

Multifunction Integrated Optic Chip for FOG

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ABSTRACT

The Multifunction Integrated Optic Chip (MIOC) is an important component of the Fiber Optic Gyroscope (FOG) which is being widely used in inertial navigation systems for Aerospace applications. In this MIOC a 3dB splitter, phase modulator and polarizer are integrated onto a single chip. Lithium niobate (LiNbO_3) material has been chosen in the fabrication of MIOC because of its excellent electro optic properties. Proton Exchange (PE) technique has been used to fabricate optical waveguides supporting only single polarization mode.

Keywords: Proton exchange, MIOC, Lithium Niobate

1. INTRODUCTION

Lithium Niobate (LiNbO_3) is a very important electro-optic material with various nonlinear, acousto-optic and integrated optic applications. One of very attractive and convenient methods for fabrication of waveguides and devices in Lithium Niobate is proton exchange (PE). PE, which involves the replacement of Li^+ ion by H^+ ion, was first established by Jackel et al¹ in 1982. This process takes place when substrate is immersed in a melt of an organic acid at a suitable temperature (typically at temperatures in the range from 180 to 300°C depending upon boiling point of organic acid). It is reported that PE lead to an increase in the extraordinary refractive index of ~ 0.12 and decrease in the ordinary refractive index of ~ 0.04 at 633.0 nm in the LiNbO_3 ^{1,2}. It has been observed that PE waveguides offer advantages of higher index change, greater power handling capability and better polarization extinction ratio (i.e. supports only one polarization mode) over other known methods of fabrication. However, waveguides fabricated by PE technique have certain detrimental effects also; for example, it leads to a reduction in the electro-optic coefficient and increase in the propagation loss & refractive index instabilities. To overcome this detrimental effect and to produce single mode low loss waveguide that exhibit nonlinear optical properties comparable to bulk LiNbO_3 , post-exchange annealing is required. Post-exchange annealing offers several advantages of reduced fabrication complexity control of mode profile by changing shape of the index profile^{3,4}. In this paper, we report fabrication of Multifunction Integrated Optic Chip (MIOC) in X-cut LiNbO_3 using proton exchange process.

2. DESIGN & FABRICATION

MIOC consists of a polarizer, splitter and phase modulator as shown in Fig.1. It has been found that PE waveguide in LiNbO_3 itself works as a polarizer because it supports only one polarisation mode¹. Direction of propagation has been chosen in Y direction to make use of maximum electro optic coefficient (r_{33}) of the LiNbO_3 . The MIOC starts with an input channel waveguide followed by a splitter with waveguide width $6\mu\text{m}$. This value of waveguide width has been estimated using various parameters obtained from planar waveguide characterization⁵. The radius of curvature of the S-bend and length of the taper region has been optimized so that the losses are minimum. Electrode length of the phase modulator has been designed for V_π voltage to be less than 4.0 volt. Similarly, the electrode gap between electrodes and width of electrode has been optimized for maximum overlap between optical and electric field profile in the waveguide region. The output separation of the two arms of the MIOC is $250\mu\text{m}$ which is compatible for fiber pig-tailing with commercially available V-grooves.

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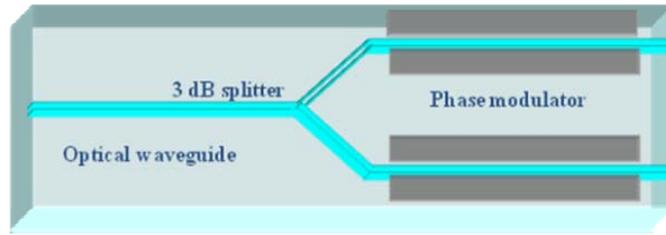


