IEEE

SiPhotonics

(Formerly GFP Conference)

IEEE Silicon Photonics Conference
4-7 April 2023 • Arlington, VA, USA
www.ieee.gfp.org

General Co-Chairs:
Haisheng Rong
Intel Corporation

Jifeng Liu
Dartmouth College

IEEE Photonics Society | IEEE

SiPhotonics 2023 | Programme | Log In / Create an Account

At a Glance | Sessions | Presentations | Search by presentation, session or author...

Tuesday

4 April 2023

8am | 9am | 10am | 11am | 12pm | 1pm | 2pm | 3pm | 4pm | 5pm | 6pm | 7pm | 8pm

Synopsys Workshop: Foundr... WS1 | B... | Synopsys Workshop... WS2 | Lunch (On Your Own) | TuC - Silicon Photonics ... TuC | B... | TuD - Advances in Passive D... TuD

Keynote | Oral | Poster | Session | Event

View Tuesday, 04 Apr in detail >>

Wednesday

5 April 2023

8am | 9am | 10am | 11am | 12pm | 1pm | 2pm | 3pm | 4pm | 5pm | 6pm | 7pm | 8pm

WA - Integrated Lasers and ... WA | B... | WB - Photonics for ... WB | Lunch (On Your Own) | WC - Photonic Integration a... WC | B... | WD - Photonic Integration a... WD | Poster & Welcome ... Poster

Keynote | Oral | Poster | Session | Event

View Wednesday, 05 Apr in detail >>

Thursday

6 April 2023

8am | 9am | 10am | 11am | 12pm | 1pm | 2pm | 3pm | 4pm | 5pm | 6pm | 7pm | 8pm

ThA - Photodetectors ThA | B... | ThB - Photonics for... ThB | Lunch (On Your Own) | ThC - SiGeSn and MIR Photo... ThC | B... | ThD - Modulators ThD | Post-Deadl... PD

Keynote | Oral | Poster | Session | Event

View Thursday, 06 Apr in detail >>

Friday

7 April 2023

8am | 9am | 10am | 11am | 12pm | 1pm | 2pm | 3pm | 4pm | 5pm | 6pm | 7pm | 8pm

FA - A Special Session FA | B... | FB - Silicon Photoni... FB | Lunch (On Your Own) | FC - Optical Sensing FC | B... | FD - Photonic I... FD | Cl...

Keynote | Oral | Poster | Session | Event

View Friday, 07 Apr in detail >>

2023 IEEE Silicon Photonics Conference (SiPhotonics) | Blog • Support • Powered by Ex Ordo

Oral : WC

WC - Photonic Integration and Architecture - I

1:30pm - 3:30pm

Wednesday, 5 April 2023

Chaired By
Haisheng Rong (United States) - Intel Corporation

Venue
Arlington Ballroom

1:30pm - 2:15pm

WC1 (Plenary) - Silicon Photonics: An Overview of the Technology and Applications

» Saeed Fathololoumi (United States) [1]

1. Intel Corporation

View Presentation

2:15pm - 2:45pm

WC2 (Invited) - Direct detection, coherent detection, or something in between for short-reach optical interconnects?

» Chris Doerr (United States) [1]

1. Aloe Semiconductor Inc

View Presentation

2:45pm - 3:00pm

WC3 - Ultra-scalable Microring-based Architecture for Spatial-and-Wavelength Selective Switching

» Liang Yuan Dai (United States) [1], Vignesh Gopal (United States) [1], Keren Bergman (United States) [1]

1. Columbia University

View Presentation

3:00pm - 3:15pm

WC4 - A Si Photonic BiCMOS Coherent QPSK Transmitter Based on Parallel-Dual Ring Modulators

» Youngkwan Jo (Korea, Republic of) [1], Yongjin Ji (Korea, Republic of) [1], Minkyu Kim (Belgium) [2], Hyun-Kyu Kim (Korea, Republic of) [1], Min-Hyeong Kim (Korea, Republic of) [3], Christian Mai (Germany) [4], Stefan Lischke (Germany) [4], Lars Zimmermann (Germany) [5], Woo-Young Choi (Korea, Republic of) [1]

