1×2 Digital Optoelectronic Switch using MZI structure and studying the Effect of Bi-Polar Voltage on Electrode

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Abstract—The electro optic switch has wide application in optical network due to capability of route the light path from one port to the desired port. In this paper, we propose a 1×2 digital optoelectronics switch based on mach-zehnder interferometer structure on a single titanium diffuse lithium niobate substrate. The design is simulate on BPM-cad simulator for switch analysis and study the effect of bipolar voltage 0v to ± 5.75v applied at 1st and center electrode region for switching. A short study of wavelength dependent switch for first optical window 8.5 µm and third optical window 1.55 µm has been simulated without use of voltage with changing titanium stripe thickness to 0.07µm.

Key words: Bipolar voltage, MZI, electro-optic effect

I. INTRODUCTION

In a modern communication network, switches are most important part of a network and in optical communication a switching in all light, means in optical domain is more important than switching in electrical domain i.e. conversion from optical to electrical and electrical to optical. With such a conversion the data transfer capability and speed of switching reliability is less. The speed of optical switches is necessarily has to match with currently new generation photonic devices in which light is not only carry information but also control the switching path is much important. The electro-optic effect is a change in optical properties of a material in response to electrical field that various slowly with compared to frequency of light. Speed of this effect is less than 1 ns. A 2×2 optoelectronic switch based on mzi structure and study the effect of electrode voltage has done in 2008 with switching voltage 0V to 6.75V at center electrode [1]. An electro-optic 3×3 switch based on integrated mach zehnder interferometer has introduced with switching voltage -8.0V to 8.0V [2]. A 4×4 banyan optical switch using optoelectronics mzi switches with low cross talk has introduced in 2009[3]. A 1×4 digital optical switch using Y structure has introduced in 2008 with switching voltage to 10V [4]. Various optoelectronics materials with various structures such as MZI, Y, MMI has been use to design Optical switch such as LiNO3, LiTaO3, InGaAs-AlGaInAs, photonic crystals etc. InP/InGaAsP Optical integrated MMI switches (shintaro et al., 2008) InGaAsP-InP MZI optical space switch (Agrawal et. al 1995) are some examples. A LiNbO3 can be doped with various dopants. Few among them dopants are titanium, iron, copper, magnesium oxide.[2] This paper propose a design of 1×2 digital optical switch based on mzi structure using titanium ion diffused in host lithium niobate substrate with low bipolar driving voltage ± 4.75V to ±5.75V for switching from one port to second port for a wavelength 1300µ in TM polarization. Ti- doped in the lithium niobate crystal increases refraction index which allows both TM and TE modes to propagate along the waveguides [7] after study the effect of bipolar voltage on electrode, we simulate our design for 8.55µm and 1.55µm wavelength with changing thickness of titanium stripe at 0.07 µm.

II. DESIGNING OF 1×2 DIGITAL OPTO-ELECTRONIC MZI SWITCH

The design switch allows switching directly in all optical domains avoiding conversion of E/O/E. This paper is oriented towards design of 1×2 integrated optical switch based on mach zehnder interferometer. The switch is created on z-cut of lithium niobate and surrounded by air cladding. The direction of z-cut is along the horizontal of the screen. The switch is oriented along the y-optical axis of lithium niobate and is perpendicular to the screen. Width of the waveguide is 8.0 µm and is along to the x axis of the screen. The crystal lithium niobate has a crystal cut along z-axis and propagation direction along y-axis. Air with refractive index 1.0 is use as a dielectric material. The whole device is constructed on 33 mm long and 100 microns wide. Waveguide is formed by diffusion of titanium ion on a host lithium niobate substrate at high temperature range from few hundred to several hundred Celsius. The thickness of titanium stripe before diffusion is 0.05. For higher wavelength say 1550µ operation, we can vary thickness up to 0.07 because Ti-doped in lithium niobate crystal increase refractive index which allows both TE and TM mode to propagate light along the waveguide which satisfied desired condition for optical signal parameter. The lateral diffusion length Dh constant and diffusion length in depth Dv is 4.0 and 3.5 micrometer respectively. The 3D wafer properties include air as a cladding material with thickness of 2 micrometer and lithium niobate substrate with thickness of 10 micrometer. The device has been created using opti bpm cad. An electrode region with three electrode set is defined on the wafer structure for controlling the light propagation to different port of the switch with buffer layer. Thickness of buffer layer is 0.2µm. vertical and horizontal permittivities of buffer layer are 4.0 respectively. The thickness of electrode is 3.0 µm. electrode are defined with three region with different parameter. First region has electrode with 10 micrometers width and 0V. Second electrode has 10 micrometer width and 0V. The gap between electrode 1 and 2 is keep 5 micrometer and gap between 2 and 3rd electrode is 5 micrometer. For Switching of light to port 1 to desired port we change the electrode voltage of 1st and center electrode from 0V, to +4.75V at first electrode and -4.75V at center electrode. The input plane is selected with...
mode as the starting field and 0.0 offset on z-axis. For simulation we set the global data with refractive index modal and wavelength 1.3 micrometer. The 2D property has set with TM polarization and 500 mesh points. We calculate 2D isotropic simulation.

