THE EFFECT OF TEMPERATURE ON REFRACTIVE INDEX OF CARBON DISULFIDE

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ABSTRACT

In this paper, the effect of temperature on the refractive index of carbon disulfide liquid based on the influence of temperature on the Sellmeier coefficient has been presented. The effect of temperature on the liquid refractive index of carbon disulfide in the visible and infrared regions according to the expression of M. Chemnitz was also investigated. From the survey results, it is concluded that as the wavelength increases, the refractive index of carbon disulfide decreases, but when the temperature is increased then the refractive index of carbon disulfide decreases faster.

Keywords: refractive index; carbon disulfide; thermo-optics.

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1. Introduction

Nowadays, photonic crystal fibers are often applied in supercontinuous sources [1]-[3]. With the flexibility to change the structure parameter, the photonic fiber allows to optimize the dispertion curve for supercontinuous. A new and topical approach is to use temperature to change the properties of optical fibers for supercontinuous [1]-[2], [4]-[5]. Specifically, the adjustment of the dispersion curve is made possible based on the thermo-optics of the optical fiber, the properties of the fiber material, such as the refractive index, which can be adjusted by changing the environment temperature.

Carbon disulfide (CS_2) is used as a nonlinear optical medium due to its large third-order nonlinear refraction, the subject of numerous experimental studies using time-resolving techniques such as the Kerr effect, nonlinear interference measurements, such as frequency domain light scattering, third harmonic generation and Z-scan and four-wave mixing. CS_2 is used in a wide range of applications as nonlinear optical fluids including liquid core optical fibers for nonlinear photonic applications, super controllability generation, slow light, ultrafast time image resolution, soliton propagation and all-optical switching, etc.

The papers [1]-[2] have measured the photothermal and photobarometric parameters of CS_2 over a spectrum extending from the visible to the near-infrared region. A theoretical model was used to establish a temperature-dependent refractive index model for CS_2 with temperature-dependent Sellmeier coefficients [6]-[9]. From there, the influence of temperature on coefficient and refractive index can be investigated by Maple software. With a topical new approach is to change the temperature to change the properties of the optical fiber for supercontinuous. In particular, the adjustment of the dispersion curve is made possible thanks to the thermo-optics of the optical fiber and the properties of the fiber material, such as the variable refractive index by varying the ambient temperature [1]-[2].

Therefore, the study of the effect of temperature on the liquid refractive index of CS_2 is necessary, topical, scientific and practical.

2. Some theoretical models of liquid refractive index

From different refractive index at different wavelengths, one can calculate a dispersion equation by fitting a nonlinear curve using the least squares method. Among the different dispersion equations, the Sellmeier and Cauchy formulas are the most popular [8]-[10]. The Sellmeier equation can be used in the entire spectral region and is subject to the second order:

$$n^2(\lambda) = 1 + \frac{A_1\lambda^2}{\lambda^2 - B_1} + \frac{A_2\lambda^2}{\lambda^2 - B_2} \ , \quad (1)$$

in which A_1, A_2 are the material parameters; $\sqrt{B_1}$ and $\sqrt{B_2}$ are the wavelengths of the absorption bands, respectively.

Far from any resonance one can use the simpler Cauchy equation. Thus, the first-order Sellmeier equation can be extended to a power series:

$$n^2(\lambda) = 1 + \frac{A_1\lambda^2}{\lambda^2 - B_1} \approx 1 + A_1\left(1 + \frac{B_1}{\lambda^2} + \frac{B_1^2}{\lambda^4}\right) = C_0 + \frac{C_1}{\lambda^2} + \frac{C_2}{\lambda^4} \, . \quad (2)$$

An improvement in refractive index correction of liquids in the visible to near-infrared regions can be expected if the $C_3\lambda^2$ term in equation (2) is added due to the infrared oscillating absorption bands [8] lead to:

$$n^2(\lambda) = C_0 + \frac{C_1}{\lambda^2} + \frac{C_2}{\lambda^4} + C_3\lambda^2 \, . \quad (3)$$

For each liquid, the constants of the Sellmeier and Cauchy formulas are calculated.

