EXCITATION OF VOLUME ION-ACOUSTIC OSCILLATIONS IN AN INHOMOGENEOUS DENSE PLASMA BY THE FIELD OF AN ELECTROMAGNETIC WAVE

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We describe briefly the results of a theory of nonlinear interaction between a strong electromagnetic wave and an opaque plasma. It has been observed that the buildup of ion-acoustic oscillations takes place in the entire volume, in spite of the fact that the field of the external waves penetrates only into the skin layer of the plasma. Thus, the investigated turbulence-producing mechanism may turn out to be effective for volume heating of the plasma by the field of an external electromagnetic wave.

We consider a plasma layer of thickness d with an inhomogeneous density profile n(z) in a transition region of width a. Outside the transition region, the plasma is assumed to be weakly inhomogeneous with a characteristic inhomogeneity dimension $(\partial \ln n(z)/\partial z|_{z=a})^{-1}$ greatly exceeding a. At such relations between the characteristic dimensions, there exist in the plasma electronic quasistatic surface oscillations. Their wavelength along the plasma boundary, $\lambda = 1/k_{\parallel}$, corresponding to the wave vector $\vec{k}_{\parallel}$, satisfies the condition $a \ll \lambda \ll d$, $(\partial \ln n(z)/\partial z|_{z=a})^{-1}$. The frequency of such quasistatic surface oscillations is [1 - 3].

$$\omega = \omega_{sur}\left\{1 - \frac{k_{\parallel}}{2(1+\epsilon_0)}\int_0^a \frac{dz}{\epsilon(\omega,z)}[\epsilon^2(\omega,z) - \epsilon_0^2] + \frac{1}{4k_{\parallel}}\left.\frac{\partial \ln n(z)}{dz}\right|_{z=a} - \frac{\omega_{sur}^2}{4k_{\parallel}^2 c^2}\right\},$$

$$\omega_{sur} = \frac{\omega_{Le}(z=a)}{\sqrt{1+\epsilon_0}}, \tag{1}$$

and the damping decrement is given by

$$\tilde{\gamma} = \omega_{sur}\frac{\pi\epsilon_0^2 k_{\parallel}}{2(1+\epsilon_0)}\int_0^a dz\,\delta[\epsilon(\omega_{sur}, z)] \tag{2}$$

$$\epsilon(\omega, z) = 1 - \frac{\omega_{Le}^2(z)}{\omega^2}.$$

Here ε_0 is the dielectric constant of the medium bounding the plasma.

Simultaneously with the surface oscillations, there exist volume ion-acoustic oscillations with frequency ω_S and decrement γ_S (see formulas (6.15) and (6.25) in [4]).

Let us discuss the case of normal incidence, on the plasma layer, of an external electromagnetic wave with electric-field amplitude E_0 and with frequency ω_0 close to the frequency ω_{sur} of the surface wave (1).

The field of the short-wave surface quasistatic ($k_{\parallel} c \gg \omega_{Le}$) waves is localized near the plasma boundary within a distance on the order of $\lambda = 1/k_{\parallel}$ shorter than the dimension of the skin layer c/ω_{Le}. It is precisely in this region that the interaction between the surface wave and the external field generates surface and ion-acoustic oscillations and leads to a growth of the latter in the entire volume of the plasma. To estimate the growth rate of the ion acoustic oscillations, we use first simple physical considerations. In the region where the surface wave is localized, the mechanism whereby the ion-acoustic oscillations are excited is similar to that existing in the case of an unbounded plasma [5]. This makes it possible to estimate the growth increment of the oscillations, in the region of the wave interaction, by using an expression derived in [5]:

$$\Gamma \approx -\gamma_S + \frac{E_0^2}{4\pi n_e T_e} \frac{\omega_S^2 \omega_{Le}^4(z = a)}{\tilde{\gamma}^2 \omega_0^3} . \quad (3)$$

