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REALIZATION OF AND AND OR OPTICAL LOGIC GATES USING 2D PHOTONIC CRYSTAL STRUCTURE

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Abstract

A novel scheme for implementation of all-optical logic gate based on 2D photonic crystal structure has been proposed. Photonic crystal structure is comprised of two-dimensional lattice of air holes in a square Silicon substrate having refractive index of 3.15. The Finite Different Time Domain (FDTD) simulation is used to analyze the behavior of the structure. The operational wavelength of the input ports is 1.55µm. Since the structure has a simple geometric with clear operating principle, it is potentially applicable for photonic integrated circuits. The logic operations are realized by a control signal and the input signal (s) applied across two adjacent faces, while the output is obtained along one of the remaining face. No control signal is used for AND Gate, However to realize OR, NOT and NOR Gates a control signal is applied at the third face.

Keywords: Optical Logic Gates, Photonic Crystal Structure, Finite Difference Time Domain, Kerr nonlinearity.

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INTRODUCTION

All optic logic gates are key elements in different signal processing techniques. It is based on Mach-Zehender Interferometer (MZI) (Deyin Zhao *et al*., 2007), semiconductor optical amplifier (SOA) (Soto *et al*., 2002), SOA based on ultrafast nonlinear interferometer (Yuji Miyoshi *et al*., 2008), SOA with optical filter (Houbavlis *et al*., 1999) and semiconductor laser amplifier loop mirror (Houbavlis *et al*., 1999).

But all these schemes suffered due to high power consumption, speed, narrow operating wavelength range and signal to noise ratio. Photonic crystal structures (PCS) have been attractive element for this purpose because of its dimension, low loss structure and high operating speed (Avramopoulos, 2001). Thus photonic crystal based all optic logic gates are considered as key components in future photonic integrated circuits and hence such optical devices have attracted significant research in recent years. Most of the recent reported works are based on nonlinear optics, but these devices again suffer due to high power consumption and narrow operating frequency range. Further there are very few references available, where optical logic gates are based on photonic crystal structure. For example in reference (Kabilan *et al*., 2009), OR and XOR logic gates are realized by introducing a line defect along TX-direction, while in reference (Kun-Yi Lee *et al*., 2008), XOR gate is realized by a line defect asymmetric Y branch waveguide (Kabilan, 2010). The different PCS, reported in the literature have mainly two disadvantages. Complex geometry of the structure which is very difficult to fabricate even using the most advanced techniques and secondly the materials where maximum work on logic gates based on PCS have been reported is silicon dioxide(Glass).Unfortunately this material is not suitable for drilling fine holes or structures required as per the simulation. For example an attempt to eatch circular air holes in silicon oxide substrate using FIB technique forms cracks along the circumference. While this issue can be taken if silicon oxide substrate will be replaced by silicon substrate. We in this investigation, proposed a simple structure on a silicon substrate which is easier for fabrication. Using FDTD simulation it is shown that one can realize AND, OR, NOT and NOR Gate in this structure.

FDTD Method

Several computational methods have been employed for analysis of photonic crystal structure, including plane wave expansion (PWE) method, transfer matrix method, Green's function method and finite difference time domain method. But we have employed the FDTD method based on Yee's algorithm (Yee, 1966), to study the 2D-PCS, because the computational time and memory requirements are reduced (Qui and He, 2000; Qui and He, 2001). The propagation of electromagnetic waves through photonic crystal structure is governed by Maxwell's four equations in a linear medium with the sources and are

$$\vec{\nabla} \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}$$

$$\vec{\nabla} \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\vec{\nabla} \cdot \vec{E} = \vec{\nabla} \cdot \vec{H} = 0$$

Using these equations, magnetic field components can be expressed in form of Helmholtz equation, which is given by

$$\frac{\partial}{\partial x}\frac{1}{\varepsilon(x)}\frac{\partial}{\partial x} H(x) + \frac{\omega^2}{c^2} H(x) = 0 \quad \ldots\ldots. (2)$$

Equations (1) and (2) are discritised so that the E and H fields are solved from the E and H field at a precise time step. The 2-D TE mode FDTD used in this paper is

