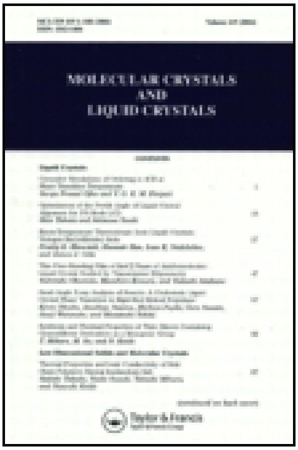

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Optical Nonlinear Behavior of Lyotropic Liquid Crystal Systems

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OPTICAL NONLINEAR BEHAVIOR OF LYOTROPIC LIQUID CRYSTAL SYSTEMS

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ABSTRACT

Optical nonlinear properties of the lyotropic liquid crystal system potassium caprylate in water (PC) have been found in different mesophases.

Optical nonlinear properties of liquid crystals have recently been studied using nematic materials [1]. The possibility of using nematic LC for constructing nonlinear waveguides and other optical devices has also been demonstrated [2,3].

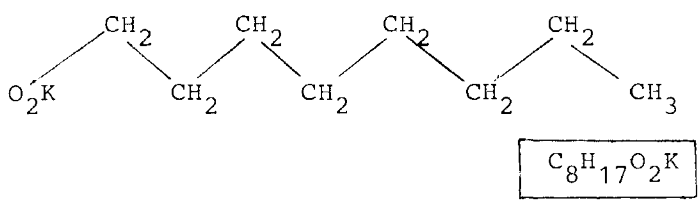
The optical nonlinear properties may have different origin according to which the change in refractive index is produced by a thermal effect due to the heating by the light source or is due to a reorientation of molecules induced by the optical wave electric field.

On these grounds it can be expected that all liquid crystals present nonlinear optical properties of the Kerr type, in the sense that their refractive index n can be a function of the light intensity

$$n = n_o + n_2 \, |E|^2 \qquad (1)$$

Thus we have studied the nonlinear behavior of the lyotropic liquid crystal potassium caprylate (PC) and water.

Potassium caprylate molecules have the structure formula



in which the O_2K part is the polar part of the molecule. This material has a phase diagramm shown in Fig.1 [4]. At room temperature several phases can be obtained depending on the potassium caprylate concentration. Starting from the micellar phase (L_1) by increasing the amphiphilic concentration we have a simple hexagonal phase (E) followed by a gel phase (G) . The L_1-E and E-G transitions occur through extended mixed phase regions. The temperature phase transitions occur, as it is shown in the diagramm,for rather high temperatures. The phase transition diagramm and structural structures have been extensively studied by Agajev et al.[4] . In the micellar phase L_1 the PC molecules aggregate into spherical clusters, dispersed in water. The system has nearly isotropic physical properties. In the hexagonal phase long shaped structures are formed with an hexagonal symmetry with respect to the long axis . Of course this mesophase has greately asymmetric physical properties. The gell mesophase G has a solid-soap structure with layered molecular disposition .

The PC has been chosen because it is monomesomorphic in large concentration and temperature ranges;in the concentration range of amphiphile from 50 wt% to 68 wt%, and in the temperature to about 150 ^{o}C it is in simple hexagonal mesophase (E).

In the experiment the hexagonal phase and the transition regions have been considered. In all phases PC is transparent to light.

To check the presence of optical nonlinearities a waveguiding geometry has been chosen as already used with nematic LC [2] . A droplet of the PC is placed on the surface of a glass waveguide, in wich the guiding region was obtained by ion exchange of Ag. Radiation from an Ar laser was coupled to the waveguide through a glass prism, guided through the region with the PC on top and coupled out with a second glass prism.

The output light intensity as a function of the input power is shown in arbitrary units for a 60wt % amphiphile concentration in water in Fig.2.

This is the typical result. Similar dependences, but with a less pronounced hysteresis have been revealed in the region of coexistence of mesophase E with gell, and mesophase E with isotropic phase.

