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Evaluation of Confinement Loss of Different Photonic Crystal Fibers on the Basis of Varying the Size and Shape of Holes

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Abstract **- 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.PCF is now finding applications in fiber-optic communications, fiber lasers, nonlinear devices, high-power transmission, highly sensitive gas sensors, and other areas.**

In this paper we design the hexagonal PCFs having circular and elliptical shape of holes and evaluate their confinement loss and chromatic dispersion and compare them.

Confinement loss is the loss which should be minimized so that the information to be transmitted is confined in the centre and it should not be dispersed. The confinement loss can be calculated on basis of the diameter, pitch and shape of holes. FDTD method is used for analyzing the losses.

Keywords: Photonic crystal fibre (PCF), FDTD method, dispersion, confinement loss

1. INTRODUCTION

The first Photonic crystal fibers (PCFs) in 1996 and have attracted much attention in recent years regarding new optical fiber applications [1]. 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 fibre. Photonic crystal fibers may be considered a subgroup of a more general class of microstructure 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.

2. VARIOUS DESIGNS OF PCF TO REDUCE CONFINEMENT LOSS

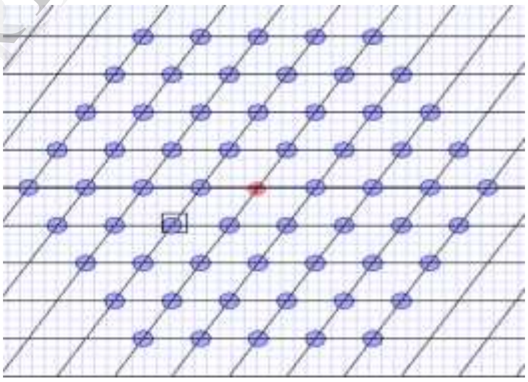
In this we have started with the basic shape that is hexagonal and the shape is being taken circular. Refractive Index is being taken to be n=1.45, pitch (distance between the cells) ʌ equal to 2.3μm and wavelength λ =1.55μm.Various designs have been taken into consideration and starting from the first design in which d = 1.6μm and hence r = 0.8μm and then the values of confinement loss and dispersion have been calculated starting from λ=0.8μm to λ=1.5μm.

In this paper we are designing the fibers by:

(i) Varying the Number of Rings of Holes
(ii) By Mixing the Elliptical Shape of Holes
(iii) Varying the Size of Holes

2.1 Varying the number of rings of holes:

2.1.1 Design-1

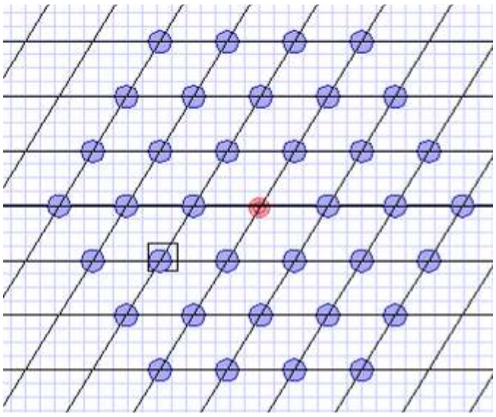


(a)

(b)

Figure 1: a) PCF with d1=d2=d3=d4=0.8μm b) Graph for Refractive Index versus Wavelength

2.1.2 Design-2



(a)

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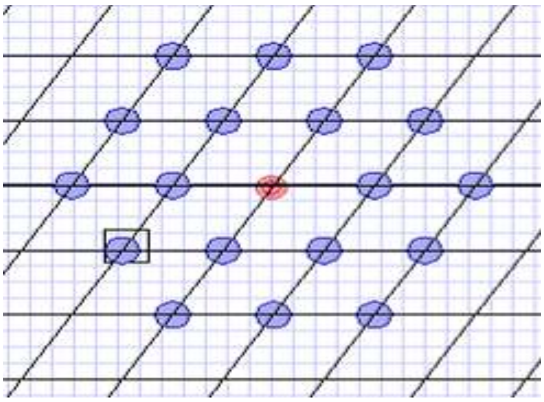
Figure 2: a) PCF with d1=d2=d3=0.8µm b) Graph for Refractive Index versus Wavelength

