New Hexagonal Borosilicate Crown Glass PCF with Circular and Square Air holes for Flat and near zero Dispersion

Mukesh Arora, JayPrakash Vijay

Abstract— **In this paper we investigate the method for chromatic dispersion of Borosilicate crown glass from the scalar effective index method using transparent boundary condition with linear and elliptic waveguide. It has been demonstrated that it is possible to obtain near zero dispersion in a wavelength range of 1.5 to 2.0 µm from a six ring into which inner three ring are designed as elliptic and the outer three ring are designed by using linear waveguide to design circular and square holes for the calculation of Flat and near zero dispersion in PCF.**

Index Terms— **Effective Refractive Index (n_{eff}), Photonic Crystal Fiber (PCF), Scalar Effective Index Method (SEIM), Transparent Boundary Condition (TBC), Linear waveguide.**

I. Introduction

Photonic crystals usually consist of dielectric materials that serve as electrical insulators or in which an electromagnetic field can be propagated with low loss. Holes are arranged in a lattice-like structure in the dielectric and repeated identically at regular intervals, is known as a photonic band gap, a range of frequencies within which a specific wavelength of light is blocked. The holes used in the lattice structure could be of different diameter or different shape. Recently the elliptic waveguide properties are used to fabricate the crystal structure. Linear waveguide is also used to design the squared shape holes. In this paper we used both Elliptic and Linear air holes. In addition, it is possible to create energy levels in the photonic band gap by introducing defects. For example, changing the size of a few of the holes in a photonic crystal is "equivalent to breaking the perfect periodicity of the silicon-crystal lattice.

In this work we use Borosilicate crown glass as material. Borosilicate glass was first developed by German glassmaker otto 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 large fraction OPTICS products. 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.

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II. Design Parameter

Fig. 1 shows the proposed PCF structure and Fig. 2 shows the 2D layout of the designed structure. In this paper inner three layers of cladding is composed with elliptic waveguide of a common air hole pitch ^ and diameter d_1, d_2, d_3 and outer three layer of cladding is composed with linear waveguide with parameter length L and width w. For achieving the larger core area we proposed the air holes of inner rings of smaller area. We have investigated the dispersion for different air hole parameter of inner holes.

Although perfect crystals are valuable for fabricating dispersive elements such as super prisms and three-dimensional (3-D) mirrors, those with defects enable researchers to custom-design photonic crystals that allow precise control of the frequencies and directions of propagating electromagnetic waves. This feature makes them especially useful in optical telecommunications and as laser applications.

PCF [1,2] is having so many unique properties seeking the attention of Research paper from the last decade as high birefringence, very high and low nonlinearity, wideband dispersion [4-10] flattened characteristics, endlessly single mode guiding [11,12], fiber sensors [13, 14] and fiber lasers [15,16] which are not realizable by conventional optical fiber. Silica as a core material [17-20] is widely used for most of the PCF structure and the cladding is surrounded by the air holes and the shape of the air holes can be designed by the elliptic waveguide, linear waveguide and Arc waveguide.

