Nanocomposites and nanomaterials

Modeling of surface-induced photorefractive mechanism in nematic liquid crystal cells

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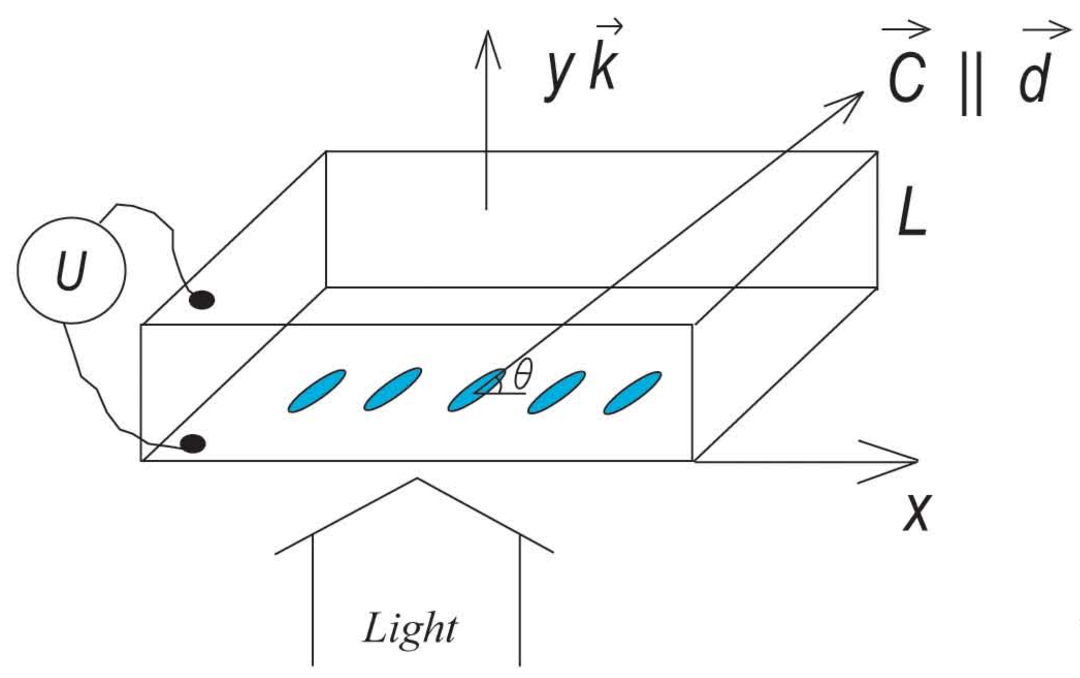
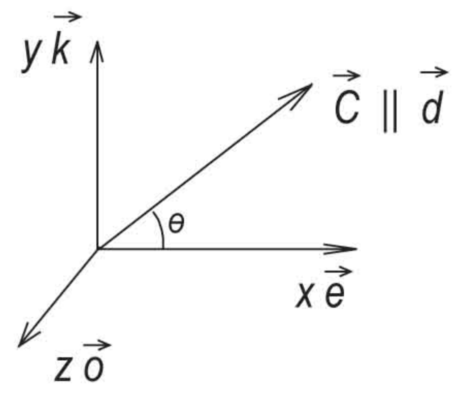
The creation of dynamic electro-optical elements based on liquid crystals with an ultra-fast switching time (less than 10 μs) has great prospects for the development of image-oriented optical information systems. Spatial reorientation of the LC director under the simultaneous action of electric voltage and light beams is the main mechanism for modulation of the refractive index in LC cells [1, 2]. Experiments prove that composite LC cells containing a nano-sized film on one substrate lead to a decreasing in the time constant and an increasing in the efficiency of the optical response [3, 4]. We have developed a mathematical model of the surface-induced photorefractive effect (SIPE) in the composite cells for the case of a two-wave mixing. Computer experiments were performed on the basis of the Comsol package.





