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Diagonally coupled hexagonal photonic crystal filter for optical supervisory channel

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ABSTRACT

Optical Supervisory channel is crucial dedicated channel for the communication of remote management of optical network elements. In this paper, photonic crystal diagonally coupled ring resonator based filter is designed for the EDFA supervisory communication channel. InP crystal pillars are formulated on the air surface with the refractive index ratio of 3.4560:1 at which the pillars are circular in shape with equal major and minor radii of 280nm. The delineated structure is established on the triangular system lattice with lattice period of 900nm. Evaluation of bands and the dynamic signal transmission are observed by plane wave expansion (PWE) and finite difference time domain (FDTD) methods. The range of 1499 nm to 1510nm is filtered as band of wavelengths by the depicted filter structure with bandwidth of 9.5nm. Quality factor procured by BPF is 140.1416 with the full width at half maximum of 10.7342nm The desired miniaturized design to reduce size of the device could be achieved by 170 nm × 160 nm scaled representation by horizontally and vertically aligned 20 × 18 InP rods. The proposed delineation is suitable for ultra-compact photonic integrated circuits which can be easily combined to EDFA amplification unit.

Index Terms: Optical Supervisory Channel (OSC), InP crystals, EDFA window, Quality factor.

1. INTRODUCTION

Photonic crystals are the spatially periodic dielectric crystals pierced on another dielectric substrate with defined periodic structures like BCC, FCC etc. These crystals are artificial structure molded on dielectric surface which can be of holes on the dielectric substrate and pillars on the air surface. Mainly these crystals are systemized onto three categories which are 1D crystals, 2D crystals and 3D crystals. More over the 1Ds are used for the photonic lens and gratings fabrication; most needed 2D crystals are useful for the designing process of photonic filters, beam splitter and power dividers, directional couplers, sensor etc. These filters are commercially needed for most applications like sensing, power dividing, carrier and signal transmission, modulation, filtering and add or drop signals. Among these three types of crystals, 3D is under research which has large difficulty to implement in practical. Thus, the effective design of Coupled resonator optical Waveguides and photonic crystal waveguides have been manipulated as tunable delay lines functioned on the silicon-on-insulator (SOI) technological manifesto [1]. At a recent time, a modern 2D photonic crystal T-cut channel drop filter has been drafted to investigate the resonant frequency dielectric constant of inner rods, coupling rods and whole rods and the radius of the coupling rods and scatter rods [2]. An additional notable and mandatory application is optical add-drop filters model contingent on ultra-compact photonic crystal ring resonators in a square pitch [4]. PCs are the influential and ever demanded assembly in the design of grating which shows that for strong confinement, the required gratings exhibit a chirped period and a varying index profile [3]. The delineation of a recent photonic crystal band-pass resonant filters and magnetically tunable narrow-band terahertz filter hinged on a triangular lattice silicon photonic crystal are realized in one missing-row waveguide with broadband acceptable bandwidth [5] and by a point and two

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line defects [6]. The optical properties of these filters have been surveyed by a sole resonant peak with the central frequency [6]. PCs are the specific approach used for the bi periodic bands pass filter by employing absolute defect to construct the waveguide and photonic crystal ring resonator [7]. A brand-new class of photonic crystal filter with two ports is delineated focusing at the necessity of high transmission in optical communications system. This could be achieved by modulating the position of resonant wavelength by changing the diameter of scattering rods [8]. These filters are used for photonic integrated circuits (PIC), wavelength division multiplexing (WDM) FTTH systems and sensor based applications. The normalized spectra of these filters are obtained using 2D Finite Difference Time Domain Method. The Photon transition band is calculated by Plane Wave Expansion method [9]. A new type of structure to obtain band pass filter consists 3x3 dual square band pass filter in a silicon square lattice [10]. A band pass filter with 45 degrees bend in an ordinary waveguide is suitable as an optical filter with respect to C band. The main attribute of this filter using elliptical rods structure with different angle in square lattice is quality factor approx. 164 for circular rods and Q factor 155 noticed for elliptical rods [11].

