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Design of Different Cavity Add Drop Filter Using 2d Rectangular Lattice Photonic Crystal Ring Resonator

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***Abstract*— In this paper, analysis and designing of different cavity based Add Drop Filter (ADF) which is formed using two Dimensional Photonic Crystal Ring Resonator (2D-PCRR) designed on rectangular lattice having silicon as a dielectric rods in air medium with Refractive Index (RI) value as 3.6730 and 1.0. Here we are designing different cavity based PCRR which are analyzed and investigated. The output efficiency of desired PCRRs are studied by varying the size of the rod radius and also by adding some defects. The transmission spectra of PCRR is calculated using Finite Difference Time Domain (FDTD) method and the Photonic Bandgap is calculated by Plane Wave Expansion (PWE) method. PBG of ADF is located in C and L-band which found its application in various satellite communication and for INMARSAT Satellite. The overall size of the PCRR is 10.5μm X 10.5μm i.e.110.25μm2.**

Keywords*— *Photonic Crystal, Band Pass Filter, FDTD method, PWE Method, Photonic Band Gap

I. INTRODUCTION

The increasing interest in photonic integrated circuits (PIC's) and the increasing use of all-optical fiber networks as backbones for global communication systems have been based in large part on the extremely wide optical transmission bandwidth provided by dielectric materials. This has accordingly led to an increase demand for the practical utilization of the full optical bandwidth available [1, 2and 3]. Add drop filter consist of two waveguide one is bus waveguide and other is dropping waveguide. It basically consist of Arrayed Waveguide Grating (AWG) or Bragg grating structure to separate the incoming/outgoing wavelength. Many optical devices which based on Photonic integrated circuit (PIs) have high operating speed, high density, highly efficient. With a specific end goal to expand the total transmission transfer speed, it is for the most part favored that the separating of all the while transmitted optical information streams, or optical information channels, be firmly stuffed to oblige a bigger number of channels. As such, the distinction in wavelength between two adjoining channels is ideally limited [4, 5].

Photonic crystal is basically a periodic structure in optical medium which totally control the flow of light. As it forces light around sharp band and multiple reflection can be done 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. 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.

In this paper, different cavity based add drop filter is designed with the feature that the resonant wavelength of ring resonator is changed while changing the dielectric constant. For calculating photonic band gap we use the Plane Wave Expansion (PWE) method, which is calculate without adding defects in the lattice structure. The analysis is done so as create quasi- square and circular Add Drop filter based PCRR with silicon as a dielectric material. 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. In this paper we are using combination of line defect (bus waveguide), point defect cavity and a single ring resonator between input and output line defect PC waveguide. The whole PCRR is designed on rectangular/ square lattice having silicon as a dielectric material with refractive index value 3.6730

Here effect of different cavity based ring resonator parameter on the resonant wavelength and transmission spectra of PCRRs are investigated. The proposed structure provides a possibility of optical channel drop filter and can be used in the future photonic integrated circuits [6, 7]. This paper is arranged as follow: In Section 'II' structural is designed. In section 'III' structural different cavity ad drop filter is designed. In section 'IV' Simulation result are discussed. In section 'V' conclude the paper.

II. STRUCTURE DESIGN

In this paper, different cavity PCRRs are designed on 2D rectangular lattice photonic crystal. The number of circular rods in X and Z direction is 19 X 19, respectively surrounded by the air medium. Here we are using silicon as a dielectric material with RI value 3.6730 and that of air is 1.0, respectively. The spacing between the two adjacent rod known as lattice constant (a) with value 543.1 nm and permittivity of the rod is 13.5(Refractive index = 3.6730). 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.

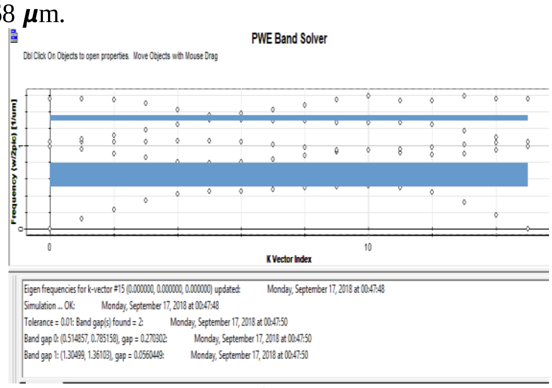

Fig 1: photonic bandgap structure of 19 X 19 square lattice without creating defects

Figure 1 show the band diagram of square lattice photonic crystal without creating any defect which give Transverse Electric (TE) and Transverse Magnetic (TM) mode. 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 two PBGs in the band structure diagram. The frequency range of first and second band are 0.785158< a/λ<0.514857 and 1.36103< a/λ <1.30499, in term of wavelength we write it as 1273.6 nm< λ <1942.2 nm and 734.7 nm <λ <766.2 nm, as our required band lie in the bandgap first. As the bandgap first cover both the band i.e. the L-band and c-band ranging from (1565nm – 1625 nm) and (1530nm – 1565nm). Here we are using this PBG for designing our different cavity based PCBPFs for wavelength lie in L- band and C-band. 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 ADD DROP FILTER USING PHOTONIC CRYSTAL RING RESONATOR

