acta phys. slov. 39 (1989), No. 3

ATTENUATION OF He-Ne LASER BEAM IN LIQUID DISPERSIONS

HENČ-BARTOLIĆ, V.[1]), PINTARIĆ, B.[2]), Zagreb

In this paper the effect of scattering, absorption and a simultaneous effect of both factors on the power of the transmitted current wave laser beam, under laboratory conditions, were observed: the light scattering in polystyrene latex dispersions, the absorption in nigrosin water solutions and both factors in their mixtures.

The sample of monodisperse polystyrene latex LS-137 used in these experiments was prepared by the Laboratory of Biocolloidal Chemistry, A. Štampar School of Public Health, Zagreb, Yugoslavia [1]. The characteristic of these particles was an almost ideal spherical shape of uniform size with the mean diameter of 531 nm [1, 2].

Nigrosin is a black dye, usually prepared by oxidation of aniline and aniline chloride with nitro benzene or nitro phenol [3]. In this work the sulphonated, water soluble product (CIBA) was used.

The change of the transmitted laser beam power in the three cases mentioned above was measured as a function of concentration and sample layer thickness. In the case of dispersion mixtures the concentration was so arranged that the experimental data obtained were comparable in all three cases. The concentration of each component in the mixture was equal to its concentration in pure solution, i.e. dispersion. It was considered that the components did not mutually affect the solubility in the mixture because of the low concentration of both dispersions. All samples were homogenized by an ultrasonic bath immediately before measurement.

The source of light was a narrow He-Ne laser beam of 632.8 nm wave length, passing through a sample placed in a high-quality optical glass cell. The layer thicknesses were 2.0, 2.5, 5.0 and 6.0 cm. The transmitted light power was measured by an optical power meter gauged to the wave length used. All measurements were performed at room temperature. The experimental setup was described in detail in our previous paper [2].

a) *Polystyrene latex dispersions*

Experimental data obtained in water dispersions of polystyrene latex confirm the law of the laser beam power (P_S) attenuation depending on the sample layer thickness (d) and the concentration (c_S) as parameters, i.e.:

$$P_S = P_0 e^{-a_S d}, \qquad (1)$$

where a_S is the scattering coefficient (Table 1) and P_0 is the light power transmitted through pure distilled water with $a = 0$.

[1]) Department of Physics, Faculty of Electrical Engineering, University of Zagreb, P. O. Box 170, 41 001 ZAGREB, Yugoslavia
[2]) Institute of Physical Chemistry, Technological Dpt., University of Zagreb, Marulićev trg 20, 41 000 ZAGREB, Yugoslavia

Table 1

The mean scattering coefficient a_S and the penetration depth $1/a_S$ of the transmitted laser beam in polystyrene latex LS-137 dispersion.

CONC.	SAMPLE	LATEX LS-137	
	$\frac{c_S}{g/100\,g}$	a_S/m^{-1}	$\frac{1}{a_S}/m$
c_1	0.013	300	0.003
c_2	0.007	146	0.007
c_3	0.003	79	0.013
c_4	0.002	39	0.026
c_5	0.001	20	0.050

The scattering coefficient, experimentally obtained, is proportional to the concentration.

$$a_S = k c_S.$$

The constant k, the specific turbidity, in this particular case is $k(exp) = 219\,cm^{-1}$ and it agrees well with $k(th) = 222\,cm^{-1}$ obtained by using the Mie's equation [4, 5]. The concentration is expressed as the total mass of the dry sample in 100 g of water dispersion.

b) *Nigrosin solutions*

The results obtained by measuring the transmitted laser beam power (P_A) through nigrosin water solutions indicate the law equal to the previous one

$$P_A = P_0 e^{-a_A d}. \qquad (2)$$

In this case the absorption coefficient a_A (Table 2) corresponds to the scattering coefficient in Eq. (1).

Table 2

The mean absorption coefficient a_A and the penetration depth $1/a_A$ for a series of nigrosin water solutions with various concentrations

CONC.	SAMPLE	NIGROSIN SOLUTION	
	$\frac{c_A}{g/100\,g}$	a_A/m^{-1}	$\frac{1}{a_A}/m$
c_1	1.38	410	0.002
c_2	0.69	187	0.005
c_3	0.35	97	0.010
c_4	0.17	49	0.021
c_5	0.09	27	0.037

c) *The mixtures of the polystyrene latex dispersion and the nigrosin solution*

The third group of measurements was performed with mixtures of polystyrene latex dispersions and nigrosin water solutions. The law of change in the transmitted laser beam power, obtained in this case is:

$$P_T = P_0 e^{-a_T d}, \qquad (3)$$

where a_T (Table 3, column 3) is the attenuation coefficient.

Table 3

The measured and calculated values of the mean attenuation coefficients a_T and the penetration depths $1/a_T$ for a series of concentrations a_T in mixtures of polystyrene latex dispersion and nigrosin water solution.

