**International Journal of Engineering and Technical Research (IJETR)**
**Volume-2012, July-December 2012.**

# Comparison of Borosilicate Crown glass Photonic Crystal Fibers & Silica Honeycomb Photonic Crystal Fibers

**Sunil Sharma**

*Abstract*— **In the conventional Photonic Crystal Fibers (PCFs), the cladding is formed by regular lattice of air holes with same diameter and silica glass is used as core material. In this paper, we have study a new structure of PCF filled Borosilicate Crown glass as core material. It is possible to control chromatic dispersion in wide wavelength range by varying the inner 3 layers hole diameter compare to outer 3 rings hole diameter. The honeycomb lattice has recently been suggested for the formation of a photonic band-gap guiding silica-core. There are so many difficulties occur during the design process because when parameters are being changed the designing varies accordingly. Using this design principle, ultra flattened dispersion is also designed through a Scalar effective index method (SEIM) with Transparent Boundary Condition (TBC). Here we have also compare Borosilicate Crown glass PCF with Conventional silica glass PCF. A PCF with flat dispersion property may be very useful for next generation optical and communication data.**

*Index Terms*— **Photonic Crystal Fiber (PCF), Chromatic Dispersion, Scalar effective index method (SEIM), Transparent Boundary Condition (TBC).**

## I. Introduction

Photonic crystal fibers (PCFs) [1,2] have made from single material with a regular array of empty holes running along the length of the cladding. This structure enables light to be controlled within the fiber. Modern optical fibers, which transmit information in the form of short optical pulses over long distances at high speeds, have become integral part of life in the information age. In these years PCF [1,2] is very attracted in the research group because of many of their attractive properties [3] 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]. Many research papers have published some optical properties of PCFs such as unique chromatic dispersion, which are almost impossible for the conventional optical fibers. Most PCFs are used silica as core material and core is surrounded by air holes called photonic crystal structure [17-20]. The PCF technology is used to create a fiber with high nonlinear coefficient and zero chromatic dispersion. Most photonic crystal fibers (PCFs) have been fabricated in silica glass.

PCF is made by a single material. Here we use Borosilicate crown glass as core material. Borosilicate glass was first developed by German glassmaker otto Schott in the late 19$^{th}$ century. Most borosilicate glass is colourless 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 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.

In this paper , we proposed two layer cladding PCF characterized by a common air hole space (pitch) and two different air hole diameters. The structure can ensure flat dispersion in a wide wavelength range and simple than the existing designs. the optical properties of solid core HPCF with different up/down doping levels are considered. The doping level of the core adds new freedom of solid core HPCF design.[3-5]. In optical communication, dispersion plays an important role as it determines the information carrying capacity of the fiber. Therefore it becomes important to study the dispersion properties of PCF. The optical properties of PCF have been used like Effective Index method (EIM), Scalar effective index method (SEIM).[3] The SEIM method is used for weak guiding approximation and accurate approximations. In the SEIM method the value selection for effective core radius of the PCF is important for the accuracy.

| Properties | Silica glass | BK7 glass |
|---|---|---|
| Density (g/cm$^3$) | 2.2 | 2.51 |
| Refractive Index (micrometer) | 1.458 | 1.516 |
| Light Transmission wavelength (micrometer) | 0.18 to 2.5 | 0.35 to 2.5 |
| Max. Temperature (degree C) | 1120 | 560 |
| Poisson's ratio | 0.17 | 0.206 |
| Specific heat capacity (J/Kg-k) | 720 | 860 |
| Speed of sound (m/s) | 180*10$^3$ | 170*10$^3$ |

Table 1. Comparisons of core material. [26]

## II. Equations

In this paper, two main properties of PCF are discussed. First Effective refractive index and second dispersion.

Effective mode index ($n_{eff}$) can be obtained as –

$$n_{eff} = \beta/k_0 \quad (1)$$

here, $\beta$ is the propagation constant and $k_0 = 2\pi/\lambda$. Where $\lambda$ is the operating wavelength.

