PROPERTIES OF PHOTONIC CRYSTAL FIBERS WITH CORE FILLED CHLOROFORM

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Abstract. A photonic crystal fiber (PCF) with a hollow core filled with chloroform ($CHCl_3$) is studied about the dispersion properties. PCF consists eight rings of air-holes with hexagonal shape and $CHCl_3$-core. The dispersion characteristics of the fundamental mode are studied numerically for diffirent geometrical parameters. The numerical simulations were set up with the lattice parameters from 1.0 µm to 2.5 µm, and the linear filling factors from 0.45 to 0.80. The results showed that the dispersion characteristic strongly depend on the geometrical parameters. Furthermore, the zero-dispersion wavelength (ZDWs) can be turned by changing the lattice parameters and the linear filling factors.

Keywords: *Photonic crystal fiber, chloroform.*

I. INTRODUCTION

The appearance of photonic crystal fibers (PCFs) in 1996 was a breakthrough in the fiber-optic field [1], simultaneously they are brought many potential applications for nonlinear fiber optics, fiber laser, supercontinuum generation, sensor, nonlinear device, optical amplifier, and communication [2]. PCFs are regarded as a promising fiber technology that has some unique features, including an endless single mode, high nonlinearity, easily controllable dispersion characteristics to obtain the expected properties. Especially, the dispersion characteristics as well as nonlinear properties can be tuned by changing geometrical parameters such as hole size, the arrangement of air-holes, shape, lattice parameter, and linear filling factors. In addition, the dispersion characteristics of the PCF can also be further modified when the air holes are infiltrated with liquids [3]. The application of liquids with various refractive indexes allows for the modification of the dispersion properties of the fiber without changing its geometrical parameters [4-6]. It is also can be further modified all curvature of the fiber dispersion characteristics [7, 8].

Recently, the use of liquid-filled PCFs has been received more attention because highly nonlinear liquids can be filled into the air core of hollow-core PCF to realize highly nonlinear PCF. Due to the higher nonlinear refractive index of selected liquids [9], it is possible to observe and control the nonlinear effects. The obtained results indicated that it is

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possible to shift the ZDW and match it with a pump wavelength of the high-power commercial laser, as well as obtaining all-normal and flat dispersion regime in the expected spectral [10]. However, until now, liquids only has been used for application in the near- or mid-infrared wavelength range.

In this work, we present a numerical simulation of the influence of geometrical parameters on the dispersion properties of a PCF. We analyzed a PCF based on fused silica glass, having core infiltrated with chloroform. The dispersion properties were only calculated for the fundamental mode.

II. DESIGN AND NUMERICAL SIMULATIONS

The cross-section of the PCF in our simulation is shown in Fig. 1.

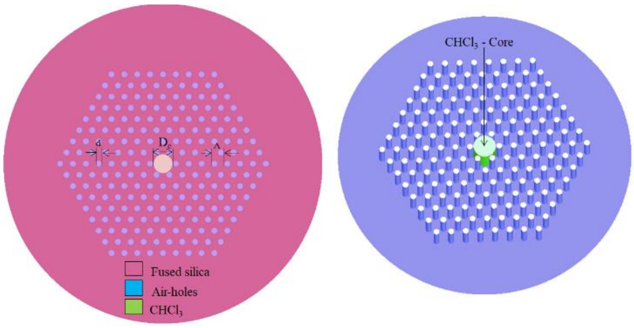

Fig. 1. *The cross-section of modeled PCF, where D_c is the diameter of the $CHCl_3$-core.*

The geometrical structure of PCF is a hexagonal shape with seven rings of air-holes, which are arranged around a core filled with chloroform ($CHCl_3$-core). The lattice pitch of PCF is Λ (µm) shifting from 1.0 to 2.5 µm with jump 0.5 mm. The linear filling factor of the cladding is given $f = d/\Lambda$, shifting from 0.45 to 0.8 with jump 0.05, leads to the diameter of air-hole d (µm) also changes respectively. The $CHCl_3$-core is bigger with the diameter D_c = 2.Λ - 1.2d. By assuming that the cladding of the PCF is made of fused silica glass (SCHOTT Lithosil), while the $CHCl_3$-core is a liquid of high refractive index and high nonlinearity ($n_2 = 1.7.10^{-18}$ m^2/W) [11]. The refractive index of materials are simulated using the Sellmeier formula, as given below:

$$n(\lambda) = \sqrt{1 + \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2} + \frac{B_3\lambda^2}{\lambda^2 - C_3}} \quad (1)$$

where, the B_i and C_i (μm^2) are Sellmeier's coefficients as given in Table 1 [12].

Numerical simulations were performed with the help of Lumerical Mode Solution software [3]. In simulations, the lattice constant was set up with values of 1.0 µm, 1.5 µm, 2.0 µm, while the linear filling factor was evenly increased from 0.45 to 0.80 for each case in the structure. As a result of growth in the lattice parameters corresponding with the linear filling factors lead to the diameter of air-holes increases, simultaneously the core diameters also linear decrease. Therefore, the core diameter was smallest D_c = 1.04 µm at Λ = 1.0 µm and f = 0.8, in contrast, the biggest core diameter was 3.65 µm for Λ = 2.5 µm and f = 0.45.

