FINE STRUCTURE OF STIMULATED SCATTERING RAYLEIGH LINE WING LIGHT

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The temperature dependence of the intensity distribution in the spectrum of stimulated Rayleigh line wing light scattering (SRW) was investigated in quinoline in the temperature interval from 2 to 70°C in various polarizations. A splitting of the SRW line was observed (fine structure) in one of the polarizations. An approximate expression is given for the SRW gain. The results of computer calculation of the SRW are compared with experiment.

1. Stimulated scattering of the light of the Rayleigh line wing (SRW) was first observed in [1] and was investigated many times principally with backward or forward scattering. The purpose of the present investigation was to study the spectrum of the SRW light at a scattering angle $\theta = 90°$ and at a polarization in which a fine structure of the Rayleigh line wing (FSW) is observed in thermal scattering [2], and also in a polarization perpendicular to it. In this investigation we observed for the first time the fine structure of SRW in quinoline at a polarization in which there is no FSW in thermal scattering. The temperature kinetics of the SRW lines was investigated in both polarizations of the scattered light in the temperature interval from 2 to 70°C.

2. In our experiment, the light from the ruby laser[1)], linearly polarized strictly in the scattering plane (x, y), was focused by a cylindrical lens into a special vessel with quinoline, placed in a spherical resonator whose optical axis made an angle 90° with the propagation direction of the exciting light. This system of observing the SRW, according to estimates, excludes the possibility of exciting stimulated Mandel'shtam-Brillouin scattering. The scattered-light spectrum was analyzed with a Fabry-Perot interferometer simultaneously in two polarizations, I_{yx} and I_{yz} [3][2)]. The temperature dependence of the intensity distribution in the SRW spectra in the two mentioned polarization components is shown in Fig. 1. A broad line of frequency $\omega_{max} \sim 1/\tau$ (τ is the anisotropy relaxation time) was observed in the I_{yz} spectrum in the entire investigated temperature interval. The experimental points corresponding to the temperature dependence of the frequency of this line are marked by crosses in Fig. 2. We can separate in I_{yx} three temperature regions in which the SRW spectrum is significantly different: From 25 to 70°C (Fig. 1a) we have $\omega_L << 1/\tau$ (ω_L is the frequency of the Mandel'shtam-Brillouin component [3]) there is observed an SRW line whose frequency shift is $\omega_R \sim 1/\tau$. From 9 to 25°C (Fig. 1b) we have $\omega_L \sim 1/\tau$ and two lines are observed. At lower tepperatures, 2 - 9°C, we have $\omega_L >> 1/\tau$, and the spectrum again contains one line whose shift is close to $\omega_R \sim 1/\tau$ (Fig. 1c). The complete picture of the temperature kinetics of the SRW spectra is shown in Fig. 2.

[1)] The ruby laser emitted a pulse of ∿25 nsec duration and 100 mW power in one longitudinal mode.

[2)] The exciting light propagates along the x axis, the scattered light is observed along the y axis, xy is the scattering plane and is horizontal, and z is the vertical axis. In the polarized components of the scattered-light intensity, the first and second subscripts denote the directions of the electric vector of the incident and reflected light waves, respectively.

3. The gain of the stimulated scattering for the two polarizations in question, under the condition that the smaller anisotropy relaxation time [3] $\tau_2 \ll \tau$ and there is no dispersion of the elastic and thermal moduli, is given by the following approximate formulas:

$$g_{yz}(\omega) = A\omega\left\{\frac{\omega^2\tau}{\omega^2 + \tau^2(\omega^2 - \omega_T^2)^2} + \frac{\tau}{1 + \omega^2\tau^2}\right\},$$

$$g_{yx}(\omega) = \frac{A\omega}{2}\left\{\frac{3\tau(\omega^2 - \omega_L^2)^2}{(\omega^2 - \omega_L^2)^2 + \omega^2\tau^2\left(\omega^2 - \omega_L^2 - \frac{4}{3}\omega_T^2\right)^2} + \frac{\tau}{1 + \omega^2\tau^2}\right\}, \quad (1)$$

where A is a constant that depends little on the temperature, ω is the frequency reckoned from the frequency of the exciting light, τ is the large anisotropy relaxation time, $\omega_T^2 = q^2(\eta/\rho\tau)$, $q' = 2k \sin(\theta/2)$, k is the wave vector of the light in the medium, η is the shear viscosity, and ρ is the density of the medium. Formulas (1) and (2) do not lead to an expression describing the positions of the maximum gains (of the SRW lines) in analytic form, so that all the calculations were performed with a computer.