In ideal add drop filter the ring resonator is sandwich between two parallel waveguide in which the upper waveguide behave as bus waveguide and lower waveguide behave as dropping waveguide. It basically consist of four port i.e. A, B, C, and D. electromagnetic signal is transmitted from input 'A', port 'C' and 'D' are forward and backward dropping terminal. Port 'B' is a forward transmission terminal for bus waveguide. Here we design three structural cavity i.e. Quasi- square and Circular cavity based PCPP They consist of two in- line quasi waveguide in X direction and three rings in resonant cavity that are positioned between them. The rods inside the resonant cavity is known as inner rods and the coupling rods is placed between in the bus waveguide and dropping waveguide.

In figure 2, quasi- square PCRR is designed by removing the inner rods by introducing point defect. Here the, coupling rod is placed in between the bus waveguide and dropping waveguide. We take radius of the coupling rod as Rc= 0.12r so that we get the best dropping efficiency [8].

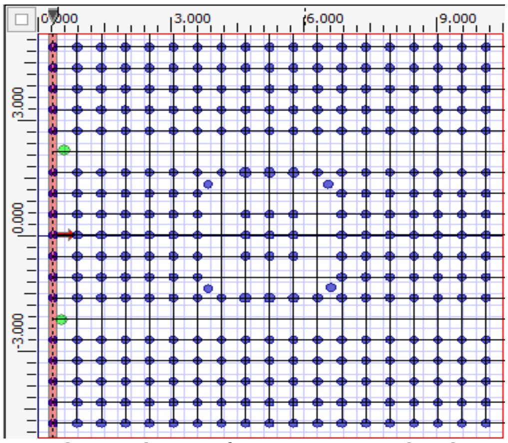

Fig 2: schematic diagram of quasi-square cavity based PCRR

In figure 3, we design a circular cavity based PCRR by removing the inner radius and creating waveguide by using point and line defect. Rods from left side is shifted into the ring resonator so as to from a circular cavity with scattered rod radius value change to 0.11μm

The radius of the coupling rod is 0.08μm so that we get the better efficiency.

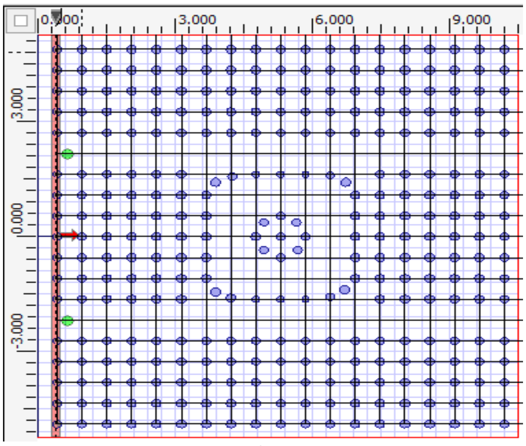

Fig 3: schematic diagram of circular cavity based PCRR

IV. SIMULATION RESULT

In this paper, we are using continuous wave which is applied to the port 'a' and from port 'B' and 'c' we get the resultant output. In Figure 4, at resonant input signal of wavelength 1595nm is entered from point 'A' where the input port is coupled through quasi-square cavity and drop out from port 'D', whereas at "Off" resonant condition signal go straight from the bus waveguide and received from port' B' shown in figure5. In these 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. For calculating the simulation result, we are using Finite Difference Time Domain (FDTD) method. 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. By varying the rod radius we design a band pass filter and also increase its overall efficiency.

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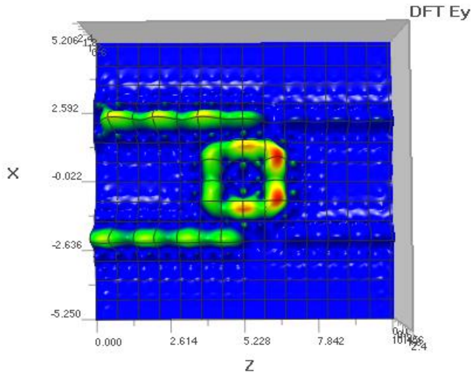

Fig 4: electric filed pattern of quasi-square PCRR based ADF at the resonant wavelength 1595nm

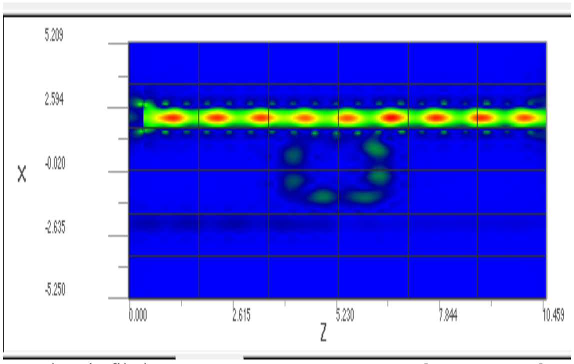

Fig 5: Electric filed pattern at 'OFF' resonance condition at wavelength 1550nm

In Figure 6, at resonant input signal of wavelength 1567.95nm is entered from point 'A' where the input port is coupled through quasi-square cavity and drop out from port 'D', whereas at "Off" resonant condition at wavelength 1520nm signal go straight from the bus waveguide and received from port' B' shown in figure 7. In these 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.

