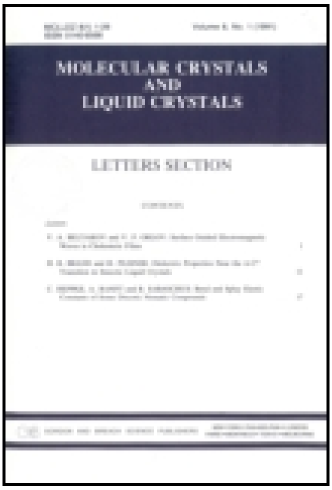

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Nonlinear Optics of Triton X-100/ $C_{10}H_{21}OH/H_2O$ Lamellar Liquid Crystal

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Nonlinear Optics of Triton X-100/$C_{10}H_{21}OH/H_2O$ Lamellar Liquid Crystal

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In this work, we described the nonlinear optical properties from thermal origin of lamellar liquid crystals by Z-scan technique in different regions of the phase diagram. The results showed that nonlinear refractive index of LLC depends on the solvent layer space. We also studied the influence of the addition of magnetic nanoparticles in nonlinear optical properties of the system.

Keywords Lamellar phase; nonlinear optics; Z-Scan; thermal effect

1. Introduction

Optical techniques are widely used to investigate the physical-chemical properties of complex and supermolecular systems such as liquid crystals, which often exhibit large optical nonlinearities [1]. Nonlinear effects from thermal or electronic origin can be study by measuring of nonlinear refractive index (n_2) as well as nonlinear absorption coefficient (β). The Z-Scan technique can be used to measure both n_2 and β in a simple setup in which a Gaussian-profile laser beam is focused by a lens caused a variation on the beam intensity along z direction [2–3].

In recent years, lamellar liquid crystals (LLC) have been received much attention due to their lubrification performance [4] as well as their use as template for nanoparticles preparation [5]. For example, Ding et al. [5] reported the preparation of silver sulfide nanoparticles (2–3 nm) using lamellar liquid crystal formed by Triton X-100, *n*-decanol and water.

Magnetic fluids are colloidal suspensions of small magnetic particles coated with surfactant agents or electrically charged particles dispersed in a liquid carrier. The interest in studying the nonlinear properties of lyotropic systems has been increasing over recent years due to the similarity between these materials and biological systems [6].

Herein, we report our study of the nonlinear optical properties from thermal origin of the lamellar liquid crystals formed by Triton X-100/*n*DeOH/H_2O, undoped and doped with magnetic fluid, using Z-scan technique in different regions of the phase diagram.

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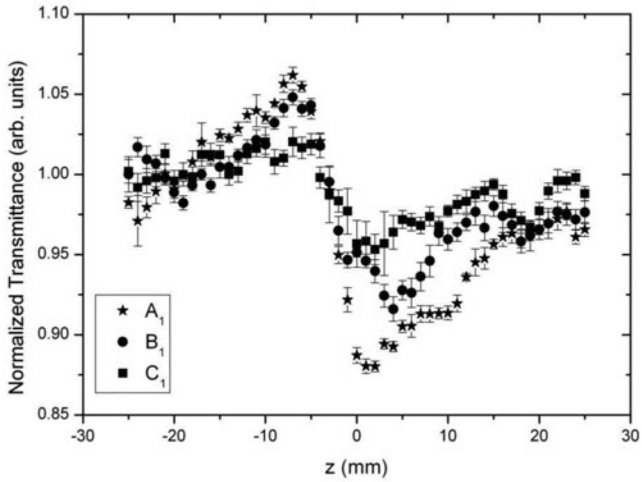

Figure 1. Normalized transmittance curve for mixtures A_1, B_1 and C_1.

2. Experimental

2.1. Samples

The lamellar liquid crystal is a mixture of non-ionic surfactant Triton X-100 (Sigma-Aldrich >99%), 1-decanol (Sigma-Aldrich, 98%) and water (distilled and deionized) with six different composition in molar%: mixture A_1 with Triton X-100 14.86, *n*DeOH 7.54, and water 77.60; mixture B_1 with Triton X-100 47.37, *n*DeOH 42.57 and water 10.06; mixture C_1 with Triton X-100 29.02, *n*DeOH 50.43 and water 20.55; mixture A_2 with Triton X-100 78, *n*DeOH 17.7, and water 7.3; mixture B_2 with Triton X-100 47.30, *n*DeOH 42.40 and water 10.30; mixture C_2 with Triton X-100 33.20, *n*DeOH 47.50 and water 19.30; All measurements were performed at $20 \pm 1°C$. The samples A_2, B_2 and C_2 were doped with a small amount of water-based magnetic fluid (1 μL of magnetic fluid per g of phase). The magnetic fluid used in this study was obtained from Chemicell© (UCC/C with concentration of 1.25 mg/mL).

2.2. Z-Scan Apparatus and Technique

The Z-Scan technique employs a focused CW diode laser excitation (Verdi V2, Coherent©, $\lambda = 532$ nm). The spatial profile of the beam, perpendicular to its propagation direction, is Gaussian. The light beam was modulated by a mechanical chopper (Model MC2000 Optical Chopper, Thorlabs Inc.) to produce the square pulses of 30 ms width (frequency $\sim$ 17 Hz) and focused by a lens of 10 cm focal length. The beam waist of the Z-Scan experiment was $\omega_0 = 32$ μm, $z_0 = 4.3$ mm and the incident power was 132.5 mW. The samples were encapsulated between optical glass slides with dimensions 25 mm $\times$ 15 mm, with a Teflon spacer L = 200 μm thick. The results analysis was performed using the formalism of the model developed by Sheik-Bahae and co-workers [2–3]. In this formalism, the normalized transmittance, as function of the z position of the sample, is given by:

$$T_N = 1 - \frac{4\emptyset_0 x}{\left(x^2+9\right)\left(x^2+1\right)} \qquad (1)$$