### III. SIMULATION AND RESULTS

The complete design was stimulated in 2D using beam propagation method in opti bpm cad software. For simulation we set the global data with refractive index model and wavelength 1.3 micrometer. The 2D property has set with TM polarization, beam propagation method solver as a paraxial, engine with finite difference, scheme parameter 0.5, propagation step 1.5 and boundary condition TBC.

A switching operation was achieved by properly changing the range of various parameters and set it as shown in table 1.

<table>
<thead>
<tr>
<th>Output</th>
<th>Electrode-1</th>
<th>Center electrode</th>
<th>Electrode-2</th>
<th>Buffer layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port</td>
<td>W (µm) V (V)</td>
<td>W (µm) V (V)</td>
<td>W (µm) V (V)</td>
<td>W (µm)</td>
</tr>
<tr>
<td>1</td>
<td>10 0</td>
<td>26 0</td>
<td>10 0</td>
<td>0.2</td>
</tr>
<tr>
<td>2</td>
<td>10 +4.75</td>
<td>10 -4.75</td>
<td>10 0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Inter gap between 1st and center electrode: -5 (µm)
Inter gap between center and 2nd electrode: -5(µm)
Electrode thickness: ≈ 3(µm)

Table. 1: Specification of Electrode region and Switching Voltage

A propose 1x2 switch Design layout is design in opti bpm waveguide layout designer which is shown in figure 1. A switching voltage play an important role for gets desired output port. A desired light propagation for port 1 is achieved by biasing voltage at 0V for all electrode regions. And for port 2 is achieved by biasing voltage +4.75V at electrode 1 and -4.7V at center electrode region. As shown in Fig. 2 and 3.

Figure 4. Shows the refractive index slice for xz slice after simulation.

Plot of normalize Power versus change in bipolar biasing voltage at electrode region 1 and center electrode is shown in Figure 5 and 6 for port 1 and 2.
As the biasing voltage from 0V to increase we can see that power decrease for port 1 and after ±3V biasing voltage light propagate form port 1 to port 2 and switching done. As the biasing voltage increase form ±5V power decrease and also coupling efficiency too. So for reliable switching we chose biasing voltage between ±4.75V to ±5.75V. The simulation results show good performance for this structure. The insertion loss (I.L.) [2] is the important parameter for the optical switching. The our propose design has I.L. -0.016db for port 1 and -0.020db for port 2 which is less and acceptable.

IV. SIMULATION FOR WAVELENGTH DEPENDENT SWITCH

As the years goes the demand of internet is growth with exponential growth in bandwidth as increasing number of users in multimedia applications and scientific computing, academic institutes, military. As a result of wavelength division multiplexing technology, the number of wavelengths per fiber has been increased to hundred or more with each wavelength operating at rates of 10gbs or higher [6]. It is expected that the traffic carried on fibers at each node in WDM mesh network will soon approach several terabits per second. Switching such a huge amount of traffic electronically becomes a very challenging, due to both the high cost of optical-electronics-optical conversion [6]. In the propose design wavelength 8.0 – 7.0 µm for port 1 and wavelength 1500 - 1550 µm used switch port 2. A proposes switch design layout is shown in figure (7)

In design layout we can see that electrode region for wavelength dependent switch has been not show because here we get switching based on wavelength. For get proper switching we change the thickness of titanium stripe at 0.07 µm. we simulate our design in opti bpm cad.

After simulation we have observe the light propagation for wavelength 0.8µm to a fix output port 1. And light propagation for wavelength 15 µm to a fix output port 2 as shown below Fig. (8) & (9).

Above Fig 8 shows that light propagation for wavelength 0.85µm at fix port 1. And Fig. 9 shows the light propagation for wavelength 1.5µm at fix port 2

The graph plotted with relative filed strength and the effective refractive index of the waveguide with the width of the wafer size used in the switch architecture shown in below Fig. 10 & 11.
V. CONCLUSION

The 1×2 Digital optoelectronics switch using Mach Zehnder structure has been designed and simulated for light switching to desired port by ±4.75V biasing voltage at 1300µm wavelength with TM polarization. Coupling efficiency of the 1×2 digital optical switch can be controlled by changing the electrode voltage. When no biasing voltage applied to electrode the coupling efficiency is almost equal to 100% and when biasing voltage applied the coupling occurs and by electro-optic effect we switch the light propagation to desired port. The future proposes work is to design a switch for high wavelength and independent polarization i.e. both TM and TE polarization with less losses. In a wavelength dependent switch we observe the switching with 0.85 µm for fix output port 1. And for 1.5 µm wavelength at fix output port 2. So we can use this switch as a wavelength de-multiplexer.

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