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Contemporary problems in experiments, theory and application of interest in ecology with lasers in laboratory and remote detection

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Multiple sensor systems and applications in ecology deserve multidisciplinary approach. Concerning laser implementation in monitoring, main parameters and processes have to be chosen in description of object of interest. The purpose of this paper is to underline the links and usability of scattering matrices in the description of biological objects (cells, nuclei, bacteria, etc). Light scattering processes are unavoidable in application and measurements, based on laser systems. Depending on the measurement systems, angular scattering and differential cross sections carry valuable information, and measurements should confirm chosen simplifications from theory. Shape recognition, size and chemical content could be certainly of interest in one part of ecological monitoring (water). Thermal imaging of objects depends on emissivity (water, ground, etc.) and some simplifications of derived cases are added to the previous.

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1. Introduction

Contemporary life pace, trends in industry and traffic have been causing considerable pollution of air and hydro sphere. Different events are organized in order to define environment on global scale. Theoretical and experimental issues that could arise during application of lasers and optical methods in control of human environment (atmosphere, water surfaces, soil, plant covered areas - lower levels and canopy) are analyzed in this paper. In order to apply different types of monitoring, based on scattering, fluorescence, absorption and other processes of interest in control, considerable amount of laboratory measurements of optical and other properties have to be done, which will be indirectly controlled by various physical processes, including acoustic. Lasers implementation in measuring technique brings forward, not only linear but nonlinear optical properties where nonlinear processes based methods are in some cases used from the start. Spotlights are on analytical approaches of important constants related to water and all water surfaces, existing software tools in the area and on consequences arising from irregular use of existing data.

For chosen cases, some areas' properties related to conditions of water and its pollution will be rated, as well as monitoring of air pollution using software packages, and considering theories of scattering on organic and inorganic scattering centers, angular distribution for specific micro organisms (bacteria) will be evaluated.

Among a huge number of data and parameters defined for fire description (as well as fire products, some of them could be treated with same methods, in industrial and real day to day conditions utilizing optical methods). Optical and acoustic methods coupling and other relations with material constants will point out possible indirect measurements i.e. products detection of interest in ecology and other areas of interest for humans [1-3].

2. Theory, experiment and simulations

Multiple sensor systems and applications in ecology - From almost half a century ago, the uses of lidar are growing as do main decisions in solving a detection problem (or monitoring). Monitoring is related to comparisons of a few of techniques which coupled achieve their full importance in ecology, although primarily they are derived for other areas [4-8]. The comparison must include multidisciplinary approach and independent from the chosen technique and devices, application of certain sensor system must include meticulous preliminary study for correct description of monitored objects with characteristic parameters, which must be correctly measured. The influence of atmosphere must be taken into account, depending on geographical location, meteorological situation as well as season during the year. Comparisons could be done on various levels. Besides differences in devices based on milimeter waves, microwaves, infrared imager, infrared tracker, laser radar, visible imager adequate parallels should be drawn with use of acoustic and other techniques concerning control of the atmosphere. A large number of references show various data about remote sensing or recognition of different: oil types, plant types (on soil or on water surfaces), state of canopy and lower vegetation levels but significant data about local types is missing. Remote recognition of algae and maturity of various plants (vegetation periods) by different multisensor systems in portions of electromagnetic spectra (wheat, woodlands, alfa-alfa, corn, soy beans, cotton, oats, grass) could be done. Volcanic eruptions and distribution of fire products and products of combustion have been monitored remotely [5-14].

Up-to-date technologies for nanoparticles production or methods for their recognition are important. For some time precious nanoparticles could be commercially obtained from mud of swamps or waste waters [15,16].

Main parameters for the use of lasers in description of objects of interest in ecology - Lasers are included in variety of techniques even as the part of combined technique of chromatographic type with lasers [17], as well as circular dihroizm, isometry, polarimetry, ellipsometry [18]. Main quantitative indicators of optical characteristics of the material: index of refraction, coefficient of reflection, emissivity could be counted in macroscopic parameters. Cross sections for scattering, absorption, fluorescence are representatives of microscopic objects. In this kind of approach using different measuring methods, object of monitoring could and must be separated. Part of continuous area covered with plants (higher levels - canopy), part of the atmosphere with smoke and dust products etc. could be studied using the same approach. Both macroscopic parameters (reflection coefficient - mean values or wheat, barley and corn fields) and observation of pollution centres (bacteria, viruses, etc.) in the a) atmosphere and b) water carry valuable information about the samples.

