Stabilization of plasma drift instability in a stellarator by an alternating electric field near the frequency of the lower hybrid resonance

V. S. Voĭtsenya, A. Yu. Voloshko, S. I. Solodovchenko, and
A. F. Shpan'

Physicotechnical Institute, Ukrainian Academy of Sciences

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We have observed, in the "Saturn" stellerator, stabilization of the drift instability of a microwave discharge plasma in hydrogen externally excited by an alternating electric field near the lower hybrid resonance.

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Investigations of the stabilizing action of alternating electric and magnetic fields on plasma instabilities have become of late traditional in plasma physics.[1] Particular interest attaches to the lower-hybrid-resonance (LHR) frequency range, which is promising from the point of view of plasma heating. We describe below preliminary results, obtained with the "Saturn" stellerator, on the stabilization of drift instability of a microwave discharge plasma by an alternating electric field near the LHR frequency.

The experimental setup is illustrated in Fig. 1. The microwave-discharge plasma was produced in hydrogen by a stationary magnetron ($\lambda \sim 3$ cm) with a power $\leqslant 15$ W (*6*). Typical plasma parameters are $n_e = 10^{10}$–10^{11} cm^{-3}, $T_e = 5$–10 eV, and $T_i < 1$ eV. The magnetic field was $H_0 = 3.1$ kOe. The density was changed by changing the microwave power fed to the plasma. The average plasma density was determined from the shift of the resonant frequency of the vacuum chamber (*3*) excited by a 4-mm klystron. To excite RF waves in the plasma, we used a system similar to that employed earlier in Ref. 2 (experiments on RF heating). This system excited mainly slow waves,[3] for which $E_z \gg E_\phi$. Oscillations near the LHR frequency, which was close to ω_{pi} under our conditions $[(\omega_{pe}/\omega_{He})^2 \ll 1]$, were excited by a stationary RF generator (*1*) rated several watts, at a frequency 32 MHz. The Rf oscillations were fed from the generator through a matching unit to the exciting electrode (*2*), a metallic plate 2 cm wide (along the magnetic field) and 8 cm long, located at the plasma boundary (its location is marked by the arrow in the insert of Fig. 1). The amplitude of the RF fields in the plasma was measured with a coaxial probe (*4*). The LF oscillations of the plasma density and of the electric field, due to the drift instability, were measured with a combined Langmuir probe (*5*) on the density gradient ($r = 4$ cm). The characteristics of these oscillations for an argon plasma are described in detail in Ref. 4.

It was observed that, without the RF generator, the levels of the LF oscillations of the density and of the electric field increase monotonically with increasing n_e, as does the associated turbulent plasma flow. When the RF generator is turned on, a slower growth of the LF oscillations is observed. Figure 2 shows the oscillograms of the

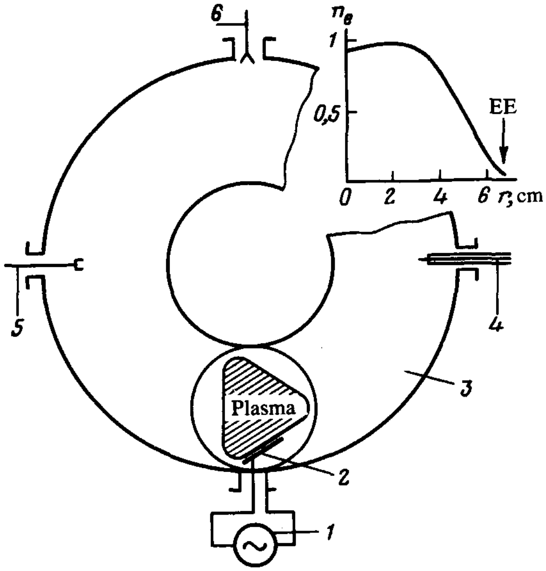

FIG. 1. Experimental setup.

envelope of the RF signal from the coaxial probe and the amplitude of the LF oscillations. The horizontal coordinate corresponds to a monotonic increase of the plasma density. It is seen that the level of the LF oscillations increases with increasing n_e, and when a certain density value is reached the level decreases resonantly. At that instant one observes also a decrease of the amplitude of the RF signal in the plasma (upper oscillogram); this seems to indicate effective absorption of the RF power near this value of the plasma density.

