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Circular Cavity Based Photonic Bandpass Filter Designed on Two Dimensional Hexagonal Lattice Used in Satellite Communication

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Abstract— A two dimensional hexagonal photonic crystal based circular bandpass filter (2D-PCBPF) basically designed in L-band, which find it application in various satellite communication. Here we are using circular cavity based PC BPFs which is proposed and investigate. The output efficiency and bandwidth of circular bandpass filter studied by varying the rode radius of the cavity. In this paper, we are using photonic crystal structure, consist of gallium (III) arsenide with RI value 3.927, which found its application in various satellite communication. The circular cavity based band pass filter gives better performance than others because of its circular resonating modes in the cavity. The simulation result is obtained using 2D finite difference time domain method (FDTD method). The photonic bandgap is calculated by plane wave expansion (PWE) method. The overall size of the 2D- PCBPF is 11.2 μm X 9.5 μm.

Keywords— Photonic crystal, Band pass filter, FDTD method, PWE method, Photonic band gap.

I. INTRODUCTION

The discovery of photonic crystal (PC), used in research field due to the existence of photonic bandgap (PBG) ability to control the spontaneous emission [1, 2]. Photonic crystal is an optical nanostructure which affect the motion of photons. It's a periodic structure in an optical medium. The material are either dielectric or metallo-dielectric that act as electric insulation [3]. Photonic crystal basically consist of three dimensional i.e. One dimensional, Two dimensional, Three dimensional, each dimensions has their specific application in optical medium. Mainly we work on two dimensional (2D) for designing of photonic crystal, main reason behind this is that we add defect (line or point defect) as same as that we do doping in semiconductor, as this will enhance the overall efficiency of the system. By introducing defect in the structure, it become possible to guide the electromagnetic light through the photonic band gap (PBG) region. Photonic crystal have photonic band gap due to its periodic structure, in photonic crystal photonic band gap is calculated using plane wave expansion (PWE) method without creating defects. The band pass filter is analyzed by adding defects i.e. line defect and point defect. As line defect is along whole row of atom in solid and point defect is where the atom is missing [4]. Analysis and simulation is done by 2D finite difference time domain (FDTD) method. In this paper, circular based band pass filter is designed on 2D hexagonal lattice for long distance transmission which mainly cover entire L- band (1565 nm- 1625nm). The structure is designed in hexagonal lattice, main reason behind using hexagonal lattice instead of using square or rectangular lattice is that in hexagonal lattice the light propagate through the entire area without overlapping. As in this design structure we are using L- band pass filter, L- band ranging from (1565 nm- 1625nm) which find its application in various satellite communication and for its efficient working we use it with band pass filter [5]. Here we use gallium (III) arsenide as a dielectric material with RI value 3.927, main technical advantage behind this that electrons move much faster as compared to silicon. This paper is arranged as follow: In Section 'II' design structural of cavity based bandpass filter is designed. In section 'III' Simulation result are discussed. In section 'IV' conclude the paper

II .STRUCTURAL DESIGN

In this paper, all proposed PCBPFs are designed based on 2D rectangular lattice PC. In designing of band pass filter we use number of rods in X and Z direction are 19 and 19 hexagonal lattice surrounded by air background. The refractive index of gallium (III) arsenide and air is 3.927 and 1.0 respectively. The spacing between two adjacent rods which is named as lattice constant 'a' set as 0.56535nm and rod radius denoted by 'r' set as 0.1μm. The ratio of rod radius (r) to that of lattice constant (a) is equals to 0.1768. The defect we created across the circular cavity is 0.12μm and 0.11μm alternatively, reason behind creating defeat is to increase the efficiency of the system and to design a bandpass filter. Figure 1 show the band diagram of hexagonal lattice photonic crystal. Analysis of photonic crystal is done by two mode i.e. TE mode and TM mode. In our proposed structure we are using TE mode.

According to figure 1, there are only one PBG in the band structure diagram for TE mode. The frequency range of PBG is 0.466083 >a/λ >0.801709 in terms of wavelength its 1.24733538 >λ> 2.145540, as our required L- band lies in the calculated photonic band gap (1565nm- 1625nm). Here we are using this PBG for designing our bandpass filter for 162.4 nm wavelength. In photonic crystal the PBG is calculated using Plane wave expansion (PWE) method without calculating defect in the hexagonal lattice structure.

