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Optimal Design of Photonic Crystal Fiber for Low-Loss and Flattened Dispersion

[1] Laxmi Chaudhary and [2] Arun JB
[1] PhD. Scholar, Bhagwant University, Ajmer
[1] PhD. Supervisor, Bhagwant University
E-mail: [1] laxmichaudhary1911@gmail.com

ABSTRACT

This paper the study reports of some optimal designs of PCF structure to study the modal features of photonic crystal fibres (PCFs) by using the Finite Difference Frequency Domain (FDFD) analysis method. The dispersion property as well as provided a flattened dispersion and low confinement loss in the 1.3 µm to 2.0 µm wavelength range has been investigated by changing air hole into elliptical and circular air hole as ring around the core and by the numerical simulation and adjusting the geometrical parameters as the hole diameter (d), pitch (Λ) etc. of PCF structure for the Hexagonal structure. The capability of PCF design with control of dispersion results the PCF as key element in super continuum application, sensing, amplification of optical parameter, imaging and other nonlinear applications in optical fiber system.

Keywords: *Photonic Crystal fibre (PCF), Dispersion, Wavelength, Pitch, Confinement Loss, Effective Area.*

1. INTRODUCTION

Photonic crystal fiber (PCF) is a particular kind of fiber made of a solitary substance that has cladding with air holes. PCF have involved in an extensive amount of attention recently, because of their unique properties that are not realized in conventional optical fibers [1, 2]. PCF give the possibility to design vast range of air hole arrangements, so the design with the controllable properties within the core and the cladding will give the unique and exclusive optical properties. Within the last years the PCF is a very much fascinated topic for the researchers since of its eye-catching properties for example very high and low nonlinearity[3],flattened dispersion characteristics ,high birefringence, , dispersion in wideband [4,5], efficient single mode guiding [7,8], fibre lasers [10,11]and fibre sensors [9]. Almost all the PCFs uses silica for the core material and core air holes surrounds the core named photonic crystal structure [12,13].The parameters for designing the cladding, can be import factors that makes flexible the designing of fibres, such as include the space between two adjacent holes or pitch (Λ), the air-holes diameter (d) and their shapes, number of rings (N), and organization of the holes. By altering and improving the propagation characteristics and optical characteristics in a PCF make it a best and the unique with its features for example low confinement loss, low flattened dispersion, and high birefringence, most suitable for optical communication applications [24-26].

2. PROPOSED STRUCTURE

The Silica is widely used as a core material in the maximum of the PCF structure and the air holes forms the cladding and for designing of the shape of the air holes can be done with the elliptic waveguide, linear waveguide and Arc waveguide [17, 18].Currently the elliptic waveguide [17] property is used to manufacture the crystal structure as shown in Fig 1. The PCF structures are proposed with the designs of six layer hexagonal lattice with solid core with a array of air holes cladding along the length of the fiber. For the complete formations examined the cladding refractive index is 1 which is smaller than the core index that is 1.458.The pitch difference (Λ) which is spacing between two adjacent air holes is varied in the designs selected to show the effect of varying the adjacent hole spacing or pitch on dispersion, and the confinement loss. The measurement of air holes of inner two elliptical rings with a=0.4µm (major axis) and b= 0.3µm (minor axis) and air holes of outer three circular rings with the diameter d2=1.4µm.So we consider the pitch for proposed designs as 2.1µm, 2.2µm, 2.3µm and 2.4µm and with the wavelength range from 0.8µm to 2.0µm. Scalar effective index method is used to simulate the dispersion property and for the simulation boundaries the finite difference time domain (FDTD) method and the TBC boundary condition are used.

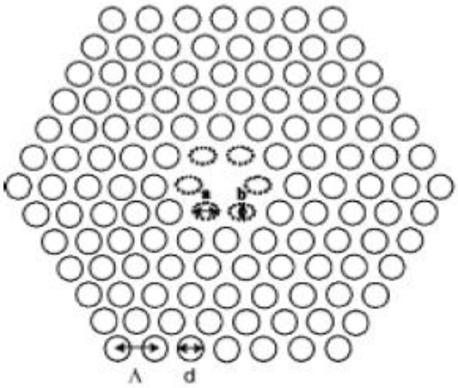

Fig.1. PCF modified with elliptical air- holes[14].

