Photonic Crystal Fiber for minimizing the Intermodal Dispersion and Enhancing the transmission profile

Mekhla Dadhich [1], Aabhas Mathur[2], Dr. Hemant Dhabhai [3]

[1] Scholar, M. Tech., Digital Communication, Aravali Institute of Technical Studies, Udaipur, India
dadhichmekhla@gmail.com
[2] Associate Professor and Head, Department of Electronics & Communication, Aravali Institute of Technical Studies, Udaipur, India
aabhas08_mathur@gmail.com
[3] Director, Aravali Institute of Technical Studies, Udaipur, India
hemant1_anu@rediffmail.com

***Abstract*—Optical fibers have brought a huge revolution in the field of communication due to their enormous properties, better quality of signals and large versatility. Therefore there is continuous research and practical implementations are taken out in hierarchal manner to exploit the great advantage of optical communication. At the same time Optical System faces some limitations with the profiles of the fiber being analyzed such as Non Linearity, Losses, and Dispersion. A class of optical fiber, Photonic Crystal Fiber (PFC), which effectively overcome above limitations to great extents. PCF is an optical fiber with the characteristics of photonic crystals. The other names of PCFs are holey and Microstructure Optical Fiber. The structure of this fiber is unique in its own way and the design is very flexible. In this paper I have made a comparative study of various parameters of all structured of PCF i.e. Circular, Rectangular, and Hexagonal. There are two cases to be considered, in first case the pitch value is constant and diameter of hole is varying for all the structure. In second case value of pitch value is varying but diameter of hole is constant. The readings have been taken to measure minimum overall dispersion. A PCF with minimum dispersion property is very useful for next generation optical and data communication. Along with the PCF, we will also see the use of Finite Difference Time Domain method and transparent boundary condition below so as to achieve minimum dispersion.**

I. INTRODUCTION

THE Communication is a common part of our life and there are several signals (like audio, radio, light, etc.) are present for communicate from source to destination. From these the use of light and visible optical waves has been common for many years.

If you look from the beginning of the graham bell time, the first revolution in communication took place, when the audio signals were converted into electrical form and were transmitted on electrical wires, and were converted back into the audio form.

The past of communication in details, the frequency of operation is increasing higher and higher day by day from the audio frequencies. Whereas, although findings of optical communication carried out in the beginning of the twentieth century. Its use was restricted to mobile, low-capacity communication links. It is because of both the lack of proper light sources and the problem that light emission in the environment is limited to line of sight. It is extremely impacted by obstacles such as rain, snow, fog, dust and atmospheric turbulence. According to their wavelengths, these electromagnetic carriers could be travelled over significant amount of distances but are limited to the quantity of information they can carry and transmit by their frequencies. A brand new absorption in the field of optical communication was started in the early 1960s with the invention of the laser.

II. PHOTONIC CRYSTAL FIBER

The returns of researchers and engineers from different parts of different laboratories, since beginning of the 1980s decade, has been captured by the unique characteristics to structure materials with respect to the optical wavelength, a micro part of micrometers or less, so as to produce new optical way, known as photonic crystals. PCF is unique optical fiber which uses the characteristics of photonic crystals. The advantages of PCF against a conventional optical fiber are ability to hold optical properties and confinement characteristics of material.

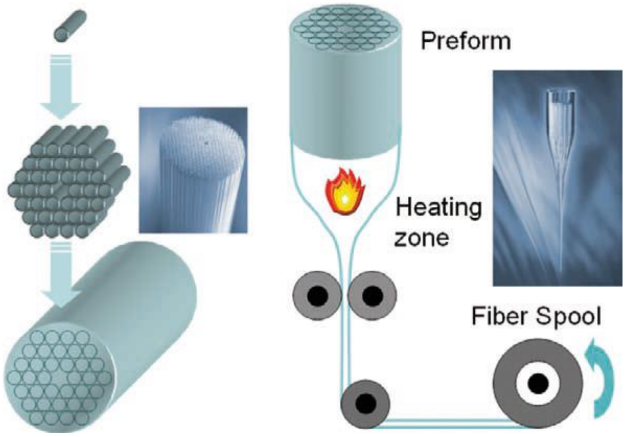


Figure 1: Process of the PCF fabrication process.

