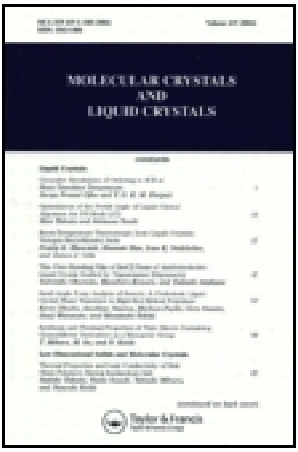
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Optics of Cholesteric Liquid Crystals with Large Both Dielectric and Magnetic Anisotropies

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Optics of Cholesteric Liquid Crystals with Large Both Dielectric and Magnetic Anisotropies

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Normal light transmission (reflection) through (from) a medium layer with a dielectric and magnetic helicity was discussed. The axes of dielectric permittivity tensor, $\hat{\varepsilon}$, and magnetic permeability tensor, $\hat{\mu}$, as well as the medium helix axis are parallel each other and they are perpendicular to the boundary surfaces. The reflection and transmission matrices are constructed, and the character of the eigen polarizations (EPs) of the reflected and transmitted waves are investigated. Particularly, it is shown that a certain transmission region can rise between the diffraction and mirror reflection regions, in certain conditions. A superluminal light propagation is observed in the transmission band, in certain conditions.

Keywords Cholesteric liquid crystals; diffraction; eigen polarizations; nanoparticles; photonics; photonic band gap; reflection; superluminal propagation; transmission

PACS numbers: 42.70.Df, 42.70.Qs, 61.30.-v, 78.67.-n,

1. Introduction

Investigations of the photonic crystals (PCs) with various properties (periodicity and aperiodicity, gradient parameters of modulation, a defect or defects in their structure, etc.) have remained very important. PCs exhibiting photonic band gaps (PBGs) in which electromagnetic wave propagation is not possible have attracted much interest due to the potential with which they can manipulate photons in optical micro devices [1–4]. Cholesteric liquid crystals (CLCs) have a self-organized helical structure which can be regarded as a 1D PCs. The recent immense growth of the interest to the CLC is due to their structural softness, to the fact that CLC helix period can easily be tuned by changing the CLC composition, temperature, mechanic stress, light, and etc [5,6].

Liquid crystalline suspensions of various micro- or nanoparticles have recently been the subject of renewed interest because they combine the fluidity and anisotropy of liquid crystals with the specific properties of the particles. The presence of nanoparticles (either ferroelectric, or ferromagnetic) in a CLC structure leads to: an essential increase of its local (both dielectric and magnetic) anisotropy; a significant change of the *isotropic phase-liquid phase* transition temperature; a significant change of the photonic band gap frequency width and the frequency localization; a change of the CLC elasticity coefficients; a significant increase of the CLC tuning possibilities, etc [7].

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Our work is devoted to the theoretical investigation of the optical properties of the CLC with large (either dielectric, or magnetic) anisotropy. We discussed the normal light incidence case. The axes of the local tensors, $\hat{\varepsilon}$ and $\hat{\mu}$, as well as the helix axis, are parallel to each other, but they are perpendicular to the system borders. We showed that, at certain conditions, a transmission region between the diffraction and mirror reflection regions is aroused. It is to be noted that investigations of the optical properties of the CLC with large anisotropy were began in [8–10].

2. Wave Vectors and Group Velocity

Let's consider light propagation in the media possessing dielectric and magnetic helicities, with the principal axes of $\hat{\varepsilon}$ and $\hat{\mu}$ coinciding with each other and let one of them (the z-axis) be coincident with the helix axis:

$$\hat{\varepsilon}(z) = \varepsilon_m \begin{pmatrix} 1+\delta_\varepsilon \cos 2az & \delta_\varepsilon \sin 2az & 0 \\ \delta_\varepsilon \sin 2az & 1-\delta_\varepsilon \cos 2az & 0 \\ 0 & 0 & 1-\delta_\varepsilon \end{pmatrix},$$
$$\hat{\mu}(z) = \mu_m \begin{pmatrix} 1+\delta_\mu \cos 2az & \delta_\mu \sin 2az & 0 \\ \delta_\mu \sin 2az & 1-\delta_\mu \cos 2az & 0 \\ 0 & 0 & 1-\delta_\mu \end{pmatrix}, \tag{1}$$

where $\varepsilon_m = (\varepsilon_1+\varepsilon_2)/2$, $\mu_m = (\mu_1+\mu_2)/2$, $\delta_\varepsilon = (\varepsilon_1-\varepsilon_2)/(\varepsilon_1+\varepsilon_2)$, $\delta_\mu = (\mu_1-\mu_2)/(\mu_1+\mu_2)$, ε_1 and ε_2 are the principal values of the local permittivity tensor; μ_1 and μ_2 are the principal values of the permeability tensor; and $a = 2\pi/p$, where p is the helix pitch. Firstly, we consider the case of light travel along the helix axis. The solution of Maxwell's equations has the form:

$$\vec{E}(z,t) = \sum_{j=1}^{4} [E_j^+ \vec{n}_+ \exp(ik_j^+ z) + E_j^- \vec{n}_- \exp(ik_j^- z)] \exp(-i\omega t), \tag{2}$$

where $\vec{n}_\pm = (\vec{x} \pm i\vec{y})/\sqrt{2}$ are the unit vectors of circular polarizations; k_j^+ and k_j^- are the z components of the wave vectors ($k_j^+ - k_j^- = 2a$), which are determined from the dispersion equation and have the form:

$$k_j^+ = 2\pi\sqrt{\varepsilon_m \mu_m}(\chi \pm b^\pm)/\lambda, k_j^- = 2\pi\sqrt{\varepsilon_m \mu_m}(-\chi \pm b^\pm)/\lambda, \tag{3}$$

where $\chi = \lambda/(p\sqrt{\varepsilon_m \mu_m})$, λ is the wavelength in vacuum, and

$$b^\pm = \sqrt{1+\chi^2 - \delta_\varepsilon\delta_\mu \pm \gamma}, \quad \gamma = \sqrt{4\chi^2 + (\delta_\varepsilon - \delta_\mu)^2}. \tag{4}$$

The boundaries of the PBGs are determined from the condition, $b^- = 0$, and have the forms:

$$\lambda_{1,2} = p\sqrt{\varepsilon_m \mu_m (1 \pm \delta_\mu)(1 \pm \delta_\varepsilon)}. \tag{5}$$

The $V_{gzi} = \frac{\partial\omega}{\partial k_{zi}}$ (group velocity) of the four refracted eigen waves (EWs) has the following form:

$$\mathrm{v}_{gz1} = \frac{c\sqrt{\varepsilon_m\mu_m}p^2\gamma b^+}{2\lambda^2 + \varepsilon_m\mu_m p^2((\delta_\varepsilon - \delta_\mu)^2 + \gamma(1-\delta_\varepsilon\delta_\mu))},$$
$$\mathrm{v}_{gz2} = \frac{c\sqrt{\varepsilon_m\mu_m}p^2\gamma b^-}{2\lambda^2 + \varepsilon_m\mu_m p^2((\delta_\varepsilon - \delta_\mu)^2 - \gamma(1-\delta_\varepsilon\delta_\mu))}, \tag{6}$$
$$\mathrm{v}_{gz3} = -\mathrm{v}_{gz1}, \quad \mathrm{v}_{gz4} = -\mathrm{v}_{gz2}.$$

When light propagates through a periodically inhomogeneous medium, a dispersion (frequency dependence) of the optical characteristics of the medium arises even in the absence of the boundaries and the frequency dispersion of the components of the dielectric permittivity and magnetic permeability tensors is absent. This dispersion is caused by the structure of the medium. Due to this fact, the group velocity of the light pulse wave packets traveling through the medium differs from the phase velocity. Here two interesting effects can be observed: the superluminal propagation ($\mathrm{v}_g > c$) and super-slow propagation ($\mathrm{v}_g \ll c$) and even stopping of the light pulse ($\mathrm{v}_g = 0$).

We are investigating the specific properties of the wave vectors and group velocities for the EWs both for the low anisotropy case and those for large anisotropies. For the case of the low local anisotropy (both $\delta_\varepsilon \ll 1$ and $\delta_\mu \ll 1$), there is a finite region of the PBG, having the borders defined by equation (5). In this case, the said group velocity is less than the light speed in the vacuum outside the PBG, and within the PBG itself the superluminal propagation ($\mathrm{v}_g > c$) is observed. In the case of large anisotropies some situations are possible, when the dielectric and magnetic tensor principal values have different signs. In this case, we are considering the following two essentially different cases, namely, the case if $\varepsilon_m\mu_m > 0$, and the case if $\varepsilon_m\mu_m < 0$.

1. $\varepsilon_m\mu_m > 0$. The cases when the large anisotropy is conditioned by the local anisotropy of the dielectric permittivity, that is, when $|\delta_\varepsilon| > 1$ and $|\delta_\mu| \ll 1$, or when it is conditioned by the local anisotropy of the magnetic permeability, that is, when $|\delta_\mu| > 1$and $|\delta_\varepsilon| \ll 1$, equation (5) has only one solution, which shows that the PBG starts at $\lambda_1 = 0$, and reaches to $\lambda_2 = p\sqrt{\varepsilon_m\mu_m(1+|\delta_\mu|)(1+|\delta_\varepsilon|)}$. In the case when both $|\delta_\varepsilon| > 1$ and $|\delta_\mu| > 1$, there is a finite region of the PBG, and its borders are defined by the equation: $\lambda_{1,2} = p\sqrt{\varepsilon_m\mu_m(1\pm|\delta_\mu|)(1\pm|\delta_\varepsilon|)}$. The region, $\lambda < \lambda_2$, corresponds to the region of the complete reflection independent of polarization (here all wave vectors are complex, i.e. they have imaginary parts even if absorption (amplification) is absent), and the waves are evanescent. The region, $\lambda > \lambda_1$, corresponds to the transmission region. All the wave vectors are real here (if absorption is absent). Here, as our calculations show, in the transmission region the light superluminal propagation is observed. It is a new result, because superluminal propagation in periodic media is usually observed in the PBG.

