hemmati, *Facebook Inc., Menlo Park, CA, USA*

Nearly half the world population has either none or poor access to the Internet. The data-rate to provide Internet service to this population is over 100 Tbps. Cost effective technology advancements at a variety of communications bands and for all telecom scenarios are required.

2:00 pm–2:30 pm ***(Invited)***

TuE3.2 High-speed Short-Range Optical Wireless Communications, Ke Wang, *RMIt*

2:30 pm–3:00 pm

TuE3.3 High Data Rate 6 Gbit/s Steerable Multibeam 60 GHz Antennas for 5G Hot-Spot Use Cases, Matthias Steeg and Andreas Stöhr, *University of Duisburg-Essen, Duisburg, Germany*

We present a steerable 60 GHz band multibeam antenna for high-capacity 5G hot-spot-scenarios. The developed SIW-LWA-antenna provides about 40° beam steering and a 14 dBi H-plane directivity. Wireless transmission to multiple users and maximum user data rates up to 6 Gbit/s are demonstrated.

1:30 pm–3:00 pm **Ballroom IV**

Session TuF3 **Long Distance Quantum Communication**

Session Chair Prem Kumar, *Northwestern University, USA*

1:30 pm–2:00 pm ***(Invited)***

TuF3.1 **Novel Technologies for Quantum Key Distribution Networks,** Zhiliang L. Yuan, G. L. Roberts, J. F. Dynes, B. Fröhlich, M. Lucamarini, A. W. Sharpe, W. W.-S. Tam, A. Plews and A. J. Shields, *Toshiba Research Europe Limited, Cambridge, United Kingdom*

Quantum key distribution (QKD) has matured rapidly towards practical use in communication infrastructures due to its unique ability of transmitting information-theoretically secure digital keys. Here, we report key advances in QKD that allow modulator-free transmitter, application into existing fiber infrastructures and cryogen-free long-distance operation.

2:00 pm–2:15 pm

TuF3.2 **Experimental Evaluation of the Impairments on a QKD System in a 20-Channel WDM Co-Existence Scheme,** Fotini Karinou, Lucian Comandar, Hans H. Brunner, David Hillerkuss, Fred Fung, Stefano Bettelli, Spiros Mikroulis, Dawei Wang, Qian Yi, Maxim Kuschnerov, Changsong Xie, Andreas Poppe and Momtchil Peev, *Huawei Technologies Duesseldorf GmbH, Munich, Germany*

We experimentally investigate the excess noise induced on a CV-QKD system in a WDM environment consisting of 4×100 Gb/s PDM-QPSK and 16×10 Gb/s OOK classical telecom signals. The influence of the receiver's noise, the Raman scattering and the four-wave mixing process are evaluated.

2:15 pm–2:30 pm

TuF3.3 **Sub-Wavelength Stabilization of Long, Deployed Optical Fibers for Quantum Networks,** Matthew E. Grein, Mark L. Stevens, Nicholas D. Hardy and P. Ben Dixon, *Massachusetts Institute of Technology, Lexington, MA, USA*

We implemented an active feedback scheme to stabilize an ~84 km deployed optical fiber between Lincoln Laboratory and MIT Campus. The residual fluctuations of less than 193 attoseconds RMS enable quantum networking and quantum secure communications.

2:30 pm–3:00 pm ***(Invited)***

TuF3.4 **Optimized Architectures for Long Distance Quantum Communication,** Linshu Li, Sreraman Muralidharan, Chang-Ling Zou, Victor V. Albert, *Yale University, New Haven, CT, USA,* Jungsang Kim, *Duke University, Durham, NC, USA,* Norbert Lütkenhaus, *University of Waterloo, Waterloo, ON, Canada*, Mikhail D. Lukin, *Harvard University, Cambridge, MA, USA,* S. Girvin and Liang Jiang, *Yale University, New Haven, CT, USA*

Efficient long distance quantum communication with quantum repeaters is discussed. We show that quantum repeater protocols can be classified into three generations, each performs optimally in different parameter regimes. The application of cat codes as a single-mode encoding to one-way quantum repeaters is analyzed.

