is the nonlocal connection between the heat flux and the temperature gradient. The nonlocality, of course, takes place in the collisionless regime, when $\ell_N >> d$. Thus, the rotation remains at arbitrarily low temperatures. In solid helium samples of the usual size, rotation should exist at $T < 1^\circ K$. Unfortunately, we cannot predict accurately the magnitude of the rotation torque, since the degree of localization of the impurities at these temperatures is not known. Measurements of the gyrothermal effect can cast light on this question.

In conclusion we note that, besides the above-described gyrothermal effect, there exists a gyroelectric effect, whereby the flow of electric current through a single-crystal metallic rod in the collisionless or hydrodynamic regime [2, 4] imparts a torque to the rod. Like the phonons, the electron gas rotates as it moves along the rod, and as a result of the conservation of the angular momentum the crystal lattice rotates in the opposite direction. It is probably more convenient to register this effect not by determining the rotation of the rod, but by determining the magnetic field directed along the axis of the rod and produced by the rotating electrons. This field may be appreciable, since a long rod is equivalent to a solenoid with a large number of turns.

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POSSIBILITY OF SUPPRESSING FLUTE INSTABILITY OF A DENSE PLASMA

V. V. Arsenin

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Experiments with a rarefied plasma using the "Ogra-2" and "Phoenix" apparatus [1, 2] have confirmed the possibility, predicted in [3, 4], of suppressing flute instability in a plasma with the aid of a feedback system controling the field of the perturbation outside the plasma. At the same time, experiments with "Phoenix" have shown that, owing to the dependence of the transfer function δ (see below) of a real high-frequency circuit on the frequency, oscillations may build up (at sufficiently large δ) at frequencies determined not by the plasma but by the high-frequency system. The plasma instability proper can then be suppressed. This possibility was not taken into account in the elementary theory [4]. The value of δ required for stabilization by the method of [1, 4] increases with plasma density. Therefore, when the system of [1, 4] is used to stabilize a dense plasma, the difficulty caused by the appearance of an additional unstable solution becomes aggravated. It will be shown below that oscillations of a dense plasma can be suppressed without exciting the system at the "extraneous" frequencies, if one "measures" not the perturbation of the electric potential, but the perturbation of the electron (or ion) density. The transfer function of the equivalent circuit responding to perturbation of the potential should depend on the frequency like ω^{-1}.

Let us examine the stability of a cylinder of collisionless plasma of radius a and

and concentration $n(r)$ with a sharp boundary (the thickness ℓ of the layer in which the density drop takes place is much smaller than a) in a simple mirror field, against potential perturbations $\psi = \phi_m(r) \exp(im\theta - i\omega t)$, where θ is the azimuthal angle and $m \geq 1$. We confine ourselves to perturbations of the surface-wave type, in which $\phi_m(r)$ has no zeroes when $0 < r < a$. We assume that a special high-frequency circuit made up of pickups and amplifiers maintains the "boundary" condition $\theta(b) = \delta(\omega)\phi_m(a)$, with $b > a$. The function $\delta(\omega)$ characterizes the high-frequency circuit. Then, in the most interesting case of a dense plasma $\omega_{0i} > \omega_{Hi}$ (ω_{0i} and ω_{Hi} are the ion Langmuir and cyclotron frequencies), the dispersion equation takes the form

$$1 + [\omega^{-1} - (\omega + m\omega^*)^{-1}]\,\omega_{Hi} = 2(\rho^m - \rho^{-m})^{-1}\omega_{0i}^{-2}\,\omega_{Hi}^2\,\delta(\omega), \tag{1}$$

where ω^* is the frequency of ion precession due to the inhomogeneity of the magnetic field, and $\rho = ba^{-1}$.

In [4] we considered the case when δ is a real constant in the region of frequencies characteristic of flute instability, $|\omega| \leq (\omega_{Hi}\,\omega^*)^{1/2}$, so that Eq. (1) is quadratic. When $\delta > 0.5\,(\delta^m - \delta^{-m})\,\omega_{0i}^2\,\omega_{Hi}^{-2}$, the roots are real (stability). However, in addition to these roots, Eq. (1) can also have unstable solutions (which were not considered in [4]) in the region $|\omega| > (\omega_{Hi}\omega^*)^{1/2}$, where the dependence of δ on ω is significant (the degree of the equation increases). We consider here another possibility. Let

$$\phi_m(b) = m\omega_{0i}^2(\omega_{Hi}\,\omega)^{-1}\Delta(\omega)\,\phi_m(a), \tag{2}$$

with $\Delta(\omega)$ close to a real constant Δ_0 at $|\omega| < \Omega \equiv \alpha(m\omega_{Hi}\omega^*)^{1/2}$, $\alpha \gg 1$, and $|\Delta|<|\Delta_0|$ in the region $|\omega| > \Omega$, $\mathrm{Im} > 0$.

