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RESONANT HEATING OF A PLASMA BY A HIGH-FREQUENCY FIELD

V. V. Chechkin, M. P. Vasil'ev, L. I. Grigor'eva, A. V. Longinov, and B. I. Smerdov

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We present in this paper the preliminary results of experiments on heating of a dense plasma with powerful high-frequency pulses under conditions when a fast magnetic-sound wave is resonantly excited in the plasma ($\Omega_e \gg \omega_e$, $\omega_i \ll \omega_e$, where Ω_e is the electron plasma frequency, ω_i and ω_e the ion and electron cyclotron frequencies, respectively, and ω the working frequency). The efficacy of heating with a magnetic-sound wave was investigated theoretically and verified experimentally in [1-5].

A diagram and a detailed description of the setup are given in [6]. The investigations were made on a decaying plasma situated in a quasi-constant longitudinal magnetic field, the intensity of which could reach 6000 Oe. The plasma was produced by a reflex pulsed discharge in hydrogen and helium at pressure $\sim 10^{-3}$ mm Hg. The inside diameter of the glass discharge tube was 6 cm and the distance between electrodes 88 cm.

A high-frequency field was applied to the decaying cold plasma (temperature ~1 eV). The field was excited by discharging a 5.25×10^{-9} F capacitor bank charged to 36 kV through inductance coils wound on the discharge tube in such a manner that the field along the axis was periodic with an axial period $\lambda = 20$ cm. The length of the coil system was ~80 cm (4 periods). The resonant-circuit oscillation frequency was 7 Mc and the amplitude of the axial hf magnetic field $\tilde{H}_z = 140$ Oe.

We measured the coefficient of energy transfer from the hf field of the plasma circuit, equal to the ratio of the energy absorbed by the plasma to the total energy stored in the circuit, by using an external probe and determining the damping of the oscillations in the resonant circuit. We measured also the average of the electron density over the cross section of the discharge tube (using a radio interferometer at wavelengths 2 and 8 mm) and the electron temperature (by optical methods and with a multigrid probe). The variation of these parameters with the intensity of the quasi-constant magnetic field was obtained.

Figure 1 shows the transfer coefficient as a function of the intensity of the quasi-constant magnetic field for different values of the initial electron density, i.e., the density at the instant when the high-frequency circuit is turned on (o - 4.5×10^{13}, x - 6.5×10^{13}, △ - 8×10^{13} cm^{-3}). The curves were obtained for a hydrogen plasma at $\sim 10^{-3}$ mm Hg.

It follows from Fig. 1 that the absorption of the hf field energy by the plasma has a resonant character, and its maximum corresponds to a frequency ω in the region $\omega_i < \omega < \sqrt{\omega_i \omega_e} << \omega_e$. The shift of the maximum toward a weaker magnetic field with increasing initial plasma density is in good agreement with the dispersion relation for magnetic-sound waves [7] propagating along the plasma cylinder. Analogous relations between the transfer coefficient and the magnetic field intensity were obtained for a helium plasma.

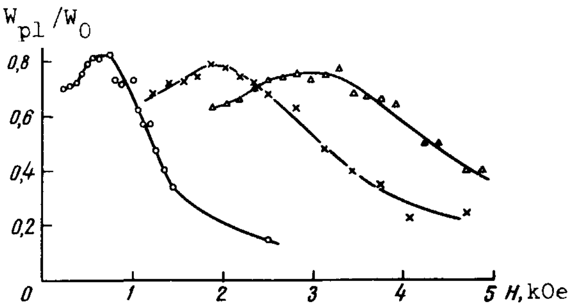

Fig. 1.

Figure 2 shows the transfer coefficient (a), the electron temperature (b), and the increment of the electron density (c) as functions of the magnetic field intensity. The curves were obtained for a helium plasma at $\sim 10^{-3}$ mm Hg and at an initial electron density 5×10^{13} cm^{-3}. The electron temperature was determined from the ratio of the emission intensities of the helium lines HeI 4921 and HeI 4713, from the rate of "burning-out" of the lines H_β 4861 and HeI 5875, from the increment of the electron density [8], and with the aid of a multigrid probe [9]. The temperature values obtained by these methods are in good agreement.

It follows from the presented plots that the electron temperature T_e increases with increasing energy absorption by the plasma, reaching a value ~ 60 eV. This is accompanied by an increase in the electron density, and the degree of ionization approaches 100%. The ion temperature T_i, measured with a multigrid probe under strong absorption conditions, is ~ 30 eV. The plasma is heated within a short time: under the conditions of maximum absorption, the amplitude of the hf oscillations in the

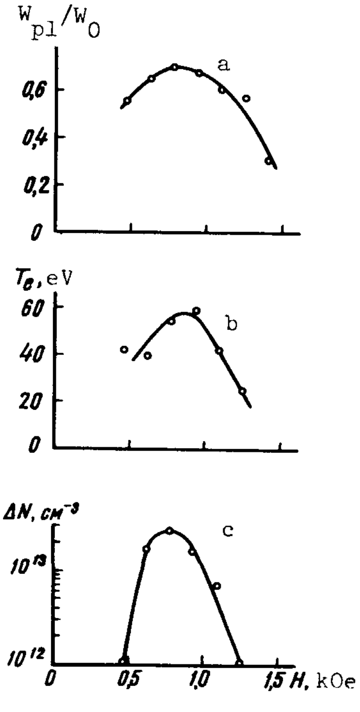

Fig. 2

circuit decrease by a factor e ≈ 2.7 within ~0.5 μsec, i.e., after 2 - 3 oscillation cycles; without the plasma, this decrease takes approximately 11 cycles.

The damping decrement calculated from the rate of decrease of the oscillation amplitude in the circuit under resonant conditions, $\gamma_{exp} \simeq 6.5 \times 10^{-2}\omega$, exceeds by more than two orders of magnitude the damping decrement of magnetic-sound waves due to Coulomb losses [10]. It is possible that the observed damping is due to Cerenkov absorption of the magnetic-sound wave energy by the plasma electrons, since the Cerenkov damping decrement for a homogeneous plasma [1,2], $\gamma_{Cer} \simeq 2 \times 10^{-2}\omega$, differs insignificantly from γ_{exp}. The presence of plasma inhomogeneities increases γ_{Cer} [3].

The temperature calculated from the energy balance under the assumption that the entire energy absorbed by the plasma goes into its heating, is $T_i + T_e \simeq 90$ eV, in good agreement with the experimental data.

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SCATTERING OF ELECTRON-GAS ENERGY IN n-InSb AT HELIUM TEMPERATURES

T. M. Lifshitz, A. Ya. Oleinikov, and A. Ya. Shul'man
Institute of Radio Engineering and Electronics, USSR Academy of Sciences

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The variation in the electric conductivity of n-type indium antimonide with impurity concentration $\gtrsim 1 \times 10^{14}$ cm^{-3} at helium temperatures with variation of the electric field is usually attributed to a change in the electron mobility, due to the heating of the electron gas. The carrier momentum is scattered in this case by the electrostatic potential of the