Design Of Borosilicate Crown Glass Photonic Crystal Fiber With Flattened Dispersion And Low Confinement Loss

Shilpa Tiwari*, Sunil Jalwania, Ajay Kumar Bairwa*****
*(M .Tech (scholar) , Department of Electronics & Communication, Jaipur National University ,Jaipur.
** (Assistant Professor, Department of Electronics & Communication, Jaipur National University, Jaipur.
*** (Assistant Professor, Department of Electronics & Communication, RITM, Rajasthan Technical University Jaipur.

ABSTRACT

In this paper, we present a borosilicate crown glass PCF for dispersion application and confinement loss having a large core diameter. Using the finite difference time domain simulation method it has been demonstrated that the proposed fiber has low loss and negative dispersion flat properties with common pitch (Λ=2.0µm).Here, a hexagonal seven ring borosilicate crown glass microstructure is used with no air holes in the first ring for having larger core with air hole diameter 'd' is 1.0 µm.

Keywords – Borosilicate Crown Glass, Dispersion, Effective Refractive Index, Finite difference time domain, Photonic Crystal Fiber

1. INTRODUCTION

PCF [1],[2] consisting of central defect region surrounded by multiple air holes ,that run along the fiber length are attaching much attention in recent years because of their unique properties which are not realized in convectional optical fibers. PCFs are divided into two different kinds of fibers. The first one, index guiding PCF, guides light by total internal reflection between a solid core and a cladding region with multiple air holes [3][4].

On the other hand, the second one uses a perfectly periodic structure exhibiting a photonic band gap (PBG) effect at the operating wavelength to guide light in a low index core region [5][6].Especially, index guiding PCFs also called holey fibers or micro structured optical fibers, possess attractive propagation characteristics, by varying the geometrical parameters such as diameter of air hole(d) and hole to hole spacing (Λ). However , in conventional PCFs , all of the same air hole diameter in a cladding region is used to control different propagation properties like chromatic dispersion ,confinement loss etc. Using conventional design technique, it is difficult to control the dispersion slope in wide wavelength range [7].

On the other hand, very recently research work is focused on different types of PCFs having solid or hollow core regular as well as irregular geometries and using different materials [8]. Non silica compound glasses like borosilicate crown glasses have been effectively used in PCFs for investigation of non-linear propagation in PCFs [9-11].The achieved high linear refractive index [Up to 1.51] and high non linearity in borosilicate crown glasses are more suitable for fiber based photonic wire devices[12].In this paper ,we reported a new controlling technique to control dispersion and confinement loss of hexagonal lattice of borosilicate crown glass PCF having large core at different wavelength ,using semi- vectorial effective index method(SVEIM).

2. PROPOSED STRUCTURE

Figure 1 shows the proposed PCF structure having large core, to make the core becomes larger we remove the first ring along with the center from the seven ring hexagonal lattice .Thus the proposed structure having six rings while in conventional borosilicate crown glass PCF there is only one missing air hole from the center of the PCF, which makes core.

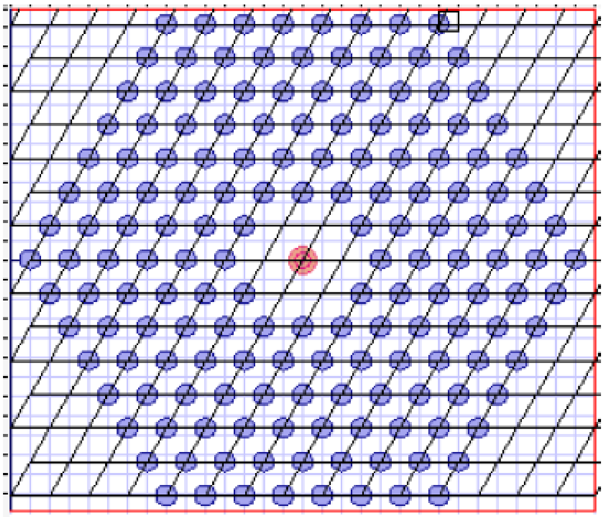

Figure 1. The structure of the proposed PCF.

