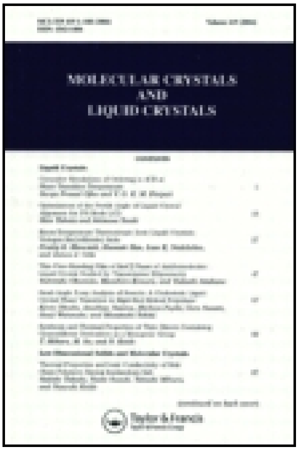

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Influence of Material and Device Parameters on the Existence of Bistabilities in Supertwisted Nematic Liquid Crystal Displays

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INFLUENCE OF MATERIAL AND DEVICE PARAMETERS ON THE EXISTENCE OF BISTABILITIES IN SUPERTWISTED NEMATIC LIQUID CRYSTAL DISPLAYS

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Abstract An analytical description of the Freedericksz transition in highly twisted liquid crystal displays with zero pretilt angle and weak surface anchoring is given. The influence of weak anchoring on the existence of bistabilities is reported.

INTRODUCTION

In recent literature, there has been an increased interest in the electro-optical properties of liquid crystal display devices (LCD's) based on bistabilities of the director configurations. It is one of the aims of display modelling, to optimize the electro-optical performance of the LCD's, i.e. to find the optimum combinations of the relevant cell and material parameters. To describe the electro-optical properties of LCD's one has first to compute the distribution of the local optical axis of the liquid crystal (LC) through the cell, which is called the director configuration. Many authors have calculated such configurations using routines for solving numerically the corresponding nonlinear continuum equations. Based on these very expansive calculations, the influence of several device and material parameters was reported (see ref. in[3]). However, it is possible to solve the continuum equations analytically in some special cases of interest. This leads to analytical criterions for the existence of bistabilities and for optimum multiplexing performance.

For the case of zero surface tilt, Raynes[1] derived analytical expresions which describe the Freedericksz transition in supertwisted LCD's. Schiller extended the results to pretilt angles using a perturbation method[2]. We have presented a model of small deformations that allows one the analytical description of the director field near the homogenity voltage for arbitrary nonzero surface tilt angles[3].

In this paper we extend the results of Raynes[1] to the case of zero pretilt but weak anchoring. Based on the analytical description of Freedericksz transition, the influence of weak anchoring on the existence of bistabilities is described.

THEORY

We consider a nematic layer of thickness d located between the planes z = 0 and z = d of a Cartesian coordinate system. The director is described by the tilt angle Θ (measured from the layer plane) and the twist angle Φ. The dielectric constants parallel and perpendicular to the layer are denoted by $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$. The elastic constant for splay, twist and bend are given by K_1, K_2, and K_3. We denote the total twist angle by Φ_T and the pitch of the material induced through a chiral dopant by p_o. The pretilt angle at both surfaces is denoted by Θ_p. Further the following abbreviations are introduced: $q_o = 2\Pi / p_o$, $\rho = \varepsilon_{\parallel} / \varepsilon_{\perp} - 1$ (here supposed to be positive) and $\Theta_m = \Theta(z = d/2)$.

To derive an analytical expression for the initial slope of the Θ_m vs. voltage curve we follow the approach of Scheffer[4] and expand the corresponding Eulerian equations of the variational principle in terms of Θ_m. We assume weak anchoring that is described by the Rapini ansatz[5],

$$W_{surf} = \frac{1}{2} \frac{\Pi K_1}{\lambda d} \sin^2(\Theta(0) - \Theta_p)$$

with the coupling parameter λ[6]. λ = 0 means strong surface anchoring.

Now the voltage near the Freedericksz transition is given by

$$\frac{U}{U_{th}} = 1 + \frac{1}{2}\Theta_m^2 \left\{ \rho(1-A) + \frac{\frac{K_3}{K_2}\Pi^2 R^2 A - q_o^2 d^2 (1-A)}{\frac{K_1}{K_2}\Pi^2 R^2 + \left(\frac{K_3}{K_2} - 2\right)\Phi_T^2 + 2\Phi_T q_o d} \right.$$

$$\left. + \frac{\Phi_T^2\left[3\frac{K_3}{K_2} - 3 - \left(\frac{K_3}{K_2}\right)^2 - \left\{5\frac{K_3}{K_2} - 5 - \left(\frac{K_3}{K_2}\right)^2\right\}A\right] - 2\Phi_T q_o d\left(\frac{K_3}{K_2} - 2\right)(1-A)}{\frac{K_1}{K_2}\Pi^2 R^2 + \left(\frac{K_3}{K_2} - 2\right)\Phi_T^2 + 2\Phi_T q_o d} \right\}$$