CONC.	SAMPLE c_T g/100 g of mixture		MIXTURES OF POLYSTYRENE LATEX DISPERSION AND NIGROSIN SOLUTION			
			MEASURED		CALCULATED	
	latex	nigrosin	a_T/m^{-1}	$\frac{1}{a_T}/m$	a_T/m^{-1}	$\frac{1}{a_T}/m$
c_1	0.013	1.38	650	0.002	666	0.002
c_2	0.007	0.69	327	0.003	333	0.003
c_3	0.003	0.35	166	0.006	176	0.006
c_4	0.002	0.17	86	0.012	88	0.011
c_5	0.001	0.09	45	0.022	47	0.021

Correlating eq. (1) to eq. (2) the expression

$$\frac{P_S P_A}{P_0} = P_0 e^{-(a_S + a_A)d}$$

is obtained, which represents a change of the laser beam power transmitted through the mixtures of latex dispersions and nigrosin solutions, described by eq. (3), and by substituting:

$$P_T = \frac{P_S P_A}{P_0} \qquad (4)$$

and

$$a_T = a_S + a_A, \qquad (5)$$

$$1/a_T = 1/(a_S + a_A). \qquad (6)$$

Expressions (4), (5) and (6) correlate the physical quantities characteristic for the three groups of measurements performed. The expression (4), which correlates the measured power of the transmitted laser beam in all three cases, is proved in our experiments.

The dependences of the transmitted laser beam power upon the layer thickness for one particular concentration, its corresponding latex dispersion concentration and the nigrosin solution concentration, respectively, are shown in Fig. 1. Calculated values of the attenuation coefficients a_T (Table 3, Column 4), obtained by adding coefficient a_S (Table 1) and a_A (Table 2) in accordance with expression (5), are in good agreement with the measured data (Table 3, Column 3) Fig. 2. This additivity is established by other authors as well (for example [6]).

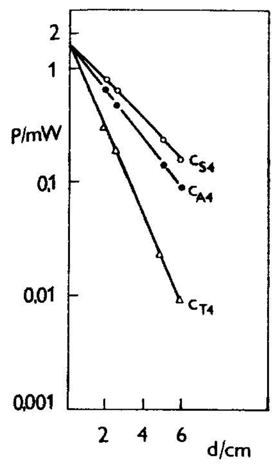

Figure 1. The transmitted light power (P) as a function of sample layer thickness (d) with one particular concentration (c_4) as parameter. 1) $c_{S,4} = 0.002$ g/100 g, latex LS-137 dispersion concentration, 2) $c_{A,4} = 0.170$ g/100 g, nigrosin (NGR.) solution concentration, 3) $c_{T,4} = (0.002$ g LS-137 + 0.170 g NGR.)/100 g mixture concentration

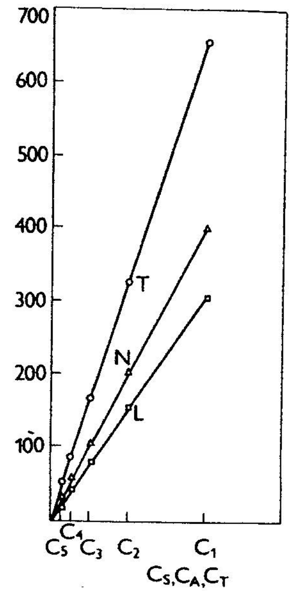

Figure 2. The experimental mean attenuation coefficient (a) as a function of the concentrations (Table 1, 2 and 3, Column 2) of (L) latex LS-137 dispersion, (N) nigrosin solution, and (T) their mixture (Tables 1, 2 and 3, Column 3)

The relative error between the measured and the calculated values of the coefficient a_T amounted to 6 %, 3 % was due to the unstable laser beam source and the rest could be attributed to the imperfection of the measurement setup and the system investigated in general.

It was determined that the attenuation coefficients experimentally obtained under our laboratory conditions have the Lambert-Beer quality. However, in investigations of the real systems, for instance, oceanographic ones [7], the Lambert-Beer behaviour has been reached only approximately.

ACKNOWLEDGMENTS

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

REFERENCES

[1] Deželić, N., Petres, J. J., Deželić, Gj.: Kolloid Z.—Z. Polym. *242* (1970), 1142.
[2] Henč-Bartolić, V., Pintarić, B.: Acta Phys. Slov. *37* (1987), 44.
[3] Noller, C. R.: *Chemistry of Organic Compounds*. W. B. Saunders Co., Philadelphia, London 1965.
[4] Heller, W., Pangonis, W. J.: J. Chem. Phys. **26** (1957), 498.
[5] Kerker, M.: *The Scattering of Light and Other Electromagnetic Radiations*. Academic Press, New York 1969.
[6] Pal, S. R., Carswell, A. I., Jammu, K. S.: Can. J. Phys. *57* (1979), 1414.
[7] Stavn, R. H.: Appl. Optics *27* (1988), 222.

Received October 10th, 1988
Accepted for publication November 29th, 1988