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The Refractive Index Of Photonic Crystal Fibers As A Function Of Some Parameters And Temperature

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ARTICLE

The Refractive Index of Photonic Crystal Fibers as a Function of Some Parameters and Temperature

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Abstract

Photonic crystal fibers in the late period occupied a wide range of studies and research because of the ease of dealing with them in terms of design and installation, as there is a group of parameters used in them that can affect the refractive index of the pulse propagation through it, including the diameter of the air holes, the distance between the air holes and their number, as this study showed in addition to the aforementioned parameters The effect of temperature on the refractive index was also studied. It has been observed that with an increase in the diameter of the air holes, the refractive index increases and, conversely, the increase in the distance between them leads to a decrease in the refractive index. As for the number of air holes, it has no clear effect. As for the temperature, which is proportional to the frequency and intensity, this increase in temperature leads to an increase in the refractive index of the pulse passing through the photonic crystal fiber. Changing the temperature of the photonic crystal fiber is an interesting for dynamics fine refractive index tuning in active refractive index shift compensation system. This paper present a numerical analysis on the effect of photonic crystal fiber temperature on refractive index and modal features. The research depend on regular hexagonal crystal lattice fibers with specific geometric parameters using finite element method.

Keywords: Photonic crystal fibers (PCFs), Temperature (T), Refractive index (n), Finite element method

1. Introduction

During the past two decades, the photonic crystal fiber (PCF) has attracted much attention and produced tremendous growth in fiber optic technology. As regards their structural and optical properties, the PCFs differ from traditional fibers. Usually PCF consists of a regular array of air holes along its entire length, similar to photonic crystal, with a defect at the center of the structure that plays a core role. Two forms of crystal have a defect in the center of the structure that plays an important role. Two types of defects are used as cores, solid or air holes, of varying sizes and shapes. In the case of a solid core with a modified effective refractive index, the light is directed and a lower refractive index is observed in the cladding. Such dynamic structure gives PCF excellent transmission characteristics, such as low loss, high nonlinearity, high-order mode limitation, etc [1–3]. PCF can be used as a temperature dependent component [4], Innovative PCFs have been incorporated into optical devices, including optical switches [5], Option for optical filter [6,7], Splitters polarizing beams [8], and optical sensors [9], An analogous, efficient phase index fiber is also used to characterize solid core photonic crystal fibers. The effective core and cladding can be highly dependent on the size of the modal field in cladding, the contribution to modal propagation from the periodic arrangement of holes is negligible as a result of the high core-cladding index contrast when the wavelength of light is larger than the thickness of the distance between the holes but smaller than the core diameter. At the other hand, the periodic lattice provides phase conditions for less confined modes or when the wavelength of light

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is commensurate with it or smaller than the interstitial hole spacing, as well as the core size itself. Coherent light scattering and therefore dispersive containment [10], The guiding mechanism is classified as "modified" since the cladding refractive index does not remain constant with wavelength, as it does in ordinary optical fibers. PCFs can be designed in a variety of ways. There are various variables to play with, including lattice pitch, air hole form and diameter, glass refractive index, and lattice type. To adjust for dispersion and the area effect with wavelength, several strategies may be utilized, one of which is to vary the diameter of the air-hole lattice. Endlessly single mode (ESM) is one of the most important advantages of solid core PCFs with respect to the standard fibers. See Fig. 1.

2. Parameters effect in pulse propagation in photonic crystal fiber

To study pulse propagation of laser in PCFs, must be start with solving the wave equation, which represents the electric field of laser pulse propagating through PCF. Photonic crystal investigating the effects of the various parameters of the photonic crystal i.e. the air hole diameter (d), the number of air holes (N), and the hole–hole distance (Λ), as shown in Fig. 2.

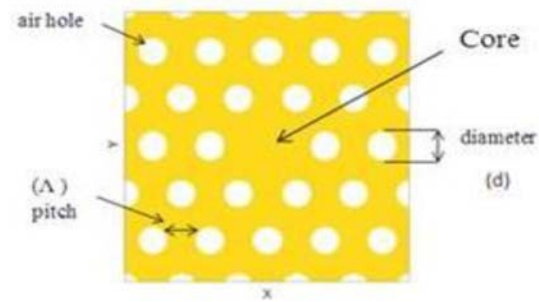

Fig. 2. Photonic crystal fiber consists of material and air hole drilled.

