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Laser scattering, optical constants and connection to other material performances (Kerr constant, mobility/diffusion coefficient/electrophoresis and depolarization)

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Abstract
Scattering of optical photons from the view of parallel methods related to absorption, scattering, fluorescence, reflection with inclusion of the polarization states of laser beams from experiment and theory give many possibilities for obtaining indirect data on material, processes, and dynamics. As a method with minimal perturbations, if low power beams are involved, certain type of data is provided. In fundamental dependences of various material properties, many phenomenological and basic laws are covered. Several coupled variables, primarily with the processes of scattering, pointing out further possibilities for linking the obtained theoretical or experimental results were presented. By including simulations, this associates with biological environments / variables for properties equivalent to defined tissues, cells, and characteristics. Along with selected formalisms including Stokes vectors and scattering matrices, a biological cell as an object can be monitored in time and influence of various environments could be predicted. Connecting Kerr's effect with depolarization and scattering makes the complete description of molecule possible. Angular scattering observation with experimental possibilities gives the fastest practical data. This enables interpretation of E. coli with the application of Stokes vector formalisms. A relatively small number of material constants for many simulation cases could give draft estimation, but the experiment depends on the measuring devices and samples. The necessary symmetries showing the size of the scattering centers are analyzed, with the scattering data for some liquids (known / less known). From measured data, depolarization could be calculated, and with refractive index (molar refraction) connection with Kerr effect/ birefringence for selected solutions and behavior of molecules could be monitored. From the experimental Rayleigh factors, cross section (apparent/ effective) and attenuation coefficients for pure liquids were calculated. An approach for the correct assessment of the measurement uncertainty in the process of calibration of polyethylene samples was used.

1. INTRODUCTION

Light/laser scattering is always an open issue, which constantly demands development of new extensions of fundamental theories, as well as a series of new approaches. Both static and dynamic perspectives are involved, and concerning that the development of the field is related to the improvement of measuring devices, computer generations, and that many new algorithms have been developed, a variety of tasks could be set. Scattering in metrology provides benefits in many areas and entry into the areas of the nucleus / atom / molecule, and then in the remote control, which includes not only the earth's atmosphere, but also the Cosmos (cosmic dust) (Sreckovic et al., 2002; Sreckovic, 1979).

Only a few lesser-known connections will be considered being of interest for the coupling of optical - acoustic - thermodynamic - mechanical disciplines (Sreckovic et al., 2014). These indirectly connect - describe system, component or material properties. It starts from various types of scattering: elastic - inelastic, quasi elastic, spontaneous and stimulated. Another point of view is connected to the cause of scattering: thermal fluctuations; fluctuations of anisotropy, concentrations and density. It is recalled that Brillouin scattering is used to obtain viscosity (bulk), besides sound velocity and absorption (Sreckovic et al., 2015; Fidanovski et al., 1996; Fidanovski 2014).

Brillouin scattering, besides the monitoring of input frequency shift and linewidth, provides multiple possibilities when equipped to follow polarization components. It holds also for Raman scattering (even today some Raman components with polarization components are not clarified enough), as well as connection to ellipsometry. Photon correlation spectroscopy and total intensity of the laser scattering is a common method for hydrodynamical studies (DNA sample fraction). Viscoelastic monomolecular thin films could be analyzed using laser scattering. We are pointing out that molecular mass, gyration radius, polidispersity have been standard methods for monitoring polymer and biopolymer systems for a long time. Quazielastic scattering is connected to the surface tensions phenomena as well as the mentioned viscosity (Huglin, 1972). It is particularly important for critical phenomena (Cummins 1978). By including chromatography in laser scattering systems, the possibility of measurement is enlarged. If the material has absorption zones in the scattering experiment, corrections should be developed. Refraction index is connected to various material performances, besides basic definitions, through molar refraction, polarizability, density, dielectric constants (Toyozawa, 2003).

In this paper theoretical bases were given connecting more or less known constants from the area of scattering, optics, coherent optics and other physical and chemical constants, including electrooptic, electromagnetic or piezoelectric processes. Processes of Rayleigh scattering are directly connected through polarizability of molecules, anisotropy and depolarization for the mentioned effects and appropriate constants (Fabelinsky 1971; Weil 1961). Polarization/ depolarization measurements provide the possibility of a complete molecule description from at least three measuring techniques.

Contemporary measurements are almost exclusively connected to quantum generators (in cw and pulse regimes). Refraction index in some of correction functions which present internal field, could link scattering of liquid state to the scattering in gaseous state. Anisotropies on the levels of molecule, atoms, acoustical and mechanical parameters are recognizable in many optical measurements starting from Brillouin and Raman (spontaneous and stimulated) scatterings and acoustical measurements. Specific modifications of holographic techniques included in nondestructive monitoring are connected to the terms of wear, surface tension, etc. and have a role in seizmics and ground physics.

Another scattering system with electrophoresis components brings new details in molecular presentations. Molecular behavior in various liquids (viscosity, optical, thermodynamical and other relevant parameters) could be monitored.

