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Analysis of non-linear Effects and Dispersion Profile of Proposed Borosilicate Crown Glass Photonic Crystal Fiber

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***Abstract*— The proposed design of Borosilicate crown glass photonic crystal fiber is for minimizing the chromatic dispersion to low level. The Finite Difference Time Domain (FDTD) method along with the transparent boundary condition (TBC) is used for preparation of this design. This method is bringing to produce zero dispersion at 0.5µm to 1.5µm diameter of circular and elliptical air holes. Such PCF have high potential to be used as a dispersion compensating fiber in optical window. The refractive index is calculated with this method is equal to the conventional Borosilicate crown glass i.e. 1.534. The proposed design is also used to show the non-linear effects of the material used.**

***Index Terms*— Photonic Crystal Fiber (PCF), Chromatic Dispersion, Transparent Boundary Condition (TBC), FDTD (Finite Difference Time Domain).**

I. INTRODUCTION

Since its invention in the early 1970s, the use of and demand for optical fiber have grown tremendously. Fiber optics is a major building block in the telecommunication infrastructure. Its high bandwidth capabilities and low attenuation characteristics make it ideal for gigabit transmission and beyond. The field of fiber optics, especially with respect to telecommunication, is a rapidly changing world in which, seemingly, each day a new product or technology is introduced. A good way to start learning about this field is to research the companies that are making major strides in this industry. Optical fiber transmission uses wavelengths that are in the near-infrared portion of the spectrum, just above the visible, and thus undetectable to the unaided eye. Since we know that Borosilicate Crown Glass fiber is well under all chemical examinations [1], Typical optical transmission wavelengths are 950 nm, 1310 nm, and 1550 nm. The basis of the FVEIM development for the parameter assessment is the inclusion of the anisotropic Perfectly Matched Layers (PMLs) which has the ability to manage several modes as needed and evaluate the leaky modes [2].

II. PROPOSED STRUCTURE

The proposed structure is designed by considering various parameters like air hole diameter is varying from 0.5 µm to 1.5 µm range. The air hole spacing i.e. pitch is maintaining at 2 µm for nine layer structure.

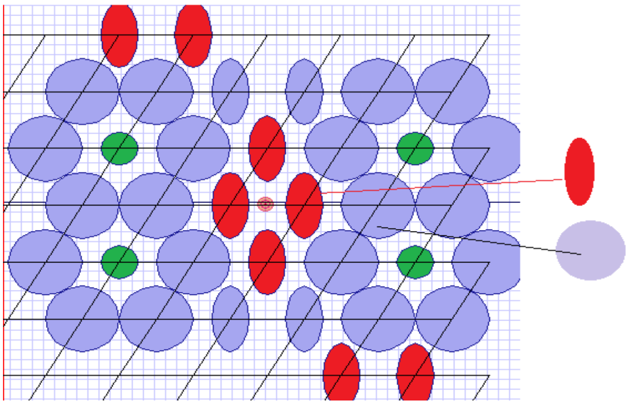

Figure 1: Proposed structure of Borosilicate crown glass

This proposed structure is used to minimize dispersion along with maintaining refractive index equal to the Borosilicate crown glass material i.e. 1.534.