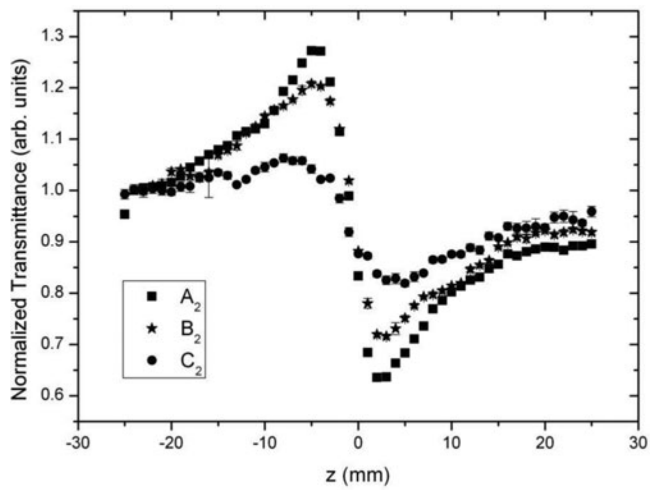

Figure 2. Normalized transmittance curve for mixtures A_2, B_2 and C_2.

where ϕ_0 is the on-axis nonlinear phase shift at focus, x is the dimensionless sample position $x = z/z_0$ and $z_0 = \pi\omega^2/\lambda$ is the Rayleigh range of the Gaussian beam with waist ω. The nonlinear phase shift ϕ_0 is given by

$$\emptyset_0 = \frac{2\pi n_2 L_{eff} I_0}{\lambda} \tag{2}$$

where λ is the wavelength, L_{eff} is the effective sample thickness ($L_{eff} = (1\text{-}e^{-\alpha L})/\alpha$) and I_0 is the on-axis intensity at the focus and α is the linear absorption coefficient. Ten measurements of the transmittance were performed for each z position of the sample and mean values were obtained to construct the Z-Scan curves.

3. Results and Discussion

Figure 1 shows the typical Z-Scan curve for samples A_1, B_1 and C_1 (without magnetic fluids) as function of the sample position, which allows us to determine n_2 using equations 1 and 2. A peak to valley curve, characteristic of sample with a negative nonlinear refractive

Table 1. Modulus of nonlinear refractive index n_2 and composition for the six samples studied

Sample	$\lvert n_2 \rvert$ ($\times 10^{-8}$ cm^2/W)	H_2O (M% − wt%)	Triton X-100 (M% − wt%)	*n*DeOH (M% − wt%)
A_1	2.92 ± 0.07	77.60–11.41	14.86–78.79	7.54–9.80
B_1	2.31 ± 0.03	47.37–2.83	42.57–91.83	10.06–5.34
C_1	1.82 ± 0.05	29.02–1.43	50.43–89.64	20.55–8.93
A_2	6.70 ± 0.03	78.20–11.63	17.70–78.76	7.30–9.61
B_2	5.31 ± 0.05	47.30–2.84	42.40–91.72	10.30–5.44
C_2	3.35 ± 0.03	33.20–1.77	47.50–89.37	19.30–8.86

index ($n_2 < 0$), was observed for all samples investigated. Nonlinear refractive index (n_2) values are showed in Table 1.

Figure 2 shows the typical Z-Scan curve for samples A_2, B_2 and C_2 (with magnetic fluids) as function of the sample position. We could observe that A_2, B_2 and C_2 showed similar behavior to those of samples A_1, B_1 and C_1, but the nonlinear refractive index of A_2, B_2 and C_2 is larger than those obtained with A_1, B_1 and C_1 (n_2 values were showed in Table 1).

Table 1 shows the dependence of nonlinear refractive index on the amount of water in the mixture. For example, sample A_1 (water content 77.5 M%) showed $n_2 = (-2.92 \pm 0.07) \times 10^{-8}$ cm^2/W, while sample C_1 (water content 29.02 M%) showed $n_2 = (-1.82 \pm 0.05) \times 10^{-8}$ cm^2/W. From the results obtained in this study, it was also possible to establish a correlation between the nonlinear refractive index and the presence of magnetic fluid in the system. The increase in the nonlinear refractive index is probably correlated to water layer length in both systems (with and without magnetic fluid).

4. Conclusion

Nonlinear refractive index of lamellar liquid crystal is negative ($n_2 < 0$). The nonlinear refractive index increases with the presence of magnetic fluid in the system as well as is in good correlation with the water amount. The addition of water increases the thickness of solvent layer making the phase more fluid, thus facilitating the formation of the thermal lens. Further small angle X-ray diffraction measurements of these systems are under investigation in our group.

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References

[1] Gomez, S. L., Cuppo, F. L. S., Figueiredo Neto, A. F., Kosa, T., Muramatsu, M., & Horowicz, R. J. (1999). *Phys. Rev.*, *59*(3), 3059.
[2] Sheik-Bahae, M., Said, A. A., & Stryland, E. W. V. (1989). *Opt. Lett.*, *14*(17), 955.
[3] Sheik-Bahae, M. Said, A. A., Hagan, T. H., Hagan, D. J., & Stryland, E. W. V. (1990). *IEEE J. Quantum Electron.*, *26*(4), 760.
[4] Ma, C. S., Li, G. Z., Shen, Q. *et al.* (1999). *J. Disp. Sci. Technol.*, *20*, 1025.
[5] Ding, Y., Xu, B., Guo, R., & Shen, M. (2005). *Mat. Research Bulletin*, *40*, 575.
[6] Alves, S., Cuppo, F. L. S., & Figueiredo Neto, A. M. (2006). *JOSA B*, *23*(1), 67.