Next level must include measurement techniques, collecting data from overall object including angular methods and their role, must be considered through use of various light, natural sources, polarised (different types) light of different wavelengths or monochromatic sources. In thus set tasks in this paper, accent will be on angular distributions, analytical approaches, measurement techniques and inclusion of matrices [19-24].

Starting from the previous consideration with multisensors, different sensors could be added (optical analyzer for the acquisition of UV absorption spectra for the estimation of qualitative and quantitative parameters), for disinfection problems and UV reactors and in general for water technology and sanitary engineering [25-27]. If a threshold limit is exceeded, or if a given UV spectrum shape is obtained (corresponding to a high polluted state, for example), the warning is generated and system make decision to start sampling. This procedure is a simplification of the previous SCADA (supervisory control and data acquisition) system, largely used for more complex industrial environments (drinking water plants, waste water, etc.).

Exact results for homogenous spherical particle using Lorenz-Mie solutions of Maxwell equations stand for uniform plane electromagnetic wave. Approximations deal with Gaussian beam and multimode case or some other shape and their influence could be different for static and dynamic scattering.

Other group of approximations refers to relation of refraction index of material and surrounding media, where diffraction is predominant for angles less than 6° and characteristic size (diameter d) larger than 10μm. Third approximation group is used for near or far-field cases.

The effect of particle shape ($d>>\lambda$, $d<<\lambda$) must be taken into account. If $d>>\lambda$, scattered field has three components (diffraction, reflection and refraction) and the particle shape influence could be accounted separately. When $d<<\lambda$, particle acts like dipole and scattering is expressed in terms of polarisability.

The shape, concentration and anomalous diffraction are issues for further analysis. For some time, correction programs have been in use, which include correction if particles are not spherical (for laser sizer), i.e. solid cubes, and octahedron.

In scattering theory there are many series which are not convergent in classic (Cauchy) sense. Because of these facts a general convergence and boundary conditions have to be used with various criteria resulting in a sum, which could in exact mathematical description be related to physical reality.

Considering relationship between light scattering and size distribution we will name the case of aerosols of different origin. Differential mass cross section ($m^2 \cdot g^{-1} \cdot sr^{-1}$) of smoke nuisance aerosols and smoke aerosols of nonflaming and flaming fires have to include two polarisations for separation of larger and smaller particles from forward scattered spectra. The relation of symmetric intensities ($I_{45°}$ / $I_{135°}$) and dependence of scattering parameter $q=4\pi\lambda^{-1}\sin(\theta/2)$ as well as ratio of polarisation were selected to complete the differentiation in this particular case and could also be used in biology.

The gravimetric and angular scattering measurement is used, to obtain aerosol mass concentration. Light scattering methods differentiate soot from other products.

Size distribution and absolute concentration could be the starting points of various interpretations. Volumetric concentration and size distribution determined simultaneously from instantaneous measurements depend of source intensity profile (laser beam profile) in forward scattering (small angles). Particle generator have carefully designed nozzle for spray forming, having in mind that the particles of different size are located in the middle or at the outline of beam. Special attention have to be paid for accuracy of determining small particles (~ 5μm), with analysis based on Mie scattering and rigorous pursue. Human health is vulnerable, independent of material toxicity, to specific particle sizes.

In general, laser scattering theory and experiment with rich history, provides tremendous possibilities for penetration deep into the material on Earth and in Space, but every experimental device, in a principal, is designed for limited practical problems. Their operation is followed by precise calibration procedures and using the working conditions minimizing the influence of approximations to the smallest possible level. The purpose of operating of some laser scattering devices has to be defined in advance for polymer, biological cell - viability or specific lidar monitoring, etc.

