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"Hexagonal Lattice Photonic Crystal Fiber with Low Confinement Loss and Low Chromatic Dispersion"

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Abstract: In this paper, We design a novel Hexagonal Lattice photonic crystal fiber (PCF) made of soft glass achieving low confinement loss and low chromatic dispersion through the optimization of the arrangement and diameter of circular air holes. The motivation behind this is to optimize the design parameter of PCF to gain low-flattened chromatic dispersion and low confinement loss at wide wavelength range. This new design of PCF having low-flattened chromatic dispersion and low confinement loss in wide wavelength range is demonstrated by carefully adjusting the air holes in each rings, air holes dimensions and spacing between air holes or pitch. 2-D finite difference time domain (FDTD) method is used for the analysis of this PCF
Keywords: Photonic crystal fibre (PCF), FDTD method, dispersion, confinement loss

I. INTRODUCTION

Optical Fibers have brought a great revolution in the field of Communication as they have provided better quality and good properties of the signal. But they also had limitations with respect to losses, dispersion and non linearity.

Photonic-crystal fiber (PCF) is a new class of optical fiber based on the properties of photonic crystals. Because of its ability to confine light in hollow cores or with confinement characteristics not possible in conventional optical fiber. Photonic crystal fibers (PCFs) were first demonstrated in 1996 and have attracted much attention in recent years regarding new optical fiber applications [4]. The most important property of PCF are that they can possess dispersion properties that are significantly different from those of conventional optical fibres, because their cladding portion consist of micrometer size air holes that run parallel along the length of the fibrer.

PCFs provide confinement and guidance of light in a defect region around the centre as they are single-material fibers with an arrangement of air holes running along the length of the fiber. For the light confinement mechanism, index guiding PCFs rely on total internal reflection to confine light in the region of a missing air hole forming a central core.

PCF is now finding applications in fiber-optic communications, fiber lasers, nonlinear devices, high-power transmission, highly sensitive gas sensors, and other areas. Photonic crystal fibers may be considered a subgroup of a more general class of microstructured optical fibers, where light is guided by structural modifications, and not only by refractive index differences.

Several methods are used for the analysis of PCFs each having its own advantages and disadvantages. In this work, the FDTD method is used to find characteristics of PCFs.

Confinement loss (CL), including cladding material losses, is comprehensively evaluated for TE and TM modes of photonic crystal fibers. However, confinement loss can significantly degrade the performance of devices based on such small core fibers. We also identify a range of fiber designs that result in high fiber nonlinearity and low confinement loss.

In this paper we have tried to study confinement loss by proposing the four rings of circular shape of holes having the radius of 0.8um with lattice pitch of 2.3um and simultaneously we have also tried to study the dispersion characteristics and tried to confine it to nearly zero dispersion. PCFs can have a significantly larger numerical aperture than conventional fiber types because the cladding region can be mostly comprised of air. When this is combined with a wavelength-scale core, PCFs can provide tight mode confinement (i.e., small values of the effective mode

II. Design Of Pcf Having Circular Shape Of Holes

In this paper we have used Opti FDTD to analyze various properties like dispersion and confinement loss of variable Photonic Crystal Fibers of circular shape of hole size of the radius 0.8um.

1.1Hexagonal lattice structure of PCF: PCF can realize endlessly single-mode operation, flexible Chromatic dispersion over a wide wavelength range, large effective area, controllable nonlinearity, ultralow loss and high group birefringence. PCFs provide confinement and guidance of light in a defect region around the centre as they are single-material fibers with an arrangement of air holes running along the length of the fiber [6]. For the light confinement mechanism, index guiding PCFs rely on total internal reflection to confine light in the region of a missing air hole forming a central core.

The proposed PCF have four air holes rings in cladding with solid core [6]. Where the each air holes of the rings are in circular shape with major axis (a) equal to 0.8μm and minor axis (b) equal to 0.8μm. The spacing between the adjacent air holes or pitch, Λ is equals to 2.3μm. The lattice structure for the proposed PCF is hexagonal. The transverse cross section for proposed PCF is shown in figure 1.

