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DESIGN OF A LOW-LOSS WAVEGUIDE FOR OPTICAL COMMUNICATION USING A 2D PHOTONIC CRYSTAL

1. Vijay Laxmi Kalyani 2. Shivam Upadhyay

Vijay laxmi kalyani, Assistant Professor, Department of Electronics and Communication, Govt.Mahila Engineering College, Ajmer, Rajasthan, India, Mobile no.-09352870886, (vijaylaxmikalyani@yahoo.com).

Shivam upadhyay, M.Tech scholar, Department of Electronics and communication, Govt.Mahila Engineering College, Ajmer, Rajasthan, India, Mobile no.-09462257514, (shivamupadhyay920@gmail.com).

Abstract— In this paper a wide band, low loss Linear waveguide has been designed for TM-polarized light. The structure consists of hexagonal lattice where circular air-holes in silicon background have been organized. For optimal design of photonic band gap, inter-cell distance and cell radius have been varied to find the largest photonic band gap which should corresponds to the optical communication wavelength ranging from 1.2µm to 1.8µm. Here hole radius of 0.138µm and lattice constant of 0.4µm were the optimum values which provided the wavelength range of 1.2µm to 1.8 µm. And a minimum loss of has been realized at wavelength 1.55 µm. By using plane wave expansion (PWE) method band gap of the structure have been evaluated. Finite difference time domain (FDTD) method has also been used to compute the transmission power, electric field distribution and magnetic field distribution properties of the system.

Keywords— Plane Wave Expansion (PWE), Plane Wave Expansion Method, Finite Difference Time Domain, Photonic Crystals, Photonic Bandgap, Transverse-Electric, Transverse-Magnetic, Line Defect Waveguide (LDW), Opti-FDTD.

I. INTRODUCTION

With the development and enhancement of technology in the field of communication system the need of fast data transfer and radiation free communication process is needed and this can be full fill by the introduction of optical networks based on integrated optics devices.

These integrated optical devices having some properties like low insertion loss, efficient fiber-to-chip coupling, low polarization loss, high integration density, and the accessibility of reliable, low-cost. These integrated optical devices are also designed and fabricated by using of Photonic Crystal (pc).

Photonic crystal is a crystal having periodic dielectric structure or showing periodicity in certain direction. Silicon material is used for its fabrication.when an electromagnetic (EM) wave propagates in a periodic structure whose period is equal to the wavelength of the wave then it generate a complete photonic band gap(CPBG). Photonic crystal is a periodic nanostructure for light, whose refractive index is change periodically and it uses Photonic Band gap(PBG) principle for propagation of light.

PBG is that range of wavelength which is opposed by that particular Photonic Crystal.So by creating some defects into the PC structure that particular range of wave is propagate inside the structure.These defects is mainly two types

1.Point Defect or Microcavity

2.Line Defect or Waveguide

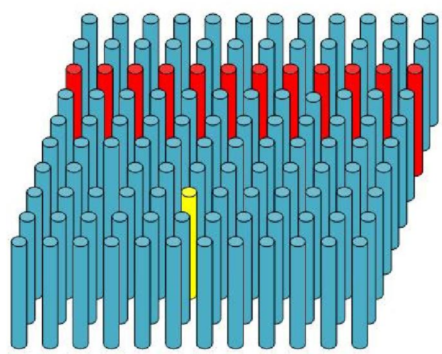

Figure 1. 2D PhC waveguide based on Point defect and Line defect[6].

Photonic crystals are having many applications in the field of optical communication and optical information processing because Photonic crystals provide a common platform to fabricate a large number of optical components on a single chip down [1-7].Among these the basic optical components for integrated optics applications are linear waveguides, waveguide bends, and Y splitters.[8]

Waveguide is the Structure which successfully guides the input wave from input end to output end with minimum losses. In past various waveguide structures based on electronics were already designed and fabricated. But with the enhancement of optical communication system a new type of linear waveguide is designe in which light is travel as a wave from one end to another end and it is based on the principle of photonics. This Photonic crystal based linear waveguide having very low losses and it does not emit any harmful radiation because it is based on the light.

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In this paper first 2D-Photonic crystal with air holes in slab structure is designed and then creating simple line defect inside the structure a linear waveguide is created which operate between the optical band and it gives minimum losses at 1.55µm wavelength.