Based on theoretical and practical investigations, values in the range (d = 0.6,0.9,1.2)μm were chosen for the diameter of the air holes to explore the effect, while the pitch (**Λ** = 2 μm) and number of air holes (N = 6) were fixed. The effective refractive index of the core does not vary with the diameter of the holes on the curves, whereas the effective refractive index of the cladding varies with the diameter of the, d, in which the difference between the refractive indices of the core and the cladding increases by increasing the diameter of the holes, as shown in Fig. 3.

While investigating the effect of the holes pitch on the effective refractive index within the curve values in the range of (Λ = 2, 4, 6)μm, were chosen for the diameter of the air holes to explore the effect, while the pitch (d = 1.2 μm) and number of air holes (N = 6) were fixed.,it was noticed that the effective refractive index of the core remains almost constant for all the pitch values within the range mentioned previously, while the effective refractive index of the core and the cladding is reduced with increasing pitch as shown in Fig. 4.

When study the influence of the number of air holes on the curve of effective refractive index. Certain values of the number of holes (N = 6, 9, 12) were chosen, while the air holes pitch and diameter of the holes were set at (Λ = 3m) and (d = 1.2m), respectively. Observed the relationship between the effective refractive index and the number of holes, it was discovered that the difference between the effective refractive indices of the core and cladding decreases as the number of holes increases, whereas for a large number of holes, the curves match each other. As demonstrated in Fig. 5, the refractive index of the core stays constant for all values of the number of holes (see Fig. 6).

3. The relationship between temperature and refractive index in PCFs

The influence of temperature variation affects the density of the PCF, which is directly proportional to the refractive index, this leads to lowering when the

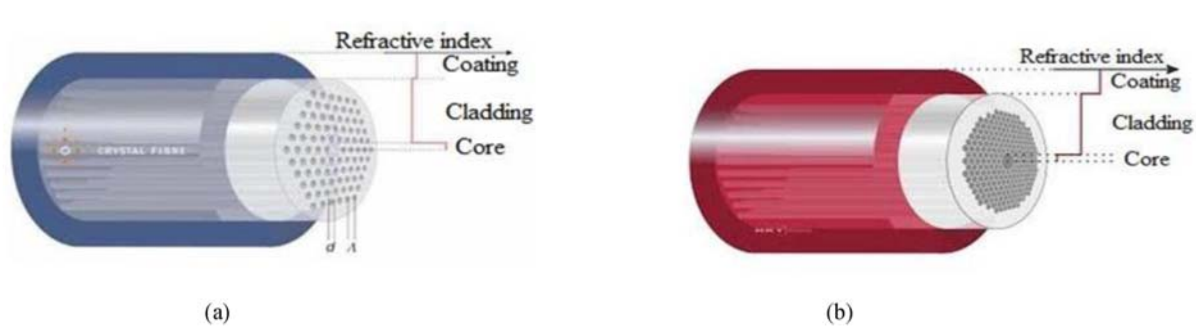

Fig. 1. Schematics of (a) solid core PCF and (b) hollow core PCF.

