# Decrease of Crosstalk Phenomenon Optic Two-Channel Demultiplexer Using Resonant Line Defect Cavity in 2D Photonic Crystal

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**ABSTRACT:**
In this article decreasing of crosstalk phenomenon optic two-channel demultiplexer to use in DWDM communicational systems with 2D photonic crystal structure has been suggested. In this research, designed two-channel demultiplexer resulted in decrease in crosstalk phenomenon to the average of -22.11 dB in photonic crystal two-channel demultiplexer according to ultra channel spacing with distance of 0.8 nm, ultra narrow bandwidth mean of 0.25 nm, and quality factor Q with ultra average amount of 6582. PWE calculation methods were used to obtain band structure and photonic band gap and FDTD numerical calculation method was used to obtain output spectrum of photonic crystal two-channel demultiplexer.

**KEYWORDS:** Crosstalk, Demultiplexer, Resonant cavity, Quality factor, Bandwidth, Photonic crystal.

## 1. INTRODUCTION

Photonic crystals are composed of periodic dielectric structures or metal [1]. Changes in physical characteristics of photonic crystal lattice structure, such as amount of radius, refractive index, and dielectric constant, lead to disorder in periodic structure of lattice, which is called "Defect" [2]. Defect is used in the form of point, linear or a combination of these two [3]. By creating linear defect in structure of photonic crystal, a structure like waveguide of photonic crystal wavelength [4] and by omitting some defects along horizontal or vertical direction, a structure like resonant cavity [5] and heterostructure ring resonators [6], are formed. Also multiplexers and demultiplexers [7], [8], optical switches [9], optical isolators [10], Laser [11], optical detector [12], and modulator [13] are some of photonic crystal structure usages in optical devises and instruments.

In a semiconductor photonic crystal structure, periodic dielectric lattice leads to change of photons to the wavelength band and wavelength gap, which is called Photonic Band Gap (PBG) [14]. If photon or light wavelength is placed inside photonic band gap, photonic crystal will reflect wavelength of light regardless of located angel [15]. Considering lack of optical states in photonic band gap, and lack of spontaneous light or wavelength emission inside photonic band gap [16], by modulating photonic band gap in the photonic crystal lattice structure, it is possible to control emission of different optical wavelengths [17]. This extraordinarily good advantage of photonic band gap is used in some photonic crystal structure-based designing such as waveguides [18], and resonant cavities [19].

## 2. DESIGNING AND CALCULATIONS OF BASEBAND STRUCTURE

Necessary calculations to obtain photonic band gap and band structure in two-dimensional (2D) photonic crystal has a key crucial role in optimum designing of basic filter [20]. Therefore to decrease crosstalk in two-channel demultiplexer the method [21] has been used to design basic filter structure based on 2D photonic crystal according to Figure 1. In this structure the lattice constant has been considered 420 nm with refractive index of 2.73.

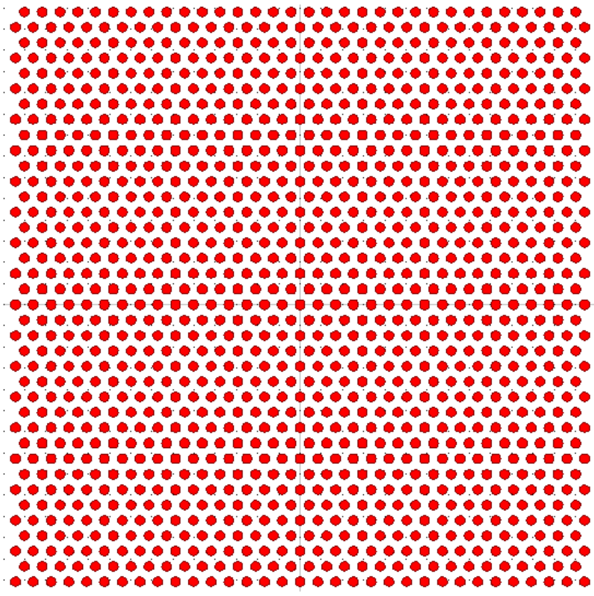


**Fig. 1.** 2D photonic crystal lattice structure for designing two-channel demultiplexer basic filter

Of the issues that we are always facing with, in calculations of 2D photonic crystal related structures, are complexity, time consuming nature, and high load of wave electromagnetic equation calculations [22]. However, calculations in numerical method are simpler and less time-consuming [23]. So, for calculations of band structure and obtaining photonic crystal structure's photonic band gap range, plain wave expansion (PWE) numerical method is used [24].
Considering the fact that photonic band gap determines working range of wavelengths of two-channel demultiplexer basic filter, Figure 2 is obtained using simulator software of Bandsolve.

