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TRANSFORMATION OF HIGH-FREQUENCY WAVES AND VANISHING OF LOW-FREQUENCY INSTABILITIES IN A RADIALLY-INHOMOGENEOUS BEAM-PLASMA DISCHARGE

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The influence of transformation of high-frequency waves on the operating regime of a plasma-beam discharge is analyzed. Experiments show that by varying the radial distribution of the plasma density it is possible to ensure effective radiation of the oscillations near the upper hybrid resonance and by the same token prevent transfer of the energy into the low-frequency oscillations. The latter quench the low-frequency instabilities in a plasma-beam discharge.

In experimental investigations of the linear transformation in an inhomogeneous plasma, principal attention is usually paid to plasma heating upon transformation of the transverse waves into longitudinal ones, or to radiation of the energy from the system in the opposite case [1 - 3]. Yet the wave transformation can exert a more diverse action on the system and, in particular, influence its stability (the possibility of using wave transformation to increase the stability of the system was first pointed out in [4]). The influence of the wave transformation on the system stability can be conveniently traced with a qualitative example, in which there are two "modes" K_1 and K_2 localized in the same region, the common region of localization of the two modes being separated by opacity barriers from the vacuum-connected transparency region of one of the modes (then part of the energy can radiate out from the system to the vacuum). Assume that the mode K_2 can be excited in the nonequilibrium system. In a homogeneous medium, the modes K_1 and K_2 are not connected with each other, and therefore the mode K_1 does not influence the instability development. In an inhomogeneous medium there can exist points where the wave vectors of both modes coincide (regions of mode "intersection") and in this case the transformation of one mode into another is frequently close to 100% in the "intersection" region [4]. Then only a "superposition mode" $K_1 + K_2$ can be excited in the medium, although far from the "intersection" region it is convenient, as before, to designate the "components" of the new mode by K_1 and K_2 respectively (see, e.g., [1, 4]). Let L be the distance between the "intersection" points of the modes, and let the dimension L of the instability region be smaller than L. In this case the condition of instability following excitation of the "superposition" mode can be written in the form

$$\alpha \exp\left(\frac{\gamma_2' L'}{V_{g2}} - \frac{\gamma_2 L}{V_{g2}} - \frac{\gamma_1 L}{V_{g1}}\right) > 1 \tag{1}$$

where γ_2' is the growth increment of mode K_2 in the region L'; γ_2, γ_1, V_{g2}, and V_{g1} are respectively the increments and group velocities of modes K_2 and K_1; α^{-1} is the factor by which the amplitude of the excited wave is reduced because of radiation of energy to the outside ($\alpha < 1$; γ_2', γ_1, $\gamma_2 < \omega$).

The situation described above is typical, e.g., of the case of interest to us, the interaction of an electron beam with high-frequency oscillations of a radially-inhomogeneous plasma (K_1 is a mode of the Bernstein type, propagating at an angle to the magnetic field H_0, K_2 is a "cold" mode with a singularity in the refractive index, the dispersion characteristic of both modes are well known [5]). If $\omega_p^2 < \omega^2 < \omega_p^2 + \omega_H^2$, then both oscillation modes exist at the center of the inhomogeneous layer and the beam can excite only a "coupled" pair (cold mode and Bernstein mode). In accordance with the statements made above, we can separate three operating regimes of the plasma-beam discharge, depending on the character of the influence of the "intersection" of the wave solutions: a) laminary regime, when a condition inverse to (1) is satisfied; b) regime of heating and of low-frequency instabilities, when (1) is valid and the region L is sufficiently large; in this case, owing to the effective interaction of one of the components of the superposition mode (i.e., K_1) with the plasma, the energy goes in part to heating the plasma and is transferred in part to the low-frequency oscillations, leading to anomalous losses of particles and heat across the magnetic field [6, 7]; c) radiative regime, when L and the opacity barriers are small when (1) is satisfied; in this case the energy is not "retained" in the system and the low-frequency instabilities should become quenched.

This premise was verified experimentally with the setup described in [8]. The work was performed on an electron beam of energy 3 - 5 keV, current up to 100 A, in a magnetic field up to 2000 G. During the experiment we registered the radiation level of the oscillations, the frequency spectrum, and the energy lost by the beam. The radiation was received outside the plasma with horn antennas of the "loop" type oriented along the magnetic component of the field. The energy lost by the beam electrons was measured by a calorimetric method.

