# International Conference on Group IV Photonics

### 14th International Conference on Group IV Photonics Conference

23-25 August (Technical Sessions)
22 August (Silicon Photonics Design Workshop)

Grand Hyatt Berlin
Berlin Germany

Herzlich Willkommen to the 14th International Conference on Group IV Photonics at the Grand Hyatt Berlin, Germany!

The Group IV Photonics Conference (GFP 2017), now in its 14th year, delivers insights on current and future innovations in Group IV element-based photonic materials and devices, including silicon photonics, as well as other integration and fabrication technologies. Scheduled as a single-track conference, GFP 2017 facilitates personal interaction between colleagues, including oral and poster sessions of contributed and invited papers, as well as a plenary session with overviews of important Group IV element photonics topics. The conference program comprises a Silicon Photonics Design Workshop on Tuesday (22 August) afternoon, as well as a Gala dinner and Best Paper Awards, so please navigate to the Special Events tab for updates!

Bis bald in Berlin!

Jeremy Witzens & Lars Zimmermann

General & Program Chairs

Silicon Photonics Workshop: 22 August
Please click here to book your room
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Conference Contact

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| Wednesday, 23 August 2017 | Thursday, 24 August 2017 | Friday, 25 August 2017 |
| --- | --- | --- |
| WA - Welcome Remarks 8:00am- 8:15am<br>WA - Plenary I 8:15am- 9:00am<br>WB - Mid-Infrared Integrated Photonics 9:00am- 10:00am | ThA - Silicon Nitride Photonics for Sensing<br>8:00am- 9:45am | FA - Plenary II 8:00am- 8:45am<br>FB - Silicon Photonics for Sensing 8:45am- 10:00am |
| EXHIBITS/COFFEE BREAK:<br>10:00am - 10:30am | EXHIBITS/COFFEE BREAK:<br>9:45am - 10:15am | EXHIBITS/COFFEE BREAK:<br>10:00am - 10:30am |
| WC - Group IV Light Sources / GeSn Devices<br>10:30am- 12:00am | ThB - Nanofabrication of Novel Passive Devices<br>10:15am- 12:00am | FC - Towards Novel Applications<br>10:30am- 12:00am |
| | LUNCH<br>12:00pm-1:30pm | |
| WD - Optical Transmitter and Filter Technology<br>1:30pm- 3:00pm | ThC - Data Transmission Modules<br>1:30pm- 3:00pm | FD - Si/III-V Lasers<br>1:30pm- 3:15pm |
| EXHIBITS/COFFEE BREAK:<br>3:00pm-3:30pm | EXHIBITS/COFFEE BREAK:<br>3:00pm-3:30pm | EXHIBITS/COFFEE BREAK:<br>3:15pm-3:45pm |
| WE - Control and Tuning Technology<br>3:30pm- 4:30pm | ThD - Nonlinear Photonics<br>3:30pm- 4:15pm | FE - Optoelectronic Devices<br>3:45pm- 5:00pm |
| Industry Forum<br>4:30-5:30 | ThP - Poster II<br>4:15-5:45<br>Grand Ballroom B | Best Paper/Student Paper/Poster Awards<br>5:00pm-5:30pm |
| WP - Welcome Reception / Poster I 5:30-7:00pm<br>Grand Ballroom B | Gala Dinner<br>Time/Location TBD | ALL GENERAL SESSIONS TO BE HELD IN<br>GRAND BALLROOM A<br>EXHIBITS/COFFEE BREAKS TO BE HELD IN<br>GRAND BALLROOM B |

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FC - **Towards Novel Applications** **Session Presider: Wim Bogaerts** **10:30am- 12:00am Grand Ballroom A**

FC.1 - **Silicon Photonics for Applications in Quantum Technologies** **Invited** **10:30-11:00**

***M. Thompson*** *, University of Bristol*

캘린더에 추가

Quantum photonic technologies have the potential to revolutionise our information and communication systems, enabling ultra-secure communication and advanced computation with applications in quantum simulation and machine learning. Here we overview the potential of silicon photonics to realise such a technology platform.

FC.2 - **A Monolithically Integrated Si Optical Single-Sideband Modulator** **11:00-11:15**

***B. Yu*** *, Yonsei Univ., Seoul, Korea,* ***J. Lee*** *, Yonsei Univ., Seoul, Korea* ***C. Mai*** *, IHP, Frankfurt, Germany* ***S. Lischke*** *, IHP, Frankfurt, Germany* ***L. Zimmermann*** *, IHP, Frankfurt, Germany* ***W. Choi*** *, Yonsei Univ., Seoul, Korea*

캘린더에 추가

We demonstrate a monolithically integrated Si optical single-sideband modulator that contains a ring-assisted Mach-Zehnder modulator, two MMI optical couplers, and an electrical quadrature hybrid coupler. The modulator successfully produces 30-GHz single sideband with 15dB suppression of the undesired sideband.

