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A New Design of Photonic Crystal Fiber With Highly Birefringence

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Abstract

In Optical Communication, highly birefringence triangular lattice photonic crystal fiber plays a major role in application like sensors, modulation and polarization dispersion compensation. Here, we have proposed a new design of photonic crystal fiber with highly birefringence. The highly birefringence is attained by modifying the fiber structural parameter like air hole diameter, pitch size, hole shape, lattice structure and also by the chosen material property. The performance parameter birefringence and respective beat length are measured using Finite Element Method. Here, we have proposed two different structures to obtain a better birefringence. In which a structure with horizontal elliptical air hole gives better value of about 0.0052m.

Key Words:Triangular lattice photonic crystal fiber, Polarization dispersion, Finite Element Method, High Birefringence.

1 Introduction

Until recently, an optical fiber was a solid thread surrounded by another material with a low refractive index. Now-a-days the photonic crystal fibers (PCFs) are accepted as an alternative technology. PCFs, which was first demonstrated in 1995-1996, are optical fiber with a periodic arrangement of low index material in a background with higher refractive index. Two broad classification of PCFs: High index guiding fibers and Photonic band gap ones. PCFs with high index guiding fibers occurs to be identical with conventional optical fibers since the total internal reflection mechanism is exploited to confine the light within a solid core. High design flexibility is one of the most important advantage offered by Photonic Crystal Fibers (PCFs). Possibility of attaining fiber properties with diametrically opposed is done by altering the structural characteristics of fiber cross section. The characteristics variation is meant to be the dispersion or air hole dimension. The birefringence was enhanced by increasing the size to pitch ratio for the bigger holes [2]. The GVDs of the two polarization modes are significantly different, especially at longer wavelength. The guided mode in optical fiber is achieved by propagating light beam with value, is the propagation constant factor which ensures light propagated along axis. Dispersion engineering is possible in PCFs in the range unachievable for classical fibers (zero-dispersion and anomalous dispersion in the visible range) [3]. The highest value that can exist in an infinite homogenous medium with refractive index n is = nk0, being k0 the free-space propagation constant. The characteristics of 2D photonic crystal like material is specified by maximum value of . The is used to indicate effective index of the material.

PCF with two ring elliptical air holes in core region and three circular air holes in cladding is used for showing the high birefringence and low confinement loss [4]. Selection of material with respect to refractive index variation is applied for obtaining total internal reflection. Likewise, high refractive index material is selected for core than the cladding. A hybrid cladding photonic crystal fiber for shaping high nonlinear and flattened dispersion in a wide range of wavelengths [5]. The photonic crystal fiber with a silica core mounted by a photonic crystal cladding with a triangular lattice of air-holes. These fibers also called as index-guiding PCFs guide light through a form of total internal reflection (TIR). However they have many different properties with respect to conventional optical fibers. In order to model photonic crystal structures especially PCFs accurately, it is crucial to use a full-vector model. The choice of modeling method can impact the computational resources and limitations of the methods, so it is important to explore the usefulness and limitations of each method. In the proposed system full vector finite element method is used for simulation.

2 PROPERTIES AND APPLICATION

Due to huge variety of air-holes arrangements, PCFs offer a wide possibility to control the refractive index contrast between the core and the photonic crystal cladding and as a consequences, novel and unique optical properties. Since PCFs provide new or improved features beyond what conventional optical fibers offer, they are finding an increasing number of application in ever widening areas of science and technology.

3 MODELLING OF PHOTONIC CRYSTAL FIBER

Based on the anisotropy of the photonic crystal material, we propose a new design of photonic crystal fiber by adding the air holes in silica glass. The designed fiber consist of outer circular air holes and inner elliptical air holes with triangular lattice. The design of photonic crystal fiber is shown in fig.,1.

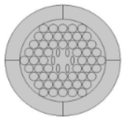

Fig.1. Design of highly birefringence photonic crystal fiber

Triangular lattice structure contains more air holes, this result in a higher air filling ratio and a lower refractive index around the core, thereby providing strong confinement ability. The chosen outer circular air holes diameter (a) is 0.9m and the distance between centers of air holes i.e., pitch size () is 1.63m and the inner elliptical air hole consist of semi axiss a and b of aboutv0.24 m and 0.75 m respectively and the pitch size is same as circular air hole. Here silica is high refractive index region and the sorrounded air holes act as for low refractive index region, this enables higher refractive index constrast and support for optical total internal reflection.

