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DESIGN AN OPTIMIZED PLASMONIC HALF-ADDER USING WAVEGUIDE

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ABSTRACT

The limitation of standard electronics is reduced by all optical integrated circuits which have potential of high-speed computing and information processing. In this work, the basic structure for a half-adder is proposed by including nonlinear Kerr-material to the Mach-Zehnder Interferometers (MZI). It can be used for fast switching in the devices like integrated circuits. The proposed design used the 1.55µm wavelength. The size of the wafer is going to design 45µm x 11µm, which is very small compared to earlier designs. The half-adder design is evaluated in the OptiFDTD software, and the proposed design is analysed in the OptiFDTD.

Keywords: MZI, Keer material, Directional couplers.

1. INTRODUCTION

Surface plasmon polarisation (SPP) all-optical devices have been the subject of much study in recent years. To get over the primary performance limitations of semiconductor electrical devices, such as their intrinsic latency and significant heat

production, and to get around the difficulty of photonics devices, namely the diffraction

limit, all-optical SPP devices stimulate intensive new research. In this way, the technologies discussed above allow for the manipulation of light at the subwavelength level. The primary goal, however, is to regulate the constructive/destructive interference of many light signals in several plasmonic wave-guides. All-optical switching devices are those that convert between constructive and destructive interferences, conceptualising this as a switch action. Future sub wavelength computers may have their fundamental components based on plasmonic logic gates performing AND, NAND, and NOR logical operations. Most recently, various all-optical plasmonic devices have delivered nanoscale logic gates. However, several all-optical designs had combinational logic capabilities. Some of these works investigate a surface plasmon polarisation (SPP) to achieve a desired function from the combinational logic functions. To the best of our knowledge, no combinational logic functions structure that meets the criteria of ultra-small feature size has been shown theoretically or experimentally to yet. In this dissertation, we propose, develop, and simulate logic functions and gates at the micro scale, including the directional coupler, Mach-Zehnder interferometer, half-adder. Results are obtained using opticFDTD. These gadgets will open the door to Nano-photonic integrated circuits in the near future. To link the various parts of the integrated nanophotonic system, waveguides play a crucial role. The effective coupling of optical signals from a dielectric waveguide to a plasmonic waveguide requires a trapped structure or a directional coupler, both of which are waveguide-based devices. Light may be distributed to many plasmonic waveguides from a single

dielectric waveguide using a Y-splitter or multimode interference (MMI). Plasmonic devices are comparable to other nanophotonic devices, but they vary significantly in that they experience propagation loss (Ohmic loss), which must be taken into account during device design. However, plasmonic devices are unique.

1.1 Advantages of Optical Components Over Electronics

The widespread use of optics may be attributed to its many benefits over electrical alternatives. The introduction of the electronic transistor brought about a qualitative improvement in information processing. Researchers sought for a solution that would allow for faster data processing at a smaller footprint. Bandwidth limits, or the bottle neck issue, mean that typical electronic systems can only go so fast. In contrast to electrical systems, which can only achieve speeds of up to 1010 hertz, optical systems can do up to 1015 logic operations per second. There will be no time lost due to propagation delays in an optical system because of the great speed at which optical signals may travel. So, unlike electronics, light is not constrained by a lack of instantaneous feedback. Therefore, an all-optical device should be able to function at a rate comparable to that of the human eye. Heat is another enemy of electronic components, and electronic gadgets create enough of it. When compared to the electron, which may interact with an electric or magnetic field, the photon does not. Thus, optical data transfer will be unaffected by the aforementioned distortions caused by electric and magnetic fields. Unlike electrical signals, optical ones don't get mixed up with one another. There will be no more cross-talk or short-circuit issues. It is simple for several optical signals (varying frequencies or colours) to travel in parallel.

An all-optical system may therefore execute a number of data-related tasks simultaneously. As a result of the parallelism that comes with optical signals, they have become more attractive for use in both high-speed data transmission and processing. Since optical channels have a lower channel need, the overall system size may be reduced. Using a cynical system, you won't have to deal with the limitations of binary logic. The ability to handle optical data in parallel via wavelength division multiplexing is a significant computational benefit. There is no need to provide signal voltage to the optical lines during an optical connection. With less energy needed for transmission, the optical system may become more compact. Miniaturized lighter and cheaper to produce. Because of its superiority in both speed and complexity, optics is favoured over electronics.

1.2 design of plasmonic mach-zehnder Interfero Meter.