Scattering coefficients for various surfaces (snow, snow on grass, concrete, asphalt, plowed ground) are studied [13] using milimeter-wave radar sensors. The incident angle was changed from 1-80°. Polarisation components of backscattered signals are analysed i.e. hh, vv, RHC/LHC (Fig. 1). The data for snow differ for dry and wet surfaces (percentage) showing maxima for small incident angles. Comparison of concrete, asphalt and plowed ground shows that small incident angles once again provoke more intensive scattering. For adequate recognition of dry and wet snow better choice are larger incident angles (20°). For comparison of concrete, asphalt and plowed ground, is more convenient to use specific angles $\theta_{scatt} > 10°$.

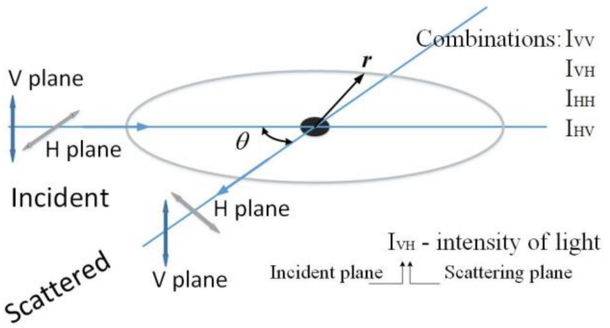


Fig. 1. Definition of indexes

Radar monitoring investigation had shown that target temperature contrast strongly depend on target nature. Interesting fact is that: a) thin grass and tree, b) grass without corner reflector, c) shingle roof and thick grass and d) corner reflector on grass are in various ranges of relative radar backscatter returns (in dB) [13].

Results for radiometer temperature (K) versus incidence angle are very different comparing water, asphalt, concrete, plowed ground, road, sand, grass, bushes (in both polarisations). In some regions (for both polarisations) there is intersection between grass and bushes on one side and concrete and asphalt on the other. These facts are drawn from passive milimeter-wave sensor monitoring [13].

Milimeter-wave and infrared multisensor methods can be useful also by using infrared imaging techniques which could be comparable with lidar methods [28,29]. Thermal imaging strongly depends on emissivity of the material. In the second part of our paper we will present some of our analytical studies of water emissivity based on references (using different software) [13].

Dynamical light (laser) scattering has as one of its tasks to study biological micro objects (bacteria, spores, viruses, etc.) from animal and human origins. In dynamical study of biological systems by dynamical light scattering, various movements are modelled: the characteristic cases are chaotic movement, directed movement, influence of temperature variations to motility, blood flow and concentration of blood particles, influence of electrical and magnetic fields, surface active molecules (micelles, colloids). In experiments firstly of static type, inclusion of polarisation monitoring of the scattering components gave a series of new possibilities including nonlinear effects [30-33].

Classic scattering theories thus were further developed using laser techniques. Experiment became more complete and results, with existing software, gave fast responses about polydispersity, microorganism's size, depolarisation factors, etc.

In the second part of the paper we calculated some of characteristic angular distributions which describe (or could describe) particular microobjects (sphere, rod, Gaussian coils), which were derived from dynamic and static scatterings. Note, that data obtained by dynamic light scattering are more complete but they demand costly and more complex measuring systems.

Scattering matrices application and measurement - Matrix descriptions of various processes arising in biomaterials offer much more complete information in comparison to *usual* descriptions with optical constants (refraction indices, coefficients of reflection, coefficients of absorption, Rayleigh factors, depolarisation, etc.). Contemporary methods include polarisation of incident light easier (laser beam) i.e. relatively new techniques of measurement in description of various materials parameters [34]. The development of matrix optics as well as computer development and analytics are inseparable. There were two development trends - one following the change at optical beam direction and the other one the change of polarisation characteristics. Among matrix formalisms the development of different Stokes' vectors and Mueller matrices, Jones' and other matrices including column vectors 1x2, 1x3, 1x4, etc and corresponding transport matrices connecting input and final values are, according to chosen formalisms square: 2x2, 3x3, or more complex. Having in mind the class of lattice for inorganic materials, with inclusion of all nonlinear and anisotropic processes and issues necessary for adequate description of beam propagation, we achieve complete set of needed formalisms. In essence, all of it was part of the plan to in some other way (user friendly) bring closer the complex tensor calculus to the final end users. Its further use is possible without the detail knowledge of tensor calculus and descriptions of anisotropic materials of biological or inorganic origins.