In this paper, the diagonally connected ring resonator based PC filter is delineated to effectuate the filtering behavior by the band pass filter. The circular crystals of InP pillars are pierced over the air surface with refractive index contrast of 3.4560/1. The major and crucial characteristic of the band pass filter is quality factor (QF). The gained Q value for the proposed band pass filter is 140.1416 which denote the filter is wide band pass filter with the bandwidth of 9.5 nm. The detailed analysis of the filter design is described in the following sections which are partitioned in to II as design formation, III as Simulations, IV as results and discussions and finally V as conclusion.

2. DESIGN FORMATION

The essential and dominant need is to design an optical filter to separate the optical supervisory channel (OSC) for the EDFA amplification process. This could be achieved by the available wavelength filters in photonics. The OSC bears the information of the outer and remote conditions at the end optical terminal as well as secure the multi-wavelength signal information. The proposed design is concentrated on the above defined need of OSC and designed as the band pass filter of dedicated band of 1499nm to 1510nm. The elucidation of the forged photonic crystal filter is stated in the following sections.

2.1. Layout configuration

The initial layout is designed by the 20×18 dielectric pillars on the triangular lattice system with period of 900nm. The refractive index contrast of the pillars and background material is chosen as 3.4560/1. The major and the minor radius of the rods are chosen to be as 280nm. According to the defined specifications of the crystals the layout is created which is shown in the Fig. 1 delivers the proposed filter initial layout where the blue colored circle denotes the pierced InP pillars on the air background.

2.2. Band gap examination

The band gap evaluation of the filter is the important factor to define the propagating wavelength of structure. The defects made by the pillar eradication in the desired formation make the forbidden bands of the filter to be broken. Thus, the broadcasting wavelengths in the depicted filter are resolved by the plane wave expansion method (PWE). Fig. 2 deals with the emerged bands after defects which can decide the amount wavelengths to be propagated and blocked in the waveguide structure.

The procured bands are situated at the normalized frequency range of $0.24609<a/\lambda<0.33559$ (band 0) and $0.449081<a/\lambda<0.575832$ (band 1) in TE polarization. By eliminating the prohibited bands, the necessary wavelength limit can be picked. For this proposed filter, preferred signal wavelengths positioned at the third window of optical communication.

2.3. Devised Band pass filter design

The initiative wavelengths for the signal propagation are at the start of the third window. Continuous wave Gaussian signal is designated as excitation field of the vertical position. Demanded constitution is procured by annihilating 53 InP rods for suitable fashion. Thus, the filter ring is fashioned by diagonally coupling the lower corner of the hexagonal rings. Fig.3 exhibits the organized band pass filter with single input and single drop port. The ring fashioned structure acts as resonator where the resonating wavelengths are dropped by the drop port and other signals are circulated inside the ring throughout the transmission. If the resonant wavelength co-insides with the input wavelength, the intensive signal will be dropped at the output port of the filter.

Fig. 4 shows the index distribution of coupled hexagonal ring filter where the red color denotes the InP pillars with refractive index of 3.4560 and blue color background provides the air index.

3. SIMULATION PERFORMANCE OF FILTER

The third window input wavelengths are considered for the filtering operation. In band pass filter, the ring looks like a stepped architecture for resonance performance. When the initiative signals are resonated