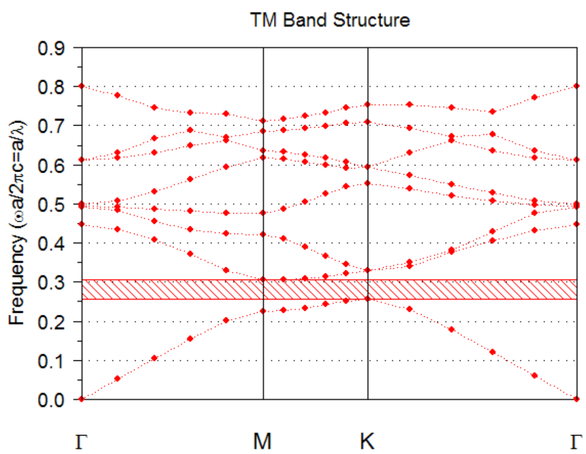



**Fig. 2**. Structure of 2D photonic crystal band gap for designing two-channel demultiplexer basic filter

According to Figure 2, bandwidth of photonic gap in terms of ratio of structure radius filling to the lattice constant is r/a= 0.2748. So the range of photonic band gap is $0.256 \leq \omega a/2\pi c \leq 0.304$ which shows that we can reach wavelengths in a range of $1381.5\text{nm} \leq \lambda \leq 1640.6$ from structure of 2D photonic crystal lattice in designing basic filter and two-channel demultiplexer.

## 3. DESIGNING AND SIMULATING BASIC FILTER OF DEMULTIPLEXER STRUCTURE

Minimizing crosstalk of two-channel demultiplexer working wavelengths needs detailed designing of basic filter in 2D photonic crystal structure. One of the methods of designing detailed basic filter is resonant cavity [25]. Resonant cavity transfers optical wavelengths which are in same wavelength of its resonance wavelength, to the waveguide. In fact the main feature of resonant cavity is that it is resonated only in a single optical wavelength. Figure 3, illustrates a sample of resonant cavity.

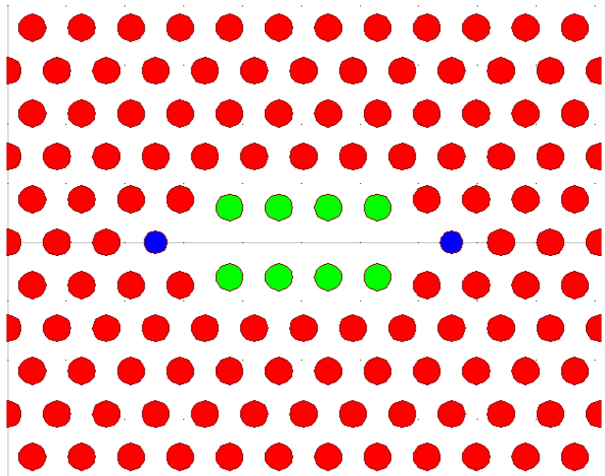


**Fig. 3**. Representation of resonant cavity of 2D photonic crystal lattice

The suggested method to design basic filter of two-channel demultiplexer is resonant cavity [26].
For this reason, we achieved the design of Figure 4, after conducting and attaining many methods based on resonant cavity in designing basic filter of two-channel demultiplexer to work in range of DWDM communicational systems.

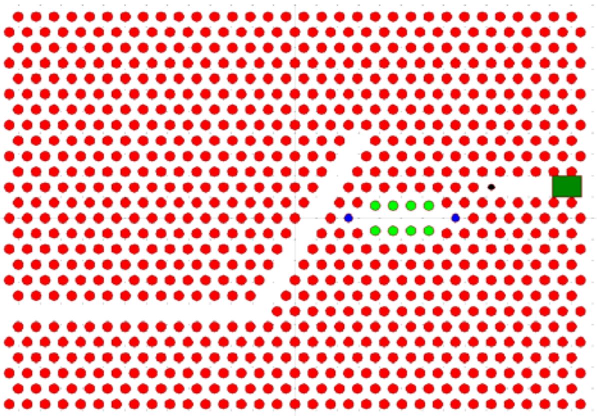
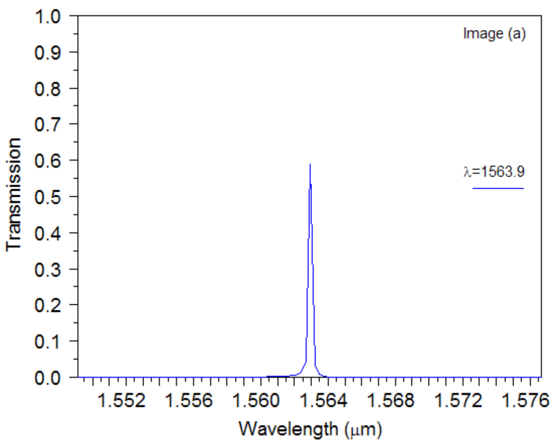


**Fig. 4**. Two-channel demultiplexer basic filter structure of 2D photonic crystal lattice

Figure 4, shows that input waveguide, resonant cavity, and output waveguide are of characteristics of basic filter. According to working wavelength in photonic band gap and band structure range, we considered changes of central defect distance without change from each other limited to 69nm and side defects of resonant cavity which act like mirror 96nm, and refractive index n=2.78 .

