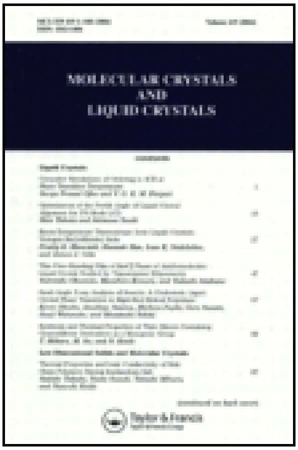

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Mechanisms of Anomalous Absorption of Radiation in Media with Periodical Structure

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Transmission and reflection of light incident normally onto a layer of medium having a helical structure with the axis perpendicular to the interfaces are under consideration. Mechanisms of anomalous absorption of radiation in periodical helical media are discussed. Existence of two mechanisms of absorption suppression and two mechanisms of anomalously strong absorption, respectively, which essentially differ from each other, are shown. Influence of group velocity onto anomalies of absorption has been studied. These two mechanisms act both on frequencies of diffraction of light on a structure of medium and on frequencies of diffraction of light in limited volume. It is shown that these mechanisms of anomalous absorption are of fairly general character, They can also manifest themselves in interaction of radiation with various periodic media. The specific features of dynamics of these mechanisms are studied. The influence of layer boundaries onto a group velocity and wave vector of total wave in the specimen have been investigated. Strong and weak resonance absorption of light on the spectral line of integral absorption in isotropic dielectric slab has been discovered. In this case the specific features of modulation of total wave in the specimen have been investigated, too.

Keywords: diffraction, anomalous absorption, cholesteric liquid crystals, reflection transmission

INTRODUCTION

An exact solution to the problem of propagation of an electromagnetic wave in media with a helical structure has been considered previous papers [1–5]. Absorption of radiation in helical periodical media (HPM) has some interesting specific features. The properties of absorption of radiation in these media in diffraction regime have been studied extensively both theoretically and experimentally [6–20].

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As it is well known, in the interaction of a light with a layer of HPM with limited thickness two mechanisms of diffraction act [4]: the diffraction of light on the structure of a medium (in respect of polarization in a defined frequency interval light undergoes selective diffraction reflection) and diffraction of light in limited volume (outside of a selective reflection region the intensity of reflected light decreases oscillating, passing through diffraction maxima and minima). It is also known that in the interaction of an electromagnetic wave with a medium its inhomogeneity reduces in modulation of a wave. In the correspondence with existence of the various forms of modulation of a wave there should be also various mechanisms of anomalies of absorption. In HPM in the presence of locally anisotropic absorption the Borrmann effect occurs, which is anomalous weak (or strong) radiation absorption in the regime of diffraction scattering. This effect is well known for X rays. The total wave exited in a specimen is modulated. This modulation is similar to one which rises in a system of two coupled oscillators. When the knots of standing wave rising in the specimen coincide with positions of atoms then the absorption will be anomalously weak, but when its combs coincide with ones then the absorption turns out to be anomalously strong. This mechanism of anomalies of absorption we shall call the first mechanism. Unlike the case of X rays, Borrmann effect in HPM is realized due to polarization properties of a total wave in a medium. To understand the specific physical mechanisms that provide the increase (or decrease) of absorption let us discuss the specific features of modulation of a total wave in a medium in the absence of absorption [4,6]. Let us consider the case when the incident light has diffracting circular polarization (the interaction between the light with opposite circular polarization and the medium does not affect the specific features of absorption). If the light frequency is in the selective-reflection (diffraction) region then total wave in the specimen has linear polarization. Moreover, if the frequency of light varies then the angle between directions of an electrical field of a total wave and the director also vary. Near to the short-wavelength boundary of a selective-reflection region the total wave field appears directed along the direction appropriate to a lesser mean value of a local dielectric-constant tensor. Near to the long wavelength boundary of a selective-reflection region the total wave field is directed perpendicularly to the direction of a lesser mean value. Of course the presence of weak absorption does not bring material changes in polarization properties of total wave in the specimen. That is why the minimum absorption will be observed at the long-wavelength boundary of the diffraction reflection region when the oscillators of absorption in the molecules of HPM are directed along the direction of the director (along the direction of the larger mean value of the dielectric-constant tensor). Minimum absorption will be observed at the short-wavelength boundary of the diffraction reflection region when the oscillators of absorption are directed perpendicular to the direction of the director. However, as we show below, this is not the only possible way of modulating the total wave in the specimen, and correspondingly it is not the only possible way of anomalous weak (or strong) absorption in HPM. Suppression of absorption and anomalous strong absorption also take place in the presence of isotropic absorption. In this case the suppression of absorption and the anomalous strong absorption take place due to diffraction character of light reflection. Because of strong reflection at the maxima of diffraction reflection light does not penetrate the depth of the specimen, and therefore absorption is much more weak than the one which is far from the diffraction reflection region. At the minima of diffraction reflection anomalous strong absorption takes place (for more details see below). We shall call this mechanism of anomalies of absorption the second mechanism.

In the presence of anisotropic absorption in defined region of a spectrum the anomalies of absorption are caused by an action of the second mechanism. However, the inverse does not take place. In the presence of anisotropic absorption anomalies of absorption caused by an action of the first mechanism are not observed.

