Design of Waveguide Crossings with Slot Waveguide for Polarization-Independent Optical Triplexer

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Abstract— **An optical triplexer with cascaded directional couplers is proposed in an optical access system. The optical triplexer includes waveguide crossings with a slot waveguide for polarization independence. The waveguide crossings were designed by use of beam propagation method.**

I. Introduction

In a fiber-to-the-home (FTTH) system, optical triplexer transceivers with good performance are key elements. An optical triplexer is used to demultiplex two downstream waves (1490nm, 1550nm) and multiplex one upstream wave (1310 nm) simultaneously. Several types of optical triplexers were proposed such as a Mach-Zehnder interferometer [1], an arrayed waveguide grating [2], and a directional coupler [3].

Recently, optical devices based on silicon photonics have been actively studied. We have investigated a polarization-independent optical triplexer which is constructed on a silicon-on-insulator (SOI) substrate. The optical triplexer consists of cascaded directional couplers and waveguide crossings. In this paper, we report on propagation characteristics of the waveguide crossings.

II. Device structure

Fig. 1 shows an optical triplexer fabricated on a SOI substrate. The optical triplexer comprises of six directional couplers and waveguide crossings. The waveguide has a Si guiding layer and a SiO_2 lower cladding layer. The refractive indices of Si and SiO_2 are 3.50 and 1.45, respectively, at a wavelength of 1.55 µm. High index contrast waveguides are realized so that a very compact device is expected.

In the optical triplexer, lightwaves incident on an input port are divided to two output ports at the first directional coupler (DC-1). The lightwaves (1310 nm) are coupled to an output port (#3) and the other lightwaves (1490 nm, 1550 nm) are coupled to the other port (#0). Then, by the second directional coupler (DC-2), the TE modes and the TM modes of the lightwaves, whose wavelengths are 1490 nm and 1550 nm, are divided to two output ports. By two directional couplers (DC-3 and DC-4), two wavelengths are demultiplexed and finally, by two directional couplers (DC-5 and DC-6), the lightwaves at 1490 nm and 1550 nm are coupled to the output port, that is, #1 and #2, respectively. Therefore, this device can separate optical signals with three wavelengths to three output ports regardless of their polarization states.

III. Design

In the optical triplexer shown in Fig. 1, waveguide crossings are required for the TE mode at 1490 nm and the TM mode at 1550 nm. The waveguide crossings were designed by use of BeamPROP (Rsoft Design Group Inc.). Fig. 2 shows a cross-sectional structure of the waveguide. Considering a single-mode condition, a core width and height are set to be 0.40 µm and 0.21 µm, respectively. Fig. 3 shows waveguide crossings for the optical triplexer. The crossing angle was set to be 14°.

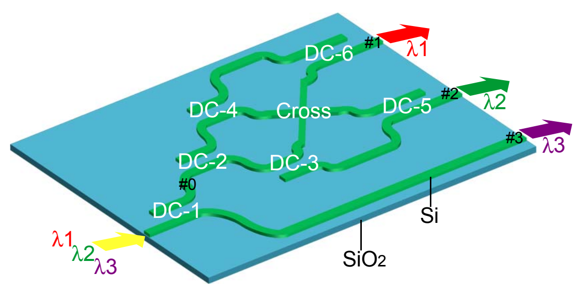

Fig. 1. Schematic diagram of optical triplexer with waveguide crossings.

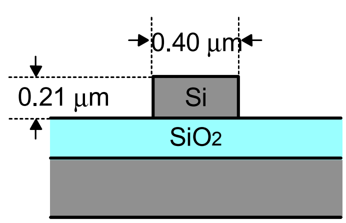

Fig. 2. Cross-sectional structure of optical triplexer.

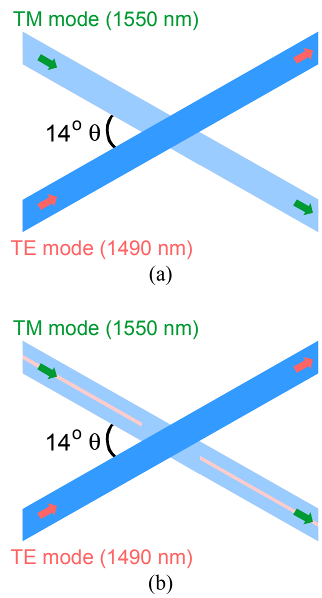

Fig. 3. Schematic diagrams of waveguide crossings (a) without slot waveguides and (b) with slot waveguides.

