Analysis and Study of Refractive Index of Different Types of PCF Core Materials

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Abstract

Photonic crystal fiber is a widely searched researched area which took the attention of researchers towards this field. Actually since last two decade, innovations and experiments have been increased in this field. For this field various materials and design have been used for calculation and verifying the refractive index [13,14,15] of the core material used. Since Photonic crystal fibers [10 -15] have various properties through which they can be used, among them the only few are widely used to calculate and measure in various design and structure. In this paper we tried to compute and compare the Refractive Index properties of various materials like the conventional material of PCF [10-11] is Silica Glass [1-2], borosilicate crown glass (BK7) [3], chalcogenide glass [4-5]. Apart from the some other properties we have considered some other physical and chemical properties of these materials. ToCompare these properties of all these materials we used to refer various articles and research papers then finally concluded that all the three material have their own merits and demerits and they shows their properties in best manner for the selected wavelength region of 0.2 micrometer to 2.0 micrometer. We have prepared various tables with the data collected and draw graphs between them to show the variation of these parameters for various material used used.

Keywords: *Dispersion, Refractive index, Photonic Crystal Fiber, Pitch value, Core and Cladding.*

1. INTRODUCTION

A. Borosilicate Crown Glass (BK7)

The BK7 [3] glass or an optical barium borosilicate crown glass is known asa higher quality optical fiber glass which is used wherever we cannot use the additional benefits of fused silica fiber. Since we know that Borosilicate Crown Glass fiber is well under all chemical examinations [3], and no extra or special type of care during handling is required, thus cost of manufacturing is reduced. It has a high transmission medium which is free of bubbles and inclusions. It also used to provide excellent transmittance through-out the visible and near infrared spectrum and down to 350 nm in the ultraviolet. This BK7 has higher losses through **higher absorption** and **scattering** and therefore cannot be used for high power applications.

It is being very well known for its high transmission rate, clean and clear appearance. It is used by far the most common material for various optical glass applications, because it providesvery good optical properties at a very reasonable cost. It's used often as a standard of comparison for other glass materials. The expressed low coefficient of expansion is also allows manufacturing it with very heavy walls providing it a high mechanical strength, while retaining reasonable heat resistance. It is a glass fiber which can be fabricated more and more easily than most other glass fibers, in this way making it more economical for researchers. Borosilicate is by far the most widely used, and preferred, glass for laboratory apparatus.

B. Chalcogenide (As_2Se_3) glass

Chalcogenide glasses [4-5] are used to demonstrate the better refractive index for glasses like sulfide. The better refractive index can availbetter Fresnel refraction [13-15] and it helps in the well-guiding mechanism of surrounding cladding medium. There are basically a major drawbacks exist which is generally relatedtothelightinjection property ofchalcogenideglassfibers.Since we know that therefractiveindex of any material (n)iswavelength dependent function, so Chalcogenide glass fibers are used as transparent from the visible to the near infrared region and can be used todesign lenses or mold into required fibers. They havewide applications in the field of commercial applications in terms of components used for the fabrication of lenses for infrared cameras. The chalcogenide glass fibers and various optical components are also used in preparation of waveguides which can be used with lasers and optical switching.

It has various other applications like Chemical and temperature sensing, phase changing memories.The Chalcogenideglasses are used to show comprehensively resultsto the latest and deployed technological advancements in the field of optics as well as show the industrial applications of the technology.

C. SilicaGlass

Due to the improvement in selection of fiber materials the Silica glass is widely used in photonic crystal fibersmaterials as a transmission medium in communication terrestrial now days. The photonic crystal fibers were proposedtwenty year back for this reason but and now a day it is mostly used medium as compared to others medium available. Apart from all the materials available for PCF Silica photonic crystal fibers is mostly used as a material for the PCF. **Silica** which is easily available in the surroundings can be used as purest form of SiO_2. This raw silica is used to convert into EGS from various processes. This glass has superior transmission chatcteristics in both the UV and IR spectra, a very low dielectric coefficient and excellent properties where fluorescence or polarization are an issue. This silica can be shaped to many forms and sizes. It has excellent resistance to non-fluorinated acids, solvents and plasmas. Fused Silica glasses can be obtained by **Heraeus** and **Nikon. T**he produced silica shows extremely high grade (pure) and exhibit excellent *ultraviolet* and *infrared* characteristic [1-2]. We can use this high quality material where purity, a non-reactive [1], durable substrate and homogeneity between melts (uniform optical properties [1-2]) are needed. This silica glass very has good mechanical strength and show almost perfect elasticity. It can be ground and polished into one of the flattest surfaces in the world due to its nearly zero coefficient of expansion and contraction capability. It can also be melted into solid ingot form from silicon rod which is drawn into hollow "fused quartz" ingots for tubing fabrication. Due to all these properties mentioned it can be processed into some of the finest optical devices available. Some of the properties are mentioned which is shown by Silica are high chemical purity, high temperature and high thermal resistance, low thermal expansion coefficient, high resistance to thermal shocks and high radiation resistance.

