THERMAL CHANGES IN REFRACTIVE INDEX OF LIQUIDS INDUCED BY A PULSED RUBY LASER BEAM

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(Received June 29, 1971, Revised paper received August 25, 1971)

Thermally induced changes in refractive index of some liquids illuminated by a powerful laser beam were investigated. Blue argon ion laser light was used as measuring beam. Heating of the liquid causes the diameter of the blue spot to increase several times, depending on the absorption coefficient of the liquids.

Propagation of light beams in liquids is always associated with heating effects which depend on the intensity of the beam as well as on the absorption coefficient of the medium. This effect causes changes in refractive index n of the liquid which are positive or negative, depending on the sign of $\frac{dn}{dT}$. Thus, thermal focusing or defocusing of the incident beam can be observed. The effect was first investigated by means of a He–Ne laser beam in liquids [1] and subsequently by others using cw gaseous [2–7] or solid state lasers [8, 9]. When using a pulsed laser beam, the effect is more complex because of transient phenomena.

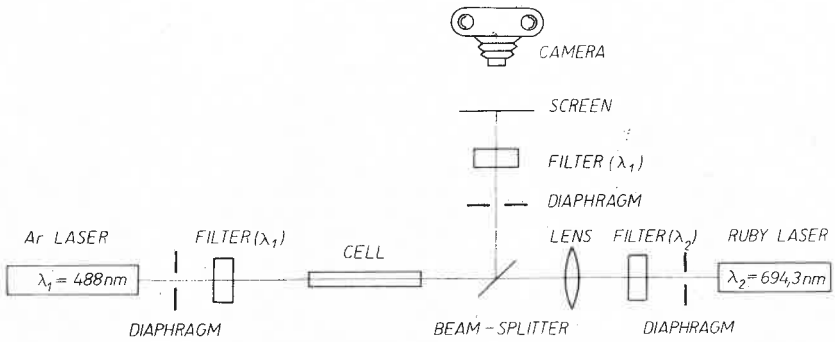

Fig. 1. Experimental set-up, schematically

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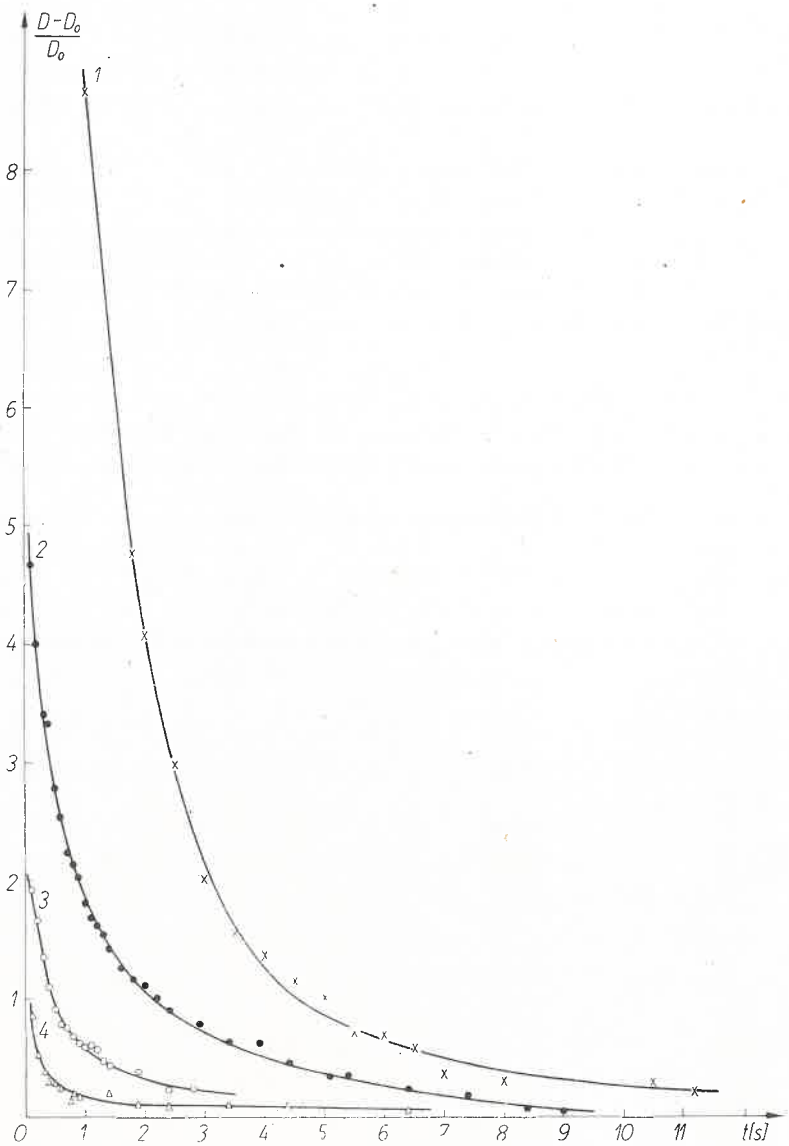
Heating of the liquid forms an effect competitive with respect to optical Kerr effect and electrostriction [10], and acts to stabilize the propagated light beam.

