asymptotic behavior of $F_{\pm}(\omega)$ and obtained by a model-independent method [9].

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ABSORPTION OF LIGHT BY AN INHOMOGENEOUS LASER PLASMA

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A very important part of the problem of obtaining high temperatures by focusing laser radiation on solid targets [1, 2] is the question of the reflection of the laser radiation by the heated surface. The point is that when laser pulses of duration $\tau < 10^{-8}$ sec and energy $\sim$10 - 100 J are used, a plasma layer of thickness $a \approx 10^{-2} - 10^{-3}$ cm and density $N \approx 10^{19} - 10^{23}$ cm^{-3} is produced at the surface; this density is higher than the critical density for the neodymium-laser frequency ($\omega = 1.8 \times 10^{15}$ sec^{-1}, $N_{cr} = 10^{21}$ cm^{-3}). Since the electron temperature T of the plasma reaches several keV, the optical thickness of the plasma with respect to bremsstrahlung absorption turns out to be less than unity: $a\nu/c < 1$ (ν - collision frequency, c - speed of light). Therefore an appreciable fraction of the laser radiation is consumed in heating the plasma and is reflected from the critical point, returning to the focusing device. The energy reflection coefficient, according to measurements [3], reaches 60%. With further increase of temperature, this value should increase even more, if it is assumed that the absorption of the light is determined as before by the Coulomb collisions. In this connection, different nonlinear effects were considered, leading to an increase of the absorption coefficient.

In the present paper we discuss, within the framework of the linear theory, the possibility of increasing the coefficient of absorption of light by an inhomogeneous laser plasma. We have in mind here the well-known phenomenon of transformation of a surface p-polarized wave with frequency close to the plasma wave into potential electronic Langmuir oscillations [4 - 6]. Let the plasma be inhomogeneous along the z axis, so that the critical density is reached at $z = 0$ and $N(z) < N_{cr}$ at $z < 0$. The xz plane of the rectangular coordinate system is chosen as the plane of incidence of the light wave. We emphasize that the transformation is possible only in the case of an obliquely incident p-polarized wave, when the angle θ between the wave vector k and the z axis differs from zero. The electric field E lies in this case in the plane of incidence, and the magnetic field B has a single component B_y perpendicular to the plane of incidence. The gist of the transformation of the light into a Langmuir oscillation of an inhomogeneous plasma consists of a sharp increase of the longitudinal component of the field E_z in the critical-density region $z \approx 0$, with a smoother variation of E_x and B_y. The transformation is a non-dissipative process. The transformation coefficient, and consequently also the coefficient of absorption of the laser radiation, does not depend on the temperature and is equal to

$$1-|R|^2=\pi\frac{a\omega}{c}\frac{\sin^2\theta}{|\cos\theta|}\left|B_y(0)\right|^2, \tag{1}$$

where $a^{-1}\equiv N_{cr}^{-1}(dN/dz)_{z=0}$. Since the condition $a\omega/c \gg 1$ is satisfied in laser experiments, we can use the results of [6], where $B_y(0)$ was calculated in the geometrical-optics approximation. It turns out here that the absorption coefficient (1) has a narrow maximum near $\sin\theta = 0.5(a\omega/c)^{-1/3}$. We can point to the conditions of target illumination ensuring the most effective transformation of the light into the Langmuir wave. Let us assume that the laser radiation is naturally polarized, and that the intensity is uniformly distributed over the cross section of the beam. Then if the axis of the focusing lens is perpendicular to the heated surface and $a = 10^{-3}$ cm, then the maximum of the absorption coefficient is 15% and is reached at a beam convergence angle $\sim 10°$. On the other hand, if the laser radiation is polarized in the incidence plane, and the convergence angle of the beam is much smaller than 10°, then from the point of view of increasing the transformation coefficient it is convenient to place the target at an angle 6 - 7° to the lens axis. The transformation coefficient amounts in this case to 40%. We emphasize that in the case of normal incidence there is no transformation at all, and therefore by choosing the method of illuminating the target one can attain an appreciable increase in the light-energy input into the plasma.

