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Crosstalk improvement in Si-wire optical cross-bar switch

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1. Introduction

Optical cross-connect is a key subsystem to reconfigure the optical transport network. There is a continuing demand of enlargement of the port count. One of the common technologies for building the cross-connect is silica planar light circuit (PLC)[1,2]. Optical cross-connect can be formed as a matrix switch, the element of which is a cross-bar switch. In the case of N × N matrix, an optical signal passes through N switches before it reaches an output port. For this reason, the cross-bar switch in the matrix must have much lower crosstalk than that used as a discrete one. In silica PLC, a cascade connection of two cross-bars has been devised for improving crosstalk perofomance[1]. This approach is also viable for silicon photonics, in which a fabrication error on the order of 10 nm should deteriorate the crosstalk performance of the element switches. In this paper, we discuss on the effect of the cascade connection for Si-wire cross-bar switches.

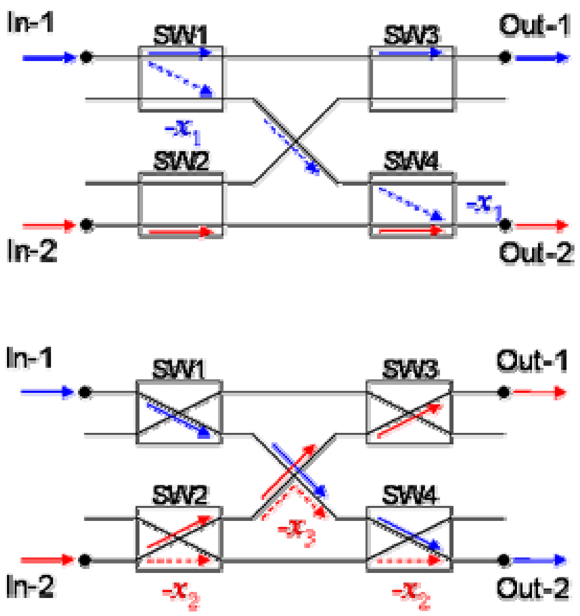

Fig. 1 Schematic of switch connection and signal paths in (a) bar and in (b) cross states.

2. Design and experimental

We have two cross-bars connected to the other two cross-bars and use them as a 2×2 switch by allocating the four ports as idle ports, as schematically shown in Fig. 1. This connection can be viewed as a generalization of that in Ref.[1]. This 2×2 switch gives a bar or cross connection

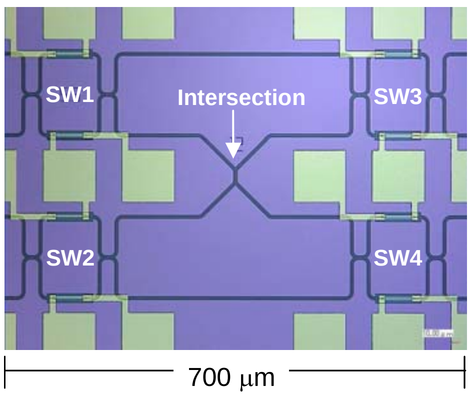

Fig. 2 Microscope image of the fabricated switch.

when the element switches are all set to the "bar" state or "cross" state. Let the leakage in an element switch be $-x_1$ dB and $-x_2$ dB below the signal on the main path for the "bar" and "cross" state states, respectively. For the "bar" state in Fig. 1(a), the leaked component in SW1 is further attenuated by $-x_1$ dB in SW4, and it will be of $-2x_1$ dB when it reaches Out-2. Likewise, for the "cross" state in Fig. 1(b), the leakage component is expected to decrease by $-2x_2$ dB at Out-2.

Fig. 2 shows a microscope image of the switch fabricated on a Unibond silicon-on-insulator wafer. The cross-bars as the element switches are Mach-Zehnder interferometers (MZI) with a Si-wire waveguide, which is 450-nm wide and 220-nm thick. A directional coupler (DC) serves as a 3-dB coupler in the MZIs. Also, a 0-dB DC is used as an intersection. It is to be noted that this DC is oriented upright. Metal (Pt) heaters are formed on a cover layer of SiO2 and they serve as thermo-optic phase shifters[3-5]. Each end of the waveguide has a spot-size converter with a narrowed waveguide for improving the coupling efficiency[6].

