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Research Paper

Optical Majority Gate Designed Using Nonlinear Cavities

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Abstract:
We are going to design an optical Majority gate. Photonic crystals will be used for designing this structure. Resonant cavities are used to realize the threshold switching for the working mechanism of the optical Majority gate. Doped glass rods are added to cavities to create the nonlinear cavities. The simulations are done with Rsoft photonics CAD based on finite difference time domain method. The proposed majority gate has 3 input ports and only one output port. The output port is ON, when at least two of the input ports are ON. The working wavelength of the proposed structure is 1550 nm. For the proposed all optical majority gate the ON/OFF contras ratio and the bit rate are 19.5 dB and 500 GS/s respectively.

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1. INTRODUCTION

All optical logic structures are needed for creating all optical digital networks. Optical digital networks and systems are required for high speed and high bandwidth communications. In order to use complete capabilities of optical communications, all structure that are used should be all optical without any none optical structure. Photonic crystals (PhC) can be used for designing different kinds of all optical devices [1-5].

Recently, different methods were used for designing all optical PhC-based logic structures [6,7]. Interference of light were used at optical logic structures [8]. In this method the logic states are determined with the constructive or destructive interference of optical waves. Optical threshold switching can be used at optical logics too [9-12]. In this method the switching task is done by using optical intensity of the optical waves.

Optical majority gate is an optical logic circuit that is needed for all optical data processing systems. A typical majority gate has 3 input and 1 output ports. The output port is ON when at least 2 of the input ports are ON. The propose structure will be designed using threshold switching method by the help of nonlinear resonant cavities.

2. DESIGN PROCEDURE

We used the nonlinear cavities [13,14] at which the linear rods are made of Silicon rods surrounded by air. And the nonlinear rods are made of doped glass. 3 parallel waveguides were created at X direction. Then 3 parallel waveguides were created at Z direction. 9 nonlinear cavities were located at the intersection of the waveguides. The cavities were labeled from C1 to C9. C1, C2, C4, C6, C8 and C9 were designed such that they can only drop high intensity optical waves at X direction. They can drop all the optical waves at Z direction. C3, C5 and C7 can drop all the optical waves at both directions.

The front sides of the X-direction waveguides were connected to the bias port of the structure. The end sides of them were connected to the output port of the proposed majority gate. The input ports were connected to the bottom sides of the Z direction waveguides. The optical Majority gate is at Fig. 1.

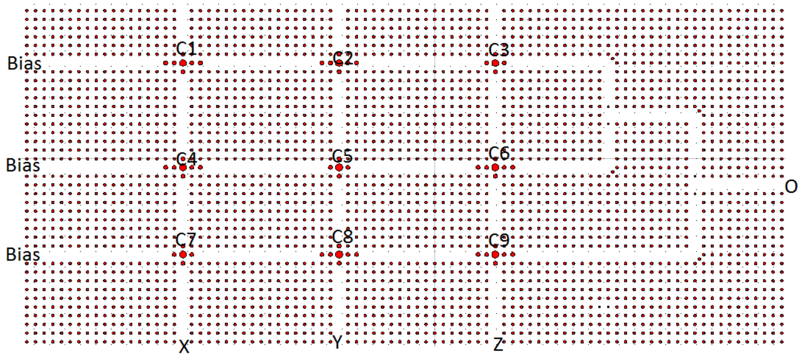

Fig. 1. All optical Majority gate.

3. SIMULATION AND RESULTS

For simulating the proposed structure we need optical sources to launch the bias signal and the optical signals that are needed at the input ports. For all the optical sources the input wavelength and the optical intensities are 1550 nm and 0.1 W/μm^2 respectively. The proposed structure has 8 working states that will be discussed at the following:

When all the input ports are OFF, the intensity at the cavities are low therefore C1, C4 and C8 cannot drop the light. As mentioned earlier these cavities can drop the light when the intensity at them is more than 0.15 W/μm^2, so because in this case the optical intensity at the cavities is about 0.1 W/μm^2 they cannot dro the light. So the output port will be OFF (Fig. 2).

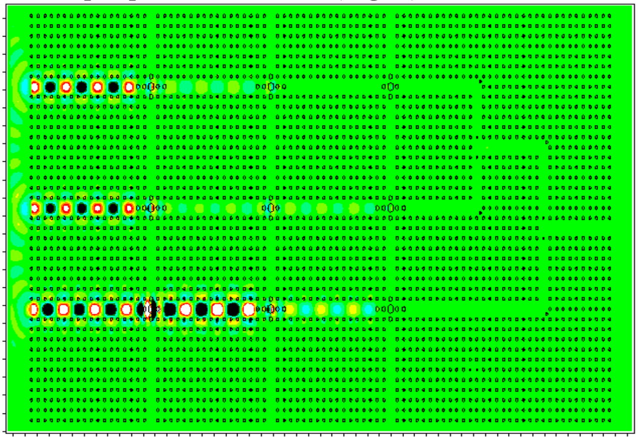

Fig. 2. The optical behavior of the proposed structure when all the input ports are OFF.