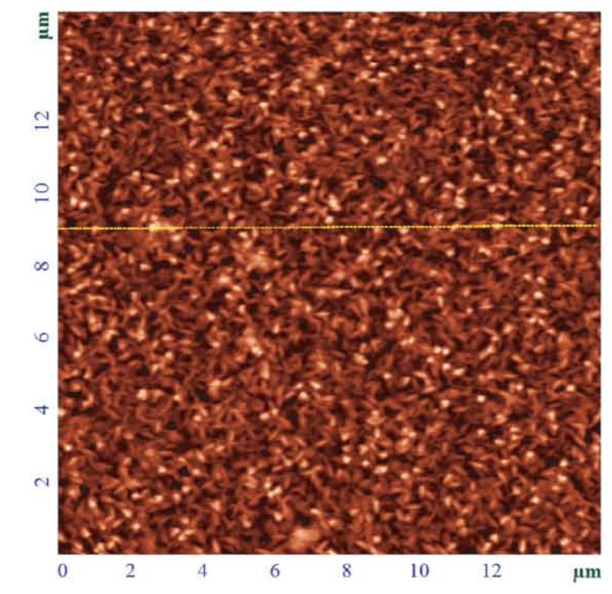
$\vec{d}$ – director LCs

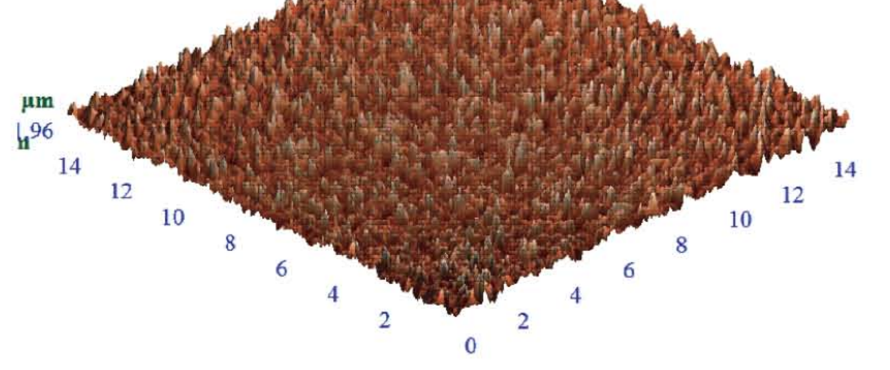
$\vec{C}$ – optical axis

$\vec{k}$ – wave-vector of light

θ – tilted angle of LC molecules

$\vec{o}$, $\vec{e}$ – polarization of light





Experiments of two-wave mixing show a temporary quickening of reorientation of liquid crystal molecules, when a gold nano-island film is deposited on a substrate of LC cell (see Figs.).

$$(K_{11}\cos^2\theta + K_{33}\sin^2\theta)\frac{\partial^2\theta}{\partial z^2}(K_{33} - K_{11})\sin\theta\cos\theta\left(\frac{\partial\theta}{\partial z}\right)^2 + \varepsilon_0\Delta\varepsilon E^2\sin\theta\cos\theta = \gamma_1\frac{\partial\theta}{\partial t}$$

- Ericksen-Leslie Model

$$\frac{\partial\theta}{\partial t} = \frac{K_{33}}{\gamma_1}\frac{\partial^2\theta}{\partial z^2} + \frac{\varepsilon_0\Delta\varepsilon}{\gamma_1}\sin\theta\cos\theta\cdot E^2$$

- Changes of the tilt angle for the case $K_{33} = K_{11}$

Electrically controlled birefringences:

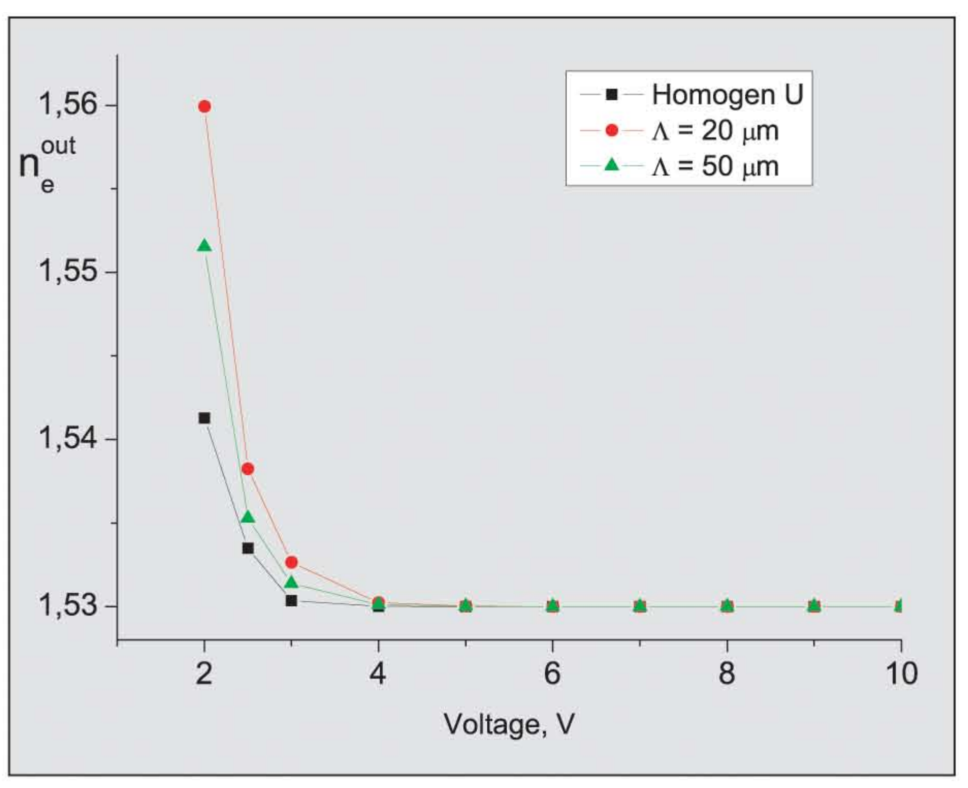
$$\Delta\Phi = \frac{2\pi}{\lambda}\int_0^L\left[n_e(t,z) - n_0\right]dz = \frac{2\pi}{\lambda}L\cdot\Delta n(t,z)$$

