Flattened Dispersion in Square Lattice Photonic Crystal Fiber of Borosilicate Material with Square & Circular Air Holes

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Abstract:
In this paper we design Photonic crystal fiber of borosilicate material. Square lattice is used with linear and elliptical waveguide in cladding. The PCF are very useful for optical transmission. For better transmission, ultra flattened dispersion is desirable. To minimize dispersion we designed different air holes of different diameter. Through simulation and optimizing the PCF, we find that the proposed photonic crystal fibers can realize flattened dispersion in wavelength range of 1.3µm to 2µm.

Keywords: Chromatic dispersion, confinement loss, photonic crystal fibers (PCFs), square lattice.

I. INTRODUCTION

Optical fiber is widely used in wavelength division multiplexing (WDM) network for optical data transmission. In WDM communication systems, it is essential to maintain a uniform response in the different wavelength channels, which requires that the transmission line approach the ideal state of ultra-flattened dispersion and ultra-low loss [1]. But flexible dispersion or losses in optical fiber have been become a major problem in high bit rate wavelength division multiplexing optical communication systems.

The dispersion is a phenomenon that causes to broaden optical pulses, when they spread in the optical fibers. So when a pulse come to receiver, it is not possible to differentiate whether it high or low. The intersymbol interference (ISI) can occur between the bits in communication channel, by linearly accumulated chromatic dispersion along the transmission channel, which can affects the communication process & communication quality. Because of this, zero and flat dispersion slope with low losses are needed in high speed optical communication.

Thus, a new technology of manufacturing photonic crystals has led to a new generation of optical fibers, namely Photonic Crystal Fibers. The PCF has some features such as controllable dispersion, very low confinement loss and flexible design. The photonic crystal fibers (PCFs) are also called microstructures fibers or holey fibers. The photonic crystal fiber structure is formed by a core and a cladding. The cladding is two dimensional photonic crystal types consisting of air holes that run along the fiber length show unique properties.

Light guidance in PCFs are depending on the core and cladding photonic crystal materials. The refractive index difference between the core and cladding is always positive in index-guiding PCF. It can be possible by choosing a core material with a higher refractive index than the cladding refractive index. Photonic crystal fiber also known as solid core photonic crystal fiber. These fibers guide light through a form of total internal reflection (TIR).

The refractive index of the cladding is higher than refractive index of the core in the fibers with air core. However, in fibers with air core, TIR is not possible. So light guidance in these fibers attained by coherent Bragg scattering, where light at wavelengths within well-defined stop bands is prohibited from propagating in the photonic crystal cladding and is confined to a central defect [2]. Only some wavelength bands are confined and guided down the fiber. Each band corresponds to the presence of a full two-dimensional PBG in the photonic crystal cladding. For this reason, these fibers are called photonic band gap fibers (PBGFs) or hollow core fibers in which light is guided in a low-index core by the PBG effect[1,2].

Reducing dispersion is main aim to designing PCF's. To designing PCF's, multiple parameters can change such as diameter & shape of the holes, the number of air hole ring and the spacing between these holes. Many designs of PCF's have been proposed for the nearly zero ultra-flattened chromatic dispersion.

II. THEORETICAL DESCRIPTION

In this paper, square lattice are used to design the photonic crystal fiber and two main parameters investigated are dispersion.

Chromatic dispersion is the main contribute to the optical pulse broadening. Chromatic dispersion is caused by combined effects of material and waveguide dispersion. Control of the chromatic dispersion in photonic crystal fiber is necessary for practical applications in optical communication systems[2,4]. The addition of the material dispersion and waveguide dispersion is called total dispersion. The chromatic dispersion of a photonic crystal fiber can calculated from the real part (Re) of the complex effective index n_{eff} by using the following equation[5,9]:

$$D = -\lambda / c \, [\partial^2 Re(neff) / \partial \lambda^2]$$

Where c is the velocity of light in vacuum, λ is light wavelength in term μm and Re(neff) is the real part of the complex effective index neff, which is calculated from Maxwell's equation using FDTD tool.

III. DESIGN PARAMETER AND SIMULATION RESULT

The new design of the photonic crystal fiber is shown in Figure 1. In this design square lattice is used of borosilicate crown glass with 1.5168 refractive index and the refractive index of the air hole is 1.0. The cladding in this PCF is composed by linear waveguide and elliptical waveguide with square air holes and circular air holes. This PCF designed by 7 air hole rings. In 1,4 and 5 ring, circular air holes are used and in 2, 3, 6, and 7 ring, square air holes are used. The diameter d1 of the holes in the inner first rings is chosen 0.12μm and the diameter d2of the holes in the fourth and fifth ring is 0.6 μm. The length L=1 and width W=1 of square air holes in the second, third, sixth and seventh ring is chosen. The spacing between the centers of adjacent holes, Λ, is 2μm.

The choosing of different air holes and unequal diameters for air holes gives better control of dispersion curve or flattened dispersion shown in Figure 2.

