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An Adiabatic/ Diabatic Polarization Beam Splitter

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Abstract

We demonstrate an on-chip polarization beam splitter (PBS) which is adiabatic for transverse magnetic mode, and diabatic for transverse electric mode. The PBS has a simple structure and experimentally exhibits high polarization extinction ratios.

Introduction

On-chip polarization beam splitter (PBS) is essential for coherent optical communications and quantum cryptography. In recent years researchers have demonstrated various type of silicon photonic PBSs[1-3], however, they either have issue with fabrication ease and robustness or need to be improved in spectral flatness and bandwidth. In this paper we demonstrate a novel design of PBS, which is an adiabatic device for transverse magnetic (TM) mode and non-adiabatic for transverse electric (TE) mode. This PBS experimentally exhibits high polarization extinction ratios (PERs). In addition, it employs a simple structure, requires one single etching process, therefore it is easy and robust to fabricate.

Principle of Operation

The structure of our PBS is depicted in Fig. 1(a). The width of the two waveguides in PBS varies along the length of the device L with a constant gap width S. The width of the lower waveguide in Fig. 1(a) tapers up from W_1 to W_2. On the other way, the upper waveguide tapers down from W_2 to W_1. This variation in the waveguide width leads to a more significant change in effective index and propagation constant for TE mode than TM mode. This device is adiabatic for TM mode, if the propagation constant of the mode changes slowly enough along the waveguide length, but non-adiabatic for TE because the device is not long enough. With all the parameters optimized, TM mode is smoothly coupled into the cross port, and the TE mode keeps propagating in the input waveguide and goes to the through port without significant attenuation, as shown in Fig. 1(c) and (b).

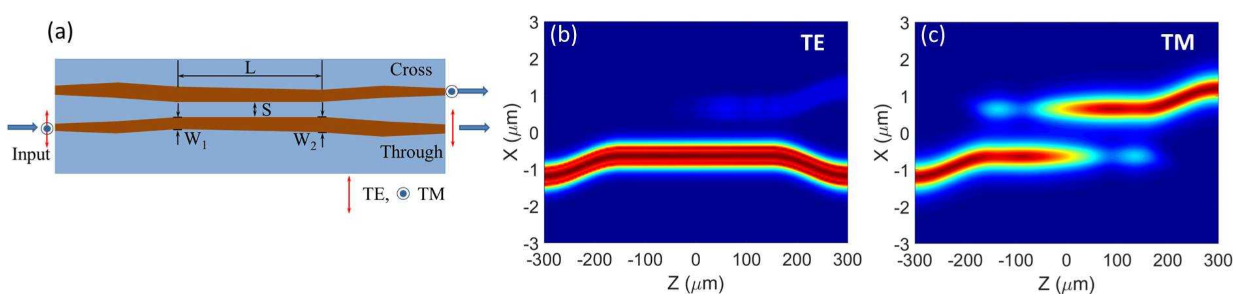

Fig. 1 Schematic of PBS fabricated on a silicon-on-insulator wafer with a 230 nm device layer (a). and simulated electrical field of TE (b) and TM (c) modes.

Measurements and comparisons

We use a Keysight N7786b polarization synthesizer to simultaneously manipulate the polarization of optical input from a single mode tunable laser (TLS). The polarization synthesizer controls its output state of polarization by rotating internal half wave and quarter wave plates, therefore, TE and TM polarized optical inputs are well separated. We couple the TE or TM polarized light into polarization beam splitter using a lensed single-mode-fiber (SMF). The transmitted light from through or cross port is collected by an identical lensed SMF, and measured by a power meter. As the TLS sweeps the wavelength over a spectral span from 1510 to 1600 nm, we obtain the transmission spectra of both TE and TM modes. Fig.2(a) shows the transmission of a typical device. The transmitted optical power is normalized using a straight waveguide on the same chip. We measure the insertion loss of TE mode from through port and TM mode from cross port lower than ~0.8 dB at the maximum over a 90 nm spectral span. As shown in Fig. 2(b), the through port of this on-chip PBS has an average PER of ~16.9 dB and minimum PER of

~11.3 dB. The average and minimum PERs of the cross port are ~19.4 dB and ~14.9 dB respectively. Here, the PER of through and cross ports are defined as

$$PER_{through} = 10log_{10}\left(\frac{P_{TE,through}}{P_{TM,through}}\right) \quad (1), \quad PER_{cross} = 10log_{10}\left(\frac{P_{TM,cross}}{P_{TE,cross}}\right) \quad (2)$$