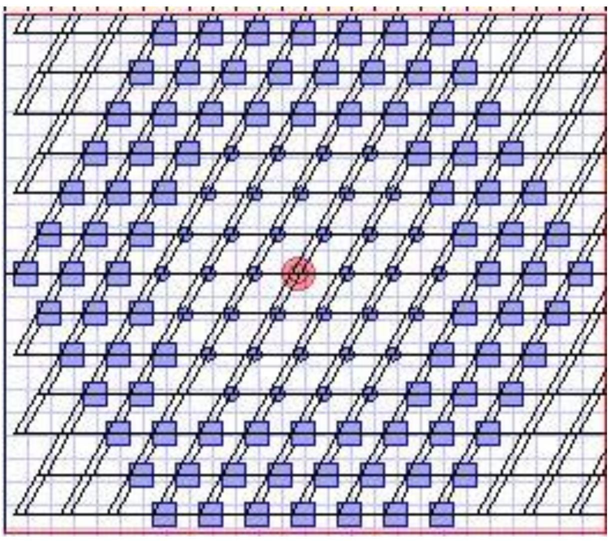

Fig. 1: Proposed PCF Structure

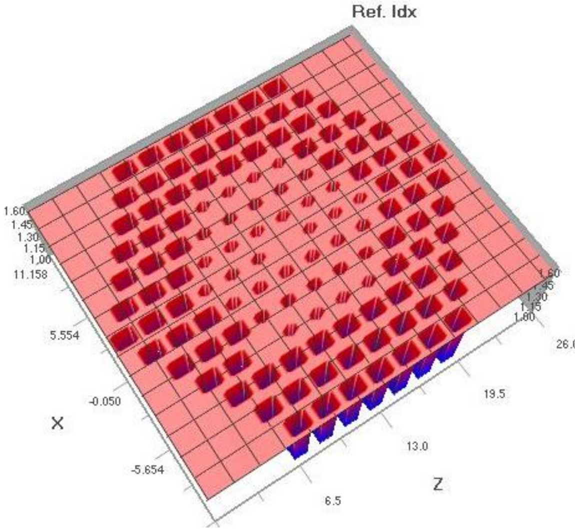

Fig. 2: 2-D layout design of Proposed PCF Structure

III. Structure Parameter

Cladding layers

1. Design 1: d_1=0.4 μm, d_2=0.6 μm, d_3=0.6 μm, L=1 μm, w=1 μm, ∧ = 2.0 μm
2. Design 2: d_1 = 0.6 μm, d_2=0.8 μm, d_3=0.6 μm, L=1 μm, w=1 μm, ∧ = 2.0 μm
3. Design 3: d_1 = 0.6 μm, d_2=0.6 μm, d_3=0.6 μm, L=1 μm, w=1 μm, ∧ = 2.0 μm
4. Design 4: d_1 is missing, d_2=0.6 μm, d_3=0.6 μm, L=1 μm, w=1 μm, ∧ = 2.0 μm

Where d_1 denotes the diameter of circular air holes of first ring, d_2 denotes the diameter of circular air holes of second ring; d_3 denotes the diameter of circular air holes of third ring. L and W denote the Length and width of the outer three linear air holes.

The wafer chosen is of Borosilicate crown glass with 1.5168 refractive index and the air hole refractive index is 1.0. Fig. 3 shows the material dispersion of Borosilicate crown glass.

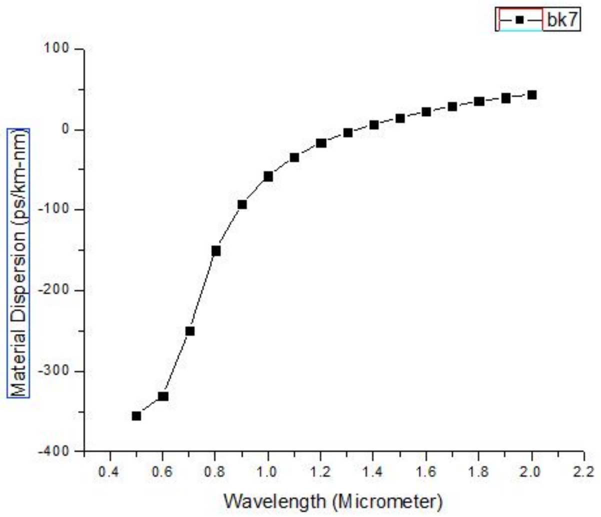

Fig. 3: Material dispersion of Borosilicate crown glass

By using the sellemier's formula [4] we can calculate the value of refractive index of Borosilicate glass-

$$n^2 - 1 = \sum_i \left(\frac{A_I \lambda^2}{\lambda^2 - \lambda_i^2}\right) \qquad (1)$$

With the help of refractive index we are calculating the value of material dispersion of Borosilicate glass.

It is a phenomenon in which the phase velocity of a wave depends on its frequency. For the calculation of dispersion from various combinations of holes we have find that the proposed PCF structure design is as shown in Fig. 2. The total dispersion consists of both waveguide and material dispersion, is proportional to the second derivative of effective index of guided mode with respect to 'λ'. Where 'λ' denotes the wavelength of light.

The waveguide dispersion [8] as given in equation (2) is defined as

$$D_W = -\left(\frac{\lambda}{c}\right)\frac{d^2}{d\lambda^2} n_{eff} \qquad (2)$$

And the total dispersion, D = D_M + D_W.