In advanced measurement methods it is considered that Mueller matrices with 4x4 (16) elements could point out a variety of properties of the measurement assembly especially if it is about the scattering centres systems – absorption – fluorescence. The inclusion of angular distribution of certain components of Stokes vectors offer possibilities for further interpretations and determination whether a scattering centre is a living organism (i.e. bacteria) or not (some blood components, etc). This paper could not include all needed descriptions of specific parts of scattering theory concerning particles dimensions and the relationship between wave vectors of incident and scattered light including the role of refraction index (Mie, Rayleigh, Lorenz-Mie,…) and questions whether an integral scattering, spectral dependencies and the cases of elastic and inelastic scatterings (Brillouin, Raman, thermal, etc) should be monitored [30-33].

The majority of optical measurements increased their resolutions with the introduction of lasers and the series of new methods followed that could have not been based on spontaneous irradiation. For Stokes parameters, nephelometers are used, which often give information only for the transmitted beam. In wider sense, angular distribution is monitored and demand more complex measuring system, including different polarisations combining R and L (Right circular and Left circular) [18 a, b], par and nor (light polarised parallel and perpendicular to the scattering plane), ± denote (light polarised obliquely to the scattering plane at +45° and -45°) - fig 1. According to the references used a certain connection among elements of Mueller matrix – scattering matrix elements and geometry of scattering exists, including polarisers i.e. analyzers. Description theory using scattering matrices has wide area of application and for ecology is of great importance – skylight polarisation, stardust, astrophysics, etc.

Photoelastic (and others) modulators improved nephelometry as well as ellipsometry and other optical and laser based methods.

Modern cases both solved and unsolved are: spherical particles with multilayer coatings, aspherical particles, cluster particles, special structures, etc [32, 35].

Biological cells – nuclei, bacteria and light scattering - Angular distribution of scattering processes is widely applied as nondestructive technique for study of microscopic objects of various origins. By analysing geometric shape of scattering centres, various ranges of sizes and structures (multi and single layers) can be modelled in cases of: viruses, bacteria, eukaryotic cells, etc [36]. Before laser-era, scattering devices and new developed variants of elastic and inelastic scattering measuring methods were based on possibilities of theory of *static* scattering.

Ranges of scattering centres sizes and their shapes determine the angular distributions; matrix elements have particular significance providing the viability of scattering centre's biological model. This present unique set of characteristics. Reproducible differences in S_{34}/S_{11} [30-32] were found for particles that could not be distinguished by other techniques. Cases of varieties for bacterial spores which can be recognized and differentiated by specific mutation could be found in references, too. This way mutations of laser irradiated bacteria could be monitored (power of laser included in measurement have to be lower than that in system used for laser-material interaction i.e. various irradiation) in order to study laser influence [30,31].

Using formalism of correlation functions and their measurements, blood flow in living and dead animals could be clearly differentiated (basically dynamics of living and dead organisms is thus monitored and could serve for differentiation of *living* and *dead* bacteria). Normalized photocount correlation function for freely swimming bacteria, for diffusing particle and for random *walk* based on theory is completely useful to differ motile and nonmotile *E. coli* [30,31].

Mutations which are obtained by exposition to different electromagnetic radiations (spontaneous and stimulated in various electromagnetic portions) could be measured easier this way instead of monitoring the usual biological processes (chemical and genetic analyses as well as monitoring of morphological changes). For biological particles Rayleigh – Gans theory was commonly the starting position (where S_{34}=0).

According to area where scattering is used for commercial measuring, numerous data exist but for each and every new scattering application: new materials, biological effects which were not measured previously, etc it is necessary to provide measurement data. It is necessary to provide in detail new data about the same scattering centers, surroundings and for specific chosen wavelength. Those data vary locally on Earth and in cosmic conditions.

