[9] R. G. Brewer, Appl. Phys. Lett. 9, 51 (1966).
[10] A. A. Chaban, ZhETF Pis. Red. 3, 73 (1966) [JETP Lett. 3, 45 (1966)].

* These measurements were made by S. V. Krivokhizha.

PLASMA PRODUCED BY A BEAM FROM A NON-Q-SWITCHED LASER ACTING ON A MEDIUM

T. U. Arifov, G. A. Askar'yan, M. S. Rabinovich, I. M. Raevskii and N. M. Tarasova
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 29 June 1967
ZhETF Pis'ma 6, No. 6, 681-682 (15 September 1967)

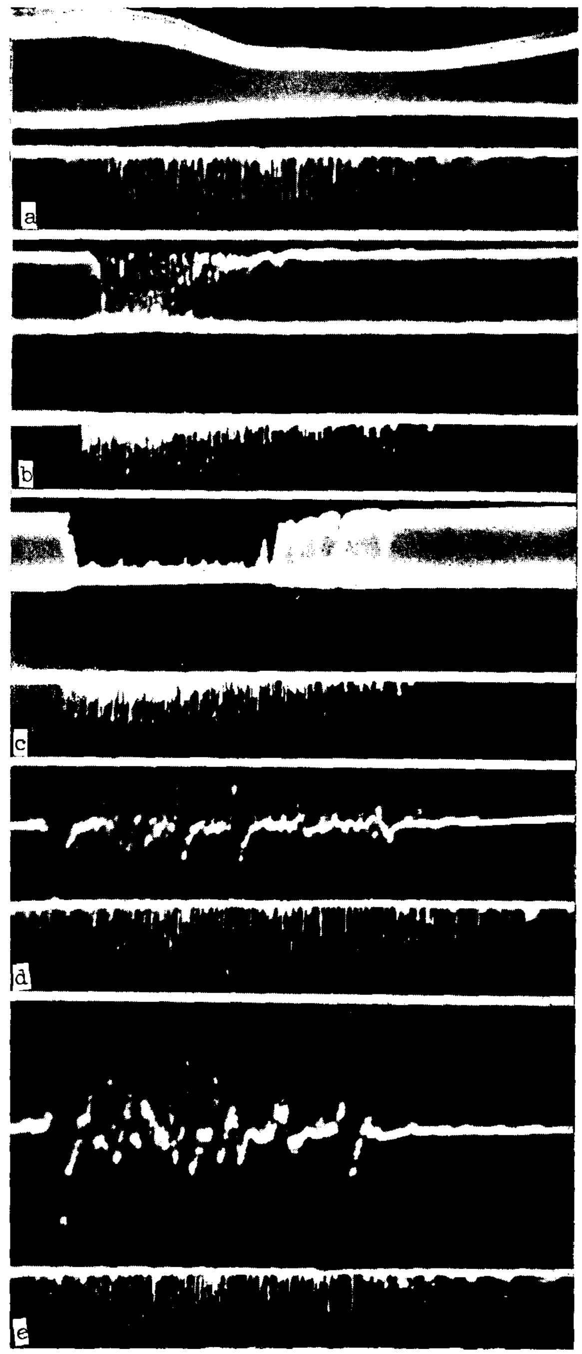
Almost all investigations in which a plasma was produced in a laser beam were made with Q-switched lasers which produced radiation of high intensity (upward of a megawatt). Lasers operating under ordinary conditions (with power 1 - 10 kW) were used only to evaporate, ignite, or break down substances, and the plasma produced in such cases was hardly ever investigated, with the exception of the skimpy data obtained with the aid of probes on thermoionic and thermoelectronic emission.

At the same time, plasma produced in this manner is of interest in view of the large energy radiated by non-Q-switched lasers (10 - 1000 J), making it possible to obtain larger amounts of plasma, and in view of the long generation time (on the order of a millisecond) of such lasers, which ensures a long time during which generation accompanied by existence of plasma takes place, and making possible the separation of the neutral particles from the ionic fraction of the plasma.

We have investigated, by microwave and diamagnetism-measurement techniques, the plasma ejected from a target acted upon by a focused beam of an ordinary laser without Q-switching. The investigations were made in the atmosphere and in vacuum, with and without magnetic fields.

The antenna of an 8-mm radio oscillator and a radio detector were placed opposite each other in front of a small target, on which was focused the beam from a ruby laser delivering 10 J in the free-generation regime; the focal distance of the lenses was f = 15 cm when the experiments were made in a vacuum chamber and f = 5 and 15 cm when the experiments were made in air.