1.1. Rayleigh scattering, depolarization scattering, birefringence effects induced by electrical field associated with laser beams and dispersion of molecular optical anisotropy

Electrical fields and selected scattering (figure 1.1) geometry, including small angles, give electrophoresis parameters (mobility) (Hanz 1978, Uzgiris 1972). Assumption holds that the electrical field is uniform considering small scattering volumes. The dependence of molecular optical anisotropy ($\gamma\omega 2$) is considered through two principal levels- quantum theoretical treatment and semi-empirical formulations. Depolarized Rayleigh scattering DRS and induced birefringence with high laser fluence BI are two optical effects with direct information about optical anisotropy. Laser use on ground emitting transitions and higher harmonics present a possibility to simplify experiments. This experimental area appeared just after the invention of the first quantum generators in optical range. Parametric and other tuning effects give the possibility to study dispersion. Specific power ranges are mandatory for cw and Q-switch laser regimes. The third important area is molar refraction measurement on laser wavelength

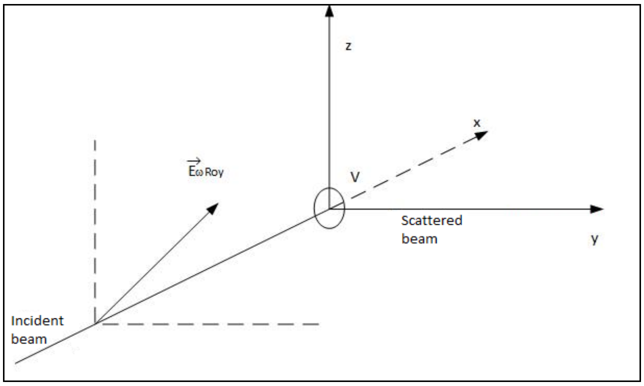

Figure 1.1 Simplified geometry for treatment of Rayleigh scattering and analysis of polarization of component for chosen geometry.

included in the previous measurements, and the obtained dispersion relations. Optical molecular anisotropy related to polarization of the first order, is defined by

$$\gamma_\omega^2 = \frac{1}{2}\left(3\alpha_{ij}^\omega \alpha_{ij}^\omega - \alpha_{ii}^\omega 3\alpha_{jj}^\omega\right) \tag{1}$$

where ω is frequency and [α] is molecular polarizability tensor of first order and dimensionless Langevin parameter of anisotropy Δ_ω is given as (2) (Lalanne et al., 1972).

$$\gamma_\omega^2 = \Delta_\omega^2 \alpha_{ii}^\omega 3\alpha_{jj}^\omega \tag{2}$$

Optical anisotropy is measured directly by devices for DRS and induced BI is possible with high intensity lasers. For both cases optical anisotropy measurement gets the attribute of apparent performances (it is different from the molar anisotropy, in particular for the molecules with high anisotropy). Dispersion point of view of anisotropy is less studied in experiments. Two empirical laws give relation of optical anisotropy to frequency. One of them is Lorentz – Lorenz formula as (3)

$$\frac{\alpha_{ii}^\omega}{3} = \frac{3}{4\pi\rho}\left[\frac{n_\omega^2 - 1}{n_\omega^2 + 2}\right] \tag{3}$$

where ρ presents number of molecules, i.e. (4) and further (5)

$$\gamma_\omega^2 \propto \left[\frac{n_\omega^2 - 1}{n_\omega^2 + 2}\right] \tag{4}$$

$$\gamma_\omega^2 \propto \bar{\alpha}_\omega^4 \propto \left[\frac{n_\omega^2 - 1}{n_\omega^2 + 2}\right]^4 \tag{5}$$

For static Kerr constant B holds (6) (Lalanne et al.,, 1972)

$$\frac{B\lambda_{ana} n_{ana}}{\left(n_{ana}^2 - 1\right)^2} = \mathrm{C}^{\mathrm{TE}} \tag{6}$$

where n_{ana} refraction index at λ_{ana}; including Langevin expressions (7)

$$B \propto \frac{1}{n_{ana}\lambda_{ana}}\left(n_{ana}^2 + 2\right)^2 \gamma_{\lambda ana} \tag{7}$$

For isotrope compound apparent anisotropy is given by approximation (8)

$$\gamma_{\lambda ana} \propto \frac{\left(n_{ana}^2 - 1\right)}{\left(n_{ana}^2 + 2\right)^2} \tag{8}$$

Further

$$\gamma_{re}^2 \approx 18\bar{\alpha}^2\left(1 + \frac{28}{5}\Delta^2 + 2\Delta^3 + \ldots\right) < r^{-6} >$$

where $< r^{-6} >$ is radial correlation parameter

$$< r^{-6} > = 4\pi\rho\int r^{-4} g(r)\,dr \tag{9}$$

The data for apparent anisotropy, redistribution of induced optical anisotropy and contribution to the redistribution could be explained through quantum theory. For isolated Langevin molecules holds

$$\gamma_\omega^2 = \left(\alpha_{||}^\omega - \alpha_\perp^\omega\right)^2 \tag{10}$$

After complex quantum mechanical calculations are included ω_{j0}, E_o, E_j, $\left|\phi_o\right\rangle$ and $\left|\phi_j\right\rangle$; $\mathrm{h}\omega_{j0} = E_0 - E_j$; $\Delta_{\omega j0}$ width of the transition $j \leftarrow 0$ and $m_{\| j0}^{\perp} = \left\langle \phi_j \middle| e r_{\|}^{\perp} \middle| \phi_0 \right\rangle$.