3:00 pm–3:30 pm **Grand Ballroom Foyer**

Coffee Break

3:30 pm–5:00 pm **Miramar Atlantic I**

Session TuA4 **Novel Si Based Integrated Photonics**

Session Chair Alexei Chelnokov, *CEA Leti, France*

3:30 pm–4:00 pm ***(Invited)***

TuA4.1 Electro-Optic and Second-Order Nonlinear Effects in Thin Film Lithium Niobate on Silicon, Ashutosh Rao, *University of Central Florida, Orlando, FL, USA,* Aniket Patil, *Partow Technologies LLC, Orlando, FL, USA,* Marcin Malinowski, Jeff Chiles, Saeed Khan, Amirmahdi Honardoost, Seyfollah Toroghi, Guillermo Camacho-González, *University of Central Florida, Orlando, FL, USA,* Payam Rabiei, *Partow Technologies LLC, Orlando, FL, USA* and Sasan Fathpour, *University of Central Florida, Orlando, FL, USA*

Our recent progress on wafer-bonded thin-film lithium niobate on silicon electro-optic modulators operating up to 50 GHz, and thin-film nonlinear optical waveguide frequency converters, based on two approaches – periodic poling and poling-free grating-assisted quasi-phase matching – will be reviewed.

4:00 pm–4:30 pm ***(Invited)***

TuA4.2 Mid Infrared Frequency Combs with Integrated Nonlinear Optics, Nima Nader, *NIST,* D. L. Maser, *NIST/University of Colorado, Boulder, CO, USA,* F. C. Cruz, *NIST, CO, USA,* C. Fredrick, *NIST/University of Colorado, Boulder, CO, USA,* D. Westly, *NIST, MD, USA,* R. P. Mirin, J. M. Shainline, *NIST, CO, USA* and S. A. Diddams, *NIST/University of Colorado, Boulder, CO, USA*

User-defined, spectral engineering of mid-IR frequency combs is presented in silicon waveguides. The generated light is suitable for dual-comb spectroscopy with negligible added intensity noise and flat spectral bandwidth. A dual-comb setup is constructed and used for gas spectroscopy at 5 um through coherent dual-comb.

4:30–5:00 pm ***(Invited)***

TuA4.3 All-Optical Switch Based on 4-Wave Mixing in Si Waveguides, Imad Agha, Yun Zhao and Jay Mathews, *University of Dayton, Dayton, OH, USA*

Four-wave mixing has been proposed as means for low-noise, low-power all-optical control of light on chip. In our recent work, we have experimentally demonstrated a transistor-like all-optical logic gate in a silicon waveguide. This gate is optimal when operated in the SWIR and mid-IR regimes.

3:30 pm–5:00 pm **Ballroom I**

Session TuC4 **Nanophotonic Devices**

Session Chair Weidong Zhou, *University of Texas at Arlington, USA*

3:30 pm–3:50 pm ***(Invited)***

TuC4.1 Optical Antennas: LEDs Faster Than Lasers, Ming C. Wu, *University of California, Berkeley, CA, USA*

With optical antennas, spontaneous light emission becomes faster than stimulated emission, but the enhancement is limited by optical losses through the "anomalous skin effect". Maintaining 50% efficiency, 10x speedup beyond stimulated emission should be possible. The antenna-LED will replace the laser for on-chip optical communication.

3:50–4:10 pm ***(Invited)***

TuC4.2 III-Nitride Integrated Photonics Platform for the Ultraviolet and Visible Spectral Range, Yuji Zhao, *Arizona State University, Tempe, AZ, USA*

III-nitride integrated photonics platform would enable a wide range of applications in biochemical sensing, quantum information, and optical communications. In this talk, I will present our recent studies on the fundamental nonlinear optical properties of GaN, which will lead to low loss GaN waveguide.

4:10–4:30 pm ***(Invited)***

TuC4.3 Modulation Bandwidth of a Double Tunneling-Injection Quantum Dot Laser: The Upper Limit and Limiting Factors, Levon V. Asryan, *Virginia Polytechnic Institute and State University, Blacksburg, VA, USA*

The modulation response in double tunneling-injection quantum dot lasers is analyzed. The highest possible modulation bandwidth and the effect of noninstantaneous pumping of quantum dots on the bandwidth are discussed.

