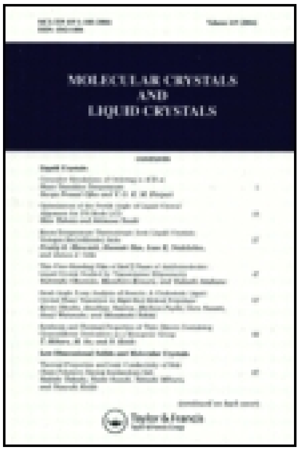

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LIGHT TRANSMISSION OF NEMATIC LIQUID CRYSTALS

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ABSTRACT
The letter describes some results obtained from measurements of regular and scattered transmission with nematic liquid crystals. A qualitative model of regular transmittance is given.

INTRODUCTION

Nematic Liquid Crystals (NLC) can be used for continuous contrast variation of a target observed through the NLC [1]. With increasing voltage applied to the cell regular transmission decreases and scattered transmission increases. These characteristics have been investigated with four substances produced by Merck GmbH:

1. Nematic phase 8A, a mixture of Schiff bases (conductivity $4 \cdot 10^{-10} \Omega^{-1} cm^{-1}$, temperature range -10°C.....+60°C)
2. Nematic phase 9A, a mixture of aromatic esters ($10^{-9} \Omega^{-1} cm^{-1}$, -20°C......+60°C)
3. ZLI 997, a mixture of azoxys and biphenylester ($1{,}3 \cdot 10^{-9} \Omega^{-1} cm^{-1}$, - 4°C.....+78°)
4. ZLI 971, a highly doped mixture of azoxys and a nematic ester, adjusted to a conductivity of $10^{-8} \Omega^{-1} cm^{-1}$ by undoped ZLI 207 (-10°.. +80°C)

The NLC-cells were prepared according to the method described by Knoll and Cremers [2]. The thickness of the layer was 10 µm and the director of the molecules was oriented normal to the glass surface.

Fig.1 shows the photometric arrangement. A

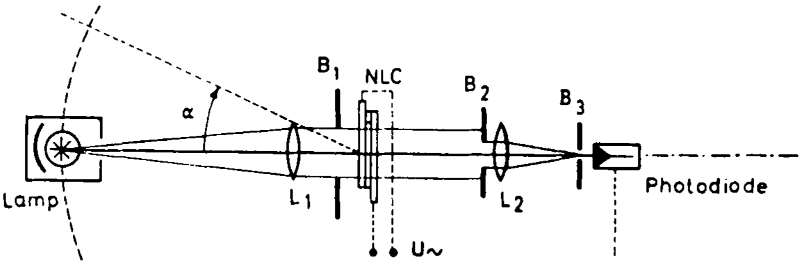

FIGURE 1. Scheme of the photometric device

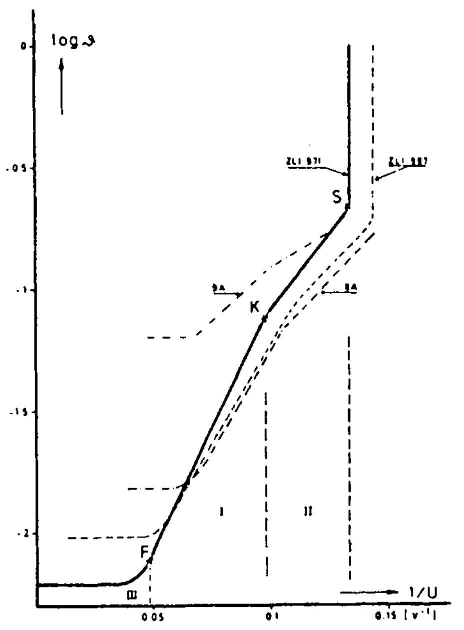

FIGURE 2. Internal regular transmittance of four nematic substances in relation to the reciprocal voltage applied to the cells.

parallel beam of light originating from a tungsten halogen lamp is projected through the NCL-cell onto a diaphragm B_2 and focused by lens L_2 on a very narrow opening B_3 with the photodetector just behind. Lamphouse, lens L_1, diaphragm B_1 and the NLC-cell are mounted on a turnable arm to measure scattered light at various angles α to the optical axis while at $\alpha = 0$ only regular transmitted light is measured.

TRANSMISSION CHARACTERISTICS

Fig. 2 shows the internal regular transmittance of the four substances on a log scale as a function of the reciprocal voltage U applied to the cells. Referring to the full line (ZLI 971) point S indicates the formation of Williams domains and point K the beginning of hydrodynamic scattering. Beyond point F the secondary hydrodynamic structure is formed.