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu}\left[-\frac{\partial E_z}{\partial y}\right]$$

$$\frac{\partial H_y}{\partial t} = \frac{1}{\mu}\left[\frac{\partial E_z}{\partial x}\right]$$

$$\frac{\partial H_z}{\partial t} = \frac{1}{\varepsilon}\left[\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. (3)$$

Each filed component is updated from the data at the previous time step. The Gaussian beam is initiated in the grid, travels through, reflects from, refracts in and resonates inside the photonic crystal. Where $\varepsilon(r)$,$\mu(r)$, $\sigma(r)$ are permittivity, permeability and conductivity of the material and all are in the function of position. For our simulation, we have used PML boundary condition. Further time step is so chosen that stability criteria is satisfied (Tripathy, ?).

Structure

The proposed 2D PCS is based on 15x15 air holes with lattice constant a_x =0.575 µm and a_y = 0.575 µm .The silicon substrate having dielectric constant 11.5 is drilled with air holes of radius r = 0.115 µm . The input signals are applied along face 1 and face2, where as the control signal is used along face3. The output is obtained along face4 as shown in the Fig 1.In the following paragraphs the various configurations of logic gates are presented

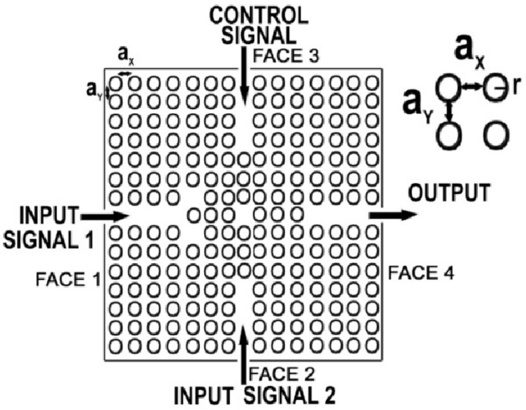

Fig 1. Proposed 2D PCS for Logic Gate

Realization of Logic Gates

To realize AND gate input signals are initiated in face-1 and face-2, while output is calculated at face-4.Someof the simulation results are shown in Fig-2. As is observed in Fig-2 for inputs given to face 1,and face 2,a strong signal is obtained at the center of face-4.While one signal is taken out either from face-1 and face-2, no signal reaches the center of face-4.The simulation results are presented in Table 1.

LOGIC AND GATE

INPUT 1	INPUT 2	OUT PUT
1	1	1
1	0	0
0	1	0
0	0	0

[Truth Table-1]

We further investigate the performance of OR gate using the cross waveguide structure using a control signal. OR gate encompasses of two inputs and an output. The stimulated results for [11],[10],[01] are shown in Fig 3 and the corresponding logic gate is presented in Table 2,where the output is logically '1' if and only if both of the input values are '0'.

LOGIC OR GATE

INPUT 1	INPUT 2	CONTROL SIGNAL 3	OUT PUT
1	1	1	1
1	0	1	1
0	1	1	1
0	0	0	0

[TRUTH TABLE 2]

A NOT Gate is realized with the control signal. The simulation results in the output are shown in Fig 4 and the results are shown in Table 3.

