Designing and Simulating AND Logic Gate with a Simple and Symmetrical Structure

MEHDI REZAEENIA[1,*]FARIBORZ PARANDIN
Department of Electrical Engineering, Kermanshah Branch, Islamic Azad University,
Kermanshah, IRAN

Abstract: In this paper, a two dimensional photonic crystal structure is used in order to design and simulate an all optical AND gate. This gate has a small size and it has two inputs and one output. 0 and 1 logic states are defined based on power values, that is, logic 0 and logic 1 are, respectively, considered for low and light source power when light is emitted. The results show that these power values are low for 0 logic state and high for 1 logic state and it is in agreement with AND gate accuracy table.

Keywords: optical logic gate, photonic crystal, defect

Received: April 12, 2022. Revised: October 11, 2022. Accepted: November 23, 2022. Published: December 23, 2022.

1. Introduction

Dimensionality reduction transistor is used to increase the data transfer speed but this technique has many problems such as the technology used for building the pieces. Since this reduction is growing fast, it seems that it may face many serious problems in the future. In addition, electron tunneling properties may limit this reduction in small dimensions [1-15].

Photonic crystals are periodic dielectric structures. Areas with different dielectric coefficients are repeated alternately and this alternate state determines light wavelengths that can be emitted. A photonic crystal is made by alternate changes in refracted index of dielectric materials or by drilling regular holes in dielectric. When light is emitted in alternate structure, it is reflected after touching dielectric. Thus, a mass reflex interference occurs in a certain wavelength and the light with those lengths does not cross the materials. The total of these wavelengths with their frequencies is called photonic band gap (PBG) which is the base of the photonic crystal function. Depending on the alternate state of the photonic crystal area, PBG can be divided in one, two or three dimensions. The simplest type for photonic crystals is alternate layers of materials with different insulation coefficient that can change in one direction. This type is called one-dimensionally periodic structure; Two and three-dimensionally structures build two or three-dimensional photonic crystals [16-20].

Photonic crystals are of many applications in designing and establishing digital and analog circuits. For example, in the field of analog, they can be used for designing sensors, diodes, optical fibers, filters as well as power dividers [21-25].

Digital circuits are one of the most significant applications of photonic crystal which researchers are hopeful to achieve optically integrated circuits by designing different types of logic gates and logic circuits. In this way, access to optical processors will be possible as well. Thus, various optical logic gates have been designed and simulated using photonic crystals. Moreover, other types of logic circuits have been designed based on photonic crystals, including half adders, half subtractors, coders, decoders and multiplexers [26-37].

One of the most serious problems in most designed circuits is their large size. In this paper, a small-sized structure is used to design and simulate AND logic gates. This structure is symmetrical and has simple linear defects that are simplified by the designer.

2. Designing gate AND using photonic crystals

The given structure is a photonic crystal with a number of rods in 15 × 19 order, in which linear defects are used. Figure 1 shows the given structure, where, a = 640nm is the lattice constant, R = 0.2108a is radius and $n_o = 1$ is air refractive index. Here air is considered as the substance and the wavelength of light sources is λ =1,539 μm.

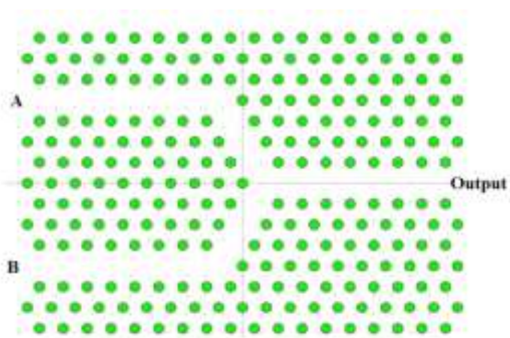

Figure 1: proposed AND gate structure

The structure shown in figure 1 includes A, B as inputs and OUT as output. For a more detailed study of the structure in this figure, the optical power distribution in the structure is shown. The power distribution is shown for inputs A = B = 0. Figure 2 shows that since the sources are off, no power is emitted in the outputs and it can be said that the outputs are in the logic 0 state.