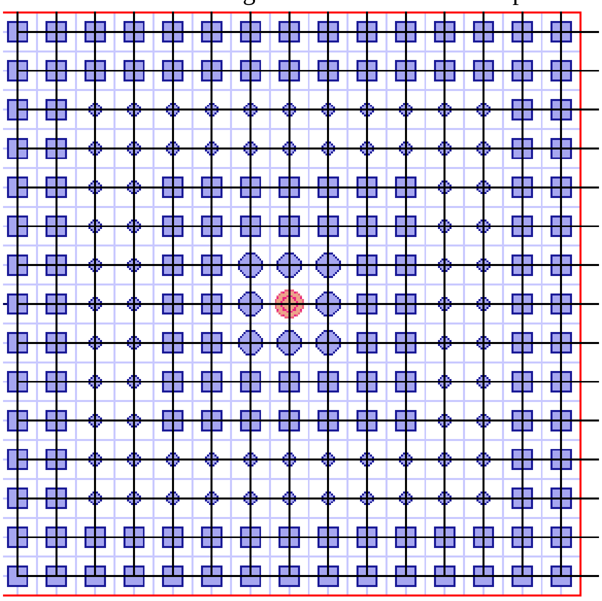

Figure 1. Proposed PCF Structure.

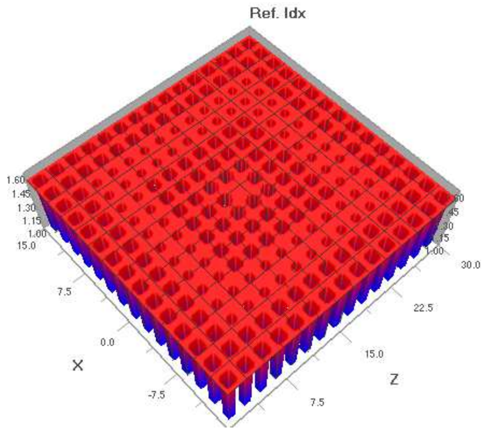

Figure 2: 2-D layout of proposed Photonic crystal fiber

IV. RESULT

Designed PCF structure provides flattened dispersion from 1.3 μm to 2 μm wavelength shown in figure 3. Calculated dispersion value is nearest to zero. In this paper of the proposed photonic crystal fiber with seven rings of circular and square air holes is designed for investigation of nearest zero dispersion and low confinement loss.

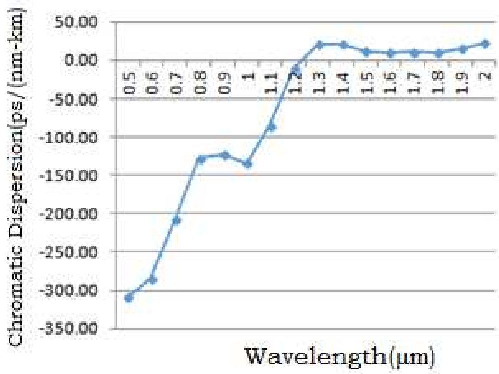

Figure 3: Chromatic dispersion curve of proposed PCF.

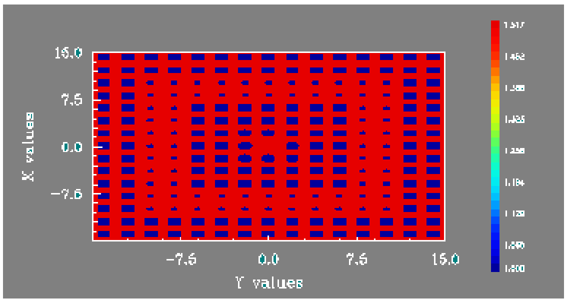

Figure 4: Mode field pattern with X values and Y values

The mode field pattern of the designed PCF of flattened dispersion and Minimum confinement loss is shown in Figure 4. Generally silica material is used in the different application of the optical fiber, but recently Borosilicate material is the replacement of the silica material with its different properties. Material dispersion is always unchanged for any structure.

Table 1: Material dispersion, Waveguide dispersion & Total dispersion on different Wavelength

V. CONCLUSION

In this paper photonic crystal fiber gives better result using scalar index method. It gives flattened dispersion. Here we have calculated the dispersion for various wavelengths from 0.5 µm to 2 µm and it gives better result or flattened dispersion in wavelength range 1.3 µm to 2 µm shown in figure 3. In future we can calculate dispersion using TE mode and TM mode.

Wavelength	Chromatic Dispersion
0.5	-309.10012
0.6	-283.83286
0.7	-207.01944
0.8	-127.15599
0.9	-122.57705
1.0	-134.33044
1.1	-84.76231
1.2	-10.117996
1.3	21.180818
1.4	20.910631
1.5	11.304066
1.6	9.88284
1.7	10.64653
1.8	9.79128
1.9	15.90926
2.0	22.17367

We can also compare the dispersion of scaler mode, TE mode and TM mode and we can find better result of flattened dispersion.

VI. REFERENCES

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