LETOKHOV SYMPOSIUM ON LASER PHYSICS AND SPECTROSCOPY

dedicated to the 80th jubilee
of Vladilen Letokhov

BOOK OF ABSTRACTS

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THE SCIENTIFIC CAREER OF V. S. LETOKHOV

Victor Balykin,
Institute of Spectroscopy of the Russian Academy of Sciences,
Troitsk, Moscow, Russia

V.S. Letokhov was born on November 10th, 1939. In 1957 he entered Moscow Physical-Technical Institute. Upon graduation in 1963, he became a PhD student under Prof. N.G. Basov at Lebedev Physical Institute in Moscow. The beginning of Letokhov's scientific career coincided with the impetuous progress of investigations in Quantum Electronics and Laser Physics. Within that period, he accomplished a number of pioneering investigations, including generation and amplification of powerful laser pulses, lasers with nonresonant feedback, development of operation principles for lasers with high stability of radiation frequency. In 1970 Letokhov was invited by the Director of just organized Institute of Spectroscopy, Prof. S.L. Mandelstam, to become his deputy for research and to lead the research in a new that time scientific field — laser spectroscopy. At the Institute of Spectroscopy Letokhov set up first a Laboratory, and later the Department for Laser Spectroscopy, which he headed practically till the end of his life. Letokhov's scientific interests included various areas of laser physics, spectroscopy, chemistry and biomedicine. The greatest fame, however, was brought to him by pioneering investigations in laser spectroscopy. He was the first to realize selective detection of atoms and molecules by methods of multiphoton resonant ionization of the particles, resulting in the development of methods for ultra-sensitive analysis. He was among the pioneers to realize laser spectroscopy with sub-wave spatial resolution. He and his collaborators suggested and developed methods of laser cooling and control of atoms' movement. His group carried out first experiments on cooling of atom by laser radiation. Letokhov and his collaborators made a decisive contribution to the development of methods of selective multiphoton laser chemistry. Specifically, methods of selective effect on atoms and molecules provided the foundation for several effective concepts of laser isotope separation. Letokhov has been engaged in explanation of laser effects in atmospheres of stars.

The results obtained by Prof. Letokhov and his collaborators won general recognition in scientific community. Both independently and in collaboration he published more than 850 scientific works, including 15 monographs. Letokhov is a laureate of the Lenin Prize and Russian Federation's State Award (2002). His interests went beyond science — he always has been interested in painting, music, literature, and was actively involved in the events of Troitsk city, honorary citizen of which he became in 2002.

Victor Balykin was born on January 1st, 1947, graduated then from Moscow Institute of Physics and Technology and received his PhD at the Institute of Spectroscopy under Vladilen Letokhov. Victor Balykin started up a research team at the Institute of Spectroscopy targeted at Laser Spectroscopy and Quantum Optics, in particular laser fluorescence detection of single atom, laser cooling and trapping of neutral atoms, atom optics, nanooptics and nanoplasmonics. In 1981 Victor and his associates first demonstrated laser cooling of neutral atoms. From 1989 to 1990 he was a research fellow of Alexander von Humboldt Foundation at Max-Planck Institute of Nuclear Physics and Heidelberg University in Germany where he and his colleges first demonstrated laser cooling of relativistic ion beam.

In 1990 – 1993 Victor worked as a senior researcher with the University of Konstanz in Germany and then, in 1996 – 1997 served as a Professor with the University of Electro-Communication inTokyo, Japan. Presently Victor Balykin is a head of the Laser Spectroscopy Laboratory at the Institute of Spectroscopy, Troitsk, Moscow, Russia.