4:30 pm–4:50 pm ***(Invited)***

TuC4.4 Nanoscale Lasers: Requirements for Dense Integration and Impact on Interconnect Bit Energy, Dennis Deppe, *University of Central Florida, Orlando, FL, USA*

3:30 pm–5:00 pm **Ballroom II**

Session TuD4 **Optically Switched Data Center Network Architectures and Optical Switching Systems III**

Session Chair **Foteini Karinou,** *Huawei, USA*

3:30 pm–4:00 pm ***(Invited)***

TuD4.1 Slotted Optical Datacenter Network with Sub-Wavelength Resource Allocation, Paraskevas Bakopoulos, Konstantinos Tokas, Christos Spatharakis and Hercules Avramopoulos, *National Technical University of Athens, Athens, Greece*

Optical switching is gaining traction for scaling datacenter networks, apace with soaring traffic demand. We experimentally evaluate a slotted optical network architecture capable of dynamically allocating network resources with sub-wavelength granularity. Network operation is demonstrated with multiple communication scenarios, using 200μs duration optical bursts.

4:00 pm–4:30 pm ***(Invited)***

TuD4.2 Traffic Engineering in Data Centers with CloudBOSS: Cloud Burst Optical Slot Switching, Yvan Pointurier, *Nokia Bell Labs, Nozay, France*

We review and demonstrate CloudBOSS, an intra-data center architecture based on optical packet switching, and its key optical building blocks. CloudBOSS, when coupled with an SDN-enabled control plane, can provide on-demand strict performance guarantees (e.g., end-to-end capacity or bounded latency).

4:30 pm–4:45 pm

TuD4.3 Quad Channel Blocker Array Based on a Commodity Liquid Crystal Display, Bernhard Schrenk, *Austrian Institute of Technology, Vienna, Austria,* Paraskevas Bakopoulos, *National Technical University of Athens, Athens, Greece* and Hannes Hübel, *Austrian Institute of Technology, Vienna, Austria*

We demonstrate channel selection and power leveling based on an off-the-shelf liquid crystal display, addressing datacenter cost targets. An extinction ratio >10dB is reported for a 16 nm spectral region. Evaluation in a 4×1 switch configuration confirms colorless channel blocking in presence of side-channels.

3:30 pm–5:00 pm **Ballroom III**

Session TuE4 **Beyond 5G**

Session Chair **Raul Munoz,** *Centre Tecnologic de Telecomunicacions de Catalunya (CTTC), Spain*

3:30 pm–4:00 pm ***(Invited)***

TuE4.1 Millimeter- and Terahertz-Wave Radio-Over-Fiber for 5G and Beyond, Pham Tien Dat, Atsushi Kanno, Toshimasa Umezawa, Naokatsu Yamamoto, *National Institute of Information and Communication Technology, Tokyo, Japan* and Tetsuya Kawanishi, *National Institute of Information and Communication Technology, Tokyo, Japan and Waseda University, Tokyo, Japan*

This paper reviews our recent research activities on millimeter-wave and terahertz-wave radio-over-fiber systems for future mobile networks. Photonic technology for signal generation, transmission, and up-conversion is utilized to realize radio-on-radio-over-fiber; signal processing-aided multiple signal transmission; high-capacity seamless system; and simultaneous power- and radio-over-fiber system.

4:00 pm–4:30 pm ***(Invited)***

TuE4.2 A 300GHz-Band Wireless Transceiver Using Si-CMOS Integrated Circuits, Minoru Fujishima, *Hiroshima University, Higashi-Hiroshima, Japan*

300-GHz band is promising for wireless communication since wide frequency band and low atmospheric attenuation are available. In this presentation, the technologies of a recently-developed 300-GHz-band transceiver chip set including 105Gbps transmitter and 32Gbps receiver are discussed using CMOS integrated circuits.

4:30 pm–5:00 pm ***(Invited)***

TuE4.3 Optical and Wireless Integrated Technologies for Mobile Networks Towards Beyond 5G Era, Masatoshi Suzuki, Shota Ishimura, Kazuki Tanaka, Sinobu Nanba and Kosuke Nishimura, *KDDI Research, Inc., Fujimino, Japan*

The peak rate of coming 5G mobile services will be comparable to that of FTTH. In this paper, we will discuss integrated optical and wireless technologies, such as RoF, for efficient use of bandwidth of future mobile back/front-haul networks towards beyond 5G era.