1. Yonsei University, South Korea, **2.** Yonsei University, now at IMEC, 3001 Leuven, Belgium, **3.** Yonsei University, now at Samsung Electronics, Hwasung, 18448, South Korea, **4.** IHP – Leibniz-Institut für innovative Mikroelektronik, 15236 Frankfurt (O.), Germany, **5.** IHP – Leibniz-Institut für innovative Mikroelektronik, 15236 Frankfurt (O.) and Technische Universität Berlin, Einsteinufer 25, 10587 Berlin, Germany

View Presentation

3:15pm - 3:30pm

WC5 - Toward FEOL integration of SiN waveguides into a photonic BiCMOS process

» Florian Goetz (Germany) [1], Stefan Lischke (Germany) [1], Anna Peczek (Germany) [1], Galina Georgieva (Germany) [2], Lars Zimmermann (Germany) [1]

1. IHP – Leibniz-Institut für innovative Mikroelektronik, **2.** Technische Universität Berlin

View Presentation

THURSDAY, 06 APR - AT A GLANCE

See what else is happening on this day. Click on any session to read more.

View All Days

8am	9am	10am	11am	12pm	1pm	2pm	3pm	4pm	5pm	6pm	7pm	8pm

ThA - Photodetectors ThA | B... | ThB - Photonics for... ThB | Lunch (On Your Own) | ThC - SiGeSn and MIR Photo... ThC | B... | ThD - Modulators ThD | Post-Deadl... PD

Keynote | Oral | Poster | Session | Event

View Thursday, 06 Apr in detail >>

A Si Photonic BiCMOS Coherent QPSK Transmitter Based on Parallel-Dual Ring Modulators

Youngkwan Jo[1], Yongjin Ji[1], Minkyu Kim[2], Hyun-Kyu Kim[1], Min-Hyeong Kim[3], Stefan Lischke[4], Christian Mai[4], Lars Zimmermann[4,5] and Woo-Young Choi[1]

1. Yonsei University, 03722, Seoul, South Korea
2. Formerly at Yonsei University when this work was done, now at IMEC, 3001 Leuven, Belgium
3. Formerly at Yonsei University when this work was done, now at Samsung Electronics, Hwasung, 18448, South Korea
4. IHP – Leibniz-Institut für innovative Mikroelektronik, 15236 Frankfurt (O.), Germany
5. Technische Universität Berlin, Einsteinufer 25, 10587 Berlin, Germany
wchoi@yonsei.ac.kr

***Abstract*— A monolithic Si photonic coherent optical QPSK transmitter is demonstrated that contains parallel-dual ring modulators and the BiCMOS driver electronics. It achieves 3.1 x 10^{-4} BER 25-Gbaud QPSK operation.**

***Keywords*—optical QPSK transmitters, photonic BiCMOS, ring modulators**

I. Introduction

Coherent optical transceivers have shown a great amount of performance progress over the past few decades with the ever-increasing digital signal processing (DSP) capability and the emerging photonic integration technology [1]. The signal impairment during the long-haul and metro transmission due to carrier phase noise, chromatic dispersion (CD), and polarization mode dispersion (PMD) can be recovered thanks to the smart and efficient DSP algorithms, and several photonic components that are needed for coherent modulation and demodulation can be integrated in a single photonic integrated circuit. With these, transmission capacity and spectral efficiency have significantly increased [2]. For short-reach optical interconnects, which is currently dominated by the pulse amplitude modulation (PAM) optical transceivers, there is an emerging interest for coherent optical transceivers since the PAM technology with such problems as the optical multipath impairment (MPI), the reduced optical modulation amplitude (OMA), and the inherent modulator nonlinearities may not guarantee the continuous performance increase required for the hyper-scale data centers application [3]. In this regard, a 64-Gbaud multiband monolithic Si photonic BiCMOS coherent optical receiver has been demonstrated [4] based on the photonic BiCMOS technology which can provide high-speed SiGe HBT electronics along with high-performance Si photonic components in a monolithic manner [5]. In addition, a full 56-Gbaud O-band coherent transceiver for intra data center optical interconnects has been demonstrated by the hybrid integration of electronics and photonics with a record-high 64-Gbaud O-band coherent transmitter [6]. In this paper, we report a single-polarization 50-Gbps coherent optical quadrature phase shift keying (QPSK) transmitter implemented on the Si photonic BiCMOS technology platform. The transmitter contains parallel-dual ring modulators (RMs) and BiCMOS driving electronics. The approach based on the RMs is pursued as they can result in the much smaller chip size, which is becoming an important factor of consideration for photonic I/O applications [7].

