## Optical Interconnects Conference 2017
### Program-at-a-Glance

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday, 5 June 2017</th>
<th>Tuesday, 6 June 2017</th>
<th>Wednesday, 7 June 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00am – 8:30am</td>
<td>Breakfast: Canyon Ballroom</td>
<td>TuA: PLENARY II</td>
<td>WA: Energy Efficiency</td>
</tr>
<tr>
<td>8:30am - 9:45am</td>
<td>Welcome/Opening Remarks 8:30-9:00am</td>
<td>TuB: Next Generation Data Centers</td>
<td>WB: High Speed Communications II</td>
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<tr>
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<td>MA: PLENARY I 9:00-9:45am</td>
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<tr>
<td>9:45am – 10:15am</td>
<td>Coffee Break/Exhibits: Canyon Ballroom</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:15am – 11:45am</td>
<td>MB: Silicon Photonics</td>
<td>TuC: High Speed Communication I</td>
<td>WC: VCSEL and Advance Communication</td>
</tr>
<tr>
<td>11:45am – 1:15pm</td>
<td>Lunch Break (ON OWN)</td>
<td></td>
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</tr>
<tr>
<td>1:15pm – 3:15pm</td>
<td>MC: Advance Devices</td>
<td>TuD: High Speed ≥ 100 Gb/s Optical and Electrical Interconnect Workshop II</td>
<td></td>
</tr>
<tr>
<td>3:15pm - 3:45pm</td>
<td>Coffee Break/Exhibits: Canyon Ballroom</td>
<td></td>
<td>Registration Hours: Mesa Ballroom Foyer</td>
</tr>
<tr>
<td>3:45pm - 5:45pm</td>
<td>MD: Is On-Board Optics the Right Solution to Reduce Power Consumption of Data Center Networking Hardware? Workshop I</td>
<td>TuD: High Speed ≥ 100 Gb/s Optical and Electrical Interconnect Workshop II</td>
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<tr>
<td>5:45pm – 7:15pm</td>
<td>Welcome Reception Canyon Ballroom</td>
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<td></td>
</tr>
</tbody>
</table>

**Registration Hours:**
- **Monday, 5 June**
  7:00am - 5:30pm
- **Tuesday, 6 June**
  7:30am - 5:00pm
- **Wednesday, 7 June**
  8:00am - 3:00pm
Welcome to the Optical Interconnects Conference 2017 at the Hilton Santa Fe Historic Plaza, Santa Fe, New Mexico!

The sixth IEEE Photonics Society Optical Interconnects Conference, whose roots trace back to the original 1990 Workshop on Interconnections within High Speed Digital Systems, seeks to facilitate the collaboration required to drive new interconnect architectures and technologies from concepts in research labs to commercial realities. The conference covers the complete spectrum of high performance interconnect challenges in network systems, architectures, applications, subsystems, and devices. The crucial role that any interconnect strategy plays can only be fully realized when optimized at the system level. This is particularly so in large future peta- and exa-scale platforms in datacenters and supercomputers. So we look forward to the participation of system architects, programmers and everyone researching the interconnect role in a more self-aware next generation platform. With the launch of the US Integrated Photonics Institute for Manufacturing Innovation, we are particularly interested in exploring how new developments in integrated photonics will impact optical interconnects and next generation systems.

Hot topics tackled this year include:

- the pros & cons of on-board optics in datacenter hardware
- how will the urgent need for 100Gb/s will be met in backplanes and chip-to-chip

The interconnect strategy is crucial in peta- and exa-scale platforms in datacenters and supercomputers. So we look forward to the participation of hardware technologists, network and system architects of peta- and exa-scale platforms in datacenters and supercomputers. We also welcome software application architects, to discuss how physical connectivity relates to application workload distribution.

Dominic Goodwill & Benjamin Lee
Conference General Co-Chairs

Ali Ghiasi & Ilya Lyubomirsky
Conference Program Co-Chairs
Optical Interconnects Conference 2017 Committee List:

**General Co-Chairs:**
Dominic Goodwill, Huawei Technologies, Canada  
Ben Lee, IBM Research, USA

**Program Co-Chairs:**
Ali Ghiasi, Ghiasi Quantum LLC, USA  
Ilya Lyubomirsky, Inphi, USA

**Program Committee:**
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Jack Bovington, Oracle Labs, USA  
Lukas Chrostowski, University of British Columbia, Canada  
Po Dong, Bell Labs, Alcatel-Lucent, USA  
Azita Emami, California Institute of Technology, USA  
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Rena Huang, Renssalaer Polytechnic Institute, USA  
Stephane Lessard, Ericsson, Sweden  
Odile Liboiron-Ladouceur, McGill University, Canada  
Frederick (Rick) McCormick, Sandia National Laboratories, USA  
Samuel Palermo, Texas A & M, USA  
Mike Peng Li, Altera, USA  
Joyce K. S. Poon, University of Toronto, Canada  
Saman Saedi, Axalume Inc., USA  
Sudip Shekhar, University of British Columbia, Canada  
Wei Shi, Université Laval, Canada  
Tomoo Takahara, Fujitsu, Japan  
Harris Turk, US Department of Defense, USA  
Ryohei Urata, Google, USA  
Peter Van Daele, Ghent University, Belgium  
S.J. Ben Yoo, University of California-Davis, USA
Table of Contents