When X is ON and the other ports are OFF, C2, C6 and C8 cannot drop the light. So the output port will be OFF (Fig. 3).

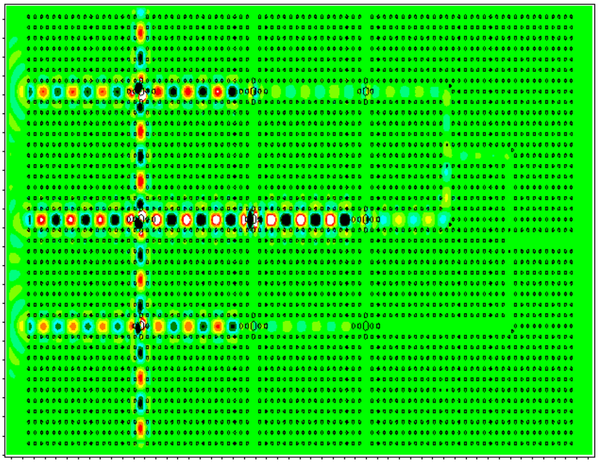

Fig. 3. The optical behavior of the proposed structure when X is ON and the other ports are OFF.

When Y is ON and the other ports are OFF, C1, C4 and C9 cannot drop the light. So the output port will be OFF (Fig. 4).

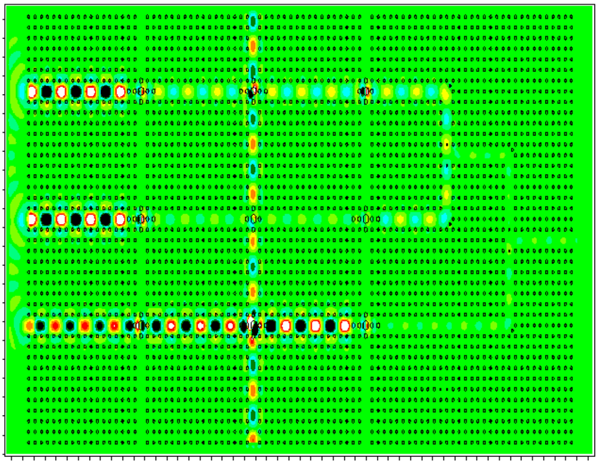

Fig. 4. The optical behavior of the proposed structure when Y is ON and the other ports are OFF.

When Z is ON and the other ports are OFF, C1, C4 and cannot drop the light. So the output port will be OFF (Fig. 5).

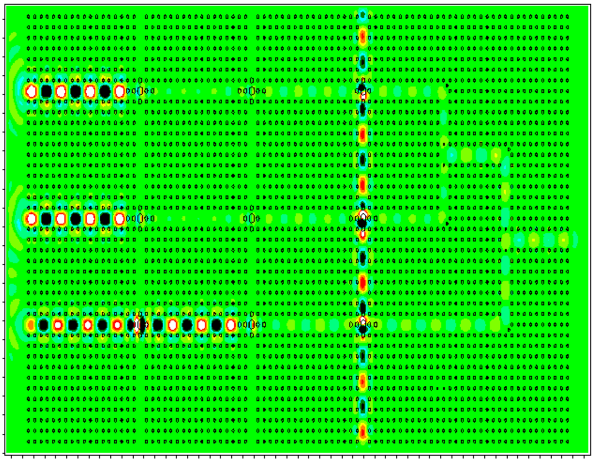

Fig. 5. The optical behavior of the proposed structure when Z is ON and the other ports are OFF.

When X and Y are ON and Z is OFF, the optical intensity near C1 and C2 can drop the light. Also as mentioned C3 can drop all the light therefore the light can reach the output port. So the output port will be ON (Fig. 6).

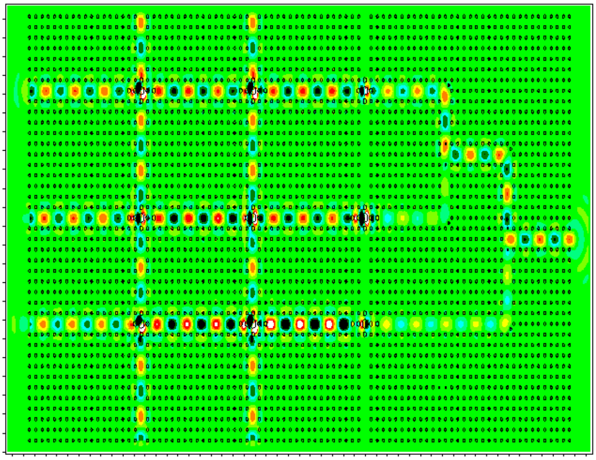

Fig. 6. The optical behavior of the proposed structure when X and Y are ON and Z is OFF.

When X and Z are ON and Y is OFF, C4 and can drop the light. On the hand as mentioned C5 can drop all the light therefore the light can reach the output port. As a result the output port will be ON (Fig. 7).