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. NRF-2020R1A2C2015089). Also, we thank IC Design Education Center (IDEC) for EDA tool support.

II. Device Description and Measurement

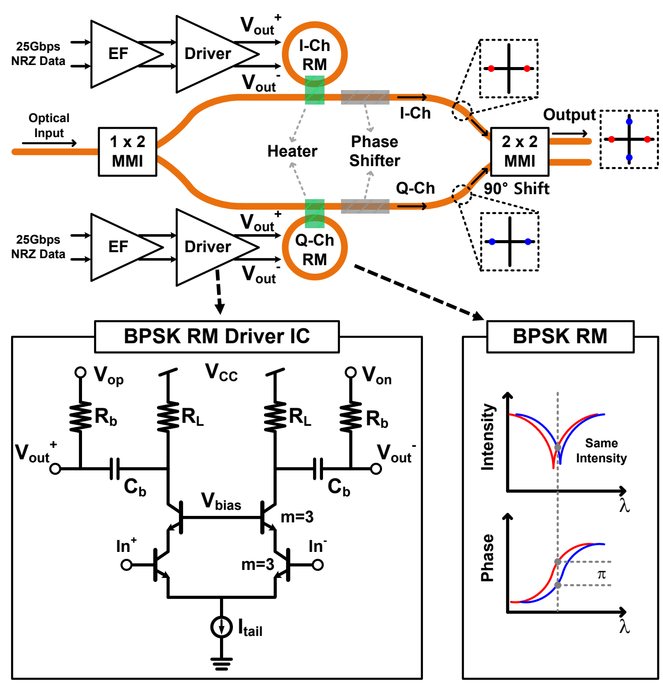

Fig. 1. Schematic of Si photonic BiCMOS coherent QPSK transmitter.

Fig. 1 shows the schematic of coherent QPSK transmitter. Input optical signal is divided into two branches by 1 x 2 multimode interferometer (MMI), and the two RMs are located in each arm of Mach-Zehnder interferometer (MZI) structure as parallel-dual RMs. The RMs are designed to have the over-coupling condition, which can have 2π phase shift near the resonance wavelength. The RMs are driven by the integrated driver composed of emitter followers (EFs) and fully differential cascode amplifiers as shown in Fig. 1, which delivers the desired V_π. The thermo-optic heaters are integrated in the directional coupler region of the RMs so that the RM resonance wavelengths can be tuned. Phase shifters are also integrated in the two arms of MZI to adjust the arm length difference. The divided optical signals are combined in the 2 x 2 MMI with the 90-degree phase shift, which enables the two RMs to have a quadrature phase difference and generate QPSK signals.

