Designing of Triple Ring Resonator based optical filter using 2D hexagonal lattice Photonic Crystal for L-Band

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***Abstract*— In this paper, analysis of Triple Ring Resonator using hexagonal cavity based photonic bandpass filter is designed on a two dimensional hexagonal lattice having gallium arsenide as a dielectric material with refractive index value 3.8. Here we are using PCBPF which is analyzed and investigated. The output efficiency and bandwidth of designed PCBPFs are studied by varying the size of the rod radius and also by adding some defects. The transmission spectra of PCBPF is calculated by using Finite Difference Time domain (FDTD) method and Photonic Bandgap (PBG) of the system is calculated by using Plane Wave Expansion (PWE) method. The above cavity design is recuperate for wavelength of 158.5 nm, having dielectric constant (10.89). The no of rods in X and Z direction is 23 X 23 with lattice constant value 0.565μm. The overall size of the PC cavity is 14 μm X 11.5 μm i.e. 161 μm ^{2}.**

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

I. INTRODUCTION

A photonic crystal is fundamentally an intermittent structure in an optical medium which absolutely controls the stream of light. As it powers light around the sharp band and numerous reflections should be possible from its surface. Photonic crystal is nanostructure whose refractive index changes with the dimensions, it is described using Maxwell's Equation, which can be solved by the application of massive computational power [1, 2]. Based upon the variation of the refractive index, photonic crystal is basically classified as One Dimensional, Two Dimensional, and Three Dimensional. Mainly we work on two dimensional (2D) photonic crystal, the reason behind using 2D is that in this we add some defect as same as we add doping in semiconductor to increase its conductivity, but in photonic crystal creating defect is to increase the overall efficiency of the design. The periodicity of the light is broken by adding defect, which may be classified as line defect and point defect. Photonic crystal have a photonic band gap (PBG) and different frequencies band is created which does not allow different frequency due to its periodic structure. By introducing defect in the structure, it become possible to guide the electromagnetic light through the PBG region [3, 4]. In Photonic crystal, photonic band gap is calculated using Plane Wave expansion (PWE) method, which is calculated without creating defects in the lattice structure. The analysis is done by creating defects so as to design quasi-square, quad shaped, hexagonal cavity and circular cavity based bandpass filter. Adding defects is of two type i.e. Line Defect and Point Defect. As Line defect is along the whole row of atom in solid and point defect is where the atom is missing [5]. In this paper we are using combination of line defect (waveguide), triple ring resonator designed on PCBP, point defect cavity and a single resonator between input and output line defect PC waveguide. Simulation result is calculated using finite difference time domain (2D-FDTD) method and photonic band gap is calculated using Plane Wave Expansion (PWE) procedure. In this paper, the different cavity is designed in L-band ranging from (1565-1625) which find its application in various satellite navigation and also find its application in DWDM and various optical devices. The whole PCBPF is designed on hexagonal lattice having gallium arsenide as a dielectric material with refractive index value 3.8. The BPF is used to select a channel from the multiplexed output spectrum in wavelength division multiplexing (WDM) system. Many PC based optical filter have been proposed such as triple ring resonator [6], band pass filter [7-8], band reject filter [9] etc. In this paper we analyzed and investigate triple ring resonator based PCBPFs. The output efficiency is studied by varying the size and position of gallium arsenide rod.

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II. STRUCTURE DESIGN

In this paper, all propound PCBPFs are designed on 2D hexagonal lattice photonic crystal. The number of circular rods in X and Z direction is 23 X 23, respectively surrounded by the air background. Here we are gallium arsenide as a dielectric material with RI value 3.8 and that of air is 1.0, respectively. The spacing between the two adjacent rod known as lattice constant (a) with value 5653 nm and permittivity of the rod is 12.5(Refractive index = 3.8). The radius of the rod is 0.1768 X a, which is close to 0.1 μm. The ratio of the rod radius (r) to that of the lattice constant (a) is equal to 0.1768 μm.

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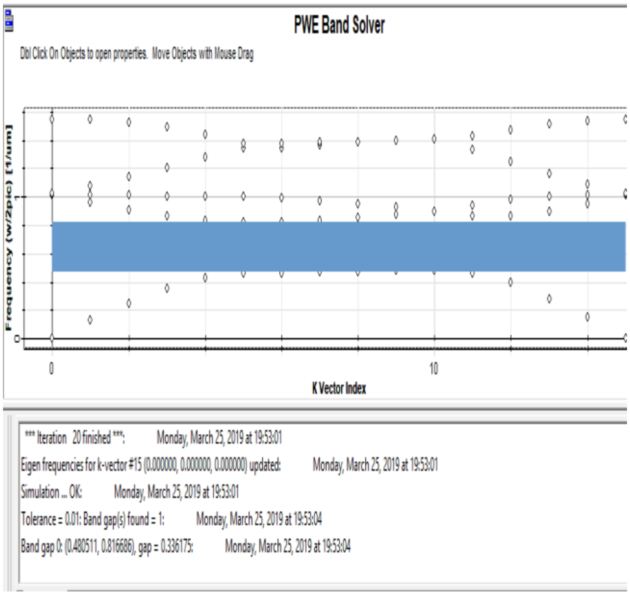

