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Photonic crystal analysis for multiplexer and de-multiplexer applications

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Photonic crystal analysis for multiplexer and de-multiplexer applications

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Abstract. In our present work, we have made an investigation of several theoretical tools using the finite element method depending on the COMSOL MULTIPHYSICS program, for intuitive insight into the optical properties of the optical crystal. Analysis of the bandgap of a two-dimensional periodic photonic crystal with square lattice, evaluate the photonic band structure by the eigenfrequency of the unit cell of the first Brillouin zone. Moreover, creating defect mode inside the bandgap of photonic crystal, such as a resonant cavity, waveguide defect, narrowband filter, sharp drop filter, channel drop filter, waveguide bends, waveguide splitter promises us to a platform to design devices that includes a certain optical range of wavelengths. The transmission, as a result, the influence of the light localized in the defect area of the periodic structure of the photonic crystal. This study is important for producing photonic integrated circuits based on photonic crystals for future advanced optical communication.

1. Introduction

Photonic crystal (PCs) represent the periodic dielectric structures; it came to be called crystals because of their periodicity and photonic because they work on light [1, 2]. PCs have generated increasing scientific interest in recent decades because they provide the ability to control and manipulate the propagation of light to an unprecedented level in the microwave regime by reflecting or trapping light [1-3]. Several applications of two-dimensional photonic crystals directed towards the integration of optical devices, such as resonant cavity [4, 5, 6], waveguide [1, 7, 8], waveguide bends [7-10], and splitters [11], these essential components to develop into photonic and electronic circuits.

Photonic crystals are characterized by their most straightforward form that is an engineered inhomogeneous periodic structure where fabricates from two or even more material with different dielectric constants [3, 9]. PCs are designed to the dispersion of wave when the electromagnetic wave (EM) propagates via this structure via Bragg scattering, the scattering of waves by a periodic is comparable to the wavelength of the wave, unexpected behaviours may occur. Among the most interesting is the possibility of creating a complete photonic bandgap (PBG), that is, the range of frequencies that photons with no frequency within this band cannot propagate through the photonic crystal. Because of the exciting property of photonic structures, it possesses extensive applications through change in geometry, such as square or hexagonal with circle rods or by changing structural parameters, such as radius of rods, periodicity, and material, all of these parameters have a significant impact on the manipulation of band structure frequencies that may reach kilohertz or megahertz [9].

Moreover, the ability to adjust the photonic crystal structure as a disordered structure by introducing several types of defects into the periodic structure of photonic lattice, such as local resonant cavity and

waveguide modes such as this structure, make photonic crystal applications significantly expand [3, 7, 9]. Waveguiding and bending modes allow the electromagnetic wave to guide by its direction [1, 7]. However, creating bend inside a photonic structure is difficult unless the radius of the bends is large compared to the wavelength, as a large portion of the light lost. This is a severe problem in creating integrated optical "circuits" because the space required for large-radius bends is not [10, 12]. Otherwise, when the waveguides trapped inside a photon crystal can have a very sharp low-loss bend, allowing for an increase in the density of the integration by several orders of magnitude [12].
COMSOL version 5.5 is a program from a theoretical point of view, one of the most important programs to develop numerical methods to solve Maxwell equations of electromagnetic wave propagation via photonic crystals; it is a reliable and fast program in addition to being able to deal with large systems as close as possible to the real ones used for experiments. Moreover, the numerical methods are essential in this area rooted in the fact that Maxwell's equations for these systems are in excellent agreement with the experiments and that they can describe the abundance of phenomena provided by these systems.
Recently, research efforts focused on infinite periodic photonic crystal and theoretically studied of the bandgap Bloch modes structure of Periodically Perforated Sheet by using COMSOL-MULTIPHYSICS [13]. Alternatively, the theoretical study of the electromagnetic wave propagates via in hexagonal lattice of photonic crystal fiber and evaluated the band structure using finite element method (FEM) based COMSOL MULTIPHYDICS [14]. Others include a theoretical study using plane wave expansion (PWE) to study photonic bandgap via the acoustic pressure wave propagation in square lattice photonic crystal [9]. Study flat-band lattice using finite-difference time domain (FDTD) method [15]. Moreover, theoretical studied include defect states inside the bandgap of photonic crystal; it was discussed in detail in [1], the design also waveguiding and bending modes in the plasma element in the air using the finite element method solver ANSYS HFSS 16.1 in [7]. Study band structure for square and hexagonal lattice photonic crystal in dielectric material, as well as the evaluate the point defect/ resonant cavities for both lattice inside bandgap using two methods, FE method and PWE method [3], besides, using FDTD method to evaluate the defect sates in photonic crystal [2]. Also, study defect photonic lattice in LiNbO3 photorefractive crystal experimentally by using multiple beams interference method [16]. Numerically, FDTD has been used to design the photonic crystal on form a resonant ring with five channels useful in demultiplexer applications, depending on the optical channel drop filter analysis [17]. Also, the same numerical method was used to photonic crystal analysis as useful 2D optical devices for multiplexing. The structure is designed very compactly and with an ultra-fast conversion speed [18], Design of a square lattice photonic crystal, consisting of silicon rods and an air background, used as a compact 2×1 optical multiplexer based on the photonic crystal for photoprocessing devices [19]. Using a PWE and FDTD methods, a two-dimensional photonic crystal was designed to serve as a platform for all optical half subtractor [20]. Also, PWE and FDTD methods were used to design a two-dimensional hexagonal lattice photonic crystal to form a 2x4 optical device as a decoder, based on Kerr effect and threshold switching procedure [21]. Furthermore, PWE and FDTD methods were used to design a two-dimensional photonic crystal whose rods are composed of an insulating material such as a GaAs immersed in a background of air. This photonic crystal acts as a nonlinear and logic gate, this is based on non-linear Kerr's effect [22].
The purpose of this study is to intuitively inform the efficiency of the finite element method using COMSOL-Multiphysics to conduct a comprehensive study of the ability of this method by investigating the optical properties of periodic photonic crystals in dielectric material, and also assessing various defect states for multiplexer-de-multiplexer application that is useful for optical communication network. The results showed that FEM using COMSOL is a very efficient, powerful, reliable and flexible method that evaluates the propagation of light within the photonic crystal in the direction that serves various applications of optical and photonic in the optical communication, one can create small light circuits to increase in the integration density of optical devices.