According to the high complexity, calculations of simulating output wavelength of demultiplexer basic filter suggested by FullWave software [27], has been obtained from finite difference time domain (FTDT) numerical method [28 , 29], and Figure 5, shows output wavelengths of suggested basic filter.



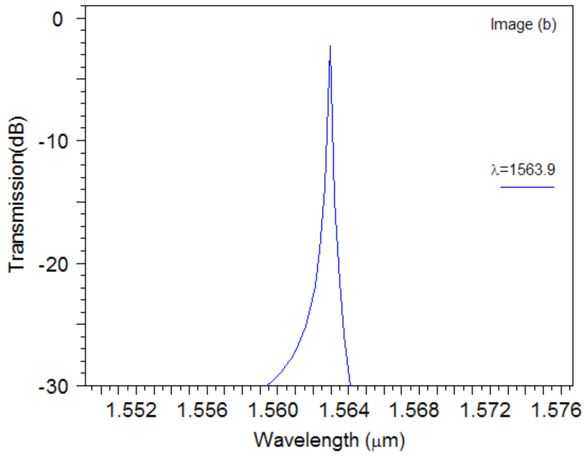




**Fig. 5**. Output spectrum of suggested two-channel demultiplexer basic filter of 2D photonic crystal lattice a) linear scale b) dB scale.

## 4. DESIGNING AND SIMULATING DEMULTIPLEXER

Now, after designing and analyzing basic filter based on resonant cavity and obtaining its wavelength spectrum, we start designing T-shaped two-channel demultiplexer which is proper for DWDM communicational systems. Designing two-channel demultiplexer has been inspired by plan [26]. Structure of demultiplexer in Figure 6, composed for receiving spectrum of optical wavelengths from input waveguide, for selecting working wavelength in range of DWDM communicational systems from resonant cavity, and for amplifying desired wavelength from output waveguide (or the defect formed in output wavelength).

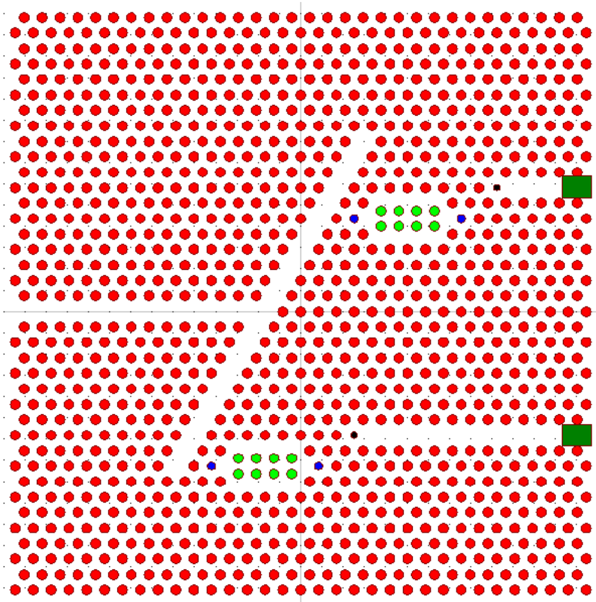


**Fig. 6**. T-shaped two-channel demultiplexer of 2D photonic crystal

Channels 1 and 2 of designed two-channel demultiplexer in sides of resonant cavities are equal to constant defect value of 96nm, and distance of central cavities from each other without change in central defects are 68nm for channel 1 and 96nm for channel 2. Refractive index for demultiplexer structure has also been considered as constant of n=2.81 . Extraction of output wavelengths of two-channel demultiplexer of Figure 7, has been simulated by FullWave software [27] and its calculations are run in numerical method of finite difference time domain (FTDT) [28], [29].

