Realization of XOR and OR Logic Gate with One Configuration in the Two-dimensional Photonic Crystals

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Abstract— Based on the theory of light beam interference effect, a new configuration is designed to realize two types of all-optical logic gates including XOR and OR logic gate in two-dimensional (2D) photonic crystals, and the distribution of the electrical field is simulated by the Finite-difference in time-domain method. The results show that through this new configuration, not only the two types of all-optical logic gates can be realized, but the higher light contrast ratio of the logic state "1" and "0" can also be obtained. The realization of two types of all-optical logic gates in one configuration is helpful and significant to the optical device integration and potential in the optical communications. It is noticed that the logic state of "1" and "0" at output port are defined as the transmission is larger than 0.5 and less than 0.1, respectively.

1. INTRODUCTION

logic gates realized by photonic crystals have been researched and attracted much attentions recently. Logic functions are usually implemented through different ways such as using closed packed 2D photonic crystal structure, self-collimated beams in 2D photonic crystal [1], single-mode wave interference for on-off keyed signals [2] and multi-mode interference for BPSK signals [3] in the photonic crystal waveguides. Waveguides are well known for their operating frequency of the photonic band gaps (PBG) which can control the light propagation of the electromagnetic wave [4, 5]. There have been many reports about logic gates such as NOR logic gate [6], AND logic gate [7] are realized by the photonic crystal waveguides, Fu et al proposed five logic gates [8], but the scheme can implement one logic gate function almost by one waveguide configuration. This paper realize XOR and OR logic gates with one configuration in 2D photonic crystal waveguides and the design is significant to application in the integrated photonic circuits.

2. PHYSICAL MODEL

The scheme of the 2D photonic crystals is shown in Fig. 1 and the black tunnel denotes the waveguide. The Silicon rods (white circles in Fig. 1) which dielectric constant is set to 11.56 are inserted into the air background. Ports A, B, C can be chosen as input ports in logic gates design and the D ports is considered as output port. The band structure of the 2D photonic crystals shown in Fig. 2 is obtained by PWE (plane wave expansion) method [8]. The normalized frequency of the PBG is from $0.46(a/\lambda)$ to $0.57(a/\lambda)$ and we chose $0.517(a/\lambda)$ as the incident wave frequency

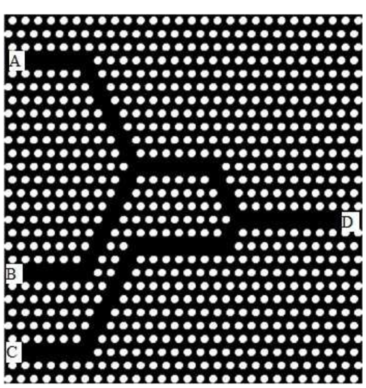

Figure 1: The scheme of the 2D photonic crystals.

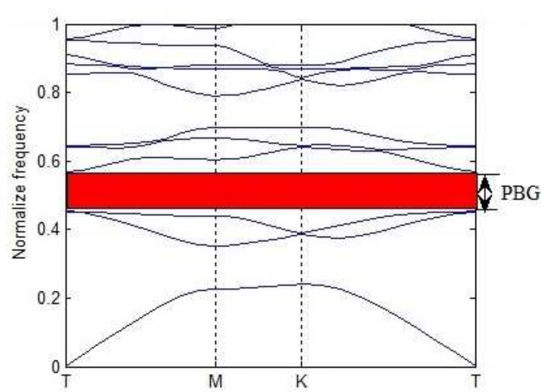

Figure 2: The band structure of the 2D photonic crystals.

which can propagate in the waveguide with little light consumption. The electromagnetic wave propagating is simulated by Finite-difference in time-domain (FDTD) method [9]. The incident wave is assumed as a continuous wave (CW) which is TM polarized in the following calculations.

3. SIMULATION OF TWO TYPES OF TWO LOGIC GATES

3.1. Realization of the XOR Logic Gate

We chose ports B and C as two input ports and the port A as an idle port. Here, we propose the amplitude of the electric field of the incident wave is 100 V/m. When the incident waves of the same amplitude and phase are simultaneously injected into both port B and C, the destructive interference will occur between the two light beams due to their phase difference equals to π. If any input port is injected into light, the higher light power can be obtained at the output port D. It is obviously that no light propagates without input waves. The distributions of the electric field are shown in Figs. 3(a)–(c), and we can conclude that the scheme realize the XOR logic gate.