Program-at-a-Glance .................................................. Inside Front Cover
Welcome Letter ................................................................. 1
Committee List ................................................................. 2
Sponsor Acknowledgment / Exhibitor Guide ....................... 4
Program ............................................................................... 9
Photography Clause .......................................................... 21
Author Index ....................................................................... 22
Hotel Map ................................................................. Inside Back Cover
INFORMATION
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Information Gatekeepers, Inc. is a publisher, trade show organizer, consultancy and
information service provider in the fields of fiber optics, high-speed Internet, wireless, and
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nanoPrecision Products is the world leader in complex material forming with
revolutionary 3D stamping processes that deliver nanometer accuracies and tolerances.
The company has pioneered a breakthrough nanoBench™ product platform and has
recently introduced two new interconnect systems respectively for single fiber (SC
Ferrolder®) and 12 fiber (SC FootballFerrule®).
NANOSYSTECC CORP.  
CONTACT: GUENTER HUMMELT

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Phone: + 800 882 8573  
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Website: www.nanosystec.com

Nanosystec offers complete solutions for development and manufacturing of optical interconnects applying active or passive alignment. Joining technologies are epoxy gluing and precision laser welding. All systems are designed for highest flexibility and productivity. Optospin a new alignment tool works with the speed of passive placement and the precision of active alignment. Alignment times are cut by factor of 10. Supporting the high productivity of the stations is the capability of automated loading/unloading and the seamless integration in production lines.

OPTOTEST CORPORATION  
CONTACT: DANIEL GALINDO

OptoTest Corporation  
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Phone: + 805 987 1700  
Email: sales@optotest.com  
Website: www.optotest.com

Fiber optics innovator, OptoTest has been providing comprehensive and tailored test solutions to the component manufacturing market since 2002. Now the leader in MTP/ribbon fiber and multichannel harsh environment testing, OptoTest continues to expand its customer base with a growing number of custom-made fiber optic test equipment in its pipeline.
PI
CONTACT: PI (Physik Instrumente)

PI
16 Albert Street
Auburn, MA 01501 USA

Phone: + 508 832 3456
Email: infocpi-usa.us
Website: www.pi-usa.us

ISO-9001-Certified, Global Leader in Precision Motion Solutions. Piezo Mechanisms, Air Bearings, Hexapods, Photonics Alignment, Nanopositioning, Micropositioning, Piezo Positioning Systems, Linear Motors & Rotary Stages for OEM & Research. Products: Nanopositioning Systems; 6-Axis Hexapod Alignment Systems, Microscopy Stages; Lens Positioning; Tip/Tilt Mirrors; Piezo Transducers, Piezo Actuators; Piezo Motors; Piezo Drivers & Digital Motion Controllers; Voice Coil Actuators, MicroMotion Robots.

SAMTEC, INC.
CONTACT: GLENN DIXON

Samtec, Inc.
2323 Owen Street
Santa Clara, CA 95054 USA

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Email:
glenn.dixon@samtec.com
Website: www.samtec.com

Samtec is a manufacturer of high speed interconnect products that will enable a transmission line from silicon to silicon at the highest data rates in the industry today. We will be showing our High Temp Firefly Mid-Board optical modules, as well as our PCIe Active Optical cables and connectors.
SANTEC USA
CORPORATION CONTACT:
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CORPORATION

Santec USA Corporation
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Phone: + 201 488 5505
Email:
info@santec.com
Website:
www.santec.com

Santec's all-new 7th generation of high performance tunable laser, the TSL-770, delivers upgrades in speed, accuracy and range. With 200nm/s sweep speeds, 0.3pm (typ.) wavelength accuracy, and available 200nm-wide wavelength range facilitates photonic investigations in the most cutting-edge of research applications. Come visit our booth to demo the TSL-770.