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II. Review of Literature

In 1987 John and Yablonovitch implement the photonic crystal after that there have been increasing attention paid to developed the nanostructure in microscale device in various applications. PCs provide ultracompact photonic component that will used in the integrated circuit designing. These photonic components are based on the planar PC structure and operate in the PBG of the periodic dielectric structures which allow control of the light propagation on the wavelength scale [1]. Photonic crystal waveguides (PCWs) are formed by line defects in PC. Thereby light is confined horizontally by an in-plane PBG and vertically by total internal reflection (TIR).Because of the PBG effect in a PCW, light can be routed around sharp corners with bending radii of the order of the wavelength. Due to the sharp bend higher-order modes are generated that affect the single mode operation in the PCW.

There are mainly two types of photonic crystal based structures.These are "photonic crystal with array of dielectric rods in air" and "photonic crystal with array of dielectric air holes in slab". The first type of structure is mainly used for the designing of splitter, multiplexer, dmultiplexer and photonic crystal based sensors are designed using second type of structure. But both these structure does not provide vertical confinement and this is the main practical limitation of photonic based devices.

III. DESIGN PROCEDURE

At first, we considered photonic crystal structure of a 3.47 refractive index material and find photonic band gap in acceptable range. Further this structure is used to design a wave guide. In this work, the results obtained from the simulation of two dimensional photonic structures made of silicon are presented for comparison. All the simulations have been performed with the Optiwave OptiFDTD 8.0 software, and 'PWE band solver' is used to calculate photonic band gap and "2D FDTD Simulation" is used to compute the different properties of the waveguide.

A. FIND PHOTONIC BAND GAP

2D photonic crystal slab with a 8×6.5 dimensions, where air holes in silicon background, as shown in Fig1. All the holes in the slab have radius 'r' called cell radius and they are separated by a distance 'a' called lattice constant. Using PWE band solver we calculate the band gap of this structure. After the above analysis, the desirable optical communication bandwidth (1.2µm-1.81µm) is founded for the structure organized by air holes in silicon background where the cell radius r=138nm and lattice constant a=400nm.Figure 2,3 shows the structure and band diagram.

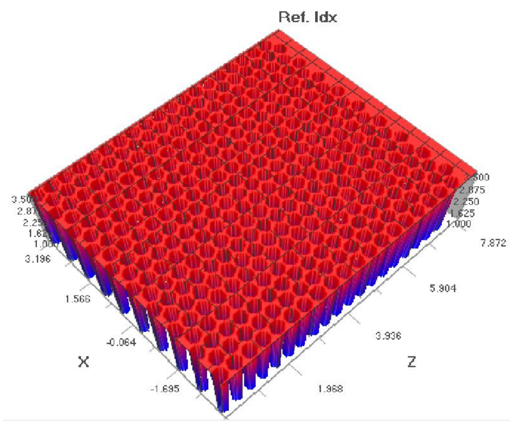

Figure 2. PC structure with 'air holes in slab'.

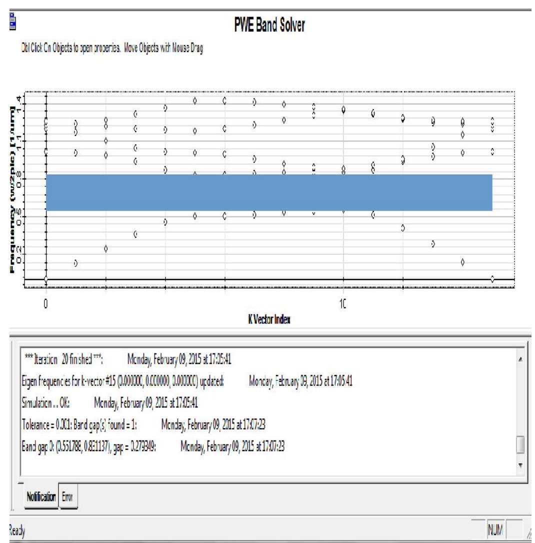

Figure 3. PWE Band solver diagram.

B.SIMULATION AND RESULTS

After finding PBG gap, perform 2D- simulation using 2D 32 bit simulator and get the results. From 2-D FDTD simulation time domain electromagnetic field is obtained. The waveguide structure is designed by creating line defect into the created photonic slab and set the input Gaussian continuous wave at 1550 µm then simulate it. This technique is very powerful and versatile and is useful for this type of waveguide [20, 21].