Scattering formalisms - For performing tasks we set through this paper, many different approaches were taken into account and results of scattering theory have to be included so it is not possible to name all formula on which calculations are based. Therefore we will mention only some of the transient or final formula. Disperse relations are certainly included through Lorentz- Lorenz or other approximations and respective theory linked to molar refraction approaches.

Effective cross-sections [32,37-39] are of interest, being the specific representation of scattering:

$$\sigma_{eff} = (10\pi/3)\, a^2 (ka)^4 , \qquad (1)$$

a is the radius, and the k is wave vector.
For θ, angle formed with direction of incident wave scattering $\frac{d\sigma_{eff}}{d\Omega}(\theta)$ for cylindrical symmetry, at axes θ=0, angular distribution is:

$$\frac{d\sigma_{eff}}{d\Omega}(\theta) = a^2 (ak)^4 \left[\frac{5}{8}\left(1+\cos^2\theta\right) + \cos\theta \right] \qquad (2)$$

D' Alembert theory (through function ψ) in spherical coordinates (r, θ, φ) has to include sphere harmonics.

$$\begin{aligned} \psi_{N,L} &= \cos(L\phi)\, P_N^L(\cos\theta)\, z_N(nkr), \\ \psi_{N,L} &= \sin(L\phi)\, P_N^L(\cos\theta)\, z_N(nkr), \end{aligned} \qquad (3)$$

where P- Legendre polynomials, z - Bessel sphere functions. By using x=2πa/λ, differential cross section is calculated for a certain wavelength which represent mathematical solution of D' Alembert equation which could be found with different notations as in [4, 32, 37, 38], using functions of Riccati-Bessel and cross sections are:

$$\sigma_{eff} = \frac{2\pi}{k^2}\sum\left(|a_N|^2 + |b_N|^2\right), \sigma_{eff} = \frac{10\pi}{3}a^2(ka)^4 \quad (4)$$

3. Results and discussion

Emissivity. Data fitting using passive mm wave sensors - Planck's radiation law, radiative transfer theory (designation temperature), impedance mismatch effects, significance of system input noise temperature, total power radiometry, Dick's radiometers, noise injection radiometers, brightness temperature contrast, minimal detectable temperatures (data for thermal vision) S/N clutter, angle tracking error, background clutter signiture are unavoidable issues considering monitoring with passive milimeter wave sensors. Material signitures with polar molecules are very important for material of interest in ecology having in mind that water has defined dipole moments. Debye formulation of dielectric constants is related to relaxation time of polar molecules and conductivity [13]

$$e(\theta = 0) = 1 - \left|\frac{1-\sqrt{\varepsilon_r}}{1+\sqrt{\varepsilon_r}}\right|^2, \quad (5)$$

$$e_H(\theta) = 1 - \left|\frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}}\right|^2 \quad (6)$$

$$e_V(\theta) = 1 - \left|\frac{\varepsilon_r\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\varepsilon_r\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}}\right|^2 \quad (7)$$

$$\varepsilon = \varepsilon_r' - j\varepsilon_r'' \quad (8)$$

$$\varepsilon_r = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + (j\omega\tau)^{1-\alpha_\tau}} - j\frac{\sigma_c}{\omega\varepsilon_o} \quad (9)$$

where ω=2πf is circular frequency, ε_∞ dielectric constant at infinite frequency, ε_s is static value of dielectric constant, τ relaxation time, σ_c ionic conductivity, α_τ empirical parameter for defining distribution of relaxation times, ε_0 permitivity of free space (vacuum) [13].

Considering that emissivity depends on dielectric constant and that emissivity is key factor for thermal imaging techniques we analysed and simplified results of Kline-Swift model [13]. We fitted angular emissivity for different components of this model results. The results are presented in Tables 1 and 2.

Tables 1 and 2 contain coefficients of fitting polinomial for angular dependance of emissivity of water where parameters are temperatures (0°, 18°, 40°C) and salinity 0‰) and 34‰ (open ocean).