2.1.3 Design-3



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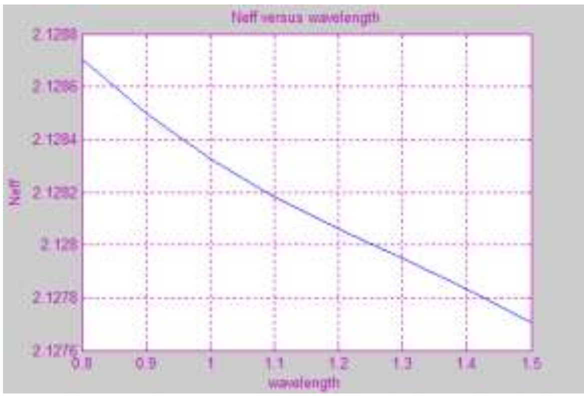


(b)

Figure 3: a) PCF with d1=d2=0.8µm b) Graph for Refractive Index versus Wavelength

Here we are starting from the first design in which d= 0.8µm and hence r = 0.4µm and when d/∧ calculated it comes out to be equal to 0.347 which is common for all the three designs. At λ=1.55µm the variation in refractive index and confinement loss for all the three designs are given below.

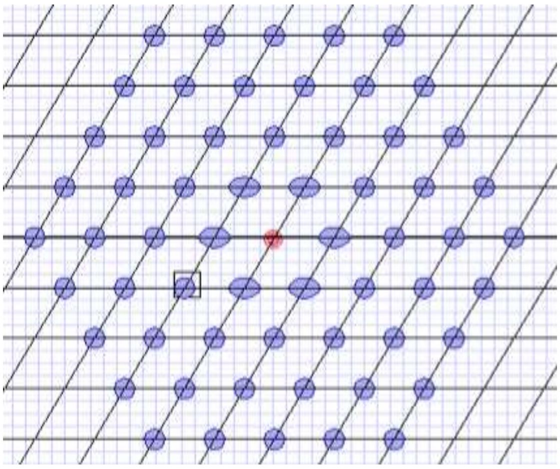
Table 1: Variation in Neff and Confinement loss for design 1,2 ,3

Design	Neff	Confinement loss	
		TE	TM
1	2.127704034	0.417838293	0.413474446
2	2.128127083	0.209100973	0.205828089
3	2.127704049	0.417838293	0.413474446

Here the design of PCF is started by taking the four rings of circular holes then in second design the number of rings is decreased by one and in third it is of two rings of holes. The refractive index for the respective designs comes out to be 2.127704, 2.128127, 2.127704.while confinement loss is equal to 0.41783829, 0.20910097, 0.41783829 respectively for TE mode and 0.413474446, 0.205828089, 0.413474446 respectively for TM mode at λ=1.5µm. Here the values of confinement loss have been calculated starting from λ=0.8µm to λ=1.5µm. So by varying the number of rings it can be concluded that for the first and third design the confinement loss is equal but it is decreased in second design.

2.2 By mixing the elliptical shape of holes

2.2.1 Design-4



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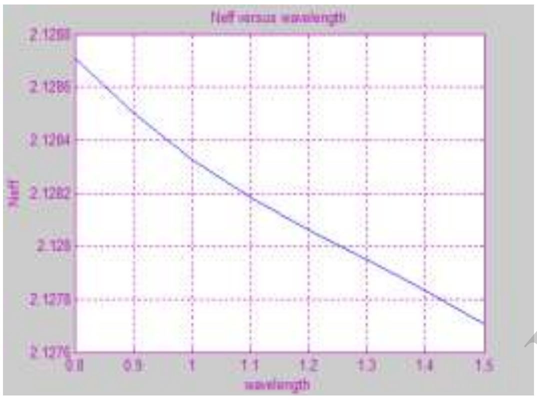
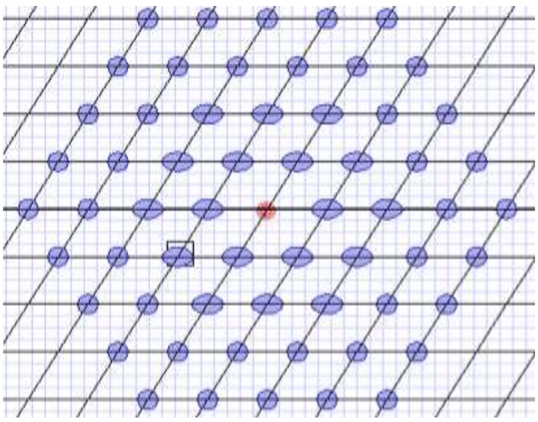


(b)

Figure 4: a) PCF with d1=(a=0.6um, b=0.4um),d2=d3=d4=0.8μm b) Graph for Refractive Index versus Wavelength