The refractive index of borosilicate crown glass is given by sellmeier formula [13]:

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

(1)

In transparency region, the sellmeier formula can be reduced in Cauchy relation [14]:

$$n^2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \qquad (2)$$

Here A= 7.56, b=1.03μm^2 and C = 0.12 μm^2 are Cauchy coefficients.

3. Photonic Crystal Fiber characteristics

3.1 Dispersion Calculation

Chromatic dispersion or total dispersion D (λ) is a sum of both waveguide dispersion D_w (λ) and material dispersion D_m (λ) i. e.:

$$D(\lambda) = D_w(\lambda) + D_m(\lambda) \qquad (3)$$

Waveguide dispersion D_w (λ) occurs due to wavelength dependence of propagation constant of propagating mode and material dispersion D_m (λ) occurs due to wavelength dependency of refractive index of material.

The dispersion coefficient D (λ) is represented as :

$$D(\lambda) = -\frac{\lambda}{c}\frac{d^2\,\mathrm{Re}[n_{eff}]}{d\lambda^2} \qquad (4)$$

Where ‘n_{eff}’ represents effective refractive index, λ is the operating wavelength and c is velocity of light in vaccum.

The material dispersion given by sellmeier formula is directly included in the calculation, so the above equation gives the total dispersion of PCFs.

3.2 Confinement Loss

Confinement loss is the light confinement ability within the core region .The confinement loss L_c is obtained from imaginary part of n_{eff} as [15]:

$$L_c = \frac{(20\times10^6)}{\ln(10)} k_0\,\mathrm{Im}[n_{eff}] \qquad (5)$$

With the unit dB/m , where Im(n_{eff}) is the imaginary part of the refractive index , $k_0 = 2\pi/\lambda$ is the wave number in free space[16].

4. Simulation Results

Fig. 2(a) and 2(b) shows the simulation field at pitch(^)= 2.0µm and hole diameter d= 1.0 µm, at wavelength (λ) = 0.4µm, of conventional PCF and proposed PCF respectively.

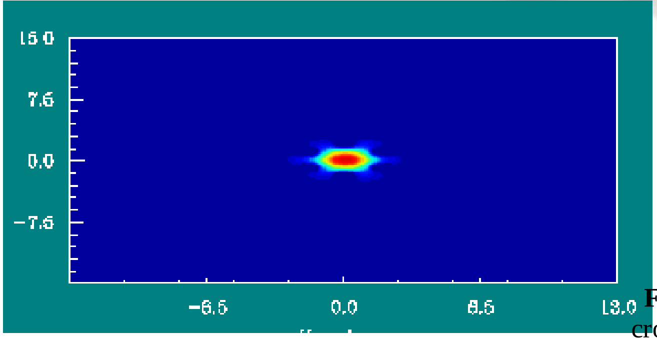

Fig 2 (a) Intensity profile of Conventional PCF

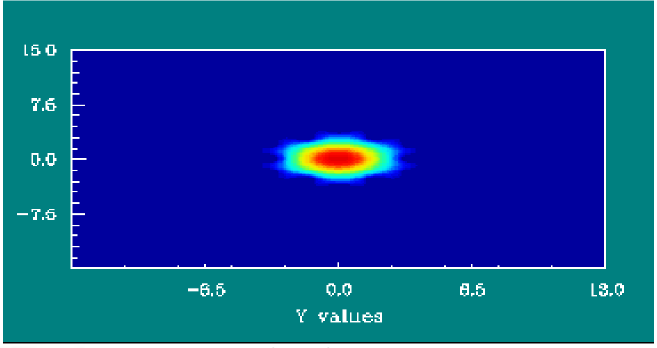

Fig 2 (b) Intensity profile of Proposed PCF

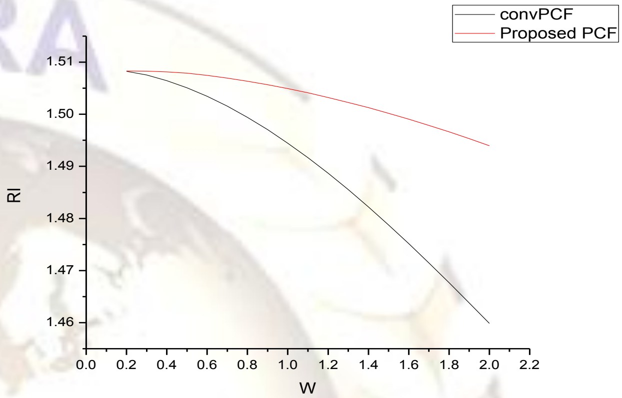

Fig 3 Comparison of refractive index

Here fig 3 shows the comparison of refractive index of conventional PCF and proposed PCF .The refractive index difference is increased between conventional PCF and proposed PCF with increasing wavelength.