2. $\varepsilon_m\mu_m < 0$. This case essentially differs from the preceding one. Here a new characteristic wavelength defined by the condition, $\gamma = 0$ appears (see (4)). The wavelength, λ_0, defined from this condition is: $\lambda_0 = \frac{p|\delta_\varepsilon - \delta_\mu|\sqrt{|\varepsilon_m\mu_m|}}{2}$. It is easy to show that: $\lambda_0 \geq \lambda_{1,2}$. Indeed, for $\lambda_0 - \lambda_{1,2}$ we have: $\lambda_0 - \lambda_{1,2} = p|\varepsilon_m\mu_m|((\delta_\varepsilon \pm 1)^2 + (\delta_\mu \pm 1)^2)$.

In Fig. 1 the three dimensional dependences of: λ_0, λ_1 and λ_2 onδ_ε and δ_μ are presented. In the region, $\lambda > \lambda_0$, γ becomes completely imaginary and, consequently, all the wave numbers become complex, and the EWs are evanescent. Here there is a complete (and independent of the polarization) reflection (specular reflection). Under the following conditions, $(1-\delta_\mu)(1-\delta_\varepsilon) < 0$ and $(1+\delta_\mu)(1+\delta_\varepsilon) > 0$ or $(1-\delta_\mu)(1-\delta_\varepsilon) > 0$ and

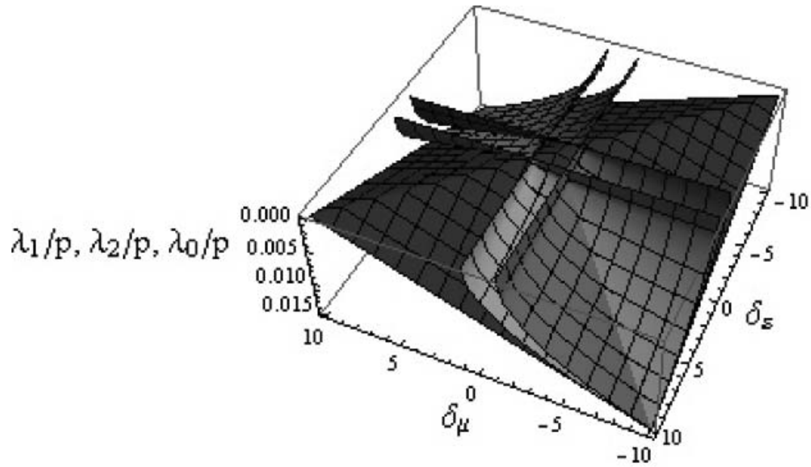

Figure 1. The three dimensional dependences of: λ_0 (gray surface), λ_1 (middle gray) and λ_2 (light gray surface) on δ_ε and δ_μ. Here $\varepsilon_m = 2$, $\mu_m = -0.2$, $p = 420$ nm.

$(1 + \delta_\mu)(1 + \delta_\varepsilon) < 0$, the equation $b^- = 0$ has only one solution, $\lambda = \lambda_2$ (in the opposite case, i.e., for $\varepsilon_m\mu_m(1 \pm \delta_\mu)(1 \pm \delta_\varepsilon) < 0$, all wave numbers are complex everywhere), and in the case when the large anisotropy is determined by the local dielectric permittivity anisotropy, and $|\delta_\mu| \ll 1$, or if the large anisotropy is determined by the magnetic permeability local anisotropy and $|\delta_\varepsilon| \ll 1$, the light and the medium interaction is of the diffraction type in the wavelength region of $0 < \lambda < \lambda_2$. The range of $\lambda_2 < \lambda < \lambda_0$ is the transmission domain. In the region,$\lambda > \lambda_0$, all the wave numbers $k_j^{\pm}$ are complex and here the reflection is specular rather than diffraction. An interesting situation arises in the case if $\varepsilon_m\mu_m < 0$ and $(1 \pm \delta_\mu)(1 \pm \delta_\varepsilon) < 0$. Diffraction reflection appears in the range, $\lambda_1 < \lambda < \lambda_2$. Specular reflection takes place for the wavelengths, $\lambda < \lambda_1$ and $\lambda > \lambda_0$. The range of $\lambda_2 < \lambda < \lambda_0$ is the transmission domain (only the Fresnel reflection is observed here). Thus, the finite domains of diffraction reflection and transmission appear between the specular reflection regions, in this case.