It was shown that group velocity of light in the periodical media is equal to the velocity of transfer of wave energy [21]. On the other hand it was shown that the change of group velocity (or wave energy transfer velocity) induces the change of the wave energy dissipation, as increase of the time of the interaction between photons and phonons brings about the increase of wave dissipation. As we show below, the group velocity of a total wave in the periodical medium has a complicated character (its dependence on wavelength has an oscillation character) which, of course, also influences anomalies of absorption of radiation in a medium both at isotropic and at anisotropic absorption.

The various manifestations of the first mechanism of anomalies of absorption were discovered and both have been theoretically and experimentally investigated in detail [6–20]. Some manifestations of the second mechanism of anomalies of absorption have been discovered and investigated in detail, theoretically [16].

Below we show that the second mechanism of anomalies of absorption is due to other forms of modulation of a total wave in a medium. We show also that the above-mentioned first and second mechanisms of anomalies of absorption act as in a regime of diffraction of light on a structure of a medium and also in a regime of diffraction of light in limited volume.

The characters of these two mechanisms of suppression of absorption essentially differ from each other: they have various dynamics with respect to the changes of parameters of a medium layer. The specific features of dynamics of the first mechanism of anomalies of absorption were investigated previously and the effects of the decrease in absorption of light was revealed, both with increasing of the layer thickness and with increasing absorption anisotropy [17–20]. In Gevorgyan [20] the interference mechanism of absorption to explain these specific features was suggested. Let's note here that in Vardanyan et al. [17–19] revealed effects do not represent as simplest manifestations of the Borrmann effect because in particular for HPM they are not conditioned only by polarization changes of a total wave in a medium, unlike the Borrmann effect. A coherent character of absorption of radiation in periodic media conditions the existence of these effects. In particular, the polarization changes of a total wave in a medium is one of the forms of their realization. Here the fact is of importance, as the optical thicknesses of a layer corresponding to absorption saturation and diffraction saturation differ from each other.

Below we present the results of theoretical studies of dynamics of the above-mentioned two mechanisms of anomalies of absorption both in the regime of light diffraction onto the medium structure and in the limited volume.

A great interest to the specific features of absorption in HPM is conditioned by the following fact. Such media are, e.g., cholesteric liquid crystals, chiral smectics, etc. The parameters of these media are easily dirigible and therefore the properties discussed below may be found to have corresponding applications. Artificial HPM with given parameters may also be created [24–28].

INITIAL CORRELATIONS

We consider transmission and reflection of light normally incident onto a layer of HPM, characterized by tensors of dielectric and magnetic constants having the forms

$$\hat{\varepsilon}(z) = \varepsilon_m \begin{pmatrix} 1+\delta\cos(2az) & \delta\sin(2az) & 0 \\ \delta\sin(2az) & 1-\delta\cos(2az) & 0 \\ 0 & 0 & 1-\delta \end{pmatrix}, \quad \hat{\mu}(z) = \hat{I}, \qquad (1)$$

where $\varepsilon_m = (\varepsilon_1 + \varepsilon_2)/2$, $\varepsilon_a = (\varepsilon_1 - \varepsilon_2)/2$, $\delta = \varepsilon_a/\varepsilon_m$, ε_1, ε_2 are the principal values of the local dielectric-constant tensor, $a = 2\pi/\sigma$, σ is the helix pitch, and $\hat{I}$ is a unit matrix. The medium axis is perpendicular to the layer interfaces.

The exact analytical solution of this boundary-value problem is known [17]. Supposing that the dielectric-constant on both sides of the medium having boundaries with a HPM layer equals the mean dielectric constant of a HPM, we can present the solution of this problem in the form

$$\vec{E}_t = \hat{T}\vec{E}_i,\ \vec{E}_r = \hat{R}\vec{E}_i, \tag{2}$$

where the indexes i, r, and t mark the fields of incident, reflected, and transmitted waves, respectively, $\hat{T}$ and $\hat{R}$ are Jones matrixes of transmitted and reflected fields, respectively, $\vec{E}_{i,t,r}$ is circular Jones vectors,

$$\begin{aligned}
&\vec{E}_{i,t,r} = E^{+}_{i,t,r}\vec{n}_{+} + E^{-}_{i,t,r}\vec{n}_{-} = \begin{pmatrix} E^{+}_{i,t,r} \\ E^{-}_{i,t,r} \end{pmatrix},\\
&R_{11} = R_{22} = iu\delta^2(s_1a_2 - s_2a_1)/\Delta,\\
&R_{12} = iu\delta(h_2s_1a_2 + h_1s_2a_1)/\Delta, \quad R_{21} = iu\delta(h_1s_1a_2 + h_2s_2a_1)/\Delta,\\
&T_{11} = \exp(iad)(h_1a_2 + h_2a_1)/\Delta, \quad T_{22} = \exp(-iad)(h_2a_2 + h_1a_1)/\Delta,\\
&T_{12} = \exp(iad)\delta(a_2 - a_1)/\Delta, \quad T_{21} = \exp(-iad)\delta(a_2 - a_1)/\Delta,\\
&\Delta = 2\gamma a_1a_2, \quad l_{1,2} = \gamma \pm 2, \quad h_{1,2} = \gamma \pm 2\chi,\\
&a_{1,2} = \cos(k_{1,2}d) \mp iul_{1,2}s_{1,2}, \quad s_{1,2} = \sin(k_{1,2}d)/(k_{1,2}d),\\
&b_{1,2} = \sqrt{1 + \chi^2 \pm \gamma}, \quad \gamma = \sqrt{4\chi^2 + \delta^2}, \quad k_{1,2} = 2ub_{1,2}/d,\\
&u = \pi d\sqrt{\varepsilon_m}/\lambda, \quad \chi = \lambda/(\sigma\sqrt{\varepsilon_m}),
\end{aligned} \tag{3}$$

$\vec{n}_{\pm}$ are the orths of circular polarizations, d is the layer thickness, and λ is the wavelength in a vacuum.

