42. Analysis of Optical Parameters of Hexagonal Solid Core PCF with Methanol filled inner Cladding ring

Shahir Uddin[1], Tarannum Parveen[1], M A Hassan[2], Dharmendra K Singh[3]*
[1]Department of Electronics & Communication Engineering, BIT Patna (Bihar), India
[2]Mechanical Engg. Department, NIT Jamshedpur, Jamshedpur, India
[3]Department of Electronics & Communication Engineering, BIT Sindri (Dhanbad), India
[1]shahir@bitmesra.ac.in, [*]tarannumparveen09@gmail.com, [2]hassan@bitmesra.ac.in, [3]dksingh@nitp.ac.in

ABSTRACT

A unique hexagonal lattice structure of silica based solid core Photonic Crystal Fiber (PCF) has been designed which is surrounded by array of air holes filled with Methanol. Optical properties like birefringence, confinement loss and negative dispersion have been investigated. A five ring hexagonal solid core PCF with inner ring filled with Methanol and outer four rings constitute as air holes is proposed. A simple approach is used to attain high birefringence, low confinement loss and negative dispersion. The designed structure has been simulated using FEMSIM module of R-Soft software. The results depict at diameter d=1.5µm, 1.8µm and 2.1µm, the birefringence and confinement loss is endow as 0.000025, 0.000029, 0.000033 and 0.001, 0.001, 0.001 at 1.55µm.

Index Terms— *birefringence, confinement loss, dispersion, methanol, photonic crystal fiber.*

INTRODUCTION

Photonic Crystal Fiber (PCF) belongs to that class of fiber which has a number of microscopic air holes throughout its entire length. It makes the use of photonic crystals to form cladding around the core Due to its unique properties it can guide light in various mechanism like TIR(Total Internal Refection) and photonic band gap [1]In PCFs photonic band gap are set up to avert light propagation in certain direction with certain range of wavelengths.. On merging the properties of optical fiber and PCF a series of unique properties like exorbitant birefringence [2], l,ow confinement loss, negative dispersion. Innumerable single mode operation[3] is achieved which leads to reduction in cross talk that is unworkable with classical fibers. Further, these guiding properties [4] can be intensified by using different materials to the holes by filling the holes [5]. Also light propagation in PCFs is at higher level when it compared to standard fiber, which uses constant lower refractive index cladding.

Today PCF are being used in many important applications which includes spectroscopy [6], metrology, medicine, imaging, tele-transmission, industrial machining and military automation [7], Dual core PCF which is used as the sensing element of the hydrostatic pressure sensor A PCF with hexagonally latticed circular air holes [8] is designed to deliver single-polarization single-mode (SPSM) operation over a broad wavelength band. A unique hexagonal lattice structure of PCF filled with Methanol has been designed.

The structure's various parameter like birefringence, confinement loss and dispersion have been scrutinized. This has been done using the Finite Element Method (FEM).The numerical method used in this study is FEM which is adequate for the analysis of general dielectric waveguide geometries [9]. The fiber manifests immensive negative dispersion because of quick slant change of refractive indices at the coupling wavelength between the inner core and outer core The reciprocity of unalike geometric parameters like hole-to-hole spacing was scrutinized in detail. The dependence of different geometrical parameters, namely, hole-to-hole spacing and different air-hole diameter was investigated in detail. With these reported guiding properties, this fiber can be used for the application of residual dispersion compensation in high speed data transmission optical system. Proper arrangement and positioning of number of air holes some captivating properties like ultraflattened chromatic dispersion, very high nonlinearity, lofty sloping negative dispersion[10], slight confinement loss, small and huge effective mode area (A_{eff}), and high birefringence is achieved [11]. The propound PCF shows higher sensitivity for chemicals like Ethanol [12] and Methanol [13] whose refractive index are low. The scrutinization represents value of confinement loss that can have a great impact on various geometrical properties like inner and outer layer diameters and pitch values. These results from the propound PCF have been used for chemical sensors that has low refractive index. Hence the requisite optical properties have been found.

DESIGN AND ANALYSIS

In Fig. 42-1 hexagonal solid core PCF with inner ring filled with methanol is shown. The background material is chosen as silica having the refractive index of 1.45. The diameter of air holes is same throughout the structure for ease in fabrication. This inner ring is filled with the liquid methanol having refractive index of 1.317. The distance between two air holes, which is known as pitch (Λ) is considered same in proposed structure i.e. 3µm.

The proposed work consists of micro-structured fiber whose air holes are of the same size. Also, the diameter of air holes of cladding region to has been varied from 1.5µm to 2.1µm and keeping the pitch (Λ) constant at 3µm throughout to compare and analyzed the results of the effect of air holes size. The proposed work is stimulated using FEMSIM module of R-Soft software and further all the requisite optical parameters are calculated and performance analysis has been done.