3. Investigate the effect of temperature on liquid refractive index of CS_2

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

The near-infrared spectrum of CS_2 $n_0(\lambda_k)$ was taken using a known Sellmeier model at wavelength λ_k where the photothermal parameter is known and assume that the pressure does not change. New values of the near infrared spectrum for the selected temperature T_l were calculated using the linear thermal-optics relationship according to the following:

$$n(\lambda_k, T_l) = n_0(\lambda_k) + \left.\frac{dn}{dT}\right|_{T_0}(\lambda_k).(T_l - T_0) \quad (4)$$

where T_0 = 293 K is room temperature.

Adjust the wavelength dependence of all $n(\lambda_k,T_l)$ with a new Sellmeier equation. The final expression for the pressure and temperature-dependent near-infrared scattering of CS_2 yields the following Sellmeier thermodynamic equation:

$$n(\lambda, T) = \left(1 + \frac{B_1(T)\lambda^2}{\lambda^2 - C_1^2(T)} + \frac{B_2\lambda^2}{\lambda^2 - C_2^2}\right)^{1/2} \quad (5)$$

The Sellmeier coefficients obtained in Tables 1 and 2 allow us to accurately describe the effects of temperature and pressure on the near-infrared dispersion of CS_2 from violet to near-infrared light wavelengths.

Table 1: *Sellmeier coefficient of CS_2 [8]*

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 2: Sellmeier coefficient of CS_2 at various temperatures

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

The dependence of the coefficients B_1 and C_1 on temperature is plotted in Figure 1.

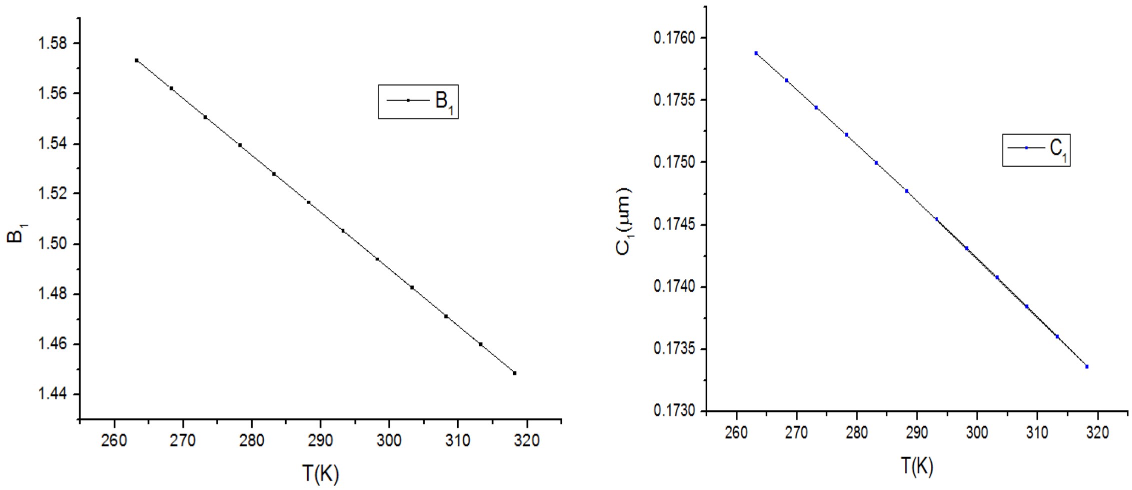

Figure 1: *The dependence of the coefficient B_1, C_1 on the ambient on temperature*

3.2. Investigate the effect of temperature on CS_2 liquid extraction in the visible and near-infrared light regions

The refractive index dependence of the CS_2 liquid according to the expression in the work [8] of M. Chemnitz in the visible and near - infrared light regions at 20 ^{0}C and 45 ^{0}C are plotted in Figure 2 for a comparison of the thermal changes leading to the change in refractive index.

