Design of Optimized All-Optical NOR Gate using Metal-Insulator-Metal-Waveguide

Srinivash Roula[1] | Potturi Srinivas[2] | Mannem Yaswanth[3] | Manthina Benarjee Sriram[4] | Vundavalli Mehar Karthik[5]

[1,]Assistant Professor, Department of Electronics and Communication Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India
[2,3, 4, 5]UG Students, Department of Electronics and Communication Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

Abstract: In this work, an optimized NOR gate using a plasmonic-based Mach-Zehnder Interferometer (P-MZI) is suggested. A metal-insulator-metal waveguide structure is used in the design. It can be used for fast switching in the devices like integrated circuits. The proposed design uses the minimum no of P-MZIs, and also it uses the 1.5μm wavelength. The size of the device is 24 x 8 μm, which is very small compared to earlier designs. The NOR gate design is evaluated in the OptiFDTD software, and the proposed design is analyzed.

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

Check for updates

DOI of the Article: https://doi.org/10.46501/GIETEC12

Available online at: https://ijmtst.com/icetee2021.html

As per UGC guidelines an electronic bar code is provided to seure your paper

To Cite this Article: Srinivash Roula; Potturi Srinivas; Mannem Yaswanth; Manthina Benarjee Sriram and Vundavalli Mehar Karthik. Design of Optimized All-Optical NOR Gate using Metal-Insulator-Metal-Waveguide. *International Journal for Modern Trends in Science and Technology* 2021, *7*, pp. 66-70. https://doi.org/10.46501/GIETEC12

Article Info. Received: 18 May 2021; Accepted: 25 June 2021; Published: 30 June 2021

INTRODUCTION

In our present world, we need electronic devices which perform the operation in a fast manner. Semiconductor devices are vulnerable to many factors like heat dissipation and low packing capacity. The signal delay is also a drawback in electric signals. As the universal logic gates are implemented by lithium-niobate (LiNbo3) and Mach-Zehnder Interferometer structure but it is having a high amount of driving current in the circuit. As it is having a greater number of drawbacks and design issues, there will be an increase in the size of the Design, but by this, it does not suitable for future applications. As an increase in size, also cost increases, then it is unreliable for use. So, this optimized Design is used for high-speed performance in the integrated circuits. The optical signal is used as an information signal by improving its frequency. This optical signal is used as input in the Design, and it is given at the two ends of the MZI 's. It brings the signal to not get in the metal-insulator-metal waveguide structure (A.Singh, 2019).

The Design of the NOR gate is of 24*8µm dimensions. Has the two MZI's are placed and combined to get the valid NOR gate output. The MZI structure is the most suitable one for designing the NOR gate using a metal-insulator-metal waveguide. The transverse electric field and the wavelength of 1.55µm are used for working of the design in a correct manner. As the light is passing into the waveguide structures and this is made possible by the surface plasmons and also by their unique features. There is a drawback in surface plasmons due to their loss inside the surface plasmons, and it is overcome by the metal-insulator-metal waveguide structure. So, in this Design, the waveguides having the capability of navigating the light signal at a smaller wavelength.

The Design is based on the Mach-Zehnder Interferometer (P-MZI), and it is proposed using the metal-insulator-metal (MIM) waveguide. The current work proposes optimization of an area in the NOR gate structure. This design is used only the two MZI's, and MIM configuration has been chosen due to its ability to route the optical signal at the nano-scale. The results have been discussed to support the proposed Design in this Design; we have S-band and linear waveguide with different sizes. With these waveguides, we designed a directional coupler that splits the light into different paths and also combines the light into a single path. We have chosen two different materials, and this will decide the propagation of light through the Design with the desired output. In this Design, we have a two-directional coupler, and it is joined through a linear waveguide of a different material. The inputs 3*e□ W/m and 0.7*e□ W/m are considered as the high and low inputs, respectively. The input-A is applied to MZI-1 and at the first input port of the Design. The input-B is applied to MZI-2 and at the second input port of the Design (Santosh Kumar, 2016).

