EFFECT OF TEMPERATURE ON OPTICAL PROPETIES OF CS_2 LIQUID CRYSTAL OPTICAL FIBERS

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Abstract. In this paper, we designed a photonic crystal fiber and investigate the dependence of dispersion on wavelength for the case where the fill factor d/Λ varies from 0.2 to 0.9 with different lattice constants Λ = 0.5 µm; 1.0 µm; 1.5 µm; 2.0 µm; 2.5 µm; 3.0 µm. The characteristics of hollow core PCF with hexagonal lattice permeable with CS_2 liquid according to temperature have been studied. It has been shown that the lattice constant Λ = 1.5 µm and the fill index f = d/Λ changed from 0.2 to 0.4 at the temperatures of 263 K, 273K, 283K, 293K, 303K and 313K.

Keywords: *Photonic crystal fiber, CS_2 liquid, temperatures.*

I. INTRODUCTION

Supercontinuous source with characteristic optical properties such as: ultraviolet to infrared, scraping stability, large output light power, is becoming more and more popular and become the first decisive event in the application and promotion of fields such as: communication, spectroscopy, biotechnology, imaging technology [1,2]. The general method for generating supercontinuous common emitters is to use laser light - with extremely high pulse energy - propagated in a nonlinear optical fiber [3]. With the special properties of optical fibers such as: confinement of light in the base space of the core leading to an increase in nonlinear properties, easy in design to optimize dispersion curves, optical fibers are used. widely in supercontinuous generation [4,5]. spectral broadening of the original pump beam

The mechanism for the spectral broadening light emission of optical fibers depends on many properties of such as: width of the mode area, polarization, loss, but most importantly, the group velocity dispersion curve [4,5]. If the spectral broadening belongs to the anomalous dispersion region of the optical fiber, the spectral broadening will be generated by the main mechanism, such as: soliton breakage, soliton shift. This results in uneven output pulses, poor stability, and low coherence of the spectral broadening source [5]. In contrast, the spectral broadening belongs to the normal dispersion region of optical fibers, the broad spectrum is generated by mechanisms such as: self-phase modulation, optical wave breaking. This results in a flatter output pulse, high stability and high coherence [4,5]. In this case, however, the input pulse energy must be larger than the broad spectrum case in the anomalous dispersion region.

The adjustment and optimization of the dispersion curve of the optical fiber for a spectral broadening source can be done such as: changing the fiber structure, changing the material of the optical fiber. Materials for optical fibers applied in supercontinuous sources must satisfy transparency in the wavelength region under investigation and have high nonlinearity. These

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materials are commonly used soft glass, such as: telluride [7], chalcogenide [8, 9]. However, these materials are often easily crystallized and mechanically unstable, making it difficult to fabricate optical fibers with complex structures. Optical fibers made from these materials generally do not yield flat group velocity dispersion curves and small dispersion values in the normal dispersion region.

Silica is a commonly used material, although it has weaker nonlinear properties than soft glass. With high transparency (from the visible light region to a wavelength of about 2.5 µm), high purity, silica allows doping optical fibers for a spectral broadening source from ultraviolet to mid-infrared.

Nowadays, photonic crystal fiber is often used in supercontinuous source [4]. With the flexibility to change the structure parameter, the photonic fiber allows to optimize the chromatic curve for supercontinuous transmission. A new and topical approach is to use temperature to change the properties of optical fibers for supercontinuous transmission. Specifically, the adjustment of the dispersion curve is made possible thanks to the thermo-optics of the optical fiber, the properties of the fiber material, such as the refractive index, can be changed can be changed by changing the ambient temperature [10].

II. STRUCTURE OF HOLLOW CORE PCF FILLED WITH LIQUID CS_2

We use Lumerical Mode Solutions software to design the structure of the PCF shown in Fig. 1 as follows: The base material is fused Silica glass and the hollow core is filled with CS_2 liquid, respectively. The photonic shell consists of eight stomatal rings of diameter d arranged in a regular hexagonal lattice with lattice constant Λ. The diameter of the core is determined by the formula $D_c = 2\Lambda$-1,1d. The linear fill factor of the crust is defined as $f = d/\Lambda$.

