Design to Analyze Low Loss Zero Dispersion in Water Filled Silica Photonic Crystal Fiber

Heema Kumari Tejiyot[1], **Sunil Sharma**[2], **Aabhas Mathur**[3] **Dr. Hemant Dhabhai**[4]

[1]Aravali Institute of Technical Studies, Udaipur
[2] Department of ECE, Faculty of Engg., Pacific University, Udaipur
[3]Department of ECE, Aravali Institute of Technical Studies, Udaipur
[4]Aravali Institute of Technical Studies, Udaipur
(heema.jain288@gmasil.comersharma.sunil@gmail.com aabhas08mathur@gmail.com hemant1_anu@rediff.com)

Abstract- **This work proposes the design and optimization of Refractive index and minimizing the loss for liquid filled silica photonic crystal fiber. Number of research papers has been investigated to get the best result with the proposed design. The core of the proposed Silica PCF structure is designed with liquid filled air holes. Numerical analysis is being carried out by using the Finite Element Effective Index Method (FVEIM) to calculate the modal dispersion, confinement loss and nonlinear coefficient of the proposed Silica PCF structure. Transparent boundary condition (TBC) is proposed here for the calculation of Refractive index. The design is proposed with three layers parallelopid hexagonal with water as a liquid filled having core diameter 1 micrometer, pitch value 2 micrometer. The calculated dispersion is near about to zero while the refractive index calculated is 1.457 which is quite similar to silica. Finally, it is concluded that the work presented in this paper shows the low loss and zero dispersion for liquid filled silica photonic crystal fiber.**

Keywords— Dispersion, PCF, SEIM, FVEIM, TBC

1. Introduction

The photonic crystal fiber received a tremendous attraction in the field of research. During the last decade various designs and applications have been proposed in this field. Researchers taking lots of interest in this entire field for getting zero dispersion, low loss and high birefringence. Due to very well known optical guiding properties like high birefringence, low confinement loss, high nonlinearity, the endlessly single mode, large effective mode area and a small bending loss Photonic crystal fibers showing a great potentiality in development of different optical functional devices.

Conventional optical fibers are commercially available worldwide, while Photonic crystal fibers are day by day in development stage to provide best properties with best structures. The filling factors are used to control the various parameters of PCF while calculating the desired parameters. The main challenge was to maintain low loss while changing other parameters like number of layers, pitch value, diameter of air hole etc. The dispersion so calculated is zero to -5 ps/km-nm in between 0.7 to 1.9 micrometer. The proposed silica PCF with rectangular parallelopid lattice having three line of air hole with liquid filled within is found [1-24]. Below figure 1 and 2 show the basic phenomenon of refraction and dispersion in light.

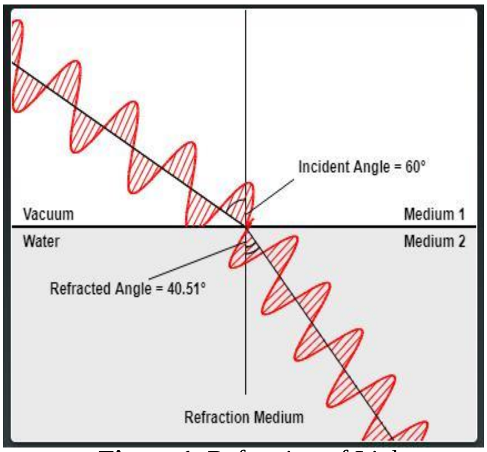

Figure 1. Refraction of Light

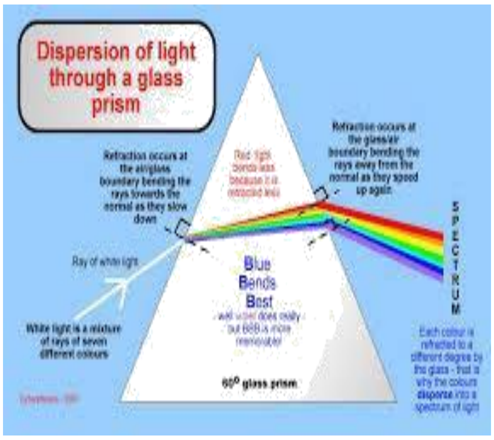

Figure 2. Dispersion phenomenon

In this work the design of low loss liquid filled silica PCF is presented which shows loss nearly zero between the selected iteration ranges.