In Fig. 2 we presented the wave vector dependences on the wavelength for the following three cases: (*a*) $\varepsilon_m\mu_m > 0$ and $|\delta_\varepsilon| \ll 1$, $|\delta_\mu| \ll 1$; (b) $\varepsilon_m\mu_m > 0$ and $|\delta_\varepsilon| > 1$, $|\delta_\mu| \ll 1$; (c) $\varepsilon_m\mu_m < 0$ and $|\delta_\varepsilon| > 1$, $|\delta_\mu| \ll 1$. In the first case, the superluminal propagation is observed in the PBG. In the second case, the superluminal propagation is observed outside the PBG as well. In the third case, there is a transmission region between the diffraction reflection and total reflection regions. It is interesting that the superluminal propagation is observed in this region, too.

3. Light Refection and Transmission Through the Layer

Let's consider light reflection and transmission for a CLC *layer* possessing permittivity and permeability. The axes $\hat{\varepsilon}$ and $\hat{\mu}$ are assumed, as before, to be coincident with the axis of the medium, which, in its turn, is perpendicular to the boundary surfaces. Light is normally incident on the layer. The solution of this boundary problem, which represents a system of eight linear equations, we present in the form:

$$\vec{E}_r = \hat{R}\vec{E}_i, \quad \vec{E}_t = \hat{T}\vec{E}_i, \tag{7}$$

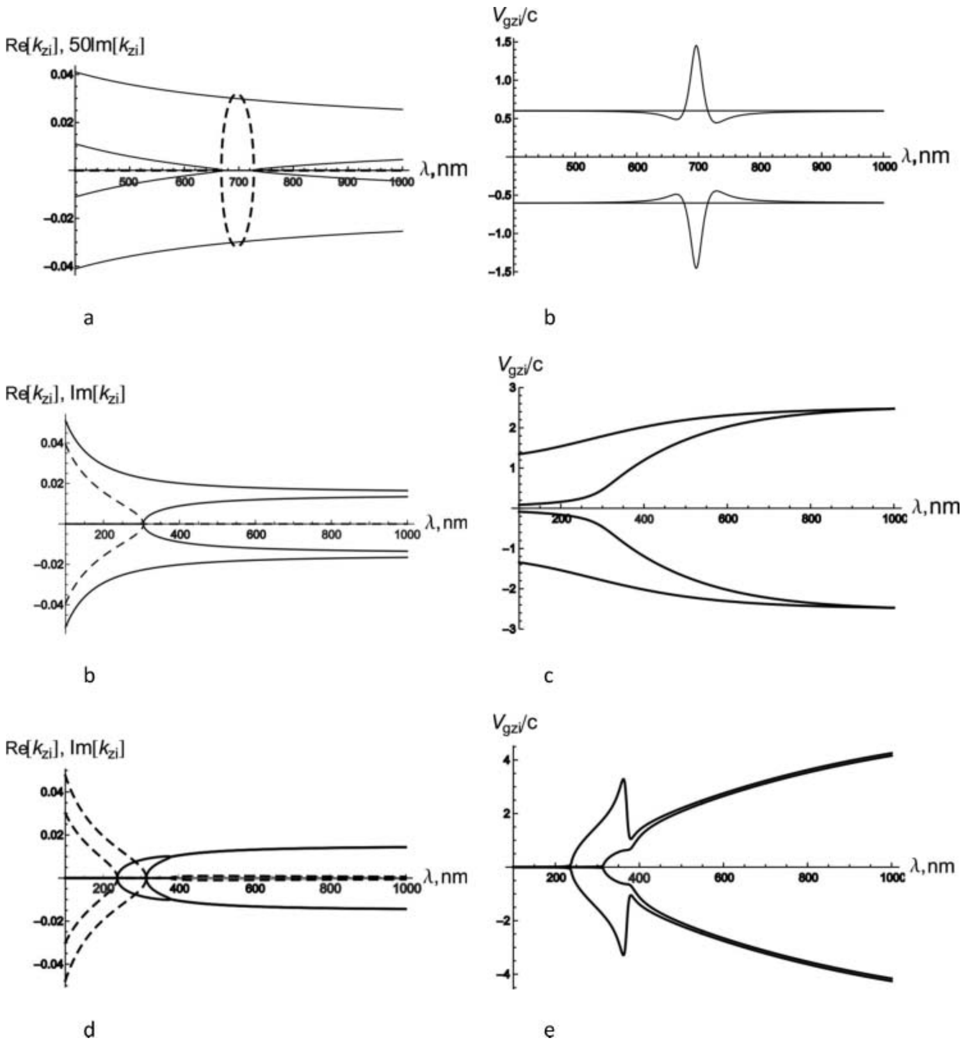

Figure 2. The dependences of wave vectors and group velocities on λ. Here, $p = 420$ nm and *a,b*: $\varepsilon_1 = 2.5 + \Delta$, $\varepsilon_2 = 2.3 + \Delta$, $\mu_1 = 1.2 + \Delta$, $\mu_2 = 1.1 + \Delta$, ($\Delta = 0(a)$ and $\Delta = 0.03i(b)$) *c,d*:$\varepsilon_1 = -0.5 + \Delta$, $\varepsilon_2 = 0.6 + \Delta$, $\mu_1 = 0.99 + \Delta$, $\mu_2 = 0.88 + \Delta$, ($\Delta = 0(c)$ and $\Delta = 0.01i$(d)) *e,f*: $\varepsilon_1 = -0.8 + \Delta$, $\varepsilon_2 = 0.4 + \Delta$, $\mu_1 = -0.7 + \Delta$, $\mu_2 = 0.8 + \Delta$, ($\Delta = 0(e)$ and $\Delta = 0.003i(f)$)

