Eleven-Channel Second-Order Silicon Microring-Resonator Filterbank with Tunable Channel Spacing

Marcus S. Dahlem[*], **Charles W. Holzwarth, Anatol Khilo,**
Franz X. Kärtner, Henry I. Smith and Erich P. Ippen
Research Laboratory of Electronics, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge, Massachusetts 02139
[*]*e-mail: mdahlem@alum.mit.edu*

Abstract: A wide-band eleven-channel second-order filterbank fabricated on an SOI platform is demonstrated with tunable channel spacing and 20 GHz single-channel bandwidths. The tuning efficiency is ~28 µW/GHz/ring.

OCIS codes: (130.3120) Integrated optics devices; (130.7408) Wavelength filtering devices; (230.5750) Resonators.

1. Introduction

Multi-channel high-order microring resonators are essential components for low-cost highly integrated wavelength-division-multiplexing (WDM) systems and photonic integrated circuits. At wavelengths of 1.5 µm, silicon-on-insulator (SOI) platforms allow low-loss single-mode propagation in submicron structures and micron-sized bending radii [1]. The resonant frequency of a silicon microring resonator is extremely sensitive to fabrication errors. Therefore, in addition to high dimensional control and low sidewall roughness, post-fabrication trimming and tuning is normally required to achieve desired device parameters. The latter can effectively be achieved by thermal tuning, due to the large thermo-optic coefficient of silicon [2,3]. In silicon, multi-channel single-ring filters have been demonstrated [4] as well as tunable single-channel high-order filters [5]. Previously we reported progress in fabricating a multi-channel second-order silicon filterbank [6] and similar work in silicon-rich silicon nitride [7]. In this work, we demonstrate an aligned second-order silicon filterbank with eleven channels, channel-bandwidths of 20 GHz, and precisely tuned channel-spacing of 124 GHz, resulting in less than -35 dB crosstalk between channels. The filterbank is intended as a multiplexer for a wavelength-multiplexed photonic analog-to-digital converter [6].

2. Design and Fabrication

The filterbank was designed to have a 20 GHz channel-bandwidth and >30 dB extinction at adjacent channels spaced apart >80 GHz. The silicon waveguide dimensions were optimized to reduce sensitivity to sidewall roughness and dimensional variations in width [8], with cross-sections of 600×105 nm (ring waveguides) and 495×105 nm (bus waveguides). The filterbank was fabricated on an SOI wafer with a 3 µm-thick oxide undercladding, and a 105 nm silicon layer (thinned from 220 nm), similar to our previous work [5,9]. The device was coated with a 1 µm-thick hydrogen silsesquioxane (HSQ) layer [10], and titanium microheaters were fabricated on top of the HSQ for thermal tuning of the resonant frequency of each individual ring. Typical heater-resistance values were between 1 and 2 kΩ. Fig. 1 is an optical micrograph of two adjacent channels of the filterbank.

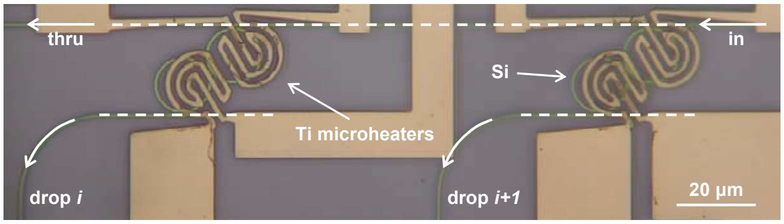

Fig. 1. Optical micrograph of two adjacent channels of the fabricated silicon filterbank.

