Effect of varying the pitch with proposed PCF Structure on Dispersion and Confinement loss

Khushbu Sharma, Yogendra Katiyar

Abstract— **A new kind of extremist flattened dispersion Octagonal Square-lattice structure photonic crystal fiber (OS-PCF) with different air-hole diameters in cladding region is projected and also the dispersion is investigated using a compact 2 -D finite distinction frequency domain methodology with the anisotropic perfectly matched layers (PML) absorbing boundary conditions. The planned result's through numerical simulation and optimizing the geometrical parameters like by changing the holes diameter (d), pitch (^) of photonic crystal fibers for the octagonal arrangement. When investigating all the result, it's been incontestable that it's potential to get zero dispersion during a wavelength range close to 1.55µm wavelength with low confinement losses from a six ring into that all the ring are designed as circular and with totally different diameter of holes further if we change the pitch (^) zero dispersion move away from the 1.55 µm wavelength.**

***Index Terms*—perfectly matched layers (PML), Octagonal Square-lattice structure photonic crystal fiber (OS-PCF), Effective Refractive Index (n*eff*), Photonic Crystal Fiber (PCF), Scalar Effective Index Method (SEIM), Transparent Boundary Condition (TBC).**

I. INTRODUCTION

Optical fibers with silica-air microstructures, termed photonic crystal fibers (PCFs) striking and out standing transmission media because of PCFs can offer dispersions as well as mode field diameters that don't seem to be gettable in typical single-mode fibers [1][2]. PCF is often characterized by a series of air holes that runs throughout the length of the fiber. Before drawing, the structure is made by stacking a number of tubes that usually organized to create square lattices as well as triangular lattices with different structure subsequently the performance is described into the fiber exploitation typical drawing techniques [3] [4].

PCFs always guide light with two different forms of effects: the first is related on total internal reflection as well as the opposite relies on photonic band gap (PBG). An important result of the oblique periodic structure is to change the effective refractive index for propagation on the direction of the fiber resulting in new dispersive properties. Numerous innovative properties unrealizable through standard fibers are achieved by this category of fibers. These embrace fibers with a single-mode property over a large wavelength range whereas still giving an oversized mode field diameter and zero-dispersion wavelength all the way down to the visible wavelength. PCFs that particularly designed with this property called the endlessly single-mode (ESM)-PCFs [3] [4]. An attractive property of PCFs is that there are the extra parameters like diameter of holes (d) as well as therefore the lattice period (Λ) (as shown in Fig. 1) they provide higher flexibility within the design of dispersion to induce the specified application. It's achievable to vary the zero-dispersion wavelength as well as dispersion curve to be ultra flattened [5] [6].

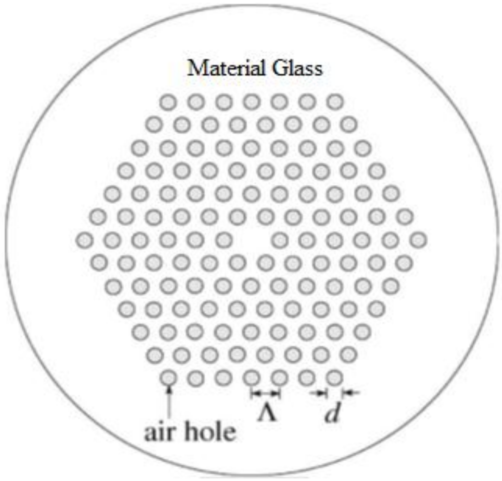

Fig. 1 Schematic representation of a PCF

On the other hand, earlier designs are all based on triangular [5] [6] [9-15] PCFs and ultra flattened dispersion properties of square-lattice PCFs is very few on the report. Subsequently it is very essential to investigate ultra flattened dispersion in square-lattice PCFs [1-4].

In recent time the elliptic waveguide property is used to fabricate the crystal structure. We can also use linear waveguide to design the squared shape holes. In this paper we used elliptic air holes [9]. Here we are using fused instead of pure silica. The calculated results show that our proposed PCF can simultaneously realize zero dispersion and low confinement losses in near 1.55µm wavelength. In this paper, we propose a new kind of square-lattice PCF with six rings air-holes.

II. FINITE ELEMENT ANALYSIS

In order to get an exacting explanation of the field allocation in excess of PCF, the Maxwell differential equations have to be cracked for an outsized set of properly chosen elementary subspaces, taking into deliberation the continuity of the fields. The initial stride contains in splitting the cross section of the modeled guide into distinct solid subspaces. This parceling ends up in a mesh of easy finite parts, triangles [2]. The Maxwell equations are unit discretized for every element resulting in a group of simple matrices. Finally the effective index and therefore the distributions of the amplitudes area

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unit numerically computed taking into consideration, the conditions of the continuity at the boundary of every space [2].

