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STANDING PATTERN OF SELF-FOCUSING POINTS OF LASER RADIATION IN GLASS

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Submitted 13 March 1970
ZhETF Pis. Red. 11, No. 9, 444 - 447 (5 May 1970)

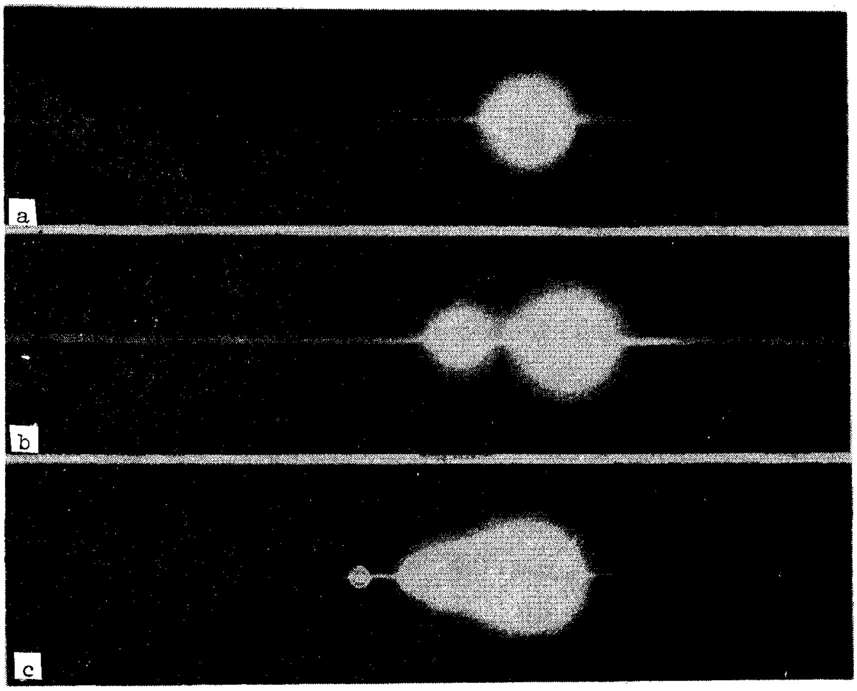
A large number of theoretical and experimental investigations (see the reviews [1]) have been devoted by now to the phenomenon of self-focusing in various media. The most studies were devoted to self-focusing in liquids, for which interesting results have been obtained recently [2 - 3], leading to definite conclusion concerning the multifocus model [4] of this phenomenon. For solid transparent dielectrics, however, in spite of the large number of investigations, the mechanisms and processes of self-focusing remain unclear.

We have investigated the self-focusing of laser radiation in glasses and observed a fundamentally new picture of the phenomenon, namely a standing pattern of focal points. This was obtained by using in the experiment a rectangular light pulse, making it possible to compare most readily the experimental results with the theoretical self-focusing models. In all the preceding investigations of self-focusing, the experiments were performed with bell-shaped pulses having a smooth time variation of the power, thereby making it difficult to obtain an unambiguous interpretation of the results on the basis of some theoretical model of this phenomenon. Thus, the filamentary faults observed in different transparent dielectrics by various investigators, and induced by laser radiation, were explained as being due either to the waveguide character of the propagation of the high-power radiation in the nonlinear medium [6], or to the motion of the self-focusing region during the course of time variation of the laser-pulse power [7].

The self-focusing regions can have different structures (waveguide, a series of focal points on the beam axis, etc.). This structure can be resolved, and the validity of some particular self-focusing model can thereby be confirmed, by observing the stationary self-focusing pattern at a time-constant power of the radiation incident on the linear medium. These were precisely the conditions realized in our experiments, in which we used rectangular light pulses.

The master generator employed was a single-mode Q-switched ruby laser. A Pockels cell was used to cut from the bell-shaped pulse of this generator a square-wave pulse of 20 nsec duration, with rise and fall times ∿2 nsec and with a top flat to ∿4%. This square-wave pulse was focused with a lens ($F = 12$ cm) inside a sample of Tf-105 lead glass 19 cm long.