Fig.1: Design layout of the IO chip

LiNbO₃ wafer of Crystal Technology, USA has been taken as substrate for the fabrication of waveguides. We have chosen Y-axis as a direction of propagation on X-cut crystal for the reason explained earlier. After cleaning the substrate a thin film of titanium metal was deposited by E-beam coating system followed by coating of a layer of photo resist over the metal deposited substrate by spin coater. Subsequently, waveguide layer of the IO chip from the mask containing 3-dB splitters was patterned with the help of mask aligner followed by wet etching of titanium. After opening of the desired window by selective etching, the fabrication was carried out in the melt of benzoic acid at a temperature of 170-185°C for 130-135 minutes followed by annealing at a high temperature for 8-12 hours. This process results in the fabrication of splitters. Now, Ti/Au layer was coated on the processed wafer for making phase modulator. Finally, electrode structure was patterned from the electrode layer mask by lithography and etching of Ti/Au in their respective etchants.

Once the processed wafer is ready, they have to be separated in the form of individual devices. Individual devices were separate out from the processed wafer by dicing. Later end faces of the devices were polished for the efficient coupling of light. The edge angle of polished waveguide was chosen 8° to reduce the back reflection. For the fabrication of complete phase modulator, an electrical connection was given from electrode's pad of the device to alumina pad. Gold wire was used as conducting wire.

3. CHARACTERISATION

Fabricated phase modulator contains splitter and electrodes on the splitter arm. Splitters were characterized using end-fire coupling technique. The typical setup for end fire coupling is shown in the Fig. 2a, which uses manual X-Y-Z-θ-φ micro stages. This setup allows us to measure the loss & other modal characteristics of the waveguide devices. Near field scanning method were used for the measurement of mode field diameter and propagation loss of the device. Output port of the splitter was imaged with the help of microscopic objective and power was measured in both the output ports. The captured image of output from the splitter is shown in Fig.2b. The characterized devices were pigtailed with 1550 nm single mode PM fibers (FC/PC connectors at one end and silicon V-grooves at the other end). Motorized X-Y-Z-θ-φ micro stages and active alignment techniques was used for optimization before dispensing the UV curable epoxy on the fiber V-grooves. Fig. 3 shows the pigtailed device with V groove at input and output end.

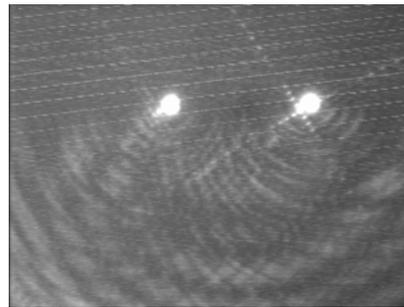
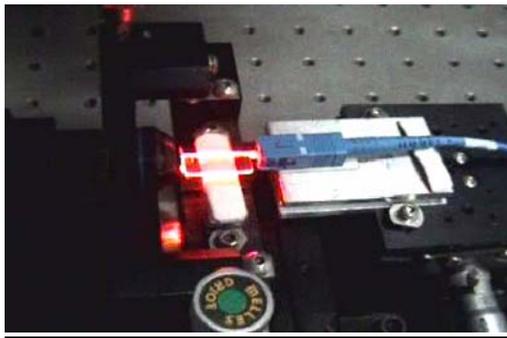


Figure 2 (a) End-fire coupling of splitter; (b) Output of the splitter

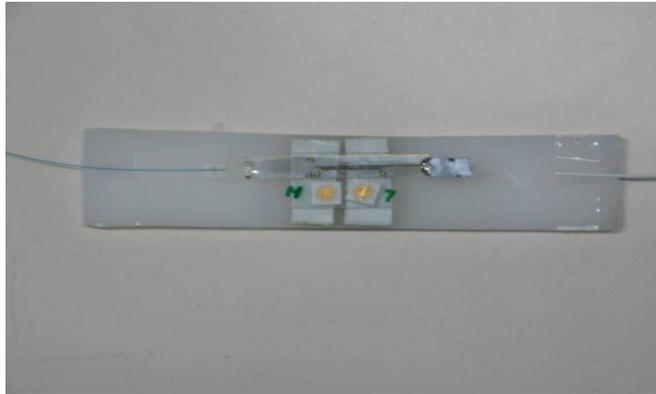


Figure 3 Image of the pigtailed chip

Various parameters of the device characterisation such as polarisation extinction ratio (PER), splitting ratio, Insertion loss and V_{π} voltage have been measured with the help of DFB laser diode, polarisation controller, polarizer, programmable RF generator, power meter and CRO as shown in Fig.4.

