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INFLUENCE OF TARGET GEOMETRY ON THE PARAMETERS OF A LASER-EMISSION DISCHARGE

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The relationship between the geometry of a plasma-forming target and the parameters of a laser-emission discharge is investigated. It is shown that by selecting the corresponding geometry of an irradiated sample it is possible to change the coefficient of laser radiation energy conversion into the energy of unidirectional quasistationary electric current.

Introduction. A laser-emission discharge is the discharge that develops in a vacuum or in a rarefied atmosphere on exposure of a plasma-forming barrier — a target — to a high-power pulse laser radiation [1]. As is shown in [2], there exist two regimes of development of a laser-emission discharge: a high-current and a low-current ones. The corresponding type of discharge is determined by the magnitude of load resistance R responsible for the galvanic coupling between the target and vacuum chamber walls. At a certain threshold value of R^*, irrespective of variation of other external parameters, the laser-emission discharge passes from one mode into another [3]. In conformity with this, the efficiency of conversion of the energy of laser radiation into the energy of unidirectional quasistationary electric current will primarily be determined by the regime of discharge development. Moreover, the efficiency of conversion depends substantially also on some other factors: the residual air pressure in the vacuum chamber [4], the atomic mass of the substance of a plasma-forming target [5], and, as it has turned out, on its geometry.

This work presents the results of investigation of the influence of the geometry of the plasma-forming target on the parameters of laser-emission discharge and its load characteristics.

Experimental. The schematic diagram of the experiment is shown in Fig. 1. The radiation of an Nd-laser (λ = 1.06 μm) that operated in the monopulse mode was focused by a lens on a target set up in a vacuum chamber. The half-width laser pulse length was 40 nsec with an energy of 1 J. With a diameter of the focus spot of 0.5 mm the density of the laser radiation flux onto the target was $q = 1.3 \cdot 10^{10}$ W/cm^2.

As the material of plasma-forming targets we used aluminum, titanium, copper, niobium, zirconium, and tantalum, which allowed us to cover the range of atomic masses from 27 to 180. To reveal the influence of the geometry of a plasma-forming target on the load characteristics of a discharge, the laser radiation was focused either on the surface of the sample studied, or into a cavity of diameter 1.5 mm and depth 2 mm made in it. Investigations were carried out at residual gas pressures in the vacuum chamber $P_1 = 10^{-3}$ Pa and $P_2 = 1$ Pa. Laser-emission currents were registered with the aid of an automated system based on a digital oscillograph. The error of measurement of amplitudes for a confidence level of 0.95 does not exceed 8%. The temporal resolution attained ~5 nsec. The experimental procedure and the technique of data processing are described in more detail in [3, 5].

Results of Investigations and Discussion. It has been found that the geometry of a target exerts a substantial influence on the load characteristics of a laser-emission discharge and correspondingly on its parameters. The dependences obtained for a zirconium target at a high vacuum ($P_1 = 10^{-3}$ Pa) and at the "resonance" pressure ($P_2 = 1$ Pa) are presented in Fig. 2. For targets made from other materials the dependences had a similar form.

Having analyzed the results of the experiments carried out, we may establish the following general laws.

First, it should be noted that the load characteristics of a laser-emission discharge when laser radiation is focused into a cavity also have two shapes for both a high vacuum and a "resonance" pressure similar to the case of

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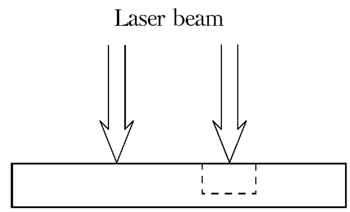

Fig. 1. Diagram of the experiment.

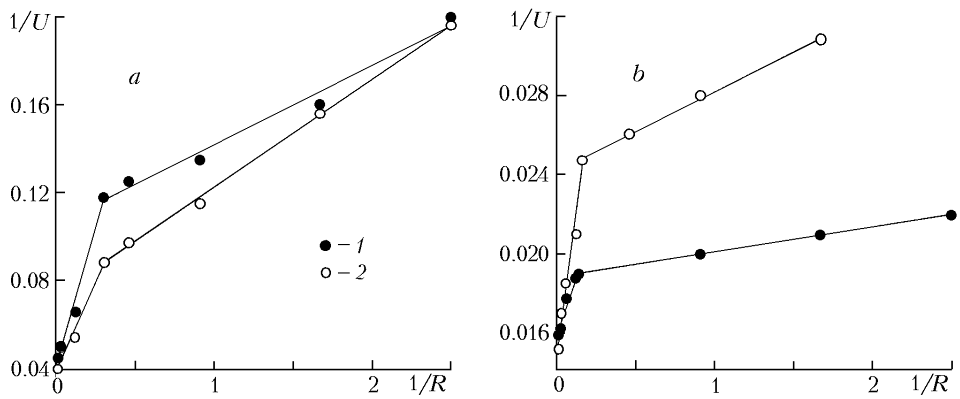

Fig. 2. Load characteristics of a laser-emission discharge at a pressure of 10^{-3} Pa (a) and 1 Pa (b): 1) focusing into a cavity; 2) focusing upon a surface. $1/U$, V^{-1}; $1/R$, Ω^{-1}.

radiation focusing on the target surface. Consequently, for this geometry of the target too there exist two modes of discharge development: a high-current one and a low-current one.

Second, as is seen from Fig. 2, the load characteristics of the discharge for the cases of focusing of laser radiation into a cavity and on the surface have different slopes for both the high-current and low-current modes of discharge development. As a result, the corresponding values of internal resistances of the discharge and e.m.f. are also different for the modes indicated. For example, when a laser-emission discharge develops in a high vacuum for a low-current mode, the e.m.f. for both the plane and the cavity turned to be approximately equal (E = 27 V); however, the internal resistances differed and were equal to r = 16 and 10 Ω, respectively. For a high-current mode with focusing onto a surface E = 9 V, r = 0.4 Ω, whereas when focusing into a cavity E = 14 V and r = 0.9 Ω, i.e., in the high-current mode with focusing of laser radiation into a cavity, at the same power of this radiation, the amplitude of the potential jump on the target increases and, consequently, so does the efficiency of laser-emission conversion of light energy.

At the pressure P_2 = 1 Pa the situation is completely different. Here, as is seen from Fig. 2, in the high-current mode the efficiency of generation of laser-emission currents is higher with focusing upon a surface (E = 53 V) as compared to focusing into a cavity (E = 42 V). However, in the low-current mode of discharge development, conversely, with focusing into a cavity E = 71 V and with focusing upon a surface, E = 62 V.

Third, one other interesting fact should be noted. It is seen from Fig. 2 that the value of load resistance at which a discharge switches from one mode to the other is determined only by the magnitude of air pressure in the vacuum chamber and does not depend on the target profile. The corresponding values of resistances for a high vacuum and "resonance" pressure were equal to R_1^* = 3 Ω and R_2^* = 8 Ω; they agree well with the data obtained earlier in [3].

Conclusions. The geometry of the plasma-forming target exerts a substantial influence on the parameters of a laser-emission discharge. By selecting the needed profile of the target, it is possible, at the same power of a laser pulse, to vary the parameters of the laser-emission discharge and correspondingly the value of the coefficient of transformation of the laser radiation energy into the energy of a unidirectional quasi-stationary electric current.

NOTATION

E, electromotive force, V; *P*, pressure, Pa; *q*, laser radiation flux density, W/cm^2; *R*, load resistance, Ω; *r*, internal resistance of a discharge, Ω; λ, wavelength, μm. Superscript: *, the value of load resistance at which change of discharge development modes occurs.

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