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The effect of cells' radius on optical filter output spectrum based on photonic crystals

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ABSTRACT

In this article, the effect of cells' radius on the behavior of wavelength switching optical filter and the effect of the radius of the optical filters' key characteristics such as wavelength resonance on an optical filter based on photonic crystals, have been investigated. Currently, the most common applied mechanism for designing optical filter based on photonic crystals is using two mechanisms such as (a) The resonant cavities and (b) Ring resonators. The applied mechanism in optical filter used in this article is the resonant cavities. In this filter, filtering act is operated by using cavity located between output Waveguide and input waveguide and it has been used to design filter at the first extracted band structure and we have applied forbidden band photonic based-crystal by using PWE method. Then, the calculations related to filter output spectrum were carried out by using an FDTD method. Thus, the effect of cells' radius on the behavior of wavelength switching optical filter has been investigated in this study.

KEYWORDS: Photonic crystals, forbidden photonic band, the cavity resonance, optical filters

1. INTRODUCTION

Currently, photonic crystals are suitable structures for applications of optical electronic and communication and optical information processing in optical electronics is one of the main objectives for researchers in the field of photonics [1]. On the other hand designing optical electronic instruments is based on photonic crystals such as common structure for designing optical electronic instruments. Photonic crystals are made of Dielectric or alternate dielectric-metal. Scalability even regarding a few nanometers, the interaction between light and matter, fast performance and storing light in a very small space is features providing a suitable structure for optical electronic devices. In this structure, the photons (equivalent to electromagnetic waves particle), either can pass through crystal or reflex relying on its wavelengths. The ranges of wavelengths that do not allow passing is called forbidden photonic band [2]. This property helps us know that the light will not spread inside when the light impacts on the forbidden band range. Thus, it will pass among a pathway called photonic waveguide. In addition, if interior part of the structure between output and input waveguide has been located as a wavelength similar to resonators or resonance cavies to operate, wavelength switching will act by using resonance properties. We can also achieve aims such as designing filters. Overall, these crystals are made by using a variety of structures such as one-dimensional, two-dimensional, and three-dimensional. Two-dimensional photonic crystal by forbidden band depends on the dielectric refractive index, rods radius and constant of the network structure. For designing optical devices photonic crystals are applied such as photonic filters [3-4] multiplexer [5]، D.multiplexer [6]. What is specifically important in optical Telecommunication of optical filters is the application of optical filter in the wavelength device multiplex (WDM) that is sent through several optical channels with different wavelength within an optical fiber in this device and optical filter applied for separating these channels [1]. So totally, the filter is basically a piece switch frequency or wavelength switch. It means that it can select special wavelengths. In recent years, different filters have been designed and presented based on photonic crystal. In 2012, AliPour Banayi and MehdiZadeh [6] have designed a structure by using One-dimensional photonic crystals that was able to omit the harmful or destructive rays of UVB. As a matter of fact, their suggested structure was an omitted-band filter not allowing the Wavelength range of 280-300 nm to pass. Roustami et.al [8] has designed a filter that the Quasi-periodic wavelength switch structure has been used on it. In the second part of this article, we consider investigating the method of designing optical fiber based on the structure of photonic crystal and next, we will survey the effect of cell radius and we will present the conclusions in last part of this article.

2- Methods and materials for designing filter

Applied structure for designing filter is based on resonance cavity of Hexagonal array 26×40 of created holes inside dielectric material with a refractive index of 2.8. The radius of the air holes in the base crystal lattice constant is 115 nm and 420 nm. Before doing any action, in designing filter based on two-dimensional photonic crystals, crystal band structure and scope its forbidden band must be calculated and extracted to understand whether the considered structure for our effectiveness wavelength is appropriate or not. Currently, for calculating band structure and extracting photonic forbidden band, the best way is using numerical calculation. One of the numerical methods is Plane Waves Expansion (PWE) method to typically calculate special Alternate structures' frequencies in the frequency domain with the numerical solution of Maxwell's equations, is to draw these frequencies in this two-dimensional diagram is obtained photonic crystal in terms of band structure network vectors and the forbidden photonic band [9].