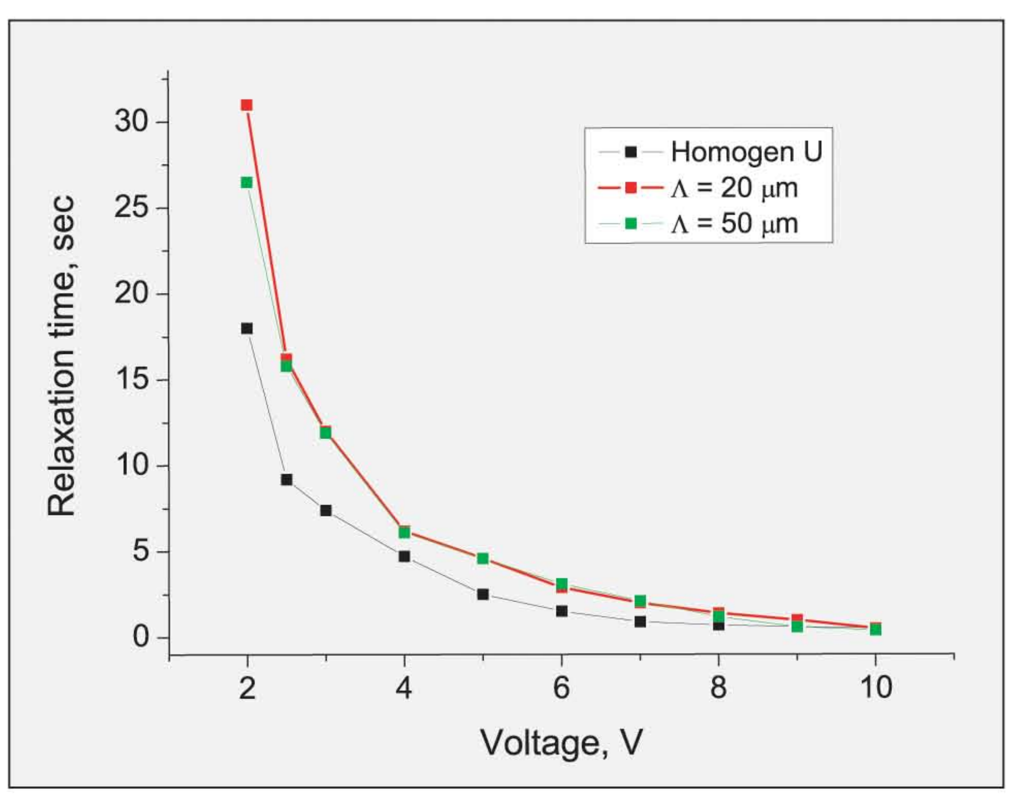
- Phase difference due to changes of refractive index