3:30 pm–5:00 pm **Ballroom IV**

Session TuF4 **Structure of Quantum Network Nodes**

Session Chair Brian Smith, *University of Oregon, USA*

3:30 pm–4:00 pm ***(Invited)***

TuF4.1 Coupling Qubits to Photons Using Dual Atomic Species for Quantum Networking, Trent Graham, Matthew Ebert, Yuan Sun and Mark Saffman, *University of Wisconsin-Madison, Madison, WI, USA*

We present a technique to implement a neutral atom quantum repeater node. We discuss how to prepare atom-photon entanglement, entangle atoms in adjacent repeater nodes, and entangle distant nodes.

4:00 pm–4:30 pm ***(Invited)***

TuF4.2 Towards a Quantum Network Based on Trapped Ions in Cavity, Florian Ong, Klemens Schüppert, Pierre Jobez, Florian Kranzl, Dario Fioretto, Markus Teller, Konstantin Friebe, Moonjoo Lee, Ben Ames, Tracy Northup, *Universität Innsbruck, Innsbruck, Austria* and Rainer Blatt, *Universität Innsbruck, Innsbruck, Austria and Institut für Quantenoptik und Quanteninformation der Österreichischen, Akademie der Wissenschaften, Innsbruck, Austria*

We are constructing a three-node quantum network using trapped calcium ions in cavities in order to test future quantum network architectures. We report here the latest progress on two nodes.

4:30 pm–5:00 pm ***(Invited)***

TuF4.3 Autonomous Quantum Error Correction by Dissipation, Christine Muschik, *University of Innsbruck, Innsbruck, Austria,* Florentin Reiter, *Harvard University, Cambridge, MA, USA,* Anders Sørensen, *Niels Bohr Institute, Copenhagen, Denmark* and Peter Zoller, *University of Innsbruck, Innsbruck, Austria*

We present a quantum error correction scheme that harnesses dissipation to stabilize a trapped ion qubit. Always-on couplings to an engineered environment protect the qubit against spin- or phase flips. The scheme operates fully autonomously without the need to perform measurements or feedback operations.

WEDNESDAY, 12 JULY 2017

8:00 am–8:30 am **Grand Ballroom Foyer**

Continental Breakfast

8:30 am–10:00 am **Miramar Atlantic I**
Session WA1 **Mid-IR Devices**
Session Chair Imad Agha, *University of Dayton, USA*

8:30 am–8:45 am

WA1.1 InP-based Multiple Type-II Quantum-Well Integrated Waveguide p-i-n Photodiodes for Mid-Infrared Detection, Bassem Tossoun, Ye Wang, *University of Virginia, Charlottesville, VA, USA,* Sadhvikas Addamane, Ganesh Balakrishnan, *University of Virginia, Albuquerque, NM,* Archie L. Holmes, Jr. and Andreas Beling, *University of Virginia, Charlottesville, VA, USA*

We present an InP-based p-i-n photodiode with multiple InGaAs/GaAsSb type-II quantum wells for 2μm detection. The fabricated photodiode shows a responsivity of 0.24 A/W at 2μm, with dark current as low as 1μA at -2V, and 3dB-bandwidth of 2 GHz under 1.55μm optical illumination.

8:45 am–9:00 am

WA1.2 High Resolution Silicon-on-Insulator Mid-Infrared Spectrometers Operating at 3.3 μm, Anton Vasiliev, Muhammad Muneeb, Roel Baets and Günther Roelkens, *Ghent University–IMEC, Ghent, Belgium*

The characterization of silicon-on-insulator arrayed waveguide grating wavelength (de)multiplexers operating at 3.3 μm is reported. The filters have a channel spacing between 200 GHz and 50 GHz and feature low insertion loss (2-3dB), low crosstalk level (20 dB) and low waveguide loss (2.6 dB/cm).

