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DESIGN OF OPTIMIZED ALL-OPTICAL XOR GATE USING PLASMONIC WAVEGUIDES

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ABSTRACT

Most of the physical quantities are analog. We need to convert analog to digital, to transmit the data. This needs much hardware to operate. So, in optics data transmission is possible with high speed. Optical gates are extraordinary applications in ultra-high-speed Boolean operations and logical computation. The limitations in electronics are overcome by all-optical integrated circuits which have the potential for high-speed computing and information processing. An all-optical XOR gate using a metal-insulator-metal waveguide is proposed and designed. The analysis of the device was performed by using the finite-difference time-domain method and results have been verified in MATLAB simulation.

KEYWORDS: Kerr Material, Mach-Zehnder Interferometer, Finite difference time domain.

1. INTRODUCTION:

The scenario of present days is drastically changing the several developments in communication technologies is achieved by the development and implementation of all-optical components like logic gates and other combinational and sequential circuit elements[1-3]. All-optical components overcome the drawbacks of conventional semiconductor technology like power dissipation interconnection delays. To achieve excellent signal transmission and signal processing optical circuits are providing promising solutions. Photonics also lags due to the diffraction limit have become more vulnerable and the size of devices becomes very small or close to the operating wavelength. The solution to the above-mentioned problem is to overcome the drawbacks of electronics and photonics is overcome by the Plasmonics. The plasmonics is capable of alleviating the diffraction limit by exploiting the properties of surface plasmon polaritons(SPPs) which are bound at the interface between the metal and dielectric[4].

There are various SPP-based waveguides are demonstrated and proposed in recent times like metal-insulator-metal (MIM) and insulator-metal-insulator waveguides. Among these MIM waveguides are mostly preferred due to the ability of confinement of light to deep sub wavelength scale which leads to functionality at the nanoscale[5]. IMI has much longer propagation than MIM waveguides. In this paper, we are proposing the design of an all-optical XOR gate based on MZI with nonlinear Kerr material in one of the arms in the MZI[6-8]. The present work is based on the Mach-Zehnder Interferometer and it is proposed using the metal-insulator-metal (MIM) waveguide. The current work proposes an XOR gate structure. This XOR gate is designed only with is used only the two MZI's and MIM type of waveguides has been chosen due to its ability to route the optical signal at the nanoscale. Here in this design, we are primarily proposing MZI[9]. Thereafter we will propose an XOR gate.

The motivation behind this research on plasmonics is the properties like it has high switching speed, power consumption, and low electromagnetic interference[10-14]. These properties are handy to attain better transmission and processing optical devices have good prospects to give promising solutions.

The major phenomenon in directional couplers and linear waveguides combined proposed a Mach-Zehnder interferometer among them one of the linear arms is filled with nonlinear Kerr material[14-17]. So, We call it a nonlinear MZI, Which has several applications in the optical domain. In this paper, we are proposing an XOR gate using nonlinear MZI within the footprint of 46.2μm*8.88μm and in this design, we have used the MZI of 18.1μm*2.4μm.

Previously some MZIs are already proposed but in this design, we got a miniature size of MZI and it has nonlinear optical Kerr material is used to change the refractive index of the waveguide[18].

