International Journal of Instrumentation Electrical Electronics Engineering
p- ISSN: 2321 – 0621 e- ISSN: 2321- 063X

PHOTONIC CRYSTAL STRUCTURE FOR DIFFERENT PHOTONIC APPLICATIONS

Mihir Hota[1], Sonali P Dash[1], Gopinath Palei[2] and Sukanta K.Tripathy[1]
[1]National Institute of Science and Technology, Berhampur-761008, Odisha
[2]Gandhi Institute of Technical Advancement, Bhubaneswar, Odisha
hotamihir@yahoo.co.in

Abstract- Photonic crystals structures (PCs) are periodic dielectric structures that allow controlled light propagation. From the fundamental prospective these materials are of great interest for their ability to alter the natures of propagation of light.PCs have become a key subject of today's engineering and technological research. In order to design a photonic crystal with a photonic band gap (PBG), some crystal features and parameters like dimensions, symmetry, topology, lattice parameter, filling fraction and effective refractive index, refractive index contrast, scalability must be engineered. We in this review article restrict to applications of 2D photonic crystal structure to optical switching, optical logic gates and sensing.

Key words: Photonic crystal structure, Optical Bistability, Optical Switching, Optical Sensor, Optical Logic Gates

1. INTRODUCTION

Photonic crystals structures are periodic structures where the length of the period is of the order of the wavelength of light. Due to the wave nature of light and interference caused by the periodic structure, there exists a band gap for light in photonic crystals [1]. In order to construct a photonic crystal component, one has to find a photonic crystal geometry that has a band gap, i.e. range of frequencies for which there are no allowed electromagnetic modes. Then it is possible to make a defect in the lattice that permits one or more localized modes that have frequencies in the band gap [2,3]. In this way waveguides and micro cavities can be formed. A waveguide is a linear defect along which light with a wavelength corresponding to the defect mode frequency can propagate. A micro cavity is a point defect that can support a localized mode. Photonic crystals that are periodic in all three dimensions are called three dimensional (3D) photonic crystals and they are the only true photonic crystals in the strict sense since in them light propagation can be forbidden in all directions. The first 3D photonic crystal was the Yablonovite, the symmetry of which resembles the diamond lattice. Structures that are periodic in two dimensions are called two-dimensional (2D) photonic crystals and they can have a band gap for in-plane propagation of light. Two-dimensional photonic crystals can consist of; for example, dielectric rods in air or air holes in a dielectric organized in a square- or hexagonal lattice [2, 3]. Most 2D photonic crystals have a band gap for sufficiently high dielectric contrast, i.e., difference between the dielectric constants of the materials. Many 2D photonic crystal devices are constructed of photonic crystal slabs, which have a finite thickness (usually less than one period of the photonic crystals) in the direction perpendicular to the periodic lattice. Thus light is confined by the band gap in the plane of the 2D photonic crystals and by total internal reflection in the vertical direction. A waveguide-coupled photonic crystal slab has been shown to exhibit a strong 2D band gap [4, 5] at the wavelength often used in telecommunications 1.5µm. Based on our recent publications we are restricted the applications 2D photonic crystal structure to optical bistablity which leads to optical switching, optical logic gates and optical sensing.

2. OPTICAL SWITCH

Optical Bistability in hybrid structures was investigated due to the importance of these structures in both light emitting diodes and Laser diodes. The possible switching action in this hybrid structures will be an added advantage. This motivated us to investigate the role of different interactions on optical bistability, (which is used to realize switching) in different hybrid structures like "Hybrid Semiconductor Photonic Crystal Structure" and "Photonic Crystal Structure closed to a Magnetic Semiconductor". Interestingly Optical Switches based on optical bistability are found to have switching speed suitable for future generation optical communication. In Reference [6] Tripathy et.al investigated a new model to analyze the effect of this self-interaction on optical bistability in hybrid semiconductor photonic crystal structure.

3. OPTICAL LOGIC GATE

A logic gate is a device that performs a certain Boolean logic operation on one or more logical inputs and produces a single logical output. Boolean algebra is comprised of operations that give "true" or "false" as a result. In this lies the foundation of digital electronics and computing. It is standard to express true and false as 1 and 0 respectively. Logic gates are bistable devices, that is, they may yield one of these two possible stable outputs. In digital electronic systems it is common to see "1" correspond to 5 Volts and "0" corresponds to 0 Volts. In reference [7], Sonali et.al proposed a 2D photonic crystal structure in such a manner that air holes of radius 0.144µm are designed in a thin silicon substrate of refractive index 3.5, to realize optical 1(light) and 0(no light) ,whose principle of operation can be explained by superposition principle. Tripathy et.al [8, 9] investigated a closed packed configuration for optical logic gates. In this structure 13 numbers of symmetric glass rods of 0.3µm radius each and dielectric constant 12 are arranged so as to form a closed pack structure in air .Using this structure all most all the optical logic gates are realized. However different threshold values are used for realizing different gates. For example for OR gate a threshold of 42V/m is used, whereas for NOT, XNOR and NAND gates a threshold of 38V/m is used .This structure has an added advantage of behaving like a switch besides optical logic gate.