9:00 am–9:30 am *(Invited)*

WA1.3 InGaAs/InAsSb Ternary SLS MWIR Photodetectors, Joshua Duran, Gamini Ariyawansa, Charles Reyner, *Air Force Research Laboratory: Sensors Directorate, Wright-Patterson AFB, OH, USA,* Elizabeth Steenbergen, *Air Force Research Laboratory: Space Vehicles Directorate, Kirtland AFB, NM, USA* and John Scheihing, *Air Force Research Laboratory: Sensors Directorate, Wright-Patterson AFB, OH, USA*

We present conceptual designs and experimental results for InGaAs/InAsSb mid-wavelength infrared photodetectors. Utilizing two ternary materials as the superlattice constituents enables greater flexibility for strain balancing than the more thoroughly studied InAs/GaSb and InAs/InAsSb material systems, translating to a wider design trade space.

9:30 am–10:00 am ***(Invited)***

WA1.4 On-Chip Quantum State Generation by Means of Integrated Frequency Combs, Stefania Sciara, *INRS-EMT, Varennes, Québec, Canada and University of Palermo, Palermo, Italy,* Michael Kues, *INRS-EMT, Varennes, Québec, Canada and University of Glasgow, Glasgow, Scotland,* Christian Reimer, Piotr Roztocki, *INRS-EMT, Varennes, Québec, Canada,* Benjamin Wetzel, *INRS-EMT, Varennes, Québec, Canada and University of Sussex, Brighton, England,* Yaron Bromberg, *The Hebrew University of Jerusalem, Jerusalem, Israel,* Brent E. Little, *Xi'an Institute of Optics and Precision Mechanics of CAS, Xi'an, China,* Sai T. Chu, *City University of Hong Kong, Hong Kong, China,* David J. Moss, *Swinburne University of Technology, Hawthorn, VIC, Australia,* Lucia Caspani, *University of Strathclyde, Glasgow, Scotland* and Roberto Morandotti, *INRS-EMT, Varennes, Québec, Canada*

We show that integrated optical frequency combs can be used as versatile sources for optical quantum states. These include the generation of multiplexed heralded single-photons, and the first on-chip realization of cross-polarized photon-pairs, multiple two-photon entangled states, and multi-photon entangled quantum states.

10:00 am–10:15 am

WA1.5 Mid-Infrared Silicon Photonic Devices and Sensors, Swapnajit Chakravarty, *Omega Optics Inc., Austin, TX, USA,* Hai Yan, Yi Zou, *University of Texas at Austin, Austin, TX, USA,* and Ray T. Chen, *Omega Optics Inc., Austin, TX, USA and University of Texas at Austin, Austin, TX, USA*

Mid-infrared silicon photonic integrated components, namely grating couplers, strip and slot waveguides, slotted and unslotted photonic crystal waveguides, photonic crystal microcavities are experimentally demonstrated in silicon-on-sapphire. Application in trace gas sensing is experimentally demonstrated. Progress towards monolithic integration of lasers and detectors are discussed.

10:15 am–10:30 am

WA1.6 1.9–3.3 µm Type-I Quantum-Well Cascade Diode Lasers, Leon Shterengas, Takashi Hosoda, Gela Kipshidze, Tao Feng, Meng Wang and Gregory Belenky, *Stony Brook University, Stony Brook, NY, USA*

Cascade pumping of type-I QWs increase power and efficiency of GaSb-based diode lasers operating in spectral region from 1.9 to 3.3 µm. Multimode lasers demonstrate watt level output and single spatial mode and ditributed feedback lasers generate tens of mW of output power.

8:30 am–10:00 am **Atlantic II**
Session WB1 **Novel Photonic Devices and Applications**
Session Chair Stefan Preble, *Rochester Institute of Technology, USA*

8:30 am–9:00 am ***(Invited)***

WB1.1 **Nanomaterial-Enhanced Optical Microcavity-Based Lasers,** Andrea M. Armani, Xiaoqin Shen, Vinh Diep, Dongyu Chen, *University of Southern California, Los Angeles, CA, USA,* Vladan Jankovic, *Northrop Grumman, Redondo Beach, CA, USA,* Brock Hudnut, Soheil Soltani, Andre Kovach and Hyungwoo Choi, *University of Southern California, Los Angeles, CA, USA*

Integrated optical cavities have demonstrated ultra-low threshold lasers based on numerous types of gain media, such as rare earth elements, doped directly into the cavity. In this presentation, I will discuss using nonlinear optical small molecules as an alternative route.

