Improved Large Mode Area High Birefringence Photonic Crystal Fiber With Flattened Dispersion

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Abstract: In this paper improved large mode area high birefringence photonic crystal fiber with single mode is proposed.The conventional single mode fiber suffer from limited output power due to small core diameter about 8 μm to 10 μm.This short coming can be overcome by using currently photonic crystal fiber of large mode area high birefringence with single mode .These properties provide scaling potential for fiber laser and amplifier systems.This type of fiber gives higher output power. The LMA 7-rod core fibers are obtained by removing the air-holes belonging to the first ring and the central one in the fiber cross-section. The 7-rod core photonic crystal fibers can provide high effective area values and single mode operation by properly choosing low air filling fraction and relatively small hole to hole distance. In this paper we compare the dispersion ,confinement loss and birefringence of 7-rod core photonic crystal fibers with 1-rod core.

Key words: *Photonic Crystal Fiber (PCF), Finite difference time domain (FDTD),*Large mode area(LMA),*confinement loss, Birefringence.*

I. INTRODUCTION

In recent years fiber lasers have much attracted. The photonic crystal fiber has many unique properties, such as low non linearity,endlessly single mode operation, Large Mode Area (LMA),and high birefringence.These properties provide scaling potential for fiber laser and amplifier systems.This type of fiber gives higher output power. For high power optical beam, effective area of optical fiber is limited by increasing core size.The 7-rod core fibers can be designed by removing first air holes ring. It requires a corresponding decreasing index step between the core and cladding. It is applicable to high power laser with very large mode area in single mode. An all silica PCF with different ratio of hole diameter to pitch d/Λ was studied in this paper.It is shown from numerical results that we can design low loss, high birefringence LMA in single mode. Previous research works on the cutoff properties of the 1-rod core triangular PCFs have shown that their ESM region is defined by d/Λ < 0.406.

By reducing the diameter of air-holes for a fixed pitch or by increasing the pitch for a constant d/Λ value, it is possible that PCF effective area can be increased. But because of the losses, there is an upper limit on the guided mode area. Thus it is seen that by the decreasing the air-filling fraction, the leakage losses can be increased.

All these problems can be removed by using LMA with 7-rod core. It is seen in results that for a constant d/Λ, the value of single mode region in 7-rod core PCFs is less than traditional triangular fibers. The region of single mode for the 1-rod core PFC is, d/Λ < 0.406 and it is,d/Λ < 0.035 for larger mode area.

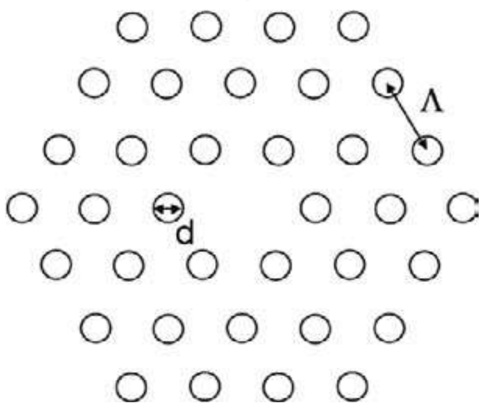

Fig.1 Triangular PCF with 1-rod core

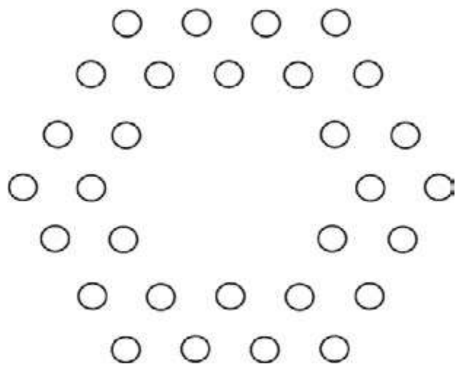

Fig. 2 Triangular PCF with 7-rod core

II. ANALYSIS

All the analyses of PCF properties have been done by using OPTI FDTD8.0.This method 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. For this it is necessary to work in single mode operation and PCF is operated close to cutoff where V= Π, the V parameter can be written

$$V = 2\Pi\Lambda / \lambda \left(\sqrt{n_{eff}^{2} - n_{FSM}^{2}} \right) \quad (1)$$

