Fabrication strategies for filter banks based on microring resonators

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Advances in the fabrication of strong-confinement microphotonic devices have made it possible to integrate photonic systems that were previously comprised of relatively large discrete components [1]. An important component of many integrated photonic systems is a wavelength-division demultiplexer. Currently, arrayed waveguide gratings are used as demultiplexers, but their size (on the order of 1 cm^2 for commercially available devices) is unattractive for integrated photonic systems. By using filter banks based on microring resonators it is possible to create demultiplexers that are two orders of magnitude smaller and achieve better performance. In this paper, we present strategies for the fabrication of microring-resonator filter banks including: accurate resonant-frequency spacing control using scanning-electron-beam lithography (SEBL), thermal trimming with microheaters, and thermal stability schemes.

The most critical aspect of fabricating filter banks out of microring resonators is accurately controlling their resonant-frequency spacing. Although possible, thermally tuning the microring resonators to the desired frequencies is impractical because it consumes large amounts of power. Alternatively, the relative resonant frequency can be controlled very accurately using the technique of dose modulation; by changing the electron-beam dose during SEBL the average width of the written microring resonator can be adjusted, thereby changing its resonant frequency [2]. Due to slight process variations this technique alone is not sufficient to control the resonant frequency to within 1 GHz (equivalent to controlling the average ring width to 30 pm). Therefore, thermal trimming with microheaters is necessary to correct for any residual frequency errors. The power consumed by thermal trimming to correct for these small residual errors is two orders of magnitude lower than the power consumption if dose modulation is not used. Also with microheaters it is possible to correct for thermal fluctuations in the environment, thermally stabilizing the filter bank.

In this study, dual-input twenty-channel filter banks, comprised of 40 second-order microring-resonator filters, were fabricated, with a target frequency spacing of 80 GHz (Fig. 1). The error in average spacing of 3 GHz corresponds to an average ring width error of only 90 pm. Dual-input two-channel filter banks with integrated microheaters were also fabricated to demonstrate that all frequency errors can be eliminated with thermal trimming, using minimal power (Fig. 2). Also, through the construction of a simple whetstone bridge, it was possible to create a feedback system to thermally stabilize the temperature of the filter from outside fluctuations.

[1] C. Gunn,, "*Fully Integrate VLSI CMOS and Photonics 'CMOS Photonics'*," in VLSI Technology, 2007 IEEE Symposium on , vol., no., pp.6-9, 12-14 June 2007.

[2] C. W. Holzwarth, T. Barwicz, M. A. Popović, P. T. Rakich, E. P. Ippen, F. X. Kärtner, and Henry I. Smith, "*Accurate resonant-frequency spacing of microring filters without post-fabrication trimming*," JVSTB Vol. 24, No. 6, p. 3244, 2006.

