Analysis of Highly Birefringent Photonic Crystal Fiber Employing Different Geometries and Determination of Optical Parameters

Divya K N[1] Syam Prasad N Pearson[2] Gayathri B[3]
[1, 2] Student, M. Tech, Communication Engineering, FISAT
[3]Assistant Professor, Electronics and Communication Department, FISAT

Abstract—In this paper we are proposed three different types of photonic crystal fibers and compared them for higher birefringence by using finite element method. Using elliptical holes instead of circular air holes we are getting high birefringence. We also obtained low dispersion for the same structure consist of a defect in the center design flexibility and high index contrast give a better birefringence in the range of 10^{-3} to 10^{-2}.Also the characteristics of PCF are plotted for a range of wavelength

I. INTRODUCTION

Photonic crystal fiber consists of a periodic arrangement of holes in the cladding in order to improve the light confinement through the core has got a wide attention due to its unique properties. These PCFs have the ability to be used in applications like high bit rate communication systems, temperature sensing etc. They are also be used in realizing single mode polarization fiber where we can guide only one polarization state of the fundamental mode by we can eliminate the polarization mode dispersion(PMD).High birefringence can be achieved in different ways.The first method is high birefringence can be achieved by introducing aasymmetry in the core region.In such designs,there will be a value of the order of 10^{-3} .The second method is introducing asymmetry in the cladding region.Thus we can use elliptical holes instead of circular air holes. Studies have proven that elliptical air hole gives higher birefringence than the circular air holes.

In this paper there are three different structures having different arrangement of holes is introduced. A comparison between these structures has been made and finalized a structure which gives higher birefringence.

This paper is organized as given below.In Section II the proposed structures are introduced and analysed, then the dependency of the birefringence on parameters of the structures is investigated thoroughly.Comparisons between the present structures are made and final structure is obtained,In Section III and in Section IV the other properties of three structures are calculated, plotted and analysed.Section V concludes the paper.

II. BIREFRINGNECE

Birefringence is defined as the optical property in which a ray of un-polarized light split into two components travelling at different directions and at different speeds. One ray of light is refracted at an angle as it passes through the medium, while the other travels unchanged. The splitting is due to the fact that the speed of the ray through the medium is determined by the orientation of the light compared with the crystal made up of the medium. The un-polarized light consists of waves that vibrates in all directions, some will pass through the lattice unaffected will others will be refracted and will change the direction. Some materials that exhibit double refraction include ice, quartz and, sugar. The resolution of a light wave into two unequally reflected waves by an optically anisotropic medium is called double refraction. Birefringence or double refraction, is defined as the decomposition of a ray of light into two rays(the ordinary ray and extraordinary ray) when it passes through such materials as calcite crystals depending on the polarization of the light. This effect occurs only, if the structure of the material is anisotropic. The division of light into two components (ordinary and extraordinary day) can be found in materials which have two different indices of refraction in different direction.

By applying rule mining algorithms, frequent itemsets are generated from large data sets e.g. Apriori algorithm. It takes so much computer time to compute all frequent itemsets. We can solve this problem much efficiently by using Genetic Algorithm (GA). GA performs global search and the time complexity is less compared to other algorithms. Genetic Algorithms (GAs) are adaptive heuristic search & optimization method for solving both constrained and unconstrained problems based on the evolutionary ideas of natural selection and genetic. The main aim of this work is to find all the frequent itemsets from given data sets using genetic algorithm & compare the results generated by GA with other algorithms. Population size, number of generation, crossover probability, and mutation probability are the parameters of GA which affect the quality of result and time of calculation.

Small imperfection in optical fiber can cause birefringence as shown in Fig.1, which can cause distortion in optic fiber communication. The imperfections are geometrically based. Mainly birefringence is formed by the non-circular air holes with different arrangements.

The parameters associated with the photonic crystal fibers are diameter of the air hole (d), the distance between the centers of the air holes which is called pitch (p). The air filling fraction is defined as the ration of diameter of the hole to the pitch.