Asymptotic value for the terms in (Lalanne et al., 1972) is obtained.

$$\gamma^2 \to \frac{4}{\mathrm{h}^2}\left\{\sum_j \omega_{j0}^{-1}\left|m_{||\,j0}\right|^2 - \sum_{j'} \omega_{j'0}^{-1}\left|m_{\perp\, j'0}\right|^2\right\} \tag{11}$$

Figures 1.2, 1.3 show simplified measuring systems for experiments with scattering and birefringence) drawn according to (Lallane et al.. 1972).

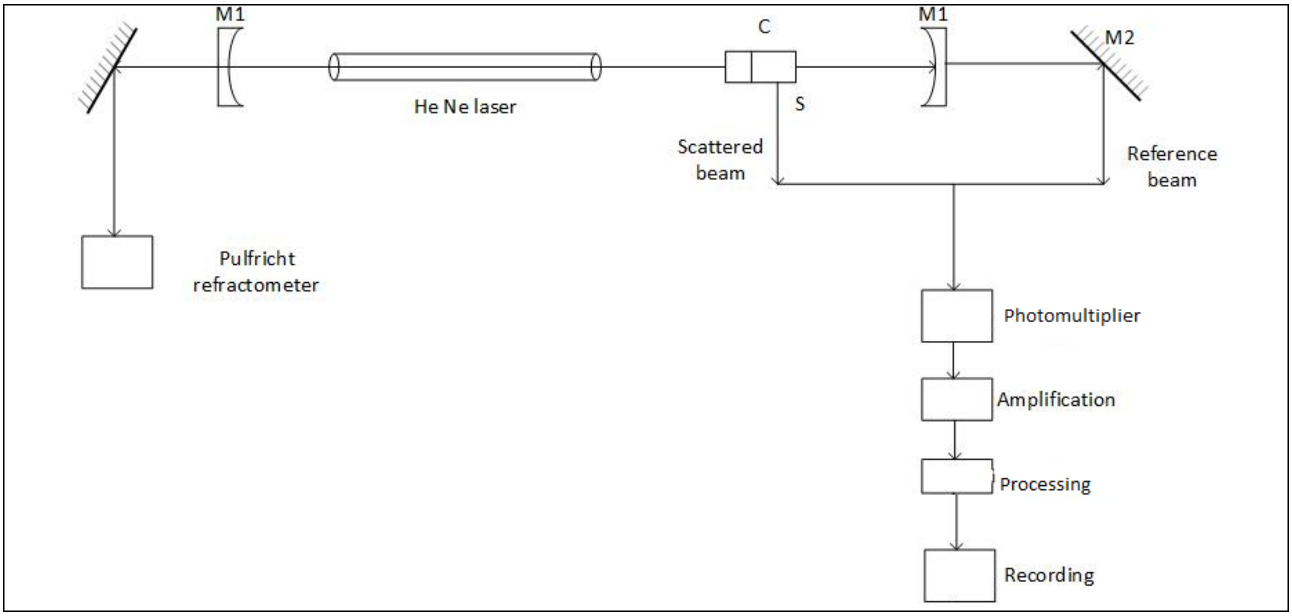

Figure 1.2. Depolarized Rayleigh scattering system with low power laser. Example He Ne laser.

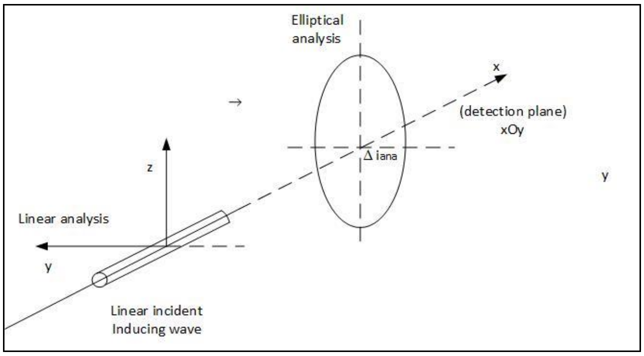

Figure 1.3 Simplified systems for birefringence effects applying high power laser and induced electrooptic effects.

References contain data for induced electrooptical effects for organic solvents.

1.2. Anisotropy

Anisotropy for the solution of low concentration could represent behavior of isolated molecules. It corresponds to the molecules in gaseous phases, if respective corrections to the internal fields are performed. Approximations with Onsager or Lorentz-Lorenz or other approaches are still the topics. By measuring the scattering in gaseous and liquid states some kind of responses could be gathered that are connected to the expression of the type $(n^2+2)/9$ and similar (at least 6 functions exist).