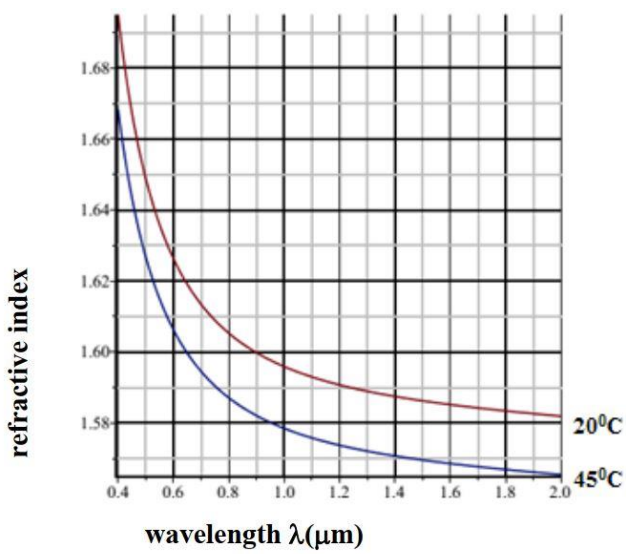

Figure 2*: The refractive index of CS_2*
in the visible and near infrared regions at 20 ^{0}C and 45 ^{0}C

Looking at the graph, as the wavelength increases, the refractive index of CS_2 decreases, but as the temperature increases, the refractive index of CS_2 decreases faster. To clearly see the influence of temperature, the dependence of CS_2 refractive index in the visible and near-infrared light domains at -100 ^{0}C, 50 ^{0}C, 250 ^{0}C and 450 ^{0}C were further investigated as shown in Figure 3.

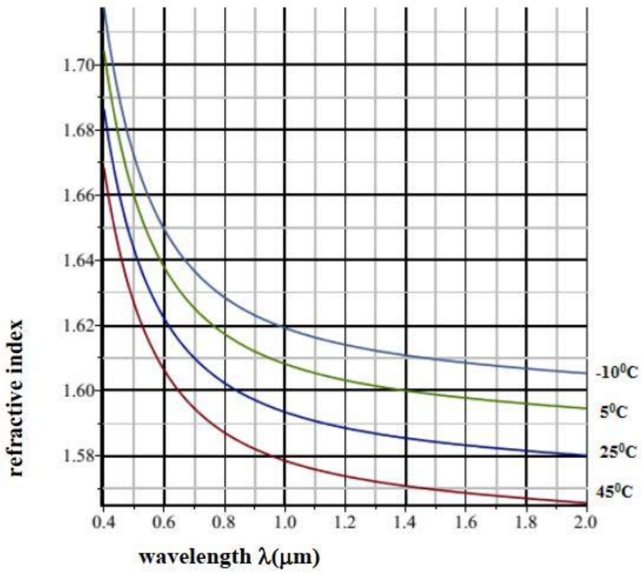

Figure 3: *The refractive index of CS_2 in the visible and near-infrared regions at -10 ^{0}C, 5 ^{0}C, 25 ^{0}C and 45 ^{0}C*

3.3. Investigation of the effect of temperature on the refractive index of liquid CS_2 according to the results of M. Chemnitz

The refractive index of the liquid CS_2 according to the expression in the work [8] of M. Chemnitz in the wavelength region of 0.3 μm to 12 μm near the temperature of 20 ^{0}C and 45 ^{0}C is plotted in Figure 4.

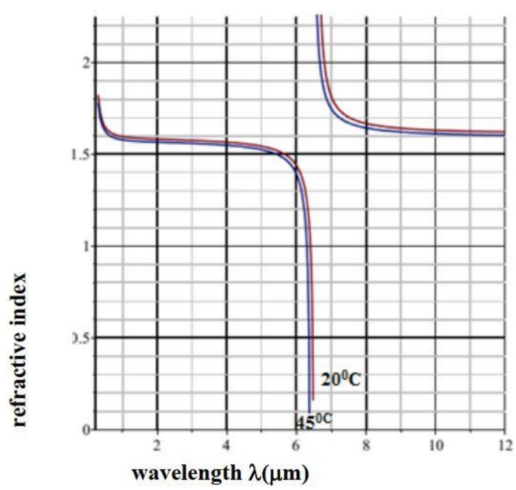

Figure 4: *The refractive index of CS_2 in the visible and near-infrared regions at 20^{0}C and 45^{0}C*

Looking at the graph in Figure 5, the refractive index of CS_2 in the long infrared region. The temperature was then changed to -10 ^{0}C, 5 ^{0}C, 25 ^{0}C and 45 ^{0}C to clearly see the effect of temperature on CS_2 refractive index. As the temperature increases, the refractive index of CS_2 decreases faster. These results can be explained as follows: here is the liquid environment, so when the temperature increases, the density of matter decreases (the density decreases). Under normal conditions, the refractive index of the material medium decreases. as the density of matter decreases.