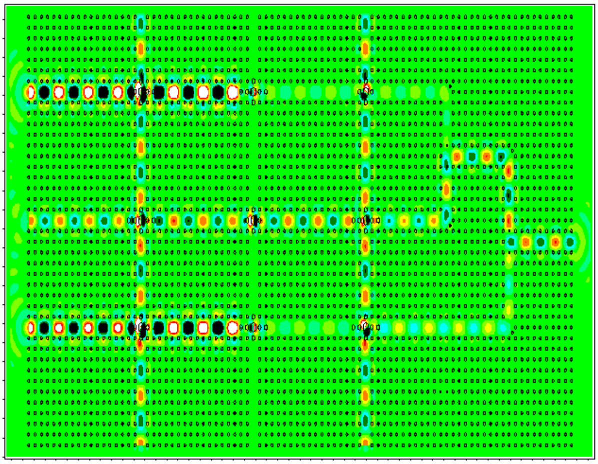

Fig. 7. The optical behavior of the proposed structure when X and Z are ON and Y is OFF.

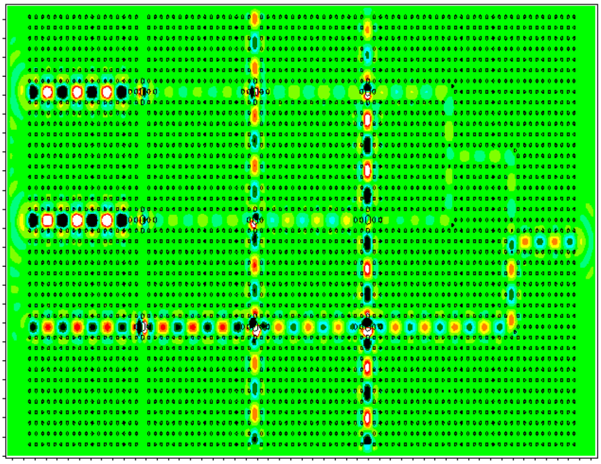

Fig. 8. The optical behavior of the proposed structure when Z and Y are ON and X is OFF.

When Y and Z are ON and X is OFF, C8 and C9 can drop the light. Also as mentioned C7 can drop all the light therefore the light can reach the output port. So the output port will be ON (Fig. 8).

Finally when all the input ports are ON, all the cavities 0 can drop the light. Therefore the light can reach the output port. So the output port will be ON (Fig. 9).

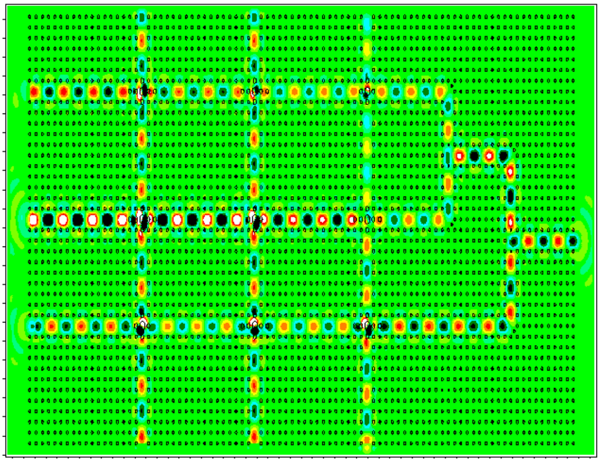

Fig. 9. The optical behavior of the proposed structure when all the input ports are ON.

The normalized intensity at the output port for logic 1 is about 90% and for logic 0 is about 1%. Therefore the ON/OFF contras ratio will be 19.5 dB. The rise and fall times for the proposed structure 1.5 ps and 0.5 ps. Therefore the bit rate of the optical Majority gate will be about 500 GS/s. The truth table of the optical Majority gate is shown at table 1. The footprint is about 1000 μm^2. The proposed structure has lower latency compared with similar previous works. Also the optical power required for correct operation of the proposed structure is lower than the similar structures.

Table 1. The truth table of the proposed structure.

X	Y	Z	O
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

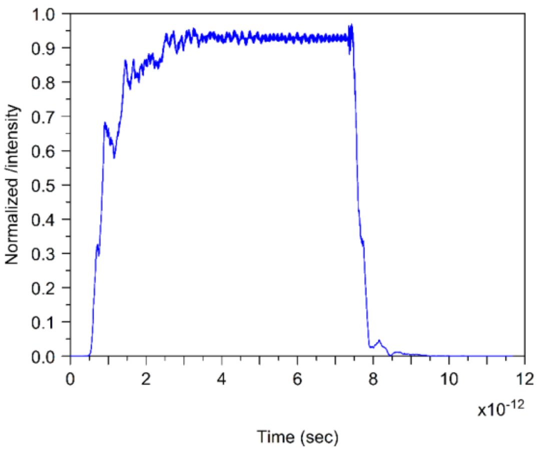

Fig. 10. Time response diagram of the proposed structure.

4. Conclusion

An all optical majority gate was proposed in this work. 9 nonlinear resonant cavities were used to realize the threshold switching method needed for designing the proposed structure. Optical sources with the wavelength and optical intensity of 1550 nm and 0.1 W/μm^2 were used for simulating the final structure. The ON/OFF contras ratio and the bit rate are 19.5 dB and 500 GS/s respectively.

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