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V. Kovalev, V. Pustovalov, A. Romanov, Vivien Stefan. TURBULENT PLASMA IN THE FIELD OF INTENSE HIGH FREQUENCY RADIATION. Journal de Physique Colloques, 1979, 40 (C7), pp.C7-609-C7-610. 10.1051/jphyscol:19797295 . jpa-00219284

HAL Id: jpa-00219284

<https://hal.science/jpa-00219284>

Submitted on 1 Jan 1979

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TURBULENT PLASMA IN THE FIELD OF INTENSE HIGH FREQUENCY RADIATION

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In present-day experiments dealing with the interaction of strong electromagnetic radiation with plasma high energy fluxes of the incident radiation are in use. For example, in the optical domain of frequencies the energy flux reaches the value of 10^{16} - 10^{17} W/cm² /1/. Along with this, situations when strong radiation propagates through the plasma with high level of turbulent noise are very often encountered (plasma focus /2,3/ or ionospheric plasma /4/). In the presence of the pump field turbulent plasma spectrum is affected in such a way that "failures" appear in the longwave domain when the wavelength is of the order of electron oscillation amplitude in the external field.

For the description of the homogeneous isotropic plasma interacting with the external radiation $E_0(t) = E_0 \sin \omega_0 t$ with the frequency ω_0 much higher than the electron Langmuir frequency ω_{Le} , Vlasov kinetic equation, in the form of the hydrodynamical system /5/, is used, on the base of which a nonlinear dispersion relation for the correlation function $\Psi = \langle \Psi_i \Psi_i^* \rangle = \frac{k^2}{2\alpha} |\Psi|^2$ can be obtained

$$\begin{aligned} & \Psi(k) \varepsilon_0(k) - \frac{2}{\varepsilon_0(k)} \int dk' dk'' \delta(k-k'-k'') \Psi(k') \Psi(k'') \times \\ & \times \left[\left(\alpha_i(k) \varepsilon_i^{(i)}(k, k', k'') + \frac{\beta(k) \beta(k') \beta(k'')}{\alpha_i(k') \alpha_i(k'')} \varepsilon_i^{(e)}(k, k', k'') \right) \times \right. \\ & \times \left(\alpha_i(k) \varepsilon_i^{(i)}(k, k', k'') + \frac{\beta(k) \beta(k') \beta(k'')}{\alpha_i(k') \alpha_i(k'')} \varepsilon_i^{(e)}(k, k', k'') \right) - \\ & \left. - \Psi(k) \int dk' dk'' \delta(k-k'-k'') \left[\frac{4}{\varepsilon_0(k'')} \left[\alpha_i(k) \varepsilon_i^{(i)}(k, k', k'') \times \right. \right. \right. \end{aligned} \quad (1)$$

$$\begin{aligned} & \left. \left(\alpha_i(k) \varepsilon_i^{(i)}(k, k', k'') + \frac{\beta(k) \beta(k') \beta(k'')}{\alpha_i(k') \alpha_i(k'')} \varepsilon_i^{(e)}(k, k', k'') \right) + \right. \\ & \times \left(\alpha_e(k) \varepsilon_e^{(e)}(k, k', k'') + \frac{\beta(k) \beta(k')}{\alpha_i(k') \alpha_i(k'')} \varepsilon_i^{(i)}(k, k', k'') \right) - \\ & \left. - 3 \alpha_i(k) \left[\varepsilon_2^{(i)}(k, k', k'') + \frac{\beta^2(k) \beta^2(k'')}{\alpha_i(k') \alpha_i(k'')} \varepsilon_2^{(e)}(k, k', k'') \right] \right\} \Psi(k'') = 0 \\ & \alpha_e(k) = 1 + \delta \varepsilon_e(k) (1 - J_0^2(\alpha)) \alpha_i(k) = 1 + \delta \varepsilon_e(k) (1 - J_0^2(\alpha)) \beta(k) = J_0(\alpha) \\ & \varepsilon_0(k) = 1 + \delta \varepsilon_0(k) + \delta \varepsilon_i(k) + \delta \varepsilon_e(k) \delta \varepsilon_i(k) (1 - J_0^2(\alpha)) \pm k = (\pm k, \pm \omega) \end{aligned}$$

Here $J_0(x)$ is Bessel function, $\delta \varepsilon_\alpha(\omega, \vec{k})$ partial plasma polarizability of " α " plasma component and $\varepsilon_i^{(i)}$ and $\varepsilon_e^{(e)}$ first and second nonlinear dielectric permeability of " α " plasma component.