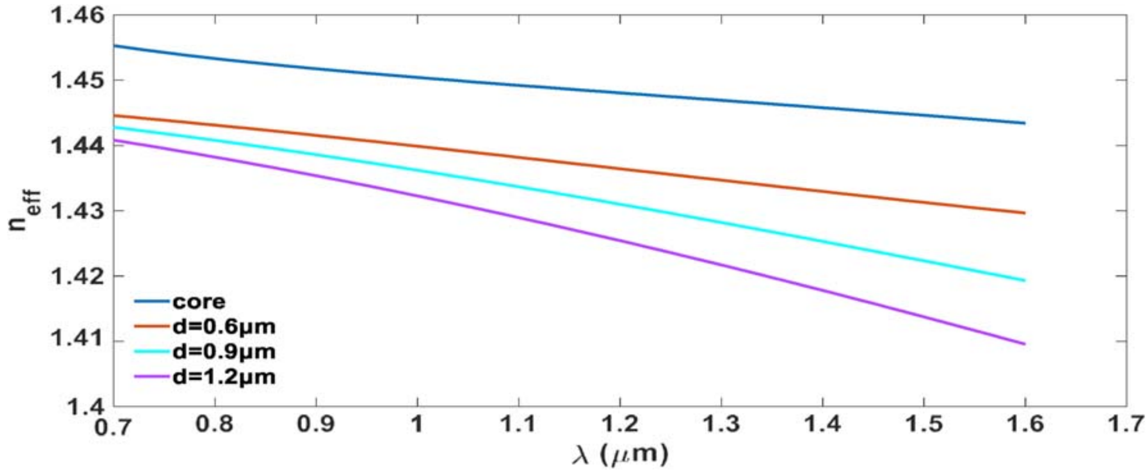

Fig. 3. Variation of effective refractive index against wavelength for diameter air hole vary as d= (0.6,0.9,1.2) µm, Λ = 2 µm, and N = 6.

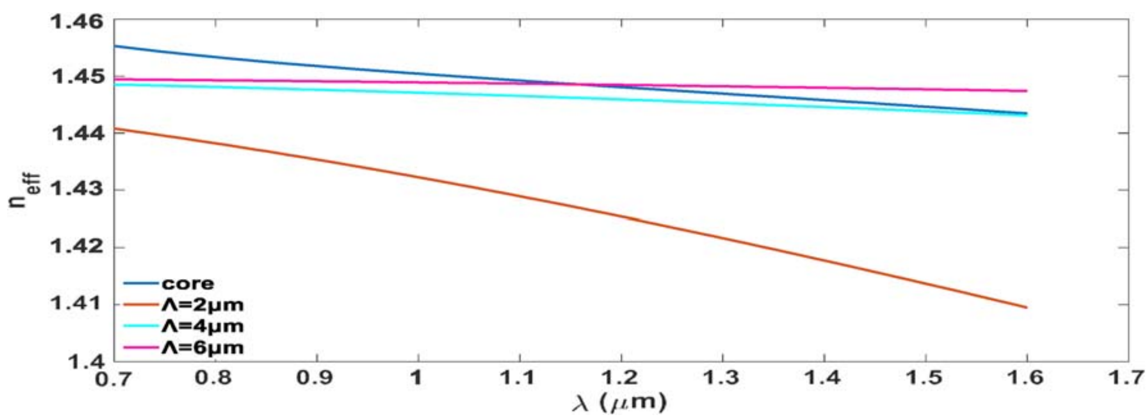

Fig. 4. Variation of effective refractive index against wavelength for pitch vary as Λ=(2,4, 6) µm, d = 1.2 µm, N = 6.

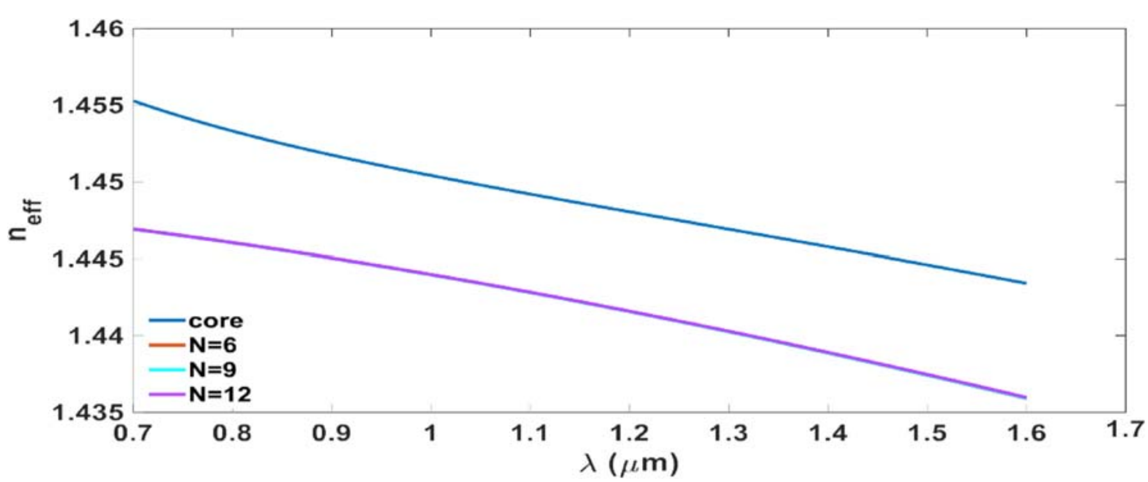

Fig. 5. Variation of effective refractive index against wavelength for the number of air holes vary as N = 6,9,12, Λ = 3 µm, and d = 1.2 µm.

