Square shaped hole photonic crystal fiber with ultra flattened zero dispersion

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Abstract : A Photonic crystal fiber with square shaped hole has been investigated. Structure has six rings of square shaped air holes. Investigated structure has reported ultra flattened zero dispersion over a wide range of wavelengths (0.7µm - 2.0µm). Birefringence reported by this structure is also very high. It is 0.021 at a wavelength of 1.55µm. Ultra low confinement loss, of the order of 10^{-14}has been obtained. Hence the designed PCF can be applicable for both linear and nonlinear applications**.**

***IndexTerms* - Photonic crystal fiber, dispersion, birefringence, confinement loss.**

I. INTRODUCTION

In comparison to conventional optical fibers , holey fibers have proved themselves to be much superior. It is due to very unique features being offered by these holey fibers. Unique features like dispersion , nonlinearity , birefringence, ultra low confinement loss and endless single mode propagation are not commonly observed in standard fibers but these features are being available in photonic crystal fibers [1-4]. Moreover due to these unique features , PCFs have appreciations in the field of medicine, fibers sensing , optical communication and other linear and nonlinear application. PCFs also termed as holey fibers offers much design flexibility. The symmetry of cladding or the core can be modified to observe such of these flexibilities in designing. Similarly, by tailoring the dimension of holes in the cladding region we can observe other kind of flexibilities. Similarly, different materials can be used as partial filling or complete filling in the holes of cladding region to give result [5-9]. Birefringence is an important property being offered by PCFs . Numerous methods have been employed to report high birefringence. Silica photonic crystal fibers have been investigated with modified structures and have resulted high value of birefringence. Li *et al.* reported birefringence of the order of 10^{-2} by investigating a noble PCF structure [10]. Man *et al.* studied an index guiding photonic crystal fibre and shows birefringence of $1.15*10^{-2}$ at a wavelength of 1.55 µm [11]. Ultra-flattened dispersion photonic crystal fiber due to its extensive applications have been always been a point of research. PCF have distinctive dispersion characteristics to shift the zero dispersion wavelength or to flattened the dispersion wavelength to other wavelength. [12] its mentioned earlier, cladding structure makes the dispersion behavior tunable [13-14]. However, to obtain flattened dispersion over a wide band spectrum many holey fibres have been designed [15]. Olyalle *et al.* studied a hexagonal PCF with different dimension of air holes. Reported dispersion varies in between 2.5 $\pm$0.8 ps/nm-km [16-17]. In conventional PCFs air holes are arranged in a periodic array arranged in regular triangular lattice . The diameter of air holes remains uniform. The air hole diameter to pitch factor ratio are kept small to realize ultra flattened dispersion. Keeping this in view, various structure with different geometrical shape of core and holes with different dimensions, photonic crystal fibers have been analyzed and realized. Confinement loss or the leakage loss are the major losses observed in photonic crystal fibres and can be reduced by increasing the numbers of rings of air holes in the cladding region. This reduces the refractive index contrast by averaging the effective refractive index. Like conventional fibers, normalized frequency, termed as V-effective in case of PCFs determines the endless single modes of the fibers.

In this work, A PCF structure with square shaped holes has been studied. Structure has six rings of square shaped air holes. Intention for studying such a structure is to obtain highly birefringent fiber with controlled dispersion. Investigated structure has reported ultra flattened zero dispersion over a wide range of wavelengths (0.7µm - 2.0µm). Birefringence reported by this structure is also very high. It is 0.021 at a wavelength of 1.55µm. Ultra low confinement loss, of the order of 10^{-14}has been obtained. Hence the designed PCF can be applicable for both linear and nonlinear applications.

II. DESIGN AND THEORETICAL METHODS

We have investigated a new kind of PCF structure with square shaped hole. Investigated structure has six ring of square shaped hole in the cladding region. The dimension of one side of the square is taken as $a=0.6\times \Lambda$. Here pitch factor(Λ) considered is 2.7µm. The structure has silica as wafer with refractive index 1.45. The schematic diagram of the structure is shown in Fig.1.