III. CLASSIFICATION OF PHOTONIC CRYSTAL FIBER

The structure of PCF contains uniform arrangement of several air holes. But there are some different properties such that geometry, material, operating principle, application are present which classified PCF in to two parts. First one is solid core PCF and second one is hollow core PCF.

A. Solid Core PCF

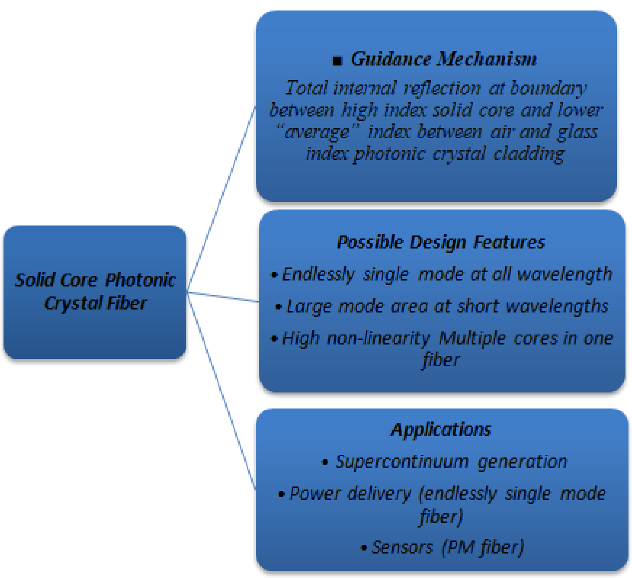


Chart 1: Classification of Solid Core PCF

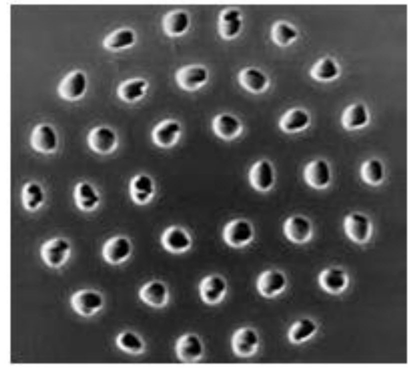


Figure 2: Representation of Solid Core PCF

B. Hollow Core PCF

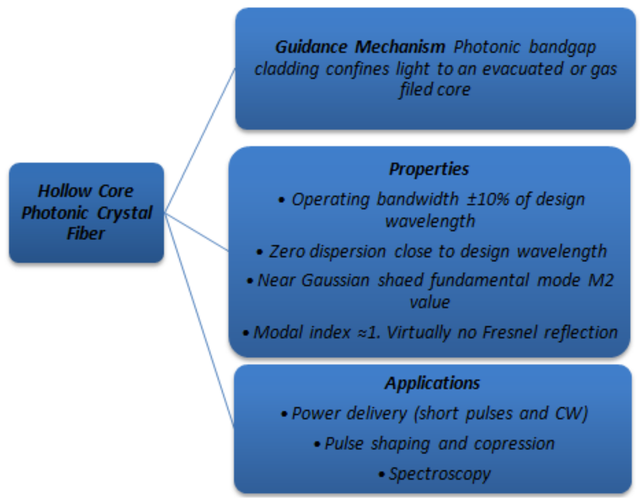


Chart 2: Classification of Hollow Core PCF

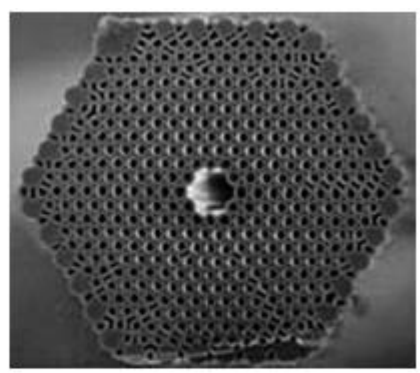


Figure 3: Representation of Hollow Core PCF

IV. GUIDING MECHANISM

Guiding mechanism is the phenomenon which provides light propagation in the fiber with respect to the refractive index. According to this mechanism PCF divided into two types: first one is index guiding fiber and second one is photonic band gap guiding fiber. In solid-core PCFs the guiding mechanism is similar as conventional optical fiber, in which the light is limited in a area of higher refractive index, updated overall internal reflection is exploited. On the other hand, when light is restricted in the area with a refractive index lesser than that of the nearby region, as in hollow-core fibers, it is compulsory to have the presence of the photonic bandgap (PBG).

