Realization of Three Input Optical AND Gate in a 2D Photonic Crystal

Savita.Soma[1], Sanjay Gowre[2], Mahesh Sonth[3]

[1]Department of ECE, GNDEC.BIDAR,585402, INDIA
[2] Department of ECE, BKIT. BHALKI, 585328, INDIA
[3] Department of ECE, BKIT. BHALKI, 585328, INDIA
(E-mail: savita.soma@gmail.com, sanjaygowre@gmail.com & maheshsonth @gmail.com,
**Corresponding author: Savita Soma, Email Id: savita.soma@gmail.com, +8123746674abc@gmail.com)*

Abstract— Proposed and designed a 2D (two-dimensional) photonic crystal(PhC) based three input optical AND gate. The proposed structure is designed by cascading two optical AND gates. Initially a two input AND gate is designed by creating a square ring resonator in a rectangular lattice structure, later two such AND gates are cascaded to realize the operation of three input AND gate.The size of this structure is 10µm*6µm with operating wavelength of 1550µm. We have obtained contrast ratio of 8.2dB for the designed AND gate. The threshold value for logic1 is above 0.5. The size of the proposed structure is small and it is suitable for optical integrated circuits. Plane Wave Expansion (PWE) method is used to calculate the bandgap and simulations are done by using and Rsoft Finite Difference Time Domain (FDTD) simulator.

Keywords— *Ring resonator, 2D Photonic Crystal (PC), Optical logic gate, Rsoft Full wave FDTD simulator.*

I. INTRODUCTION

In recent years, photonic crystals provide the excellent platform for construction of optical logic devices. Optical devices can be used in optical memory, optical computing units, processors, and controllers [1]. Using all-optical devices, we can afford wide bandwidth, high speed and compact size. Optical logic gates are the most essential devices used in optical signal processing [2,5,6], as they improve the speed and consumes less power and can be used in optical integrated circuits. Numerous methodologies like Semiconductor Optical Amplifier (SOA), MZI and photonic crystal are used to design all-optical logic gates. The former method consumes more power and requires large space which can be improved by using photonic crystal [3,7].

Photonic crystals are dielectric structures in which refractive index of the dielectric material is varied periodically. Photonic band gap in a photonic crystal is the range of frequencies in which light cannot propagate through the structure.

Photonic bandgap is calculated by using plane wave expansion method. The band diagram of the proposed structure is shown in Fig.2, The frequency bandgap of the proposed structure (a/λ) = 0.36 to 0.48 and corresponding wavelength range from 1.34µm to 1.79µm.

By creating Point and line defect in a PhC structure we can manipulate the propagation of light. This behavior of PhC can be used to design and realize many PhC devices. Photonic crystals have some unique properties such as compactness, high speed, low power consumption, better confinement which make them promising candidate in photonic integrated circuits.

II. STRUCTURAL DESIGN

Initially, two input AND gate is designed by using structure [4] as shown in Fig.1. Optical AND gate is constructed by using a square lattice photonic crystal structure with 25 and 15 Si rods in X and Z direction respectively. Three parallel line waveguides are created by removing Si rods and a square ring resonator is placed between them. High spectral selectivity is provided by four scattering rods placed at four corners of Square ring resonator. Optical input signals are launched at ports A and B, output is observed at port Y. Fig.2. shows the cascading of two gates to form a three input AND gate.