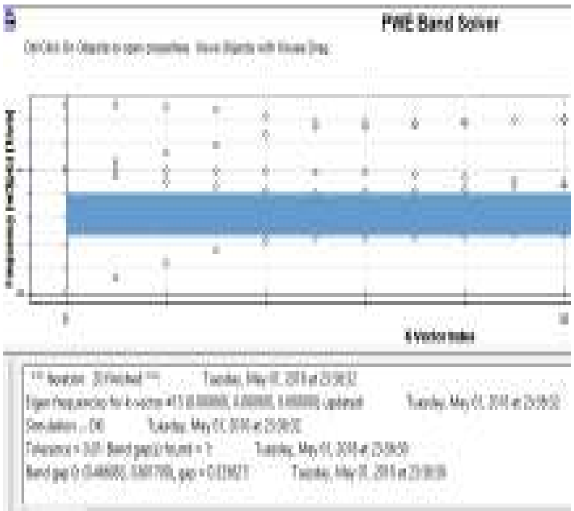


Figure 1. Photonic Band Diagram Of basic PC

In the above band, light propogate easily without any reflection. When the defect introduce in the structure , the PBG is broken and light propogate inside the PBG region. Both point and line defect is used in the designing of the band pass filter

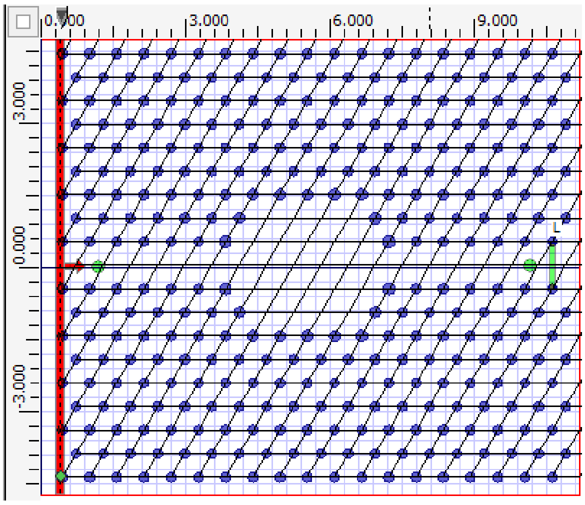


Figure 2. Structure Diagram of band pass filter.

Figure 2 consist of circular waveguide designed on hexagonal lattice structure. In this, circular cavity based BPF if formed by changing the rod radius across the circular cavity. The defect we created by the changing the rod radius across the circular cavity is 0.12μm and 0.11 μm alternatively. The desired design consist of two ports i.e. input port and output port. Here we are using continuous signal, which cover the whole frequency range. The signal is being launched into the input port and using ouput detector we get the required output signal. The main reason behind adding defect is to allow a particular signal to pass through the waveguide and also increase the overall efficiency of the system. In Figure 3 we conclude all the parameter and its value which we use in the designing of BPF

Table 1. Designing parameter of PCBPF

S.no	PARAMETER	
1	No of rods in X and Y direction	19 X 19
2	Lattice Constant	0.56535
3	Rod Radius	0.11μm
4	Dielectric Material	Gallium(III) Arsenide
5	Refractive Index	3.927
6	Lattice Structure	Hexagoanl
7	Band	L-Band

III. SIMULATION RESULT

For calculating the simulation result, we are using finite difference time domain (FDTD) method. In the above design we are using continuous wave which is import to input port and using the output detector we detect the signal at output port. Figure 3 show the electric field pattern at resonant wavelength of 162.4 nm. In this, the input port is coupled with the circular cavity and output is provided the output efficiency. The ratio of the output power to the input power is known as coupling efficiency [6]. A 2d 32 bit simulation is done to obtain the simulation parameter. The simulation process run for 10000 time step. The resonating based circular cavity gives better performance. In this paper by varying the rod radius we deign a band pass filter and also increase its overall efficiency.

