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NEW EXPERIMENTS ON THE FORMATION OF A SELF-FOCUSING FILAMENT FROM THE FOCUS OF THE BEAM ON THE SURFACE OF A MEDIUM

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Submitted 2 September 1971
ZhETF Pis. Red. 14, No. 8, 452 - 455 (20 October 1971)

One of the modifications of self-focusing [1 - 4] is the formation of filaments from the focus of laser radiation in a medium, and was observed first in [5]. However, the conditions and mechanism of the formation of the filaments and their nature and properties have not yet been investigated, in spite of the attractive prospects of obtaining a narrow concentrated beam by focusing a broad one.

We describe here new results on the formation of filaments from the focus of a laser beam in a liquid; these results demonstrate the important role played in the formation of the filaments by the proximity of the focus to the surface of the medium.

The experimental setup is shown in Fig. 1. The beam from a Q-switched ruby laser (1) rated 20 - 30 MW was focused by a lens (2) inside a special vertical cell (3) filled with nitrobenzene. The cell had a large diameter (6 cm) and was lined on the outside with a dull-surface bent sheet of teflon to eliminate false images on the axis by specular reflection of light scattered and radiated from the region near the focus from the glass walls of the cell. An open gap was left between the edges of the teflon sheet to permit lateral observation and photography. By incompletely filling the vertical cell we were able to place the focus very close to the surface of the liquid without the danger of damaging the end window of the cell. (Such experiments are impossible with the horizontal cells previously used by others.) The investigations revealed the important role played in the formation of the filaments by the proximity of the focus to the surface of the medium.

Figures 2(a, b, c, d, e) show side-view photographs of the cell, taken with the lens (focal length 5 cm) successively shifted to the left. As the lens was moved, the focus passed through the surface of the liquid. We see that the drawing process is the most effective when the focus is located ~5 mm from the surface inside the liquid (d).

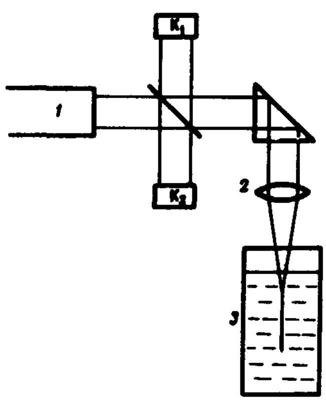

Fig. 1. Experimental setup.

The filament diameter was 100 - 150 μ (determined from a comparison with a standard wire placed on the axis of the filled cell. The length of the wave guide filaments exceeded 10 cm, i.e., filaments in which the divergence was smaller by a factor of 10 than the diffraction value were observed.

By bringing the focus close to the surface, it is possible to obtain consistently long filaments with the aid of lenses having different focal lengths (under ordinary conditions, filaments were obtained only with short-focus lengths and not for all rubies, and even the optimal choice of the laser power did not make it to obtain filaments as long as obtained when the focus was brought close to the surface of the liquid, for different lenses and different rubies).

The influence of the proximity of the surface on the formation of the waveguide may be due to a number of causes, for example the decreased attenuation of the beam by scattering, the deformation of the surface, peculiarities of the nonlinearity near the surface, etc. However, measurements of the back-reflected light with the focus in the interior of the liquid did not yield, under our conditions, a noticeable increase of the reflection, thus apparently excluding a possible role of SMBS in the beam attenuation. The impossibility of obtaining such long filaments by adjusting the power when the focus is deep in the interior of the cell also demonstrates that the reason lies not only in the decrease of the energy loss. The results provide better conditions for the formation of concentrated powerful light fluxes and provide a direct confirmation of the waveguide propagation of light in a nonlinear medium. (The theory of this effect, with allowance for a real nonlinearity, was recently developed in [6].)

