Suppression of the second harmonic in a dispersing laser plasma

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The theoretically predicted correlation of the decrease in intensity of the second-harmonic radiation and the increase of radiation scattered from a laser plasma at the fundamental frequency was detected experimentally for the first time. The role of supersonic breakup of a plasma in the suppression of the second-harmonic radiation is explained.

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The theory of interaction of a laser radiation with a plasma indicates that the second-harmonic generation and radiation absorption[1] closely associated with it have a highly nonstationary nature. According to this theory, the second-harmonic radiation maxima and the absorption peaks corresponding to them are due to the appearance of cavitons in the plasma that accumulate strong fields causing the indicated nonsteady-state condition. It also follows from this theory that as one goes from the subsonic-plasma-breakup regime to the supersonic a suppression of the absorption peaks occurs along with an appreciable decrease in the second-harmonic radiation intensity. In addition, it should be noted that, according to the theory, the presence of the *P* component of the laser radiation favors the formation of cavitons and the accompanying effects in the plasma.

Spectral-time investigation of the scattering from a laser plasma at the fundamental and doubled frequencies was performed to verify experimentally the conclusions of Ref. 1. The radiation of a single-frequency neodymium laser was used to do this.[2] The experiments were conducted for cases of normal and oblique ($\theta = 22.5°$) incidence of the laser radiation on an aluminum target. For normal incidence the time dependence of the intensity of the laser radiation and the backscattering at the fundamental and second-harmonic frequency was investigated in each firing of the laser by using an electron-optical camera. In addition, spectral-time measurements of the backscattering near the fundamental frequency were also performed by the method described in Ref. 2, using a second electron-optical camera coupled to a spectrograph. In the first electron-optical camera the spectral regions of the scattering were isolated by color and interference filters. The time and spectral resolution was ~ 0.04 nsec and ~ 1 Å, respectively. All optical paths in the recording scheme were carefully equalized. The results of the experiments for normal incidence are illustrated in Fig. 1. The backscattered radiation at the frequencies ω (Fig. 1b) and 2ω (Fig. 1a) was modulated with the characteristic beat times of 0.2–0.4 nsec. Such modulation can also be observed in the spectrum sweep near ω (Fig. 1d). At the same time, the laser radiation (Fig. 1c) has no modulation. As a rule, the reflection minima at the fundamental frequency correspond

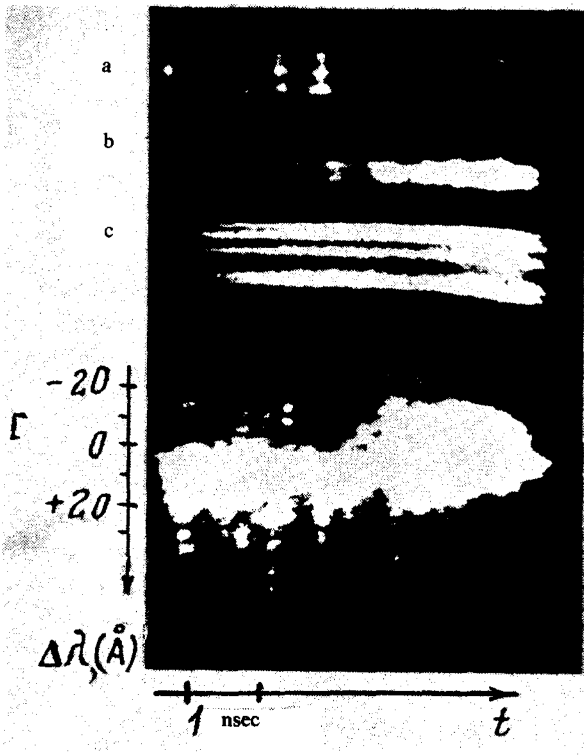
a
b
c
-20
0
+20
Γ
Δλ,(Å)
1 nsec
t

FIG. 1.

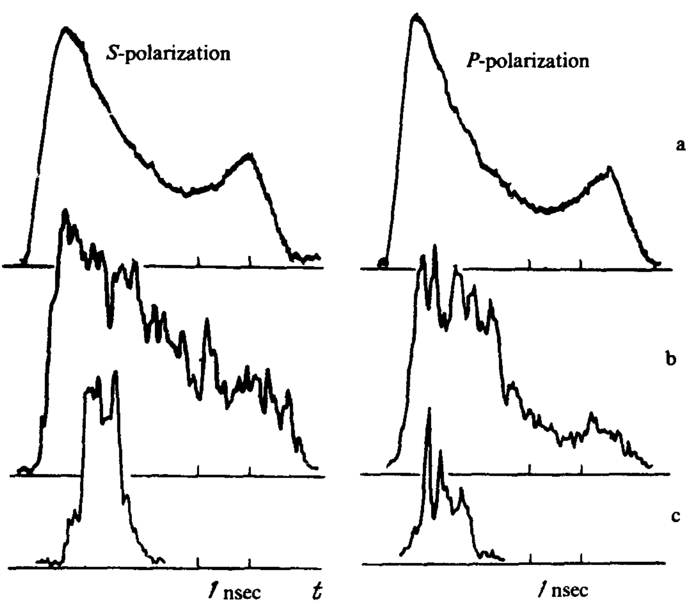
S-polarization
P-polarization
a
b
c
1 nsec
t
1 nsec

FIG. 2.