In equation (1) the first addendum includes the effect of high-frequency field $E_0(t)$ on plasma dielectric permeability $\varepsilon_0(k)$ /6,7/ the change of nonlinear interaction of plasma waves in the presence of the high-frequency field is included in remaining addends.

Let us consider now the process of induced scattering of the Langmuir waves on particles in the external field $E_0(t)$ when $\omega \gg kv_{Te}, \omega' \gg kv_{Te}, \frac{\omega - \omega'}{|\vec{k} - \vec{k}'|} < v_{Te}$ is satisfied. For the spectral density of oscillation energy $W(k)$ the following equation is obtained

$$\begin{aligned} & \frac{\partial W(k)}{\partial t} + \frac{dW(k)}{dk} \frac{\partial W(k)}{\partial \vec{r}} = 2 \gamma(k) W(k) + W(k) \int Q(\vec{k}, \vec{k}') W(\vec{k}') d\vec{k}' \\ & Q(\vec{k}, \vec{k}') = \frac{1}{16\pi^3} \frac{e^2}{M_e^2} \frac{(\vec{k} \vec{k}')^2}{(k k')^2} \frac{k^2}{(\omega \omega')^2} \frac{\delta \varepsilon_e(k'') (1 - J_0^2(\alpha))}{\varepsilon_0(k'')} \end{aligned} \quad (2)$$

In a magnetized plasma, the turbulence of the oblique Langmuir waves, excited, for example, by encountering electron beams

with velocities $\pm \vec{u}_b$, parallel to magnetic field $\vec{B}_0$ is characterized by stationary spectral distribution /4/ which in a strong high-frequency field $a = (k \vec{r}_e) > 1$ appeared to be modulated over the frequency with the period $T_m \omega_e^2 u_b / e E_0$.

$$W(\vec{r}) \sim \tilde{S}(\cos \theta) \left(\frac{e E_0 u_b}{m \omega_e^2} \right) \delta(k - \frac{\omega_e}{u_b}), \vec{E}_0 \parallel \vec{B}_0.$$

$$\cos \theta = \vec{k} \vec{E}_0 / k B_0$$

Here $\tilde{S}(\cos \theta)$ describes angle distributions of plasma turbulent noise in the presence of the external field $\vec{E}_0(t)$. The characteristic modulation of the spectral distribution $(W_o^2(a))$ connected with the effective amplification of nonlinear interaction of waves in a strong high frequency field, appears in the form of kernel modification $(Q(\vec{k}, \vec{k}') \sim \nabla_o^2(\omega))$.

Spectral distribution (3) also describes the modulation of the plasma noise in the case when instabilities arise because of the presence of electron beams in the current-carrying plasma with velocity u_b (velocity of a beam is oriented along drift velocity $\vec{u}$, $(\vec{u} \vec{u}_b) > 0$). The angle distribution of plasma noise in that case, certainly, has other form /8/. Let us note that modulation of plasma noise by high-frequency external field appears if intensity of external field is strong enough $E_0 \sim \frac{m \omega_e^2}{e k}$. So, in the above case of current carrying plasma with electron beam defined by parameters $n_e = 10^{18} \text{ cm}^{-3}$, $n_b/n_e = 10^{-3}$, $u_b = 4 \cdot 10^9 \text{ cm/s}$, $u = 4 \cdot 10^7 \text{ cm/s}$, $T_e = T_i = T_b = 100 \text{ keV}$ characteristic for plasma focus, oscillations with wave number

with wave number $k \sim 2 \cdot 10^4 \text{ cm}^{-1}$ could be excited. Here n_b - particle density of beam electrons, n_e - particle density of current carrying plasma electrons, $T_{e,i}$ temperature of electrons (ions) of current carrying plasma and T_b temperature of beam electrons. In the case of using CO_2 laser as source of high-frequency field, necessary value of energy flux is $q \sim 4 \cdot 10^{14} \text{ W/cm}^2$, obtainable in present time devices.

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