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A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on December 26, 1974 at the conference hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. A. A. Galeev, R. Z. Sagdeev, V. D. Shapiro, and V. I. Shevchenko, Nonlinear Effects in an Inhomogeneous Plasma.
2. L. I. Dorman, Cosmic Rays and the Solar Wind.

We publish below brief contents of the papers.

A. A. Galeev, R. Z. Sagdeev, V. D. Shapiro, and V. I. Shevchenko, Nonlinear Effects in an Inhomogeneous Plasma. When an electromagnetic wave propagates in an inhomogeneous plasma, it is transformed at the plasma-resonance point $n = m\omega^2/4\pi e^2$ (ω is the frequency of the wave) into plasma oscillations [1]. Because of their low group velocity, plasmons accumulate in the neighborhood of the resonance. The increase in the longitudinal electric field in this region significantly lowers the threshold for the appearance of nonlinear effects, which takes the form [2, 3] $\epsilon = (H^2(0)\sin^2\theta/16\pi n_0 T)L^2/\lambda_D^2 > 1$. $H(0)$ is the magnetic field of the wave at the resonance point, θ is the incidence angle, L^{-1} is the unperturbed-density gradient, and λ_D is the Debye length. The principal nonlinear effects in the plasma-resonance region are deformation of the density profile by the high-frequency pressure force and dissipation of electromagnetic energy due to modulation instability.

Modulation instability results in the formation of "cavities"—regions of lowered density with plasmons trapped in them—in the neighborhood of resonance against the background of the rather smooth electric-field distribution. The "collapse" of the "cavities" and the growth of the field in them is a process of explosive nature (the singularity is reached during a finite time) and is limited on attainment of the short scales at which resonant absorption of plasmons by electrons becomes significant [4, 5]. Absorption occurs on fast electrons, the parameter $k\lambda_D < 1$, and the other dissipation mechanisms (energy transfer to ions of the plasma being displaced from the cavities, intersection of electron trajectories) are not as significant.

The average field in the resonant region acts as a pump wave for cavities with plasmons. Cavities are produced from the pump wave with a characteristic dimension $l \sim \lambda_D\sqrt{16\pi n_0 T/\langle E^2\rangle}$, which is much smaller at $\epsilon \gg 1$ than the width $\Delta z \sim L\langle E^2\rangle/16\pi n_0 T$ of the resonance. The subsequent collapse of the cavities results in short-wave pumping of plasmons into the part of the spectrum for which resonant attenuation on electrons is significant. The spectrum in the inertial range (between large scales, where energy is pumped into the cavities, and small scales, where attenuation occurs) is calculated from the condition of constant energy flux (Kolmogorov hypothesis): $|E_k|^2 \sim 1/k^{1+(r/2)}$ (r is the dimension of the collapsing cavities). The rate at which energy is pumped into the plasma turbulence is determined by the effective plasmon scattering frequency $\nu_{eff} = s\omega_p\langle E^2\rangle/16\pi n_0 T$, where s is a numerical coefficient; in machine experiments (see, for example, [6]), $s \approx 1/4$. The average energy in the turbulent fluctuations is found from the condition under which the energy dissipated from the pump wave is cancelled by the energy flux into the shortwave part of the spectrum, $\langle E^2\rangle \approx \langle E\rangle^2(Ms^2/m)\langle E\rangle^2/16\pi n_0 T$.

The spatial distribution of the average field in the neighborhood of resonance is determined by the solution of Maxwell's equations with a nonlinear dielectric constant in which the dissipation of electromagnetic energy is taken into account by introducing the effective collision frequency ν_{eff}. In this way, it is possible to obtain a quantitative explanation for experimental results on nonlinear effects in the plasma-resonance region that were obtained in a series of studies made at the University of California [7–9]. Displaced from the resonance neighborhood, the plasma forms a potential well in which plasmons are trapped. The average field in the region is found from the formula $\langle E\rangle = H(0)\sin\theta/\epsilon_N$; $\epsilon_N = -(z/L) + (\langle E_r^2\rangle/16\pi n_0 T)(1 + is)$ is a dielectric constant that takes account of both the displacement of the plasma by the high-frequency pressure force and the nonlinear dissipation of electromagnetic energy. The orders of magnitude of the field amplitude at resonance and the width of the resonance are

$$\frac{E_0^2}{16\pi n_0 T} \approx \left(\frac{m}{Ms^2}\right)^{2/5}\left(\frac{H^2(0)\sin^2\theta}{16\pi n_0 T}\right)^{1/5},$$

$$\Delta z \approx L\left(\frac{Ms^2}{m}\right)^{1/5}\left(\frac{H^2(0)\sin^2\theta}{16\pi n_0 T}\right)^{2/5}.$$

The coefficient of absorption of the wave (the ratio of the energy dissipated per unit time in the region of the plasma resonance to the energy flux in the incident wave) does not depend on s, and its maximum value $R_{max} \approx 0.4$. The phase of the field changes by π on passage through the resonance. Figures 1 and 2 show characteristic curves of the absolute value of the field vs. the coordinate. Figure 2 pertains to a case of rather weak dissipation in which the wave acts as an electromagnetic piston. The depth of penetration of the wave into the plasma is $\sim\Delta z/s^{2/5}$. The spatial-distribution features of the electric field that are characteristic for this case can be observed experimentally by switching the electromagnetic field on pulsewise, in which case there is not enough time for modulation instability to develop during the "on" time [10].

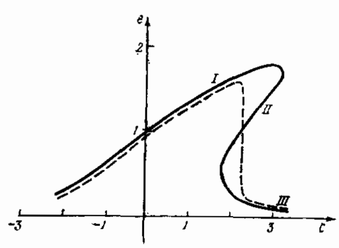

FIG. 1

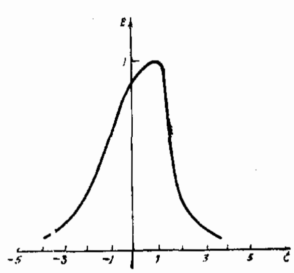

FIG. 2

The above formulas pertain to the case in which the field amplitudes in the incident wave are not very large: $(H_e^2/16\pi n_0 T) < \sqrt{m/Ms^2 \sin^2\theta}$. In this case, as in the linear theory[1], the wave penetrates into the plasma-resonance region at rather small angles $\theta \sim (c/\omega L)^{1/3}$. At large wave amplitudes, the penetration region broadens to values $\sin\theta \sim \sqrt{H_e^2/16\pi n_0 T\sqrt{Ms^2/m}}$. The basic result of the above analysis—the presence of an effective electromagnetic energy dissipation mechanism in the resonance region due to modulation instability—also persists in this case; this is a highly important point for the problem of initiating a pulsed thermonuclear reaction with powerful laser radiation[11].

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