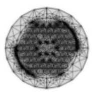

Fig .2. Mesh size for triangular lattice photonic crystal fiber

In this project we also compare and analyze the design of photonic crystal fiber structure with transversal cross arrangement of air holes for this configuration. Compared to existing structure-s, the new hexagonal PCF structure can potentially offer the following design benefits for achieving simultaneous broadband ultrahigh birefringence and nonlinearity.

• The removal of air holes and different dimension of inner air holes leads higher asymmetric in the fiber and provides high birefringence.

• The hexagonal structure is compact and able to achieve tight light confinement, small effective mode area and large nonlinearity.

• Additionally the circular air holes adopted in the hexagonal PCF structure facilitate easy fabrication.

4 PARAMETER ANALYSIS

A. Birefringence

Birefringence is the optical property of a material having a refractive index that depends on the polarization and propagation direction of light. The birefringence is often quantified as the maximum difference between refractive indices exhibited by the material. Effective modal index for X polarization Y polarization respectively , .

=

B. Beatlength

The polarization holding capacity of a birefringent fiber is measured in terms of its beat length.

= (10)

5 RESULT AND DISCUSSION

To verify the proposed hexagonal PCF design, the simulation results can be carried out. The designed fiber results are carried out by Finite Element Method (FEM) using COMSOL software.

A. Simulation of Hexagonal Triangular Lattice Structure

The hexagonal triangular lattice PCFs field distribution and effective modal index simulated in COMSOL MULTIPHYSICS. The designed PCFs cladding is droped with material air with refractive index n=1 and the core is filled with glass of refractive index n = 1.4. The diameter of the air hole & hole to hole distance can be inserted as per our consideration. The dependence of birefringence on wavelength for various diameters of circular and elliptical air holes and pitch size is examined.

C. Simulation Output of Hexagonal Triangular Lattice Structure

We have considered two different structure of air holes, they are vertical elliptical air holes and horizontal elliptical air holes. In which, we have to modify the outer diameter of air holes for better birefringence. For vertical elliptical inner air holes, the chosen outer circular air holes diameter (a) is 0.9m and the distance between centers of air holes i.e., pitch size () is 1.63m and the inner vertical elliptical air hole consist of semi axiss a and b of about 0.24 m and 0.75 m respectively and the pitch size is same as circular air hole. We have considered wavelength value starts at 1.4m to 1.6m. The refractive indices and are noted by increasing the wavelength. Using these refractive index we have to calculated birefringence.

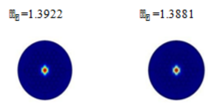

Fig .3. PCF output at diameter of circular air hole 0.75m, vertical elliptical air hole a semi axis is 0.24m, b semi axis is 0.75m and pitch size is 1.63m, =1.6m.

This figure 3 shows that when the wavelength increases birefringence also get increase. In vertical elliptical air holes, the higher birefringence (0.004) are attained at 1.6m wavelength.

Here, we have considered outer diameter of air hole is 0.75m, horizontal elliptical inner air hole: a semi axis=0.75m, b semi axis=0.24m and pitch size () is 1.63m.

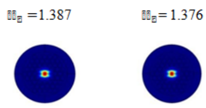

Fig.4. PCF output at diameter of circular air hole 0.75m, horizontal elliptical air hole a semi axis is 0.75, b Semi axis is 0.25 and pitch size is 1.63m.

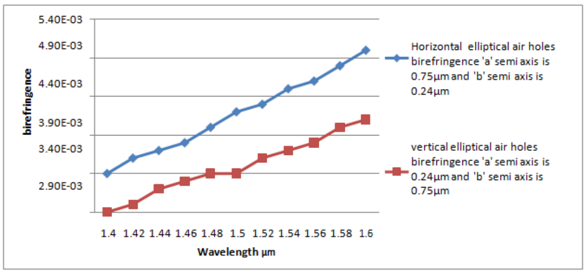

Fig.5. Plot for comparing vertical and horizontal inner elliptical air holes.