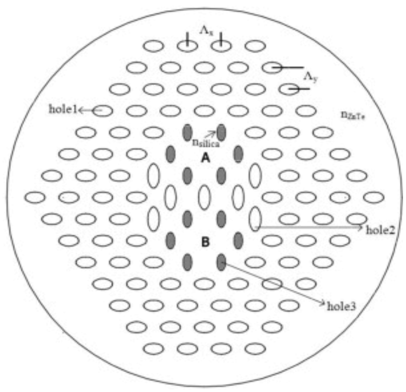

Fig. 1:Hexagonal PCF structure

Our proposed structure 1 consists of circular air holes in teragonal lattice arrangement.It is shown in Fig.2The cirlce has a diameter of 1.6µm and has pitch of 2.3µm.Silica gas a refrative index of 1.45 and the air hole refractive index is 1. Here we are designed the structure with 6 rings.By finite element method we are simulating the structure and finding the effective refractive indices for a range of wavelength.

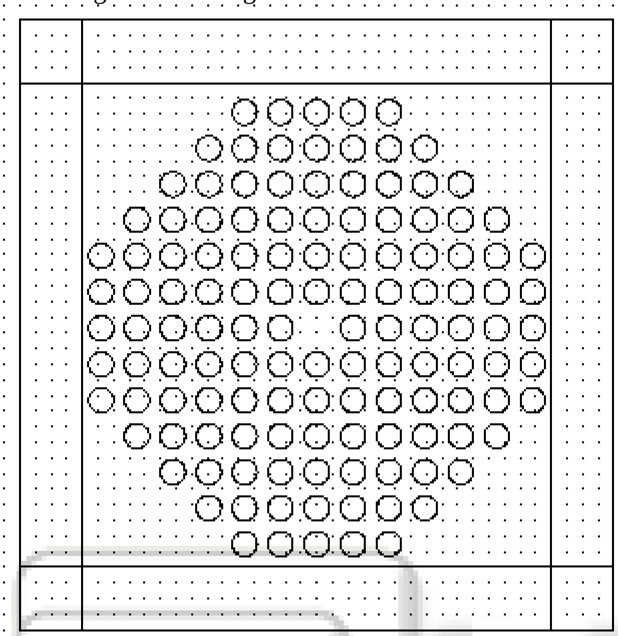

Fig. 2: Cross section of tetragonal PCF with circular holes

By simulation, the structure gives the profile as shown below in Fig.3.By analysing the values of the effective refractive indices for a wavelength range of 600nm to 2000nm, we are obtaining a birefringence value of the order of $1*10^{-3.}$

In the Fig.3 the light is confined through the core for a particular wavelength at a specific value of refractive index.

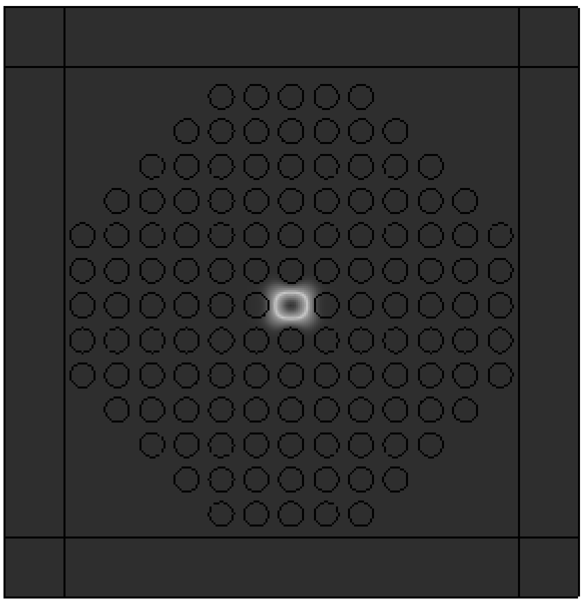

Fig.3 Confined structure for tetragonal circular PCF

There will be two polarized modes for the light i.e. and $E_y$respectively. The birefringence is calculated by

Birefringence=$|n_{eff}^{x}|-|n_{eff}^{y}|$(2.1)

Where n_{eff}^{x} and n_{eff}^{y} are the effective indices of the fundamental modes E_x and $E_y$respectively Fig.4 shows the power profile

