High transmission in All-optical Logic gate formed by crystal photonic Y-junction

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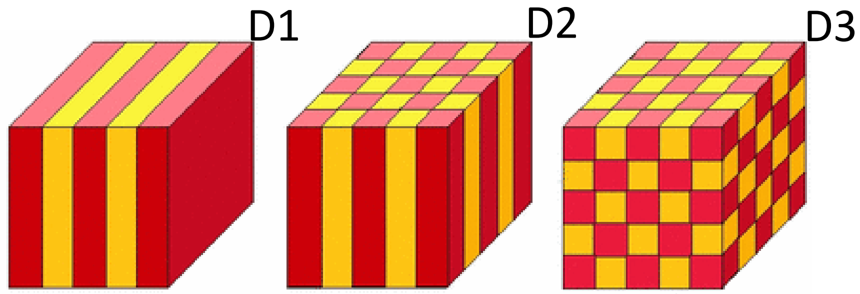
Photonic crystals (PhCs) are the best platforms for designing all optical devices suitable for all optical integrated circuits. The periodic distribution of refractive index in these artificial structures results in a forbidden wavelength region for propagation of light; this forbidden wavelength region is called photonic band gap (PBG) [1-2]. By use of PBG we can control the behavior of light inside PhCs in very small spaces. For this reason, designing ultra-compact devices based on PhC suitable for optical integrated circuits is feasible. Optical reflectors [3]. optical band rejection filters [4] are some examples of proposed devices using PBG property of PhCs.



we design a logic gate to realize the function of AND gate. The logic AND gate formed by Y-junction and two microcavities with a triangular lattice of air holes in silicon. The device studied is widely used in future optical microelectronics. The FDTD method has been used to simulate optical propagation in this junction. Two holes have been located in the intersection of the input and output channel waveguides. Their size has been varied in order to optimize the transmitted power and reduce the losses. To validate our results numerically, we use a finite difference time-domain (FDTD-2D) method to simulate the wave propagation inside the double bend and the Y-junction splitter in a two-dimensional photonic crystal,

References

[1] Ref. 1K. Sakoda, Optical Properties of Photonic Crystals, Springer-Verlag, Berlin, 2001

[2] Ref. 2Z. Wu, K. Xie, H. Yang, Band gap properties of two-dimensional photonic crystals with rhombic lattice, Optik 123 (2012) 534–536

[3] Ref. 3F. Mehdizadeh, H. Alipour-Banaei, Z. Daie-Kuzekanani, All optical multi reflection structure based on one dimensional photonic crystals for WDM communication systems", Optoelectronics Adv. Mater-Rapid Commun 6 (2012) 527–531

[4] Ref. 4H. Alipour-Banaei, F. Mehdizadeh, A proposal for anti-uvb filter based on onedimensional photonic crystal structure, DigestJ. Nanomater. Biostruct. 7 (2012) 361–367

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THE FIELD EQUATIONS

To study the behavior of light in photonic crystals, it is necessary to solve Maxwell's equations. Maxwell's equations consist of two main equations, those of TE and TM polarization [5].

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad (1)$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} \qquad (2)$$

$$\nabla . \vec{D} = 0 \ , \ \nabla . B = 0 \qquad (3)$$

References

[5] Ref. 5Zhang, Z., Satpathy, S. "Electromagnetic Wave Propagation in Periodic Structures: Bloch Wave Solution of Maxwell's Equations", *Phys. Rev. Lett. 65*

THE FIELD EQUATIONS

Which in the above relationships: **$D(r,t)=\epsilon_0\epsilon_r \vec{E}(r,t)$** and **$\vec{B}(r,t)=\mu_0 \vec{H}(r,t)$.** In the given relations, ϵ_r is relative electric permittivity ϵ_0 is the air permittivity and μ_0 is the magnetic permittivity For the purpose of this study, we were most interested in analyzing this type of mode, considering that the forbidden band gap was apparently created for TM polarization Using the Maxwell's equations, it is possible to find the time-independent equation for the wave equation [5],

$$\nabla \times \frac{1}{\varepsilon} \nabla \times H(r) = \frac{\omega^2}{c^2} H(r) \qquad (4)$$

Using the acquired equation and solving it, it is possible to calculate the optical power distribution and special frequencies in a lattice

References

[5] Ref. 5 Zhang, Z., Satpathy, S. "Electromagnetic Wave Propagation in Periodic Structures: Bloch Wave Solution of Maxwell's Equations", *Phys. Rev. Lett. 65*

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DESIGN AND ANALYSIS

The model proposed formed by a Y-junction, which is the basic building block of integrated optics coupled with two microcavities introduced in the center of the three waveguide as shown in Fig. 1. This structure based on a triangular lattice of air holes in silicon, which has been chosen because triangular lattices may exhibit large band gaps and the silicon is expected to be a good platform for integrated photonics circuits and ultra-compact optical devices [6].

