Wavelength Conversion in a Silicon Mode-split Micro-ring Resonator with 1G Data Rate

Ziyang Zhang[1], Qiang Li[2], Fangfei Liu[2], Tong Ye[2], Yikai Su[2] and Min Qiu[1*]

[1] *Department of Microelectronics and Applied Physics, Royal Institute of Technology (KTH), Electrum 229, Kista 16440, Sweden*

[2] *Department of Electronic Engineering, Shanghai Jiaotong University, 800 Dongchuan Rd, Shanghai 200240, China*

[*]*Email: min@kth.se.*

Abstract: We experimentally demonstrate the wavelength conversion based on free carrier dispersion effect induced by non-linear absorption in a silicon micro-ring resonator. The pump and signal wavelengths are set by the split resonances spaced by 0.4 nm induced by deformation in the coupling region. The results of 500 Mbps and 1Gbps are presented.

OCIS codes: (250.5300) Photonic integrated circuits; (140.4780) Optical resonators; (190.4390) Nonlinear optics

1. Introduction:

Highly compact wavelength conversion device is desired in all-optical networks. The applications cover optical switching, data traffic control and format conversion. Recently, several wavelength conversion experiments have been demonstrated on the silicon-on-insulator (SOI) platform [1-3]. In particular, utilizing the high Q factors of micro-ring resonators [1], the control light powers on the order of a few mW could be sufficient to induce signal conversions between wavelengths while the device is only on the micrometer scale.

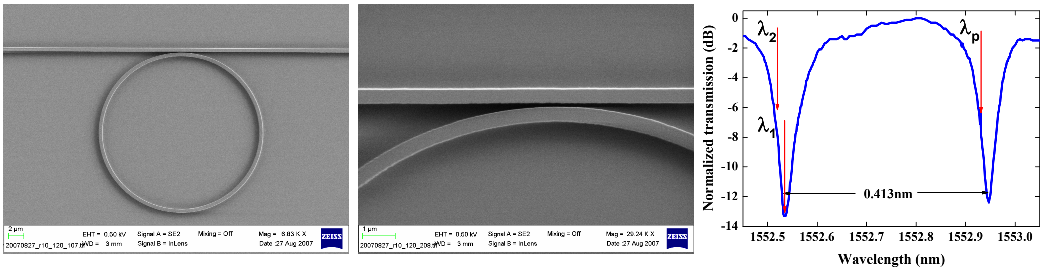
In the previous reports, however, the control (pump) and signal resonances are separated by at least one free spectrum range (FSR). For small-radius ring resonators in SOI, large FSRs usually limit the choices of wavelengths that can be converted. For a ring resonator side coupled to a waveguide, if some local deformation is introduced in the ring, both propagating and counter-propagating modes can be excited. The two modes can be separated by manipulating the deformation parameter. The split modes enable more channels for conversions, thus significantly increasing the system capacity. In this paper, for the first time to our best knowledge, we demonstrate high-speed wavelength conversion using the split modes at 1-Gbps rate.

2. Experiment

The device is fabricated in a commercial SOI wafer with a 3-μm-thick silica buffer and a 250-nm crystalline silicon top layer. The radius of the ring is 10 μm. The ring/waveguide cross-section is 450 nm by 250 nm. The air gap between the waveguide and the ring is controlled at 120 nm to approach critical coupling. The scanning electron microscope (SEM) photos are shown in Fig. 1 (a) and (b). The waveguide is slowly tapered to a width of 10 μm at both ends, and then gold gratings are added to couple light near-vertically from single mode fibers [4].