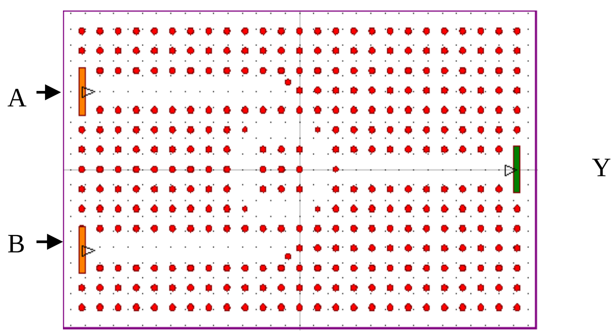


Fig.1. structure of two input AND gate using square ring resonator

Fig.3. shows the structure of three input AND gate, which is formed by connecting the output of one two input AND gate to the input of another two input AND gate and band diagram of the proposed cascaded gate structure is shown in Fig.4. The size of the structure is reduced by cascading two such gates. The structure comprises of an array of 30×20 Si rods in the air host and with the same structural parameters as of the two input AND gate.

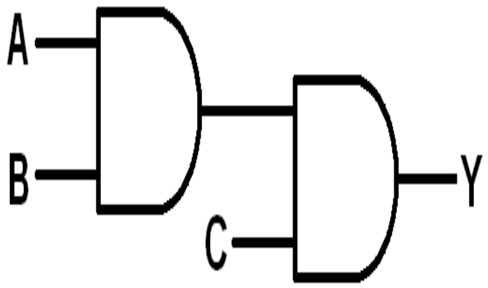


Fig.2. Structure of three input AND gate by cascading two input AND gates.

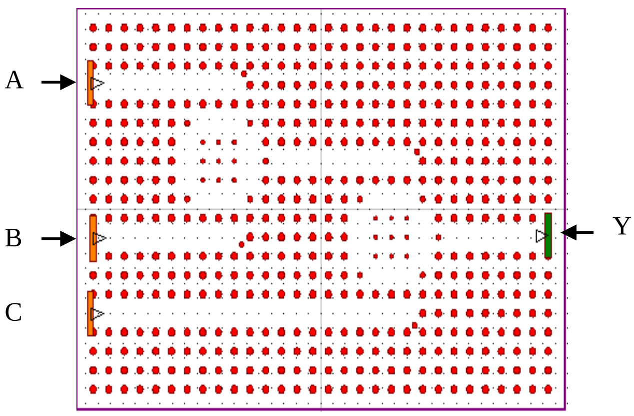


Fig.3. structure of three input AND gate using square ring resonator

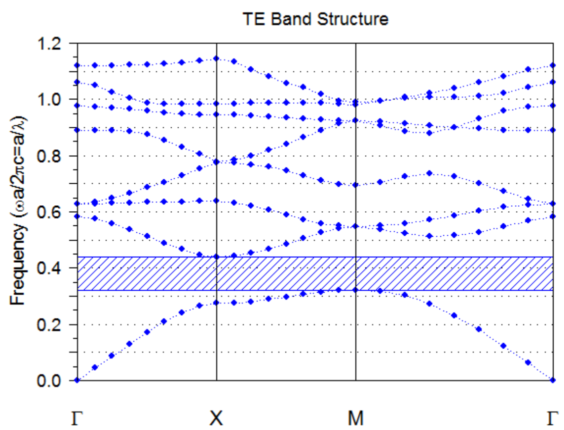
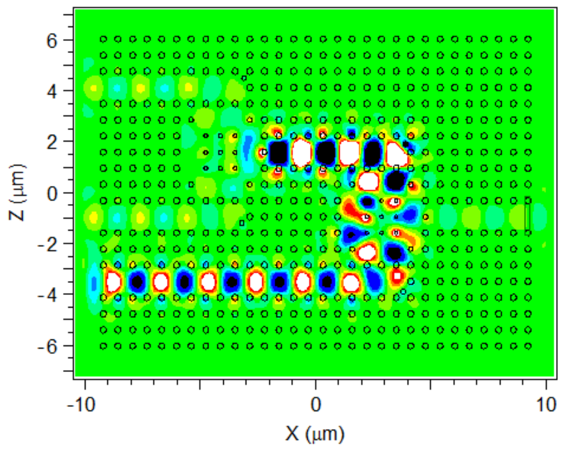


