

Orientational Optical Nonlinearity of Nematic Liquid Crystals Induced by High-Molecular-Mass Azo-Containing Compounds¹

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Abstract—Processes of light-induced reorientation of nematic liquid-crystalline molecules induced by the addition of low concentrations (0.1–2.0 wt %) of comb-shaped polymers and carbosilane dendrimers containing azobenzene fragments are studied. When the molecular structure of the above compounds becomes more complicated, the induced orientational nonlinearity increases. The introduction of 2G and 3G dendrimers into a nematic has for the first time made it possible to visualize and study a purely optical first-order Fredericksz transition in the field of a linearly polarized wave.

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INTRODUCTION

The light-induced reorientation of molecules entails changes in the refractive index of a medium and various nonlinear optical phenomena, such as self-focusing and self-defocusing, wavefront conjugation, optical bistability, and formation of solitons etc. This phenomenon can be used for data recording, control over propagation of light beams, optical modulation, and other applications. The phenomena of optical reorientation are most pronounced for a “soft matter,” whose simplest representatives are nematic liquid crystals (NLCs).

In liquid crystals, the nematic phase is produced by rodlike molecules. Owing to the action of intermolecular forces, they align primarily in one direction that is locally characterized by a unit vector, director $\mathbf{n}$ [1, 2]. The NLC director can be easily rotated by an external low-frequency electrical field. This phenomenon serves as a basis for diverse applications of NLCs. A similar effect is observed for light fields [3–6]. A light beam passing through a layer of a transparent NLC rotates director $\mathbf{n}$ and aligns it along the direction parallel to the direction of light field $\mathbf{E}$, thus increasing the refractive index of an extraordinary wave. The corresponding (“positive”) orientational optical nonlinearity of the NLC is nine orders of magnitude higher than the Kerr nonlinearity of conven-

tional liquids [4]. The mechanism of optical orientation in nonabsorbing NLCs is related to the action of light field $\mathbf{E}$ on dipoles induced in the NLC molecules by the same field. The torque acting on molecules of a nematic matrix and normalized to the unit volume of the NLC has the form

$$\Gamma = \frac{\Delta\epsilon |A|^2}{8\pi} (\mathbf{n}\mathbf{e})[\mathbf{n}\mathbf{e}], \quad (1)$$

where $\Delta\epsilon$ is the dielectric anisotropy at the light frequency, A is the light-field amplitude, and $\mathbf{e}$ is the light-polarization unit vector.

When a nematic matrix is doped with dye molecules, orientational optical nonlinearity can increase by three orders of magnitude (when the concentration of the additive is ~1 wt %) [7]. In the doped NLCs, the director can rotate both parallel and perpendicularly to the light-field direction. In the second case, the refractive index of the extraordinary wave decreases. (“Negative” nonlinearity is observed [8].)

The mechanisms leading to the light-induced rotation of the director in the absorbing NLCs cannot be considered indisputable, and several models of this phenomenon are known [9–14]. However, it is common knowledge that the rotation of the director requires the development of an ensemble of excited dye molecules whose orientational distribution is asymmetric with respect to the director [7]. The torque acting on the director of the absorbing NLC can be described by a relationship that is similar to Eq. (1):

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