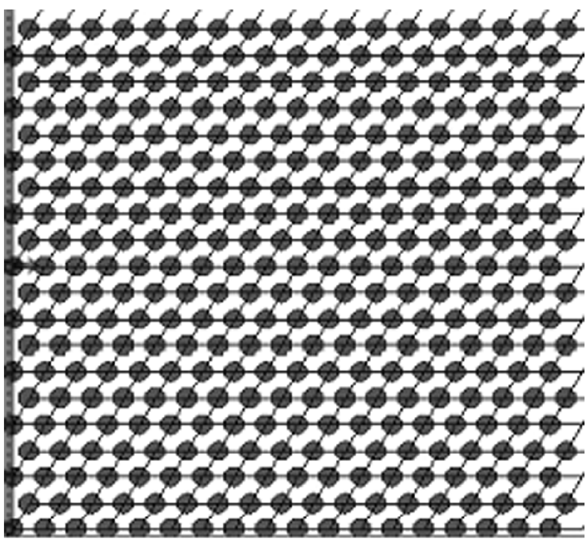

Figure 1: Initial layout of filter

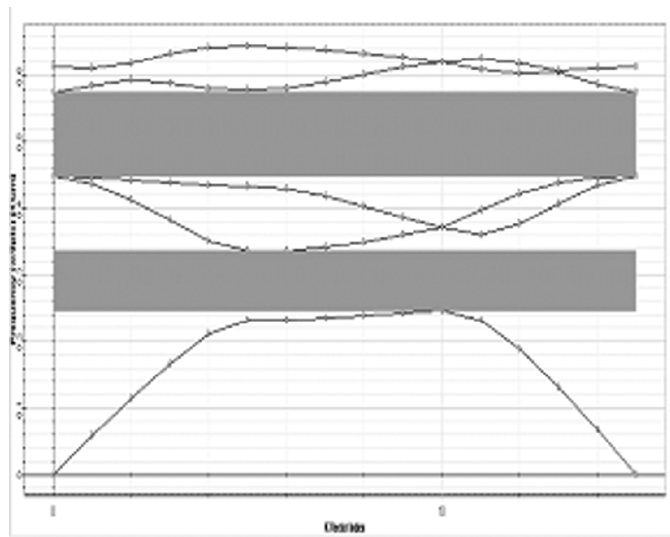

Figure 2: Band gaps observed after defects in the initial layout

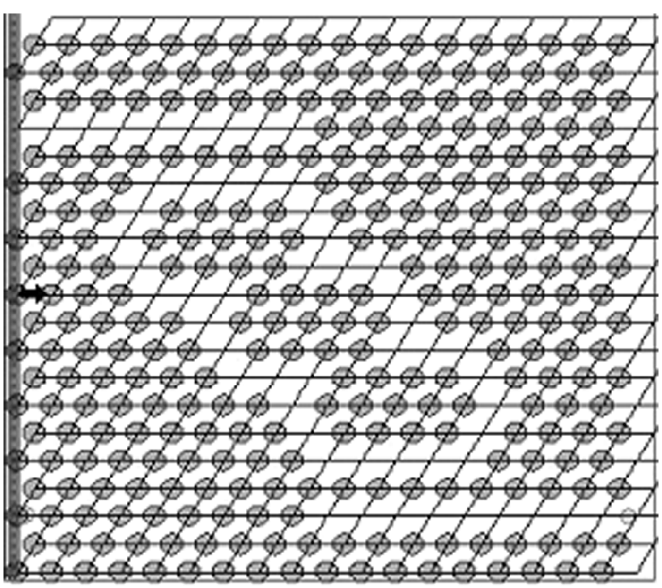

Figure 3: Delineated InP pillar band pass filter on air surface

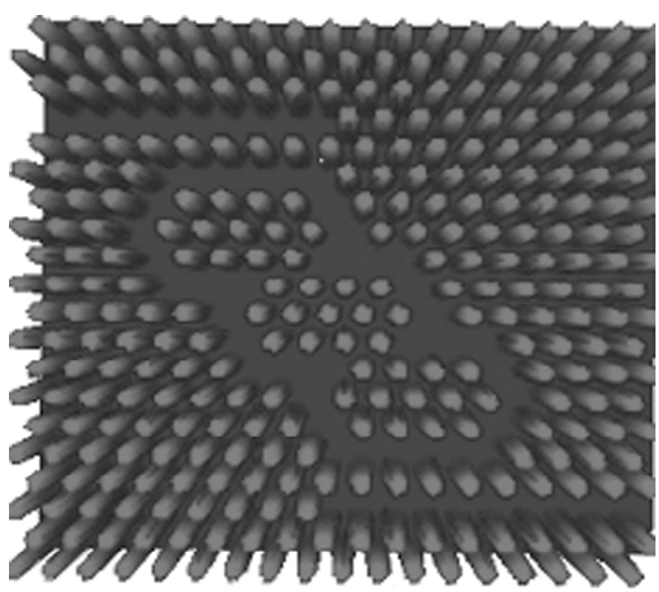

Figure 4: Index distribution of BPF

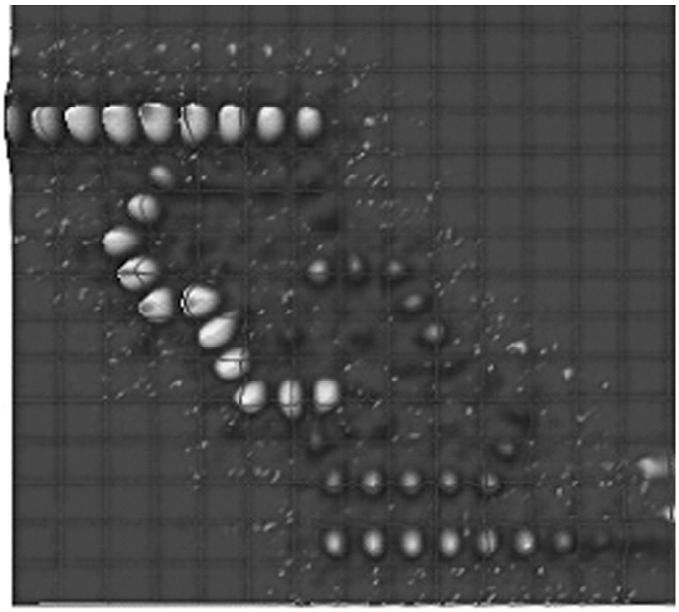

Figure 5: Drop signal at the wavelength of 1499nm

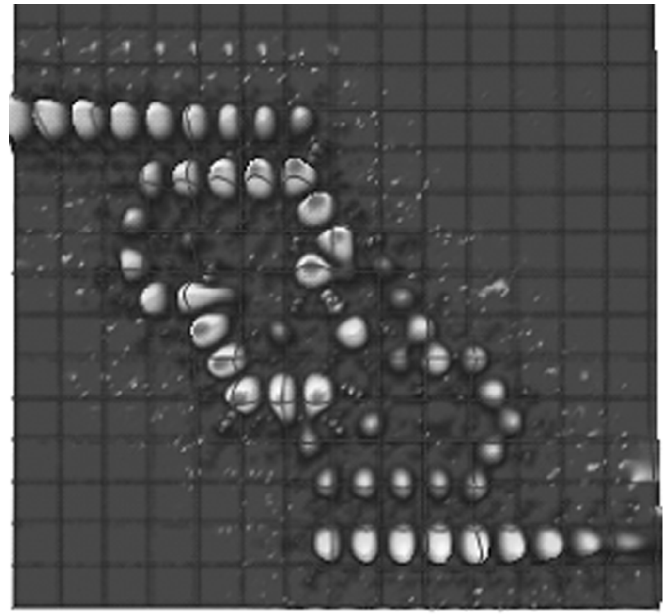

Figure 6: Filtrated signal at 1505 nm

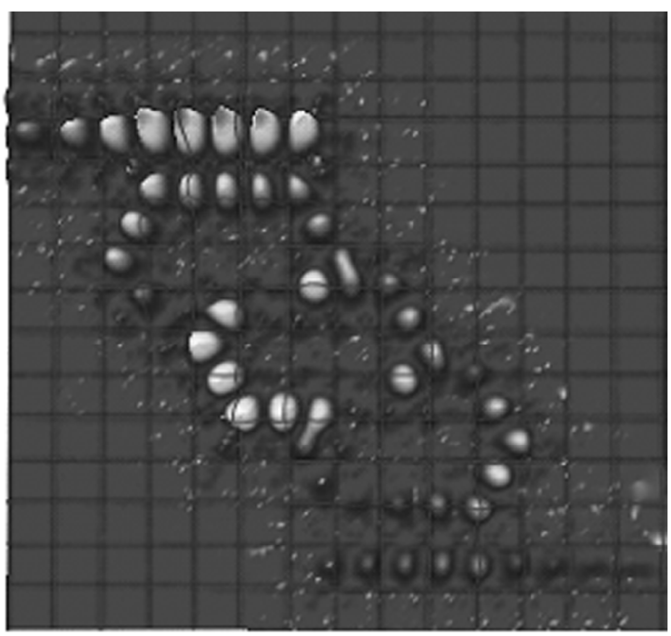

Figure 7: Intensity profile of the filter at 1510 nm

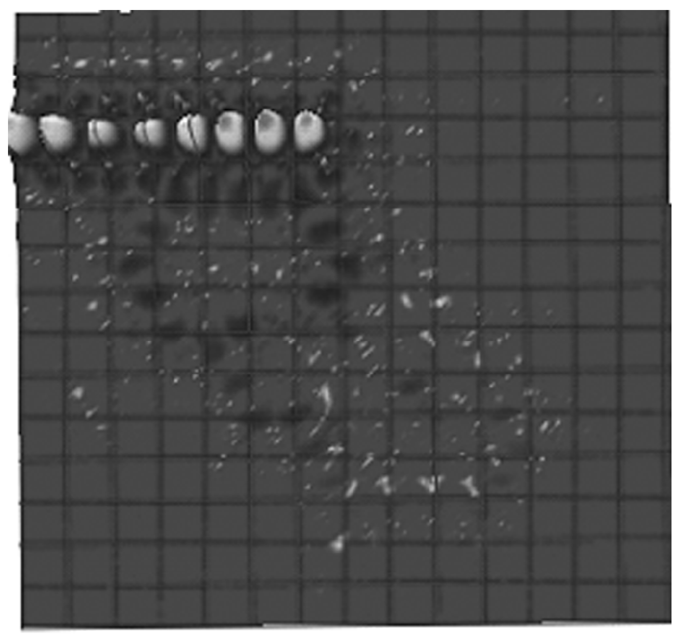

Figure 8: Non-resonance wavelength at 1515nm

