Ultrashort Polarization Converter on InP/InGaAsP

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A compact, ultra short, integrated polarization converter has been fabricated using electron-beam writing and a combination of reactive ion and wet chemical etching. The conversion efficiency as a function of length and width of the polarization converter has been simulated and measured for TE and TM polarizations. The measurements and simulations are in good agreement. The conversion efficiency of 120 um long converter is more than 95% (up to 99%) at 1.55 um wavelength. The total length of the converter is 325 µm, which includes input and output tapers; this is half the length of the smallest InP/InGaAsP polarization converters fabricated till now.

Introduction

Polarization is a fact of life for planar integration of optical functions. Waveguiding, electro-optic effects, amplification and absorption all can differ between the two polarizations TE and TM. This is problematic, as many applications of photonic integrated circuits (PIC) are based on connection with standard monomode fibres, which don't preserve the polarization. So in general PICs should be designed to operate independent of the state of polarization. Solutions use until now are based on removing the polarization dependence in the components of the circuit, e.g. by changing waveguide and material properties [1]. This works for single components, but such an approach severely limits design options, which will lead to problem and sub optimal performance for larger circuits with more types of components.

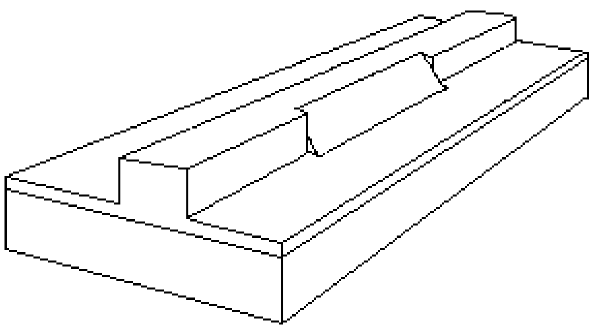

Fig. 1: Single section polarization converter based on an asymmetric waveguide

An alternative is to add polarization-manipulating components to the circuit, allowing to define the polarization in the circuits to match optimal performance in the components. This allows optimizations of the optical functions without restrictions from the polarization independence requirement. The essential component in this is the polarization converter (fig. 1), which can convert TE in TM and vise versa. As such it is the planar equivalent of a half wave plate. About 10 years ago the first passive planar polarization converters were reported, consisting of periodic asymmetrically loaded waveguide sections [2]. Then it was discovered that a very efficient conversion can be obtained with asymmetric waveguide cross-sections, having a straight and an angled side [3]. Length of these devices is important, since adding them to circuits should not lead to appreciable increase of chip surface needed. Very short devices with high conversion have been designed and made based on this idea, in a number of material systems [4].

In this paper we report on a polarization converter with very high conversion, which is, to the best of our knowledge, the shortest one reported until now. It is realized with electron beam lithography in InGaAsP/InP, the material system of choice for applications in optical communications. A similar device realized fully optically is reported in [5].

Design and realization

The polarization converter is designed in a layer stack consisting of a 600 nm thick InGaAsP (quaternary 1.3 micron) and a 300 nm thick InP toplayer on an InP substrate. The design (fig. 1) aims at high conversion, low losses and minimal length of the device. This requires an optimal choice of the width of the asymmetric waveguide (820 nm), its length (117 µm) and using tapers to connect to the 3-micron access wide waveguides. Simulations with the commercial waveguide solver FIMMWAVE predict that with an optimal design a conversion of better than 99% can be obtained with excess losses (due to coupling of the different waveguide sections of 0.5 dB. The final mask design contains variations of the 2 parameters that determine the operation of the converter: the width and the length of the asymmetric waveguide. Furthermore, to test the reproducibility of the results, every converter is repeated once.

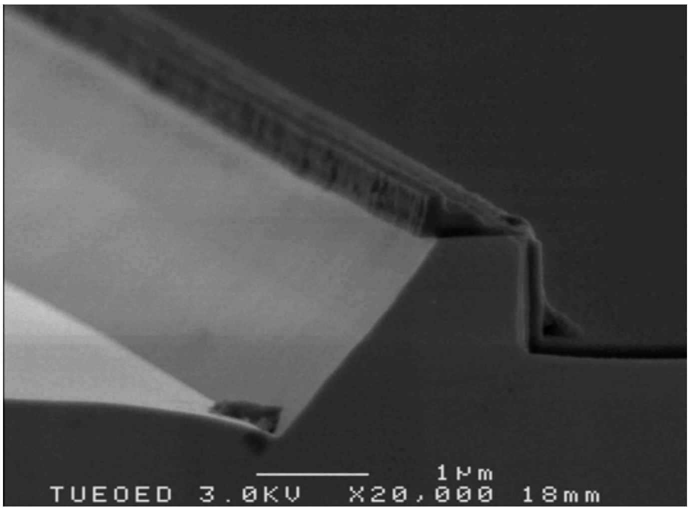

Fig. 2: SEM micrograph of the realized asymmetric waveguide. Remains of the etch masks are still present.

The realization of the converter is done in the layer stack described above, but with a deviation in the quaternary layer (1.25 micron), which has a thickness of 550 nm. Realization starts with depositing a 400 nm SiN-masking layer. Then the waveguide pattern is written in a PMMA resist with an Electron Beam Lithography (EBL), after which a Ti pattern is defined by evaporating Ti and lift-off. This is transferred into the SiN layer by a CHF_3 reactive ion etch (RIE). An extra Ti-cover is defined on the waveguide pattern with EBL, to protect the angled side of the asymmetric waveguide. The access waveguides and the straight side of the polarization converter are then etched in a CH_4/H_2 RIE-process, alternated w ith oxygen plasma to remove polymers []. In the final stage of the realization the Ti-cover is removed, and an opening window is defined in a new SiN-layer for the wet etch process (Br_2/Methanol) when the SiN layer protects all the previously etched parts. In this way the angled side is realized. A micrograph of the device is shown in fig. 2.

