Mini Review

Lasing in grandjean–cano wedge as an option to study surface anchoring

Abstract

In this paper, theoretical consideration to study the surface anchoring in liquid crystals by means of distributed feedback (DFB) lasing in Grandjean–Cano wedge is presented with a short survey of low threshold lasing in chiral liquid crystals.

Keywords: grandjean–cano wedge, surface anchoring, optical edge modes, DFB lasing in photonic liquid crystals

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Introduction

An essential progress was recently achieved in the model independent restoration of the actual surface anchoring potential in liquid crystals with the help of Grandjean–Cano (GC) wedge.[1–3] A principal element of this restoration is a measuring the director orientation distribution at the wedge surface in an individual GC zone.[2] There are various approaches to measure the director orientation distribution at the wedge surface[2] and in Belyakov et al.[1] it was reported on measuring large director angular deviations from the easy direction, up to the angle $\pi / 4$ by polarization microscope technique. Correspondingly, the actual surface anchoring potential was restored in Belyakov et al.[3] up to angle $\pi / 4$. In this angular interval the restored surface anchoring potential differs essentially from the known model anchoring potentials and, in particular, from the very popular Rapini–Papoular potential.[4]

Because there is a need to restore the actual surface anchoring potential in a whole angular range of it determination (up to the director angular deviations from the easy direction equal to $\pi / 2$) new approaches to measuring the director angular deviations from the easy direction are quite actual. In the present paper a new approach based on a measuring the distributed feedback (DFB) lasing frequency dependence in GC zones on the coordinate is studied.

General approach

We shall consider below a GC wedge filled by a cholesteric liquid crystal (CLC) containing dyes admixture ensuring a DFB lasing at the wave–length close to the CLC pitch. We also assume, for obtaining a maximal director angular deviations from the easy direction, that at one wedge surface the anchoring is infinitely strong (the director orientation coincides with the easy direction) and at the opposite wedge surface the anchoring is finite (the director orientation is capable to deviate from the easy direction). Because the director deviation angle φ is changing with the coordinate in GC zone (being equal to zero in the middle of zone) the local value of CLC pitch in each individual zone is also changing with the coordinate in GC zone (being equal to the equilibrium pitch only in the middle of zone). As known[5] a minimal value of DFB lasing threshold happens at the frequency of edge mode (EM) depending on the CLC pitch, CLC dielectric anisotropy, and local wedge thickness. So, the lasing frequency for a minimal value of DFB lasing threshold occurs to be dependent on the local pitch value in a GC wedge. It is why an observed local lasing frequency allows determining the local pitch value. So, a measuring of the local lasing frequency allows to find the local director deviation from the easy direction angle via the formula

$$\varphi = \pi\left[2L / p - N\right], \tag{1}$$

Where L is the local wedge thickness, p is the local pitch value found from the local value of DFB lasing frequency (coinciding with the EM frequency) and N is the GC zone number. The local EM frequency is determined by the solution of the dispersion equation[5]

$$tgqL = i\left(q\tau / \kappa^2\right) / \left[\left(\tau / 2\kappa\right)^2 + \left(q / \kappa\right)^2 - 1\right], \tag{2}$$

Where $q = \kappa\left\{1 + \left(\tau / 2\kappa\right)^2 - \left[\left(\tau / \kappa\right)^2 + \delta^2\right]^{½}\right\}^{½}$,

$\tau = 4\pi / p$, $\kappa = \omega_{EM}\varepsilon_0^{1/2} / c$, ε_0 is the average CLC dielectric constant, ω_{EM} is the lasing frequency and δ is the CLC dielectric anisotropy (see [5]). A solution of dispersion equation (2) determines the dependence of the lasing frequency ω_{EM} on the local value of pitch, local value of the wedge thickness L and other CLC parameters and allows connecting the local lasing frequency with the local director deviation from the easy direction applying formula (1).

Unfortunately, in a general case the solution of the Equation (2) can be found only in a numerical approach and the functional dependence of local pitch p on the local lasing frequency ω_{EM} can't be presented in an analytical form.

Analytic approach for a limiting case

However, for the case of a large value of the local thickness L the dependence of p on the local lasing frequency ω_{EM} (and vice versa) can be presented in an analytical form.[5] The EM frequencies in this case are coinciding with the frequencies of minima values of the reflection coefficient for a CLC layer of the thickness L and are determined by the relation:

$$L\kappa\left\{1+\left(\tau/2\kappa\right)^{2}-\left[\left(\tau/\kappa\right)^{2}+\delta^{2}\right]^{½}\right\}^{½}=\pi n, \quad (3)$$

Where n is the EM number. Because the lasing threshold is the lowest for the first EM (n=1 in (3)) we shall discuss further only a DFB lasing for n=1. In this case, as follows from (3), the local pitch value is connected with the lasing frequency by the following relation

$$p = 2\pi c/\left[\omega_{EM}\varepsilon_{0}^{1/2}\left(1-\delta\right)^{½}\right], \quad (4)$$

Where the Equation (4) relates to the high frequency edge of the stop–band. Inserting (4) in (1) one finds for the director deviation angle for an individual GC zone:

$$\varphi = \pi\left[\omega_{EM}\varepsilon_{0}^{1/2}\left(1-\delta\right)^{½}L/\pi c - N\right], \quad (5)$$

The found connection (5), between the local director deviation from the easy direction and the local lasing frequency, can be used for a model–independent obtaining the director orientation as a function of coordinate in an individual GC zone if the corresponding measurements of coordinate dependence of the lasing frequency ω_{EM} in GC zone were performed. However, one should keep in mind that the Equation (5) is sufficiently accurate only for a thick part of the GC wedge, i.e. for a large N.

It should be noted that the lasing measurements needed for a measuring of the director orientation as a function of coordinate in an individual GC zone are very similar to the ones performed in Sanz–Enguita et al.[6] where the lasing intensity was measured as a function of coordinate in a GC zone. In Sanz–Enguita et al.[6] nothing was said about the coordinate lasing frequency changes, however quite probable that the corresponding frequency measurements were also performed in Sanz–Enguita et al.[6] and can be used for obtaining an angular director distribution in the individual GC zone.

Conclusion

We present a new approach based on a measuring the distributed feedback (DFB) lasing frequency dependence in GC zones. The results of the study can be used for a model–independent obtaining the director orientation as a function of local wedge thickness. The corresponding frequency measurements can be used for obtaining an angular director distribution in the individual GC zone.

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Conflict of interest

Author declares there is no conflict of interest.

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