Table 1. Coefficients of fitting polinomial for angular dependance of emissivity of water where parameters are temperatures (0°, 18°, 40°C) and salinity 0‰ (x is incident angle)

Horizontal emissivity for water salinity 0‰				
Temperature [°C]	Approximation	A	B	C
0	$A+Bx+Cx^2$	0.52179	$1.7124\text{x}10^{-4}$	$-6.2165\text{x}10^{-5}$
18		0.46041	$1.03169\text{x}10^{-4}$	$-5.71728\text{x}10^{-5}$
40		0.42263	$-7.90443\text{x}10^{-5}$	$-4.93171\text{x}10^{-5}$

Vertical emissivity for water salinity 0‰					
Temperature [°C]	Approximation	A	B	C	D
0	$A+Bx+Cx^2+Dx^3$	0.5231	$-3.0835\text{x}10^{-4}$	$5.36207\text{x}10^{-5}$	$3.14323\text{x}10^{-7}$
18		0.45941	$1.64951\text{x}10^{-4}$	$2.80597\text{x}10^{-5}$	$5.91349\text{x}10^{-7}$
40		0.42176	$1.95402\text{x}10^{-4}$	$1.82316\text{x}10^{-5}$	$7.70573\text{x}10^{-7}$

Table 2. Coefficients of fitting polinomial for angular dependance of emissivity of water where parameters are temperatures (0°, 18°, 40°C) and salinity 34‰ (open ocean). (x is incident angle)

Horizontal emissivity for water salinity 34‰ (open ocean)				
Temperature [°C]	Approximation	A	B	C
0	$A+Bx+Cx^2$	0.52515	$1.65477x10^{-4}$	$-6.31229x10^{-5}$
18		0.45629	$2.02139x10^{-4}$	$-5.66565x10^{-5}$
40		0.42124	$-3.33436x10^{-5}$	$-5.02257x10^{-5}$

Vertical emissivity for water salinity 34‰ (open ocean)					
Temperature [°C]	Approximation	A	B	C	D
0	$A+Bx+Cx^2+Dx^3$	0.52756	$-4.59304x10^{-4}$	$6.1836x10^{-5}$	$2.4826x10^{-7}$
18		0.45818	$2.97883x10^{-4}$	$2.08897x10^{-5}$	$7.27728x10^{-7}$
40		0.42029	$6.63203x10^{-4}$	$7.74969x10^{-6}$	$8.45621x10^{-7}$

Angular distributions and analysis for determination of optimal detection angle -

Among biophysical methods for characterisation of living (and dead) microogranisms in various fluids on-chip immersion refractometry method stands out. Since water is natural environment, thus measurements in water are of great importance for investigation of various types of bacteria, etc. Important cases are connected to bacteria *E.coli* and *Baccilus Suptilis*. For the use of this method a significant data base including a large number of bacteria and water types could be of interest [30].

For *E.coli* using immersion method [34] was obtained index of refraction. MiePlot software demands that for calculation there must be entered at least 4 different indexes of refraction (on different λ) so we used this index for the simulation. For spectra of interest we approximated index to be the measured value from reference and then the angular scattering was obtained at principal line of commonly used He-Ne laser. Chosen conditions were: the environment was water, the shape of the sample is approximately in diameter 2.83 μm (approximation, because the *E.coli* is rod shaped) [34], wavelength of light λ=632.8nm. Angular scattering - polar plot was depicted in Figure 2. for above mentioned conditions.

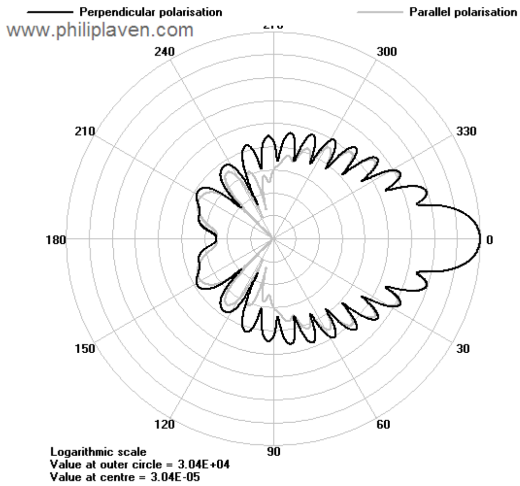


Fig. 2. Angular scattering - Polar plot for case of E.coli in water environment. The used simulation values are: shape sphere (approximation) diameter is 2.83 μm, λ=632.8nm

Matrix approach based on theory and software packages - Scattering matrices were calculated using MiePlot software. Characteristic elements normalised (or not) were calculated. The case of *E.coli* in water environment for the scattering angles from 0 to 180° is presented in Fig. 3 using data from [34].

