Directional Coupler – based Polarization Beam Splitter using dissimilar waveguides in InP Membrane on Silicon (IMOS)

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Abstract – A very short Polarization Beam Splitter (PBS) for the InP Membrane in Silicon (IMOS) platform is presented. For the device, a combination of normal and slot waveguides is deployed. The PBS exhibits 23dB extinction ratio (ER) @1550nm and above 18dB for the whole C-band. A fabrication error investigation is carried out to determine its tolerance.

Introduction

As higher data rates are being accommodated by photonic integrated circuits, polarization has been deployed as a multiplexing dimension. This tendency and the need for miniaturization towards higher integration density chips, where devices become more polarization sensitive, requests an efficient manipulation of the polarization states. Components like polarization beam splitters (PBS), polarization convertors/rotators and polarizers are vital for building larger and more complex photonics circuits.

In this abstract a very short directional coupler – based PBS, designed for the InP Membrane on Silicon (IMOS) platform [1], is presented. Similar devices with comparable lengths have been demonstrated in Silicon On Insulator (SOI) [2]. The PBS deploys dissimilar waveguides which allows for a very short length. Extinction ratios (ER) from 18 to 25dB are calculated for the whole C – band (1530 -1560nm). The device's tolerance to fabrication errors is also investigated.

Operation Principle and Design

A directional coupler is one of the basic devices in integrated photonic circuits. It is based on the power transfer between two waveguides that are in close proximity so that their field profiles are overlapping. The coupling length L_c is defined as

$$L_c = \frac{\pi}{\beta_e - \beta_o}$$

where β_e and β_o are the propagation constants of even and odd system mode respectively. In this study, the directional coupler is comprised of a normal and a slot waveguide.

Slot waveguides [3] have been widely used over the last few years due to their unique property of guiding a considerable amount of TE polarized - light in the low index region (slot) due to the electromagnetic boundary conditions. On the other hand, TM polarized light sees a very small change compared to the normal waveguide, thus giving rise to a considerable geometrical birefringence. This can be used to obtain very short coupling lengths for the TE mode and relatively longer ones for the TM. Moreover, one should ensure that complete power transfer can be achieved by matching the propagation constants of the two waveguides for a certain polarization mode.

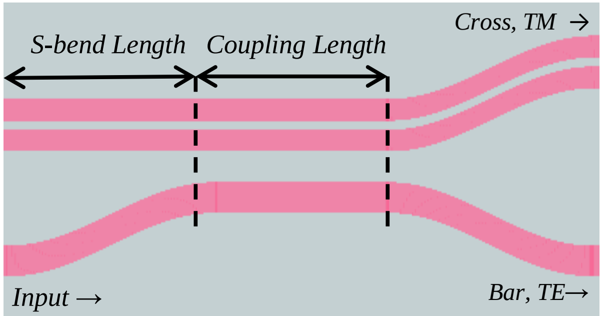

Fig.1. Passive PBS schematic – Top view

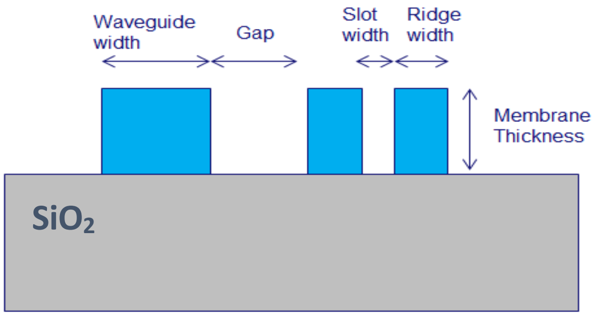

Fig. 2. PBS schematic – Cross section

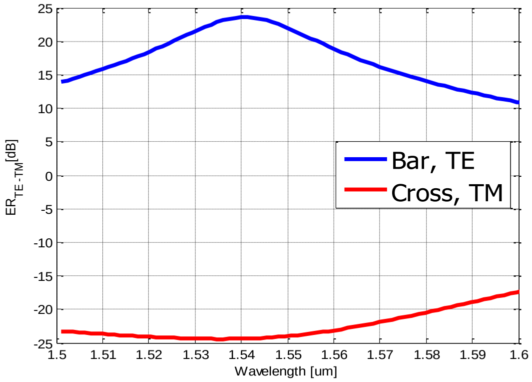

Fig. 3. ER as a function of wavelength

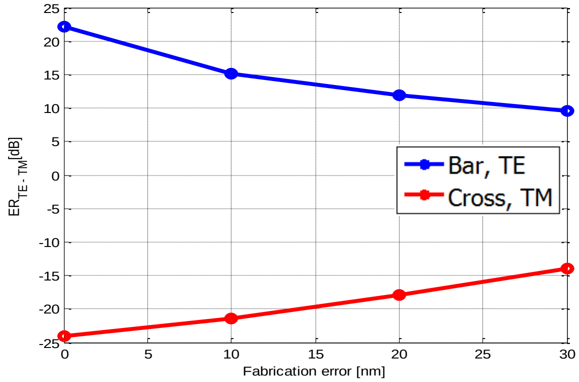

Fig. 4. ER as a function of fabrication error @1.55μm.

The PBS's top view and cross section are shown in Fig. 1 and Fig.2 respectively. Membrane thickness and waveguides' height are chosen to be 300nm as most of the devices of the platform are optimized for this thickness. As dissimilar waveguides are coupled, widths are chosen so that the effective indices of the two waveguides match. As expected, the TM mode is easy to match and it should end up in the cross state (odd number of crossings) while TE, which cannot be completely transferred, ends up in the bar state (even number of crossings). For this, the normal waveguide width is chosen to be 360nm and slot waveguide's ridges 265nm. The effective indices of the waveguides were obtained using Lumerical Mode Solver. The slot width is 100nm for fabrication feasibility and a relatively high confinement factor (~30%) of the TE mode in the slot region. The slot is filled with air. The gap between the two waveguides determines the coupling length for the two modes and it is 180nm. In this case, L_{TE} is 2.57um and L_{TM} is 5.4um thus $2L_{TE} \approx L_{TM}$. In practice the coupling length (Fig. 1) is somewhat shorter due to the contributions of the s-bends. The total length of the PBS is the sum of the coupling length and the 2 s-bends.

Results and Discussion

In Fig.3 the extinction ratios at the two outputs ports which are defined as *ER[dB] = TE [dB] – TM[dB]* are illustrated. For the simulations Lumerical FDTD commercial software was used. For the cross state and the whole C-band the ER remains above 20dB and for the bar state above 18dB. The small peak detuning originates from the fact that $2L_{TE} - L_{TM}$ is not exactly 0 but rather quite close and that s-bend contributions are not identical for both polarization states. Fabrication errors are significant for obtaining a similarly good performance in practice so an investigation into the PBS's tolerance is carried out. In Fig. 4 the ER is presented as a function of the fabrication error. The fabrication error here indicates the waveguides' width deviation from the design parameters. The offset is assumed to be positive. With a 30nm error (30nm wider waveguides) the ER is 10dB and 14dB for the bar and cross state respectively. This implies a good fabrication tolerance if waveguides are defined using Deep UV (DUV) optical lithography.

Conclusions

A 14um long PBS for the IMOS platform is proposed and simulated using FDTD simulations. The PBS exhibits high ER for the whole C-band and the fabrication error tolerance is shown to be reasonable for the IMOS platform. The structure can be used for polarization diverse applications with main advantages its short length, straightforward fabrication and good performance.

References

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