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Design and Analysis of low coupling, high transmission optical wavelength Demultiplexer based on two dimensional photonic crystal

Gloria Joseph[1], Ritika Dhaka[2]

[1]Department of ECE, Swami Keshvanand Institute of Engineering and Technology, Jaipur, India
[2]Department of ECE, Govt. Women Engineering College, Ajmer, India

Abstract— *In this work, design and simulation of two dimensional photonic crystal with hexagonal lattice based wavelength division multiplexer is investigated. It is consists of high dielectric rods of GaAs with refractive index 3.375, surrounded by air. This device is ultra compact. The demultiplexing of wavelengths 1330nm and 1470nm is done, based on different output line defects with different radius by pitch ratio. The Discrete Fourier Transforms and power spectrum is obtained using OptiFDTD method and results are compared for various wavelengths.*
Keywords— DFT, Fast Fourier Transform, photonic crystal, wavelength division demultiplexing, FDTD.

I. INTRODUCTION

Photonic crystals (PhCs) are inhomogeneous dielectric media with periodic variation of the refractive index. In general, photonic crystals have a photonic band gap. That is the range of frequencies in which light cannot propagate through the structure. Photonic crystal has periodic crystal like an organized structure so to get tailor made properties and its arrangement can be varied. As it works on photons (optical frequency) so called photonic. Guiding of light occur better when the pitch (distance between adjacent rods) is smaller than the wavelength of the signal [1].

Photonic bandgap materials can be viewed as a subclass of large family of material called Meta material. In which property is derived from structure rather than material itself. These materials have highly periodic structures that can be designed to control and manipulate the propagation of light. And can be designed to acquire escalate properties over conventional optical fibers. Philip Russell in 1998, who first developed the photonic crystal fiber. Electromagnetic wave propagation in periodic media was first studied by Lord Rayleigh in 1888 [Ray1888].In 1987, Yablonovitch and John - by using the tools of classical electromagnetism and solid-state physic introduced the concepts of omnidirectional photonic band gaps in 2D and 3D structure [2].

In communication system there are various multiplexing techniques which provide multiplexing of different signals in different format. For optical networks, different light source emit diverse wavelength thereby wavelength division multiplexing is one of the important enabling technologies in optical communication. WDM combines these input signals, and are launched over single optical fiber channel, this process is called multiplexing. Multiplexing allows to access very large band width available in an optical fiber. At the destination, a wavelength division demultiplexer separates the prismatic signal into integral wavelengths, which are narrow band channels. This process is called demultiplexing. Traditionally, de-multiplexing components are realized using thin-film filters, fiber Bragg gratings (FBG), or arrayed waveguide gratings [3].

II. PROPOSED STRUCTURE

In this paper, a novel design of 2-D photonic crystal based demultiplexer with hexagonal lattice is proposed and analyzed for optimized performance. Plane wave expansion (PWE) method is utilized to obtain photonic band gap (PBG) of the structure. The device is ultra compact. Hexagonal lattice based demultiplexer is made of high dielectric rods suspended in low dielectric air. High dielectric contrast provides large bandgap for photonic crystal. Bandgap is the range of frequencies that are allowed to pass through the structure. Various other parameters such as refractive index, lattice constant, radius of holes, lattice structure, air hole shape etc. determine the photonic crystal waveguide [4]. Number of rods in x- direction are taken 11, whereas in z- direction 15. The lattice constant (distance between the centres of two neighboring rods) is .570 µm and is denoted by ‘a’, and the radius of the GaAs rod is 0.114 µm.