In this paper, we use such a method for extracting forbidden photonic band but for accelerating calculations and reducing the possibility of errors in calculations, we have used BANDSOLVE device in RSOFT software for calculating PWE.

2-1. Studying forbidden band photonic crystals with a hexagonal network

There are two effective facts in two-dimension forbidden photonic crystals band:

- Applied dielectric refractive index for making photonic crystals
- The proportional of radius of the cells to network(r/a)

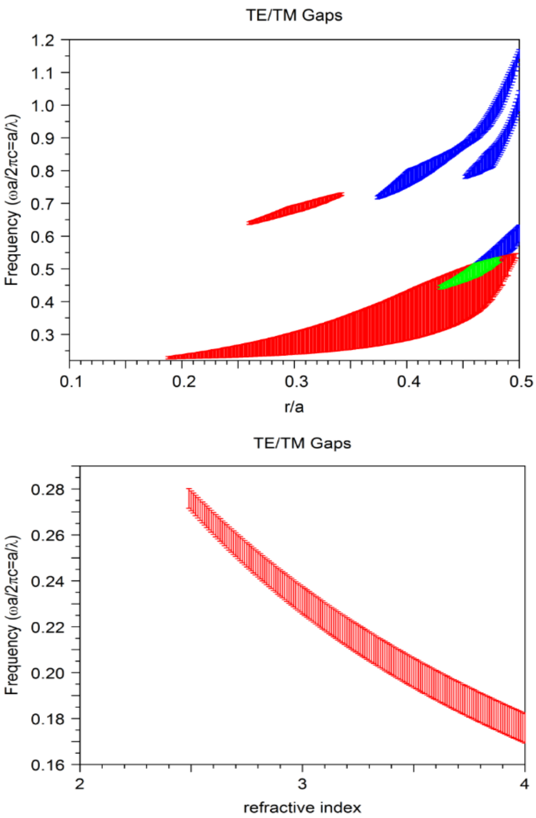

Fig.1.Forbidden photonic Band variations curve of Hexagonal crystal photonic consisted of Dielectric air cylinders in terms of (a) r/a and (b) the refractive index.

The different curves of forbidden Squared Photonic crystals band consists of dielectric rods in air environment in terms of ratio r/a and the refractive index of the dielectric rod have been shown in fig 1(a) and 1(b), respectively. It has been observed that forbidden band formed the majority in mode TE for this structure. Forbidden band is less located in the normalized frequency by increasing the refractive index.

2-2. Extracting band structure

The considered Crystal band structure has been obtained with the above values for dielectric refractive index, radius rods and stable network shown in fig 2.

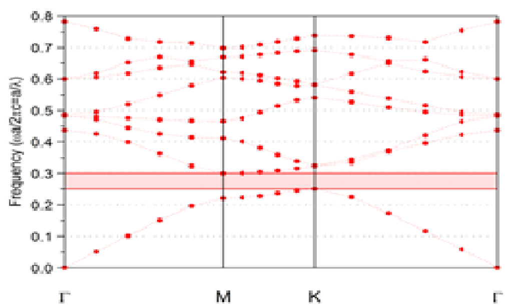

Fig.2. Basic photonic crystal band structure

According to this form, considered structure has a forbidden band in TM mode $0.25 \langle r/a \langle 0.3$ and range of equal to wavelength range of $1400nm \langle \lambda \langle 1680nm$.

3- INVESTIGATING RADIUS EFFECT ON THE FILTER OUTPUT SPECTRUM

Different factors are affected by characteristics of filter output spectrum. One of these factors is variations of cell radius. In this research, the effect of three types of radiuses on the behavior of filters has been investigated. First type is the variations of unrighteousness radius Rc related to unrighteousness both ends of the cavity. Second type is unrighteousness radius RO where unrighteousness is located on the beginning of the output waveguide. Moreover, the third type, the radius variations of the base crystal is holes' maker. About the three followed parameters output spectrum, wavelength, bandwidth and output range surveyed were varied and the effect of other parameters such as refractive index, based crystal maker radius holes, stable network and so on have been supposed constant.

