and is practically equal to the equilibrium value. The upper curve (solid section), plotted under the assumption that $T_e = T_a$ (the highest temperature), is a rigid upper bound. At small values of x this estimate is not valid, since the oscillation temperature is low in this case, and the molecules can heat the electrons only to $T_e = T_v$, corresponding to the dashed upper curve of i.

It is also possible to attribute the radiation peak in a band spectrum behind strong shock waves to excitation of the molecules by electrons. Thus, for example, the populations of the first excited states of N_2^+ arising in the case of associative iionization soon reach the local-equilibrium values. The calculated radiation intensities are in good agreement with the earlier measurements [2].

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POSSIBILITY OF EXCITING CYCLOTRON INSTABILITY IN SEMICONDUCTORS

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Increased interest has been recently evinced in the excitation of microwave oscillations in solid-state plasma [1,2]. It is not without interest to consider in this connection the possibility of exciting cyclotron instability in a solid-state plasma by means of a current. It is known that ion-cyclotron instability can be excited in this manner in a gas-discharge plasma [3] and that these results can be carried over to the case of a solid-state plasma.

The dispersion equation describing cyclotron instability in a solid-state plasma is [3][1)]

$$\sum_i \alpha_i \exp(-s_i) \sum_{n=-\infty}^{\infty} I_n(s_i)[1 + i\sqrt{\pi}(z_{ni} + nh_i)W(z_{ni})] = 0, \quad (1)$$

where

$$s_i = (k_\perp \rho_i)^2, \ \rho_i = v_i/\omega_{ci}, \ \omega_{ci} = eH/m_i c, \ z_{ni} = (2)^{-\frac{1}{2}}(\omega - k_\parallel u_i - n\omega_{ci})/k_\parallel v_i,$$

$$h_i = \omega_{ci}/k_\parallel v_i, \ \alpha_i = \omega_{pi}^2 m_i/\epsilon_0 k^2 T_i, \ \omega_{pi}^2 = 4\pi n_i e^2/m_i.$$

u_i are the carrier velocities, v_i the thermal velocities, i denotes summation over the particle species, $I_n(s_i)$ are Bessel functions of imaginary argument, and $W(z_{ni})$ is Kramp's function.

The plasma can consist of either unlike carriers (electrons and holes) or of carriers of the same sign but different effective masses [2)]. We shall henceforth consider a two-component plasma. Quantities pertaining to the light and heavy components will be denoted by the letters "a" and "b" respectively, and it will be assumed that $s_0 \ll 1$. Since we are interested in excitation of the cyclotron instability by the first harmonic $\omega \approx \omega_{cb}$, we retain the zeroth and first terms in the sum over n. We shall investigate the dispersion equation (1) in the approximation

$$|z_{0a}| \ll 1, \ |z_{1a}| \gg 1, \ |z_{0b}| \gg 1, \ |z_{1b}| \gg 1 \quad (v_b \ll \omega/k_\parallel \ll v_a). \tag{2}$$

In this approximation the dispersion equation (1) takes the form

$$\omega - \omega_{cb} = \omega_{cb}(\alpha_b/\alpha_a)\exp(-s_b)I_1(s_b)[1 + i\sqrt{\pi/2}(-\omega_{cb} + k_\parallel u_a)/k_\parallel v_a]. \tag{3}$$

The quantity $I_1(s_b)\exp(-s_b)$ reaches a maximum when $s_b \approx 1.5$ and is equal to 0.2. The criterion for the excitation of cyclotron instability is

$$u_a > \omega_{cb}/k_\parallel. \tag{4}$$

Starting from (2) and (3) we have $k_\parallel \lesssim 0.2(\alpha_b/\alpha_a)(\omega_{cb}/v_b)$ and the criterion (4) takes the form

$$u_a > 5(\alpha_a/\alpha_b)v_b. \tag{5}$$

From the condition for the applicability of the employed approximation (only resonance at the first harmonic is considered!) we obtain $\alpha_a/\alpha_b > 0.2$, and therefore the least stringent criterion for the carrier velocity of the light component, at which the instability at the cyclotron frequency of the heavy component is excited, is

$$u_a > v_b. \tag{6}$$

The increment of the instability is

$$\gamma \sim 0.3\,\omega_{cb}\,(u_a/v_a)(\alpha_b/\alpha_a). \tag{7}$$

Since $\alpha_a/\alpha_b \sim (n_a/n_b)(T_b/T_a)$, the least stringent criterion corresponds to the case when $n_b > n_a$ and $T_a > T_b$.

Let us obtain a numerical estimate of the possibility of excitation of a hole cyclotron instability for the case of indium antimonide (electron-hole plasma). For $T = 78°K$, $b_e \sim 10^8$ cgs esu and $b_e/b_h \sim 20$ [5] (b_e and b_h are the mobilities). The condition $\omega_{ch}\tau_h > 1$ is satisfied when $H > 3 \times 10^3$ Oe, and the condition of the "classical" problem, $\hbar\omega_{ce,h} < T$ is satisfied. 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:

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