ATTOSECOND SCIENCE: FROM BASIC RESEARCH TO CANCER DETECTION

Ferenc Krausz and Mihaela Žigma,
Max Planck Institute of Quantum Optics, Garching, Germany;
Ludwig-Maximilians-University München, Munich, Germany

Born around the turn of the new millennium, attosecond metrology has provided real-time insight into atomic-scale electron motions and light field oscillation, previously inaccessible to human observation. Until recently, this capability has relied on attosecond extreme ultraviolet pulses, generated and measured in complex vacuum systems. Next-generation attosecond metrology is now about to change this state of matters profoundly. Sub-femtosecond current injection into wide-gap materials can directly probe ultrafast electron phenomena in condensed matter systems and can also be used for sampling the electric field of light up to ultraviolet frequencies. Petahertz field sampling draws on a robust solid-state circuitry and routine few-cycle laser technology, opening the door for complete characterization of electromagnetic fields all the way from the far infrared to the vacuum ultraviolet. These fields, with accurately measured temporal evolution, serve as a unique probe for the polarization response of matter. Field-resolved spectroscopy will access valence electronic as well as nuclear motions in all forms of matter and constitutes a generalization of pump-probe approaches. Its implementation with a solid-state instrumentation opens the door for real-world applications, such as early cancer detection by measuring miniscule changes of the molecular composition of blood via field-resolved vibrational molecular fingerprinting.

Ferenc Krausz (born 1962 in Mór, Hungary) earned his degree in Electrical Engineering at the Technical University Budapest (1985). He completed his doctorate in Laser Physics at the Technische Universität (TU) Vienna (1991) where he habilitated in the same research field in 1993, took up assistant professorship in 1998 and full professorship in 1999. In 2003 Ferenc Krausz was appointed Director of the Max-Planck-Institute of Quantum Optics (MPQ) in Garching. In October 2004 he became professor at the Faculty of Physics of Ludwig-Maximilians-Universität (LMU) Munich and has since then held the Chair of Experimental Physics — Laser Physics. In 2015 Ferenc became the director of the Centre for Advanced Laser Applications in Munich, Germany.

In a series of experiments performed between 2001 and 2004 Ferenc and his team succeeded in producing and measuring attosecond light pulses and applying them for the first real-time observation of atomic-scale electronic motions. These achievements earned him the reputation as the co-founder (along with Paul Corkum) of the field of Attosecond Physics, a scientific discipline devoted to real-time observation and control of electron phenomena, as also acknowledged by their selection as 2015 Thomson Reuters Citation Laureates. More recently, he turned his attention to capitalizing on ultrafast laser techniques for disease detection by the molecular fingerprinting of human bio-fluids. In 2019 Ferenc was awarded the EPS/RAS Vladilen Letokhov medal, which recognizes outstanding contributions in laser-matter interaction, in particular spectroscopy of atoms and molecules, laser manipulation of atoms, and strong field processes.

Ferenc Krausz's current research is focused at the development of ultrafast laser sources and techniques; their applications for (i) exploring solid-state electron phenomena for attosecond metrology, (ii) pushing the frontiers of electron-based signal processing, and (iii) field-resolved molecular fingerprinting for early detection of diseases, such as cancer.

Dr. **Mihaela Žigman**, Research group leader of Broadband Infrared Diagnostics (BIRD), Max-Planck-Institut für Quantenoptik (MPQ), Ludwig-Maximilians-Universität München (LMU), 85748 Garching b. München

MULTIDECADE SUPERCONTINUA AND RELATIVISTIC PHYSICS WITH ULTRASHORT PULSES IN THE MID-INFRARED

Aleksei Zheltikov, *Physics Department, Intl. Laser Center, M.V. Lomonosov Moscow State University, Moscow, Russia; Department of Physics and Astronomy, Texas A&M University, USA; Russian Quantum Center, Moscow, Russia*

