The Designs of XOR Logic Gates Based on Photonic Crystals

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Abstract: We propose a XOR logic gate based on photonic crystal with cylindrical silicon structure. The simulation results confirm the optical logic gate can show their capabilities. This device is potentially applicable for photonic integrated circuits.

Keywords: logic gate, photonic crystal, photonic integrated circuit

1. Introduction

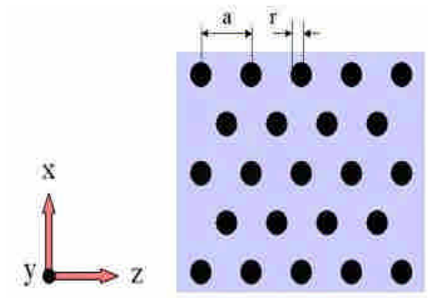
As the development of high-speed and high-capacity telecommunication systems, the demands for all-optical signal processing techniques are rapidly increasing. All-optical logic gates are key elements in all-optical signal processing techniques such as addressing, switching, header recognition, data encoding, and encryption. So far, several schemes have been investigated to realize various all-optical logic functions [1-4]. These approaches have showed some advantages, but which are difficult to operate at very high speed data rate. The inevitable spontaneous emission noise affects the operation performance. In addition, logic implementation techniques are usually limited to mach-zehnder interferometer and fiber-based devices.

In recent years, photonic crystal based optical devices have attracted significant research efforts[5-7]. The ability to interact with light on a wavelength scale promises ultra-compact structures for optical integrated circuits. In photonic crystal waveguide devices, photons with wavelength within the bandgap cannot propagate through the crystal. Due to the periodic arrangement is destroyed so placing some defects in the crystal and it is possible to build a waveguide to guide light along certain path.

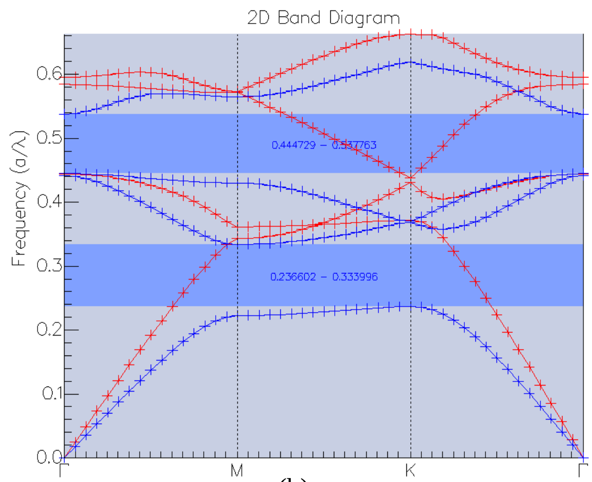
In this paper, we propose a XOR logic gate based on photonic crystal with cylindrical silicon structure. The simulation results confirm the optical logic gates can show their capabilities. This device is potentially applicable for photonic integrated circuits.

2. Design and numerical experiment

We consider a array of two dimensional triangular lattice photonic crystal composed of cylindrical silicon (Si) rods in air as shown in Figure 1(a). The radius and the lattice constant [8] of the silicon rods are r = 0.2μm and a=0.7 μm, respectively. In this structure, the band diagram is shown in Figure 1(b). The bandgap opens for the frequency range of 0.4447-0.5378(a/λ) for the ***E***-polarized mode (electric-field is parallel to the rod axes), where λ is the wavelength in free space. The width and the central width of bandgap are 0.093 and 0.491,respectively, which corresponding to a central wavelength of 1.55 μm. The results are same in three ΓK, MK, and KΓ directions of the band diagram mentioned above. So, a line defect is created and the photons with wavelength within the bandgap can propogate along certain path.



(a)



(b)

Fig. 1 (a) A array of two dimensional triangular lattice photonic crystal composed of cylindrical silicon rods in air, where r is the radius and a is the lattice constant of the silicon rods, respectively. (b) Band diagram of the photonic crystal structure for both E-polarized and H-polarized modes.

Table 1 Truth table for XOR logic gates.

