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Polarization Rotator with High Performance for Integrated Photonic Membranes

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Polarization diversity is important for the implementation of polarization-independent circuits [1], polarization division multiplexing [2], etc. Generally there are two kinds of polarization converters: those based on mode interference and those which rely on an adiabatic mode evolution [1]. In this contribution, we propose a polarization rotator (PR) device for InP-membranes on Silicon (IMOS) [3] based on adiabatic mode evolution that exploits the strong confinement of photonic membranes to operate with mode cut-off waveguides, i.e. single-mode single-polarization (SMSP) waveguides. This novel feature guarantees high polarization conversion efficiency (PCE), since the undesired polarized mode is cut-off. While most of the devices reported in literature focus only on achieving high PCE, our design achieves overall high performance, i.e. ultra-high PCE, negligible insertion loss (IL) and large bandwidth.

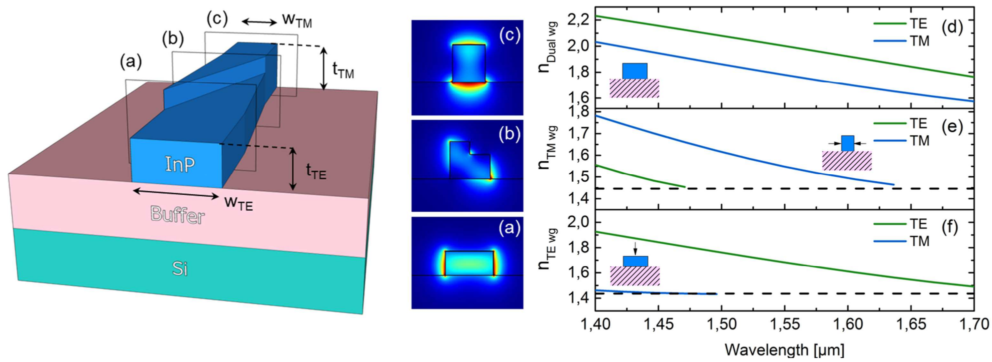

Fig. 9. Left: Schematic of the polarization rotator for IMOS. The insets show the mode profile (modulus squared of the electric field) at different cross sections for λ=1.55 µm. (a) Quasi-TE mode (b) Hybrid polarized mode (c) Quasi-TM mode. Blue: low intensity. Red: high intensity. Right: Effective mode index. The dashed line indicates approximately the mode cut-off limit (i.e. refractive index value of SiO_2). (d) Dual polarization waveguide with dimensions 400x300 nm² (e) SMSP TM waveguide with w_{TM} = 270 nm and t_{TM} = 300 nm (f) SMSP TE waveguide with w_{TE}=400 nm and t_{TE} = 200 nm.

Figure 1 shows a schematic of the polarization rotator. The buffer layer consists of a combination of SiO_2 and a 50 nm thick Benzocyclobutene (BCB) bonding layer. The rotator itself consists of an adiabatic transition that connects a SMSP transverse electric (TE) waveguide with a SMSP transverse magnetic (TM) waveguide. In a practical implementation, the rotator ports can be connected to a standard dual-polarization waveguide through adiabatic tapers that should be 15 µm long according to our 3D FDTD simulations (to guarantee >99.9% transmission).

Using a mode solver, we investigated the waveguide dimensions (width *w* and thickness *t*) required to get SMSP operation around 1.55 µm (see Fig. 1-right). As it can be observed in Fig. 1e, a 270 nm wide IMOS waveguide is cut-off for the TE mode, whereas it still supports the TM mode. Oppositely, a 200 nm thick waveguide is cut-off for the TM mode and supports only the TE mode as it is shown in Fig. 1f.

We also simulated the transmission from the SMSP TE waveguide to the SMSP TM waveguide and found that the rotator exhibits a constantly decreasing insertion loss, which is negligible (below 0.01dB) for a length of 40 μm (see Fig. 2-left). The inset shows the rotation from the TE-mode (injected at the left side) to a TM-mode. In Fig. 2-left, the polarization conversion efficiency is defined as PCE = $100 \cdot P_{TM}/(P_{TM}+P_{TE})$, where P_{TM} and P_{TE} are the power in the TE and TM modes, respectively, at the PR output. The insertion loss is defined as IL = $10 \cdot \log(P_{TEin}/P_{TE}+P_{TM})$, where P_{TEin} is the power in the TE mode at the PR input. A large bandwidth was obtained through broadband FDTD simulations, which is typical for adiabatic transitions (see Fig. 2-right). The rotator has a bandwidth larger than 180 nm for a length of 40 μm.

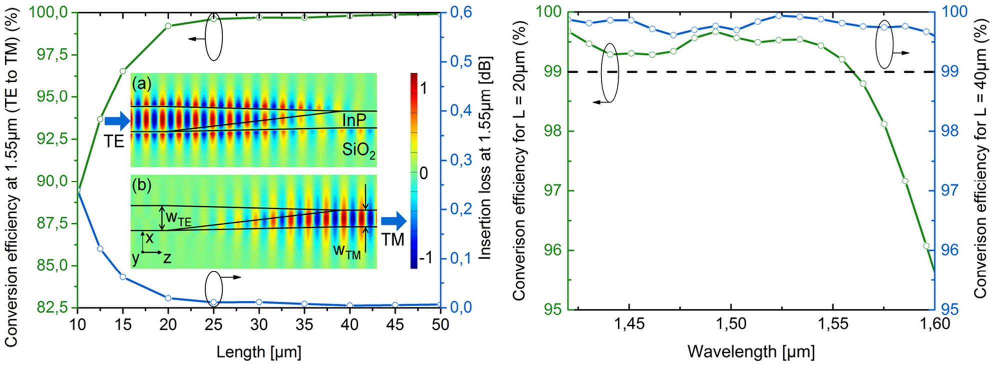

Fig. 10. Left: Polarization conversion efficiency and insertion loss as a function of taper length. The inset shows the cross section (top view) of a 10*μm* long PR showing the dominant electric field components (a) *Re*{E_x} and (b) *Re*{E_y}, during polarization conversion for λ = 1.55 μm. The color plots are in arbitrary units and the aspect ratio was adjusted for easy visualization. Right: Bandwidth of the PR device for a length of 20 μm and 40 μm. The dashed line indicates the level of *PCE* = 99%.

We proposed a polarization rotator for the IMOS photonic platform. The rotation is performed in an adiabatic transition between two SMSP waveguides. High efficiency up to 99.9% and negligible insertion loss over a bandwidth larger than 150 nm are predicted. The device fabrication is tolerant (not shown) and can be implemented in the same two etching steps required for passive components. To our knowledge it is the first PR design offering both, ultra-high PCE and negligible insertion loss.

References

[1] T. Barwicz, M. R. Watts, M. A., P. T. Rakich, L. Socci, F. X. Kartner, E. P. Ippen, and H. I. Smith, Nature Photonics 1, 57 (2007).
[2] D. Dai, J. Bowers, Nanophotonics 3, 4 (2014).
[3] J. van der Tol, R. Zhang, J. Pello, F. Bordas, G. Roelkens, H. Ambrosius, P. Thijs, F. Karouta, and M. Smit, IET Optoelectronics 5, 218 (2011).