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Abstract: An MMI-based polarization splitter/combiner with a TE-TM splitting ratio above 15 dB over a 21 nm wavelength range is demonstrated. The compact device is integrated in a photonic circuit within an InP multi-project wafer run.

OCIS codes: 230.3120 Integrated optics devices; 130.5440 Polarization-selective devices; 060.2340 Fiber optics components.

1. Introduction

Modern telecommunication networks are evolving to support high speed services, which require polarization handling. The orthogonal polarizations TE and TM can be used to double the capacity of the optical transmission system through polarization diversity. This functions can be achieved thanks to a device capable of splitting and combining the polarization states of light. Ultra short polarization beam splitters (PBS) based on directional mode couplers [1–4] or multi-mode interferometer (MMI) [5] have been designed in silicon technology. However, a PBS device in indium phosphide (InP) substrate is also required since it can be integrated with active components, i.e. lasers, modulators, and photo-detectors. A number of InP PBS with different structures have been reported, e.g. directional couplers [6], MMI [7], Mach-Zehnder interferometer with polarization converter [8]. The drawback is that the InGaAsP-InP layer stack has a lower index contrast compared to Silicon-On-Insulator (SOI), leading to a weak birefringence between TE and TM polarized modes. Thus, the TE-TM coupling length is longer in InP PBS devices than silicon ones, resulting in less compact devices. The shortest device device reported is 600 μm with a splitting ratio (SR) of 10 dB [8]. In this paper, a 370 μm MMI-based polarization splitter is demonstrated. The TE and TM birefringence is obtained with a shallow etched gap in the middle of the MMI section. The different TE and TE beating lengths ensure the splitting of the two modes at the device output ports. The PBS is fabricated by SMART Photonics B.V. within an InGaAsP-InP multi-project wafer (MPW) run [9].

2. Design and simulations

The PBS device (Fig.1(a)) consists of a single mode input waveguide (W_{wg} = 1.5 μm), a short tapered section (L_{gap} = 36 μm) for a smooth mode transition, an MMI section (W_{MMI} = 2.5 μm and L_{MMI} = 370 μm) and two output ports ($\text{port}_{1,2} = W_{wg}$). The input/output ports and the MMI section are fabricated in deeply etched trenches. The MMI section presents a shallow etched gap of 0.5 μm. The shallow etch depth (nominally 0.1 μm into the core layer) is defined by the foundry, thus the gap width is the design parameter that defines the TE and TM propagation constants. Fig.1(b) shows the fundamental and first order TE and TM modes in the MMI section. Due to the different coupling length for TE and TM, the mode interference in the MMI section is such that the TE and TM input mode couple out to port 1 and port 2 respectively. Fig.1(c) shows the field propagation along the PBS device for TE or TM polarized input.

The TE and TM coupling lengths in the MMI section are defined as

$$L_{\pi_{TE}} = \frac{\pi}{\beta_{TE0} - \beta_{TE1}}, \qquad L_{\pi_{TM}} = \frac{\pi}{\beta_{TM0} - \beta_{TM1}},$$

where β_{TE0} and β_{TE1} are the mode propagation constant for the fundamental and first order TE modes, while β_{TM0} and β_{TM1} are the mode propagation constant for the fundamental and first order TM modes. The calculated beat lengths are 37.52 μm for TE mode and 53.76 μm for TM mode. To split the TE and TM modes to port 1 and port 2 respectively, the optimal MMI length is 370 μm.

