An exact solution of (1) was found for $\mathcal{H} = \mathcal{H}_{sec}$ ($\mathcal{H}_{sec}$ is that part of the Hamiltonian which commutes with S_z). This approximation is valid when $(\omega_0\tau_0)^2 >> 1$ ($\tau_0 \geq 5\times10^{-11}$ sec). Theoretical EPR spectra were constructed for the entire interval of partcical interest 10^{-10} sec $\leq \tau_0 \leq 10^{-7}$sec ($0.07 \leq \sigma\tau_0 \leq 70$). Examples of the derivatives of the absorption lines in the region of slow rotations are shown in Fig. 1.

We investigated experimentally magnetically-dilute solutions of the radical in mixtures of glycerine and water, the viscosity of which was measured independently. Examples of the derivative of the EPR line shape (λ = 3 cm) of the radical at different temperatures are shown in Fig. 2.

To identify the experimetal spectra, we used the Stokes-Einstein formula customarily employed in the theory of magnetic relaxation [10], derived within the framework of hydrodynamic concepts

$$\tau_c = \frac{4\pi a^3}{3kT}\eta ,$$

where η is the viscosity of the medium and a is the effective radius of the radical. In the region of fast rotations ($\tau_c < 10^{-9}$ sec) τ_c was determined independently from the with of the resonance lines [11]. This has made it possible to calculate the hydrodynamic radius of the radical (a = 1.6 ± 0.1 Å. The values of τ_c corresponding to the experimental spectra in the region of slow rotations (Fig. 2) were calculated with the aid of formula (2), using the known radius and viscosity.

The theoretical and experimental spectra practically coincide, making it possible to conclude that the rotational diffusion can be effectively described by the relatively simple model of the purely-discontinuous random process. However, the fact that the parameters τ_0 and τ_c coincide within the limits of experimental error (~15%) for identical spectra raises the question of the possible equivalence of the models of jumplike and continuous diffusion for the description of paramagnetic-resonance phenomena.

In conclusion, the authors thank E. G. Rozantsev for synthesizing and furnishing the radical with N^{15}, and N. N. Korst and E. I. Rashba for useful discussions and I. F. Shchegolev ofr interest.

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DEFLECTION OF POWERFUL LIGHT BEAMS UNDER THE INFLUENCE OF WIND IN ABSORBING MEDIA

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Submitted 18 June 1970
ZhETF Pis. Red. 12, No. 2, 112 - 115 (20 July 1970)

The subject of the present communication is a discussion of the effect of lateral wind on the propagation of a powerful laser beam under conditions of thermal self-action in absorbing media. As is well known, heating of the medium by the light beam gives rise to lens feffects, such as thermal self-focusing or self-defocusing. The removal of heat by the wind from the beam region changes the thermal regime in the medium, and hence also the properties of the thermal lens. The asymmetry of the heating of the medium (the temperature is higher on the leeward side than on the windward side) cause the beam to be deflected from its initial propagation direction [1]. The deflection of the beam in the direction opposite to that of thewind was experimentally registered in liquids [2] (argon laser) and in air (CO_2 laser) [3].

We present in this paper the thoery of this effect under conditions close to the experimental ones. We derive expressions for the deflection angles and for the deformation of the beam at arbitrary wind velocities (the flux is assumed to be stationary and homogeneous).

Let a Gaussian light beam pass along the z axis through layer of absorbing medium of length ℓ. The heat-conduction equation with allowance for a side wind blowing along the y axis with velocity v is

$$\frac{\partial T}{\partial T} + v\frac{\partial T}{\partial y} = \chi\left(\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial z^2}\right) + \frac{\delta P_o e^{-\delta z}}{\pi a^2 \rho C_p} e^{-\frac{x^2+y^2}{a^2}}, \tag{1}$$

where χ is the temperature conductivity coefficient, δ the absorption coefficient, P_0 the input power, a the beam radius, and ρC_p the specific heat.

Neglecting the longitudinal heat diffusion in (1) ($\partial^2T/\partial z^2 = 0$), we can find the stationary temperature distribution in the form of an expansion in the coordinates x and y near the mean axis

$$T = \frac{\delta P_o e^{-\delta z}}{4\pi\kappa}\left\{2T_y\frac{y}{a} - T_{yy}\left(\frac{y}{a}\right)^2 - T_{xx}\left(\frac{x}{a}\right)^2 + \dots\right\} \tag{2}$$

where

$$T_y = \gamma \exp(2\gamma^2)[K_o(2\gamma^2) - K_1(2\gamma^2)] + \frac{1}{2\gamma}, \tag{3}$$

$$T_{yy} = [4\gamma^2 K_o(2\gamma^2) - (4\gamma^2 - 1)K_1(2\gamma^2)]\exp(2\gamma^2) - \frac{1}{2\gamma^2}, \tag{4}$$

$$T_{xx} = \frac{1}{2\gamma^2} - K_1(2\gamma^2)\exp(2\gamma^2). \tag{5}$$

Here K_n is the Macdonald function, $\gamma = va/4\chi$ is the ratio of the heat-conduction time $\tau_T = a^2/2\chi$ to the time of travel of the wind across the beam, $\tau_W = 2a/v$, and $\kappa = \chi\rho C_p$ is the heat-conduction coefficient. Plots of functions (3) - (5) are shown in Fig. 1. As a result of the uneven heating, the medium becomes optically inhomogeneous: $n = n_0 + (dn/dT)T(xy)$. Retention in (2) of only the terms written out there corresponds to an aberration-free description of the thermal lens, in which case T_y determines the slope of the beam, and T_{xx} and T_{yy} determine its defocusing (divergence). The deflection effect is strongest in the far field, where the angular distribution of the intensity is given by

