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Tilted MMI based (de)multiplexer for monolithically integrated multichannel transmitters on InP platform

(Student paper)

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We present a wavelength (de)multiplexer based on a tilted multimode interferometer structure on the InP platform in O band. The device shows an average cross-talk of 13 dB and insertion loss below 9 dB. It presents a footprint of 0.09 mm^2 and a remarkable fabrication tolerance with a sensitivity to dimensional errors of < 110 pm/nm. The fabrication process is compatible with the integration of active components such as electrically modulated lasers.
Keywords: *(de)multiplexer, InP, integrated photonics*

INTRODUCTION

Wavelength division multiplexers (WDM) and (de)multiplexers are key building blocks for the monolithic integration of high-speed telecommunication photonic integrated circuits (PIC). They allow to achieve higher transmission capacity, by supporting the transmission of different wavelengths at the same time. The most common structure used for this component are the arrayed waveguide gratings (AWG) [1], where broad coarse wavelength multiplexing has been demonstrated [2]. Other structures have also been explored such as waveguide grating routers (WGR) [3]. These structures allow to have low crosstalk, low insertion loss and have been demonstrated on different material platforms such as SOI, Si_3N_4, etc [4]. However, their combination with high performance III-V lasers is challenging. On the other hand, the inclusion of passive components on InP platforms, offers the possibility to realize complex PICs, leveraging mature technologies available for high-performance active components (such as laser, modulators and amplifiers) [5]. Nonetheless, InP passive components, such as AWGs, have a considerable footprint and require high fabrication precision. In this work, we study a 5-channel (de)multiplexer based on angled multimode interferometer (AMMI) made on InP platform. The experimental results show a more fabrication tolerant component with a sensitivity to dimensional errors up to 110 pm/nm and gives the device with a compact footprint.

FABRICATION AND CHARACTERIZATION

The device was fabricated on a n-doped InP substrate, where the epitaxial layers were grown by metalorganic vapour phase epitaxy (MOVPE). The waveguide shown on Fig. 1 (a) consists of an optical guide layer of GaInAsP surrounded by two InP claddings. The fabrication starts with the deposition of a Si_3N_4 layer by plasma enhanced chemical vapor deposition (PECVD). The devices were defined by electron beam lithography, in order to guarantee high-accuracy on the definition of the waveguides. However, it is important to point out that the fabrication is fully compatible with a state of the art contact lithography. The pattern is transferred to the Si_3N_4 mask by reactive ion etching (RIE). The waveguides are deeply etched (3.3µm) using the Si_3N_4 mask on inductively coupled plasma (ICP) etching, with a $Cl_2/H_2/Ar$ gas. Finally, a passivation was made with Si_3N_4 to protect the surface of the structure.

Fig. 1 (b) shows the structure of the wavelength division (de)multiplexer studied on this work. It is based on a tilted multimode interferometer, with a multimode waveguide section width W_{MDW} varying from 19.5 µm to 20.5 µm, according to the wavelength desired to be extracted. The input and output 2-µm wide waveguides are tilted with respect to the main multimode waveguide's horizontal axis. For this study, it was chosen an angle of 7° for compatibility with the active components.

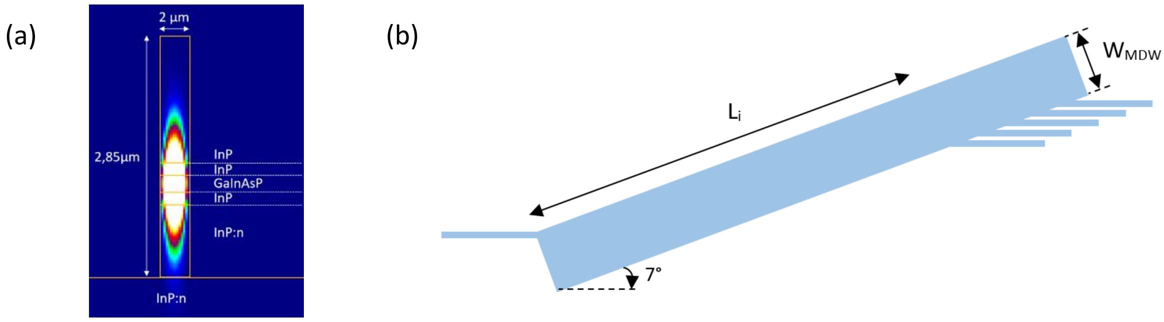

Fig. 1. (a) Waveguide cross-section. (b) Schematics of the angled MMI (de)multiplexer with five output channels.

