out to be approximately proportional to the square of the concentration of the given component.

These results can be written in the form of a general formula:

$$I = Bc^2 f(x). \tag{2}$$

Here B—a factor which is constant for the given experimental conditions. The function f(x) is described with sufficient accuracy by the expression

$$f(x) = e^{kx} - 1, \tag{3}$$

where k—coefficient that depends on the choice of the measurement units for x. Taking (3) into account, we can rewrite (2) in the form

$$kx = \ln(1 + y), \tag{4}$$

where we put $y = kI/B'c^2$; $B' = kB$. The values of the constants B′ and k can be obtained in the following fashion. For small x and y we get from (4) $kx = y$, which yields $B' = I/c^2x$ (here I and x are expressed in the arbitrary units adopted in the given experiment). The constant k is determined from the requirement that Eq. (4) be satisfied for a certain (sufficiently large) value of x.

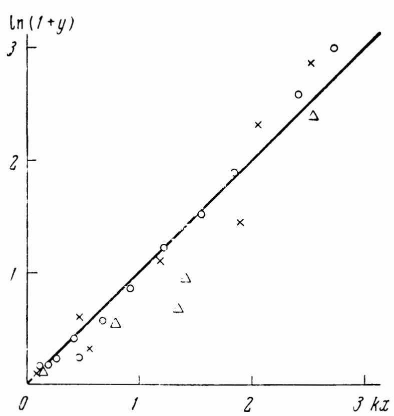

FIG. 2. Dependence of the intensity in the spectrum of induced Raman scattering on the excess of intensity of the excited light above the threshold (CS_2, 656 cm^{-1}): ○ – pure CS_2; × – mixture 60% CS_2 + 40% C_6H_6; Δ – mixture 50% CS_2 and 50% C_6H_6.

Figure 2 shows the measurement results for the 656 cm^{-1} line in pure CS_2 and in its mixtures with benzene (as in the investigation of the threshold, we measured the first Stokes components). It can be seen that all the experimental points lie within the limits of experimental error, on one straight line. This shows that formula (2) represents sufficiently accurately the experiment results.

3. The nonlinear dependence of the line intensity on the concentration, observed in our experiments, is in our opinion of independent interest. In usual Raman scattering, each molecule scatters like an independent system. Accordingly, the intensity of the lines is proportional to the number of particles. Deviations from this law are observed, but are usually small.

The nonlinearity of the radiation intensity relative to the number of particles can occur if the molecules radiate like a single quantum system. The theory of this process is given in the well-known papers by Dicke[2], Faĭn[3] and others. However, this theory cannot be applied directly to Raman scattering. On the other hand, Faĭn and Khanin[4] indicate that a quadratic dependence of the intensity on the number of particles is characteristic of any stimulated emission, independently of the particle interaction. We can hope that the results obtained by us will help answer this group of questions.

In conclusion we thank P. A. Bazhulin, N. G. Basov, and A. M. Prokhorov for interest in the work.

1)It turned out that the transmission of pulsed high-power radiation through the optical filters was considerably larger than when ordinary radiation of the same wavelength is used.

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CURRENT-CONVECTIVE INSTABILITY OF COLLISIONLESS PLASMA

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IT was shown in[1] that when current flows through a plasma, an instability may arise, connected with the spatial inhomogeneity of the current. This result was obtained under the assumption that the frequency of collision between the particles and the neutral atoms is much larger than the oscillation frequency, $\nu \gg |\omega|$, that is, in the limiting case of frequent collisions. This instability was called current-convective instability, since it is accompanied by plasma convection.

We show in this paper that a similar type of instability can occur also in the case when the collisions between the particles play no role. An equation describing this type of instability can be obtained by considering the motion of ions in the magnetohydrodynamic approximation, assuming their temperature to be equal to zero and the motion of the electrons to correspond to the drift approximation. Assuming the perturbation field to be potential, $E = -\nabla\psi$, and expressing all the perturbed quantities in terms of ψ, we obtain the following differential equation for ψ:

$$\operatorname{div}\left\{\left(1+\frac{\omega^2_{0i}}{\omega^2_{Hi}-\omega^2}\right)\nabla_\perp\psi\right\} - k_z^2\psi\left\{1-\frac{\omega_{0i}^2}{\omega^2}+\frac{4\pi e_e^2}{M_e k_z}\int\frac{(\partial f_0/\partial v_z)\,dv_z}{\omega-k_z v_z}\right\} + \frac{i\omega_{0e}^2}{n_0\omega_{He}}\left\{-\frac{[\nabla n_0,\nabla\psi]_z}{\omega(\omega^2_{Hi}-\omega^2)}\omega^2_{Hi}+\int\frac{dv_z\,[\nabla f_0,\nabla\psi]_z}{\omega-k_z v_z}\right\}=0. \quad (1)$$

