Hysteresis in planar liquid crystal cells illuminated by polarized light

Adrian Jacobo[1], Giampaolo D´ Alessandro[2], Damià Gomila[1] and Pere Colet[1]
[1]*Instituto de Física Intedisciplinar y Sistemas Complejos, IFISC*[†] *(CSIC-UIB)*
Campus Universitat de les Illes Balears, E-07122 Palma de Mallorca, Spain
[2]*School of Mathematics, University of Southampton.*
University Road, Southampton SO17 1BJ, United Kingdom.

Work by F. R. Mahamd Adikan et. Al. at the University of Southampton, demonstrated an electrically tunable first-order Bragg gratings via liquid-crystal index modification[1]. With a maximum tunability of 141 GHz at 1562 nm and 114 GHz at 1561.8 nm for transverse magnetic (TM) and transverse electric (TE) polarized input light. Also two distinct threshold behaviors that manifest only during an increase of supply voltage where observed, giving hysteresis in the tuning curve.

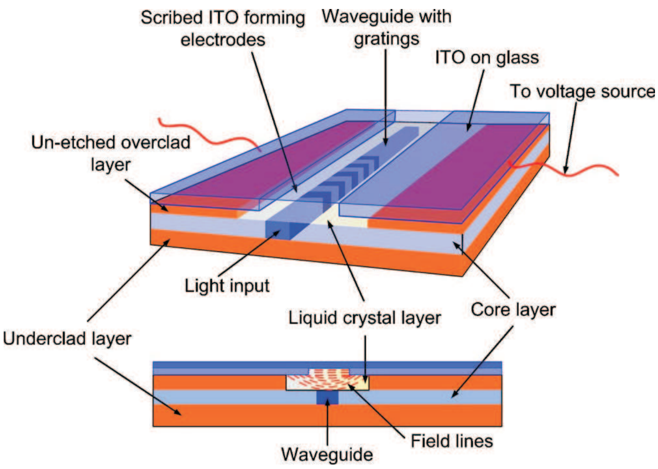

Figura 1. Schematic set-up

To clarify the origin of the hysteresis and why the shift on both the TM and TE modes are the same a simpler cell has been considered. This cell is formed by two microscopic slides. The bottom one is covered with ITO. The electrodes are formed by scratching a $50\mu m$ wide channel in the ITO layer. Measurements of cross polarized intensity (input field at 45^o to the direction of the applied electric field) show the formation of a line defect that disappears at approx 75V and reappears only when the voltage has been lowered to approximately 25V. This seems to suggest that the hysteresis in the frequency shift is associated to hysteresis in the appearance and disappearance of the line defect. However, it is not immediately obvious why the line defect should show hysteresis.

We integrate a standard Landau- de Gennes model[2,3,4] for the tensor order parameter of the liquid crystal:

$$\frac{\partial Q}{\partial t} = \xi_0^2 \nabla Q + \vartheta_Q Q - 3\sqrt{6} Q^2 + 2Tr(Q^2)Q + \chi_a \nabla\phi \otimes \nabla\phi$$

Q is constructed from the average molecular orientation unit vector $\mathbf{n}$ as

$$Q_{ij} = \sqrt{2} S(n_i n_j - \frac{1}{2}\delta_{ij}) \Leftrightarrow Q = S\ \mathbf{n} \otimes \mathbf{n}$$

where $\mathbf{n} \otimes \mathbf{n}$ is the traceless symmetric tensor product of $\mathbf{n}$ with itself and S is a scalar order parameter that indicates the local phase of the liquid crystal; from a physical point of view $0 \leq S \leq 1$, with $S = 0$ and $S = 1$ in the fully isotropic or ordered phases respectively. With this notation we have that $S^2 = Tr(Q^2)$

We consider the orientation of the liquid crystal constrained in the (x,y)-plane. Hence we can use a 2 x 2 traceless symmetric tensor to represent the orientation of the liquid crystal. The scalar order parameter S is assumed to be constant and equal to 1, since in the experiment the crystal is in the nematic phase. Finally we assume that the anchoring energy of the crystal to the boundary is infinite. Steady state solutions can be obtained with arbitrary precision using a Newton method and its linear stability can be evaluated. Together with continuation methods this allows to follow these solutions in parameter space, therefore explore the possible instabilities or bifurcations in parameter space and determine the regime of parameters for which hysteresis exists. We also plan to explore the landscape of the liquid crystal energy as a function of the parameters to get a better insight of the origin of the hysteresis.

* jacobo@ifisc.uib.es
† `http://ifisc.uib.es`

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