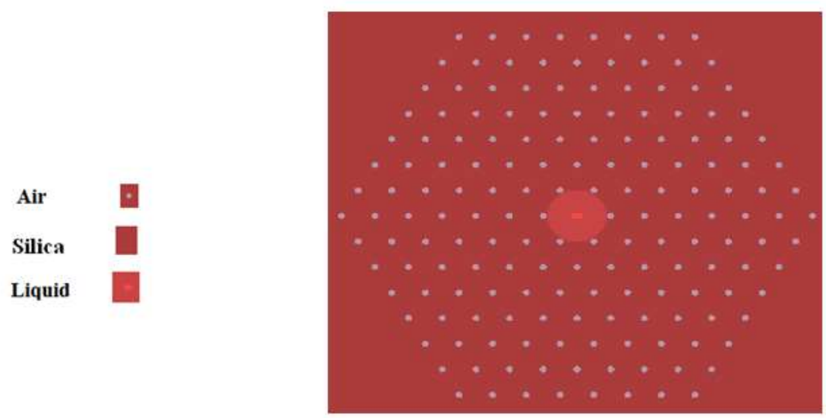

Fig. 1. *Geometrical structure of PCF with hollow core filled CS_2 liquid.*

In numerical simulation, we use the following lattice constants: 0.5 µm; 1.0 µm; 1.5 µm; 2.0 µm, 2.5 µm and 3.0 µm, and fill factors: 0.2; 0.3; 0.4; 0.5; 0.6; 0.6; 0.7; 0.8 and 0.9. The smallest core (D_c = 0.56 µm) is achieved with Λ = 0.5 µm and f = 0.8, while the largest core (D_c = 5.34 µm) is achieved with Λ = 3.0 µm and f = 0.2. The selected range of parameters corresponds to the technological requirements of the stacking method commonly used to develop PCFs.

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Table 1: *Parameters for the PCF structure designed to perform the simulations.*

Λ = 0,5 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	
d	0.1	0.15	0.2	0.25	0.3	0.35	0.4	
D_c	0.89	0.85	0.78	0.725	0.67	0.165	0.56	
Λ = 1 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
d	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
D_c	1.78	1.67	1.56	1.45	1.34	1.23	1.12	1.01
Λ = 1,5 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
d	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1,35
D_c	2,67	2,505	2,34	2,175	2,01	1,875	1,68	1,515
Λ = 2 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
d	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8
D_c	3.56	3.34	3.12	2.90	2.68	2.46	2.24	2.02
Λ = 2,5 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
d	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25
D_c	4.450	4.175	3.900	3.625	3.350	3.075	2,800	2.525
Λ = 3 µm								
d/Λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
d	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7
D_c	5.34	5.01	4.68	4.35	4.02	3.69	3.36	3.03

In Fig. 2, we show the wavelength dependence of dispersion for the case where the fill factor d/Λ varies from 0.2 to 0.9 with different lattice constants Λ = 0.5 µm; 1.0 µm; 1.5 µm; 2.0 µm; 2.5 µm; 3.0 µm. The obtained results show that, with the same set of structural parameters, the wavelength-varying dispersion curve has the same shape.

III. STUDY ON DISPERSION CHARACTERISTICS OF HOLLOW CORE PCF WITH CS_2 LIQUID PERMEABLE HEXAGONAL NETWORK

3.1. Effect of temperature on the liquid Sellmeier coefficient of CS_2

Adjust the wavelength dependence of all n(λ,T) with a new Sellmeier equation. The final expression for the pressure and temperature-dependent near-infrared scattering of carbon disulfide yields the following Sellmeier thermodynamic equation-[10]:

$$n(\lambda,T)=\left(1+\frac{B_1(T)\lambda^2}{\lambda^2-C_1^2(T)}+\frac{B_2\lambda^2}{\lambda^2-C_2^2}\right)^{1/2} \tag{1}$$

The Sellmeier coefficients obtained in Tables 2 and 3 allow us to accurately describe the effects of temperature and pressure on the near-infrared dispersion of carbon disulfide from violet to near-infrared light wavelengths.