3. TYPES OF LOSSES AND CALCULATION

The dispersion can be described as the condition when the pulse changes with the distance of the propagation of light (per unit distance) and so that splits a wave into its spectral components. There is considerable effect on bandwidth and the bit rate of a fiber. Dispersion is to be controlled so that to make sure the practical application of PCFs may not get affected .As in equation(1) defines that the sum of wavelength dispersion (Dw) and material dispersion (Dm) gives the dispersion in PCF as follows[15]

$$D = D_w + D_m \qquad (1)$$

Pulse broadening occurs as launching of numerous spectral components into the fiber and as they travel with different group velocities within the fiber and this is called material dispersion [19][20-24]

$$D_m = -\frac{\lambda}{c}\frac{d^2 n_m}{d\lambda^2} \qquad (2)$$

Here the refractive index of the material is denoted by the nm and is derived using Sellemier's equation [15, 16]:

$$D_w = -\frac{\lambda}{c}\frac{d^2 \mathrm{Re}[n_{\mathrm{eff}}]}{d\lambda^2} \qquad (3)$$

Here Re [neff] is the real part of neff(effective RI of the fundamental mode), and λ and c signify the wavelength and velocity of light in vacuum.

Because of the low refractive index variance between the core and cladding the mode fields spread much greater from the core area to the cladding area. Further by using a perfectly matched boundary condition the imaginary part of the neff(effective RI of the mode) is achieved. Im [neff] is the Imaginary part provides the calculation of mode confinement loss as follows [16]:

$$C_L = \frac{20}{\ln(10)} \times \frac{2\pi}{\lambda} \times \{\mathrm{Im}[n_{\mathrm{eff}}]\}. \qquad (4)$$

Confinement loss is expressed in dB/km.Confinement Loss is a supplementary imperious loss which occurs due to leakage from the limited width of the cladding. Choosing the air-holes diameter (d) and pitch (Λ) properly in PCFs the confinement loss can be formulated.

4. SIMULATION & RESULTS

All the four PCF structure provides zero order dispersion values in wide band range from 1.3µm to 2.0µm.

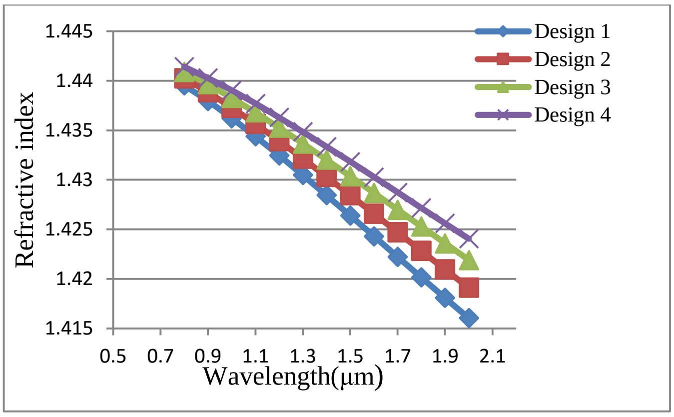

Fig. 2. Refractive index dependence with wavelength on altering pitch Λ.

The value of refractive index with wavelength on altering spacing between air holes or pitch in below refractive index decreases with increase in wavelength and it can also be observed that refractive index decreases with increase in wavelength and decrease in air hole spacing respectively. The waveguide dispersion decreases with increase in wavelength and it shifts toward zero dispersion. In the fig.4, the chromatic dispersion shifts toward the lower value when we reduce the spacing between air holes for wavelength above 1.3µm.

Among all these variations it can be observed that pitch=2.1µm in design -1 gives the most flattened dispersion in wide band range from 1.3µm to 2.0µm.

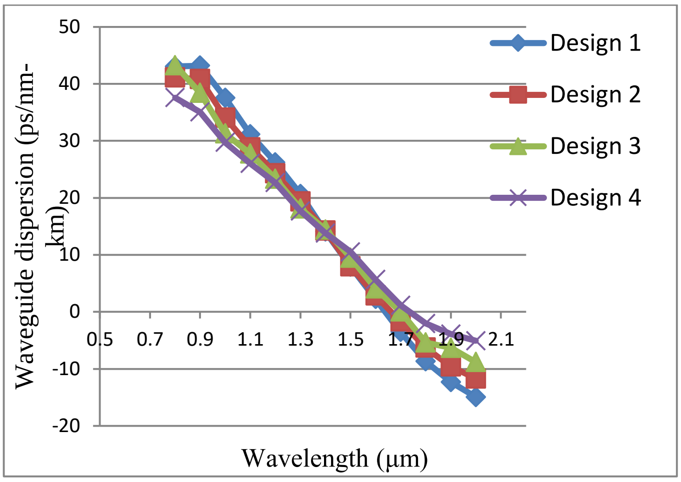

Fig.3 Waveguide dispersion dependence with wavelength on altering pitch Λ.