Where λ is the operating wavelength and c is the velocity of light.

D_M is the material dispersion, D_W is the waveguide dispersion

IV. RESULTS

We have already shown that the proposed PCF can exhibit almost Flat Dispersion. For practical applications, however, other propagation properties such as confinement loss should be investigated to justify the usefulness of the PCF. In this paper of the proposed PCF with six rings of array of air holes is designed for investigation of near zero dispersion and minimum confinement loss with the elliptic and linear air holes.

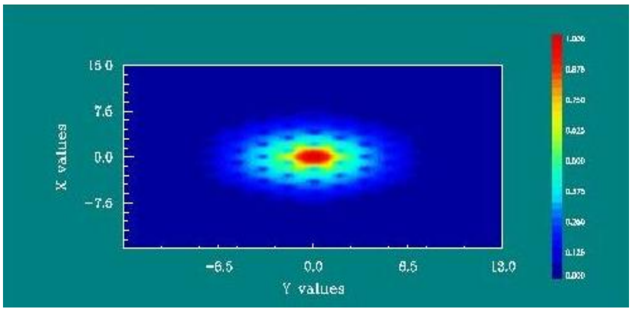

Fig. 4: 3D Mode field layout with X values and Y values

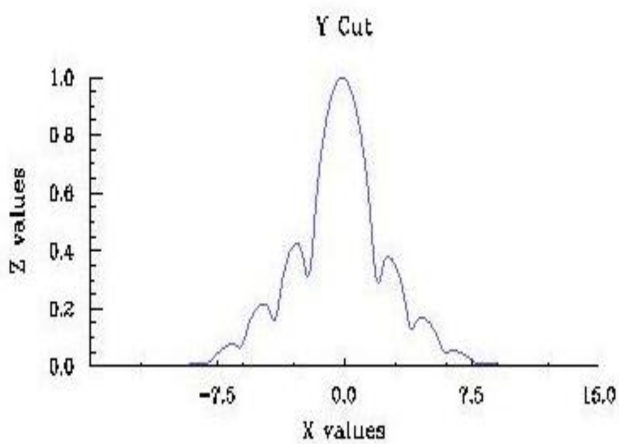

Fig. 5: Mode field pattern with X values and Z values

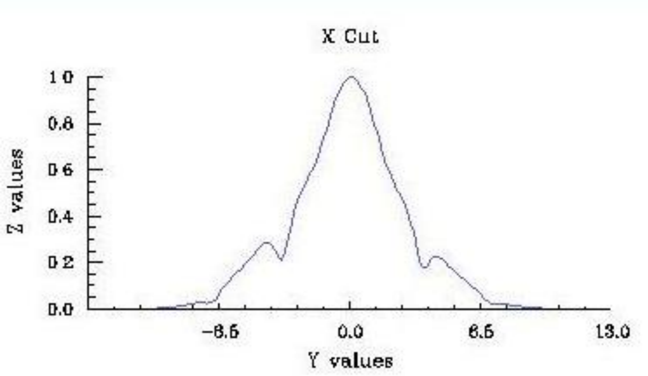

Fig. 5: Mode field pattern with X values and Z values

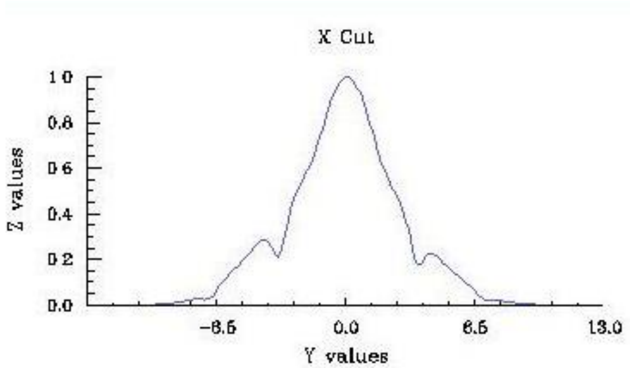

Fig. 6: Mode field pattern with Y values and Z values

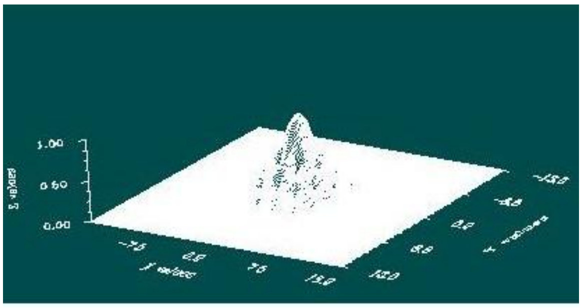

Fig. 7: 3D Mode field pattern with X values, Y values and Z values

Fig. 4 shows the Mode field layout, Fig. 5 shows Mode field pattern with X values and Z values, Fig. 6 Mode field pattern with Y values and Z values and Fig. 7 3D Mode field pattern with X values, Y values and Z values of the proposed PCF of zero dispersion. In general, silica material is used in the different application of the optical fiber, but recently Borosilicate material is the replacement of the silica material with its different properties. Material dispersion is always unchanged for any lattice structure (hexagonal or Rectangular). It is also independent of structure parameter as air hole diameter 'd' and pitch '^'. Fig. 8 shows the different output of the proposed PCF by changing the diameter of the inner three rings but the best result is obtained in Design 3.