In this paper, radius of GaAs rods for hexagonal lattice ‘r’ is chosen to be 0.2*a. material GaAs has negative differential mobility due to this it is more suitable for microwave applications and is low noise material. Defects are added by altering the radius of rods, it can be seen

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from the fig. 1 that at radius 'r' equals to 0.25*a, the wavelength 1330nm will have minimum losses and high transmission and will follow the straight path. Whereas at radius equals to 0.27*a, wavelength 1470nm will follow bend path with high transmission [6]. This photonic crystal structure is designed, simulated and analyzed by using optiFDTD simulation software. Line defects are utilized to design this demultiplexer. Observation points are placed to obtain DFT response and observation lines are placed for power spectrum response. Fig. 1 represents the layout of proposed photonic crystal structure. And fig.2 shows refractive index profile in which red part represent refractive index of GaAs rods whereas blue part shows refractive index of air.

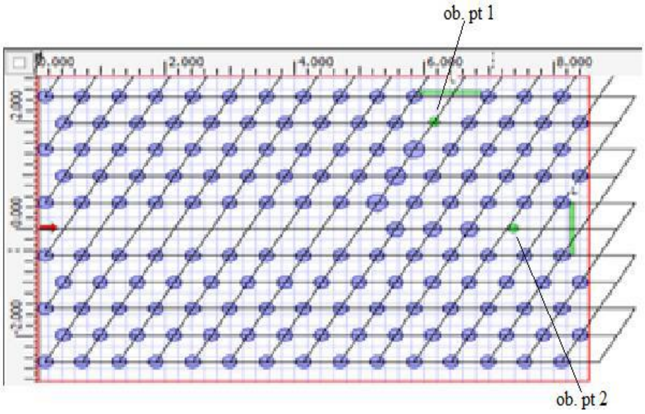

Fig. 1: Layout of the proposed de-multiplexer design based on photonic crystal architect

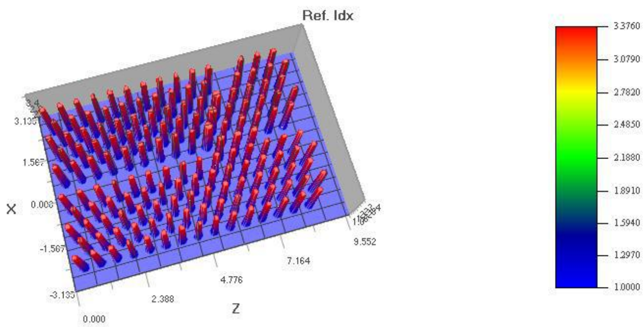

Fig. 2: Refractive index profile of proposed de-multiplexer design

It can be seen from fig. 4 that at wavelength 1.33 µm loss is minimum at radii 0.1425µm line defect and for 1.47µm wavelength, at 0.1539µm line defect. Based on this structure is drawn. Which is more compact and observation points are placed in such a position to have most optimum and better results than the previously proposed demultiplexer structure.

III. SIMULATION AND RESULTS

A 2-D 32 bit simulation is performed to obtain the transmission response of this demultiplexer. The result shown is of transverse electric (TE) polarization.

3.1 Band-gap Calculation

A photonic band gap is the range of frequencies where the light cannot propagate through the structure. This interaction results in the formation of allowed and forbidden energy levels. Fig. 3 represents the photonic band-gap for the hexagonal lattice structure. It has been found that for TE polarization largest photonic band gap occurs when shape of the Brillouin zone is hexagonal lattice [5].

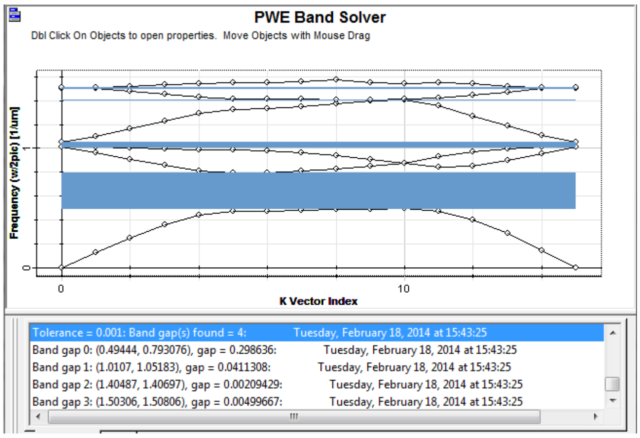

Fig. 3.:Photonic band gap diagram for the proposed structure

3.2 Discrete Fourier Transform

Fig.4 below shows the DFT plot for wavelength range from 1.1µm to 1.6µm.

