has often been emphasized (see Ref. 5 and the literature cited there). However, there is as yet no definite point of view about the actual mechanism connecting this instability with the observed pulsar emission. This is connected with the complexity of the problem and the fact that the theory of two-stream instability has not been worked out sufficiently for the particular case of the pulsars. In particular, the results given above indicate that the dynamics of the Langmuir turbulence excited by that instability in the pulsar plasma must evidence itself appreciably differently from what would happen in a non-relativistic plasma. It is also clear that one needs further studies for an actual use of the ideas of Langmuir turbulence in the problem of the interpretation of pulsar emission.

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Possibility of diagnostics of magnetic fields in a laser plasma using the spectral composition of the scattered radiation

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The possibility of diagnostics of the spontaneous magnetic fields in a laser plasma using the spectral composition of the scattered radiation near $\omega_L/2$ is investigated. It is shown that at $\Omega\tau > 1$ it is possible to determine, from the shift of the spectral components, the intensity of the magnetic field and at sufficient spatial resolution also its orientation.

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Calculations and experiment[1,2] show that magnetic fields of the order of or larger than 1 MOe can be produced in a laser plasma because of the presence of spatial inhomogeneity of the density and of the temperature. This circumstance can influence the symmetrical compression and the heating of the laser target, so that it is important to have reliable information on the intensities and force-line configurations of the magnetic fields. Measurements with the aid of magnetic probes or by rotation of the plane of polarization encounter great difficulties because of the small dimensions and inhomogeneities of the laser plasma. It is of interest in this connection to be able to effect the diagnostics of the magnetic fields by means of the spectral composition of the scattered radiation near $\omega_L/2$ (ω_L is the frequency of the laser radiation). Diagnostics using the spectral composition of other harmonics ($3\omega_L/2, 2\omega_L$, etc.) is less direct because the interpretation of the $3\omega_L/2$ and $2\omega_L$ spectra calls for analysis of the mechanism of the coalescence of the waves that result from the decay.[3,4]

Magnetic fields generated in a laser plasma influence the dispersion of the electromagnetic waves and the processes of transformation of the incident radiation. Parametric instability of the pump wave near a density $n_{cr}/4$ can lead in a magnetoactive plasma to frequency shifts of the scattered waves relative to $\omega_L/2$ by an amount $\sim\Omega$ (the cyclotron frequency of the electrons),[5] if one of the scattered waves propagates collinearly with the laser radiation in a cone with apex angle $\lesssim k_0/k_L$ ($k_0 \equiv (\Omega\omega_p)^{\frac{1}{2}}/c$, $k_L = 3^{\frac{1}{2}}\omega_p/c$, $k_2 \sim k_L$), while the other has a wave vector $k_3 < k_0$. In this case $\omega(k_3) = \omega_p \pm \Omega/2$ or $\omega(k_3) = \omega_p$ at any orientation of the magnetic field relative to the vector $\mathbf{k}_3$.

To calculate the thresholds and the increments of the paramagnetic instability of the incident wave, we consider the system of equations for slow amplitudes of

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waves 2 and 3 that result from the decay:

$$-k_2^2\mathbf{E}_2+\mathbf{k}_2(\mathbf{E}_2\mathbf{k}_2)+i(\mathbf{k}_2\nabla)\mathbf{E}_2-i\mathbf{k}_2\operatorname{div}\mathbf{E}_2-i[\mathbf{k}_2\times\operatorname{rot}\mathbf{E}_2]$$

$$+\frac{\omega_2^2}{c^2}\hat{\varepsilon}(\omega_2)\mathbf{E}_2-i\frac{\omega_2^2}{c^2}\frac{\partial\hat{\varepsilon}(\omega_2)}{\partial k_2}\frac{\partial\mathbf{E}_2}{\partial x}=-\frac{4\pi i\omega_2}{c^2}\mathbf{j}_{\rm nl}(\omega_2), \quad (1)$$

$$\frac{\omega_3}{c^2}\hat{\varepsilon}(\omega_3)\mathbf{E}_3=-\frac{4\pi i\omega_3}{c^2}\mathbf{j}_{\rm nl}(\omega_3). \quad (2)$$

Here $\hat{\varepsilon}(\omega)$ is the dielectric tensor at the corresponding frequency in a coordinate frame in which the laser radiation propagates along the x axis ($\mathbf{k}_2 \| \mathbf{k}_L$) and the magnetic field lies in the (x,z) plane and makes an angle θ with the z axis (see Fig. 1); $j_{\rm nl}(\omega_i)$ is the nonlinear current at the frequency ω_i:

$$\omega_2=\omega_p+\frac{1}{3}\frac{\Omega^2\cos^2\theta}{\omega_p}+\frac{k_2^2v_T^2}{2\omega_p}, \quad \omega_3=\omega_p+\Delta,$$

where $\omega_L=\omega_2+\omega_3$, and $v_T=(3T/m)^{\frac{1}{2}}$. For the E_2 wave, the spatial dispersion is significant, since it is assumed that $k_2v_T>\Omega$ [the last term in the left-hand side of Eq. (1)]. Equation (2) is valid under the condition $(\Omega/\omega_p)^2<\nu/\omega_p$, where v is the effective collision frequency. At the same time it is assumed that the E_2 wave is weakly damped. This occurs if $\nu<\omega_p v_T^2/c^2$.