In the transmission measurement, the light source was a wavelength tunable (1520~1630 nm) laser diode. The output of this source was focused by a lens module onto the chip facet on the input side. The module contains a polarizer and launches a TE-like mode. Output light was picked up by a lensed fiber and its power was recorded. The propagation loss of a Si-wire waveguide was estimated to be 8 dB/cm and the coupling loss 4.5 dB per port.

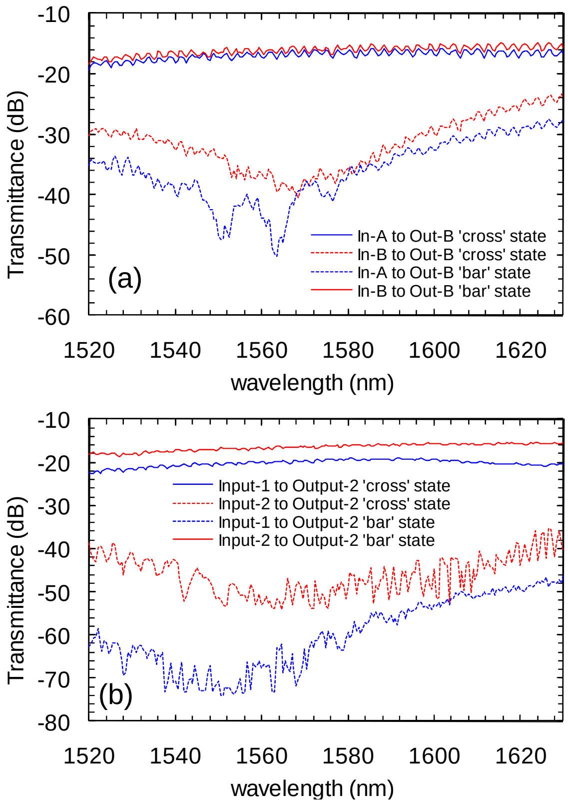

Fig. 3 Transmission spectra of a single cross-bar switch, (a), and of the arrayed switch, (b).

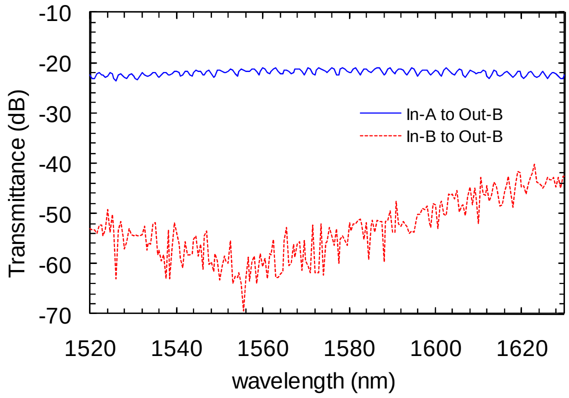

Fig.4 Transmission spectra of 0-dB directional coupler that is aligned vertically.

3. Results and discussion

Fig. 3(a) shows the results on a single cross-bar (MZI) switch, which was fabricated on the same chip as a reference. The estimated excess loss was 4 dB. The lowest crosstalk for a single cross-bar is -25 dB(at 1550 nm) for the "bar" state, while it is -20 dB(at 1570 nm) for the "cross" state. This indicates that the power division ratios of the splitters in an MZI should shift by a few percent due to a fabrication error in waveguide width.

Fig. 3(b) shows the results on the 2×2 switch, when Output-2 was monitored. The lowest crosstalk is -50 dB(1550 nm) for the "bar" state, whereas it is -30 dB(1570 nm) for the "cross" state. In the "bar" state, the figure of –50 dB is two times that for a single cross-bar (-25 dB). This improvement agrees well with our design aim. For the "cross" state, however, the figure of – 30 dB is not as good as the target (- 40 dB). This degradation can be ascribed to the intersection. If some leakage ($-x_3$ dB in Fig. 1(b)) occurs at the intersection, it will get mixed with the main signal. The experimental result suggests that the leakage from the intersection places a limitation on the crosstalk for the "cross" state. We suppose that the leakage is caused by a backscattering component that arises from the sidewall roughness of the waveguide [7]. The other intersection designs may eliminate this limitation [8-10].

4. Conclusion

We have demonstrated an improvement of crosstalk by cascading Si-wire cross-bars. Achieved crosstalk, -50 and -30 dB for "cross" and "bar" states, is significantly lower than that for a single cross-bar switch.

Acknowledgements

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