3-1: The effect of Variations Of unrighteousness radius in two-head resonant cavity (RC)

In this research, we get output spectrum of filter for different values of RC according to fig 3.

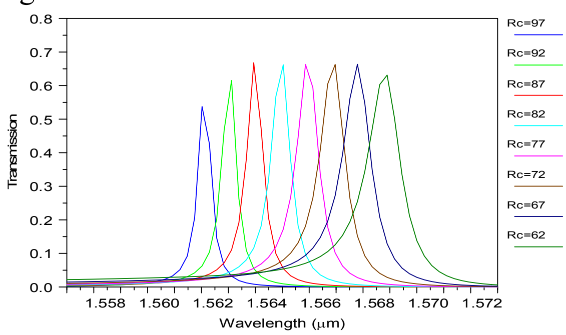

Fig.3. Output spectrum of filter for different values of RC

According to fig (3), in lieu of each 5 nm in RC value, filter output spectrum has been located about 1 nm forward lower wavelength. So we calculated as obtained results and figs, the wavelength resonance, bandwidth and output range that the curve variations of resonant wavelength has obtained for different values of unrighteousness radius of the resonance cavity as fig (4). In this diagram, the extents of RC variation have been rated from 40 nm to 120 nm. According to attained results observed by increasing RC, resonance wavelength has been reduced as a linear model.

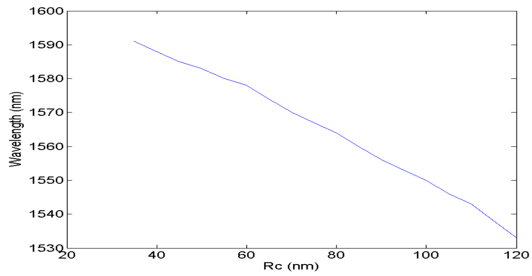

Fig.4. The diagram of resonance wavelength variation of RC

The diagram of output spectrum range variations regarding RC, has been shown in fig (5). According to this diagram, it is observed that the variation of output range is ascension for RC in a range of 35 nm to 105 nm and the variations is descending from 105 nm to 120 nm. The maximum output range value is 78 percent happened in RC=105 nm and the minimum value of output range is also 20 percent happened in RC=120 nm. Fig (6) shows the diagram of bandwidth variations regarding RC. In this diagram it is observed that the bandwidth is descended for RC in range of 35 nm to 105 nm and variations are ascension from 105 nm to 120 nm. The maximum of bandwidth is 4, 2 nm happened in RC=35 nm and the minimum of band width is 1,5 nm happened in RC=115 nm. Comparing obtained results for bandwidth and output range shows that the value of RC=105 nm is the best output range value and the best bandwidth value.

