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ANALYSIS OF INDEXED-GUIDED HIGHLY BIREFRINGENT PHOTONIC CRYSTAL FIBER EMPLOYING DIFFERENT CLADDING GEOMETRIES

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ABSTRACT

In this paper, a comparative study of three geometries of highly birefringent photonic crystal fibers (HB PCF) is presented. The proposed geometries are: V type PCF, Pseudo-Panda PCF and selectively liquid-filled PCF. Based on the famous Finite Difference Time Domain (FDTD) method with the perfectly matched layer (PML) boundary condition, the simulations are carried out in the aim to find a tradeoff between the chromatic dispersion, the birefringence and the confinement loss.

Key-word: photonic crystal fiber, high birefringence, FDTD.

1. INTRODUCTION

In the past decade, photonic crystal fibers (PCFs), known as micro-structured optical fibers or holey fibers have been extensively investigated due to their unusual properties such as endlessly single mode operation over wide range of wavelengths [1], tailor able group velocity dispersion [2] and large effective core area [3]. These powerful properties combined with high degree of design freedom give rise to many practical applications in optical communications, nonlinear optics and in various optical devices and sensors [4-5].

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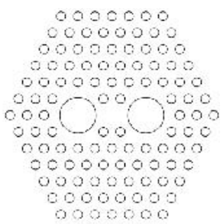
High birefringence (Hi-Bi) can be easily obtained with PCF because of the design flexibility and the high index contrast [6-7], giving the possibility to reach an order of magnitude of 10^{-3} or 10^{-2}, which is larger than conventional fibers (10^{-4}) [8]. Several approaches have been explored to achieve high birefringence in photonic crystal fibers. One can use elliptical instead of circular air-holes in the cladding region [9-11], another can employ air-holes with different diameters [12-14]. Filling selectively some air-holes by a liquid with a refractive index lower than silica is also investigated [15-17].

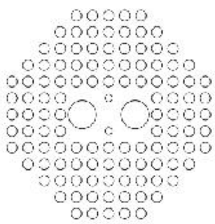
In this paper, we report the numerical analysis of several Hi-Bi PCF patterns with the aim to give an optimal design for the tradeoff between three criterions: the chromatic dispersion, the birefringence and the confinement loss. The analysis will be carried out using the Finite-Difference-Time-domain (FDTD) method. The investigated patterns are: The Pseudo-Panda PCF [8], the V type PCF [16] and the selectively liquid filled PCF [15] with the triangular and the tetragonal lattice. Based on three criterions:, the results will be analyzed and discussed.

2. MODELS

Figure.1 shows the two main structures of our study. The index of silica is 1.46. Both structures are specified by two parameters, the radius of the air-holes and the pitch between two adjacent holes. Initially, the holes radius and the pitch are set to be 0.8µm and 2.3 µm, respectively. To ensure that light is well confined in the structure, the cladding is selected to be formed by six layers (rings) of air-holes.



(a)



(b)

Fig.1. Cross section of PCF with triangular lattice (a) and tetragonal lattice (b) with: *d* the holes radius and Λ the pitch

2. 1. V type PCF

This kind of PCF was proposed by J. Wojcik et al for hydrostatic pressure sensing [16]. As it is shown in figure. 2, the cladding is designed in such way to have selectively and differently sized holes.

(a) (b)

Fig.2. Cross section of V type PCF: the radius of the small and the big holes is 0.8 µm, 1.2 µm, respectively

2. 2. PP-PCF

The geometrical structure of the pseudo-panda PCF is illustrated in the figure. 3 Two enlarged air-holes have been introduced along the x axis between the cladding and the core. The large hole occupies seven small holes in the triangular lattice and six holes in the tetragonal lattice.

(a) (b)

Fig.3. Schematic section structure of PP-PCF with triangular (a) and tetragonal (b) lattice

2. 3. Selectively liquid-filled PCF

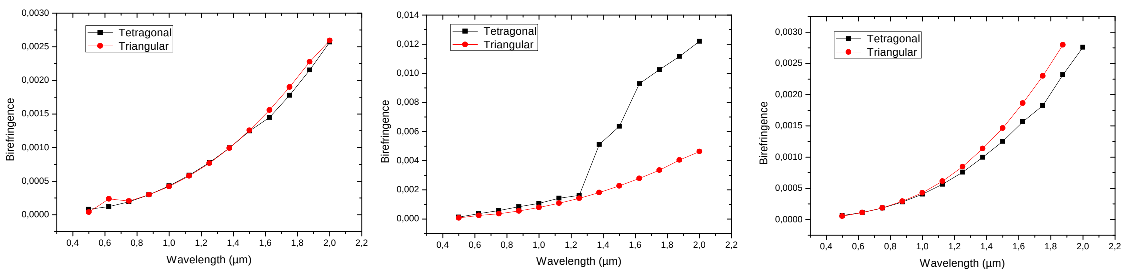
For this case, the birefringence is introduced by infiltrating an index tunable liquid, polymer or optofluid into the air-holes of the PCF [15]. The variation of the infiltrated material index can be achieved thermally or electrically [18-24]. Figure. 4 give the cross section of such PCF.

