Modal Index Analysis of PCF Using Different Cross Section Geometry

Md. Mahbub Hossain[#1], Md. Maniruzzaman[*2]
[#] *Assistant Professor, Electronics and Communication Engineering Discipline, Khulna University, Bangladesh*
`mahbub.eceku@yahoo.com/ronyeceku@yahoo.com`
[*] *Professor, Electronics and Communication Engineering Discipline, Khulna University, Bangladesh*
`m_m_zaman@hotmail.com`

***Abstract*—The use of Photonic Crystal Fibers (PCF) is understood within their exclusive chromatic dispersion uniqueness and nonlinear behavior, which is appropriate for dispersion compensation or transmission of information without pulse spreading, leading to an inter symbol interference. Pulse spreading being the result of chromatic dispersion in optical fibers is considered as one of the critical issues in the design of optical fibers. Since the dispersion can result in worse system performance, it is necessary to prevent its occurrence or to compensate it. To compensate the dispersion it is necessary analysis the modal behavior of Photonic Crystal Fiber on different cross section geometry. When the modes are found is it possible to find not only dispersion but also loss and cutoff. In this paper we have first created two types of PCFs layout both hexagon and rectangular shape and next calculate modal index using center wavelength 1.3um. Result showed that mode to be confined most strongly in the core region. After getting the modal index we can easily calculate the dispersion, conifinement loss etc.**

***Keywords*—Dispersion, Chromatic, Loss, PCF, Wavelength**

I. INTRODUCTION

PCFs, also known as microstructured or holey fibers, are investigated in view of their unique properties of light guidance [1]. Unlike conventional step-index fibers, PCFs guide light through confining field within microstructure periodic air holes. PCFs are characterized by the periodicity of refractive index, implemented as an array of air holes around the core. The guidance mechanism in some aspects resembles the operation of semiconductor materials. In other words, the photons in PCFs have a function, which is similar to the operating principle of electrons in semiconductors.

PCFs are classified in two categories: solid core high-index guiding (or simply an index guiding) fibers and hollow core low-index guiding fibers. The Index Guiding Photonic Crystal Fiber (IGPCF) guides light in a solid core by Modified Total Internal Reflection (M-TIR) [2]. This principle is similar to the guidance in conventional optical fibers. The other category of PCFs, Hollow Core Photonic Crystal Fiber (HCPCF) guides light by the Photonic Band Gap (PBG) effect. Light is confined in the low-index core, since the distribution of energy levels in the structure makes the propagation in the cladding region impossible. The M-TIR principle of light guidance relies on a high-index core region, typically pure silica, surrounded by a lower effective index material, provided by air holes in the cladding.

The effective index of such a fiber can be approximated by a standard step-index fiber, with a high-index core and a low-index cladding. However, the refractive index of a microstructured cladding in PCFs exhibits strong wavelength dependence very different from pure silica, which allows PCFs to be designed with a new set of features unattainable within the classical approach. This is fundamentally different from the conventional fibers where, at huge core diameter to wavelength ratios, a multi-mode operation is unavoidable at shorter wavelengths, because the cladding index is constant and normalized frequency arises with wavelength, once exceeding the value critical for single-mode operation. In addition, the presence of air holes in the cladding can change the spectral characteristics of microstructured fibers. Among PCFs with modified spectral properties, zero dispersion or anomalous dispersion fibers are very promising for group velocity dispersion compensation.

The accurate computation of mode effective refractive index of PCF is needed for the fiber structure design, mode dispersion analysis and fiber grating mode coupling research [3]. In this paper, based on five rings IGPCF for hexagonal and rectangular model both elliptic and ring waveguide. The modal index is found by using OPTI FDTD 8 software.

II.SIMULATION METHOD

Huge possibilities of geometry manipulation and air-holes shapes arrangements have increased the complexity of numerical analysis of PCFs. The main objective of simulations is to find out the correct mode effective refractive index which will be essential for study of chromatic dispersion characteristics of IGPCF. Such structures demand efficient numerical methods to analyze them accurately. Thus, many modeling methods applied in this perspective, such as the plane wave expansion method, localized function method, finite element method, finite difference time domain method, finite difference frequency domain method, Fourier composition method or multipole method. The results presented in this paper have been achieved by using the Finite Difference Time Domain method (FDTD), which was described in details by Zhu [4]. For a given frequency, the numerical propagation constants and mode patterns can be calculated. The main geometrical quantities concerned: hole diameter d, the hole pitch Λ used in the implementation are displayed in Fig. 1. and Fig. 2.