During the course of the experiment, we registered simultaneously on the oscilloscope the pulses incident on the sample and the pulse passing through it, and also photographed the glass specimen from the side at the instant of passage of the radiation through it.



Pattern of scattering of laser radiation (rectangular pulse) in Tf-105 glass at different values of power: a) $\eta = P_i/P_d \approx 1$; b) $\eta \simeq 3$, distance between scattering centers ∿5 mm; c) $\eta \simeq 6$. Bright scattering halos are seen around the damage points, as well as a weak trace of the ordinary scattering in the glass. The laser beam propagates from left to right.

At laser-radiation power values P_i close to the glass destruction threshold P_d we observed in the specimen a strong nonlinear absorption, revealed by the characteristic change of the waveform of the pulse transmitted through the specimen. At $P_i \geq P_d$, pointlike damage was observed in the specimen, along the beam axis. The number of these damage points, their relative arrangement, and their dimensions depended on the value of $\eta = P_i/P_d$. The number of points increased from one to three when η increased from 1 to 6 (see the figure). Each succeeding fault occurred closer to the lens, and the distance between it and the preceding point decreased with increasing number of points. The presented damage patterns, revealed by the scattering of the laser radiation from the damage points, lead to definite conclusions concerning the concentration of the energy at each damage point. Namely, the closer the point is to the lens, the smaller its dimension (the dimension of the first damage point was ∿0.1 mm), and consequently the lower the energy focused in it.

We associate the described pattern of damage points with the discrete multifocus model of self-focusing [4, 5]. This self-focusing develops under the influence of a rectangular light pulse. To elucidate the decisive role of the rectangular character of the pulse in the formation of the standing pattern of the self-focusing, a control experiment was performed, in which the pulse of the radiation incident on the sample had an essentially nonstationary (sawtooth or bell-shaped) form. In this case, filamentary damage was observed at radiation powers exceeding the threshold power, and the length of the filaments depended on the quantity $\eta = P_i/P_d$. With increasing η, from one to several discrete filaments analogous to those observed, in particular, in [8], developed on the beam axis, and ultimately merged into a single filamentary fault.

It can be concluded from the described damage patterns for different incident pulse waveforms that the filamentary damage observed in the case of sawtooth and bell-shaped pulses are the consequence of the motion of the self-focusing focal points.

Thus, the experimental data obtained by us are in qualitative agreement with the multifocus model of self-focusing. A quantitative comparison of the experimental data with the theory is difficult, since our experiments showed only the result (the damage to the glass), and not the very process of the self-focusing. Furthermore, we do not know precisely the mechanism of the nonlinearity of the refractive index of the investigated glasses.

We note that the use of laser pulses of rectangular form and variable duration makes it possible to investigate the temporal evolution of the pointlike self-focusing pattern and to ascertain the mechanism of its occurrence in various media.

The authors are grateful to V.N. Shkilev for help in the preparation and performance of the experiments.

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CONTINUOUS OPTICAL DISCHARGE

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ZhETF Pis. Red. 11, No. 9, 447 - 449 (5 May 1970)

We report in this communication, the production, for the first time, of a continuously burning hot plasma, maintained by a beam from a cw CO_2 laser. The plasma burns in the center of a gas volume, far from all solid surfaces. This confirms experimentally the feasibility of producing the "optical plasmotron" considered theoretically in [1].

Our work is related to a certain degree to the work of P.L. Kapitza [2], who obtained a free continuous microwave discharge in a resonator. In our case the plasma was maintained continuously at higher frequencies ($\lambda = 10.6$ μ).

It is important that the intensity of the light feeding the discharge is lower by two orders of magnitude than the breakdown threshold of the cold gas, and the discharge is ignited in the beam by producing an initial absorbing plasma with the aid of an external source. The possibility of forced ignition of a laser spark at light intensities below the breakdown threshold was noted in [3], where the question of the initiation and the limits of "detonation" of the beam was discussed. Such an ignition was realized in experiments [4] performed with a millisecond pulse from a neodymium laser; these experiments revealed another laser-spark propagation mode, namely "slow burning" of the beam, requiring less power than "detonation."

To maintain the plasma, we used in our experiment the commercial laser "Lund-100," the power output of which was raised by modification to 150 W. The