Experimental results

The performance of the polarization converters is determined in a transmission setup for a wavelength of 1550 nm. Losses are found by comparing the total throughput of the devices with that of straight waveguides on the same chip. Excess loss of the converters was determined in this way to be less than 2 dB. Simulations suggest that this loss is mostly due to couplings between different waveguide section (access waveguides, tapers, input and output waveguides and the asymmetric waveguide).

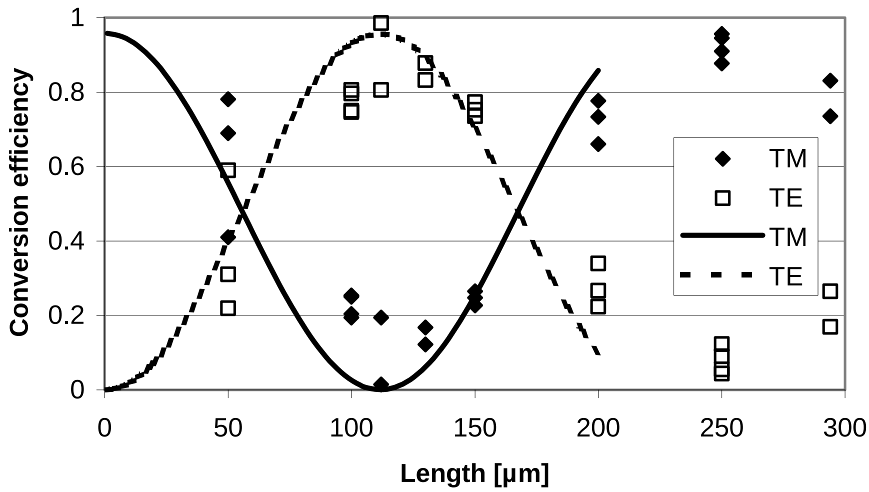

Fig. 3: For TM input, measured (marks) and simulated (lines) polarization conversion as a function of length, for a designed width of 820 nm.

Polarization conversion was measured by injecting a pure TE or TM signal into the devices, and than determine the optical output power in both the TE- and the TM-mode with an accurately oriented polarization filter. Results are given in fig. 3 as a function of length, and in fig. 4 as a function of width. For reasons of clarity only results for TM input are given; results for TE show the same behavior. It is seen that the highest conversion measured is 99%, for a design width of 780 nm and a length of 112 micron. This very high conversion is found in both converters with these parameters, and for both TE and TM input. Taking into account the length of the input and output waveguides and of the tapers for connecting to the access waveguides the total length for the converter is 220 micron, making it the shortest device ever with this functionality. The realized asymmetric waveguides show some underetch with respect to the mask patterns. This originated in the wet-etch process and resulted in a reduction of the actual width with 150 nm. Therefore the best conversion was obtained for a realized width of 630 nm.

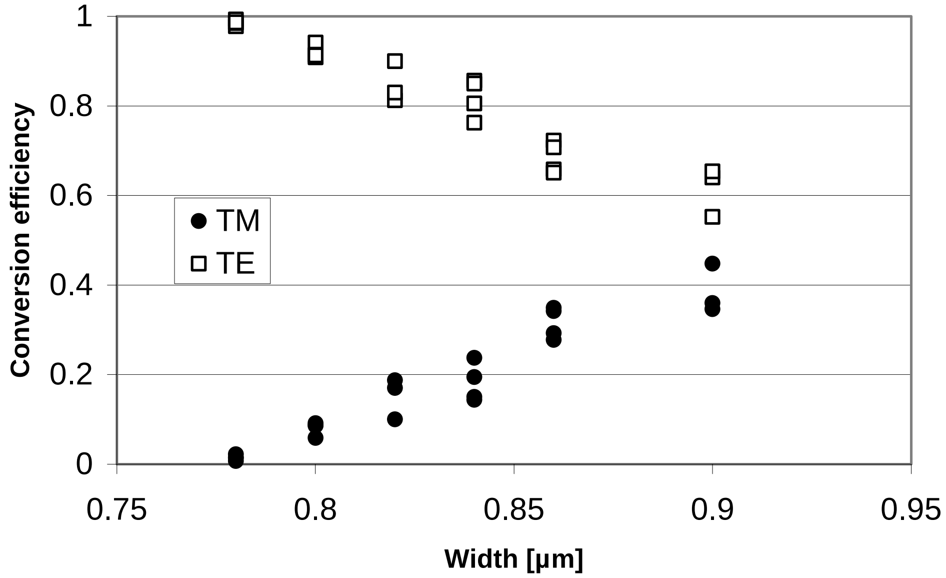

Fig. 4: Measured polarization conversion as a function of the designed width, for TM input. (Note that the actual realized width is 150 nm less than the designed width).

Discussion and conclusions

The results show that a very high conversion (99%) can be obtained in polarization converters, with losses that are acceptably low. This high conversion is found by using narrow asymmetric waveguides with an angled and a straight side. The width for optimal conversion deviates from the design value, probably because inaccuracies in the refractive index models used in the design and because of the different thickness of the quaternary layer.

In conclusion, a high performance polarization converter, the shortest ever reported, is realized. This device can be used for polarization manipulation in InP/InGaAsP based photonic integrated circuits, so that flexible solutions to polarization handling in these chips are now a feasible option.

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