III. TYPES OF LOSSES AND CALCULATION

Material dispersion: Pulse broadening due to material dispersion results from the different group velocities of various spectral components launched into the fiber from the optical source. It occurs when the phase velocity of the plane wave propagating in the dielectric medium varies nonlinearly with wavelength and a material is set to exhibit material dispersion [1] [2].

Waveguide dispersion: The wave-guiding of the fiber may also create intramodel dispersion. This result, from the variation in the group velocity with wavelength for a particular made. From the ray theory it is equal to the angle between the ray and the fiber axis varying with wavelength which subsequently leads to a variation in the transmission time for the ray, and hence dispersion occurs. With a single mode fiber where the effects of the different dispersion mechanisms are not simple to divide, I the addition to this waveguide dispersion may be important [1] [2].

The dispersion (D) is proportional to the second derivative of the effective refractive index η_{eff} with respect to the wavelength (λ) obtained as [4-6] [10]:

$$D = -\left(\frac{\lambda}{c}\right)\frac{d^2}{d\lambda^2}\left[Re\left(\eta_{eff}\right)\right] \qquad \text{(Eq. 1)}$$

Where Re $[\eta_{eff}]$ is the real part of η_{eff}, λ is wavelength, and c is the velocity of light in vacuum.

The total dispersion is depends upon the calculation of the sum of the geometrical dispersion (or waveguide dispersion) and the material dispersion obtained as: [4-6] [10]

$$D(\lambda) = D_g(\lambda) + D_m(\lambda) \qquad \text{(Eq. 2)}$$

Confinement Loss: An additional imperative loss is confinement or leakage loss originates from the finite width of the cladding structure. By selecting the parameters *d* and Λ properly in PCFs we can formulate confinement loss minor. On the other hand, for miniature core fibers wherever the core size is analogous or slighter in dimension than the conceded light-weight wavelength, a foremost involvement in full loss of the fibers is accessible by the confinement loss [4]. Confinement loss is predominantly dominating within the wavelength region attention grabbing for telecommunication applications, as typically imperative negative conductor dispersion is absolute because of dispersion. The bulky negative conductor dispersion around 1550 nm may be achieved by lease the sphere go through into the shield region, which consecutively provides rise to augmented confinement loss [10] [12]. Low confinement loss may be achieved for small core PCFs by coming up with the fibers with a minimum of 6 rings of air holes for a closely packed structure. Raising the amount of air hole rings ends up in a supplementary reduced confinement loss (Eq.3) [4] [15]

$$\text{Confinement Loss (dB/m)} = 8.686\ \text{Im}[k_0 * \eta_{eff}] \qquad \text{(Eq. 3)}$$

Where $k_0=\frac{2\pi}{\lambda}$, λ is wavelength of light and η_{eff} is the effective refractive index of the proposed.

IV. PROPOSED DESIGN

Table 1 Structure parameter of Design-I

Parameter(unit)	Value
Pitch	2 µm
Holes diameter (d) (µm)	Variable
Air fraction refractive index	1.0
Silica glass refractive index	1.458
Propagating wavelength (µm)	1.55 µm
Number of rings in the cladding	6 Rings

Design-1

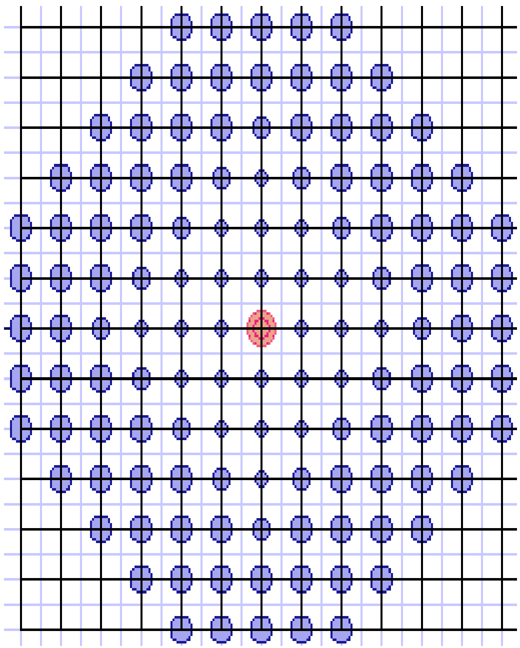

Fig. 2 Proposed design PCF Design-I

As shown in Fig. 2, we have proposed Design-1 structure which has variable diameter holes and pitch is 2 µm common design parameter except the diameter of holes in all the rings as shown in Table 1.