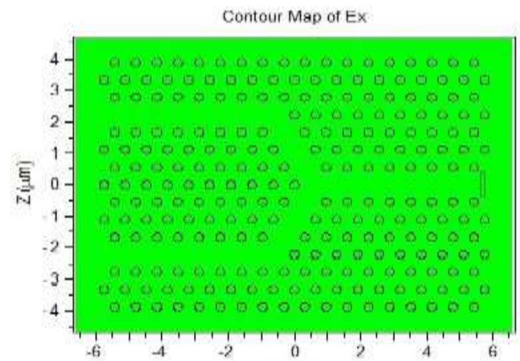

Figure 2: Optical power distribution for inputs A = B = 0

If the inputs are A = 0, B = 1, the optical power emission curve is shown in figure 3. In this case, the power at the output is very low and its normalized value is equal to 0.12, which can be considered as logic 0 state.

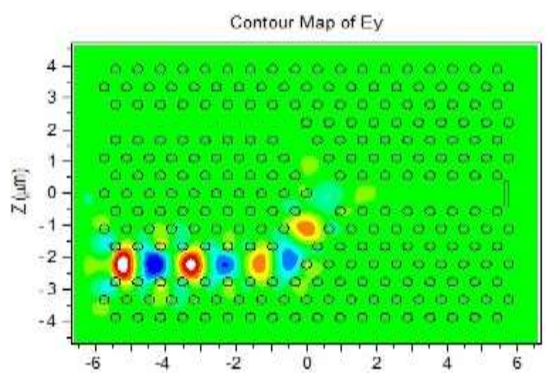

Figure 3: Optical power distribution for inputs A = 0, B =1

The power distribution for this mode is shown in figure 4 for inputs A = 1, B = 0. In this case, input source A is on and the other source is off. The optical power distribution in this case is shown in Figure 4. It can be seen that in this case, the light intensity at the output is small and in fact, the output equal to 0 is reasonable. The value of the output power in this case at the output is equal to 0.12, which is a reasonable, as well.

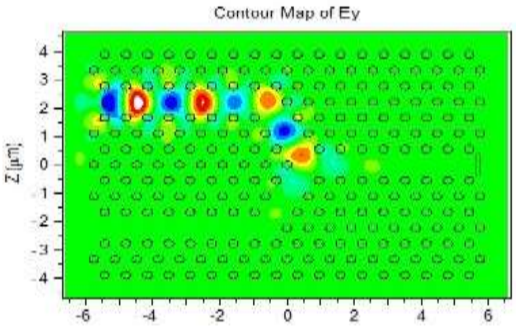

Figure 4: Optical power distribution for inputs A = 1, B = 0

At final, the light source is on in both A and B ports. The optical power emission curve for this mode is shown in Figure 5. According to this figure, it can be said that the light intensity at the output has a significant value, and in fact the output in this equal to 1 state. The amount of normalized power at the output in this case is 0.6, which is equal to 1 state.

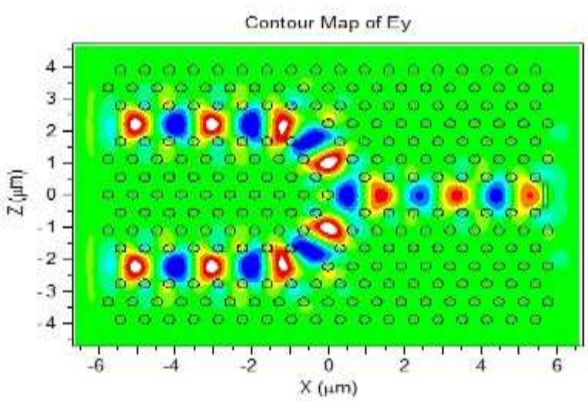

Figure 5: Optical power distribution for inputs A=B=1

Table 1 shows the accuracy of AND gate and the normalized optical power at the outputs for the designed circuit. According to the obtained power values, it can be seen that this circuit can be used as an AND gate. This structure has very small dimensions that can be used in integrated light circuits. In addition, the values of power in logic states 0 and 1 are very different, which is also suitable for detecting them in the output.

Table 1: Table of AND gate accuracy and power at the output in different input states

A	B	logic Out
0	0	0
0	1	0
1	0	0
1	1	1

3. Conclusion

In this paper, light emission paths to achieve an AND gate are built using two-dimensional photon crystals and linear defects. The power in the outputs has been measured for different modes of input placing light sources in the inputs. The results show that the amount of output power in different input modes corresponds to the AND gate accuracy table. One of the advantages of this optical gate is its small size, which is suitable for integrated optical circuits. Moreover, the simplicity of the structure and the use of simple defects have decreased the problems of this circuit during its building.

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