2. Full Vectorial Effective Index Method

This structure of Silica PCF utilizes the FVEIM to examine the suggested parameters of PCF structures. 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. The PML is strictly speaking not a boundary condition but an additional domain that absorbs the incident radiation without producing reflections. The Loss *Lc*, in decibels per meter is given by

$$L_c = \frac{40\,\pi}{\ln(10)\lambda}\ Im\{n_{eff}\} \qquad (1)$$

where, $Im\{n_{eff}\}$ is the imaginary part of the effective refractive index of the mode.

3. Proposed Structure

A three-layer Silica photonic crystal fiber with liquid filled is proposed and shown below in figure 3. The 2D Reference imaginary and real images of proposed design are also shown in below figure 4.

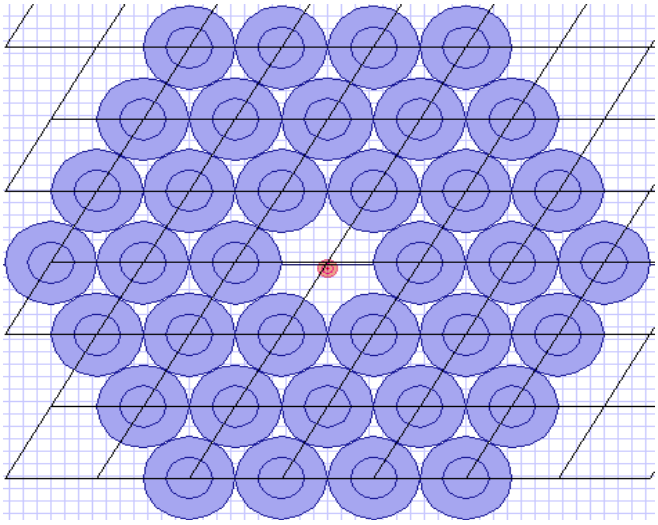

Figure 3. Proposed Design

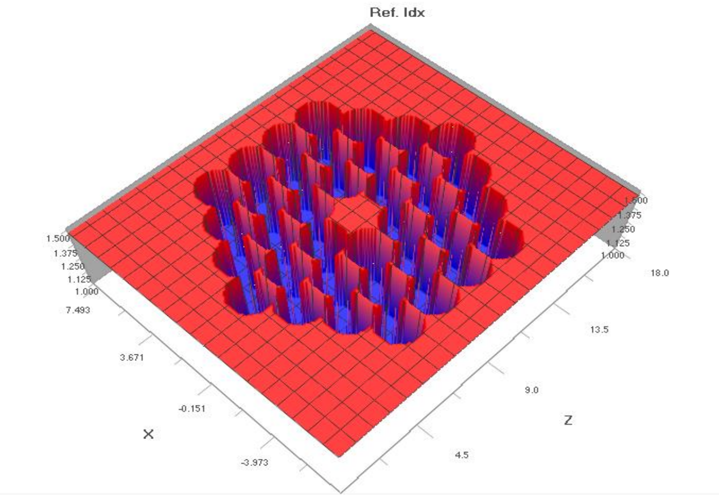

Figure 4. 2D Reference Real and Imaginary image

The proposed structure is designed by considering air hole diameter of 1 micrometer, pitch value of 2 micrometer and three-layer parallelopid lattices. The liquid material is filled within the core design. The low loss is to be achieved in the proposed structure to transmit light efficiently. The mode profile of the proposed structure is shown in below figure 5.