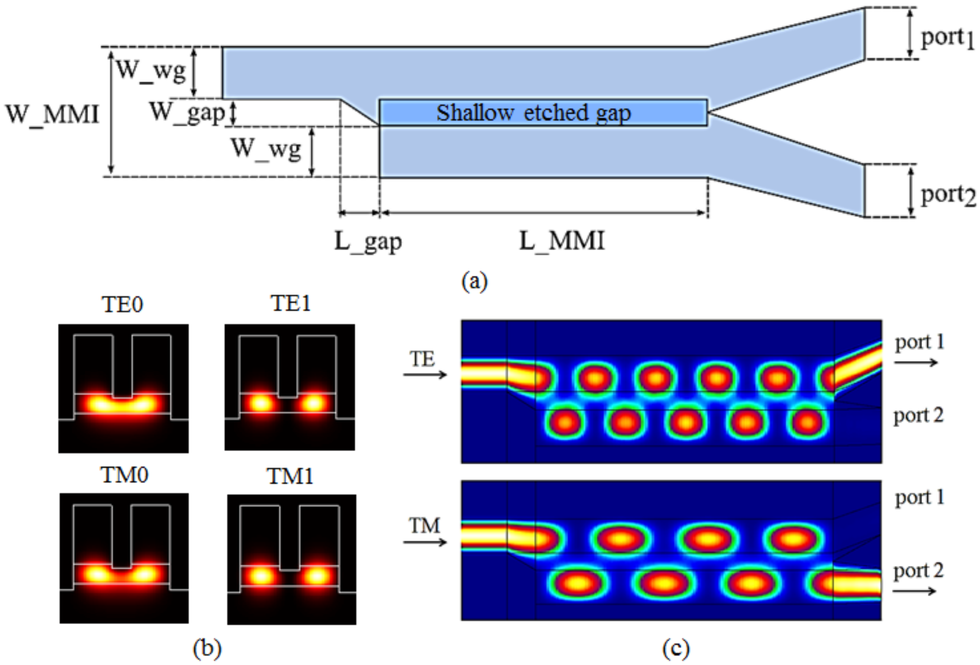

Fig. 1. (a) PBS device scheme. (b) Cross-section view of the MMI TE and TM modes. (c) TE and TM field propagation in the PBS device.

3. Measurements

The performance of the device is evaluated in terms of splitting ratio and insertion loss for both TE and TM polarized input mode. When the input mode is TE polarized, the splitting ratio is found as [8]

$$SR(TE_{in}) = 10\log\left(\frac{P_{TMout1} + P_{TEout1}}{P_{TMout2} + P_{TEout2}}\right) \tag{1}$$

whilst, if the input mode is TM polarized the splitting ratio (SR) can be calculated as

$$SR(TM_{in}) = 10\log\left(\frac{P_{TMout2} + P_{TEout2}}{P_{TMout1} + P_{TEout1}}\right) \tag{2}$$

The insertion loss is estimated with respect to the propagation loss of a single mode straight waveguide, used as a reference. The characterization of the PBS consists in determining the splitting ratio for both TE and TM input polarizations. At the input side of the PBS device, an erbium-doped fiber amplifier (EDFA) is used as a light source. The EDFA is connected to a polarization beam splitter (off chip) to define the polarization at the input coupling fiber. The polarization maintaining (PM) fiber, that couples the light into the PBS device, is rotated to launch a TE or a TM polarized mode[1]. At the output side, the total power (TE+TM) is coupled one at the time from the PBS output ports to a PM fiber. The output spectra are recorded using an optical spectrum analyzer (OSA). Measurement results (Fig.2(a)) show an SR above 15 dB over a wavelength range of 36 nm (1526-1562 nm) for the TE input and 32 nm (1515-1547) for the TM input. The two wavelength ranges have an overlap region of 21 nm (1526-1547 nm). The measured PBS insertion loss (Fig.2(b)), over the TE and TM SR overlap wavelength region, is 4-5.5 dB for the TE mode and 2-4 dB for the TM mode. The discrepancy between simulation and measurements results could be explained with a deviation of the design parameters during the PBS fabrication.

[1]Prior the PBS characterization, the orientation of the fiber to the TE or TM mode is performed in free space using a polarizer.

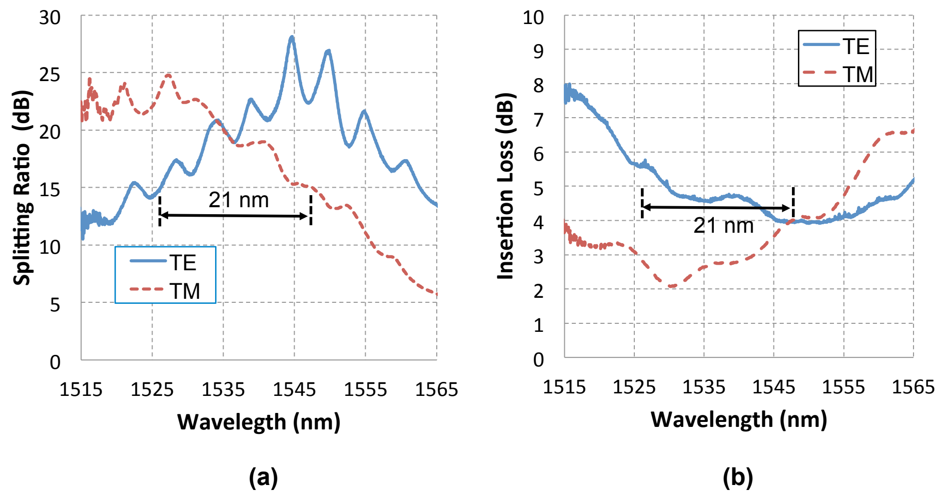

Fig. 2. (a) PBS splitting ratio (SR) and (b) insertion loss (Loss) as a function of the wavelength.

4. Conclusions

An MMI-based polarization splitter/coupler integrated in an InP photonic circuit has been designed. The compact 370 μm device is fabricated using a standard foundry process within an MPW run. The measurement results demonstrate the good performance of the device with an SR above 15 dB over a wavelength range of 21 nm (1526-1547 nm) for both TE and TM input. In this wavelength range, the measured PBS insertion loss is 4-5.5 dB for the TE mode and 2-4 dB for the TM mode. The device performance could be further improved with a refinement in the device design and/or fabrication processes.

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