For applications that need wavelengths below the diffraction limit, plasmonic waveguides may be used to confine the plasmons. In the suggested architecture, transverse electric polarisation optical communication is prioritised. In order to replicate this layout, the finite difference time domain method is used. There are flaws in the way electrical signals are often used in electronic circuits, such as excessive power consumption and signal latency. Optical signal, which is employed as information signal, gives minimal high frequency in comparison, and so we are contemplating it as a means to address these flaws. One possible answer to the difficulties posed by the size difference between electrons and photons is plasmonic. When incoming photons interact with electrons at the surface, Surface Plasmon Polarizations (SPPs) are produced. They meet in the middle, between the dielectric and the metal. The exchange often reduces the size of the dielectric gap between two metals, where the optical beam stops. However, ohmic losses hinder the spread of such Surface Plasmons across associated materials. In order to lessen the impact, several plasmonic waveguide designs have been studied, such as Insulator-Metal-Insulator(IMI) waveguides, Metal-Insulator-Metal(MIM) waveguides etc. MIM waveguides are often used in the construction of optical devices because of their profound sub-wave length confinement capabilities. These are vey essential in dealing of all things in sequential manner.

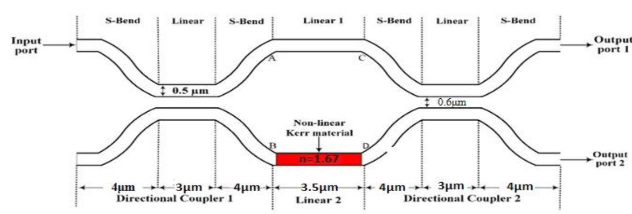

Fig 1- nonlinear Mach-Zehnder interferometer

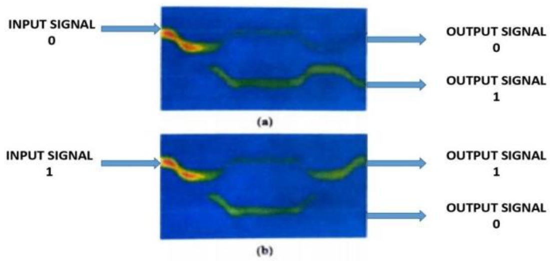

Fig.2 : Propagation of light through single plasmonic MZI for high intensity (a) and low intensity (b)

Case: (a)

When Continuous wave source of wavelength 1.55µm with the intensity of 0.7e9 W/m (considered as logic '0') is incident at first input port then output is obtained at through port (output port 1). As shown in fig.2(a) due to destructive interference (cross phase modulation).

Case: (b)

When Continuous wave source of wavelength 1.55µm with the intensity of 3e9 W/m (considered as logic '1') is incident at first input port th t then output is obtained at cross port (output port 2). As shown in fig.2(b) due to constructive interference (self-phase modulation).

1.3 Design of Half-Adder Circuit Using Plasmonic Wave-Guides

Similarly, we using the wave-guides instead of the AND and EX-OR gates. We use plasmonic wave-guide which is working with the help of MZI (Mach-Zehnder Interferometers) to transmission of light waves in a wave-guides. Light is more speed than electrons. The speed of the light is 3xe8 m/s but the speed of electron is about 22000 km/s. By using this we can build the high speed plasmonic IC (Integrated Circuit). Those plasmonic IC can replace the old solid-state IC and makes a revolution in electronic. As we compare with the solid-state ICs plasmonic ICs are much better as compare in size and speed and efficiency. It uses less power as we compare with the solid-state ICs. Here we mostly give priority to the speed then power because the speed is our priority in quantum computers to work faster than the normal computers and in lesser time and more accurate manner.

INPUT (A)	INPUT (B)	SUM	CARRY
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Table 1: Truth table of half-adder.

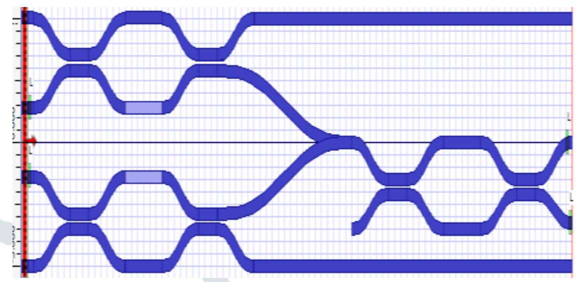

Fig:3 Design a plasmonic half-adder using wave-guides

Parametrss	Values
Wave length	1550nm
Polarization type	TE
Mesh sixe X(µm)	0.062
Mesh sixe Y(µm)	0.062
No.of mesh cells X	177
No.of mesh cells Y	806
Low intesity signal	0.7e9 W/m
High intensity singal	3e9 W/m

Table 2: parameters used to construct a plasmonic half-adder

3. RESULTS

Case (a): A=0 and B = 0:

For the input Signals A = 0 and B = 0, the MZI-1 and MZI-2 undergoes constructive interference and the output is obtained from the second output port of MZI-1 and first output port of MZI-2. Form the MZI-3 we are getting the output signals carry (0) and sum (0). The optical field propagation for '00' condition is shown in the below figure.

Case (b): A=0 and B = 1:

In this case, For the input Signals A = 0 and B = 1 the MZI-1 undergoes constructive interference while MZI-2 undergoes destructive interference. Hence, only output from the second output port of

MZI-3 is considered as the output signal. Form the MZI-3 we are getting the output signals carry (0) and sum (1). The optical field propagation for '01' condition is shown in the below figure.