Now, the material dispersion which is calculated by using sellmeier formula .Material dispersion is independent of structure parameter of fiber (like d, λ),so material dispersion remains constant for any lattice structure of Borosilicate Crown glass PCF.The below fig 4 represents the graph of material dispersion for different wavelengths.

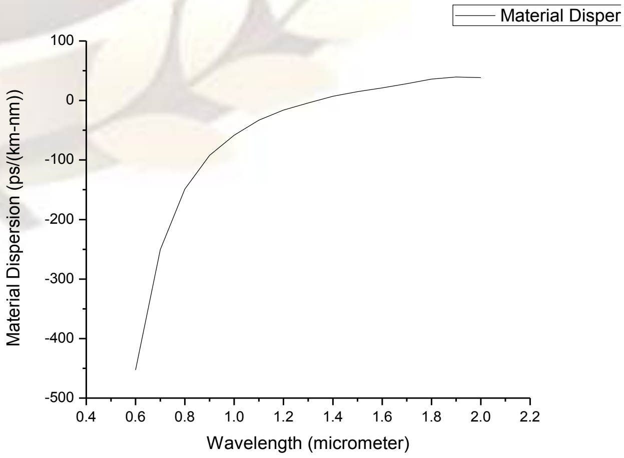

Fig 4 Material Dispersion curve of borosilicate crown glass PCF.

Now the chromatic dispersion characteristics is given by fig 5.The chromatic dispersion is the sum of material dispersion and waveguide dispersion ,which has been determined by using semivectorial effective index method with Neumann boundary condition at different wavelengths.

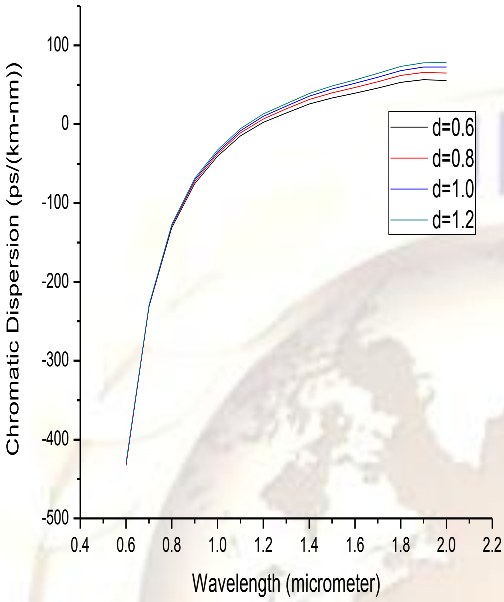

Fig 5 Chromatic Dispersion of the proposed PCF , using different diameters and a common pitch Λ=2.0µm

The confinement loss characteristics of the proposed borosilicate crown glass PCF with air hole diameter d=1.0µm and hole to hole spacing Λ=2.0µm is shown as fig 6.

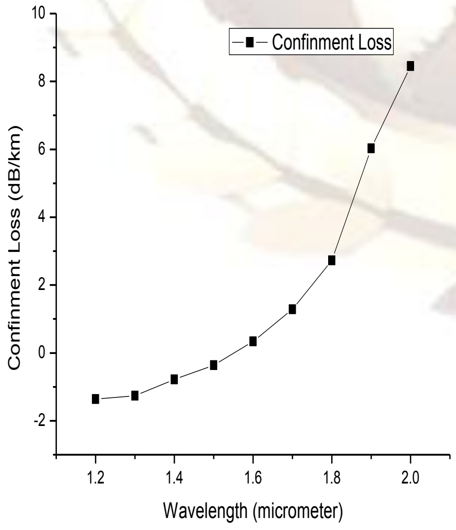

Fig 6 Confinement Loss of the proposed PCF at different wavelengths

The confinement loss in dB/km, for different wavelength is given as below:

λ(µm)	Loss(dB/m)
1.1	-1.487885
1.2	-1.363732
1.3	-1.258828
1.4	-0.779273
1.5	-0.363656
1.6	0.340933

Table 1

5 Conclusion

In this paper a technique has been proposed to acquire flattened dispersion and low confinement loss, using Non silica material i.e. borosilicate crown glass.