SYNOPSYS
CONTACT: SYNOPSYS
OPTICAL SOLUTIONS GROUP

Synopsys
690 East Middlefield Road
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USA

Phone: + 626 795 9101
Email: optics@synopsys.com
Website: optics.synopsys.com

Synopsys’ RSoft products are leading solutions in photonic design software and serve several industries including optical communications, optoelectronics and semiconductor manufacturing. RSoft products provide a full range of design, optimization and planning tools for optical communications, as well as solutions for optoelectronics components and subsystems.
VPIPHOTONICS, INC.
CONTACT: JUDITH MEESTER

VPIphotonics Inc.
89 Access Road
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Norwood, MA 02062 USA

Phone: + 781 762 3902
Email: judith.meester@vpi photonics.com
Website: www.vpi photonics.com

VPIphotonics provides flexible simulation software and design services supporting requirements of active/passive integrated photonics, doped-fiber applications, optical system and network applications, and cost-optimized equipment configuration. Join us for live demos on modeling transmission systems with 4D modulation formats, complex integrated devices in Silicon Photonics and InP, and pulsed or high-power doped-fiber applications.
Final Program

MONDAY, 5 JUNE 2017

8:00 am–8:30 am  Canyon Ballroom
Breakfast

8:30 am–9:45 am  Mesa Ballroom
Session MA  Welcome & Plenary I
Session Chair  Dominic Goodwill, Huawei Technologies, Canada

9:00 am–9:45 am
MA1  Silicon Photonics and the Future of Optical Connectivity in the Data Center (Plenary),
Thomas Liljeberg, Intel Corp., USA
The bandwidth growth inside data centers has driven significant innovations in networking and
optical connectivity. We’ll review recent advances in silicon photonics, discuss where silicon
photonicis is deployed in the data center of today, and how it will be transforming future data centers.

9:45 am–10:15 am  Canyon Ballroom
Coffee Break/Exhibits

10:15 am–11:45 am  Mesa Ballroom
Session MB  Silicon Photonics
Session Chair  Frederick McCormick, Sandia National Laboratories, USA

10:15 am –10:45 am
MB1  Use of 3D Technology for Silicon Photonics (Invited), Sylvie Menezo, CEA-LETI

10:45 am–11:00 am
MB2  Intermodulation Crosstalk of Graphene-Enabled Electro-Optic Microring Modulators for
DWDM Interconnects, Nathan C. Abrams, Meisam Bahadori, Christopher T. Phare,
Michal Lipson and Keren Bergman, Columbia University, New York, NY, USA
The intermodulation crosstalk of graphene modulators integrated on silicon nitride is experimentally
characterized for the first time on 1 Gb/s signals. We show that 25 GHz channel spacings are
supported with <0.1 dB penalty for DWDM applications.
### 11:00 am–11:15 am

**MB3**  
A Two-Segment Optical DAC 40 Gb/s PAM4 Silicon Microring Resonator Modulator Transmitter in 65nm CMOS, Ashkan Roshan-Zamir, Binhao Wang, Shashank Telaprolu, Kunzhi Yu, Texas A&M University, College Station, TX, USA, Cheng Li, M. Ashkan Seyedi, Marco Fiorentino, Raymond Beausoleil, Hewlett-Packard Enterprise, Palo Alto, CA, USA, and Samuel Palermo, Texas A&M University, College Station, TX, USA

A two-segment silicon photonic microring modulator implements an optical DAC for PAM4 modulation. Independent level and edge-rate control is achieved using segmented MSB/LSB pulsed-cascode drivers. The 65nm CMOS transmitter achieves 40Gb/s operation at 4.38mW/Gb/s while driving each microring modulator segment with 4.4Vppd swing.

### 11:15 am–11:30 am

**MB4**  
Comparison of DAC-Less PAM4 Modulation in Segmented Ring Resonator and Dual Cascaded Ring Resonator, Anthony H. K. Park, Ajith S. Ramani, Lukas Chrostowski and Sudip Shekhar, University of British Columbia, Vancouver, BC, Canada

We compare the performance of 25 Gb/s PAM4 modulation in segmented ring and dual cascaded ring resonators driven by CMOS drivers designed in 65nm process. With optimized frequency detuning, the segmented ring modulator is found to achieve larger eye opening with lower power consumption.

### 11:30 am–11:45 am

**MB5**  
29-GHz Small-Signal Modulation Bandwidth for Directly Current-Modulated 980-nm Oxide-Aperture VCSELs, Ricardo Rosales, Technische Universität Berlin, Berlin, Germany, Philip Moser, Stanford University, Stanford, CA, USA and James A. Lott, Technische Universität Berlin, Berlin, Germany

An epitaxial design with a half-lambda optical cavity surrounded by only two oxide-current apertures as small as 2-micrometer in diameter leads to highly confined optical fields and carriers and to a record 29.3-GHz small-signal modulation bandwidth at room temperature for 980-nm vertical-cavity surface-emitting lasers.

