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Hysteresis of surface plasmon polariton effective index induced by liquid crystal reorientation

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We present a theoretical study of the effect of the orientational instability of a nematic liquid crystal (NLC) on the value of the effective refractive index of a surface plasmon polariton. A plane-parallel NLC cell with an initial homeotropic orientation of the director is considered. The cell is placed in a constant electric field parallel to its substrates (Figure 1a). The external electric field can lead to a change in the orientation of the director in the NLC cell. One of the polymer substrates of the cell is in contact with a thin layer of metal, so that a surface plasmon polariton can propagate at the interface "NLC" - "polymer film" - "metal". Surface plasmon oscillations are very sensitive to the dielectric properties of the medium, therefore, by changing the electric field strength, it is possible to control the propagation properties of the surface plasmon polariton, in particular, its effective refractive index. The equilibrium distributions of the director in the NLC cell were found by minimization of the free energy functional taking into account different elastic constants and the finite energy of the NLC anchoring with the substrates. Analytical expressions for the propagation parameters of the surface plasmon polariton in the structure "NLC" - "polymer film" - "metal" were obtained by applying the adapted perturbation theory [1].

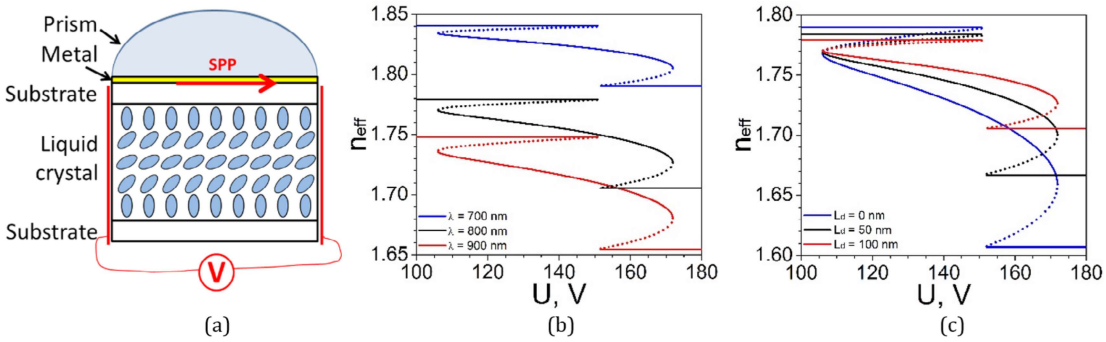

Figure 1. Geometry of the NLC cell (a). Dependence of the effective refractive index of the surface plasmon polariton on the applied voltage at different wavelengths (b) and at different thicknesses of the polymer film (c)

It was established that the change in the effective refractive index of the surface plasmon polariton can be accompanied by hysteresis. Analytical expressions for the parameters and conditions for the existence of hysteresis were obtained, and it was established that the latter depend significantly on the values of the cell parameters: when the coupling energy increases and when the dielectric permittivity ratio $\varepsilon_a/\varepsilon_{\|}$ decreases, the width of the hysteresis decreases. The value of the effective refractive index increases with an increase in the energy of the director's anchoring with the substrate and with a decrease in the values of the wavelength and the applied voltage (Figure 1b, c). The range of possible values of the effective index of the surface polariton expands as the thickness of the polymer film decreases and the wavelength increases.

References:

[1] K. Daly, S. Abbott, G. D'Alessandro, D. Smith, M. Kaczmarek. J. Opt. Soc. Am. B. 28 (2011) 1874.