LOGIC OR GATE

INPUT SIGNAL 2	CONTROL SIGNAL	OUT PUT
0	1	1
1	1	0

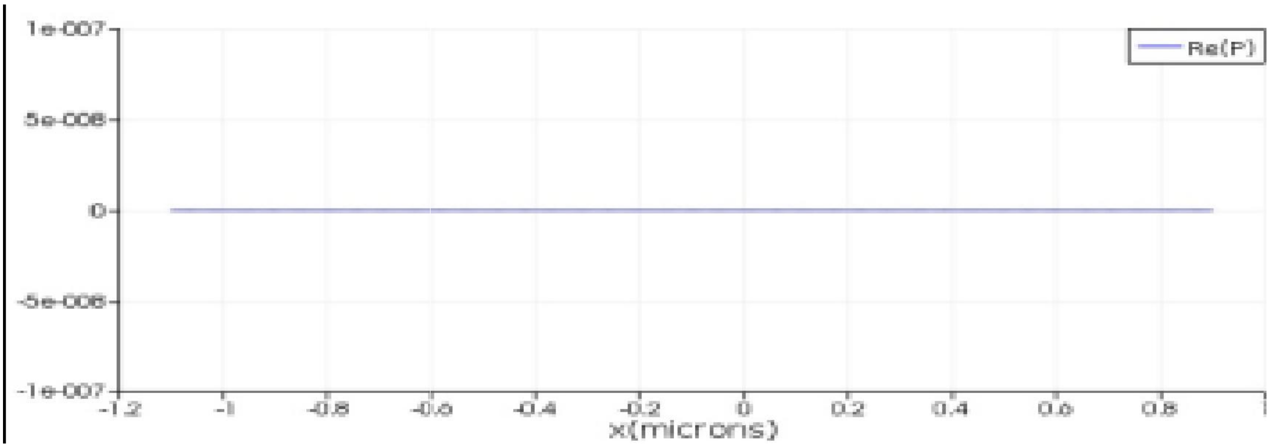

Fig 2.A. Simulation for AND gate [10, 01]

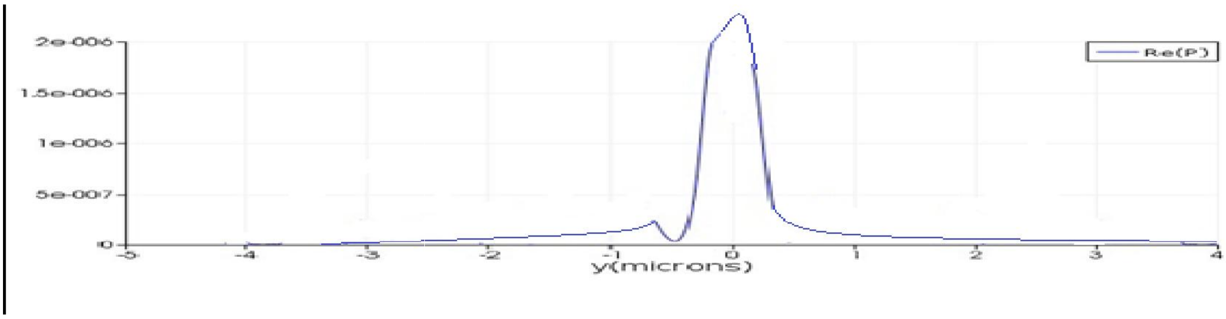

Fig 2.B. Simulation for AND gate [11]

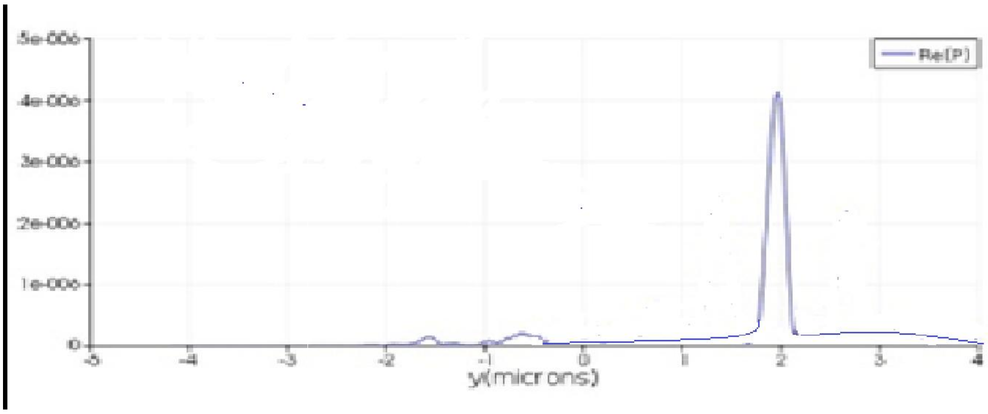

Fig 3.A. Simulation for OR Gate [01]