Total dispersion $D_T = D_W + D_M$

Here, $D_W$ is waveguide dispersion and $D_M$ is material dispersion. The waveguide dispersion is defined as-

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

C is the velocity of light [25] .
The material dispersion given by sellemier formula

$$n^2 - 1 = \sum_i \left(\frac{A_i \lambda^2}{\lambda^2 - \lambda_1^2}\right) \tag{3}$$

The Scalar wave equation is :

$$[\Delta_t^2 + (k^2 n^2 - \beta^2)]\,\Psi \tag{4}$$

### III. Design Principle and Simulation Results

Figure 1. shows the proposed PCF. The inner three layer of cladding is composed of a common air hole pitch ∧ and diameter $d_1$ and outer three layer of cladding is composed diameter $d_2$, where $d_1$ is less than $d_2$. To achieve larger mode area we design the air holes of inner rings are chosen smaller. We have investigated the dispersion for different air hole diameter of inner and outer ring.

The wafer chosen is of Borosilicate crown glass with 1.5168 refractive index and the air hole refractive index is 1.0. In figure 1 we have change the inner and outer ring air hole diameter. While This structureof HPCF is designed for seven layer structure and having d = 1.0 µm.

It is clear from the figure that as the air filling fraction increases the credibility of the SEIM reduces as the difference between the refractive index of the silica and the refractive index of the fundamental space filling mode increases, which is the foremost requirement of the weakly guided approximation

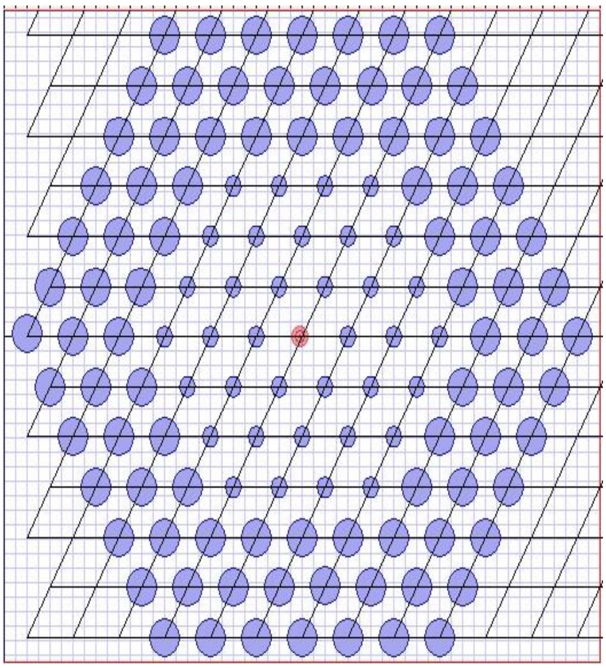

Figure 1. Proposed PCF.

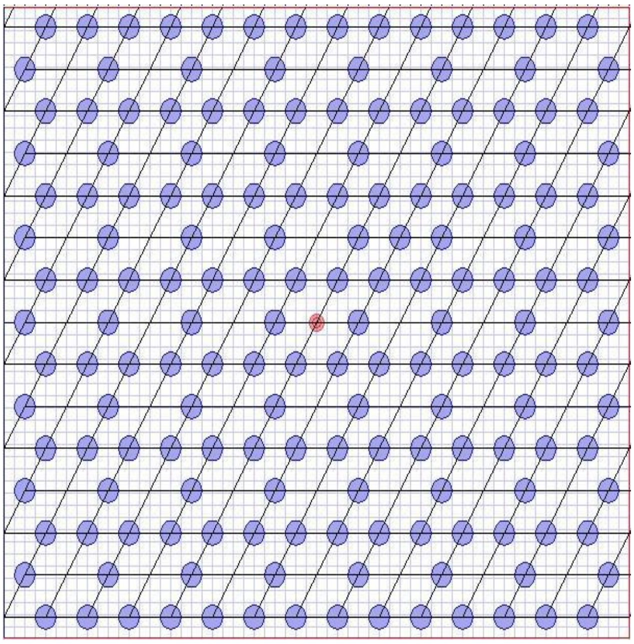

Figure 2. Proposed HPCF.

