OPTICAL INTERCONNECTS CONFERENCE 2015

20 - 22 April 2015

Final Program is Posted

Welcome to the Optical Interconnects Conference 2015

20 - 22 April 2015

Wyndham San Diego Bayside, San Diego, California USA

Welcome to the Optical Interconnects Conference at Wyndham San Diego Bayside, San Diego, California!

The IEEE Photonics Society Optical Interconnects Conference seeks to facilitate collaboration required to drive new interconnect architectures and technologies from concepts in research labs to commercial realities. To this end, the conference covers the complete spectrum of high performance interconnect challenges in network systems, architectures, applications, subsystems, and devices. In addition, 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.

The conference provides a mix of high caliber invited talks in addition to refereed oral and poster papers, each providing a unique opportunity to learn and exchange ideas with the authors. In addition, this year the conference includes an evening panel discussion entitled "Optical Interconnects Supply Chain in 2020: Who Owns the Interface?". The panelists who are recognized experts in the industry and academia will bring different views to create thought provoking exchanges. All attendees will have a chance to ask questions and participate in exciting technical discussions. The panel will enable all participants to more richly engage in the conference. This year the panel will be held on Tuesday evening, April 21. We urge you all to attend the panel and learn what the panelists and other attendees envision for the future of optical interconnects.

We extend our personal thanks to each of the Program Chairs and the Program Committee Members who have volunteered and invested their time realizing this conference. We also thank our invited speakers for sharing their perspectives on the challenges and opportunities for new and emerging interconnect technologies and architectures. We believe that the combined efforts of the organizers and speakers will continue the great tradition this conference series has achieved its esteemed reputation. Finally, we want to express our sincere appreciation to the Photonics Society staff for their professional organization and arrangements for this conference.

We look forward to seeing all of you at this year's Optical Interconnects Conference!

Azita Emami and Xuezhe Zheng

Optical Interconnects Conference General Co-Chairs

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Optical Interconnects Conference 2015 Program-at-a-Glance

MONDAY, 20 APRIL 2015	TUESDAY, 21 APRIL 2015	WEDNESDAY, 22 APRIL 2015
BREAKFAST/COFFEE BREAK: PACIFIC B 8:00am-8:30am		
Opening Remarks 8:30am-9:00am	**TuA: Plenary II & Advanced Optical Devices** 8:30am-9:45am	**WA: Plenary III & Optoelectronic Interfaces** 8:30am-9:45am
MA: Plenary I 9:00am-9:45am	**EXHIBITS/COFFEE BREAK:** PACIFIC B 9:45am-10:15am	
EXHIBITS/COFFEE BREAK: PACIFIC B 9:45am–10:15am	**TuB: Silicon Photonics** 10:15am-12:15pm	**WB: Packaging Solutions for Optical Interconnects** 10:15am-12:15pm
MB: Interconnect Applications 10:15am-12:15pm	**LUNCH BREAK (ON OWN)** 12:15pm-1:30pm	
LUNCH BREAK (ON OWN) 12:15pm–1:30pm	**TuC: Poster Session** Pacific B 1:30pm-3:30pm	**WC: Modulators** 1:30pm-3:30pm
MC: Transceivers 1:30pm-3:30pm	**EXHIBITS/COFFEE BREAK:** PACIFIC B 3:30pm-4:00pm	
EXHIBITS/COFFEE BREAK: PACIFIC B 3:30pm-4:00pm	**TuD: Circuit Integration for Optical Interconnect** 4:00pm-5:30pm	**WD: Advanced Photonics** 4:00pm-5:30pm
MD: Chip-to-Chip and Backplane 4:00pm-5:30pm	**Panel Session** Pacific A 6:00pm-7:30pm	**Closing Remarks** 5:30pm-5:45pm
Welcome Reception Pacific B 5:30pm-7:00pm	**ALL SESSIONS ARE IN PACIFIC A**	**Registration Hours:** Pacific Foyer Monday, 20 April 7:00am-5:00pm Tuesday, 21 April: 8:00am-5:00pm Wednesday, 22 April: 8:00am-4:00pm

WC5 2:45 PM - 3:00 PM

Modeling of Self-Heating Effect for Depletion-Type Si Micro-Ring Modulator, Y. Ban, B. Yu, J. Rhim, J. Lee and W. Choi, *Yonsei University, Seoul, Korea*

We present an accurate model for self-heating effect in depletion-type Si micro-ring modulator which describes incident-power dependent transmission and dynamics. Its accuracy is confirmed with measurement. It can be useful for determining optimal modulation conditions.