Where $n_{eff.}$ and n_{FSM} are effective indices respectively. FSM is the fundamental guided mode of fundamental space filling. The Λ is air hole pitch that choices as the effective core radius for the PCF. For a single mode operation, the resulting curves of normalized frequency V against Λ/ƛ for various hole sizes and hole pitches, value of V in PCF is lower than Π.(4)

Optical Properties Of Improved PCF: The chromatic dispersion, modal birefringence and leakage losses can be determined by following formulas:

$$L = 8.686 * I_m \left[k_o n_{eff} \right] * 10^{3} \quad (2)$$

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

$$B = \left| n_{eff}^{y} - n_{eff}^{x} \right| \quad (4)$$

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

III. DESIGN MODEL

The proposed PCF is made of pure silica and has a circular array of air holes running along its length.This is index guiding PCF. For designing large area 7 rod PCF, first ring of air holes is removed.The total no. of air holes rings are nine.

We have worked on two designs with **d/Λ=0.4**

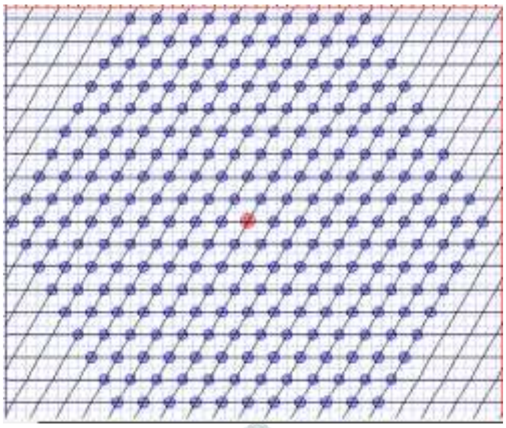

Figure 3: Layout of one rod PCF

The figure 3 shows the layout for the 1-rod core with 9 rings. Here ʎ= 1.55 µm , d=1.0µm, Λ= 2.5µm. Similar layouts have been made for 7-rod core with 9 rings.

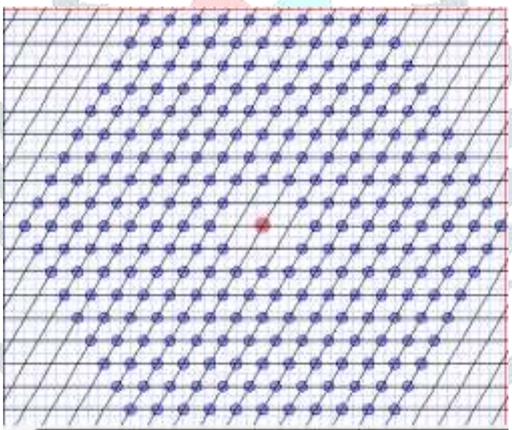

Figure 4: Layout of of seven rod PCF

IV. SIMULATION RESULTS

Comparison is done for properties of the birefringence, dispersion, confinement loss in 1-rod core fibers and 7-rod core fibers. By increasing the no. of air holes in fiber, dispersion can be reduces. Large dimensions of the core are helpful for flat graphs in dispersion. The dispersion decreases with increase in the air-hole rings. As the air filling fraction increases, the dispersion also increase.

The increase of air hole rings leads confinement of light in core region, due to this, there is smaller losses than those with less air hole rings. By increasing the air holes diameter, we can increase air filling fraction and losses can be decreased.

