Tunable Vernier Microring Optical Filters Using p-i-p Resistor-Based Micro-Heaters

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Abstract: We report a microring optical filter using Vernier effect. Tuning is enabled by a p-i-p resistor-based micro-heater integrated inside the resonators. Experiments show the filter wavelength can be tuned by 47 nm.

OCIS codes: (230.7408) Wavelength filtering devices; (230.3990) Micro-optical devices; (230.3120) Integrated optics devices

1. Introduction

Optical filters using micro-ring resonators have attracted much attention in recent years due to their diverse applications in optical signal processing and wavelength-division multiplexing (WDM) systems for optical communication and interconnect [1-4]. An optical filter with a large FSR that can span the C-band would be beneficial, as this would increase the number of channels that could be multiplexed or demultiplexed. Conventional method to increase the FSR is to reduce the radius of microring [5, 6]. However, for microrings with very small bending radii, substantial loss arises not only from the bending loss but also from scattering from the bus-to-ring coupling junctions, leading to the decrease of qulity factor. Hence, two series-coupled microring resonators that have different sizes are rountinely used to achieve a large FSR owing to the Vernier effect.

In this paper, we experimentally demonstrate a Vernier microring optical filter. The filter wavelength is tuned by a p-i-p resistor-based micro-heater integrated inside the resonators. Our experiments show that the filter wavelength can be tuned by 47 nm with cross-talk better than -20 dB.

2. Device structure

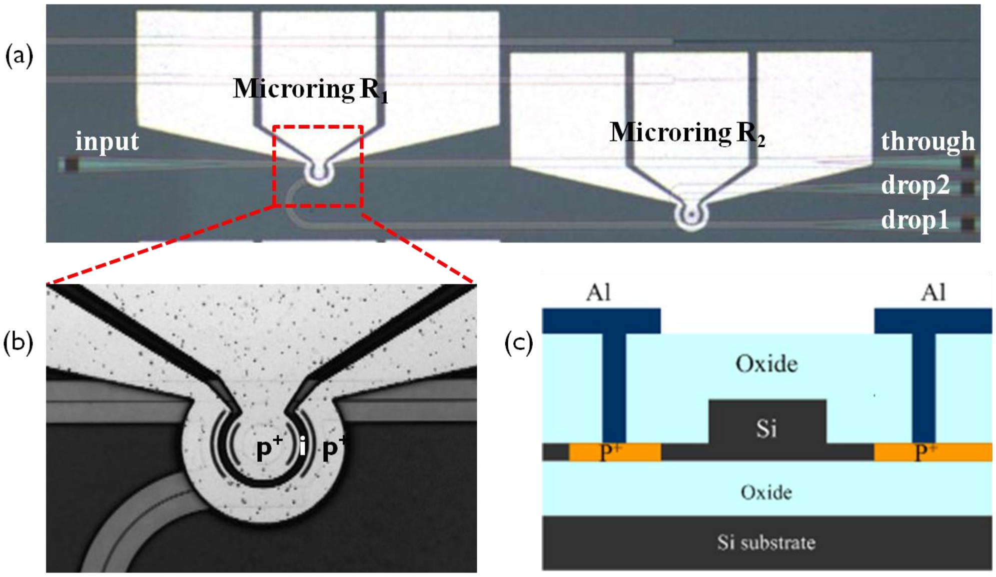

Fig. 1 (a) Microscope image of the tunable Vernier microring optical filter. (b) Zoom-in view of the active microring resonator. (c) cross-sectional schematic of the p-i-p micro-heater

Fig. 1 (a) shows the optical microscope image of the Vernier microring filter, which comprises two series-connected microrings with slightly different radii of R_1 = 10 μm and R_2 = 12 μm. The two microring resonators have different FSRs, and as a result, the Verneir output has resonance peaks located only at the common resonant wavelengths of these two cascaded rings, leading to an expanded FSR. Fig. 1(b) shows the zoom-in view of one of the active microrings. The waveguide width is 500 nm. The waveguide height is 220 nm with a thin slab of 60 nm thick. The gap between the ring and the bus waveguide is 200 nm. To couple light in and out of the waveguides, grating couplers with 630 nm period and 70 nm shallow etch depth are used.

Fig. 1(c) shows the p-i-p micro-heater embedded in the microrings. As the intrinsic region has high resistivity, heat will be generated when a current is applied to the p-i-p junction. Due to thermo-optic effect, the refractive index of the ring waveguide is changed. Because the thermal resistor is formed by the silicon waveguide, the generated heat can immediately interact with the waveguide optical mode, and thereby, this type of thermal resistor is more efficient and can potentially switch faster than conventional metal resistors. Moreover, the fabrication process of the p-i-p resistor is CMOS-compatible and can be fabricated together with p-n diodes which are routinely used in silicon photonic devices, such as modulators, switches etc.

3. Experiments

The transmission performance of the Venier microring filter is mainly dependent on the alignment of the two sets of resonances. Fig. 2 shows the transmission spectra without active tuning form the three output ports indicated in Fig. 1(a). The two microring resonators do not have a common resonance wavelength, and therefore there is no pronounced resonance peaks in the transmission spectrum of drop2. Only around 1554 and 1562 nm, the resoances from the two micorings are close, resulting in small peaks in drop2. From Figs. 2(a) and (b), it can be observed that the transmision is not uniform over the whole spectral range due to the limited bandwidth of the grating couplers.