On the other hand, we have also proposed Design-2, Design-3 and Design-4 structure which has same parameter as Design-1 or Table 1 except pitch between holes as following 2.03µm, 2.05µm and 2.07µm.

In our proposed work there is a comparison between these four designs, is based on Total dispersion (chromatic dispersion) in the wavelength .7µm to 1.7µm and Confinement loss as shown in Figure 3. The total dispersion or chromatic dispersion is the sum of waveguide dispersion and material dispersion.

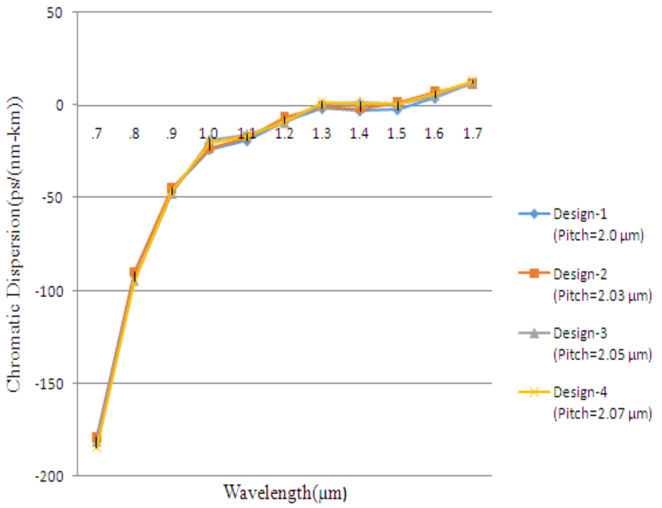

Fig. 3 Zero order Dispersion comparison at wavelength 1.55µm between Design-1, Design-2, Design-3 and Design-4 proposed structures

Also Figure 5 showing the confinement loss comparison loss between all four design structures.

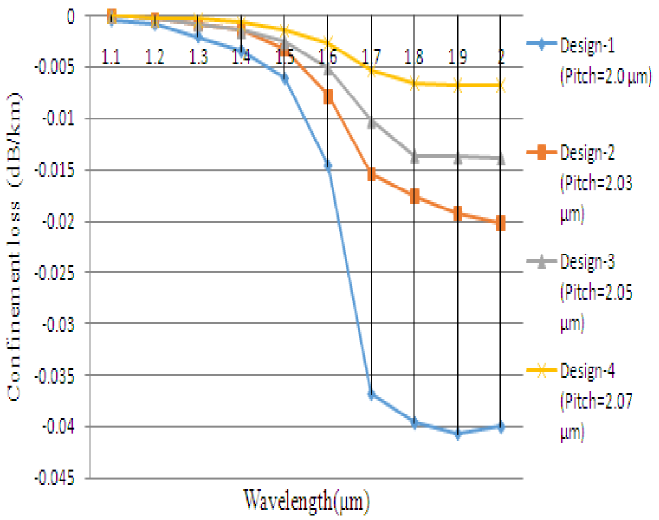

Fig. 4 Confinement Loss comparison at wavelength 1.55µm between Design-1, Design-2, Design-3 and Design-4 proposed structures

V. RESULT

From the above investigation, it can be found that the dispersion of the optimized PCFs becomes zero near at wavelength 1.55 µm as soon as the pitch of the circular air holes is 2.0µm and from above we also optimize the minimum confinement loss. In Design-I the value of chromatic dispersion at wavelength 1.5 µm and 1.6 µm, is -2.53 and 3.76ps/ (nm-km) and the value of confinement loss is -0.00618 and -0.01466 dB/km. The proposed PCF has the rings of circular air holes of different diameter; the circular air holes in the cladding are a positive influence on zero values of dispersion and the flat value at higher wavelength and minimum confinement loss. The pitch we have chosen in Design-I is 2.0µm, which shows the gap between the air holes, can be explained by the fact that when the small holes are introduced into the cladding area which contains circular air holes, the asymmetry in the cladding will be decreased. It can be observed from Fig. 3 that for Design-1 has zero order dispersion at near 1.55µm as compare to other designs.

VI. CONCLUSION

A new Octagonal square lattice photonic crystal fiber (OS-PCF) structure was proposed to achieve zero order dispersion over near to 1.55µm wavelength along with a high non-linearity. According to above conclude result, so we obtained that the dispersion calculated for proposed photonic crystal fiber using the Scalar index method gives best result in Design-1 as compared to Design-2, Design-3 and Design-4. When change pitch from 2.0µm to 2.05µm, the zero dispersion is moving away towards minimum wavelength. Finally the conclusion is that the variation in pitch shows the variation in dispersion and confinement loss. The fiber parameters are optimized to yield best agreement with available data.

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