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Analysis of Honeycomb PCF with Elliptical Holes

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Abstract: In this paper a new design of elliptical air hole silica with honeycomb Photonic crystal fiber is proposed for high birefringence and flattened negative dispersion. Here core defect is produced by manipulating the cladding region rather than core region itself. A Full Vector Finite Difference Time Domain Method (FV-FDTD) analysis with Transparent Boundary Condition (TBC) applied to investigate characteristics of Photonic Crystal Fiber (PCF) through numerical simulation and optimizing the geometrical parameters. High birefringence of $6.0*10^{-3}$ and Better flattened negative dispersion at higher wavelength above 1.4 μm can be achieved by changing the orientation of elliptical holes.

Key Words: Finite Difference Time Domain Method (FDTD),Photonic Crystal Fiber (PCF), ,Transparent Boundary Condition (TBC)

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I. INTRODUCTION

Photonic crystal fiber have diverse applications in telecommunication, super continuum generation, sensors, lasers and medical instrumentation.In conventional PCF to reduce confinement loss and dispersion is very difficult due to uniformity of air holes. By using honeycomb cladding arrangements of the air-holeswith the core defect formed byremoving or adding an additional air-hole in the lattice, a nearly-zero flattened or highly negativedispersion curve over large wavelength can be achieved. An improved photonic band gap (PBG) effect in honeycomb structure in telecom window and lower air filling fraction makes fiber fabrication and splicing strong compared to triangular holey fiber.The air filling fraction is definedas total area of air holes in unit cell relative to total unit cell area.

Honey comb structure have been proven superior to triangular structure with respect to broader PBGs in case of same air filling fraction. Index guiding fibers allow accurate control of dispersion that can result single mode transmission fiber for wide range of wavelength, very short wavelength to micrometers.Thus flattened symmetry can lead to long range transmission without chromatic dispersion.

Neils Asger Mortensen and Martin Dybendal Nielsen,**Jacob Riss folkenberg, et al** In this paper, it is experimentally demonstrated,how index guiding silica core can be formed by fluorine doping of honey comb lattice.[1] **S.S.Misha and Vinod kumar singh** In this paper, hollow core honey comb PCF are analyzed by using Full Vector Finite Element Method (FV-FEM). In hollow core honey comb PCF by removing 6 air holes in cladding region, low confinement loss of $0.1*10^{-4}$ is achieved at wavelength of 1.55 μm.[2] **Jingyuan wang,chun jiang et al** proposed a high birefringence photonic band gap fiber with elliptical holes in cladding and circular air hole in core. In result it is found the high birefringence of 10^{-3} order higher than conventional PCF.[3]

II. PPROPERTIES

Optical Properties Of Improved PCF: The modal birefringence, leakage losses and dispersion 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

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

Birefringence

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

$$B = \left| n_{eff}^{y} - n_{eff}^{x} \right| \quad (2)$$

Where Re denotes the real part, ʎ 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]

Dispersion

Material dispersion in fiber is proportional to the operating wavelength and second order derivative of refractive index.

$$D = -\frac{\lambda}{C}\frac{\partial^2 neff}{\partial \lambda^2} \quad (3)$$

III. DESIGN

The structure of proposed honeycomb index guiding PCF is shown in fig 3. The designed honey comb PCF consists of solid core region with regular array of elliptical air holes running along the length of fiber acting as cladding .The refractive index of core material (silica) is 1.45 and refractive index of air holes in cladding is 1.

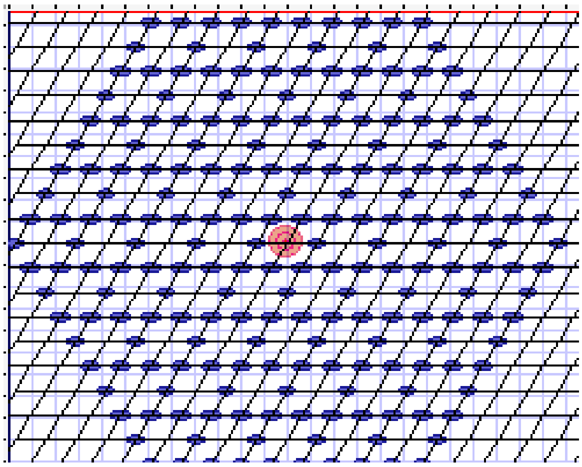

Fig 1: Layout design 1 of Honeycomb structure with with 9 rings of elliptical holes.