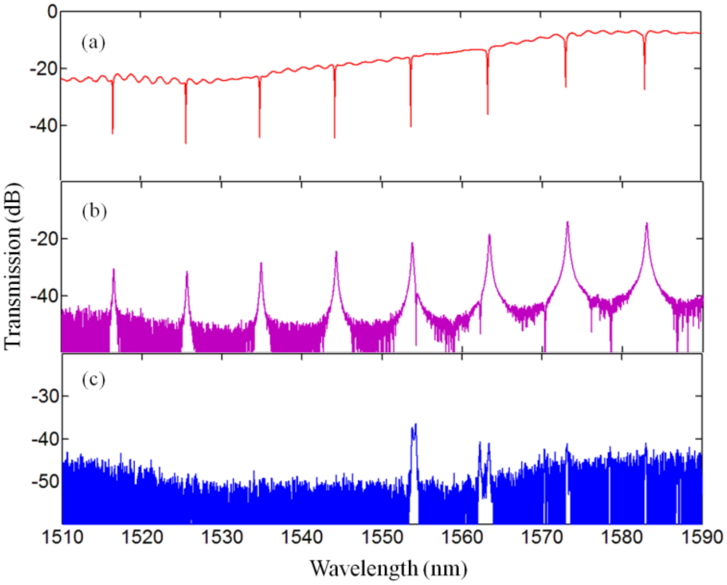

Fig. 2 Transmission spectra of the Vernier microring filter without active tuning. (a) through-port; (b) drop1-port; (c) drop2-port.

To actively tune the resonators, a pair of metal-probes were used to connect the electrodes of the devices to an external current source. A voltmeter was used to monitor the voltage drop on the p-i-p thermal resistor, and hence the power dissipation can be obtained. Fig. 3 shows the tuning of the transmission spectrum of drop2 with the power consumption either on the first microring or the second. When the second microring is heated up, its resonances move to the longer wavelength side (due to positive thermo-optic coefficient of silicon), and at a certain power level, two resoances from the two rings are exactly matched, resulting in a high resoannce peak in drop2. As the second ring has a larger size, its FSR is samller than the first one. Therefore, when the second ring is further heated up, the next matched resonance peak appears to the right of the previous one. Figs. 3(d)-(f) show the movement of the resoannce peak with power dissipation on the second ring. In contrast, when the first ring is gradually heated up, the matched resonance peak moves to the left instead, as shown in Figs. 3(a)-(c) (Note that the resonances of ring 1 still shifts to the longer wavelength side). In this way, the filtering wavelength can be both shifted to the left and right side, covering a broad spectral range. From Fig. 2, it can also be seen that the FSR of the Vernier drop port is 47 nm, much larger than that of the single microring resonator. The crosstalk is better than -20 dB, and the bandwidth is ~12 GHz. With 18 and 24 mW power consumptions on the first and second microring resonators, the Vernier microring filter wavelength can be tuned to cover one FSR. In our present experiment, we only tuned the resonators individually because of our limited probes. If the two resonators are both tuned, the filter wavelength could move to any spectral position, practically useful for WDM applications.

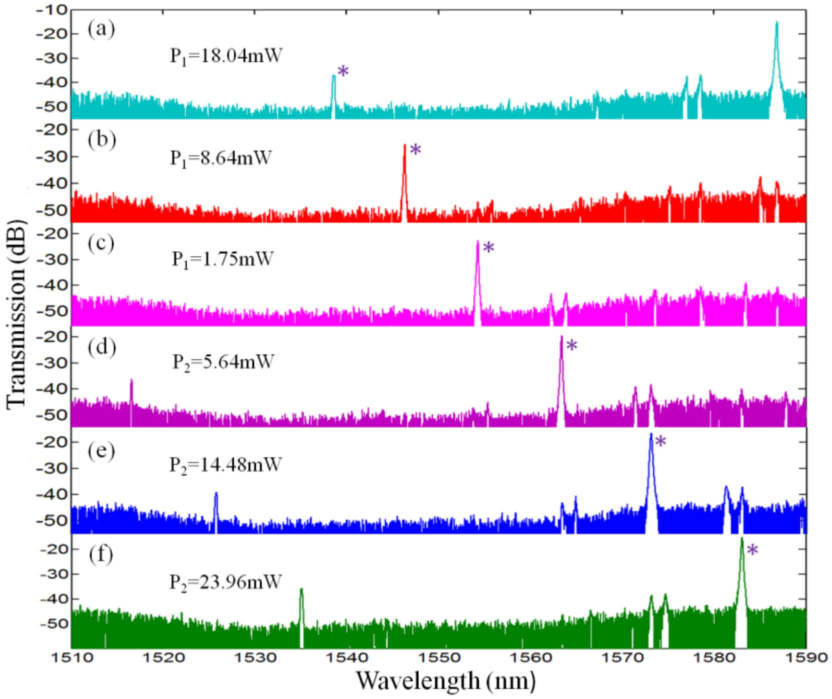

Fig. 3 Tuning of the transmission spectrum of drop2 port (the Vernier drop port). The current is either applied to the first micorirng or the second one.

4. Conclusion

We experimentally demonstrated a tunable Vernier microring optical filter. The filter passband width is 12 GHz and crosstalk is better than -20 dB. Filter wavelength was tuned by applying a current to the p-i-p junction based micro-heaters embedded inside the microring resonators. With 18 and 24 mW power consumptions on the first and second microrings, the filter wavelength can be tuned to cover one FSR of 47 nm.

Acknowledgements

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