at the peculiar wavelengths, the exactly matched wavelengths are downloaded at the drop port of the BPF. Thus, the percolated wavelength ranges between 1499nm and 1510nm. This comprehends the optical supervisory channel wavelength field which performs the monitoring function of the remote terminals of the optical components in networks. The intensity profile of the filter channels are shown in the following figures. Fig. 5, 6 & 7 betray the signal propagation evidence of the filter which can filter the wavelengths at the range of 1499nm to 1510nm with the bandwidth of 9.5nm. Height plot of the signal are shown in green color. The other range of signal may be circulated inside the ring or attenuated at the entrance of the filter.

Figure 8: indicates the non-resonance wavelength that does not proceed towards the output port at 1515nm.

IV. RESULTS AND DISCUSSIONS

Proper wavelength drop could be attainable by the resonating function of the rings connected in diagonal. Fig 9, 10 & 11 determines the peak spectra of the filter for three different wavelengths of 1499nm, 1505nm and 1510nm respectively. The band pass filters possess the paramount characteristics which are Quality factor, bandwidth and tunability. On accounting the importance of the Q factor, this filter has the full width at half maximum (FWHM) value of 10.7342nm. By revealing the direct relationship between the Q factor and the FWHM, value of 140.1416 is gained as Q value. This elucidates the filter peculiarity in the direct correspondence of bandwidth. Thus, the value of low Q expounds that the filter is wide band of 9.5nm.

