An on-chip partial drop wavelength selective broadcast network

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Abstract: A wavelength selective 1-by-8-port optical broadcasting system is proposed and demonstrated utilizing partial drop adiabatic microring tunable filters, achieving a 92.7GHz filter bandwidth, 36.2nm Free-Spectral-Range, low power-variation (0.11dB), and aggregate excess loss of only 1.1dB.

OCIS codes: (130.3120) Integrated optics devices; (230.5750) Resonators; (230.7370) Waveguides.

1. Introduction

With the scaling of chip multicore microprocessor systems, communications between the cores on-chip and to memory-systems off-chip have become the limiting factor to system performance. Integrated photonics provide an alternative solution to both on- and off-chip communications [1]. Among all of the on-chip optical network topologies, the bus-based broadcasting topology, the most widely used network topology in electronics, has advantages in simplicity, flexibility, and scalability. With integrated photonic devices, bus topologies can be implemented by cascaded power splitters [2] connected to multiprocessors. However, to make full use of wavelength division multiplexing (WDM), wavelength selectivity needs to be incorporated into optical broadcasting system [3]. Previously, single large radius rings with multiple drop ports have been utilized to act as a power divider [4]. However, the limited free spectral range (FSR) and resulting bandwidth of this approach make it incompatible with data- and telecom communications. To overcome this limitation, we propose a new optical broadcasting system based on small radius ring resonators to enable large FSRs and resulting optical bandwidth in the on-chip network.

In this paper, we introduce a new wavelength-selective on-chip optical broadcasting system based on integrated small-radius tunable resonant filters which offer high tuning efficiency and a large FSR [5,6] to support additional wavelength channels. The demonstrated 1-by-8 broadcasting system shows an average 3-dB bandwidth of 92.7GHz with a standard deviation of only 3.7GHz, capable of handling high speed data for communication purpose. The aggregate excess loss of the parallel drop is only 1.1dB with an optical power variation of only 0.11dB between drops. This wavelength-selective parallel drop enables immediate applications such as on-chip optical broadcasting and high-sensitivity transmitters and receivers in on-chip WDM communication networks [7].

2. Design and Experimental Results

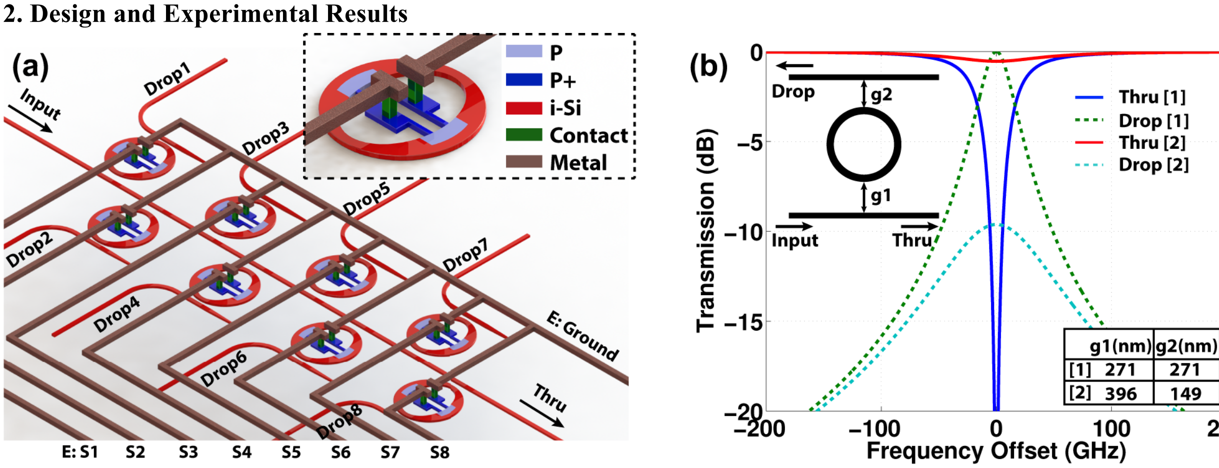

Figure 1 – (a) Schematic of the optical broadcasting system. All the microrings shown in the figure have the same resonant frequency with different coupling to the bus waveguide and drop waveguide. Inset: schematic of the tunable adiabatic microring filter. (b) Comparison between a traditional full drop filter (g1 = g2) and a partial drop filter (g1 ≠ g2).

Fig. 1(a) shows the schematic of the proposed 1-by-8-port WDM optical broadcasting system. All of the rings have the same resonant wavelength and share the same bus waveguide. The approach differs from traditional filter design where symmetric coupling to bus and drop waveguide is utilized. To achieve equal power distribution and spectrum across drop ports, partial drop filter designs are proposed consisting of asymmetric coupling to the bus and drop waveguides. The differences between the traditional and partial drop designs are shown in Fig. 1(b). By adjusting the gap sizes (g1 and g2), different power splitting ratios and bandwidths can be readily achieved. To compensate for the wafer and fabrication variations and coupling induced frequency shift (CIFS) [8], an integrated heater design is incorporated into the system. The single device of the tunable adiabatic microring resonator is shown in the inset of Fig.1 (a) with contacts created from doped silicon tethers.