For this quantity $Q = 1 - (R + T)$ characterizing absorbed in the specimen light energy (R and T are the reflection and transmission coefficients, respectively) at incidence of light with the cases of diffracted and reverse circular polarizations, we obtain

$$\begin{aligned}
Q^{\pm} = 1 - [&|h_{1,2}a_2 + h_{2,1}a_1|^2 + |\delta(a_2 - a_1)|^2\\
&+ |u\delta^2(s_1a_2 - s_2a_1)|^2 + |u\delta(h_{1,2}s_1a_2 + h_{2,1}s_2a_1)|^2]/|\Delta|^2.
\end{aligned} \tag{4}$$

The field in the specimen may be presented in the form [4]

$$\vec{E}(z,t) = \sum\{E^{+}_j \exp[i(k_j + a)z]\vec{n_{+}} + E^{-}_j \exp[i(k_j - a)z]\vec{n_{-}}\}\exp(-i\omega t), \tag{5}$$

where $k_3 = -k_1$, $k_4 = -k_2$, and z is the distance from a HPM layer left boundary. From boundary conditions for $E^{\pm}_j$ we obtain the following exact analytical expressions (under the condition $ad = 2\pi n$, n is whole number):

$$E_j^{\pm} = -\chi\eta_j(1 \mp i\alpha_j)[E_{in}^{+}(1 + i\beta_j) + E_{in}^{-}(1 - i\beta_j)]$$
$$[(1 + \gamma_j) - -iu\delta(1 - -\gamma_j)s_j/a_j]/(4i\gamma a_j), \quad j = 1, \ldots, 2, 4, \tag{6}$$

where

$$\alpha_j = [2\chi^2 - \delta - \gamma\eta_j]/(2i\chi b_j), \quad \beta_j = -[\delta + \gamma\eta_j]/(2i\chi), \quad \eta_j = (-1)^j,$$
$$\gamma_j = [2 + \delta - \gamma\eta_j]/(2b_j), \quad a_3 = a_1, \quad a_4 = a_2, \quad b_3 = -b_1, \quad b_4 = -b_2, \tag{7}$$

and the $E_{in}^{\pm}$ are the circular components of incident wave amplitude.

To investigate the peculiarities of absorption anomalies we can determine the polarization function of total wave in the specimen $\xi = E^-/E^+ = (E_1^- + E_2^- + E_3^- + E_4^-)/E_1^+ + E_2^+ + E_3^+ + E_4^+)$. Under the condition $ad = 2\pi n$ for ξ we obtain

$$\xi = \frac{\frac{u\delta}{2i\gamma}\left[(2\chi - \gamma)\frac{s_1}{a_1} - (2\chi + \gamma)\frac{s_2}{a_2}\right] + \xi_0\left[1 + \frac{u\delta^2}{2i\gamma}\left(\frac{s_2}{a_2} - \frac{s_1}{a_1}\right)\right]}{\xi_0\frac{u\delta}{2i\gamma}\left[(2\chi - \gamma)\frac{s_2}{a_2} - (2\chi + \gamma)\frac{s_1}{a_1}\right] + 1 + \frac{u\delta^2}{2i\gamma}\left(\frac{s_2}{a_2} - \frac{s_1}{a_1}\right)}, \tag{8}$$

where $\xi_0 = E_{in}^-/E_{in}^+$ is the polarization function of incident wave.

Ellipticity e and azimuth ψ of total wave in the specimen are determined by the expressions

$$e = \arctan[(|\xi| - 1)/(|\xi| + 1)], \quad \psi = -0.5 \arg(\xi). \tag{9}$$

As the calculations show, we can present the total field in Eq. (5) in the specimen with quite enough accuracy in the form

$$\vec{E}(z,t) = \overrightarrow{A(z)} \exp[i(kz - \omega t)], \tag{10}$$

where

$$A_{x,y} = \sqrt{(\text{Re } E_{x,y})^2 + (\text{Im } E_{x,y})^2},$$
$$k = \frac{1}{z}\arctan\left(\frac{\text{Im } E_x}{\text{Re } E_x}\right) = \frac{1}{z}\arctan\left(\frac{\text{Im } E_y}{\text{Re } E_y}\right), \tag{11}$$

and $E_{x,y}$ are x, y components of the total wave in Eq. (5). We determine the group velocity of total wave in the specimen as $v_g = d\omega/dk$. Such defined group velocity takes into account the influence of layer boundaries onto it. Of course, such determined group velocity (and also wave vector) of total wave in the specimen depends on the parameters of the layer (layer thickness, parameters characterizing the absorption, etc.) and incident light polarization and wavelength, too. Criterion of validity of representation in Eq. (10), or group velocity defined in this way, is conditioned by the fulfilled exactness of Eq. (11) is exactly fulfilled. Analogical definition of group velocity is detailed in Agranovich and Ginzburg [29].