II. REFRACTIVE INDEX PROFILE:

A **refractive index profile** can be defined as the distribution of refractive indices of materials used within an optical fiber. Since there are various optical materials available among them some optical fiber shows step-index profile in which the core has uniformly-distributed index and the cladding has a lower uniformly-distributed index. The available optical characteristics of the fiber materials includes mode field diameter (MFD) ranging from the selected wavelength region, cut-off wavelength i.e. threshold wavelength and chromatic dispersion can also be derived from the refractive index profile. The refracted near-field technique is used to determine thefibre's refractive index profile. Beside it a refracted ray technique can also be implemented for this calculation..Modern fiber or slab waveguide designs are based on index profiles distribution which assuresthe proper operation of PCF within theselected range of wavelengths i. e. 0.2 micrometer to 20 micrometer.

In terms of theoretical knowledge the refractive index profile is shown below in the Maxwell equations, where x can be given as region's local coordinate of wavelength and w is given as the width from the region.

It is shown as

Constant index profile:

$$n(x) = const \tag{1}$$

Linear index profile:

$$n(x) = n(0) + x \cdot \frac{n(w) - n(0)}{w} \tag{2}$$

Parabolic index profile:

$$n(x) = [n(w) - n(0)] \cdot \left(\frac{x}{w}\right)^2 + n(0) \tag{3}$$

Exponential index profile:

$$n(x) = [n(0) - n(w)] \cdot \frac{e}{e-1} \cdot \exp\left(-\frac{x}{w}\right) + \frac{e \cdot n(w) - n(0)}{e-1} \tag{4}$$

where n (0) and n (w) show the refractive index at x=0 and x=w, respectively.

Gaussian index profile:

$$n(x) = n_{max} \exp\left\{-\ln 2 \cdot \left[\frac{2 \cdot (x - x_0)}{h \cdot w}\right]^2\right\} \tag{5}$$

ISSN: 2233-7857 IJFGCN

Here $\mathbf{n_{max}}$ show the maximum index value x_0 at the peak position, and h is the normalized value ofFull width at half maximum (FWHM).

Alpha-peak index profile:

$$n(x) = n_{max} \cdot \sqrt{1 - 2\Delta \cdot \left(\frac{x}{w}\right)^{\alpha}} \tag{6}$$

Here $\mathbf{n_{max}}$ show the maximum index value and Δ shows the normalized index difference. This difference is defined as

$$\Delta = \frac{n_{max}^2 - n_{min}^2}{2n_{max}^2} \tag{7}$$

Alpha-dip index profile:

$$n(x) = n_{max} \cdot \sqrt{1 - 2\Delta \cdot \left(1 - \frac{x}{w}\right)^{\alpha}} \tag{8}$$

Here $\mathbf{n_{max}}$ show the maximum index value, and Δ is the normalized index difference.

III. ANALYSIS OF REFRACTIVE INDEX OF DIFFERENT MATERIALS FOR SAME STRUCTURE:

Chalcogenide Glass:

Among the various material studied , in this paper we have selected three materials for calculation of refractive index due to their unbeatable properties and withstanding with all other materials we decide to analyze only three core materials. For this chalcogenide glass, borosilicate crown glass and silica glass is selected and their structure having seven layers, 1 micrometer diameter and two micrometer pitch value and 0.2 micrometer to 20 micrometer wavelength region is being selected for all the materials. With these parameters structures are designed which is shown below in figure 1.

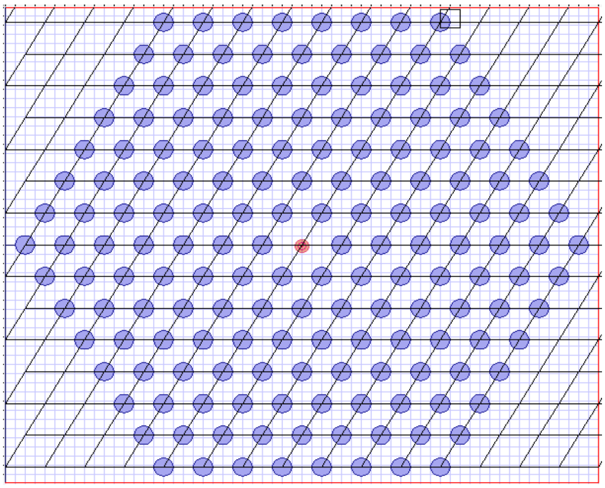

Figure 1: structure of Chalcogenide Glass

With the use of this structure the variation of refractive index is shown below in figure 2. It is obtained that refractive index of Chalcogenide Glass from the plot is 2.824 which is equivalent to the material itself.