2. Theory
Maxwell's equations govern the electromagnetic wave propagation through the photonic; use a scalar wave equation that described the transverse electric field given by [14, 23]:

$$-\nabla.\nabla E_z(\vec{r}) - \epsilon_r k_0^2 E_z(\vec{r}) = 0 \quad (1)$$

Where E_z represents the electric field in the direction of z-component at the position $(\vec{r} = x, y, z)$. The free- space is wave number $k_0 = \omega/c$, ω is the angular frequency of the incident electric field on the crystal and c is the space of light in free-space, $\epsilon_r = (n - ik)^2$ refer to the inhomogeneous relative dielectric constant of the photonic crystal, and by proposing the photonic crystal is not are non-conducting and non-magnetic, such as $\mu_r = 1$ and $\sigma = 0$. The solution of Eq. (1) is the time-harmonic field is analyses as [3, 14]:

$$\vec{E}(\vec{r}, t) = E_z(\vec{r})\, exp(-i\omega t)\, \hat{z} \quad (2)$$

In the simulation, we must put the perfect electric conductor (PEC) condition or the perfect magnetic conductor (PMC) that reflect the simulation field and used along each symmetric plane, can be described by the equations below as [3, 12, 14]:

$$n \times E = 0 \quad (3)$$

$$n \times H = 0 \quad (4)$$

For periodicity of the PC is used Floquet periodicity as the periodic condition at the boundary of unit cell for photonic crystal, by using the wave vector such as the x and y components, such as k_x and k_y.

3. Design methodology

The first numerical design is to analysis bandgap of photonic crystal, by assuming the two-dimensional photonic crystal structure consists of square lattice made of dielectric pillars as gallium arsenide material with radius r is 0.065um that are occupied the centres' sites of air square lattice with the lattice constant a is 0.365um as in Figure 1 (a). The distance between the pillars determines the relationship between the wave number and the frequency of light falling on the optical crystal that prevented from spreading within the crystal for a given frequency range are known bandgap, evaluating the light frequency of a photonic crystal by analysis the periodic unit cell. The unit cell of the square lattice includes a relatively small range of wave vectors covering the edges of the first irreducible Brillouin zone (1BZ). The symmetric point of 1BZ extends from Γ to X to M and then back to Γ, as shown in Figure 1 (b).

We are using the model of COMSOL-Electromagnetic wave-frequency domain model to study the eigenfrequency of a unit cell of the square photonic crystal. We put the periodic condition at the boundary of the square lattice by using the Floquet Bloch wave vector periodicity for wave vectors kx and ky. Using mesh-free triangular meh elements with a physics-controlled finer mesh in Figure 1 (c), than chose the study is an eigenfrequency who calculates the eigenfrequency into a unit cell of the crystal. From the simulation results, we found the electric field norm distribution of five eigenvalues of the 1st Brillouin zone in the unit cell of the square lattice, as shown in Figure 2 (a-k). The dispersion relation (band diagram) for the first five lower bands in Figure 2 (l), shows there is no electromagnetic wave (no frequency range state) propagated between the third and four bands. Therefore, this area defined as a bandgap of photonic crystal at the symmetry point expressed by Γ, X, and M.

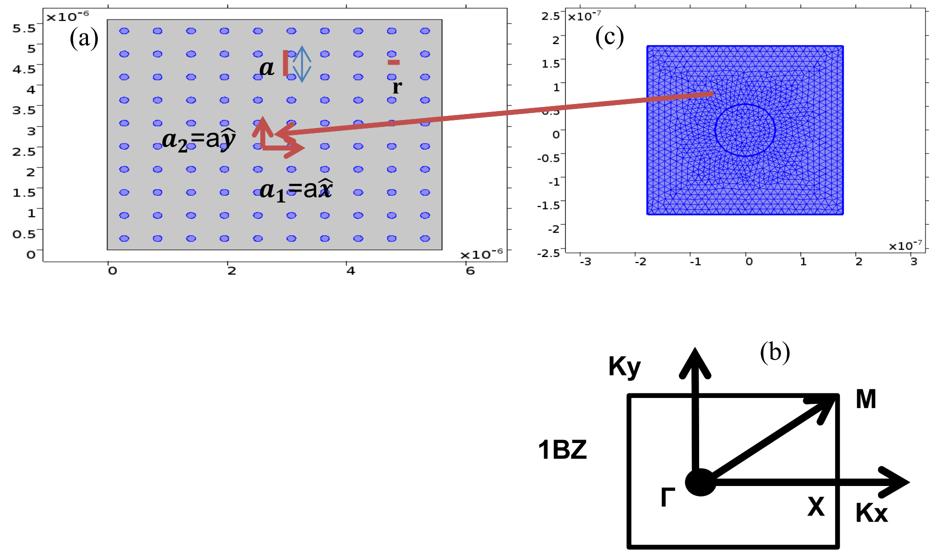

Figure 1. COMSOL MULTIPHYSICS simulation design two-dimensional periodic square photonic crystal with lattice constant a=0.42um and radius pillars r=0.15*a in (a), a free triangular.