### 11:45 am–1:15 pm

Lunch Break (on own)

### 1:15 pm–3:15 pm

**Session Chair**  
Stephane Lessard, Erickson, USA

**MC1**  
Photonic Integration in Commercial Manufacturing Lines (Invited), Ajey Jacob, Global Foundries

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:15 pm–3:15 pm</td>
<td>Advance Devices</td>
<td>Mesa Ballroom</td>
</tr>
<tr>
<td>1:15 pm–1:45 pm</td>
<td>MC1</td>
<td>Mesa Ballroom</td>
</tr>
</tbody>
</table>
1:45 pm–2:00 pm

**MC2 Characterization of Systematic Process Variation in a Silicon Photonic Platform,**
Nicholas Boynton, *Sandia National Laboratories, Albuquerque, NM, USA and University of New Mexico, Albuquerque, NM, USA*, Andrew Pomerene, Andrew Starbuck, Anthony Lentine and Christopher T. DeRose, *Sandia National Laboratories, Albuquerque, NM, USA*

We present quantitative analysis of the correlation of resonant wavelength variation with process variables, and find that 50% of the resonant wavelength variation for microrings is due to systematic process conditions. We also discuss the improvement of device uniformity by mitigating these systematic variations.

2:00 pm–2:15 pm

**MC3 Scalable and Broadband Silicon Photonics Chip to Fiber Optical Interface Using Polymer Waveguides,** Antonio La Porta, Roger Dangel, Daniel Jubin, Norbert Meier, Folkert Horst and Bert Jan Offrein, *IBM Research - Zurich, Rüschlikon, Switzerland*

We present a silicon photonics optical I/O interfacing solution based on adiabatic optical coupling between silicon and polymer waveguides working for both O- and C-band. In the O-band, a fiber-to-chip coupling loss < 4 dB was found, with a PDL < 0.5 dB.

2:15 pm–2:30 pm


We present results of ultra efficient (2.16 nm/mW) thermally tunable modulators with n-type heaters and Si substrate removed. To our knowledge, this is the most efficient thermally tunable modulator at 1550nm. We include results of externally heated modulators with commensurate enhancements through substrate removal.

2:30 pm–2:45 pm

**MC5 The Benefit of Mid-Board Optic and Other Flyover Technology**, Fred Coppinger, David Langsam, Adam Page and Marc Verdiell, *Samtec Inc., New Albany, IN, USA*

We experimentally study the performance difference between a mid-board optic solution, a copper flyover to a QSFP cage solution and a Direct Attached Copper solution using a Xilinx VCU118 evaluation board. We show that the mid-board optic solution provides the highest quality eye diagram.

2:45 pm–3:15 pm

**MC6 Hybrid Optical Engines for On-Board Optical Applications (Invited)**, Bardia Pezeshki, *Kaiam Corp.*
3:45 pm–5:45 pm Mesa Ballroom

OBO Workshop  Is On-Board Optics the Right Solution to Reduce Power Consumption of Data Center Networking Hardware?

Session Chair  Ilya Lyubomirsky

Despite improved efficiencies, the power consumed by data center networking hardware is growing rapidly in proportion to increasing network capacity. Networking is expected to contribute a significant fraction of the overall power budget when data center networks transition to 400G interfaces. New approaches are needed to further improve efficiency and reduce energy per bit. This workshop will explore the potential benefits of moving optics closer to the switch ASIC to eliminate power hungry SerDes, and thus reduce overall power consumption. The workshop will try to answer the questions: Can on-board optics provide a solution in the near term or do we need co-packaged optics to gain a significant benefit? What are the engineering and techno-economic tradeoffs? Is fully integrated optics still a dream or reality?

Speakers  Jim Tatum, Director at Finisar
Rob Stone, Director of Broadcom
Brad Booth, Principal Engineer at Microsoft
Alex Wright-Gladstein, CEO of Ayar Labs
Chieh-Ju Lee, Technical Leader at Cisco

5:45 pm–7:15 pm Canyon Ballroom

Welcome Reception
TUESDAY, 6 JUNE 2017

8:00 am–8:30 am  Canyon Ballroom
Breakfast

8:30 am–9:45 am  Mesa Ballroom

Session TuA  Plenary II
Session Chair  Benjamin Lee, IBM Research, USA

8:30 am–9:15 am
TuA1  Attojoule Optoelectronics – Saving More Energy with Optics (Plenary), David A. B. Miller, Stanford University, Stanford, CA, USA

Energy in short interconnects inside machines dominates scaling of information processing and communication. Low-energy integrated optoelectronics can eliminate much energy in links themselves and, with space-multiplexing in 2D arrays, could eliminate link circuit energies, allowing 10–100 fJ/bit for all links from 1cm to 10m.