MECHANISMS OF ANOMALIES OF ABSORPTION

Figure 1a shows the dependences of absorption of radiation Q in the specimen: ellipticity e, azimuth ψ, and group velocity v_g (more accurate of v_g/c, c is light velocity) of total wave in the specimen onto the wavelength λ in the presence of anisotropic absorption ($\mathrm{Im}\,\varepsilon_a \neq 0$, $\mathrm{Im}\,\varepsilon_a = \mathrm{Im}\,\varepsilon_m$) in one figure are represented. Incident on the layer light has diffracting circular polarization. Figure 1b shows the dependences of radiation Q and group velocity v_g onto the wavelength λ in the presence of isotropic absorption ($\mathrm{Im}\,\varepsilon_m \neq 0$, $\mathrm{Im}\,\varepsilon_a = 0$). Figure 1 shows the following:

1. The first mechanism of anomalies of absorption occurs both in the regime of light diffraction onto the medium structure and in the same in the limited volume, which manifest themselves in the following ways. At $\mathrm{Im}\,\varepsilon_a \neq 0$, both anomalous strong and anomalous weak absorption occur inside and outside of the selective-reflection region (the selective-reflection region defined as a region, where resonance wave vector k_2 is imaginary at the absence of absorption). In both cases they are conditioned by polarization properties of total wave in the specimen.
2. The second mechanism of anomalies of absorption also occurs both in the regime of light diffraction onto the medium structure and in the limited volume. At $\mathrm{Im}\ \varepsilon_a = 0$, $\mathrm{Im}\ \varepsilon_m \neq 0$, anomalies of absorption are also observed both inside and outside the selective-reflection region (about mechanisms of these anomalies of absorption see below).
3. The first mechanism of anomalies of absorption is conditioned not only by polarization properties of total wave in the specimen but also by the changes of group velocity of total wave, which manifest themselves in the following ways. On maxima of absorption Q the group velocity is minimum, and on minima of absorption the group velocity is maximum. The fact that the maxima (the minima) of the absorption of radiation Q does not exactly coincide with the minima (the maxima) of the group velocity v_g or with the maxima (the minima) of the ellipticity e, and simultaneously with the values $\psi = \pi/2$ (maximum deflections from value $\psi = \pi/2$) of azimuth ψ of total wave in the specimen, shows that in the absorption Q introduces contributions both in the changes of group velocity v_g and in the changes of modulation of total wave in the specimen.
4. Analogously, the second mechanism of anomalies of absorption also is not only conditioned by multiple-reflections (on the structure of the medium or on the boundaries of a layer) but also by changes of the group velocity.

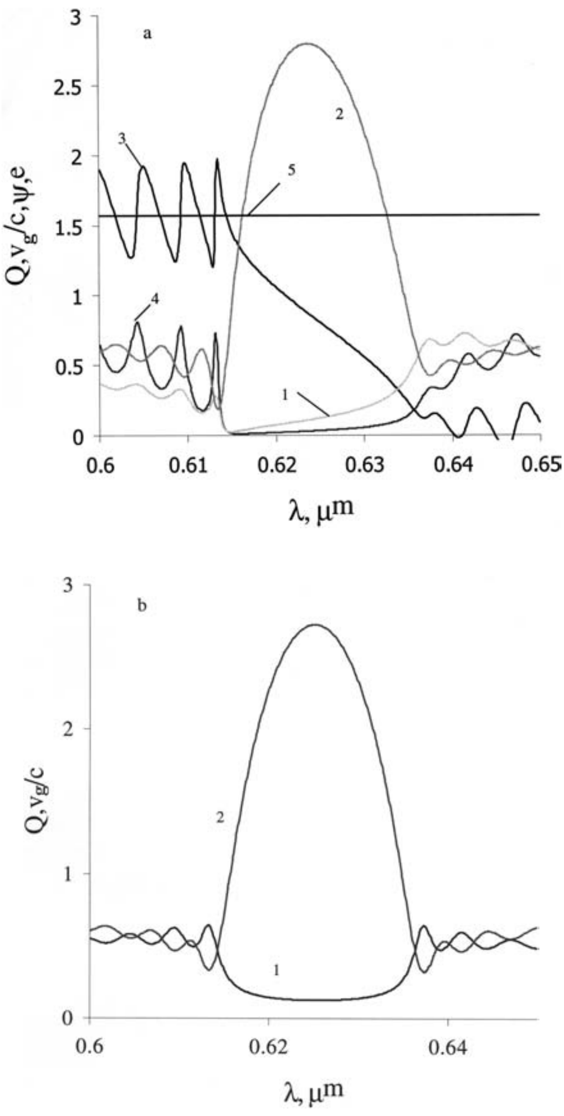

FIGURE 1 (a) Dependence of absorption Q in the specimen (1), ratio of group velocity v_g to light velocity c (2), polarization azimuth ψ (3), and ellipticity e (4) of total wave in the specimen on the wavelength λ in the presence of anisotropic absorption (Im $\varepsilon_a =$ Im $\varepsilon_m = 0.005$). Curve 5 shows the azimuth of minimum absorption. The other parameters are Re $\varepsilon_1 = 2.29$, Re $\varepsilon_2 = 2.143$, $\sigma = 0.42\,m\mu$, $d = 50\sigma$. (b) Dependence of absorption of Q in the specimen (1), ratio of group velocity v_g to light velocity c (2) of total wave in the specimen on the wavelength λ in the presence of isotropic absorption (b, Im $\varepsilon_a = 0$, Im $\varepsilon_m = 0.005$). The parameters are as in (a).

