Novel Compact Optical Channel Drop Filter for CWDM Optical Network Applications

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Abstract- Channel drop filter is designed and simulated in this paper using two dimensional photonic crystal structures by the use of novel design of photonic crystal ring resonator. The novelty in the design is all about its designing parameters as well as the ring resonator structure. The filter is optimized for the telecommunication wavelength 1511 nm. The filter is designed using Aluminium Gallium Arsenide (AlGaAs) dielectric material with refractive index 3.40. The number of rod are 21 and 20 in Z and X directions respectively with lattice constant 540 nm and the dielectric rods in air structure having radius 0.01µm. The design filter gives 99% dropping efficiency with good quality factor around 192 at 1511 nm resonant wavelength for CWDM communication systems. The design and analysis is done by FDTD method and the photonic band gap is calculated by the PWE band solver. The structure is minimized in size about 123µm\textsuperscript{2}. Such kind of device could be useful for CWDM optical communication networks and Photonic Integrated Circuits.

Key Words: FDTD method, photonic crystal, PWE method, Channel drop filter, CWDM, Optical communication system.

1. INTRODUCTION

Photonic Crystals (PhCs) are periodic artificial structures. They are called photonic on the grounds that they follow up on light and crystals as a result of their intermittent course of action. Photonic crystals happen when the period is not exactly the wavelength of light. PhCs may limit the propagation of certain scope of wavelengths in it is possible that one heading or in every one of the bearings, giving the likelihood to bind and trap the light [1]. At a particular recurrence range, electromagnetic waves can't go through the structure; this recurrence extent is called as the photonic band gap (PBG). In this manner by making the imperfections either point surrender or line deformity in the crystal light can be incredibly kept at this recurrence range. Numerous optical devices have been planned by the analysts bunches the world over. Because of the electromagnetic wave properties the field of photonic crystals is becoming much popular these days, which promotion uncommon capacities to them either by: altering, controlling, and directing the stream of light [2].

Scientists in this world presented numerous PhC based devices like power splitters, multiplexers, power combiners, demultiplexers, channel drop filters and band pass filter [3-7] using different kind of dielectric materials like: Silicon (Si) [3-6], Gallium Arsenide (GaAs) [7], Indium Phosphide [8]. Here we have designed using Aluminium Gallium Arsenide.

As per the ITU-T G.694.2 recommendation, there are around 18 wavelengths from 1271nm to 1611 nm for Coarse Wavelength Division Multiplexing (CWDM) technique with 20nm channel spacing. Coarse Wavelength Division Multiplexing (CWDM) provides a cost-effective alternative to DWDM in many metro and regional networks, and provides a capacity increase in the access networks. CWDM is technologically simpler and having easier installation than DWDM, and it controls the traffic growth demands without overbuilding the already designed structure. With some technical details, a typical 8-channel CWDM system, is inexpensive to deploy, offers 8 times the amount of bandwidth that can be achieved using a SONET/SDH system, for a given transmission line speed and with using the same optical fibers [4-5]. This concludes that large, power-consuming thermo-electric cooling circuitry is not necessary in the CWDM systems. So the uncooled laser design could be largely useful for the CWDM systems, as small size, low cost, and low power consumption [6]. The schematic perspective of PCCR based CWDM correspondence system is appeared in Fig. 1.

![Fig. 1: Schematic view of PCRR based CWDM optical communication network.](image)

The Fig. 1 explains that while using on the CWDM multiplexing and demultiplexing technique, we can have the multiple applications. The Fig. shows for four mux/demux CWDM system, where we are having three channel drop filters in the communication system [5]. As per the application we are going to drop the desired wavelengths. For particular
application either residual, large enterprises or small/medium enterprises, we required particular selective wavelength optical channel drop filter. In this way, in last few years many researchers around the world have designed, simulated and fabricated such kind of filters for different applications of optical communication networks. In our proposed work we have also designed the ring resonator based channel drop filter it is different with others in such a way with designing parameters, ring structure and most important dielectric material. With the help of this concept, we have tried to achieve 92.7% dropping efficiency with 172 Quality factor and further improved [7].

2. PHOTONIC BAND GAP ANALYSIS

At the point when the electromagnetic waves go through the photonic crystal, there is a connection between the frequencies and wave vectors, i.e., scattering connection. So this connection is called as the PCs band gap structure.

\[ e(r) = e(r+R) \]  \hspace{1cm} (1)

\( e(r) \) is a periodic function [1-2].

A 2DPC has the PBG which is basically the gap between the air-line and the dielectric-line in the scattering connection of the PBG system. The PBG of the outlined channel drop channel is being ascertained by PWE method as given by K.M. Leung et al. [9].