In this paper, changes in refractive index of liquids induced by a pulsed ruby laser beam are reported. The experimental arrangement is shown in Fig. 1. The laser operated in so-called free running régime. An argon ion laser (λ = 488 nm, TEM_{00} mode) supplied the measuring beam. Thus, separation between the inducing and the measuring beams was easily obtained. The liquids under investigations were placed in a glass cell 20 cm in length and 1 cm in diameter. The power density of the ruby laser beam was increased by focusing



a

the beam ($f = 27$ cm) inside the cell. The diameter of the incident and output beam was the same (0.4 cm). The measuring beam, 0.15 cm in diameter, penetrated the inducing light channel exactly along its axis. The beam splitter *BS* directed the blue light towards a diffusing screen *S*, placed 65 cm apart from the liquid cell. It was verified that the meas-

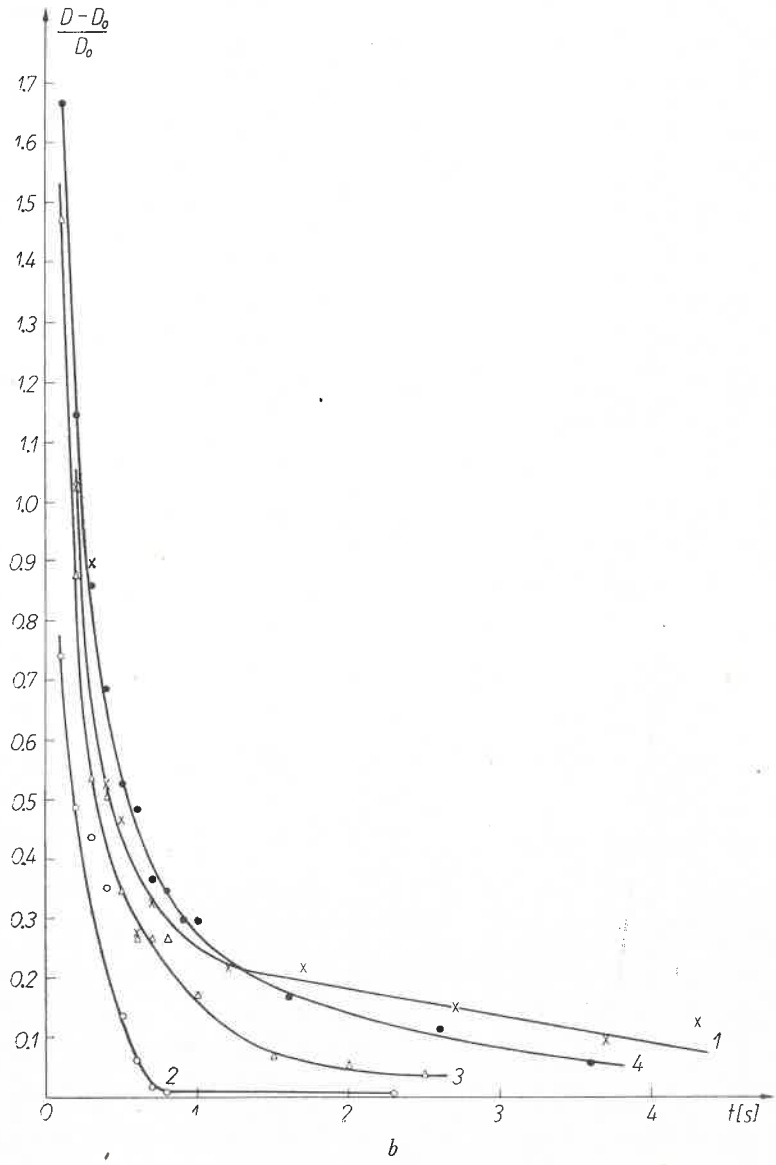


Fig. 2. Relative changes in diameter of the measuring spot, $\frac{D-D_0}{D_0}$, as function of time; a) *1* – nitrobenzene, *2* – benzene, *3* – toluene, *4* – water; b) *1* – cyclohexane, *2* – carbon tetrachloride, *3* – carbon disulphide, *4* – acetone