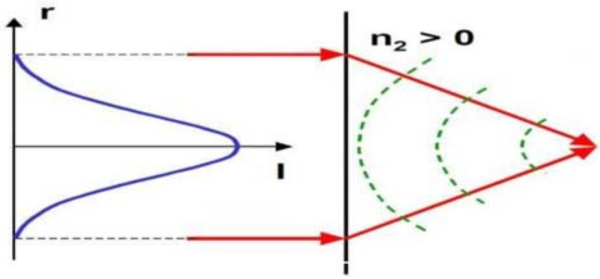

Fig. 6. Self-focusing of a Gaussian beam.

temperature rises, this is due to the high temperature in the PCF density that the PCF extends and loses the attraction strength between the molecules, thus increasing the distance between the particles and the internal molecular movers. Temperature is one of the fundamental recognizable optical properties for each material, where it is regarded to be one of the physic–chemical properties of the material since it specifies the effects of the electromagnetic waves on the material. The refractive index depends on the density and the wavelength, where the refractive index of a material is the ratio between the speed of light in the vacuum and the speed of light in that material as shown in the following expression [11].

$$n = \frac{c}{v} \tag{1}$$

where the refractive index of the material is n;, the light speed in the material is v and c; that's the speed of light in the vacuum. Hence, the refractive index. Makes the velocity of light within the medium decrease according to the following Relationship of:

$$n^{\circ} = \frac{n_1}{1} \tag{2}$$

where, η_0 is the material refractive index before the change Temperature, η_1 is the refractive index of the material when the material changes. Temperature, λ_0 is the wavelength of the material before the temperature changes and $\lambda_1$is the wavelength of the materials after changing the temperature [12]. The refractive index calculated by two methods by refractometer Temperature or Brix degree specified i.e., by material change Depend on concentration. Refractive index depends on the density and temperature,the refractive index may specify the dispersive power of the prism, and the power of the lenses or some materials, such as water, may know the purity of the prism determination of the refractive index by changing its concentration [13]. The change in the refractive index with respect to temperature can be described by the relationship [14]:

$$\frac{dn(,T)}{dT} = \frac{n^2(,T_0) - 1}{2.n(,T_0)} \bullet \left(D_0 + 2.D_1.\Delta T + 3.D_2.\Delta T^2 + \frac{E_0 + 2E_1.\Delta T}{2 - 2_{kT}} \right) \tag{3}$$

T_0 is the standard temperature.

T; Silysi degree temperature.

The temperature difference is above standard grade. ΔT

λ the wavelength of the electromagnetic wave in the vacuum and in units μm;.

As for (λ_{kT}, E_1, E_0, D_2, D_1, D_0) are constants that have specific values and depend on the type of glass used and their values as shows in Table 1.

The laser beam when passing through a certain medium will lead to a rise in temperature in the form of the so-called thermal lenses, which is a phenomenon photothermal, and these thermal lenses are like normal convex lenses [15], thermal lenses are considered a criterion for changing the refractive index of medium because of the irregular thermal distribution of the media [16]. To illustrate the concept of thermal lenses we impose a system in which the fallen light suffers from partial absorption and this absorption leads the system to climb to the upper level and return back down but without the emission of energy thus increases the temperature of the system and thus form a thermal lens([15,17]). The effect of the thermal lens is the result of the relaxation of the stimulus conditions from the medium and not the radiation, which was pumped by the laser beam with a Gaussian wave front and during these irradiated relaxation processes, which include vibratory relaxation that converts the heat absorbed from the fallen laser light to heat, as a result, the temperature of the radiation sample changes, the temperature of the radiation sample changes, the temperature of the radiation sample changes, the refraction index is similar to the Gaussian distribution of the fallen laser beam resulting from the laser beam radius, as well as a change in the intensity of the laser beam [17]. The propagation of light in a homogeneous medium, optical diffraction occurs, a geometrical effect leading

Table 1. Shows the parameters for glass.