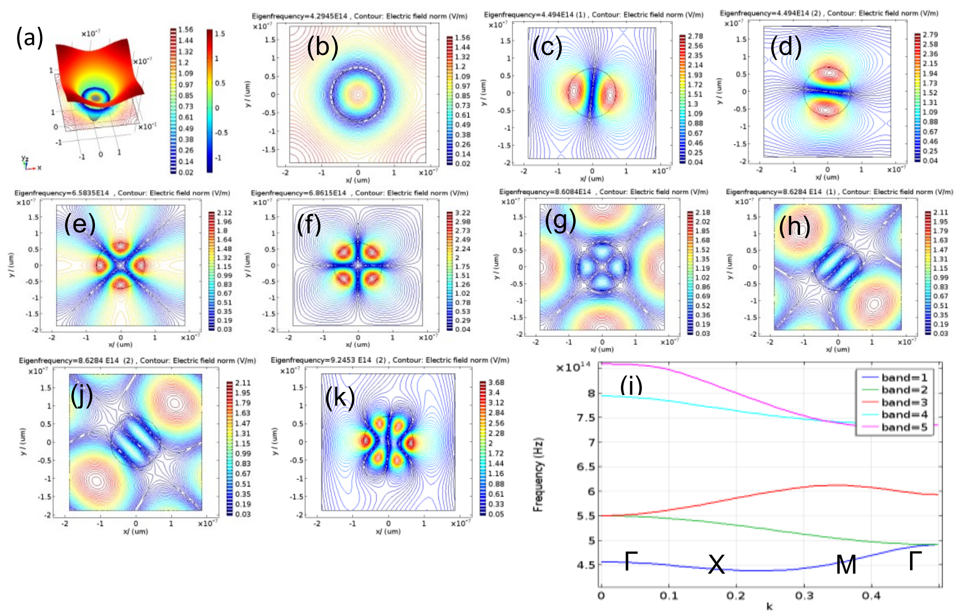

Figure 2. Contour: distribution of Electric field norm (V/m) for first five eigenmodes for TE polarized electromagnetic wave in the unit cell of the (1BZ) (a-k), and their dispersion relation (band diagram) by using COMSOL for the first five lower bands structure at symmetry point Γ, X, and M.

4. Defect state in square photonic crystal

In the previous study, we analyzed the band structure of the optical crystal and found that no modes propagation within the band structure: this means the density of states (the number of possible modes for each frequency unit) is zero. With complete similarity with semiconductors physics, disordered photonic crystal can be done [2, 3], through perturbing the periodic of photonic crystal structure via creating defects within the beam gap, which promises us the potential applications of particular importance for optical communication. There are two main types of defects; one is called resonant cavities defects and called line defects [1]. Resonant cavities defects or called point defect an associated with perturbing just one pillar in the lattice and this causes the desolation of the translational symmetry of the lattice, this perturbation is localized to a particular point in the lattice and creating a cavity that supports one mode defect in bandgap at a discrete frequency.

On the other hand, because the bandgap of the photonic crystal reflects the light with a specific frequency, such this defect-induced state is forbidden from propagation inside the crystal. The line defect is creating by removing one row from the lattice; causes create waveguide carved out inside bandgap. Using to guide the light from one location to the other with a frequency inside the bandgap of crystal, and confined the light along with the defect. Otherwise, when creating a bend defect with different shapes inside the crystal that is formed from coupling two perpendicular waveguides, since the light cannot be propagated in crystal and cannot escape, therefore, the only possibility to reflected [1]. In addition, the possibility designed the splitter defect with different shapes inside the bandgap of the crystal, the field of propagation divided into two waveguides, and the light is equally divided between the waveguides because the bandgap cancels the radiation loss and only possibility to reflect the light.

Besides, to reduce the losses, we designed a filter structure that can be removing two rows and one pillar to produce the coupled two waveguides with point resonant cavity to form as called a Fan resonance, one can obtain on a very sharp filter or called a Fan resonance. As well as, the channel drop filter can be designed by removing two rows and two pillars to produce coupled two waveguides with two point's cavity.

5. Simulation results and discussion

5.1. Resonant cavity defect for multiplex-de-multiplexer

Numerically, we designed the defect state inside bandgap of the two-dimensional photonic crystal for a multiplex-de-multiplexer designer of the wavelengths 1.55 µm and 1.30 µm. The structure square lattice made of dielectric pillars as gallium arsenide material with a lattice constant (a) is 0.56 µm and radius r is 0.23a µm in the air of the square lattice as in Figure 3 (a and b) it represents the engineering design of the structure and free triangular mesh. The results show the Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d) for waveguides 1.55 µm and 1.30 µm of point-defect/ resonant cavity inside bandgap by single pillar missing in a square lattice. In (e), represent the electric field norm (V/m) with Arg length, this cavity defect support single-mode formed with frequencies $\omega a/2\pi c = a/\lambda = 0.361$ and 0.430 for representing wavelengths 1.55 µm and 1.30 µm. The fields bounce back and forth in the defect, then the light cannot escape and trapped around the defect, the mode decays exponentially into the crystal. Really theoretical modeling shows the results were surprising and visually intuitive to the resonant cavity, these results are very exciting compared to [1], and this application can be useful for controlling light in a narrow frequency range.

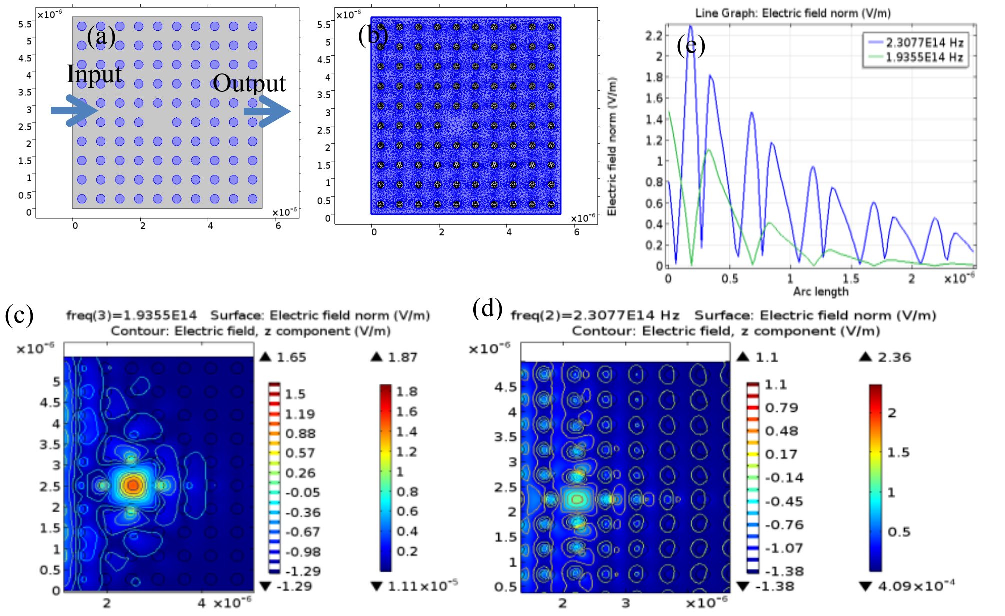

Figure 3. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d) for wavelengths 1.55 µm and 1.30 µm of point-defect resonant cavity inside bandgap by single pillar missing in a square lattice when radius pillar r=0.23a in as in (a and b) represent the engineering design of the structure and free triangular mesh. In (e), represent the electric field norm (V/m) with Arg length, this cavity defect support single-mode formed with frequencies $\omega a/2\pi c = a/\lambda = 0.361$ and 0.430 for representing wavelengths 1.55 µm and 1.30 µm.