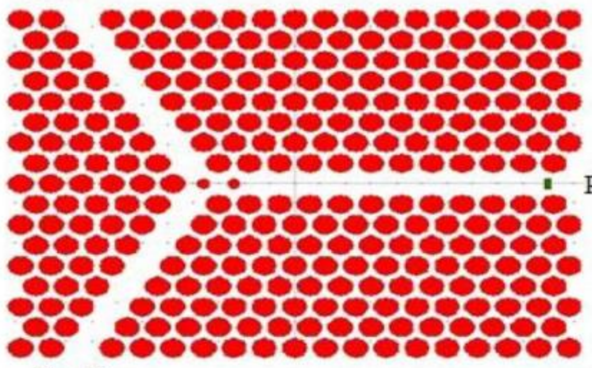

Figure. 1. The proposed structure for AND logic gates.

DESIGN AND ANALYSIS

Fig. 2 shows the band structure for the proposed photonic crystal lattice. It has been calculated by employing a 2D plane wave expansion method. A complete photonic band gap centered at telecommunication wavelengths can be determined.

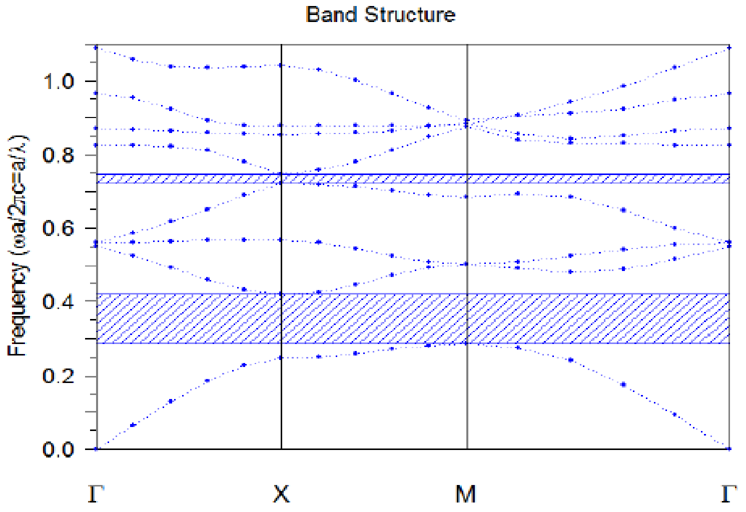

Figure. 2. The obtained band structure for the given photonic crystal lattice

References

[6] Ref. 6 Y. Tetsuro, G. Masahiro, K. Toshiaki, N. Kazuhiro,S. Shinnosuke, IEEE J. Quant. Electr. 38, 37 (2002)

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THE TRANSMITTED IN PROPOSED ALL-OPTICAL AND LOGIC GATE

Figure 3 shows the design of an all optical AND logic gate on the platform of 2D crystal photonic. In this structure a symmetric Y-shaped waveguide is formed and a hole is introduced at the center of the three waveguides. (Figure 3 "a"). The normalized transmission obtained by 2D-FDTD is illustrated in (figure 3"b").

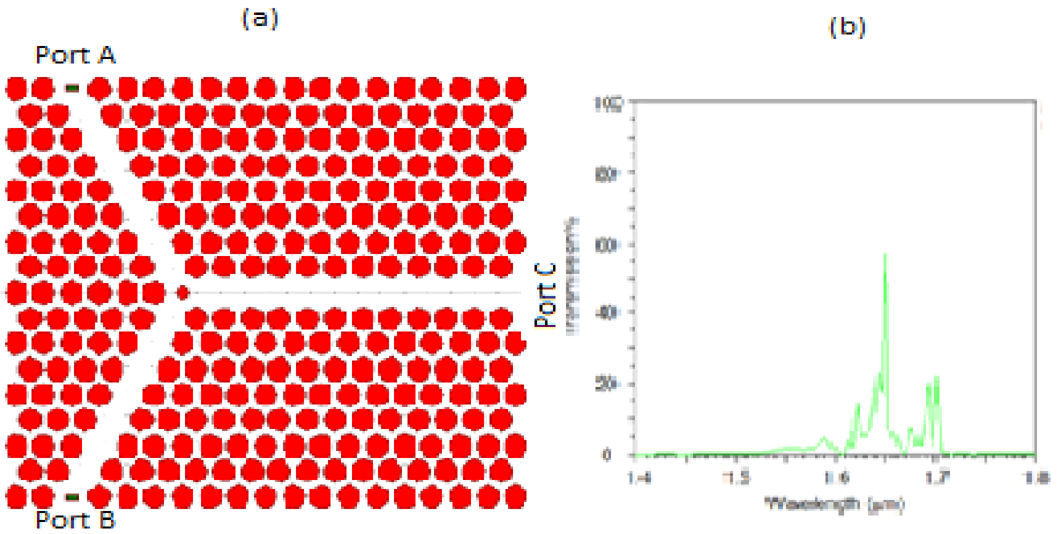

Figure 3: (a) Design of the Y-junction. (b) Transmission of the AND logic gate with one cavity

AFTER ADDING THE CAVITY: When we add another hole at the center of the Y-junction figure 1, higher order modes are removed. The total transmission at the output ports is improved compared to the last structure this is clearly seen in (figure 4).

