TIME-DEPENDENT CHANGES OF THE CHARACTERISTICS OF LIGHT SCATTERING BY AN AQUEOUS MEDIUM SUBJECTED TO A HYDRODYNAMIC PERTURBATION

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The present article describes the results of an experimental investigation of the dependence of laser light scattering by distilled water upon hydrodynamic perturbations introduced in the water. It was found that after a perturbation, the light flux which is scattered by the liquid increases. The effect occurs only in water which has settled. The influence of a magnetic field was investigated.

Fluctuations of laser radiation scattered by a stationary liquid in which an instantaneous perturbation was created via a falling body have been studied in [1]. We consider in the present work the scattering by water which is enclosed between two coaxial disks. The prehistory of the scattering medium was taken into consideration; the hydrodynamic perturbation was generated by rotating one of the disks.

The scheme of the experimental setup is shown in Fig. 1. A beam of a helium–neon laser 1 was focussed with a lens of great focal length and directed into the space between disks 2 and 3 inserted in a vessel with distilled water. The disks had a diameter of 90 mm, and the distance h between the disks could be adjusted. The beam had equal distances from the plane of the disks. The radiation scattered at angles $\alpha = 45°$, 90°, and 135° relative to the axis of the beam was recorded with the aid of photomultipliers 4, 5, and 6 (light originating from a volume of about 0.4 mm^3). The volume was fixed and was the same for all three directions. A particular section of the light beam was cut out by slits which were situated in the image planes of the lenses directly before the photocathodes of the photomultipliers. In addition, a photomultiplier 7 was used to record changes in the intensity of the radiation transmitted through the vessel. A diaphragm shielded photomultiplier 7 from the radiation scattered at small angles in forward direction.

The frame of the vessel, the disks, and all other components immersed in the water were made of brass which had been blackened by oxidation. The window was made of polished window glass. A hydrodynamic disturbance was introduced by rotating the upper disk. The initial rate of rotation was of the order of 4 revolutions per second, and the time of rotation until the disk had come to rest was about 3 sec. After that, the disks remained stationary during the entire experiment. Simultaneous recordings with all four channels were made with the aid of microammeters (the photocurrents were fixed with the disks stationary) and a loop oscillograph 8 with low-frequency vibrators.

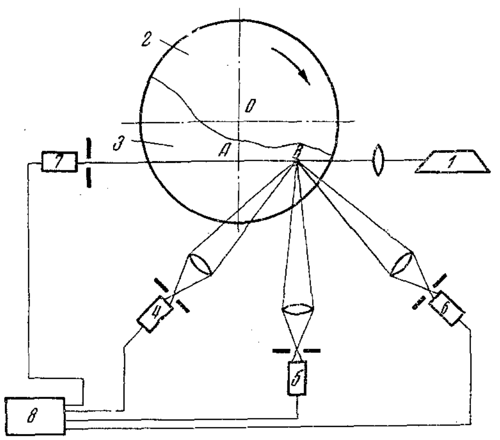

Fig. 1

Figures 2 and 3 display characteristic oscillograms of the intensity of the scattered light measured at the angles 45°, 90°, and 135° (curves 1, 2, and 3, respectively) and of the light transmitted through the vessel (curve 4). The time is plotted to the horizontal scale (t = 0 denotes the time at which the perturbation was generated); the readings of the photomultiplier are indicated on the vertical scale. The time interval between a preceding perturbation and the following perturbation (Δt) is 60 hours in the case of Fig. 2, and 5 min in the case of Fig. 3. The

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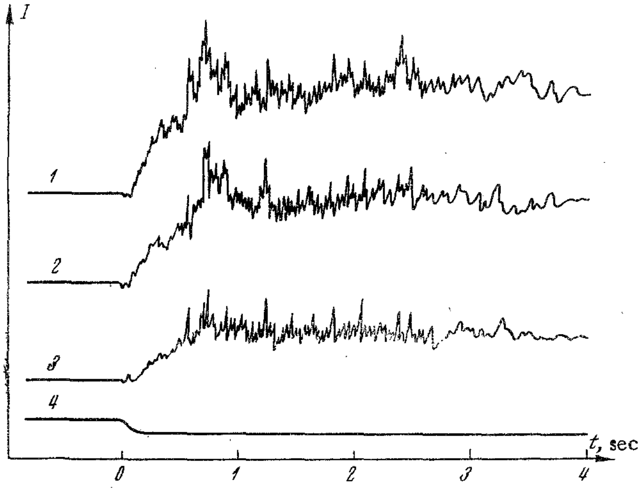

Fig. 2

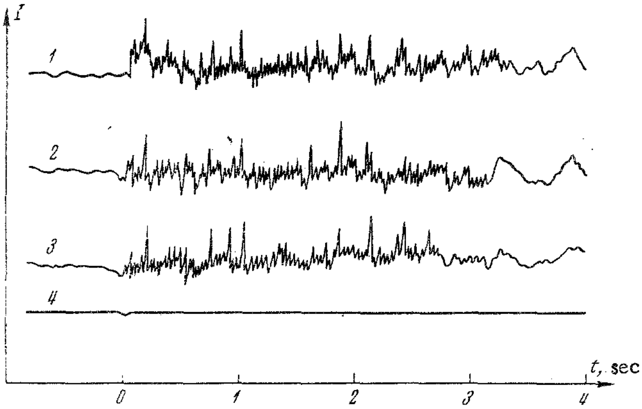

Fig. 3

initial photocurrents for all the figures are approximately identical as far as curves 1, 2, and 3 are concerned and amount to 30 μA; the photocurrent is 200 μA for curve 4; h = 2.5 mm. It follows from the oscillograms of Fig. 2 that the average intensity of the scattered radiation in water which had come to rest after the introduction of an instantaneous perturbation increased, with the increase being the stronger the smaller the scattering angle. The new values of the photocurrent exceeded the initial values by 200, 170, and 100% for angles α of 45°, 90°, and 135°, respectively. The light transmitted through the vessel was attenuated by about 5%. Introducing a perturbation in water which had not been at rest for a sufficient time did not modify the optical properties of the water (Fig. 3). Pulsations of the intensity of the scattered radiation are of approximately the same form in these two figures.