From the Rayleigh scattering measurement, the following could be evaluated (Tomic et al., 2008; Sreckovic et al., 2010):

- Contribution to the concentration fluctuations, density fluctuations and anisotropy fluctuations in pure liquids and solutions,
- Thermodynamical and other data (isotherm compressibility from static light scattering, i.e. Rayleigh factors)

From the dynamic scattering diffusion coefficient could be calculated using the linewidth after confirmation of the Lorentzian shape.

From the linewidth of the Rayleigh line follows the coefficient of diffusion and thermal conductivities (in scattering both Lorentzians exist); that represents diffusion and thermal diffusion in the case of solution, but the widths are very different and the equipments are directed to one of them only).

By using similar data (or the same) every measuring system should be equipped with respective calibration procedure to confirm non-measured new materials.

All these need to be confirmed by comparative monitoring of data for other substances obtained by similar or other techniques. The presented paper is related to the samples of organic solvents which serve as etalons and phytol $C_{20}H_{39}OH$. Their molecules are of relatively small mass M=296.54 au, comparing to macromolecules $M \approx 10^6$ au.

Phytol as a part of chlorophyll is of special interest so this was primarily the aim of research in (Sreckovic et al., 1979; Sreckovic et al., 2017; Leicknam et al., 1977; Sreckovic et al., 1971; Sreckovic et al., 1986; Fidanovski, 1992). UV, X and Raman spectra were recorded too. Light scattering measuring techniques require preparation for a reliable experiment in obtaining optically pure measuring samples. The possibilities of interpretation of measuring results are more complex, although the information gathered through scattering itself hides a lot of structure related data.

Data of importance are:

- Anisotropy of material, pure and optical anisotropy of common solvents i.e. obtaining the apparent anisotropy in solutions.
- Contributions of density concentrations and anisotropy in pure liquids (and in solutions concentration fluctuations) (Sreckovic et al., 2009; Tomic et al., 2007).
- Evaluation / calculation of the above-mentioned data (Standard & NIST, 1994); Obtained results were not usually presented by angular distributions, so a comparison could be made for cyclohexane, commonly used as solvent; benzol was used before cyclohexane as etalon for static scattering and was of interest related to wavelengths of Ar^+ : ion and He Ne. Electrooptic and electromagnetic methods include the effects expressed by high electric fields that change some molecular (microscopic and macroscopic performances). For small electric fields and dynamic light scattering measurements provide diffusion coefficient by processing scattering data. In case of setting the sample in weak electric fields chaotic movement of molecules gets the directed component trough adequate geometry. The shift of Lorentzian provoked by used fields gives the possibility to study electrophoretic performances of the ions in solutions and to calculate their mobility. In modern scattering systems, electrophoretic processes are regularly measured and studied, being of interest in biology, too.

2. MATERIAL AND METHODS

In the experimental part of the paper, measurements of angular distribution are presented, for more and less known liquid solvents, which even though belong to *classic* measurements, including possibilities of measurement of components' polarizations status and preparing for more complex tasks for dynamic light scattering.

Phytol, according to known references, is still less known in terms of measurements involving light and laser, in general. Lately it has been achieving a new role if related to PLGA nanoparticle as a modulator of Alzheimer toxic Aβ peptide, prone to aggregation and fibrillation associated to impaired function of neural cells (Sathya et al., 2018). Numerous values for relative intensities for all 4 components of vertical and horizontal incident beams are provided and compared to most common etalons. Measurements are expressed through Rayleight factors which later got their pairs in Coumo – F factors and other, but still are good for comparison to classic results of quantitative nature.

These data are interpreted later through visualization of anisotropy coefficient and other characteristics. Expressions are in molecular and atomic contributions. Comparison with the data obtained from the concepts of the gaseous state provides the representation of internal fields or the evaluation of molecular anisotropy and molar refraction in their particular interpretations.

2.1. Application of light scattering for characterization of microorganisms in vivo

After a sudden increase in experiments with laser beam scattering and the development of a dynamic theoretical approach with the possibility of measuring scattering objects in numerous applications, the research progressed in several directions depending on the dimensions of the micro scatterer and the wavelength of the applied quantum generator. In addition to cw sources, very short pulse lasers were used, so classical scattering theories had to be modified (Bronk et al., 1995). In addition to the large areas of macromolecules, micelles, gels, concentrated solutions and very diluted solutions, all experiences from the experiment with scattering have been transferred to human andveterinary medicine, with the highlight on the behavior of microobjects (bacteria, viruses, red blood cells.), monitoring the dynamics of microsystems, behavior of these individuals in various environments of biological origin (body fluids) or in the area of the medicines introduced. A special area has expanded into the field of plants and introduced the possibility of remote recognition of targeted plant species, pollen powders, algae in various natural environments, etc. In all these tasks, parallel scattering, fluorescence and absorption are seen, and according to the chosen problem the optimal technique and theory are chosen.

