KERR CONSTANT OF WATER

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Measurements are conducted of the Kerr constant of ultrapure water with resistivity $10^7\ \Omega \cdot$cm. Values of the Kerr constant of $(3.26 \pm 0.10) \cdot 10^{-7}$ and $(2.29 \pm 0.07) \cdot 10^{-7}$ esu were obtained at a temperature of 30°C for wavelengths of 441.6 nm and 632.8 nm.

The Kerr effect in water is widely used in physical experiments [1-7]. In a number of cases, for example, in absolute measurements of the electric field strength in water [2, 3], in physicochemical studies of a water molecule [4-7], and in other fields, the accuracy to which the Kerr constant B of water is known also determines the accuracy of the corresponding experiments. Unfortunately, absolute values of B previously presented [1, 4, 7-16] differ substantially. Experimental studies containing data on measurements of the Kerr constant of water were analyzed. Values of B obtained by different authors are presented in Table 1 which also indicates the wavelength and temperature at which the measurements were conducted. The last column of the table gives values of the Kerr constant calculated for the wavelength $\lambda = 589$ nm using Havelock's law* [8]:

$$B(\lambda) \sim \frac{[n^2(\lambda) - 1]^2}{n(\lambda)} \frac{1}{\lambda},$$

where $n(\lambda)$ is the index of refraction of water.

The fact that different experiments were carried out at different temperatures cannot be used to explain the variance observed in the values of B, since [6] the Kerr constant of water varies by at most 3% in the range 20-40°C.

The value of the Kerr constant of water most often encountered in [9-12] ($B_{589} = 4.7 \cdot 10^{-7}$ esu) is presented either without any reference or [10] with a reference to new studies [17-19]. However, these studies did not refer to the Kerr constant of water.

The Kerr constant has been determined [13, 14] for nonmonochromatic light, and, consequently, results of these works are only of the type of an estimation.

No detailed description of the procedure of the measurements or an analysis of the experimental errors was given in the papers cited in Table 1, except for [4]. It is thus difficult to establish the reasons for the variance of the experimental values of B obtained by different authors.

The current work was carried out in order to refine the value of the Kerr constant of water. Measurements were conducted for two wavelengths: $\lambda = 441.6$ nm and $\lambda = 632.8$ nm. Experiments were conducted with ultrapure water with resistivity $10^7\ \Omega \cdot$cm at a temperature of 30°C.

The experimental setup is depicted in Fig. 1. An He–Cd and an He–Ne laser 1 were used as the light sources. Two broad parallel plates made of stainless steel of length $l = 72$ cm, between which two insulators 4 made of Plexiglas about 4 mm thick were situated in such a way that the effective field of the Kerr cell was in the form of a square measuring 4×4 mm^2, were used as the electrodes 5 of the Kerr cell. A uniform electric field was created in the cell of this configuration because of the substantial difference between the permittivities of Plexiglas and water.

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*This law does not hold near the natural absorption band ($\lambda_{\text{abs}} = 190$ nm for water).

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TABLE 1

Paper	Characteristics of water	T°,c	λ, nm	$10^7 B$, esu	$10^7 B_{589}$, esu
[9–12]		20	589		4,7
[17]	Distilled water	17	"Yellow"	$1{,}23 \cdot B_{CS_2}^*$	4‡
[16]		25	"White"	2,4	
[1]	$\rho = 10^5\ \Omega \cdot cm$	25	210—300	~10	
[7]			210	0,8†	
			300	5,2	
			400	3,9	2,5
			600	2,7	2,7
[4]	Doubly distilled water	25	436	3,72±0,14	2,64±0,10
			546	2,89±0,04	2,65±0,04
			578	2,72±0,11	2,66±0,11
Current paper	$\rho = 10^7\ \Omega \cdot cm$	30	441,6	3,26±0,10	2,35±0,07
			632,8	2,29±0,07	2,46±0,08

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* B_{CS_2} is the Kerr constant of carbon disulfide.

†In the current work, the experimental points have a variance of about 30%.

‡Calculated under the assumption that measurements were conducted at λ = 5 98 nm; the value of B_{CS_2} was taken from [20].

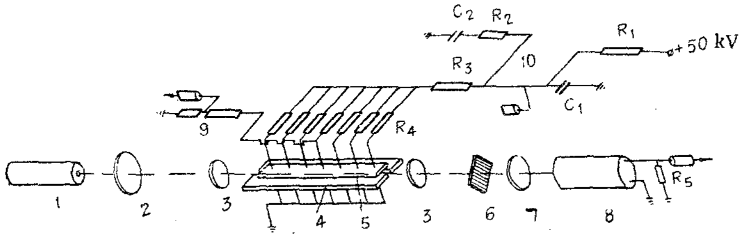

Fig. 1

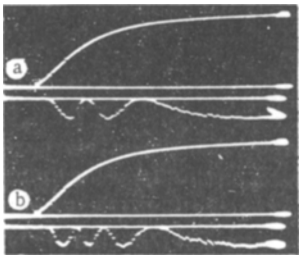

Fig. 2

Laser radiation polarized at an angle of 45° to the electrode plane passes through the lens 2 and the window 3 of the vessel along the cell axis and is recorded by an FÉU-14B photomultiplier 8 after passing through the analyzer 6 and the gray-light filter 7. The analyzer is mounted at the light-transmission minimum in the absence of an electric field in the cell.