where the indices i, r and t denote the incident, reflected and transmitted waves, $\hat{R}$ and $\hat{T}$ are the reflection and transmission matrices, $\vec{E}_{i,r,t} = E^{+}_{i,r,t}\vec{n}_{+} + E^{-}_{i,r,t}\vec{n}_{-} = \left[\begin{smallmatrix} E^{+}_{i,r,t} \\ E^{-}_{i,r,t} \end{smallmatrix}\right]$, $\vec{n}_{\pm} = (\vec{x} \pm i\vec{y})/\sqrt{2}$, and the matrices $\hat{R}$ and $\hat{T}$ (according to [8,9]) are as follows:

$$\begin{aligned} R_{jj} = \{&\chi^2 r_1 r_2 (c_1 c_2 - 1) + 2u^2[r_1 r_2 (2\chi^2(m_1 - \delta_\varepsilon \delta_\mu) - \gamma^2) - g_1 g_2 \gamma^2] s_1 s_2 \\ &- iu\sqrt{\alpha}\gamma(p_1 s_1 c_2 + p_2 s_2 c_1)\}/\Delta,\; R_{jk} = \{\eta_j q_2 \chi r_2 \sqrt{\alpha}(c_1 c_2 - 1) + 4u^2\sqrt{\alpha}[q_1 \gamma^2 \sqrt{\alpha} \\ &- \eta_j \chi[g_1(2\chi^2 - m_2) + m_1(\alpha\delta_\mu + \delta_\varepsilon) + q_2(\delta_\mu^2 - \alpha\delta_\varepsilon^2)] s_1 s_2 \\ &+ iu\gamma\sqrt{\alpha}(v_1 s_1 c_2 - v_2 s_2 c_1)\}/\Delta, \end{aligned}$$

$$T_{jj} = \gamma\sqrt{\alpha}\exp(-\eta_j ad)\{(\gamma\sqrt{\alpha}+\eta_j\chi r_1)c_1 + (\gamma\sqrt{\alpha}-\eta_j\chi r_1)c_2$$
$$-iu[(t_1+2\eta_j l_1\sqrt{\alpha})s_1 + (t_2++2\eta_j l_2\sqrt{\alpha})s_2]\}/\Delta,$$
$$T_{jk} = \gamma\sqrt{\alpha}\exp(-\eta_j ad)\{\sqrt{\alpha}q_2(c_1-c_2) - iu[(r_1q_2+\gamma g_2)s_1 - (r_1q_2-\gamma g_2)s_2]\}/\Delta,$$
$$j,k = 1,2; j \neq k, \tag{8}$$

where $\Delta = -\chi^2 r_2^2 + (\chi^2 r_2^2 + 2\alpha\gamma^2)c_1c_2 + 2u^2\{\gamma^2 g_2^2 - r_1^2 q_2^2 - 2\chi^2[m_1(r_1^2+4\alpha) + r_2^2\delta_\varepsilon\delta_\mu - 2\alpha q_2^2]\}s_1s_2 - 2iu\gamma\sqrt{\alpha}(t_1s_1c_2+t_2s_2c_1)$, $p_{1,2} = r_1w_{1,2} \pm q_2g_1$, $g_{1,2} = \delta_\mu \pm \alpha\delta_\varepsilon$ $q_{1,2} = \delta_\mu \pm \delta_\varepsilon$ $v_{1,2} = r_2q_2 \pm \gamma g_1 + 2\sqrt{\alpha}\eta_j q_1\chi$, $t_{1,2} = r_1w_{1,2} \pm q_2g_2$, $m_{1,2} = 1 \pm \chi^2$, $w_{1,2} = \gamma \pm 2\chi^2$, $l_{1,2} = \gamma \pm 2$, $s_{1,2} = \sin(k_{1,2}d)/(k_{1,2}d)$, $c_{1,2} = \cos(k_{1,2}d)$, $k_{1,2} = 2\pi\sqrt{\varepsilon_m\mu_m}b^\pm/\lambda$, $\eta_j = (-1)^j$, $r_{1,2} = 1 \pm \alpha$, $\alpha = \sqrt{\frac{\varepsilon_m}{\mu_m\varepsilon}}$, ε is the dielectric permittivity of the surrounding of the CLC layer, $u = \pi d\sqrt{\varepsilon_m\mu_m}/\lambda$, d is CLC layer thickness.