2. DESIGN OF MZI

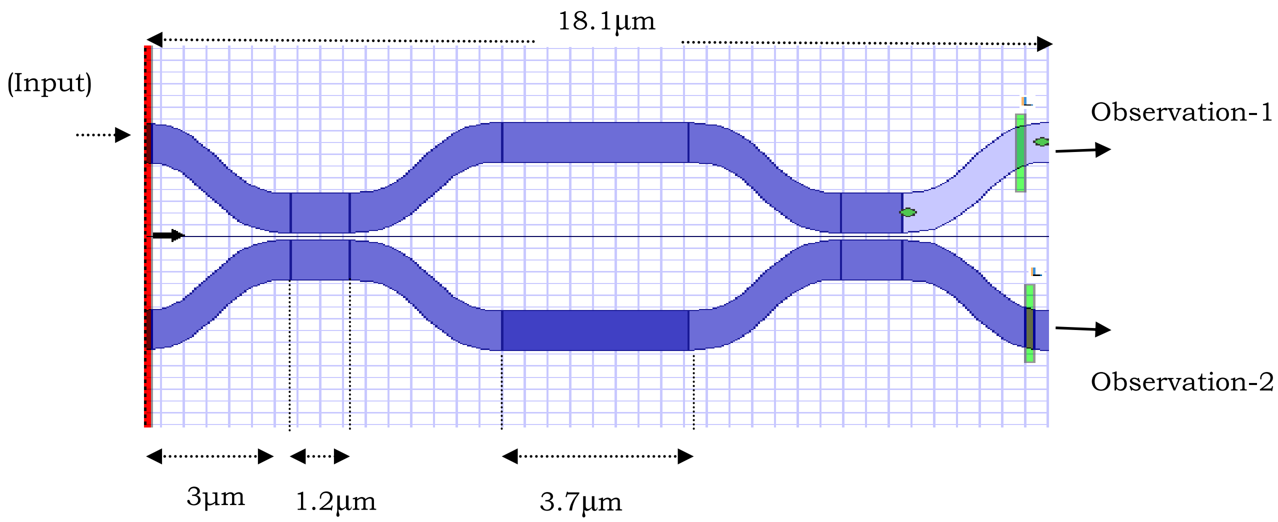

Figure 2: Design of MZI

The basic optical device used for switching of light is Mach-Zahnder Interferometer. And it has been used to a great extend for developing the various gates. The Mach-Zahnder Interferometer is designed in the length of 18.1μm and width is 2.4μm. In this we got a miniature size and it has nonlinear optical kerr material is used to change the refractive index of the waveguide. When it gives the low intensity power it goes through the observation-2. And when it gives the high intensity power it goes through the observation-1.

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3. DESIGN AND WORKING OF ALL OPTICAL XOR GATE:

The XOR structure is designed using the metal-insulator-metal waveguides which helps the plasmonic modes. Which we are using three MZIs to introduce the XOR gate. The total length of the XOR gate is 46.2µm and the length of MZI is 18.1µm. The proposed design is operated at 1.55µm is connected to the first and second input ports of MZI1 and MZI2 respectively, and these two MZIs are connected to the third MZI. The output will be propagated to the input of the third MZI and it is attained from the second port of MZI3.

