RESONANCE EXCITATION OF ION-CYCLOTRON OSCILLATIONS IN A ROTATING PLASMA

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We have investigated the collective interaction in a plasma magnetron lens [1], in which the radial electric field E_r and the longitudinal magnetic field H_z cause the plasma to rotate at an angular frequency $\omega_{rot} \sim cE_r/aH_z$ (a - plasma radius).

Resonance excitation of ion cyclotron instability was observed when the ion cyclotron frequency ω_{Hi} became equal to a multiple of the angular rotation frequency ($\omega_{Hi} \sim 2\omega_{rot}$). In this case, intense longitudinal oscillations were excited in the plasma, leading to an effective heating of the ions (to 100 eV), and to a powerful epithermal radio emission. The cause of this instability may be the interaction of the ion flux due to the centrifugal force and to plasma inhomogeneity with the electrons under the resonance conditions.

The ion energy was measured by a multiple-grid probe by the blocking-potential method. The plasma density (of the order of 10^{10} cm^{-3}) and the plasma electron temperature ($T_e \sim 10$ eV) were measured by a modified Langmuir double probe. The electromagnetic fields excited in the plasma were detected with both electrostatic and magnetic probes. A special unit made it possible to locate these probes at any point of the discharge without breaking the vacuum.

Experimentally, the discharge was produced in to distinct operating regimes, the first at $\omega_{rot} >> \omega_{Hi}$ and $H < H_{cr}$, and the second at $\omega_{rot} \lesssim \omega_{Hi}$ and $H \geq H_{c}$.

In the first regime the frequency of the electrostatic oscillations is proportional to the electric field intensity and is inversely proportional to the magnetic field intensity.

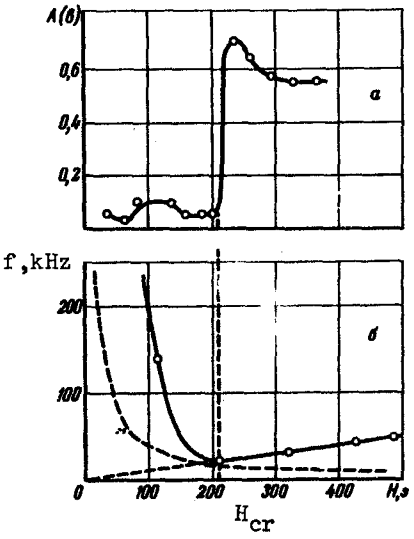

Fig.1

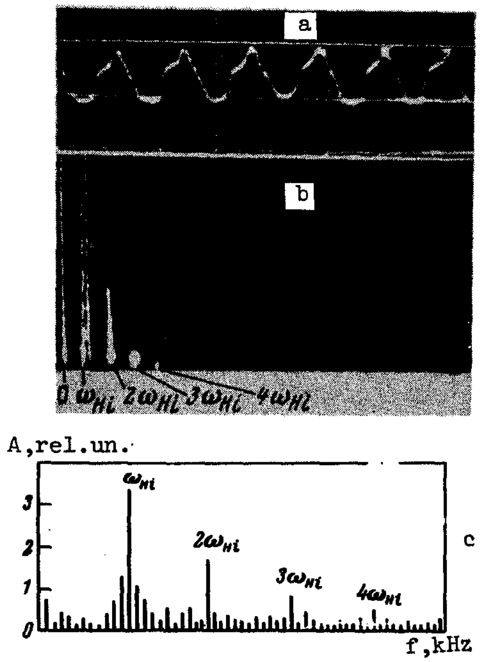

Fig.2

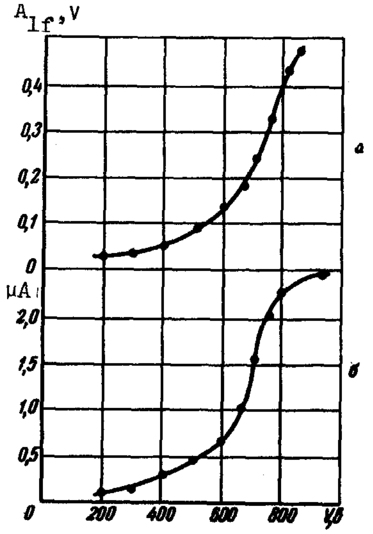

Fig.3

The oscillations in this regime can be identified with longitudinal oscillations of an inhomogeneous rotating plasma with frequency $\omega \sim \omega_{rot} \sim \omega_{Hi}$, excited as a result of the development of beam-centrifugal instability.

The second generation regime is accompanied by a sharp increase of the oscillation amplitude and by a fundamental change of the character of the dependence of the frequency on the electric and magnetic fields. The curve on Fig. 1a shows the dependence of the radiation amplitude on the magnetic field. As seen from Figs. 1a and b, the amplitude of the oscillations increases by more than one order of magnitude when the condition $2\omega_{rot} \sim \omega_{Hi}$ is satisfied, and resonance excitation of a series of harmonics of the ion-cyclotron oscillations takes place.

Figure 2a shows the form of the plasma oscillations picked up by the electrostatic probe and their spectral analysis. The spectrum was determined either by harmonic analysis with an electronic computer (b) or with the aid of a panoramic radio receiver (c).