9:15 am–9:30 am
TuA2  Programmable Optical Power Distribution in Silicon Photonic Platform, Alexander Gazman, Meisam Bahadori, Ziyi Zhu and Keren Bergman, Columbia University, New York, NY, USA

We demonstrate a reconfigurable, software-controlled, C-band optical power distribution system leveraging a 1x7 cascaded microring-based silicon photonic device. The thermo-optic effect and the spectral response of each ring is characterized and utilized in FPGA-based control plane algorithm to achieve precise power distribution profiles.

9:30 am–9:45 am
TuA3  Integrated Fresnel Zone Plate in the SOI Backend for Improved Laser to Chip Coupling Efficiency, Marvin Henniges, Sicoya GmbH, Berlin, Germany and Technische Universität Berlin, Berlin, Germany, Stefan Meister, Hanjo Rhee, Christoph Theiss, Sicoya GmbH, Berlin, Germany, Hendrik Robers, Technische Universität Berlin, Berlin, Germany, Moritz Grehn, Sicoya GmbH, Berlin, Germany, David Stolarek, Lars Zimmermann, IHP, Frankfurt (Oder), Germany and Ulrike Woggon, Technische Universität Berlin, Berlin, Germany

A zone plate, etched into the backend of a silicon-on-insulator chip, was designed to improve the optical coupling efficiency between grating couplers and non-perpendicular light sources with an elliptical beam profile. Measurements of a highly divergent light source showed efficiency improvements up to 8.7dB.
9:45 am–10:15 am Canyon Ballroom

Coffee Break/Exhibits

10:15 am–11:45 am Mesa Ballroom

<table>
<thead>
<tr>
<th>Session TuB</th>
<th>Next Generation Data Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session Chair</td>
<td>TBD</td>
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</tbody>
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10:15 am–10:45 am

TuB1  **Roadmap to Optical I/O (Invited)**, Brad Booth, Microsoft

10:45 am–11:00 am


Photic weight banks employing multivariate statistical techniques could extend performance limits of multi-antenna radio systems. We characterize the aggregate bandwidth penalty imposed by a silicon microring weight bank and assess application regimes for multivariate RF photonics.

11:00 am–11:15 am

TuB3  **Flexible On-Chip Frequency Comb Generation Using a SOI Dual-Drive MZM**, Jiachuan Lin, Hassan Sepehrian, Leslie A. Rusch and Wei Shi, Université Laval, Québec, Canada

We demonstrate comb generation on 220-nm silicon-on-insulator, enabled by a dual-drive Mach-Zehnder modulator, by which 7 comb lines with 7dB flatness and 5-lines with 3dB flatness have been achieved. This provides a promising solution for flexible multicarrier transmitters on silicon.

11:15 am–11:45 am

TuB4  **Microprocessor with Photonics I/O (Invited)**, Chen Sun, Ayer Lab

In this work, we provide an overview of the technology and architecture of a microprocessor memory system with optical I/O. Zero-change photonics integration enabled the processor chip to be fabricated in a commercial electronics CMOS foundry.

11:45 am–1:15 pm

Lunch Break (on own)
1:15 pm–3:15 pm  
Mesa Ballroom

Session TuC  High Speed Communication I
Session Chair  Samuel Palermo, Texas A&M University, USA

1:15 pm–1:45 pm

TuC1  DSP Solutions for Next Generation Intra and Inter-Data Center Connectivity (Invited), Sudeep Bhoja, Inphi

We review DSP solutions for 100G & 400G intra-data center and data center interconnect applications. We review modulation and FEC techniques including fundamental Shannon limits for both copper and optics. Practical implementation challenges including power, performance and area that can be achieved in advanced CMOS.

1:45 pm–2:00 pm


We demonstrate single-wavelength, serial and real-time 100 Gb/s NRZ-OOK transmission over 500 m SSMF with a GeSi EAM implemented on a silicon photonics platform. The device was driven with 2 Vpp without 50? termination, allowing a low-complexity solution for 400 GbE short-reach optical interconnects.