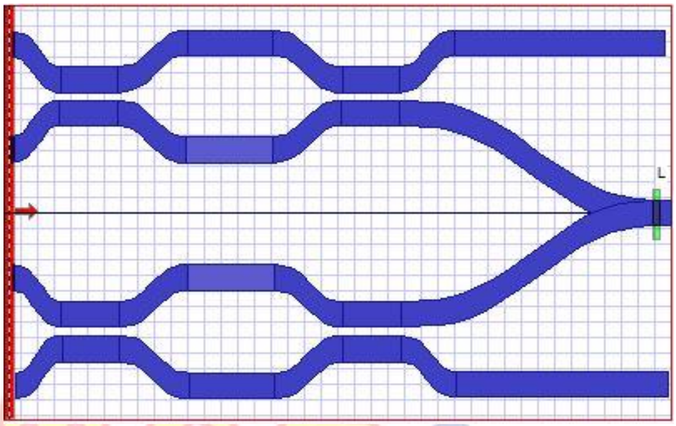

Figure 1-Block diagram of ALL-Optical NOR

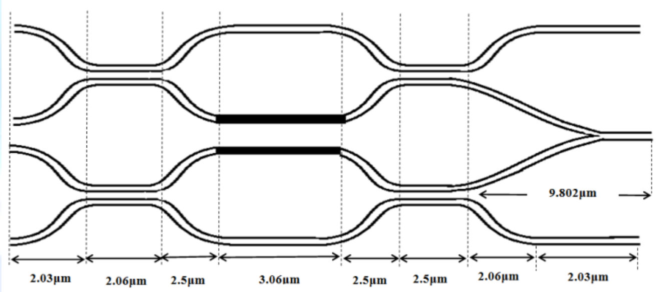

Figure 2 - Design of NOR gate using MIM waveguide

DESIGN OF OPTICAL NOR GATE:

The optimized NOR gate is designed using the two plasmonic-based Mach-Zehnder Interferometer within the dimensions of 24*8 µm. Figure1 shows the block diagram of an optical NOR gate using plasmonic-based MZI with MIM configuration. We have chosen a nonlinear Kerr material having a refractive index of 2. To get the desired output for the NOR gate, we applied input signals at the first input of MZI 1 and the second input port of MZI 2. The nonlinear material will provide the phase shift from the first input port to the second vice versa. The output signals from the second port, MZI 1, and the first port of MZI 2 are cascaded to obtain the NOR gate output.

By taking two input signals, we can consider four different combinations of inputs as two-input. NOR gate truth table is shown in Table 1. The first input port of MZI 1 is considered as A=0, and the second input port of MZI 2 is considered as B=0. Due to constructive interference, the output signals are obtained at a second input port of MZI 1, and the first input port of MZI 2, and these signals are merged together to provide NOR output (Y). Similarly, the remaining different combinations of inputs are verified. The continuous Gaussian wave is used for evaluating the output of the NOR gate. Different operating parameters are considered for getting the desired output, as shown in Table 2.

RESULTS AND DISCUSSION:

FDTD software is used for stimulating the NOR gate design. The results of the Design are verified. A Gaussian wave of wavelength 1.55µm is provided for both inputs with power 0.7 * e□ W/m and 3 * e□W/m are considered as low and high-intensity optical signals, respectively. The basic Traverse Electric (TE) mode of a plasmonic waveguide is accelerated by the source with Gaussian wave for the inputs. Results of different combinations of input are given in Figure 2.

i) Case 1 A = 0, B = 0:
In this case, A = 0 and B = 0 imply low-intensity signals are fed inputs to the first and second input ports of MZI-1 and MZI-2. Due to varying in the refractive index of the waveguide and also by the surface plasmons, the output will be obtained from the second and first output ports of the MZI-1 and MZI-2, respectively. This is considered as the Normalized power is of 0.5309 W/m.

ii) Case 2 A = 0, B = 1:
In this case, A = 0 and B = 1 imply low and high-intensity signals are fed inputs to the first and second input ports of MZI-1 and MZI-2. Due to varying in the refractive index of the waveguide and also by the surface plasmons, the output will be obtained from the second output port of MZI-2, and no output will obtain from the second output port of MZI-1. As this is considered as the Normalized power is of 0. 4404W/m.

