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Group Index Engineered Photonic Crystal Waveguides and Microcavities in the 2 μm Waveband

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Abstract: We experimentally demonstrate photonic crystal waveguides and microcavities with group index engineering at the 2 μm waveband. The matched group index enhances the coupling efficiency and suppresses Fresnel reflections and Fabry-Perot resonance fringes.

1. Introduction

Photonics integrated devices show many advances in communication and sensing applications [1,2]. Photonic crystals (PC) are widely used in many optical systems to achieve better performance or specific functions [3]. The slow light feature in photonic crystals decreases the group velocity of light and enhances light-matter interaction [4, 5]. However, low group velocity causes the group index mismatch between the PC waveguide and straight waveguide. To reduce the group index mismatch in 2 μm waveband [6,7], we experimentally demonstrate the PC group index engineered taper in PC waveguides and resonators to verify the coupling effect.

2. Design and Simulation

We design the photonic crystal waveguides (PCWs) and PC microcavities in the 2 μm waveband on the SOI platform. The silicon slab is 220 nm with 2 μm buried oxide and 1μm silicon dioxide cover. As shown in Fig. 1(a), these structures are composed of one PCW or PCW coupled microcavity and two PC tapers. In this paper, the PC lattice constant a varies from 527 nm to 533 nm, and the silicon dioxide hole radius is $0.25a$. The width of the PC waveguide is $\sqrt{3}a$, and the PC taper width is increased from $\sqrt{3}a$ to $1.08 \times \sqrt{3}a$ in eight PC periods with a step of $0.01 \times \sqrt{3}a$. A pair of shallow etched grating couplers are applied to couple light into and out of the chip.

The band diagram is shown in Fig. 1(b). The calculated group index of a standard √3a PCW is around 19.9 when a = 530nm. With group index engineered PC tapers, whose width varies from √3a to 1.08 × √3a, the PC device matches the strip waveguide better with a similar group index and possesses a sharp band edge. Fig. 1(c) shows the simulated transmission of the PCW and PC microcavity with a = 530 nm. The L3-type PC microcavity is optimized by slightly shifting the edge holes of the L3 microcavity. Fig. 1(c) shows the resonance peak when the edge holes are shifted outward by 80 nm.

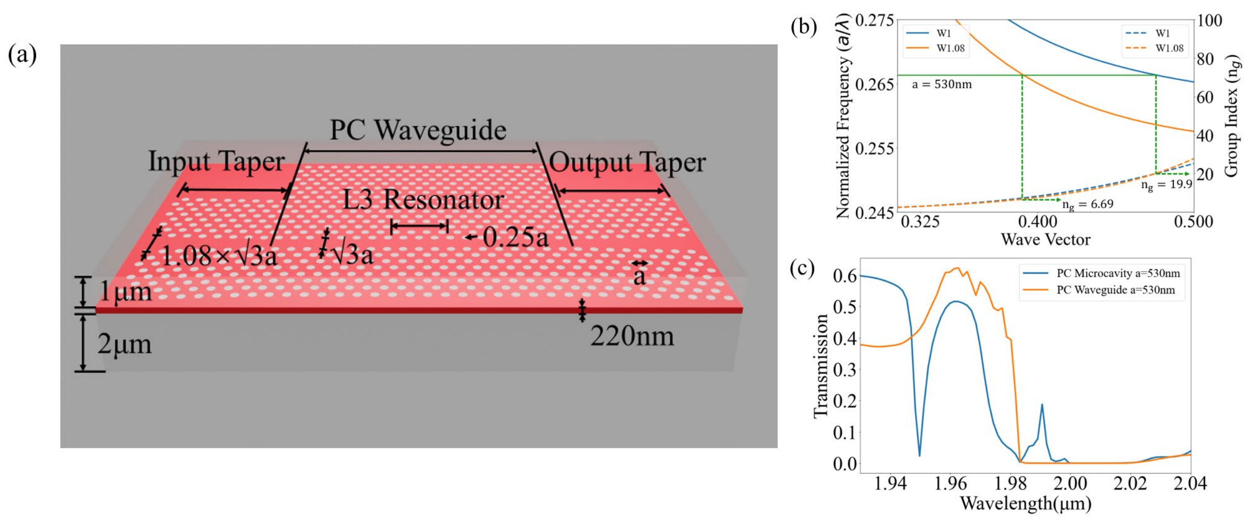

Fig. 1. (a) Schematic of the proposed PC structure. (b) PCW band diagram. (c) Simulated transmission of the PCW and PC microcavity.

3. Experiment and Result

The devices are fabricated in ShanghaiTech Quantum Device Lab (SQDL) with a fabrication process similar to our previous papers [8]. The 2 μm amplified spontaneous emission laser is adopted as a light source for measurements.

The light is coupled into the input grating coupler and transmitted through the PC structures. Finally, the output light from the grating coupler is sent into an optical spectrum analyzer (YOKOGAWA AQ6376). The single-side coupling loss is around 8 dB. Fig. 2(a) depicts the normalized measurement result of each PCW. Their band edges are about 2000nm, consistency with the simulation result. The insertion loss of the PCW is around 4.7 dB. The resonance peaks of the PC microcavities are shown in Fig. 2(b). The resonance wavelength shifts as the lattice constant changes. The extinction ratio is around 15dB corresponding to the Q-factor of 2000, and its insertion loss is about 7.9 dB.

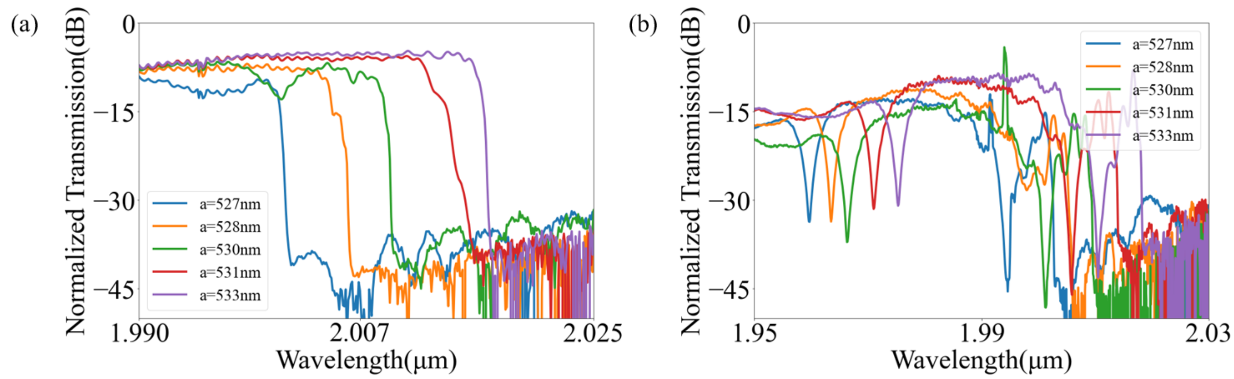

Fig. 2. (a) PCW transmission spectrum (b) PC microcavities transmission spectrum

4. Conclusion

In summary, we design PCWs and PC microcavities with group index taper at the 2 μm waveband. Their lattice constants are 527nm, 528nm, 530nm, 531nm, and 533nm, respectively. Each PC device with the group index engineering taper will achieve gradient n_g change and finally match the strip waveguide n_g to improve the light coupling efficiency and suppress the Fresnel reflection and Fabry-Perot resonance fringes.

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