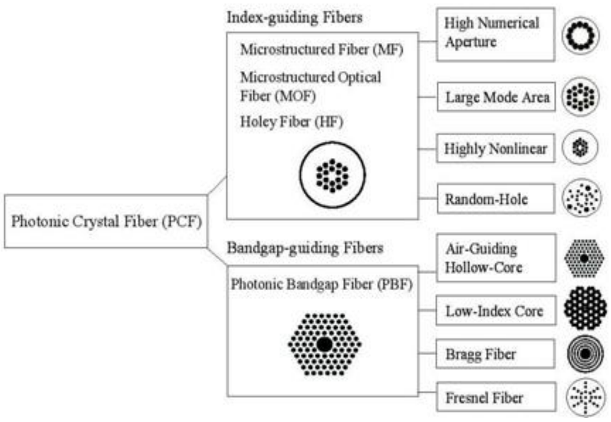


Figure 4: Allocation of PCF

V. ADVANTAGES OF PHOTONIC CRYSTAL FIBER

PCFs have more advantages as compare to the conventional optical fiber. From them one is important that is to control all possibility of optical characteristics and restraint characteristics of material.

a) PCF carry large amount of power with larger cores as compare to conventional fibers.
b) Hollow fibers (air holes) are present for guidance so attenuation becomes smaller than conventional fibers.
c) For effective index guidance PCFs having larger contrast.
d) In PCF dispersion can be control or become zero in the range of visible light by varying air holes size and position.

VI. DIS-ADVANTAGES OF PHOTONIC CRYSTAL FIBER

For the telecommunication purpose there are few disadvantages present in PCF such as high cost, small in length, and coupling with other waveguides and devices.

VII. TYPES OF LOSSES IN FIBER

Dispersion is the time domain spreading of transmission light pulses when they travel through the fiber.

The dispersion D is changes from the next derivative of the η_{eff}, with respect to the wavelength λ calculated as

$$D = \left(-\frac{\lambda}{c}\right)\frac{d^2 R_e(n_{eff})}{d\lambda^2} \qquad \text{…….. (i)}$$

Where Re [ηeff] is the actual element of ηeff, λ is wavelength, and c is the velocity of light in vacuum. [15]

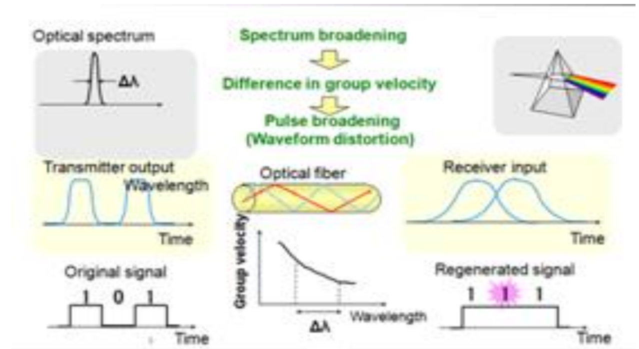


Figure 5: Process of dispersion

Material Dispersion-

There are some other group velocities of different spectral sub-category available into the fiber from the optical source, because of which the pulse broadening observed and produce material dispersion [1] [4-6] [8]. It observed when the part rate of the simple wave propagating from insulator path varies uncertainly with the wavelength and a fabric is about to represent material dispersion.

$$M = \frac{1}{L}\frac{d\tau_m}{d\lambda} = \frac{\lambda}{c}\left|\frac{d^2 n_1}{d\lambda^2}\right| \text{ps nm}^{-1}\text{km}^{-1} \qquad \text{…….. (ii)}$$

Wave guide Dispersion-

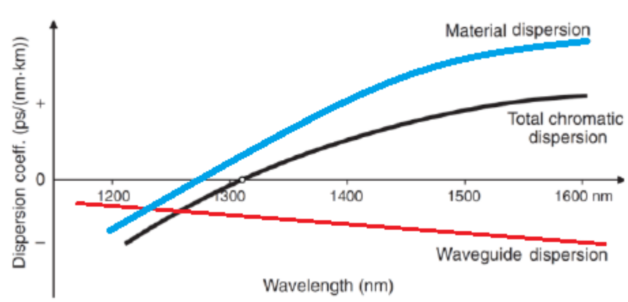
Waveguide dispersion is outcome of power distribution in the fiber's core and cladding, which is wavelength dependent. We can control it by changing the fiber's refractive index. A single mode fiber whose propagation constant is β, having waveguide dispersion when

$$\frac{d^2\beta}{d\lambda^2} \neq 0 \qquad \text{……. (iii)}$$

Whereas the multimode fibers are almost free from waveguide dispersion.