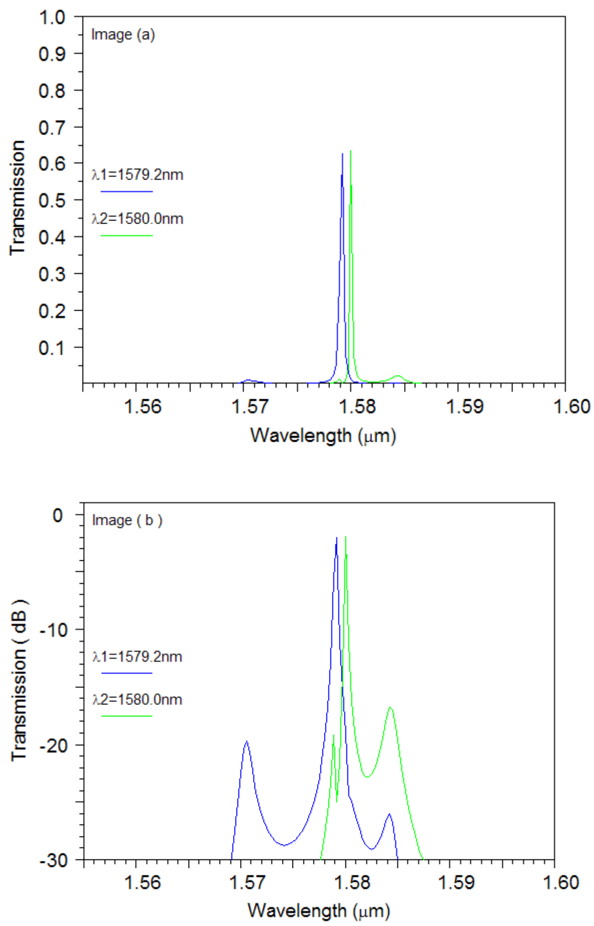



**Fig. 7**. Transfer spectrum of T-shaped two channel demultiplexer of 2D photonic crystal a) linear scale b) dB scale

## 5. RESULTS OF SIMULATION

Using simulation of designing basic filter and by improving its refractive index condition, we simulated two-channel multiplexer based on photonic crystal structure. To decrease demultiplexer crosstalk we considered refractive index, lattice constant, and cavity radius as n=2.81, 420nm, and 115nm respectively. Since we needed exact calculation of structure, we used PML boundary condition for simulating [30]. Structure of has been composed of demultiplexer in TM mode, and 33*38 aerial cylinders respectively in X and Z axes.

To decrease crosstalk in two-channel demultiplexer we designed structure of resonant cavity of photonic crystal lattice in a way that bandwidth of wavelengths (Δλ) be less than or equal to 0.3nm. This advantage of extreme narrow bandwidth of wavelength would cause high quality in isolating wavelengths from each other in two-channel demultiplexer. By proper designing of two-channel demultiplexer resonant cavity in structure of 2D photonic crystal, according to figure 7a, bandwidth of channel 1 became 0.3 nm, in central wavelength of 1579.2nm, and bandwidth of channel 2 became 0.2nm, in central wavelength of 1580nm. In Table 1 results of calculations related to quality factor Q has been presented as 5264 for channel 1 and 7900 for channel 2 respectively.

**Table 1.** Results of simulating output spectrum of two-channel demultiplexer

| Quality factor | Δλ(nm) | Transmission domain | λ (nm) | Channel |
|---|---|---|---|---|
| | | | | |
| 5264 | 0.3 | 62.61% | 1579.2 | 1 |
| 7900 | 0.2 | 63.38% | 1580.0 | 2 |

For channels 1 and 2, ultra high quality factor and ultra narrow bandwidth show that we have obtained minimum crosstalk in two-channel demultiplexer, according to figure 7b. Results of calculations in dB scale of figure 7b, according to table 2 show that crosstalk effect of channel 1 in channel 2 is -19.62 dB and crosstalk effect of channel 2 in channel one is -24.59 dB.

**Table 2.** Results of two-channel demultiplexer crosstalk values

| Channel | Xt12 | Xt21 |
|---|---|---|
| 1 | -19.64 | - |
| 2 | - | -24.59 |

## 6. CONCLUSION

In this article, decreasing crosstalk phenomenon in two-channel demultiplexer was designed and simulated using 2D photonic crystal structure. Spectrum of output wavelength range of channels 1 and 2 of two-channel demultiplexer structure with average of 62.99% show proper power of optical wavelength transfer for working in DWDM communicational systems. With ultra narrow bandwidth mean of 0.25nm, and achieving quality factor Q with extraordinary mean value of 6582, we obtained minimizing crosstalk phenomenon of channels to each other with average of -21.11 dB. Therefore, this two-channel demultiplexer is an ideal 2D photonic crystal structure for use in DWDM communicational systems considering high channel spacing of channels from each other with distance of 0.8nm and reduction of crosstalk phenomenon to average of -22.11 dB.

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