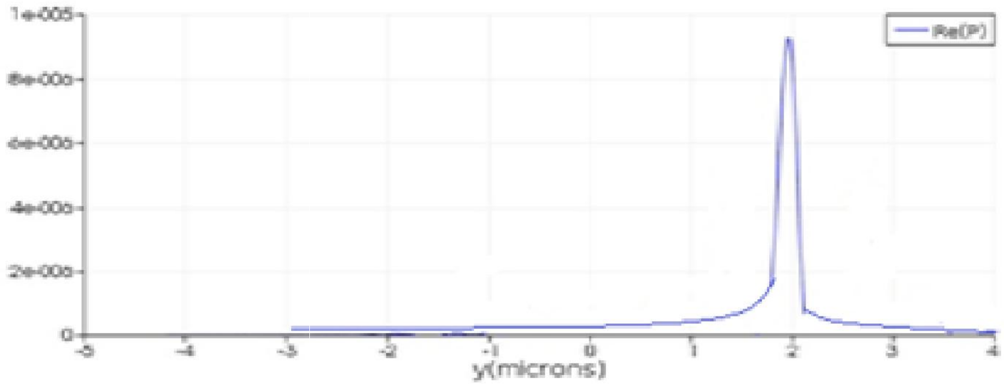

Fig 3.B. Simulation for OR Gate [10]

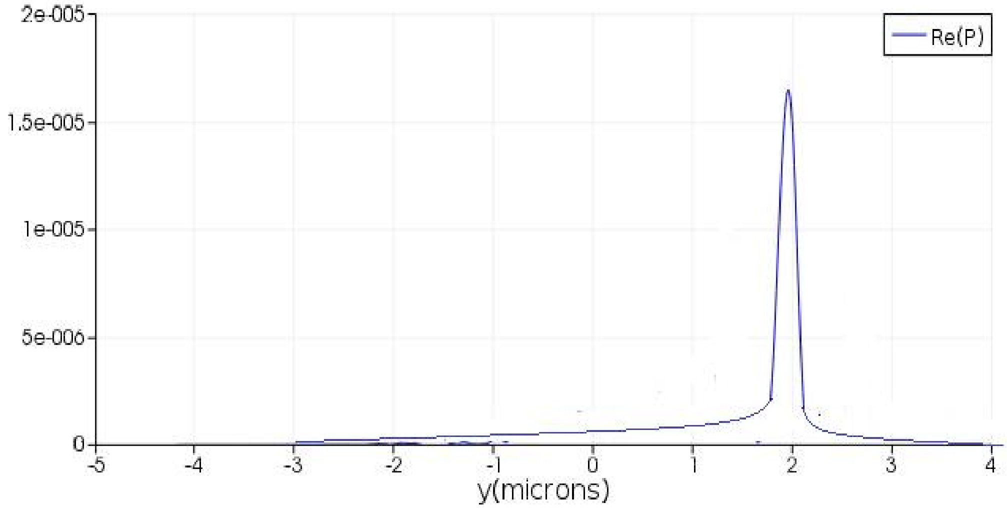

Fig 3.C. Simulation for OR Gate [11]

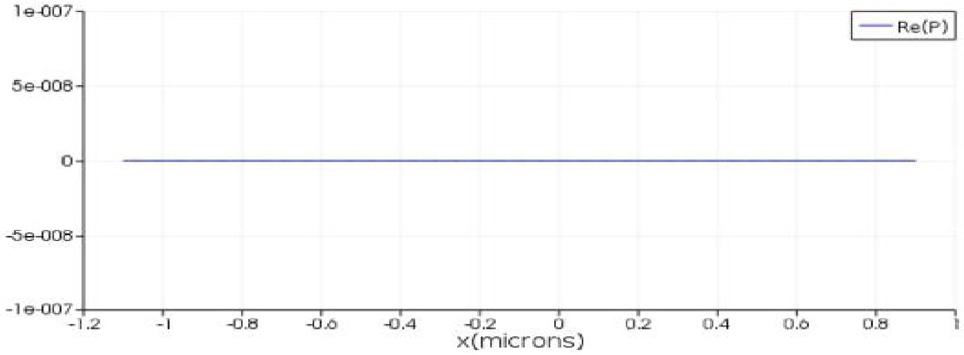

Fig 4.A. Simulation for NOT Gate [11]