iii) Case 3 A = 1, B = 0:
In this case, A = 1 and B = 0 imply high and low-intensity input signals are fed inputs to the first and second input ports of MZI-1 and MZI-2. Due to varying in the refractive index of the waveguide and also by the surface plasmons, the output will be obtained from the second output port of MZI-1, and no output will obtain from the second output port of MZI-2. This is considered as the Normalized power is off
0. 0793 W/m.

iv) Case 4 A = 1, B = 1:
In this case, A = 1 and B = 1 imply high-intensity input signals are fed inputs to the first and second input ports of MZI-1 and MZI-2. Due to varying in the refractive index of the waveguide and also by the surface plasmons, the output will be obtained from the first output port of MZI-1, and no output will obtain from the second output port of MZI-2. This is considered as the Normalized power is of 0.0522 W/m.

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

Table 1 Truth Table of NOR gate

Input field Traverse	Gaussian
Wavelength	1.55µm
Polarization	Transverse Electric
No of mesh cells X	103
No of mesh cells Z	309

Table 2 Operating parameters of NOR design

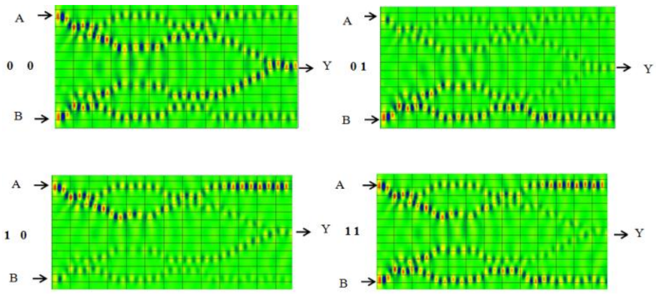

Figure 3 Outputs of the NOR gate design

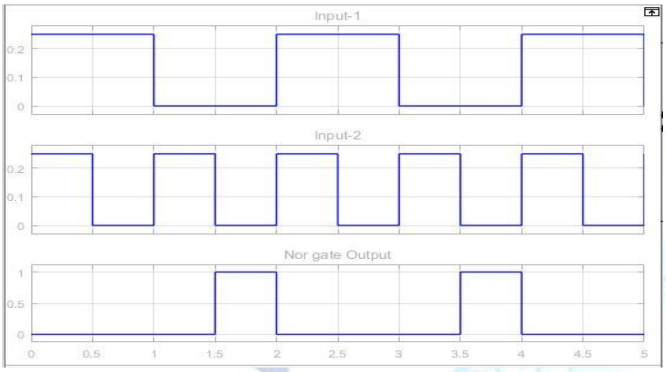

Figure 4 MATLAB stimulation for NOR gate design

Parameter	**Specifications: Plasmonic**
Wafer dimension	L=24µm, W= 8µm, thickness=0.5µm
Substrate material	MEH-PPV
Cladding material	Air, thickness=2µm
Channel profile	Dielectric material (RI=2)

Table 3 Design Specifications of NOR design

S No	**Parameter**	**Formula**	**Output**
1	Extinction ratio	$10\log_{10}$ (Pon/Poff)	10dB
2	Insertion loss	$10\log_{10}$ (Pout/Pin)	2.1dB

Table 4 Parameters of the Design

S No	**Parameter**	**Design of NOR gate**	
1	No of MZI's	Three MZI's	Two MZI's
2	Size	45x8 µm	24x8 µm

Table 5 Comparisons of NOR gate designs

S No	**Inputs**		**Normalized Power**
1	0	0	0.5309
2	0	1	0.4404
3	1	0	0.0793
4	1	1	0.0522

Table 6 Normalized power for different input values.

CONCLUSION:

In this work, an improvised NOR gate structure in terms of its dimension using plasmonic-based MZI is designed . By using only two, MZI's the size of the design is decreased, so it can be more suitable for chip fabrication and increases the packing density. So, we can manufacture each component within a small size. The performance is analyzed, and few parameters like ER and IL are obtained 10 dB and 2.1 dB, respectively. The Design is simulated through the Opti-FDTD and verified through MATLAB.

ACKNOWLEDGEMENT:

This work is supported by the GIET(A) college Rajahmundry, India. We would like to thank Optiwave for providing the demo version of OptiFDTD software to carry out for the research work. We would like to thank Assistant Professor Mr. Srinivash Roula sir, for encouragement and support during the research work, and also the authors would like to thank the anonymous reviewers for their valuable suggestions.