When they leave the interaction region, the ion-acoustic oscillations attenuate with a decrement γ_S. Upon reflection from the opposite boundary of the layer, they return to the interaction region. It is clear that the change of the ion-acoustic oscillation amplitude in the segment $0 \leq z \leq \lambda$ is determined by the time required to traverse this distance and is proportional to $\exp\{\lambda\Gamma(\partial\omega_S/\partial k_z)^{-1}\}$. Accordingly, on passing through the remaining volume of the plasma, the amplitude of the ion-acoustic wave decreases by a factor $\exp\{-\gamma_S(d - \lambda)(\partial\omega_S/\partial k_z)^{-1}\}$. The effective growth increment γ of the ion-acoustic oscillations in the entire volume of the plasma is given by

$$\gamma d = \Gamma \lambda - \gamma_S (d - \lambda) . \quad (4)$$

A rigorous calculation on the basis of the kinetic equation leads to the following expression for the increment of the simultaneous growth of the surface and volume ion-acoustic wave:

$$\gamma = -\gamma_S + \frac{1}{k_{\parallel} d} \frac{3\sqrt{3}}{32} \frac{E_0^2}{4\pi n_e T_e} \frac{\omega_S^2 \omega_{Le}^4(z = a)}{\tilde{\gamma}^2 \omega_0^3} . \quad (5)$$

This expression differs only by a numerical coefficient from the increment (4) obtained on the basis of the qualitative consideration.

A wave extraction process analogous to that considered above may turn out to be significant in the case of a parametric coupling of the volume plasma oscillations with the ion acoustic oscillations.

In conclusion, the authors consider it their pleasant duty to express sincere gratitude to V.P. Silin for valuable remarks and constant interest in the work.

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INSTABILITY IN OPTICALLY-PUMPED SEMICONDUCTORS IN STRONG MAGNETIC FIELDS

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The possibility of realizing situations in which the conduction current flows in a direction opposite to that of the electric field has been predicted in a number of papers (e.g., [1, 2]). Such an effect has been named absolute negative conductivity. It is connected as a rule with an appreciable lack of carrier equilibrium. It is known [3] that a homogeneous state in a system with such a conductivity can be unstable. However, the presence of equilibrium carriers, if their density is not low enough, suppresses the absolute negative conductivity and the associated instability (see [4]), since the conductivity produced by these carriers is positive.

We call attention in this paper to the possible existence in such systems of another type of instability. This instability can occur, as will be shown below, even when the total conductivity is positive.

Let us consider, for concreteness, a p-type semiconductor with short electron lifetimes, placed in a strong magnetic field. Assume that photoelectrons are generated in the conduction band under the influence of a monochromatic source of light. Let the magnetic field intensity be large enough ($\omega_c\tau \gg 1$, where ω_c is the cyclotron frequency of the electrons and τ the relaxation time) to satisfy the conditions for quantization of the electron energy. In this case the photoelectrons are concentrated in a narrow-energy interval, and their contribution to the conductivity is negative [2]. We assume also that the conductivity due to the holes (both majority holes and photo-holes) exceeds in absolute magnitude the photoconductivity due to the photoelectrons, i.e., the total conductivity is positive. Such a situation is close to that observed in the experiment [4].

To describe the low-frequency processes in the system under consideration, we can use the Poisson equation and the continuity equations. The latter, if we assume that all the quantities depend only on the coordinates transverse to the magnetic field, is given by

$$\frac{\partial n}{\partial t} - \operatorname{div}\,[n(\mu_n E + \mu_n^H[\mathbf{E}\times\mathbf{h}]) + D_n \operatorname{grad} n] = -\frac{\partial N}{\partial t} = gN - \gamma n(N_i - N), \tag{1}$$

$$\frac{\partial p}{\partial t} + \operatorname{div}[p(\mu_p \mathbf{E} + \mu_p^H[\mathbf{E}\times\mathbf{h}]) - D_p \operatorname{grad} p] = 0. \tag{2}$$

Here n, μ_n, μ_n^H, D_n, and p, μ_p, μ_p^H, and D_p are respectively the concentrations, mobilities, and diffusion coefficients of the electrons and holes ($\mu_n < 0$, $\mu_p > 0$), N_i and N are the concentrations of the impurities from which and to which electron pumping is effected, g and γ characterize the generation and recombination of the electrons, and $\vec{h} = \vec{H}/H$. We have neglected in (1) and (2) the dependence of the mobilities on the electric field, assuming the latter to be small (there is no external electric field). We also assume that the total number of holes remains constant.