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NEW METHOD FOR THE DETERMINATION OF ANISOTROPY RELAXATION TIME AND MODULATION OF LIGHT IN A KERR CELL

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A light beam transmitted through an anisotropic material located in a Kerr cell (condenser, segment of wave guide, resonator) is modulated in frequency and amplitude [1] if a variable field is applied to the Kerr cell.

The use of the Kerr cell as a light modulator has been considered frequently, [1-5] especially in recent years, as a method of modulating coherent optical radiation. [3,6] In the present note we propose a new method for determining the relaxation time of the anisotropy based on measurements of the intensity of the components of the amplitude-modulation spectrum of the light transmitted through a Kerr cell.

Optimum amplitude modulation of the light is realized when the principal directions of the polarization device form an angle of 90° with each other and an angle of 45° with the electric field (another case of optimum amplitude modulation corresponds to parallel orientation of the principal directions of the polarizers and an angle of 45° with the field direction). The field of a light wave transmitted through the polarizer, Kerr cell, and analyzer is expressed as follows:

$$Y_a = Y_p \sin\left\{\frac{k}{2}\int_{-L/2}^{+L/2}(n_p - n_s)\,dx\right\} \times \exp\left\{i\left[\omega t - \frac{k}{2}\int_{-L/2}^{+L/2}(n_p + n_s)\,dx \pm \frac{\pi}{2}\right]\right\}, \qquad (1)$$

$$n_p = n + \tfrac{2}{3}\lambda B E^2(t), \qquad n_s = n - \tfrac{1}{3}\lambda B E^2(t), \qquad (2)$$

where Y_p is the amplitude of the field leaving the polarizer; k and ω are the wave number and frequency of the light; L is the path length of the light in the electric field; n_p and n_s are the refractive indices for light with electric vector parallel and perpendicular to the electric field E; n is the refractive index in the absence of field; B is the Kerr constant and λ is the wavelength of the light.

If the frequency of the electric field $\Omega \gg 1/\tau$ (τ is the relaxation time of the anisotropy) the molecules cannot follow the field variations and Eq. (1) will not contain frequency-dependent components, but will only exhibit a constant (dc) component; the spectrum of the transmitted light will only contain the frequency of the incident light. However, if $\Omega\tau \ll 1$ the transmitted light will contain all the components of the modulation spectrum with maximum intensity. In the intermediate case $\Omega\tau \sim 1$ the strengths of the amplitude-modulation components will depend on Ω or, for fixed Ω, on τ.

In order to describe the effects quantitatively we assume that $y_i = (n_i - n)$ [where $(n_i - n)$ is either $n_p - n$ or $n_s - n$ at a definite point in the Kerr cell] and is given by the following equation:

$$\frac{dy_i}{dt} + \frac{1}{\tau_i} y_i = \frac{1}{\tau_i} b_i \lambda B E^2(t). \qquad (3)$$

Here, the subscript $i = p$ or s, with

$$b_p = {}^2/_3, \qquad b_s = -{}^1/_3.$$

If $dy_i/dt = 0$, then $y_i = b_i B E^2(t)$ and we obtain Eq. (2); however, if the field E is switched on and off instantaneously, i.e., if $E = 0$ in Eq. (3) then $y_i = y_i^0 \exp(-t/\tau)$ and the artificial anisotropy produced by the field decays exponentially.

We assume for simplicity that $E(t)$ does not contain a dc term and is expressed by the harmonic function $E(t) = E_0 \cos \Omega t$. Solving Eq. (3) for this case we have

$$y_i = \tfrac{1}{2} b_i B \lambda E_0^2 \{1 + [1 + (2\Omega t)^2 \tau_i^2]^{-1/2} \cos(2\Omega t + \varphi)\}. \qquad (4)$$

Here, φ is the phase shift between the electric field and the double refractor with $\tan \varphi = 2\Omega\tau_i$. The usual methods for determining τ_i are essentially different ways of determining φ.

