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Light scattering by small macroscopic particles in nematic cell

M.F.Ledney, I.P.Pinkevich, V.Yu.Reshetnyak, T.J.Sluckin[*]

T.Shevchenko Kyiv National University, Physics Department,
6 Acad. Glushkov Ave., Kyiv 03022, Ukraine
[*]University of Southampton, Faculty of Mathematical Studies,
Southampton SO17 1BJ, United Kingdom

Differential cross-sections of light scattering on the director inhomogeneities near small spherical and cylindrical particles in nematic liquid crystals are calculated under the Rayleigh-Gans approximation. The Percus-Yevick approximation has been used to account for interference effects. Effects of boundary conditions influence on the particle surf ace as well as of an external electric field on the angular dependence and value of the light scattering cross-section has been studied.

В приближении Релея-Ганса вычислено дифференциальное сечение рассеяния света на неоднородностях директора, возникающих вокруг малых сферических или цилиндрических частиц в нематическом жидком кристалле. Для учета интерференционных эффектов использовано приближение Перкуса-Йевика. Изучено влияние граничных условий на поверхности частицы, а также внешнего электрического поля на угловую зависимость и величину дифференциального сечения рассеяния света.

Recently, filled liquid crystals (LC), in particular filled nematics, have drawn a considerable interest [1]. These materials comprise colloidal silica particles of approximately 100 Å diameter suspended in a nematic liquid crystal. The particles induce strong defects in the local nematic texture resulting in an increased light scattering. In an external electric field, the texture-field interaction can induce strong changes in the system optical properties that may be used in display applications.

In this paper, we present results of theoretical study of light scattering on colloidal inclusions in filled nematics. We suppose that the multiple scattering can be ignored and that the light scattering on a silica particle is due mainly to the director inhomogeneity it causes, so that the scattering by the particle itself can be ignored, too. Finally, we use the Rayleigh-Gans approximation.

Let undisturbed nematic director and wave vector $\mathbf{k}$ of the incident light be directed along the axis z of Cartesian frame. The yz plane is that of the incident and scattered $(\mathbf{k}')$ light wave vectors, (Fig. 1).

Under the Rayleigh-Gans approximation, the light scattering differential cross-section is given by the expression [2]

$$\frac{d\sigma}{d\Omega} = \frac{k^4}{16\pi^2} \left| \mathbf{i}\hat{\varepsilon}(\mathbf{q}_s)\mathbf{f} \right|^2 , \quad (1)$$

where

$$\hat{\varepsilon}(\mathbf{q}_s) = \iiint (\hat{\varepsilon}(\mathbf{r}) - \hat{\varepsilon}^0) \exp(-i\mathbf{q}_s\mathbf{r}) dV, \ \mathbf{q}_s = \mathbf{k}' - \mathbf{k} \ . \quad (2)$$

Here $\mathbf{i}$, $\mathbf{f}$ are unit vectors denoting the polarization of the incident and scattered light waves, $\hat{\varepsilon}(\mathbf{r})$, $\hat{\varepsilon}^0$ are the dielectric permittivity tensors for the disturbed and undisturbed nematics, respectively. The integration is carried out over the nematics volume neglecting the small volume occupied by the particles.

Assume the particles concentration to be small enough so the regions of director disturbance by different particles do not overlap. Then we can write