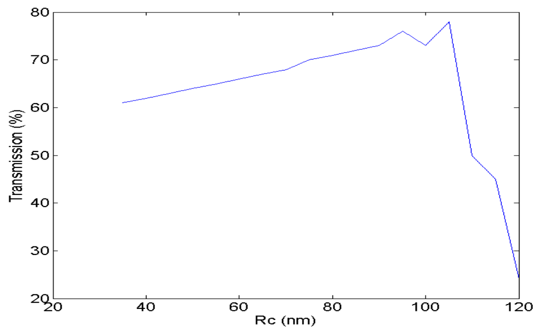

Fig.5. The diagram of output range variations regarding RC

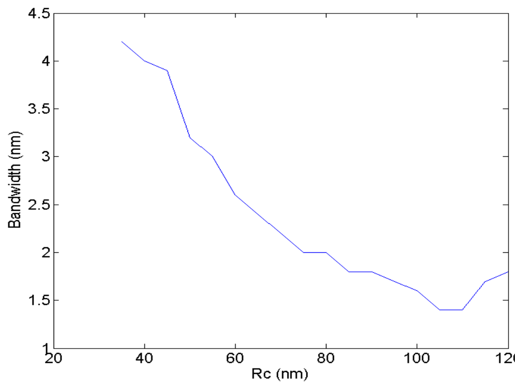

Fig.6. The diagram of bandwidth variation regarding RC

3-2 The effect of unrighteousness radius

variations at the beginning of the waveguide (R0).In this research, also the filter output spectrum has been calculated for different values of RO. Then we calculated from obtained diagrams, wavelength resonance and bandwidth and output range. The curve of resonant wavelength Variations has been drawn for different values of unrighteousness waveguide radius at the beginning of the output as shown in fig (7).

In this diagram, the extents of Variations have been rated from 20 nm to 110 nm. According to obtained results, the variation of RO has no effect on filter resonance wavelength and it is constant for all values of RO. The output spectrum range variation diagram has been shown in fig (8), regarding RO. In according to this diagram is observed that output range variations is totally decrease regarding RO. The maximum output range values is related to RO=20 nm equal to 21 percent. Also according to minimum output range value related to Ro=110 nm, it is equal to 60 percent.

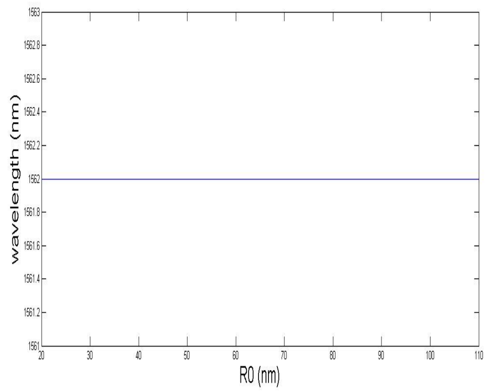

Fig.7. The diagram of resonance wavelength variation regarding RO

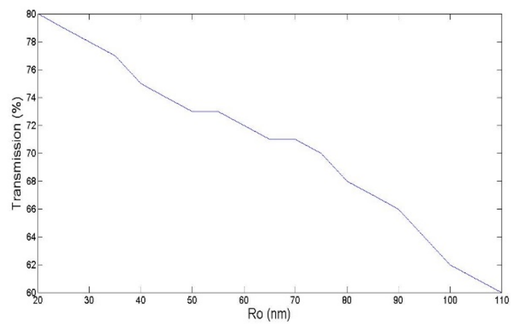

Fig.8. The diagram of spectrum range resonance variations regarding RO

The diagram of output spectrum bandwidth variation has been shown in fig (9) regarding RO. According to this diagram, it is observed that the variation of output bandwidth is totally ascension regarding RO. The maximum bandwidth value is related to RO=20 nm equal to 1,8 nm. The minimum of bandwidth value is related to RO=110 nm what is equal to 0.7 nm.

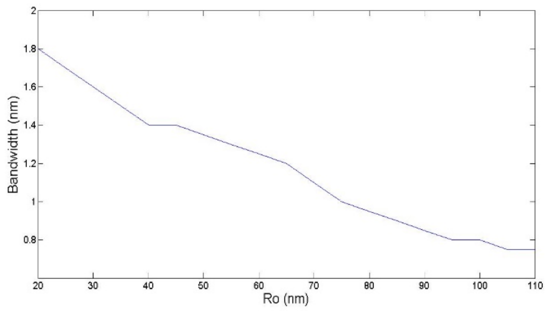

Fig.9. The diagram of output spectrum bandwidth variation regarding RO

3-3 The radius of the holes maker crystal base

In this research, the ratio of holes radius variation is listed from 0.24*a to 0.44*a. That is lack of output spectrum for values of less than 0.24*a. The diagram of resonance wavelength variations has been shown in fig (10) regarding radius to network to be constant. It is observed that filter output wavelength has been reduced by increasing radius ratio to network constant. Of course, descent gradient is not constant in all ratios. It means that the least value of resonance wavelength is close to 1200 nm for radius ratio to network constant 0.44 and the maximum of resonance wavelength value for radius ratio to network constant is close to 1600 nm.