Voltage from a storage capacitor $C_1 = 0.1$ μF is simultaneously fed through a gap 10 at seven points through equally long conductors in order to decrease reflection effects. The voltage across the cell is measured by a calibrated resistance divider 9, whose signal enters the oscillograph plate. The signal from the photomultiplier is recorded on the second oscillograph beam. Typical oscillograms of the voltage applied to the cell (upper beam) and signals from the photomultiplier are presented in Fig. 2 (sweep interval of 2.5 μsec). Signal lag due to the finite time within which the electrons drift through the photomultiplier (about 40 nsec) was found by means of a pulsed light into the test circuit of the resistance divider. Photomultiplier signal lag observed in Fig. 2 relative to the moment voltage is fed across the cell is apparent and is explained by the low value of the Kerr effect in the region of low voltages ($\varphi \sim E^2$).

The value of B can be determined using the well-known equations

$$B = \frac{\varphi}{2\pi l E^2}; \quad \frac{I}{I_0} = \sin^2\frac{\varphi}{2} \qquad (1)$$

from oscillograms (cf. Fig. 2) for any moment of time. Here φ is the optical difference of phases (in rad) between the usual and unusual waves accumulated through the cell. We determine B by processing oscillograms at points corresponding to light-transmission maxima and minima ($\varphi = \pi, 2\pi, \ldots$). In these cases, B was found directly using Eq. (1). The highest statistical precision of the results was obtained by processing oscillograms at the point at which the photomultiplier signal reaches its final minima, where photomultiplier noise is absent, while the field strength E is determined with least error. Values of the Kerr constant determined from the remaining extrema have a higher statistical variance, but the same value within their precision.

An analysis of the experimental errors demonstrated that the basic error is due to variations of the electric field strength in the cell as a consequence of fluctuations of the insulator thickness, which determine the distance between the electrodes ($d = 3.9 \pm 0.05$ mm). The magnitude of this error $2\Delta d/d = 2.6\%$. A significantly lesser contribution is made by the remaining errors, which are due to the precision of the amplitude calibration of the oscillograph tube and the resistance divider. Errors associated with the divergence of the laser beam passing through the cell and with fringe effects at its entry and exit were neglibibly small. The statistical measurement precision of the strength determined from a series of 15 oscillograms amounted to 0.52% and 0.76% ($\lambda = 441.6$ nm and $\lambda = 632.8$ nm, respectively). The total relative error of the Kerr constant of water $\Delta B/B = 3.0\%$ and 3.1% ($\lambda = 441.6$ nm and $\lambda = 632.8$ nm, respectively) in the experiments.

Results from Table 1 are closest to results presented in [4, 7]. Some difference in values of the Kerr constant is apparently due to the difference in the degree of purity of the water and the presence of unregulated impurities. In fact, double distilled water that had been stored for a week in polythylene vessels was used in [4], while our cell was directly connected to the water purification circuit with activated charcoal and ionites. A substantial influence of the presence of impurities on the size of the Kerr constant is known, for example, in the case of nitrobenzene [16] and carbon disulfide [20].

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INTERACTION OF LIGHT WITH A TURBULENT LIQUID

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A paper [1] recently published in a scientific journal summed up a recently conducted set of studies [2, 4] on the optics of heterogeneous media. A number of fundamental statements of these studies require examination.

§ 1. Turbulent pressure pulsations, reducing to, by means of density pulsations, fluctuations of the refractive index r, according to [1-4], are the basic factors resulting in scattering of light by a turbulent flow of a transparent liquid not undergoing external heat exchange.

These authors [1-4] were apparently not aware of the fact that the approach they adopted to the analysis of the phenomenon had already been used by other researchers and had been criticized in terms of the lack of theoretical correspondence to the actual conditions of a turbulent atmosphere. We may suggest that an analysis of the previous [5] data may have convinced these authors of the inapplicability of this approach for the case of turbulent flow of a dropping liquid they had considered.

§2. It was assumed [1-4] that in a liquid, "in particular, isothermal conditions may occur as light passes into the ocean and that turbulence will manifest itself in terms of the effect of pressure pulsations, as if the latter were low" [1]. Unfortunately, no grounds were given [1-4] for this disputable thesis regarding the substantial role of compressibility as light interacts with a liquid.

Results are given below of estimates of the degree of isothermicity in a turbulent liquid flow, such that the effective compressibility associated with pressure pulsations predominate over the effect of temperature pulsations. The dependence [1-4]

$$P' \approx \langle\rho\rangle \langle u\rangle u', \tag{2.1}$$

where $\langle\rho\rangle$ and $\langle u\rangle$ are the mean densities and velocities and P' and u' are pressure and velocity* pulsations, was the basis of the estimates.

It is assumed [6] that u' is 4% of the mean liquid velocity in the tube.

Results of the estimate show that it is necessary for the flow to become isothermal to within $10^{-5\circ}$ in order to ensure that pressure pulsations will predominate in the characteristic case examined by these

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* Apparently the presence of only the component u' in the dependence was due to the fact that the pulsating velocity components in a near-axial region of the turbulent flow in a tube are equal; P' and u' denote the root-mean-square values of the corresponding pulsations.

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