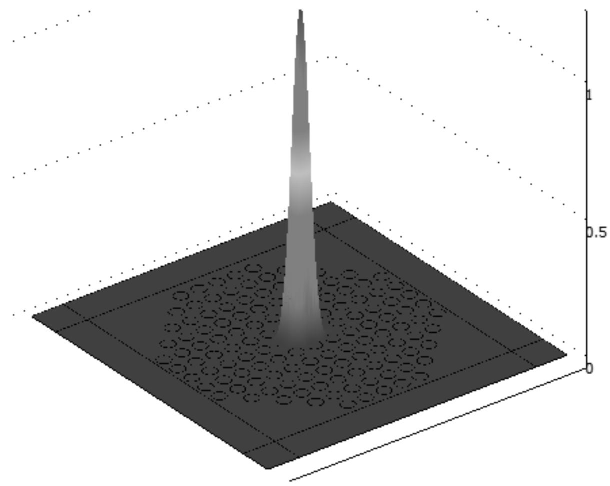

Fig. 4: Power profile of structure

The electric field distribution is shown in Fig 5.Here the loss is very much less due to the arrangement of circular holes.

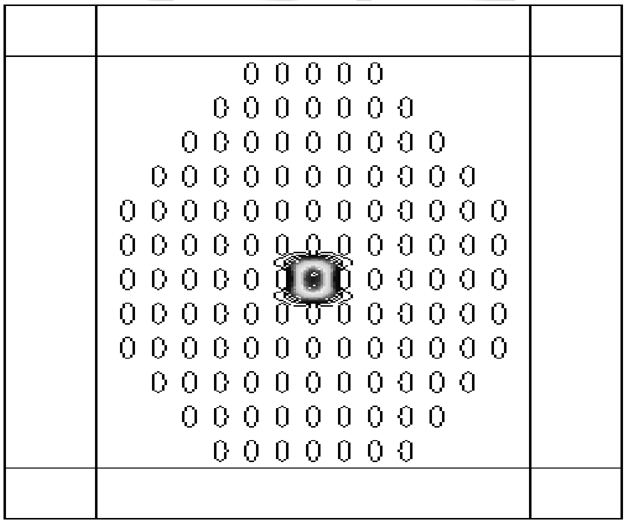

Fig 5: Electric field distribution

Another structure to compare the birefringence is tetragonal PCF with elliptical air holes. Here the dimensions associated with the ellipses are the semi major axis and minor axis b and a respectively. The ration b/a is called ellipticity. Here in Fig.6 axes are shown.

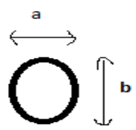

Fig 6:.major and minor axes

Here we have the dimension for elliptical holes.
This is a 6 ring structure with a=.2µm,b=.6µm and pitch is 2.3µm.The simulation results for this structure is shown in Fig. 7 and 8.

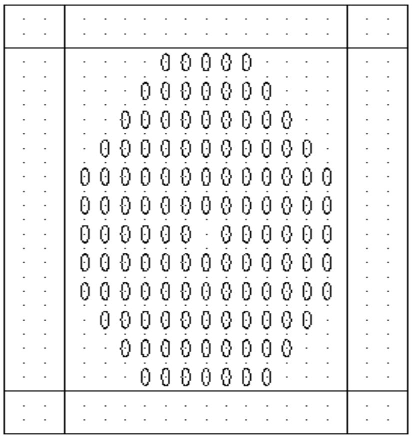

Fig. 7: Proposed structure for tetragonal PCF

The third structure proposed consist of elliptical hole sin hexagonal lattice. Generally studies have proven that hexagonal lattice have higher birefringence compare to other structures.
Fig.9 shows the hexagonal structure with elliptical holes. This have the dimensions a=.2µm,b=.6µm, and pitch=2.3µm.