REFERENCES

[1] A. Singh, A. Pal, Y. Singh, and S. Sharma, "Design of optimized all-optical NAND gate using metal-insulator-metal waveguide," Optik (Stuttg)., vol. 182, no. January, pp. 524–528, 2019.

[2] S. Kumar, L. Singh, N.K. Chen, Design of all-optical universal gates using plasmonics Mach Zehnder interferometer for WDM applications, Plasmonics 13 (4) (2018) 1277–1286.

[3] P. Sharma and V. D. Kumar, "All-Optical Logic Gates Using Hybrid Metal Insulator Metal Plasmonic Waveguide," IEEE Photonics Technol. Lett., vol. 30, no. 10, pp. 959–962, 2018.

[4] D. N. S. Cavalcante et al., "Experimental AND and OR Logic Gates with MZI and SOA Using PAM Modulation," IEEE Photonics Technol. Lett., vol. 31, no. 1, pp. 11–14, 2019] H. Yang, X.

[5] Santosh Kumar, Lokendra Singh, Nan-Kuang Chen "Design of All-optical universal logic gates using plasmonics Mach-Zehnder Interferometer for WDM applications".2017.

[6] Santosh Kumar, Lokendra Singh, Sandip Swarnakar "Design of one-bit Magnitude comparator using nonlinear plasmonic waveguide" 2016

[7] Kumar S, Singh G, Bisht A, Amphawan A (2015a) An optical synchronous up counter based on the electro-optic effect of lithium niobate-based Mach–Zehnder interferometers. Opt Quant Electron 47:3613–3626.

[8] Caulfield HJ, Shamir J (1990) Wave-particle duality processors characteristics, requirements, and applications. J opt Soc Am A 7: 1314–1323.

[9] Veronis G, Kocabas SE, Miller DAB, Fan S (2009) Modeling of plasmonic waveguide components and networks. J Compute Theory Nanosci 6:1808–1826.

[10] Charbonneau R, Lahoud N, Mattiussi G, Berini P (2005) Demonstration of integrated optics elements based on long-ranging surface plasmon polaritons. Opt Express 13:977–984.

[11] Gramotnev DK, Vernon KC, Pile DFP (2008) Directional coupler using gap plasmon waveguides. Appl Phys B Lasers opt 93:99–106.

[12] Alam MZ, Caspers JN, Aitchison JS, Mojahedi M (2013) Compact, low loss, and broadband hybrid plasmonic directional coupler. opt Express 21:16029–16034

[13] Li Q, Song Y, Zhou G, Su Y, Qiu M (2010) Asymmetric plasmonic dielectric coupler with short coupling length, high extinction ratio, and low insertion loss. Opt Lett 35:3153–3155.

[14] J. Yu, J. Zhang, Recent progress on high-speed optical transmission, Digit. Commun. Netw. 2 (2) (2016) 65–76.

[15] J. Scheuer, All-optical gates facilitated by soliton interactions in a multilayered Kerr medium, 22, 6 (2005), pp. 1260–1267.

[16] S.K. Raghuwanshi, A. Kumar, S. Kumar, one × four signal router using three Mach-Zehnder interferometers, Opt. Eng. 52 (3) (2013) 1–9 035002.

[17] W. Nanodisk, The Transmission Characteristic of Metal – Dielectric – Metal Slot Waveguide-Based Nano disk Cavity with Gain Medium, 7, 2 (2015).

[18] S.A. Khan, et al., Metal-insulator-metal waveguides for particle trapping and separation, Lab Chip 16 (12) (2016) 2302–2308.

[19] M. Armacost, et al., A high-reliability metal insulator metal capacitor for 0.18 µm copper technology, Scanning 00 (2000) 2–5 no. C.

[20] E.L. Wooten, et al., A Review of Lithium Niobate Modulators for Fiber-Optic Communications Systems, 6, 1 (2000).

[21] M. Zhang, K. Chen, W. Jin, S. Chiang, Electro-optic mode switch based on lithium-niobate Mach – Zehnder interferometer, Appl. Opt. 55 (16) (2016) 4418–4422.