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Research Article

IMPROVED HIGH BIREFRINGENCE PHOTONIC CRYSTAL FIBER WITH LOW CONFINEMENT LOSS

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ABSTRACT

In this paper high birefringence and low confinement loss photonic crystal fiber with single mode operation is proposed. The birefringence is largely dependent on degree of irregularity and fiber design parameters. The numerical result show that improved PCF possesses the properties of high birefringence, low confinement loss and single mode operation. By inserting the asymmetry in cladding region, model birefringence increases greatly in comparison to original PCF and confinement loss is about 10^4 times smaller.

INTRODUCTION

Photonic crystal fibers have diverse applications in lasers, sensors, telecommunications and medical instrumentation. Photonic crystal fiber allow guided propagation by means micro structured air holes of cladding. In Kang Hwang *et al* [2] have analyzed irregular symmetry by using plane wave expansion method. Fu Bo *et al* [3] have proposed a PCF of high birefringence and reduces confinement losses 10^4 times smaller than original PCF. J.R. Folkenberg[4] have report on polarisation maintaining large mode area photonic crystal fiber which exhibits a typical birefringence of $1.5* 10^{-4}$. Mikko soderlund *et al* [5] proposed a large mode area polarisation maintaining double clad fiber which gives high average power (>100W), High birefringence ($2*10^{-4}$). Yaw-Dong Wu *et al* [6] proposed a large mode area PCF with effective mode area 1000 µm^2. This fiber reduces confinement losses to 0.486 dB/km at wavelength of 1.064 µm.

In this paper two main parameter investigated confinement loss and birefringence. In these fibers ratio of air hole diameter to air hole pitch are kept small to single mode operation& high birefringence. By increasing the no. of rings we also tried to reduce confinement loss[12]. For fiber have to work in single mode, we have taken $d/\Lambda < 0.406$. PCF can be made Highly Birefringent (HB) by having different air hole diameters along the two orthogonal axes or by asymmetric core design.[2]

METHODOLOGY

All the analysis of PCF properties have been done by using OPTIFDTD 8.0.It is done by using full vector finite element method with an-isotropic perfectly matched layers (PML). It gives sufficient accuracy, efficiency and reliability. The triangular lattice PCFs present wider effective area for large pitch Λ so that they can be applied practically for high power delivery.

Properties

Optical Properties of Improved PCF: The modal birefringence and leakage losses can be determined by following formulas:

Confinement loss

In core region presence of finite air holes causes leakage of optical mode from core inner region to outer air holes is unavoidable and results in confinement loss. Confinement loss is calculated from imaginary part of complex effective index n_{eff} using

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$$L = 8.686 * I_m \left[k_o \, n_{eff} \right] * 10^3 \qquad (1)$$

Birefringence

Birefringence of single mode fiber is defined as effective refractive indices difference of two fundamental modes.

$$B = \left| n^{y}_{eff} - n^{x}_{eff} \right| \qquad (2)$$

Where Re denotes the real part, λ and c are the wavelength and velocity of light in a vacuum, I_m denotes imaginary part. The n_x and n_y are effective refractive indices of fundamental mode in x and y polarization mode.[3]

Design

Highly birefringence structures are obtained in this single mode structure by slightly varying the defects as air holes diameter and shapes. The large air holes near the core provides the asymmetry and it significantly increase the birefringence and the large diameter circular air holes in the cladding region provide strong confinement ability. In figure 3 we introduce asymmetry by increasing the diameter of four air holes in first ring $d_1 = 1.2$ µm.

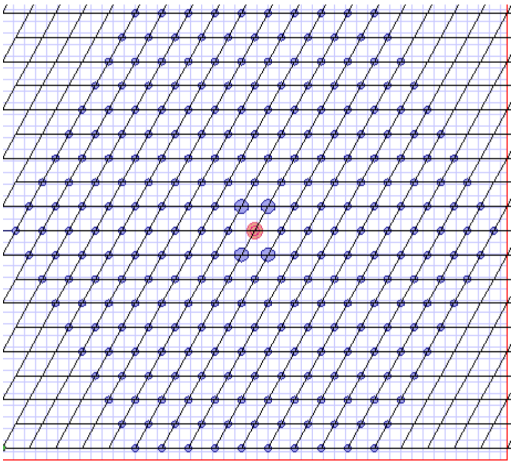

Fig 1 Layout design 1 with circular air holes asymmetry (d_1= 1.2 µm).

The result shows that by introducing asymmetry near core region and also by changing the shape of air holes, refractive index difference increases and high birefringence can be achieved.

The result shows that when diameter and shape of air hole changes, high birefringence can be achieved at operating wavelength 1.55µm.

Now we introduce asymmetry by using two different sizes of elliptical air holes in figure 2. In first ring enlarge elliptical air holes of major radius $a_1 = 0.8$ µm, minor radius $b_1 = 1.0$ µm&in second ring smaller elliptical air holes of major radius a_2= 0.8 µm., minor radius $b_2 = 0.6$ µm are introduced.

