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Characteristics of Terahertz Photonic crystal fiber using core mode coupling

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Abstract: - ***We propose a Photonic crystal fiber with smaller air hole in the first ring of cladding. Finite element method is used to design and investigate the properties like mode coupling between excited modes and fundamental mode along with effective mode area and dispersion. Almost zero flattened dispersion from 1.3 to 2.0 THz is seen in this model and effective mode area 3.80E-01 mm^2 of HE$_{11}$ fundamental mode at 220 µm is achieved.***
Keywords:-Fiber properties, photonic crystal fiber, Terahertz, mode coupling, dispersion.

I. INTRODUCTION

Photonic crystal fibers (PCF's) are optical Fibers which consist of a central defected core region. They have combining properties of optical fibers and photonic crystals. They possess a series of unique properties impossible to achieve in classical fibers. The design of PCFs is very flexible. There are several parameters to manipulate: pitch, air hole shape and diameter, refractive index of the material and type of lattice etc. Photonic crystal fibers are helpful in making high power delivery systems [1, 2]. In this paper a design is proposed with nearly flattened dispersion and large mode area and analyses of coupling of HE$_{11}$ fundamental mode with other excited modes is done.

II. PROPOSED PCF STRUCTURE AND DESIGN

The PCF structure we proposed is shown in figure1. In a square base we make air holes carrying triangular geometry. We make the diameter of first ring small as compare to other two rings as to provide maximum area for propagation of light to achieve large mode area. PML is also used in this model with proper parameters to make design better. Diameter of first ring near core is 100 µm whereas the other two rings have diameter 200 µm air hole pitch used is 500 µm. Here the diameter to pitch ratio of air holes is about 0.20 for first ring and 0.40 for other two rings.
We use HDPE as material because in terahertz region HDPE has minimum losses and almost zero dispersion. This will help in avoiding absorption loss in PCF. Finite element method (FEM) based software COMSOL MULTYPHYSICS 4.2 is used to study various characteristics for our PCF.

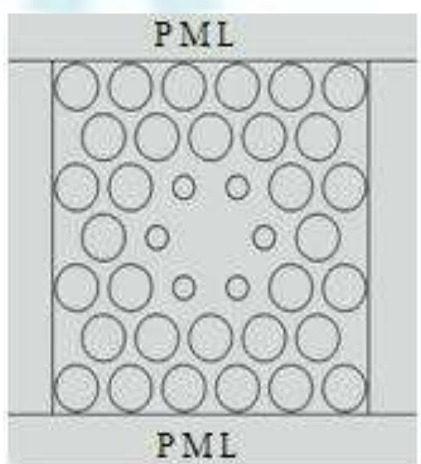

Figure 1: Proposed design of PCF

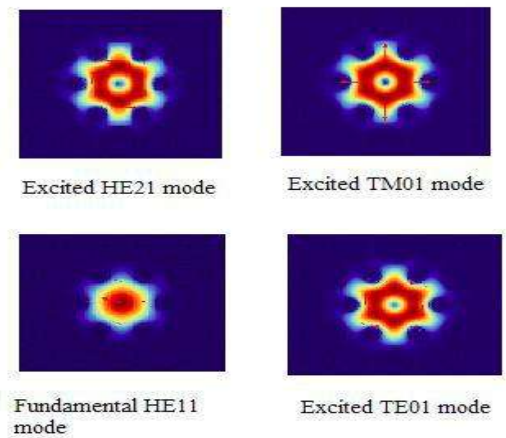

Figure 2: Fundamental and Excited modes.

In this paper we have investigated the four modes i.e. HE_{11} (fundamental mode), TE_{01} , TM_{01} , and HE_{21}.

III. DISPERSION

Dispersion is one of the important parameter for PCF's. Since HDPE has almost zero dispersion in terahertz range, therefore the total dispersion is mainly due to waveguide dispersion. Following formulation is used to calculate dispersion.

$$D = -\frac{\lambda d^2 Re(Neff)}{C\, d\lambda^2} \qquad (1)$$

C = velocity of light, Re (Neff) = Real part of effective refractive index of HE_{11} mode. In this model we get nearly flat dispersion. This type of fiber is useful in communication and transmission. The value for dispersion is 0.085 ps/nm.km for wavelength 150 µm and 0.11 ps/nm.km for wavelength 220 µm. The dispersion is mainly dependent on the air holes nearest to the core and act as cladding. In our model we achieve flat dispersion by optimizing the radius of the first ring nearest to the core by making it smaller as compared to the other rings. Figure 3 shows the variation of dispersion with different wavelength values for HE_{11} mode.