Figure 1: Photonic band diagram of 23 X 23 hexagonal lattice without introducing defect

The analysis of PC is done by using TE and TM mode. In our proposed structure we are using TE mode. According to the figure 1, there are one PBG in the band structure diagram whose frequency range is 0.480511< a/$\boldsymbol{\lambda}$< 0.816686, in term of wavelength we write it as 1224.4 nm< $\boldsymbol{\lambda}$ <2081.11, as the above triple ring resonator is design for L- band whose range is in between 1565 to 1625 nm and our required wavelength lie in the above band i.e. 1597nm. As the above band also satisfied the L-band ranging from (1565nm – 1625 nm). Here we are using this PBG for designing triple ring resonator based PCBPFs for 1585nm. In the photonic crystal the PBG is calculated using Plane Wave Expansion (PWE) method. When the defect introduce in the structure light propagate through the PBG region.

III. STRUCTURAL CAVITY BASED TRIPLE RING RESONATOR BASED BAND PASS FILTER

In figure 2 we design triple ring resonator based PCBPFs. They consist of two in- line quasi waveguide in X- direction and three rings in resonant cavity that are positioned between them. From the input port we transmit electromagnetic signal and output is detected by using output detector at the output port. The in-line quasi waveguide is formed by introducing line defect and the resonant cavity is formed by point defect [10]. The rods inside the resonant cavity is known as inner rods and the coupling rods is placed between in the in – line quasi waveguide and resonant cavity

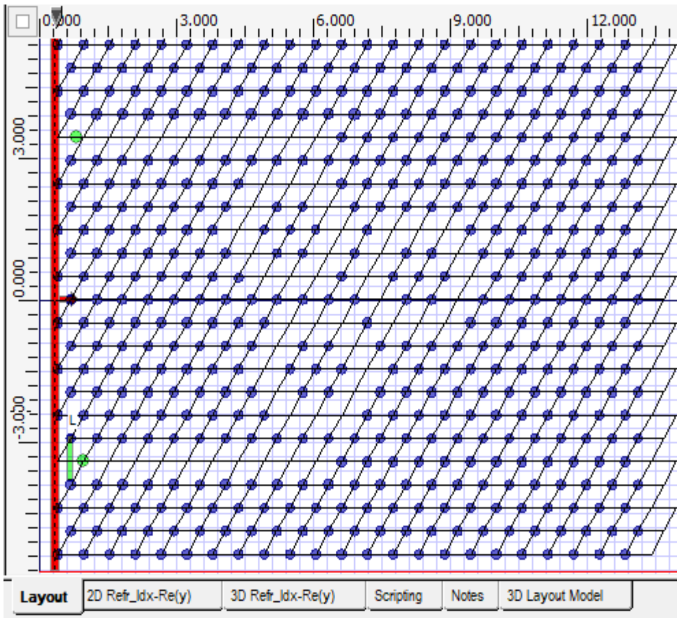

Figure 2: Schematic design of Triple Ring Resonator based PCBPF

Triple ring resonator is design by removing the inner rods by introducing point and line defect. Here the coupling rods is placed between the bus waveguide and dropping waveguide. The efficiency is increased by changing the rod radius along the bus waveguide from 0.1$\boldsymbol{\mu}$m to 0.12$\boldsymbol{\mu}$m. The three rings are design in between the bus waveguide and dropping waveguide.

IV. SIMULATION RESULT

In this paper, we are using continuous wave which is applied to the port ‘a’ and using output detector, we get the required output from port ‘b’. Figure 3 shows the transmission spectra for the wavelength 1597 nm. In this figure, input signal is coupled with waveguide and output provide the output efficiency. In order to increase the efficiency we add defects by changing the rod radius. The ratio of output power to that of input power is called coupling efficiency [11]. For calculating the simulation result, we are using Finite Difference Time Domain (FDTD) method.