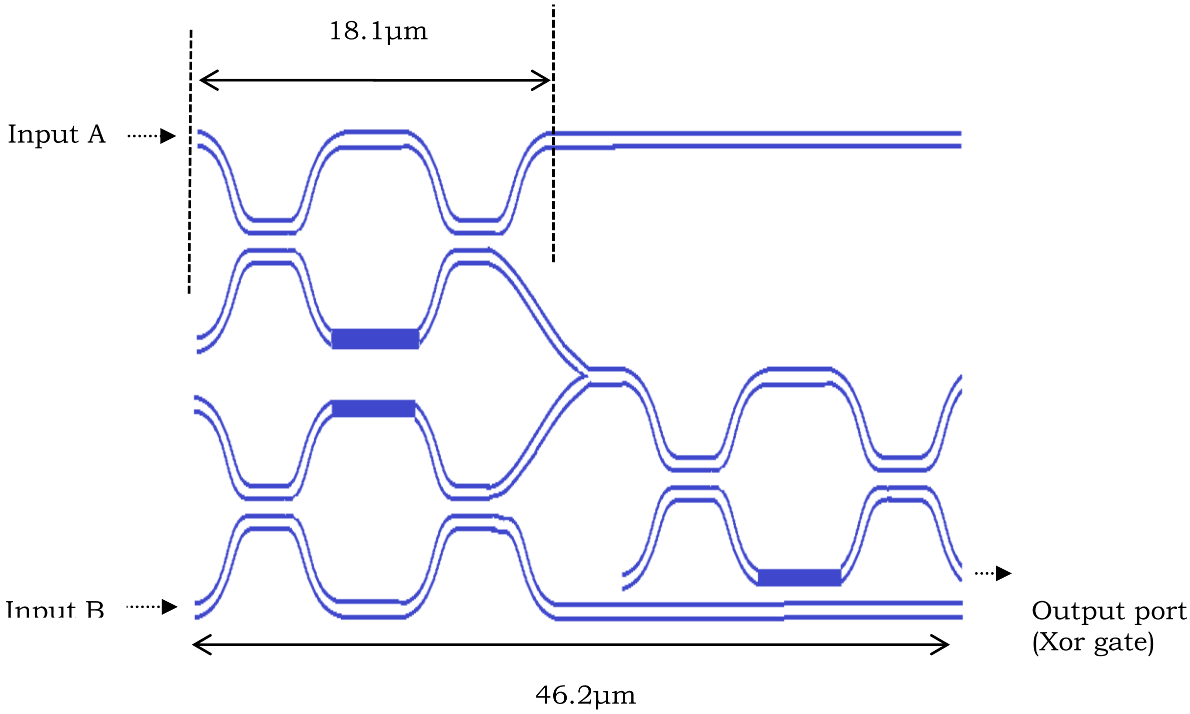

Figure 3: Design of XOR gate using MIM Waveguide

Input-A	Input-B	Output-Y
0	0	0
1	0	1
0	1	1
1	1	0

Table 3: Truth table of Xor gate

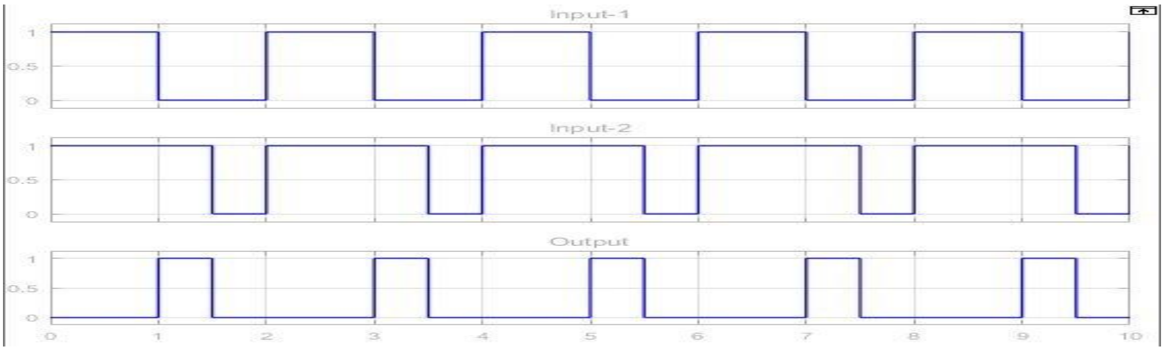

Figure 3.1: Timing diagram of XOR gate obtained from MAT lab

Input field Traverse	Gaussian
Wavelength	1.55μm
Polarization	TE(transverse electric) mode
No of mesh cells X	193
No of mesh cells Z	745

Table 3.1: Specifications of Xor gate

Parameter	Specifications: Plasmonic
Wafer dimension	L=46.2μm, W= 12μm, thickness=0.5μm
material	Kerr material
Cladding material	Air
Channel profile	Dielectric material (RI=2.5)

