G. A. Askar'yan and B. M. Manzon. *The "Laser Dragon"—flash-discharge of light into the atmosphere in the direction of the beam.*[4] Detonation light flashes in a gas[1,2] usually propagate from the focus against the beam of light, with the absorption front moving at a velocity $V_D \simeq (I/\rho_0)^{1/3}$ where ρ_0 is the density of the gas and I is the light flux density (for typical discharges $I \approx 10^9-10^{10}$ W/cm^2 and $V_D \approx 10^6$ cm/sec at a pressure of 1 atm).

What would happen if the gas were evacuated from in front of the focus and allowed to remain behind it? How would the discharge flash behave, especially in the case

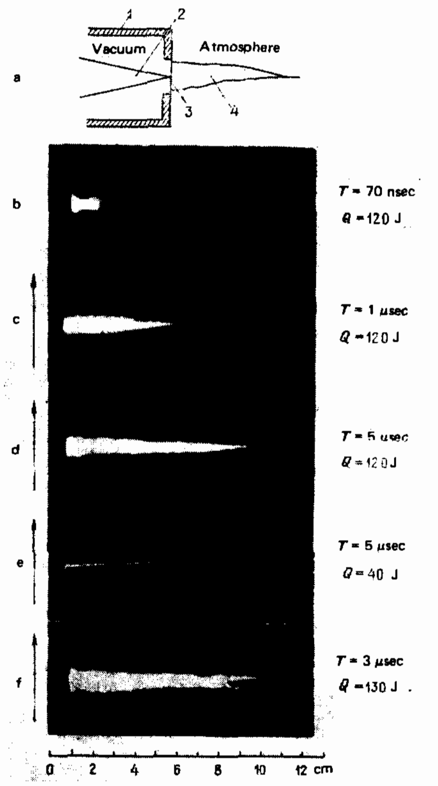

FIG. 1. Burst of light discharge into atmosphere in direction of beam. a) diagram of experiment (1—vacuum chamber; 2—laser beam; 3—thin lavsan film maintaining pressure difference; 4—light discharge; b–f) integral photographs of light discharges at various durations T and energies Q of laser pulses; Fig. b) the usual 70 nanosecond giant pulse; Figs. c–d)—long giant pulses; as the energies decrease (Fig. e) we observe a slender straight puncture filament 0.2 mm in diameter; at higher energies, a cluster of filaments is often produced at discrete angles (Fig. f).

of long giant laser pulses? We addressed ourselves to this problem after building a new type of laser[3] which produces pulses of duration from hundreds of nanoseconds to tens of microseconds.

A diagram of the experiment[4] appears in Fig. 1a. The beam 2 of a powerful neodymium laser was focused into vacuum chamber 1 onto a thin (10 μm) fast-puncturing lavsan film 3 that covers the window and maintains the pressure difference. The lens had a focal length of 1 m and the focus spot was 1 mm across. The energy in the pulse was $Q \leq 100$ J. The length of the pulse in the lasing-wave mode could be varied from 0.3 to 10 μsec. A normal 50 nsec pulse of the same energy was used as a control. On evacuation of air from the chamber, we immediately obtained a directional burst of flash discharge into the atmosphere, the length of which increased with increasing pulse duration T: from 3 cm at $T \approx 0.3$ μsec to 17 cm at $T \approx 5$ μsec[4] (Fig. 1, b–f).

The small cross section of the energy-release channel and the concentrated propagation of the light and the leader initiating the rupture were quite striking. The discharge filament was no more than a few tenths of a millimeter thick, i.e., a small fraction not only of the length of the discharge, but also of the initial size of the focal spot. All this indicated focusing in the discharge and concentrated conduction of the light in the plasma,[5-6] for which plasma concentrations $n_e \approx \theta^2 n_{cr} \ll n_{cr} \approx 10^{21}$ cm^{-3} are sufficient in view of the small angle of capture ($\theta \approx 0.1$–0.05 rad). A single filament was observed at low energies, an indication of capture of the beam even as it turns with the motion of the lasing wave.[3] Lapses of capture and the formation of bursts at several discrete angles were observed. Forward burst velocities up to $5 \cdot 10^6$ cm/sec were registered on high-speed photoscans. We note that the linear energy releases amounted to several J/cm, which is definitely sufficient for high temperatures and low densities of the residual tracks.

This directional flash-discharge burst into the atmosphere, which we have named the "laser dragon" in honor of the mythical flame-breathing creature, is not merely of interest as a new type of light plasmotron. It opens up a new field in radiation gasdynamics that describes the concentrated propagation of a powerful light beam in an absorbing medium in which the beam self-focuses as it heats up and expels the medium along its path. The propagation of the intrusion front has much in common with hypersonic gas dynamic flow around a slender body.[7]

One of the important factors that enabled us to produce long discharge bursts and to elucidate and analyze the structure of the discharge was the use of superlong giant pulses produced by a new type of laser.[3]

These pulses have also made it possible to obtain[11] long continuous light discharges in the atmosphere that have ranged up to 20 cm in length (Fig. 2) and differ from nonuniform intermittent discharges in ordinary giant pulses (see Fig. 2b) in that they are continuous,

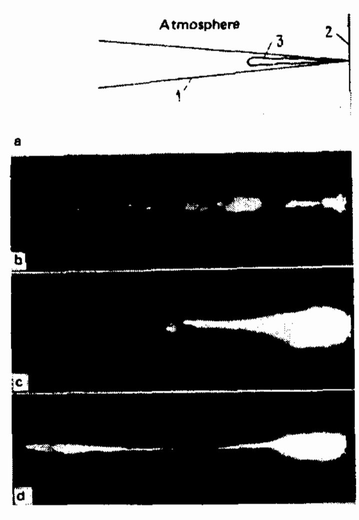

FIG. 2. Long continuous discharge in gas against beam. a) diagram of experiment (1—laser beam; 2—target; 3—discharge); b) beaded nonuniform discharge in ordinary giant pulse with $T \approx 50$ nsec; c, d) continuous long sparks at durations $T \approx 3$ and 10 μsec, respectively. Scale of image same as in Fig. 1.

something that is highly desirable in various practical cases. The length L of the discharge depends on the pulse duration T very nearly in accordance with theory: $L \approx v_D T \sim T^{2/3}$ at a given energy Q.

The light discharges that have been produced can be used to form channels[8,9] of lowered density and plasma channels in a gas with the object of guiding beams of particles, radiation and fast particles, to create[10] plasma antennas, reflectors, and guidance systems for radio waves, to bring about directional puncture and closure of discharges, to create plasma electrodes, etc.

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