fied. The carrier effective masses are $m_e = 1.3 \times 10^{-2} m_0$ and $m_h = 1.8 \times 10^{-1} m_0$. In the case when $n_e = n_k$ (intrinsic semiconductor) and $T_e = T_h$ the criterion (5) takes the form

$$u_e > 5v_h. \tag{8}$$

This criterion is satisfied for the example in question when $E \gtrsim 150$ V/cm.

One cannot exclude the possibility that the microwave radiation observed by Larrabee [2] from InSb under the above-mentioned conditions is due to hole cyclotron instability ($f \approx 4 \times 10^{10}$ sec^{-1}).

In doped semiconductors ($n_e < n_h$) the hole cyclotron instability can be excited also in weaker fields (for p-InSb, E_{min} can be ~30 V/cm).

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1) This equation was derived for oblique electrostatic waves $\exp(-i\omega t + i\vec{k}\cdot\vec{r})$ ($\beta \equiv 4\pi nT/H^2 \ll 1$, $\omega/k \ll c$) in the approximation $\alpha_i \gg 1$, $\omega_{ci}\tau \gg 1$, where τ_i is the momentum relaxation time and $\hbar\omega_{ci} \ll T$.

2) The case of a many-valley band structure is implied [4].

CYCLOTRON RADIATION FLASHES

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Cyclotron radiation accompanied by ejection of particles, in the form of periodic bursts spaced in time [1], was observed in a number of experiments on adiabatic plasma containment. This phenomenon has received no theoretical explanation so far. We attempt in this paper to relate the explosive character of the radiation with certain singularities in the development of cyclotron oscillations with negative energy. Such oscillations appear in an anisotropic plasma if the plasma-particle velocity distribution is far from equilibrium [2,3].

Let, for example, the average energy $E_{\perp i}$ of ion motion transverse to the magnetic field be much larger than the longitudinal energy $E_{\parallel i}$, and let the plasma density and electron temperature be sufficiently high:

$$E_{\parallel i}/E_{\perp i} \ll T_e/E_{\perp i} \ll \mathrm{Min}\,\{1;\ \omega_{pi}^2/\omega_i^2;\ (E_{\perp i}/T_e)(m/M)\},$$

where $\omega_{pi} = (4\pi e^2 n_0/M)^{\frac{1}{2}}$ and $\omega_i = eH/Mc$ are the plasma and cyclotron frequencies of the ions. Then the dispersion equation for the natural oscillations of the plasma when $\omega_i/V_e \ll \omega_i/V_{\perp i}$ and $\omega \approx \ell\omega_i$ (ℓ is an integer) takes the form

$$\epsilon = (\omega_{pe}^2/k^2V_e^2)(1 + i\sqrt{\pi}\ \omega/k_{\parallel}V_e) - [\omega_{pi}^2/(\omega - \ell\omega_i)^2](k_{\parallel}^2/k^2)\varphi_\ell(k_\perp V_{\perp i}/\omega_i) = 0. \quad (1)$$

Here $\epsilon = \sum_{p,q}(k_p k_q/k^2)\epsilon_{pq}$, ϵ_{pq} is the dielectric tensor of the plasma, and the quantity φ_ℓ depends on the form of the ion distribution function relative to $V_\perp$. Thus in the case of Maxwellian distribution $\varphi_\ell(x) = I_\ell(x^2)\exp(-x^2)$ and in the case of a distribution in the form of a δ-function $\varphi_\ell(x) = I_\ell^2(x)$. The oscillations are assumed potential and the perturbations of the initial quantities are chosen in the form $\exp(-i\omega t + i\vec{k}\cdot\vec{r})$. The magnetic field and the plasma density in the initial state are assumed homogeneous.

From the real part of (1) we obtain

$$\omega - \ell\omega_i = \pm\sqrt{T_e\varphi_\ell/M}\ k_{\parallel}.$$

It is easy to see that oscillations with $\omega > \ell\omega_i$ have positive energy $W = (\omega/8\pi)(\partial\epsilon/\partial\omega)|E^2| > 0$ and oscillations with $\omega < \ell\omega_i$ have negative energy. Therefore the absorption of energy by resonant electrons leads to attenuation of the former and buildup of the latter, with an increment (decrement) equal to $\gamma \approx \sqrt{m/M}\ \omega_i$ [2,3].

We now consider nonlinear effects of interaction between oscillations with different signs of energy. Dikasov et al. [4] have shown (see also [2]) that as a result of such an interaction the buildup of oscillations should become stronger. Indeed, by means of nonlinear processes the energy is pumped over from the growing oscillations to the damped ones, and this leads to an increase of the increment of the unstable oscillations (whose energy is negative) and to excitation of the damped oscillations with positive energy. As a result, two signals should appear near the cyclotron frequency, separated by a frequency interval of the order of $\sqrt{m/M}\ \omega_i$, and this should be observable in experiments.

