

Introduction

The growing need of higher data rates over fiber optic communication link has created an interest in dense wavelength division multiplexing (DWDM), with the ITU channel spacing being reduced from 200 GHz to 100, 50 and 25 GHz. DWDM uses interleaver/de-interleaver devices to improve the performances at both transmitter and receiver ends. Using an interleaver (de-interleaver), every alternative channels or alternate bands of channels are (de-) multiplexed. We have demonstrated an integrated optical interleaver on a Silicon-on-Insulator (SOI) platform which can separate alternate ITU channels, with a channel spacing of 100 GHz across the entire optical C+L bands.

Device Description and Working Principle

The integrated optical interleaver can be realized by pair of coupled waveguide structures. It is basically consists of two input ports and two output ports - the internal passive waveguide circuitry has been described in Figure 1.

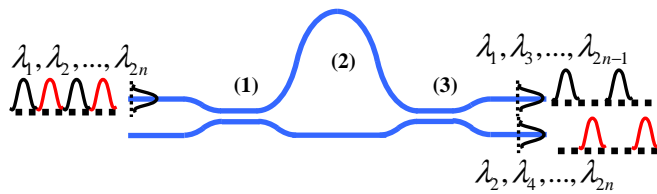


Fig. 1: Scheme of a Mach-Zehnder based 2×2 integrated optical interleaver: regions (1) & (3) are two wavelength independent power splitters, and region (2) is the un-balanced arms of the interferometer. The difference in length between the arms has been chosen as $\Delta l \sim \lambda_n^2 / (2n_{eff} \Delta \lambda)$, where $\Delta \lambda$ is the ITU channel spacing, and n_{eff} is the effective index of the waveguides.

The circuit is an un-balanced Mach-Zehnder interferometer where two directional couplers have been used as wavelength independent power splitters. The two arms of the Mach-Zehnder are identical single-mode waveguides (for C+L band), but unbalanced by a differential length of Δl . This differential length has been chosen such that the DWDM channels will interfere constructively or destructively, thus separating adjacent 100 GHz channels at the two output ports.

Fabrication and Experimental Results

The interleaver chip has been fabricated using commercially available optical grade SOI wafer (device layer = 5 μm). The device structure was photo lithographically defined by Cr-mask first and subsequently a controlled reactive ion etching process to obtain the require rib heights of the waveguides. The width of rib waveguide is 5 μm and the separations between the waveguides are kept at 2.5 μm in the coupling region. The device length comes out to be about 3 cm. The input/output ports of the interleaver are designed to be 250 μm

apart so that they can be fiber pigtailed with standard telecommunication fibers. The mode-size of guided light at the output ports have been measured to be $\sim 11 \mu\text{m} \times 5 \mu\text{m}$ ($\lambda = 1550 \text{ nm}$, nearly polarization independent) – which is very much close to that of standard single-mode fiber.

The waveguide loss and S-bend loss have been measured to be $\sim 1 \text{ dB/cm}$ and $\sim 1 \text{ dB}$, respectively. The interleaver was characterized by tuning the laser light (with 30 pm wavelength intervals, power = 5 mW, $\lambda \sim 1550 \text{ nm}$) launched at one of the input ports and measuring the transmitted powers at both the output ports (cross port and bar port). The typical wavelength characteristics measured at both the output ports have been shown in Fig. 2. It is evident that the device is acting as an interleaver for 100 GHz input channel spacing. The inter-channel cross talk was estimated to be $\sim 8 \text{ dB}$. The cross talk and overall insertion loss could be reduced by improved design of 3 dB power splitter, further process optimizations, and antireflection coatings at both end-facets.

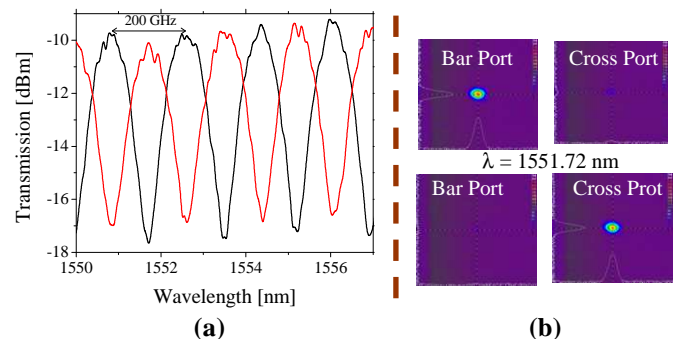


Fig. 2: (a) Transmission characteristics (part of C+L band) of an integrated optical interleaver chip fabricated using SOI substrate (TE-pol, $P_{in} \sim 7 \text{ dBm}$): black – bar port, red - cross port. (b) The intensity profile at output ports for two adjacent ITU channels separated by 100 GHz ($\Delta \lambda = 0.8 \text{ nm}$).

Conclusions

The integrated optical interleaver chip has been demonstrated in SOI platform using large cross-section single-mode rib waveguide structure for the first time. The device has been shown to be operating for ITU channels with 100 GHz channel spacing. The design parameters of the device has been standardized for fiber pigtailling and packaging.

More at <http://www.ee.iitm.ac.in/mems/iolab>

This work was supported in part by the Dept. of Information Technology, Govt. of India.