Combined optical nonlinearity of bound and free electrons in a fast-ionizing medium driven by ultrashort, high-peak-power mid-infrared (mid-IR) pulses gives rise to a vast variety of ultrafast nonlinear-optical scenarios, producing bright and remarkably broad radiation in spectral ranges as different as ultraviolet (UV) and terahertz (THz) frequency bands. Given its enormous bandwidth, a quantitative experimental analysis of this type of nonlinear response is anything but simple. Here, we confront this challenge by performing ultrabroad spectral measurements across the spectral range stretching from the UV to the millimeter-wave (MMW) band jointly with beam-profile analysis in the THz and MMW bands along with direct time-domain field-waveform characterization based on electro-optical sampling and autocorrelation analysis. As one of the most striking results, these experiments show that the nonlinear response of a fast-ionizing gas driven by a two-color field, consisting of a high-peak-power sub-100-fs mid-IR pulse and its second harmonic, provides a source of a bright multiband supercontinuum radiation, spanning over about 14 octaves, stretching from below 300 nm in the UV all the way beyond 4.3 mm in the MMW band. The MMW-to-THz part of this supercontinuum is emitted, as direct pulse and beam characterization along with absolute power measurements show, in the form of half-cycle field waveforms that can be focused to yield a field strength of ≈ 0.5 MV/cm. At least 1.5% of the MMW–THz supercontinuum energy is emitted in the MMW range, giving rise to MMW field strength up to 10 kV/cm in the beam-waist region.

High-order harmonic generation (HHG) in plasmas induced by ultrashort, relativistic-intensity laser pulses on solid surfaces can provide an efficient source of attosecond pulses and opens routes toward new regimes of laser–matter interactions, x-ray generation, laser particle acceleration, and relativistic nonlinear optics. However, field intensities in the range of Irel ~ 10^{19} W/cm^2 are typically needed to achieve the relativistic regime of HHG in experiments with near-infrared laser pulses. Here, we show that, in the mid-infrared range, due to the λ^{-2} scaling of I_{rel} with the driver wavelength λ, relativistic HHG can be observed at much lower levels of laser field intensities. High-peak-power 80-fs, 3.9-μm pulses are focused in our experiments on a solid surface to provide field intensities in the range of 10^{17} W/cm^2. Remarkably, this level of field intensities, considered as low by the standards of relativistic optics in the near-infrared, is shown to be sufficient for the generation of high-order harmonics with signature properties of relativistic HHG – beam directionality, spectra with extended plateaus, and a high HHG yield sustained for both p- and s-polarized driver fields.

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Aleksei Zheltikov graduated from M.V. Lomonosov Moscow State University in 1987. He received his Candidate of Science (PhD) degree in 1990 and his Doctor of Science degree in 1999. He is a professor at M.V. Lomonosov Moscow State University since 2000, professor at Texas A&M University since 2010, and an international group leader at the Russian Quantum Center since 2010. From 2013 until 2016, Prof. Zheltikov has served a scientific director of the Russian Quantum Center. With a megagrant of the Russian Government awarded to Prof. Zheltikov in 2017, he organized a research group and built a laboratory of fiber-optic systems for quantum technologies at A.N. Tupolev Kazan Technical University. Prof. Zheltikov is a winner of the Russian Federation State Prize for young researchers (1997), Lamb Award for achievements in quantum electronics (2010), Shuvalov Prize for research at Moscow State University (2001), and Kurchatov Prize for achievements in neurophotonics (2014).

EXPLORING FAST CAVITIES AND QUANTUM WALKS WITH FEW ATOMS

Dieter Meschede,
Institute of Applied Physics,
University of Bonn, Bonn, Germany

In the so called bottom-up approach to controlled atomic quantum matter small quantum systems are synthesized involving single, few or many atom systems. I will discuss two examples:
(i) I will discuss controlled interaction of atoms with a "fast" optical resonator, which allows strongly preferred emission of light into optical wave guides (Purcell effects) and makes storage of photons with bandwidths exceeding the atomic linewidth efficient.
(ii) With quantum walks — i. e. driven discrete transport on a lattice conditioned on the spin state — we operate a new tool realizing coherent transport of atoms over tens of lattice sites — up to the so called quantum speed limit. I will present the experimental realization of "ideal negative measurements" showing strong violation of the Leggett-Gard inequality. The experiment distinguishes quantitatively the macro realist's world from the quantum world. The new transport device also allows transport in 2D space promising to retro engineer low entropy Mott states. Quantum indistinguishability is now opening up a new window to study interacting few body systems in unusual lattice settings including very strong pseudo magnetic fields, topologically interesting situations, and a scheme to create entanglement without interaction. The ultimate aim of these experiments is the creation of quantum cellular automata.

