acta phys. slov. 37 (1987), No. 1

He—Ne LASER IN TURBID LIQUIDS INVESTIGATIONS

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The transmission of a narrow He—Ne laser beam through nearly monodisperse polystyrene latices was investigated. The diameters of the particles employed were 137.6 nm, 531.2 nm and 733.3 nm. The dependence of the attenuation coefficient on latex concentration was found to be linear. The experimental values of the specific turbidity, $(26 \pm 4)\ \mathrm{cm}^{-1}$, $(226 \pm 7)\ \mathrm{cm}^{-1}$ and $(292 \pm 10)\ \mathrm{cm}^{-1}$, respectively, were in good agreement with theoretical ones, based on Mie's theory.

I. INTRODUCTION

The power (P) of an electromagnetic wave propagating through a fluid decays according to the equation [1]

$$\mathrm{d}P = -aP\,\mathrm{d}x \qquad (1)$$

where a is the attenuation coefficient and x is the layer thickness. In this paper investigations were carried out using monodisperse polystyrene latices as model systems of turbid liquids. The systems used were colloidal dispersions, consisting of almost ideally spherical particles of uniform size.

The power of the central part of the laser beam transmitted through latex dispersions was measured as a function of layer thickness. The diameter and concentration of particles were employed as parameters.

II. EXPERIMENTAL

II. 1. Materials

Samples of monodisperse polystyrene latices, used in these measurements, were supplied by the courtesy of the Laboratory of Biocolloidal Chemistry, A. Štampar School of Public Health, Zagreb, Yugoslavia [2]. The spherical shape of the particles employed, as well as the particle size distributions were evaluated from electron microscopic data. The characteristic parameters of the latices employed are given in Table 1, where $\bar{D}$ is the arithmetic mean diameter, $PR = (D_w/D_n)^3$ is the polydispersity ratio, D_w is the weight average diameter and D_n is the number average diameter.

Table 1

The characteristic parameters of latices employed

Sample	$\bar{D}$/nm	PR
LS 54-PJ	137.6	1.066
LS 137-T	531.2	1.009
LS 142	733.3	1.007

The measurements were performed with three polystyrene latices of various particle sizes. For each latex dispersion, a series of dilutions was prepared volumetrically from a stock latex dispersion by adding distilled water. Stock latex dispersions were filtered, using filter paper, immediately before measurements, to separate possible aggregates. The concentration of stock dispersions was determined gravimetrically.

II. 2. Apparatus

The laser beam source was a He—Ne laser HNA 50 (C. Zeiss—Jena) with maximal laser power of 4 mW and a wavelength in vacuo of 632.8 nm. The sample container was a high-quality optical glass cell. The layer thicknesses were 2.5, 3.0, 6.0 and 8.0 cm. The light beam was propagated directly from the light source through the sample. The transmitted light power was measured at a distance of 10 cm from the light source in the forward direction. For this purpose, an optical powermeter LM 1 (C. Zeiss-Jena) was applied, and it was gauged to the wavelength of the monochromatic light used. In front of the detector there was an iris-diaphragm, to ensure that the detecting system did not intercept a significant amount of the light scattered near the forward direction.

III. RESULTS AND DISCUSSION

The experimental results given in Figs. 1—3 show the transmitted light power as a function of the sample layer thickness with the size of the particles and the

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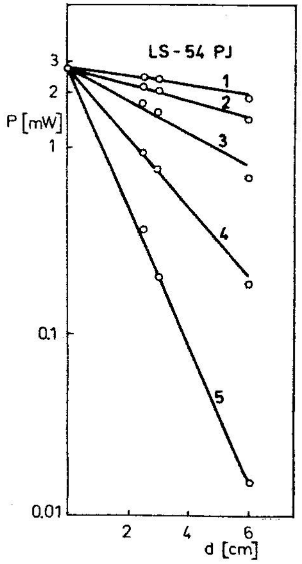
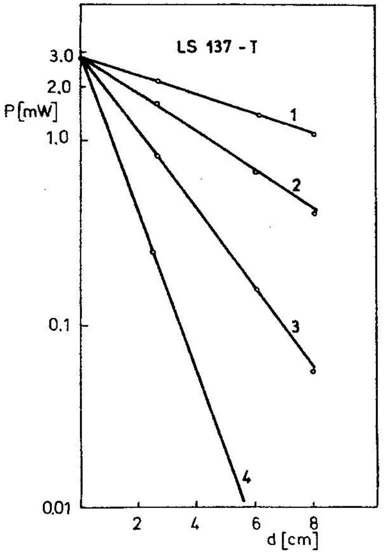
concentration as parameters. The concentration is expressed as the total mass of the particles in 100 g of the scattering system.

The experimental data obtained show that the transmitted light power decreases with sample layer thickness, in accordance with the law expressed by the equation

$$P = P_0 \, e^{-ad} \qquad (2)$$





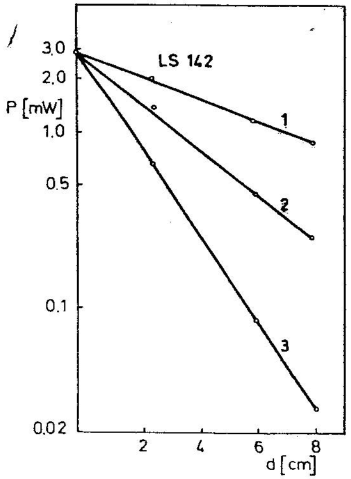


Fig. 1. The transmitted light power (P) as a function of sample layer thickness (d) with the concentration as parameter. 1) 0.002 g/100 g, 2) 0.004 g/100 g, 3) 0.008 g/100 g, 4) 0.016 g/100 g, 5) 0.032 g/100 g.