WC6 3:00 PM - 3:15 PM

Coupled Photonic Crystal Microcavities for Optical Switching Over Wide Spectral Range, X. Zhang, *University of Texas at Austin, Austin, TX, USA*, S. Chakravarty, *Omega Optics, Inc., Austin, TX, USA*, C. Chung, Z. Pan and R. Chen, *University of Texas at Austin, Austin, TX, USA*

A compact thermo-optic switch comprising a 3.78µm-long coupled photonic crystal resonators coupled to a photonic crystal waveguide is demonstrated with 6nm optical bandwidth, 20dB optical extinction ratio, 18.2mW switching power, and 14.8µsec rise time.

WC7 3:15 PM - 3:30 PM

Backside-Gate-Assisted Broadband Modulation on Silicon-Polymer Hybrid Photonic Crystal Waveguide, X. Zhang, *University of Texas at Austin, Austin, TX, USA*, A. Hosseini, H. Subbaraman, *Omega Optics, Inc., Austin, TX, USA*, J. Luo, A. Jen, *University of Washington, Seattle, WA, USA*, C. Chung, H. Yan, Z. Pan, *University of Texas at Austin, Austin, TX, USA*, R. Nelson, *Air Force Research Laboratory at Wright Patterson, Dayton, USA* and R. Chen, *University of Texas at Austin, Austin, TX, USA*

We demonstrate an electro-optic polymer filled slot photonic-crystal waveguide modulator with a record-high effective in-device r33 of 1230pm/V. Assisted by a backside gate-field, 3-dB bandwidth of 15GHz and energy consumption of 94.4fJ/bit are experimentally demonstrated.

3:30 PM - 4:00 PM Exhibits/Coffee Break: Pacific B

4:00 PM - 5:30 PM
Session WD: Advanced Photonics
Session Chair: Anthony Lentine, Sandia National Laboratories, USA

WD1 4:00 PM - 4:30 PM (Invited)

High Channel Count DFB Laser Array with Precise Channel Spacing for Future PICs Based on REC Technique, X. Chen, *College of Engineering and Applied Sciences, Nanjing University, Nanjing, China*

We have demonstrated high channel count DFB semiconductor laser arrays with precise channel spacing based on reconstruction-equivalent-chirp technique, which are aimed for future large-scale photonic integrated circuits.

Modeling of Self-Heating Effect for Depletion-Type Si Micro-Ring Modulator

Yoojin Ban, Byung-Min Yu, Jinsoo Rhim, Jeong-Min Lee, and Woo-Young Choi
Department of Electrical and Electronic Engineering, Yonsei University, Seoul, Korea

Abstract: We present an accurate model for self-heating effect in depletion-type Si micro-ring modulator which describes incident-power dependent transmission and dynamics. Its accuracy is confirmed with measurement. It can be useful for determining optimal modulation conditions.

Si photonics has a great potential for realizing cost-effective, high-bandwidth, and small-footprint optical interconnect systems [1,2]. Among several photonic devices that can be used for Si photonic interconnect system realization, the Si micro-ring modulator (MRM) is of special interest as it can provide very large bandwidth with the small size and low power consumption [3]. However, it suffers from the self-heating effect caused by free-carrier absorption (FCA) of the input light circulating the ring waveguide [4]. With the self-heating effect, the resonance wavelength of the Si MRM shifts depending on the input optical power level and, in a severe case, optical bi-stability can occur.

This self-heating effect is especially serious for the depletion-type Si MRM based on the reverse-biased PN junction because the entire ring waveguide is doped either P- or N-type as shown in Fig. 1, which shows the structure of the Si MRM used for our investigation. The ring waveguide is based on 220 nm thick and 500-nm wide Si rib structure on 2μm thick buried oxide on Si. As can be seen in Fig. 2, its transmission characteristics as well as eye patterns strongly depend on the input power level. The eye diagrams shown in Fig. 2 are for 1Gbps modulation. Such dependence on input power level can be a serious problem for using depletion-type Si MRMs and an accurate model for the self-heating effecting must be established in order to come up with solutions that can mitigate the self-heating effect.