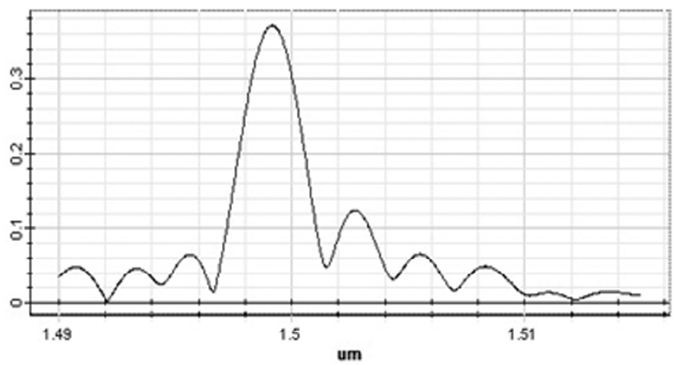

Figure 9: Signal peak of 1499nm

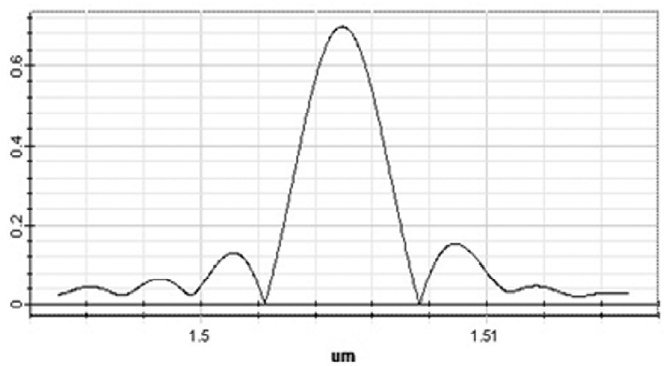

Figure 10: Peak signal of 1505nm wavelength

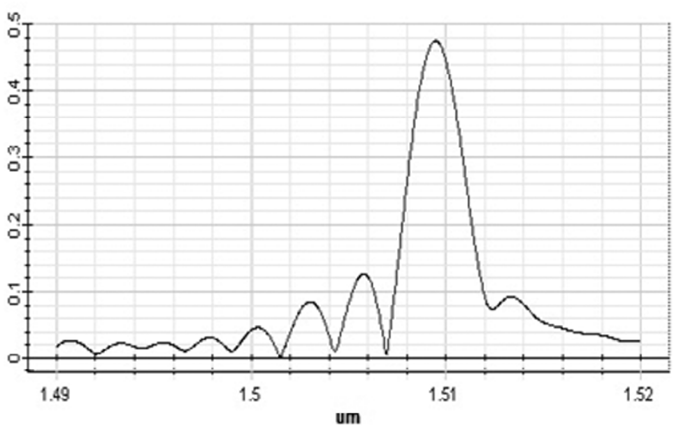

Figure 11: Peak spectra of OSC wavelength 1510nm

Table 1
Obtained Filter Parameters

Parameters	*Obtained Value*
Resonance wavelengths	1499nm – 1510nm
Full width at Half maximum	10.7342nm
Quality factor	140.1416
Bandwidth	9.5nm

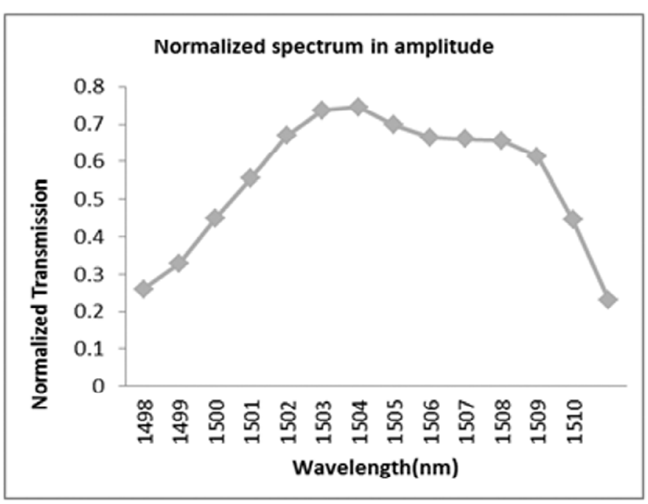

Figure 12: Normalized spectrum of filter in terms of its amplitude.

