Design a New Borosilicate Honeycomb Photonic Crystal Fiber for Negative Chromatic Dispersion

Arjun Singh Dhakar, Yogendra Kumar Katiyar

***Abstract*— In this paper we proposed a new design ofBorosilicate Honeycomb photonic crystal fiber for Negative chromatic dispersionFinite Difference Time Domain (FDTD) method and transparent boundary condition (TBC) is used to analyze the dispersion property in a high-index core PCF. This method produced best result at zero dispersion at 1.6µm and 1.7µm wavelength of 0.6µm diameter.It is also shown that borosilicate glass PCF provides much better dispersion as compared to silica of the same structure, so such PCF have high potential to be used as a dispersion compensating fiber in optical window.**

***Index Terms*— Effective Refractive Index (neff), Photonic Crystal Fiber (PCF), Finite Difference Time Domain (FDTD) method, Transparent Boundary Condition (TBC)**

I. INTRODUCTION

Now, today's, photonic crystal fibers (PCFs) have been played a important role in optical communication systems providing characteristics such as a wide single-mode wavelength range, a bend-loss edge at shorter wavelengths, a very large or small effective core area, irregular group velocity dispersion at visible and near-infrared wavelengths . In PCFs, the guiding of light is obtained by an arrangement of air holes running along the length of the fiber. If a defect is introduced in the fiber, frequencies in the band gap can propagate only in the defect since they are forbidden from propagating in the lattice, and thus a waveguide is formed. Single core material as silica glass, borosilicate glass and chalcogenide glass etc that type of fiber is called photonic crystal fiber (also called hole and micro structured fiber. Many PCF designs have been proposed to achieve ultra-flattened chromatic dispersion. Such as hexagonal PCFs (H-PCF), square PCFs(S-PCF), circular PCFs(C-PCF), triangular PCFs. H-PCFs are the most conventional type of PCF structures and are the most widely used. Conventional PCFs have the same and uniform air holes and it is difficult to reduce confinement loss and dispersion characteristics, simultaneously. One of the most important aspects of optical fibers is to achieve a nearly-zero flattened or highly negative dispersion curve over a wide wavelength range which can be achieved by honeycomb cladding arrangements of the air-holes have been considered with the core defect formed by removing or adding an additional air-hole in the lattice, respectively. Honeycomb structure has improved photonic band gap (PBG) effect in telecom window and lower air-filling fraction compared with triangular holey fiber, which makes fiber fabrication and splicing strong.

There are so many reports have been available about Honeycomb PCFs with low confinement loss and ultra-flattened chromatic dispersion properties such as PCFs structures and materials with gradually increasing the diameter of the holes from the inner ring to the outer ring[1-8],HPCFs with hybrid cladding, Borosilicate PCFs with elliptical holes[9], and so on. Minimizing dispersion and confinement loss are of the main concern in designing PCFs. Today, exploiting multiple design parameters such as diameter, shape of the holes and pitch difference, using different materials(like silica, As2Se3 ,borosilicate crown glass etc.) ,the number of air hole rings and the spacing between these holes facilitates development of PCFs with improved properties.

In this paper, we proposed a new design of borosilicate honeycomb photonic crystal fiber in order to shape negative flattened dispersion in a broad range of wavelength. This method produced best result at zero dispersion at 1.6µm and 1.7µm wavelength of 0.6µm diameter

Here we focus on improving the negative dispersion flattening by adjusting the diameter of circular air-holes of honeycomb pattern and that design compare with the silica also.

Design a nanofiber here we use Borosilicate crown glass as core material. Borosilicate glass was first developed by German glassmaker Schott in the late 19th century. Most borosilicate glass is colorless 70 % silica, 10% boron oxide, 8% sodium oxide, 8% potassium oxide and 1% calcium oxide are used in the manufacture of borosilicate glass. Borosilicate crown glass (BK7) is an optical material used in a large fraction OPTICS product. It is relatively hard glass, doesn't scratch easily. Another important feature of BK7 is very good transmission down to 350 nm. Due to these properties, BK7 are widely used in the optics industry.[9]

Several modeling methods have been proposed to study the modal properties of PCFs. Among all these methods, the FDTD method has been recognized as a powerful technique [10].

II. THEORY OF DISPERSION

The chromatic dispersion (D) of a PCF is easily calculated from the second derivative of the mode index, $neff = \beta / k0$, with respect to wavelength. Once the mode index is solved, the chromatic dispersion parameter can be obtained.

$$D_w = -\left(\frac{\lambda}{c}\right)\frac{d^2}{d\lambda^2}\lambda_{eff} \qquad (1)$$

Where, Re[neff] is real part of (neff).And the total dispersion, D = DM + DW. Where λ is the operating wavelength and c is the velocity of light. DM is the material dispersion, DW is the waveguide dispersion.

The chromatic dispersion profile can be easily controlled by varying the hole diameter and the hole pitch. By using the sellemier formula we can calculate the value of

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refractive index of Borosilicate glass.

$$n^2 - 1 = \sum_i \left(\frac{A_i\lambda^2}{\lambda^2-\lambda_i^2}\right) \text{ .... (2)}$$

whereλ is operating wavelength in µm

III. DESIGN AND SIMULATION

The proposed Borosilicate honeycomb PCF is an array of air holes running along its length. Now here we will analyze the dispersion properties of photonic crystal fiber and compared the properties for both materials silica and borosilicate. The designed PCF consists of a solid core with a regular array of air holes running along the length of the fiber acting as the cladding. For the entire configurations analyzed the mean cladding refractive index is lower than the core index. The core material is borosilicate glass which refractive index is 1.5186 and the refractive index of cladding air holes is 1. The pitch difference (Λ=2.0µm) which is center to center spacing between two nearest air holes for entire configuration. The lattice structure is in triangular lattice and it form Hexagonal shape. Here various design of PCF are considered by changing the air hole diameter (d).The dispersion property is numerically simulated by scalar effective index method. The finite difference time domain method and the TBC boundary condition is used for the simulation The software is used for various layouts designed and investigated is OPTIWAVE SYSTEM-FDTD mode solver tool.