Fig. 2. The transmitted light power (P) as a function of sample layer thickness (d) with the concentration as parameter. 1) 0.0005 g/100 g, 2) 0.00109 g/100 g, 3) 0.00218 g/100 g, 4) 0.00437 g/100 g.

Fig. 3. The transmitted light power (P) as a function of sample layer thickness (d) with the concentration as parameter. 1) 0.00053 g/100 g, 2) 0.00107 g/100 g, 3) 0.00213 g/100 g.

where P_0 is the light power transmitted through distilled water with $a = 0$, and d is the layer thickness. The attenuation coefficients were calculated using the linear regression method.

The intercept on the ordinate axis was of the same value, ln P_0, in all cases. The mean attenuation coefficient was determined as a function of the concentration for each latex sample (Fig. 4). It may be seen that the attenuation coefficient is proportional to the latex concentration following the equation

$$\bar{a} = kc \qquad (3)$$

where k is the specific turbidity, and c is the concentration of the latex employed.

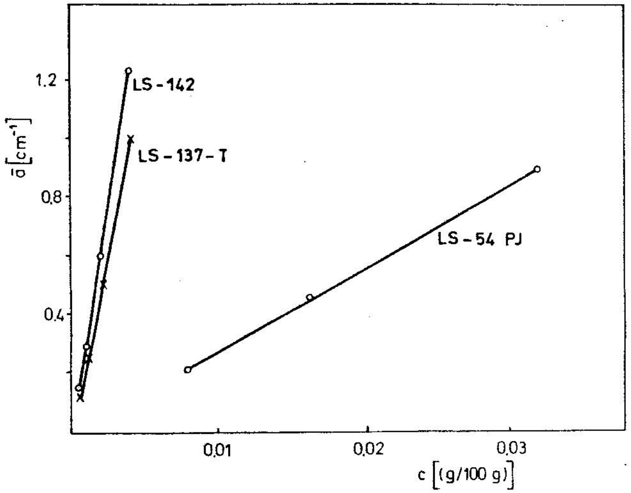


Fig. 4. The mean attenuation coefficient ($\bar{a}$) as a function of the concentration.

This results are in good agreement with those obtained with suspensions of teflon particles [3]. The k values for polystyrene latices employed are given in Table 2, where $k(exp)$ is the experimental specific turbidity, $k(th)$ is the theoretical specific turbidity and α is the relative particle diameter. The experimental specific turbidity for the latices employed was compared with the theoretical values based on Mie's theory [4, 6], (Table 2). For this purpose the m and α values should be calculated:

$$m = n_2 / n_1 \qquad (4)$$

where n_2 and n_1 are the refractive index of the particles and of the medium, respectively, and

$$\alpha = \pi \bar{D} / \lambda \qquad (5)$$

Table 2

The experimental and theoretical specific turbidities for $\lambda = 475.4$ nm

Sample	α	$k\,(exp)$/cm	$k(th)$/cm
LS 54-PJ	0.9	26 ± 4	22.74
LS 137-T	3.5	226 ± 7	221.53
LS 142	4.9	292 ± 10	297.18

where $\bar{D}$ is the mean diameter of the particles, and λ is the wavelength in the surrounding medium. The $k(th)$ values were calculated for polystyrene latex dispersions in pure water at 25.0 °C, where $n_1 = 1.331$, $n_2^D = 1.59$ [5], $m = 1.19$, $\lambda = \lambda_0 / n_1 = 475.4$ nm and $\lambda_0 = 632.8$ nm is the laser wavelength in vacuo. The $k(th)$ values were obtained following Mie's equation and using Heller's tabulated data of the specific turbidity for $\lambda' = 409.4$ nm [4]. The comparison could be done by translating the tabulated data to the wavelength used ($\lambda = 475.4$ nm) in accordance with the equation

$$k(th) = k'(th)\,(\varrho_{12}/\varrho_2)\,(\lambda'/\lambda) \qquad (6)$$

where $k'\,(th)$ means the tabulated data, ϱ_{12} is the density of the entire system and $\varrho_2 = 1.06$ g cm^{-3} [6] is the density of the particles. All measurements were performed at 25 °C, approximately.

IV. CONCLUSION

The experimental data obtained satisfy the exponential dependence of the light power transmitted through the latex dispersion on the sample layer thickness and the concentration (Lambert's law):

$$P = P_0\,e^{-kcd} \qquad (7)$$

where the specific turbidity k is the individual constant of the system employed.

Experimentally determined specific turbidities for the three polystyrene lattices investigated (Table 2) are in good agreement with those calculated on the basis of Mie's equation. The experimental errors of $k(exp)$ are primarily assumed as due to the unstable power of the light source used.

In the system observed the attenuation coefficient is attributed to light scattering, while the other effects upon the attenuation could be neglected.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. J. J. Petres for valuable discussion.

This research has been supported by the SMCI for Scientific Research of SR Croatia.

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Received October 8th, 1985
Revised version received April 23rd, 1986

ИССЛЕДОВАНИЯ ПРОХОЖДЕНИЯ ПУЧКА ГЕЛИЕВО-НЕОНОВОГО ЛАЗЕРА В МУТНЫХ ЖИДКОСТЯХ

В работе исследовано прохождение узкого пучка гелиево-неонового лазера через почти монодисперсных лаешексов полистирола. Диаметры использованных частиц равнялись 137,6 нм, 531,2 нм и 733,3 нм. Найдехо, что зависимость коэффициента ослабления от концентрации латекса имеер линейный вид. Экспериментальные значения удельной мутности, которые соответственно равны (26 ± 4) см$^{-1}$, (226 ± 7) см$^{-1}$ и (292 ± 10) см$^{-1}$, хорошо согласуются с теоретическим значениями, полученными на основе теории Ми.