A Polarization Beam Splitter based on MZI-Structure

Ruiyong Zhang*, H.-G. Bach, R. Kunkel, K. Janiak, P. Runge, G. Zhou, A. Seeger and S. Schubert
Department of Photonic Components
Fraunhofer Institute for Telecommunications
Heinrich Hertz Institute
Berlin, Germany
*Ruiyong.zhang@hhi.fraunhofer.de

Sebastián Romero García, Alejandro Ortega Moñux, Robert Halir and Iñigo Molina Fernández*
Departamento de Ingeniería de Comunicaciones
Universidad de Málaga
Málaga. Spain
imf@ic.uma.es

***Abstract*—This paper describes a polarization beam splitter (PBS) based on Mach-Zehnder-Interferometer and fabricated in InP technology. The splitting ratio (SR) is better than 16 dB over the optical C-Band.**

Keywords-PBS; InP; Integrated Optics; Optical lithography

I. Introduction

To extend the data capacity for next generation networks quadrature phase shift keying (QPSK) modulation format and polarization multiplexing is adopted. Therefore PBS becomes a key component in integrated optical receivers. PBSs have already been realized with InP technology with different methods like directional coupler with metal overlay [1], Mach-Zehnder interferometer (MZI) integrated with polarization converter [2], or by modal birefringence of higher order modes [3]. In this paper, we present a PBS based on MZI-structure fabricated with a single optical lithography step. Our design does not require a polarization rotator like in [2], and we use waveguide widths to introduce birefringence rather than metal overlay as in [4].

II. Design and Fabrication

The schematic layout of the MZI-PBS is shown in figure 1. It is composed of two identical 2x2 multimode interference couplers (MMI) and two straight waveguides between the MMIs.

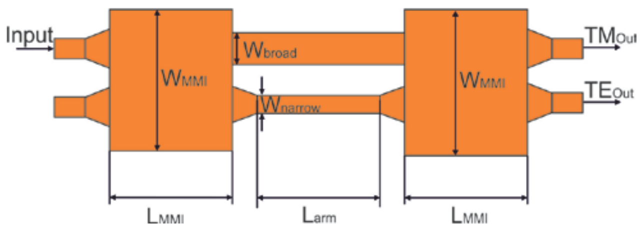

Figure 1. Schematic view of the MZI-PBS

The first MMI equally splits the input light into two straight waveguides with a phase difference of 90° for both polarizations. Subsequently, the arm length and widths are designed to achieve a 180° phase shift between TE and TM polarization.

$$\Delta\varphi_{TE} = k_0\,(N_{eff,broad,TE} - N_{eff,narrow,TE})\,L_{arm} = 0 \qquad (1)$$

$$\Delta\varphi_{TM} = k_0\,(N_{eff,broad,TM} - N_{eff,narrow,TM})\,L_{arm} = \pi \qquad (2)$$

Here, k_0 is the wave number, N_{eff} is the effective refractive index of the mode, L_{arm} is the length of the straight waveguides. The subscripts broad and narrow refer to the upper and the lower waveguides respectively. After the first MMI and the straight waveguides, the relative phase differences between the upper and the lower path are 90° and 270° for TE and TM, respectively. After the second MMI, TM polarization is eliminated in the lower output of the PBS and TE polarization is eliminated in the upper output.

The PBS is integrated on a semi-insulating waveguide layer stack being composed of three quaternary optical guiding layers embedded within InP and an upper thicker waveguide layer. The deeply etched rib waveguide was patterned using optical lithography and dry etching techniques. A fabricated PBS-chip is depicted in Figure 2.

The two facets of the chip are anti reflection coated against air.

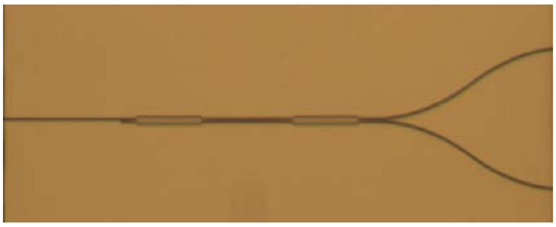

Figure 2. Top view of the fabricated chip

III. Measurements

After fabrication and anti reflection coating the PBS was characterized. A tapered single mode fibre was used for coupling the light into the chip. At the output side we used a collimator to couple the light into a measurement photodiode. The polarization of the input light was set to TE and TM separately. The splitting ratio was calculated from the photocurrent of the photodiode. The splitting ratios for the two polarization states are defined as follows:

$$SR_{TE} = 10 \log (I_{TE\_Out}/I_{TM\_Out}) \tag{3}$$

$$SR_{TM} = 10 \log (I_{TM\_Out}/I_{TE\_Out}) \tag{4}$$

where I_{TE_Out} and I_{TM_Out} are the measured photocurrents for the output TE and the output TM, respectively.