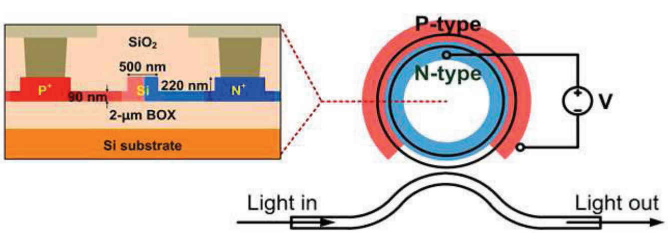


Fig. 1. Structure of Si micro-ring modulator

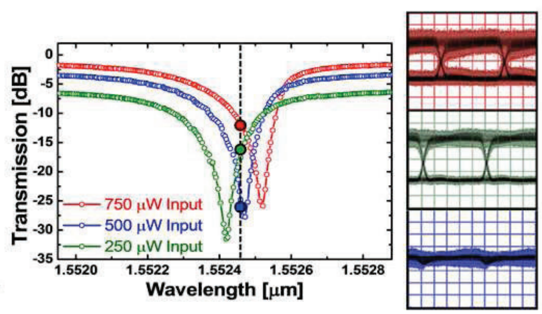


Fig. 2. Power-dependent transmission characteristics and eye patterns

Our model is based on the couple-mode theory, which describes Si MRM dynamics as [5]

$$\frac{d}{dt}a(t)=(j\omega_0-1/\tau)a(t)-j\mu E^i(t) \text{ and } E^t(t)=E^i(t)-j\mu a(t), \quad (1)$$

where a represents the total energy amplitude stored in the ring and the resonance angular frequency ω_0 is given as $2\pi mc/(\eta L)$ with the mode number m, the speed of light c, the group refractive index of the ring waveguide η, and the ring circumference L. E^i and E^t represent input and output optical field, respectively. τ is the decay time constant and μ is the mutual coupling coefficient, both of which depend on the ring modulator device geometry. Any change in the energy amplitude in the ring, Δa, at time t_0 causes change in group refractive index, $\Delta\eta$, due to FCA in the following manner:

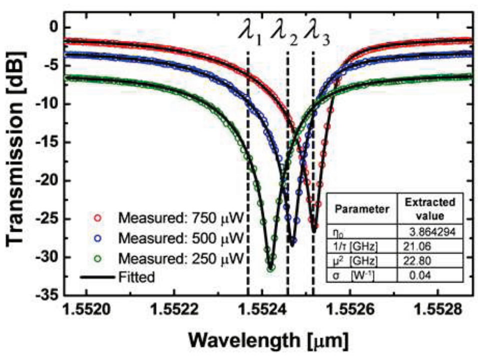
$$\Delta\eta=\sigma|A|^2[1-\exp(-(t-t_0)/\tau_d)]=\sigma|\Delta a|^2\frac{c}{\eta L}[1-\exp(-(t-t_0)/\tau_d)] \text{ for } t>t_0, \quad (2)$$

where σ is the thermal coefficient, τ_d is the thermal dissipation time constant, and $|A(t)|^2$ is the optical power flowing through any cross section of the ring waveguide.

Since Eq. (1) and (2) are recursively coupled, obtaining their accurate solutions can be complicated. However, the time scale we are interested in for Eq. (1) (for example, it takes 0.65 ps for one round trip for the structure shown in

Fig. 1) and that for Eq. (2) (τ_d is estimated to be about 1 μs [6]) are very different and, consequently, we can use an approach in which the optical power at a given time is first determined by numerically solving Eq. (1) with a constant value for η and, from this, a new value for η can be determined for a time-step later using Eq. (2), and the process is repeated. In this way, the transmission characteristics as well as eye diagrams of the depletion-type Si MRM can be numerically solved. In fact, it can be confirmed that the exact value of τ_d does not affect the accuracy of our solution and τ_d = 1 μs is used for our model.