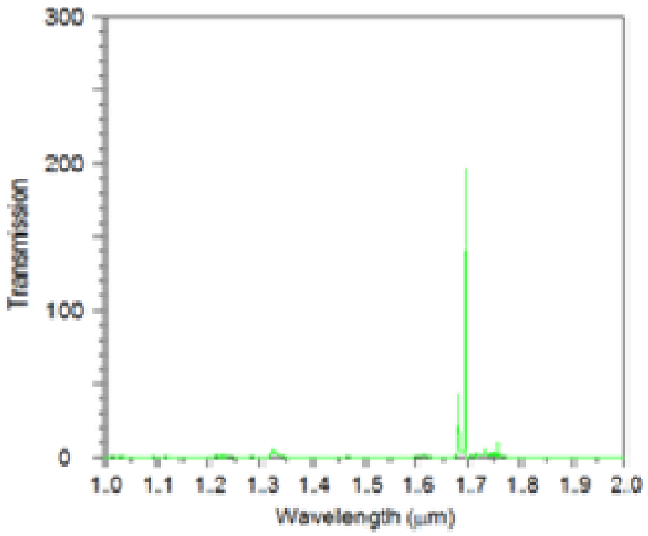

Figure 4:The spectral response in transmission of the all-optical AND logic gate after adding the cavity

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THE TRANSMITTED IN PROPOSED ALL-OPTICAL AND LOGIC GATE

AFTER OPTIMIZATION:

In order to improve the transmission properties we have change the position of the two cavities (Figure 5) by moving them inside the right guide.

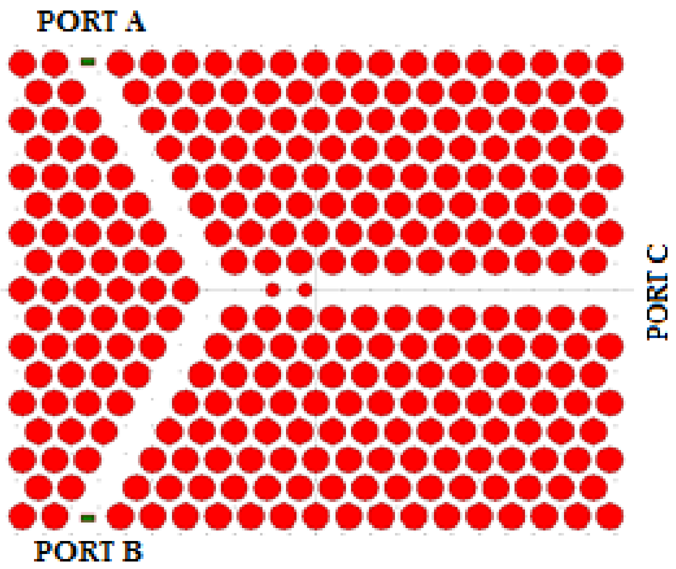

Figure 5: Design of the optimized All-optical AND logic gate

In (figure 6) the transmission is clearly increased with this new configuration, so we can conclude that the last modification proved the theoretical results who say that in crystal photonic the substitutions defects change the transmission

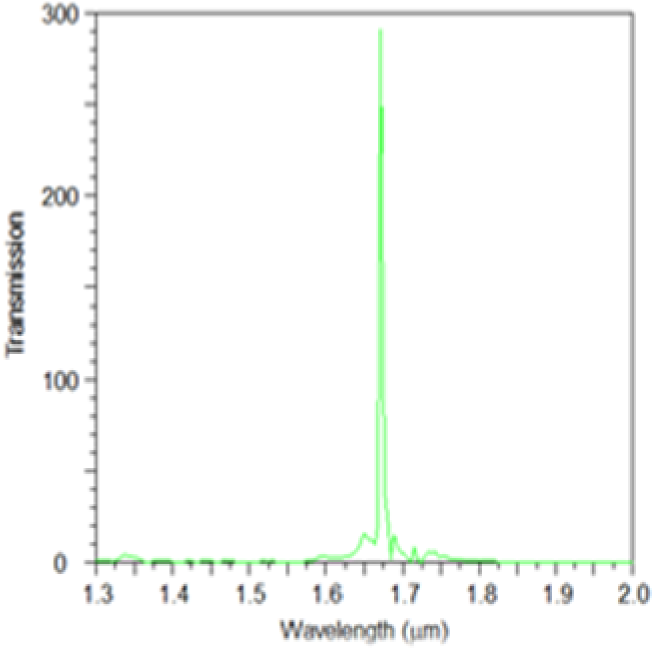

Figure 6: the spectral response in transmission of the optimized All-optical AND logic gate.