FC.3 - **Integrated All-optical Phase-sensitive Amplifier Using the Thermal Nonlinearity** **11:15-11:30**

***T. Van Vaerenbergh*** *, Hewlett Packard Labs, Palo Alto, CA, United States,* ***G. Mendoza*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***D. Kielpinski*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***J. Pelc*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***N. Tezak*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***R. Bose*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***C. Santori*** *, Hewlett Packard Labs, Palo Alto, CA, United States* ***R. Beausoleil*** *, Hewlett Packard Labs, Palo Alto, CA, United States*

캘린더에 추가

We demonstrate an all-optical phase-sensitive amplifier, a critical component in integrated circuits for all-optical computing. The amplifier is fabricated in amorphous silicon-on-insulator and relies on thermo-optic self-heating in a ring-loaded Mach-Zehnder interferometer. changing the power and phase of the bias input tunes the gain.

FC.4 - **Laser Integration on Si** **Invited** **11:30-12:00**

***P. Doussiere*** *, Intel , Santa Clara, CA, United States*

캘린더에 추가

In this presentation we will review the progress of silicon III-V semiconductor hybrid near-infrared lasers and show that they can meet the performance and reliability required for commercial datacom transceivers at 100 Gbit/s and beyond.

# A Monolithically Integrated Si Optical Single-Sideband Modulator


**Byung-Min Yu, Jeong-Min Lee, Christian Mai[+], Stefan Lischke[+], Lars Zimmermann[+], and Woo-Young Choi**

*Department of Electrical and Electronic Engineering, Yonsei University, 134 Shinchon-dong, Seodaemoon-gu, Seoul, 120-749, Korea*
*[+]IHP, Im Technologiepark 25, 15236 Frankfurt (Oder), Germany*



**Abstract:** We demonstrate a monolithically integrated Si optical single-sideband modulator that contains a ring-assisted Mach-Zehnder modulator, two MMI optical couplers, and an electrical quadrature hybrid coupler. The modulator successfully produces 30-GHz single sideband with 15-dB suppression of the undesired sideband.



**Keywords:** optical single-sideband modulator, photonic-electronic integration, ring-assisted Mach-Zehnder modulator


Optical single-sideband (OSSB) modulation eliminates the frequency-dependent power fading problem when high-frequency electrical signals are delivered in optical domain over dispersive fiber for Radio-over-Fiber applications [1]. It also allows more efficient use of the optical spectrum for dense WDM transmission systems. OSSB can be realized with an a Mach-Zehnder modulator (MZM) having 90-degree optical phase difference between optical input signals in two arms and 90-degree electrical phase difference between two electrical modulation signals, as schematically shown in Fig. 1, for the case of OSSB modulation producing the upper sideband.

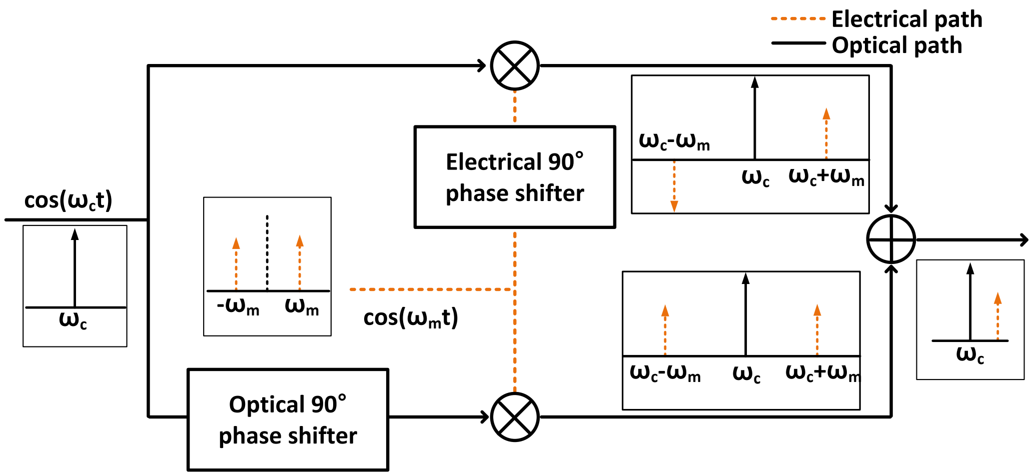


Fig. 1 Block diagram of OSSB modulator

OSSB modulators have been realized with various MZMs along with external electrical modules that produce required electrical I/Q signals [2, 3]. In this paper, we demonstrate for the first time a single-chip Si OSSB modulator which includes an optical modulator and an electrical I/Q signal generator, both integrated on a Si wafer. Such monolithic integration of photonic and electronic components provides smaller sizes and, possibly, cost reduction, both of which should be of great advantage for many applications. Our OSSB modulator is fabricated with IHP's Photonic BiCMOS technology, which provides high performance Si photonic devices and Si circuits on the standard Si platform [4].