Dieter Meschede studied physics at the University of Cologne with a diploma in 1979 and received his doctorate in 1984 at the Ludwig-Maximilians-University Munich. As a post-doctoral student, he was a lecturer at Yale University from 1984 to 1986, where he became assistant professor in 1986. From 1988 to 1990 he was senior scientist at the Max Planck Institute for Quantum Optics in Garching. In 1990 he became full professor of physics at the Leibniz University of Hanover and in 1994 at the Rheinische Friedrich-Wilhelms-Universität Bonn. In 1999/2000 he was there in the physics department and from 2008 to 2012 he was a member of the senate.

Dieter Meschede teaches at the Institute of Applied Physics of the University of Bonn, where he co-founded the Bonn International Graduate School of Physics and Astronomy (BIGS-PA) in 2001. He is also the group leader of the Quantum Technology Group at the University of Bonn, and was Coordinator of the Nanostructure Fabrication by Controlled Deposition of Atoms (NanoFab) program of the European Commission from 1998-2003. In 2007 he was a member of the program committee of the International Quantum Electronics Conference (IQEC) and in 2009 he was the European Quantum Electronics Conference (EQEC). In 2010 he was spokesman for the joint project Quantum Communication of the Federal Ministry of Research. From 2018 to 2020 he is President of the German Physical Society.
Research interests of professor Meschede are atomic, molecular and quantum physics. One of the interesting experiment of his group is the so-called “Conveyor Belt of Light”, which moves and sorts individual atoms with the help of laser beams, which could be used as an arithmetic unit for a quantum computer. Another important area of research is atom lithography, which can be used to structure material surfaces using atomic beams with an accuracy in the sub-micron range — a method of nanotechnology.

Dieter Meschede is editor of the last three editions of the textbook “Gerthsen Physics” and author of the textbook “Optics, light and laser” and since 2012 chief editor of the journal Applied Physics B – Optics and Lasers, which plays a central role in applied physics. Since 2012 he is a full member of the Academia Europaea.

From 2005 to 2018 he was scientific director of the Physics Center Bad Honnef of the DPG, in whose scientific advice he was since 1998.

NEW FRONTIERS OF STRONGLY INTERACTING FERMI GASES

Rudolf Grimm,
Center for Quantum Physics, University of Innsbruck;
Institute for Quantum Optics and Quantum Information (IQOQI),
Austrian Academy of Sciences, Innsbruck, Austria

Since the first realization of a degenerate Fermi gas in 1999 [1], the field has attracted enormous interest. In particular, the possibility to introduce strong interactions by means of Feshbach resonances [2] has opened up unprecedented possibilities to study many-body quantum phenomena, like the crossover from a Bose-Einstein condensate to a BCS-type system and fermionic superfluidity in the crossover regime. So far, all experiments in this field have been based on only two ultracold systems (9Li and 40 K), which offer the necessary interaction properties.

Mass-imbalanced ultracold fermion systems have been widely considered in the theoretical literature, and exciting predictions have been made for novel few- and many-body phenomena. Most prominently, the elusive symmetry-broken Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) phase may become observable under realistic experimental conditions. Experimentally, however, no ultracold system was available to realize such states in the lab.

We report on a recent breakthrough in our laboratory. By combining the isotopes ^{161}Dy and 40K [3], we have created the first mass-imbalanced mixture of fermions that features tunable interactions and long-term stability. As an essential prerequisite, we found a broad Feshbach resonance at 218 G and demonstrated long lifetimes (few 100 ms) of the resonantly tuned mixture. In first experiments on the resonant mixture, we observed several signatures of strong interactions, like deeply hydrodynamic behavior in the expansion and collective oscillation modes. The unique mixture of ^{161}Dy and 40 K thus opens up a new world for few- and many-body physics with ultracold atoms.