5.2. Waveguide cavity defect for multiplex-de-multiplexer

In previous simulations, when we modeled a point defect/resonant cavity, we observed that light can be trapped within a certain range of the band's structure of the optical crystal. But when we needed to extend the defect inside band gap, we designed to line and two line defects by missing single row and two rows in a square lattice for waveguiding configuration with radius pillar r = 0.2a, as shown in Figure 4 (a and b) it represents the engineering design of the structure and free triangular mesh. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d) for wavelengths 1.55 µm and 1.30 µm. In (e), represent the electric field norm (V/m) with Arg length show a single guided mode inside the bandgap by one waveguide curved out in square photonic crystal formed with frequencies $\omega a/2\pi c = a/\lambda = 0.35$ and 0.417 for representing wavelengths 1.55 µm and 1.30 µm. In Figure 4 (c1 and d1), represent two guided modes propagation inside the bandgap by two waveguides curved out in square photonic crystal. In (e1), represent the electric field norm (V/m) with Arg length show with frequencies $\omega a/2\pi c = a/\lambda = 0.35$ and 0.417 for representing wavelengths 1.55 µm and 1.30 µm, and also this shows the photonic crystal property of its ability to direct the light in the air.

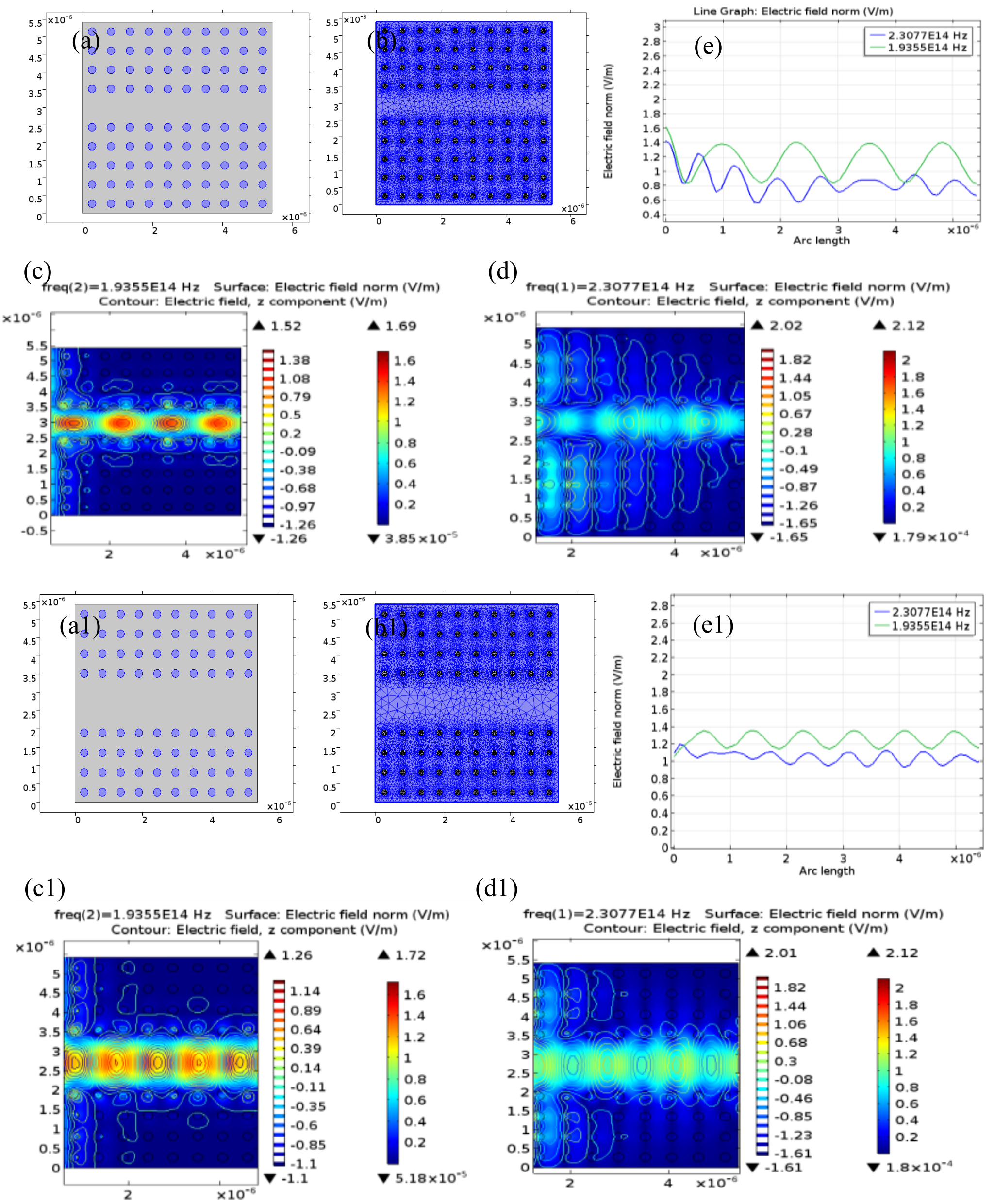

Figure 4. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c, c1, and d, d1) for wavelengths 1.55 µm and 1.30 µm of line or two line -defect waveguide formed inside bandgap by missing single row and two rows in a square lattice for waveguiding configuration with radius pillar r=0.2a, as in (a, a1 and b, b1) represent the engineering design of the structure and free triangular mesh. In (e and e1), represent the electric field norm (V/m) with Arg length, this defect support single/ two single-mode waveguide formed with frequencies $\omega a/2\pi c = a/\lambda = 0.35$ and 0.417 for wavelengths 1.55 µm and 1.30 µm.

