quadratically, as should be the case on the basis of the two-band theory [8,9].

The decrease of resistance in strong fields when H is parallel to the binary and bisector axes is apparently the result of the rearrangement of the energy spectrum and the appearance when H > 320 kOe of a new "three-ellipsoid" hole equal-energy surface, which greatly increases its electric conductivity.

For more data on this question, measurements in stronger fields are necessary.

We take this opportunity to thank M. Ya. Azbel' for a discussion of the results and valuable remarks, A. I. Shal'nikov for interest in the work, N. L. Shofman, T. V. Gorskaya, and A. N. Radionova for help with the measurements, and senior machinist A. P. Popov for the high grade mechanical work.

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STABILIZATION OF LOW-FREQUENCY PLASMA INSTABILITIES

Ya. B. Fainberg and V. D. Shapiro
Physico-technical Institute, Ukrainian Academy of Sciences
Submitted 8 May 1966
ZhETF Pis'ma 4, No. 1, 32-36, 1 July 1966

1. Several possible ways of stopping microscopic instabilities of a plasma were indicated earlier [1,2]. One of these methods is to modulate the beams of charged particles with external high-frequency fields. Theoretical and experimental research [3,4] has confirmed the efficacy of such a method for stabilization of two-stream instability. Stabilization of two-stream instability by means of a high-frequency electric field was considered by Aliev and Silin [5].

In this note we investigate the possibility of stabilizing drift instability of an inhomogeneous plasma by superimposing an external high-frequency electric field

$$E_0(t) = \mathcal{E}_0 \cos\Omega t,$$

parallel to the magnetic field. High-frequency stabilization of hydrodynamic instabilities of a plasma were considered earlier [6].

2. Let us see how the frequency of the drift waves is altered by the electron oscillations in a high-frequency electric field. We seek the dependence of all the quantities in the drift wave on r and t, in the quasiclassical approximation, in the form

$$\exp[i(\int k_x d_x + k_y y + k_z z - \omega t)].$$

We substitute in the equation of motion of the electrons along H_0 the perturbed electron velocity and density in the form

$$v_{ze} = \nu_z \exp(-ia \cos\Omega t),$$

$$n_e = \eta_e \exp(-ia \cos\Omega t) \quad (a = [k_z e\mathcal{E}_0]/[m_e\Omega^2])$$

and average over the high-frequency oscillations; we then obtain for $\omega \ll k_z\sqrt{T/m_e}$

$$\langle E_z \exp(ia \cos\Omega t)\rangle = -ik_z \frac{T}{en_0} \langle \eta_e \rangle. \qquad (1)$$

We represent the electric field E_z in the form $E_z = \langle E_z \rangle + E_z^{(1)}$, where $E_z^{(1)}$ is the high-frequency part of the field. Determining $E_z^{(1)}$ from the Poisson equation, we obtain for $a \ll 1$ the following relation for $\langle E_z \rangle$:

$$\langle E_z \rangle = -\frac{ik_z}{en_0}\left(T + \frac{2\pi e^2 n_0 a^2}{k^2}\right)\langle \eta_e \rangle. \qquad (2)$$

The averaged continuity equation for the ions is written when $\omega \gg k_z\sqrt{T/m_i}$ in the form

$$-i\omega \langle n_i \rangle + (c/H_0) \langle E_y \rangle (dn_0/dx) = 0. \qquad (3)$$

Substituting $\langle E_z \rangle$ from (2) in (3) and using the quasineutrality condition for the averaged densities, $\langle n_i \rangle \simeq \langle \eta_e \rangle$, which is valid when $a \ll 1$, we obtain

$$\omega = -k_y \frac{T}{m_i \omega_{Hi}} \kappa(1 + \beta), \qquad (4)$$

where

$$\kappa = d \ln n_0/dx, \quad \beta = a^2/2k^2\lambda_0^2 = \frac{1}{2}\left(\frac{\omega_{0e}^2 k_z^2}{\Omega^2 k^2}\right)\left(\frac{m_e u_0^2}{T}\right)$$

($u_0 = e\mathcal{E}_0/m_e\Omega$ is the amplitude of the electron velocity in the external field). In deriving (2) we have neglected terms of the type $a\langle(\eta_e^{(1)} - n_i^{(1)}) \cos\Omega t\rangle$ (the index "1" denotes the high-frequency part of the density) compared with $a^2\langle \eta_e \rangle$. For this to hold true when $\Omega \ll \omega_{He}$ it is necessary that the frequency Ω be high compared with the characteristic frequencies of the Langmuir plasma oscillations with "magnetized" electrons:

$$\Omega \gg \left(\omega_{0e}^2 \frac{k_z^2}{k^2} + \omega_{0i}^2\right)^{\frac{1}{2}}, \quad \frac{\omega_{0e}^2}{\omega_{He}} \frac{k_y \kappa}{k^2} \quad \left(\omega_{0\alpha}^2 = \frac{4\pi e^2 n_0}{m_\alpha}, \quad \omega_{H\alpha} = \frac{eH_0}{m_\alpha c}, \quad \alpha = e, i\right).$$