As is shown in figures 1a and 1b inside the selective-reflection region, v_g is larger than light velocity c in vacuum. Here the resonance wave vector becomes complex (in the absence of absorption it is completely imaginary) and the group velocity conception is inapplicable. However, we can confirm that total wave energy transfer velocity change influences the absorption anomalies.

And now we shall discuss several specific features of the second mechanisms of anomalies of absorption in more detail. If the physical mechanisms of anomalies of absorption in the presence of locally anisotropic absorption have been investigated completely, we cannot tell the same in respect of case when isotropic absorption is present. For a more complete understanding of a physical nature of anomalies of absorption in the presence of isotropic absorption we again pay attention to specific features of eigenwaves in the specimen. According to Eq. (5), in the specimen modulated wave rises and there are essential distinctions between the dependences of amplitude of this total wave on z, both inside and outside of selective-reflection region. Inside the selective-reflection region the amplitude of this modulated wave exponentially decreases with z, and already at z of the order $20 \div 30\sigma$ it practically vanishes, the diffraction reflection happens force. The absorption influence on the structure of the field in the specimen is little, and as the absorption of radiation takes place in a comparatively small region of the specimen the absorption of radiation received is anomalously weak. Outside the selective-reflection region amplitude of the modulated wave oscillates with z and beatings rise. At the minima of diffraction reflection, layer boundaries $z = 0$ and $z = d$ coincide with the minima of beatings, but at the maxima boundary $z = 0$ coincides with the maximum of beatings and boundary $z = d$ with the minimum of beatings. At the first minimum of diffraction reflection only one comb having large height rises. Moreover, here the amplitude of the total immobile wave in the center of layer is much more than the one of the incident wave. Because of multiple reflections on the medium structure and on the layer boundaries the accumulation of radiation in the center of the layer takes place. The light energy density in the specimen is much more than that outside the specimen that is why the existence of small absorption (small Im ε_m) causes the light anomalous strong dissipation. At the second minimum of diffraction reflection two combs of beatings already rise, but with a comparatively small height. Therefore, at this wavelength anomalous (strong) absorption expresses itself more weakly. At the third minimum three combs with smaller height rise, etc. At the first maximum of diffraction reflection the comb of the first beating coincides with the boundary $z = 0$, and the minimum of the second beating with boundary $z = d$. However, the heights of combs at the maxima of diffraction reflection are much less than the ones at the corresponding minima. Presence of absorption practically does not change the height of the first comb, but it decreases the height of the second comb. Therefore, as in this case the energy density in the specimen is small, and strong absorption takes place only in the small region of a medium. Integrated absorption of radiation received is anomalously weak. With the increased number of maxima the number of rising combs increases, and therefore anomalous weak absorption begins to manifest itself more and more weakly.

Thus, outside the selective-reflection region in the presence of locally isotropic absorption the anomalies of absorption are observed because they arise in the specimen standing wave, with large amplitude and with knots on the layer boundaries (anomalous strong absorption), or with small amplitude and with a loop on the first boundary and a knot on the second boundary (anomalous weak absorption). Figure 2 shows the dependence of amplitude of total wave in the specimen on z/σ in the presence of isotropic (1) and anisotropic (2) absorption, for the wavelength of incident light is

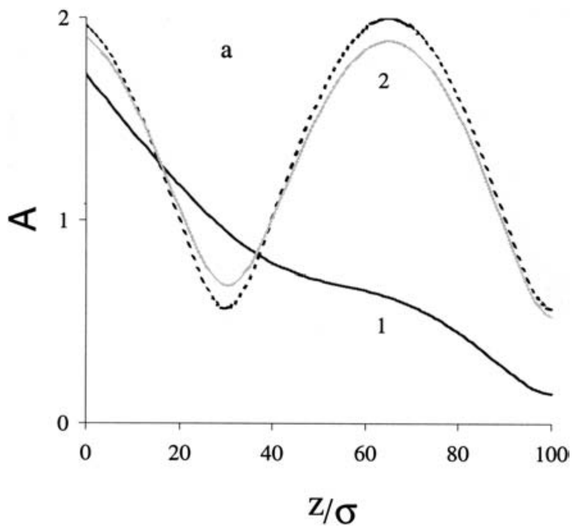

FIGURE 2 Dependence of total wave amplitude A from distance z from the left boundary for the wavelengths of incident light are outside the selective-reflection region at the first maximum (a, $\lambda = 0.61395\,\mu m$), at the first minimum (b, $\lambda = 0.61439\,\mu m$), inside the selective-reflection region (c, $\lambda = 0.625\,\mu m$), in the presence of isotropic absorption (1, Im $\varepsilon_a = 0$, Im $\varepsilon_m = 0.005$) and anisotropic absorption (2, Im $\varepsilon_a = \text{Im}\ \varepsilon_m = 0.005$), and in the absence of absorption (dashed lines). $d = 100\sigma$. The parameters are as in Figure 1a.