4. SENSING ELEMENT

A novel method to measure the strength of Cygel™ using 2D photonic crystal structure has been developed by Palei et al [10,11]. As the photonic band gap in this structure varies linearly with strength, it is concluded that 2D photonic crystal structure can be a good material for measuring strength of solution.

5. CONCLUSION

Photonic crystals are periodic dielectric structures that have a band gap that forbids propagation of a certain frequency range of light. This property enables one to control light with amazing facility and produce effects that are impossible with conventional optics. In future, some more components, like optical switch, optical logic gates, and sensors are expected to come the market. However we are yet to see the product of 3D photonic crystal structure. The use of shortlength PCF sandwitched between two SM fiber can also behave as sensor is also demonstrated recently[12].

REFERENCES

[1] E. Yablonovitch, Journal of the Optical Society of America B 10 (1993) 283.
[2] Hirayama, Hamano, Aoyagi, Applied Physics Letters 69 (1996) 791.
[3] J. Joannopoulos, Steven G. Johnson, J. Winn, R.D. Meade, Photonic crystals: Molding the flow of light, second ed. Princeton University Press, 1995.
[4] E. Yablonovitch, T.J. Gmitter, K.M. Leung ; "Photonic band structure: the face-centered-cubic case employing nonspherical atoms"; Physical Review Letters; Vol. 67, Issue 17; page(s): 2295–2298; Oct. 1991.
[5] E. Yablonovitch; "Photonic band-gap structures"; J. Opt. Soc. Am. B ,Vol. 10, Issue 2;page(s): 283-295, February, 1993.
[6] S.K.Tripathy, Mihir.Hota, T. Panigrahy "A Model for Optical Bistability in a Hybrid Semiconductor Photonic Crystal Structure", IEEE Photonic Technology Letters, Photonic Crystal Structure" vol.21, No.12, pp.772-774, 2009.
[7] Sonali Prava Dash, Sukanta Kumar Tripathy, " Y-shaped Design in Two Dimensional Photonic Crystal Structure for Applications in Integrated Photonic Circuits", Optik International Journal for Light and Electron Optics, accepted for publication.
[8] S.K.Tripathy, Subikash Sahu, Chinmay Mohapatro, Sonali Prava Dash, "Implementation of optical logic gates using closed 2D-photonic crystal structure", Optics Communications, 285,pp 3234-3237,2012.
[9] S.Rath,S.P.Dash,M.Hota and S.K.Tripathy, "Realization of Optical XOR and OR Gates Using Asymmetric Y Structure in a Two Dimensional Photonic Crystal", AIP conference Proc. Vol.1461, pp. 369-373,2012.
[10] G.Palai,S.K.Tripathy; A novel method for measurement of concentration using two dimensional photonic crystal structures ;Optics Communications, Volume 285, Issues 10–11, , Pages 2765-2768, 15 May 2012.
[11] G. Palai, S.K.Tripathy, N.Muduli, S.K.Patnaik,D.Patnaik.; A novel method to measure the strength of Cygel™ by using two dimensional photonic crystal struct ures; AIP Conf. Proc.Vol. 1461, 383-386, 2012.
[12] Jitesh Kumar Verma ,Sonali Prava Dash , Mihir Hota, Sukanta Kumar Tripathy, "Design of a Concentration Sensor Based on Photonic Crystal Fiber Placed Between Two Single Mode Fibers" accepted in Nano Letters,2013.

Biography

"Dr. Mihir Hota, completed his Ph.D in Optical Communication from Berhampur University.Completed his M.Sc from Utkal University, Bhubaneswar.Completed his L.L.B from Samblapur University.Completed his B.Ed from Nagaland University.and P. G. Diploma in Human Resource Management from IGNOU. Now he is Associate, Prof., in Department of Physics in NIST, Berhampur. He has published many National and International Journals. His area of Interest is Fiber Optics, Holographic Coupler & Optical bistability, Optical switching, and Application of Nanotechnology (Opto Electronics)