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Rudolf Grimm received his physics education at the University of Hanover in Germany (diploma in 1986) and at the Swiss Federal Institute of Technology in Zurich (PhD in 1989). Then he spent half a year as a postdoctoral researcher at the Institute of Spectroscopy in Troitsk, where he worked in Vladilen Letokhov's group on novel optical forces for the laser manipulation of atoms. Returning to Germany in 1990, he took the position as a researcher at the Max-Planck-Institute for Nuclear Physics in Heidelberg. There he started a new group on laser cooling and trapping. In 1994, he received his habilitation degree and became lecturer at the University of Heidelberg. In 2000, he was appointed Full Professor at the University of Innsbruck in Austria and, in 2003, he became one of the Research Directors at the newly founded Institute of Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences. Rudolf Grimm's main research interests are in the field of ultracold quantum gases, in particular in strongly interacting systems realized with ultracold fermions.

SPECTRAL PROBING
OF Cs VAPOR-SURFACE INTERACTIONS

Martial Ducloy,
Laboratoire de Physique des Lasers,
UMR CNRS 7538, Institut Galilée, Université Paris 13,
Sorbonne Paris-Cité, F-93430 Villetaneuse, France

Selective reflection spectroscopy at dielectric-vapor interfaces allows one to probe the optical response of atoms (molecules) at a distance range ~ $\lambda/2\pi$ from the surface. It thus gives access to Casimir-Polder atom-surface interactions [1]. These interactions can be controlled via resonant coupling with surface polaritons: either by thermal excitation of surface polariton modes (Cesium vapor with hot sapphire surfaces [2]), or by frequency-tunable surface plasmon polaritons in adequate metallic metasurface (hybrid atom-metamaterial devices [3]). Those Doppler-free investigations have been carried out via selective reflection on electric dipole transitions (E1) of atoms & molecules. Extension to dipole-forbidden transitions, e.g. electric quadrupole transitions (E2), has been recently performed and will be discussed in relation with the coupling of surface plasmon modes with atomic quadrupole excitations [4].

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Martial Ducloy received his physics education at the Ecole Normale Supérieure, Paris (1964-8); Doctorat de 3éme cycle (1968); Doctorat d'Etat 1973, University of Paris. Research interests are laser spectroscopy, quantum and nonlinear optics, nano-optics, cavity QED, atom to surface interations and metamaterials.

Scientific awards:
• "Doistau-Blutel" Award of the French Academy of Sciences (1976)
• "Public Understanding of Physics" Award of the European Physical Society (2005)
• "Golden Sigma" Award of the Russian Academy of Sciences (2007)
• Member, "Academia Europaea" (2004)
• Foreign Member of the Bulgarian Academy of Sciences (2008)
• Former President of the European Physical Society (2001-2003)
• Former President of the French Physical Society (2010-2012)

FULL SOLID ANGLE IMAGING OF QUANTUM EMITTERS

Gerd Leuchs,
Max Planck Institute for the Science of Light, Erlangen, Germany;
Department of Physics, University of Erlangen-Nürnberg, Erlangen, Germany;
Institute of Applied Physics, Russian Academy of Sciences, Nizhniy Novgorod, Russia;
Department of Physics, University of Ottawa, Ottawa, Russia

A single quantum emitter radiates light in all directions, typically creating an electric dipole wave. Standard optical equipment cannot collect all this light. We experiment with a deep parabolic mirror, the depth being 5.5 times the focal length, allowing for collecting more than 90% of the emitted light without affecting the emission process itself. This novel geometry also acts as a mode converter, transforming a dipole wave into a collimated paraxial wave and vice versa. We discuss the unusual imaging properties of such a deep parabolic mirror. As quantum emitters we use single ions in a radio-frequency trap in vacuum as well as optically trapped quantum dots (dot in rod) in ambient air. In the case of the ion, the imaging allows for determining the temperature and heating rate of the ion in the trap.