The figure 5 shows when compare vertical and horizontal inner elliptical air holes, the horizontal inner elliptical holes gives high birefringence by increasing the wavelength .

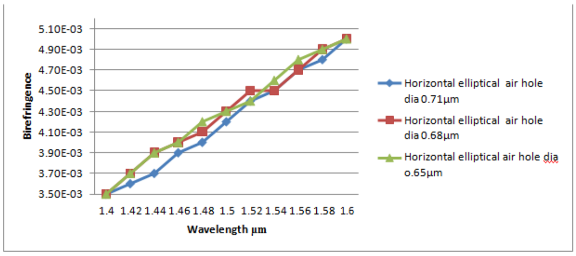

Fig.6. A plot for wavelength vs birefringence for changing the diameter of circular air holes is 0.71m, 0.68m, 0.65m and pitch size=1.63m.

This fig 6 shows that decreasing the outer diameter of inner circular air holes birefringence get increased.

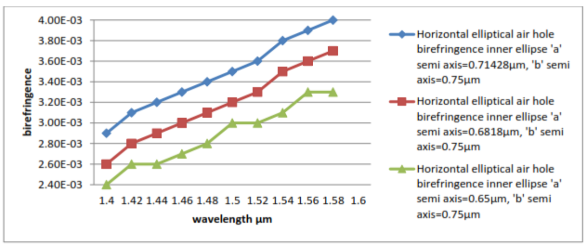

Fig.7. A plot for wavelength vs birefringence for changing the diameter of elliptical air holes (asemi axis) = 0.71m, 0.68m,0.65m, b semi axis=0.75m and pitch size=1.63m.

The above fig. 7 describes that decreasing the horizontal elliptical air holes inner ellipse a

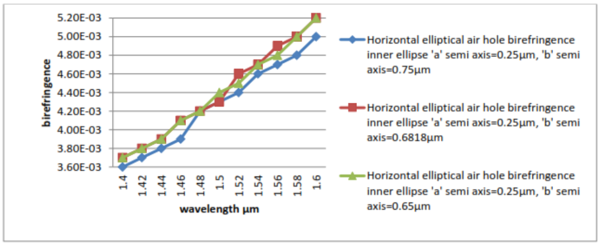

Fig.8. A plot for wavelength vs birefringence for changing the diameter of elliptical air holes bsemi axis = 0.71m, 0.68m, 0.65m, a semi axis =0.25m and pitch size=1.63m.

The above fig 8 describes that decreasing the horizontal elliptical air holes inner ellipse b semi axis gets increasing the birefringence.

The dependence of birefringence on wavelength for various diameters of all circular air holes and pitch size is depicted in fig.8 the birefringence increases almost linearly with the wavelength. The birefringence is directly proportional to the operating wavelength as per the theoretical consideration.

The birefringence increases with the increase in diameter of circular air holes and elliptical air holes. The relationship between them is approximately linear. The effective area is found to be inversely proportional to nonlinear coefficient. This is because as the air hole diameter increases which definitely reduces the effective area leads to high non linearity. If the air hole diameter decreases this definitely increases the effective area and it leads to lower non linearity values.

The non linearity decreases as the wavelength increases because of reduced confinement of light in the core. The lower value of the effective area, the higher the confinement of light in the core region and so high non linearity is achieved. The non linearity is inversely proportional to both effective area and wavelength. So with increase in the wavelength, the non linearity decreases in the designed PCF as per the theoretical consideration.

6 CONCLUSION

In this project a novel design of hexagonal PCF design is presented. A full vector finite- element method is used to characterize the performance of the designed PCF. By optimizing the diameter of circular air holes and elliptical air holes, high birefringence of about 5.2 103and beat length of 0.3mm is obtained. Within a wavelength range of 1.4m to 1.6m, the designed PCF offers high birefringence and beat length. A laudable goal is achieved by taking full use of the design freedom of PCF and obtained high birefringence, beat length which might be importance in highly efficient wideband signal processing applications, nonlinear fiber optics and long distance telecommunication applications. The circular and elliptical air holes adopted in the triangular lattice PCF structure facilitate easy fabrication. In comparison with other lattice structure, it is believed that the proposed PCF is very promising for near future applications.

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