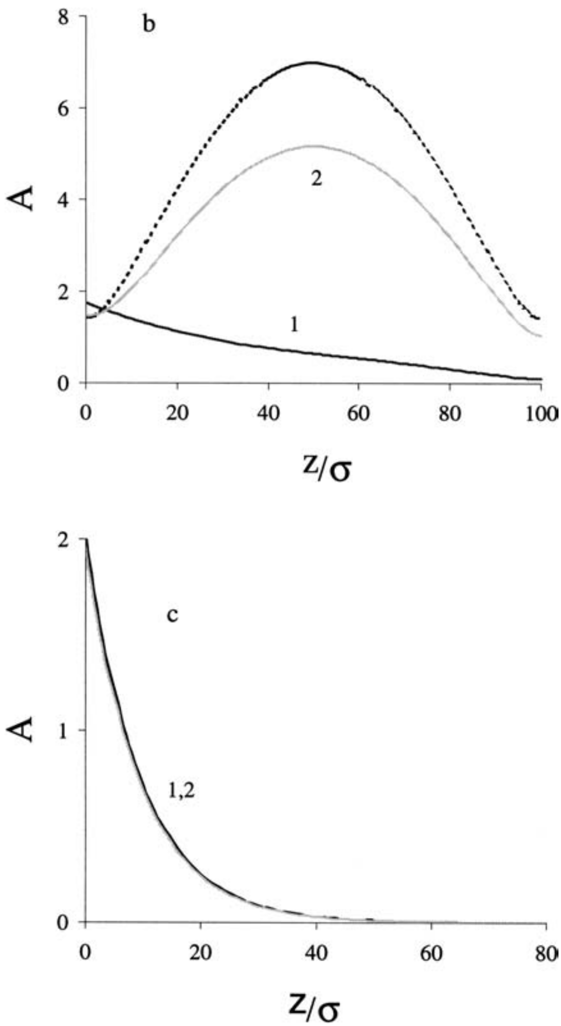

FIGURE 2 (Continued).

inside (c) and outside the selective-reflection region, as well as at the first maximum (a) and the first minimum (b) of diffraction reflection. Dashed lines correspond to the case where the absorption is absent.

It must be noted here that even in the case when the anisotropy of the imaginary part of dielectric tensor is zero (Im $\varepsilon_a = 0$), the imaginary parts of wave vectors $k_{1,2}$ differ from each other. That is, different eigenwaves have different absorption. Correspondingly, the imaginary part of the reflection index is polarization-dependent. But we show below that this second mechanism of anomalies of absorption also affect cases where the imaginary part of the index is polarization-independent.

Let us consider the problem of light propagation in an isotropic homogeneous dielectric slab. Plane wave incident direction is normal onto the dielectric slab, with $\varepsilon = \varepsilon' + i\varepsilon''$ and thickness d and the slab surrounded by a medium with ε_0. Some constants are bounded by a medium of permittivity $\varepsilon_0, \varepsilon', \varepsilon''$, and ε_0. As the solution this boundary-value problem is well known [30,31], we pass to the study of the specific features of integral absorption of light Q for such slab. Figure 3a shows the dependence of

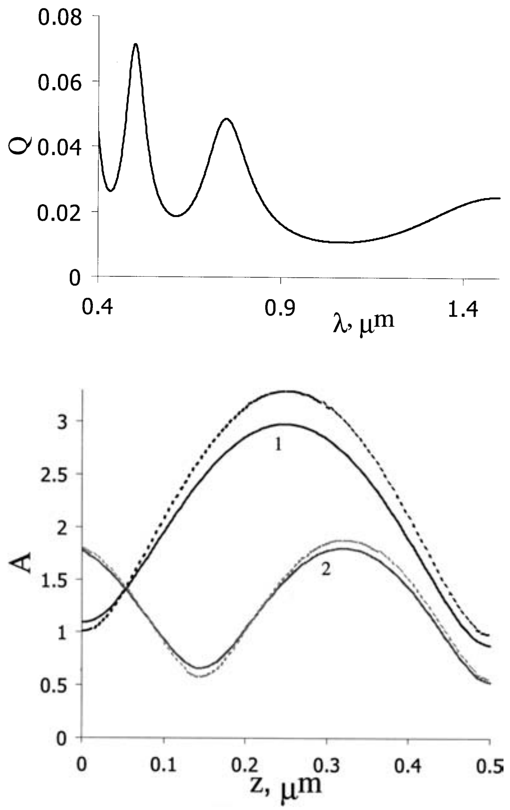

FIGURE 3 (a) Dependence of absorption Q in the specimen on the wavelength λ at transmission of light through the isotropic slab. $\varepsilon = 2.25 + i0.01$ $d = 0.5\,\mu m$, $\varepsilon_0 = 25$. (b) Dependence of total wave amplitude A from distance z from the left boundary for the wavelengths of incident light are on the maximum (1, $\lambda = 1.494\,\mu m$) and on the maximum (2, $\lambda = 1.066\,\mu m$) of Q in the presence of isotropic absorption (solid lines, $\varepsilon'' = 0.1$) and in its absence (dashed lines). The parameters are as in Figure 3a.

