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OBSERVATION OF MAGNETIC-DRIFT INSTABILITY IN A SYSTEM WITH LARGE β

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We have observed and investigated the low-frequency magnetic-drift instability in a θ-pinch plasma with $\beta \sim 1$. Its appearance is connected with the onset of the mechanism of thermalization of the accelerated-electron energy. The oscillation amplitude is comparable with the magnitude of the main magnetic field.

It is well known that in a bounded collisionless plasma of low pressure ($\beta \equiv 4\pi nT/H_0^2 \ll 1$) there can be excited potential drift oscillations (see [1, 2] and the literature cited therein). Theoretical studies were made also of the excitation of nonpotential magnetic-drift waves in a plasma of finite pressure ($\beta \gtrsim 1$) [3, 4]. It follows from these studies that in systems with $\beta \sim 1$ the conditions for the excitation of magnetic-drift waves depend in essential fashion not only on the density and temperature gradients of the plasma, but also on the magnetic-field gradient.

The present paper is devoted to a study of magnetic-drift instability in a θ-pinch system. The length and diameter of the coil for the production of the magnetic field was 34 kOe at a discharge half-period 5.6 μsec. Figure 1-1 shows oscillograms of the magnetic field, measured with a magnetic probe placed on the discharge axis. It is clearly seen that at a definite instant of time t_1 there are excited in the discharge magnetic-field oscillations with amplitude on the order of the value of the external magnetic field.

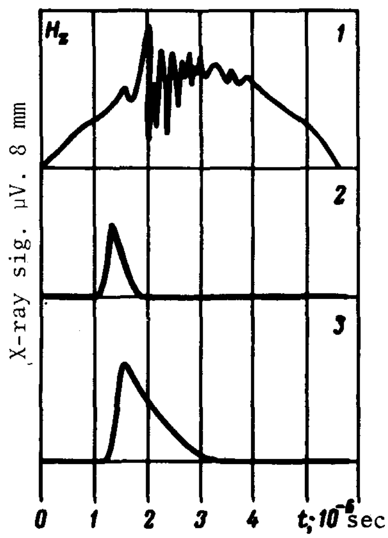

Fig. 1

An analysis of the electron temperature measured with an x-ray probe (see Fig. 1-3) and of the microwave radiation from the discharge near the upper hybrid frequency (Fig. 1-2) has shown that at that instant of time there excited in the discharge, obviously, a high-frequency kinetic instability connected with the acceleration of the electrons by the vortical electronic field of the θ pinch. This instability, as is well known, has a resonant character and is excited when one of the even harmonics of the electron cyclotron frequency becomes equal to the upper hybrid frequency $n\omega_{He} = \sqrt{\omega_{oe}^2 + \omega_{He}^2}$. It was shown in [3] that this instability leads to an intense turbulent heating of the plasma electrons in the central region of the discharge.

In our experiment, the plasma electron temperature reached at that instant of time a value on the order of several keV at a plasma density $n \simeq 10^{14}$ cm^{-3}. This corresponded to $\beta \sim 0.5$. It should be noted that in this case the ions remained practically cold.

Figure 2 shows the radial distributions of the amplitude of the low-frequency oscillations and of the electron temperature of the plasma, measured with magnetic and x-ray probes, respectively. It is clearly seen that the largest amplitude of the low-frequency oscillations of the magnetic field are in the region of the maximal gradient of the electron temperature of the plasma.

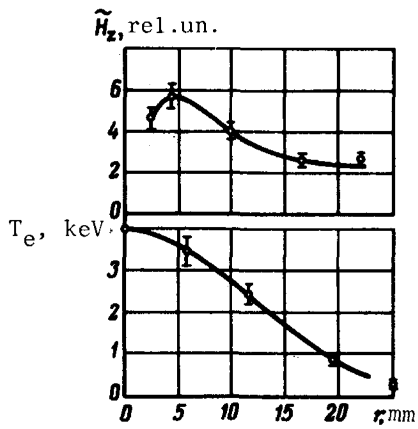

Fig. 2

A distinguishing feature of the investigated low-frequency instability is the presence of a wave structure along the magnetic field ($k_z \neq 0$). The correlation analysis of the signals from two magnetic probes located at different distances from each other along the system axis makes it possible to determine the dependence of the phase of the temporal harmonic of these oscillations. The oscillation wavelength obtained in this manner turned out to be $\sim$ 70 cm, corresponding to $k_z = 2\pi/\lambda_z \simeq 0.1$. There was no noticeable magnetic-field gradient along the axis in this interval of phase variation.

It must be emphasized that the instability observed in the present study is an electromagnetic wave whose frequency ω is much lower than the ion cyclotron frequency, the transverse length to the wave is of the order of the plasma-pinch radius, and the longitudinal length of half the wave is close to the length of the coil. The wave structure of the oscillations is the azimuthal direction for the first temporal harmonic (see Fig. 1) is shown in Fig. 3. It is clearly seen that in this case the azimuthal wave number is equal to unity and the wave propagates in the direction of the electron cyclotron rotation.

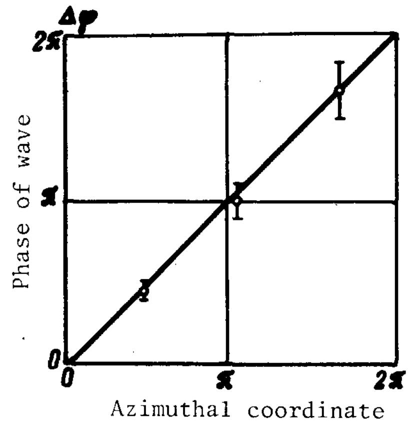

Fig. 3

In spite of the lack of a theory for the excitation of such long waves, it is useful to compare them with the known branches of drift oscillations. Since $\omega \sim \omega^* \sim 0.1 k_z v_{Te}$ (ω^* is the drift frequency and $v_{Te} \equiv \sqrt{T_e/m_e}$), it follows that, according to [4], the observed instability can be a branch of the magnetic-drift oscillations that are the natural continuation of the potential drift waves [1, 5] in the region $\beta \sim 1$. As shown in [1, 4], the drift oscillations are then excited both at $(\partial \ln T_e/\partial \ln n) < 0$ and at $(\partial \ln T_e/\partial \ln n) > 2$, and when the ion inertia is taken into account [2, 5], the drift instabilities take place even under conditions when $n \neq 0$ and $T_e = 0$.

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