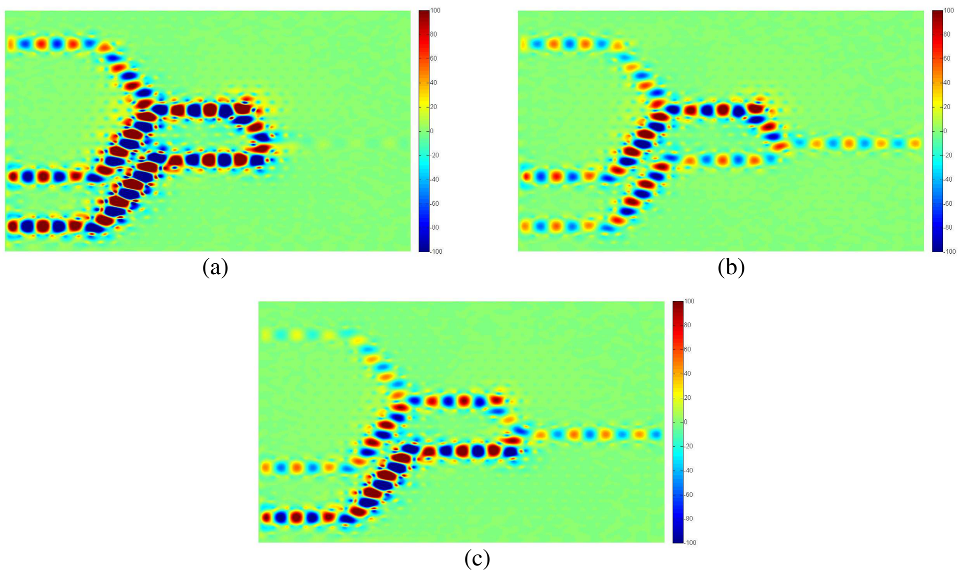

Figure 3: (a) The electric distribution as $E_C = E_B = E$. (b) The electric distribution as $E_B = E$, $E_C = 0$. (c) The electric distribution as $E_C = E$, $E_B = 0$.

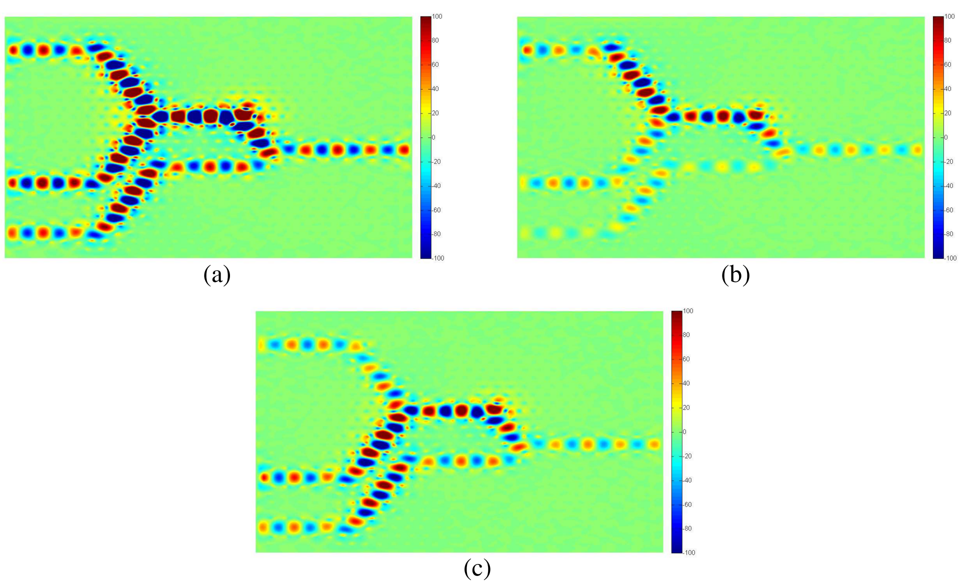

Figure 4: (a) The electric distribution as $E_A = E_B = E$. (b) The electric distribution as $E_B = 0$, $E_A = E$. (c) The electric distribution as $E_B = E$, $E_A = 0$.

3.2. Realization of the OR Logic Gate

If we consider ports A and B as two input ports and the port C as an idle port. When the two incident waves with the same amplitude and phase are excited at both port A and B, the constructive interference occurs. If any input port is injected into light, the higher light power can be obtained at the output port D. If no input wave is injected into any of the input port, there will be no light power obtained at output port D. The distributions of the electric field are shown in Figs. 4(a)–(c), and the scheme is considered as OR logic gate.

4. CONCLUSIONS

In this paper, the design of two types of logic gates in 2D photonic crystals is proposed and higher light contrast ratio between logic state "1" and "0" can be obtained by FDTD method. The results show that this configuration is helpful in optical device compactness and integration and significant to optical communications.

ACKNOWLEDGMENT

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