Flattened Dispersion of Hexagonal Chalcogenide As$_2$Se$_3$ Glass Photonic Crystal Fiber with a Large Core

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Abstract: In this paper, we have proposed a novel structure of the fabrication of a chalcogenide As$_2$Se$_3$ glass photonic crystal fiber (PCF) with increased core diameter. As comparison with the normal PCFs in which silica glass is used as core material, the proposed PCF has following feature; firstly we have used the chalcogenide As$_2$Se$_3$ glass as core material in which the first ring area contains no air holes. Then the proposed PCF has a large core area chalcogenide As$_2$Se$_3$ glass photonic crystal fiber. There are low chromatic dispersion in the proposed PCF compared to normal As$_2$Se$_3$ glass PCF. The chromatic dispersion is almost flat in the range of 2.4 micrometer to 4.0 micrometer range when the air hole diameter ‘d’ is 1.0 micrometer and air hole space ‘s’ is 2.0 micrometer.

Index Terms— chalcogenide As$_2$Se$_3$ glass, chromatic dispersion, photonic crystal fiber.

I. INTRODUCTION

Optical fibers have are used as good transmission medium for short, medium and large distances. Now a days, research is carried on photonic crystal fibers (PCFs) which are also called holey fibers [1,2]. The PCF technology is used to create a fiber with high nonlinear coefficient and zero chromatic dispersion. The PCFs have a central region called core surrounded by periodic air holes which work as a cladding. We can control the chromatic dispersion of the PCFs by changing the core material, air hole diameter ‘d’ and air hole spacing ‘s’. When we increase the ratio of the air hole diameter to the air hole spacing (d/s), the zero dispersion is achieved [3,8]. In the recent years, research works are focused on different type of core and cladding material in different type of PCFs. Now a days non silica glasses like soft glasses, chalcogenide are used in PCFs [4,9]. Chalcogenide glasses have large refractive index (2.4 – 3.0) compare to other glasses. This means non-linearity of chalcogenide glasses As$_2$Se$_3$ fiber is almost 10,000 times higher than silica glass at 1.55 micrometer [5].

In this paper, we worked on a novel structure of PCF in very long wavelength region. In the proposed PCF, chalcogenide As$_2$Se$_3$ glass is used as core material and second, the center core is made larger than that of conventional As$_2$Se$_3$ PCFs. We have use semi-vectorial effective index method (SVEIM) for comparing dispersion properties.

II. PROPOSED STRUCTURE

Figure 1 shows the proposed PCF structure. In conventional As$_2$Se$_3$ glass PCF we normally find that there is one missing air hole in the center of the PCF, which makes core of the PCF, and six air holes are arranged in the first ring of hexagonal PCF. On proposed structure to make larger core total seven holes are removed from As$_2$Se$_3$ glass PCF, one from center of hexagonal and six holes from first ring. Then total seven missing air holes in core region is called large core. The second ring area and all outer rings are same arranged, like conventional PCFs. Semi-vectorial effective index method is used for TE mode and Neumann boundary condition is used for the simulation.

The value of refractive index of As$_2$Se$_3$ glass can be calculated by sellemier formula [6].

\[ n^2 - 1 = \sum_i \frac{\Delta \lambda_i^2}{\lambda^2 - \lambda_i^2} \]  \hspace{1cm} (1)

However in the transparency region, we can reduced the sellemier’s formula into Cauchy relation [7,10].
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\[ n^2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} \]  
\[ \text{(2)} \]

Here, A = 7.56, B = 1.03 µm$^2$ and C = 0.12 µm$^2$ are Cauchy coefficients. Using these relations we can also calculate the material chromatic dispersion, which is defined in equation (3).

\[ D_M = \left( \frac{\lambda}{\gamma} \right) \frac{d^2}{d\lambda^2} n \]  
\[ \text{(3)} \]

Where c is the velocity of light in vacuum and \( \lambda \) is the wavelength of light.

### III. SIMULATION RESULTS

Figure 2 (a) and (b) shows the simulated modes field at \( \Lambda = 2.0 \) µm and air hole diameter \( d = 1.0 \) µm at 2.4 µm wavelengths of conventional PCFs and proposed PCFs respectively.

![Figure 2 simulated mode field of the (a) normal PCF (b) proposed PCF with \( \Lambda = 2.0 \) µm and \( d = 1.0 \) µm at 2.4 µm](image)

Figure 3. Notable difference of refractive index between conventional PCF and proposed PCF.

In figure 3 plot of the refractive index of conventional PCF and proposed PCF are shown. The refractive index of proposed PCF is much higher than the conventional PCF. The refractive index difference is increased between the conventional PCF and proposed PCF with the increasing wavelength, and the refractive index difference is 0.0334 at 2.4 µm wavelength.

### IV. CHROMATIC DISPERSION

For good explanation first we have plotted material dispersion of chalcogenide As$_2$Se$_3$ PCF as shown in figure 4. The total dispersion \( D = D_M + D_W \). Waveguide dispersion \( D_W \) is defined as-

\[ D_W = -\left( \frac{\lambda}{\gamma} \right) \frac{d^2}{d\lambda^2} n_{eff} \]  
\[ \text{(4)} \]

Here refractive index \( n \) for core material is calculated by sellemier formula. Material dispersion is always independent on pitch ‘\( \Lambda \)’ and diameter of air holes ‘d’.

Figure 4. Material dispersion curve of As$_2$Se$_3$ glass PCF.

Figure 5 shows the simulated chromatic dispersion of the proposed PCF for different values of air hole diameter \( d \). the chromatic dispersion is almost flattened in range of 2.4 µm to 4.5 µm, when pitch ‘\( \Lambda \)’ is 2.0 µm. decreasing the air hole diameter the chromatic dispersion is also decreased.

Figure 5 chromatic dispersion of the proposed PCF for different values of the air hole diameter \( d \) when air hole spacing \( \Lambda = 2.0 \) µm.
The structure of the proposed PCF (large center core) makes the chromatic dispersion flat in long wavelength region.

Figure 6 shows the simulated chromatic dispersion of the proposed PCF when $\lambda = 2.0$ $\mu$m and $d = 1.0$ $\mu$m.

V. CONCLUSION

In this paper we have proposed a novel structure of flattened and low dispersion compare to normal PCF structure. The features of the proposed PCF is that the center core is larger than that of conventional $As_2Se_3$ glass PCFs means seven air holes are missing in core. The core material is used $As_2Se_3$ glass in both PCF. The large core structure makes the flat and near by zero chromatic dispersion compare to conventional PCF. Negative, positive and almost zero flat dispersions are also achieved by changing air hole diameter $d$ while keeping pitch $\lambda$ constant.

REFERENCES


AUTHORS PROFILE

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