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A design of hybrid elliptical air hole ring chalcogenide As_2Se_3 glass PCF: application to lower zero dispersion.

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Abstract

Photonic crystal fibers(PCFs) are a different type of optical fibers. Photonic crystal fibers (PCFs) are made with an internal periodic air holes structure, laid to form of square and hexagonal lattice. In this paper, a hybrid ring hexagonal lattic PCF with circular and elliptical (with different angle) air holes has designed and shifting of zero dispersion wavelengths towards higher wavelength range with change of elliptical air holes angle. Here chalcogenide As_2Se_3 glass is used as a core material because chalcogenide glass transmit to a large IR wavelength. In this design we have achieve zero dispersion wavelength. When we design the hybrid elliptical air holes and change the air holes angle (horizontal to vertical), dispersion is decreased. We used transparent boundary condition (TBC) for zero dispersion.

Keywords: *Effective refractive index (n_{eff}), Finite difference time domain (FDTD), Photonic crystal fiber (PCF), transparent boundary condition (TBC).*

1. Introduction

Photonic crystal fibers (PCFs) [1,2] are attracting in recent years because of there different and unique properties that are not present in conventional optical fibers. Photonic crystal fibers are made with a periodic air holes structure along its length and single core material as silica glass, chalcogenide glass. [3-7]. Here we use the chalcogenide As_2Se_3 glass as a core material because chalcogenide glasses are based on chalcogen elements as S, Se and Te and other additional elements, as Ge, As and Sb. Chalcogenide glasses have lower energy less than 350 cm^{-1} compare to oxide glasses [8,9]. In the PCF central region is called solid core when we removed the central air hole. First we designed a hexagonal six layer chalcogenide As_2Se_3 glass PCF and calculate the dispersion. When we change the first, third and fifth ring periodic circular air holes to elliptical air holes the PCF is called hybrid elliptical air hole PCF. The dispersion of hybrid elliptical air hole ring PCF is calculated using fully vectorial FDTD method and transparent boundary condition (TBC). Proposed hybrid vertical elliptical air hole ring is also compared with the conventional circular air hole chalcogenide As_2Se_3 glass PCF. It is possible to control the PCF dispersion properties by changing the air hole diameter'd' and pitch '^' [10-13].

In the proposed As_2Se_3 glass PCF we change the major and minor diameter of air holes and change it into elliptical air holes.

2. Design principle

Figure 1 shows the conventional As_2Se_3 glass PCF. In conventional hexagonal As_2Se_3 glass PCF we find that there is only one missing air hole, which make solid core of the PCF.

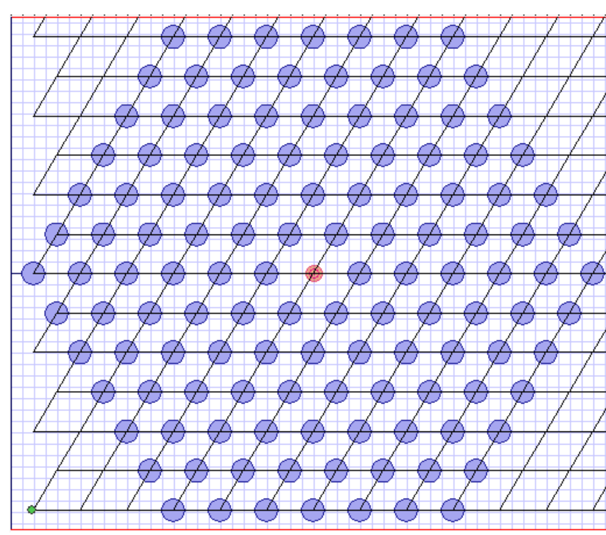

Figure 1. layout of circular air hole rings PCF having six rings and air hole diameter 'd' = 1.0 µm.

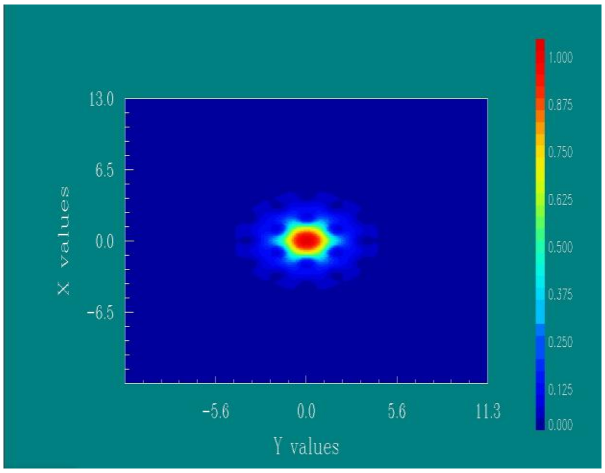

Figure 2. 2-D mode field pattern of conventional PCF.

