STABILIZATION OF THE ANTISYMMETRICAL MODE OF CYCLOTRON INSTABILITY OF A LOW-DENSITY PLASMA IN OGRA-2 WITH THE AID OF A FEEDBACK SYSTEM

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Submitted 9 January 1970
ZhETF Pis. Red. 11, No. 4, 213 - 215 (20 February 1970)

The plasma density in the Ogra-2 apparatus, a trap with injection of fast atoms [1] in a simple mirror field, is limited by flute instability at the 10^7 cm^{-3} level. Depending on the magnetic field, there can develop at this density either a symmetrical mode of cyclotron instability with wave number m = 1 (perturbation potential $\phi(z) = \phi(-z)$, z axis directed along the axis of the apparatus), or else an antisymmetrical mode ($\phi(z) = -\phi(-z)$).

Suppression of the simplest, symmetrical mode of cyclotron instability with the aid of feedback was reported in [2]. In this paper we report the possibility of suppressing the mode with more complicated wave structure, the antisymmetrical one (Fig. 1). This mode leads to a broadening of the plasma along the axis of the apparatus. Two foil detectors [1] registered the flux of fast charge-exchange neutrals. The first detector was located in the central plane of the trap, and the second at a distance z = 18 cm away. In the absence of the antisymmetrical cyclotron-instability mode, the plasma dimension along the z axis did not exceed 20 cm and the neutral flux registered by the second detector was smaller by a factor of 100 than that of the first. In the presence of the antisymmetrical mode, the flux at the second detector was smaller than that of the first by a factor 5 - 10.

According to the theory developed in [2], when the potential of the cyclotron-instability oscillations is subject to the boundary condition

$$\phi_b = \delta\phi_{pl},$$

where ϕ_b is the potential on some surface surrounding the plasma, ϕ_{pl} is the potential of the oscillations on the surface of the plasma, and δ is a coefficient (generally complex and dependent on the frequency and the wave vector), the instability can be stabilized by suitable choice of δ. The maximum suppression of the instability occurs when $|\delta| \simeq 1$ and $\arg\delta = -\pi/2$. Physically, suppression of the cyclotron instability means that the damping decrement introduced by the feedback system is larger than the instability-development decrement.

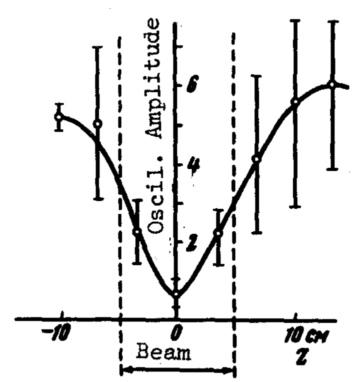

Fig. 1. Oscillation amplitude distribution along apparatus axis. The amplitude scatter during one injection pulse is shown.

The feedback system included an electrostatic antenna offset from the central plane of the trap by a distance equal to half the plasma radius, and located on the surface of the vacuum chamber. The signal from the antenna was fed through two paraphase symmetrical inputs to two electrodes located near the plasma boundary

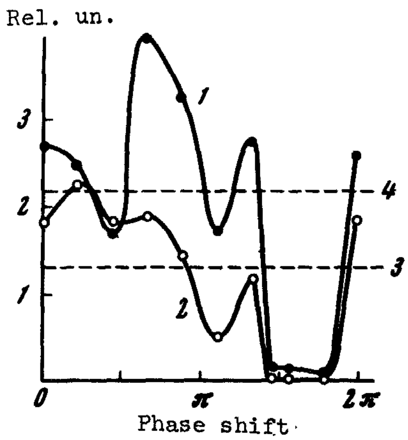

Fig. 2. Oscillation amplitude (curve 1) and flux of neutral particles to second foil detector (curve 2) vs. phase shift in the feedback circuit. The dashed lines indicate the oscillation level (3) and the flux of charge-exchange neutrals to the second foil detector, respectively, without the feedback. The phase is reckoned from an arbitrary value. The oscillation frequency is 17 MHz.

symmetrically relative to the central plane of the trap. The total length of the electrodes in the direction of the trap axis was twice the plasma dimension in the same direction. The electrodes subtended an azimuthal angle of 30°. The displacment of the antenna in the azimuthal direction relative to the electrodes was compensated for by varying the delay in the feedback network, with which the phase of the electrode-potential oscillations was regulated. Except for this item, the mutual placements of the antenna and of the electrodes did not affect the results of the experiments.

Figure 2 shows the amplitude of the cyclotron oscillations and the neutral flux to the second foil detector as functions of the phase shift in the feedback circuit. The null of the phase was chosen arbitrarily. It is seen that the oscillation amplitude and the fast-neutral flux to the second detector decrease appreciably in a certain phase interval. The small residual level of the oscillations was due to the symmetrical mode, which was not suppressed by this system. An estimate shows that the greatest suppression occurs at $|\delta| \sim 1$ and at a phase $\sim -\pi/2$.

Stabilization of the instability was observed in a relatively narrow phase interval spanning about 60°. We note that unlike the results of [2], where the symmetrical cyclotron-instability mode was suppressed, the range of gain coefficients at which the antisymmetrical mode is suppressed is small and does not exceed 10 dB. One cannot exclude the possibility that the condition calling for the decrement introduced by the feedback to exceed the instability increment is satisfied only in the observed phase interval. If this is so, then the phase interval in which stabilization is observed might be increase by increasing the fraction of the plasma surface covered by the electrodes (by increasing the number of electrodes and accordingly the number of feedback loops).

[1] Artemenkov et al., Plasma Physics and Controlled Nuclear Fusion Research(Proc. II Intern. Conf. on Plasma Physics, Culham, 1965), 2, 45, Vienna.

[2] V. V. Arsenin, V. A. Zhil'tsov, V. Kh. Likhtenshtein, and V. A. Chuyanov, ZhETF Pis. Red. 8, 69 (1968) [JETP Lett. 8, 41 (1968)].