Let us consider now the question of the dissipation of the energy of the Langmuir oscillations resulting from the transformation of the laser radiation. The solution of the field equations near the critical point, with allowance for collisions and Landau damping, has for a weakly-inhomogeneous plasma the form

$$E_z=-i\sin\theta\frac{a\omega}{v_T}B_y(0)\times\int_0^\infty dr\,\exp\left\{-\frac{a\omega}{v_T}\left[i\frac{z}{a}r+i\frac{r^3}{3}+\frac{\nu}{\omega}r+\sqrt{\frac{3\pi}{2}}e^{-3/2r^2}\right]\right\}, \tag{2}$$

where $v_T=(\kappa T/m)^{1/2}$ is the thermal velocity of the plasma electrons with temperature T. Expression (2) makes it possible both to investigate the structure of the field near the point of reflection and to determine the scattering length, i.e., the characteristic length over which the energy of the Langmuir oscillations is transformed into heat. At low temperatures, when the thermal velocities of the electrons are small and the collision frequency is large,

$$(\nu/\omega)(a\omega/\sqrt{3}v_T)^{2/3} \gg 1, \tag{3}$$

both the amplitude of the Langmuir oscillations at the critical point and its damping length $\ell \simeq a(\nu/\omega)$ are determined by the collision frequency [5, 6]. In a high-temperature laser plasma, to the contrary, the role of the collisions is small and the following inequality is satisfied:

$$(a\nu/\sqrt{3}v_T) \ll 1. \tag{4}$$

Then the thickness of the absorbing layer is determined by the inverse Cerenkov effect $\ell \sim a[\ln(\sqrt{2}\pi a\omega/v_T)]^{-1}$. At $a \simeq 10^{-3}$ cm and $T \simeq 1 - 10$ keV, the left side of (4) changes from 0.3 to 0.1, so that the damping length is $\ell \simeq 10^{-4}$ cm. A case intermediate between (3) and (4),

$$(\nu/\omega)(a\omega/\sqrt{3}v_T)^{2/3} << 1 << (a\nu/\sqrt{3}v_T), \qquad (5)$$

is also possible, and is realized, for example, in a plasma with a smoother inhomogeneity: $a \simeq 10^{-2}$ cm, T = 1 keV. In this case, unlike in (4), the Langmuir waves attenuate because of the Coulomb collisions and $\ell \simeq a(\sqrt{3}v_T/a\nu)^2$. The damping lengths of the Langmuir oscillations obtained above are smaller by one order of magnitude than the characteristic dimension of the inhomogeneity a, and are much smaller than the absorption length of s-polarized light (larger than a), for which the plasma is optically transparent. Roughly speaking, the plasma is transparent to light, but is optically thick for Langmuir oscillations, so that the absorption (1) is the result of transformation of light into this oscillation. We note that the idea of collisionless heating of an inhomogeneous plasma by an electromagnetic wave is extensively used and being developed as applied to a magnetoactive plasma confined by an external magnetic field.

The absorption mechanism discussed here differs in principle from the nonlinear anomalous absorption. Although nonlinear absorption was observed experimentally only in the microwave band [7], a theoretical analysis [8, 9] and a numerical experiment [10] gave grounds for hoping that such an effect exists also in the optical band. The theory of a weakly-turbulent plasma makes it possible to calculate the coefficient of anomalous absorption [8], which turns out to be proportional to the square E^2 of the field intensity of the electromagnetic wave. The anomalous absorption arises only at sufficiently large field intensities E, exceeding the threshold value E_0. In the critical region of a laser plasma $N = N_{cr}$ with temperature $T \simeq 1$ keV, such a threshold (with respect to collisions) is $E_0 = 5 \times 10^7$ V/cm (see, e.g., [11]). The transformation of light into a Langmuir oscillation increases the light absorption by the inhomogeneous plasma at a field intensity below threshold, i.e., when there is no nonlinear anomalous absorption.

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