Although we do not know exact values of η_0, τ, μ, σ, they can be extracted by fitting simulated results to measured transmission characteristics. Fig. 3 shows the measured and simulated results with extracted parameter values shown within the figure. As can be seen from the figure, measured and simulated results agree very well. In addition, extracted values for η_0, τ, μ are close to those that we can determine from full simulation of the Si MRM based on processing information and device geometry.



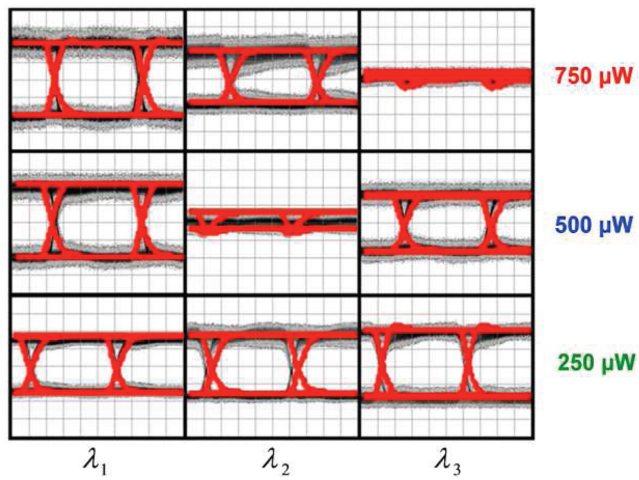


Fig. 3. Transmission curves with different input power levels. **Fig. 4.** Eye patters with different input power levels and operating points.

Figure 4 shows the overlap of measured (grey) and simulated (red) eye patterns of the Si MRM modulated by 1 Gbps PRBS7 driving signals for three different input power levels at three different operating wavelengths. The wavelengths are indicated by dotted lines in Fig. 3. As can be seen in the figure, measured and simulated eye-diagrams are in very good agreement. This clearly demonstrates that the input light power as well as its wavelength should be very carefully controlled in order to achieve optimized modulation characteristics. Although our modulation is at 1Gbps, above observation should be equally applicable at the higher modulation speed as the self-heating effect is a very slow process and it basically depends only on the input power as long as the modulation speed is much larger than the thermal process.

With our Si MRM self-heating model, the influence of self-heating can be accurately described and, furthermore, it can be easily implemented as a behavior model in CADENCE, so that the driver electronics design can be done with full knowledge of Si MRM modulation characteristics including the self-heating effect.

Acknowledgments

This work was supported by the National Research Foundation of Korea funded by the Korean Government (MEST) under Grant 2012R1A2A1A01009233.

References

[1] R. Soref , "The Past, Present, and Future of Silicon Photonics," IEEE J. Sel. Top. Quantum Electron. **12**(6), 1678-1687 (2006).

[2] Q. Xu, B. Schmidt, S. Pradhan, M. Lipson, "Micrometre-scale silicon electro-optic modulator," Nature **435,** 325-327 (2005).

[3] P. Dong, S. Liao, D. Feng, H. Liang, D. Zheng, R. Shafiiha, C.-C. Kung, W. Qian, G. Li, X. Zheng, A. V. Krishnamoorthy, and M. Asghari, "Low Vpp, ultralow-energy, compact, high-speed silicon electro-optic modulator," Opt. Express **17**(25), 22484-22490 (2009).

[4] X. Zheng, Y. Luo, G. Li, I. Shubin, H. Thacker, J. Yao, K. Raj, J. E. Cunningham, and A. V. Krishnamoorthy, "Enhanced optical bistability from self-heating due to free carrier absorption in substrate removed silicon ring modulators," Opt. Express **20**(10), 11478-11486 (2012).

[5] B. E. Little, S. T. Chu, H. A. Haus, J. S. Foresi, and J.-P. Laine, "Microring resonator channel dropping filter," J. Lightwave Technol. **15**, 998-1005 (1997).

[6] Q. Xu and M. Lipson, "Carrier-induced optical bistability in silicon ring resonators," Opt. Letters **31**(3), 341-343 (2006)