$$U_{th} = \left\{ \frac{1}{\varepsilon_o(\varepsilon_\parallel - \varepsilon_\perp)} \left\{ K_1 \Pi^2 R^2 + (K_3 - 2K_2)\Phi_T^2 + 2K_2 \Phi_T q_o d \right\} \right\}^{1/2}$$

with the Freedericksz voltage U_{th} that was already calculated by Becker et al.[7] The parameters R and A are given as solutions of the implicit relations:

$$\cot\left(\frac{\Pi}{2}R\right) = \lambda R \qquad\qquad A = \frac{1}{2}\left(1 + \sin(\Pi R)/(\Pi R)\right)$$

DUSCUSSION

As we suppose ρ to be positive, the director will turn into the field direction if high voltage is applied, i.e., the maximum tilt angle Θ_m increases with increasing voltage U. The existence of a bistability is characterized by a range of voltage in which U becomes smaller with increasing Θ_m. Therefore it is sufficient that $U/U_{th} < 1$ for $\Theta_m > 0$, i.e. the derivative $(d^2U/d\Theta_m{}^2)_{\Theta_m=0}$ becomes negative. (Note, that the condition is not necessary because bistabilities may exist due to higher deformations, too.) Optimum multiplexing occurs for infinite initial slope and the corresponding condition is $(d^2U/d\Theta_m^2)_{\Theta_m=0} = 0$.

Fig. 1 shows the curves with zero derivative $(d^2U/d\Theta_m^2)_{\Theta_m}=0$ in the Φ_T-god-plane for strong and weak surface anchoring, respectively. It can be seen that weak anchoring (λ = 0.5) decreases the value of the twist angle necessary for the existence of bistabilities. We have found this behaviour also in our numerical calculations which showed always a steeper electro-optical curve or a greater hysteresis due to weak anchoring compared with the corresponding results for strong anchoring. The conclusion is, that it would be useful to look for surface coatings that provide a smaller anchoring energy with the aim of steep electro-optical characteristics even for lower total twist angles.

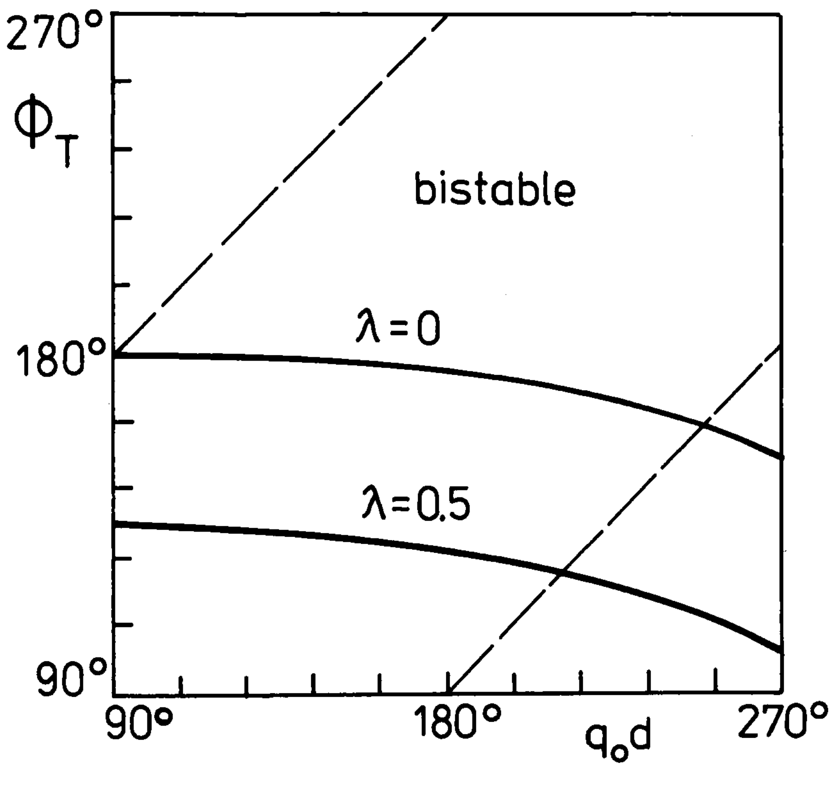

FIGURE 1. Φ_T-$q_o d$ - nomogram for supertwisted LCD with strong and weak anchoring, respectively. The other parameters are K_1/K_2 = 1.2, K_3/K_2 = 2.4, ρ = 1 and Θ_p = 0. Note that only white range leads to physically stable deformations according to the condition $|\Phi_T - q_o d| < 90°$.

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