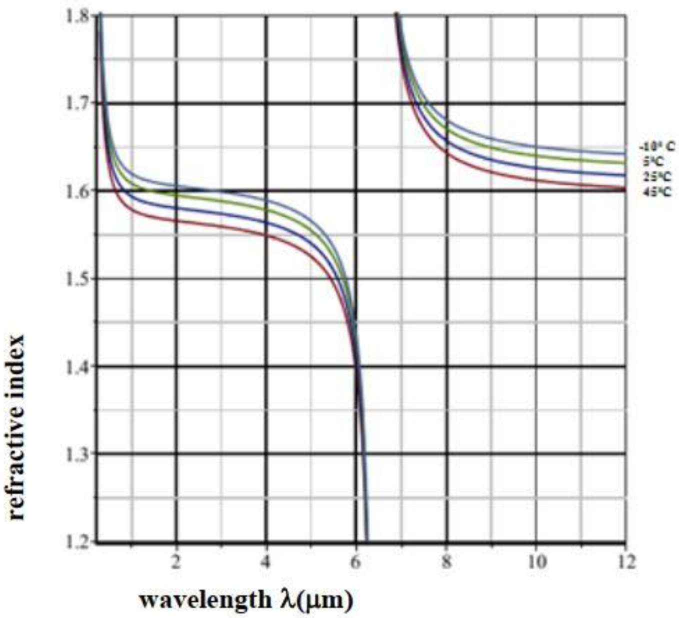

Figure 5: *The refractive index of CS_2 in the visible and near-infrared regions at -10 ^{0}C, 5 ^{0}C, 25 ^{0}C and 45 ^{0}C*

With the direction of changing the temperature to change the refractive index CS_2 in the visible and near-infrared light regions, if the pump CS_2 liquid was used for the crystal optical fiber core, one can simulate and experimentally study the influence of temperature effect on supercontinuity. Specifically, the dispersion curve is changed because the refractive index can be changed by changing the ambient temperature, from which the optimal temperature conditions for supercontinuous emission can be determined or the direction of temperature sensor research can be opened, etc.

4. Conclusions

In this paper, the refractive index expression of the temperature-dependent carbon disulfide (CS_2) liquid according to the Sellmeier model with the temperature-dependent Sellmeier coefficients was determined. The results of the investigation of the influence of temperature on the Sellmeier coefficient are shown in Table 2 and Figure 1. The influence of temperature on the liquid refractive index of CS_2 in the visible and visible light domain were also investigated. Infrared close to the following temperatures: -10 ^{0}C, 5 ^{0}C, 25 ^{0}C and 45 ^{0}C. The survey results show that the refractive index of CS_2 decreases faster with increasing temperature and is the basis for opening a direction to study the influence of temperature on the supercontinuity of crystalline optical fibers with liquid-injected cores by CS_2 liquid.

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TÓM TẮT

SỰ ẢNH HƯỞNG CỦA NHIỆT ĐỘ LÊN CHIẾT SUẤT CARBON DISULFIDE

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Trong bài báo này, biểu thức chiết suất của chất lỏng carbon disulfide phụ thuộc vào nhiệt độ theo mô hình Sellmeier với các hệ số Sellmeier phụ thuộc vào nhiệt độ đã được xác định. Kết quả khảo sát ảnh hưởng của nhiệt độ lên hệ số Sellmeier được thể hiện trong Bảng 2 và Hình 1. Sự ảnh hưởng của nhiệt độ lên chiết suất chất lỏng carbon disulfide trong miền ánh sáng nhìn thấy và hồng ngoại gần với các nhiệt độ: -10 ^{0}C, 5 ^{0}C, 25 ^{0}C và 45 ^{0}C cũng đã được khảo sát. Kết quả khảo sát cho thấy chiết suất carbon disulfide giảm nhanh hơn khi nhiệt độ tăng và là cơ sở cho phép mở ra hướng nghiên cứu ảnh hưởng của nhiệt độ lên sự phát siêu liên tục của sợi quang tinh thể có lõi bơm chất lỏng carbon disulfide.

Từ khóa: chiết suất; carbon disulfide; quang-nhiệt.