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Table 1. *The coefficients of fused silica and chloroform.*

Sellmeier's coefficients	Values
Fused silica	
B_1	0.6694226
B_2	0.4345839
B_3	0.8716947
C_1	4.4801 x 10^{-3} μm^2
C_2	1.3285 x 10^{-2} μm^2
C_3	95.341482 μm^2
Chloroform	
B_1	1.50387
C_1	3.049 x 10^{-2} μm^2
B_2	0.00345
C_2	0.15207 μm^2

III. RESULTS AND DISCUSSION

We have calculated the dispersion characteristics as a function of the wavelength in the range of 0.5-2.0 μm for the fundamental of the PCF with $CHCl_3$-core. The waveguide dispersion D as a function of wavelength are plotted in Fig. 2. with various values Λ and f.

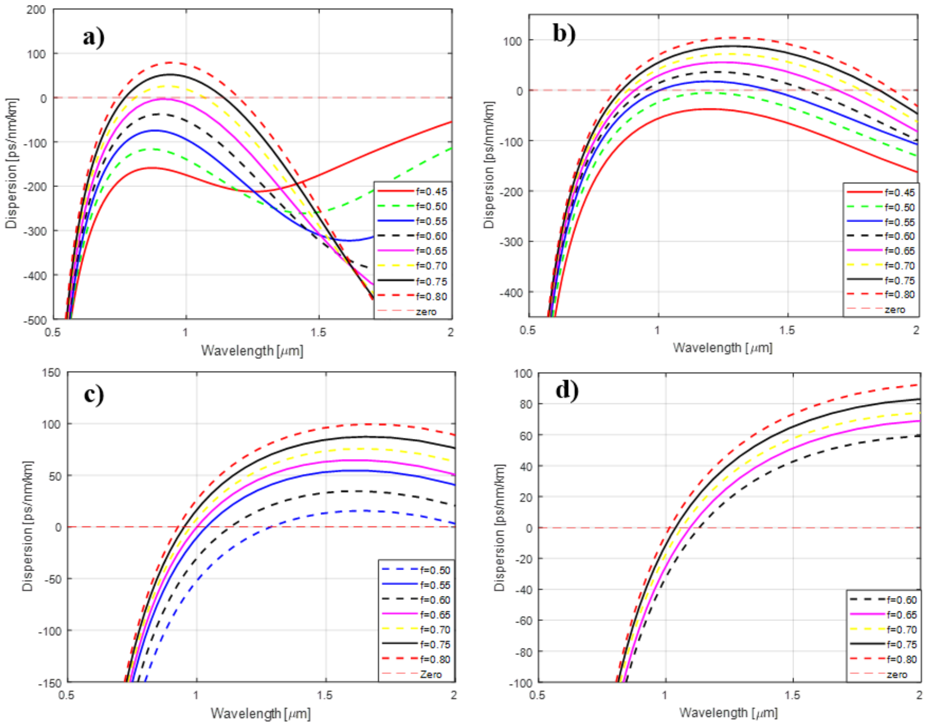

Fig. 2. *Characteristics of the PCF mode dispersion for filling factor from 0.45 to 0.80 and lattice constants (a) 1.0 μm, (b) 1.5 μm, (c) 2.0 μm, and (d) 2.5 μm.*

Figure 2 showed that the dispersion characteristics of $CHCl_3$-core PCF can be tuned by changing the linear filling factor (f) and lactice constant (Λ). For given Λ = 1.0 μm. the dispersion characteristics are all-normal dispersion when the linear filling factor is less than 0.65. For higher f values, the dispersion characteristics exist in both normal and anomalous dispersion regimes, simultaneously occur the ZDWs. When the Λ values increase, the line-dispersions shifts to an anomalous dispersion region, simultaneously the ZDWs are shifted

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toward longer waves with decreasing *f*. Especially, for Λ = 2.5 μm, if *f* values are getting smaller 0.60 then no physical mode located in the PCF core, because the effective refractive index of the cladding is increases according to the Maxell–Garnett theory of mixing and overtakes the refractive index of the $CHCl_3$-core.

IV. CONCLUSION

In this work, we presented a numerical study of the dispersion properties of the PCF with core filled chloroform. Photonic crystal fibers are made of fused silica consisting of 8 rings of air-holes ordered in a hexagonal lattice, which are defined by the lattice parameters from 1.0 to 2.5 μm, and the linear filling factors from 0.45 to 0.80. The results of numerical simulations indicate that the dispersion characteristics of PCFs are greatly influenced by its geometrical parameters. The fiber has all normal dispersion with lattice pitch equal to less than 0.6. Meanwhile, for higher *f* values, the dispersion characteristics exist in both normal and anomalous dispersion regimes. In addition, the ZDWs are shifted toward longer waves with decreasing Λ or increasing *f*. In detail, The ZDW point is moved a maximum of 275 nm at Λ = 2.5 μm and *f* = 0.80.

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