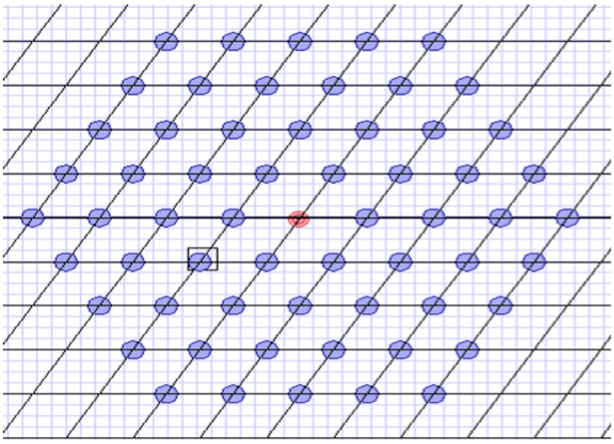


Figure1: Hexagonal Lattice Structure of the PCF having circular shape of holes with (i) radius of 0.8 um and (ii)lattice pitch Λ=2.3um

1.2 Simulation results:

1.2.1 Effective refractive index: Fig. 2 shows the effective refractive index of the photonic crystal fiber having circular shape of holes in it having the radius of 0.8 um and lattice pitch Λ is 2.3 um.

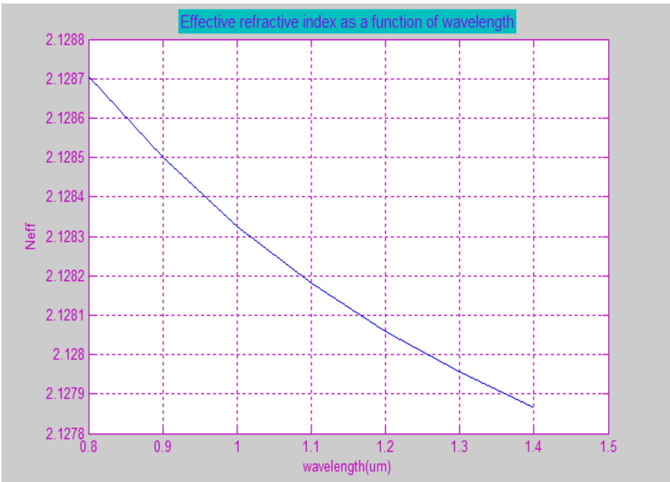


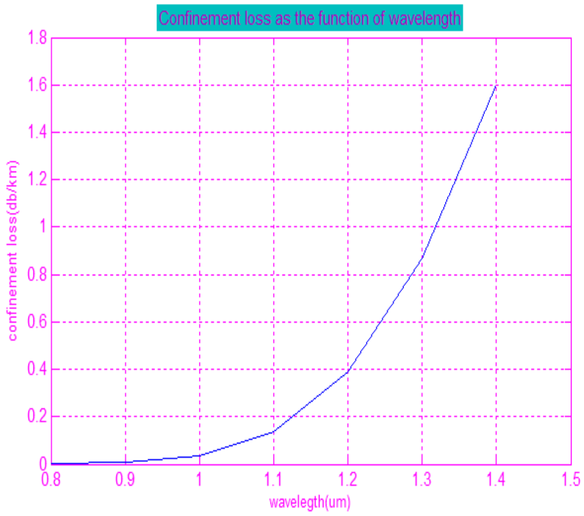
Figure 2: Effective refractive index of a PCF having circular shape of holes as a function of wavelength

