Natural oscillations of thermal lens in thermochromic liquid

M. V. Vasnetsov
Institute of Physics, Academy of Sciences of the Ukrainian SSR

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Natural oscillations of a thermal lens which are excited in a thin layer of a themochromic liquid by the focused beam from a cw argon laser have been studied experimentally.

Shafeev[1,2] has recently described the onset of an optical bistability during the heating of a thermochromic liquid, specifically, a mixture of saturated aqueous solutions of $CuSO_4$ and KBr, by a laser beam. A resonatorless positive feedback occurred in this system because the absorption of the liquid increased with increasing temperature. The experiments which we are reporting here are the first demonstration of a natural oscillation process which occurs in a thermochromic liquid when exposed to a focused laser beam. This process is a consequence of the formation of a thermal lens.

A distinctive feature of the experimental procedure is that the liquid is not a mixture of saturated $CuSO_4$ and KBr solutions but instead a solution which is saturated in terms of both components. In this case the absorption is considerably higher, $\approx 33\ cm^{-1}$ at room temperature for the wavelength $\lambda = 0.488\ \mu m$ of an argon laser. Because of the high absorption, we used thin layers of the solution ($< 100\ \mu m$).

The experimental layout is shown in Fig. 1(a). The beam from an Ar^+ laser ($\lambda = 0.488\ \mu m$) is focused through a 90° glass prism into the layer of liquid, which is on the upper face of the prism. A cover glass 1 mm thick is on top of the liquid. The thickness of the liquid layer can be varied from 4 to 100 μm with the help of calibrated spacers. In several of the experiments, a thermal lens appeared and disappeared periodically in the liquid layer when the power of the laser beam exceeded a certain threshold (≈ 40 mW). The transmitted beam underwent a structural change between states b and c in Fig. 1. The frequency of the oscillations was a few hertz. This regime of natural oscillations also had an upper limit in terms of the excitation power: Above this limit, a steady-state thermal lens was set up.

To determine the mechanism for the feedback responsible for the natural oscillations, we used lenses with various focal lengths to vary the diameter of the beam in the liquid layer. At a beam diameter of 100 μm at the lens caustic, natural oscillations were not observed at any layer thickness. In addition, we were unable to achieve the natural oscillations at layer thicknesses above 70 μm, regardless of the focusing. At smaller thicknesses and beam diameters, the region in which the natural oscillations exist is shown in Fig. 2. The correlation observed between the thickness of the liquid layer and the beam diameter suggests that the reason for the appearance of the natural oscillations is a change caused in the size of the region of heated liquid by a deformation of the beam by the thermal lens. As was shown in Ref. 2, the transmission of a layer of a thermochromic liquid changes abruptly when it is heated by a laser beam. In our case, however, the transition to the "darkened" state, with a high absorption, is

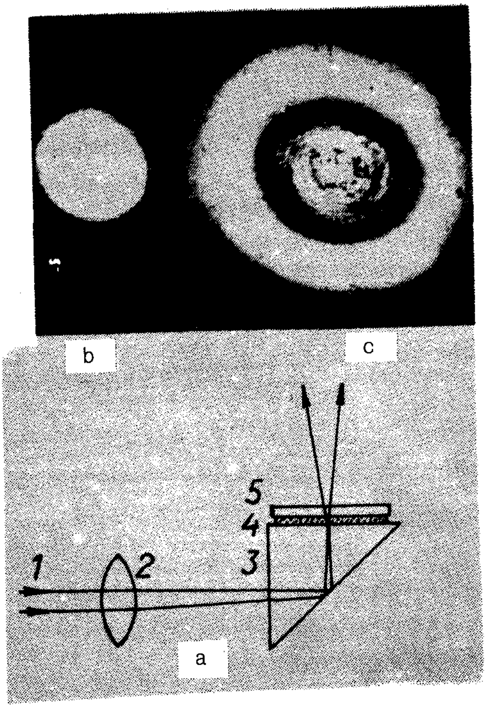

FIG. 1. a: Experimental layout in the study of the natural oscillations of the thermal lens. 1—Beam from Ar^+ laser; 2—focusing lens; 3—prism; 4—liquid layer; 5—cover glass. b: Transmitted beam at minimum thermal lens; c—at maximum thermal lens.

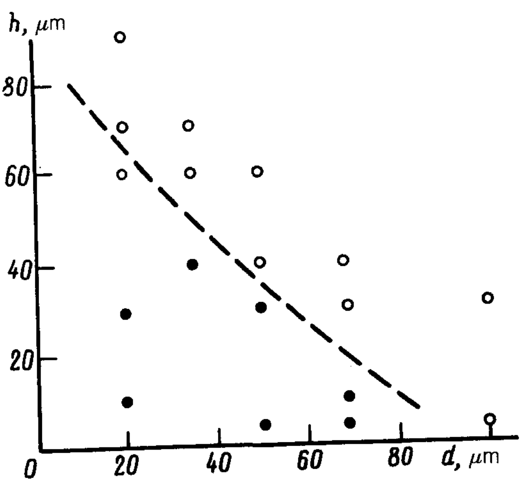

FIG. 2. Region in which natural oscillations exist in the plane of the beam diameter d and the layer thickness h. ●—Oscillations observed; ○—no oscillations.

accompanied by the formation of a thermal lens, which defocuses the beam. Because of the decrease in the local heating, the system reverts to its "brightened" state, the thermal lens disappears, and then the entire process repeats itself.

In summary the negative feedback in the system results from a defocusing of the beam. Instead of optical bistability, there is a regime of regenerative pulsations.[3]

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[1]G. A. Shafeev, in *Proceedings of the Thirteenth International Conference on Coherent and Nonlinear Optics*, Part IV, Minsk, 1988, p. 36.
[2]G. A. Shafeev, Izv. Akad. Nauk SSSR. Ser. Fiz. **53**, 563 (1989).
[3]H. Gibbs, *Optical Bistability*, Academic Press, Orlando, 1985.

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