2.2.2 Design-5



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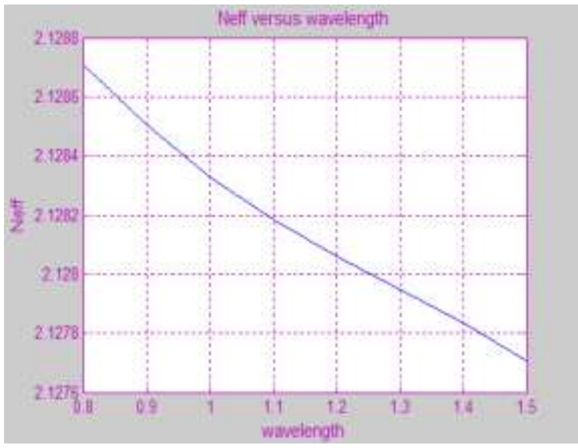


(b)

Figure 5: a) PCF with d1=d2=(a=0.6um,b=0.4um),d3=d4=0.8μm b) Graph for Refractive Index versus Wavelength

Here we are replacing the inner most layer with elliptical shape of holes in design 4 and in design 5 we are replacing the innermost two rings of elliptical shape of holes. The variation in Refractive index and in confinement loss is given below:

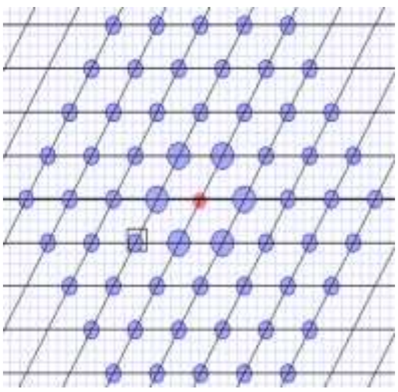
Table 2: values of Effective refractive index and minimum confinement loss for design 4 and 5

Design	Neff	Confinement loss	
		TE	TM
4	2.127704355	0.417838293	0.413474446
5	2.128556564	0.097459236	0.094913659

The refractive index for the respective designs comes out to be 2.127704355, 2.128556564.while confinement loss is equal to 0.41783829, 0.097459236 respectively for TE mode and 0 0.413474446, 0.094913659 respectively for TM mode at λ=1.5μm. By replacing the inner rings by elliptical shape of holes it can be concluded that the confinement loss is less in design 5 than in design 4.

2.3 Varying the Size Of Holes

2.3.1 Design-6



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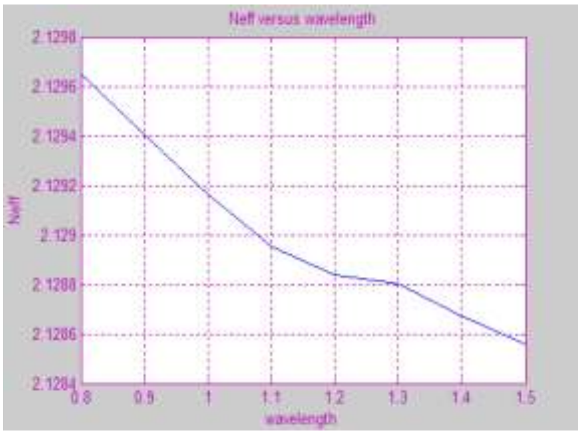
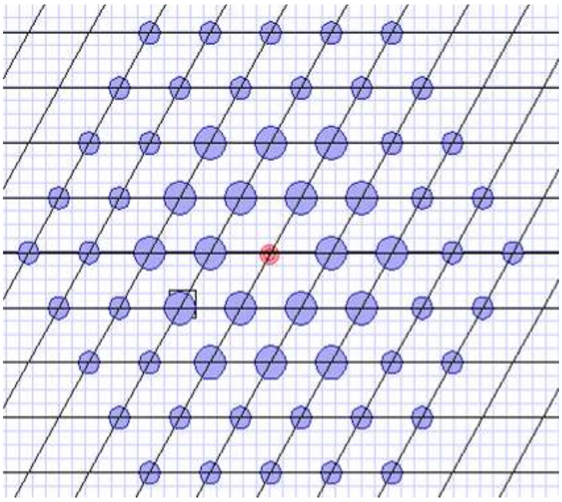


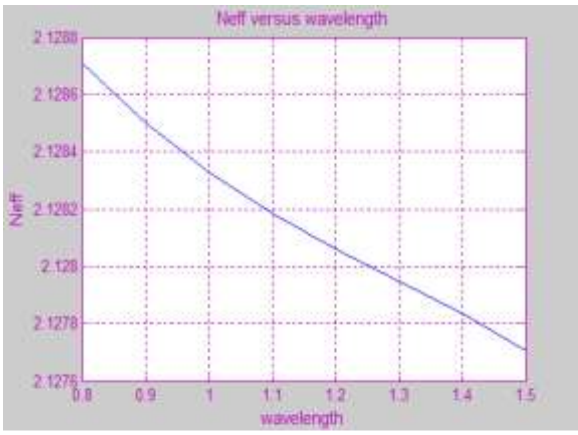
(b)

