Kielich, S.
1967

Physica 34
586-588

LETTER TO THE EDITOR

Opticostriction and optically induced electric anisotropy

Recently, Shen[1]) calculated numerically for some liquids the variations in refractive index due to electrostrictive pressure and optical birefringence, and discussed their role in the self-focussing of laser beams in liquids[2]).

This letter brings numerical calculations of the electric anisotropy which can be induced in liquids by intense light, and a comparison is made with the variations in dielectric permittivity due to opticostriction[3]).

In the general case, light of intensity I will cause the dielectric permittivity tensor $\varepsilon_{\sigma\tau}$ to vary by[4])

$$\varepsilon^{I}_{\sigma\tau} - \varepsilon\delta_{\sigma\tau} = Q_{\mathrm{is}} I \delta_{\sigma\tau} + Q_{\mathrm{anis}}(I_{\sigma\tau} - \tfrac{1}{3} I \delta_{\sigma\tau}), \tag{1}$$

Q_{is} denotes isotropic variations of $\varepsilon_{\sigma\tau}$ related i.a. with opticostriction (those from the electrocaloric effect and nonlinear polarization are not considered here):

$$Q_{\mathrm{is}} = \frac{\varepsilon - 1}{8\pi} \left\{ 2n \left(\frac{\partial n}{\partial p}\right)_T - (n^2 - 1)\, \beta_T \right\} \left(\frac{n^2 + 2}{3}\right)^2, \tag{2}$$

whereas Q_{anis} is the constant of optically induced electric anisotropy discussed theoretically in ref. 4 which in a satisfactory approximation can be written as

$$Q_{\mathrm{anis}} = 2\lambda n K_{\lambda}, \tag{3}$$

K_{λ} being the experimentally measured Kerr constant.

At incidence along the laboratory y axis, eq. (1) yields the difference in dielectric permittivities measured along the x and z axis as

$$\varepsilon_{zz} - \varepsilon_{xx} = Q_{\mathrm{anis}}(I_{zz} - I_{xx}) \tag{4}$$

defining the optically induced electric anisotropy, which is thus seen not to depend on variations due to opticostriction.

In table I are assembled the numerical values of Q_{is} and Q_{anis} calculated from eqs. (2), (3) and available experimental data (see refs 5–7). It results that for liquids with a low Kerr constant the changes in dielectric permittivity due to opticostriction are comparable to or exceed the changes due to induced electric anisotropy, which predominate strongly in liquids with a high Kerr constant. Shen's[1]) calculations of refractive index variations due to intense light result in a similar situation.

Evaluations of Q_{anis} show that, in liquids with a high Kerr constant, present laser techniques are clearly adequate for the detection of optically induced electric anisotropy. Thus, in nitrobenzene the latter amounting to $\varepsilon_{zz} - \varepsilon_{xx} \simeq 7 \times 10^{-9} I$ would become accessible to observation already when using a laser beam of intensity $I \simeq 10^5$ esu. Liquids like pyridine, acetone, methyl-ethyl ketone, or chlorobenzene would demand intensities of $I \simeq 10^6$ esu. In the other liquids, detection of optically induced

TABLE I

Calculated variations of the dielectric permittivity of some liquids due to opticostriction and optically induced electric anisotropy*)

Liquid	ε	n $\lambda = 5460$ Å	$\left(\frac{\partial n}{\partial p}\right)_T \times 10^{12}$ $\left(\frac{\text{cm}^2}{\text{dyn}}\right)$	$\beta_T \times 10^{12}$ $\left(\frac{\text{cm}^2}{\text{dyn}}\right)$	$K_\lambda \times 10^9$ esu $\lambda = 5460$ Å	$Q_{\text{is}} \times 10^{12}$ (esu)	$Q_{\text{anis}} \times 10^{12}$ (esu)
Benzene	2.28	1.503	52.3	95	40.3	3.85	6.61
Toluene	2.38	1.499	48.6	92	71.4	3.40	11.69
Cyclohexane	2.03	1.426	50.8	112	5.9	10.39	0.92
n-Hexane	1.89	1.374	66.5	170	6.6	1.89	0.99
n-Octane	1.96	1.398	52.8	125	8.6	1.88	1.31
n-Decane	1.98	1.413	46.9	105	10.3	1.88	1.58
Carbon tetrachloride	2.24	1.460	52.8	106	8.4	3.18	1.13
Carbon disulphide	2.63	1.634	68.2	94	355.0	10.50	63.34
Methyl ethyl ketone	18.59	1.379	44.2	108	1382.0	29.12	208.11
Water	80.3	1.334	15.2	46	436.7	182.85	63.63
Chloroform	4.8	1,446	37.7	87	−308.0	7.28	−48.63
Acetone	21.4	1.359	43.6	125	1792.8	14.28	266.05
Chlorobenzene	5.7	1.521	46.4	75	1050.0	12.86	174.41
Nitrobenzene	35.5	1.560	33.3	49	38600.0	100.09	6577.44
Ethyl alcohol	25.0	1.362	38.2	110	85.2	17.41	12.67
Ethyl ether	4.34	1.356	63.6	184	−66.0	3.95	−9.77
Methyl alcohol	33.5	1.328	39.4	127	106.5	20.46	15.44
Ethylene dichloride	10.6	1.419	37.8	80	502.0	17.68	77.81
Pyridine	13.23	1.509	29.1	48	2243.6	20.51	369.74
Aniline	7.02	1.586	32.5	45	−181.1	18.95	−31.37

*) Values of ε and K_λ for $t = 20$°C are from ref. 5; those of n, $(\partial n/\partial p)_T$ and β_T – from refs 5–7.

electric anisotropy would require a giant pulse laser with focussed beam of intensity $I \simeq 10^7 - 10^8$ esu.

Strictly, beside electric anisotropy, intense light gives rise to magnetic anisotropy also which, however, is undetectably small in diamagnetics[8]).

Investigation of optically induced anisotropy will provide information on the molecular properties of liquids like that hitherto gained from the Kerr effect. Moreover, measurements of the absolute changes in dielectric constant due to intense light will by eq. (1) provide data on opticostriction, which plays so great a part in various nonlinear optical processes[1–3]).

Received 24-1-67

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