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Thermally Tuned Dual 20-Channel Ring Resonator Filter Bank in SOI (Silicon-on-Insulator)

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Abstract: Two 20-channel second-order optical filter banks have been fabricated. With tuning, the requirements for a wavelength multiplexed photonic AD-converter (insertion loss 1-3 dB, extinction >30 dB and optical bandwidth 22-27 GHz) are met.

OCIS codes: (230.3120) Integrated optics devices; (230.5750) Resonators

1. Introduction:

Ring resonator filters have frequently been investigated for add-drop filters in optical communications applications. Additionally, it has been proposed to use a bank of such filters to do demultiplexing in a photonic analog to digital converter [1]. Such a system requires two nominally identical banks of filters, so that the two complementary outputs of a modulator can both be sampled. Ring resonator filters in high index contrast systems, such as silicon or silicon nitride (typically with a surrounding cladding of silicon dioxide), enable filters that are compact and have large free spectral range. However, the tight light confinement leads to a strong dependence of the resonant wavelength of a filter on the precise dimensions of the ring. This leads to unrealistic dimensional control requirements for the rings in the filter bank, unless some sort of post-fabrication trimming is used. In this work, thermal tuning, by heaters fabricated on top of each ring, was used for post-fabrication adjustment of the resonant frequencies of the rings. An additional challenge for high index contrast waveguides is light scattering due to sidewall roughness. This can lead to both excess optical loss in the device and unwanted reflections [2,3]. By using a waveguide thickness of only 114 nm, instead of the more typical value near 200 nm for silicon, the confinement of our waveguide is lowered [4], and the amount of light scattering is significantly reduced.

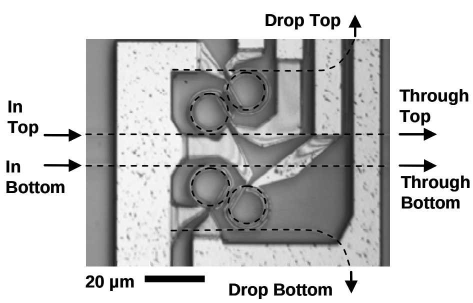

Fig 1. Optical microscope image of one channel of the two complementary filter banks. The two banks are labeled top and bottom. The dashed lines show the paths of the rings and waveguides, which are mostly hidden under the heaters and metallization. The spiral-like patterns at each ring are the heaters.

2. Design and Fabrication:

Two nominally identical filter banks with 20 channels each and two coupled rings per channel were fabricated using conventional optical lithography with a 248 nm wavelength stepper. Figure 1 shows an optical microscope image of one channel of both filter banks. The ring diameters are approximately 6.3 µm, and the waveguides in the ring are nominally 600 nm x 114 nm. The input and output waveguides are 500 nm wide. The waveguides are fabricated in silicon using Unibond silicon-on-insulator (SOI) material with a buried oxide that is 3.0 µm thick. The upper cladding is a 3.0 µm layer of PECVD deposited oxynitride, with a refractive index near 1.55. To couple light in and out of the silicon waveguides, a reverse adiabatic taper [5] was made inside a fiber-matched 3.0 x 2.0 µm oxynitride rib waveguide fabricated directly into the cladding. The heaters, also shown in Figure 1 are made of titanium wires nominally 500 nm wide and 300 nm thick. The heaters are in the middle of the cladding, 1.2 µm above the waveguides.

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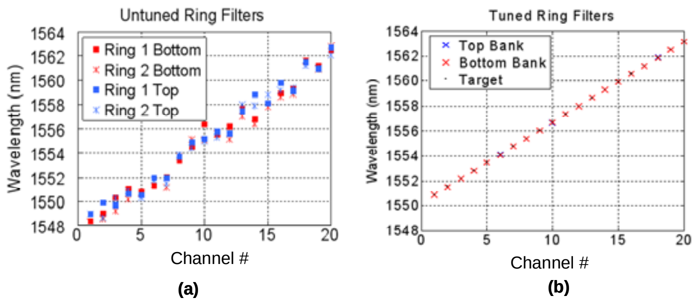

Fig 2. (a) Resonant wavelengths for the rings as-fabricated with no power in heaters. There are two filter banks (top and bottom), with two coupled rings each, for a total of four rings at each channel. (b) Center wavelengths for the filters after tuning.

3. Experimental Results:

Figure 2a shows the resonant frequencies of the 80 rings in the filter banks before tuning. For the photonic A/D converter application, only the spacing between channels needs to be controlled. Before tuning, the resonant wavelengths are off by an average of 100 GHz from the nearest possible arrangement of target frequencies with the desired spacing of 80 GHz. Because heating can only adjust to longer wavelengths, however, the resonant frequencies have to be adjusted by an average of 250 GHz to achieve proper spacing of the filter banks. Putting power into a heater shifts the resonant wavelength of a ring with a sensitivity of about 20 µW/GHz, making the total power to tune the dual filter bank 400 mW. The center frequencies of the filters channels after tuning are shown in Figure 2b, and have an average error of 0.65 GHz from the target spacing of 80 GHz.

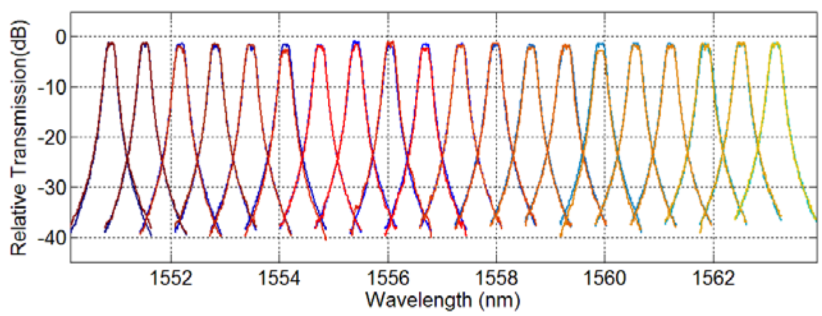

Fig. 3. Drop-port transmission characteristics of the filter banks after tuning. The blue-green colors are the top bank, and the red-yellow colors are the bottom bank. Because the data from the two filter banks match well, the data from the top bank is largely hidden behind the data from the bottom bank.

Figure 3 shows the performance of the 40 channels in the filter banks after tuning. It should be noted that the measurement was made by adjusting one filter channel at a time and measuring that individual filter channel. The insertion loss of the drop filters are all between 1-3 dB, relative to the through port. The bandwidths of the filters are between 22-27 GHz, which agrees well with the 25 GHz design. The channel-to-nearest-channel extinction is >30 dB, suitable for photonic ADCs operating at a 10 ENOB level.

The Lincoln Laboratory portion of this work was sponsored by the EPIC Program of the Defense Advanced Research Projects Agency under Air Force Contract FA8721-05-C-0002. Opinions, interpretations, conclusions, and recommendations are those of the authors, and do not necessarily represent the view of the United States Government.

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