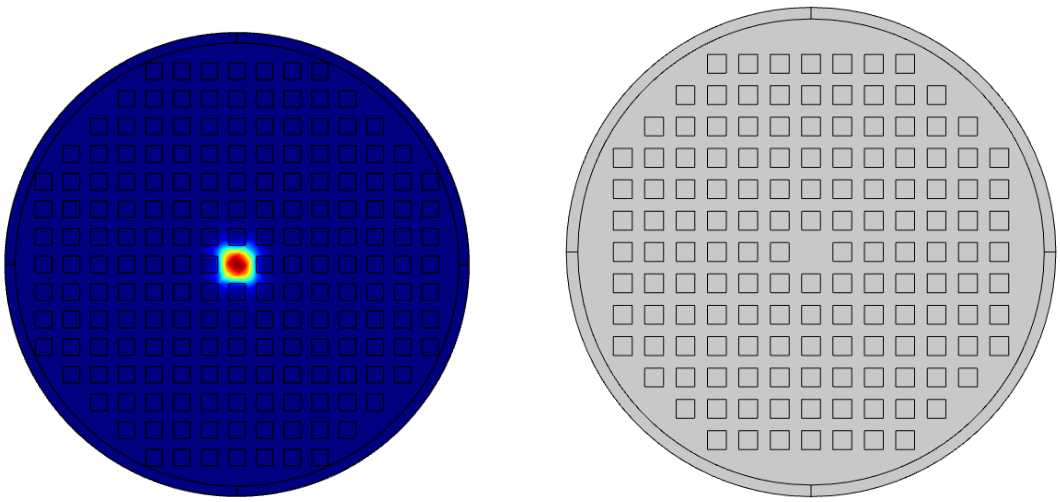


Fig. 1 (a) PCF structure with square shaped air holes

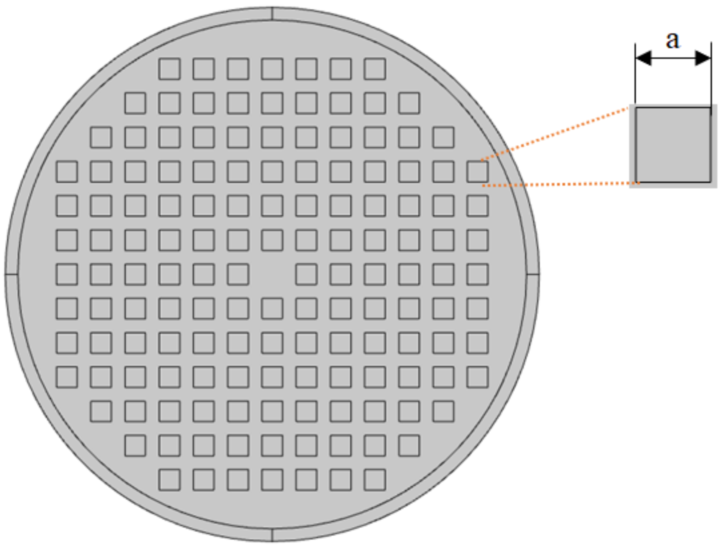


Fig. 1 (b) PCF structure with dimension of square shaped air holes (one side of square, 'a'=0.6* Λ) and Λ = 2.7µm.

Dispersion limits the data carrying capacity of fibers. Hence the dispersion needs to be minimized. Dispersion in total is a sum of material dispersion and waveguide dispersion. Material dispersion for single mode fiber, generally is zero. However, waveguide dispersion of PCFs can be obtained as [18]:

$$D = -\frac{\lambda}{c}\left(\frac{d^2 n}{d\lambda^2}\right) \tag{1}$$

Birefringence decides the probability capacity of any fiber. It is the difference in between vertical polarization and horizontal polarization mode hence[19]:

$$B = \left|n_x - n_y\right| \tag{2}$$

Compared to standard fibers , PCF offers very low loss. However, the losses like confinement loss, splice loss etc. can not be neglected. Number of air rings in the cladding region strongly affects the confinement loss and can be obtained as [20]:

$$L_c = 8.686\,\mathrm{I}_m(n_{eff}) \times K \tag{3}$$

$V_{effective} \leq 4.1$ ensure the fibres to be single mode. It is obtained as [20]:

$$V_{eff} = \frac{2\pi\Lambda}{\lambda}\sqrt{n_1^2 - n_2^2} \tag{4}$$

III. SIMULATION AND RESULTS

We have investigated a new kind of PCF structure with square shaped hole. COMSOL MultiPhysics 4.0 has been used for simulating the designed PCF structure. Birefringence , difference between two orthogonal polarized modes decides the sensor applications of PCFs. Higher value birefringence shown in Fig. 3, have a value of 0.036. Hence it can be applied as optic sensor.

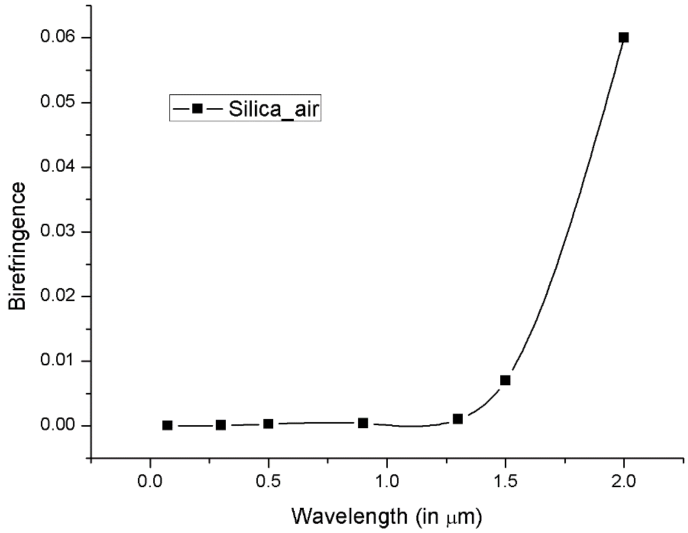


Fig. 2 Birefringence

Ultra flattened dispersion has been observed in the designed PCF. The ultra flattened zero dispersion fiber are highly desirable due to its various linear and nonlinear applications. Fig.3 shows the dispersion behavior . The designed fiber have zero flattened dispersion aver a wide wavelength of 0.7 µm to 2µm.

