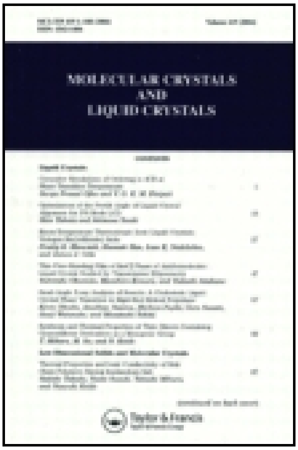

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Self-Phase Modulation in a Dye-Doped Liquid-Crystal

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Self-Phase Modulation in a Dye-Doped Liquid-Crystal

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Abstract A nematic liquid crystals doped with 0.1 wt % dye were made into a 60 μm cell of homogeneous alignment. A self-phase modulation ring pattern made upon irradiation of the laser beam was investigated at different pump wavelengths and sample temperatures. Various contributions to this phenomenon including thermal indexing and reorientation of the molecules were discussed.

INTRODUCTION

Liquid crystals show exceptional nonlinear optical properties arising from correlated motions of the molecules in the mesophase [1]. One example is self-phase modulation (SFM), in which continuous-wave (cw) laser beam of moderate intensity can cause a significant change in the refractive index and produce a ring pattern in the transmitted beam [2]. Recently, Janossy and coworkers found this nonlinear optical effect can be enhanced by more than two orders by mixing a ~1% of dye (guest) in the liquid crystal host [3]. They explained the results by the difference in the interaction potential between the host and the guest molecule in the ground and excited states. Later this enhancement effect was found even when a host material is in an isotropic, liquid state [4]. However, in most of the cases, especially with the exposure of cw lasers, the refractive index change is thermal in origin. The local heating of the sample caused by the absorption changes the order parameter and this can locally change the refractive index of the sample. This aspect of self-phase modulation has been studied quite extensively by Ono and the coworkers [5]. In our recent investigations with dye-doped LC, we observed interesting effects in the pump wavelength and temperature dependence of the SFM. In this paper, we report our findings with the discussion.

EXPERIMETAL

The host LC was ZGS-5102 with a transition temperature T_{NI}=100.3 C. The 0.1 wt-% of guest molecules (mixture of three different azo dyes) were put in the LC host. The LC was made into a homogeneous cell of 60 μm thickness. The absorption spectrum of this cell was shown in Fig. 1. The second harmonic of Nd:YAG, He-Ne, and Ti:sapphire laser beams (all cw) were incident normally to the cell to investigate the wavelength dependence of the SFM effect. The transmitted light was measured as a function of position from the beam center and also the function of time (from the beginning of the exposure) to investigate the temporal change of the refractive index.

RESULTS AND DISCUSSION

Figure 1 shows the absorption spectrum of the dye-doped LC cell. Also shown in the figure are the relative strengths of the SFM at several different pump wavelengths. As expected, the index change is larger where the absorption is strong. Since the refractive index change is negative and the response was very fast (~30ms) in this region (532nm and 633nm), it should be thermal in origin. On the other hand, at the absorption edge (800nm), the index change is smaller. The response time of the medium was found to be much longer, suggesting at this wavelength range the reorientation of the molecules is responsible for the index change.

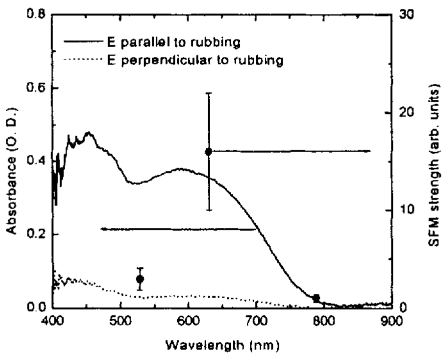

FIGURE 1 Absorption spectra of the dye-doped LC cell. Also shown are relative strengths of the self-phase modulation effect measured at room temperature and polarization parallel to the rubbing direction.

Figure 2 shows the intensities of the transmitted light at the beam center at several different LC temperatures. At the room temperature and up to 50 C, one can only observe single-component change. In the temporal development at higher temperatures, it can be seen that the initial component becomes faster and is succeeded by a slow change [6]. It can be interpreted that at low temperatures the change is solely due to thermal indexing effect. At higher temperatures, reduced order parameter of the molecules in addition to the temperature rise due the pump beam facilitates the dipole reorientation (optical Freedericksz transition), which was not possible at room temperature.

In conclusion, we have observed the strong self-phase modulation in a dye-doped liquid crystal cell. The temperature dependence and pump wavelength dependence of this phenomenon was explained qualitatively by different mechanisms. We thank W. S. Kim of LG LCD for help with preparation of the sample. This work was supported by grant No. 19994035 from the Basic Research Program of the Korea Science & Engineering Foundation.

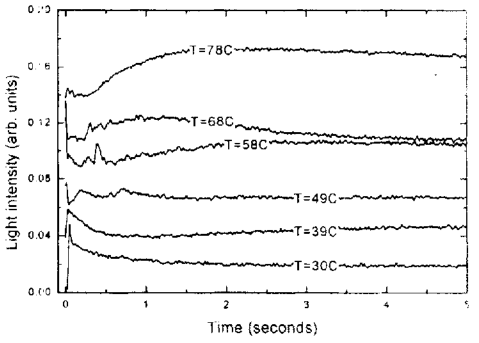

FIGURE 2 Temporal change of the transmitted light intensity at the beam center for several different temperatures. Polarization was parallel to the rubbing direction.

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