The presence of the high-frequency field leads, according to (2) and (4) to an increase of the electric field in the drift wave $\langle E \rangle$ and its frequency ω. With increasing ω the stabilizing term of the form

$$\frac{\partial f_0^e}{\partial v_z}\left(\frac{\omega}{k_z}\right) \simeq -\frac{m_e\omega}{Tk_z} f_0^e(0)$$

increases in the expression for the growth increment γ of the drift wave. In order to determine the width of the interval of the values of the parameter $\xi = d \ln T/d \ln n$, in which high-frequency stabilization takes place, let us estimate the work performed by the drift wave on the resonant electrons (see [7]):

$$-e \langle E_z\rangle \langle \int v_z f_1^e d\vec{v}\rangle = -\frac{\pi e^2}{m_e}\frac{\omega}{k_z|k_z|}\left(\frac{\partial f_0^e}{\partial w} - \frac{k_y}{k_z}\frac{1}{\omega_{He}}\frac{\partial f_0^e}{\partial x}\right)\Bigg|_{w = \omega/k_z},$$

$$\langle E_z\rangle \langle E_z \exp(ia \cos\Omega t)\rangle = \tfrac{1}{4}\sqrt{T/2\pi m_e}\,\frac{\omega_{0e}^2}{\omega_{He}^2}\frac{k_y^2\kappa^2}{k_z^2|k_z|}\,(\beta + \tfrac{1}{2}\xi)\,\langle E_z^2\rangle, \quad (5)$$

where we put

$$f_0^e = n_0(x)\sqrt{m_e/2\pi T(x)}\,\exp(-m_e w^2/2T(x), \quad w = v_2 + u_0 \sin \Omega t.$$

The high-frequency field leads thus to stabilization of the drift instability in the interval $-2\beta < \xi < 0$.

3. We present also the solution of the dispersion equation for a collisionless "drift" instability in a plasma situated in a high-frequency field in the case when $k_z\sqrt{T/m_i} \ll \omega \ll \sqrt{T/m_e}$ and the Larmor radius of the ions is finite, $\rho_i = (k_\perp/\omega_{Hi})\sqrt{2T/m_i} \sim 1$. The dispersion equation was obtained by the method used by Aliev and Silin [5]. In this case ω and γ are given by

$$\omega = k_y \frac{T}{m_i\omega_{Hi}}\kappa A(1 + \beta)\,\frac{1 - (\delta/2)\xi}{2 - A + \beta(1 - A)}\,; \quad (6)$$

$$\gamma = \sqrt{(\pi/2)(T/m_e)^3}\,\frac{k_y^2\kappa^2}{k_z}\,\frac{A}{\omega_{He}^2}\,\frac{1 - (\delta/2)\xi}{[2 - A + \beta(1 - A)]^3}\,\{2(1 - A) + \beta(1 - 2A) - \tfrac{1}{2}\xi[2 - A(1 + \delta) + \beta(1 - A + \delta\cdot A)]\}. \quad (7)$$

We have used here the notation

$$A(\rho_i) = \exp(-\rho_i^2/2)I_0(\rho_i^2/2), \quad \delta = \rho_i^2[1 - I_1(\rho_i^2/2)I_0^{-1}(\rho_i^2/2)].$$

As $a \to 0$ formulas (6) and (7) go over into the results of Galeev et al. [7]. The influence of the high-frequency oscillations becomes noticeable when $a \gtrsim k\lambda_0$, i.e., when $u_0 \gg \sqrt{T/m_e}$ in the case considered in the present note, for which $\Omega \gg \omega_{0e}k_z/k$. It follows from (7) that the width of the interval in which high-frequency stabilization takes place is maximal when $\rho_i \to 0$. With increasing ρ_i this width decreases and tends to zero as $\rho_i \to \infty$. It must be noted, however, that when $\rho_i \sim 1$ and β is sufficiently large, the oscillation growth increment determined by (7) decreases noticeably ($\gamma \sim 1/\beta^2$).

4. A high-frequency electric field can also stabilize drift instability of a plasma with frequent collisions (drift-dissipative instability [8,9]), but this calls for larger field

amplitudes than in the case of a "collisionless" drift instability. The dispersion equation for the drift-dissipative instability in the presence of a high frequency field is

$$\omega^2 + \omega[i\omega_s - \beta \frac{\omega_{0i}^2}{\omega_{Hi}} k_y \kappa \lambda_0^2] + i\omega_e \omega_s - \beta \omega_{0i}^2 \frac{k_y^2}{k_\perp^2} \kappa^2 \lambda_0^2 = 0, \quad (8)$$

where

$$\omega_s = (k_z^2/k_\perp^2)(\omega_{He}\omega_{Hi}/\nu)(1 + \beta \frac{\omega_{0i}^2}{\omega_{Hi}^2} k_\perp^2 \lambda_0^2),$$

ν is the electron-ion collision frequency, and

$$\omega_e = k_y \frac{T}{m_i \omega_{Hi}} \kappa (1 + \beta)(1 + \beta \frac{\omega_{0i}^2}{\omega_{Hi}^2} k_\perp^2 \lambda_0^2)^{-1}.$$

As $a \to 0$ Eq. (8) goes over into the result of Galeev et al. [8] It follows from this equation that for high-frequency stabilization of drift-dissipative instability it is sufficient to use field amplitudes for which $\omega_{Hi} \ll a \ll 1$.

The authors are grateful to B. B. Kadomtsev and A. B. Mikhailovskii for a discussion of the results and to V. I. Shevchenko for help with the work.

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1) In a dense plasma ($\omega_{0e} \gtrsim \omega_{He}$) it is necessary to make substitution $\beta \to N^1\beta$, where $N = 1 + \omega_{0e}^2/\omega_{He}^2$, and the condition for the frequency Ω then takes the form

$$\Omega \gg N^1(\omega_{0e}^2 \frac{k_z^2}{k^2} + \omega_{0i}^2)^{\frac{1}{2}}, \quad N^1 \frac{\omega_{0e}^2}{\omega_{He}} \frac{k_y \kappa}{k^2} .$$