At small oscillation amplitudes, when allowance need be made for three-wave processes only (in our case this takes place when $(e\varphi)^2 \ll [(m/M)E_{\perp i}]^2$, where $\varphi^2 = \int d\vec{k}|\varphi|^2_{k,\omega_k}$), the equation for the number of waves

$$n_k = (k^2/8\pi)(\partial\epsilon/\partial\omega)|\varphi|^2_{k,\omega_k}$$

takes the form:

$$\frac{\partial n_k}{\partial t} = 2\gamma_k n_k + \int d\vec{k}'\sum_{\ell'} V^{\ell,\ell',\ell-\ell'}_{k,k',k-k'}(n_{k'}n_{k-k'} - n_k n_{k-k'} - n_k n_{k'})\delta(\omega_k - \omega_{k'} - \omega_{k-k'}). \quad (2)$$

Here

$$\gamma_k = \mathrm{Im}\ \epsilon_k/(\partial\epsilon_k/\partial\omega) \approx \sqrt{m/M}\ \omega_i$$

is the linear increment, and

$$V^{\ell,\ell',\ell-\ell'}_{k,k',k-k'} = 2\pi^2[1/k^2k'^2(k-k')^2]\left(\frac{\partial\epsilon_k}{\partial\omega}\frac{\partial\epsilon_{k'}}{\partial\omega}\frac{\partial\epsilon_{k-k'}}{\partial\omega}\right)^{-1}(e/M)^2\omega^4_{pi}$$

$$\times [k_{\parallel}k'_{\parallel}(k_{\parallel} - k'_{\parallel})/(\omega - \ell\omega_i)(\omega' - \ell'\omega_i)(\omega - \omega' - (\ell - \ell')\omega_i)]^2\{k_{\parallel}/(\omega - \ell\omega_i) + k'_{\parallel}/(\omega - \ell'\omega_i)$$

$$+ (k_{\parallel} - k'_{\parallel})/[(\omega - \omega') - (\ell - \ell')\omega_i]\}^2\int_0^\infty V_\perp dV_\perp f_{0i}(V_\perp)I_\ell(k_\perp V_\perp/\omega_i)I_{\ell'}(k'_\perp V_\perp/\omega_i)I_{\ell-\ell'}$$

$$\times [(k_\perp - k'_\perp)V_\perp/\omega_i].$$

It was found [4] that in the presence of interaction between oscillations with opposite energy signs the equation describes perturbations that grow with time without limit. We shall not solve Eq. (2), but merely determine the order of magnitude of the nonlinear increment $\gamma_{nl} \approx (e\varphi/T_e)^2\sqrt{m/M}\,\omega_i$. With increasing amplitude, when the cascade interactions with allowance for the 4th, 5th, etc. waves are included, the nonlinear increment becomes larger still.

Thus, the development of instability is of explosive nature. Of course, the amplitude of the oscillations cannot increase without limit. It can be assumed that its growth terminates when the longitudinal ion energy increases so much that the very existence of oscillations with negative energy becomes impossible [1]. During the initial stage of the process the growth of $E_{\parallel i}$ can be easily estimated by means of the quasilinear theory

$$\frac{\partial E_{\parallel i}}{\partial t} \approx [(e\varphi)^2/T_e]\sqrt{m/M}\,\omega_i$$

The dissipative processes (Landau damping by electrons) lead in this case to damping of the oscillations, and the next radiation flash will appear only after the initial form of the ion distribution function is restored.

It follows from this consideration that the explosive character of the development of the instability is connected with the presence of oscillations with negative energy. We have considered a plasma with anisotropic ions and hot electrons; it is easy to show that under certain conditions oscillations with negative energy are possible also in a plasma with cold electrons, and also in an electronic anisotropic plasma.

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POSSIBILITY OF OBSERVING INDUCED INFRARED RADIATION IN RAMAN SCATTERING OF LIGHT

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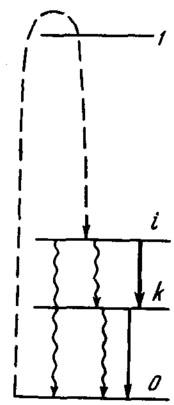
We discuss below a new mechanism of producing population inversion between vibrational or vibrational-rotational levels of molecules.



Let us consider a molecule with the level scheme indicated in the figure. We assume that: (i) the transition 0-i is allowed in the Raman spectrum and forbidden for the single-photon process; (ii) the transition 0-k, to the contrary, is forbidden for Raman scattering and allowed for the single-photon process; and (iii) the transition k-i is allowed for the single-photon process. These conditions are satisfied, for example, for vibrational transitions of all molecules possessing an inversion center. When conditions (i - iii) are satisfied, the level k will not become populated in the case of Raman scattering of light, so that the thermal distribution of the molecules over the vibrational levels may become disturbed and population inversion may occur. The gain per centimeter for the i-k transition near the generation threshold is

$$k = \frac{\lambda^2}{8\pi}\frac{A_{ik}}{\Delta\nu} g_i\left(\frac{N_i}{g_i} - \frac{N_k}{g_k}\right) = \frac{\lambda^2}{8\pi}\frac{A_{ik}}{\Delta\nu} g_{ik}\left(\frac{q_i}{w_i g_i} - \frac{N_k}{g_k}\right), \quad (1)$$

where g_i and g_k are the statistical weights of the upper and lower levels, λ is the wavelength of the i-k transition, N_i and N_k are the numbers of molecules per cm^3 at the upper (i) and lower (k) levels, A_{ik} is the Einstein coefficient for spontaneous emission, q_i is the rate of "pumping" of molecules to the upper level, w_i is the total probability of decay of this level, and $\Delta\nu$ is the line width of spontaneous emission in sec^{-1}. Far from resonance the absolute quantum yield of Raman scattering per molecule $\bar{\sigma}$ does not depend on the frequency of the exciting light, and then $q_i = \bar{\sigma} N_0 \bar{P}/\hbar\bar{\omega}_0$, where $\bar{P}$ is the effective value of the power density of the incident radiation, $\bar{\omega}_0$ is the effective value of the circular frequency of the incident light, and N_0 is the number of molecules per cm^3 in the ground state. At sufficiently low temperatures the second term in (1) can be neglected, and then at a resonator length ℓ = 10 cm and at a mirror reflection coefficient R = 99% we obtain the following necessary condition for generation: