ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

Hetero Structure Channel Drop Filters using Photonic Crystal Ring Resonators

D.Pujitha[1], T.Sreenivasulu Reddy[1]

Dept. of Electronics and Comm. Engg, SVUCE, Tirupati, India

ABSTRACT: In this paper, a channel drop filter based on photonic crystal ring resonators has been proposed in single and dual stage and investigated its properties by using the finite-difference time-domain (FDTD) method numerically.This structure consists of a 2-D square lattice with two waveguides and a ring resonator in single stage design.By changing the radius from 0.1 to 0.12nm the resonant wavelength is shifted.By closing the second bus waveguide the structure is acting like a stop band filter. 45 degree rotation of scattering rods are giving characteristics as BPF at port2.By changing the photonic crystal ring resonator from square to circular the wavelength is shifted. The resonators are located in two regions in dual ring structure with each region has a specific dielectric constant. At resonance of ring resonator, the power with certain wavelength transferred to one of the drop waveguides .Different types ofapplication are presented different designs of channel drop filter.

KEYWORDS: FDTD, Photonic crystal, Hetero structure, Ring resonator.

1.INTRODUCTION

The optical add-drop filter (ADF) is one of the fundamental building blocks for optical add drop multiplexers (OADMs), reconfigurable OADMs, optical modulators, and optical switches needed for silicon photonics, photonic integrated circuits(PICs),and wavelength division multiplexed(WDM) optical communication systems [1-3]. Significant progress has been made on ADF based devices in the areas of compactness, high spectral selectivity, wide spectral tunability, fast switching, and low-power switching [4,5]. Photonic crystals (PCs), can exhibit frequency ranges in which the propagation of electromagnetic waves is prohibited known as photonic band gaps(PBG). These structures have many potential applications because oftheir ability to control light-wave propagation. By introducing crystal defects like point or line defects ,Photonic crystals exhibits resonant state inside the crystal. Insertion of line defects inside the photonic crystal optical waveguides in two dimensional lattice can be constructed.Channel drop filter consists of two parts as waveguiding elements and frequency-selective elements. The performance of such filters isbased on the coupling between cavity modes of ring resonators andguiding modes of waveguides.

II. NUMERICAL ANALYSIS

There are many methods such as Transfer Matrix Method (TMM), Plane Wave Expansion (PWE) method, Finite Element Method (FEM), Finite Difference Time Domain (FDTD) method and etc., available to analyze the dispersion behaviour and transmission spectra of PCs. In our analysis, The Finite Difference Time Domain(FDTD) method is used to calculate the spectrum of power transmission .The FDTD mesh size and time step used in this study are dx=dy=a/21 and dt=dx/(2*c),where c is speed of light in free space and a is lattice constant.

A Gaussian pulse is broadend sufficiently launched into input port and a detector is placed inside each waveguide channel of the filter .The detector is used to measure the time-varying electric and magnetic field. The Fast Fourier Transform (FFT) is used to compute power transmission spectrum of the fields which are calculated by FDTD and integrating the pointing vector over the output port cells.In this paper we use FDTD method to calculate the spectrumof the power transmission, in our MATLAB code during 30,000 timestep (about 240 min running time for final structure).The computerused in this simulation is P4 3.00 GHz and has 4 GB of RAM.

III. PHOTONIC CRYSTAL RING RESONATORS

A typical ring resonator is depicted in Fig.1. By removing a ring shape of columns from a square lattice of dielectric rods the ring resonator is obtained. Photonic crystal ring resonators arenew kinds of cavity defects which their size is

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

determined by thedesired resonant wavelength, and the tradeoff between the cavityQ and the modal volume. Compared to point-defect cavities, ringresonators offer scalability in size, flexibility in mode design dueto their multi-mode nature and adaptability in structure designbecause of numerous design parameters . These parameterscan be the radius of the scatterers, coupling rods and the dielectricconstant of the structure. The ring resonator side-coupled to a linedefect waveguide traps photons at resonant frequency from thewaveguide through evanescent coupling, and emits close to wholeof them in the drop waveguide. Using this method, complete wavelengthselective operation and perfect power transfer from the buswaveguide to the drop waveguide are obtained in our filter.