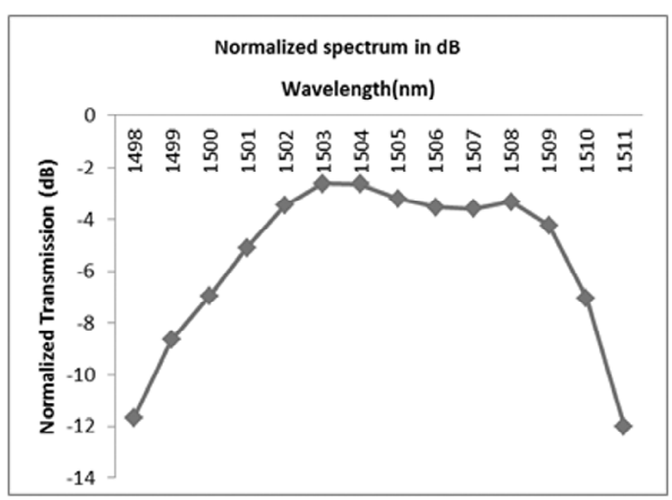

Figure 13: Normlaized spectrum of filter in terms of dB

Transmission spectrum of whole band of the filter is expressed in fig 12 & 13. Table 1 represents the determined features of the proposed filter design.

5. CONCLUSION

In this paper, Optical supervisory channel filter has been designed to incorporate the filter with the Erbium doped amplifier suitable to work at the EDFA window. Hexagonal inner ring is diagonally coupled at three levels and ring is formed with two ports. Band of third optical window is dropped at the range from 1499nm to 1510nm with the bandwidth of 9.5nm. Transmission spectra and band of photons are described by FDTD and PWE methods. The perceived quality factor of the OSC filter is 140.1416 with FWHM of 10.7432. Thus, the formulated filter structure behaves as the wide band pass filter for the third optical window. The specific channel 1510nm performs supervising function of the multi wavelengths and collecting the information of the remote components connected in optical terminal of networks of FTTH, WDM and EDFA.

REFERENCES

[1] A. Melloni, A. Canciamilla C. Ferrari F. Morichetti L. O'Faolain T. F. Krauss R. De La Rue A. Samarelli M. Sorel "Tunable Delay Lines in Silicon Photonics: Coupled Resonators and Photonic Crystals, a Comparison", IEEE Photonic Journal, vol. 2, April, 2010.

[2] Mehrdad Djavid, Faraz Monifi, Afshin Ghaffari, and Mohammad Sadegh Abrishamian, "T-shaped channel-drop filters using photonic crystal ring resonators" Integrated photonic and Research Applications, Optical Society of America, 2008.

[3] Jacob Scheuer and Amnon Yariv "Optical annular resonators based on radial Bragg and photonic crystal reflectors", OPTICS EXPRESS, Vol. 11, No. 21, 2003.

[4] Zexuan Qiang, Weidong Zhou "Optical add-drop filters based on photonic crystal ring resonators", OPTICS EXPRESS 1823, Vol. 15, No. 4, 19 February 2007.

[5] Seunghyun Kim, Jingbo Cai, Jianhua Jiang, and Gregory P. Nordin "New ring resonator configuration using hybrid photonic crystal and conventional waveguide structures", OPTICS EXPRESS 2356, Vol. 12, No. 11, 31 May 2004.

[6] Shaopeng Li, Hongjun Liu, Qibing Sun, and Nan Huang," A tunable terahertz photonic crystal narrow-band filters" IEEE Photonics Technology Letters, 2015.

[7] Arpita Sharma, Pawan Kumar Inaniya," Biperiodic structure based band pass filter for CWDM system using photonic crystal", (SPIN), 2015.

[8] Wei Wang, Bo Yang, Hongru Song, Yue Fan, "High Transmission Photonic Crystal Filter Based on Squarely Lattice"IEEE, 2012.

[9] Abdelali. Boudissa, Malek. Benslama, "Simulation Effects of Lateral Coupling Between L3 Cavity and Two Quasi Waveguides Bends in 2D Photonic Crystal Band pass Filter", IEEE, 2012.

[10] Arpita Sharma, Pawan Kumar Inaniya, "Dual Square Ring with 3x3 Dielectric Rods Structure Based Band Pass Filter using Two Dimesional Photonic Crystal", Fifth International Conference on Communication Systems and Network Technologies, 2015

[11] Arpita Sharma, Pawan Kumar Inaniya, "Elliptical and Circular rods based band pass filter with 45 degree bend in waveguide for different dielectric rods structure using photonic crystal", International Conference on Computing Communication Control and Automation, 2015.