Design and Analysis of All-Optic Circuits using 2D Photonic Crystals

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Motivation/ Introduction

In recent years, optical logic circuits have been attracting wide attention because of their potential application in fields of optical computing systems, optical signal processing and optical interconnection networks, because as the conventional electronic technology would reach its speed limit in computation and communication of information in future, all optical IC will become the most promising alternative to face this problem. Keeping this in mind, we have created an all optic Flip-Flop, encoder and decoder in which all the inputs and outputs are completely optical.

SCOPE of the Project

In this project, a basic flip flop, 4*2 Encoder and 2*4 Decoder design is proposed using two dimensional photonic crystal (2D PhC). Encoder has four input and two output waveguides as the ports, Decoder has three input(including one reference input) and four output waveguides as the ports, and flip-flop has four input(including two reference inputs) and two output waveguides as the ports. The design of these all-optic devices based on photonic crystal waveguides is much smaller than the conventional design due to large dispersion in photonic crystals. They can control, guide and limit the light in nanometre scale. Many more concepts have been introduced in the design of logic devices (like compactness).

Methodology

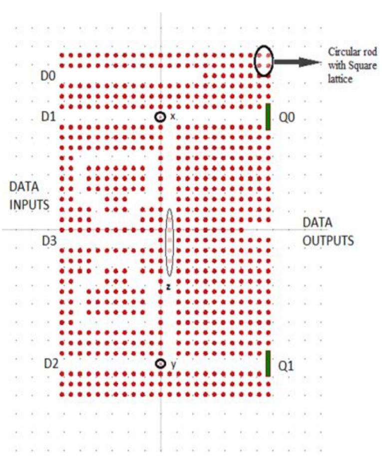

Figure 1

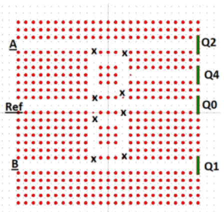

Figure 2

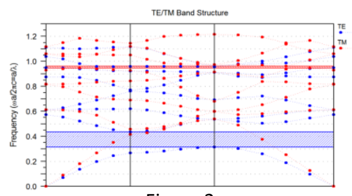

Figure 3

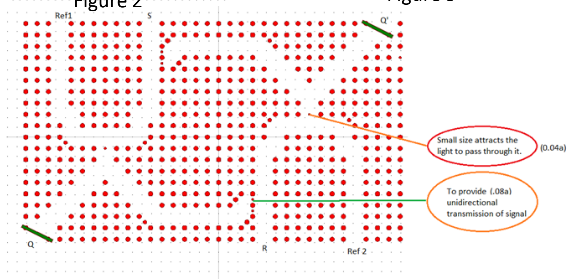

Figure 4

Figure 1: In figure 1 we have shown proposed design of encode, It has 24a´34a square lattice silicon rods at air (used as background) with the refractive index of 3.39 and the radius r is 0.2a, where ‘a’ is the lattice constant of the photonic crystal structure.
Figure 2: In figure 4.1.3.1 we have shown proposed design of decoder, It has 25a´25a square lattice silicon rods at air(used as background) with the refractive index of 3.9 and the radius r is 0.2a, where ‘a’ is the lattice constant of the photonic crystal structure.
Figure 3: PBGs have been extensively studied and have demonstrated a range of novel physical phenomena leading to many applications, particularly in lasing where defects in the lattice are used to produce highly-intense coherent radiation. For certain lattice configurations, EM waves with specific frequencies are not able to propagate through the lattice. Figure shows the band structure (wavenumber versus frequency) for a triangular 2D lattice of sapphire rods with the frequency normalized to the speed of light.
Figure 4: The permittivity of the dielectric Silicon rods in the structure is equal to e = 10.1 9 10-11 farad/m(er = 11.49), and the refractive index of n = 3.39, where the overall circular Si rods are surrounded by air. The bandgap range of this structure is equal to a/k = 0.32 to a/k = 0.44. The bandgap range of the overall structure is approximately equal to a/k = 0.32 to a/k = 0.44 at operating wavelength k = 1550 nm.