Table 3.2: Parameters of the design

S No	Parameter	Design of XOR gate
1	No of MZI's	3
2	Size	46.2μm * 8.88μm

Table 3.3: Parameters of the design

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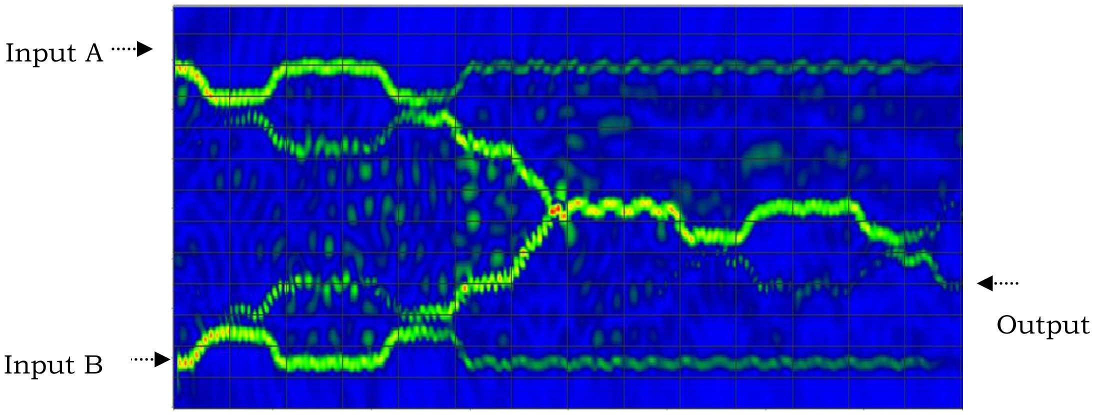
4. SIMMULATION RESULTS AND DISCUSSION

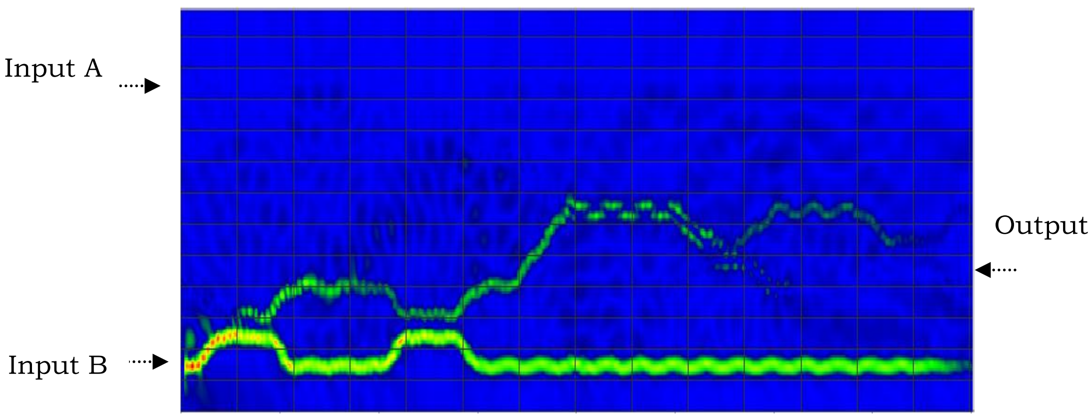
Case 4.1: 00(Input 'A' low, Input 'B' low)

In this case, giving low-intensity signals as 0.01w/µm. The signal is passed through MZI1 and MZI2 given two signals merged and combined into the third port of MZI and passes through an output of MZI the output will be observed through simulation which we will give the low signals to the two ports of the two MZIs then it will give the low power signal to the output port of the third MZI. This is the output of the XOR gate. In the XOR gate, when we give a low power signal then it gives the low power signal as the output, which we can observe in the simulation.



Case 4.2: 01(Input 'A' low, Input 'B' high)

And in this case, we are giving the first MZI as low intensity power signal and for the second MZI we are giving high power signal. At low signal, it arrives at the desired output port of MZI3 by obeying phenomenon of the constructive interface. Hence output is obtained at output port of XOR gate which is complement of the input(A).