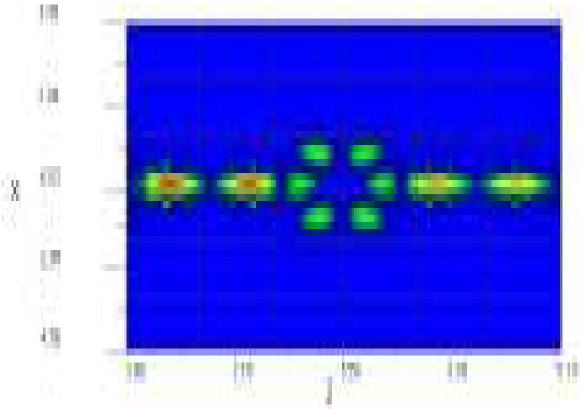
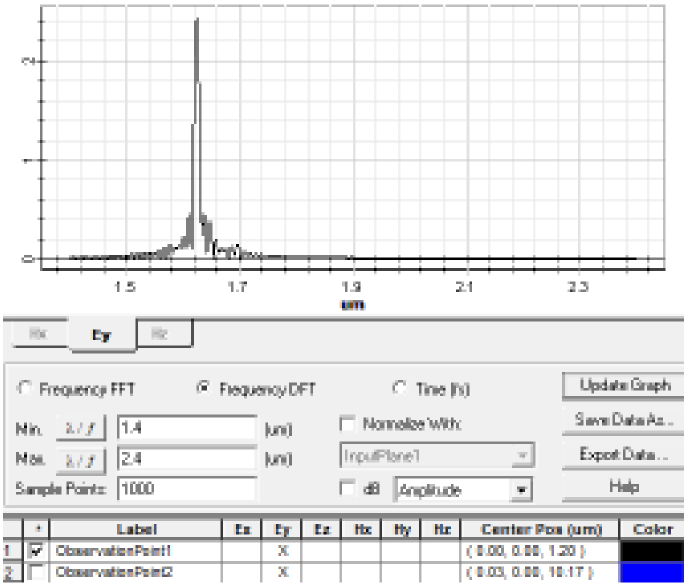


Figure 3. Electric field pattern at frequency 162.4 nm

The transmission spectra for the design is shown in figure 4, for the whole system when the refractive index is 3.927 and rod radius is 0.1μm along with some defects across the circular cavity having 0.12μm and 0.11 μm rod radius. The observation area analysis for both the observation point i.e. observation 1 and observation 2 is shown by figure 4 and figure



○ Frequency FFT ● Frequency DFT ○ Time (fs)

Min. λ / f 1.4 (um)

Max. λ / f 2.4 (um)

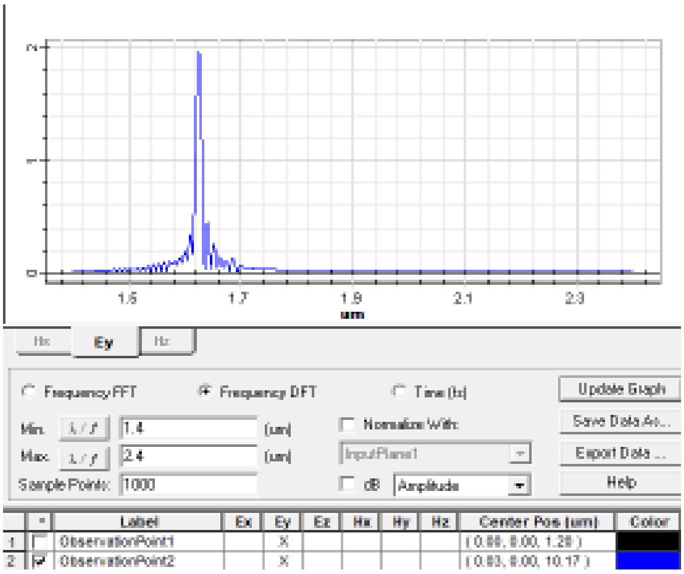
Sample Points: 1000

☐ Normalize With: InputPlane1

☐ dB Amplitude

	*	Label	Ex	Ey	Ez	Hx	Hy	Hz	Center Pos (um)	Color
1	☑	ObservationPoint1		X					(0.00, 0.00, 1.20)	■
2	☐	ObservationPoint2		X					(0.03, 0.00, 10.17)	🟦

Figure 4 transmission spectra for observation point 1 at 162.4 nm wavelength



○ Frequency FFT ● Frequency DFT ○ Time (fs)