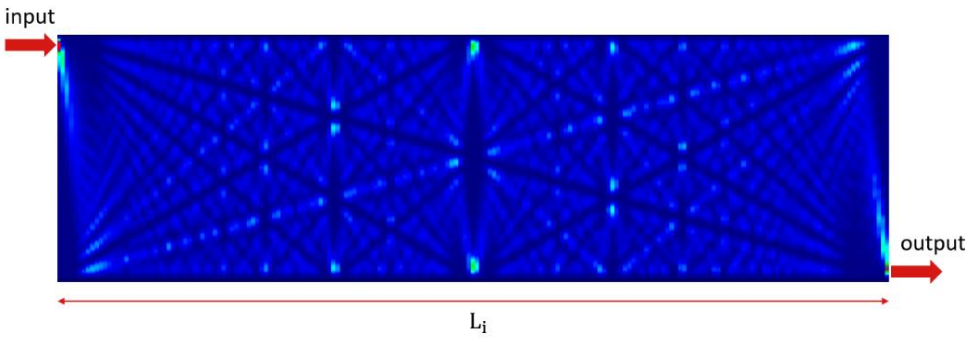

Fig. 2. Simulation of the multimode waveguide to determine the position of the channel for the wavelength desired to be extracted, TE polarization.

The output channels have a spacing of 20 nm. Their position L_i was calculated using the self-imaging condition of a MMI described at [4]. Then, it was precisely determined by simulation with FIMMPROP [6] as shown in Fig.2.

A SOA-based broadband source operating in the O-Band wavelength range (1260 nm – 1360 nm) was used to characterize the device in TE polarization. Then, both input and output facets of the device were coupled with lensed polarization maintaining fibers to keep control of the polarization state. Finally, the device transmission was recorded on an optical spectrum analyzer.

RESULTS AND DISCUSSION

A photograph of the fabricated device is shown in Fig. 3. The obtained device's footprint is as low as 0.09 mm^2. The bends used for access waveguides are implemented with high curvature radius (>1mm) to avoid radiation loss.

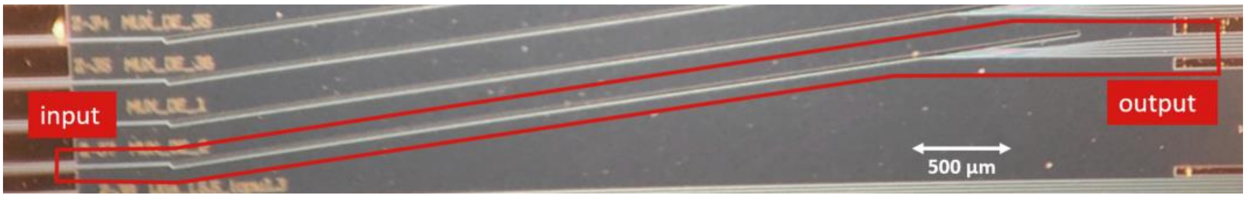

Fig. 3. Microscope photo of the angled MMI (de)multiplexer with five channels.

Different device configurations, based on different geometries, were studied. For each configuration, the width of the multimode waveguide (W_{MDW}) and the position L_i of the output channels are varied and optimized, based on simulation results. For all devices, an output channel spacing of 20nm was chosen. We present a configuration that allows having channels with output wavelength of 1290 nm, 1310 nm, 1330 nm and 1350 nm as shown on Fig. 4(a). The position of the transmission spectra for the design is in a good agreement with the simulation shown on Fig.4(b) and can be adjusted at will. An average cross-talk of 13dB and IL below 9 dB were obtained. IL can be further reduced by lowering waveguide propagation loss. In this particular case, the used deep etch waveguide technology was the limiting factor, with propagation losses >4 dB/cm.

The fabrication sensitivity ($\Delta\lambda/\Delta W_{MDW}$) of the device is around 110 pm/nm as evaluated experimentally by width variation implementation on the chip, as shown on Fig. 4(c) and makes it compatible with state of the art lithography. The tolerance to dimensional errors measured on this device is comparable to the tolerance measured on the SOI platform [7].