9:00 am–9:30 am ***(Invited)***

WB1.2 **Deep Learning with Coherent Nanophotonic Circuits,** Yichen Shen, Nicholas C. Harris, Scott Skirlo, Dirk Englund and Marin Soljačić, *Massachusetts Institute of Technology,Cambridge, MA, USA*

Artificial Neural Networks have dramatically improved performance for many machine learning tasks. We demonstrate a fully optical neural network that enables a computational speed enhancement of at least two orders of magnitude and three orders of magnitude in power efficiency over state-of-the-art electronics.

8:30 am–10:00 am **Ballroom I**
Session WC1 **Plenary – Integrated Photonics**
Session Chair Michael Gerhold, *US Army Research Laboratory, USA*

8:30 am–9:15 am ***(Plenary)***

WC1.1 **Nanophotonic Computing: Scalable and Energy-Efficient Computing with Attojoule Nanophotonics,** S. J. Ben Yoo, *University of California, Davis, Davis, CA, USA*

We will discuss architectures, technologies, and 3D system integration aspects of nanophotonic computing. Attojoule nanophotonics co-integrated with nanoelectronics and nanomems can form future logic, memory, and interconnects. Bio-inspired event-driven and hierarchical many-to-many interconnection help realize a scalable and extremely-low energy computing system.

9:15 am–9:45 am ***(Invited)***

WC1.2 **Current and Future Trend of Energy/Bit for High Speed Uncool Optical Links (50 Gb/s and 75°C),** Milton Feng, Nick Holonyak, Jr., Junyi Qiu and C. Y. Wang, *University of Illinois at Urbana-Champaign, Urbana, IL, USA*

VCSEL bandwidth is limited by slow nanosecond e-h recombination lifetime of ~ 30 GHz (60Gb/s). The transistor laser (TL) has picosecond recombination lifetime; thus, it will have modulation bandwidth higher to achieve 300 Gb/s error free transmission and low energy/bit toward 10 fJ/bit.

9:45 am–10:05 am ***(Invited)***

WC1.3 Plasmonic Nanophotonic Modulators, Muhammad Z. Alam, *Caltech, Pasadena, CA, USA,* H. W. Lee, *Baylor University, Waco, TX, USA,* Y-W. Huang, *Harvard University, Cambridge, MA, USA,* R.A. Pala, *Caltech, Pasadena, CA, USA,* K. Thyagarajan, *PARC, Palo Alto, CA, USA,* G. K. Shirmanesh, R. Sokhoyan and H. A. Atwater, *Caltech, Pasadena, CA, USA*

Developing a compact, low power and high speed electro-optic modulator is crucial for overcoming the performance bottleneck of electronics. We review progress in chip based silicon compatible plasmonic modulator design, and discuss recent designs which have switching energy close to 1 fJ/bit.

8:30 am–10:00 am **Ballroom III**

Session WE1 **Test & Measurement for 5G**

Session Chair Andreas Umbach, *Finisar, Germany*

8:30 am–9:00 am ***(Invited)***

WE1.1 Optical and RF Metrology for 5G, David A. Humphreys, Irshaad Fatadin, *National Physical Laboratory, Teddington, United Kingdom,* Mark Bieler, Paul Struszewski, *Physikalisch-Technische, Braunschweig, Germany* and Martin Hudlička, *Czech Metrology Institute, Brno, Czech Republic*

Specification standards will soon be available for 5G mobile RF communications. What optical and electrical metrology is needed or available to support the development of the supporting optical communication systems? Device measurement, digital oscilloscope impairments and improving system resolution are discussed.

9:00 am–9:30 am ***(Invited)***

WE1.2 5G Technologies, Their Impact on Optical Networking and New Approaches to Test, Alan Anderson, *Keysight Technologies, Edinburgh, United Kingdom*

The move to higher radio frequencies, a new generation of high-bandwidth optical connectivity and a diverse set of use cases make 5G systems very different from previous cellular standards. We will explore the challenges of testing these new systems.