Results of more careful measurements with discrete variation of the value of n_e are shown in Figs. 2(b) and 2(c). An abrupt decrease of the level of the LF oscillations of the electric field and of the turbulent flow [Fig. 2(c)] seems to occur when $n_e \approx 2.5 \times 10^{10}$ cm^{-3} in the region of the density gradient, i.e., when $\omega_{pi}/2\pi$ is equal to the frequency of the RF generator ($f = 32$ MHz). Addition of argon to the hydrogen led to an increase of that value of n_e at which a resonant decrease of the amplitude of the drift oscillations was observed, in proportion to the ratio n_{Ar}/n_{H_2} in accord with the LHR frequency shift.

The influence of the amplitude of the RF voltage applied to the exciting element on the level of the drift oscillation is illustrated in Fig. 3. The ordinates represent here the level ratio of the LF oscillations, obtained with (A_{RF}) and without (A_0) the RF voltage, for two values of the plasma density: 1) $n_e = n_{LHR}$ and 2) $n_e > n_{LHR}$. In either case the change of the LF oscillations as a function of the RF voltage had a threshold. In the resonance case 1), the decrease of the oscillation amplitude started at a lower RF voltage.

We have thus observed experimentally an appreciable ($A_{RF}/A_0 \approx 0.3$) stabilization of the drift oscillations by the RF field excited in the plasma at a frequency close to the LHR frequency. Among the possible mechanisms responsible for the observed

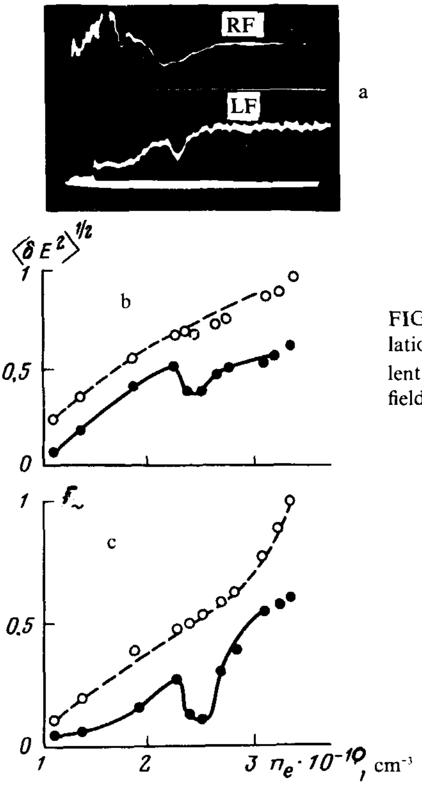

FIG. 2. Amplitude of the RF signal and LF plasma density oscillations $\langle n_\lambda^2 \rangle^{1/2}$ (a), fluctuations of the electric field (b) and turbulent flux (c) as functions of the plasma density: O—without RF field, ●—$U_{\rm RF} = 110$ V, just as for the oscillograms.

effects, mention can be made of the increase of the effective frequency of the collisions of the ions with the RF field ($\nu_i \sim \omega_{pi} \widetilde{W}/nT$) when the latter becomes randomized[5] or the stabilizing action of the large E_z component[6,7] of the RF field of the slow wave in

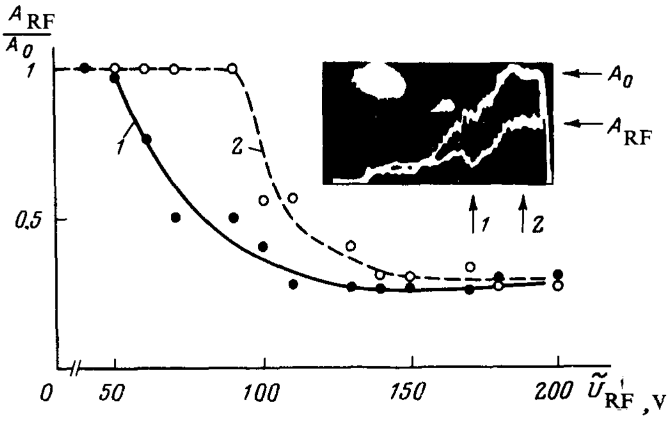

FIG. 3. Effect of RF field on the amplitude of the fluctuations of the plasma density for two values of n_e: 1) $n_e = n_{\rm LHR}$; 2)$n_e > n_{\rm LHR}$.

the LHR region. The threshold dependence of the oscillation level on the RF voltage points also to the possibility of parametric effects that lead to stabilization of the drift instability.[8]

It should be noted that in the described experiments, buildup of LF oscillations was observed in some cases when an RF field was applied. The next stage of our investigations is therefore the determination of the mechanisms and conditions that lead both to stabilization and to excitation of the LF oscillations.

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