The dispersion is directly proportional to the calculation of the addition of the geometrical dispersion and the material dispersion observed as [1] [4-6] [10]:

$$D(\lambda) = D_g(\lambda) + \Gamma D_m \qquad \text{…….. (iv)}$$



Graph 1: Total dispersion of fiber (By changing the

Waveguide dispersion and balancing it against the Material dispersion)

VIII. DESIGNING PARAMETER OF PHOTONIC CRYSTAL FIBER

PCFs are fabricated by stacking macroscopic silica tubes in an array, inserting them into larger silica tube and drawing into fiber on draw towers the same way as standard optical fibers. [15] The designed PCF consists of a microstructure cladding region and a solid core. The covering has lesser value of refractive index than core. The core material is made up of silica glass which having refractive index of 1.458 and the refractive index of covering air pores is 1. The pitch delta Λ which is center to center positioning between two closest air pores is assembled as 2.0μm for the all over configuration. The lattice structure is also considered in two forms hexagonal lattice and rectangular lattice with circular air holes.

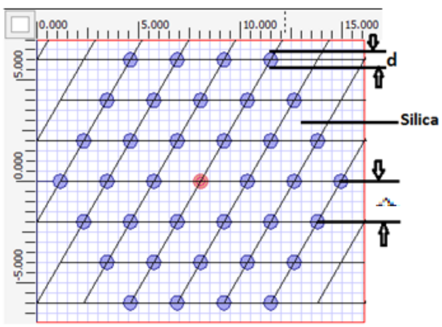


Figure 5: Counterfeit Structure of Hexagonal lattice with circular air holes

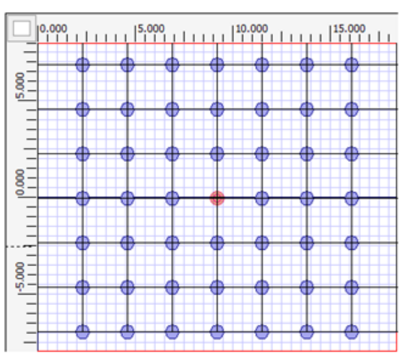


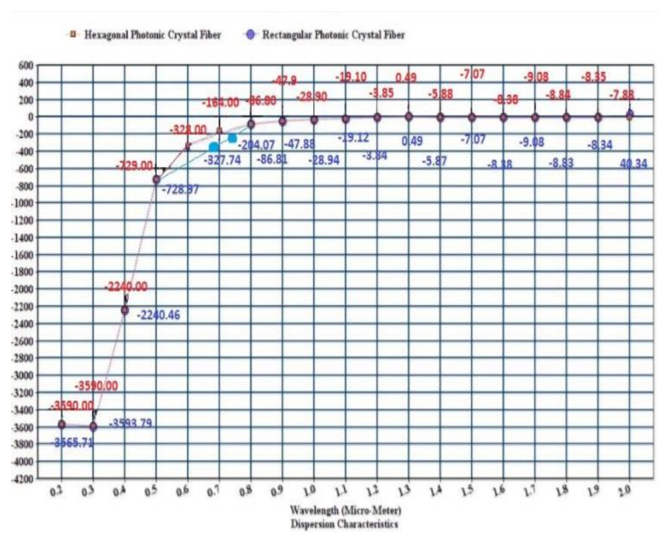
Figure 6: Counterfeit Structure of Rectangular lattice with circular air holes.

IX. COMPARISION BETWEEN DIFFERENT STRUCTURE OF PHOTONIC CRYSTAL FIBER

DISPERSION FOR CONSTANT DIAMETER ‘D’= 1 μm & PITCH VALUE= 2.0 μm.