Gerd Leuchs is professor adjunct at the physics department of the University of Ottawa and director emeritus at the Max Planck Institute for the Science of Light in Erlangen. After 15 years in academic research at the Universities of Cologne, Munich and at JILA, Boulder, Colorado, he worked at a Swiss optics company for five years. His scientific work includes quantum beats, photo-electron angular distributions in multi photon ionization, quantum noise reduced and entangled light beams and solitons in optical fibres, quantum communication protocols, focusing light beams and nanophotonics. For five years, Gerd Leuchs led the German gravitational wave detection group (1985-1989). He has been Visiting fellow of JILA, Feodor-Lynen fellow of the Alexander von Humboldt Foundation, Heisenberg fellow of the German Science Foundation, Visiting Professor at the Australian National University, at the University of Adelaide and the Laboratoire Kastler Brossel of the Ecole Normale Supérieure. He is member of the German Physical Society, the German Society for Applied Optics, the European Physical Society and the German Academy of Sciences Leopoldina, and Fellow of the Institute of Physics and of the Optical Society of America. He is foreign member of the Russian Academy of Sciences. He holds honorary degrees from the Danish Technical University and Saint Petersburg State University. In 2005 he received the Quantum Electronics Prize of the EPS, and in 2018 the Herbert Walther Prize jointly awarded by the Optical Society (OSA) and the German Physical Society (DPG).

FROM WAVE COLLAPSE TO LASER-PLASMA TERA-HERTZ SPECTROSCOPY: A TRIBUTE TO MY RUSSIAN MENTORS IN NONLINEAR SCIENCE

Luc Bergé,
Commissariat à l'Energie AtomiqueCEA,
DAM, DIF-91297 Arpajon-France

I have always been inspired by Russian physicists throughout my scientific life. My PhD thesis in theoretical physics was already devoted to the strong Langmuir turbulence in plasma physics, modeled by the well-known Zakharov equations that describe the finite-time collapse of nonlinear plasma waves. In the nineties, I developed perturbative treatments for deriving the blowing-up solutions of the multi-dimensional nonlinear Schrödinger equation and proposed mathematical tools to predict the dynamics of ultrashort pulses propagating in Kerr media. Some of these methods were inspired from Russian researchers who gained international recognition. This education naturally led me to deepen several aspects on the self-focusing of light in nonlinear optics and to contribute to the field of laser filamentation theoretically, numerically, and in close connection with experimental discoveries. More recently, my team and I have been involved in the generation of terahertz waves by two-color ultrashort laser pulses ionizing air. We brought the first experimental proof-of-principle of a remote, ultrabroadband spectroscopy of various materials by means of atmospheric plasmas created by terawatt lasers. These scientific results will constitute the topic of my talk. A special emphasis will also be given to the V.S. Letokhov Medal of the European Physical Society, the first edition of which has been presented this year.

Luc Bergé graduated in pure mathematics and in theoretical physics from the Universities of Toulouse and Paris-Sud, Orsay, France. In 1989, he received his PhD in theoretical physics, devoted to the strong Langmuir turbulence in laser-driven plasmas. In 1997, he passed his Habilitation thesis on wave collapse in physics. Since 1990, he has been a research scientist at CEA (French Commission for Atomic Energy). Working first on parametric instabilities in plasmas, he turned to nonlinear optics in 1995 and investigated the self-focusing of powerful light pulses in Kerr media, proved the stability of quadratic solitons in chi2 crystals and the arrest of wave collapse by normal group-velocity dispersion. He next devoted his research to the filamentation of ultrashort laser pulses in transparent materials and related properties such as supercontinuum generation and pulse self-compression, which he pioneered in the early 2000. From 2010, Luc Bergé focused his scientific activities on terahertz pulse generation induced by multi-color femtosecond pulses in gases and on nanosecond light pulses subject to stimulated Brillouin scattering in glasses. He cleared up the underlying physics of photocurrents emitting THz waves when two-color laser pulses ionize a gas. Currently, Luc Bergé and his team are developing new theoretical and numerical treatments for the production of energetic THz waves produced by ultra-intense laser pulses, bridging the fields of extreme nonlinear optics and relativistic plasma physics. Also involved in experimental efforts on innovative detection methods, Luc Bergé is coordinating the project ALTESSE, which is devoted to ultrabroadband terahertz spectroscopy and funded by the National Research Agency in France.