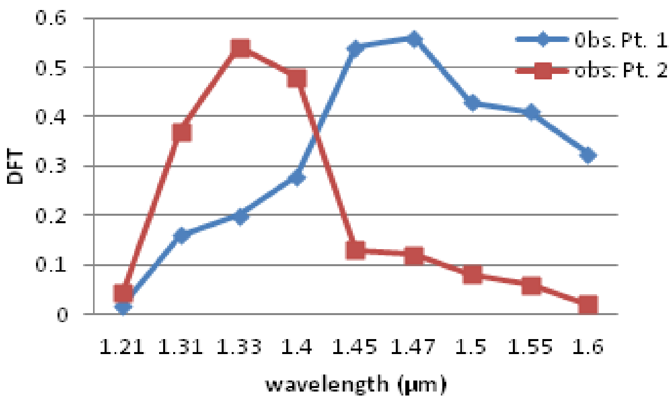

Fig. 4: DFT plots at two observation point for various wavelengths

3.3 Electric Field Distribution

Fig.5 depicts the electric field distribution of two wavelengths. The presented demultiplexing characteristics are for TE polarization only.

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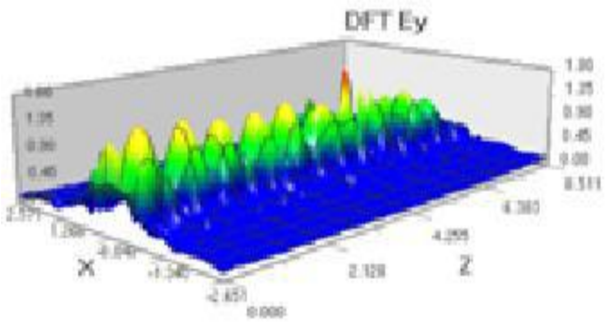

Fig. 5 Simulated electric- field distribution for 1.33µm

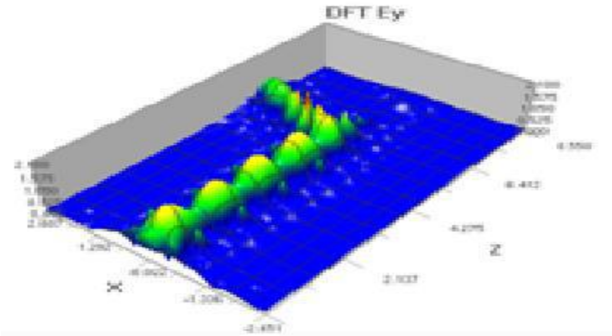

Fig. 6: simulated electric- field distribution for 1.47µm

The demultiplexing action is clear from fig. 5 and fig. 6, such that the wavelength 1.33µm will pass through the defect having radius of holes 0.1425µm and will follow the straight path. And the 1.47µm wavelength will pass from the rods having radius 0.1539µm through the bend path. At wavelengths other than specified wavelength, transmission is very low with high interference. It can be observed that at observation point 1, wavelength 1.47µm has peak value of DFT compared to other wavelengths. Similarly at observation point 2, 1.33µm wavelength has peak value of DFT compared to other wavelengths. Also the plots show that coupling at both the observation points is negligible. Simulated results are highly improved and low interference than reported till date for hexagonal lattice structure.

3.4 **Fast Fourier Transform**

Fig. 7 and fig. 8 illustrate the FFT graph for both l.33 and l.47 µm wavelengths respectively.