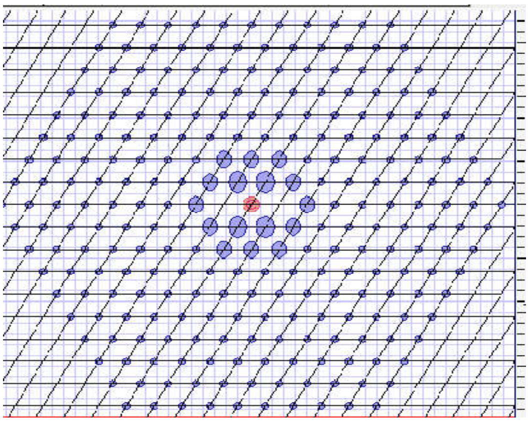

Fig 2 Layout design 2 with elliptical air holes asymmetry

Now by increasing the no. of elliptical holes in third ring to introduce asymmetry in design 3 and also increase the refractive index difference between core and cladding. The highest birefringence of $1.4*10^{-3}$ have achieved.

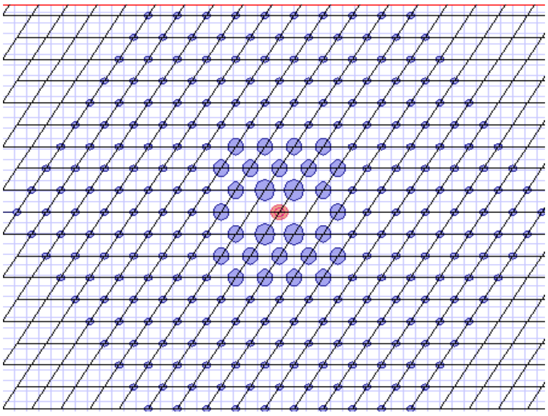

Fig 3 Layout design 3 with increased no. of elliptical air holes asymmetry

Simulation Results

Table 1 Design Parameters of Simulation

Parameter	Design 1	Design 2	Design 3
Cladding air holes µm	d = 0.6	d = 0.6	d = 0.6
Enlarge Circular air holes for asymmetry in µm	d1=1.2		
Inner 4 enlarge elliptical air holes in µm (In first ring)		a_1= 0.8 b_1= 1	a_1=0.8 b_1= 1
Outer enlarge elliptical air holesin µm		a_2= 0.6 b_2=0.8 (In second Ring)	a_2= 0.6 b_2=0.8 (In second & third ring)
Pitch µm	2.4	2.4	2.4
No. of rings	9	9	9

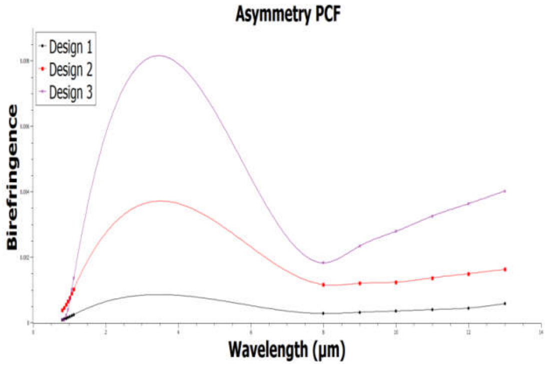

Figure 4 Birefringence Vs wavelength with circular & elliptical air hole asymmetry

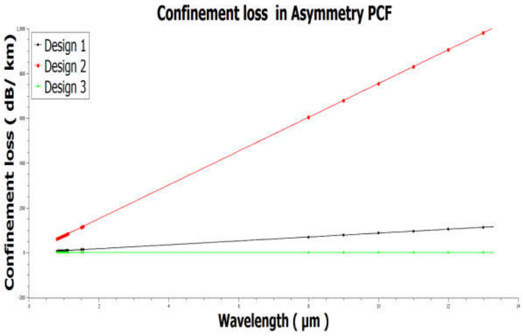

Figure 5 Confinement loss Vs wavelength with circular & elliptical air hole asymmetry.

This result shows that by introducing asymmetry using elliptical air holes in near core region, we can achieve high birefringence. We have also compared confinement loss in circular air holes asymmetry and elliptical air hole asymmetry. This result shows that confinement loss in elliptical air holes asymmetry is very less at operating wavelength of 1.55µm with comparison to circular air holes asymmetry.

CONCLUSION

In this paper confinement loss and birefringence for asymmetry structure are modeled and simulated using a full-vector Finite element method with an-isotropic perfectly matched boundary layer. If we introduced elliptical asymmetry in near core region, high birefringence can be achieved. The highest birefringence obtained at the excitation wavelength 1550nmis $1.4*10^{-3}$ with lowest confinement loss of $-8.1*10^{-6}$ dB/km**.** Therefore, these properties of high birefringence, low confinement and single mode operation are combined in the improved PCF perfectly. These PCFs will have important in laser and other sensor applications.High birefringence PCF is used where light have to maintain linear polarisation. Further work can be extended by controlling the parameters and working at different operating frequency.

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