Calculation shows that in the entire interval of temperature variation $g_{yx}^{(\omega)}$ has one maximum at the frequency $\omega_{max} \sim 1/\tau$, and a minimum at a frequency ω_L. Such a frequency dependence of $g_{yx}^{(\omega)}$ (Fig. 3) can explain the presence of the

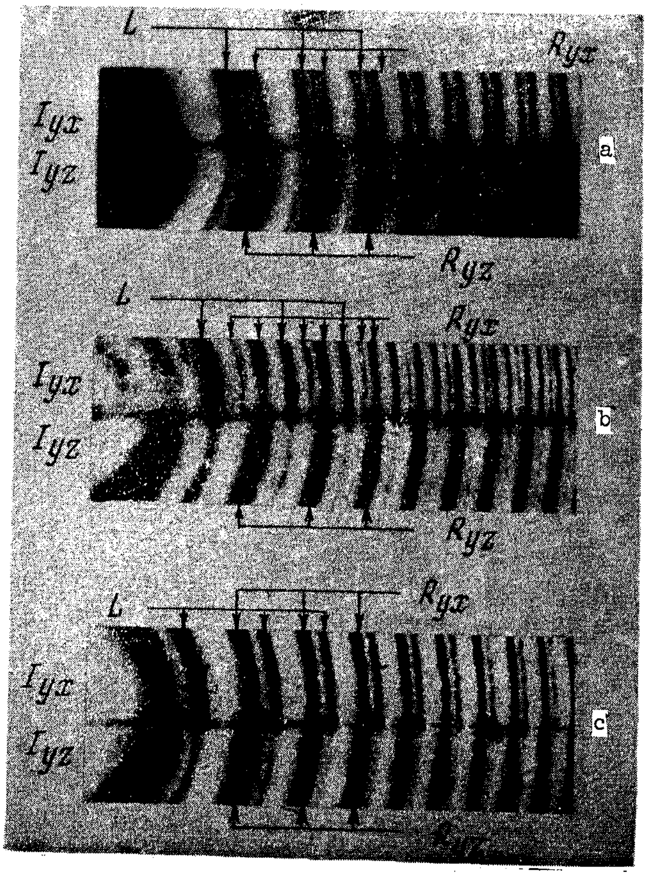

Fig. 1. Interference patterns of light scattered in I_{yx} and I_{yz} polarizations. Fabry-Perot interferometer dispersion region $\langle\Delta\nu\rangle = 0.33$ cm^{-1}. L - ruby laser line, R_{yx} and R_{yz} - SRS line in I_{yx} and I_{yz} polarizations, respectively: a) t = 30°Cm shift of lines R_{yz} and and R_{yx} corresponds to $\omega_R \sim 1/\tau$; b) t = 15°C, shift of lines R_{yz} and R_{yx} corresponds to $\omega_R \sim 1/\tau$; R_{yx} line is split into two lines; c) t = 6°, shift of lines R_{yx} and R_{yz} corresponds to $\omega_R \sim 1/\tau$.

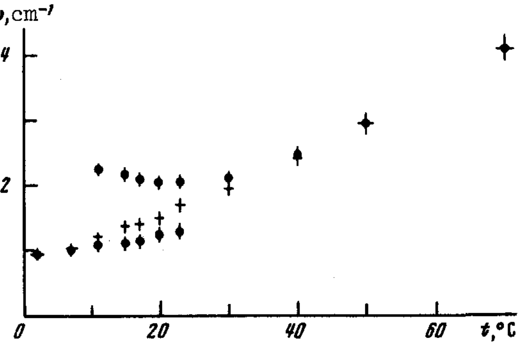

Fig. 2

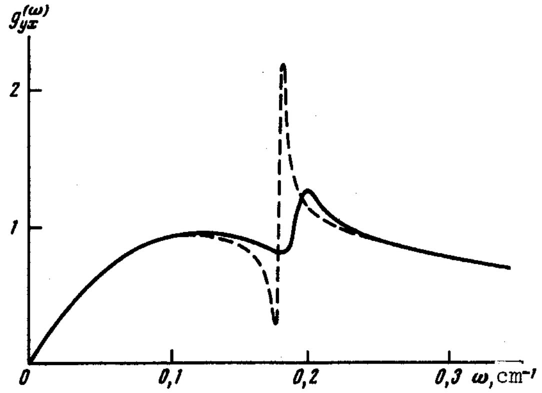

Fig. 3

Fig. 2. Temperature dependence of the positions of the SRW components ω (in cm^{-1}) obtained in our experiments. The data for I_{yz} and I_{yx} are marked by crosses and dark circles, respectively.

Fig. 3. Calculated dependence of $g_{yx}^{(\omega)}$ on the frequency ω (in cm^{-1}) for a scattering angle $\theta = 90°$. The dashed line is the result of a calculation by formula (2). The solid lines represent the result of a calculation by formulas that take the relaxation of the volume viscosity into account.

two lines in the SRW spectrum observed in our experiment (Fig. 1b). The splitting of the SRW line in the I_{yx} spectrum, predicted by the approximate formula (2), differs from that observed in our experiment in the temperature region for which $1/\tau > \omega_L$. One can speak of a discrepancy between theory and experiment, however, only after calculating the gain from exact formulas.

In the calculation of the gain we used the constants obtained from thermal scattering [3, 4]. The value of τ determined from our experiments is in good agreement with the results obtained from the thermal-scattering spectra.

In thermal scattering the difference from a Lorentz contour for I_{yx} is quite negligible [3]. In our experiment, however, at temperatures for which $\omega_L \sim 1/\tau$, the I_{yx} spectrum shows two distinct lines, which we have called the SRW fine structure. This effect is due to the interaction of the anisotropy waves with longitudinal acoustic waves. This phenomenon and its temperature kinetics can apparently by studied more easily and more effectively in stimulated scattering than in thermal scattering.

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