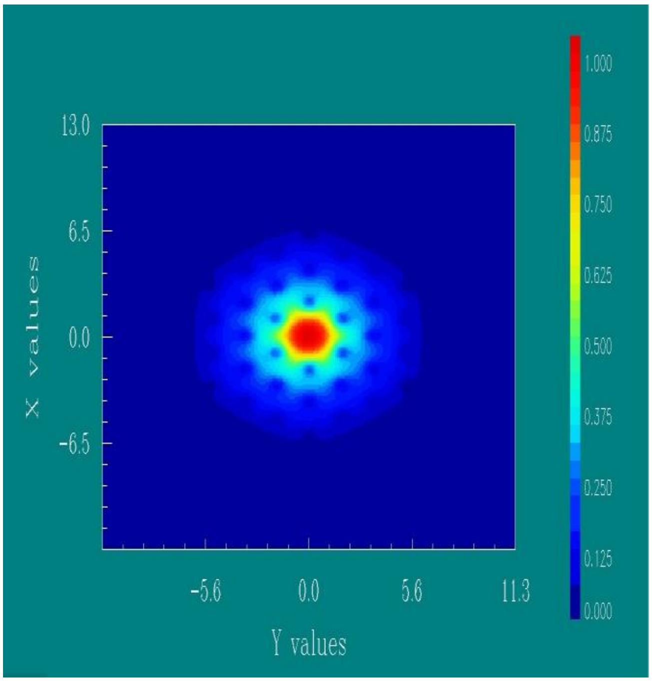


Figure 3. Shows mode field pattern of proposed PCF

The phase velocity of a wave depends on its frequency From the calculation of dispersion for various combination we have find that the proposed Honeycomb PCF structure is design as shown in figure 3. The dispersion coefficient D(Λ), which include both waveguide and material dispersion, is proportional to the second derivative of effective index of guided mode with respect to Λ'.

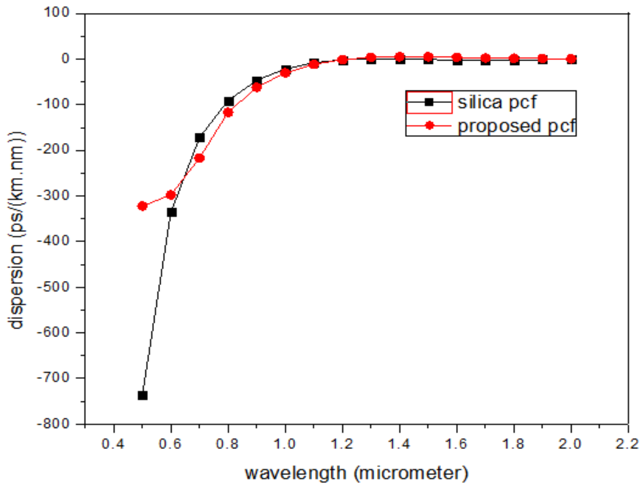


Figure 5. Shows the chromatic dispersion of proposed Borosilicate crown glass PCF and silica glass PCF when pitch 'Λ' = 2.0 μm, $d_1$ = 0.7 μm and $d_2$ = 1.3 μm.

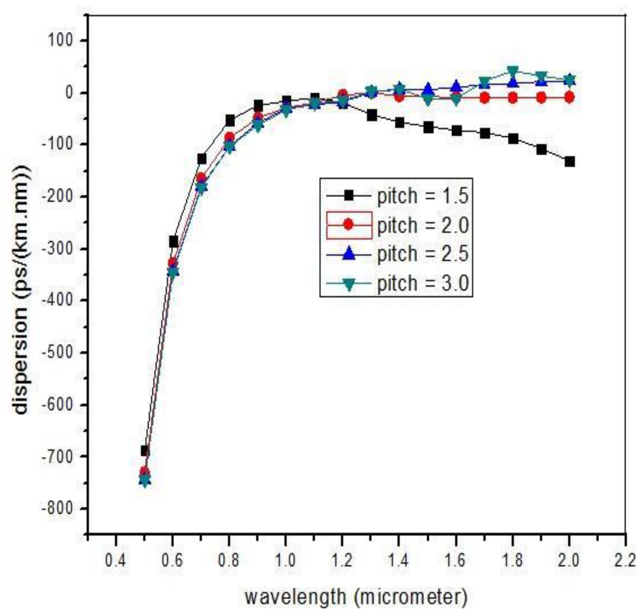


Figure: 6. Comparison of chromatic dispersion of proposed Honeycomb PCF when air hole diameter is 1.0μm.

### IV. Conclusion

The above results indicate that the proposed Borosilicate crown glass PCF has almost zero and flat dispersion in low wavelength range as silica glass PCF. But Borosilicate crown glass has good properties (like cheaper, good transmission, easy availability) compare to silica glass. So we can use Borosilicate crown glass as a core material on the place of silica glass. Borosilicate crown glass can substitute of silica glass. The fiber parameters are optimized to yield best agreement with available data. The discrepancy observed at higher wavelength values is due to the fact that the refractive index of the silica and the effective cladding index are wavelength dependent.