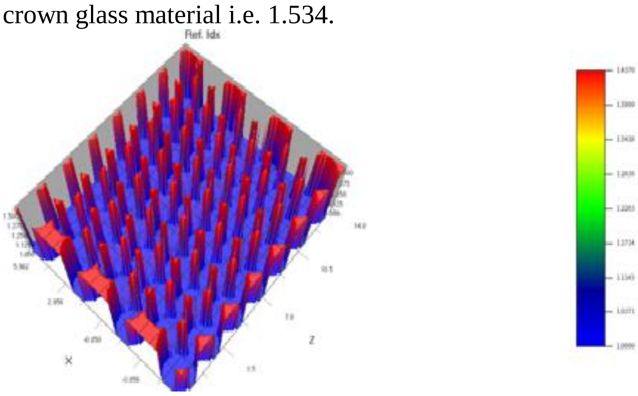

Figure 2: 2D structure of proposed design

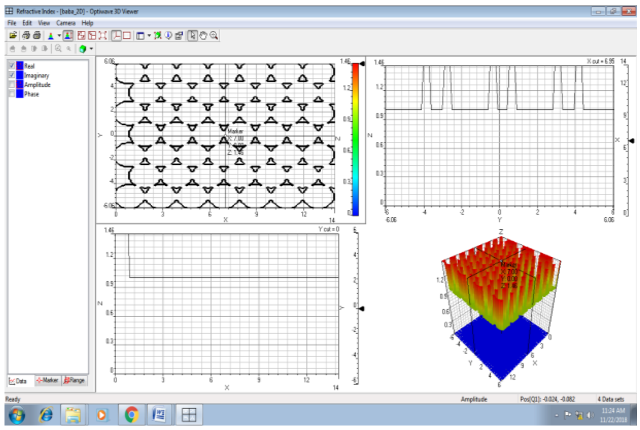

Figure 3: 3D viewer of amplitude variation of proposed design

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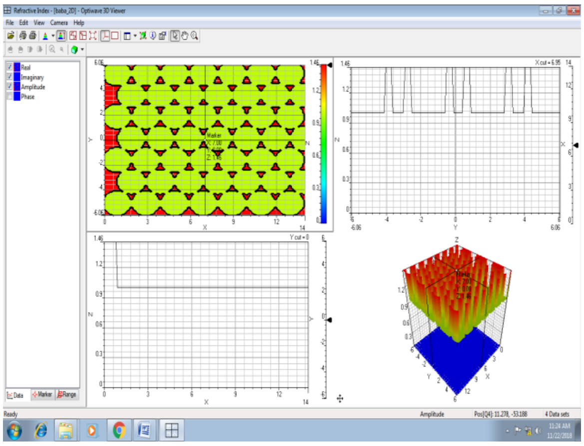

Figure 4: 3D Real view of proposed design

Various mode filled designs have been obtained to show the variation of Refractive index of Borosilicate crown glass with the proposed structure.

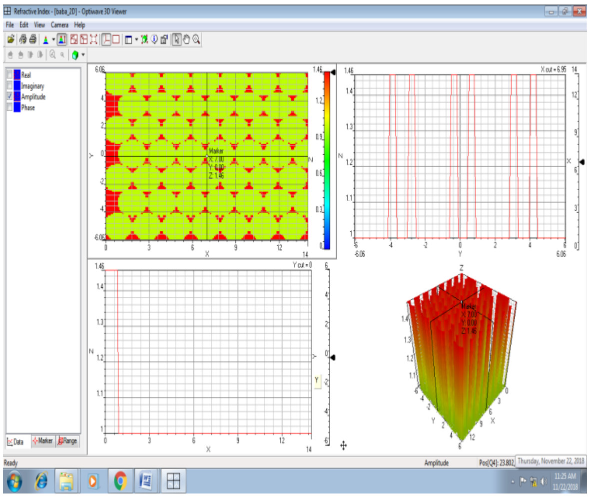

Figure 5: 3D viewer of phase variation of proposed design

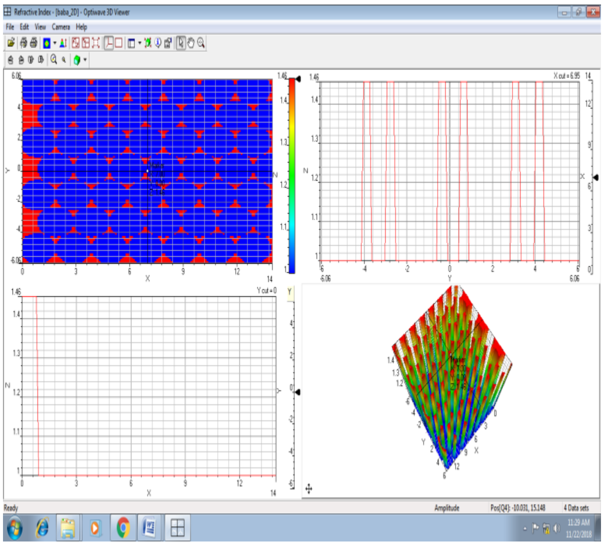

Figure 6: 3D imaginary view of proposed design

Above figure no. 3, 4, 5, and 6 shows the various 3 D viewer of the proposed structure but with varying parameters. All the above mentioned figures are showing changes with respect to change in dimensions and parameters selections. They also show variation in the amplitude and phase accordingly.

III. Mathematical Explanation

Inside a dielectric, the time independent Maxwell curl equations with a positive time convention ($e^{j\omega t}$) are

$$\nabla \times \mathbf{E} = -j\omega\mu_0 \mathbf{H} \qquad \nabla \times \mathbf{H} = j\omega\varepsilon_0\varepsilon \mathbf{E} \tag{1}$$

and the divergence equations are

$$\nabla \cdot (\varepsilon \mathbf{E}) = 0 \qquad \nabla \cdot \mathbf{H} = 0 \tag{2}$$

In the magnetic formulation, the electric field is eliminated from (1) by taking the curl of the second equation and substituting from the first. For regions of constant permittivity ε , there are no gradients of ε , and the equation simplifies to

$$\nabla \times \nabla \times \mathbf{H} = \omega^2 \mu_0 \varepsilon_0 \varepsilon \mathbf{H} \tag{3}$$

In view of the vector identity $\nabla\times\nabla\times\mathbf{A} = \nabla(\nabla\cdot\mathbf{A}) - \nabla^2\mathbf{A}$, and the property of **H** having zero divergence, (3) becomes

$$\nabla^2 \mathbf{H} + k^2 \varepsilon \mathbf{H} = 0 \tag{4}$$

where $k = \omega\sqrt{\mu_0\varepsilon_0}$ is the free space wave number.