In the case of the target in the atmosphere, the microwave overlap signal increased slowly, in a time on the order of fractions of a millisecond. Fig. 1a shows oscillograms of the overlap signal (upper trace) and the signal from a photomultiplier, registering the laser intensity (lower trace), at a sweep duration 900 μsec. Targets of four metals - titanium, copper, aluminum, and stainless steel - were tried. The strongest and longest overlap was obtained with titanium and aluminum targets. For a lens with f = 15 cm, the overlap was observed only for the titanium target. The geometric overlap cross section was close to the cross section of a body with 1 cm diameter (as checked by placing bodies of different diameters and modulating the microwave radiation). The fact that a plasma from a flare of thickness $\sim\lambda$ produced strong overlap of the microwave radiation indicated either that $\omega_p > \omega$ (when $\omega > \nu$) or $\omega_p \sim (\omega\nu/2\pi)^{1/2}$ (when $\nu > \omega$), i.e., $\omega_p > \omega_{cr}$, or else that the plasma concentration is $n_e > n_{cr} \approx 10^{13}$ cm^{-3}. The overlap oscillogram shows a slow growth in the amount of plasma, integrating, as it were, the contribution of the light energy, as well as a very slow decrease in the concentration, which may be attributed to the long lifetime of the produced plasma and to very slow leakage.



Microwave signal in atmosphere; sweep 0.9 msec.

Microwave signal in vacuum; H = 0; sweep 0.7 msec.

Microwave signal in vaccum; H = 5 kOe; mirror field; sweep 0.7 msec.

Diamagnetic signal in vacuum; H = 1.25 kOe; mirror field; sweep 0.3 msec.

Diamagnetic signal in vacuum; H = 1.25 kOe; sweep 0.3 msec. The signal in this case is larger than in the case of a mirror field.

When the target was placed in a vacuum chamber, the character of the overlap of the microwave signal was radically altered. Figures 1b and 1c show the overlap signals without and with the magnetic field. At a sweep of 700 μsec, a small growth time of the overlap is observed, indicating that the plasma batches produced in the spikes of the laser generation move rapidly. When a magnetic field is produced (with mirror or anti-mirror configuration) near the target, the overlap becomes stronger and longer, this being attributed to an increase in the plasma concentration resulting from limitation of leakage or from accumulation.

A 15-turn coil of 40 mm diameter located 7 cm away from the target in the vacuum was used to register the diamagnetic signals. Figures 1d and 1e show the characteristic diamagnetic signal from the plasma of a titanium target for magnetic fields of different magnitudes and different configurations. Individual bursts of diamagnetism from plasmoids emitted by strong spikes can be seen. The diamagnetic signal for not very weak fields decreases with increasing magnetic field like ~1/H, apparently indicating that the pressure due to the magnetic-field gradient limits the transverse dimension of the plasma jet or that the magnetic field suppresses the diamagnetism and the conductivity of the plasma.

The results show that a sufficiently dense and long-lived plasma can be obtained with the aid of non-Q-switched lasers, and that such a plasma interacts quite strongly with magnetic fields and radio waves; it can be used to produce antennas, reflectors of directional elements, magnetohydrodynamic devices, sources of sets of plasmoids from many radiation spikes, etc.

FORMATION OF SHOCK WAVES WITH THE AID OF POWERFUL LASER RADIATION

N. G. Basov, O. N. Krokhin, and G. V. Sklizkov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 30 June 1967
ZhETF Pis'ma 6, No. 6, 683-684 (15 September 1967)

When radiation of density exceeding 10^{11} W/cm^2 (corresponding to a focused Q-switched laser beam) interacts with the surface of a solid target, a plasmoid (flare) heated to hundreds of thousands of degrees is produced [1,2]. After the termination of the laser pulse, the flare scatters in vacuum with a speed ~10^7 cm/sec, and at the end of the laser pulse the internal energy and the energy of kinetic motion of the heated matter constitute comparable fractions of the total heating energy [3,4]. From the physical point of view, it is of interest to use also the kinetic part of the energy to heat the substance.

We have investigated the scattering of a flare in air at a pressure of several millimeters mercury. With this, formation of a strong nearly-spherical shock wave was observed. The shock waves were recorded by shadow photography [2] in the beam of a ruby laser synchronized with neodymium, the radiation of which was used to heat the substance. The ruby-laser beam was divided into five beams which, after passing through an optical delay, converged in the plane of the film in such a way that five spatially-separated frames were obtained on the film. The frame exposure was equal to the ruby-laser pulse duration (3 nsec), and the instant of exposure was determined by the path of the corresponding beam to the flare.

Figure 1 shows a five-frame shadowgram of the shock wave produced by expansion of the flare in air at a pressure of 2 mm Hg. The neodymium-laser radiation energy was 6 J at a pulse duration 15 nsec. The frames follow in 50-nsec intervals, the fifth frame being in