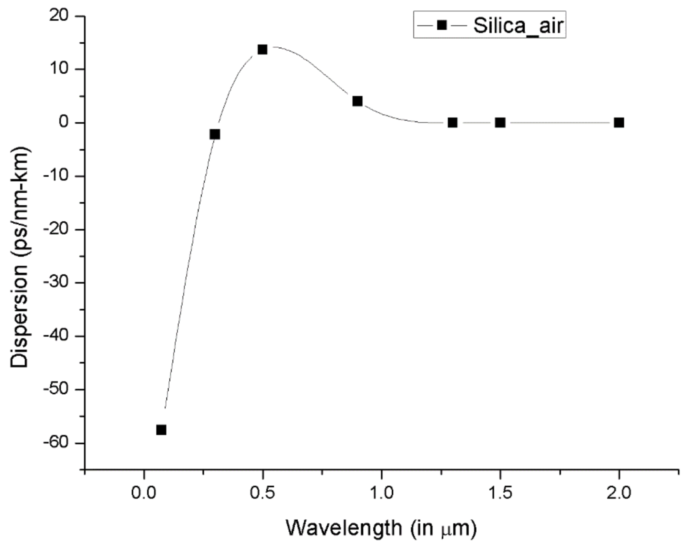
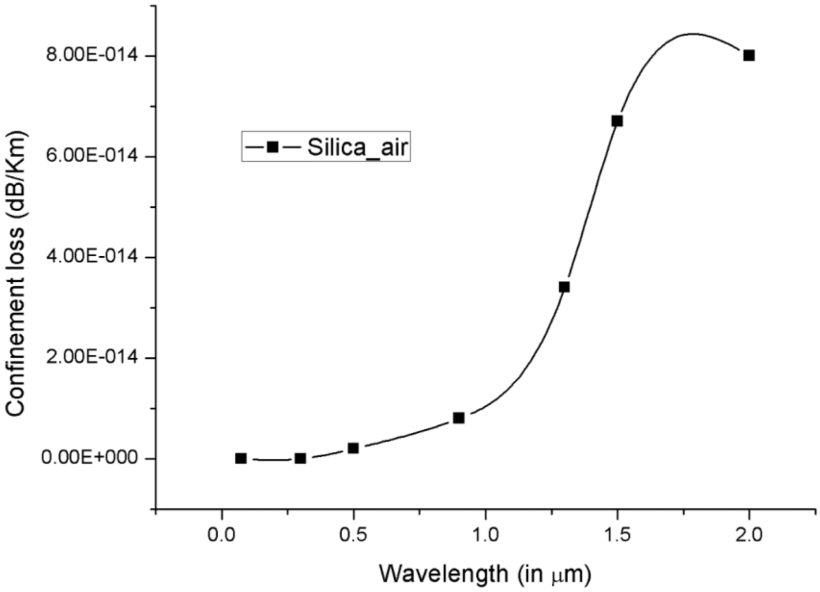


Fig. 3 Dispersion behavior

Confinement loss shown by the designed structure is ultra low. Fig. 4 shown the confinement loss of the designed fiber . The obtained value of the confinement loss is the order of 10^{-5}.



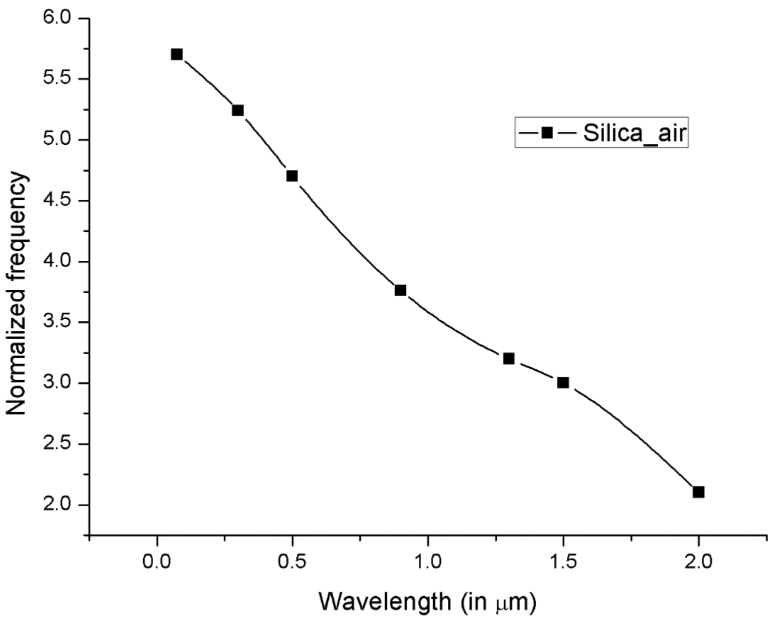


Fig. 5 Normalized frequency

Fig. 5 shows the normalized frequency of the designed fibers. The value of normalized frequency lesser than 4.1 shows the single mode propagation.

IV. Conclusion

Hence, PCF structure with square shaped holes has been studied. Structure has shown excellent result. Investigated structure has reported ultra flattened zero dispersion over a wide range of wavelengths (0.7µm - 2.0µm). Birefringence reported by this structure is also very high. It is 0.021 at a wavelength of 1.55µm. Ultra low confinement loss, of the order of 10^{-14}has been obtained. Hence the designed PCF can be applicable for both linear and nonlinear applications.

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