Within the voltage range U_S<U U_F the internal regular transmittance can be described sectionally by

$$\vartheta = A_1 \exp\left(\frac{K_1}{U}\right) \qquad U_K < U < U_F$$
(1)
$$\vartheta = A_2 \exp\left(\frac{K_2}{U}\right) \qquad U_S < U < U_K$$

where U_K indicates the voltage of transition. The constants A and K can be determined from Fig. 2 (see Table 1). For the substances investigated

Table 1 Constants derived from Fig. 2

	K_1 [V]	K_2 [V]	$A_1 \cdot 10^{-3}$	$A_2 \cdot 10^{-3}$
ZLI 971	46.4	28.6	0.80	4.62
ZLI 997	39.5	26.8	1.49	7.16
N.P. 8A	38.0	23.1	0.59	5.79
N.P. 9A	20.6	13.6	15.4	31.6

we found

(2) $$\frac{K_1}{K_2} \approx 1.56 \qquad \frac{\log A_1}{\log A_2} \approx 1.33$$

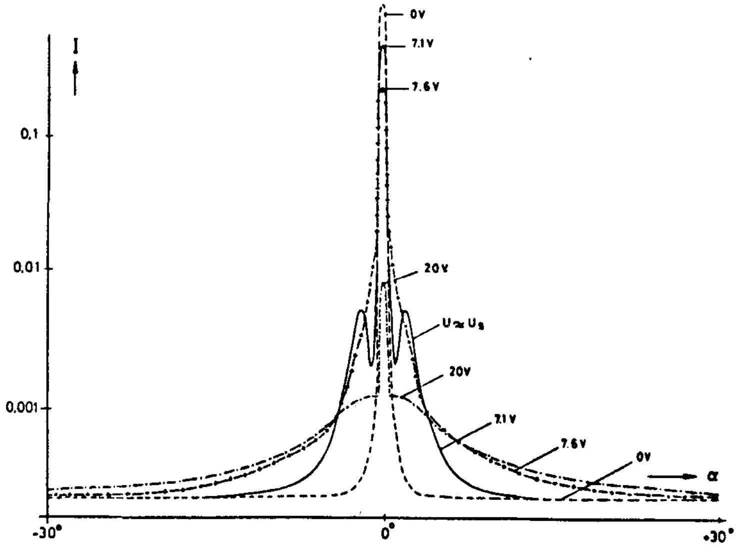

FIGURE 3. Angular intensity distributions of transmitted light (ZLI 971).

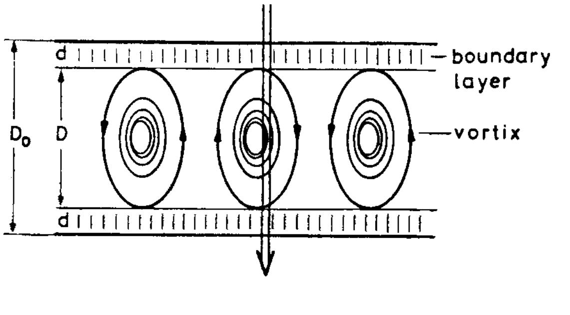

FIGURE 4. Illustration of flow pattern in the Williams domain range.

Fig. 3 shows typical angular distributions of transmittted light at increasing voltages. I is the luminous intensity plotted on a log scale relative to I_o ($U=0, \alpha=0$). The curve for U=0 represents the instrumental profile of the apparatus due to regular transmission of the NLC. At $U \approx U_s$ the Williams domains form a regular grating pattern exhibited by the two peaks at small angles. According to Bragg's equation the grating constant is somewhat larger than the thickness of the layer [3]. With higher voltages light scattering occurs insreasingsly both in quantity and angular width at the cost of regular transmission.

QUALITATIVE MODEL OF REGULAR TRANSMISSION

We consider a system of cylindrical vortices illustrated in Fig. 4 with decreasing flow velocities towards outer zones of a vortix. The vortical dimension D (see Fig. 4) is limited by stiff boundary layers [4] of thickness d which are proportional to 1/U.

Hence we obtain

(3) $$D = D_o \left(1 - \frac{\mathrm{const}}{U}\right)$$

It is assumed that the boundary layers do not contribute to scattering however a light beam passing through a vortix will be partially scattered due to the change of molecule orientation within the vortix. The attenuation of an elementary light beam shown in Fig. 4 is given by the law of extinction. Since the effective pathlengh for the average of all elementary light beams incident from 'above' onto a number of vortices within the aperture of the photometer is proportional to D we obtain

(4) $$\vartheta = \exp(-\mathrm{const}\ D) = A \exp\left(\frac{K}{U}\right)$$

where A and K are constants for a given flow pattern of a cell.

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