Dispersion in Circular Geometry Based Solid Core Photonic Crystal Fibre

Ashish Kulshrestha, Deepmala Kulshreshtha, Vikas Sharma, Manish Yadav

Abstract— The proposed provides a numerical analysis of circular geometry based PCF. The guiding properties and chromatic dispersion of the proposed structure is analysed. The photonic crystal fibre guides the light through index guiding mechanism with minimum value of group velocity dispersion. Finite elementary method is used for analysing the design. Low value of dispersion and flat dispersion over a wide range of wavelength can be used for realizing various significant applications like dispersion compensating unit (DCU), super continuum generation (SCG) etc.

Index Terms— Chromatic dispersion, solid core photonic crystal fibre, confinement loss, group velocity dispersion, modified total internal reflection.

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1 INTRODUCTION

Nowadays PCF has been used widely for making optical fibres throughout the world to serve various important applications. It provides many significant advantages over conventional optical fibre. These advantages include flat dispersion, high degree of nonlinearity, large mode area and controllable dispersion. Unlike conventional fibre, PCF provides a dynamic characteristic of dispersion properties which is controlled by its structural parameters such as air hole diameter, pitch length and number of rings of air holes in cladding region. By changing these parameters for a PCF we can achieve ultra low dispersion which is required for various applications such as super continuum generation, soliton propagation etc.

Photonic crystal fibre is a class of optical waveguide which consists of a regular periodic arrangement of air holes throughout its length. By creating a band gap in the solid core, light can be made to guide and confine through these types of fibres. There can be many ways in which we can adjust the values of number of rings, pitch length, air hole diameter and geometry of air hole arrangements. In this way, photonic crystal fibre provides a fine degree of design flexibility unlike conventional optical fibres. There is a lot of research work in this field with different geometries of air hole arrangement such as triangular, square, rectangular, hexagonal, octagonal and de cagonal. Different designs with such geometrical structures with a variety of values for number of layers, pitch and air hole diameter has been analysed. There dispersion curves also has been investigated. This time our efforts are to design a circular geometry based photonic crystal fibre. Our aim is to analyse its dispersion and modal area dependency on pitch length and air hole diameter.

2. GEOMETRY DESIGN:

In this paper we presented a solid core photonic crystal fibre. In such fibres core is a solid glass region, which is surrounded by cladding constituted by array of holes. For these types of structures the guidance mechanism is modified Total Internal Reflection. This design is analogous to step index fibre which have a high index solid core and low index cladding. This lower effective refractive index of fibre is a function of wavelength for the incident light. It indicates that cladding has a very large waveguide dispersion which can be controlled through air hole diameter and pitch length.

To achieve a single mode fibre, which has one central hole missing, the values of pitch and air hole diameter are adjusted such that the ratio of air hole diameter to pitch distance, air filling fraction d/p should be less than 0.45. The value of this ratio decreases as the number of missing holes in the central region increases. For example when number of missing holes is seven, then this ratio d/p must be less than 0.15. Silica has been selected as the background material for cladding.

The Sellmeier Equation for silica is given as under-

$$\boxed{n^2 = 1 + \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2} + \frac{B_3\lambda^2}{\lambda^2 - C_3}}$$

Here λ is wavelength of operation and B1 ,B2 ,B3, C1, C2, C3 are Sellemeier equation coefficient whose values for silica are given as under-

B1= 0.6961663 um	C1= 0.0684043 um
B2= 0.4079426 um	C2= 0.1162414 um
B3= 0.8974794 um	C3= 9.896161 um

3. EFFECTIVE MODE AREA:

It can be defined as a quantitative measure of the area which a waveguide or a fibre mode effectively covers in the transverse dimensions. In order to suppress nonlinear effects fibre should

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be designed with large mode areas. It can be calculated by following formula-

$$A_{eff} = \frac{\left(\iint |E_t|^2 dxdy\right)^2}{\iint |E_t|^4 dxdy}$$

where Et represents transverse electric field which can be calculated by solving eigen values of Maxwell Equations.

. CHROMATIC DISPERSION:

It is a phenomenon in which different wavelength components of light signal do not arrive simultaneously at the destination and causes spreading or dispersion of signal which contains information to be transferred. It varies with effective refractive index of fibre and wavelength with a relation given as under-

$$D = \frac{\lambda}{c} \frac{d^2\left(Re\left[n_{eff}\right]\right)}{d\lambda^2}$$

Where λ represents operating wavelength, c is speed of light in air or vacuum, Re indicates real part and neff represents effective refractive index.

Total dispersion presented by a fibre can be understood as the sum of waveguide dispersion and material dispersion including the effect of confinement loss for that particular material. Mathematically we can represent this relation as-

$$D(\lambda) = D_g(\lambda) + \Gamma D_m(\lambda)$$

Here Dg (λ) represents waveguide dispersion and Dm(λ) represents material dispersion. Γ is confinement loss in silica.