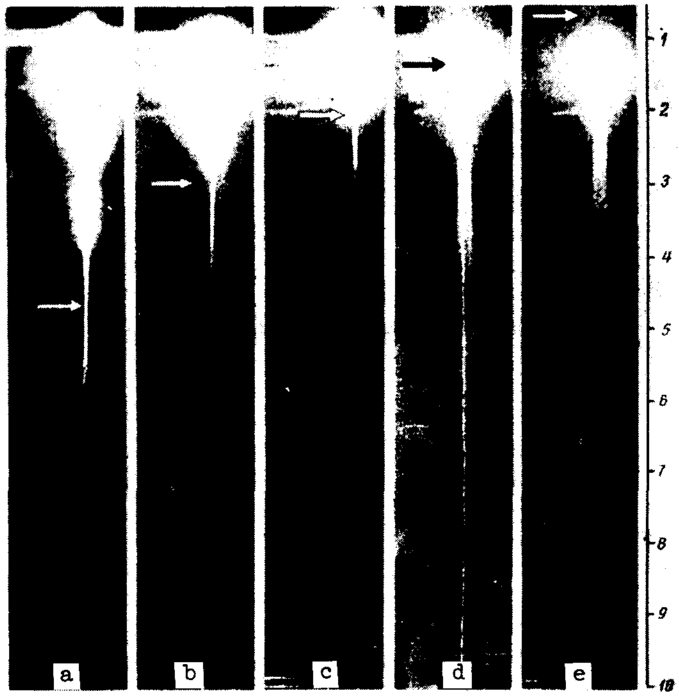

Fig. 2. Side-view photographs of the cell. The figure shows the influence of the shift of the focus of the beam on the formation of the filaments; laser power 6 - 7 MW in a beam of 5 mm diameter. The lens was moved upward; the distance in mm from the focus to the surface (FS) and from the lens to surface (LS): a - FS = 40, LS = 25; b - FS = 23, LS = 35; c - FS = 15, LS = 40; d - FS = 5, LS = 47 (optimal position, filament length ∿10 cm); e - FS = -3, LS = 53. The position of the focus is marked by an arrow.

We note that the waveguide concept of self-focusing does not require in any way a waveguide of constant cross section. Indeed, self-focusing [1] is a decrease of the divergence (or an increase of the convergence) of a powerful beam as a result of nonlinear effects (all the manifestations of the cell focusing are the consequence of this process), and the spatially distributed character of the self-focusing make it analogous to the appearance of a dielectric waveguide [1]. Since waveguides in the usually employed broad sense (see, e.g., [7]) have arbitrary cross sections (including variable cross sections, e.g., the long-employed paper used to enhance the field), it follows that the waveguide description of self-focusing is sufficiently broad and complete. We note that variation of the beam power should also be accompanied by a gap at the start of the waveguide. Incidentally, the experiments on a multifocused structure [8, 9] can be explained from the point of view of a modulated waveguide.[1)]

In conclusion, the authors are grateful to Academician D.V. Skobel'tsyn for interest in the work and for collaboration in the development of the research on self-focusing.

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TRANSVERSE ACOUSTOELECTRIC EFFECT IN A LAYERED $LiNbO_3$-Si STRUCTURE

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Submitted 6 September 1971
ZhETF Pis. Red. 14, No. 8, 455 - 458 (20 October 1971)

If an ultrasonic wave (USW) propagates in a piezosemiconducting crystal in the piezoactive direction, then, as a result of the transfer of momentum from the conduction electrons to the phonon flux, electrons are dragged by the acoustic wave, and an acoustoelectric field is produced in the direction of the USW in the open-circuited sample, compensates for the action of the acoustic wave. This phenomenon is known as the acoustoelectric (AE) effect and in the case of three-dimensional USW was investigated in detail (see, e.g., [1 - 2]). The acoustoelectric effect in surface waves and its characteristic features were first considered in [3], and an experimental investigation of the AE effect, produced when purely transverse surface USW propagate in piezosemiconductors, was reported in [4]. In the case investigated in that paper, just as in the case of three-dimensional waves, the AE effect was produced in a piezoactive medium, where the USW wave itself propagated.

On the other hand, in layered structures consisting of a piezodielectric and a semiconductor, there is no acoustic contact between the media, and the

[1)]We indicate, incidentally, that in spite of the statement made in [10], the process considered in [11] is not self-focusing, since [11] deals with plane waves and a longitudinal redistribution of the field and of the plasma in the direction of wave propagation, whereas in self-focusing there is a transverse redistribution and a change in the divergence of the beam in an initially homogeneous medium, as a result of the appearance of a transverse gradient of the nonlinear refractive index.