Matrices $\hat{R}$ and $\hat{T}$ for CLC layer are essentially simplified for $\alpha = 1$. For this case, we have:

$$R_{jj} = iu\delta^2(s_1a_2 - s_2a_1)/\Delta,\ R_{jk} = iu\delta(h_ks_1a_2 + h_js_2a_1)/\Delta,$$
$$T_{jj} = exp(-\eta_j ad)(h_ja_2 + h_ka_1)/\Delta,\ T_{jk} = -\delta exp(-\eta_j ad)(a_1-a_2)/\Delta, \tag{9}$$

where $\Delta = 2\gamma a_1a_2$, $a_{1,2} = c_{1,2} \mp iul_{1,2}s_{1,2}$, $h_{1,2} = \gamma \pm 2\chi$.

In Fig. 3 the reflection spectra for the eigen polarizations (EPs) are presented. The same cases as in the Fig. 2 are considered.

The EPs are the two polarizations of the incident light, which do not change when light transmits through the system [11]. The EPs and eigen values (EVs, the amplitude transmission coefficients for the incident light with EPs) deliver much information about the peculiarities of light interaction with the system. Therefore, the calculation of EPs and EVs of every optical device is important. It follows from the definition of the EPs that they must be connected with the polarizations of the internal waves (the eigen modes = EWs) aroused in the medium. Naturally, there are certain differences in the general case: there exist only two EPs; meanwhile, the number of the eigen modes (EMs) can be more than two, and polarizations of these modes can differ from each other (for a non-reciprocity media, for instance). The EPs bear information about the influence of the dielectric borders. As it is known, at the normal incidence, the EPs of either CLCs, or gyrotropic media practically coincide with the orthogonal circular polarizations; meanwhile, they coincide with the orthogonal linear polarizations for the non-gyrotropic media. It follows from the above-said that the investigation of the EP peculiarities is especially important for the case of inhomogeneous media for which the exact solution of the problem is unknown.

Now we pass to the group velocity peculiarity investigation. When light propagates through a layer of a finite thickness, one more mechanism of dispersion appears, caused by multiple reflections from the dielectric boundaries. In the case in which the interaction of light pulses with the optical system (with a layer of a finite thickness) is considered in the form of narrow-band wave packets, the effective (averaged) group velocity of the transmitted light pulses normalized by c (light velocity in vacuum) are determined [12–14]. It is expressed through the complex transmission coefficient:

$$\mathrm{v}_g = \frac{d}{c\tau_g}, \tag{10}$$

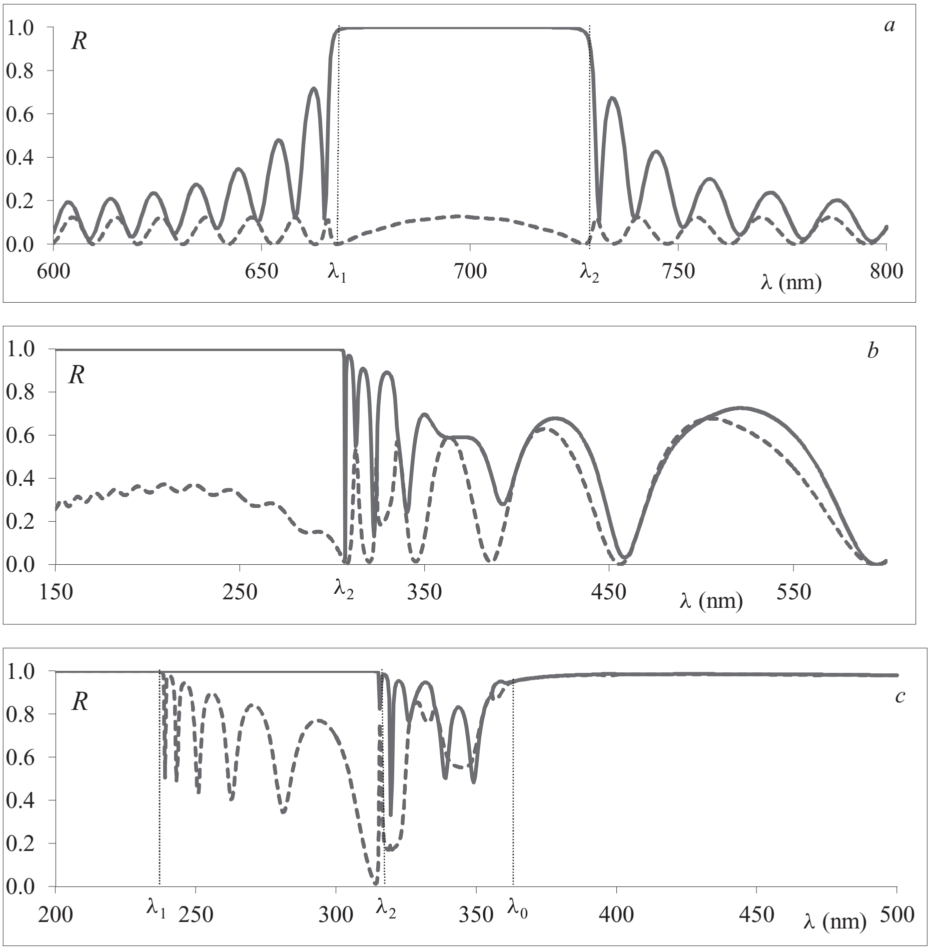

Figure 3. The reflection spectra for the eigen polarizations. Here, $p = 420$ nm and *a*: $\varepsilon_1 = -0.8$, $\varepsilon_2 = 0.4$, $\mu_1 = -0.7$, $\mu_2 = 0.8$; *b*: $\varepsilon_1 = -0.5$, $\varepsilon_2 = 0.6$, $\mu_1 = 0.99$, $\mu_2 = 0.88$; *c*: $\varepsilon_1 = -0.8$, $\varepsilon_2 = 0.4$, $\mu_1 = -0.7$, $\mu_2 = 0.8$.

where

$$\tau_g = \frac{\lambda^2}{2\pi c}\frac{\partial \arg t}{\partial \lambda}. \quad (11)$$

Particularly, as our calculations show, in the case when there are the transmission and diffraction reflection regions between the total reflection regions, again, superluminal light propagation is observed in the transmission region.

The dielectric anisotropy, $\Delta = \frac{\varepsilon_1 - \varepsilon_2}{2}$, for the ordinary CLCs is of order 0.5 and smaller. But recently artificial crystals (metamaterials) are made, which have a dielectric anisotropy that can be varied in a large interval. It seems that helical periodic media - like CLCs having huge local anisotropy—can be created on their base. Such media with comparatively weak anisotropy have been created long ago [15, 16]. On the other hand, as it is already mentioned above, recently, significant interest in the CLC enriched with nanoparticles has been aroused. The presence of nanoparticles (either ferroelectric or ferromagnetic) in the