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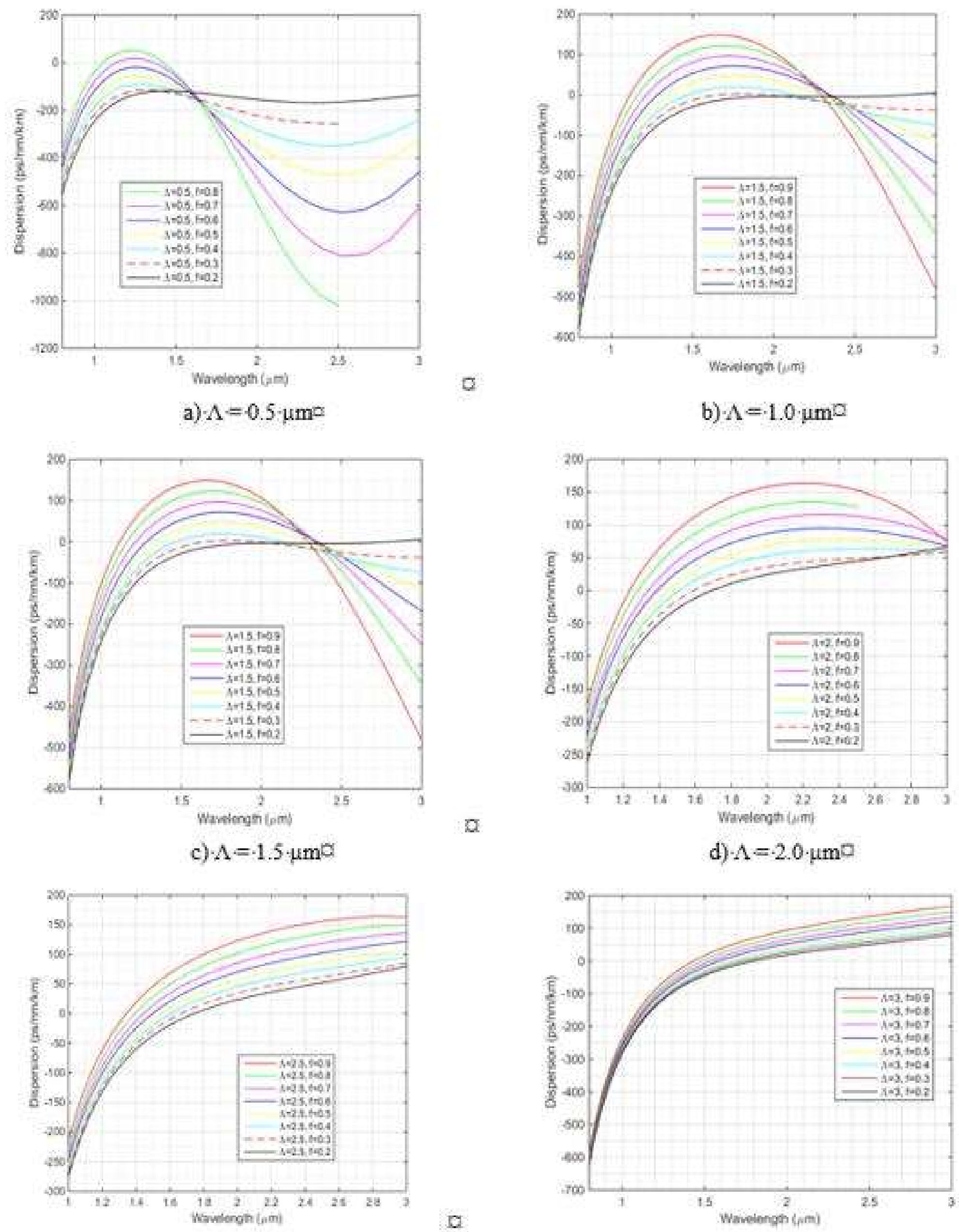

a) Λ = 0.5 μm

b) Λ = 1.0 μm

c) Λ = 1.5 μm

d) Λ = 2.0 μm

e) Λ = 2.5 μm

f) Λ = 3.0 μm

Fig. 2. *Dependence of dispersion on wavelength, $f = d/\Lambda = 0.2 \div 0.9$ at 293K temperature.*