From the equations of motion for the electrons, using $\Omega\ll\omega_i$, we can obtain

$$\mathbf{j}_{\rm nl}(\omega_2)=\frac{e^3n_0\mathbf{k}_2}{m^2\omega_L\omega_2\omega_3}(\mathbf{E}_L\mathbf{E}_3^*), \quad \mathbf{j}_{\rm nl}(\omega_3)=\frac{e^3n_0(\mathbf{k}_2\mathbf{E}_2^*)}{m^2\omega_L\omega_2^2}E_L \quad (3)$$

From (1), by eliminating the components E_{2y} and E_{2z}, we can obtain an equation for the amplitude E_{2x}, by separating the $\exp(-i\omega_2t+ik_2x-\gamma_2x)$ dependence (at $k_2v_T>\Omega$):

$$-2ik_2\frac{\partial E_{2x}}{\partial x}=\frac{4\pi i\omega_p}{v_T^2}j_x(\omega_2)e^{\gamma_2x}, \quad \gamma_2=\frac{1}{2}\frac{\nu\omega_p}{k_2v_T^2}. \quad (4)$$

Solving Eq. (2) relative to the components of the field E_3 and substituting in (3), we obtain in the limit $\Omega>(\nu_T/c)^2\omega_L$:

$$j_x(\omega_2)=-\Lambda E_{2x}e^{-\gamma_2x}, \quad (5)$$

where

$$\Lambda=\frac{3\pi}{16}\frac{e^2}{m^2c^2}\Big[|E_{1y}|^2\frac{2i\Delta+\nu}{\Omega^2-4\Delta^2+\nu^2+4i\Delta\nu}$$
$$-\frac{i}{2\Delta-i\nu}|E_{1z}|^2\left(1+\frac{\Omega^2\sin^2\theta}{4\Delta^2-\Omega^2-\nu^2-4i\Delta\nu}\right)$$
$$-2i\operatorname{Im}(E_{1y}E_{1z}^*)\frac{\Omega\sin\theta}{4\Delta^2-\Omega^2-\nu^2-4i\Delta\nu}\Big].$$

By virtue of (4) and (5) the instability growth rate is equal to

$$\gamma_L=\frac{2\pi\omega_p}{k_2v_T^2}\operatorname{Re}\Lambda-\gamma_2$$

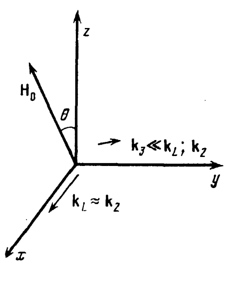

FIG. 1. Orientation of magnetic field and wave vectors of the incident and scattered waves.

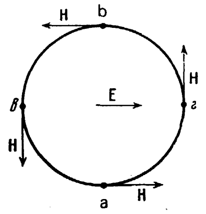

FIG. 2. Possible geometry of the magnetic field when a flat target is irradiated.

The threshold intensity is in this case of the order of $I_{\rm thr}\sim nmc^3(\nu/\omega_p)^2\sim10^{14}$ W/cm^2 for a plasma produced by a neodymium laser. At $\nu/\Omega<1$, the maximum value of γ_L corresponds to $\Delta=\pm\Omega/2$ (E_3 is an extraordinary wave) or $\Delta=0$ (E_3 is an ordinary wave). The frequencies of the scattered waves turn out to be in this case

$$\omega_2=\omega_L/2-\Delta/2+{}^3/_8(v_T/c)^2\omega_L, \quad (6)$$

and the radiation E_2 is concentrated in a narrow cone near the direction of the incident wave and

$$\omega_3=\omega_L/2+\Delta/2-{}^3/_8(v_T/c)^2\omega_L, \quad (7)$$

in which case the radiation E_3 propagates isotropically in the total solid angle.

Thus, the spectrum of the scattered radiation contains near $\omega_L/2$ components that are located at a distance $\sim\Omega/4$ from the center of the line. At $\nu/\Omega>1$, the scattered radiation spectrum should contain one peak with width $\sim\nu$. Since expression (5) depends on the angle θ and on the ratio of the polarizations of the incident wave, we can determine from the analysis of the spectra of the scattered radiation (at sufficient spatial resolution) makes it possible to determine the orientation of the magnetic field, while the position of the maxima can determine its intensity. For example, if the magnetic field lies in the target plane, then at normal incidence ($\theta=0$), for the polarization shown in Fig. 2, we can observe the components corresponding to $\Delta=0$ in reception of radiation from points *a* and *b*, and the components corresponding to $\Delta=\pm\Omega/2$ in reception of radiation from points *c* and *d*.

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