Fig. 4 shows simulated propagation characteristics of the waveguide crossings without slot waveguides. In a simple crossing, crosstalk is dominant for the TE mode at 1490 nm. Fig. 5 shows simulated propagation characteristics of the waveguide crossings with slot waveguides. It is found that the propagation loss can be reduced by employing the slot waveguide in the waveguide crossings.

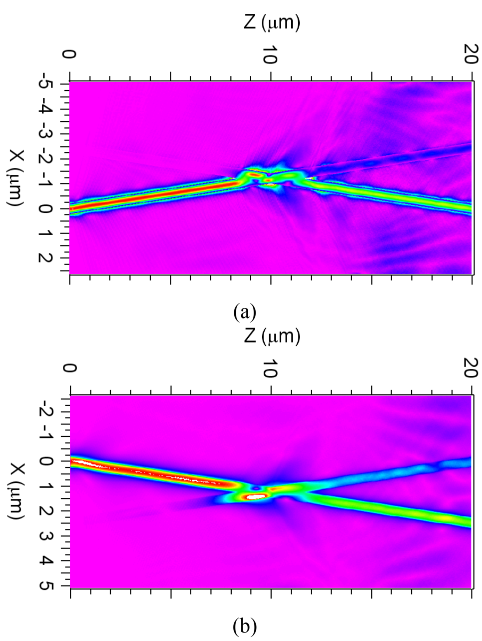

Fig. 4. Propagation characteristics of waveguide crossings without slot waveguides for (a) TE mode at 1490 nm and (b) TM mode at 1550nm.

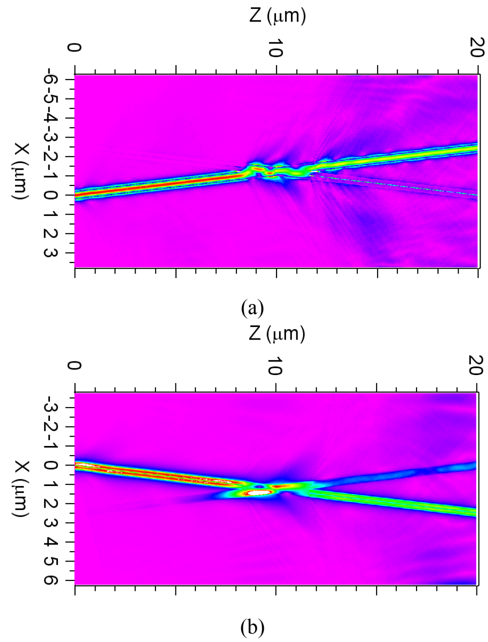

Fig. 5. Propagation characteristics of waveguide crossings with slot waveguides for (a) TE mode at 1490 nm and (b) TM mode at 1550nm.

IV. Conclusion

An optical triplexer constructed on a SOI substrate was proposed. The optical triplexer utilized cascaded directional couplers and waveguide crossings to demultiplex two downstream waves and multiplex one upstream wave simultaneously. The waveguide crossings were designed by beam propagation method. By employing the slot waveguide in the waveguide crossings, propagation characteristics were markedly improved.

Acknowledgment

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References

[1] R. G. Walker, J.Urquhart, I. Bennion, and A. C. Cater, “1.3/1.53µm Mach-Zehnder wavelength duplexers for integrated optoelectronic transceiver modules,” *Proc. Inst. Elect. Eng.*, vol. 137, no. 1, pp. 33-38. Feb, 1990.

[2] R. Mestric, H. Bissessur, B. Martin, and A. Pinquier, “1.31-1.55 µm phased-array demultiplexer on InP,” *IEEE Photon. Technol. Lett.*, vol. 8, no.5, pp. 638-640, May, 1996.

[3] C. H. Choi, N. Kim, S. Jo, M. W. Lee, B. O, S. Lee, and S. Park, “Design and fabrication of a novel 1310nm/1550nm directional coupler wavelength demultiplexer,” *Proc. SPIE*, vol. 5273, pp. 368-376, Apr, 2005.