(a) (b)

Fig.4. Schematic section structure of selectively liquid-filled PCF with triangular (a) and tetragonal (b) lattice

3. NUMERICAL RESULTS AND DISCUSSION

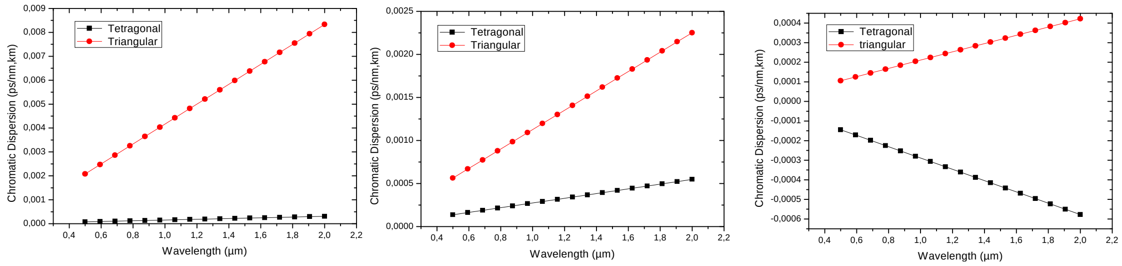
As it was previously mentioned, the FDTD engine is used to calculate the complex effective index for each case and than we employ the formulas given above to analyze them. Firstly, figure (5) gives the evolution of the birefringence with wavelength for the three types. Clearly, for the V type and the selectively liquid-filled PCF, the evolution of the birefringence is quietly the same for both the tetragonal and the triangular lattices (it reaches 1.25×10^{-3} around 1.55µm). For the PP-PCF, we have the same observation up to 1.2 µm, for higher wavelengths, the PP-PCF with tetragonal lattice become ultra birefringent and reach the order of magnitude of 10^{-2} (a value of 6×10^{-3} of birefringence around 1.55 µm)



V type Hi Bi PCF PP-PCF Selectively liquide-filled PCF

Fig.5. Evolution of the birefringence with wavelength

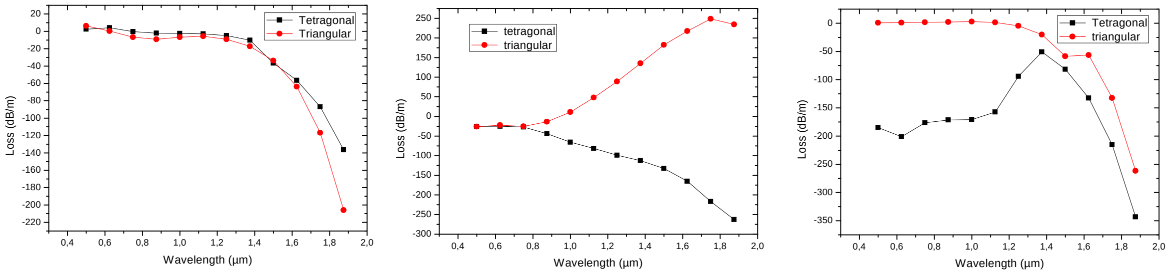
The analysis of the chromatic dispersion is always settled in favor of the tetragonal lattice giving a huge advantage to this geometry (figure (6)).



V type Hi Bi PCF PP-PCF Selectively liquide-filled PCF

Fig.6. evolution of the chromatic dispersion with wavelength

Figure (7) shows the variation of loss with wavelength. For both the PP-PCF and the selectively liquid-filled PCF, the loss is lower when the tetragonal lattice is employed. For the V type, the loss is quietly lower when the triangular lattice is used.



V type Hi Bi PCF PP-PCF Selectively liquide-filled PCF

Fig.7. evolution the confinement loss with wavelength

4. CONCLUSION

We numerically studied and compared the mode birefringence, the chromatic dispersion and the confinement loss of three types of high birefringent PCFs by using two lattices in the cladding region based on the FDTD method. It has been found that PCFs with tetragonal lattice are more birefringent whatever the cladding geometry, and a maximum can be obtained with PP-PCF. This advantage is also reinforced by the fact that chromatic dispersion and confinement loss are the both lowest. For the three combined criterions, the PP-PCF with tetragonal lattice is recommended, and can be optimized for further works.

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