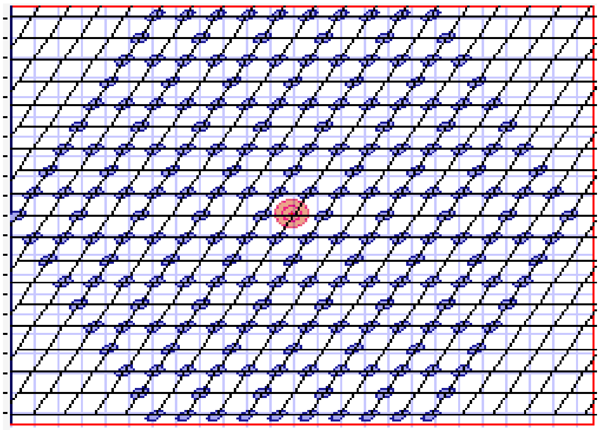

Fig 2: Layout design 2 of Honeycomb structure with 9 rings of elliptical holes 30° orientation.

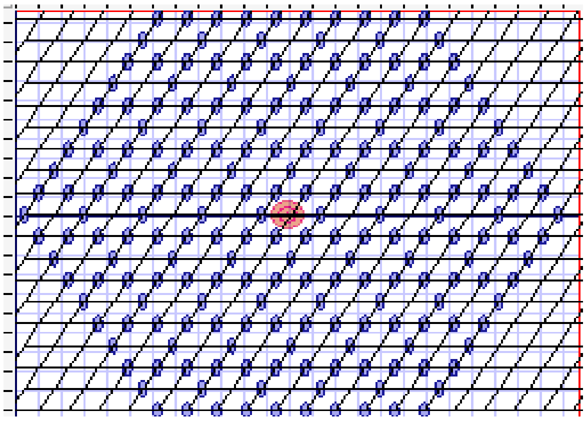

Fig 3: Layout design 3 of Honeycomb structure with 9 rings of elliptical holes 90° orientation

IV. SIMULATION RESULTS

It is analyzed by Full Vector Finite Element Method (FV-FEM).We consider honey comb PCF with three types of orientation of elliptical holes at 0°, 30°, 90° which are Design 1, Design 2, Design 3 for same parameters.

In design 1 the elliptical holes semi major axis a= 0.4 μm, semi minor axis b= 0.2 μm and no. of rings are 9. In design II all elliptical holes have 30 degree orientation with respect to x axis for same parameter. In design III all elliptical holes have 90 degree orientation with respect to x axis for same parameter.

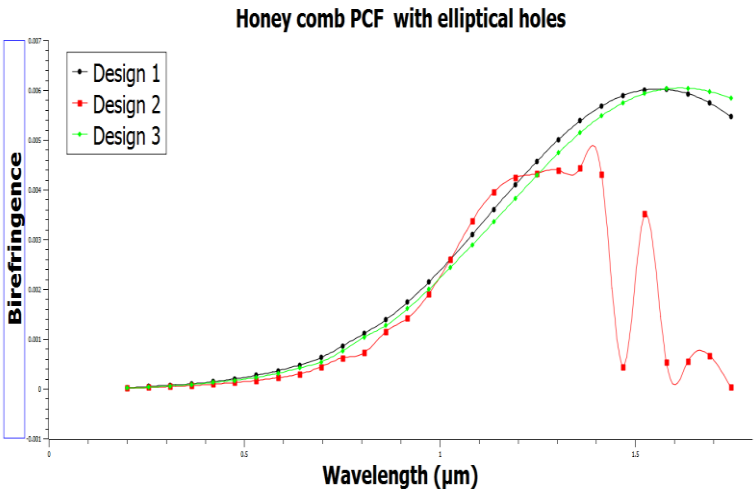

Fig. 4: Birefringence Vs wavelength with elliptical air holes.