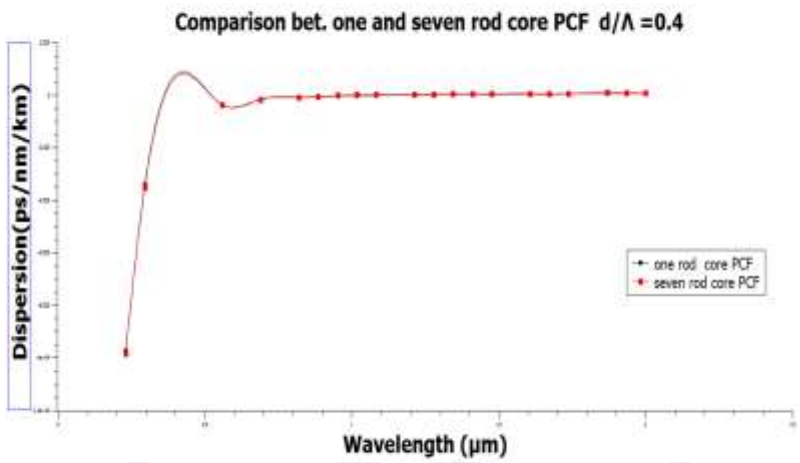

Figure 5: Comparison between one rod and seven rod PCF d/Λ=0.4

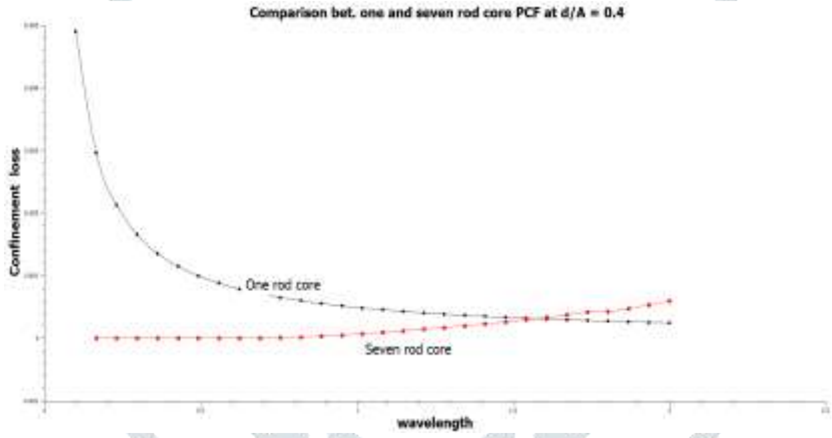

Figure 6: Comparison between one rod and seven rod PCF d/Λ=0.4

As we can see from the figure above that the value of confinement loss decreases for large mode area fibers.

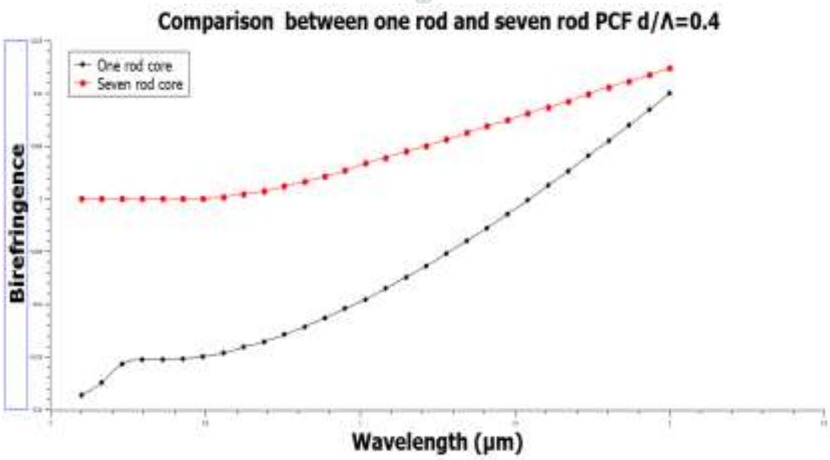

Figure 7: Comparison between one rod and seven rod PCF d/Λ=0.4

As we can see from the above figure that the value of birefringence increases for large mode area fibers.

By reducing the d/Λ, four designs with d/Λ=0.27 & 0.25 for one rod core and seven rod core

We decrease ratio of d/Λ to 0.27 and 0.25 by decreasing the value of pitch and diameter. Here we take Λ= 2.3 and d= 0.60 and 0.65.