2:00 pm–2:15 pm

TuC3  56 Gb/s Direct Modulation of an InP-on-Si DFB Laser Diode, Amin Abbasi, Bart Moeneclaey, Jochem Verbist, Xin Yin, Johan Bauwelinck, Gunther Roelkens and Geert Morthier, Ghent University – IMEC, Ghent, Belgium

We demonstrate 56 Gb/s direct modulation of a high bandwidth heterogeneously integrated InP/Si DFB laser, and transmission over 2 km of non-zero dispersion shifted single mode fiber. The high bandwidth of the laser is achieved by exploiting the photon-photon resonance effect.
Towards Efficient 100 Gb/s Serial Rate Optical Interconnects: a Duobinary Way *(Invited)*

Xin Yin, Michiel Verplaetse, Laurens Breyne, J. Van Kerrebrouck, Timothy De Keulenaer, Arno Vyncke, Ramses Pierco, Renato Vaernewyck, Ghent University, Gent-Zwijnaarde, Belgium, Silvia Spiga, Markus-Christian Amann, TUM, München, Germany, Jiaja Chen, KTH, Stockholm, Sweden, Geert Van Steenberge, Guy Torfs and Johan Bauwelincx, Ghent University, Gent-Zwijnaarde, Belgium

Recent advances in integrated opto-electronic devices and frontend circuits have made it possible to efficiently transmit very high data rates over optical links for HPC/datacenter applications. This paper reviews our current progress towards serial 100-Gb/s optical interconnects, with emphasis on electrical duobinary (EDB) modulation.

100G Transition: Electrical & Optical, Challenges & Opportunities *(Invited)*

Francessco Caggioni, MACOM

The demand for BW is increasing at an unbelievable pace, the Chip, System and Optics industries are trying to converge on the next generation signaling rate to cater to this surge in BW demand. IEEE 802.3 is already working on 100G signaling for 100BASE-DR1 and 400GBASE-DR4 & OIF PLL group has started to work on CEI-112G-PAM4-VSR. MACOM has envisioned this transition early and has had the opportunity to “play” with this technology in the lab for over a year. In this presentation we’ll touch on some of the experiments conducted so far.

High Speed ≥ 100 Gb/s/Lane Optical and Electrical Interconnect Workshop

Session Chair Ali Ghiasi, Ghiasi Quantum LLC

IEEE P802.3 standard and OIF are currently defining chip-to-module, chip-to-chip, and backplane signaling based on 50Gb/s/lane PAM4 signaling. IEEE P802.3 standards currently are defining single lamda 100 Gb/s optical links based on PAM4 signaling. The 50 Gb/s electrical IO allows doubling the BW of a 128 lane switch from 3.2 Tb to 6.4 TB and allow doubling the BW of a 256 lane switch from 6.4 Tb to 12.8 Tb. The switch IO bitrate has been doubling approximately every 3 years. Assuming the current trend continues, we will have switches based on 100 Gb/s/lane in 2019. Switches with native 100 Gb/s IO expect to offer seamless interface to pluggable optical modules or an OBO (on board optics), but supporting conventional backplane at 100 Gb/s may not be feasible and instead eco-system may need to convert to copper cable or optical backplanes. What are the key challenges to transition to 100 Gb/s electrical and optical ecosystems and is the industry investing enough for such a major transition that is expected to occur in next 3 years? What are the practical solutions beyond 100 Gb/s? Is the right solution 200 Gb/s with higher Baudrate, stronger FEC, and/or higher order modulation, or a co-packaged PIC with WDM to increase the IO BW?

Speakers Sudeep Bhoja, CTO Inphi
Haoli Quian, CTO of Credo Communication
Mike Sorna, Distinguished Engineer Global Foundry
Jeffery Lee, Member of Technical Staff Bell Lab
Azita Emami, Professor of Electrical Engineering Caltech
WEDNESDAY, 7 JUNE 2017

8:00 am–8:30 am Canyon Ballroom
Breakfast

8:30 am–9:45 am Mesa Ballroom
Session WA Energy Efficiency
Session Chair Tomoo Takahara, Fujitsu, Japan

8:30 am–9:00 am
WA1 Datacenter Optical Interconnects: Requirements and Challenges (Invited), Chongjin Xie, Alibaba Group, San Mateo, CA, USA

From a service provider’s point of view, we review the requirements on and status of datacenter optical interconnects and discuss the challenges for future datacenter networks, including both intra- and inter-datacenter optical interconnect technologies.

9:00 am–9:15 am
WA2 Scalability of Microring-Based Crossbar for All-to-All Optical Interconnects, Xian Xiao, Roberto Proietti and S. J. Ben Yoo, University of California, Davis, Davis, CA, USA

We investigate the scalability of all-to-all crossbar switch with microring resonators. State-of-the-art –18.1 dB crosstalk in resonators cannot support a 4×4 switch fabric while below –40 dB crosstalk is necessary for 32×32 switch fabrics.

9:15 am–9:30 am
WA3 Highly Scalable, Low-Crosstalk Architecture for Ring-Based Optical Space Switch Fabrics, Qixiang Cheng, Meisam Bahadori, Sébastien Rumley and Keren Bergman, Columbia University, New York, NY, USA

A ring-based switch architecture that combines the Clos network with populated switch-and-select stages is proposed, achieving significantly reduced crosstalk compared to other non-blocking architectures. Detailed physical-layer simulation results show a 128×128 switch exhibits a power-penalty of 18dB, improving >10dB compared to the Benes switch.