Fig.4. Band diagram of the proposed three input AND gate structre

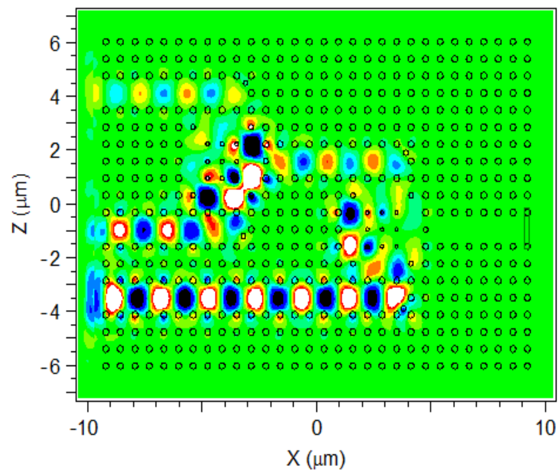
III. SIMULATION RESULTS

To realize three input AND gate an optical input signal of 1.55μm wavelength is applied at A, B, C ports and output is measured at Y port. According to wave optic theory, constructive interference occurs when a phase difference between two optical inputs is 2kπ and destructive interference occurs when a phase difference between two optical inputs is (2k+1)π (where k=0,1,2,…)

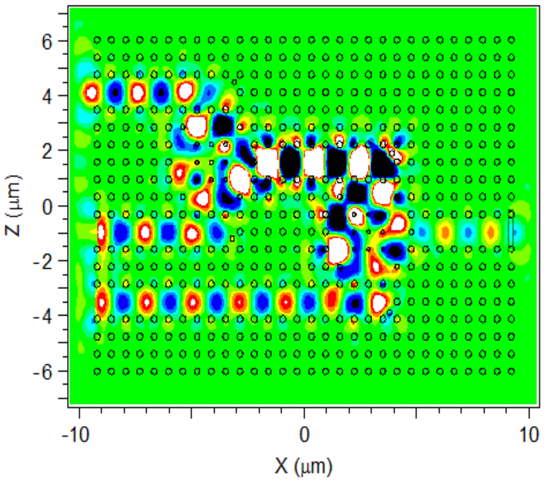
Destructive interference occurs when any one input or two inputs are low, and output is less than 10% of the input as shown in Fig.5. a and Fig.5. b respectively. Constructive interference occurs when all the inputs are high, and we obtain output transmission power is more than 80% of the input as shown in Fig 5.c.



a) A=0,B=0,C=1



b) A=0,B=1,C=1



c) A=1,B=1,C=1

Fig.5. Electromagnetic field distribution in the lattice structure for different combination of input

Similarly, we can obtain the output for different combination of the input. The ON to OFF contrast ratio for logic gate can be given by Eq.1

$$\text{Contrast ratio} = 10\log P_{on}/P_{off},$$

The ON/OFF Contrast Ratio of the three input AND gate is 8. 64dB. The ideal and simulated output of the proposed AND gate for different combination of input is shown in Table.1.

Table 1. Truth table of three input AND logic gate

Input			Ideal output	Practical output power P_o in a.u.
A	B	C		
0	0	0	0	0.1
0	0	1	0	0.1
0	1	0	0	0.1
0	1	1	0	0.1
1	0	0	0	0.1
1	0	1	0	0.1
1	1	0	0	0.1
1	1	1	1	0.8

IV. CONCLUSION

We have proposed a three input AND gate in a 2D photonic crystal using square wave ring resonator which plays a very important role in the photonic integrated circuit. Initially we have designed two input AND gate and cascaded such two gates to form a three input AND gate. The performance of that gate is realized for all the combination of inputs. We have obtained the contrast ratio of 8.2dB for an operating wavelength of 1.55µm. This new proposed structure helps in designing and realizing many optical devices used for high-speed broadband optical communication networks. Further, the size of the proposed three input AND gate small as compared to the cascaded structures in the literature.

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