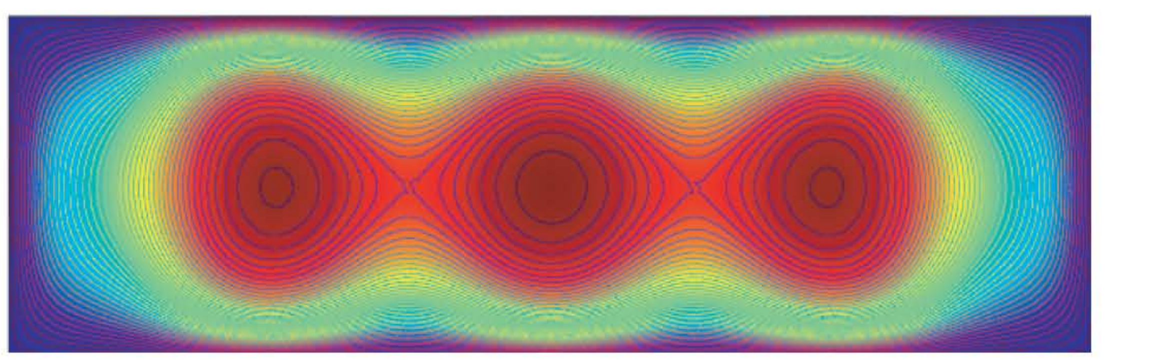
$$n_e(t,z) = \frac{n_\parallel n_\perp}{\left[n_\parallel^2\sin^2\theta(t,z) + n_\perp^2\cos^2\theta(t,z)\right]^{1/2}}$$

$$I = I_0\sin^2 2\varphi_0\sin^2\Delta\Phi/2$$

- Light intensity on output of LC cell

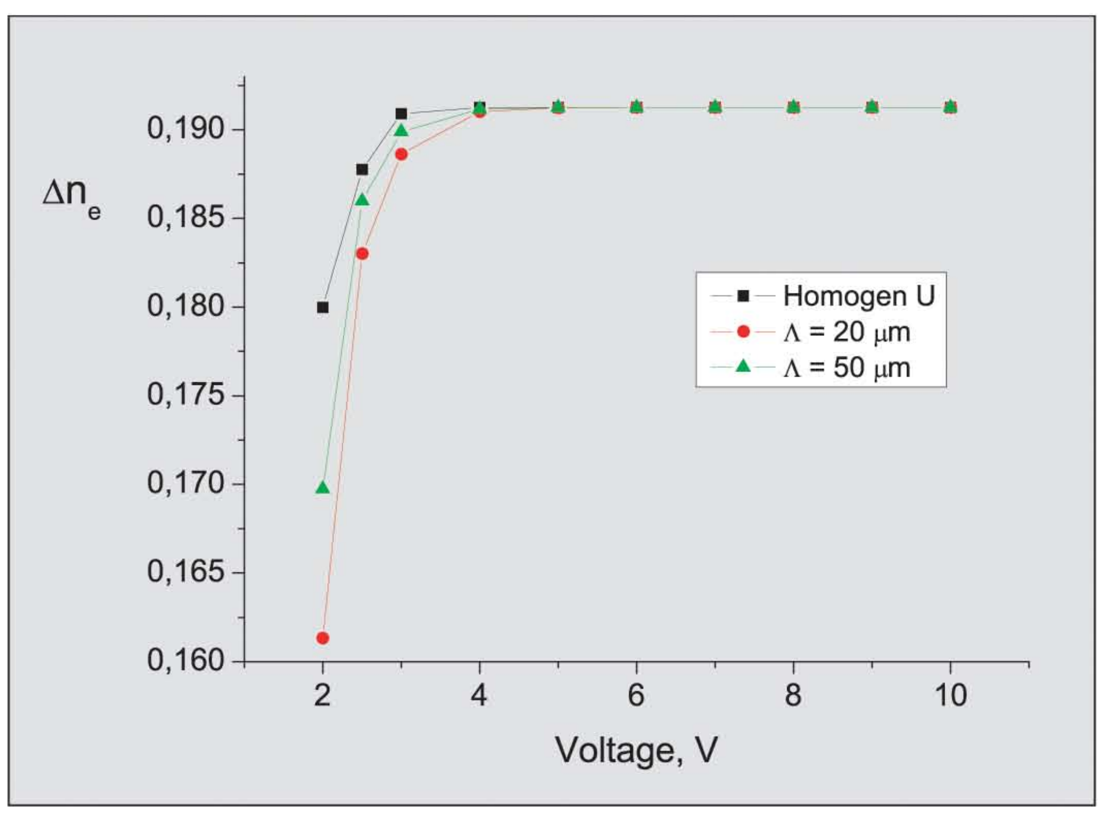






Distribution of the tilte angle in a cell, sinusoidal distribution of voltage, Λ=50 μm.

The thikcness of a cell L=30 μm.



Calculated values of refractive index and relaxation time.

$\Delta n_e = n_e(U{=}0) - n_e(U)$

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2. L.M. Blinov, Structure and Properties of Liquid Crystals (2011).

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