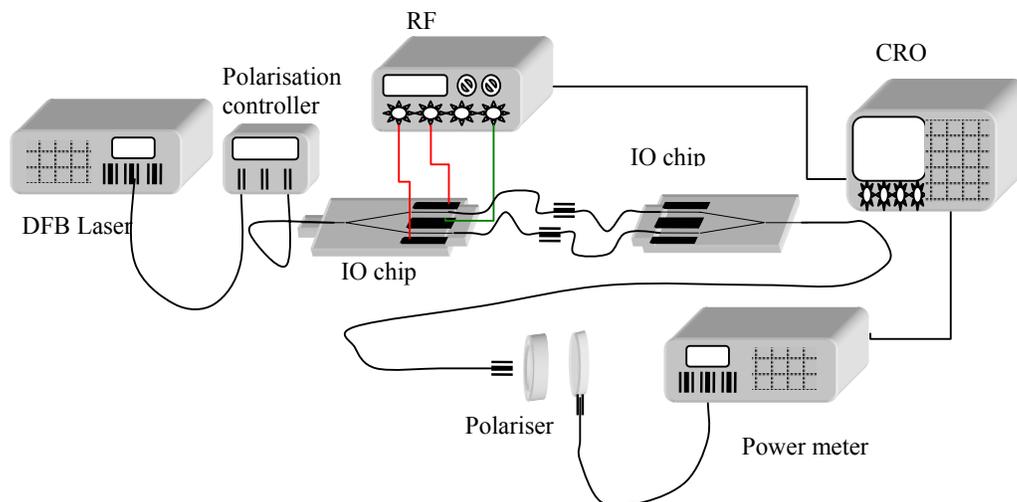
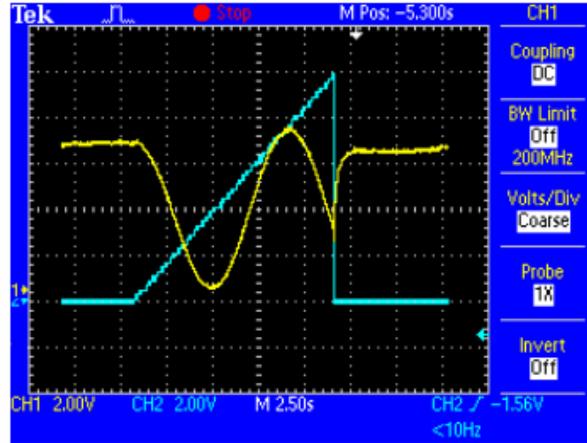


Figure 4 Schematic of the characterisation setup

For Intensity modulation & V_{π} voltage measurements, a ramp voltage from the RF source was given to device and the output was measured with the help of power meter interfaced with CRO. The variation of the power as function of ramp voltage captured by CRO is depicted in Fig.5. Intensity modulation & V_{π} voltage has been measured from the data obtained from CRO. Measured parameters are given in the Table 1.



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Figure 5 schematic of the characterisation setup

Table 1	
Measured Parameters of the MIOC	
Wavelength, μm	1.550
Insertion Loss(pigtailed), dB	~ 6.0
Splitting Ratio(pigtailed)	46 / 54
Polarization Extinction Ratio (Chip), dB	~ 35
Intensity Modulation, %	< 0.15
Half Wave Voltage(V_{π}), V	~ 3.5

4. CONCLUSIONS

We have fabricated MIOC by proton exchange process in X-cut LiNbO_3 using benzoic acid. Different parameters like Polarisation extinction ratio (PER), splitting ratio, Insertion loss and V_{π} voltage have been measured after pigtailed.

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