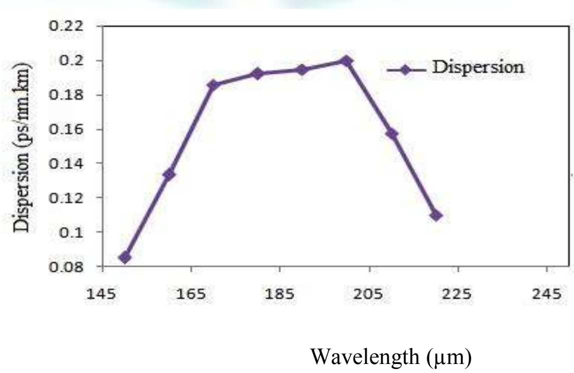

Figure 3: Dispersion as a function of wavelength

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IV. EFFECTIVE MODE AREA

Effective mode area is calculated for fundamental HE_{11} mode using the following standard formula.

$$A_{eff} = \frac{(\iint F(x,y)^2 dxdy)^2}{(\int F(x,y)^4 dxdy)} \quad (2)$$

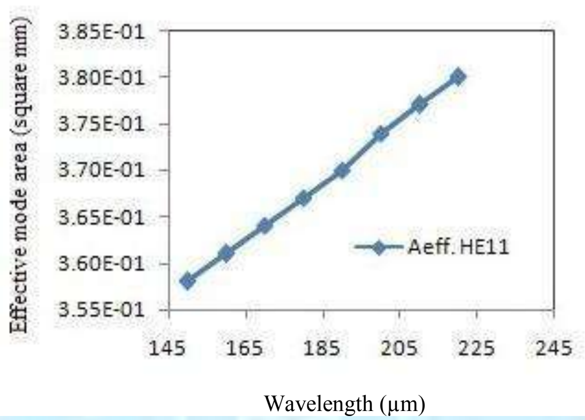

Figure 4: Effective mode area as a function of wavelength

V. MODE COUPLING

Mode coupling specify the coupling between fundamental mode and other excited modes in core or cladding. Mode coupling mainly depends on phase match condition:

$$\beta_0-\beta=\Delta\beta=2\pi/L \quad (3)$$

Where β_0 and β are the propogation constant of fundamental mode and other excited modes, as seen from Figure 5 the value of $\Delta\beta$ rises as the wavelength increases. This shows narrowband spectrum.

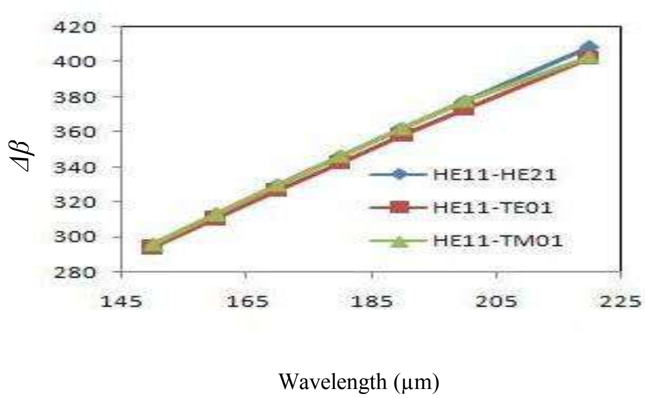

Figure 5: variation of $\Delta\beta$ with wavelength

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Figure 6 shows the variation of coupling length of excited modes with the fundamental mode. As we see with increase in wavelength, the coupling length decreases showing narrow band coupling.At particular wavelength all excited modes disappear and only fundamental mode propagates. This phenomenon is very crucial for communications and power delivery operations where all the power is associated with fundamental mode only.

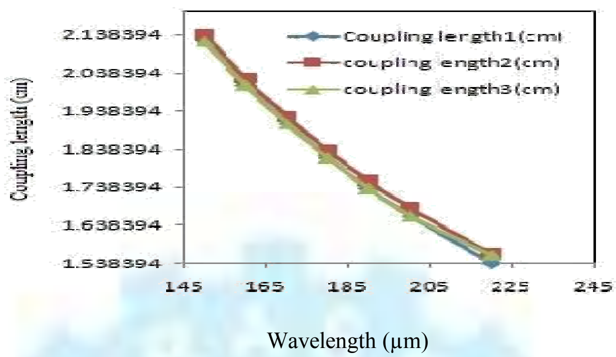

Figure 6: variation of coupling length with wavelength

where F(x, y) represent the distribution of HE_{11} field. It is shown that for this model we get nearly large mode area (LMA) of 3.80E-01 mm^2 for wavelength 220 µm. This type of fiber with large mode area can be used for high power delivery operations which is one of the great applications. Figure 4 shows effective mode area as a function of wavelength.