IV. PROPOSED DESIGN

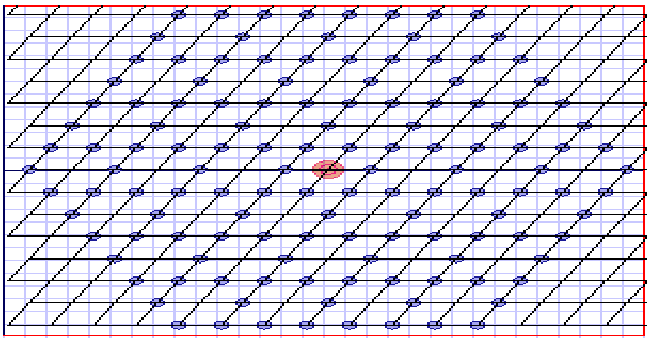

Fig.1. Proposed HPCF

Our proposed HPCF design is made up of seven layer having air holes diameter (d)=0.6µm,core (BK7)diameter d=1.5168,pitch difference(Λ=2.0µm)

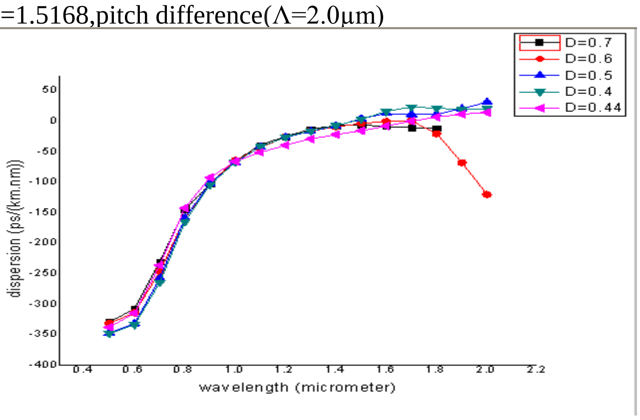

Fig.2. Negative flattened dispersion graph of proposed model BK7.

V. MATERIAL DISPERSION

The graph between silica and BK7 is given in figure 3.

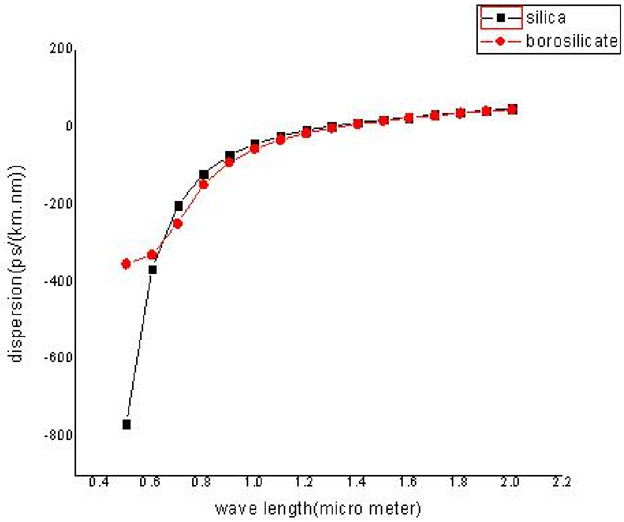

Fig.3. Material dispersion between silica and borosilicate glass.

Table I Comparison Of Silica With BK7

Properties	Silica glass	BK7(borosilicate)glass
Density(g/cm^3)	2.2	2.51
Refractive Index (micrometer)	1.458	1.516
Light transmission Wavelength (micrometer)	0.18to2.5	0.35to2.5
Max. Temperature (degree C)	1120	560
Material dispersion at 1.55nm	18.01246 ps/km.nm	15.01038(ps/km.nm)

VI. COMPARISON BETWEEN PROPOSED MODELS WITH SILICA MODEL.

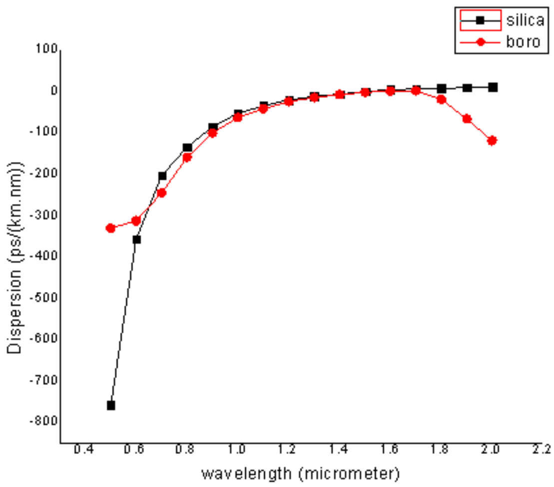

Fig.4. Simulation result of proposed HPCF with silica HPCF.

VII. CONCLUSION

According to our designs the best one is D=0.6µm that structure simulations results get zero dispersion at 1.6µm to 1.7µm and negative flattened dispersion characteristics over wide wavelength range that has better performance than conventional photonic crystal fiber. It is also shown that borosilicate glass PCF provides much better dispersion as compared to silica of the same structure, high negative dispersion we choose the honeycomb structure. We can use Borosilicate crown glass as a core material on the place of silica glass because Borosilicate crown glass has good properties (like cheaper, good transmission, easy availability) and BK7 is very good transmission down to 350 nm compare to silica glass and low dispersion at 1.55µm.

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