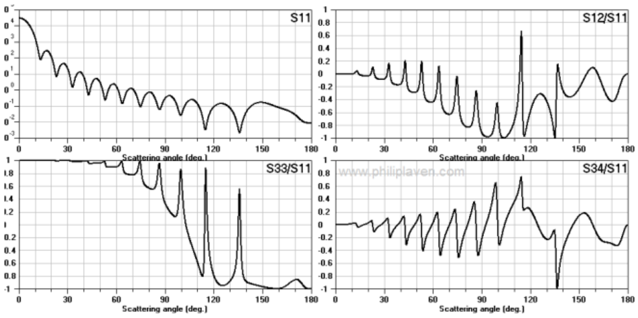


Fig. 3. Scattering matrix for case of E.coli in water environment. The used simulation values are: diameter is 2.83 μm, λ=632.8nm

Case of water in air is depicted in Fig. 4. Specific data related to this calculation is given in text following figure.

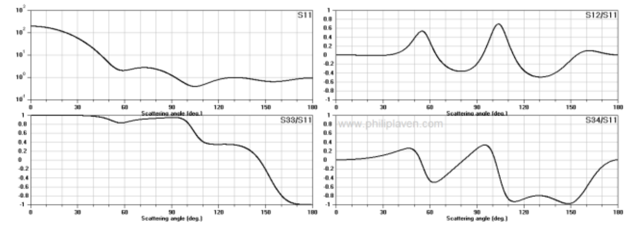
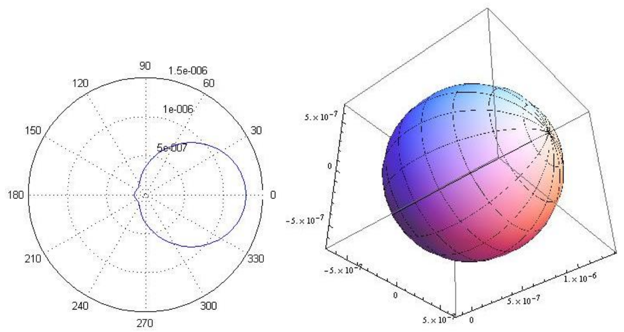


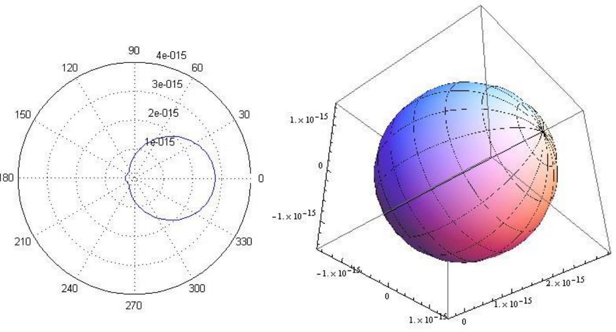
Fig. 4. Mueller matrix elements- case of water in air. The used simulation values are: shape sphere, radius is 0.4 μm, λ=632.8nm

Angular distribution for different sphere shaped scattering centres - As results of Mie theory and respective software packages angular scattering intensity on various most common laser lines (or filtered spontaneous sources) scattering were simulated and simulation results are presented in Figs. 6-9. The results of models were obtained using MatLab (6a, 7a, 8 and 9) and Mathematica (6b and 7b).



a) b)

Fig. 6. Angular scattering distribution λ =589.3nm from scattering centre of diameter a=1.88 μm in 2D a) and 3D b) presentation



a) b)

Fig. 7. Angular distribution for λ =1060 nm (Nd^{3+}:YAG) from scattering centre of diameter a=0.1 μm in 2D a) and 3D b) presentation