3. Experimental Results

The individual rings show intrinsic Q factors of ~250k and ~130k, without and with the titanium heaters. This corresponds to propagation losses of about 2-2.5 dB/cm and 4.5 dB/cm, respectively. To demonstrate the wide and precise thermal tuning capabilities, we used a filterbank with large fabrication mismatches. Fig. 2(a) shows the drop-port responses of the eleven channels before any thermal tuning, overlaid with a grid showing the targeted 124 GHz-spacing and 20 GHz-bandwidth. Most of the channels are misaligned, with up to 150 GHz frequency mismatch between the two rings, and the channel spacing is non-uniform. Both rings of each channel are first

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individually tuned in order to compensate for the frequency mismatch, and then the entire channel is tuned to its targeted channel frequency. Fig. 2(b) shows the obtained drop-port responses. All channels are now sharply defined with 20 GHz single-channel bandwidths, channel-spacing of 124 GHz, and >35 dB extinction at adjacent channels. The relative magnitude between the drop-port responses and the thru-port response (not shown) indicates a drop loss of about 1.5-2.5 dB. The measured tuning efficiency is ~28 µW/GHz/ring. The average power per channel required for complete tuning of the eleven channels at the targeted 124 GHz-spaced grid was about 16 mW, with a total power dissipated on the chip of about 180 mW. In order to achieve this result, all 22 microrings were precisely tuned using a multi-channel DAC board which controlled the power of each ring-heater individually. Up to 5 channels were tuned simultaneously, limited only by the number of control ports available from our DAC. Thermal crosstalk between adjacent rings and adjacent channels is low and can easily be compensated for.

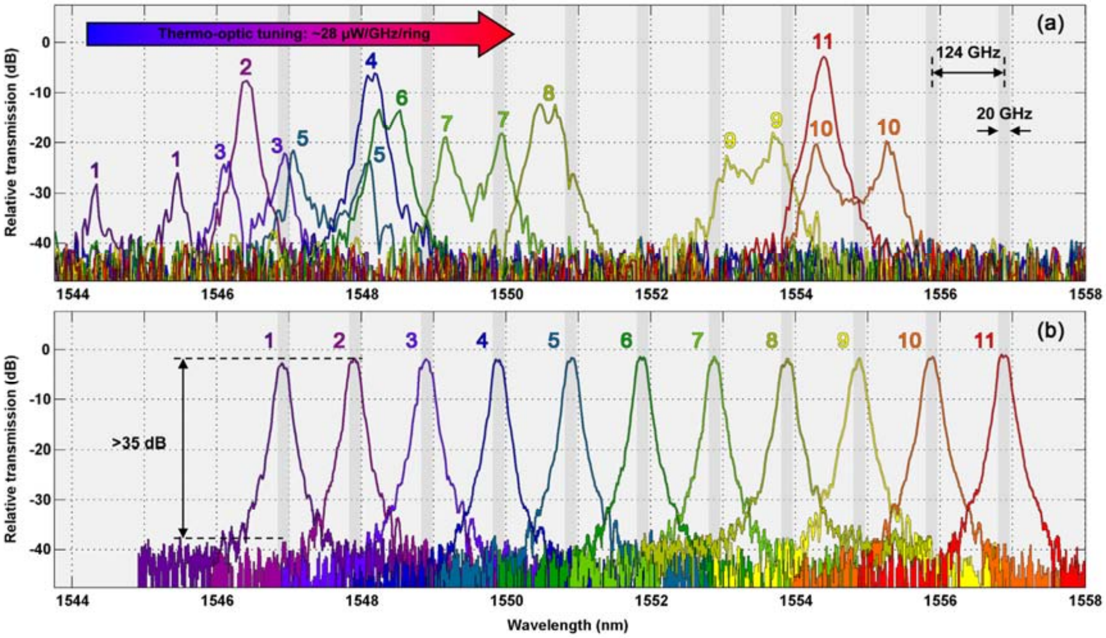

Fig. 2. Drop-port responses of an eleven-channel second-order silicon filterbank (a) before and (b) after thermal tuning. The targeted channel spacing is 124 GHz, and the measured channel bandwidth is 20 GHz. Extinction of any channel is over 35dB at adjacent channels.

4. Conclusion

We demonstrated an eleven-channel second-order filterbank fabricated on an SOI platform. The filterbank has a tunable channel spacing which was set to 124 GHz, and single-channel bandwidths of about 20 GHz. The tuning efficiency was measured to be ~28 µW/GHz/ring, and the total power dissipated on the chip is estimated to be close to 180 mW for the targeted channel spacing.

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