Załącznik nr 2-ENG

Daniel Jakubczyk

Institute of Physics

Polish Academy of Sciences

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Author's Summary of Professional Accomplishments

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1. Academic and Research Career

1.1. Prior to obtaining the degree of doctor

In 1991, I submitted my Master thesis at the Warsaw University of Technology, the Faculty of Technical Physics and Applied Mathematics, major in integrated optics. The thesis, entitled "Effect of magnetic field on the operation of non-linear waveguide resonant cavity," was prepared under the guidance of prof. Jan Petykiewicz. It was a theoretical work, in which we looked for the possibility of bistable operation of so designed a device. The search yielded a positive answer. A possibility of bi- and even multi-stable operation was confirmed, which opened up the possibility of using such cavities as a variety of switches.

At the same time, from the beginning of 1991, I started working as a lab assistant at the Institute of Physics in the group of prof. Maciej Kolwas. In December of that year, I began my PhD studies. I joined in the research on the laser-light-induced condensation of sodium vapour, then recently discovered by the group. Analysis of the evolution of resulting nano-droplet cloud (cloud of clusters) became the subject of my doctoral dissertation. The studies were conducted in a heat-pipe-type cell filled with a mixture of hot sodium vapour and helium. Sodium vapour condensation was induced by a strong laser beam, and the resulting nano-droplet cloud was probed with a weak laser beam. The parameters of the scattered light were analysed in the framework of the Rayleigh-Gans model. In the process of the study we developed a model describing the observed effects in the language of the equations of mass and heat transport and simple thermodynamics. The model equations were solved analytically, which increased the clarity of the results and enabled fast and stable numerical calculations. The developed theoretical apparatus enabled to establish that the spatial distribution of Na^{2+} ion concentration and the diffusion of atomic sodium vapour are responsible for the spatial distribution of the concentration of clusters in the cloud and for the dynamics of evolution in its early stage. In turn, the diffusion of clusters was found to be responsible for the formation of the maximum concentration of clusters lying off the cell axis at later stages of evolution. The analysis of resonances visible in the intensity of scattered light allowed to measure the evolution of the average size of the clusters, and hence, the growth rate of the clusters and its spatial distribution. Mastering the mathematical apparatus of equations of transport/diffusion enabled, in the subsequent studies, to create models of the evolution of a droplet of various liquids and suspensions evaporating in diverse gaseous environments.

1.2. After obtaining the doctoral degree

1.2.1. Postdoctoral research

From August 1998 to August 1999 I was doing postdoctoral research at Photonics Research Laboratory (PRL) headed by prof. Paras N. Prasad at the Faculty of Chemistry, State University of New York at Buffalo. I participated there in studies on non-linear optical phenomena at the nanoscale. My primary working tool was a near-field optical microscope working either in NSOM mode (Near-field Scanning Optical Microscope) or in PSTM mode (Photon Scanning Microscope Tunelling), adapted to work with a (Ti: sapphire) laser generating femtosecond pulses in the near-infrared (800 nm). In the late 90s, near-field microscopy techniques allowing to overcome the diffraction limit (Abbe criterion) were new. Available devices operated in transmission mode, and even observation of one-photon stimulated fluorescence was considered difficult, because of the low levels of signal obtained. My main task was to obtain reliable images of, as small as possible, two-photon stimulated objects. Such stimulation enables further increasing of the resolution, due to quadratic dependence of the optical response as a function of the intensity of excitation light. The task was very difficult, because of the need to operate at the micro and nanoscale with light power density suitable for the observation of nonlinear phenomena. I managed, however, to efficiently solve it. The objects of research were various nano-objects (mainly spherical nanoprobes) containing two-photon excited dyes (upconversion), as well as nanocrystals of the second-harmonic-generating substances. The next task was to use photobleaching of two-photo-exited dyes in the near optical field to record information of density of the order of 1.5 Gb/cm^2. Observation of single and two-photon-stimulated-dye-labelled bacteria was also attempted. I was manufacturing samples using the materials produced in PRL, as well as nanocrystals I was growing myself. At the same time I was carrying out numerical calculations of electromagnetic field distribution around the NSOM / PSTM probe, using multiple-multipole method (MMP). Using an atomic force microscope (AFM) I was also carrying out studies of photonic crystals obtained in PRL and of materials such as (nano) porous silica. In the course of the work I designed and built several electronic devices (e.g. the dedicated, miniature electrometer and the interfacing amplifier), which enabled to increase the accuracy of measurements. The result of a year work has been five publications [A6, A8-A11]. The results of our work were also presented at the 218th ACS National Meeting 1999 [K9]. At the turn of September and October 1998 I attended also Nanoscale Science & Technology Symposium held at the University of Buffalo. With a wide range of work carried out in PRL I had the opportunity to come into contact with a variety of problems and measuring techniques of physics, chemistry and biology.

1.2.2. Further work at the Institute of Physics PAS

After returning from the University of Buffalo I joined in the research on the electrical properties of light-induced sodium nano-droplets and in the ensuing construction of (electro-optical) traps to levitate small groups and individual droplets of sodium in the heat-pipe cell. The acquired experience allowed then building electrodynamic traps for levitation of individual droplets of water and other liquids. This in turn paved the way for the study of the thermodynamics of evaporation processes, to which I devoted most of the time and about what I write below. Single levitated droplets are also a grateful object for studying the interaction of light with matter. This involves developing methods of optical particle characterisation. In our case, it is static light scattering mainly analysed in the framework of Mie theory. The method enables very accurate measurement of the radius of a droplet and fairly accurate measurement of the droplet refractive index. This involves a need of developing computational methods. Recently, for example, the software using parallel computing on graphics cards has been developed and implemented in our lab. The resonant interaction of light with dropletss of suspensions was also investigated. The analysis of such scattering, inter alia, through the study of whispering gallery modes, allows the assessment of the internal structure of the suspension droplet and its evolution.

2. Achievement Justifying the Application for Habilitation.

As an achievement, as defined in Art. 16 paragraph 2 of the Act of 14 March 2003 on Academic Degrees and Academic Title and on Degrees and Title in Arts, I am indicating a series of eleven monothematic publications entitled:

"Studies of thermodynamics of evaporation of free, single droplets at micro- and nanoscale":

1. P. Markowicz, D. Jakubczyk, K. Kolwas, M. Kolwas**. Trapping of light-induced sodium clusters in a modified quadrupole trap,** J. Phys. B, 33, 3605-3614 (2000).
2. D. Jakubczyk, M. Zientara, W. Bazhan, M. Kolwas, K. Kolwas. **A device for light scatterometry on single levitated droplets,** Opto-Electron. Rev., 9, 423-430 (2001).
3. D. Jakubczyk, M. Zientara, K. Kolwas, M. Kolwas, **Temperature dependence of evaporation coefficient for water measured in droplets in nitrogen under atmospheric pressure,** J. Atmos. Sci., 64, 996-1004 (2007), DOI: 10.1175/JAS3860.1.
4. M. Zientara, D. Jakubczyk, K. Kolwas, M. Kolwas, **Temperature dependence of evaporation coefficient of water in air and in nitrogen under atmospheric pressure; study in water droplets**, J. Phys. Chem. A, 112, 5152-5158 (2008), DOI: 10.1021/jp7114324.
5. D. Jakubczyk, M. Kolwas, G. Derkachov, K. Kolwas, **Surface states of micro-droplet of suspension**, J. Phys. Chem. C, 113, 10598-10602 (2009), DOI: 10.1021/jp9007812.
6. D. Jakubczyk, G. Derkachov, T. Do Duc, K. Kolwas and M. Kolwas, **Coefficients of Evaporation and Gas Phase Diffusion of Low-Volatility Organic Solvents in Nitrogen from Interferometric Study of Evaporating Droplets**, J. Phys. Chem. A, 18, 114, 3483-3488 (2010), DOI: 10.1021/jp911466e.
7. D. Jakubczyk, M. Kolwas, G. Derkachov, K. Kolwas and M. Zientara, **Evaporation of micro-droplets: the "radius-square-law" revisited,** Acta Physica Polonica A, 122, 709-716 (2012).
8. D. Jakubczyk, G. Derkachov, M. Kolwas and K. Kolwas, **Combining weighting and scatterometry: application to a levitated droplet of suspension,** J. Quant. Spectrosc. Radiat. Transfer, 126, 99–104 (2013), DOI: 10.1016/j.jqsrt.2012.11.010.
9. M. Zientara, D. Jakubczyk, M. Litniewski and R. Hołyst, **The transport of mass at the nano-scale during evaporation of droplets: the Hertz-Knudsen equation**, J. Phys. Chem. C, 117, 1146-1150 (2013), DOI: 10.1021/jp3091478.
10. R. Hołyst, M. Litniewski, D. Jakubczyk, K. Kolwas, M. Kolwas, K. Kowalski, S. Migacz, S. Palesa and M. Zientara, **Evaporation of freely suspended single droplets: experiment, theory and computer simulations**, Rep. Prog. Phys., 76, 034601 (19pp) (2013), DOI: 10.1088/0034-4885/76/3/034601.
11. R. Hołyst, M. Litniewski, D. Jakubczyk, M. Zientara and M. Woźniak, **Nanoscale transport of energy and mass flux during evaporation of liquid droplets into inert gas: computer simulations and experiments**, Soft Matter, 9, 7766-7774 (2013), DOI: 10.1039/C3SM50997D.

2.1. The context and scientific background of the research

Droplets - a natural effect of separation of fluid phases - are ubiquitous, and the process of droplets evaporation and condensation underlies many physical phenomena. Theoretical descriptions of droplet evaporation created in the late nineteenth and early twentieth century [D1, D2] prove effective (under normal conditions) from the macro to the micro scale. However, the phenomena of mass and energy transport taking place at the submicron- and nanoscale, at the gas-liquid interface, have eluded the sound analytical description. In the era of great interest in the processes occurring at the nano-scale and the rapid development of nanotechnology, the uncertainty as to the order of magnitude in predicting the evaporation time of a (nano) droplet rises to the rank of a significant problem waiting to be solved.

Similar difficulties are encountered in predicting the temperature of evaporating micro- and nanodroplets. In 1999, Fang and Ward [D3] in an elegant experiment showed that the temperature profile crossing the gas/liquid interface is different than predicted by theory. Difficulties encountered by the theory at submicron- and nanoscale also clearly manifest in measurements of, so-called, evaporation coefficient (introduced by Knudsen [D4]), associated with the ballistic transport in close proximity to the surface. Measurements contributed by various authors over the century extend over 3 orders of magnitude. In particular, the contemporary results of careful experiments, using Raman thermometry, concerning evaporation of droplets in vacuum, obtained by the group from Berkeley [D5], seem to disagree with the equally careful measurements, made with isotopic methods, of mass transfer between the droplet and the vapour in equilibrium, obtained by the group from Boston [D6].

One gets the impression that the fundamental principle underlying the phenomenon has not yet been identified and complexity of available descriptions surpasses the complexity of the phenomenon itself. It can be expected that the phenomena of evaporation and condensation can be described using a significantly smaller number of parameters than in the available theoretical models, and ultimately with a parameterless model.

A good understanding of the fundamental processes of evaporation of droplets raises hopes for significant progress in many areas, even such seemingly far apart as multi-scale models of weather and cost efficient running of internal combustion engines. One should, however, reckon the scale of difficulty of the problem that had not been solved for a century.

2.2. Summary of work

In the process of finalising work on my doctoral thesis, the issue of investigation of transport of vapours in gases, and in particular the phenomenon of evaporation of droplets, began to crystallise. The first object of our research on the evaporation of droplets was quite exotic[1]: laser-light-induced cloud of nano-droplets of liquid sodium suspended in a hot mixture of sodium vapour and helium [A7, A12-A15, A21-A24]. It served, however, as a valuable experimental plot. It turned out that as a result of the resonant interaction of laser light with sodium dimers in helium the cold plasma is created and the suspended nano-droplets (clusters) of sodium acquire electric charge (see [D7]). Thus an idea was born to use an electrodynamic trap to isolate single droplets, since the observations carried out on individual droplets are

[1] Though by no means a purely academic. The study of nano-droplets of sodium has practical value, due to the presence of sodium in the Earth's atmosphere: in troposphere - originating from sea water, and in the sodium layer in mesosphere - originating from meteorites, and due to technical applications: discharge lamps, coolant in nuclear reactors, heat-pipes, etc.

inherently more accurate than on a cloud [1]. A linear (quadrupole) electro-optical trap was built, with a unique capability of working in an aggressive and conductive environment, allowing to isolate small groups and even individual nano-droplets (see [D8]). A further step, taken in view of applications in physics of atmosphere, was the shift from exotic objects to the most common, that is, to droplets of water. This required building of a new trap with the three-dimensional minimum of (pseudo) potential, as well as a climatic chamber to enable creation of the necessary conditions of temperature and humidity / composition of the atmosphere [2]. It was necessary to solve a number of design issues using unconventional technologies. The resulting apparatus enabled to carry out many interesting measurements, both of pure liquids (water, glycols) as well as of aqueous suspensions (silica nanospheres, fullerene nano-crystallites). The analysis of thermodynamics of evaporation has been based on studying the evolution of droplet radius, which we have learned to measure with optical methods with the interferometric accuracy (at an early stage it was a few dozen nanometers).

At this stage, the research focused mainly on thermodynamics of evaporation of water droplets. It concerned the value and temperature dependence of the so-called mass and temperature coefficient of evaporation. Those empirically found coefficients, matching kinetic and diffusion description of evaporation, are a consequence of some shortcoming of already existing theories of evaporation. Classically they have been understood as the probabilities of penetration of an evaporating / condensing molecule through the interface and the completeness of energy transfer at the impact of a molecule at the surface. They are extremely difficult to measure experimentally. The values obtained over a century cover 3 orders of magnitude [D9].
The first measurements of temperature dependence of the mass coefficient of evaporation [3] yielded the results of confirming, as to the order of magnitude, studies of contemporary authors, which in itself was a valuable contribution to the discussion. Unfortunately, the resulting temperature dependence was burdened with high uncertainty and could not be reconciled with any proposed model of such dependence.

At a later stage of the study we noticed [4] that all previous authors were making quite significant simplifying assumption that led to a significant underestimation of the mass coefficient of evaporation, under certain conditions, by up to a factor of 2. This result, together with the continuous improvement of the setup and methods of results processing, enabled to find a more reliable temperature dependence, which further proved to excellently extend towards higher temperatures the results obtained by another group with entirely different methods [D6]. This result still remains a very important contribution to the discussion on the mechanism of evaporation of a single droplet of water.

Mastering the theoretical and experimental tools for studying the evaporation of droplets enabled to try them on droplets of suspensions. A particularly interesting result was the study of surface thermodynamics of evaporating nano-droplet of a suspension of nano-spheres (compare [D10]). Nano-spheres located at the surface can be treated as a kind of two-dimensional substance, which is subject to phase transitions. Such phase transitions could be detected by analysing the evolution of droplet radius [5].

In order to go further, our experimental tools had to be further improved. We also accumulated sufficient knowledge and experience. We therefore embarked on the construction of the apparatus, in particular the trap, which would be free from the encountered limitations and drawbacks. The project was successful - we built an electrodynamic trap, with excellent experimental characteristics (geometric/mechanical and electrical), equipped with an active stabilisation of the droplet vertical position. We also designed a new climatic chamber for high purity measurements in a dry atmosphere of nitrogen, and a number of associated devices, for example, allowing better control of droplet injection timing. In the new setup, the absolute accuracy of measurement of the droplet radius increased nearly by an order of magnitude, reaching under favourable conditions about ±10 nm. Such accuracy of studying the evolution of the droplet radius, already approaching the width of the density profile at the gas-liquid interface, enables extremely precise probing of put forward hypotheses concerning, for example, the model of evaporation. This opens up the possibility of studying nanoscale deformations of droplets, surface waves, etc.

The capabilities of the new setup were first used to study the very slowly evaporating droplets [6]. Analysing the evolution of such droplets enables finding thermodynamic parameters such as vapour pressure (or alternatively the diffusion coefficient of vapour in gas). In case of a very slowly evaporating liquid, such as glycerol (cf. [11]), the saturated vapour pressure at low temperatures (e.g. room temperature) is so low that it is impossible or very difficult to measure with other methods. Due to the exponential nature of the dependence, the extrapolation of measurement results from higher temperatures to lower is burdened with a large uncertainty whereas for a droplet in a trap, the direct measurements at low temperatures are possible (cf. [D11]).

At this stage, summing up our knowledge and acquired expertise, we analysed the scope of applicability of, so-called, "radius-square law" [7]. This law, resulting from the elementary analysis of droplet evaporation, is just an attempt to find a simple explanation of the phenomenon (compare, for example, [D12]). However, it is not a universal solution to the problem, since there are many exemptions from its applicability. In work [7] we also performed an analysis of the masking effect which the presence of impurities has on the measurement of the mass coefficient of evaporation. This effect was predicted by some authors, but primarily bound (as it turns out, rather inaccurately) with the actual changes in coefficient of evaporation caused by surface-active agents. The performed analysis demonstrates, in a way, the measure of uncertainty of evaporation coefficient found with analysis of the evolution of radius of a micron-sized droplet. Using this analysis, we selected those measurements in which the kinetic effects are undoubtedly visible, and which are suitable for measuring the coefficients of evaporation. They were presented in works [7,10,11].

An important conclusion emerging from [7] is that the analysis of kinetic effects requires using in experiment as small droplets as possible, or extending the free path of the molecules in gas. Since the existing experimental setup enabled only studying droplets with radius larger than ~0.3 μm at atmospheric pressure, further work progressed in two directions. On the one hand, in the direction of extension of capabilities of the setup, and on the other hand in the direction of studying the droplets simulated with MD calculations.

In order to make a full use the setup capabilities, we introduced the technique of droplets weighting and combined it with our optical methods of radius analysis. Weighting is carried out by measuring, the appropriately calibrated, DC voltage used for the stabilisation of the droplet vertical position [8]. Such a combined method enables studying the droplets for which the optical methods stop working, or lose accuracy as for example, for the droplets of suspensions or very small droplets.

The other direction of research could be pursued due to co-operation established with the group from the Institute of Physical Chemistry PAS, having adequate numerical tools and, above all, the appropriate skills and experience in MD calculations (see for example [D13]. Further study using this technique progressed in several directions.

First, the range of applicability of terms used to describe the macroscopic continuous media to nanoscale was investigated [9]. This approach proved to be successful from the practical, engineering point of view. After precise determination of such basic concepts as the radius of the (nano) droplet and the meaning of evaporation coefficients at the nano scale, it proved possible to use this description for extremely small droplets - just few nanometers of radius. Another major result of this work, both theoretical and practical, is finding a more complete form of surface tension dependence upon the droplet radius. This casts a new light on Tolman equation describing the effect (see [D14]).

On the other hand, it became possible to present in a renowned journal (in the form of a review article) the overall vision of studied phenomena from the micro- down to the nanoscale [10]. Our results for the micro-droplets along with the results of MD for droplets at the nano scale were analysed using both the model developed by us (in the framework of the classical continuous media theory) as well as the Statistical Rate Theory (SRT) proposed by Fang and Ward [D15]. The approach we had developed proved effective in a much broader scope than the SRT.

The analysis performed in [10], along with further results of our experiments and further MD calculations of the IPC PAS group, enabled our partners from IPC to propose a new, very elegant and effective parameterisation of evaporation model [11]. This result of combining our experimental works with theoretical modelling has been a valuable outcome of many years of studies.

2.3. Literature

D1.J. Maxwell, Collected Sci. Papers**,** 11, 625 (1890)
D2.I. Langmuir, The dissociation of hydrogen into atoms: II. Calculation of the degree of dissociation and the heat of formation, J. Am. Chem. Soc., 37**,** 417 (1915)
D3.G. Fang and C. Ward, Temperature measured close to the interface of an evaporating liquid, Phys. Rev. E, 59, 417 (1999)
D4.M. Knudsen, *The Kinetic Theory of Gases: Some Modern Aspects* (London: Methuen, 1950)
D5.J. Smith, C. Cappa, W. Drisdell, R. Cohen and R Saykally, Raman thermometry measurements of free evaporation from liquid water droplets, J. Am. Chem. Soc., 128, 12892 (2006).
D6.P. Davidovits, D. Worsnop, J. Jayne, C. Kolb, P. Winkler, A. Vrtala, P. Wagner, M. Kulmala, K. Lehtinen, T. Vesala and M. Mozurkewich, Mass accommodation coefficient of water vapor on liquid water *Geophys. Res. Lett*., 31**,** L22111, (2004)
D7.M. Synowiec, K. Kolwas, M. Kolwas, Large sodium clusters in an electrostatic field, Zeitschrift fur Physik D, 40, 271 (1997).
D8.W. Bazhan, K. Kolwas, M. Kolwas, Depolarization of light scattered by a single sodium nanoparticle trapped in an electro-optical trap, Opt. Com., 211, 171 (2002).
D9.C. Kolb, R. Cox, J. Abbatt, M. Ammann, E. Davis, D. Donaldson, B. Garrett, C. George, P. Griffiths, D. Hanson, M. Kulmala, G. McFiggans, U. Pöschl, I. Riipinen, M. Rossi, Y. Rudich, P. Wagner, P. Winkler, D. Worsnop, C. O'Dowd, An overview of current issues in the uptake of atmospheric trace gases by aerosols and clouds, Atmos. Chem. Phys., 10, 10561 (2010).

D10. A. Adamson, and A. Gast, *Physical Chemistry of Surfaces* (New York: Wiley, 1997)
D11. NIST Chemistry WebBook, NIST Standard Reference Database Number 69, http://webbook.nist.gov/chemistry/
D12. H. Pruppacher and J. Klett, *Microphysics of Clouds and Precipitation* (Dordrecht: Kluwer, 1997)
D13. R. Hołyst and M. Litniewski, Heat transfer at the nanoscale: evaporation of nanodroplets, Phys. Rev. Lett., 100**,** 055701 (2008).
D14. R. Tolman, The effect of droplet size on surface tension, J. Chem. Phys., 17, 333 (1949)
D15. C. Ward and G. Fang, Expression for predicting liquid evaporation flux: statistical rate theory approach, Phys. Rev. E, 59, 429 (1999).

3. Bibliometric Data

- total *impact factor* of scientific publications as given by Journal Citation Reports (JCR), for each corresponding publication year (for publications from before 2008, IF2008 was used, while for publications from 2013, IF2012 was used) – **72,398**
- sum of the times publications were cited as given by Web of Science (WoS) – **291** (without self-citations – **231**)
- Hirsch index of publications as given by WoS – **8**

4. List of publications not included in the achievement set out in Chapter 2

4.1. Scientific publications in journals contained in Journal Citation Reports (JRC) database

A1. M. Kolwas, D. Jakubczyk, G. Derkachov, and K. Kolwas, Interaction of optical Whispering Gallery Modes with the surface layer of evaporating droplet of suspension, J. Quant. Spectrosc. Radiat. Transfer, 131, 138 (2013), DOI: 10.1016/j.jqsrt.2013.03.009.

Participation in analysis of experimental data and in interpretation of results. The leading part in performing the measurement. Content-related and linguistic editing of the work. I estimate my total share at ***50%****.*

A2. G. Derkachov, K. Kolwas, D. Jakubczyk, M. Zientara, and M. Kolwas, Drying of a Microdroplet of Water Suspension of Nanoparticles: from Surface Aggregates to Microcrystal, J. Phys. Chem. C, 112, 16919 (2008), DOI: 10.1021/jp806349q.

Participation in performing the measurement, in analysis of experimental data and in interpretation of results. Content-related and linguistic editing of the work. I estimate my total share at ***30%****.*

A3. M. Zientara, D. Jakubczyk, G. Derkachov, K. Kolwas and M. Kolwas, Simultaneous determination of mass and thermal accommodation coefficients from temporal evolution of an evaporating water microdroplet, J. Phys. D: Appl. Phys, 38, 1978 (2005), DOI: 10.1088/0022-3727/38/12/018.

Participation in formulation of the task, in performing the measurement, in analysis of experimental data (droplet radius determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at ***35%****.*

A4. D. Jakubczyk, G. Derkachov, M. Zientara, M. Kolwas, K. Kolwas, Local-field resonance in light scattering by a single water droplet with spherical dielectric inclusions, JOSA A, 21, 2320 (2004)

The leading part in formulation of the task. Participation in performing the measurement, in analysis of experimental data (droplet radius and refractive index determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at ***40%****.*

A5. D. Jakubczyk, G. Derkachov, W. Bazhan, E. Łusakowska, K. Kolwas, M. Kolwas, Study of microscopic properties of water fullerene suspension by means of resonant light scattering analysis, J. Phys. D: Appl. Phys., 37, 2918 (2004), DOI: 10.1088/0022-3727/37/20/021

*The leading part in formulation of the task. Participation in performing the optical measurement, in atomic force microscope (AFM) sample preparation, in analysis of experimental data (droplet radius and refractive index determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A6. Y. Shen, J. Swiatkiewicz, D. Jakubczyk, F. Xu, P.N. Prasad, Vaia RA, BA. Reinhardt, High-density optical data storage with one-photon and two-photon near-field fluorescence microscopy, Appl. Opt., 40, 938 (2001).

*Participation in experimental setup and sample preparation, in performing the measurement with near-field microscope (NSOM/PSTM) and in interpretation of results. I estimate my total share at **25%**.*

A7. P. Markowicz, D. Jakubczyk, K. Kolwas, M. Kolwas, Evolution of size and charge of sodium nanoparticles in an electro-optical trap, J. Phys. B, 33, 5513 (2000).

*Participation in formulation of the task, experimental setup preparation (in particular, writing software), in performing the measurement, analysis of experimental data and in interpretation of results. Content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A8. Yuzhen Shen, Friend CS, Yan Jiang, D. Jakubczyk, J. Swiatkiewicz, P.N. Prasad, Nanophotonics: interactions, materials, and applications, J. Phys. Chem. B, 104, 7577 (2000).

*Participation in experimental setup and sample preparation, in performing the measurement with near-field microscope (NSOM/PSTM) and atomic force microscope (AFM), analysis of experimental data and in interpretation of results. The leading part in performing the measurement of the secend-harmonic generation and two-photon fluorescence at the nanoscale and in near-field distribution calculation with multiple multipole method (MMP). I estimate my total share at **30%**.*

A9. Yan Jiang, D. Jakubczyk, Yuzhen Shen, J. Swiatkiewicz, and P.N. Prasad, Nanoscale nonlinear optical process: theoretical modelling of second-harmonic generation for both forbidden and allowed light, Opt. Lett., 25, 640 (2000).

*Participation in preparation of near-field distribution calculation with multiple multipole method (MMP) and in content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A10. Yuzhen Shen, D. Jakubczyk, Faming Xu, J. Swiatkiewicz, P.N. Prasad, BA. Reinhardt, Two-photon fluorescence imaging and spectroscopy of nanostructured organic materials using a photon scanning tunneling microscope, Appl. Phys. Lett., 76, 1 (2000).

*Participation in experimental setup and sample preparation, in performing the measurement with near-field microscope (NSOM/PSTM), analysis of experimental data and in interpretation of results. I estimate my total share at **30%**.*

A11. D. Jakubczyk, Y. Shen, Lal M, Friend C, Kim KS, Świątkiewicz J, P.N. Prasad, Near-field probing of nanoscale nonlinear optical processes, Opt. Lett., 24, 1151 (1999).

*The leading part in experimental setup and sample preparation, in performing the measurement of secend-harmonic generation and two-photon fluorescence at the nanoscale with near-field microscope (NSOM/PSTM) and with atomic force microscope (AFM), in analysis of experimental data and in interpretation of results and in content-related and linguistic editing of the work. I estimate my total share at **70%**.*

A12. D. Jakubczyk, M. Kolwas, K. Kolwas, Study of the formation and growth of light-induced sodium clusters, J. Phys. B, 30, 5567 (1997).

*The leading part in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results. Content-related and linguistic editing of the work. I estimate my total share at **60%**.*

A13. M. Kolwas, K. Kolwas, D. Jakubczyk, Sodium clusters produced by laser light, Appl. Phys. B, 60, S173 (1995).

*Participation in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results as well as in linguistic editing of the work. I estimate my total share at **25%**.*

A14. M. Kolwas, K. Kolwas, D. Jakubczyk, Evolution of laser light induced sodium clusters, Acta Phys. Pol. A, 86, 257 (1994).

*Participation in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results as well as in content-related and linguistic editing of the work. I estimate my total share at **20%**.*

A15. B. Hnat, D. Jakubczyk, K. Kolwas, M. Kolwas, Size evolution of the light induced sodium clusters, Acta Phys. Pol. A, 81, 629 (1992).

*Participation in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results as well as in content-related and linguistic editing of the work. I estimate my total share at **25%**.*

4.2. Monographs and scientific publications in international or national journals other than those contained in JRC database

A16. S. Chudzyński, D. Jakubczyk, G. Karasiński, A. Kardaś, K. Kolwas, M. Kolwas, A. Schady, W. Skubiszak, T. Stacewicz, K. Stelmaszczyk, A. Szczurek, M. Zientara, A. Zwoździak, J. Zwoździak, Badania aerozolu miejskiego. Monografia Wydawnictwa Uniwersytetu Warszawskiego, 2007. Rozdział 3: Rozpraszanie światła na pojedynczej cząstce.

*Participation in analysis of experimental data and in interpretation of results by means of the equations of mass and heat transport. The leading part in performing the measurement. Content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A17.D. Jakubczyk, G. Derkachov, W. Bazhan, E. Łusakowska, K. Kolwas and M. Kolwas, Effective refractive index of drying droplet of water fullerene suspension, Proc. SPIE, 5849, 158 (2005).

*The leading part in formulation of the task. Participation in performing the optical measurement, in atomic force microscope (AFM) sample preparation, in analysis of experimental data (droplet radius and refractive index determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A18.D. Jakubczyk, G. Derkachov, M. Zientara, M. Kolwas, K. Kolwas, Determination of mass and thermal accommodation coefficients from evolution of evaporating water droplet, Proc. SPIE, 5849, 162 (2005).

*The leading part in formulation of the task. Participation in performing the measurement, in analysis of experimental data (droplet radius determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at **60%**.*

A19.D. Jakubczyk, G. Derkachov, M. Zientara, M. Kolwas, K. Kolwas, Light scattering by microdroplets of water and water suspensions, Proc. SPIE, 5849, 62 (2005).

*The leading part in formulation of the task. Participation in performing the measurement, in analysis of experimental data (droplet radius and refractive index determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at **50%**.*

A20.D. Jakubczyk, M. Zientara, G. Derkachov, K. Kolwas, M. Kolwas, Investigation of the evolution of charged water droplets in the electrodynamic trap, Proc. SPIE, 5397, 23 (2004)

*The leading part in formulation of the task. Participation in performing the measurement, in analysis of experimental data (droplet radius determination) and in interpretation of results by means of the equations of mass and heat transport. Content-related and linguistic editing of the work. I estimate my total share at **50%**.*

A21.P. Markowicz, D. Jakubczyk, K. Kolwas and M. Kolwas, Experimental investigation of large sodium clusters in electro-optical trap, Słupskie Prace Matematyczno-Przyrodnicze 13a, 199 (2000).

*Participation in formulation of the task, experimental setup preparation (in particular, writing software), in performing the measurement, analysis of experimental data and in interpretation of results. I estimate my total share at **30%**.*

A22.M. Kolwas, K. Kolwas, D. Jakubczyk, Interaction of laser light with sodium clusters in *Laser technology IV: Research Trends, Instrumentation, and Applications in Metrology* *and Materials Processing*, Wiesław Woliński, Zdzisław Jankiewicz, Editors, Proc. SPIE, 2202, 453 (1995).

*Participation in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results. The leading part in content-related and linguistic editing of the work. I estimate my total share at **25%**.*

A23.D. Jakubczyk, K. Kolwas, M. Kolwas, Scatterometry of laser-light-induced sodium clusters, (Invited Paper) in *Difractometry & Scatterometry*, Maksymilian Pluta, Mariusz Szyjer, Editors, Proc. SPIE, 1991, 207 (1994).

*The leading part in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results as well as in content-related and linguistic editing of the work. I estimate my total share at **40%**.*

A24.B. Hnat, D. Jakubczyk, K. Kolwas, M. Kolwas, Evolution of laser-light-induced sodium clusters, in *High-Performance Spectroscopy*, Maksymilian Pluta, Aleksandra Kopystyńska, Mariusz Szyjer, Editors, Proc. SPIE, 1711, 185 (1993).

*Participation in experimental setup preparation, in performing the measurement, in analysis of experimental data and in interpretation of results as well as in content-related and linguistic editing of the work. I estimate my total share at **25%**.*

5. Conference Performances

K1. B. Hnat, D. Jakubczyk, K. Kolwas, M. Kolwas, “The evolution of laser induced sodium clusters”, International Conference on High Performance Optical Spectrometry, Warsaw, June 1-5, 1992.

K2. M. Kolwas, K. Kolwas, D. Jakubczyk, “Oddziaływanie światła laserowego z klasterami sodowymi”, Sympozjum Techniki Laserowej, Szczecin, September 1993.