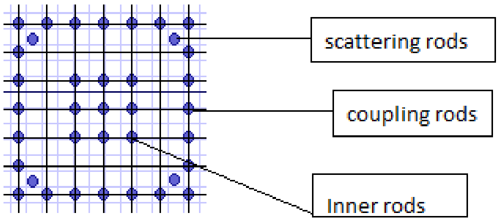

Fig 1.Photonic crystal ring resonator

IV. SINGLE STAGE PHOTONIC CRYSTAL CHANNEL DROP FILTER

First, in order to couple to the signal being sent in the waveguideformed by removing one row of rods, a basic requirement isthat the resonator modes wavelengths lie in the bandgap of thephotonic crystal structure and match that of a guided mode of thewaveguide. As shown in Fig. 2(a), by putting waveguides next tothe ring resonator, an add-drop filter is formed. In this structure,top waveguide can couple to the ring resonator at its resonant frequency to trap the electromagnetic energy which is propagatingin the waveguide and localized it in the ring resonator.
In anotherword, the light is dropped from the top waveguide by ring resonatorand it is sent to the bottom waveguide . This structure consistsof an input waveguide labelled A, and three output channelslabelled as B, C and D. In this structure, by choosing the refractiveindex of 3.46, the lattice constant (a) of 540 nm and the rods radii (r) of 99.9 nm, bandgap opens for the normalized frequencya/λ = 0.31–0.46 for TM polarization (electric field parallel to the rodaxis), where λ is the wavelength in free space.The transmitted spectra in the top and bottom waveguide areshown in Fig2(b). These were calculated by sending in a Gaussianpulse centered at the resonant frequency of the ring resonatormodes and normalizing using the transmission of input waveguide.As seen, the transmission in the drop waveguide is about98% at resonance and the transmitted flux in the bus waveguideis about 96%. Snapshots of time domain simulation are depicted inFig. 2(a),2(b),2(c).

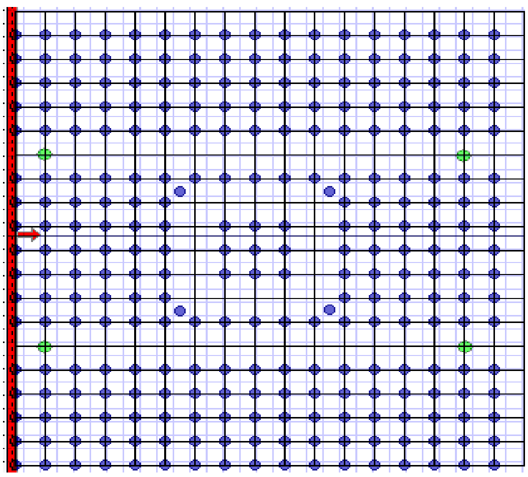

Fig 2(a) Single stage add drop filter design

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

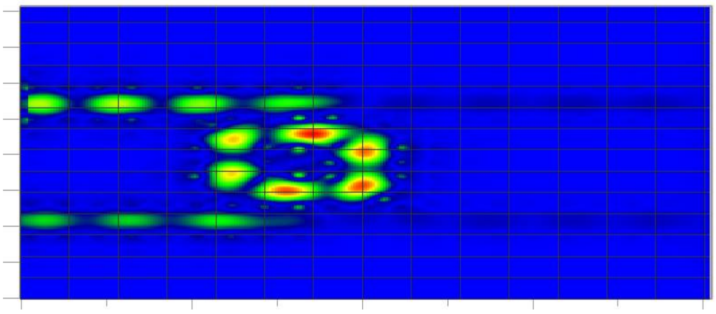

Fig 2(b) Electric field pattern of single channel drop filter at 1577nm.

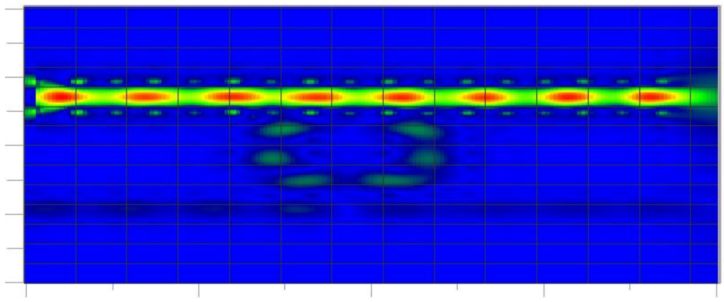

Fig2(c) Electric field pattern of single channel drop filter at 1500nm.

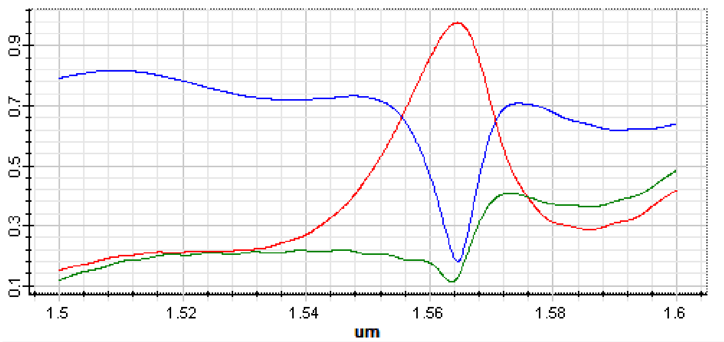

Fig 2(d) Normalized transmission of single stage design.

