Realization of coupled-resonator-induced-transparency effect in germanium-on-insulator photonics

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【Introduction】Germanium (Ge) has recently emerged as an ideal optical material for the extension of operating wavelengths from near-infrared to mid-infrared (MIR) range due to its inherent beneficial properties. In particular, Ge possesses broader transmission transparency from 2 to 14 µm, a threefold higher thermo-optic coefficient than silicon (Si), and compatibility with complementary metal-oxide-semiconductor (CMOS) process [1, 2]. In this paper, we demonstrate couple-resonator-induced-transparency (CRIT) on a germanium-on-insulator (GeOI) photonic platform by using two evanescently coupled microring resonators. We observe an anti-crossing behavior and a coupling rate of 1.25 GHz when the resonances of the microring resonators are aligned.

【Device structure】Fig. 1 shows the schematic of the coupled microring resonators. By using the Smart-cut process, we obtained a Ge device layer of 250 nm. The Ge photonic waveguides are designed to be 500 nm wide and the two microring resonators, R1 and R2, have radii of 10 µm and 20 µm respectively. Both the gaps between R1 and the bus waveguide, and R1 and R2 are similarly designed to be 100 nm for evanescent coupling. After a 1 µm thick silicon dioxide (SiO_2) cladding layer is deposited, a 120 nm thick nickel metal line is sputtered on each microring resonator to provide tuning.

【Result and Discussion】Simulations of the CRIT effect are done using finite-difference time-domain (FDTD) method as shown in Fig. 2. When the resonance wavelength of R2 is smaller than R1, as shown in Fig. 2(a), there are two distinct resonances and the resonance due to R2 has a lower coupling efficiency. When the resonances of R1 and R2 are aligned to a single wavelength, this results in a resonance splitting, also known as a CRIT window as shown in Fig. 2(b). From the electric field distribution (inset of (b)), light is shown to be circulating within both resonators although only R1 is coupled to the bus waveguide. When the resonance wavelength of R2 is higher than R1, the coupling strength of R2 reduces once again as shown in (c). The measurement results of the coupled microring resonator with various heater powers added to R2 are summarized in Fig. 3. As shown in Fig. 3(a), the resonance wavelength of R2 is found to have blueshift significantly from the resonance wavelength of R1 when there is no heating. As predicted from the FDTD simulations, the extinction ratio due to R1 is also found to be larger. When the heater power of R2 increases, the resonance of R2 redshifts and the extinction ratio of the resonance increases. As depicted in Fig. 3(b), the resonances of R1 and R2 align at a heater power of 6.29 mW. A resonance split is observed at 1943.88 nm, hence realizing a CRIT window. When applying past this heater power as shown in Fig. 3(c), the resonance of R2 redshift while showing lower extinction ratio. The resonance detuning of the coupled microring resonators system is described by [3]:

$$\omega_{s,as} = \omega_{avg} \pm \sqrt{\frac{\Delta\omega^2}{4} + \gamma^2} \qquad (1)$$

where ω_{avg} is the average of the resonance frequency of R1 and R2, given by $0.5(\omega_{r1} + \omega_{r2})$. $\Delta\omega = \omega_{r1} - \omega_{r2}$ is the relative detuning between the two resonances and γ is the coupling rate. By using Eq. 1 and fitting the calculation results with the experimental results, the maximum coupling rate is found to be 1.25 GHz at a heating power of 6.95 mW.

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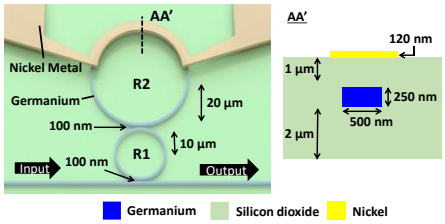

Fig. 1 Schematic of coupled microring resonators with heater lines.

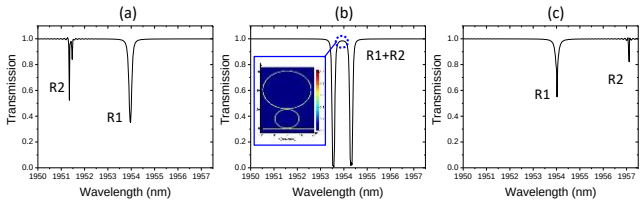

Fig. 2. Simulations of coupled microring resonators system.

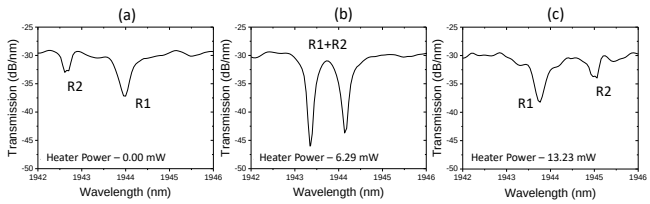

Fig. 3 Measurements of coupled microring resonators system.