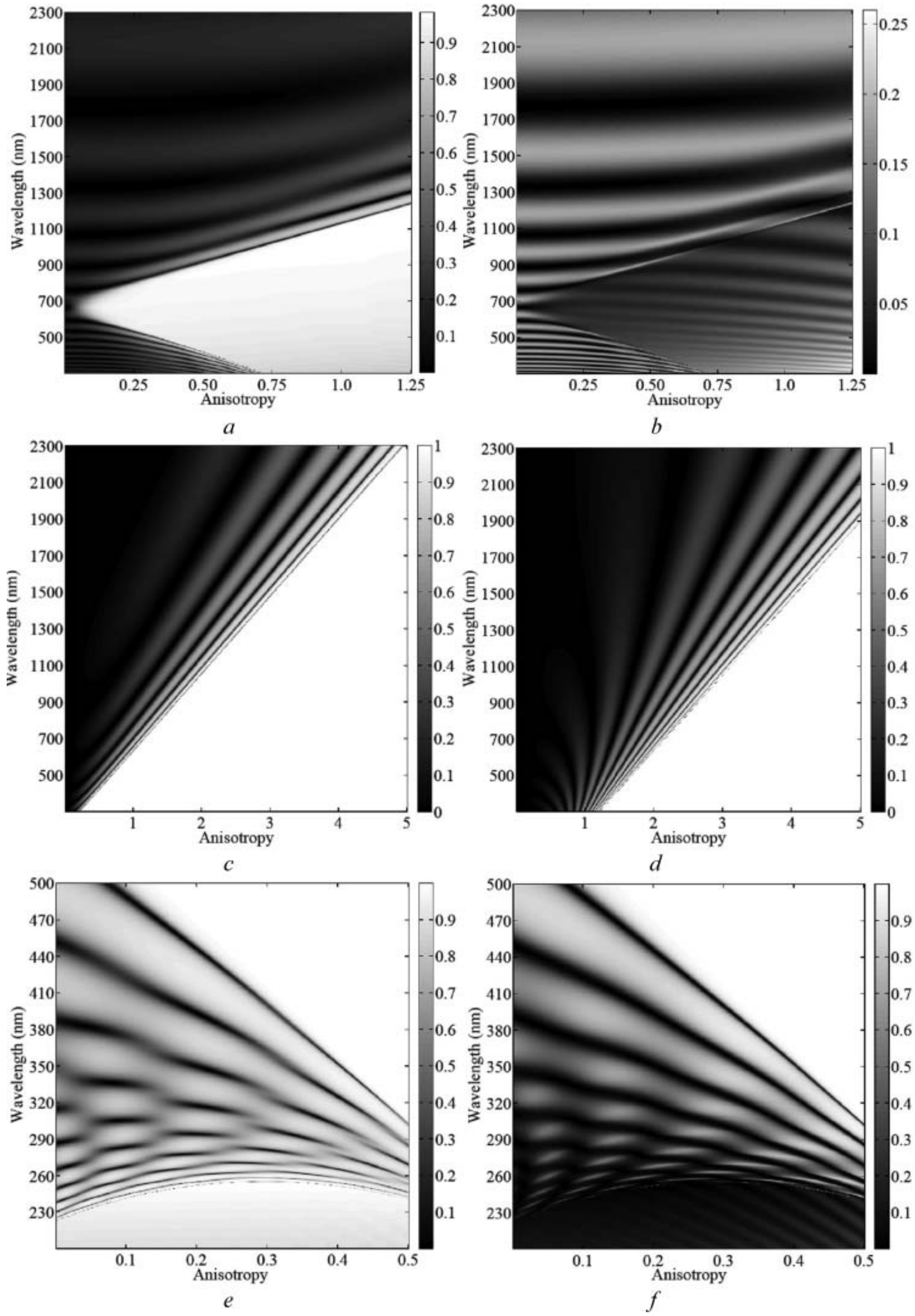

Figure 4. The density plot of the reflection spectra as a function of the anisotropy, Δ. The incident light has the right circular polarization (*a,c, e*) and the left circular polarization (*b, d, f*). $\varepsilon_m = 2.5$ and $\mu_m = 1$,(*a, b*): $\varepsilon_m = 0.5$ and $\mu_m = 0.5$, (*c,d*) and, finally $\varepsilon_1 = -1.1+\Delta$, $\varepsilon_2 = 0.9-\Delta$, $\mu_1 = 1.49-\Delta$, $\mu_2 = 0.31 + \Delta$ (*e,f*). $p = 420$ nm.

CLC structure leads to: an essential increase of its local (both dielectric and magnetic) anisotropy. It follows from the above said that investigations of the optical peculiarities of a stack of the right- and left- handed chiral photonic crystal layers for various values of its local dielectric anisotropy can have great interest. Representing the principal values of the dielectric permittivity tensor of CLC layer in the form $\varepsilon_1 = \varepsilon_0 + \Delta$ and $\varepsilon_2 = \varepsilon_0 - \Delta$, $\mu_1 = \mu_0 + \Delta$ and $\mu_2 = \mu_0 - \Delta$, we investigate the influence of the anisotropy, Δ, on the reflection spectra. Fig. 4 presents the density plot of the reflection spectra as a function of the anisotropy, Δ. The incident light has the right circular polarization (*a, c, e*) and left circular polarization (*b, d, f*). Fig. 4 *a, b* presents the case when the anisotropy, Δ, changes from 0 to 1.25, at $\varepsilon_m = 2.5$ and $\mu_m = 1$, and Fig. 4 *c, d* presents the case when the anisotropy, Δ, changes from 0 to 5, at $\varepsilon_m = 0.5$ and $\mu_m = 0.5$, and, finally Fig. 4 *e, f* presents the case when $\varepsilon_1 = -1.1 + \Delta$, $\varepsilon_2 = 0.9 - \Delta$, $\mu_1 = 1.49 - \Delta$, $\mu_2 = 0.31 + \Delta$.

Conclusion

Concluding, it is to be noted that we considered light transmission and reflection in the case of normal light incidence on a CLC layer with dielectric and magnetic helicities. The axes of the local tensors, $\hat{\varepsilon}$ and $\hat{\mu}$, as well as the helix axis are parallel to each other, being perpendicular to the system borders. The wave vectors and group velocities of the eigen waves are calculated. Both cases of large and low anisotropies are considered, as well as the case when the system has an effective negative refraction. The reflection and transmission matrices are constructed, and the character of eigen polarizations of the reflected and transmitted waves are investigated. The influence of the local anisotropy on the reflection is considered. In particular, it is shown that a transmission region between the diffraction and specular reflection is aroused at certain conditions.

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