Wavelength	Hexagonal PFC	Rectangular PCF
	Total Dispersion	
0.2	-3570.00	-3565.71
0.3	-3590.00	-3593.79
0.4	-2240.00	-2240.46
0.5	-729.00	-728.97
0.6	-328.00	-327.74
0.7	-164.00	-204.07
0.8	-86.80	-86.81
0.9	-47.90	-47.88
1.0	-28.90	-28.94
1.1	-19.10	-19.12
1.2	-3.85	-3.84
1.3	0.49	0.49
1.4	-5.88	-5.87
1.5	-7.07	-7.07
1.6	-8.38	-8.38
1.7	-9.08	-9.08
1.8	-8.84	-8.83
1.9	-8.35	-8.34
2	-7.88	40.34

Table 1: Comparison of Dispersion in Different PCF



Graph 2: Graphical representation of total Dispersion according to table 1

X. Conclusion

As per the result listed above, we found that the change in dispersion observed for both proposed PCF hexagonal and rectangular with the scalar index method gives expected output. On differentiating total dispersion in hexagonal and rectangular with circular air holes, the quantity of dispersion turns to zero on value of wavelength is 1.3 µm.

XI. References

[1] P. Yeh, A. Yariv, E. Marom, "Theory of Bragg Fiber" JOSA, Opt. Lett. Vol. 68, 1196 (1978).

[2] J.C. Knight, T.A. Birks, P.St.J. Russell, D.M. Atkin, "All-silica single-mode optical fiber with photonic crystal cladding" Opt. Lett. Vol. 21, 1547 (1996).

[3] S.S. Mishra and Vinod K. Singh "Highly birefringent PCF with low confinement loss at wavelength 1.55µm" Elsevier GmbH, Dec. 2010.

[4] M. Pourmahyabadi and Sh. Mohammad Nejad "Design of Single Mode PCFs with Low-Loss and Flattened Dispersion at 1.55µm Wavelength" ISSN-1803-7232, 2009.

[5] TAN Xiao-ling, GENG You-fu, TIAN Zhen, WANG Peng, and YAO Jian quan "Study of ultraflattened dispersion square-lattice photonic crystal fiber with low confinement loss" OptoElectronics Letters, Vol.5 No.2, March 2009.

[6] ENG You-fu, TIAN Zhen, WANG Peng, and YAO Jian quan "Study of ultraflattened dispersion square-lattice PCF with low confinement loss" OptoElectronics Letters, Vol.5 No.2, 1 stMarch 2009.

[7] Jingyuan Wang, Chun Jiang, Weisheng Hu, Mingyi Gao and Hongliang Ren "Dispersion and polarization Characteristics of elliptical air-hole-containing PCFs" science direct Optics & Laser Technology Elsevier, 2007.

[8] Jung-Sheng Chiang, Rui-Sheng Wang, Hsi-Cheng Yang and Yu-Liand Chen "Analysis of Elliptical-Hole PCF" 2nd International Symposium on Next-Generation Electronics (ISNE) IEEE, Kaohsiung, Taiwan, ISSN No. 9781978146733037, Feb. 2013.

[9] Federica Poli, Annamaria Cucinotta, Stefano Selleri "PCFs-Characteristics and Application" ISSN 0933033x, 2007

[10] Shish Ram, Ritu Sharma, And Vijay Jayani, Rotash Kumar "Comparison of Dispersion Characteristics for Different Lattice of PCF" ICEICE No. 3, Dec 2011

[11] T. A. Birks, J. C. Knight, and P. St. J. Russell "Endlessly single-mode PCF" Vol. 22, PP 961-963, 1997.

[12] Anders Bjarklev, Jes Broeng , Kim Dridii, and Stig E. Barkou "Dispersion Characteristics of PCFs" June 2010

[13] Jan Sporik, Miloslav Filka, Vladimir Tejkal, Pavel Reichert "Principle of PCFs" Vol.2, No. 2, June 2011.

[14] S.Olyaee, M. Sadeghi and F.Taghipour "Design of Low Dispersion fractal PCF" IJOP, Vol. 6, 2012.

[15] P. AndrCs, A. Ferrando, E. Silvestre, J.J. Miret, and M.V. AndrCs "Dispersion and Polarization Characteristicsin PCFs" ICTON, PP 98-103, 2002.