The radial distribution of the plasma density was varied by applying a negative potential to a cylindrical electrode coaxial with the electron beam placed in the initial region of the interaction, in analogy with the procedure used by us in [6, 7], where we investigated the influence of external potentials on the instability of a plasma-beam system. The plasma density and its spatial distribution were measured with movable Langmuir double probes.

Figure 1 shows the variation of the radial distribution of the plasma density following application of a potential minus 40 V to the electrode. The points A and A' note the spatial positions of the points $\omega^2 = \omega_p^2 + \omega_H^2$. Figure 2 shows the levels of the radiation from the plasma following variation of the radial distribution of the plasma density in a certain direction. A comparison of Figs. 1 and 2 shows that when L decreases (the distance from the center of the beam to the point where $\omega^2 = \omega_p^2 + \omega_H^2$) the radiation intensity increases 16 times.

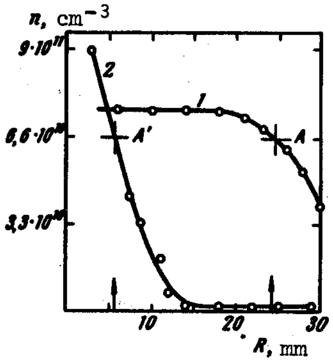

Fig. 1. Radial distribution of plasma density: 1 - zero electrod potential; 2 - electrode potential - 40 V, A, A' - points in space where $\omega^2 = \omega_p^2 + \omega_H^2$.

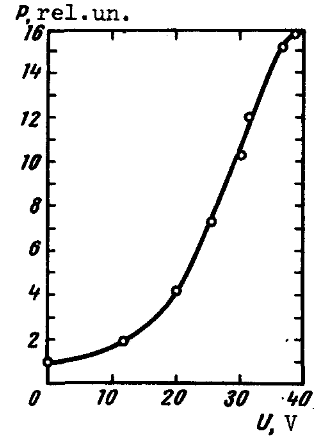

Fig. 2. Oscillation radiation power level as a function of the electrode potential.

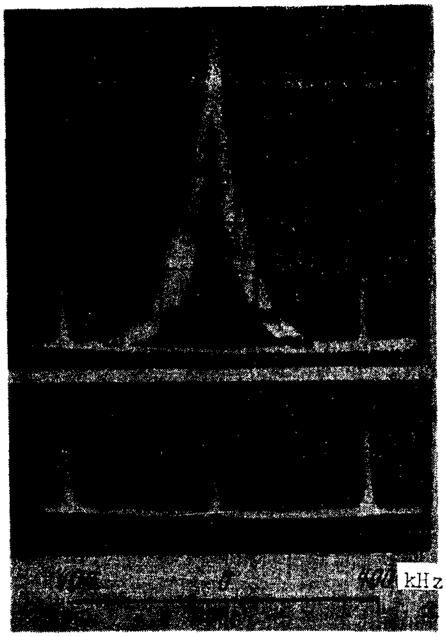

Fig. 3. Oscillation spectra: a - zero electrode potential, b - potential 40 V.

In the presence of radiation, the energy loss by the beam electrons increases, and the low-frequency occillations (drift and drift-dissapative) disappear (Fig. 3). The accelerated ions also disappear in this case. The change of the radial distribution of the plasma density leads to a transition from regime (b) to regime (c) and to stabilization of the low-frequency instabilities. Our investigations show that the same results on the quenching of low-frequency instability can be obtained also by specifying density gradients analogous to Fig. 1, by choosing the pressure in the interaction region, or by magnetic-field gradients.

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LOW-THRESHOLD BREAKDOWN OF AIR NEAR A TARGET BY CO_2 RADIATION, AND THE ASSOCIATED LARGE RECOIL MOMENTUM

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A sharp drop (by more than two orders of magnitude) was observed in the threshold intensity for the breakdown of air near a target by CO_2-laser radiation. The target recoil momenta due to the optical breakdown of the air are measured. The experimental data are interpreted on the basis of the theory of a point-source explosion.