5.3. Narrowband filter defect for multiplex-de-multiplexer
Also, we designed the narrowband filter defect in bandgap of the photonic crystal fiber, as shown in Figure 5 (a) it represents the engineering design of the structure by missing single row of waveguide from right and left and missing single cavity when we want this model to excite a cavity pattern directly from a single waveguide depending on the frequency of the wave that incidents on the optical crystal and Free triangular mesh in (b). The results show Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d) for waveguides 1.55 μm and 1.30 μm. In this model waveguide-cavity- waveguide filter shows appear single mode of the input waveguide and absence the cavity mode inside the bandgap, and also absence the single mode of the output waveguide formed for both waveguides 1.55 μm and 1.30 μm with frequencies $\omega a/2\pi c = a/\lambda = 0.35$ and 0.417 for representing. In (e), represent the electric field norm (V/m) with Arg length, in this carving show several sharp dip that corresponding to non-zero guided modes and one sharp dips that corresponding to zero guided modes. These results are somewhat similar to [1] though different structural design, parameters, and frequency used.
While used another design model as two-waveguide-two cavity-two waveguide filter, this structure by missing two rows of the waveguide from the right and left and missing two- cavity as in (a1) and Free triangular mesh in (b1). The results show Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c1 and d1) for waveguides 1.55 μm and 1.30 μm. In this model, two waveguide-two cavities- two waveguide filters, show appear two modes of the input waveguides and appear the 90% of resonant cavity mode inside the bandgap of wavelength 1.55 μm while slightly appear for wavelength 1.30 μm, and slightly appear the two modes of the output waveguides. In (e), represent the electric field norm (V/m) with Arg length, and show several sharp dips in this carve that correspond to the non-zero guided modes. The sharp peak cavity means that the device operates as a narrow-band filter. The coupling between the input waveguide and the cavity, and then the cavity is coupled with the output waveguide. Thus, the light travels at frequencies near the frequency of the cavity and then is reflected in frequencies that may be high or low as a result of the propagation of light in the crystal instead of confining it to the cavity and waveguides (Looking at the fact that when light spreads out of the gap it escapes) as in (c and d), Or we notice that some light is due to propagation in the output waveguide due to interference in the oscillating wave as in (c1 and d1).

5.4. Sharp and channel drop filter defect for multiplex-de-multiplexer
Also, we are trying to design everything related to the coupling between the one cavity and two waveguides (by missing a single cavity and missing two waveguides) to produce. For example one, a very sharp filter via the resonator tunnel through the photonic crystal, as in Figure 6 (c and d) for the wavelengths 1.55 μm and 1.30 μm. Or the coupling between the two cavity and two waveguides (by missing two-cavity and missing two waveguides) to produce for example two a channel drop filter, as in Figure 6 (c1 and d1) for the wavelengths 1.55 μm and 1.30 μm. In the first example sharp drop filter, the results show the light propagates only in the input waveguide and decays in the resonator cavity and also in the output waveguide, with a partial reflection back to the input waveguide at wavelength 1.55 μm. While we notice it is propagated in the input waveguide and in the resonator cavity and partly propagated the output waveguide at wavelength 1.30um. For the second example channel drop filter, the results indicated that the light directs 100% of the input waveguide and propagates through two resonance cavities and redirects it to the output waveguide and only a narrow bandwidth is reflected. This is well demonstrated in wavelength 1.55um more than wavelength 1.30um. We found an example of two results is to [1], although there is a difference in the engineering design, structural parameters, and frequency used.