The measurement results (solid lines) for SR are depicted in figure 3 together with the simulated curves (dashed lines).

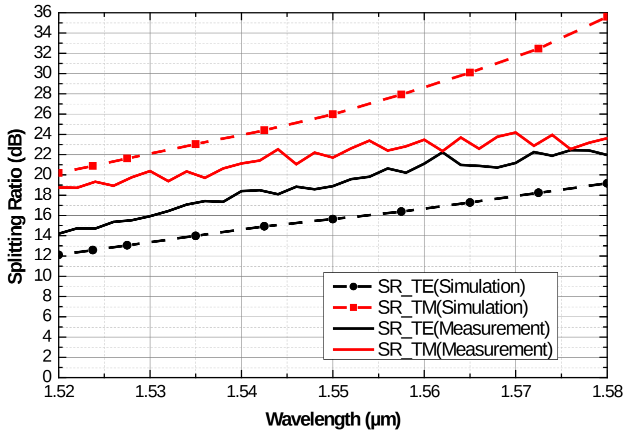

Figure 3. Simulated (dashed lines) and measured SR (solid lines)

Figure 3 shows that the splitting ratio is better than 16 dB over the optical C-Band for both TE and TM. The best value arrives at 22 and 24 dB for TE and TM, respectively. The saturation of the measured SR around 24 dB can be attributed to a limitation of the measurement setup. According to the measured dimension of the PBS using atomic force microscopy (AFM), a simulation was carried out, which indicates a reasonable agreement with the measurements. The measurement errors of the AFM could be attributed to the uncertainty between simulation and measurement.

The measured insertion loss is also calculated and depicted in figure 4. It is defined as follows:

$$IL_{TE} = 10 \log ((I_{TE\_Out}+I_{TM\_Out}) /I_{TE}) \tag{5}$$

$$IL_{TM} = 10 \log ((I_{TE\_Out}+I_{TM\_Out}) /I_{TM}) \tag{6}$$

where I_{TE} and I_{TM} are measured photocurrents as references without the PBS.

The relatively high insertion loss stems from the coupling loss between the tapered fibre and deeply etched straight waveguide. Although required for mode matching, we did not integrate a spot size converter to avoid any unwanted influence on the TE/TM loss difference.

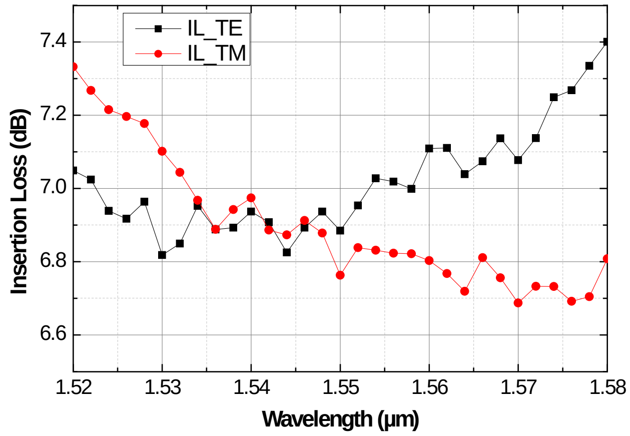

Figure 4. Measured inertion loss as a function of wavelength

Conclusion

We designed and fabricated a PBS based on MZI-Structure using different waveguide widths to get the necessary birefringence. The splitting ratio of the PBS achieved more than 16 dB over the optical C-Band.

Acknowledgment

The authors gratefully acknowledge contributions from their colleagues W. Ebert, D. Schmidt, R. Graulich and R. Steingrüber at the FhG Heinrich-Hertz-Institut, Berlin. We thank colleagues A. Steffan and J. Honecker from u2t for giving some helpful ideas. This work was financed partly by the EU project MIRTHE.

References

[1] Albrecht et al, “TE-TM mode splitters on InGaAsP-InP,” IEEE Photonics Technology Letters, Vol. 2, No. 2, Feb. 1990.

[2] Augustin et al, “A Compact Integrated Polarization Splitter_Converter in InGaAsP/InP”, IEEE Photonics Technology Letters, Vol. 19, No. 17, September 2007.

[3] J. J. G. M. van der Tol et al, “A short polarization splitter without metal overlays on InGaAsP/InP”, IEEE Photonics Technology Letters, Vol. 9, No. 2, FEBRUARY 1997.

[4] L. B. Soldano et al, “Mach-Zehnder Inteferometer Polarization Splitter in InGaAsP/InP”, IEEE Photonics Technology Letters, Vol. 6, No. 3, March 1994.