Q on wavelength λ. As seen from Figure 3 the dependence of Q onto λ has an oscillation behavior. At some wavelengths strong absorption takes place, and at others weak absorption takes place. Again presenting a total wave field in the specimen in the form in Eq. (10), let us investigate the specific features of the dependence of $A(z)$ on z for the wavelengths of the incident light corresponding to the maximum and minimum absorption. Figure 3b shows the dependence of amplitude of total wave in the specimen $A(z)$ onto the z for the wavelength of incident light $\lambda_1 = 1.494\,m\mu$, where $Q = Q_{\max}$, and for the wavelength $\lambda_2 = 1.066\,m\mu$, where $Q = Q_{\min}$. As seen from Figure 3 the same forms of modulation of a total wave in a medium take place here which took place in the HPM in the same way—in the presence of isotropic absorption for wavelengths outside of selective-reflection region. Note, however, that these are not the only possible forms of modulation of total wave in the specimen for the wavelengths of maximum and minimum absorption. When $\varepsilon_0 < \varepsilon$, that is when the total wave energy density in the specimen is larger than the one outside of the specimen, other forms of modulation take place.

DYNAMICS OF ABSORPTION

In Figure 4 a comparison of the dependences of radiation absorption Q in the specimen—ellipticity e, azimuth ψ, and group velocity v_g/c of total wave in the specimen on layer thickness (on parameter d/σ)—are represented for the wavelength of incident light which is in the vicinity of selective-reflection region (a), and inside the selective-reflection region (b) in the presence of isotropic (dashed lines) and anisotropic (solid lines) absorption. Figure 5 shows the dependences of the same quantities on parameter ln(Im ε_m). An analysis of these results and their comparison with the ones represented in Vardanyan et al. [17–19] shows the following:

1. Dynamics of both the first and second mechanisms of anomalies of absorption essentially differ from each other. They exhibit themselves in the following way. In the presence of anisotropic absorption for wavelengths of incident light inside the selective-reflection region Q has a peak, while in the presence of isotropic absorption it does not have such a peak.
2. Dynamics of absorption suppression in the regime of light diffraction on the medium structure and in the regime of light diffraction in the limited

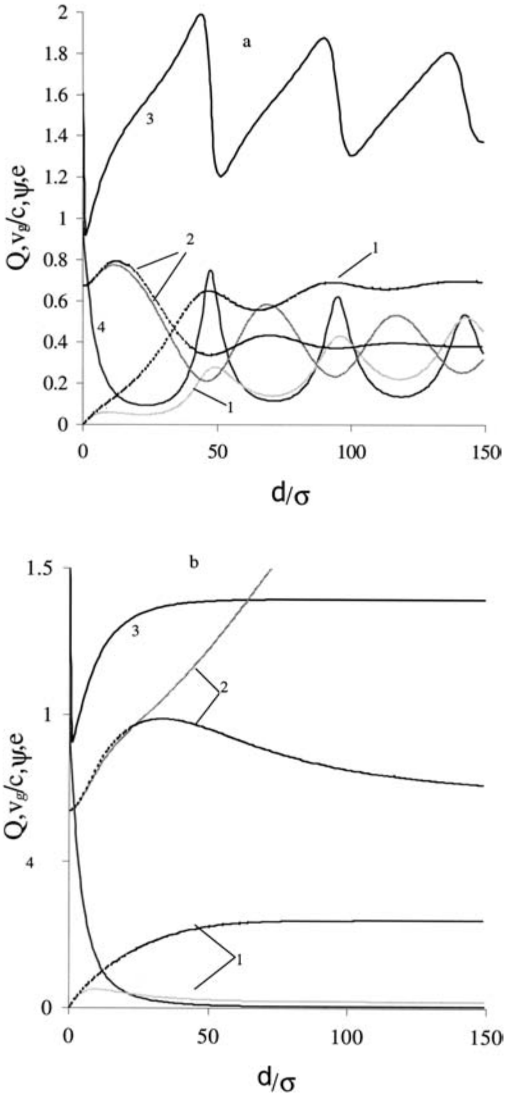

FIGURE 4 Dependence of absorption Q in the specimen (1), ratio of group velocity v_g to light velocity c (2), polarization azimuth ψ (3), and ellipticity e (4) of total wave in the specimen on the number of helix pitches d/σ in the presence of anisotropic absorption (solid lines, $\text{Im}\ \varepsilon_a = \text{Im}\ \varepsilon_m = 0.005$) and isotropic absorption (dashed lines, $\text{Im}\ \varepsilon_a = 0$, $\text{Im}\ \varepsilon_m = 0.005$) for the wavelengths of incident high that are outside selective-reflection region (a) and inside it (b). The parameters are as in Figure 1a.

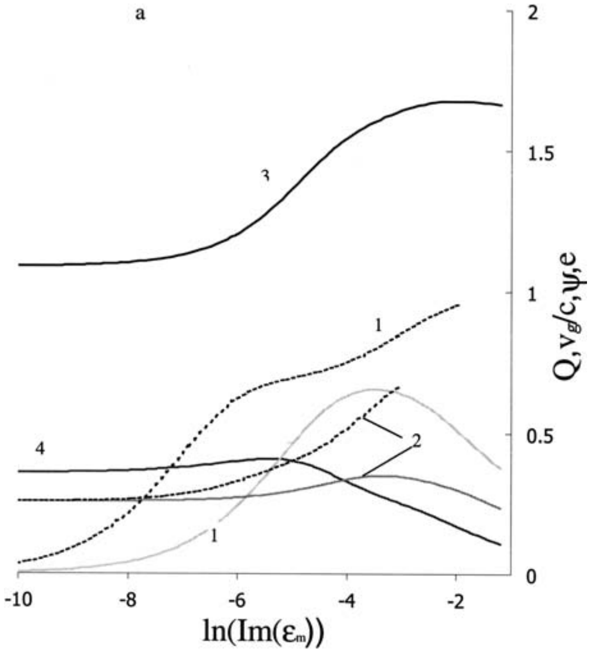

FIGURE 5 Dependence of absorption Q in the specimen (1), ratio of group velocity v_g to light velocity c (2), polarization azimuth ψ (3), and ellipticity e (4) of total wave in the specimen on the parameter $\ln(\mathrm{Im}\ \varepsilon_m)$ in the presence of anisotropic absorption (solid lines) and isotropic absorption (dashed lines) for the wavelengths of incident light that are outside the selective-reflection region (a) and inside it (b). The parameters are as in Figure 1a.