Here

$$\omega_0^2 = 4\pi e^2 n_0/M,\quad \omega_H = eH_0/Mc,$$

n_0—plasma density, the subscripts i and e correspond to ions and electrons, and f_0—electron distribution function. The magnetic field H_0 is directed along the z axis. The dependence of ψ on t and z is chosen in the form $\exp(-i\omega t + ik_z z)$. The consequences that result from this equation are simplest to analyze under the assumption that $k_z v_z \ll \omega \ll \omega_{Hi}$. In addition, we assume that the plasma has cylindrical symmetry, so that $\psi \sim \psi(r)e^{im\varphi}$.

Using these assumptions and integrating (1) over space with weight ψ^*, we obtain

$$\omega^2\int r\,dr\left\{\left(\left|\frac{\partial\psi}{\partial r}\right|^2+\frac{m^2}{r^2}|\psi|^2\right)\left(1+\frac{\omega_{0i}^2}{\omega^2_{Hi}}\right)+k_z^2|\psi|^2\right\} - \int r\,dr\,|\psi|^2\omega_{0e}^2\left(k_z^2-\frac{mk_z}{e_e n_0\omega_{He}}\frac{1}{r}\frac{\partial j_0}{\partial r}\right)=0. \quad (2)$$

We see therefore that the perturbations in question can correspond to an aperiodic instability, $\omega^2 < 0$, if

$$\frac{m}{k_z}\overline{\left(\frac{1}{r}\frac{\partial j_0}{\partial r}\right)} > \frac{e^2H_0}{cM_e}\bar{n}_0, \quad (3)$$

where the bar denotes some averaging over r.

If all the plasma electrons are fast, $j_0 \approx e_e n_0 U$, then qualitatively condition (3) signifies that

$$mUL > (\pi e H_0/M_e c)\,r_0^2, \quad (4)$$

where r_0—radius of beam and L—its longitudinal dimension. If some of the electrons do not have a directional velocity, then $j_0 = en_1U$, $n_0 = n_1 + n_2$, where n_2—density of the slow electrons. Then, for fixed U and L, we can obtain from (3) an estimate for the ratio n_2/n_1, corresponding to the instability:

$$\frac{n_2}{n_1}+1<\frac{UL}{r_0^2}\frac{M_e c}{\pi e H_0}m. \quad (5)$$

An analysis of (1) for an arbitrary ratio ω/ω_{Hi} shows that the unstable interval $|\omega|$ extends up to the ion cyclotron frequency ω_{Hi}. In this case $|\omega| \gg k_z v_z$ and the increment does not depend on the details of the distribution of the electrons over the velocities. It is interesting to note that conditions typical for the manifestation of the instability in question are realized in experiments described by Nezlin and Solntsev[2-4]. The results of these experiments offer evidence that significant anomalous phenomena accompany the passage of electric current through the plasma, such as an appreciable spatial diffusion of the particles, heating of the ions to an energy comparable with the energy of the beam electrons, formation of a region with large negative space charge blocking the current, and others. For a theoretical analysis of these effects, it is obviously necessary to employ nonlinear analysis. However, the limit of manifestation of the anomalous effects should be determined from the linear instability theory. In this connection, it is of interest to compare the experimental results of these papers with the estimates obtained here. In particular, relation (5) gives the threshold value n_2/n_1 at which the instability arises. This quantity was also determined experimentally. Under conditions when $H_0 \sim (2-3)\times 10^3$ Oe, we get $U \sim 10^9$ cm/sec, L = 20—50 cm, and 2r = 1 cm, the critical value for n_2/n_1 amounted to several times 10, which was in qualitative agreement with (5). This gives grounds for assuming that the observed anomalous effects[2-4] are connected with the instability considered here.

I am grateful to B. B. Kadomtsev for a discussion of the results.

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