K3. M. Kolwas, K. Kolwas, D. Jakubczyk, “Evolution of Laser Light Induced Sodium Clusters” International Conference Quantum Optics III, Szczyrk, September 3-9, 1993.

K4. D. Jakubczyk, K. Kolwas, M. Kolwas, “The evolution of the laser light induced sodium clusters” **invited lecture** at SPIE International Conference Difractometry & Scatterometry, Warsaw, May 24-28, 1993.

K5. D. Jakubczyk, K. Kolwas, M. Kolwas, “Diffusion Processes in the Cell Containing Laser Light Induced Sodium Clusters”, 26th EGAS Conference, Barcelona, July 12-15, 1994

K6. K. Kolwas, M. Kolwas, D. Jakubczyk, “The dependence of sodium clusters radius on the laser light intensity inducing clusters”, 26th EGAS Conference, Barcelona, July 12-15, 1994.

K7. M. Kolwas, K. Kolwas, D. Jakubczyk, “The dependence of the sodium cluster radius on the external conditions”, 10th European Conference on Dynamics of Molecular Collisions, Salamanca, 28 VIII – 2 IX 1994.

K8. D. Jakubczyk, M. Kolwas, K. Kolwas, “Study of formation and growth of light induced sodium clusters”, Quantum Optics, Jaszowiec, June 17-24, 1997.

K9. P. Markowicz, D. Jakubczyk, K. Kolwas, M. Kolwas, “Quadrupole Trap for Sodium Clusters in Conducting Medium”, ECAMP VI, Siena, July 14-18, 1998.

K10. P.N. Prasad, M. Lal, C.S. Friend, A. Biswas, J. Swiatkiewicz, K. Kim, S.J. Chung, J.G. Winiarz, D. Jakubczyk, Y. Shen, T.C. Lin, “Organic and organic-inorganic hybrid materials for nanophotonics: Nanoscale optical science and technology” 218th ACS National Meeting American Chemical Society, New Orleans, Fall 1999.

K11. Daniel Jakubczyk, Marcin Zientara, Wolodymyr Bazhan, Krystyna Kolwas, Maciej Kolwas, “A device for light scatterometry on single levitated droplets”, International Conference and Annual Meeting of European Optical Society: “From Quantum Optics to Photonics”, Zakopane, 28 June – 3 July 2001.

K12. M. Zientara, D. Jakubczyk, W. Bazhan, M. Kolwas, K. Kolwas, “Dynamics of Evaporation of Water Microdroplet in Paul Trap”, EPS-12: General Conference: Trends in Physics, Budapest, August 26-30, 2002.

K13. D. Jakubczyk, M. Zientara, G. Derkachow, K. Kolwas, M. Kolwas, “Observation of the formation of photonic crystals in electrodynamic levitator” Workshop on Quantum Chaos and Localisation Phenomena, Warsaw, May 24-25, 2003.

K14. Daniel Jakubczyk, Marcin Zientara, Gennadij Derkachov, Krystyna Kolwas, Maciej Kolwas, “Investigation of the evolution of the charged water droplets in the electrodynamic trap” **invited talk** at X Joint International Symposium “Atmospheric and Ocean Optics. Atmospheric Physics”, Tomsk, June 24-28, 2003.

K15. D. Jakubczyk, G. Derkachov, M. Zientara, M. Kolwas and K. Kolwas, “Manifestation of local-field resonance effect in effective refractive index of water droplet with spherical dielectric inclusions”, Fourth International Symposium on Theory of Atomic and Molecular Clusters, Toulouse, April 24-28, 2004.

K16. D. Jakubczyk, G. Derkachov, W. Bazhan, E. Łusakowska, K. Kolwas and M. Kolwas “Investigation of resonant properties of water fullerene suspensions by means of laser light scattering analysis”, Workshop on Quantum Chaos and Localisation Phenomena, Warszawa, May 19-22, 2005

K17. M. Zientara, D. Jakubczyk, G. Derkachov and M. Kolwas, “Evaporation of Microdroplet of Water. The Mass and Thermal Accommodation Coefficients”, 13th General Conference of the European Physical Society “Beyond Einstein – Physics for the 21st Century” Bern, July 11-15, 2005.

K18. D. Jakubczyk, G. Derkachov, W. Bazhan, E. Łusakowska, K. Kolwas i M. Kolwas, “Badanie rezonansowych właściwości rozpraszania światła laserowego na wodnej zawiesinie fulerenów”, XXXVIII Zjazd Fizyków Polskich, Sesja specjalistyczna: Fizyka atomowa, molekularna i optyka, Warszawa, September 11-16, 2005.

K19. M. Zientara, D. Jakubczyk i M. Kolwas, „Parowanie mikrokropli wody. Współczynniki parowania.” XXXVIII Zjazd Fizyków Polskich, Sesja specjalistyczna: Fizyka atomowa, molekularna i optyka, Warszawa, September 11-16, 2005.

K20. D. Jakubczyk, G. Derkachov, W. Bazhan, E. Lusakowska, K. Kolwas and M. Kolwas, “Effective refractive index of drying droplet of water fullerene suspension” V Warsztaty Fizyki Atomowej i Molekularnej (FAMO), Jurata, September 16-18, 2004.

K21. M. Zientara, D. Jakubczyk, G. Derkachov, K. Kolwas and M. Kolwas, “Determination of mass and thermal accommodation coefficients from evolution of evaporating water droplet” V Warsztaty Fizyki Atomowej i Molekularnej (FAMO), Jurata, September 16-18, 2004.

K22. Daniel Jakubczyk, Marcin Zientara, Gennadiy Derkachov, Krystyna Kolwas and Maciej Kolwas, “Light scattering by microdroplets of water and water suspensions” V Warsztaty Fizyki Atomowej i Molekularnej (FAMO), Jurata, September 16-18, 2004.