1.2.2 Confinement loss:

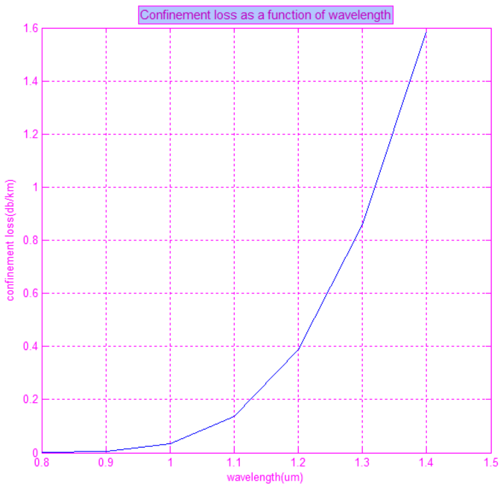
The jacket of the fiber is far from cladding and core area, propagation of the light in the core area is due to a finite number of layers of air holes in bulk silica extending to infinity. Due to the fixed number of layers of air holes, leaking of the light from the core to the exterior matrix material takes place through the bridges between air holes, resulting in confinement loss. The confinement loss is calculated from the imaginary part (Im) of the complex effective index, using the following equation:

$$CL= 8686(2\pi/\Lambda).Im(n_{eff})\ dB/km \quad (1)$$

The field confinement and its decay rate have a fundamental role in the leakage properties [9]. Confinement loss (CL), including cladding material losses, is comprehensively evaluated for TE and TM mode as shown in figure 3 for the photonic crystal fiber having circular shape of holes.



(a)



(b)

Figure 3:Confinement loss of PCF having circular shape of holes for (a)TE mode (b) TM mode

Table 1 gives the values of confinement loss for TE and TM mode respectively for the fiber having circular shape of holes having diameter of 1.8um.

CONFINEMENT LOSS (db/km)		
WAVELENGTH(um)	For TE mode	For TM mode
0.8	0.002045553	0.000681851
0.9	0.007273077	0.006060898
1	0.036001733	0.034910771
1.1	0.138849658	0.136866092
1.2	0.391837041	0.387745935
1.3	0.867734073	0.85892246
1.4	1.600596519	1.586180241

Table 1:Confinement loss calculation for the PCF having circular shape of holes

1.2.3 Dispersion:

In optics, dispersion is the phenomenon in which the phase velocity of a wave depends on its frequency. Dispersion is given by the following formula:

$$D=-\lambda/c.d^2n_{eff}/d\lambda^2 \quad (2)$$

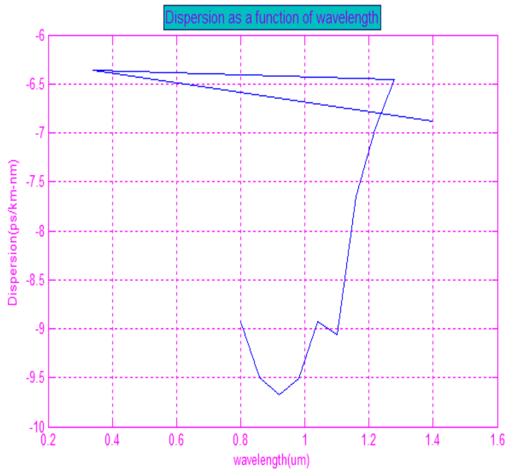


Figure 3:Dispersion of PCF having circular shape of holes as a function of wavelength

Table 2 gives the values of Dispersion of the PCF having circular shape of holes having diameter of 1.6um.

DISPERSION(PS/NS-KM)	
WAVELENGTH(um)	**Dispersion**
0.8	109.6426667
0.85	108.3160667
0.9	106.7691
0.95	104.90185
1	102.566
1.05	99.56625
1.1	95.6604
1.15	90.55905
1.2	83.9248
1.25	75.37375
1.3	64.47436667

Table 2: Dispersion calculation for PCF having circular shape of holes

III. CONCLUSIONS

Photonic crystal fibers can be divided into two modes of operation, according to their mechanism for confinement. Those with a solid core, or a core with a higher average index than the micro structured cladding, can operate on the same index-guiding principle as conventional optical fiber — however, they can have a much higher effective refractive index contrast between core and cladding, and therefore can have much stronger confinement for applications in nonlinear optical devices, polarization-maintaining fibers. In this paper we have designed the fiber having circular shape of holes having same diameter is showing the lowest confinement loss and hence the best design proposed is this one. We can also propose in future a design having less confinement loss by changing the shape of the holes like square or rectangular. Fabrication of the proposed PCFs is believed to be possible with a high feasibility and is not beyond the realm of today's existing PCF technology.

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