Min. λ / f 1.4 (um)

Max. λ / f 2.4 (um)

Sample Points: 1000

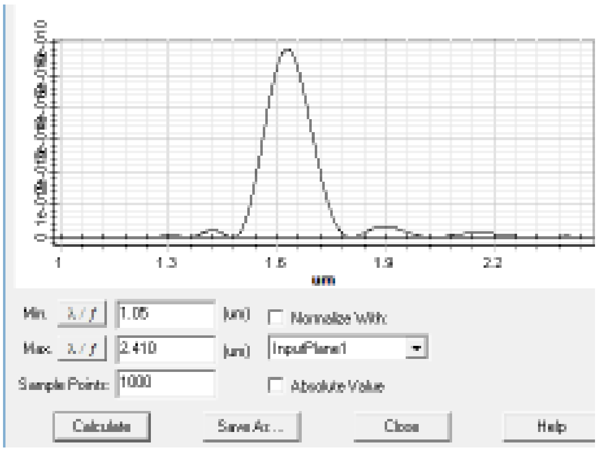
☐ Normalize With: InputPlane1

☐ dB Amplitude

	*	Label	Ex	Ey	Ez	Hx	Hy	Hz	Center Pos (um)	Color
1	☐	ObservationPoint1		X					(0.00, 0.00, 1.20)	■
2	☑	ObservationPoint2		X					(0.03, 0.00, 10.17)	🟦

Figure 5 Transmission spectra for observation point 2 at 162.4 nm Wavelength

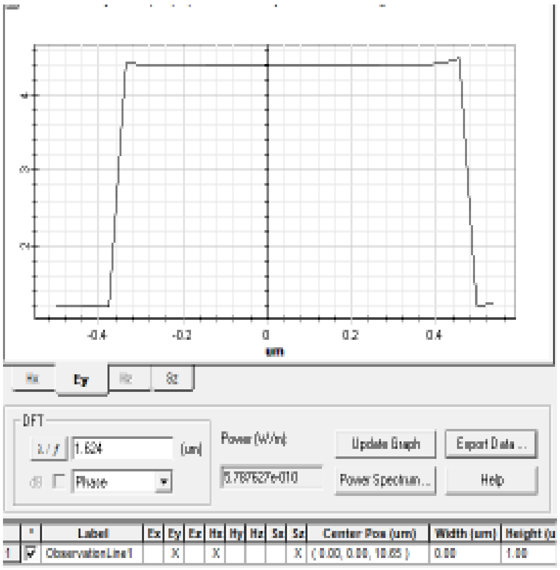
Similarly power spectrum for the above design at wavelength 162.4 nm is shown in figure 6



Min. λ / f 1.05 (um)
Max. λ / f 2.410 (um)
Sample Points: 1000
☐ Normalize With: InputPlane1
☐ Absolute Value

Figure 6. Power spectrum for wavelength 162.4 nm

Figure 7 show the phase diagram for 162.4 nm wavelength



DFT
λ / f 1.624 (um)
dB ☐ Phase
Power (W/m) 5.787627e-010

	*	Label	Ex	Ey	Ez	Hx	Hy	Hz	Sx	Sy	Sz	Center Pos (um)	Width (um)	Height (u
1	☑	ObservationLine1		X		X					X	(0.00, 0.00, 10.65)	0.00	1.00

Figure 7. The phase diagram for observation area analysis

IX. CONCLUSION

In this paper, we designed a circular based band pass filter using FDTD method. The whole structure designed on 2D hexagonal lattice with dielectric material gallium arsenide with RI value 3.927. The photonic bandgap is calculated using plane wave expansion (PWE) method. The above circular cavity based bandpass filter is optimized for wavelength of 162.4 nm. As the circular cavity gives better performance as compared to other resonant cavity. Here we designed the BPF for L- band, due to this reason it find its application in various satellite communication. This above design concept can also be used in" INMARSAT SATELLITE" as it provide telephone and data services and using this we communicate on remote region. As we use gallium arsenide as a dielectric material which used in manufacturing of devices. The bandwidth of the given Band pass filter is 15 nm and overall size of the structure is 11.2 μm X 9.5 μm. By varying the parameter it is observed that the above designed used in various satellite communication.

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