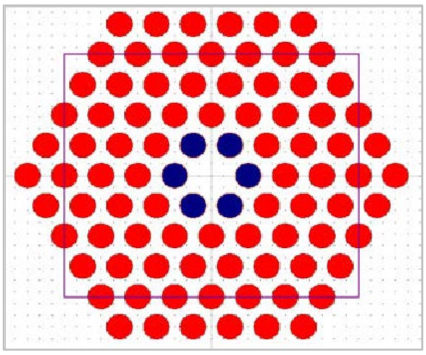

Figure 42-1 Cross-sectional view of proposed structure with inner ring filled with methanol

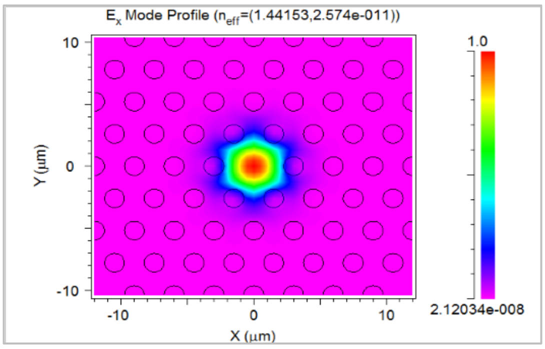

Figure 42-2 Light confinement in x polarization for hexagonal solid core PCF

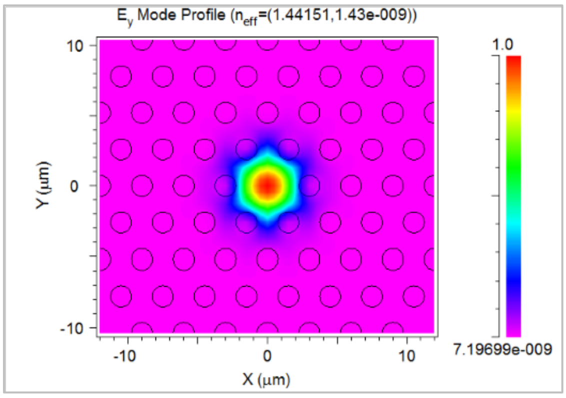

Figure 42-3 .Light confinement in y polarization for hexagonal solid core PCF

To be guided along solid core PCF, light must be confined to a central core by reflection from the cladding that surrounds it. The modes does increase with the increase in the wave number k rather they gets stabilized above kthreshold wavelength or remains constant below k-threshold wavelength. The guiding structures can be acquired for particular designs in which this constant number is just 1. In that “interminable” single-mode fiber is obtained [14] and [15]. The light confinement in PCF results in two values; the real value and the imaginary value which are used for finding dispersion and the losses of PCF respectively are shown in Fig. 42-2 and Fig. 42-3.

The birefringence, *B* is calculated as

$$B = \text{Real}|n_{effx} - n_{effy}| \qquad (1)$$

Where $_{|}$neff $_{-}$ neff $_{|}$ are the effective index of X and Y polarization mode.

It can be seen that with increment in diameter for hexagonal solid core PCF with methanol filled inner cladding ring, value of birefringence increases for the same value of wavelength i.e., for λ=1.7μm and at d=1.5μm value of birefringence is 3×10^{-5}, at d=1.8μm it is 3.2×10^{-5} and for d=2.1μm it gives the highest value among three i.e., 3.8×10^{-5} shown in Fig. 42-4. Exploration reveals that fibers with [6] high birefringence leads to better polarization and propagation of light energy.

Confinement Loss can be calculated as:-

$$L_c = \text{Loss (dB)}/z = 8.686\ k_0 \text{Im}\ [n_{eff}] \qquad (2)$$

where *c* is the speed of light in vacuum and Im[n_{eff}] is the imaginary part of the effective refractive index

Fig. 42-5 depicts the confinement loss when the diameter d=1.5μm, lowest and highest value of confinement loss in Xpolarization are 0.01db/m and 0.09 db/m and in Ypolarization are 0.015db/m and 0.10db/m. When the diameter change from d=1.5μm to d=1.8μm the lowest and highest value of confinement loss in X-polarization are 0.015db/m and 0.09db/m and in Y-polarization is 0.015μm and 0.07μm. At last when diameter d=1.8μm lowest and highest value of confinement loss in X-polarization are 0.015db/m and 0.095db/m and in Y-polarization is 0.015μm and 0.08μm respectively between the wavelength 1.2μm to 1.7μm.

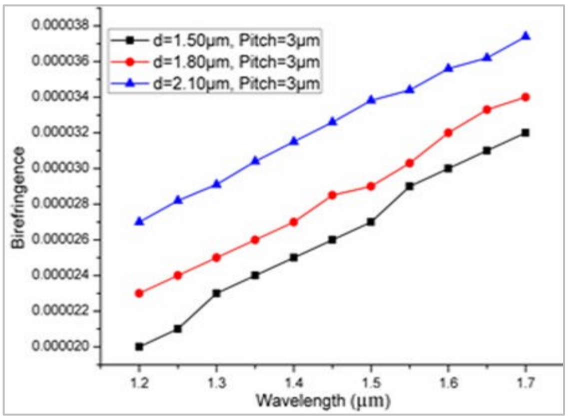

Figure 42-4 Birefringence curves of the proposed designed with methanol filled inner Cladding ring