In the above structure, when input is applied in waveguide, only wavelength that match rectangular PCRR is passed through structure, while others are blocked. In favour of wavelength 1577nm applied signal is completely attached by circular PCRR moreover wavelength appears at output port "D". Regarding the wavelength 1500nm applied signal do not paired by rectangular PCRR moreover signal reflect to the opposite side.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

V. PROPOSED DESIGNS

A. MODIFING THE RODS RADIUS

By changing the radius from 0.1 to 0.12 the wavelength is shifted from 1570nm to 1593nm as shown in Fig4.

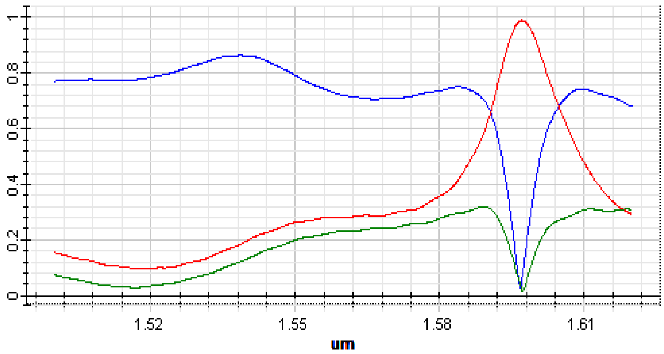

Fig 4 Normalized transmission for channel drop filter with radius 0.12.

B. BAND STOP FILTER DESIGN

By using a single bus waveguide and ring resonator the structure is acting like a band stop filter. Whenever the signal transmitted from input port the signal energy is coupled through the ring resonator and sent back through the input port, so that output will not receive energy. If the energy rotates in the clock wise direction in the ring resonator, energy is transferred through the output. But we are interested in anti clockwise, in this energy is sent back through the input port. The structure is shown in fig below

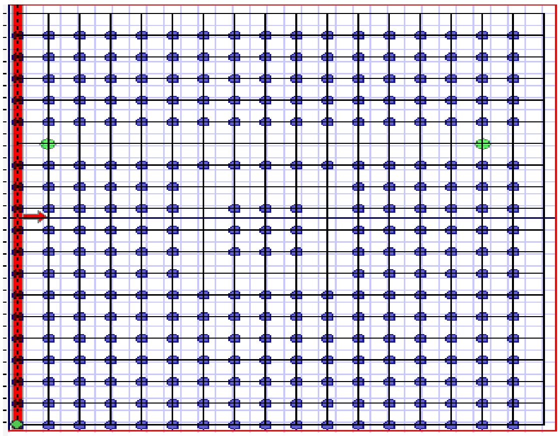

Fig 5.7 Band stop filter

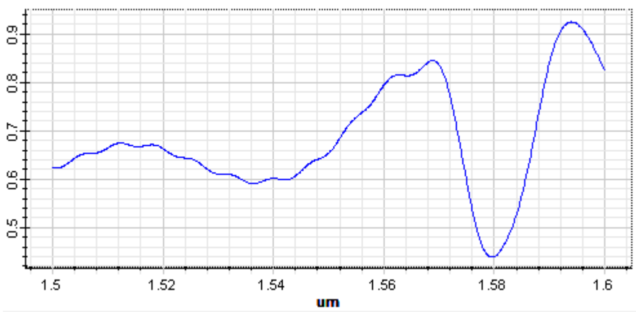

Fig.5(b)Normalized transmission in band stop filter at 1580nm.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

By placing the ring resonator 2 rods apart from the waveguide in the above structure the stop band will be narrower which is used to select finer wavelengths effectively.

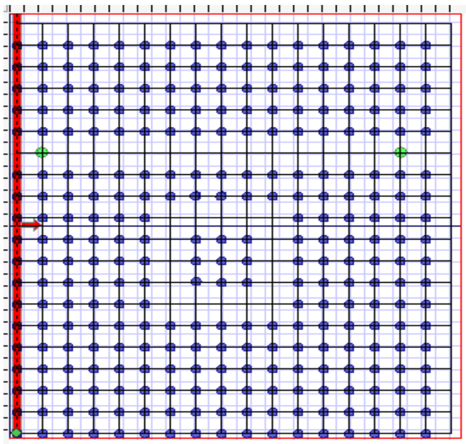

Fig 6(a)Modified band stop filter design

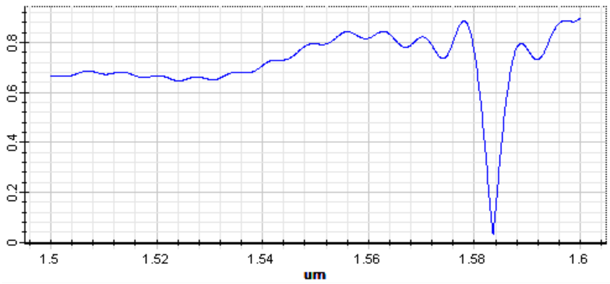

Fig6(b) Normalized transmission for modified band stop filter

VI. DUAL STAGE RING RESONATOR

The dual ring add drop filter structure is as shown in fig below with the transmission profile as below