To determine the quantity $\psi = \int_{-L/2}^{L/2} (n_i - n)\,dx$ we must integrate Eq. (4) in the direction of the light beam within the limits $-L/2$ and $L/2$ with the origin of coordinates taken at the center of the element. Account should also be taken of the fact that $t = nx/c$ in Eq. (4) while the phase of the electric field is Ωt at the time the light passes through the origin. In this case

$$\psi = \frac{1}{2} L\lambda BE_0^2\left[1 + A_i \frac{\sin KL}{KL}\cos(2\Omega t + \varphi)\right],$$

$$A_i = [1 + (2\Omega)^2\tau_i^2]^{-1/2}, \quad K = 2\pi/\Lambda. \qquad (5)$$

Choosing the length of the Kerr cell so that $L = \Lambda/4$, where Λ is the wavelength in the medium, we have

$$\psi = \frac{1}{2} Lb_i\lambda BE_0^2\left[1 + \frac{2}{\pi} A_i \cos(2\Omega t + \varphi)\right]. \qquad (6)$$

Taking account of Eqs. (2) and (6) and substituting the values n_p and n_s in Eq. (1), we have

$$Y_a = Y_p \frac{1}{2i}\exp\left[i\left(\omega t - \frac{4}{3}a - kLn \pm \frac{\pi}{2}\right)\right]\left\{\exp(i2a) \times \exp\left[ia\frac{4}{3\pi}A_i\cos(2\Omega t + \varphi)\right] \times \exp\left[ia\frac{8}{3\pi}A_i\cos(2\Omega t+\varphi)\right]\right\}, \qquad (7)$$

where $a = \frac{1}{2}\pi LBE_0^2$. Expanding Y_a in Eq. (7) in Bessel functions and computing the intensity of the n-th component at frequency $2n\Omega$ (n is an integer) we have

$$I_n = Y_a^* Y_a = \frac{1}{4} I_p \left\{J_n^2\left(\frac{4}{3\pi}aA_s\right) + J_n^2\left(\frac{8}{3\pi}aA_p\right) - 2(-1)^n J_n\left(\frac{4}{3\pi}aA_s\right)J_n\left(\frac{8}{3\pi}aA_p\right)\cos 2a\right\}. \qquad (8)$$

The quantity A_i varies from zero to unity and at small values of a the ratio of $I_{\pm 1}$, the intensity of the light at frequency $\omega \pm 2\Omega$, to I_0, the intensity of the light at the fixed frequency, will be zero (assuming that $A_p = A_s$, i.e., that $\tau_p = \tau_s = \tau$)

$$I_{\pm 1}/I_0 = \pi^{-2}[1 + 4\Omega^2\tau^2]^{-1}. \qquad (9)$$

Equation (10) can be used to find τ.

The relaxation time for the anisotropy can also be found from the formulas given above without assuming that $\tau_p = \tau_s = \tau$.

A very clean pattern of discrete splitting of the frequency of light transmitted through a Kerr cell filled with nitrobenzene has been observed at a modulation frequency $\Omega = 2\pi \times 10^7$ cps[4] and light has been modulated at $\Omega \sim 2\pi \times 10^{10}$ cps;[6] these results indicate the effectiveness of the method and show that it may be useful in resolving the discrepancy between the measurement of τ in the Kerr effect[7] and in scattering of light.[8]

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COMPARISON OF THE ABSOLUTE MEASUREMENTS OF THE ENERGY IN A BREMSSTRAHLUNG BEAM PERFORMED IN THE LABORATORIES OF DIFFERENT COUNTRIES

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AT present the energy in a bremsstrahlung beam is measured in different laboratories by several types of ionization chambers, which are calibrated by means of a calorimetric or some other absolute method.

In several Soviet Laboratories the measurements are performed by means of a standard chamber developed by the A. F. Ioffe Physico-technical Institute. The sensitivity of this chamber was determined calorimetrically in the energy range $E_{\gamma max} = 10-90$ MeV.[1] In the USA the Cornell thick-walled chamber[2] and the duraluminum chamber of the National Bureau of Standards are used; the latter has been calibrated by means of a calorimeter in the range $E_{\gamma max} = 7-170$ MeV.[3]

The duraluminum chamber is used also in sev-