160-Gb/s Broadband Wavelength Conversion on Chip Using Dispersion-Engineered Silicon Waveguides

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Abstract: We demonstrate 160-Gb/s wavelength conversion across 21 nm in the C-band using four-wave mixing in dispersion-engineered silicon photonic waveguides. Measurements show a conversion efficiency of -15.5 dB and a pulse broadening factor of 38%.

OCIS codes: (130.7405) Wavelength conversion devices; (190.4380) Nonlinear optics, four-wave mixing.

1. Introduction

Parametric optical processing systems are expected to alleviate the bandwidth bottleneck associated with current optical-electronic-optical conversion occurring inside edge node interfaces to the optical core and access networks, allowing continued bandwidth scaling through all-optical data grooming, aggregation, and de-aggregation. These systems, which benefit from an ultrafast response time, have demonstrated wavelength conversion, optical regeneration, amplification, multicasting, and time-division multiplexing and demultiplexing at very high data rates. To date, much of this work has been performed in fiber-based systems [1] and in III-V semiconductors [2].

As a result of recent advancements in CMOS-compatible silicon photonics, dispersion-engineered silicon waveguides have proven to be a strategic new choice for four-wave mixing applications due to the drastic reduction in both size and cost of the optical devices [3]. Broadband wavelength conversion has already been demonstrated [4], and systems-level measurements of 40-Gb/s non-return-to-zero (NRZ) signal conversion have been performed [5]. Furthermore, a pulsed return-to-zero (RZ) time-division demultiplexer, using organic materials within a silicon slot waveguide, has been characterized [6]. Here, we demonstrate for the first time to our knowledge 160-Gb/s pulsed RZ wavelength conversion within a CMOS-compatible silicon photonic platform.

2. Experiments and results

The device discussed here is a silicon waveguide of 1.1-cm length with a 290-nm × 660-nm cross section. It was fabricated at the Cornell Nanofabrication Facility using electron-beam lithography followed by reactive-ion etching. Each end of the waveguide has an inverse-taper mode-converter for efficient coupling to tapered fibers. The experimental setup is shown in Fig. 1. A 10-GHz mode-locked fiber laser, a 40-Gb/s pattern generator, and two 4X optical time-division multiplexers (OTDM) are used to generate a 160-Gb/s signal, which is then combined with a continuous-wave (CW) pump signal and injected into the device. The second OTDM employs fiber patchcords for adequate decorrelation between the tributary 40-Gb/s data streams, which are encoded with a 2^7–1 pseudo-random bit sequence (PRBS). Following the device, an optical spectrum analyzer and autocorrelator are employed for signal characterization.

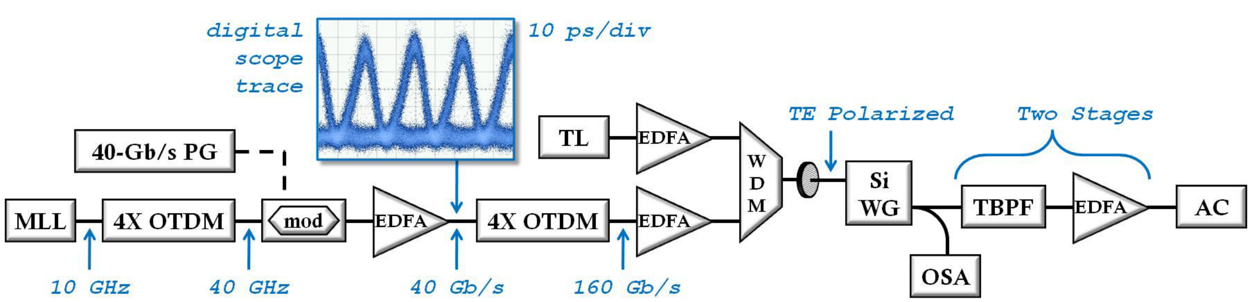

Fig.1. Experimental setup consisting of a mode-locked fiber laser (MLL), optical time-division multiplexers (OTDM), pattern generator (PG), $LiNbO_3$ modulator (mod), tunable laser (TL), erbium-doped fiber amplifiers (EDFA), wavelength-division multiplexer (WDM), fiber polarizer, silicon waveguide (Si WG), optical spectrum analyzer (OSA), tunable bandpass filters (TBPF), and autocorrelator (AC). The inset shows a 40-Gb/s RZ eye diagram following the optical modulator and EDFA.