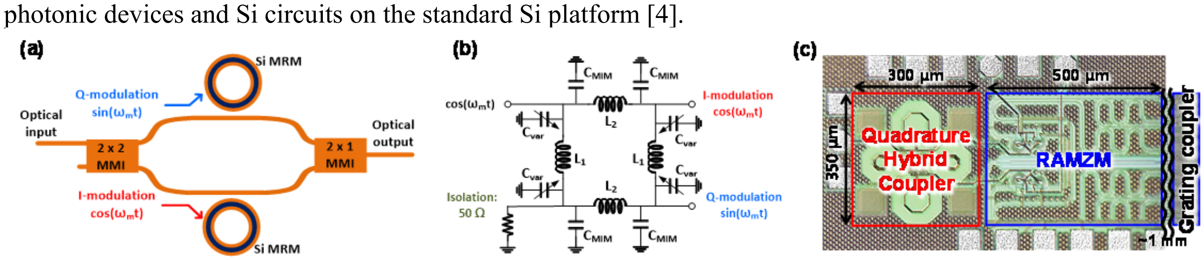


Fig. 2 Schematics of (a) RAMZM with input/output MMIs and (b) QHC, and (c) microphotograph of OSSB modulator

In our OSSB modulator, the optical modulation is realized with a ring-assisted Mach-Zehnder Modulator (RAMZM) [5] along with input and output MMI couplers, as shown in Fig. 2(a). The RAMZM is much smaller than the conventional Si MZM, which with the smaller total chip size allows more cost-effective realization of the OSSB modulator. Each ring modulator is a depletion-type modulator having 11-μm radius. In order to compensate different modulation characteristics for two ring modulators due to process variation, heaters are added, which allows thermal tuning of the optical modulation characteristics. Input 2 × 2 MMI coupler (only one of two inputs is used) providing 90-degree phase shift between two outputs, and output 2 × 1 MMI are implemented with Si waveguides.

Electrical I/Q signal generation is realized with Quadrature Hybrid Coupler (QHC) [6]. As schematically shown in Fig. 2(b), it is composed of inductors and capacitors, and produces I/Q signals at a given frequency $f$, when $L_1 = 50/2\pi f$, $L_2 = 50/(\sqrt{2}\times 2\pi f)$, and $C = (1+\sqrt{2})/(50\times 2\pi f)$, where $C = C_{MIM}+C_{var}$, are satisfied. $L_1$ and $L_2$ are implemented with spiral inductors after careful simulation. $C_{MIM}$ and $C_{var}$ are realized with MIM capacitors and varactors, respectively, provided by the Photonic BiCMOS technology. Externally controlling $C_{var}$ allows fine tuning of $C$ for the target modulation frequency. Fig. 2(c) shows the microphotograph of the fabricated Si OSSB modulator containing RAMZM and QHC. Its size is 800 × 350 μm$^2$ and optical input/out coupling is achieved with grating couplers.

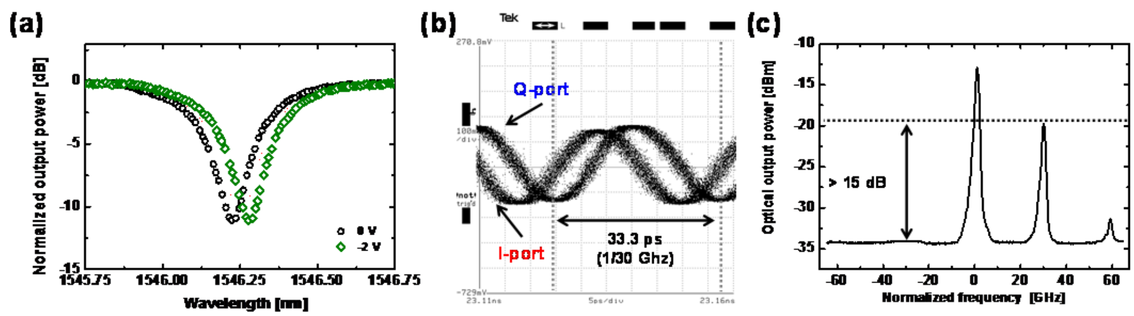


Fig. 3 Measured (a) RAMZM transmission characteristic at two different bias voltages, (b) I- and Q-port output signals for QHC 30GHz, and (c) output optical spectrum of OSSB modulator

Fig. 3(a) shows the transmission characteristics of the RAMZM. It has about 27 pm/V modulation efficiency. Fig. 3(b) shows the measured output signals of QHC when 30 GHz signals are applied to the input. As can be seen, I and Q signals with similar amplitudes are produced at two outputs. Fig. 3(c) shows the output optical spectrum of the OSSB modulator at λ = 1546.17 nm, when 30 GHz input signal is introduced to the OSSB modulator. As can be seen, OSSB modulation is successfully achieved with about 15-dB suppression for the lower sideband. The suppression is limited by the background noise in our measurement setup not by the OSSB modulator. The second-order sideband can be also observed, which is due to non-linear modulation characteristics of RAMZM.

In summary, we successfully demonstrated a monolithically integrated OSSB modulator that contains an optical modulator, MMIs, and an electrical I/Q signal generator on the Si wafer.

This work was supported by National Research Foundation of Korea grant funded by the Korean Ministry of Science, ICT and Future Planning (2015R1A2A2A01007772) and Materials and Parts Technology R&D Program funded by the Korean Ministry of Trade, Industry & Energy (Project No. 10065666).

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