Now, we change the first, third and fifth ring of conventional As_2Se_3 glass PCF, circular air hole to horizontal elliptical air holes. The elliptical air hole is defined as the ratio of 'a' and 'b'. here 'a' is the major diameter and 'b' is the minor diameter of air hole. However, elliptical air holes are very difficult to control when the fabrication of PCF [14].

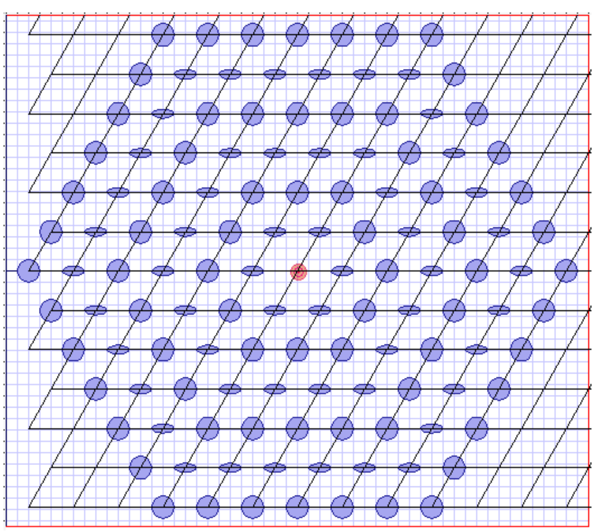

Figure 3. layout design for a hexagonal chalcogenide As_2Se_3 glass PCF with first, third and fifth ring horizontally elliptical air holes, here 'a' = 1.0 µm and 'b' = 0.4 µm for elliptical air holes and 'd' = 1.0 µm for circular air holes.

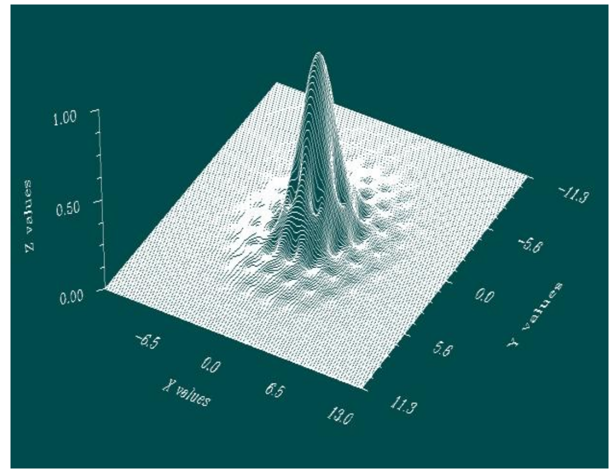

Figure 4. 3-D Mode field pattern of hybrid horizontally elliptical As_2Se_3 glass PCF having six rings.

Chalcogenide As_2Se_3 glass is used as a core material with 2.82 refractive index and air holes refractive index is 1.0. The wafer is designed for width 26 micrometer amd thickness 22.5166 micrometer.

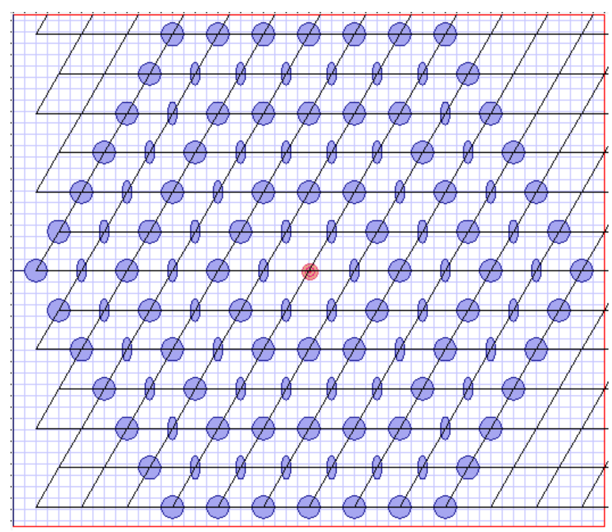

Figure 5. A hexagonal chalcogenide As_2Se_3 glass PCF with first, third and fifth ring vertically elliptical air holes, here 'a' = 0.4 µm and 'b' = 1.0 µm for elliptical air holes.

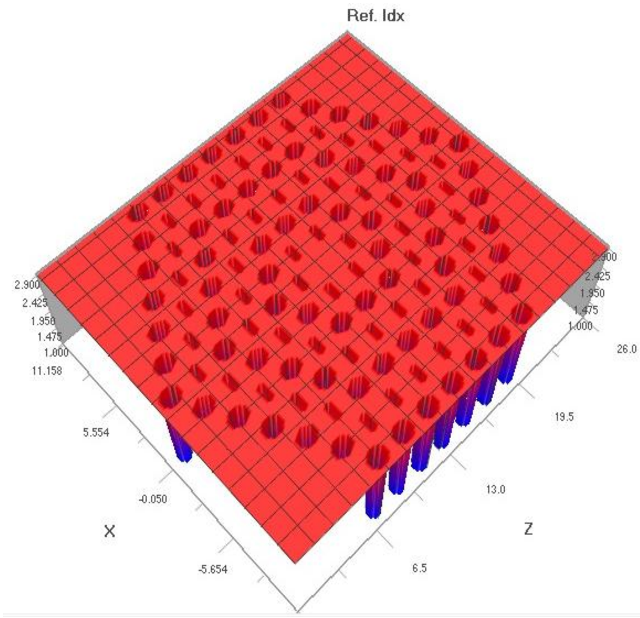

Figure 6. Three diamensional view of refractive index of proposed hybrid elliptical air hole ring.