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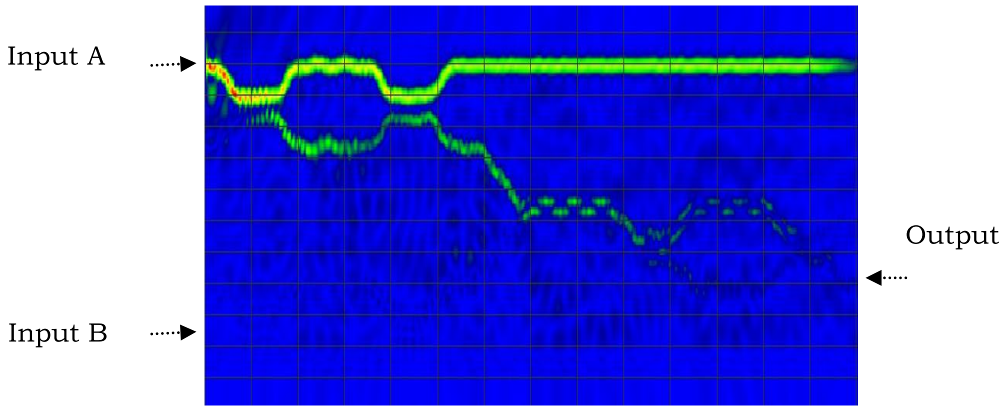
Case 4.3: 10(Input 'A' high, Input 'B' low)

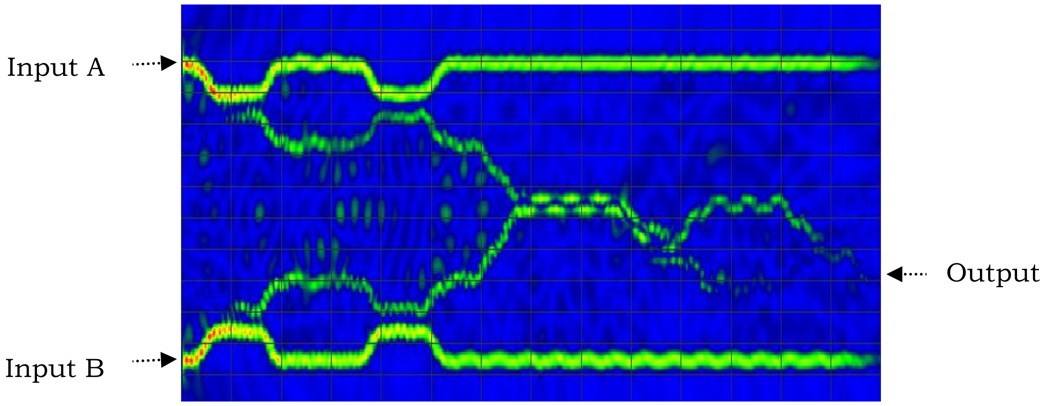
Here, we are giving high power signal to the first MZI input port and the low power signal to the second MZI input port. Due to the low power signal, it goes to second output port of MZI3, which gives the high normalized power, which is the output of the XOR gate.



Case 4.4: 11(Input 'A' high, Input 'B' high)

Here in this case, input of MZI1 and input of MZI2 are giving as high intensity power signal, and the two output signals of the two MZIs propogated towards through port of the same MZI. Which there is no signal at desired output port of the XOR gate.

So, finally it is concluded if one of the input is low power signal and another is high power signal then it is obtained. So, it is the XOR gate.



S No	Inputs		Normalized Power
1	0	0	0.047
2	0	1	0.46
3	1	0	0.49
4	1	1	0.027

Table 4.1: Normalized Powers

SNO	Parameter	Formula	Output
1.	**Extinction ratio**	**10log (Pout/Poff)**	**21.7dB**
2.	**Insertion loss**	**10log (Pout/Pin)**	**2.1dB**

Table 4.2: Parameters

CONCLUSION:

In this work, we designed an optimized XOR gate design using Plasmonic-based MZI. By using only three MZI's the size of the design decreases so it can be more suitable for chip fabrication and increases the packing density. So, we can manufacture each component in a small size. The design is stimulated through the FDTD design and it is verified through MATLAB.

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