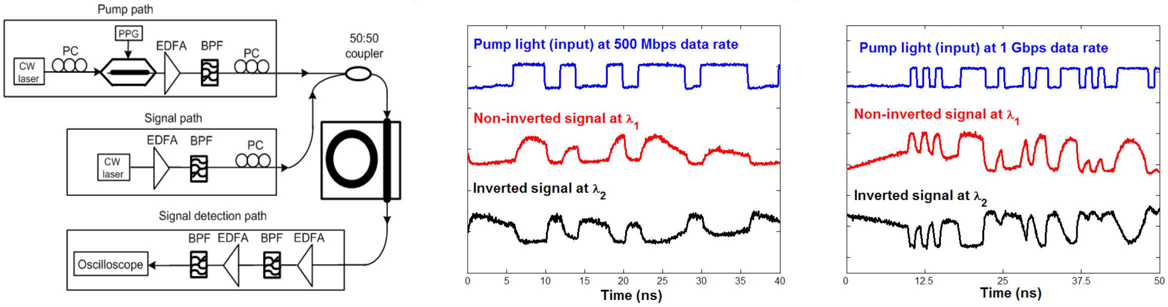
A slight structure deformation of the ring is introduced in the coupling area, which gives rise to the mode splitting effect as shown in Fig. 1 (c). From numerical simulations, we found that the wavelength separation (λ_s) can be tuned by the deformation size and position. However, the experimental demonstration of the λ_s variation versus the deformation will be included in our future work. In this experiment, λ_s is fixed at 0.413 nm. The left resonance at 1552.534 nm has a full-width half-maximum bandwidth ($\Delta\lambda_{FWHM}$) of 0.092 nm and the notch depth is 13.2 dB, while the right resonance is at 1552.947 nm with $\Delta\lambda_{FWHM}$ = 0.071 nm and a notch depth of 12.4 dB.

The experimental setup is shown in Fig. 2 (a). The pump wavelength λ_p (close to the right resonance) is chosen to offset the thermal nonlinear effect which is low-speed effect with the thermal dissipation time of ~ 1μs. The signal wavelength λ_1 is close to the left resonance for the non-inverted case and λ_2 around the left resonance for the inverted case. The pump power is 14.3 dBm and the signal power is 6 dBm at the input of the fiber. The results are shown in Fig. 2 (b) for a 500 Mbps data rate and Fig. 2 (c) for a 1 Gbps data rate, respectively. Both non-inverted and inverted waveforms are provided.



(a) (b) (c)

Fig.1 (a) and (b) SEM photos of the SOI 10-µm-radius micro-ring resonator. (c) The transmission spectrum demonstrating the mode splitting effect due to the coupling region structural deformation.



(a) (b) (c)

Fig. 2 (a) experiment setup. (b) wavelength conversion at 500 Mb/s. (c) wavelength conversion at 1Gb/s.

For intrinsic silicon, the carrier lifetime limits the operation speed to ~ 1 Gbps. The pump power needed for wavelength conversion can be further reduced by fabricating ring-resonators with much higher Q factors and improving the efficiency of the fiber-to-waveguide coupling.

3. Conclusion

We demonstrate the wavelength conversions in a silicon micro-ring resonator utilizing the mode-splitting effect up to 1 Gbps. The mode-splitting phenomenon in silicon micro-ring resonators opens up opportunities to convert more wavelengths that are densely spaced, thus effectively increasing the system capacity.

This work is supported by the Swedish Foundation for Strategic Research (SSF), the Swedish Research Council (VR), the National Natural Science Foundation of China (60777040), and the Shanghai Rising Star Program Phase II (07QH14008).

5. Reference:

[1] Q. Xu, V. R. Almeida, and M. Lipson, “Micrometer-scale all-optical wavelength converter on silicon,” Opt. Lett. **20**, 2733 (2005)

[2] H. Rong, Y. -H. Kuo, A. Liu, M. Paniccia, and O. Cohen, “High efficiency wavelength conversion of 10Gb/s data in silicon waveguides,” Opt. Express, **14**, 1182 (2006)

[3] M. A. Foster, A. C. Turner, R. Salem, M. Lipson, and A. L. Gaeta, “Broad-band continuous-wave parametric wavelength conversion in silicon nanowaveguides,” Opt. Express **15**, 12949-12958 (2007)

[4] S. Scheerlinck, J. Schrauwen, F. Van Laere, D. Taillaert, D. Van Thourhout, and R. Baets, “Efficient, broadband and compact metal grating couplers for silicon-on-insulator waveguides,” Opt. Express **15**, 9625-9630 (2007)