Initially, a 40-GHz pulse train is obtained by leaving out the modulator and second OTDM, and an autocorrelator trace is recorded both before and after passing through the silicon waveguide, without wavelength conversion. Noticeable pulse broadening of approximately 38% at the full-width half maximum is observed (Fig. 2a); however, with this broadening factor no inter-symbol interference is expected for 160-Gb/s signals. Next, the second OTDM is added to the setup generating a 160-GHz pulse train, and autocorrelator traces are taken again before and after the waveguide, without wavelength conversion (Fig. 2b). A third autocorrelator trace is also taken on the converted pulse train by enabling the CW pump and adding filter and amplifier stages before the autocorrelator to select and amplify the converted signal (Fig. 2b). The results show little degradation of the pulse trains passing through the chip, apart from the noise increase in the converted signal trace, which is attributed to the lower power level of the converted signal nearing the autocorrelator's sensitivity limit. Finally, the modulator is inserted into the setup to provide a 160-Gb/s data signal, which is wavelength converted in the waveguide, and the result is monitored on the optical spectrum analyzer (Fig. 2c). A conversion efficiency of -15.5 dB is observed for a 21-nm conversion using 24.1 dBm and 16.5 dBm for the pump power and average signal power, respectively, measured before insertion into the waveguide. Spurious four-wave mixing is also observed near the pump in wavelength with 160-GHz spacing likely resulting from nondegenerate conversion of the harmonics of the input signal.

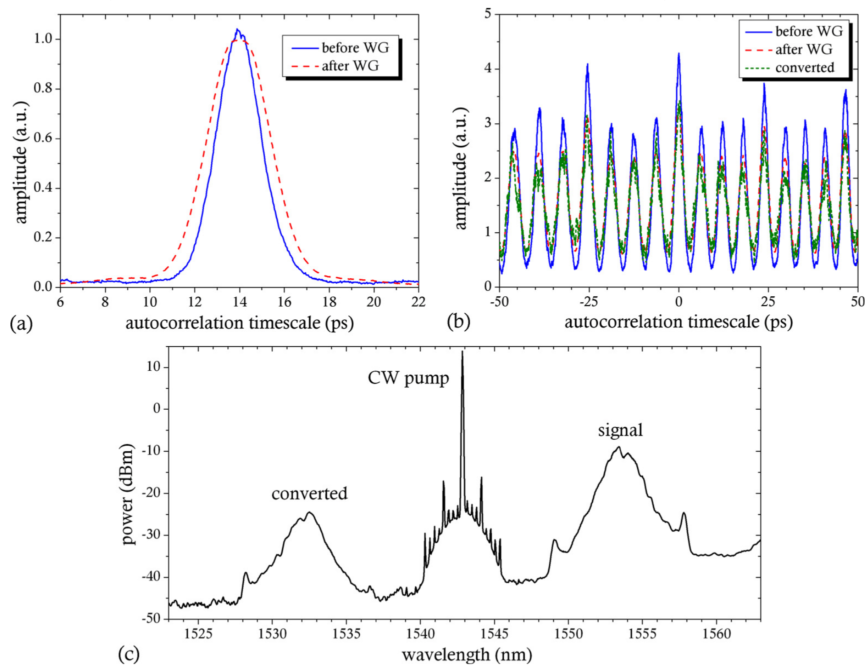

Fig. 2. (a) Autocorrelator traces recorded for a picosecond pulse before and after injection into the waveguide, without wavelength conversion. (b) Autocorrelator traces taken on a 160-GHz pulse train before and after injection into the waveguide without wavelength conversion, and also after injection into the waveguide with wavelength conversion. (c) OSA trace displaying the spectrum immediately following the waveguide, demonstrating wavelength conversion of a 160-Gb/s data signal.

3. Conclusion

We have demonstrated 160-Gb/s wavelength conversion in a CMOS-compatible platform, realizing the highest data rate achieved for a single-channel conversion in silicon to date. A 21-nm conversion range and -15.5-dB conversion efficiency are shown with moderate pulse broadening.

4. References

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