Silicon Microring Resonator-Based Broadband Comb Switch for Wavelength-Parallel Message Routing

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Abstract: **We demonstrate error-free propagation of wavelength-parallel 160-Gb/s optical data in a broadband silicon microring resonator-based comb switch, and observe no power penalty increase associated with inter-channel crosstalk when scaling from one to 16 wavelength channels.**

Introduction

As the performance of electronic on-chip and chip-to-chip interconnects becomes increasingly constrained by power and speed limitations, photonic integrated circuits (PICs) emerge as an attractive solution to the problems of on-chip connectivity and off-chip bandwidth. The silicon-on-insulator (SOI) platform has gained significant attention, becoming the material system of choice for integrated optical interconnects owing in part to its favorable optical properties, enabled by high index contrast, and its compatibility with electronic integration [1,2]. Microring resonators present valuable building blocks for these systems, and have already been shown to perform passive operations such as filtering and multiplexing, as well as active functions including electro-optic, all-optical, and thermo-optic switching and modulation [1,2]. It is of great interest to develop broadband components based on these devices in order to harness the ultrahigh-bandwidth associated with the photonic wires interconnecting them [3].

The device discussed here, previously reported in [2], consists of a microring with resonator modes spaced by approximately 100 GHz, intended for use in wavelength-division-multiplexed (WDM) systems. This spacing allows the ring to operate as a comb switch on a broadband, wavelength-parallel data stream in much the same way a smaller-diameter ring would act upon a single-channel signal. All-optical switching of a two-wavelength-channel signal has been recently demonstrated using the device [2].

We have demonstrated the propagation of very-large-bandwidth data streams totaling 160 Gb/s through the all-optical ring resonator-based comb switch, and measured the signal degradation due to wavelength crosstalk [4]. The experimental setup is described in [4]. The device comprises a ring resonator coupled to two straight waveguides (Fig. 2). On resonance, light is coupled into the ring resonator, and is sent to the drop port. Off resonance, light propagates virtually unaffected to the through port. The free spectral range (FSR) of the ring resonator is 0.83 nm, corresponding to its diameter of 200 µm. The resonator modes are quite uniform, producing over 32 consecutive channels with extinction ratios better than 15 dB (Fig. 1). Leveraging the small FSR, multiple channels are able to be switched simultaneously for broadband WDM interconnection network routing applications.

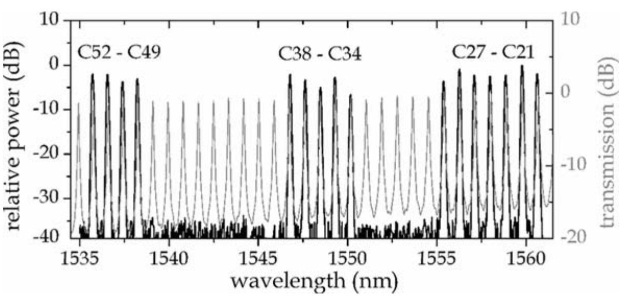

Fig. 1. WDM signal spectrum (black, left axis) and relative transmission spectrum of the drop port (gray, right axis).

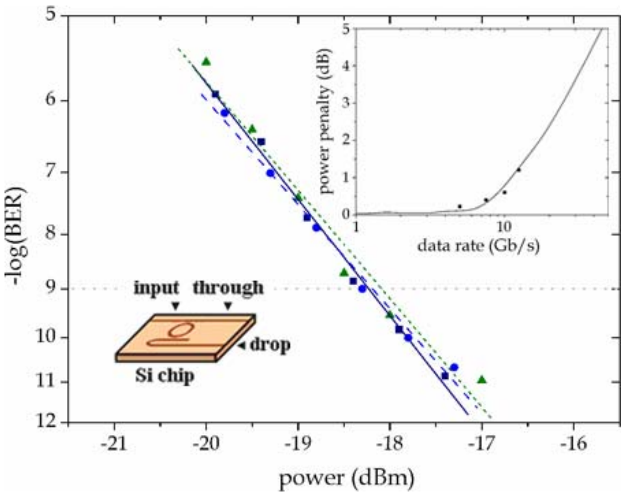

Fig. 2. BER plots recorded at the drop port for 16 (■, solid line), 12 (●, long-dashed line), and 1 (▲, short-dashed line) signals; measured (■) and simulated (line) single-channel power penalty of the drop port versus data rate (right inset); switch layout (left inset).

Results and Conclusion

All 16 channels are verified to operate error free, which is defined as having a bit error rate (BER) of less than 10^{-12}, at 10 Gb/s through the drop port of the device. To measure the increase in power penalty due to wavelength crosstalk within the microring, a BER curve is taken for a single channel at the drop port of the device when all 16 channels are enabled (Fig. 2). The same measurement is then repeated after turning off nearby channels, leaving 12 channels enabled, and taken again after disabling all but one channel. No significant penalty due to wavelength crosstalk was observed (Fig. 2), indicating additional wavelength-channel capacity within the device.

The power penalty of the device as a function of the incident optical signal data rate is measured using a similar experimental setup, except only a single wavelength channel is used. The power penalty is measured for data rates of 5.0, 7.5, 10.0, and 12.5 Gb/s, and (due to the ring's low-pass characteristics) increases sharply as the data rate exceeds the resonator bandwidth of about 10 GHz. These measurements are also verified using the model described in [5]. For the current device structure, assuming 40 wavelength channels each modulated at 20 Gb/s, an overall bandwidth of 0.8 Tb/s can be envisioned with a power penalty of less than 2.5 dB. Furthermore, future devices designed to accommodate higher-speed signals could enable data rates of 40 Gb/s per channel or more, scaling the bandwidth well past a terabit per second.

KB, AB, and BGL acknowledge support from the NSF under contract CCF-0523771. The work of ML and PD was part of the Interconnect Focus Center Research Program at Cornell University, supported in part by MARCO, Structured Materials Inc. under Grant 41594, and NSF CAREER Grant 0446571.

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