Case (c): A=1 and B = 0:

Similar to the above case of A = 0 and B = 1, here MZI-1 undergoes destructive and MZI-2 undergoes constructive interference. As a result, the output from the first output port of MZI-3 is drawn at the output port. Form the MZI-3 we are getting the output signals carry (0) and sum (1). The optical field propagation for '10' condition is shown in the above figure.

Case (d): A=1 and B = 1

In this case, the first input port of MZI-1 and second input port of MZI-2 are supplied with high intensity signals (logic 1). The two MZI's undergoes destructive interference and as a result no signal is obtained at the output port. Form the MZI-3 we are getting the output signals carry (1) and sum (0). The optical field propagation for '11' condition is shown in the above figure.

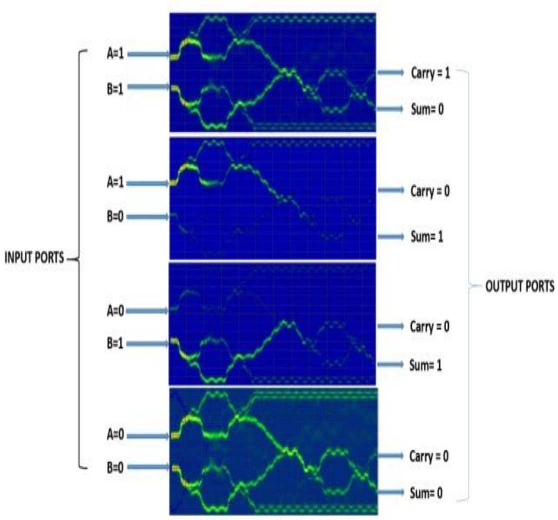

Fig 4: Simulated outcome of half-adder using optifdtd

The analysis of this paper work is carried out using FDTD method. Several performance parameters like Insertion loss (IL) are calculated.

The Insertion Loss is obtained by:

$$\textbf{Insertion loss (IL)} = 10\log_{10}\left(\frac{P_{OUT}}{P_{IN}}\right)$$

Where P_{OUT} is peak output power.

P_{IN} is peak input power.

The insertion loss of this work is found to be 0.291dB. These parameters determine the performance of the half-adder and hence the losses must be reduced to get higher outputs. The lower the insertion loss the higher performance will achieve.

The Transmission Efficiency is obtained by:

$$\textbf{Transmission Efficiency } (^{0}/_{0}) = \left(\frac{P_{out}}{P_{in}}\right) \times 100\,\%$$

Where P_{OUT} is peak output power.

P_{IN} is peak input power.

The transmission efficiency is more when it is compared with the previous designs. Due to the less insertion losses. The transmission efficiency of this model is 80%

4. CONCLUSION

Nonlinear MZI is used to suggest a compact plasmonic half-adder circuit, which is then confirmed by the FDTD. The half adder is constructed with 2 kerr materials and a wafer size of 45µm x 11µm. Calculations of key metrics, such as transmission efficiency (80%) and insertion loss (0.291 dB at 1550 nm), have been used to evaluate the functionality of an all-optical half-adder. Mathematical calculations and high x0002 speed processing in optical communication both benefit greatly from the proposed plasmonic half-adder.

S.NO	PARAMETERS	EXISTING HALF-ADDER DESIGN	PROPOSED HALF-ADDER DESIGN
1	Components	Three MZI'S	Three MZI'S
2	Dimensions	85µm x 10µm	45µm x 11µm
3	Coupling distance	0.6µm	0.6µm
4	Channel profile	Dielectric (n = 2.01)	Dielectric (n =2.5)
5	Wave length	1.55µm	1.55µm
6	Polarization	TE	TE
7	Transmission Efficiency	74%	80%
8	Insertion losses	0.332 dB	0.291 dB

9	No of Keer materials	3	2

Table 3: Comparasion of existing and proposed design of half-adder

FUTURE SCOPE

Physicists, engineers, chemists, biologists, medical doctors, food scientists, and environmentalists are all contributing to the rapidly expanding field of plasmonics. Plasmons are electron density waves produced when light strikes a metal surface under very certain conditions. It follows that light may be used to locally activate them on the surface of a substance. This has the potential to enable plasmons to rapidly transfer data between different parts of a microprocessor through nanoscale cables (called interconnects).

Several potential future research directions became clear as I worked on my dissertation. The following is a brief overview of the subjects that were voted as most interesting.

1. These half-adder designs feature a high extinction ratio, a small size, and a low power consumption, making them suitable for application in the construction of complicated logic circuits, future optical networks, and communication systems.

2. The phase difference between the input signals has been considered in this thesis. The generated optical signal relies on the linear interference concept. For the same structures, simulation studies may be conducted while accounting for the phase difference.

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