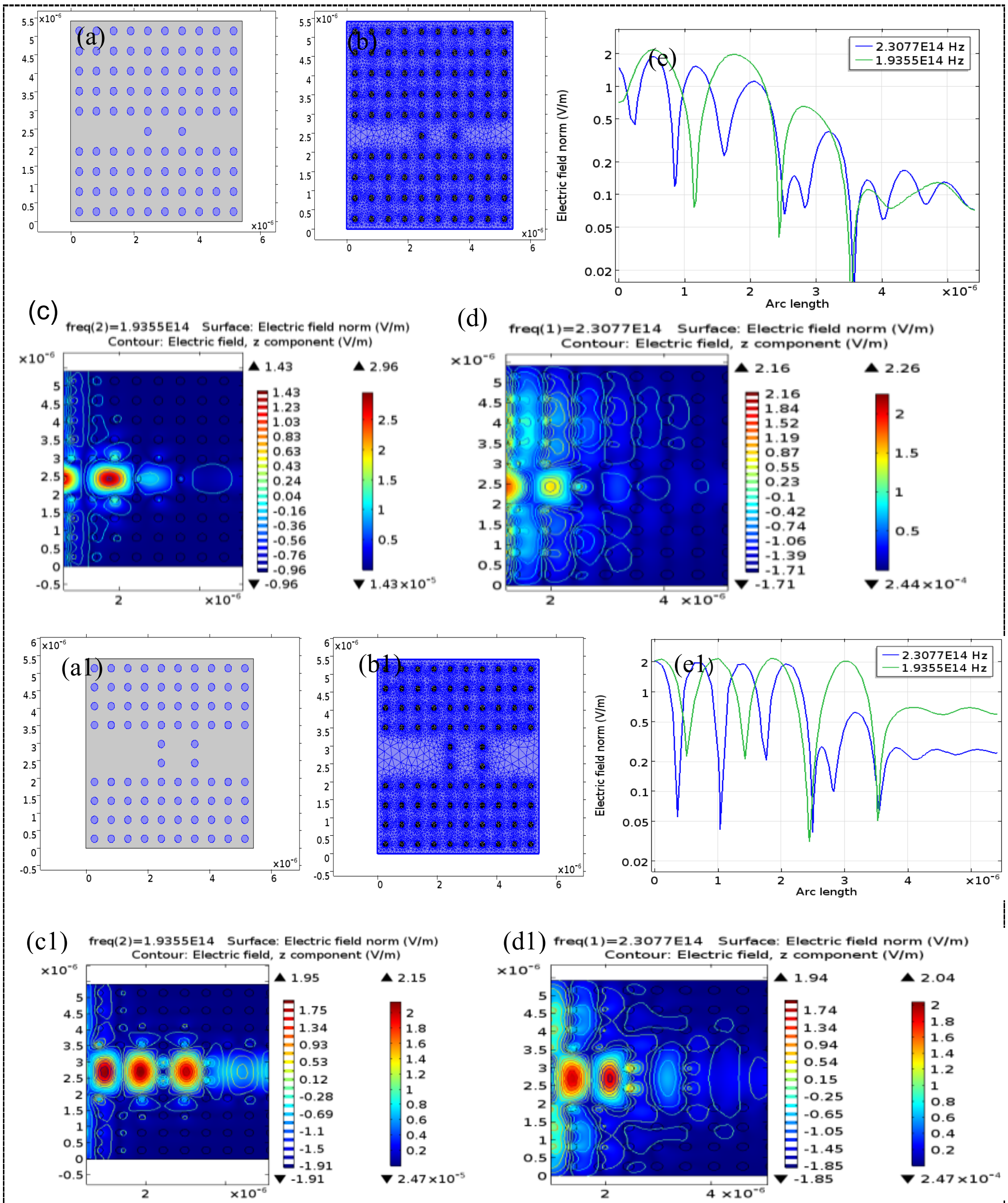

Figure 5. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c, c1, and d, d1) for wavelengths 1.55 µm and 1.30 µm of waveguide-cavity- waveguide filter/ two waveguide- two cavity- two waveguide filter creates by missing single/two rows of waveguides from right and left and missing single/two cavities, in (a, a1 and b, b1) represent the engineering design of the structure and free triangular mesh. In (e), represent the electric field norm (V/m) with Arg length, in this carve show several sharp dip that corresponding to non-zero guided modes and one sharp dip that corresponding to zero guided modes and several sharp dip that corresponding to non-zero guided modes in In (e1) for both wavelengths 1.55 µm and 1.30 µm**.**

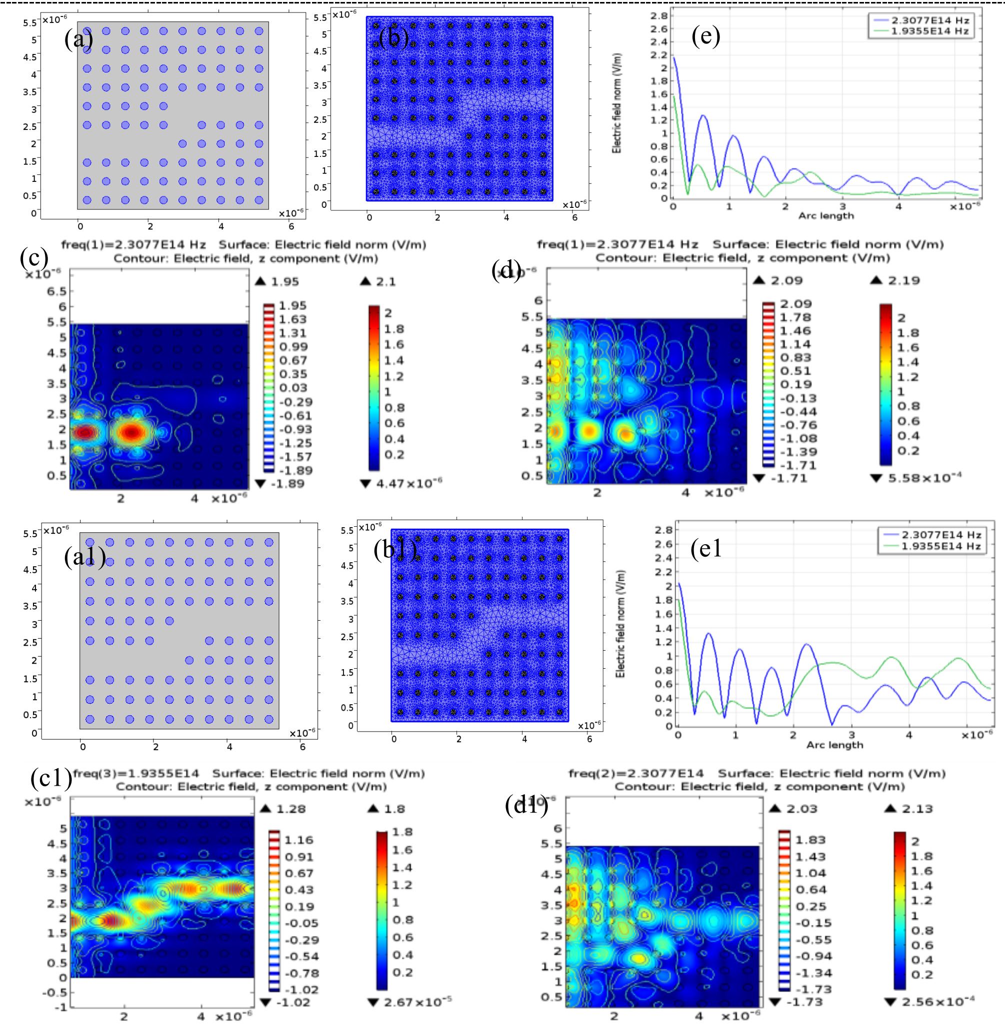

Figure 6. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d) for wavelengths 1.55 µm and 1.30 µm of waveguide-cavity- waveguide filter/ (sharp drop filter) by missing single cavity and missing two waveguides. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c1 and d1) for wavelengths 1.55 µm and 1.30 µm (channel drop filter) by missing two-cavity and missing two waveguides. In (a, a1 and b, b1) represents the engineering design of the structure and free triangular mesh, in (e), represent the electric field norm (V/m) with Arg length, shows the dip of the side coupled cavity is exciting for the wavelength 1.30 µm more than the 1.55 µm. Resonance cavities applications enhance the efficiency of the laser, taking into account that the density of the states is high at the resonance frequency.

5.5. Waveguide bends defect for multiplex-de-multiplexer

Besides, in order to enhance the coupling between two waveguides, we designed various with waveguide bend as a sharp 90-degrees bend configurations formed in the square lattice, by missing two rows, one from right and other from down (example.1), or one from right and other from up (example. 2). Also, we tried to change the design by taking the coupling of four waveguides, each pair of waveguides has a sharp 90-degree bend, by missing four rows, from left- down-left-down with a sharp 90-degree bend (example. 3) to note what happens when we increase the waveguides at the same degree of curvature, as in Figure 7 (a, a1, a2 and b, b1, b2) represent the engineering design of the structure and free triangular mesh. The results show in Figure 7 (c, c1, c2 and d, d1, d2), we find Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) for the field of propagation around the tight corner appears at frequencies 0.35 and 0.417 for the wavelengths 1.55 µm and 1.30 µm. By creating a waveguide carved out with a sharp 90-degree bend, part of the light reflects and the other parts of the light radiate loss, and because the bandgap forbids radiation losses and organize to be the reflection loss is zero. Almost all the light that comes from the input waveguide is transfer to the output waveguide; hence, the photonic crystal can show 100% transmission bands in the spectral region even that the bend radius is the weakest wavelength. Depending on the given frequency, we notice that the 1.55um is more visible in the 100% transmission of light than the wavelength 1.30 µm for all cases. This means that the losses over the wavelength are less at the wavelength 1.55 µm than the wavelength 1.30 µm, as shown in (e, e1, e2), represent the electric field norm (V/m) with Arg length, shows the dip off the side coupled waveguides is exciting for the wavelength 1.30 µm more than the 1.55 µm, therefore, optical crystal is suitable to direct the light to the sharp curves with very little losses, and this applied to all cases. In example. 1, the results were almost identical to [1], although the design is different and the engineering factors are different.