Table 2. *Sellmeier coefficient of Carbon disulfide.*

TT	Sellmeier coefficient	Calculation expression (T(K), T_0 = 293 K)
1	B_1(T[K])	2.17144765-0.66589562(T/T_0)
2	B_2	0.085924705
3	C_1(T[K])(μm)	0.18382049-0.00505833(T/T_0) – 0.00421529$(T/T_0)^2$
4	C_2(μm)	6.48315928

Table 3. *Sellmeier coefficient of carbon disulfide at various temperatures [10].*

T	B1	B2	C1	C2
318.15	1.44876407	0.085924705	0.173365871	6.48315928
313.15	1.460121662	0.085924705	0.173606976	6.48315928
308.15	1.471479254	0.085924705	0.173845628	6.48315928
303.15	1.482836846	0.085924705	0.174081828	6.48315928
298.15	1.494194438	0.085924705	0.174315575	6.48315928
293.15	1.50555203	0.085924705	0.174546870	6.48315928
288.15	1.516909622	0.085924705	0.174775712	6.48315928
283.15	1.528267214	0.085924705	0.175002102	6.48315928
278.15	1.539624806	0.085924705	0.175226039	6.48315928
273.15	1.550982398	0.085924705	0.175447523	6.48315928
268.15	1.56233999	0.085924705	0.175666555	6.48315928
263.15	1.573697582	0.085924705	0.175883134	6.48315928

3.2. The effective refractive index of a crystalline optical fiber depends on the structural parameters and the temperature of CS_2 liquid

Fig. 3, illustrate the wavelength dependence of the dispersion for the case where the fill factor d/Λ varies from 0.2 to 0.4 with lattice constant Λ = 1.5 µm with temperature T varies from 263 K, 273 K, 283 K, 293 K, 303 K to 313 K. The obtained results show that, with the same set of structural parameters, the wavelength-varying dispersion curve has the same shape. As the temperature increases, the height of the dispersion line increases.

From Fig. 3a we see that when the holes are filled with liquid CS_2 will result in a non-dispersive wavelength shift towards the long wavelength, from 1.50 µm to 1.840 µm as the temperature decreases. The result due to an increase in the refractive index of the filler in the hole coincides with the conclusion-[7]. The dispersion lines are relatively flat towards the long wavelength and are capable of transitioning between normal and anomalous dispersion modes.

From Fig. 3a we notice that when the holes are filled with liquid CS_2 will result in a dispersive wavelength shift without two regions from 1.52 µm to 1.70 µm at heat and 1.53 µm to 2.5 µm with temperatures of 263 K, 273 K, 283 K and non-dispersive wavelength from 1.45 µm to 1.48 µm degrees down to 313 K, 303 K to 293 K. Thus, there are temperature regions where there is a magnetic transition between normal and anomalous dispersion modes. On the contrary, there are temperature regions where there is only magnetic transition between normal and anomalous dispersion modes.

Fig. 3c shows that temperature regions with transition from between normal and anomalous dispersion modes and vice versa with the investigated temperatures of 313 K, 303 K, 293 K and 283 K. There are temperature regions with only canopy normal color with survey temperatures of 273 K, 263 K.