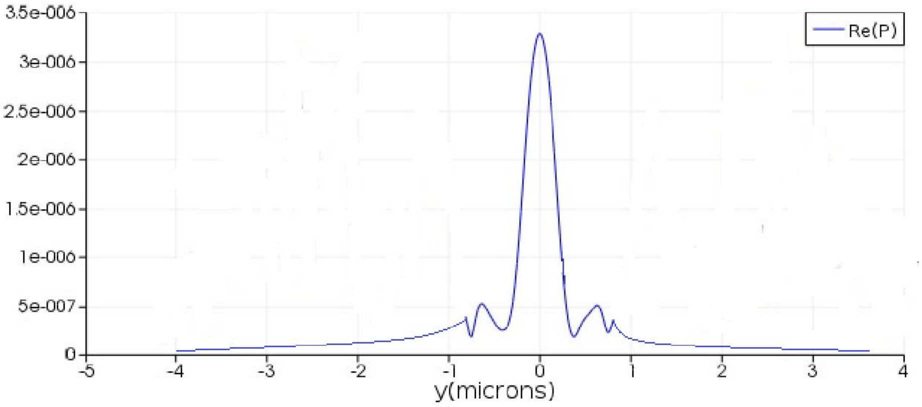

Fig 4.B. Simulation for NOT Gate [01]

LOGIC NOR GATE

IN PUT 1	IN PUT 2	CONTROL SIGNAL 3	OUT PUT
1	1	1	1
1	1	0	1
1	0	1	1
1	0	0	0

[TRUTH TABLE 4]

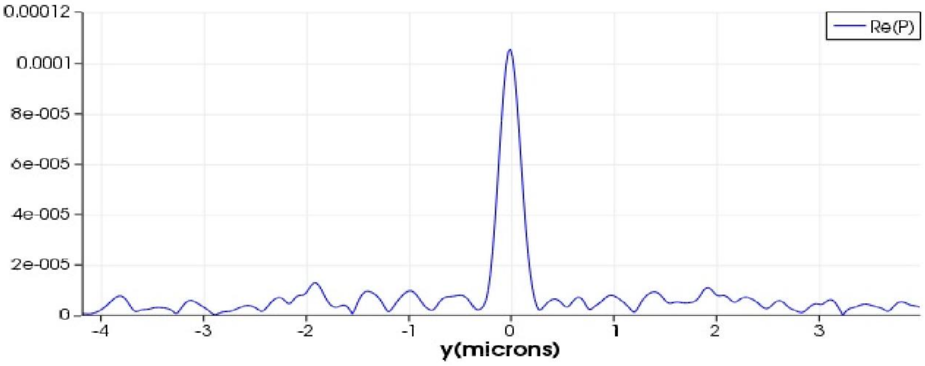

Fig 5.A. Simulation for NOR Gate [11]

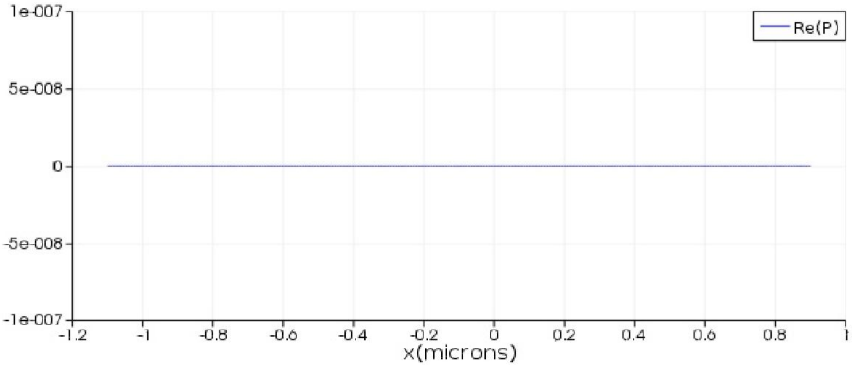

Fig 5.B. Simulation for NOR Gate [00]

Similarly In this case of NOR gate we apply a fixed signal into the input 1 ,by applying input signal 2 and control signal 3, we find NOR Gate. The Simulated results are shown in Fig 4 and corresponding results are presented in Table 4. We use the signals 2 and the control signal 3 and the output taken along face 4 in Fig 5

Conclusion

A design procedure for AND, OR, NOT, and NOR Optical operation in a 2D PCS on silicon substrate is proposed in this paper.2D PCS is realized by drilling air holes so as to form line defect. To the best of our knowledge this is the first report on optical logic gate in silicon substrate. The proposed device benefits a simple and small structure. The structures can be strong candidates for future photonic integrated circuits.