Correlation measurements of the phase shifts of these oscillations have shown that the azimuth spans two wavelengths and that the radial wave vector ($k_r \sim 1\ \mathrm{cm}^{-1}$) greatly exceeds the longitudinal one ($k \leq 3 \times 10^{-12}\ \mathrm{cm}^{-1}$). This indicates that the investigated waves propagate in a direction almost perpendicular to the magnetic field.

The increment of these oscillations was measured with the system operating in the pulsed mode. The results have shown that the time necessary for the amplitude with frequency $\omega \sim \omega_{Hi}$ to reach maximum amplitude is shorter than half the period of these oscillations. Thus, the increment of the observed instability turns out to be larger than (or of the order of) its frequency.

Unlike the beam-centrifugal instability, the instability develops in this case when the relative velocity of ion rotation turns out to be of the order of their thermal velocity (for example, at $E_r = 0.5$ V/cm we have $v_{rot} \approx 0.5\ v_{Ti}$).

To study the effectiveness of the ion heating, we measured the energy spectra with the aid of a multiple-grid probe [3] by the blocking-potential method. Figure 3a shows the dependence of the amplitude of the cyclotron oscillations on the anode voltage, and Fig. 3b shows the analogous dependence of the flux of ions with energy higher than 50 eV to the collector along the magnetic field. It is seen from this figure that if the anode voltage exceeds the critical value $v_{cr} \sim H^2_{cr}$, then the flux of the ions across the electric field increases strongly and the amplitude of the plasma oscillations increases. This indicates that the heating of the ions is connected with the development of a resonance cyclotron instability in the discharge.

The results may be useful for the understanding of a number of experiments on the containment and heating and a plasma, in which the radial electric field is produced either on purpose or spontaneously [4, 5].

In conclusion, the authors are grateful to Professor V. T. Tolok for constant interest in the work and useful discussions, to O. M. Shvets, V. G. Marinin, and V. V. Dolgopolov for taking part in a discussion of the results, and to M. G. Krivonos for help with the experiments.

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REVERSAL OF THE SIGN OF THE LOW TEMPERATURE THERMAL EMF AND THE KONDO EFFECT

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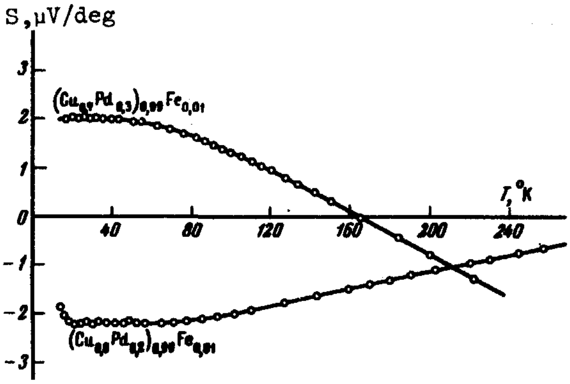
According to [1-5], the sign of the thermal emf due to a paramagnetic impurity is determined by the sign of the integral I of exchange interaction between the conduction electrons and the localized magnetic moments (under the condition $V \sim L^2 > 0$ [2], where L is the difference between the number of electrons of the impurity and host atoms and V is the amplitude of the scattering connected with the electrostatic potential of the impurity).

It is of interest to determine experimentally the sign of the thermal emf of the alloys $(Cu_{0.8}Pd_{0.2})_{0.99}Fe_{0.01}$ and $(Cu_{0.7}Pd_{0.3})_{0.99}Fe_{0.01}$, in which a negative and a positive sign of I is obtained when the results of the investigation of the temperature dependence of the electric resistance are reduced in accordance with the Kondo model [6].

We have investigated the temperature dependence of the thermal emf of the alloys $(Cu_{1-x}Pd_x)_{0.99}Fe_{0.01}$ (x = 0.05, 0.1, 0.2, 0.3, and 0.6) relative to the corresponding host matrices. The thermal emf S measured in this manner characterizes the interaction of the conduction electrons with the Fe ions. This interaction consists of the scattering of the conduction electrons, connected with the localized magnetic moment and with the static potential of the impurity ion.

It turned out that the S = f(T) plots of alloys containing 5, 10, and 20 at.% Pd were similar in form, differing only in the magnitude of the thermal emf (S = 4 μV/deg for the $(Cu_{0.95}Pd_{0.05})_{0.99}Fe_{0.01}$ alloy at T ∿ 40°K). The temperature dependence of the thermal emf of the alloy $(Cu_{0.8}Pd_{0.2})_{0.99}Fe_{0.01}$ is shown in the figure.

At concentrations 30 and 60 at.% Pd, the character of the S = F(T) curves changes qualitatively, as can be seen from the plotted results for the alloy $(Cu_{0.7}Pd_{0.3})_{0.99}Fe_{0.01}$.



Temperature dependence of thermal emf, due to impurity iron atoms.

In the temperature interval 20 - 60°K, the thermal emf of the alloys in question is practically independent of the temperature. According to the Kondo model [1 - 4], this is due to the interference mechanism.

S < 0 at concentrations 5, 10, and 20 at.% Pd and S > 0 at higher concentrations. In the assumed model, this corresponds to a negative exchange interaction between the conduction elec-