5.6. Waveguide splitter defect for multiplex-de-multiplexer

Moreover, we are trying as much as possible to design devices and the transmission analysis that may be useful for the future of optical crystal in optical communication, so here we have tried to take several models for the design of the splitter within the band structure of the optical crystal in order to obtain the same power with each waveguide output. Also here we enhance the coupling between waveguides according to our designs. We designed a splitter in which power is divided equally by each output waveguide by removing coupled waveguides for wavelengths 1.55 µm and 1.30 µm as shown in Figure 8 (a, b) represent the engineering design of the structure and free triangular mesh. We find from the results that showed in the Figure 8 (c, d) the Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) for the field of propagation divided into two waveguides, and the light is equally divided between the waveguides because the bandgap, and appears 90% transmission (45% for each waveguide) for both wavelength 1.55 µm and 1.30 µm, however, the transmission characteristics appear high at the wavelength of 1.55 µm of the wavelength 1.30 µm, therefore we enhance the transmission properties dependent on the frequency used, as shown in (e) that represent the electric field norm (V/m) with Arg length since the bandgap impedes the radiation losses, then we design this forms in order to reduce reflectivity and increase the transmission power in the device, the results were almost identical to [1], although the design is different and the engineering factors are different.

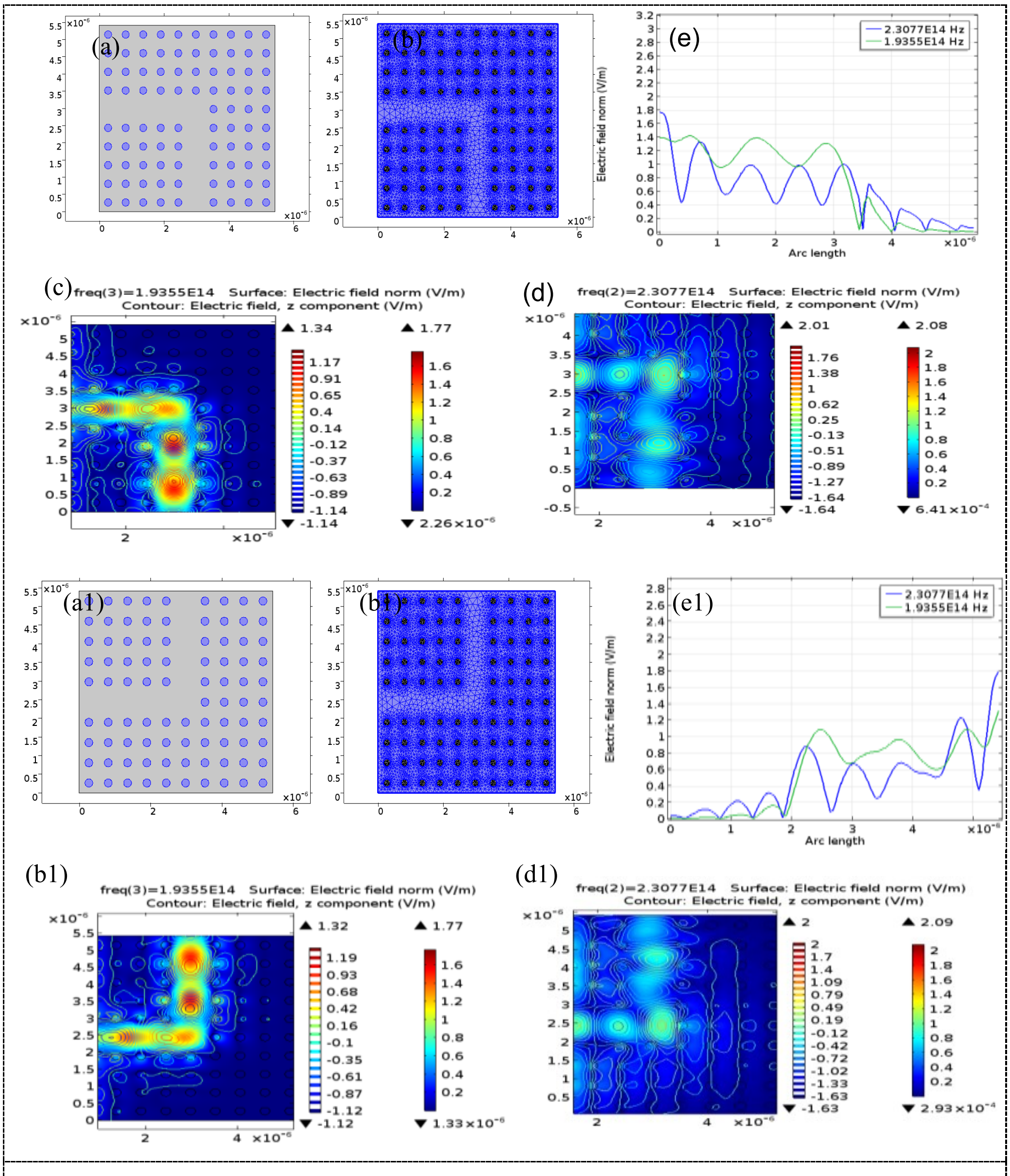

Figure 7. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c, c1, c2 and d, d1, d2) for wavelengths 1.55 µm and 1.30 µm by missing two rows, one from right and other from down, or one from right and other from up, or by missing four rows, from left- down-left-down with a sharp 90-degree bend as in Figure 7 (a, a1, a2 and b, b1, b2) represent the engineering design of the structure and free triangular mesh. In (e, e1, e2), represent the electric field norm (V/m) with Arg length, shows the dip off the side coupled waveguides is exciting for the wavelength 1.30 µm more than the 1.55 µm, therefore, This means that the losses over the wavelength are less at the wavelength 1.55 µm than 1.30 µm.