We introduce $\bar{\Delta} \equiv 2m(\rho^m - \rho^{-m})^{-1}\Delta_0$. Equation (1) can have solutions $|\omega| > \Omega$, $\mathrm{Im}\,\omega > 0$, only if $|\bar{\Delta}|\,\omega_{Hi} > \Omega$. We assume that $|\bar{\Delta}|\omega_{Hi} < \Omega$, so that only solutions with $|\omega| < \Omega$ can be unstable ($\mathrm{Im}\,\omega > 0$). In this region we put in first approximation, $\Delta = \Delta_0$, and then Eq. (1) becomes quadratic. The roots are real if $\bar{\Delta}^2 > 4m\omega_{Hi}^{-1}\omega^*$. When account is taken of the deviation of Δ from Δ_0, the roots acquire imaginary increments. The oscillations attenuate if for both roots

$$\mathrm{Im}\,\Delta\,\omega\frac{d}{d\omega}\left(\frac{1-\bar{\Delta}}{\omega} - \frac{1}{\omega + m\omega^*}\right) < 0. \tag{3}$$

Thus, the flute perturbations are stable[1)] when

$$\alpha > (m\omega^*)^{-1/2}\,\omega_{Hi}^{1/2}\,\bar{\Delta} > 2 \tag{4}$$

and (3) is satisfied.

Relation (2) means that when $|\omega| < \Omega$ the high-frequency circuit follows the azimuthal component of the electric field on the plasma boundary (or the radial displacement of the

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1) An analogous sufficient condition for instability can be obtained for the hydrodynamic model, which can be readily seen to be equivalent to a system with $\delta \sim \omega_{01}^2\omega^{-2}$.

boundary), and integrates the signal with respect to time. In order for the plasma to be stable against flute perturbations during the course of slow accumulation or decay, it is necessary to vary the gain in proportion to the concentration. Since $m\omega_{0i}^2 (\omega_{Hi}\omega)^{-1} \phi_m = 4\pi e a \ell n_{em}$, where n_e is the perturbation of the electron density in the region $dn/dr \neq 0$, it follows that condition (2) will be realized if one "measures" directly n_e and $\psi(b) = 4\pi e a \ell \Delta n_e$. It can be stated that in a system responding to concentration oscillations, the role of that part of the high-frequency circuit which forms the required transfer function $\omega_{0i}^1 \omega^{-1}$ is performed by the plasma itself.

Let us consider one more possibility of stabilizing flute oscillations, namely by introducing controlled sources of electrons inside the plasma [5, 6][2]. Let the source intensity be proportional to the perturbation of the electron density: $S = sn_e$. The dispersion equation is

$$1 + [(\omega - is(\omega))^{-1} - (\omega + m\omega^*)^{-1}]\omega_{Hi} = 0\ . \tag{5}$$

Let $s = -i\omega\Delta_1$, where Δ_1 is a real constant in the region $|\omega| < \Omega$, i.e., $S = \Delta_1(\partial n_e/\partial t)$. When $|\Delta_1| \ll 1$, the sufficient condition for stability is

$$\Delta_1^2 > 4m\omega_{Hi}^{-1}\ \omega^*. \tag{6}$$

We consider another example, $s = i\omega\Delta_2$ $(S = \Delta_2(\partial n_e/\partial\theta))$, where $\Delta_2 > 0$. The oscillations are stable if

$$\Delta_2 > \omega^*\ . \tag{7}$$

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KINETIC DIAMGNETISM AND PARAMAGNETISM

L. E. Gurevich
A. F. Ioffe Physico-technical Institute, USSR Academy of Sciences

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A conducting medium in a non-equilibrium state, for example in the presence of a temperature gradient or an electric field, or else in the presence of convective motion, has special magnetic properties. Depending on the carrier-scattering mechanism and on the

[2]This method can be used to suppress not only surface but also internal (upper radial) modes.