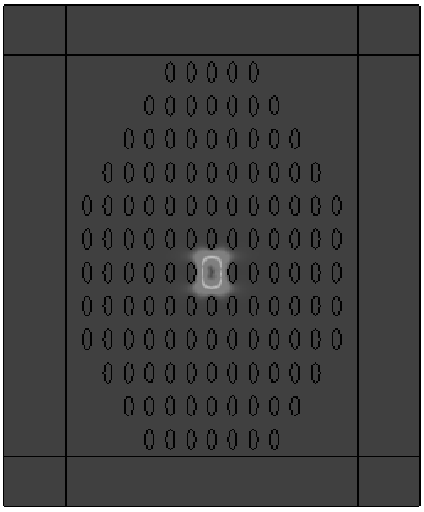

Fig. 8: Confined structure

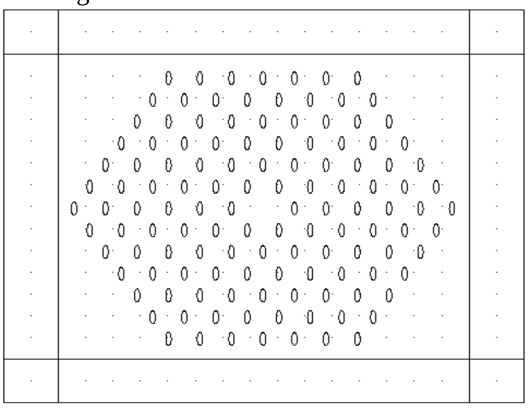

Fig. 9: Hexagonal structure with elliptical air holes

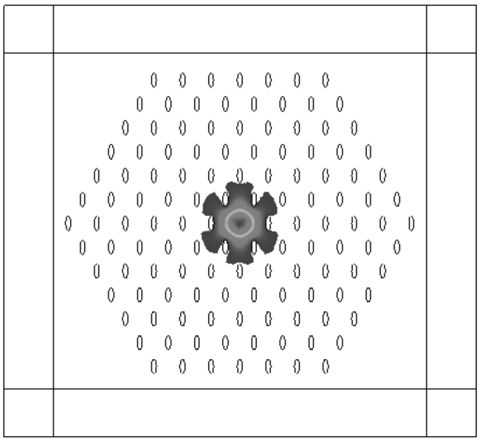

Fig. 10.Confined structure

III. COMPARISON

The proposed structures are compared and the values for effective refractive indices have been calculated.By using the formula for calculating birefringence for a wavelength region of 600nm to 2000nm we obtained different values.By using MATLAB 7.1 we plotted the graphs for three structures.From the figure itself we can understand that the birefringence is higher for the hexagonal structure PCF with elliptical air holes.It has got a value of $6*10^{-3.}$
Fig.11 shows the birefringence value for three different structures.The values are in the order of 10^{-3}.

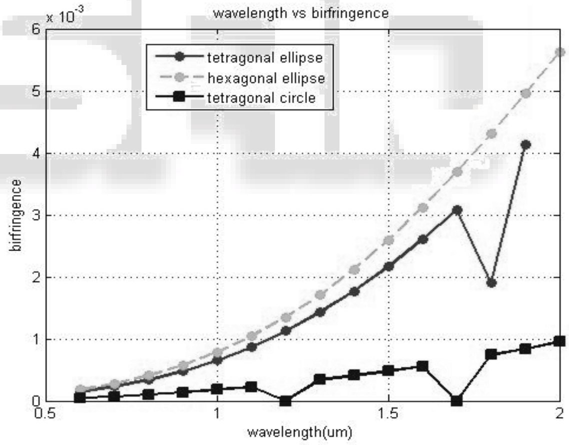

Fig.11 Plot for birefringence of three

IV. DETERMINATION OF OTHER PROPERTIES

The other main properties of photonic crystal fiber are dispersion, confinement loss, effective area, effective refractive index etc. chromatic dispersion, each wavelength of light travels through the same material at its own particular speed which is different from that of other wavelengths. It is the result of the different color. Or a light wavelength on a light beam arriving at their destination at slightly different times.
The dispersion is calculated by

$$D(\lambda)=-\frac{\lambda}{c}\, d^2Re[n_{eff}]/d\lambda^2 \qquad (4.1)$$

Where λ is the wavelength is the speed of light $Re[n_{eff}]$ is the real part of effective refractive index. The dispersion for three structures are shown in Fig.10