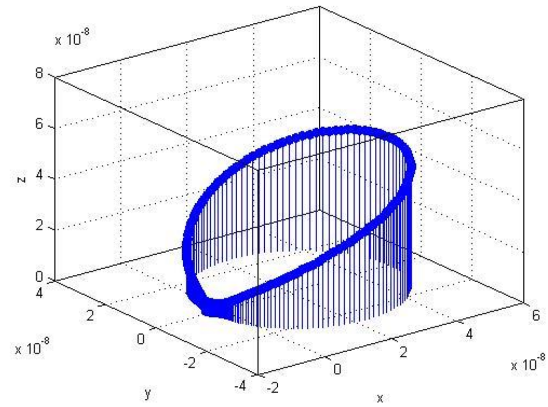


Fig. 8. Angular distribution for Ar^{+}:ion laser λ=514 nm, from scattering centre of diameter a= 1μm in 3D presentation (stream)

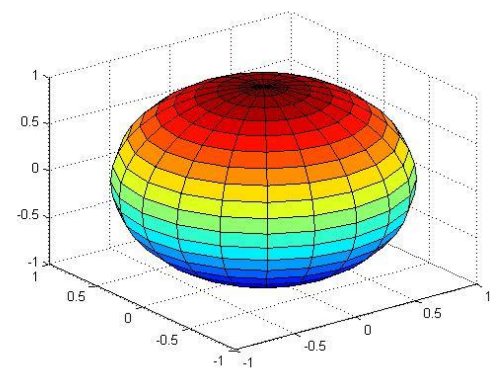


Fig. 9. Angular distribution for Ar^{+}:ion laser λ=514 nm, from scattering centre of diameter a= 1μm in 3D presentation

Examination of character of dynamics and morphology of bioobjects with methods of dynamic spectroscopies (Hertzian spectroscopy) and determination of optical constants of pigments in cells are high accuracy methods providing a lot of gathered information about the living cell (viruses, bacteria, elements of blood stream dynamics, chloroplasts). Scattering theories where the scattering centres are regular and irregular geometric objects (linear dimensions 20-15000 nm) are constantly developed. Complex formulation of refraction index for the cell in fluids, as well as absorption processes in visible and NIR define the level of approximation for application of light scattering. Dynamical properties and morphology, translational and rotational coefficient of diffusion, fluctuation frequencies of light intensity, scattered from centres of interest showing specific movement (dynamics) have been a topic of numerous papers. The broadening (and shifting) of characteristic spectral line shapes on moving microorganisms is very important for many analyses including polydispersity as well as the fluctuations of different origin. Dispersion properties, various bioobjects and biological processes are included in basic method of measurement related to distribution probability, amplitudes and intensities with autocorrelation and spectra development. One of the results of statistical investigation is connection of movement dynamics with the forms of scattered spectral lines, which could have not been measured before the era of quantum generators. The multiple scattering was also studied and various engineering approaches are formed for the issues of climate change and cosmos problems studies, for oceanography, etc. In the near era of development the levels of polarisation and scattering centres in multilayer objects are introduced in the description.

4. Conclusion

Laser measuring methods for laboratory and remote monitoring are widely applied. Still, in spite of large experimental and theoretical background a numerous specific cases are yet to be examined, having in mind the parallel techniques which are to confirm results of particular measurements. In this paper we wanted to point out the complexity of theories, calculus, measurements and software packages (unavoidable approximations).

Data for water and other samples and materials differ in references. Differences could be related to years of measurements and resolution of the measurement methods, including different light sources. Numerous systems could be of interest concerning the water purity research. One of the measurement methods, which compare pollutants indexes of refraction and those of immersion liquid is specific from optical parameters' point of view.

Explicitly we obtained using MiePlot results (principal line of He-Ne laser):

- angular scattering for *E.coli* in water environment (intensity - polar plot),

- scattering matrices elements for *E.coli* in water environment,

- matrix elements for case of sphere shape water in air.

Using Matlab and Mathematica we obtained results for several cases of spherical centres and various wavelengths and various diameters of scatterers (different visualizations).

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