It is true that it is usually the electric field, and not the magnetic field, that is of interest for applications. The motivation for solving the problem with a magnetic formulation is that the waveguide structure is created by introducing discontinuities in electric permittivity,ε, and not magnetic permeability, μ . When matching boundary conditions at layer boundaries, the normal component of the electric field is discontinuous, since it is the electric displacement, $\mathbf{D} = \varepsilon\varepsilon_0 \mathbf{E}$, and not the electric field that is to be made continuous.[4]

IV. Results & Discussions:

For the proposed structure of Borosilicate crown glass fiber the dispersion is so obtained and a graph is plotted for the design which shows that it is zero for the selected diameter range. The variation of dispersion is shown below in figure 7.

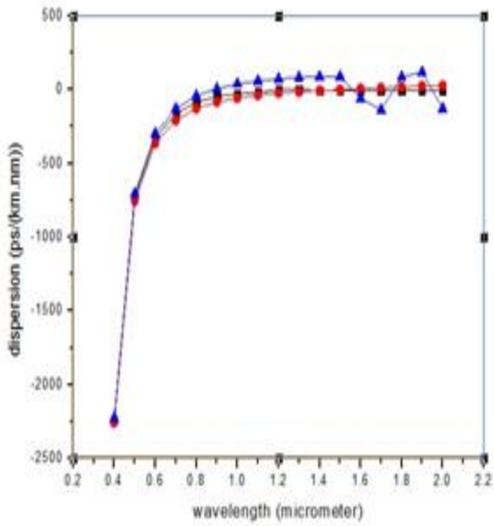

Figure 7: Dispersion obtained of proposed design

The above graph shows that the dispersion obtained for proposed structure is wquivalent to zero among the diameter region selected. It is shown clearly that it may vary for varying diameter.

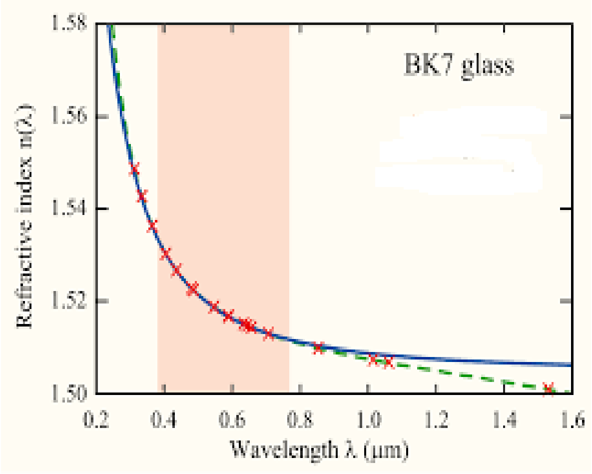

Figure 8: Refractive index

The refractive index profile of the proposed structure is obtained and plotted in a graph which shows that it is quite similar to the Borosilicate crown glass i.e. 1.534. It is shown above in the figure 8.

The transmission curve of the proposed structure is shown below in figure 9.

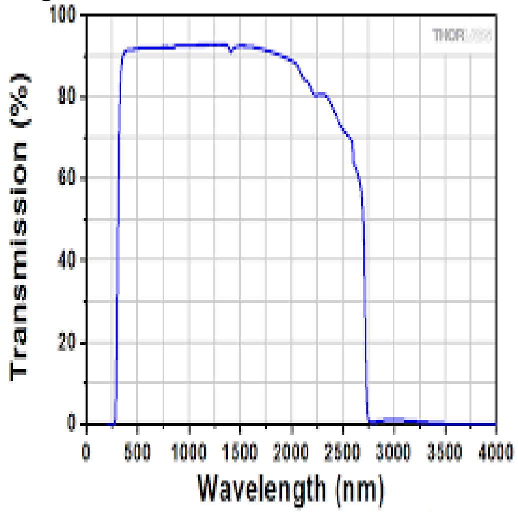

Figure 9: Transmission curve of proposed design

This transmission curve shows that the signal can propagate without loss in the selected wavelength region. Below and above this region the signal can degrade, which can be shown by the figure shown above.

V. Conclusion

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 material and the effective cladding index are wavelength dependent. It is also observed that Borosilicate crown glass PCF provides much better dispersion results as compared to other of the same structure and parameters.

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