All oscillograms displayed were recorded for point B (see Fig. 1). The processes at point A differ by the duration of the transition period, which is reduced by about one order of magnitude in the change of the intensity of the scattered light from the initial value (immediately before the perturbation) to the final value. The difference results from the direction of the disturbing motion relative to the laser beam, i.e., motion parallel to the beam (point A) or perpendicular to it (point B).

The measurements were made in the following sequence. A certain time after the last perturbation, points were recorded in all four channels; then the oscillograph was switched to recording, the next perturbation was generated, and new current values were recorded 5-10 sec later. The current readings were recorded several times during the following 20-30 sec. The weighted mean value of the readings was calculated and the relative excess of the currents over the initial currents was calculated from these mean values. The initial values were assumed as 100%.

Afterwards, the intensity of both the scattered light and the radiation passing through the vessel was assumed to be proportional to the corresponding photocurrents. The instrument-dependent errors could be

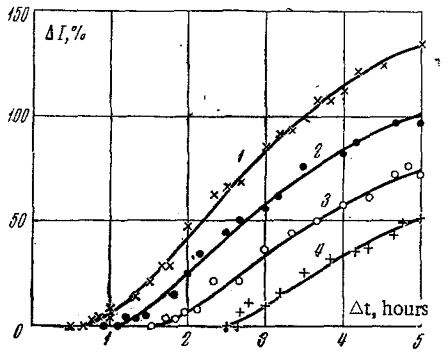

Fig. 4

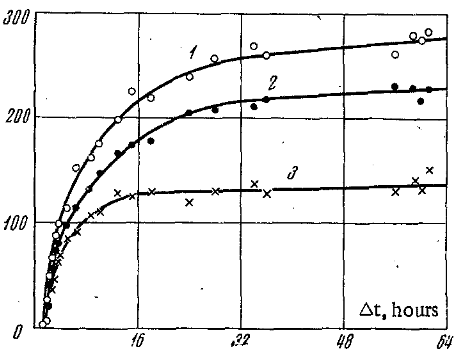

Fig. 5

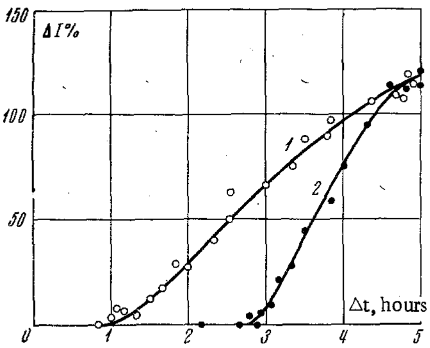

Fig. 6

greatly reduced by using the relative changes of the currents in place of their absolute values for the analysis of the experimental data. Figures 4, 5, and 6 show several typical graphs which were constructed from the experimental data. The time intervals between the preceding and the subsequent (at the time of the measurements) disturbances (Δt) was always plotted to the horizontal axis; the relative increase (%) of the intensity of the scattered radiation after a perturbation (ΔI) was plotted to the vertical axis.

The graphs of Fig. 4 correspond to various distances between the disks for $\alpha = 90°$ (h = 1.0, 1.5, 2.0, and 2.5 mm, corresponding to curves 1, 2, 3, and 4, respectively). It follows from the graphs that the effect under consideration begins to manifest itself after a time interval which had a certain value for each h. After that, the effect increased linearly for about 2 hours and then the curves became convex. When h decreases, the time interval decreases and the increment of the effect grows more rapidly and reaches higher values. These relations are valid for all α.

The graphs of Fig. 5 correspond to h = 1.5 mm for angles α of 45°, 90°, and 135° (curves 1, 2, and 3, respectively). The effect increases more rapidly and reaches higher values when α decreases. The time at which the effect appears is almost independent of α.

The difference between the curves becomes more pronounced with increasing Δt for vaious α values and increases from a ratio of about 1.0 : 1.1 : 1.2 on the initial section to the ratio 1.0 : 1.6 : 2.0 on the section $\Delta t > 24$ hours. These relationships hold also for other h. Though the curves are almost horizontal for $\Delta t > 24$ hours, a certain increase in ΔI at increasing Δt is still conserved.

The graphs of Fig. 6 refer to the case h = 1.5 mm and $\alpha = 45°$. Curve 1 was recorded under the same conditions as the preceding graphs, whereas curve 2 was recorded in the field of a permanent magnet. The magnetic field delayed the beginning of the effect which, once it started, reached 2-3 hours later the same values as without the magnetic field. After that, the two curves are practically identical. The orientation of the magnetic field does not affect the results.

LITERATURE CITED

1. N. P. Verkhovykh, Yu. S. Verkhovykh, V. M. Sysak, and A. M. Trokhan, On the Scattering of Light by a Turbulent Liquid, Zh. Prikl. Mekh. i Tekh. Fiz., No. 1 (1970).