LOW-FREQUENCY INSTABILITY OF ELECTRON-CYCLOTRON WAVES IN A PLASMA

B. I. PATRUSHEV, A. A. IVANOV, V. P. GOZAK, and D. A. FRANK-KAMENETSKIĬ*

Submitted March 26, 1970

Zh. Eksp. Teor. Fiz. 59, 1080—1082 (October, 1970)

Cyclotron heating of plasma electrons has been found to cause excitation of waves with a frequency ~ 100 MHz; these waves attenuate rapidly after the initial cyclotron wave is turned off. The maximum of the spectrum of the excited waves is close to the lower hybrid frequency, making it possible to identify them as anisotropic ion sound. The mechanism of their excitation can be attributed to distortion of the averaged distribution function of the electrons by high-frequency currents.

IN experiments on electron-cyclotron heating of plasma[1], we observed and investigated a high-frequency instability manifest in an excitation of waves at the cyclotron harmonics; soon afterwards, instability at the second harmonic was reported also in[2]. In[3] it is reported that noise of very low frequency ~100 kHz, was observed under similar conditions, where according to the theoretical estimates the instability increment should be very small. The theoretical papers[4,5] give grounds for expecting preferred excitation of waves in the vicinity of the lower hybrid frequency, which for the experimental conditions of[1,3] corresponds to frequencies higher by three orders of magnitude than ~100 MHz.

Accordingly, we have undertaken experiments aimed at recording alternating fields in the plasma in the indicated frequency region. Retaining the setup and the general procedure of the experiments in[1], we introduced into the plasma a double electric probe and its signal was fed through a filter and an amplifier, after detection, to an oscilloscope. A typical oscillogram at 140 MHz is shown in Fig. 1. As can be seen, a noise signal appears soon after turning on the magnetron that supplies the heating cyclotron waves. When the magneton is turned off, this signal vanishes within a time shorter than 5 μsec, from which it follows that, unlike the instability at the cyclotron harmonics, which is distinctly seen also in the afterglow, we have here an instability not of the plasma itself, but of the cyclotron wave in it.

The frequency spectrum of the oscillations observed by us is shown in Fig. 2; it has a maximum near 120 MHz. Under the conditions of the maximum development of the instability, this frequency is close both to the lower hybrid frequency and to the ion plasma frequency (under these conditions the electron cyclotron and electron plasma frequencies practically coincide). However, in spite of the growth of the concentration of the plasma by several times during the initial stage of the process, the noise amplitude at the chosen frequency remained practically unchanged (Fig. 1). We can therefore conclude that we did not observe a shift of the frequency spectrum as a function of the plasma concentration, i.e., that the peak of the spectrum is sooner tied to the lower hybrid frequency than to the ion plasma frequency. Consequently, the observed waves should be classified by their physical nature, not as ordinary but as anisotropic[4] ion sound.

*Deceased.

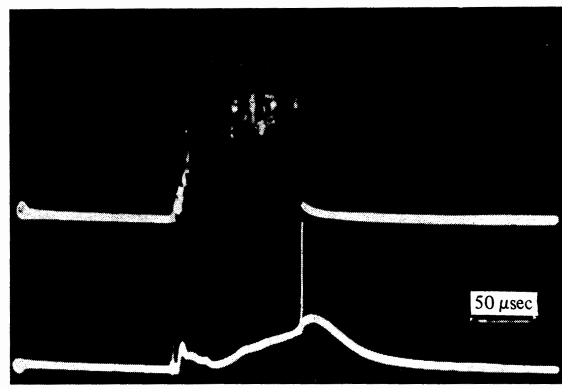
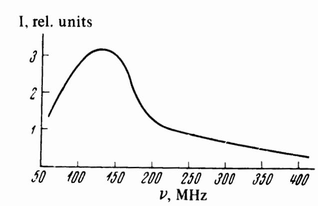


FIG. 1. Noise signal (upper curve) and concentration (lower curve) (the vertical line marks the instant of turning off the magnetron).

FIG. 2. Noise spectrum.



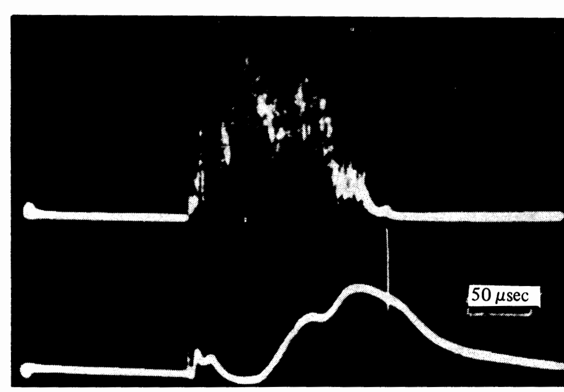


FIG. 3. Noise signal (upper curve) and concentration (lower curve) at an increased duration of the magnetron pulse (the vertical line denotes the instant when the magnetron is turned off).

When the magnetron pulse duration increases more than 100 μsec, and the plasma concentration goes through a maximum, the noise amplitude decreases sharp'y (Fig. 3). The cause of this drop calls for further investigations.

Only low-frequency noise was observed in[3]. It can be naturally attributed to relaxation oscillations arising as a result of ejection of the plasma from the system when the instability develops.

The mechanism of the observed instability requires further research. It is probably connected with a distortion of the averaged distribution function of the electrons by the high-frequency currents. This is apparently exactly the physical nature of the instability calculated in the theoretical paper[5]. The interaction of the wave excited during instability with the initial wave affords a reasonable explanation of the broadening of the spectrum of the cyclotron wave in the plasma, which leads, as shown in our paper[6], to a stochastic heating of the electrons.

We are grateful to R. Z. Sagdeev for valuable discussions.

[1] B. I. Patrushev, V. P. Gozak and D. A. Frank-Kamenetskiĭ, Zh. Eksp. Teor. Fiz. 56, 99 (1969) [Sov. Phys.-JETP 29, 56 (1969)].

[2] R. A. Blanken, T. H. Stix and A. F. Kuckes, Plasma Phys., 11, 945 (1969).

[3] J. Musil, F. Zacek, J. Datlov and J. Teichmann, Plasma Phys., 11, 961 (1969).

[4] V. I. Aref'ev, I. A. Kovan and L. I. Rudakov, ZhETF Pis. Red. 7, 286 (1968) [JETP Lett. 7, 223 (1968)].

[5] Yu. M. Aliev and D. Zyunder, Zh. Eksp. Teor. Fiz. 57, 1324 (1969) [Sov. Phys.-JETP 30, 718 (1970)].

[6] A. A. Ivanov, M. D. Spektor and D. A. Frank-Kamenetskiĭ, ZhETF Pis. Red. 11, 136 (1970) [JETP Lett. 11, 84 (1970)].

Translated by J. G. Adashko
124