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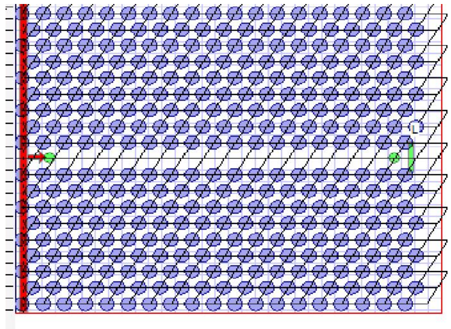

Figure 4. 2D-Layout of waveguide.

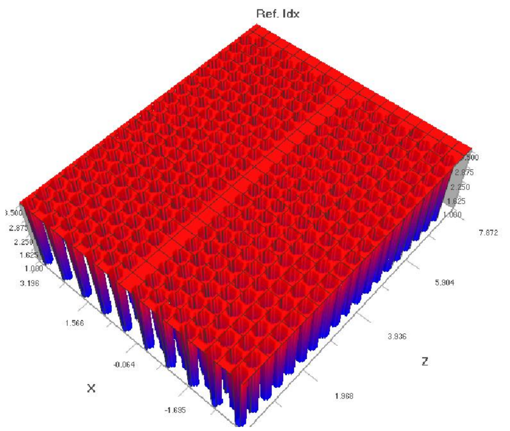

Figure 5. Refractive Index profile of waveguide.

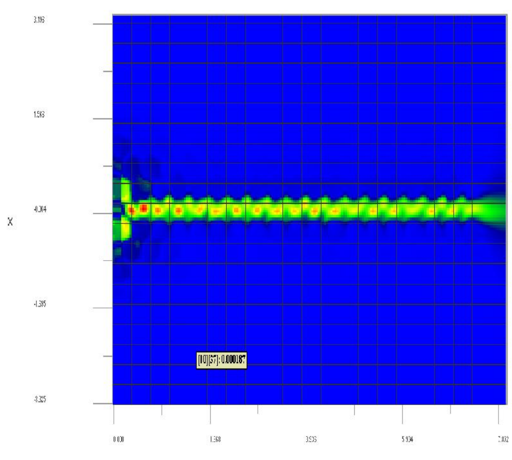

Figure 6. The Magnetic field distribution of the waveguide.

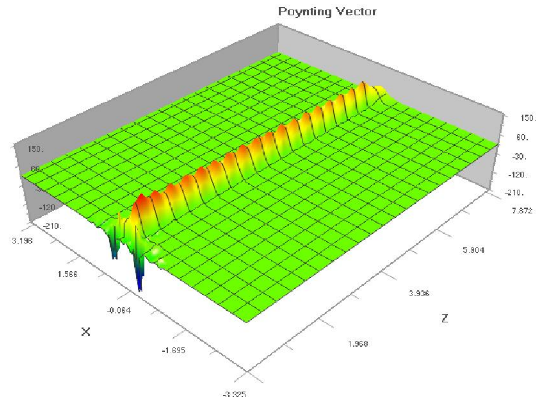

Figure 7. Poynting vector of waveguide.

The field distribution characteristics of the designed Waveguide is uniform and not spread out that means the signal is not attenuated. Since the radiation loss or the power loss of the waveguide is vary with the wavelength of the propagating wave within the band gap. After analyzed with 2D FDTD simulation, the guiding properties such as the electric field and magnetic field distribution, radiation loss of the designed single line defect wave guide have been obtained and they are given in figure 8,9.

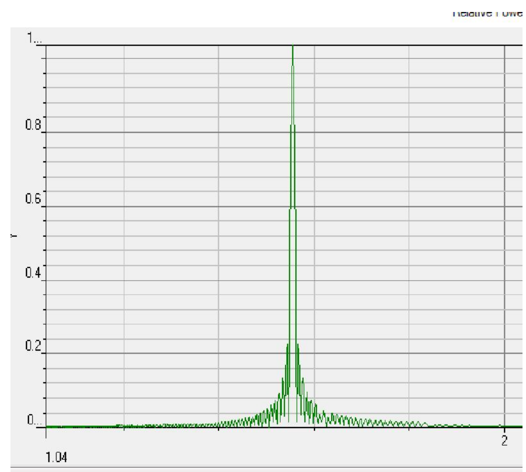

Figure 8. Power curve for the waveguide input power.

