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SHORT COMMUNICATION

Design, Fabrication and Preliminary Characterisation of *Ti:LiNbO*$_3$ Directional Coupler Switch

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ABSTRACT

Titanium-indiffused lithium niobate directional coupler switch with $\Delta\beta$-reversed electrode structure is designed, fabricated and characterised. The fabricated 2 × 2 directional coupler has crosstalk of 4.8 dB at 1.31 μm transmitting wavelength.

Keywords: Titanium-indiffused lithium niobate waveguides, directional coupler switch

1. INTRODUCTION

Titanium-indiffused lithium niobate (*Ti:LiNbO*$_3$) waveguides and directional couplers are important components for fibre-optic communication systems and networks. With proper electrodes and material properties, these directional couplers can be used as integrated optic switches and modulators. In this paper, fabrication and preliminary characterisation of a 2 x 2 directional coupler at 1.31 μm transmitting wavelength are presented.

2. DESIGN LAYOUT OF SWITCH

The design layout of the 2 x 2 switch is as follows. The *Ti* strip width and gap between the waveguides are 6.3 μm and 3.1 μm, respectively, for Z cut *LiNbO*$_3$ directional coupler. The coupling length of the directional coupler with *Ti* film thickness 0.095 μm before diffusion is 1.7 mm for transverse-magnetic (TM) mode at 1.3 μm transmitting wavelength[1,2]. At the input and output modes of the directional coupler, *S*-type bends are used to accommodate single-mode fibres. The estimated bending loss for TM polarisation for 5 mm transition length and 100 μm offset is theoretically negligible[3]. $\Delta\beta$-reversed electrode structures are designed to control both the bar and crossed states of the switch[4]. The required mask patterns of the 6.3 μm wide waveguides and directional coupler switches have been designed and fabricated using electron beam pattern generator at Indian Telephone Industries, Bangalore. The electrode width, length, and metal thickness are chosen to optimise the stray capacitances.

3. FABRICATION & CHARACTERISATION

2 x 2 *Ti:LiNbO*$_3$ switch on *LiNbO*$_3$ substrate involves three steps in the fabrication process: (i) fabrication of *Ti:LiNbO*$_3$ waveguides and directional couplers, (ii) deposition of *SiO*$_2$ buffer layer to reduce the waveguide propagation loss for TM modes in the presence of metal electrodes, and (iii) aluminium electrode fabrication. Titanium metal is deposited on a cleaned *LiNbO*$_3$ substrate by electron beam evaporation unit (Varian, Inc). The deposition pressure and the rate of deposition are 10^{-7} mbar and 2Å/min, respectively. The deposited titanium

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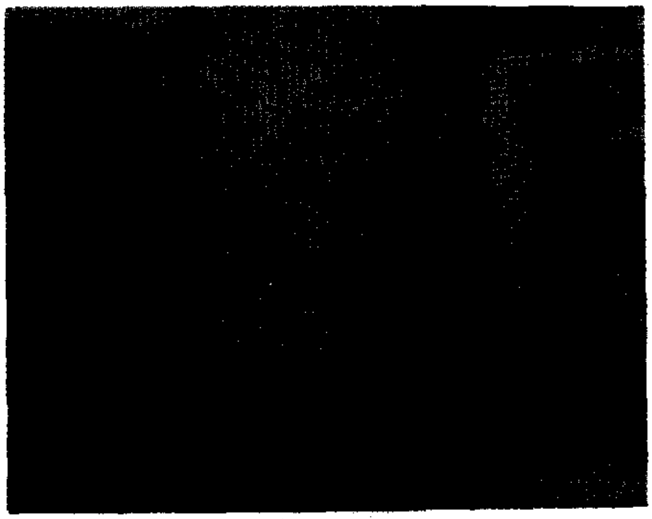

Figure 1. Fabricated 2 x 2 directional coupler switch

metal thickness was measured using a surface profiler, with an accuracy of ± 40 Å along the direction of propagation of the waveguides. Titanium metal diffusion was carried out in a horizontal diffusion furnace (Inotherm, Inc.) at 1050 °C for 6 hr. The fabricated directional coupler (Fig.1) was edge-polished and first coupled with a *He-Ne* laser of wavelength 0.6328 µm, and the output intensity distributions were observed using a 20x microscope objective and a 5x eyepiece. Finally, a laser source (Newport, Inc) of wavelength 1.31 µm with fibre pigtail was coupled, and the near-field optical intensity distribution along depth and lateral directions at 1.31 µm wavelength were measured using pinhole micrometer detector arrangement[5]. The measured mode profiles (of lateral mode width 6.2 µm and depth mode width 4.3 µm) ensure the single-mode behaviour of the fabricated waveguides at 1.31 mm wavelength for TM polarisation[6]. The propagation loss of the $Ti{:}LiNbO_3$ waveguide was measured and found to be 0.3 dB/cm at 1.31 µm wavelength.

The fabricated directional coupler was then covered with a SiO_2 film to avoid extra absorption because of metal electrodes. An aluminium film approx. 0.90 µm thick was deposited using thermal evaporation unit. The deposition pressure was 7 x 10^{-6} mbar and the deposition rate was more than 20 Å /min. The aluminium electrodes were formed by conventional photolithographic technique using positive photoresist. The output peak power ratio between the cross port and the bar port measured at 1.31 µm wavelength is 0.24 without applying any voltage, and 0.40 after applying 30 V. The increment of optical output in cross port is 33 per cent and the decrement of light output in bar port is 18 per cent. The crosstalk in the cross state of the directional coupler is 4.8 dB.

4. DISCUSSIONS

Two Z-cut $LiNbO_3$ samples have been processed simultaneously. In one, the waveguides are along X-axis, and in the other, along Y-axis. After diffusion it was observed that the inter-waveguide gaps of the directional couplers in two substrates are different. In one substrate, the diffusion coefficient along the lateral direction is much larger than in the other substrates and zero-gap directional coupler are formed which indicates that the diffusion coefficients along X and Y directions are markedly different. The crosstalk of the fabricated directional coupler switch having the same mask patterns can only be improved using Z-cut $LiNbO_3$ substrates of higher electrooptic coefficient and better edge-polishing facilities. Efforts to improve the device quality are in progress.

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