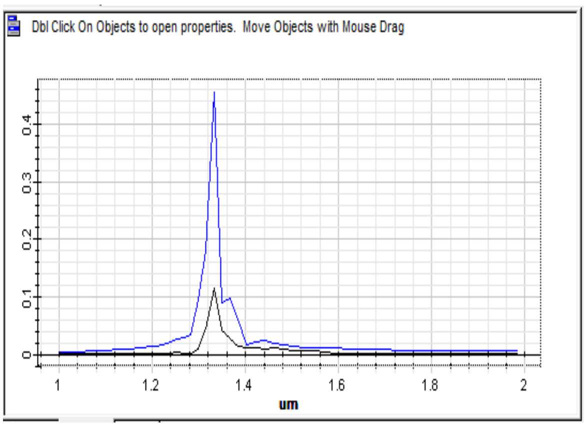

Fig. 7:FFT graph at 1.33µm wavelength

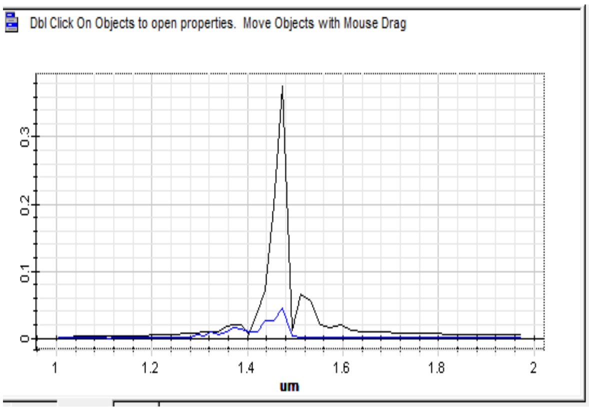

Fig. 8: Power spectrum at 1.47µm wavelength

3.5 **Coupling Measurement**

While DFT for the observation point gives the spectral response for a series of wavelengths. Transmission graphs show better demultiplexing with highly efficient response and very low coupling at both the receiving points.

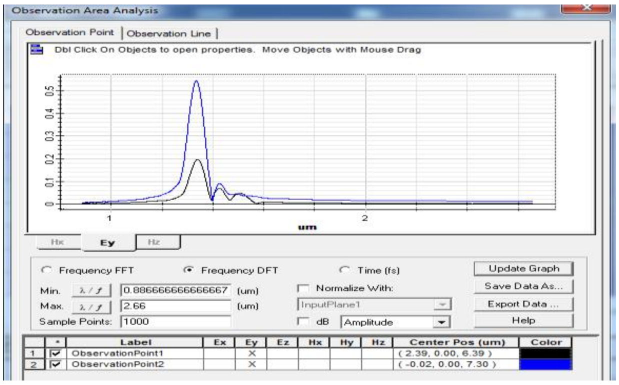

Fig. 9: Coupling of 1.33µm wavelength

Fig. 9 depicts the transmission of signal with wavelength 1.33µm at both the observation points in the term of coupling which is very small.

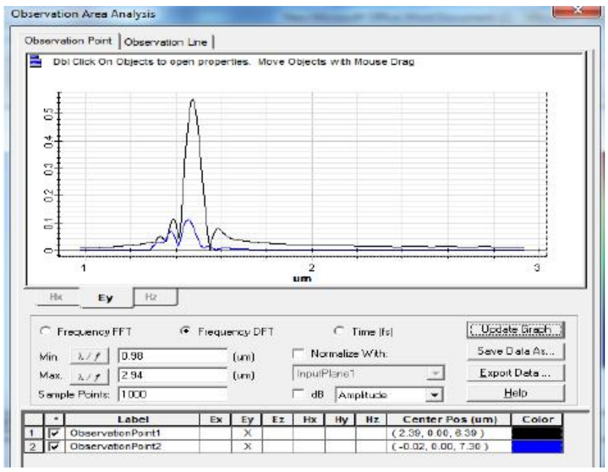

Fig. 10.:Coupling of 1.47µm wavelength

Fig.10. shows transmission of 1.47µm signal at both

observation points with negligible coupling.

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