Effect of Cavity in Bi-periodic Photonic Crystal Switch

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ABSTRACT

In this paper designing of Narrow Band Pass filter which is based on the Bi-periodic structure and its performance is analyzed considering the knowledge of cavity as resonator with the optiFDTD™ software.

***Keywords**: Photonic crystals, resonator, cavity, FDTD method*

1. INTRODUCTION

Photonic crystal has the inherent property of confining light into small region. So, they are very suitable to provide ultra compact photonic components [1], due to which we can reduce the size of the optical circuits and promise to revolutionize integrated optics. Recently, photonics crystals either 2-D or 3-D which has periodic structures, have attracted many researchers due to the capability of controlling electromagnetic propagation and manipulating of light propagation. Photonic crystals have the novel property of Photon localization and photonic band gap (PBG). PBG is the range of frequency that the light cannot propagate in them. The PBG can be created by introducing point defects, line defects or both in the structure [1]. In past two decades, a mass of theoretical and applied investigation of PCs was proposed. Due to these attractive properties some optical communication devices uses photonic crystals, such as threshold Laser diode (LDs), Low loss and sharp bend waveguides, Recently single mode fibres and Mach-zender interferometer [2] has been proposed and fabricated. Several compact photonic devices based on photonic crystal waveguides(PCWs) has been demonstrated such as power splitters[3], add-drop filter[4], power switches[5], triplexes [6-7], dispersion compensator[8] etc. Also, PC waveguides can be implemented as optical filter into wavelength division multiplexers.(WDMs)[9] and dense wavelength division multiplexers (DWDMs). In optical communication system significant progress has been done in the area of compactness, highly selectivity, wide spectral tenability, fast switching and low power switching [10].

Optical filters are very essential components in dense wavelength division multiplexing (DWDM) system because they can act as a multiplexers and demultiplexers to allow or reject single wavelength. The Band Pass filter and Band Reject filter is the right candidate to select and reject the particular wavelength. The importance of these filter is small in size, easy to control, and better selectivity. We can realize by introducing line defect (W1) or point defect.

2. PROPOSED METHODOLOGY

A novel 2-D photonic crystal based Band Pass filter is proposed by introducing Line defect (W1) and resonant cavity, which is created by removal of two or three adjacent air holes, are introduced to the lattice. The structure composed of a 19×13 square lattice of Silicon rods with linear refractive index of

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3.14 at 1.55µm wavelength. The rods are located in air with radii of r = 0.4a, where a is the lattice constant. A power of amplitude 1V/m of centered wavelength at 1.55µm is injected in the waveguide through Port A. It is a Band Pass filter so; we want to get a particular peak of wavelength at the output port B. To increase the quality factor of the filter, we introduce the cavity and by varying the size of cavity we can increase or decrease the power level of the filter at the output port B.

3. SIMULATION RESULTS

In this paper, the two-dimensional FDTD (2D-FDTD) method is used to calculate the spectrum of the power transmission. Here we used a computer in simulation is 2.4GHz and has 4GB RAM. The figure of proposed filter is shown in below figure.

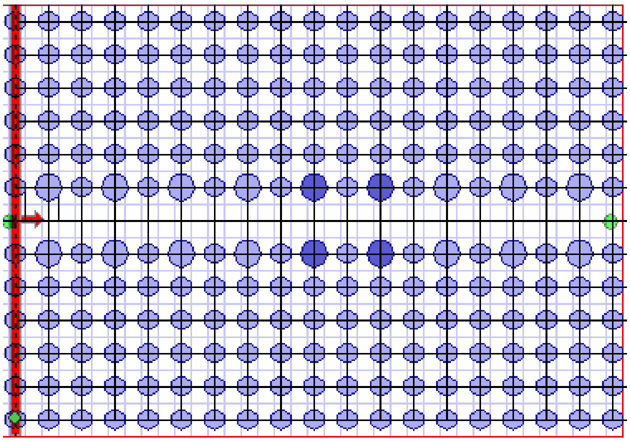

Fig.1. Schematic Diagram of Photonic Crystal Based Narrow Band Filter

The above figure is known as bipolar structure because, we have used two different Lattice constant. Now the structures with two, three, four etc. period act as a narrow band pass filter. We can see that transmission amplitude of filter increased by increasing the number of periods in a structure. Firstly when we do not introduce any cavity, the amplitude of the o/p is not so high it is approximately half of the given amplitude and the output is also not a narrow it has very large bandwidth.

Below Fig.2 (a) represent electric field pattern and Fig.2 (b) represent electric field reflection coefficient of the proposed design. From the figures, it is clear that maximum transmission does not occur at desired wavelength. The main objective of this paper is to enhance the quality factor of the filter at desired operating wavelength and this can be achieved by introducing photonic crystal resonator cavity.