9:30 am–9:45 am
WA4 Accelerated Out-of-Band Arbitration of a Microring-Based Silicon Photonic System, David M. Calhoun, Erik F. Anderson, Maarten H. N. Hattink, Sébastien Rumley and Keren Bergman, Columbia University, New York, NY, USA

We present an architecture towards accelerating compute element operations on a fully arbitrated silicon photonic (SiP) system. An 8×8 SiP network is controlled in a distributed fashion, with connectivity consisting of two 10Gbps wavelength division multiplexed data links that are arbitrated out-of-band.
Coffee Break/Exhibits

10:15 am–11:45 am  
**Session WB**  
**High Speed Communication II**  
**Session Chair**  
Mike Peng Li, *Altera, USA*

10:15 am–10:45 am  
**WB1**  
*Silicon Photonics for Nx56G NRZ Optical Interconnects (Invited)*, Joris Van Campenhout, *IMEC*

10:45 am–11:00 am  
**WB2**  
*A 48-Gb/s Software Defined Optical Transceiver Using Multi-Tone PAM/CAP Modulation*, Fan Yang, Wenjia Zhang and Zuyuan He, *Shanghai Jiao Tong University, Shanghai, China*  
A 48-Gb/s software defined optical transceiver based on the multi-tone PAM/CAP signalling is proposed and experimentally demonstrated over 10-km SSMF. BER below 7% FEC threshold is achieved with equalization, which is better than direct PAM4 transmission.

11:00 am–11:15 am  
**WB3**  
*Machine Learning of SVM Classification Utilizing Complete Binary Tree Structure for PAM-4/8 Optical Interconnection*, Guoyao Chen, Lin Sun, *Shanghai Jiao Tong University, Shanghai, China*, Ke Xu, *Harbin Institute of Technology, Shenzhen, China*, Jiangbing Du and Zuyuan He, *Shanghai Jiao Tong University, Shanghai, China*  
A machine learning method of effective nonlinear decision frame for PAM-N system based on SVM using CBT structure is demonstrated in this work. The simulations results indicate improved performance by the method enhances the power sensitivity by 2-dB and 6-dB in 100-Gbps PAM-4/8 respectively.

11:15 am–11:45 am  
**WB4**  
*High-Capacity PAM4 and DMT for Short Reach Interconnects (Invited)*, Jeffrey Lee, *Nokia Bell Labs, USA*  
An overview of PAM4 and DMT modulation in short-reach, optical intensity-modulated and direct-detection channel is presented and impairments limiting the performance, such as clipping distortion, quantization noise, and thermal noise are introduced and discussed.

11:45 am–1:15 pm  
Lunch Break (on own)
1:15 pm–3:00 pm
Session WC  VCSEL and Advance Communication
Session Chair  Harris Turk, Department of Defense, USA

1:15 pm–1:45 pm

**WC1  VCSEL Based SWDM Links for Data Centers (Invited),** Chris Kocot, Anna Tatarczak and Jim A. Tatum, *Finisar Corp., Sunnyvale, CA, USA*

We review several techniques for expanding the carrying capacity of MMF data links using SWDM and selective modal launch. Our approach utilizing four SWDM VCSELs and novel diffractive optical components enables 100 GbE transmission in a single 300 m OM3 MMF lane.

1:45 pm–2:00 pm


A common-cathode VCSEL driver implemented in 28-nm digital CMOS, assembled with a commercial VCSEL is presented. Electro-optical measurements show 30-Gbit/s operation with 1.7-pJ/bit from 2.9-V supply. When operated at 15-Gbit/s the power can be reduced while maintaining the modulation amplitude. Power/datarate tunability is demonstrated.

2:00 pm–2:30 pm

**WC3  VCSEL Modulation Capacity: Continued Improvements or Physical Limits? (Invited),** Anders Larsson, Johan S. Gustavsson, Erik Haglund, Emanuel P. Haglund, Tamas Lengyel, Ewa Simpanen and Mehdi Jahed, *Chalmers University of Technology, Gothenburg, Sweden*

The need for higher capacity interconnects raises the question whether the speed of VCSELs can be improved or whether physical limits have been reached. The presentation will address this, also in the context of other performance parameters and techniques for improving VCSEL-based interconnect capacity.