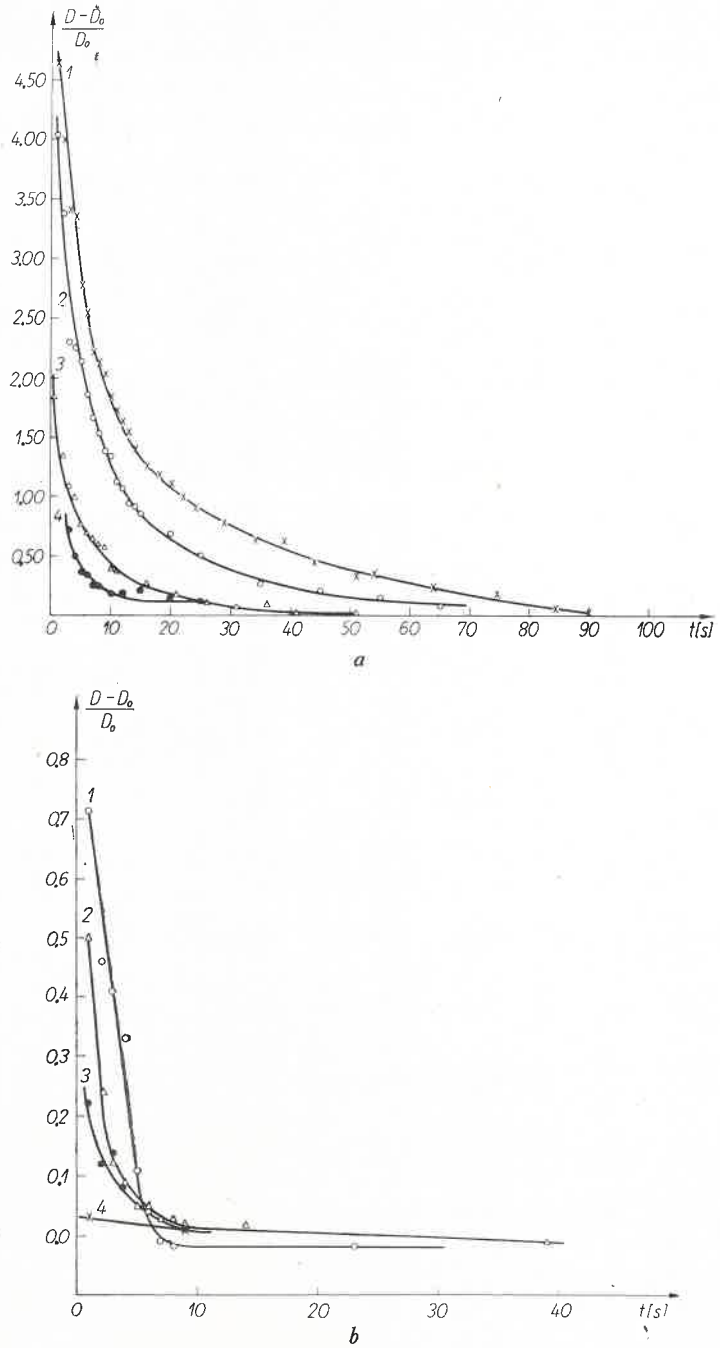


Fig. 3. $\frac{D-D_0}{D_0}$ as function of time for various energies of the ruby laser pulse and various pulse durations τ; *1* – $E = 32.15$ J/cm², $\tau = 3.5$ ms; *2* – $E = 17.15$ J/cm², $\tau = 3$ ms; *3* – $E = 5.00$ J/cm², $\tau = 2.1$ ms; *4* – $E = 0.72$ J/cm², $\tau = 1.8$ ms, a) benzene, b) carbon tetrachloride

uring beam (2 mW) did not cause any detectable changes in refractive index of the liquid. The observed blue light spot had a diameter of 0.2 cm at the screen and did not change with time. The following liquids were investigated: benzene, toluene, nitrobenzene, cyclohexane, acetone, carbon disulphide, carbon tetrachloride, and distilled water; all of them exhibiting $\frac{dn}{dT} < 0$ at room temperatures. Absorption of energy from the ruby laser beam causes the refractive index of the liquid to decrease. As a result, the blue measuring spot at the screen increases in diameter abruptly several times with respect to its initial value. Using the arrangement here described, no delay between the laser pulse and this increase was detectable. The diameter of the blue spot increases depending on the liquid illuminated, and then decreases slowly during a few seconds. The time-dependence of the spot diameter change was measured by means of a moving camera, placed behind the screen. The speed of the film was from 10 to 32 frames per sec. The results obtained are presented in Figs 2 