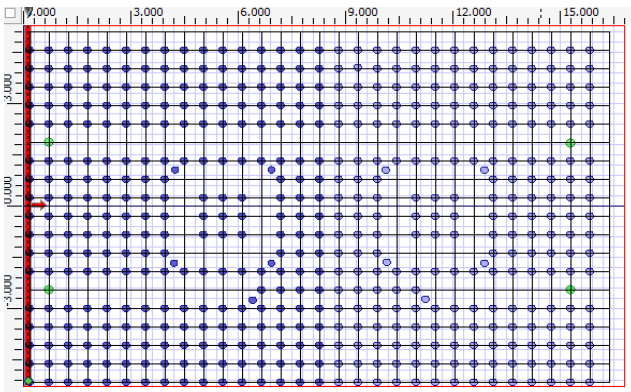

Fig 7(a).Two rings hetero structure photonic crystal channel drop filter.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 11, November 2016

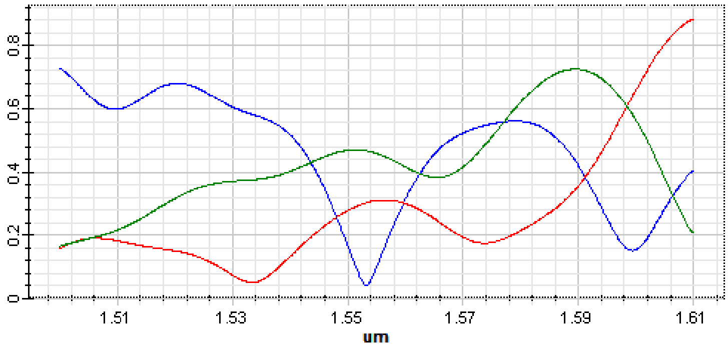

Fig7(b).Normalized transmission of dual ring structure.

The above fig shows the normalized transmission of multi channel drop filter. The structure consists of two regions, one with a refractive index of 3.8 and other with a refractive index of 3.34.It consists of two photonic band gaps regions. The overlapping of regions depends upon dielectric constant and r/a value.The structure consists of two photonic crystal ring resonators. One of them is in region1 and second one is in region2.Six dielectric rods are placed between the two ring resonators. The bottom waveguide performance can be improved by placing scattering rods. The scattering rods lattice constant is shifted by 25% from the original position. The structure consists of four ports. The output efficiencies are over 87%,82% and 91% at the frequencies 1500nm,1550nm and 1593nm.

VI. CONCLUSION

The single channel drop filter is designed by using photonic crystal ring resonator for 1570nm wavelength. By changing the radius of rods from 0.09 to 0.12 the wavelength is shifted from 1570 to 1595nm.By changing the photonic crystal ring resonator shape from square to circular the structure is acting like a band pass filter. By using single bus waveguide and photonic crystal ring resonator it is acting like band stop filter for 1580nm wavelength.By placing the photonic crystal ring resonator two rods apart from the bus waveguide the stop band become narrower.
The multi channel drop filter is designed by using photonic crystal ring resonator.The hetero structure is designed on 2-D photonic crystal structure by using two different refractive indices.The structure consists of three output ports.The output consists of three different wavelengths in the third communication window with transmissions are above 81%.

REFERENCES

1. Robinson S and Nakkeeran R “Add Drop Filter for ITU-T G.694.2 CWDM Systems” 2011.
2. S. Robinson, R. Nakkeeran “PCRR Based Bandpass Filter for C and L+U Bands of ITU-T G.694.2 CWDM Systems” Optics and Photonics Journal, 2011, 1, 142-149.
3. AlirezaTavousi, Mohammad Ali MansouriBirjandi, and Mehdi Saffari “Add-Drop and Channel Drop Optical Filters Based on Photonic Crystal Ring Resonators” IJCIT-2012-Vol.1-No.2 Dec. 2012.
4. Robinson and R. Nakkeeran, “Photonic Crystal Ring Resonator Based Bandpass Filter,” Proceedings of IEEE ICCCCT-10, Pondicherry, 7-9 October.
5. KalraAnd R K Sinha “Photonic band gap engineering in 2D photonic crystals” Vol. 67, No. 6 December 2006 physics pp. 1155-1164.
6. G. Guida A. de Lustrac A. Priou “an introduction to photonic band gap (pbg) materials” In Electromagnetics Research, PIER 41, 1–20, 2003.
7. S. Robinson! and R. Nakkeeran2 “Hetero structure Based Add Drop Filter for ITU-T G.694.2 CWDM Systems Using PCRR” IEEE-201S0.