REFERENCES

Avramopoulos, H. 2001. “Optical TDM devices and their applications,” in *Optical Fibe Communication (OFC)*, Vol. 54 of OSA Trends in Optics Photonics Series (Optical Society of America, Washington, D.C., 2001), Tutorial paper.

Deyin Zhao, Jie Zhang, Peijun Yao, Xunya Jiang and Xiyao 2007. “Photonic crystal Mach-Zehnder Interferometer based on selfcollimation,” *Applied Physics Lette, 90, pp231114-1-3*

Houbavlis, T., Zoiros, K., Hatziefremidis, A., Avramopoulos, H., Occhi, L., Guekos, G., Hansmann, S., Burkhard, H. and R. Dall‟Ara, “10 Gbit/s alloptical Boolean XOR with SOA fiber Sagnac gate,” *Electron. Lett.,* vol. 35, *(* 1999,*)* pp. 1650–1652.

Kabilan , A.P., Susan Christina, X. and Elizabeth Caroline, P. 2010. “Photonic Crystal based all Optical OR and XOR Logic Gates”, Second International conference on *Computing, Communication and Networking Technologies*, *IEEE* 2010, 978-1-4244-6589-7/10

Kabilan, A.P., Susan Christina, X. and Elizabeth Caroline, P. 2009. “Realization Of Optical Logic Gates Using Photonic Crystal” *ICOP 2009- International Conference on Optics and Photonics Chandigarh,India*, Nov.30 Oct.-1

Kun-Yi Lee, Jhe-Min Lin, Yi-Cheng Yang, Yi-Bin Yang, Jia-Sing Wu, Yen-Juei Lin, Wei-Yu Lee, 2008. “The Designs of XOR Logic Gates based on Photonic Crystals”, *Proc. of SPIE*, Vol. 7135 71353Y1-8.

Qui, M. and He, S. 2000. Phys. Rev. B, Vol.61, page 12871-12876.

Qui, M. and He, S. 2001. Phys Lett A, Vol 278, page 348-354.

S. K. Tripathy, Subikash Sahu,Chinmsys Mahspstro,Sonali Prava.Dash,‘*Implementation of Optical logic gates using closed packed 2D-photonic crystal structure’* Optic communication-vol 286 issues 13- 14, June 12 page 3234=3237.

Soto, H., Diaz, C.A., Topomondzo, J., Erasme, D., Schares, L. and Guekos, G. 2002. “All-Optical AND gate Implementation using cross polarization modulation in a semiconductor optical amplifier,”*IEEE Photon. Technol Lett.*, 14, Pp498-500

T. Houbavlis, K. Zoiros, A. Hatziefremidis, H. Avramopoulos, L. Occhi, G. Guekos, S. Hansmann, H. Burkhard, and R. 1999. Dall‟Ara, “10 Gbit/s alloptical Boolean XOR with SOA fiber Sagnac gate,” *Electron. Lett,*vol. 35, ,pp. 1650–1652,.

Yee, K.S. 1966. Numerical solution of initial boundary value problems involving Maxwell‟s equations in isotropic media‟, *IEEE Trans.Antennas Propag.,* 14, pp.302-307

Yuji Miyoshi, Kensuke Ikeda, Hideaki Tobioka, Takashi Inoue, Shu Namiki, and Ken-ichi Kitayama, 2008. "Ultrafast all-optical logic gate using a nonlinear optical loop mirror based multi-periodic transfer function," *Opt. Express.*, vol. 16 , No 4, 2570-2577

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