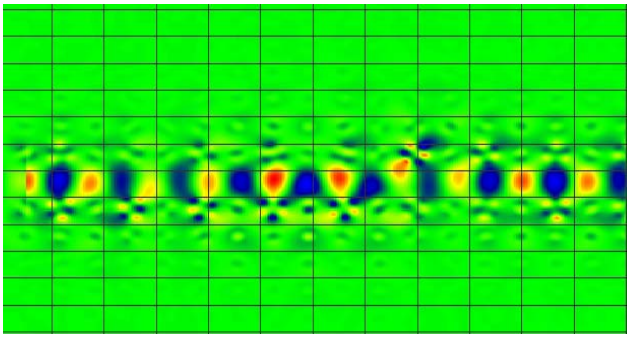

Fig.2 (a). Electric Field Pattern of Waveguide

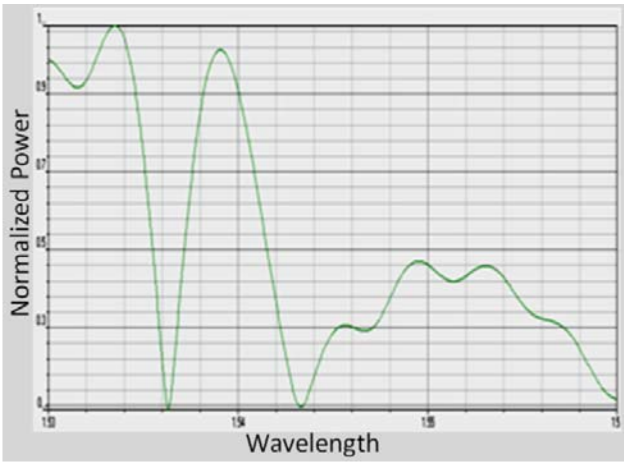

Fig.2(b). Power Vs Wavelength Diagram of NBPF at Output Port B

For increasing the efficiency of the filter and improving the Bandwidth of the filter, we introduce cavity in the waveguide by removing three crystals from the waveguide. In Linear state, when the frequency of the input signal is the same as the resonant frequency of the cavity, that is f = 0.3816(c/a), the input light wave couples to the cavity and there is no output power at the output port. Since the defect involves removing dielectric material of the crystal, the effective refractive index of the cavity decreases and the modes moves towards the higher edge of the gap.

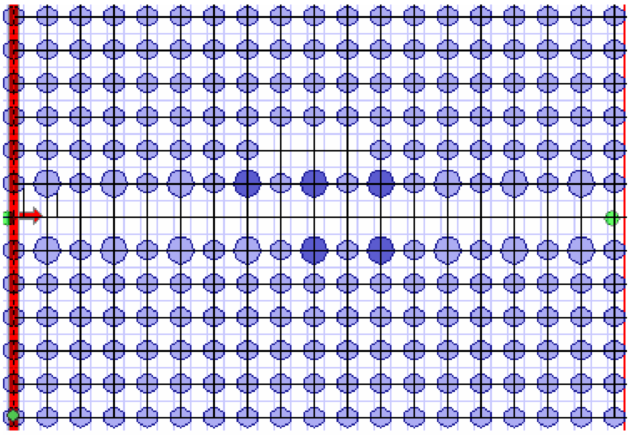

Fig.3. Schematic Diagram of Photonic Crystal Based Narrow Band Filter

Then, it is seen that the amplitude of the waveguide is increasing so much. Recently, a cavity which is introduced in above mentioned waveguide structure has been proposed as a filter in a rectangular lattice Photonic crystal waveguide of air holes in dielectric background as shown in Fig.3. The studies point out that the quality factor (Q-factor) can be increased by varying the size and the number of air holes between the cavity and waveguides.

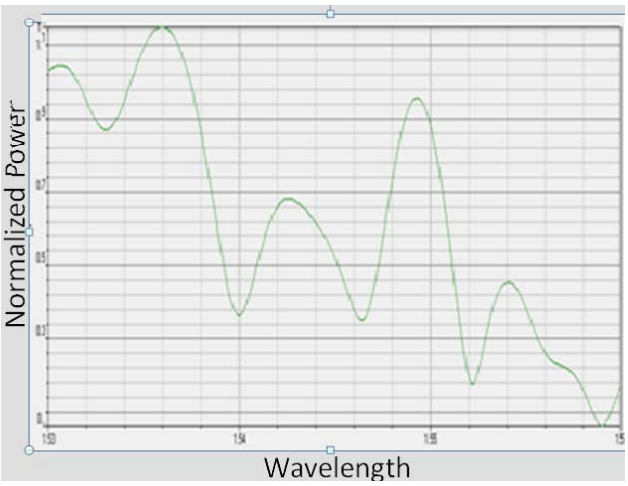

Fig.4. Power Vs Wavelength Diagram of NBPF at Output Port B after Introducing Cavity

From the above Fig.4. it is clear that we get approximately 1V/m power at the output port and the bandwidth of the filter become narrow.