and 3. The relative change in diameter of the spot marked by the beam from the argon ion laser, $\frac{D-D_0}{D_0}$, is plotted in function of time. Curves for the 8 investigated liquids are shown in Figs 2a and 2b; the energy density of the ruby laser pulse was 32.2 J/cm^2 and its duration $3.5 \cdot 10^{-3}$ s. Changes in $\frac{D-D_0}{D_0}$ *versus* the radiation energy for benzene and carbon tetrachloride are shown in Figs 3a and 3b. The energy of the laser pulse was measured using a "rat-nest"calorimeter. The irradiated liquid behaves like a concave lens and causes an increase in divergence of the beam. In the case of benzene, the blue measuring beam increased its divergence from 2′ to 18′. The calculated negative focal distances are listed in Table I.

TABLE I

Relative changes in $\frac{D-D_0}{D_0}$, and calculated focal distances. Energy of the laser pulse was 32.2 J/cm^2, duration 3.5 ms

Liquid	Benzene	Toluene	Nitro-benzene	Cyclo-hexane	Acetone	Carbon disulphide	Carbon tetra-chloride	Water
$\frac{D-D_0}{D_0}$	4.64	1.91	8.65	1.62	1.64	0.71	1.49	0.86
f(cm)	14.0	34.0	7.5	40.1	39.6	91.7	43.3	75.5

All liquids under investigations were "analysis pure".

It is interesting to point out that the effect here investigated was not observed where a gigant pulse laser beam was used.

Thanks are due to Professor S. Kielich and to Docent F. Kaczmarek, for their interest and encouragement.

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