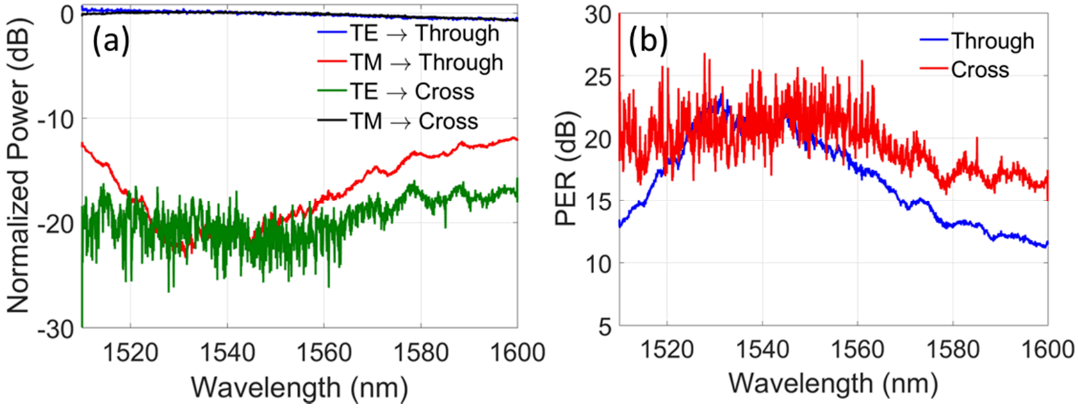

Fig.2 (a) TE and TM mode transmission spectra of a PBS. (b) PER of through and cross ports.

To determine the optimal PBS structure, we fabricate PBSs with different combinations of design parameters. Fig. 3 (a) and (b) show 2-D contour maps of through and cross port PERs as a function of PBS gap width S and coupling length L extracted from the experimental measurements of different devices. The through port shows a lower PER when the gap is wide and the coupling length is short, because TM mode is not yet sufficiently coupled to the cross waveguide. When the gap is narrow and the coupling length is long, a small portion of TE mode can be coupled into cross waveguide, thus results in a lower PER of the through port. The PER of cross port is dependent on the TE mode coupled into the cross port. Therefore, we measured high PER from devices with a wide gap and a short coupling length.

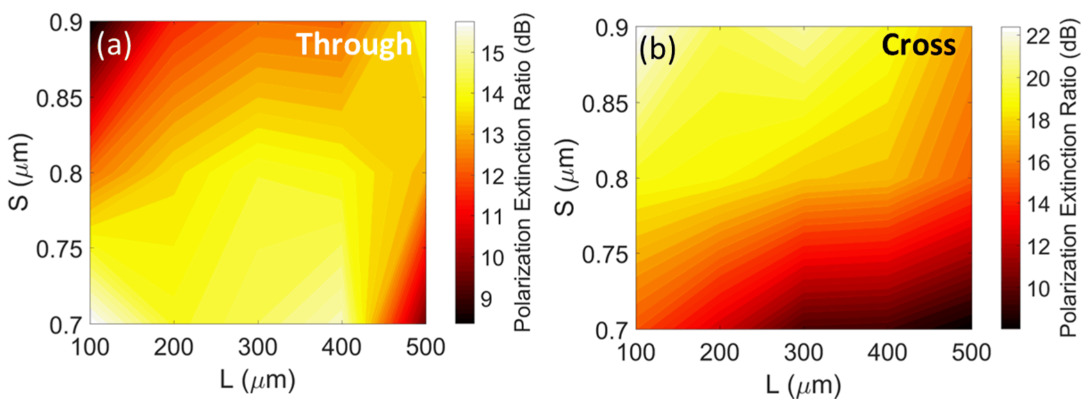

Fig.3 2-D contour map of through (a) and cross (b) port PERs as a function gap width S and coupling length L.

Conclusion

We design and fabricate a novel PBS adiabatic for TM mode and non-adiabatic for TE on a 230 nm SOI platform. With a simple structure, the through and cross ports of the PBS exhibit PER higher than ~11.3 and ~14.9 dB respectively over a 1510 to 1600 nm wavelength range.

Acknowledgments

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