Integrated Kerr Comb Link with Multi-Channel DWDM Silicon Photonic Receiver

Stuart Daudlin[1,*], Asher Novick[1], Maarten Hattink[1], Vignesh Gopal[1], Anthony Rizzo[1], Bok Young Kim[2], Xingchen Ji[1], Yoshitomo Okawachi[2], Alexander Gaeta[1,2], Michal Lipson[1], and Keren Bergman[1]

[1]*Department of Electrical Engineering, Columbia University, New York, NY 10027*
[2]*Department of Applied Physics and Applied Mathematics, Columbia University, New York, NY 10027*
[*]*srd2162@columbia.edu*

Abstract: We demonstrate an error free silicon photonic receiver of a frequency-comb at 16Gb/s/λ that is the first to de-multiplex channels on-chip. These results pave the way to massively parallel links with chip-scale combs and transceivers.

1. Introduction

Integrated Kerr comb sources can pair with silicon photonic (SiP) transmitters and receivers for a completely on-chip optical link with over 100 wavelength channels. Toward this goal, SiP transmitters using Kerr comb sources have been demonstrated with aggregate data transmission over 500Gb/s [1,2]. A comb sourced SiP transmitter to receiver link was shown in [3], but with off-chip channel filtering and bit-error rates (BERs) between 1E-2 and 1E-3. Here, we demonstrate a SiP receiver of comb lines that is the first to have integrated filtering from a common bus to photodiodes (PDs) and is the first with error free reception (BER below 1E-12), obviating the need for error correction. This work shows a clear path to an entirely on-chip comb-sourced SiP link.

2. Experiment and Results

Figure 1a shows a schematic of the experimental comb to SiP receiver link. A pump laser at 1561.5nm is coupled into a silicon nitride comb chip, producing the normal group-velocity dispersion Kerr comb with a 200GHz channel spacing displayed in Figure 1b. Details on the comb source can be found in [4]. The comb is filtered off chip by a band-pass filter for three wavelength channels adjacent to the pump at 1556.7nm, 1558.3nm, and 1559.9nm. A BER tester (BERT) connected to a commercial Mach-Zehnder Interferometer (MZI) modulator encodes a non-return-to-zero on-off-keyed (NRZ-OOK) pseudo-random bit sequence of length 2^{31}-1 (PRBS31) onto the three