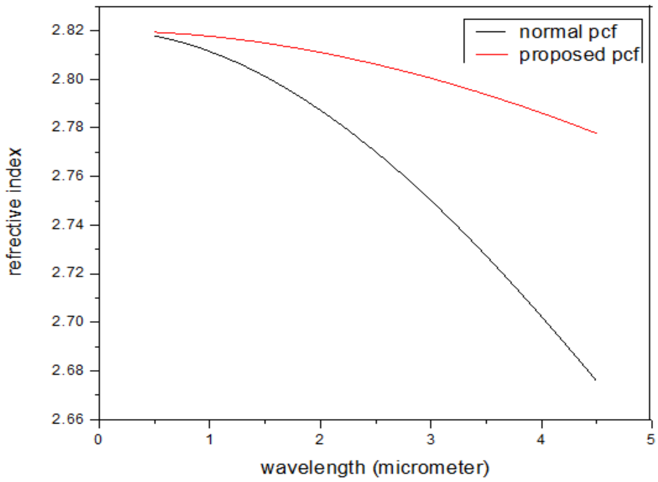

Figure 2: Variation of Refractive Index of Chalcogenide Glass

Borosilicate crown glass: With the same parameters used for chalcogenide glass, we have design this structure for borosilicate crown glass.

With the use of this structure the variation of refractive index is shown below in figure 3. It is obtained that refractive index of Borosilicate crown glass from the plot is 1.524 which is equivalent to the material itself.

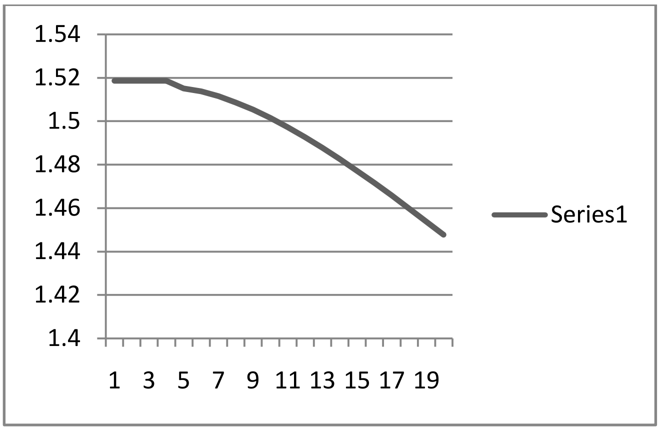

Figure 3: Variation of Refractive Index of borosilicate crown Glass

Silica Glass: With the same parameters used for chalcogenide glass, we have design this structure for silica glass.

With the use of this structure the variation of refractive index is shown below in figure 4. It is obtained that refractive index of Silica glass from the plot is 1.457 which is equivalent to the material itself.

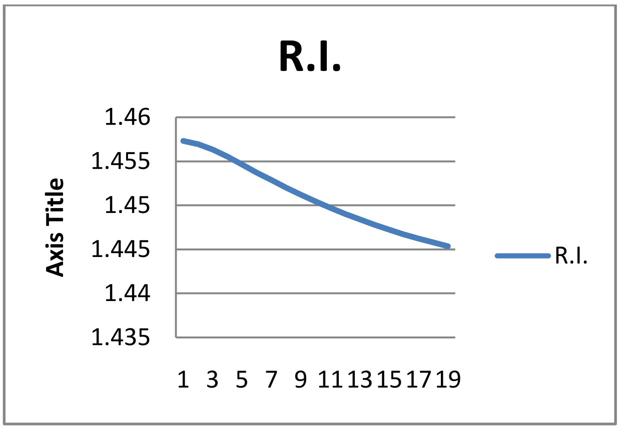

Figure 4: Variation of Refractive Index of Silica Glass

3. CONCLUSION:

From the above mentioned properties and application of various materials it is concluded that every material has their own advantages and disadvantages in their application domain. But since we have use three prime materials for the calculation and analysis of refractive index profile, we found that each material has significance roll in designing and analysis of these parameters. Finally it is concluded that the material selected for designing structure shows the respective refractive index of material used for the structure for the proposed structure.

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