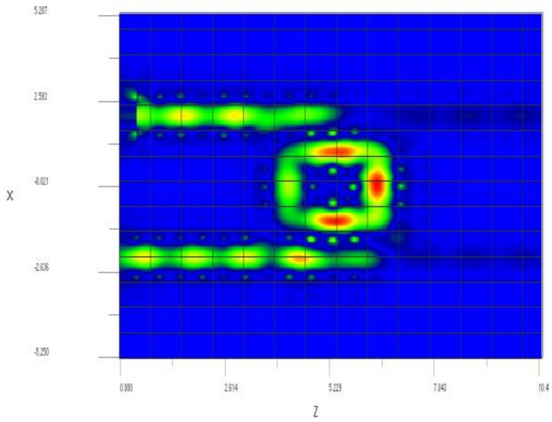

Fig 6: electric field pattern of circular cavity PCRR based ADF at the wavelength 1569.75nm

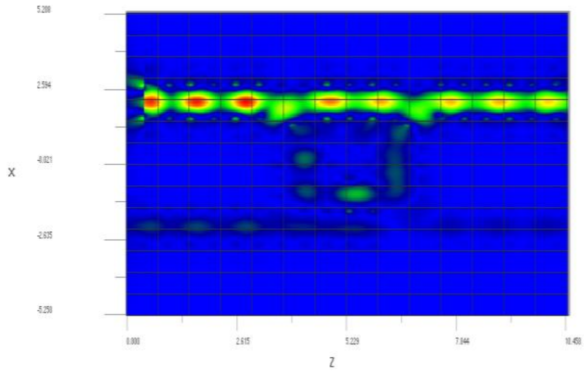

Fig 7: Electric field pattern at 'OFF' resonant condition at wavelength 1520nm

The transmission spectra for quasi-square cavity PCRR based add drop filter in shown by figure 8 for the resonant wavelength 1595nm and with coupling rod radius as 0.12μm similarly for circular cavity PCRR based add drop filter, the transmission spectra is shown by figure 9 for the resonant wavelength 1569.75nm and coupling rod radius as 0.08μm whereas scattered rod radius value is 0.11μm. An OPTIFDTD method is used to simulate the design.

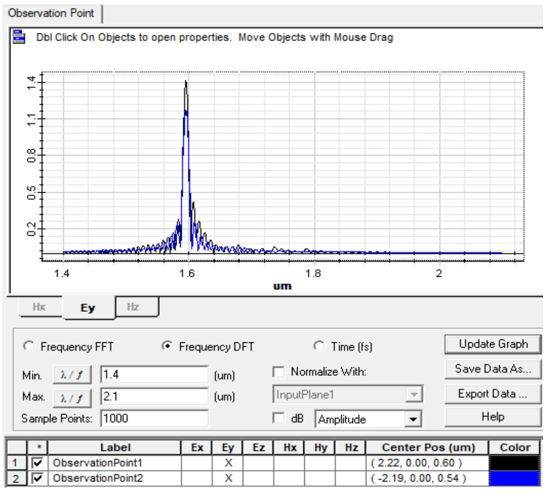

Fig 8: Transmission spectra for quasi-square cavity PCRR based ADF at resonant wavelength 1595.0nm

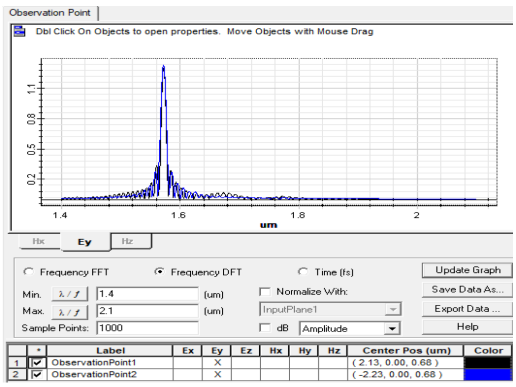

Fig 9: Transmission field spectra for circular cavity PCRR based ADF at resonant wavelength 1569.75nm

V. CONCLUSION

In this paper, Quasi-Square cavity and circular cavity PCRR based ADF are analyzed and investigated by using Finite Difference Time Domain Method. The whole system structure designed on 2D rectangular lattice having silicon as a dielectric material with RI value 3.6730. The photonic bandgap is calculated using Plane Wave Expansion (PWE) method. The above Quasi- Square cavity PCRR based ADF is optimized for 1595nm whereas Circular cavity is optimized for 1569.75nm. The proposed and suggested PCBPF is compact and overall size of the chip is 10.5μm X 10.5 μm i.e. 110.25μm2As both the proposed design is optimized within the L-band so it find many application in various photonic integrated circuits and use in CWDM application

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