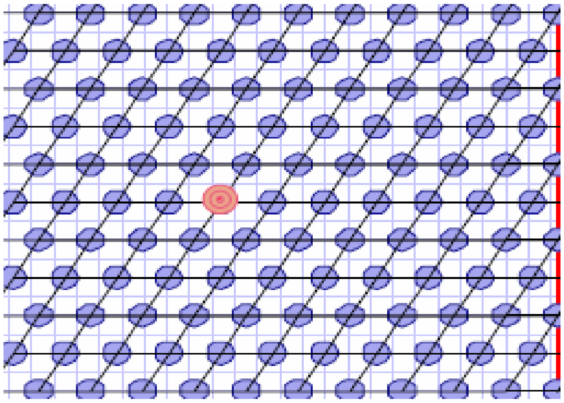

Fig. 1. Cross Sectional Geometry of Hexagonal PCFs

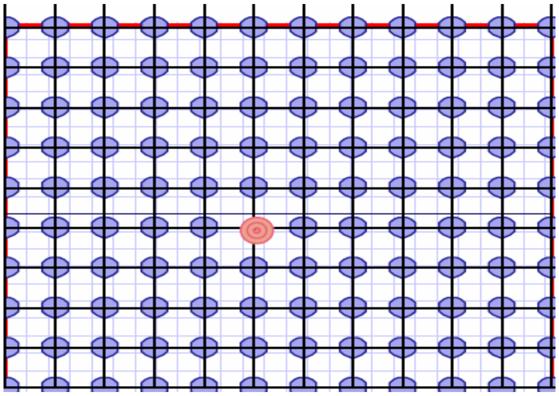

Fig. 2. Cross Sectional Geometry of Rectangular PCFs

The basic flow of simulation is executed with several randomly taken parameters to calculate the modal index. Once the physical structure is created, the simulation parameters and mesh are set, as well as the monitors are defined, the simulation is run. The time domain information is available at any point of the cross-section of a modeled fiber.

III. SIMULATION RESULTS

In order to find out the modal index of hexagonal and rectangular PCFs, cladding includes five rings of air holes and the core, which doped with high-index material, of which the refractive index is equal to 1.46 is used. Relatively small air holes are preferred. The parameters that were used in the simulation are given below:

Pitch Λ [µm] - 2.3
Hole's diameter d [µm] - 0.6
Air-fraction refractive index [-] - 1
Silica glass refractive index (high-index cladding region) [-] 1.46
Propagating wavelength [um] - 1.3
Number of rings at the cladding - 5

Below Fig. 3 & 4 shows the refractive index distribution of both hexagonal elliptic and ring waveguide and Fig. 5 & 6. shows the refractive index distribution of rectangular elliptic and ring waveguide where the simulation parameters are almost identical.