The borosilicate crown glass PCF with a large core provides more negative dispersion and low confinement loss as compare to the conventional PCF. It is analyze that by having different air hole diameter‘d’ and keeping hole to hole spacing ‘ Λ’ constant , we can acquire negative as well as positive and also zero flattened dispersion.

6. Acknowledgement

I really thankful to Prof. R.L. Dua , Prof R.P. Gupta and Mr. Ravindra Kumar Sharma for their valuable efforts in this paper.

References

[1] J. Broeng, D.Mogilevstev,S. E. Barkon , and A. Bjaruev, “Photonic crystal fibers : A new class of optical waveguides ,” *Opt. fibers Technol. vol. 5,pp.305-330,July 1999.*

[2] T.A. Birks, J.C. Knight, B.J. Mangan, and P.St.J.Russell,”Thotonic crystal fibers: An endless variety.” *EICE Trans. Electron. E-84- C, pp. .585-592, May 2001.*

[3] J.C.Knight, T.A.Birks, P.B.J.Russell,and D.M.Atkin, “All –silica single mode optical fiber with photonic crystal cladding” *Opt. Lett. vol.21-pp.1547-1549, Oct. 1996.*

[4] T.A. Birks,J.C. Knight,and P.St.J.Russell, “Endlessly single mode photonic crystal fiber” *Opt. Lett. vol. 22, pp.961-963, July 1997.*

[5] J.C. Knight, J.Broeng, T.A.Birks, and P.St.J. Russell, “photonic band gap guidance in optical fiber”, *Science vol. 282, pp.1476-1478,Nov. 1998.*

[6] RF. Cregan, B.J. Mangan , J.C. Knight, T.A. Birks, P.St.J.Russell,P.J. Roberts, and D.C.Allan, “Single mode photonic band gap guidance of light in air,” *Science vol. 285,pp.1537-1539,Sept. 1999.*

[7] Kunimasa Saitoh and Masanori Koshiba, “Unique dispersion properties of photonic crystal fibers,” *IEEE, ICICS-PCM2003, 1A7.3, Dec 2003.*

[8] Bhawana Dabas, R.K.Sinha, “Dispersion characteristic of hexagonal and square lattice chalcogenide As_2Se_3 glass photonic fibers,” *Opt. Comm.283, 1331-1337(2010)*

[9] A.V.Husakou, J.Herrmann, *Appl. Phys B77* (2003) 277.

[10] T.M.Monro, D.J. Richardson, *C.R.Physiqu 4*(2003) 175.

[11] S.Roy, P.R. Choudhuri, *Opt.Commun.282* (2009) 3448.

[12] M.R.Lamont, B.Luthe-Davies, D.Choi,S.Madden,B.J.Eggleton,Opt. *Express16*(2008)14938.

[13] G.P.Agarwal *,Non linear Fiber Optics, third ed.* (Academic Press, New York, 1995).

[14] G.Boudebs,S.Cherukulappurath ,M. Guignard, J.Troles,F.Smektala, and F.Sanchez, “Linear optical characterization of chalcogenide glasses ,”*Opt. common. 230,331-336(204).*

[15] Sh. Mohammad Nejad, M. Ahramezani, M. Pourmahyabadi, “Design and simulation of a dual core photonic crystal fiber for dispersion compensation over E to L wavelength band,” *International Symposium on Telecommunications, pp.138-43,2008.*

[16] Sharam. Mohammad Nejad, Nasrin. Ehteshami, “Novel design to compensate dispersion for index guiding photonic crystal fiber with defected core,” *IEEE, ICMEE 2010, vol. 2, pp.417-421, 2010*