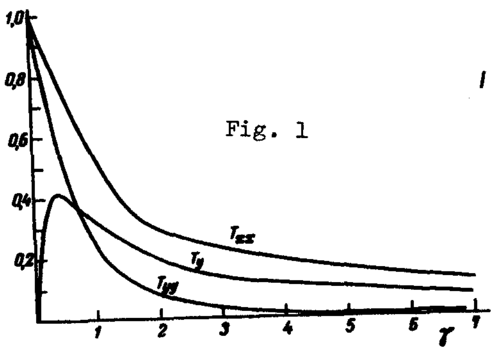

Fig. 1

$$I(\theta_x, \theta_y) = \frac{4\pi\theta_d^2 E_c^2}{\sqrt{\theta_d^2 + (\theta_{nl}T_{xx})^2}\sqrt{\theta_d^2 + (\theta_{nl}T_{yy})^2}}\exp\left\{-\frac{(\theta_y + \theta_{nl}T_y)^2}{\theta_d^2 + (\theta_{nl}T_{yy})^2} - \frac{\theta_x^2}{\theta_d^2 + (\theta_{nl}T_{xx})^2}\right\}, \tag{6}$$

where $\theta_d = \lambda/2\pi a$ is the diffraction divergence of the beam, λ is the wavelength, and θ_{nl} is the nonlinear divergence entering in the theory of stationary thermal decocusing [4]: $\theta_{nl} = \theta_d(P_\delta/P_{cr})$, $P_\delta = P\,[1 - \exp(-\delta \ell)]$ is the power absorbed in the medium, and $P_{cr} = \lambda\kappa/(dn/dT)$ is the critical power.

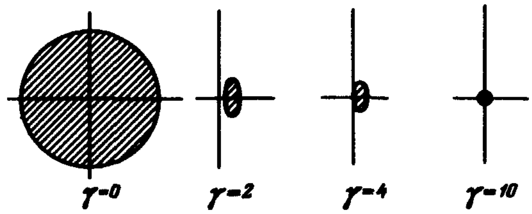

Fig. 2

The behavior of the beam for $P/P_{cr} = 10$, at different wind velocities (y = 0, 2, 4, 10) is shown in Fig. 2, where the changes of the beam contour (at the e^{-1} intensity level), in accord with formula (6), are presented. We now proceed to discuss the results.

The effects of defocusing decrease monotonically with increasing wind velocity, namely, the angular dimensions of the beam decrease. The defocusing along the wind is much smaller than in the perpendicular direction (when $\gamma >> 1$ we have $T_{xx} \sim \sqrt{\pi}/2y$ and $T_{yy} \sim 1/2y^2$). This is due to the ever decreasing role played in the heat transfer by the mechanism of heat conduction along the wind, compared with the removal of heat by the wind current. At the same time, the heat conduction in the transverse direction is the only heat-transfer mechanism. As a result of the non-uniform defocusing, the beam takes on an elliptic form elongated across the wind. The eccentricity of the ellipse first increases with increasing velocity ($\varepsilon \sim \gamma$). At very large velocities, however, when the action of the thermal lens becomes much weaker, $\theta_d \simeq \theta_{nl} T_{xx}$, the decisive role is assumed by the diffraction spreading of the beam, and its cross section becomes round again.

The beam deflection first increases rapidly with increasing velocity, reaching an absolute maximum at $\gamma = 0.3$. Here, however, the inclination of the beam against the background of still-strong defocusing is manifest rather poorly. The strongest deflection action of the wind occurs at medium velocities, when the inclination of the beam greatly exceeds the defocusing along the wind ($T_y >> T_{yy}$). The defocusing across the wind and the deflection are comparable in magnitude: $T_y \sim 1/2y$, $T_{xx} \sim \sqrt{\pi}/2y$. Thus, the deflection of the beam against the background of the defocusing becomes more and more pronounced with increasing wind velocity. This continues until diffraction spreading of the beam comes into play. We note that in the region of medium velocities the deflection angle depends relatively little on the velocity (an effect called saturation [3]). At large velocities (y >> 1), the effect can be adequately described by the theory proposed in [1].

Let us estimate the effects. In the case of radiation with $\lambda = 10.6\ \mu$, the value of the critical power P_{cr} is 0.4 W in water and 0.25 W in air. The regions of medium velocities (y = 1) for a beam with a = 2 mm propagating in a liquid correspond to $v = 10^{-2}$ cm/sec, as against 10 cm/sec in air. At a large margin of input power, the thermal phenomena will be observed up to velocities corresponding to $y = P_\delta/P_{cr}$.

The described picture of thermal defocusing and of the deflection of a beam by a wind agrees with the experimental observations [2, 3]. Some deviation of the beam cross section from ellipticity is due to aberrations. It would be of interest to consider in the future these phenomena in extended media (with allowance for the accumulating action of the wind and of the defocusing), and also in the case of nonstationary turbulent streams. A unique effect, namely wind-induced flickering of a light beam, be occur here.

The authors thank S. A. Akhmanov and R. V. Khokhlov for useful discussions.

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