volume essentially differ from each other. They exhibit themselves in the following way. For wavelengths of incident light inside the selective-reflection region, Q passes through only one peak in its dependence on layer thickness, while the same dependence on the wavelengths of the incident light outside the selective-reflection region has oscillation character. The last is conditioned by the dependence of frequency of diffraction maxima upon the layer thickness.

3. The investigation of dynamics of absorption shows that in the presence of anisotropic absorption the specific features of absorption, as has been already noted, are not always conditioned only by polarization properties of total wave in the specimen (see, for example, the dependence of Q on $\ln(\mathrm{Im}\ \varepsilon_m)$ for the wavelength of incident light outside the selective-reflection region; Figure 5a). In this case the decrease of Q after passing across the peak is conditioned by the fact that at the increase of anisotropy of absorption the given frequency of light from frequency of a maximum of a diffraction reflection turns to minimum.

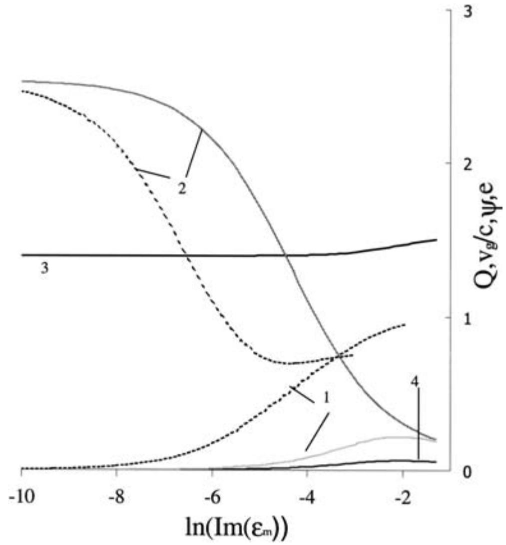

FIGURE 5 (Continued).

CONCLUSION

Let's now consider the problem of light propagation in isotropic stratified media in the presence of absorption by a layer-adding method [32]. Let's consider two cases: (1) $\varepsilon(z) = (\varepsilon' + i\varepsilon'')[1 + \cos(az)]$; (2) $\varepsilon(z) = \varepsilon'[1 + \cos(az)] + i\varepsilon''$, where ε', ε'', and a are some constants. Results obtained in these cases show that

1. in the first case the first mechanism of anomalies of absorption acts as it did in the case of X-rays. The anomalous strong (weak) absorption is conditioned by the rise of standing wave with zeroes of amplitude coinciding with the positions of minimum (maximum) absorption in the specimen.
2. in the second case the second mechanism of absorption acts, and as in the case of isotropic absorption in a layer of HPM it is conditioned by diffraction character of light reflection.

The specific features of absorption in both cases are connected also with the specific features of a group velocity of a total wave in the specimen.

Thus comparing results obtained here with the ones obtained by other researchers [4–6,8,10–12,15–20,33], we can conclude the following:

1. The various mechanisms of anomalies of absorption act at the interaction of radiation with media in correspondence with the existence of various forms of modulation of a total wave in the specimen.
2. Two mechanisms of anomalies of absorption act at the interaction of radiation with media having periodical structure, which are essentially different from each other.
3. On the basis of manifestations of all varieties of the first mechanism, in conditions of diffraction the various eigenwaves have absorption both large and smaller than outside of regime of diffraction. Necessary condition of a realization of effects of the first mechanism is the discrete and periodic, or simply periodic, distribution of absorbing centers, or periodic in a change of orientation of oscillators of absorption at their continuous distribution in space.
4. On the basis of manifestations of all varieties of the second mechanism, the fact is that the forms of modulation and the energy densities of total wave in the specimen are different for various wavelengths of an incident wave. The presence in a medium of the absorption continuously distributed in space has, in particular, an isotropic component that is a necessary condition of realization of effects of the second mechanism.

Anomalous transmission (the Borrmann effect) experimentally has been studied at normal incidence [6,7,10] and at oblique incidence [12]. The effects of absorption were exhibited also in experimental spectrums of a reflection of light, in particular in optics of cholesterics [9]. The intensity beatings of reflected light [9] in minima do not reach zero. It is apparently caused by the presence of isotropic absorption in a medium. The asymmetry in these oscillations of a reflection coefficient to the left and to the right of Bragg reflection region is apparently caused by the presence of an anisotropic component in absorption as well.

In conclusion we'd like to note that the effects considered here may be verified in real experiment and applied to create conditions for maximum absorption of radiation and also to create conditions to get a beam of radiation in the definite interval of wavelength and its absorption in other regions.

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