K23. G. Derkachov, D. Jakubczyk, M. Zientara, K. Kolwas and M. Kolwas, “Formation of three-dimensional microcrystallites during the evaporation of water microdroplet with inclusions”, Wrocław, 2006.

K24. G. Derkachov, K. Kolwas, D. Jakubczyk, M. Zientara and M. Kolwas, “Probing of surface properties of droplets of suspension with optical methods”, International School and Conference on Optics and Optical Materials, Belgrade, September 3-7, 2007.

K25. M. Zientara, D Jakubczyk, K. Kolwas and M. Kolwas, “The influence of thermal effusion on the evaporation of water micro-droplet”, The 20th International Symposium of Gas Kinetics, Manchester, July 20-25, 2008.

K26. D. Jakubczyk, G. Derkachov, K. Kolwas, M. Kolwas, “Probing the composition of a drying microdroplet of water suspension of nanoparticles with optical methods”, Mie Theory 1908-2008. Present developments and interdisciplinary aspects of light scattering, Halle September 15-17, 2008.

K27. G. Derkachov, A. Derkachova, D. Jakubczyk, K. Kolwas, M. Kolwas, “Light scattering by random structure object with arrangement changing in time”, The Ninth International Conference “Correlation Optics 2009”, Chernivtsi National University, Chernivtsi, Ukraine, September 20-24, 2009.

K28. G. Derkachov, D. Jakubczyk, A. Derkachova, K. Kolwas, M. Kolwas, “The light scattering by drying droplet of suspension of spherical nanoparticles”, Workshop “Nano particles, nano structures and near field computation”, Institut für Werkstofftechnik, IWT, Bremen, March 11-12, 2010.

K29. Gennadiy Derkachov, Anastasiya Derkachova, Daniel Jakubczyk, Krystyna Kolwas, Maciej Kolwas, “Optyczna diagnostyka parującej mikrokropli z nanoinkluzjami i powstających mikrokrystalitów”, Polska Konferencja Optyczna, Międzyzdroje 27.06. – 01.07.2011.

K30. D. Jakubczyk, G. Derkachov, M. Kolwas and K. Kolwas “Levitated droplet of suspension: to weigh or to measure?” Marie Sklodowska-Curie symposium on the Foundations of Physical Chemistry The Copernicus Science Center, Warsaw, November 18-19, 2011.

K31. D. Jakubczyk, G. Derkachov, M. Kolwas and K. Kolwas “Combining weighting and scatterometry: application to a levitated droplet of suspension”, LIP 2012 - Lasers and Interactions with Particles, INSA de Rouen - CORIA, March 26-30, 2012.

K32. D. Jakubczyk, S. Migacz, G. Derkachov, M. Woźniak, J. Archer, K. Kolwas “Analysis of single droplet evaporation with Mie theory using parallel computing on graphic processing units”, Workshop “Scattering by aggregates (on surfaces)”, Institut für Werkstofftechnik, Bremen, March 24- 25, 2014.

6. Teaching Activity

1. From 1999 to 2001, I was giving "The Computers Architecture" classes within the Computer Laboratory for students in their second year of the College of Science.
2. In the years 2004-2006 and in 2012 I supervised 5 students at their scientific (one-month) summer practice. The practice of 2012 resulted in further co-operation with Mr. Szymon Migacz and the creation of state-of-the-art parallel software for computing on graphics cards.
3. In 2005 I promoted the BA thesis at Cardinal Stefan Wyszyński University in Warsaw, entitled "The computer program for controlling INNOVA 300 argon-ion laser" by P. Deptuła.

7. Participation in Research Projects

- From 2010 to 2013 I participated **as key investigator** at IP PAS in the non-co-financed international project "Physical phenomena in small systems: evaporation at the nano and micro scale" under the Programme of the European Science Foundation (ESF), Physical and Engineering Sciences committee (PESC) "Exploring the Physics of Small Devices."

- I participated in **9** national research projects:

✓ **as principal investigator (project manager)**

1. „Study of the role of diffusion phenomena in the process of formation of light-induced sodium aggregates" (1995-1996), 2 P03B 048 08
2. "Study of dynamics of evaporation of electrically charged levitating liquid droplets" (2005- 2008), 1 P03B 117 29

✓ **as co-investigator**

3. "The dynamics of formation with laser light and evolution of sodium clusters in gaseous environment" (1992-1994), 2 0485 91 01
4. "Resonant interaction of laser light with large alkali metal clusters" (1994-1997), 2 P03B 058 08
5. "Electrical trapping of sodium clusters in gaseous environment" (1997-2000), 2 P03B 016 13
6. "Investigation of the processes of exchange between gaseous pollutants, aerosols and clouds" (1999-2001), 6 P04G 030017
7. "Laser-light diagnostics of individual microparticles of carbon (soot) constrained in electrodynamic trap" (2002-2005), 2 P03B 102 22 **key investigator**
8. "The study of urban aerosols"(2002-2005), 3 P04G 052 22
9. "Evaporation of a free microdroplet with nanoinclusions: from spherical nanolayer of surface aggregates to microcrystal" (2009-2013) NN202 126837

8. Reviewing Activity

I refereed several articles in international journals, such as:

- The Journal of Physical Chemistry
- Journal of Physics D: Applied Physics
- Journal of Quantitative Spectroscopy and Radiative Transfer
- Measurement Science and Technology
- Journal of the Atmospheric Sciences

9. Awards for Scientific Activity

In 2013, I was awarded Silver Cross of Merit "for outstanding achievements in research, teaching and organisational work, for achievements in promoting Polish scientific and technical ideas."