The proposed structure was fabricated on a 300-mm SOI wafer with a 220-nm device layer using 193-nm optical immersion lithography. The scanning electron microscope (SEM) image of the fabricated device is shown in Fig. 2(a). Integrated heaters are introduced by p-type doping at a concentration of $1\times10^{18}cm^{-3}$ in the adiabatic ring waveguide and contacts are connected to heaters by small tethers of silicon with p+ doping at a concentration of $1\times10^{20}cm^{-3}$. This way, all rings in this system can be thermally tuned. The fabricated adiabatic ring is 6-μm in diameter [shown in the inset of Fig. 2(a)], ensuring a large FSR for WDM applications.

A transverse electric (TE) polarized tunable laser was coupled into the fabricated device by using a lensed single-mode-fiber (SMF) and the spectra of the through-port and 8 drop ports were measured. At both ends of the chip, identical inversely tapered waveguide couplers were used to match the waveguide mode to the fiber mode, maximizing the coupling between the fiber and chip. For the active heater control, a nine-pin-probe was utilized to control the resonant frequencies for each ring separately. Though all of the rings were designed to be identical, the resonant frequencies with no voltage applied differed from one to another due to layer thickness and lithographic variations as well as differing CIFS for each drop port. The drop port responses reveal a resonance variation of 0.27nm and power difference of more than 5dB in average wavelength of 1553.6nm. With the aid of thermal tuning, the wavelength variation was removed. The corresponding spectra after thermal tuning are shown in Fig. 2(b) and (c), revealing a resonance variation of 14pm and a power variation of 0.11dB, which are low enough to ensure equal power distributions among all drop ports. Besides, the 3-dB bandwidth variation is extracted to be 3.7GHz with an average value of 92.7GHz, wide enough to handle high-speed data transmission. Moreover, the device exhibits a wide uncorrupted FSR of 36.2nm [shown in the inset of Fig. 2(b)], enabling large numbers of communication channels. Though large numbers of rings and heaters are utilized in this device, the total loss of this parallel drop is only 1.1dB in aggregate and requires a tuning power consumption of only 2.96mW, a number which can be further reduced by utilizing higher efficiency filters [9].

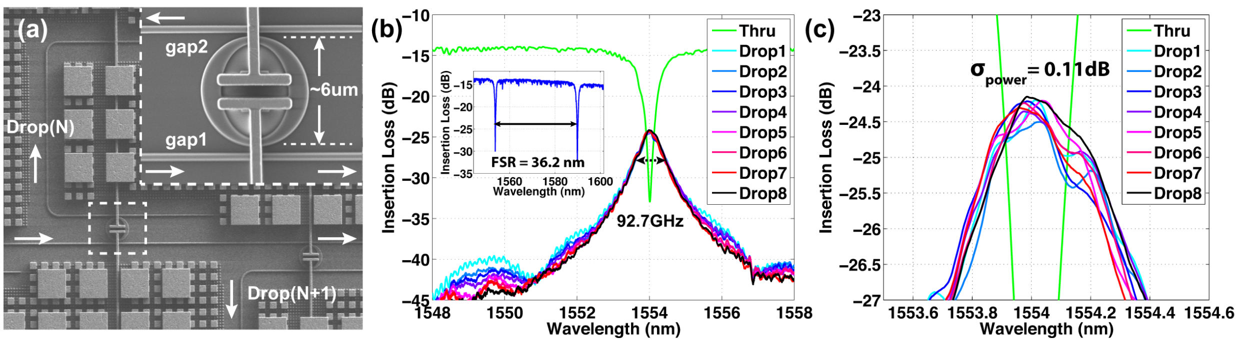

Figure 2 – (a) Scanning electron microscope (SEM) image of the fabricated device. Inset: zoom-in of fabricated tunable adiabatic microring filter. (b) Transmission spectra of the optical broadcasting system after thermal tuning. Inset: spectral response of the device, showing an uncorrupted 36.2 nm FSR. (b) Zoom-in of the transmission spectra of the system after thermal tuning, showing a power variation of 0.11dB.

By incorporating more rings with different radii, a WDM broadcasting system can be readily achieved. Moreover, higher order filter designs can be incorporated to improve the crosstalk levels between adjacent wavelength channels.

3. Conclusions

We proposed and demonstrated a novel 1-by-8 wavelength selective optical broadcasting system based on partial drop tunable adiabatic microring filters. The system demonstrates low power variation (0.11dB) among all of the outputs and a small excess loss of 1.1dB in aggregate. The wavelength selectivity and large FSR (36.2nm) enabled by small-radius rings offer a promising solution to WDM optical broadcasting and high-sensitivity transmitters and receivers.

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4. References

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