2:30 pm–2:45 pm


42.5Gbps PAM4 transmission over 100 to 600 m NG-WBMMF at 850, 880, 910, 940 and 976 nm using PAM4 CMOS-IC chipset with real-time digital signal processing is investigated. The dispersion power penalty shows an inverse correlation with the overall bandwidth of the transmission links.
We demonstrate that error-free data transmission can be easily obtained without optical isolators and/or precise fiber alignments by using a low-noise graded-index plastic optical fiber (GI POF) with microscopic core heterogeneities. The novel GI POF is paving the way for consumer-friendly 4K/8K optical interface.
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AUTHOR INDEX

Abbasi, Amin ..............................................TuC3
Abrams, Nathan C. ...........................................MB2
Absil, Philippe ...........................................TuC2
Amann, Markus-Christian ..................TuC4
Anderson, Erik, F. ..........................WA4
Bahadori, Meisam ..........................MB2, TuA2, WA3
Balakrishnan, Sadhishkumar ..............TuC2
Bauwelink, Johan ...........................TuC2, TuC3, TuC4
Beausoleil, Raymond ......................MB3
Belfiore, Guido ..................................WC2
Bergman, Keren ..................MB2, TuA2, WA3, BWA4
Bhoja, Sudeep ...............................TuC1, WC4
Booth, Brad ........................................TuB1
Boynton, Nicholas ..........................MC2
Breyne, Laurens ..........................TuC4
Caggioni, Francesco ........................TuC5
Callhoun, David, M. .................WA4
Chang, Frank ..................................WC4
Chang, Matthew P. ........................TuB2
Chen, Guoyao ...............................WB3
Chen, Jiaya ......................................TuC4
Cheng, Qixiang .................................WA3
Chrostowski, Lukas .......................MB4
Coppinger, Fred .................................MC5
Dangel, Roger .................................MC3
De Heyn, Peter .....................................TuC2
De Keulenaer, Timothy ..................TuC2, TuC4
DeRose, Christopher T. ................MC2, MC4
Du, Jiangbing ................................ WB3
Ellinger, Frank .................................WC2
Ferreira de Lima, Thomas ..............TuB2
Fiorentino, Marco .........................MB3
Gazman, Alexander .........................TuA2
Gray, Timo .........................................WC4
Grehn, Moritz .................................TuA3
Gustavsson, Johan S. .......................WC3
Haglund, Emanuel P. .....................WC3
Haglund, Erik ..................................WC3
Hattink, Maarten H. N. ....................WA4
He, Zuyuan .................................WB2, WB3
Henker, Ronny .................................WC2
Henniges, Marvin .........................TuA3
Horst, Folkert .................................MC3
Inoue, Azusa ..................................WC5
Jacob, Ajey .................................MC1
Jahed, Mehdi .................................WC3
Jarecki, Robert .................................MC4
Jubin, Daniel .................................MC3
Kocot, Chris ..................................WC1
Koike, Yasuhiro ...............................WC5
La Porta, Antonio .........................MC3
Langsam, David ...............................MC5
Larsson, Anders ................................WA3
Lee, Jeffery .................................WB4
Lengyel, Tamas .................................WC3
Lentine, Anthony ..............................MC2
Lentine, Anthony L. .........................MC4
Leplage, Guy .................................TuC2
Li, Cheng ......................................MB3
Liljeberg, Thomas .........................MA1
Lin, Jiachuan .................................TuB3
Lingle Jr., Robert .........................WC4
Lipson, Michal .................................MB2
Lott, James A. .................................MB5
Martinez, Nicholas J. D. .................MC4
Meier, Norbert .................................MC3
Meister, Stefan .................................TuA3
Menezo, Sylvie .................................MB1
Miller, David A. B. .........................TuA1
Moeneclaey, Bart .........................TuC3
Morthier, Geert .................................TuC3
Moser, Philip .................................MB5
Namias, Mitchell A. .........................TuB2
Offrein, Bert Jan .............................MC3
Page, Adam .................................MC5
Palermo, Samuel .............................MB3
Pantouvaki, Marianna .....................TuC2
Park, Anthony H. K. .........................MB4
Pezeshki, Bardia ..............................MC6
Phare, Christopher T. .....................MB2
Pierco, Ramses ......................TuC2, TuC4
Pomerene, Andrew ............................MC2
Pomerene, Andrew T. .......................MC4
Proietti, Roberto .............................WA2
Prucnal, Paul R. ............................TuB2
Raman, Ajith S. .................................MB4
Rhee, Hanjo .................................TuA3
Robers, Hendrik ..............................TuA3
Roelkens, Gunther ........................TuC2, TuC3
Rosales, Ricardo .............................MB5
Roshan-Zamir, Ashkan .....................MB3
Rumley, Sébastien ............................WA3, WA4
Rusch, Leslie A. ...............................TuB3
Scott, Kristine .................................WC4
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