3. RESULTS AND DISCUSSION

Although it is assumed that dynamic scattering gives richer descriptions of materials, even bacteria, with regard to the price of the devices, the fact that static relatively simple devices can be used to describe microsystems without much perturbation is a plus (Rvacev, 1978; Cabannes 1929; Drewel 1985; Eitel et al., 2017; Gaussman 1972). One of the effective methods is the application of angular distributions in a well-defined experiment and subsequently as a part of real-life conditions application. All this is accompanied by statistical approaches, developed formalisms, but also with numerous software solutions or for the specific systems with developed interfaces in order to expand the capabilities and specific input of new data (databases). The angular function for elements of the Mueller matrix in case of polarized light scattering from the microorganisms suspensions is used for various changes in relation to the types of bacteria (log i.e. exponential growth stage). Stability of dimension and distribution shape for cells is a matter of special analysis. E. coli is one of the most common cells - bacteria in references and presented by results of angular scattering has been considered multiple times. In particular, the angular dependence between the components of the Mueller matrices S34 / S11 is particularly investigated. (Jevtic et al., 2015; Ostojic et al., 2014; Bohren, Hufman, 1998; Sreckovic et al., 2013). Calculations were made with the approximation of coupled dipoles by the electromagnetic radiation scattering model on particles where the shape of an individual is approximated by a sphere, a stick or a Gaussian coil. E. coli belongs to a group of cylindrical geometry; it is sometimes approximated by a hemisphere of the same radius as a cylinder. Using the previously measured values for the distribution of the length and refraction index of cells, the calculation of the scattering curve often coincides well with the measurements (Bronk et al., 1995; Jevtic 2016). The values obtained for the cell diameters are close to the diameters obtained by the optical microscope. However, the question of the matching of one and the other measurement is questionable, since the preparation of the sample for microscopic recording has a fundamental difference considering the dimensions of the dry in relation to the wet sample and that the aerodynamic nature of the movement is more evident in the scattering. This is considered a fast and conventional method for observing bacterial diameter in vivo even where there is no significant distribution in bacterial lengths in the population.

The method starts from Stokes vectors (I, Q, U, V) (Berne and Pekora, 2000; Shurcklif and Ballard, 1964). The formalisms of the initial matrix elements should be considered, since there are modifications in the references. A detailed study of the angular distribution of the elements of the Mueller matrix gave several explicit facts in respective formulation: S11 corresponds to the scattering function for the intensity of unpolarized light. Angular variation of S11 depends on the particle size. The particles of the larger dimension show higher scattering intensities in the forward direction. The matrix component S34 is sensitive to the relative phase changes of the components of the scattered polarized light from the interaction with the scattering center (microorganism or other particles). It was found to be particularly sensitive to growth conditions of microorganisms. The appropriate formulas for scattering (Bohren and Hufman, 1998) would require a look at the bacterial population. Some results could be found in the references. Selected data could be used to further describe the given characteristic samples, particularly bacteria. Software Mieplot is one of the possible choices to support faster description and obtain the first estimations.

3.1. Angular distribution of liquid samples of interest in static measurements

Table 1 and Figures 3.1-3.4, show the angular distribution of the Rayleigh scattering components at 632.8 nm for some of the measurement series (Sreckovic 1979).

Table 1. Angular distribution of the Rayleigh scattering for phytol in relative units, 632.8m, for angles 30-150°

30^0	45^0	60^0	75^0	90^0	105^0	120^0	135^0	150^0
I_{vv}								
1.0975	0.7743	0.8079	0.69496	0.68494	0.67843	0.67178	0.665	0.673
0.8517	0.7191	0.6953	0.60541	0.68494	0.59034	0.65244	0.6486	0.668
I_{hv}								
0.099	0.09737	0.1019	0.0977	0.08619	08532	0.08314	0.0818	0.086
0.08687	0.08676	0.8943	0.09591	0.08619	0.08807	0.76669	0.08881	0.089
I_{hh}								
2.21	1.356	0.84397	0.45674	0.3427	0.4629	1.1609	1.4679	1.62
I_{vh}								
0.3859	0.3761	0.38299	0.37471	0.38684	0.379	0.3691	0.378	0.379

Usually Rayleigh factors as representative of scatterer's *effectiveness* are evaluated only for 90° and respective laboratories made their list of scatterers (as mentioned before –cyclohexane, benzene, etc). If angular distribution is included more exact estimations could be made. Figures .3.1-3.4 present some of the experimental nonfitted dependences for performed run of measurements material - phytol of optical purity.

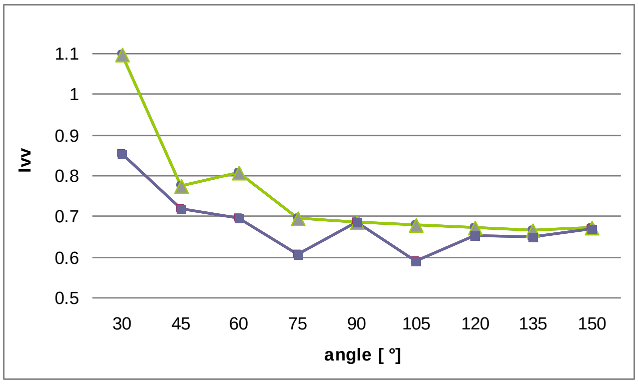

Figure 3.1 Experimental values in relative (arbitrary) units for I_{vv} component, with the measurement increment of 15° for phytol.