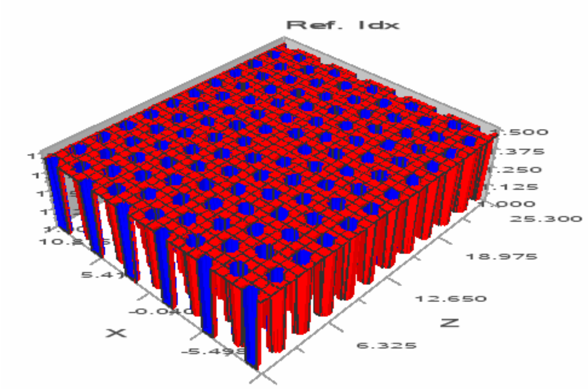

Fig. 3. Refractive Index distribution of Hexagonal elliptic PCFs

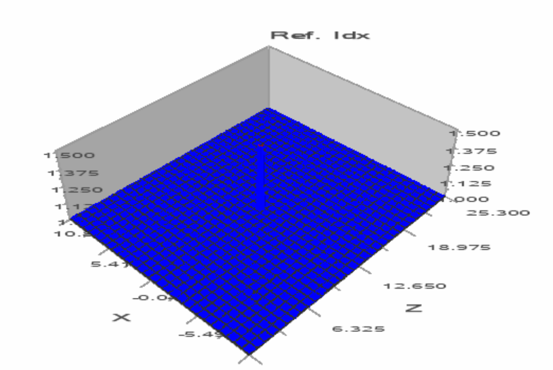

Fig. 4. Refractive Index distribution of Hexagonal ring PCFs

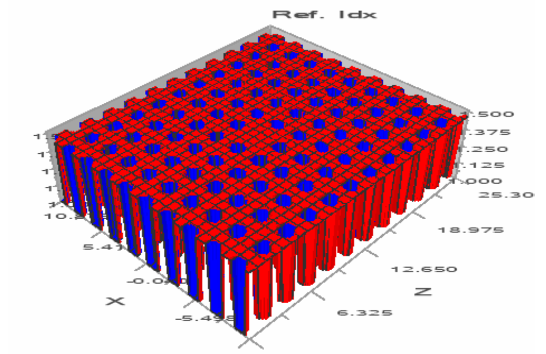

Fig. 5. Refractive Index distribution of Rectangular Elliptic PCFs

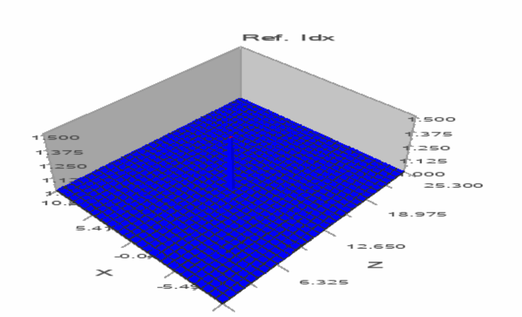

Fig. 6. Refractive Index distribution of Rectangular ring PCF

After simulation the modal index is found for both the hexagon and rectangular elliptic and ring waveguides and the intensity is shown in the Fig. below:

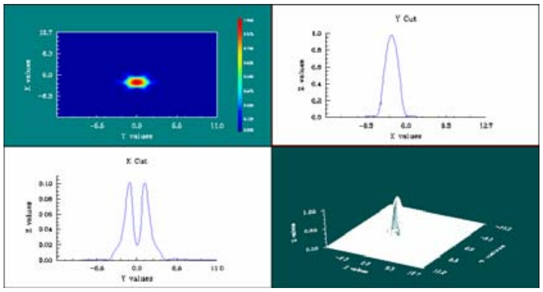

Fig. 7. Electric Field Intensity for Hexagonal Elliptic PCFs

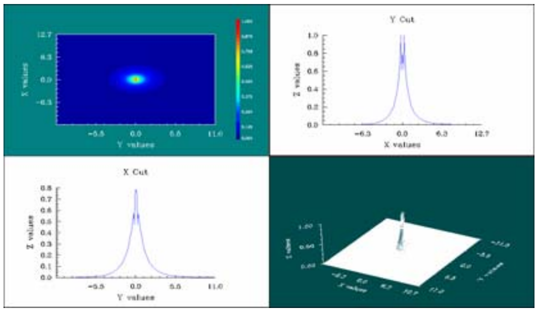

Fig. 8. Electric Field Intensity for Hexagonal Ring PCFs

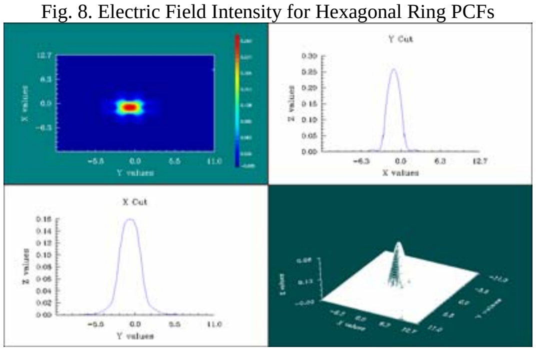

Fig. 9. Electric Field Intensity for Rectangular Elliptic PCFs

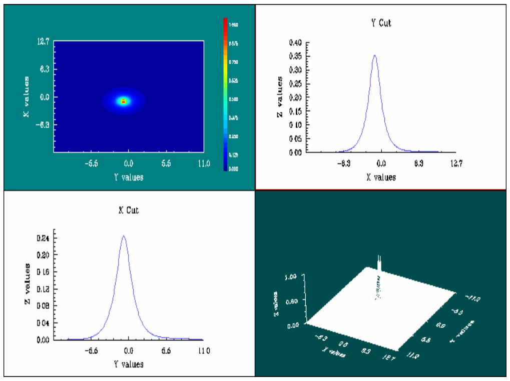

Fig. 10. Electric Field Intensity for Rectangular Ring PCFs

IV.RESULT AND DISCUSSION

In this simulation method, we used five rings holy fiber or IGPCF where the material refractive index is used 1.46,air-hole diameter 0.6µm and hole to hole distance 2.3µm using OPTI FDTD 8 software. The simulation parameters are set complex modal solver with center wavelength 1.3µm with appropriate mesh point and setup time is 1 sec. After simulation, the effective modal index for hexagonal shape PCF was 1.44023030(elliptic) and 1.440385139(ring). Again using the same simulation parameters the effective modal index for rectangular shape PCF was 1.00936841(ring) and 1.00963331(elliptic). Also, from the figure (Fig.7 –Fig.10) it is clear that the electric field intensity of scale 1 is shown. It also reveals that the most of the power is confined in the core region.

The impact of this research is that, after getting the effective refractive index one can easily find out the Chromatic Dispersion, Confinement Loss etc which is very important for PCF applying in long distance telecommunication.

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