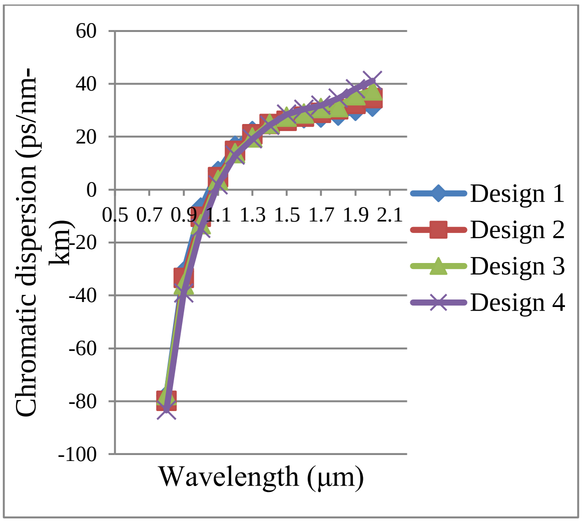

Fig.4. Chromatic dispersion dependence wavelength on altering pitch Λ

The confinement loss shifts toward the lower value on increasing hole spacing and it increases for higher wavelengths. Thus, design-4 (Λ=2.4µm) shows the lowest confinement loss and design- 1(Λ =2.1µm) show the highest confinement loss among all these variations.

Among four structures, design-1 has a waveguide dispersion 7.940493ps/nm-km, chromatic dispersion 25.94049ps/nm-km and confinement loss 0.017459dB/km so for lower and flattened dispersion we considered design-1. But Design-4 (Λ=2.4µm) shows the lowest confinement loss so there is trade-off between dispersion and confinement loss for higher wavelengths.

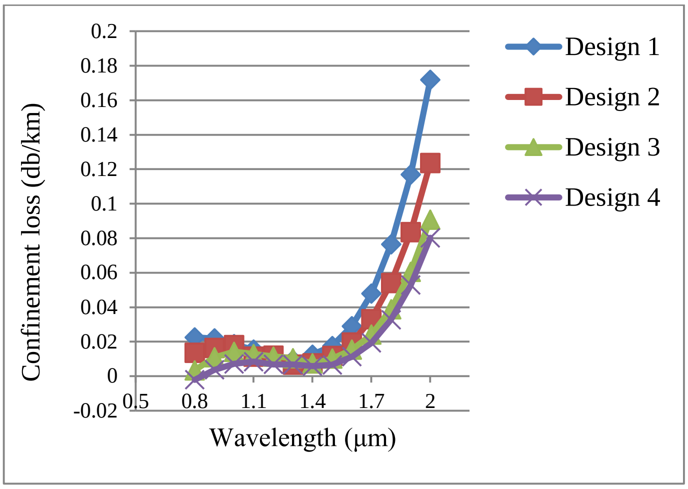

Fig. 5. Confinement loss dependence with wavelength on altering pitch ʌ.

5. CONCLUSION

PCFs with circular and elliptical air holes and have presented the effect of altering the diameters of the air holes and lattice constant on the dispersion, confinement loss properties. Design-1 also has a flatted dispersion in wavelength range 1.3µm to 2.0µm which is the application for high data rate WDM technology. Hence from the above study on change in dispersion, confinement loss, with altering the design parameters, we proposed some more designs which have low- flattened dispersion, low confinement loss and high birefringence simultaneously in wide band range. Designs proposed in this section are well suited for transmission.

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AUTHOR PROFILES

Laxmi Chaudhary, has received her B.E degree in ECE branch from Rajasthan University in 2008 and M.Tech in Digital Communication in 2012 from RTU,Kota. Currently she is PhD scholar in Bhagwant University, Ajmer (Raj.)

Arun JB has received his degree for BE, ME and PhD from MBM Engg. College, Jodhpur. Currently he is PhD supervisor.