D_0	D_1	D_2	D_0	D_1	λ_{kT}
1.86×10^{-6}	1.31×10^{-8}	-1.37×10^{-11}	4.34×10^{-7}	6.27×10^{-10}	0.170

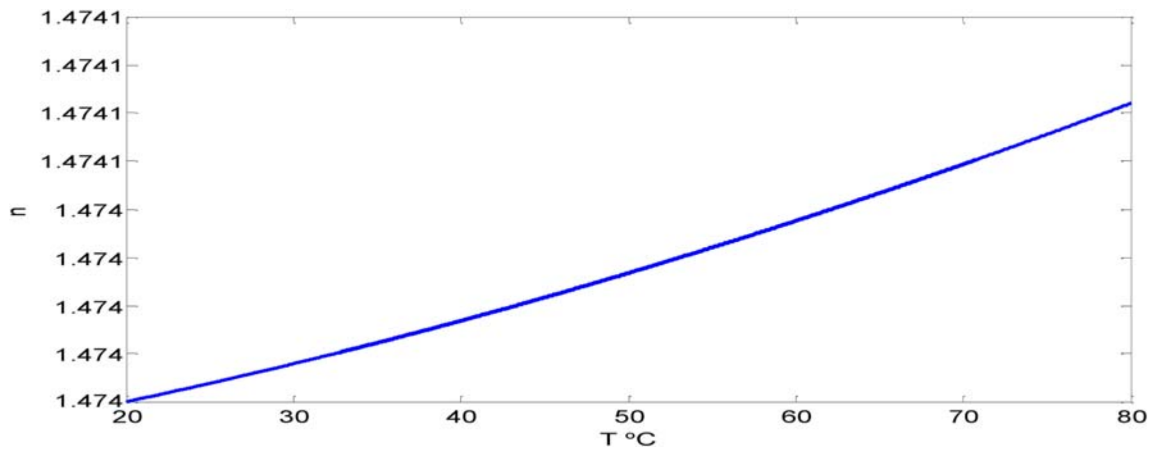

Fig. 7. The effect of temperature on refractive index in PCFs.

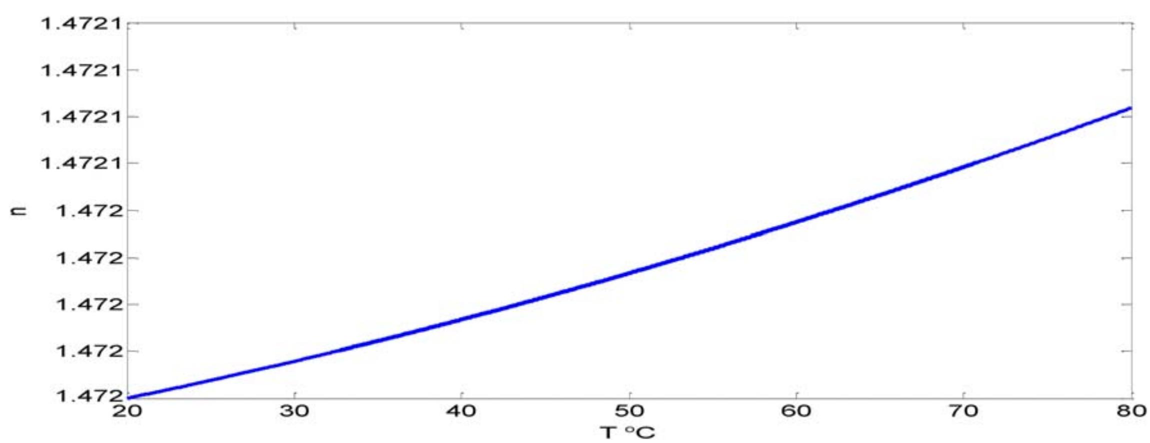

Fig. 8. The effect of temperature on refractive index in PCFs.