To get the effective communication and high performance indices with photonic crystal fibre our aim is to minimise the value of dispersion. As we know its value will get change by changing lattice parameters, air hole geometry and number of air hole rings , so we can have different design combinations to best suited the low value of dispersion. Other than this new techniques like liquid infiltration are also being used worldwide. In some research papers some designs of photonic crystal fibre with non-uniform air holes cladding structure is also proposed. These kind of fibre designs provides very low values of chromatic dispersion and flattened dispersion in communication window with wavelength range 0.9 to 2.0um.

5. CONFINEMENT LOSS:

Confinement loss is also an important parameter which contributes towards the performance of photonic crystal fibre. As the refractive index of core and cladding region in absence of air holes is same hence there are chances of leaky modes in the fibre. So we have to take care of confinement loss, which changes as a function of structural parameters such as air hole diameter and pitch length. We can calculate the value of confinement loss by the following relation-

L(DB/cm)= (8.686 X 2π X Im(n_eff) X 〖10〗^7)/λ

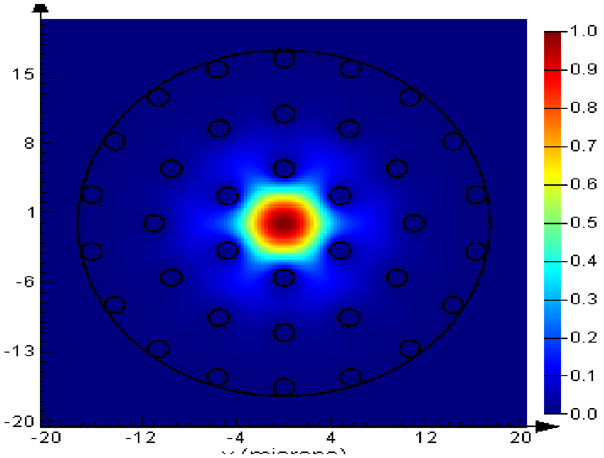

Fig.1. Mode field diagram of proposed PCF

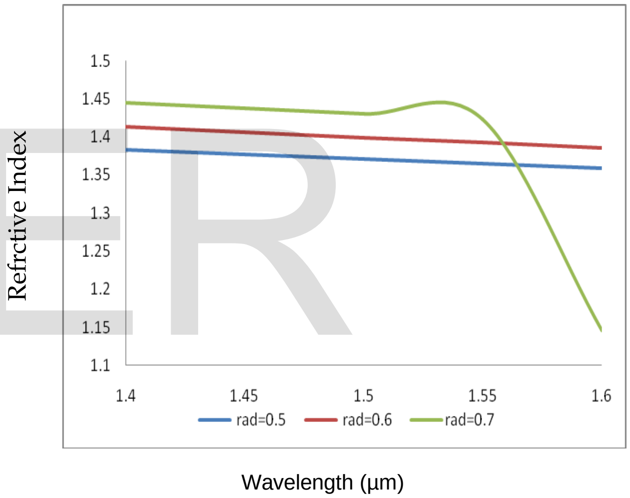

Fig.2. Plot of effective refractive index v/s wavelength for different values of air hole radii

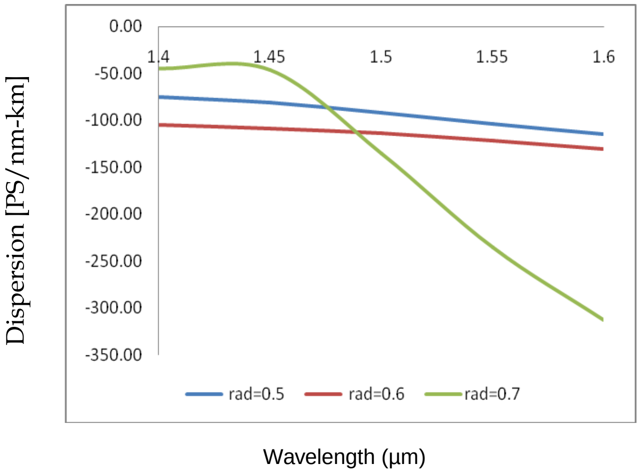

Fig.3. Plot of dispersion of PCF as a function of wavelength for different values of air hole radii

6. CONCLUSION:

In this paper a simple structure of solid core photonic crystal fibre is investigated to study the dispersion characteristics. For the proposed circular geometry of PCF effective refractive index and chromatic dispersion were evaluated and plotted as a function of wavelength. The result shows the unexpected change in the fibre characteristics for higher value of air hole size we taken in our observations. For the other two values of air hole size fibre characteristics were showing a similar relationship.

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