Table 1 shows the value of Chromatic dispersion of Design-1 to Design-4 in the wavelength range from 0.5 µm to 2.0 µm.

TABLE 1
CHROMATIC DISPERSION OF PROPOSED DESIGNS

	Design-1	Design-2	Design-3	Design-4
Wavelength (µm)	Chromatic Dispersion(ps/(nm-km))			
0.5	-306.72932	-283.8	-332.87449	-345.25138
0.6	-291.53319	-270.64	-292.53738	-313.87815
0.7	-219.57037	-201.99	-206.35515	-229.52367
0.8	-122.85701	-107.57	-117.8769	-132.88462
0.9	-74.12728	-59.38	-63.41813	-74.33443
1	-46.86242	-32.27	-33.15544	-36.67788
1.1	-27.54656	-14.52	-24.91941	-17.44616
1.2	-15.84496	-5	-13.4503	-0.41428
1.3	-4.45667	2.95	-9.69171	11.5585
1.4	2.20186	6.22	-11.05949	19.12323
1.5	7.8792	8.73	-5.4813	27.833
1.6	15.39732	10.53	1.14613	33.72333
1.7	21.24912	11.77	1.93084	38.20985
1.8	25.85689	13.03	2.33562	43.67422
1.9	29.56229	14.02	5.30625	48.27915
2	32.35238	14.87	8.31742	51.89089

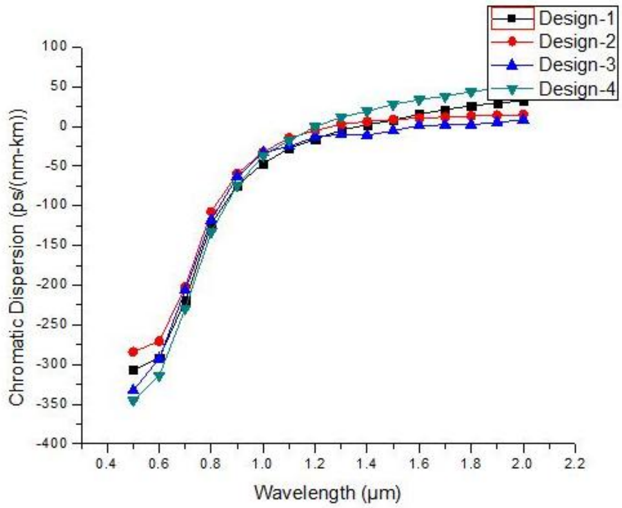

Fig. 8: Comparison of chromatic dispersion of proposed PCF

V. CONCLUSION

The result, so obtained, gives that the dispersion calculated for proposed photonic crystal fiber using the Scalar index method gives best result in comparison of other structures. Here we have calculated the dispersion for various data but it shows that when we consider inner three layer air holes diameter 0.6 µm and Pitch 2.0 µm and select total 6 layers then it gives best result. The fiber parameters are optimized to yield best agreement with available data.

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