9:30 am–10:00 am ***(Invited)***

WE1.3 Optical Fiber Network-Connected Distributed MM-Wave Radar System, Tetsuya Kawanishi, *Waseda University, Tokyo, Japan and National Institute of Information and Communications Technology, Tokyo, Japan,* Atsushi Kanno, Naokatsu Yamamoto, *National Institute of Information and Communications Technology, Tokyo, Japan,* Naruto Yonemoto, *Electronic Navigation Research Institute, Tokyo, Japan,* Nobuhiko Shibagaki and Ken-ichi Kashima, *Hitachi Kokusai Electric, Koganei, Japan*

This presentation reviews radar systems with many antenna units connected by optical networks, which distribute waveforms of wideband frequency modulated millimeter-wave signals, where the range resolution can be a few centimeters.

8:30 am–10:00 am **Ballroom IV**
Session WF1 **Quantum Network Theory**
Session Chair William Munro, *NTT Basic Research Labs, Japan*

8:30 am–9:00 am ***(Invited)***

WF1.1 Quantum Walk Searches, Mark Hillery, *Hunter College of CUNY, New York, NY, USA*

Quantum walks, quantum versions of random walks, can find structural anomalies in graphs with a quantum speedup. Examples of such anomalies are distinguished vertices, extra edges, and other structures that break the symmetry of the graph.

9:00 am–9:30 am ***(Invited)***

WF1.2 Quantum Internetworking, Rod Van Meter, *Keio University*

10:00 am–10:30 am **Grand Ballroom Foyer**

Coffee Break

10:30 am–12:00 pm **Ballroom I**
Session WC2 **High-Speed Devices**
Session Chair Ali Adibi, *Georgia Institute of Technology, USA*

10:30 am–10:50 am ***(Invited)***

WC2.1 Optical Modulation in Hybrid Integrated Nanophotonic Platforms, Ali Adibi, *Georgia Tech*

10:50 am–11:10 am ***(Invited)***

WC2.2 Reducing Optical Confinement Losses for Fast, Efficient Nanophotonic Modulators, Gordon A. Keeler, Salvatore Campione, Michael G. Wood, Darwin K. Serkland, S. Parameswaran, Jon Ihlefeld, Ting S. Luk, Joel R. Wendt and Kent M. Geib, *Sandia National Laboratories, Albuquerque, NM, USA*

We demonstrate high-speed operation of ultracompact electroabsorption modulators based on epsilon-near-zero confinement in indium oxide (In_2O_3) using field-effect carrier density tuning. Additionally, we discuss strategies to enhance modulator performance and reduce confinement-related losses by introducing high-mobility conducting oxides such as cadmium oxide (CdO).

11:10 am–11:30 am ***(Invited)***

WC2.3 Temperature Dependence of a Sub-Wavelength Compact Graphene Plasmon-Slot Modulator, Zhizhen Ma, Sikandar Khan, Mohammad Tahersima and Volker J. Sorger, *George Washington University, Washington, DC, USA*

We investigate a plasmonic electro-optic modulator with an extinction ratio exceeding 1 dB/μm by engineering the optical mode to be in-plane with the graphene layer, and show how lowering the operating temperature enables steeper switching.

11:30 am–11:50 am ***(Invited)***

WC2.4 Engineering vdW Heterostructure for Ultrafast Optoelectronics, Sufei Shi, *Rensselaer Polytechnic Institute, Troy, NY, USA*

Two-dimensional materials has attracted much research attention. Due to strong light-matter interaction, they are promising candidates for photodetectors beyond scaling limit. In particular, van der Waals (vdW) heterostructure provides unprecedented opportunities in material engineering. We will explore the possibility of exploting vdW heterostructure for ultrafast.

10:30 am–12:00 pm **Ballroom II**

Session WD2 **Photonic Integrated Circuits for Advanced Functionalities in Optical Switching I**

Session Chair Fabrice Raineri, *CNRS*

4:45 pm–5:15 pm ***(Invited)***

WD2.2 High-Capacity InP-Based Photonic Integrated Circuits for Data Center Interconnect Applications, Maria Anagnosti, Vikrant Lal, Joseph Summers, Amir Hosseini, Scott Corzine, Peter Evans, Naksum Kim, Mingzhi Lu, Corey Tsai, Gloria Hoefler, Tim Butrie, Matthew Mitchell, Mehrdad Ziari, Dave Welch and Fred Kish, *Infinera, Sunnyvale, CA, USA*

This paper presents an overview of state-of-the-art InP-Based photonic integrated circuits (PICs) for data center interconnect applications, including multi-channel monolithic InP-PIC devices operating at multi-Tb/s capacities using coherent modulation. PICs that offer high density design are demonstrated integrating up to 14-channels enabling multi-Tb/s capacity.