Deformities like line defect and point defect are used to plan this filter. The PBG [9-12] for the design extends from 0.541628 \( 1/\lambda \) to 0.877675 \( 1/\lambda \), as shown in Fig. 3, whom corresponding range of wavelength extends from 1139 nm to 1846 nm, this range of photonic band gap covers the whole range of CWDM telecommunication wavelength from 1271 to 1611, as we know that as per ITU-T G.694.2 CWDM recommendation there are around 18 wavelengths with 20nm spacing, so with the band gap calculations this material is appropriate for the CWDM application [12].

3. DESIGN OF CHANNEL DROP FILTER

The refractive index of dielectric rods is 3.40 for the structure of aluminium gallium arsenide material and 0.1 \( \mu m \) is radius of dielectric bars. The lattice constant is taken as 540 nm. In the designed structure the number of rod are 23 in z direction and 19 in x direction. The dielectric rods are surrounded by air with refractive index \( n=1 \). In the structure there is a photonic crystal ring resonator, one input port and having two output ports. Two observation point focuses are set at the two yield ports [5]. Four scatterer bars are put at all the four corners of PCRR, to motive to put these scatterer rods is to improve the dropping efficiency of the designed filter and to improve the quality factor of the PCRR based filter structure [6].

P. Andalib et. al [13] presented a ADF consists of a dual curved PCRR that is placed between two open-ended waveguide. In that design the resonator is having two coupled curved Fabry–Perot resonators or a Fabry–Perot cavity with a curved structure rather than a straight closed waveguide. The length and curvature radius of resonator could be selected according to conditions for having more compact photonic crystal optical integrated circuits, a specific operational wavelength, enlarging mode spacing or higher quality factor and drop efficiency.

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P. Andalib structure consists of a background of BSC glass and the rods GaAs having a refractive index of 1.507 and 3.57, respectively [13]. The radius of the rod (r) is 0.2a where ‘a’ is 487 nm. The normalized frequency range is 0.259a/\( \lambda \) to 0.325a/\( \lambda \).
The same concept is utilized and improved dropping efficiency is analyzed by designed filter as shown in Fig. 3. The dual curved PCRR consists of two curved Fabry–Perot resonators, in which energy can be exchanged between them by means of evanescent wave coupling. In the resonator, facing two curved cavities toward each other causes three contact points with high coupling intensity instead of the single one found in coupled ordinary Fabry–Perot or ring resonators. The resonator resonates at $\lambda = 1511$ nm; the $Q$ factor of this resonator is 192 and its drop efficiency is 99%. The $Q$ factor of this ADF increases by enhancing the period of the coupling section between the resonator and two open-ended waveguides, however drop efficiency decreases. The refractive index view of the designed filter is shown in Fig. 4.

**4. RESULT AND DISCUSSION**

It is clear from the Fig. 3 that in the designed filter structure there is one input vertical plane source to transmit the Gaussian modulated continuous wave to the structure [6]. To get the simulation result a 32-bit OptiFDTD design simulator is used see the transmission spectra of the designed filter. About 10000 time steps were used to run the design. There are different way to see the desired output response like; time, DFT and FFT, in which DFT $E_y$ view is used to see the transmission characteristics [14-16].

Fig. 6 demonstrates the DFT $E_y$ field pattern of the desired response of 1511 nm resonant wavelength [17]. Through the Fig. we can find two resonant peaks, one is higher for dropping wavelength and lowest one for the bus waveguide and less for third observation point.
The Fig. 6 describes the electric field view of the designed filter at resonance condition, like when there is resonance at 1511 nm wavelength the light dropped at observation point 2 and when there is no resonance the light passes through the bus waveguide and reached to the observation point 1 is shown in Fig. 7.

Further, the examination is finished by doing various analysis like changing the design parameters as radius, lattice constant and dielectric material at last the scatterer rod radius analysis by changing their rod radius size at different levels to improve the quality factor [17].

5. Conclusion

The outlined channel drop channel structure is designed and simulated using ring resonator of dielectric material Aluminium Gallium Arsenide (AlGaAs) with 3.40 as the refractive index. The size of the designed structure is about 11.4 µm x 10.8 µm nearly equal to 123 µm2 which is compact in size. The outlined channel gives 99% dropping efficiency as around 192 quality factor for the dropping of 1511nm resonating wavelength. Further to get much better output response the designing parameters can be reconFig.d. Future work involves to improve more quality factor while changing some designing parameters and to go for the fabrication process for practical applications. So, such sort of devices might be valuable in CWDM networks and photonic integrated circuits (PICs).

REFERENCES