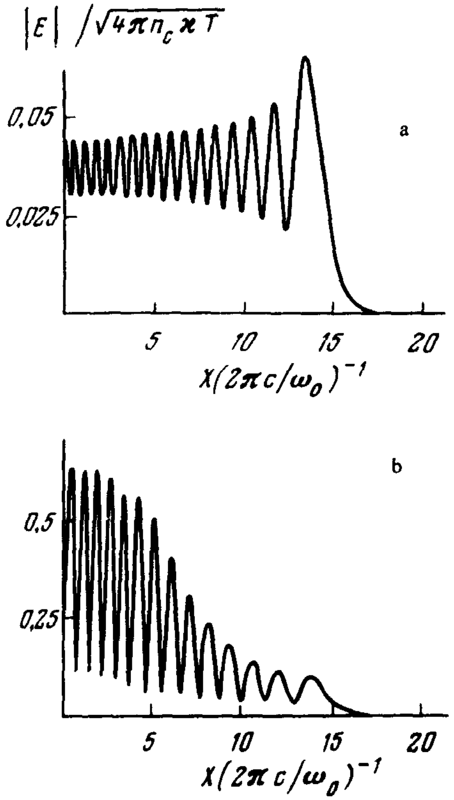

FIG. 3.

to the peaks of the second-harmonic radiation. In this case, an intense second-harmonic radiation is present only in the first half of the laser flash when the scattering spectrum near the fundamental frequency is broadened primarily in the red direction. An abrupt decrease in the second-harmonic intensity coincides in time with the appearance of appreciable broadening in the blue direction of the scattering spectrum near the fundamental frequency (Fig. 1). This indicates the onset of supersonic flow of plasma, which correlates with the suppression of second-harmonic generation. We can see from the sweeps in Figs. 1b and 1d that the scattering intensity at the fundamental frequency increases considerably (by a factor of 3–4) at the end of the pulse. Such behavior of the scattering at the fundamental frequency can also be due to stimulated Mandel'shtam-Brillouin scattering.

To determine the role of laser radiation polarization, we conducted time measurements of the intensity of "specular" scattering at two frequencies with oblique incidence of the radiation on the target for *S* and *P* polarization. The degree of polarization of the laser radiation was ~20. The orientation of the laser polarization plane was changed by changing the direction of the electric current in the Faraday cup. The results of the experiment are shown in Fig. 2. Like in the case of normal incidence, the duration of the second-harmonic radiation is much shorter (1.5–2.5 nsec) than the laser pulse. The second-harmonic lasing peaks coincide with the minima of the scattering pulse at the fundamental frequency, whose envelope approximately duplicates the shape of the laser pulse. It should be noted that the intensity of "specular" scattering at frequency 2ω for P polarization of the laser radiation is about an order of magnitude greater than its intensity for S polarization. We also note that the time correlation of the radiation peaks at the frequency 2ω and the reflection minima at frequency ω in the "specular" scattering are more pronounced for P polarization (see Fig. 2).

In conclusion, we give a new result of the theory, which, in contrast to Ref. 1, refers to a smooth plasma density profile and indicates that the second-harmonic generation is suppressed as a result of supersonic breakup of the plasma. It turns out that for the flow of supersonic matter ($V > V_s$) the electric field decreases due to strictive nonlinearity of the plasma as the critical density (n_c) is approached. To illustrate this, we write the expression for the dielectric constant

$$\epsilon = 1 - N/n_c - |\mathrm{E}|^2/E_V^2 \text{ , when } E_V^2 = (V^2/V_s^2 - 1)16\pi n_c \kappa T.$$

According to this dielectric constant, the electric field in the region of classical (linear) plasma transmittance for $V > V_s$ cannot exceed the value $4(\pi n_c \kappa T)^{1/2}[1 - N/n_c)(V^2/V_s^2 - 1)]^{1/2}$, which decreases as the critical density is approached. The results of linear and nonlinear theory of radiation penetration in a plasma moving with a supersonic velocity are shown in Fig. 3. According to our theory, the electric field intensity decreases in each case for both S and P polarization as the critical density is approached, if the plasma density profile is relatively smooth; this, as expected, occurred in our experiment in the second half of the laser pulse when a supersonic breakup of the plasma was observed. Such weakening of the field weakens the second-harmonic radiation produced in the neighborhood of the critical density.

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[2]L. M. Gorbunov, Yu. S. Kas'yanov, V. V. Korbkin, A. N. Polyanichev, and A. P. Shevel'ko, Preprint No. 126, FIAN, 1979.