## References

[1] E. Yablonovitch, Phys. Rev. Lett. 58, 1987, pp 2059.
[2] J.C. Knight, T.A. Birks, P.St. J. Russell, D.M. Atkin, Opt. Lett. 21, 1996, pp 1547.
[3] Razzak S.M.A, Namihira Y, Begum F., " Ultra flattened dispersion photonic crystal fiber", Electronics Letters 43(11), 2007, pp 615- 617.
[4] Agrawal A, N. Kejalakshmy, J. Chen, B.M.A. Rahman and K.T.V. Grattan, " Golden spiral photonic crystal fiber : Polarization and dispersion properties", Opt. Lett, Vol. 33, 2008, pp 2716- 2718.
[5] Shen L.P, W.P. Huang and S.S. Jain, " Design of photonic crystal fiber for dispersion related applications", J. Lightwave Technol, vol. 21, 2003, pp 1644- 1651.
[6] Ferrando A, E. Silvestre, J.J. Miret and P. Andres, " Nearly zero ultraflattened dispersion in photonic crystal fibers", Opt. Lett, Vol. 25, 2000, pp 790- 792.
[7] Ferrando A, E. Silvestre, P. Andres, J. Miret and M. Andres, " Designing the properties of dispersion flattened photonic crystal fibers", Opt. Express, Vol. 9, 2001, pp 687- 697.
[8] Saitoh K, M. Koshiba, T. Hasegawa and E. Sasaoka, " Chromatic dispersion control in photonic crystal fibers : Application to ultra flattened dispersion", Opt. Express, vol. 11, 2003, pp 843- 852.
[9] Poletti F, V. Finazzi , T.M. Monro , N.G.R. Broderick, V. Tsc and D.J. Richardson, " Inverse design and fabrication tolerences of ultra flattened dispersion holey fibers", Opt. Express, vol. 13, 2005, pp 3728- 3736.
[10] Huttunen A and P. Torma, " Optimization of dual core and microstructure fiber geometries for dispersion compensation and large mode area", Opt. Express, Vol. 13, 2005, pp 627- 635.
[11] Saitoh K and M. Koshiba, " Single polarization single mode photonic crystal fibers", IEEE Photon Technol. Lett, Vol. 15, 2003, pp 1384- 1391.
[12] Kubota H, S. Kawanishi, S. Koyanagi, M. Tanaka and S. Yamaguchi, " Absolutely single polarization photonic crystal fiber", IEEE Photon. Technol. Lett, Vol. 16, 2004, pp 182- 184.
[13] Dobb. H, K. Kalli and D.J. Webb, " Temperature insensitive long period gratting sensors in photonics crystal fiber", Electron. Lett, Vol. 40, 2004, pp 657- 658.
[14] Dong X and H.Y. Tam, " Temperature insensitive strain sensor with polarization maintaining photonic crystal fiber based on sagnac interferometer", Appl. Phys. Lett, Vol. 90, 2007.
[15] Wadsworth. W.J, J.C. Knight, H.H. Reewes, P.S.J. Russell and J. Arriaga, " $Yb^{3+}$ doped photonic crystal fiber laser", Electron Lett, Vol. 36, 2000, pp 1452- 1453.
[16] Liu X, X. Zhou, X. Tang, J. Ng, J. Hao, T. Chai, E. Leong and C. Lu, " Swithable and tunable multiwavelength erbium doped fiber laser with fiber bragg grating and photonic crystal fiber", IEEE Photon. Technol. Lett, Vol. 17, 2005, pp 1626- 1628.
[17] Hansen T.P, J. Broeng, S.E.B. Libori, E. Knudsen, A. Bjarklev, J.R. Jonson and H. Simonson, " Highly birefringent index guiding photonic crystal fibers", IEEE Photon. Technol. Lett, Vol. 13, 2001, pp 588- 590.
[18] Sapulak M, G. Statkiewicz, J. Olszewski, T. Martynkine, W. Urbanczyk, J. Wojcik, M. Makara, J. Klimek, T. Nasilowski, F. Berghmans and H. Thienpont, " Experimental and theoretical investigations of birefringent holey fibers with a triple defect", Appl. Opt., Vol. 44, 2005, pp 2652- 2658.