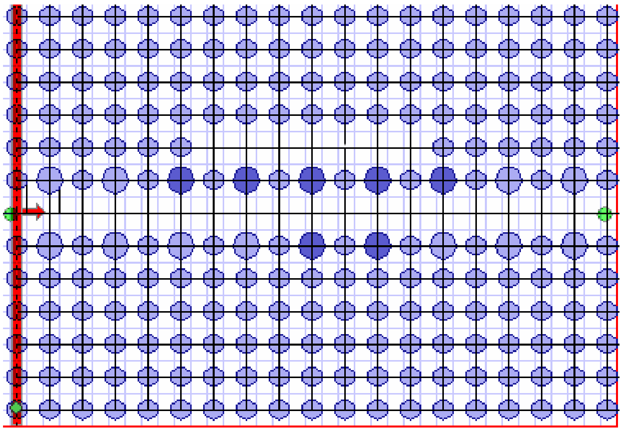

Fig.5. Schematic Diagram of Photonic Crystal Based Narrow Band Filter

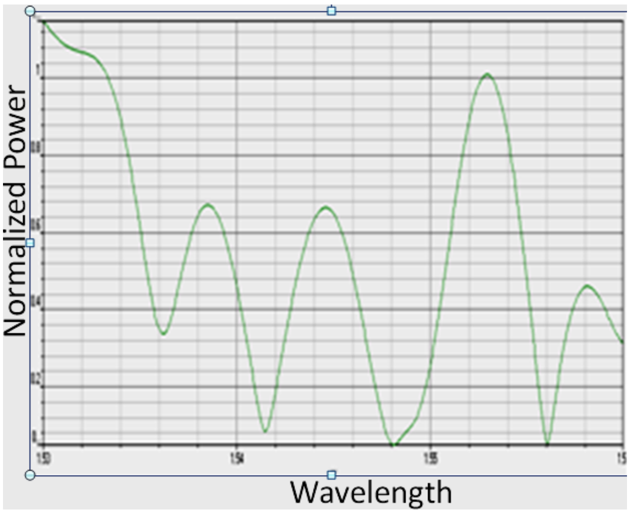

Fig.6. Power Vs Wavelength Diagram of NBPF at Output Port B After Introducing Cavity

From the Fig. 5 & 6 one can visualize that by introducing the cavity the quality Q factor of the filter gets enhanced and also power increases so much and the peak of wavelength shifted by increasing the size of cavity.

4. CONCLUSIONS

Using theoretical analysis design of narrow band pass filter based on Bi-periodic photonic crystal has been presented in this paper. Our designed structure has acceptable narrow bandwidth and normalized transmission spectra for the band-pass and band-stop filter are respectively 95%. We can achieve tunability by increasing the size of the cavity and altering the refractive index of the bigger rods in biperiodic structure.

REFERENCES

[1] Sub-femto joule all-optical switching using a photonicrystal nanocavity" natue photonics"

[2] Zexuan Qiang, Weidong Zhou, and Richard A.Soref, "optical adddrop filters based on photonic crystal ring resonators," *Opt. Express*,vol. 15, no. 4, 2007.

[3] A.Ghaffari, F.Monifi, M.Djavid, and M.S.Abrishamian, "Analysis of photonic crystal power splitters with different configurations,"*Journal of Applied Science* (8), pp. 1416-1425, 2008

[4] K. H. Hwang and G. H. Song, "Design of a high-Q channel-drop multiplexer based on the two-dimensional photonic-crystal membrane structure," *Opt. Express*, vol. 13, pp. 1948–1957, 2005.S. Zhang, C. Zhu, J. K. O. Sin, and P. K. T. Mok, "A novel ultrathin elevated channel low-temperature poly-Si TFT," *IEEE Electron Device Lett.*, vol. 20, pp. 569–571, Nov. 1999.

[5] T.B.Yu, M.H.Wang, X.Q.Jiang, "Coupling characteristics of electromagnetic wave in parallel three photonic crystal waveguides and its applications," *Acta phys sinica*, vol. 55 (4), pp. 1851-1856, 2006.

[6] F. Monifi, M. Djavid, A. Ghaffari, and M. S. Abrishamian, "A new bandstop filter based on photonic crystals," Proc. PIER, Cambridge, USA, 2008.

[7] Tien-Tsorng shih, Yaw-Dong Wu, and Jian-Jang Lee, "Proposal for compact optical triplexer filter using 2-D Photonic crystals," IEEE *Pho. Tech. Lett.*, vol. 21, no. 1, pp. 18-21, 2009.

[8] D. S. Park, B. H. O. , S. G. Park, E. H. Lee, and S. G. Lee, "Photonic crystal-based GE-PON triplexer using point defects," Proc. SPIE vol. 6897, pp. 689711, 2008.R. E. Sorace, V. S. Reinhardt, and S. A. Vaughn, "High-speed digital-to-RF converter," U.S. Patent 5 668 842, Sept. 16, 1997.

[9] E. A. Camargo, H. M. H. Chong, and R. M. De La Rue, "2D photonic crystal thermo-optic switch based on AlGaAs/GaAs epitaxial structure," *Opt. Express*, vol. 12, pp. 588–592, 2004. (2002) The IEEE website. [Online]. Available: http://www.ieee.org/

[10] M. Shell. (2002) IEEE tran homepage on CTAN. [Online]. Available: http://www.ctan.org/texarchive/macros/latex/contrib/supported/IEEE