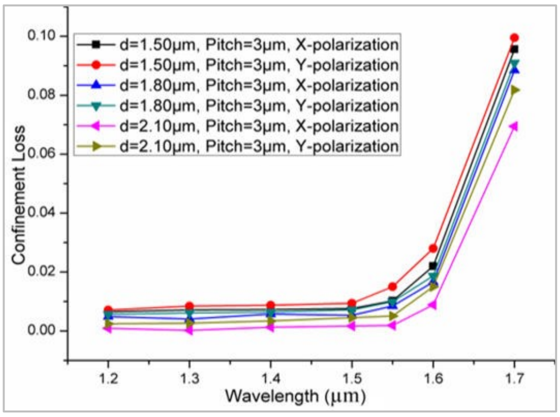

Figure 42-5 Wavelength versus confinement loss (dB/m) for hexagonal solid core PCF

The dispersion D can be calculated as:-

$$D(\lambda) = -\frac{\lambda}{c}\frac{d^2 Re(n_{eff})}{d\lambda^2} \qquad (3)$$

Where D is the dispersion, λ is the wavelength, n_{eff} is effective refractive index, c is the speed of light.

Fig. 42-6 depicts the dispersion curve when air hole diameter d=1.5 μm where positive dispersion occurred 0.7μm to 1.7μm wavelength. Fig. 42-7 shows the dispersion between 0.7μm to 1.8μm wavelength where the maximum negative dispersion -300 ps/km-nm is achieved when air hole diameter is 1.8μm. In Fig. 42-8 the diameter 2.1μm is consider achieving better results, shows the dispersion values are 0 ps/km-nm or negative over the entire proposed wavelength. It can be observed from the graph that increasing air holes diameter from d=1.5μm to 2.1μm we have more negative values for dispersion which reduces the crosstalk effect and attenuation for better and long distance communication. In each case the value of dispersion decreases with increase in wavelength.

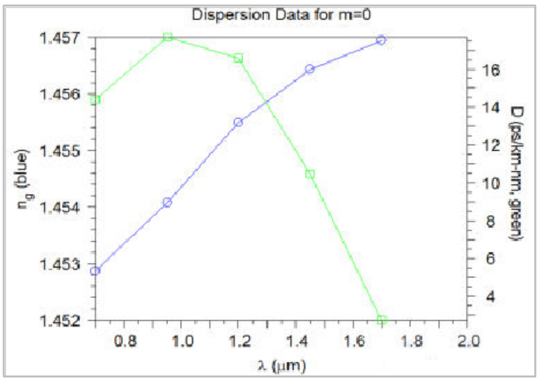

Figure 42-6 Dispersion curves of the proposed design at d= 1.5µm

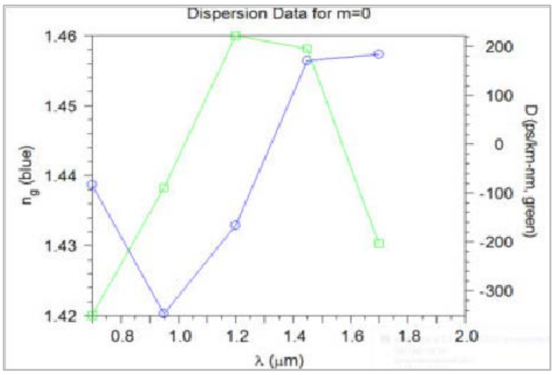

Figure 42-7. Dispersion curves of the proposed design at d=1.8µm

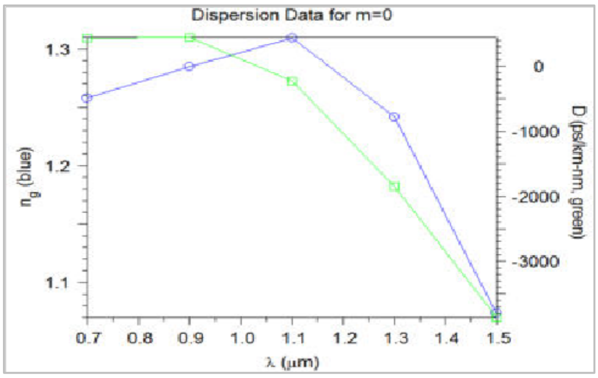

Figure 42-8 Dispersion curves of the designed hexagonal solid core PCF with methanol filled inner Cladding ring at d= 2.1µm

CONCLUSIONS

In this PCF, important design parameters such as the refractive index, confinement loss and negative dispersion have been thoroughly investigated and presented. By increasing diameters of air holes better results for birefringence, confinement loss and negative dispersion is obtained. It shows that innermost ring have maximum impact on the values of birefringence, confinement loss and dispersion. Moreover, study has shown that it is possible to achieve high birefringence and low confinement loss simultaneously. Methanol as filling material is focused because as it holds applications in chemical industries and in making chemical and biological solutions. Propound PCF holds great latency in optical parameter so it is applicable in chemical sensing applications.

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