Table 1: Design Parameters for Simulation

Parameter	Design 1	Design 2	Design 3
Elliptical air holes in μm	a= 4 b= 2	a= 4 b= 2	a= 4 b= 2
Orientation of elliptical air holes in degree	0°	30°	90°
Pitch in μm	1.3	1.3	1.3
No. of rings	9	9	9

Birefringence dependence on wavelength shown in fig 4. It is analyzed that high birefringence achieved by changing the orientation of elliptical holes and at 90° highest birefringence of $6.0*10^{-3}$

achieved.Confinement loss dependence on wavelength shown in fig 5. It is also observed that low confinement loss of 0.024 dB/km achieved at 90° orientation of elliptical holes. Dispersion dependence on wavelength shown in fig 6. It is analyzed that flattened negative dispersion can be achieved by using elliptical air holes with different orientation. Better flattened negative dispersion can be achieved at higher wavelength above 1.4 μm.

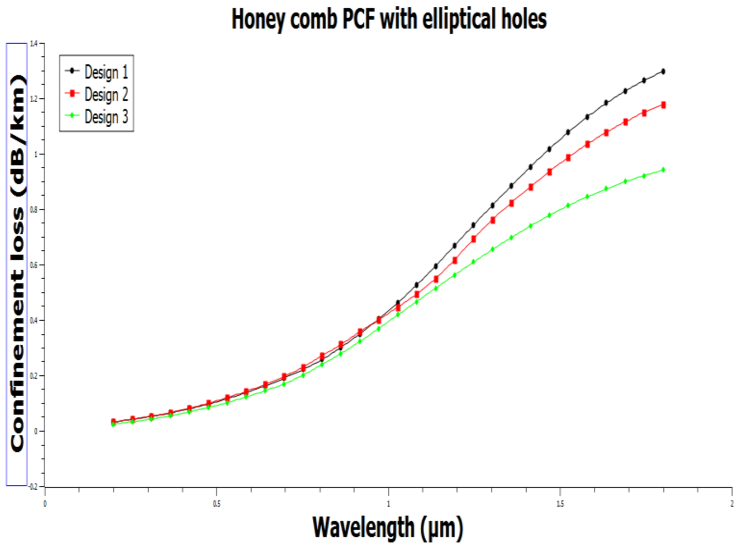

Fig.5 : Confinement loss Vs wavelength with elliptical air holes

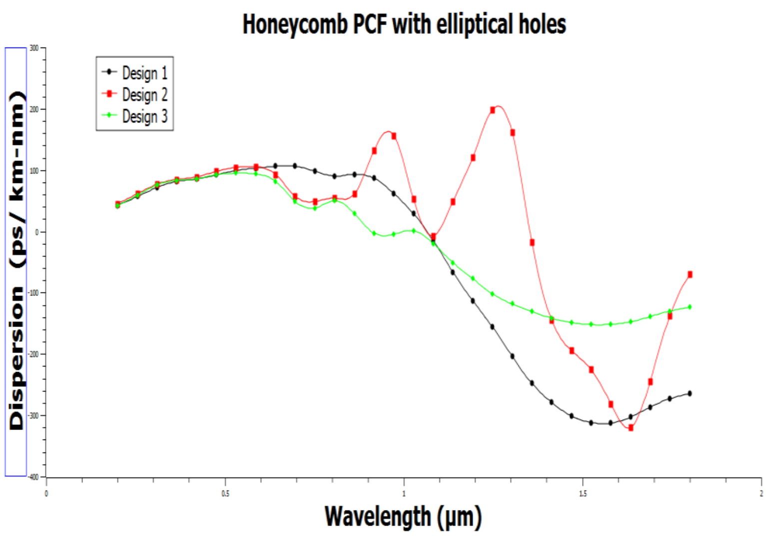

Fig. 6: Dispersion with elliptical air holes

V. CONCLUSION

In this paper honeycomb index guiding PCF with elliptical holes are proposed. By changing the orientation of elliptical holes from 0° to90 ° with respect to x axis, high value of birefringence $6.0*10^{-3}$, low confinement loss 0.024 dB/km and Better flattened negative dispersion can be achieved at higher wavelength above 1.4μm achieved at 90°.This kind of Honey comb PCF may be suitable for sensors, lasers, telecommunications and medical instrumentation.

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