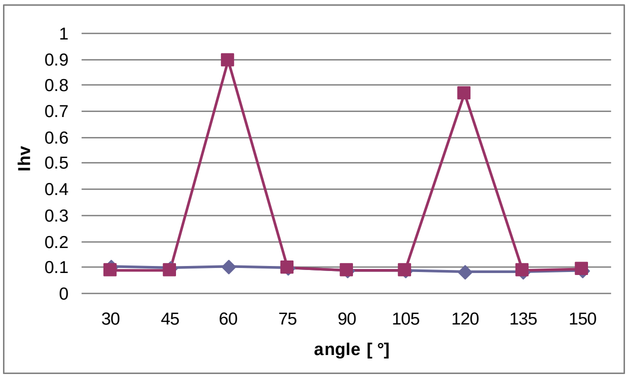

Figure 3.2 Experimental values in relative (arbitrary) units for I_{hv} component, with the measurement increment of 15° for phytol.

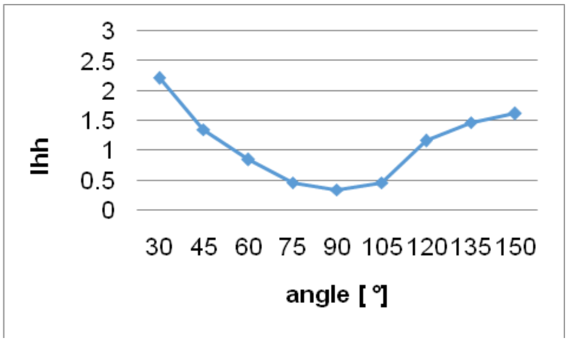

Figure 3.3 Experimental values in relative (arbitrary) units for I_{hh} component, with the measurement increment of 15° for phytol.

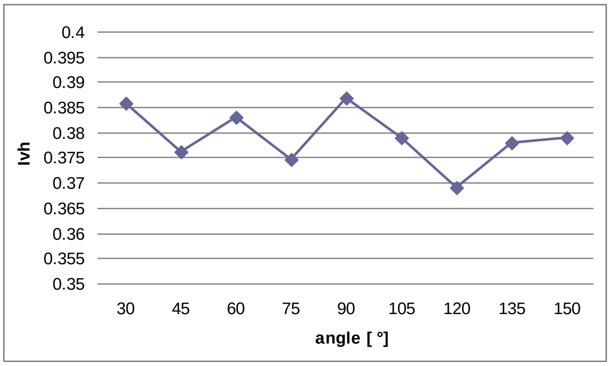

Figure 3.4 Experimental values in relative (arbitrary) units for I_{vh} component, with the measurement increment of 15° for phytol.

Figures 3.5-3.8 give experimental values in arbitrary units for cyclohexane. Table 2 shows data for components in the case of cyclohexane (Sreckovic, 1979). Particularly for phytol we made more than one series of measurements but depending on the manufacturer of the sample, and products' origin, the final results could be different including fluctuation in measuring procedures. Therefore, in the figures we highlighted some parasite points which were recorded.

Table 2. Angular distribution of Rayleigh scattering components at 623.8nm for cyclohexane

30^0	45^0	60^0	75^0	90^0	105^0	120^0	135^0	150^0
I_{vv}								
1	1.1397	0.7946		0.7545	0.726	0.72	0.7463	
I_{hv}								
0.0289	0.022	0.0161	0.01489	0.0117	0.0134	0.0162	0.0177	0.02
I_{hh}								
2.5	1.5998	0.7944	0.2413	0.1036	0.2374	0.6672	1.2625	1.997
I_{vh}								
0.1267	0.0845	0.081	0.07488	0.02575	0.606	0.0651	0.0733	0.065

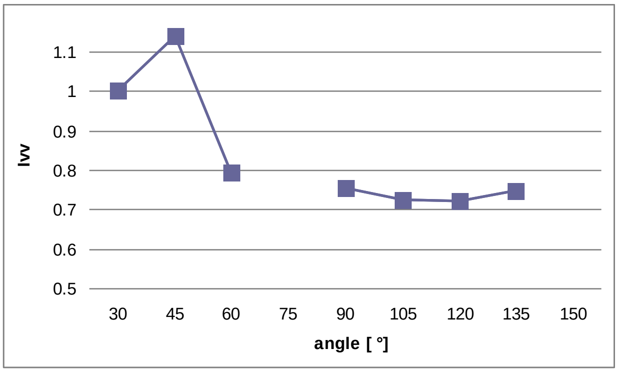

Figure 3.5 Experimental values in relative (arbitrary) units for I_{vh} component, with the measurement increment of 15° for cyclohexane.