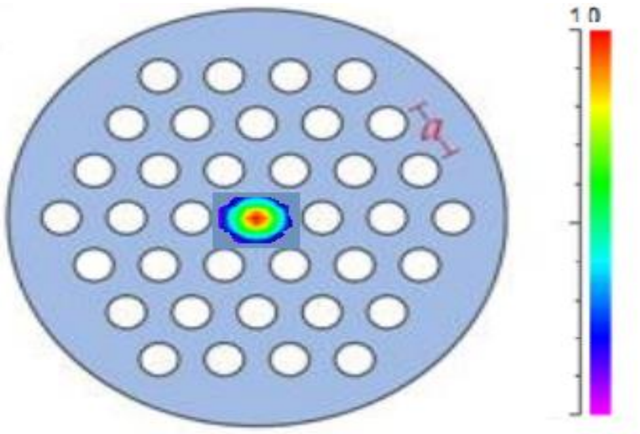

Figure 5. Mode profile of proposed structure

4. Methodologies Followed

The proposed structure may not be easy to fabricate but it gives best results when simulated on software. This is because it is shown that current movement in PCF technology showed that fabrication of complex structures is possible now. The fabrication error possibilities such as air hole to hole spacing, variation in air hole diameter can be considered precisely. The PCF can be considered as a two-dimensional waveguide which is periodic in X and Y direction. Finally the refractive index and there after dispersion is calculated for the proposed design.

Finite Element Method (FEM) has been utilized for the proposed PCF. Using the Finite Element Method (FEM) two key properties such as sensitivity and confinement loss have been investigated. The guided light penetrates into the cladding region from the core due to finite number of air holes and it is known as confinement loss. The confinement loss Lc can be calculated through the imaginary part of the refractive index neff.

$$L_c = \frac{40\,\pi IM(\text{neff})106}{\lambda \ln 10}\ \text{(dB/m)} \quad (2)$$

5. Result & Discussion

The proposed structure is designed to minimize the dispersion having low loss. With these things the proposed work was started and finally the structure is designed having diameter of air hole is 1 micrometer, pitch value of 2 micrometer and for three-layer parallelopid lattice. The 3D mode solver characteristics of the proposed structure are also shown below.

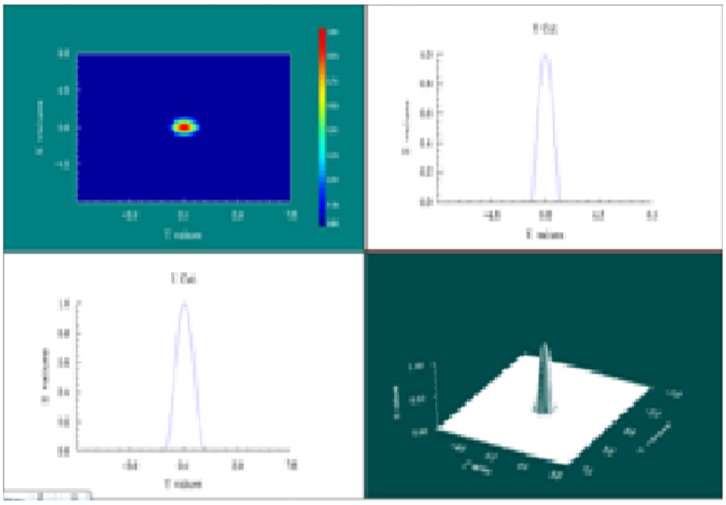

Figure 6.3D mode solver of proposed structure

The refractive index so calculated for the proposed structure is shown below in figure for 19 iteration values. With these parameters a graph is drawn showing that refractive index of proposed structure is found as similar to the material used.

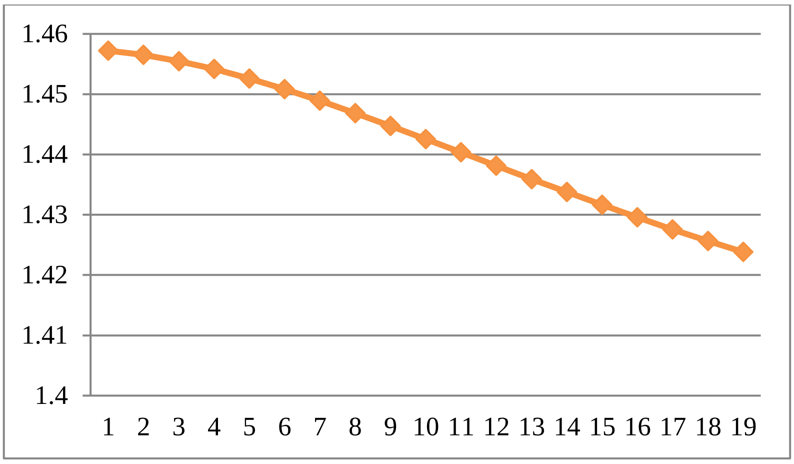

Figure 7. RI of proposed structure

The above graph shows that the refractive index of the proposed structure is equivalent to the material's refractive index, i.e. 1. 457.After this the dispersion is calculated of the proposed structure for the same wavelength region. It shows that dispersion is near about to zero is calculated for the given wavelength range for proposed structure.