Figure 6: a) PCF with d1=1.2um,d2=d3=d4=0.8μm b) Graph for Refractive Index versus Wavelength

DESIGN-7



(a)



(b)

Figure 7: a) PCF with d1=d2=1.2um,d3=d4=0.8μm b) Graph for Refractive Index versus Wavelength

Here we are increasing the radius of the holes in the inner most layer design 6 and in design 7 the radius of inner two rings of holes is increased. The variation in Refractive index and in confinement loss is given below:

Table 3: values of Effective refractive index and minimum confinement loss for design 6 and 7

Design	Neff	Confinement loss	
		TE	TM
6	2.127704064	0.417838293	0.413474446
7	2.127704603	0.417838293	0.413474446

The refractive index for the respective designs comes out to be 2.127704064, 2.127704603 while confinement loss is equal to 0.417838293 for both of the designs for TE mode and 0.413474446 for both of the designs for TM mode at λ=1.5μm. By increasing the size of holes in inner rings it can be concluded that the confinement loss is same for both of the designs 6 and 7.

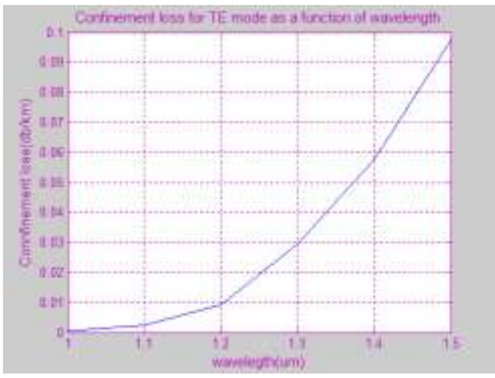
3. CONFINEMENT LOSS:

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:

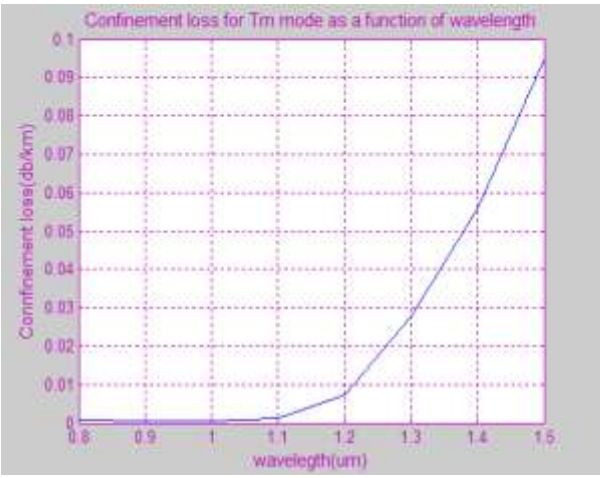
$$CL = 8686(2\pi/\lambda).Im(neff)\ dB/km$$

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.

Here the minimum confinement loss is found in design 5 so the confinement loss for TE and TM mode for design 5 is shown as below:



(a)



(b)

Fig 8: (a) Confinement loss for TE mode as a fumction of wavelength (b) Confinement loss for TM mode as a function of wavelength

Table4: Confinement loss calculation for the design-5(PCF having 2 inner rings of elliptical shape of holes)

Wavelength	Confinement loss(db/km)	
	TE mode	TM mode
0.8	mode not found	0.000681851
0.9	mode not found	0.00060609
1	0.000545481	0.000545481
1.1	0.002479458	0.000991783
1.2	0.009091347	0.007273077
1.3	0.029372043	0.027693641
1.4	0.057665113	0.055716967
1.5	0.097459236	0.094913659

In the table 4the values of confinement loss is given for the wavelength range starting from 0.8um to 1.5um.

4. CONCLUSIONS

In this paper we have designed various types of fibers and by comparing the different designs the minimum confinement loss is found is 0.097459236 for design 5 which has the two inner rings of elliptical shape of holes in it at the wavelength λ=1.5μm.

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Surbhi Gupta was born in 1990. She has done B Tech. from MIT Kota in 2011 and pursuing M Tech from Arya Institute of Engineering And Technology under the University of Rajasthan Technical University. She has done practicality work on 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.