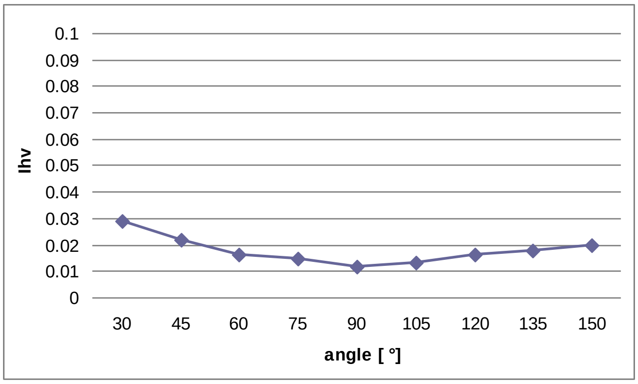

Figure 3.6 Experimental values in relative (arbitrary) units for I_{hv} component, with the measurement increment of 15° for cyclohexane.

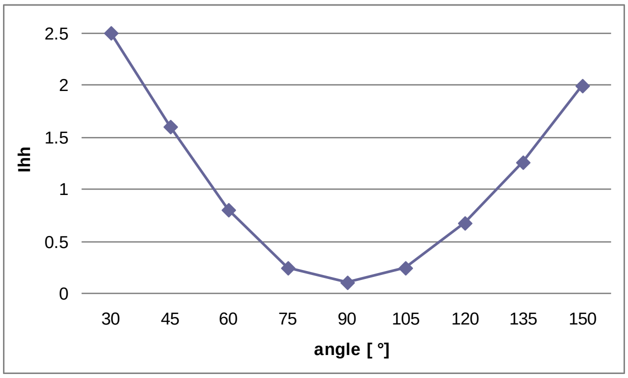

Figure 3.7 Experimental values in relative (arbitrary) units for I_{hh} component, with the measurement increment of 15° for cyclohexane.

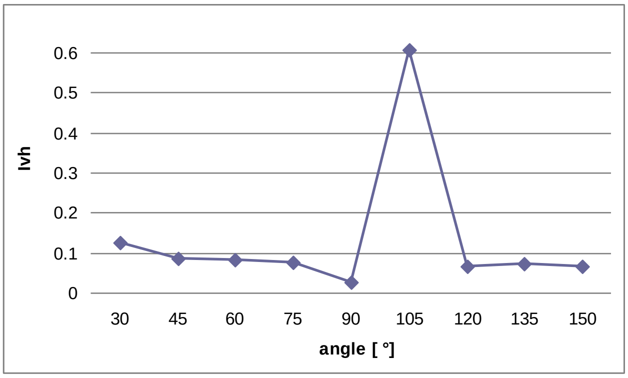

Figure 3.8 Experimental values in relative (arbitrary) units for I_{vh} component, with the measurement increment of 15° for cyclohexane.

3.2. Effective cross-sections for liquid materials

Effective cross sections for scattering in condensed liquid materials have been proposed in references for a long time in spite of common cross sections defined for scattering centers which are isolated (without interactions). For practical reasons, they are defined for optical solvents too, and have a meaning of apparent/conditional/effective cross section. Table 3 gives the values estimated based on the scattering measurements. Usually references use primarily scattering intensities and measurements under the angle of 90°. They could be more accurately estimated by fitting of data and taking into account new data from experiments in which all 6 components were recorded I_{vu}, I_{hu}, I_{vv}, I_{hv}, I_{vh}, I_{uv}, for organic solvents including solutions, concentrated and diluted, in the case of micelles, macromolecules and biopolymers. In these, the most common measurements were with water as the medium, so the intensities of water scattering were much lower than the scattering of the macromolecule. In cases when the material has no internal absorption, scattering cross section is transformed to coefficient of attenuation. For the case of the liquids with low absorption, manipulation with scattering data deserves particular attention.

Table 3. Cross sections for scatterings, attenuation coefficient (due to scattering) from measuring results and values of wavelength of primary transition He Ne laser 632.8nm.

Liquid	**R 10^6cm^{-1}**	**M molecular mass**	**Density ρ, g/cm^3**	**Cross section ,barn 10^4 (1barn=10^{-24}cm^2)**	**Linear attenuation coefficient**
Benzene	9.041	78.11	0.87901$_{25}$	123.5	1.5148
Cyclohexane	3.311	84.162	0.88389$_{25}$	100.1	0.5547
Chlorbenzol	14.108	112.56	1.1036$_{25}$	400.1	2.3638
Nitrobenzol	38.7134	123.112	1.19835	1106	6.4865