The diagram of resonance range variations regarding radius ratio to network constant has been represented in fig. (11).

According to this diagram it is observed that output ratio variations regarding radius ratio are not constant and regular and they have a mode of oscillation.

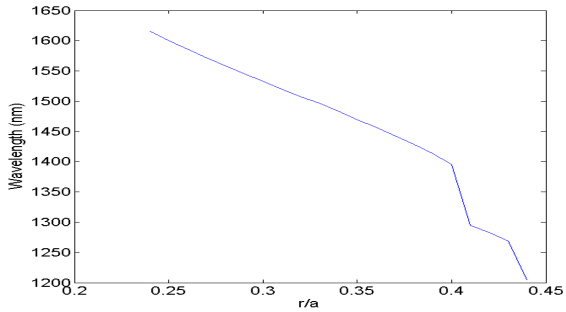

Fig.10. The diagram of filter resonance wavelength variations regarding radius ratio to network constant

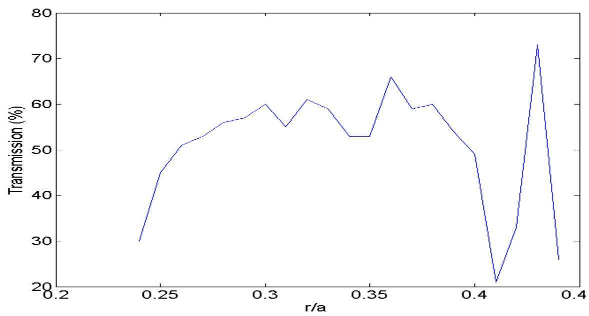

Fig.11.The diagram of resonance range variations regarding radius ratio to network constant

The least resonance ratio for radius ratio to network constant is 0.41 and it is equal to 22 percent, whereas the maximum of resonance ratio regarding radius ratio to network constant is 0.43 and it is equal 73 percent. Fig 12 shows the diagram of bandwidth variation regarding radius ratio to network constant. It is observed at this diagram that bandwidth variation regarding radius ratio to network constant is decreased, but this process is not regular and linear. The maximum resonance ratio regarding radius ratio to network constant is 0.25 and is 2.6 nm. Whereas the least bandwidth value related to radius ratio to network constant is 0.44 is equal to 0.4 nm.

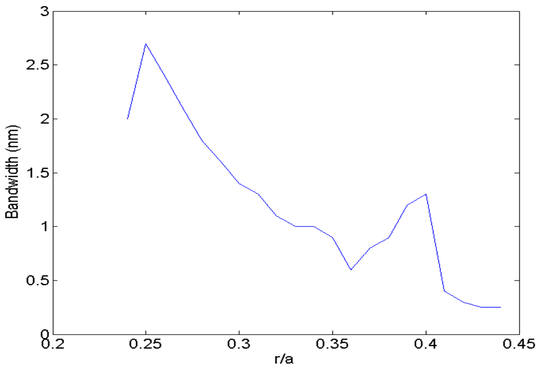

Fig.12.Bandwidth variation regarding radius ratio to network constant

4- CONCLUSION

In this paper the effect of radius on optical filter output spectrum based on photonic crystals, has been investigated and it showed us that the effective factors are the filtering function and wavelength switching mechanisms. The cells radius of both cavity-head and basic holes structure directly affected wavelength and bandwidth and output ratio, and the unrighteousness radius of beginning of the output waveguide is not effective, but has some effect on band width. In any parts of this paper, the optimized values have been presented for narrow band filter and a maximum range.

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