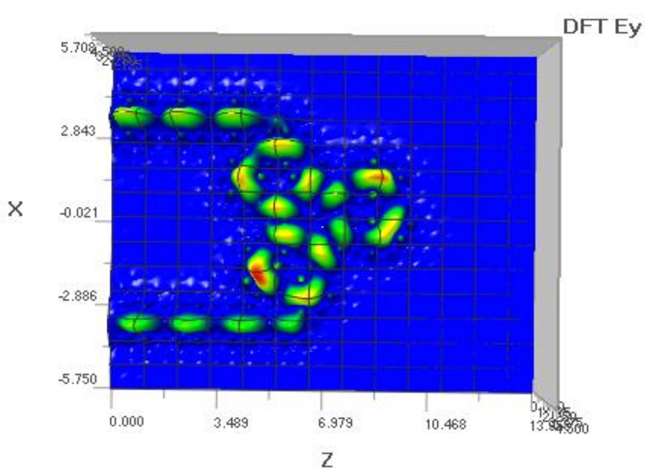

Figure 3: Electric field pattern of triple ring resonator based PCBPF at 1597nm

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A 2D, 32 bit simulation is done to obtain the simulation parameter. The simulation process run for 10000 time step. The transmission spectra of the design is shown by figure 4, for the whole system when the refractive index is 1597 nm and rod radius 0.1 μm along with some defect and also changing radius of bus waveguide by 0.12μm. The observation analysis for different cavity based PCBPF along with both observation point i.e. observation point 1 and observation point 2.

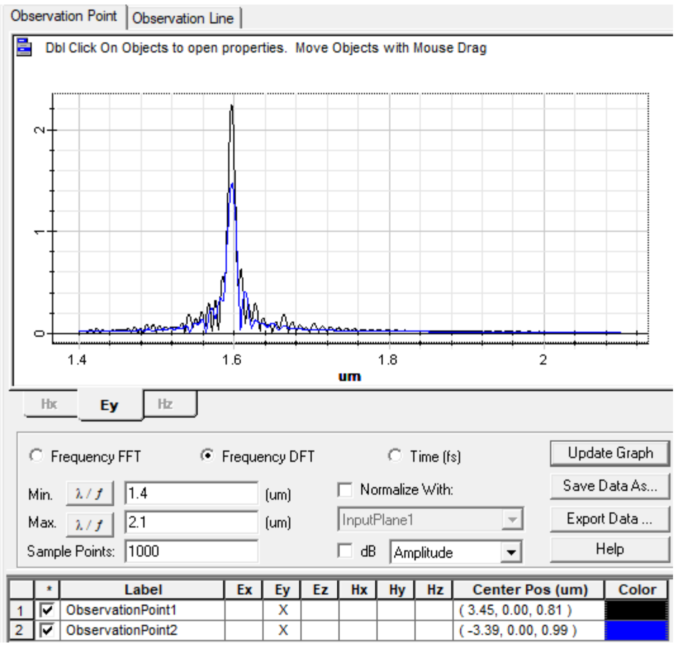

Figure 4: Transmission spectra for triple ring resonator cavity PCBPF at 1597nm wavelength

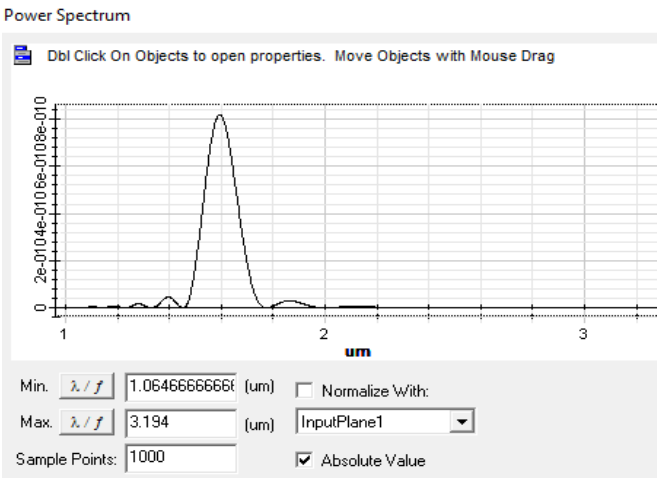

Figure 5: Power spectrum for triple ring resonator cavity PCBPF at 1597nm wavelength

V. CONCLUSION

In this paper, triple ring resonator PCBPF is analyzed and investigated by using Finite Difference Time Domain Method. The whole system structure designed on 2D hexagonal lattice having gallium arsenide as a dielectric material with RI value 3.8 and designed for the wavelength 1597nm whose value lie in the L- band due to this reason it used in signal and processing system and various satellite communication. The photonic bandgap is calculated using Plane Wave Expansion (PWE) method. The proposed and suggested PCBPF is compact and overall size of the chip is 14μm X 11.5 μm. Triple ring resonator found it application in DWDM and various optical devices.

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