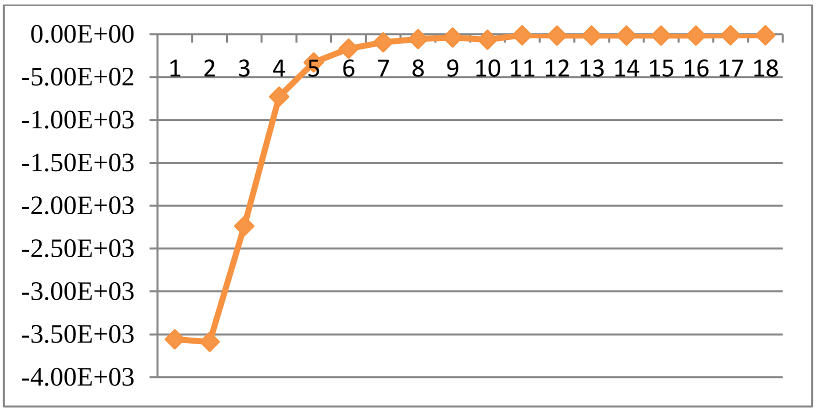

Figure 8. Dispersion calculation for proposed structure

This graph shows that dispersion of proposed structure is nearly zero for the selected wavelength region in between 0.7 to 1.9 micrometer range. For some wavelength region it shows negative dispersion also.

6. Conclusion

The presented paper numerically investigates various propagation characteristics of proposed liquid filled silica photonic crystal fiber including low loss and sensitivity for a wide range of wavelength. The behavior of the proposed liquid filled silica photonic crystal fiber changes for different parameters which have also been investigated by using Water as analytes. The investigated results indicate that the increment of ring number increases sensitivity until a certain time and confinement loss is vice versa. Better performance of sensitivity and confinement are also shown through the increment of pitch value, air filling ratio, core diameter such as increment by ring number. The proposed design shows dispersion so calculated is zero to -5 ps/km-nm in between 0.7 to 1.9 micrometer range with loss near about to zero.

Appendix

The OptiFDTD software has seven interdependent modules:

OptiFDTD_Designer—Create the photonic devices to model

OptiFDTD_Simulator—Perform the FDTD simulation and DFT analysis

OptiFDTD_Analyzer—Post-process the simulated data

FDTD Band Solver—Generate band diagram for photonic crystal

PWE Band Solver– Band diagram analysis by PWE method

Cross Section Layout Designer– Design Layout Cross Section and perform mode analysis

Tool Box- Allows different post-date analysis

This lesson describes how to start using OptiFDTD to perform FDTD simulation. The procedures are:

Create a new project

— Opening OptiFDTD_Designer

— Initializing the project

— Opening the Waveguide Profile Designer

— Defining the material

— Defining the 2D and 3D channel profile

— Setting up the initial properties

Create a design

— Drawing a Linear Waveguide

— Drawing a Ring Waveguide

Set up the Input Plane

— Inserting the Input Plane

Observe the Refractive Index Distribution

— Observing the Refractive Index Distribution

Set up observation points, areas, and lines

— Setting up an Observation Point

Run the simulation

— Setting up the simulation parameters

— Running the 32bit simulation

Analyze the simulation results

— Opening OptiFDTD_Analyzer

— Analyzing the results

— Calculating the Mode Overlap Integral (MOI)

— Calculating the Input Overlap Integral (IOI)

— Calculating the Input Overlap Integral Scanner (IOIS)

— Calculating the Far Field Transform

— Performing the Observation Object Analysis

Export results

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