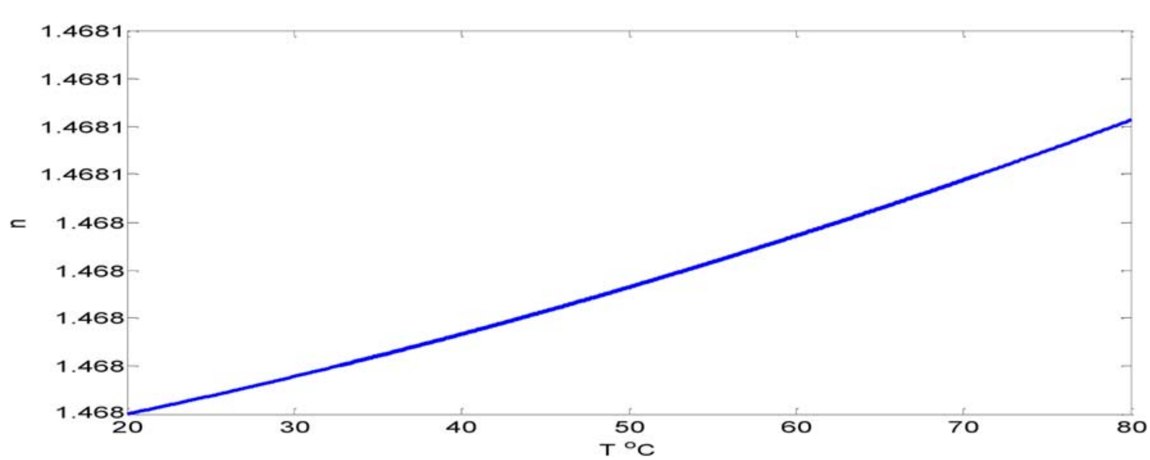

Fig. 9. The effect of temperature on refractive index in PCFs.

to a spatial broadening the beam propagation direction, depends on refractive index of the media [18]. Self-focusing is a nonlinear optical phenomenon refers to the nonlinear process counteracts against natural propagation of an optical beam when power exceeds a critical value of origin self-focusing in the nonlinear refractive index,n_0n_2I, where any increase in the intensity,I, leads to $n_2 > 0$, this produces a convergent wave front through the nonlinear phenomenon of self-phase modulation (SPM) during the beam propagation in the medium [19].

4. The effect of temperature on the refractive index in the PCFs

If one insert a wavelength Gaussian's pulse (850nm) to the PCFs and the core refractive index (1.474), will note that the temperature increase for the PCFs and therefore the refraction index will increase too because the change of the density of the medium by the effect of heat, and the Fig. 7 shows the relationship between the temperature within the range (20c0) to (80c0) and the refractive index of the PCFs.

But if one insert 1000) re refractive index of PCFs(1.472), will note that by increasing the frequency of the Gaussian's pulse will increase the intensity of the pulse and thus will lead to a rise in the temperature of PCFs will gradually increase the refractive index and as shown in Fig. 8 which describes the behavior of the refractive index with temperature within the range ($20c^o$) to ($80c^o$) For PCFs.

And by increasing the wavelength of the Gaussian's pulse entering the PCFs to (1300nm) and the refractive index of the core (1.468) We note when the frequency and intensity of the pulse increase, the temperature of PCFs increase too, therefore the refractive index of the PCFs will increase, Fig. 9 shows the relationship between the refractive index and the temperature in the PCFs.

4. Conclusion

To conclude, simultaneous control of self-focusing, which can be selectively enabled by the incident laser wavefront, has been demonstrated for the first time in the same nonlinear PCFs made of SiO_2 the nonlinear refractive index coefficient of the PCFs, responsible for the self-focusing phenomenon, is retrieved by fitting the broadened spectrum resulting from the nonlinear propagation of chirped pulses inside the PCFs to a theoretical model. It is found that an incident beam with a diverging wavefront can be focused in the PCFs quickly due to enhanced inverse diffraction caused by the linear η_0 of the PCFs the effect of self-focusing governed by the nonlinear η_2 of the PCFs. Such unusual phenomena, which are attributed to the negative n_0 and positive n_2, may give a distinct way to protect nanostructured devices from laser damage and provide a future method for manipulating laser propagation in PCFs and can be gate normal convex lenses which act as thermal lenses.

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