5:15 pm–5:45 pm ***(Invited)***

WD2.3 Performance Assessment of VCSEL-Based Systems for Next-Generation Datacenter Switching Architectures, Fotini Karinou, Cristian Prodaniuc and Nebojsa Stojanovic, *Huawei Technologies, Munich, Germany*

We discuss the transmission over short-reach networks employing VCSELs for rack-to-rack optical interconnects in datacenters. The penalties imposed are compensated by DSP at the receiver. We analyze the DSP complexity and we infer on its impact on the BER performance of the system.

5:45 pm–6:00 pm

WD2.4 Terahertz Microjets and Graphene: Technologies towards Ultrafast All-Optical Modulation Mark H. Bergen, Brandon Born, Simon Geoffroy-Gagnon and Jonathan Holzman, *University of British Columbia, Kelowna, BC, Canada*

Key technologies for ultrafast all-optical THz modulation are introduced. A graphene monolayer is applied for modulation, on a picosecond timescale, and a dielectric sphere is applied to form a high-intensity THz microjet within the graphene monolayer.

10:30 am–12:00 pm **Ballroom III**

Session WE2 **Photonic/RF Components & FSO for 5G**

Session Chair Leif Johanson, *Freedom Photonics, USA*

10:30 am–11:00 am

WE2.1 A 16-Gb/s Millimeter-Wave CMOS Transmitter with Integrated Optical Receiver for 5G Baseband-over-Fiber Systems, Haikun Jia, Guang Zhu, Yipeng Wang, *Hong Kong University of Science and Technology, Hong Kong, China,* Zhihua Wang, *Tsinghua University, Beijing, China* and Patrick Yue, *Hong Kong University of Science and Technology, Hong Kong, China*

This paper presents a 65-nm CMOS baseband-over-fiber system-on-a-chip that integrates a 28–32 GHz transmitter with a 16-Gb/s optical receiver. The SoC directly up-convert broadband optical signals to the lower mm-wave band, with an efficiency of 8.6 pJ/bit, for providing backhaul connectivity in 5G base-stations.

11:00 am–11:15 am

WE2.2 High-Speed Modeling of Thin-Film Lithium-Niobate-on-Silicon Electrooptic Modulators, Amirmahdi Honardoost, Ashutosh Rao and Sasan Fathpour, *University of Central Florida, Orlando, FL, USA*

A model is developed for frequency-dependent response of compact high-speed thin-film lithium-niobate-on-silicon electrooptic modulators. The model predicts potential for > 100 GHz modulation bandwidth.

11:15 am–11:30 am

WE2.3 Tandem Dual-Electrode Mach Zehnder Modulators Generating W-Band Signals for an OCDMA Radio-over-Fiber System, Morad Eghbal and Mehdi Shadaram, *University of Texas at San Antonio, San Antonio, TX, USA*

We propose a W-band optical code division multiple access radio-over-fiber system generated by tandem dual-electrode Mach Zehnder modulators. The simulation results are presented. 7-segment M-sequence codes are used for optical encoding. The capacity is increased while the cost and complexity are reduced.

11:30 am–12:00 pm ***(Invited)***

WE2.4 Next Generation Data Center Interconnection Networks, Mohsen Kavehrad, *Pennsylvania State University, University Park, PA USA*

Paper aims to replace data center networks based on fiber optic cabling with networks based on free-space optical transceivers that would create more flexible networks than the state of the art, given that the cabling interconnect, imposes an priori structure on existing network designs.

10:30 am–12:00 pm **Ballroom IV**

Session WF2 **Breakdown Session**

Session Chair Michael Brodsky, *Air Force Research Labs, USA*

END OF PROGRAM

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