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SIMULATION AND RESULTS

Truth table 1 for AND logic gate, where the output signal is as a function of input power Pi show that the system performs as an AND gate.

PORT A	PORT B	PORT C	LOGICAL OUTPUT
0	0	0Pi	0
0	1	0.017Pi	0
1	0	0.017Pi	0
1	1	1.038Pi	1

Table1: The truth table for AND logic gate, where the output signal is as a function of input power Pi

The cavity mode whose magnetic field configuration is depicted in figure 7 needs to be coupled to one of the guided modes in the PC waveguide.
The results prove that the structure suggested could really (functioned as a logical gate "AND" using the devices optic based on photonic crystals.

SIMULATION AND RESULTS

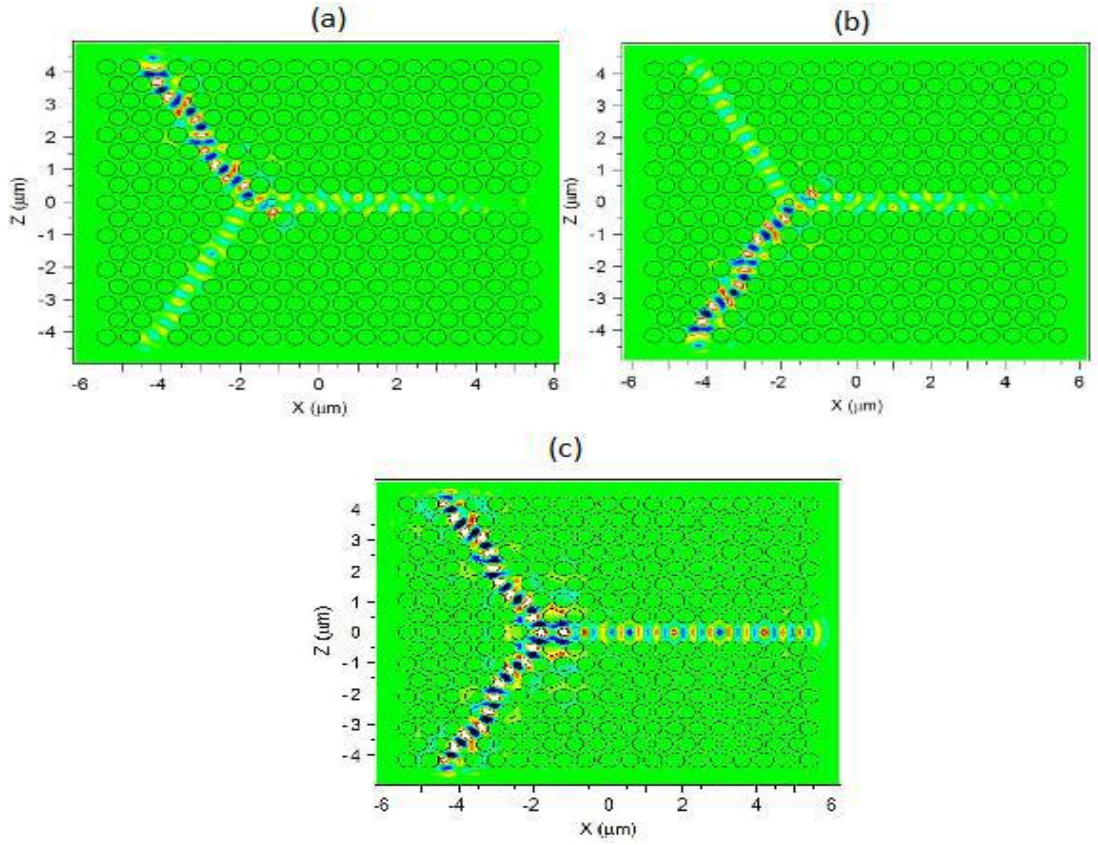

Figure 7 : Field distributions at steady state of the ''AND'' logic gate for (a) A=1, B=0; (b) A=0, B=1 and (c) A=1, B=1.

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The most significant result are:

*To increase the transmission and obtain a wide bandwidth at the output port. we have performed numerical simulations on Y-junction waveguide, and achieved an improvement of transmission by placing two microcavities in the center of the three waveguides.

*We found through this study that the transmission properties are clearly improved, the propagation mode is not affected by the accident posed by the corners, allowing the wave to follow the direction of bends and we have proved that the proposed structure could really function as an AND logic gate with a highest transmission and low losses.

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