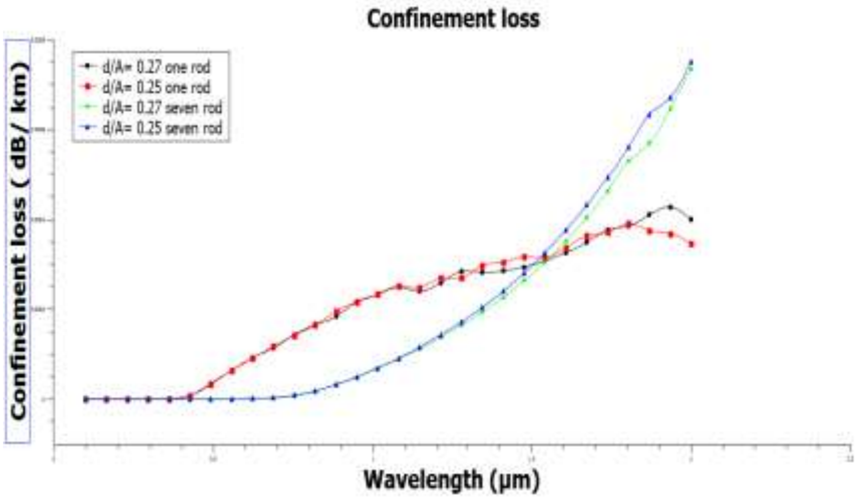

Figure 8: Comparison between one rod and seven rod PCF for different d/Λ

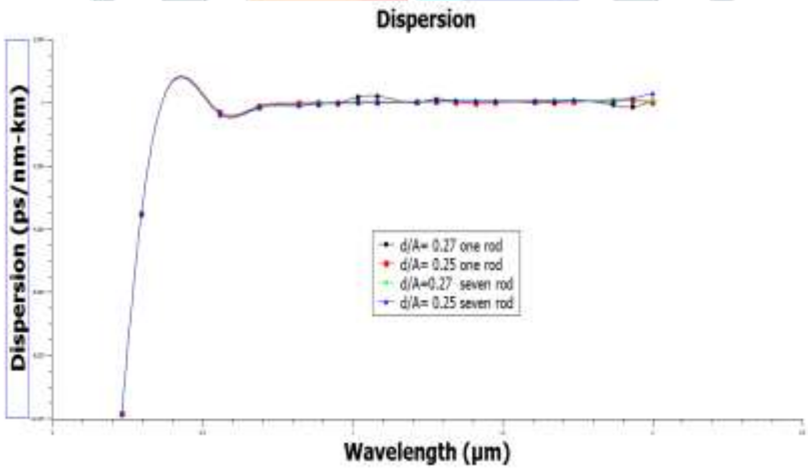

Figure 9: Comparison between one rod and seven rod PCF for different d/Λ

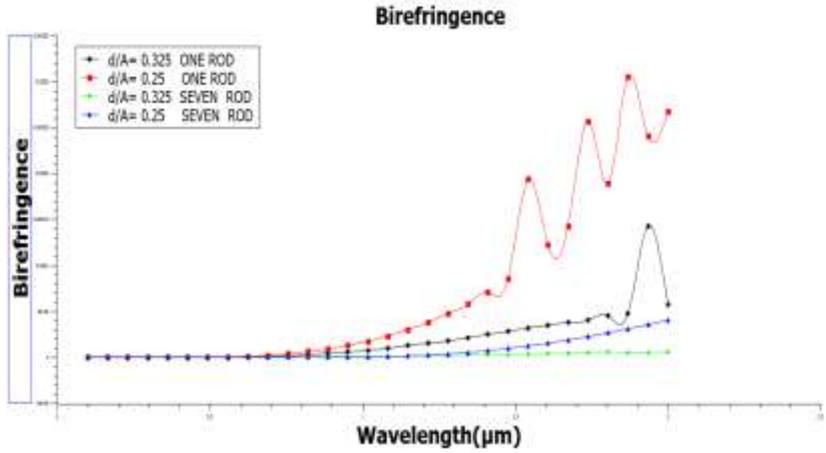

Figure 10: Comparison between one rod and seven rod PCF for different d/Λ.

As we can see from above figure that by decreasing the value of d/Λ confinement loss can be much reduced in seven rod core but there is minor change in dispersion & birefringence. Since there is a trade off between ultrahigh birefringence and low confinement loss.By increasing the number of air hole rings ultra low confinement losses can be achieved with negligible reduction in birefringence.

V. CONCLUSION

It has been found that when the dimensions of the core are increased almost flat graphs for dispersion are obtained. Thus 7-rod core fibers act as a better dispersion compensation fibers.We also see that in seven rod core confinement loss is low and birefringence is very high with respect to single rod fiber. It is shown from our numerical results that it is possible to design a low loss & high birefringence PCF with LMA at 1.55μm. We believe that our proposed design is useful for laser application.

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