In all the studied cases by increasing the input power the output power shows a sublinear behavior at high input powers. When P_{IN} is decreased a loop is followed as shown in Fig.2. These results can be qualitatively understood by assuming that the refractive index of the liquid crystal is a function of the input intensity according to eq.(1) and taking account also of the finite absorption of light in the LC.

The light guided in the waveguide has an evanescent field which decreases exponentially at boundaries therefore penetrating in the LC. This evanescent field is responsible for the change of refractive index of PC. If the sign of the coefficient n_2 in eq.(1) is taken positive so that n increases with the light intensity, the difference of refractive indices between the PC and the waveguide decreases and the evanescent field increases.

Because the LC has a finite absorption, more power is therefore absorbed. As a consequence by increasing P_{IN} the power coupled out from the waveguide does not increase linearly because more and more power is absorbed in the LC. This explains the sublinear behavior of P_{out} vs P_{IN} .

To explain the loop we need to consider that the liquid crystal droplet is not aligned. The LC can therefore be considered as made by different domains with different orientations.

The change of n with P can be produced by an irreversible merging of differently oriented domains under the action of the incoming light which gives the hysteresis effect very similar to what happens in ferromagnetic or ferroelectric substances.

For what concerns the mechanism by which n is changed at the present state it is not possible to discriminate between a thermal or an orientational effect, and research is at present in progress to asses this point.

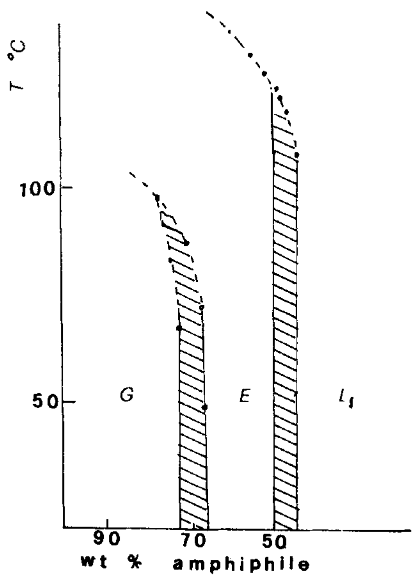


Fig.1 - State diagramm for PC

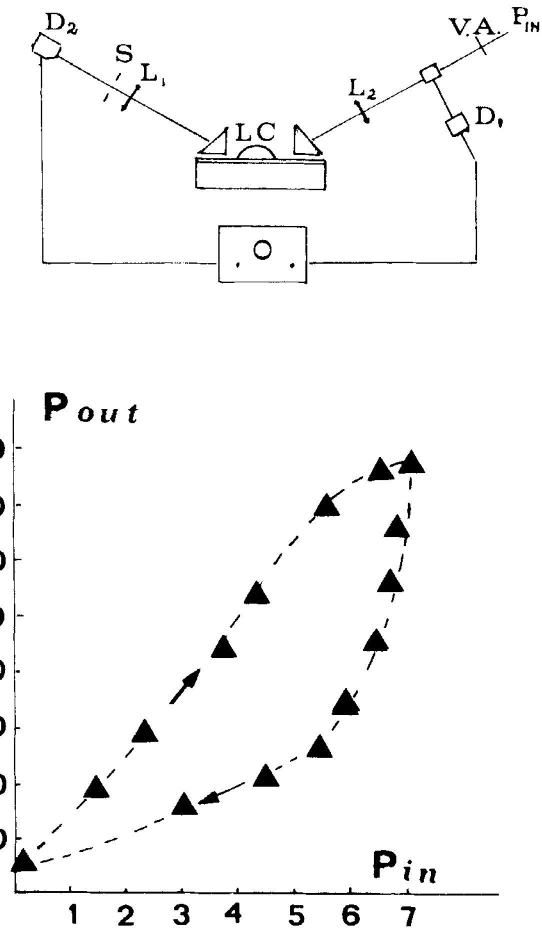


Fig. 2 Experimental Result for 60 wt% of amphiphile , and experimental configuration

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