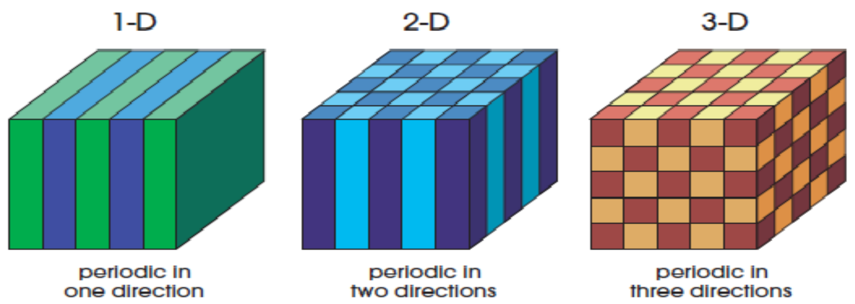

Figure 5: In 1D PhCs, the periodic modulation of the permittivity occurs in one direction only, while in two other directions structure is uniform.

Results

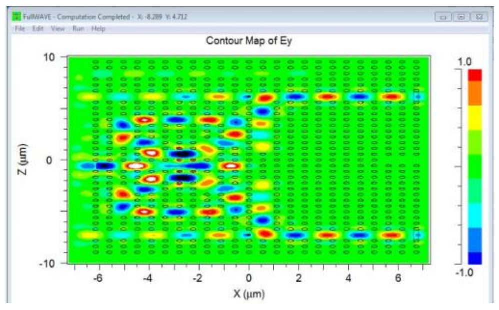

Figure 5

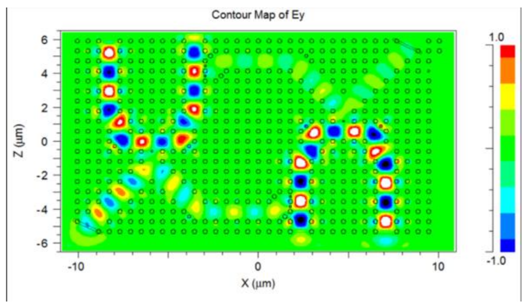

Figure 6

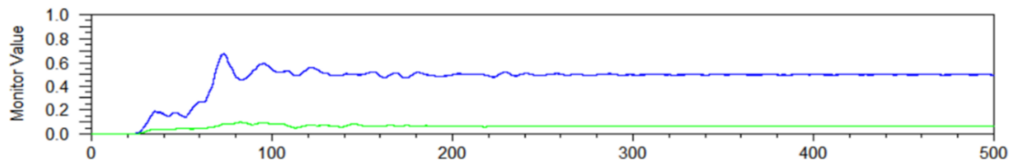

Figure 7

Figure 5: HereD3=1, D0=D1=D2=0, which gives output as Q0=1, Q1=1. here two resonators are used to get identical output at Q0 and Q1. Here time taken is 60 millisecond.
Figure 6: Clearly in the above normalized power graph we can observe that it is taking 100 microseconds to give the stable output. This phenomenon is due to the complexity in the circuit feedback loops.
Figure 7: Set is high and Reset is low, as per the truth table, the output q is high as represented in the simulation screenshot above.

Technical Specifications:

Contents	ENCODER	FLIP-FLOP	DECODER
Lattice constant(a):	556nm	523nm	582nm
Dimensions:	24a×34a	25a x 25a	35a×20a
Material used:	Silicon	Silicon	Silicon
Refractive index:	3.39	3.39	3.39
Rod type:	Circular	Circular	Circular
Lattice arrangement:	Cubic	Cubic	Cubic
Operation wavelength:	1.56μm	1550nm	1.55μm
Frequency range(a/λ):	0.32167-0.4403	0.32129-0.43992	0.27558-0.4465
Wavelength range(a=0.56):	272nm<λ<1717nm	188nm<λ<1634nm	1.29899-2.10465

Conclusion/ Summary

A basic flip flop, 4*2 Encoder and 2*4 Decoder design is proposed using two dimensional photonic crystal based (2D PhC). Encoder has four input and two output waveguides as the ports, Decoder has three input(including one reference input) and four output waveguides as the ports, and flip-flop has four input(including two reference inputs) and two output waveguides as the ports. we have created an all optic Flip-Flop, encoder and decoder in which all the inputs and outputs are completely optical. The deployment of all-optical digital processing is dependent upon being able to add functionality directly at the optical layer.

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Acknowledgments/ References

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2. Tamer A. Moniem "All-optical S-R flip flop using 2-D photonic crystal." Springer Science+Business Media New York 2015.
3. Gaurav Kumar Bharti, Jayanta Kumar Rakshit "Design of all-optical JK, SR and T flip-flops usingmicro-ring resonator-based optical switch." Springer Science+Business Media, LLC, part of Springer Nature 2018