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Realization of all-optical three-person voting function based on self-collimation with the two-dimensional photonic crystals

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Abstract

In the paper, a simple structure of three-person voting circuit is proposed and based on self-collimation effect with the two-dimensional photonic crystals. The electric field intensity of the proposed structure is deduced according to optical interference theory. The results show that the simple structure with two-dimensional photonic crystals can realize the three-person voting either from the optical interference theory or simulation, meanwhile, the light contrast ratio between the output logic signal "1" and "0" can reach as high as 19 dB. When compared with three-person voting designed with digital electronic technology, the size of the proposed design in this paper is more smaller, which is valuable in photonic device integration and compactness.

Keywords: Photonic crystals; Self-collimation; Line defect; Light contrast ratio

1. Introduction

Photonic crystals (PCs) were originally proposed by Yablonocvitch [1] and John [2] almost at the same time in 1987, and they are spatially periodic dielectric or magnetic structures with the photonic band gaps (PBGs) which attracts more and more researchers on their studies and applications [3–6]. If the wave vector propagating direction and working frequency are in some special range, the all optical device doesn't always need to work on frequencies in PBGs like all optical waveguide as a line or several line rods removed (or holes filled), instead, the electromagnetic wave can keep traveling along a designated direction, meanwhile, the divergence of the collimated beam is much smaller than that generated in conventional Gaussian optics [7], and this self collimated effect is therefore used as self-guiding in two-dimensional photonic crystals (2D PCs) [8]. Due to its light beam focusing without the waveguide guiding the electromagnetic wave, the self-collimation effect is widely studied [9–12]. Therefore, in many cases, self-collimation effect in 2D PCs can replace waveguide functions without any diffraction. In the reference [13], polarization-independent drop filters based on phonic crystal self-collimation ring resonators are realized and highly desirable for applications in photonic integrated circuits. A device for optical switches and logic gates is also proposed based on self-collimated beams in 2D PCs by Zhang et al. [14], in addition, all optical half adder is also realized based on self-collimation effect in

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the reference [15]. Presently, more and more all optical logic devices are designed with PCs and need to be ultra-compact in size.

In this paper, we first describe the simple structure of 2D PCs which function as three-person voting circuits, followed by the analysis of optics interference theory. Finally, we simulate the electric field distribution in the cases of different input signals from three referees. The results of simulation are excellently agree with optics interference theory.

2. Physical model

Three-person voting circuits design (always appears) in the digital electronic technology and may be realized in different ways such as logic gates combination, decoder, data selector and adder [16]. In this paper, a simple structure of 2D PCs is designed to functions (function) as three-person voting and has great advantages in device compactness. The voting system of three referees includes one chief referee and two assistant referees. If the chief referee agrees, the logic state of the result is "1" despite of the two assistant referees' decision, otherwise, the logic state of the result is "0" except for the two referees (agreeing) simultaneously.

If the signal of input *a* represents the chief referee's decision, and that of input *b* or *c* represents the other two assistant referee's decision, the logical function for three-person voting is shown in Table 1.

Self-collimation is an interesting confinement mechanism of light guiding without line defect or nonlinearities, and it occurs when the incident wave with special frequency is excited in a designated direction. Reference [17] studied dispersion-based beam splitter in photonic crystals, and the reflection or transmission varies with the radii of the air holes of the splitting

Table 1
Truth table for the three-person voting.

Input *a*	Input *b*	Input *c*	Logic output
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1
0	1	0	0
0	0	1	0
0	1	1	1
0	0	0	0

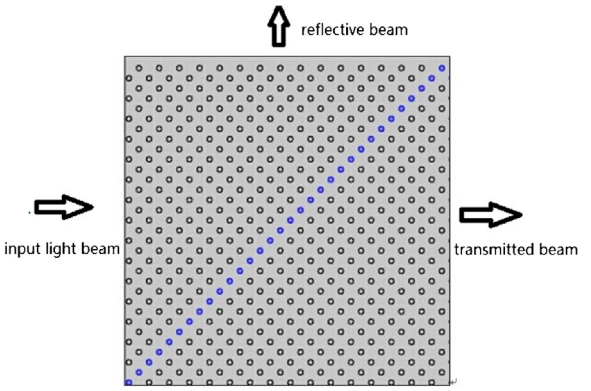

Fig. 1. The scheme of the light splitter.

structure experimentally. In Fig. 1, the reflection or transmission of the split beams also depends on the refractive index of the line defect. When the refractive index is chosen appropriately, the structure can function as a 3 dB splitter [14,17] which can split the incident light beam into two beams (the reflected beam and the transmitted beam) with the same light intensity.

Fig. 2 shows the schematic structure of the three-people voting based on 2D PCs with square lattice. The diameter of the dielectric rods composed of silicon is

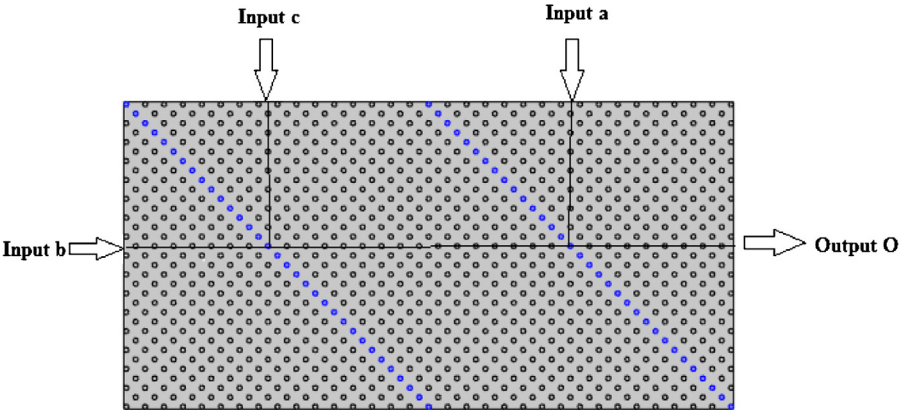

Fig. 2. The scheme structure of the three-person voting.