3.3. Correct procedures for verifying the spectral characteristics of transparency measurements

Considering the connection of optical performances, the procedure for transparency measurements was presented through operation of calibration. Those types of measurements in case of plastic foils (as references) are much less sensitive than the scattering processes. In references, (Sreckovic et al., 2014; Ostojic et al., 2014) presented transparency for a few known samples deserve comments about preliminary calibration of the equipment. These procedures have to be followed for common use of measuring results in the protection of plantsand the influence of solar radiation on plant growth. Spectral characteristics of PMMA foils are or interest for covering greenhouses and determination of coefficient transparencies in relation to the available spectra of the sun, location etc. The causality of measurements and the type of etalons were taken into account, as well as, the relationship between national and international etalons. Special attention should be paid to calibration equipment and some detailed procedures are in (Zarubica et al., 2018). From the hypothetical distribution of solar illumination and experimental measurements of the transparency coefficients, the change in intensity is usually estimated (the trend of the incident solar radiation on plants). Previously referenced conditions connected to working (operation) temperature for filters etc (Sreckovic et al., 2014; Ostojic et al., 2014) have to be followed by confirmation of regular calibration procedures. Table 4 presents calibration results for PMMA and other materials.

3.1. Simulation of angular distribution of light scattering for characterization of microorganisms in vivo

Figure 3.9 shows scattering intensity vs angle for E. coli (n=1.388) in water environment for various diameters of the bacteria (Jevtic et al., 2015).

Note that He Ne laser beam could be polarized linearly but also unpolarized and the performed simulation depicts this case.

Table 4. Calibration results of PMMA and other materials concerning spectral transmission coefficients.

Calibration value of the spectral coefficient of transmission λ= 630nm	**Measured value of the transmission coefficient**	**Absolute deviation**	**Relative deviation %**	**Measurement uncertainty %**
0.7742	0.6779	-0.00370	0.95	3.21
0.31772	0.3170	0.00072	0.97	0.84
0.03961	0.0400	-0.00070	2.32	0.24
Calibration value of the spectral coefficient of transmission λ= 830nm	**Measured value of the transmission coefficient**	**Absolute deviation**	**Relative deviation %**	**Measurement uncertainty %**
0.65400	0.6478	0.00620	0.95	1.36
0.41423	0.4102	0.00403	0.97	0.84
0.12285	0.1200	0.1200	2.32	0.24

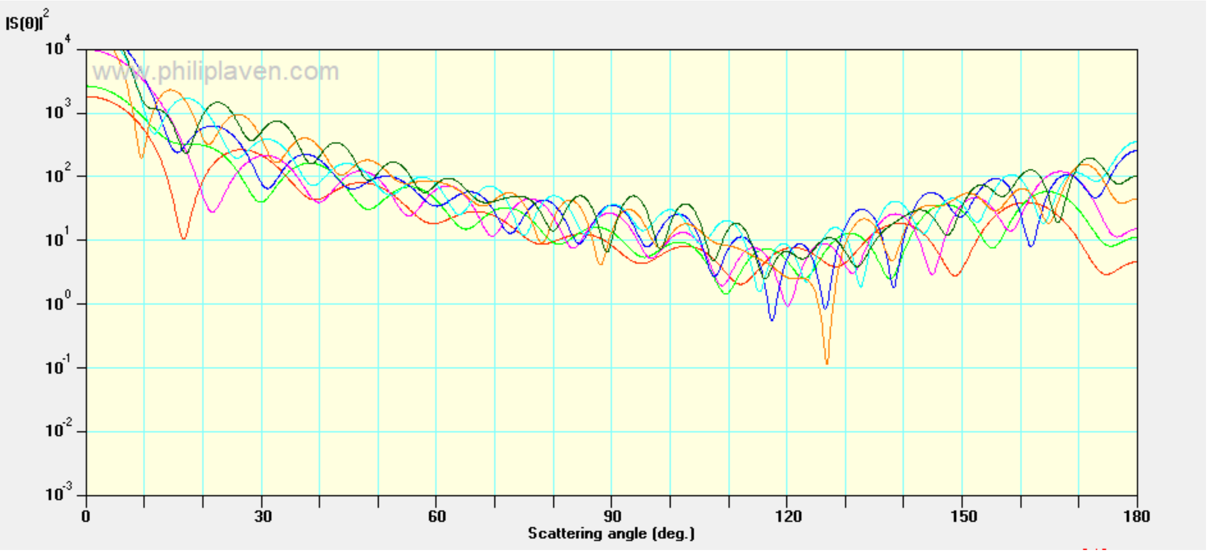

Figure 3.9. Scattering intensity vs angle for E. coli (n=1.388) for unpolarized light λ=632.8nm, diameters 0.9nm – red, 1.08nm – green, 1.26nm – magenta, 1.44nm-blue, 1.62nm – cyan, 1.80nm – orange, 1.98nm – olive.

4. CONCLUSIONS

Light scattering, particularly laser scattering, as a relatively sophisticated discipline in connection to electrophoresis and electrooptical – electromagnetic processes could present many optical parameters in materials. Here are presented some cases of rough experimental data, without fitting, their transformation to Rayleigh factors and derivations of effective cross sections, and further to attenuation data. On the other hand, attention is paid to calibration procedures for new equipments. Obtained experiences and theory that connect shape of the scattering center vs angular distribution are used with the support of software modules to acquire the measuring issues of scattering which represent size of the microorganisms.

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