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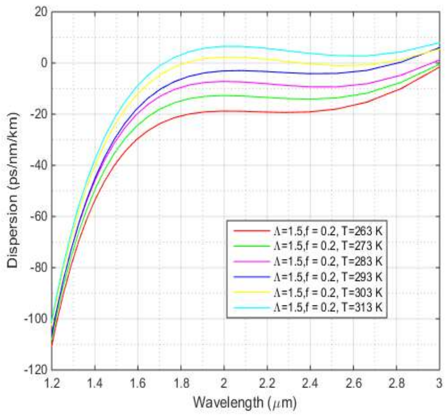
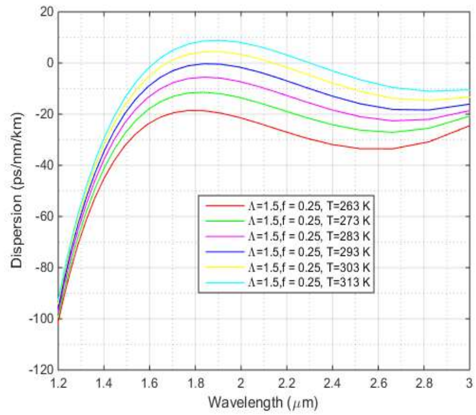
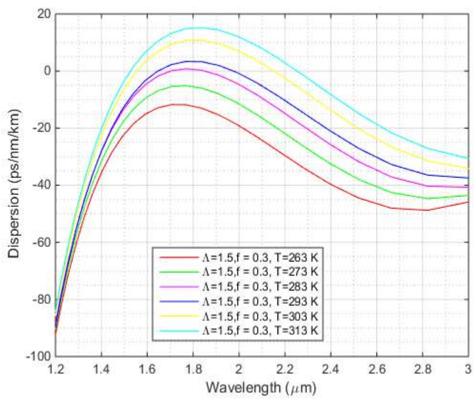


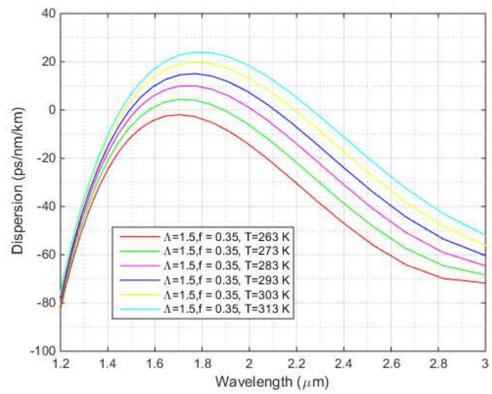
a) f = d/Λ = 0.20



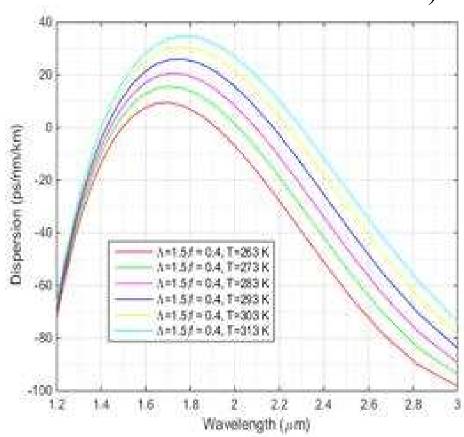
b) f = d/Λ = 0.25



c) f = d/Λ = 0.30



d) f = d/Λ = 0.35



e) f = d/Λ = 0.40

Fig. 3. *Wavelength dispersion dependence with lattice constant Λ = 1.5 μm and fill factor f = d/Λ = 0.20 ÷ 0.40 at temperatures of 263 K, 273K, 283K, 293K, 303K and 313K.*

Fig. 3d we see that there are temperature regions with transition between normal and anomalous dispersion modes and vice versa with the investigated temperatures of 313 K, 303K, 293K, 283K, 273K and there are temperature regions only has normal dispersion with the investigation temperature of 263K.

From Fig. 3e with lattice constant Λ = 1.5 μm and fill factor f = d/Λ = 0.4, we see that there are temperature regions with magnetic transitions between dispersion modes normal and anomalous vice versa with the survey temperatures of 313 K, 303 K, 293 K, 283 K, 273 K and 263 K.

IV. CONCLUSIONS

In this paper, we show the dependence of dispersion on wavelength for the case where the fill factor d/Λ varies from 0.2 to 0.9 with different lattice constants Λ = 0.5 μm; 1.0 μm; 1.5 μm; 2.0 μm; 2.5 μm; 3.0 μm. The obtained results show that, with the same set of structural parameters, the wavelength-varying dispersion curve has the same shape.

Studying the characteristics of hollow core PCF with hexagonal lattice permeable with CS_2 liquid according to temperature, it has been shown with lattice constant Λ = 1.5 μm and forming index f = d/Λ varies from 0.2 to 0.4 at temperatures of 263 K, 273K, 283 K, 293 K, 303 K and 313 K.

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