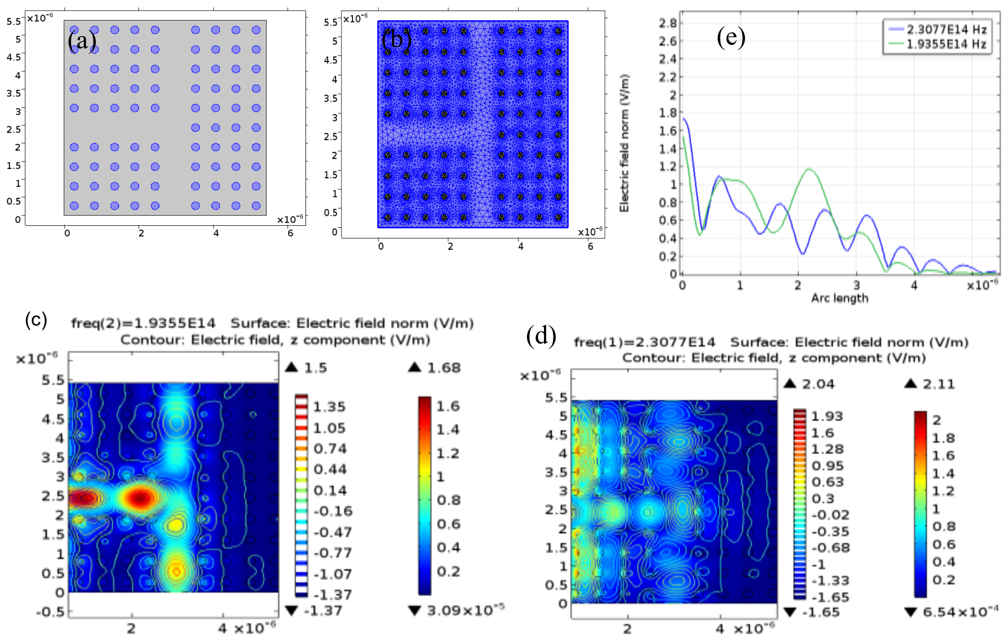

Figure 8. Surface: Electric field norm (V/m) and Contour: Electric field, z-component (V/m) in (c and d), the field of propagation divided into two waveguides, and the light is equally divided between the waveguides because the bandgap, and appears 90% transmission (45% for each waveguide) for both wavelength 1.55 µm and 1.30 µm. By removing coupled waveguides for wavelengths 1.55 µm and 1.30 µm as shown in Figure (a, b) represents the engineering design of the structure and free triangular mesh. In (e) that represent the electric field norm (V/m) with Arg length, the transmission characteristics appear high at the wavelength of 1.55 µm of the wavelength 1.30 µm, therefore we enhance the transmission properties dependent on the frequency used.

For the study of the optical crystal design as a point defect as a resonator cavity , this design is considered in the future as a promising candidate to enhance the strong coupling between the resonant cavity and quantum dots, or perhaps It is considered as an essential component for many applications in several engineering and physical fields. Our results were compared with other results, whether theoretical using PWE, FEM methods [1, 3], or practical [4, 5, 6], and therefore there was agreement with the other results. As for the engineering design to create as a waveguide inside the optical crystal, which consists of one input and one output and for several wavelengths, we can control the resonance wavelength from the resonance cavities through the optical intensity entering the device. Compare our results with other results using the PWM [١], or using the theoretical results of FEM and compare them with the practical results from the same source [7], or with the experimental results [5], so our results are in agreement With the above results. Geometric design to build a 90° curvature waveguide inside the photonic crystal, which consists of one input and one output and of several wavelengths, through which the photonic crystal acts as the waveguide, in the bending mode, where the waveguides are coupled to each other at a 90 degree bend, this allows the electromagnetic waves to spread around corners. Our results were compared with other results using the PWM method [1], and also with the theoretical results using the FEM method and compared with the experimental results from the same source [7], we found that our results are consistent with the indicated results. The waveguide inside the photonic crystal is designed as a beam splitter. With this design, it is possible to realize the function of splitting the package considering the recycling capacity. So we notice that the light rotates several times in the fiber ring to achieve a multiplexing of the light path. Our results were compared with other theoretical results using the FDTD method [11], we found a match of our results with those results.

6. Conclusions

In this paper, we proposed several structures within the optical crystal structure to realize all the optical devices that can be implemented within this structure to be useful in the multiplex optical communication system. In this paper, we present the characteristics of photonic crystal modes by modeling several defects that propagate light within the photonic bandgap, such defects can trap light within the optical bandgap or be directed directly into the bandgap with a certain frequency, we review some of these defects as resonator cavities, linear waveguide, curved waveguide, narrow band filter, sharp drop filter and channel drop filter and splitter. The resonant cavity creates a cavity within the band gap of the crystal, and the mode of light can be determined as it is frequency. These resonant cavities promise strong light-matter interactions via wavelength mode perception and are of high quality. Line or two-line defects by carving waveguide or waveguides out as a tunnel through the material, the mode of light behaviour as a function of frequency, we can also excite a cavity and become the greatest peak near the resonance cavity frequency when we connect with it a single waveguide to form what is called a narrow band filter. Alternatively, coupled two waveguides with one cavity to form a very sharp filter to obtain low loss, where the light reflects back into input waveguide. Also, maybe coupled two waveguides with two cavities to formed channel drop filter, just a narrow bandwidth is 100% redirected the light from input waveguide to output waveguide. Bends defect formed from coupled two at 90 degrees waveguides to show propagation light in tight corners with appears 100% transmission bend with zero reflection loss. Finally, the photonic crystal was modeled as a beam splitting.

The modified modulated waveguide is split into split modulation waveguides and shows 100% transmission of both waveguides by preventing the resultant waves from being over-transmitted. All of these devices that have been designed can predict the future of photonic crystal / optical crystal fibers to form photonic micro-devices with superior properties, which makes it superior to traditional fibers in terms of design and configuration of multiplexed functions that can be applied in the optical communication system.

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