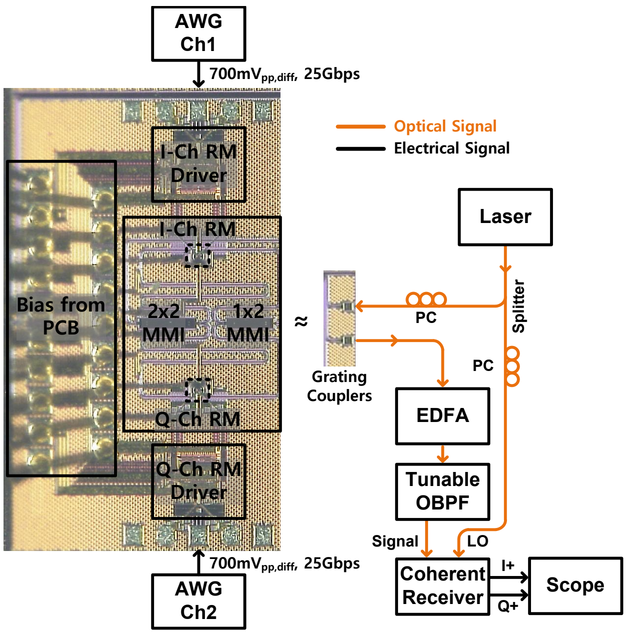

Fig. 2. Micro photo of fabricated chip and measurement setup

Fig. 2 shows the micro photo of the fabricated chip and the measurement setup. The device is fabricated by IHP's 0.25-µm Si photonic BiCMOS platform (SG25H4_EPIC). The integrated RMs have 16-µm radius, 220-nm coupling gap and 500-nm waveguide width, and their nominal peak carrier concentrations are 7 x $10^{17}/cm^3$ for p-region and 3 x $10^{18}/cm^3$ for n-region. From the measurement of identical RM in the same die reveals that the RMs have the over-coupling conditions with V_π of 5.7 V and 12.2-dB insertion loss for the BPSK modulation. The 25-Gbps nonreturn-to-zero (NRZ) signals having 700 $mV_{pp,diff}$ are supplied from the arbitrary waveform generator (AWG) whose sampling rate is 25 Gs/s and analog bandwidth is 13.5 GHz by GSGSG probes so that -3 V_{dc}, 5.7 $V_{pp,diff}$ signals can be delivered to each RM. For the generation of QPSK signals, the half-pattern-length-shifted pseudo random bit sequence 7 (PRBS-7) is used in the measurements.

A pair of grating couplers (GCs) is used as an optical IO for the measurement. The resonance wavelength difference of RMs and arm length difference of MZI are compensated by the integrated RM heater and the phase shifter, and their power consumptions are 0.85 mW and 19.4 mW, respectively. The input optical is split into one for the coherent QPSK transmitter and the other for the local oscillator (LO) port of commercial coherent receiver to have a homodyne reception of modulated signal. The output QPSK signal is amplified by erbium-doped fiber amplifier (EDFA) and filtered by a tunable optical bandpass filter (OBPF), and finally injected into the coherent receiver. The output signals (I+ and Q+) of coherent receiver are acquired by a real-time oscilloscope for the off-line DSP whose sampling rate is 80 GS/s and analog bandwidth is 33 GHz. For off-line processing, recursive-least-square blind equalizing and carrier phase estimation and bit-error rate calculation are performed [1,8].

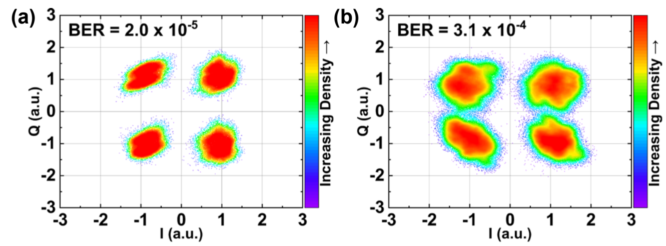

Fig. 3. Constellation after off-line DSP for (a) 10-Gbaud QPSK and (b) 25-Gbaud QPSK signals.

Fig. 3(a) and (b) show the measured constellation for 10-Gbaud and 25-Gbaud QPSK signals, respectively. The BER is 2 x 10^{-5} for 10-Gbaud and 3.1 x 10^{-4} for 25-Gbaud, which are below the forward error correction (FEC) limit (3.8 x 10^{-3}).

III. Conclusion

The parallel-dual RMs and driver ICs are monolithically integrated for the single-polarization 50-Gbps coherent optical QPSK transmitter in the Si photonic BiCMOS technology. The RMs are aligned by the integrated thermo-optic components and individually driven by the integrated driver electronics, generating the BPSK signals and combined with 90-degree phase shift for QPSK signal generation. The BER performances of the device are under the FEC limit, confirming the possibility of Si RMs as coherent optical modulators.

References

[1] Kikuchi, Kazuro. Journal of lightwave technology 34.1 (2015): 157-179.

[2] Zhou, Xiang, Ryohei Urata, and Hong Liu. Optical Fiber Communication Conference. Optica Publishing Group, 2019.

[3] Xie, Chongjin, and Bo Zhang. Proceedings of the IEEE (2022).

[4] Seiler, Pascal M., et al. Journal of Lightwave Technology 40.10 (2022): 3331-3337.

[5] Lischke, S., et al. Optical Sensing, Imaging, and Photon Counting: From X-Rays to THz 2019. Vol. 11088. SPIE, 2019.

[6] Aaron Maharry, et al. 2022 European Conference on Optical Communication (ECOC). IEEE, 2022.

[7] Fathololoumi, Saeed, et al. Journal of Lightwave Technology 39.4 (2020): 1155-1161.

[8] Dong, Po, et al. Optics letters 37.7 (2012): 1178-1180.