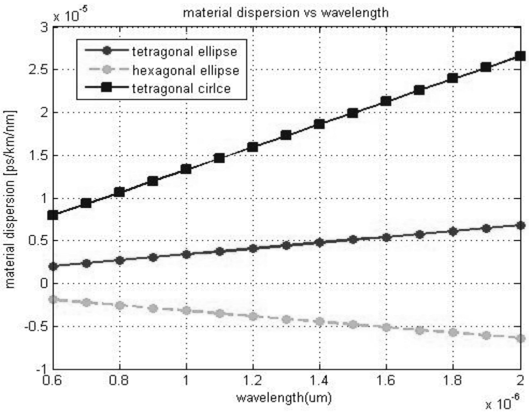

Fig. 12: Plot for dispersion of three structures

Confinement loss is the light confinement ability within the core region. It is defined as the leakage power from core to the cladding. It is given by

$$L_C=8.686\ k_0\ \mathrm{Im}[n_{eff}] \qquad (4.2)$$

Where $K_0=\frac{2\Pi}{\lambda}$ is the wavenumber in free spaceFig. 11 shows the confinement loss is high foe hexagonal PCF with elliptical holes because its high birefringence.

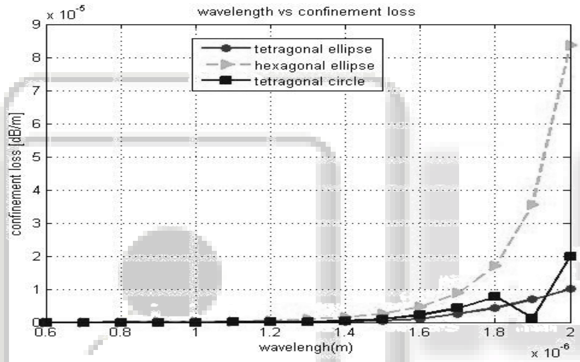

Fig. 13.confinement loss for three structures

The effective mode area of an optical fiber provides an effective measure of the area over which the fundamental mode is confined during the propagation through the core. In PCF the effective area is lower compared to the standard fibers. Fig. 12 shows the effective area for the structures

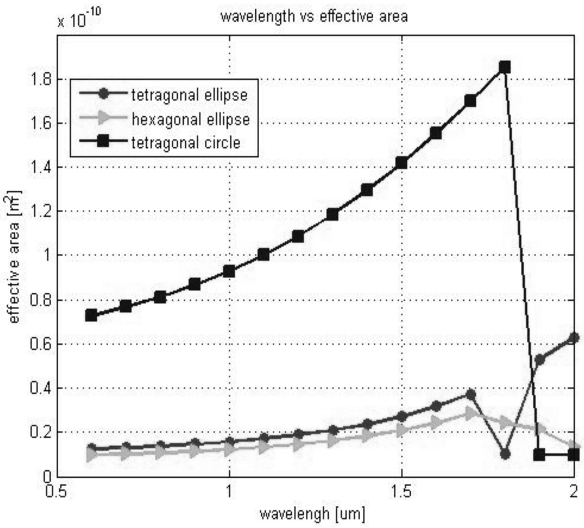

Fig. 12: Effective mode area for structures

The effective refractive index is defined as the number of quantifying the phase delay per unit length in a waveguide relative to the phase delay in vacuum. Fig .13 shows the plot for effective refractive index.

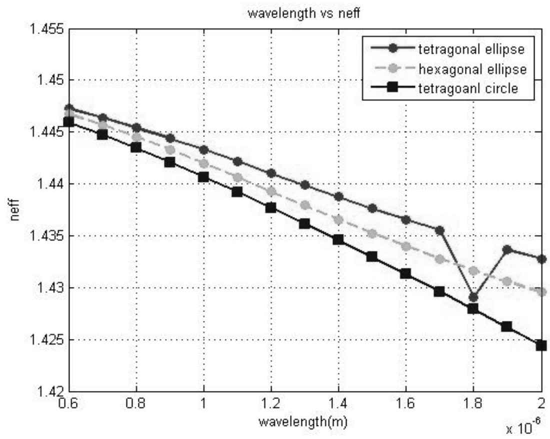

Fig.13 plot for effective refractive index

V. CONCLUSION

In this paper we are designed and simulated three structures. The birefringence for the three structures has been plotted and compared. The hexagonal PCF with elliptical holes is found to be more birefringent and useful for sensing applications. Also the other characteristics of PCF i. e, dispersion, effective area are plotted.

FAREFERENCES

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