A	B	XOR
0	0	0
0	1	1
1	0	1
1	1	0

Table I shows the truth table for XOR logic gates. The logic 0 and 1 in the table indicate without and with input/output signal, respectively. Whether the output signal of XOR is high (1) or low (0) depending on the input A and B signals indicated by the pairs (00), (01), (10), (11). The schematic diagram of the proposed XOR optical logic gate is shown in Figure 2. The behavior of the XOR for input (01), (10) and (11) is shown in Fig. 3, in which the simulation results confirm the optical logic gate can show their capabilities.

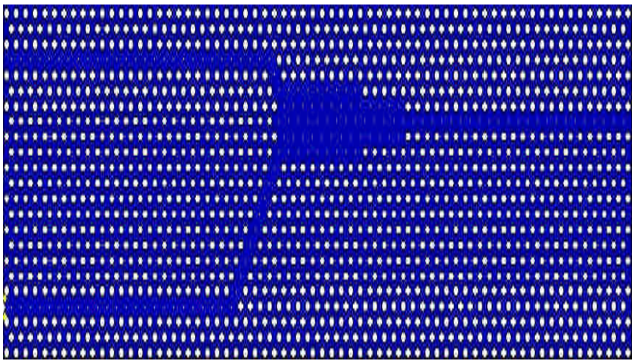
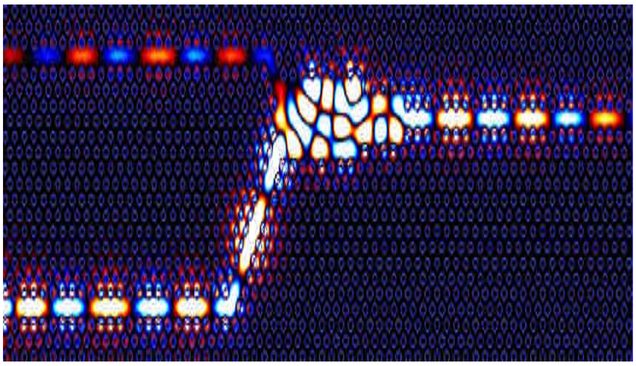
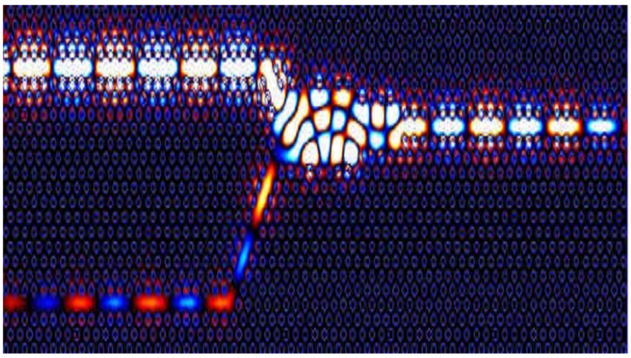


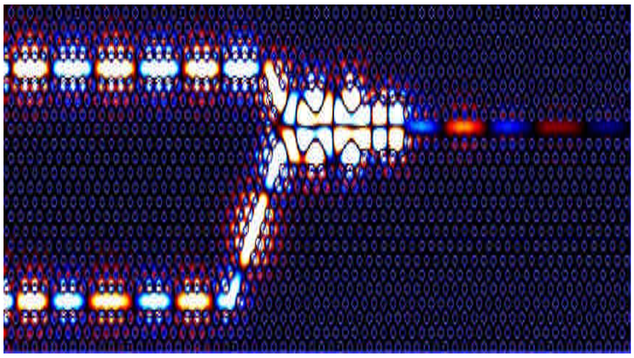
Fig. 2 Schematic diagram of the proposed XOR optical logic gate.



(a)



(b)



(c)

Fig. 3 The behavior of the proposed XOR optical logic gate for input (a) (01), (b)(10) and (c)(11), respectively.

5. Conclusions

A device for XOR optical logic gate, based on an array of two dimensional triangular lattices photonic crystal composed of cylindrical silicon rods in air, is proposed and demonstrated. The logical function is based on the interference of the reflected and transmitted beams and which is applicable in frequency range 0.4447-0.5378(a/λ). The device has simple geometric structure and clear operating principle, which shows that this device could be a strong candidate for future photonic integrated circuits.

6. References

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