Light induced Fredericks transition threshold in liquid crystal lightguide

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Light induced Fredericks transition threshold is considered for nematics in a cylindrical metallic waveguide with planar director anchoring to the waveguide surface. Assuming the single mode regime the threshold value dependence on the director anchoring energy is obtained for the light wave TE_{01} mode and TM_{01} one.

Рассмотрен порог светоиндуцированного перехода Фредерикса в нематическом жидком кристалле в круглом цилиндрическом металлическом волноводе с планарными граничными условиями для директора на поверхности волновода. Ограничившись одномодовым режимом, получена зависимость величины порога от энергии сцепления директора для TE_{01}- и TM_{01}-мод световой волны.

If the incident light wave field is polarized perpendicular to the director of nematic liquid crystal (NLC), the light induced director reorientation takes place only for the light intensity exceeding a certain threshold value [1]. This phenomenon referred to as light induced Fredericks transition (LIFT) is generally used to control the light passing across a NLC cell. The light intensity threshold value depends substantially on the energy of the NLC director anchoring to the cell surface. The influence of the director anchoring energy as well as the character of its inhomogeneity on the LIFT threshold in plane-parallel nematic cells was studied in [2, 3].

In this paper, we consider the LIFT threshold in a cylindrical metallic waveguide filled with NLC. The boundary conditions for the director on the waveguide internal surface are assumed to be planar (parallel to the waveguide axis). We study theoretically the LIFT threshold dependence on the director anchoring energy to the waveguide surface for TE_{01} and TM_{01} modes propagating in the waveguide. Some results of the Fredericks transition study in NLC between two concentric cylinders have been reported in [4].

Let us consider a round cross-section cylindrical waveguide of infinite length with ideally conducting metallic surface filled with NLC where a light wave propagates along the cylinder axis (axis z). Assume the waveguide is excited symmetrically, so the electromagnetic field amplitude is independent of the azimuth angle φ.

The free energy of NLC contained in the waveguide can be expressed as

$$F = F_{el} + F_E + F_S, \qquad (1)$$

where

$$F_{el} = \frac{K}{2}\int [(\mathrm{div}\,\mathbf{n})^2 + (\mathrm{rot}\,\mathbf{n})^2]\, dV,$$

$$F_E = -\frac{1}{16\pi}\int \varepsilon_{ik}E_iE_k^*\, dV,$$

$$F_S = -\frac{W}{2}\int (\mathbf{n}\,\mathbf{e})^2\, dS .$$

Here, F_{el} is the Franck elastic energy in the one-constant approximation; F_E, the contribution of the light electric field to the NLC free energy [5]; F_S, the director anchoring energy to the waveguide surface assumed to be like to the Rapini potential [6]; $\mathbf{n}$, the nematic director; $\mathbf{e}$, the unit vector along the easy orientation axis on the waveguide