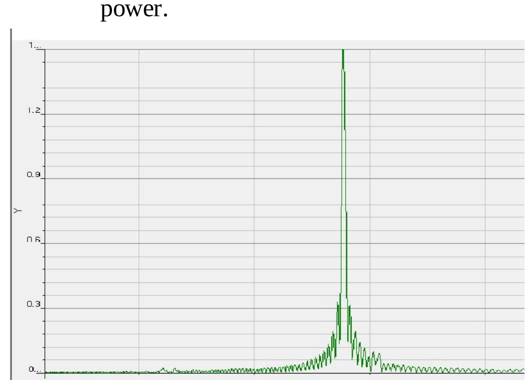

Figure 9. Power curve for the waveguide output power.

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From the input and output power curve, we calculate the radiation losses which is very minimum, that means the waveguide has low loss guiding properties and from the electric and magnetic field distribution we observe that the input signal does not spreads throughout the crystal structure.

IV. FUTURE SCOPE .

This "air holes in slab" like structure is further implemented in the designing of various refractive index based Sensors and Biophotonic Sensors. Photonic Crystal based Sensors are further implemented in wireless Communiction System, Security and Medical system etc.

V. CONCLUSION

The design of low loss Waveguide for optical communication is based on a line defect formed in 2-D slab PC is analyzed primarily by using 2-D FDTD computational method. As a consequence, 94% of input power is transmitted with 1550 nm (1.2µm -1.8µm) broad spectrum. A remarkable result is obtained with the low losses.

VI. ACKNOWLEDGMENT

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VII. REFERENCES

[1] C.R.Simovski, S.He, Microw. Opt. Technol.Lett. 31(2001) 214.
[2] F.-R.Yang, K.-P. Ma, Y. Qian, T.Itoh, IEEE Trans. Microw. Theor. 47(1997) 1509.
[3] Z.Wang, C.T. Chan, W. Zhang, N. Ming, P.Sheng, Phys. Rev. B 64 (2001) 113108.
[4] E. Yablonovitch, "Applied Physics –How to be truly photonic," Science, 289,557-559,2000.
[5] S.Noda and T.Baba (eds), Roadmap on Photonic Crystals, Kluwer Academic Publishers, Springer, 2003.
[6] K.M.Ho, C. T.Chan,"Existence of a photonic gap in periodic dielectric Structures," Phys. Rev. Lett, 1990.
[7] S.Noda, N.Yamamoto"New realization method for three-dimensional photonic crystal in optical wavelength region,"Jpn. J.Appl. Phys., 35, L909-L912, 1996.
[8] C. Yeh, Applied Photonics (Academic, New York, 1990), Chap. 11.
[9] S. Y. Lin, E. Chow, V. Hietala, P. R. Villeneuve, and J. D. Joannopoulos, Science 282, 274 (1998).
[10] S. Y. Lin, E. Chow, S. G. Johnson, and J. D. Joannopoulos, Opt. Lett. 25, 1297 (2000).
[11] E. Chow, S. Y. Lin, S. G. Johnson, and J. D. Joannopoulos, Opt. Lett. 26, 286 (2001).
[12] A. Talneau, L. Le Gouezigou, N. Bouadma, M. Kafesaki,C, C. M. Soukoulis, and M. Agio, Appl. Phys. Lett. 80, 547 (2002).
[13] P. R. Villeneuve, S. Fan, S. G. Johnson, and J. D.Joannopoulos, IEEE Proc. Optoelectron. 145, 384(1998).

VIII. Author's Details

Vijay Laxmi Kalyani is currently working as Assistant Professor in the department of E&C in GWEC,Ajmer. She has attended various workshops, conferences, FDP, STC and also published many research papers in various Journals (National and International) and conference proceedings.

Shivam Upadhyay received the B.E. degree in Electronics &Communication Engineering in 2011 from MIT Ujjain M.P., and pursuing M.Tech in Digital Communication from GWEC, Ajmer, Rajasthan. Her current research includes Photonic-Crystal and Wireless Communiction.

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