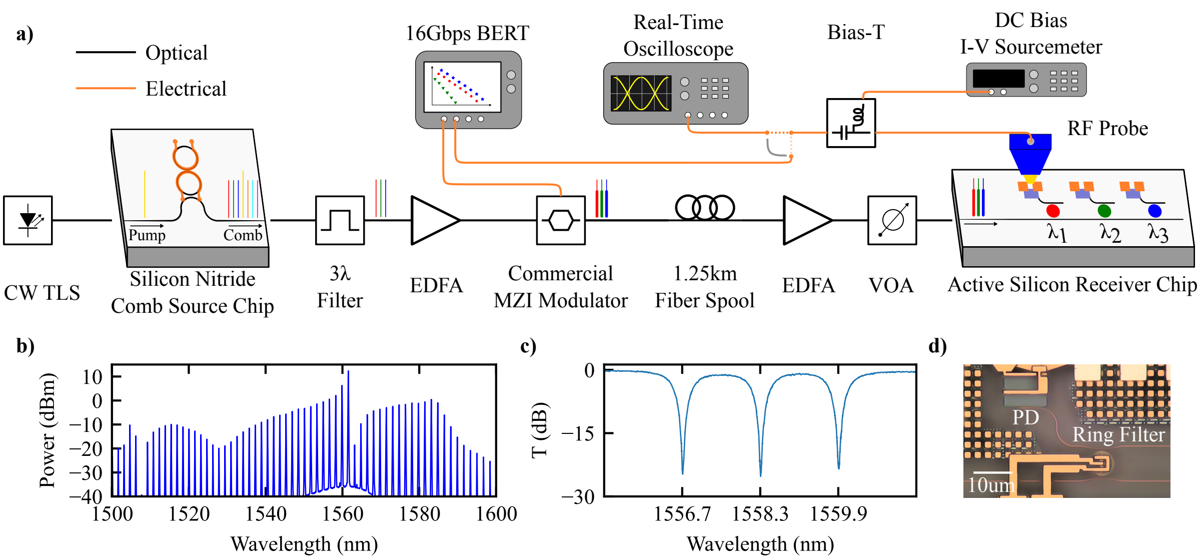

Fig. 1. (a) Schematic of the comb to silicon photonic (SiP) receiver link. CW-TLS: contiuous-wave tunable laser source, EDFA: erbium-doped fiber amplifier, MZI: Mach-Zehnder Interferometer, VOA: variable optical attenuator, BERT: bit-error rate tester. Polarization controllers before each chip are not pictured. (b) Measured comb spectrum. (c) Measured SiP bus spectrum with aligned ring filters. (d) Micrograph of a single ring filter and photodiode (PD) on the SiP receiver.

channels at 16Gb/s/λ. Data on each channel is offset by 0.5 unit intervals after passing through 1.25km of SMF28 fiber with a dispersion of 18ps/(nm x km). An EDFA is then used after the fiber spool to account for its losses. Before coupling to the receiver, polarization controllers are placed in the link for TE on-chip polarization.

The SiP receiver is fabricated on a 300mm silicon on insulator wafer through the AIM Photonics multi-project wafer run service. Couplers, ring filters, and PDs on the receiver are from the AIM process design kit [5]. Fiber carrying the three channels is edge-coupled to the receiver with an insertion loss of 4.5dB. Channels are then dropped from a common bus by ring filters with an FSR of 25.6nm and a FWHM of 80GHz. Doped silicon heaters with a 1nm/mW efficiency are used to align filter resonances to the comb channels. Figure 1c shows the aligned filter spectrum. Light from each channel is absorbed by a germanium photodiode with 1.1A/W responsivity, 25nA dark current, and a 3dB bandwidth >27GHz. Figure 1d shows a micrograph of the ring filter and photodiode. The three photodiodes are individually probed with a 50Ω S-G RF probe and reverse biased 2.5V using a bias-T to minimize carrier transit-time. Electrical signals are switched from the RF probe between the BERT and a 33GHz real-time oscilloscope for eye-diagrams.

BER curves and eye diagrams of the received channels are shown in Figure 2, with received power detected on the sourcemeter biasing the photodiode. Channels 2 and 3 are error free at -1.25dBm and -2dBm received power, respectively, and have forward error-correctable BERs down -10dBm received power. Channel 1 has higher relative BERs due to the nonlinear EDFA gain of the higher power channels 2 and 3. BERs can be expected to decrease further after removing the 1.25km of fiber or with reduced parasitics by packaging electronics with the SiP chip.

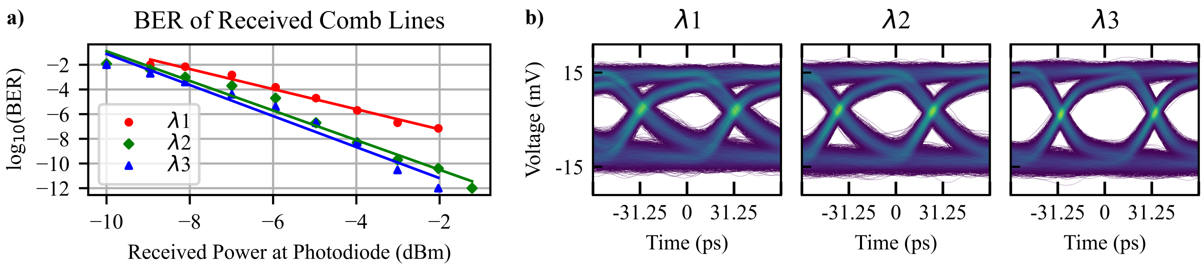

Fig. 2. (a) Bit-error rate (BER) of comb channels vs. received power. $\lambda 1$, $\lambda 2$, $\lambda 3$ = 1556.7nm, 1558.3nm, 1559.9nm. (b) Eye diagrams from probed photodiodes receiving comb lines at 16Gbps.

3. Conclusion

We demonstrated the first Kerr comb driven link with a SiP receiver that filters channels to PDs on-chip. This link is error free at -2dBm received power with 16Gb/s/λ. The low BERs indicate that comb-sourced SiP links can be used without the energy and latency overhead of heavy digital signal processing. This experiment opens the possibility of multi-Tbps massively parallel wavelength links in which channels are generated, encoded with data, and received by integrated photonic devices.

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