VI. CONCLUSION

In this paper wehave investigated several parameters for proposed design. Our model has achieved nearly flattend dispersion which has a great application in communication field. It also offers large mode area (LMA) which is essential for high power delivery systems. After 320 µm, this model supports only fundamental HE_{11} mode and all other excited modes disappear i.e cutoff wavelength for our model is 320 µm. At this wavelenth onwards confinement loss for other modes are cosiderably higher compaerd to fundamental mode.

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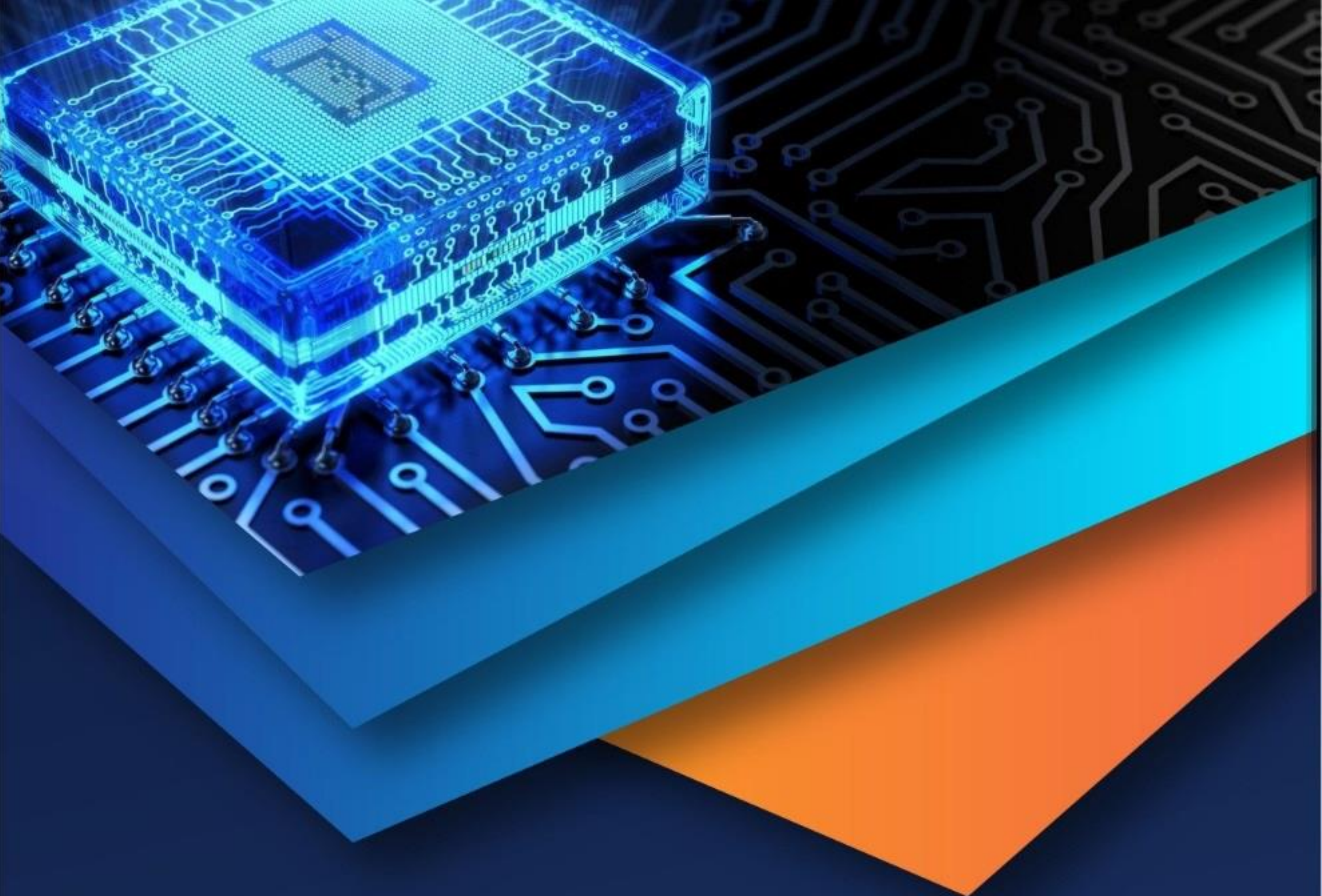

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