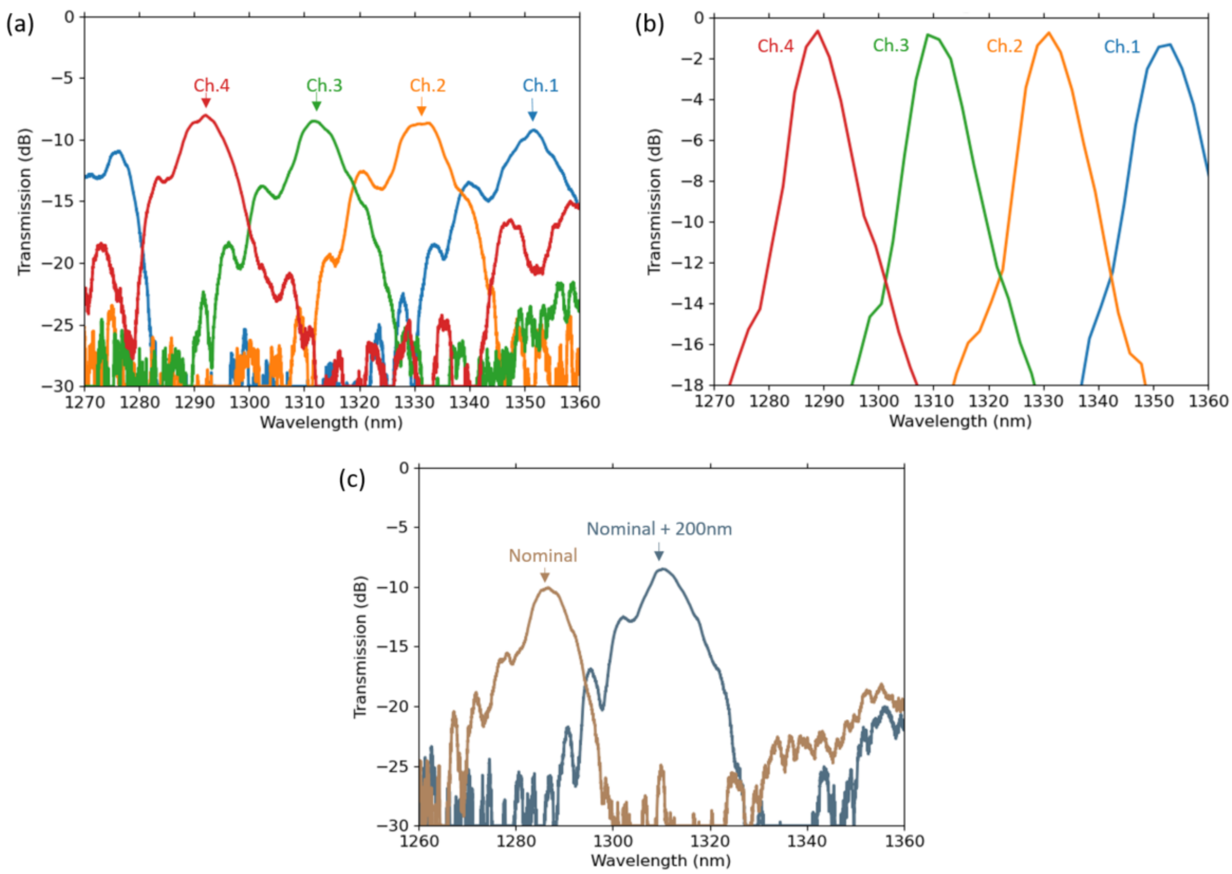

Fig. 4. Transmission spectra (a) measured and (b) simulated. (c) Transmission spectra measured showing the fabrication sensitivity.

CONCLUSION

In summary, we have designed and experimentally demonstrated an angled MMI (de)multiplexer in the O band on InP platform with IL below 9 dB, average crosstalk lower than 13 dB, high fabrication tolerance with a sensitivity to dimensional errors of <110 pm/nm and a footprint as low as 0.09 mm^2. This first result paves the way for the implementation of high performance multi-wavelength III-V transmitters.

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