The effective refractive index is $n_{eff} = \beta/k_0$, β is propagation constant. The waveguide dispersion parameter D_w is obtained as –

$$D_w = -\left(\frac{\lambda}{c}\right)\frac{d^2}{d\lambda^2}n_{eff} \qquad (1)$$

and total dispersion $D = D_W + D_M$. where λ is the signal wavelength and c is velocity of light in a vacuum [15,16].

We can calculated the refractive index of chalcogenide As_2Se_3 glass PCF by sellemier formula[17,18].

$$n^2 - 1 = \sum_i \left(\frac{A_i \lambda^2}{\lambda^2 - \lambda_1^2}\right) \qquad (2)$$

3. Simulation Results

Material dispersion is always unchanged for any lattice structure as hexagonal and square. It is also independent of structural parameter as air hole diameter 'd' and pitch '^'. So for good explanation first we have plotted material dispersion of chalcogenide As_2Se_3 glass.

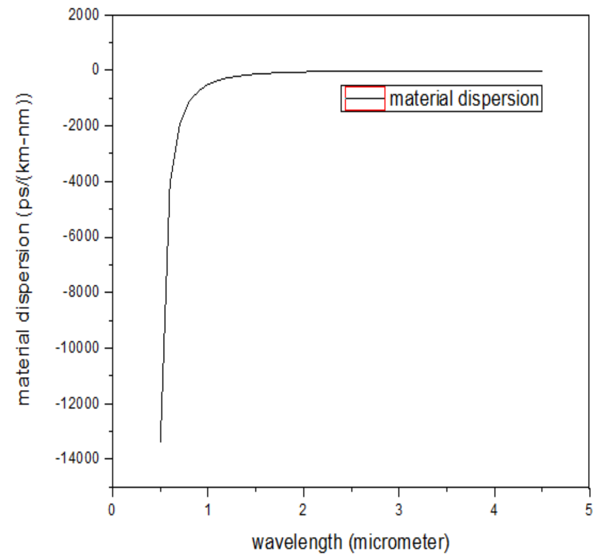

Figure 7. Material dispersion curve of As_2Se_3 glass PCF.

The proposed As_2Se_3 glass PCF (hybrid vertically elliptical air hole ring) makes almost zero and flat dispersion compare to conventional six layer hexagonal PCF.

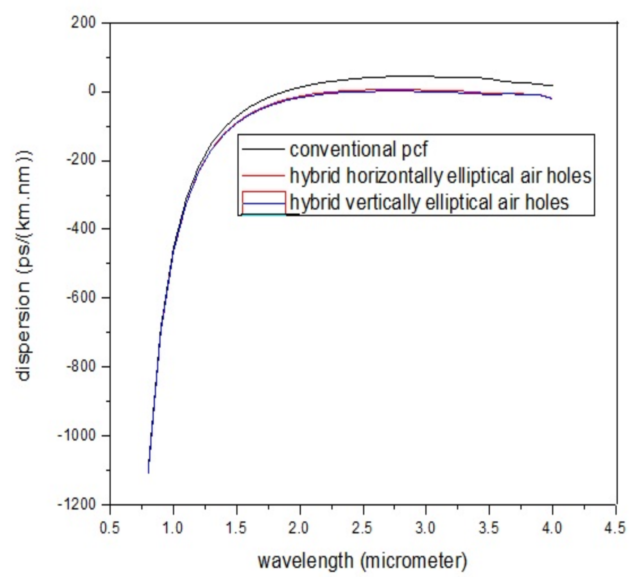

Figure 8. Shows the comparision of chromatic dispersion of the proposed As_2Se_3 glass PCF and conventional As_2Se_3 glass PCF when pitch '^' = 2.0 µm.

4. Conclusions

The above results indicate that the proposed hybrid vertically elliptical air hole ring PCF has almost zero and flat dispersion compare to normal conventional As_2Se_3 glass PCF. It has been shown the results of flattened dispersion of 0.37317 ps/(km.nm) can be obtained in the range 2.5 µm to 2.9 µm. As shown in figure 3 and figure 5 the axis of elliptical air holes has roated by 90 degree.

5. Future work

The above design can be done by changing the air hole diameter and also changing the layers of air hole rings. The further analyses can be done by removing inner layer and changing circular air holes to elliptical.

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