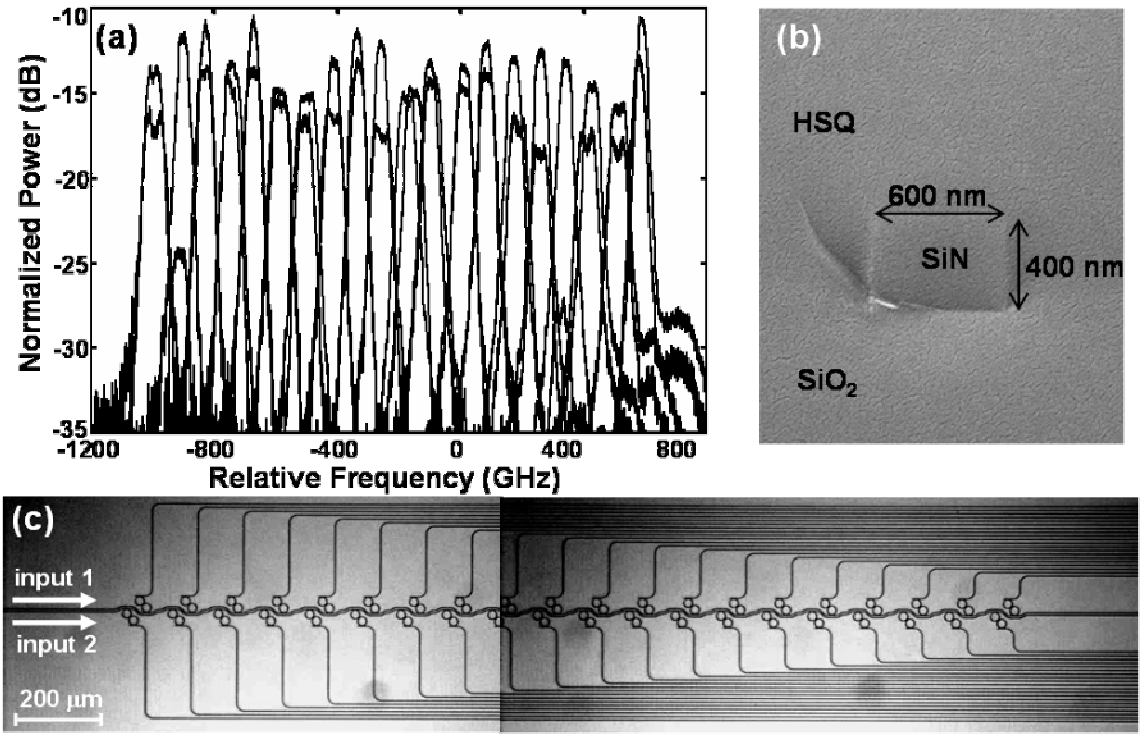

Fig 1: (a) Frequency response for all drop-ports of a dual-input twenty-channel filter bank with all non-filter related losses removed. (b) Cross-section of waveguide overclad with hydrogen silsesquioxane (HSQ). (c) Top-view optical micrograph of the filter bank without microheaters.

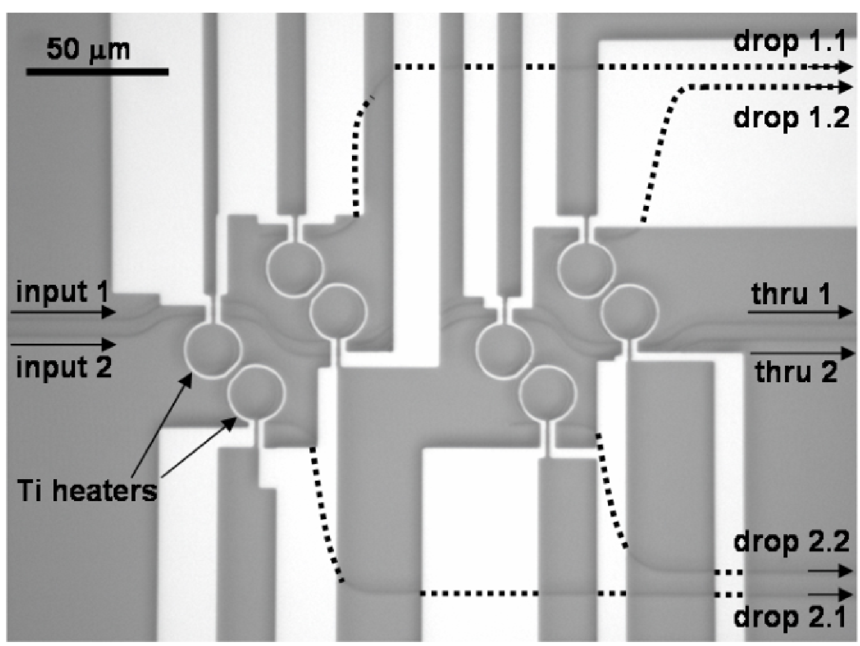

Fig 2: Optical micrograph of integrated titanium microheaters above a dual-input two-channel filter bank. There is 1.5 μm of optimally annealed HSQ between the top of the microring resonators and the heaters making it not possible to focus on both the optical device layer and the heater layer simultaneously.