Luc Bergé's activities have been expressed in more than 140 articles, six book chapters and 160 conferences. He is APS Member and was elected OSA Fellow in 2009, Fellow of the European Physical Society (EPS) in 2016 and Fellow of the European Optical Society in 2018. He received the DGA-Young Researcher Prize in 1997, the second Bull-Fourier Prize in 2012 and the 2018 Gentner Kastler Prize jointly attributed by the German and French Physical Societies. He is Director of Research at CEA, where he is heading a laboratory dedicated to radiation-matter interaction. Luc Bergé served as Chair of the Quantum Electronics and Optics Division of the EPS until 2017 and is a Member of the EPS Executive Committee. He was General, coordinating Chair of the conference CLEO/Europe-EQEC in 2015. He was member of the Editorial Board of the journal "Remote Sensing" between 2009 and 2014, and Guest Editor of the Special Issue of EuroPhysics News on the Science of Light in 2015.

COLD AND TRAPPED METASTABLE HELIUM

Michèle Leduc, *CNRS Research Director emeritus at Laboratoire Kastler-Brossel, Ecole normale supérieure, Paris, France*

This international symposium in memoriam of Vladilen Letokhov is a very welcome opportunity for re-minding the scientific exchanges between French and Russian teams all along the last two decades. We developed a fruitful cooperation in the broad domain of laser physics with groups in Moscow and Novosibirsk. Further exchanges occured in the fast developing field of cold atoms. Our many visits in Troïtsk offered chances for creative discussions with Vladilen Letokhov on atomic spectroscopy, new laser applications, as well as fundamental questions opened up by recent advances in quantum physics and modern astrophysics.

Our group focussed on the unique opportunities offered by helium atoms [1,2]. Helium is one of the simplest existing atoms, thus an appealing candidate for high precision measurements and tests of Quantum Electrodynamics. The 3He isotope carrying a ½ nuclear spin is a playground for many fields of physics. The first excited state of the helium atom is the long lived 23S1 triplet metastable which can be manipulated with infra-red lasers, either solid state LNA lasers or diode lasers, operating on the 23S1-23P transition. These lasers were first developed for tranferring nuclear polarisation from optically pumped metastable states to ground states of 3He atoms through metastability exchange collisions. Unexpected applications to NMR imaging of the human lungs with hyperpolerized 3He gas could be developped.

The progress with the laser technology allowed the laser cooling and trapping methods to be successfully applied to 4He atoms in the 23S1 metastable state, a rich field in which our team embarked. These atoms carry a large internal energy of 20 eV, a unique feature highly valuable for detecting then with spatial and temporal resolution by impact on a microchannel plate. The gas could be taken down much below the single photon recoil limit using Velocity Selective Coherent Trapping methods. Bose-Einstein condensation of metastable helium could then obtained, a premiere for an atom not in the ground sate. We then turned to photoassociation with spin polarized ultracold metastable atoms. One-photon photoassociation provided exotic He2 molecules, which could be called giant as the two excited atoms are constantly kept more than 50nm apart. The experiment was refined with two-photon photoas-sociation, inducing atom-molecule dark resonances, from which a very precise value of the scattering length could be derived.

This symposium will also provide an opportunity to present SIRTEQ, a new research network for Quantum Technologies recently created in the Paris area. This multidiscipline ensemble of 80 teams de-velops fundamental physics for quantum simulation of open questions in condensed matter, as well as innovative high precision cold atom instruments such as clocks for space applications and gravimeters for geophysics. Some exemples will be given of successful collaborative experiments and developing startups.

1. Michèle Leduc and Claude Cohen-Tannoudji, «Ultracold Metastable Helium, from Atoms to Exotic Molecules» in Laser Physics 2009, volume 19, N°9, pp1-10, in the honor of Vladilen Letokhov
2. Wim Vassen et al, «Cold Trapped Metastable Noble Gases» in Review of Modern Physics, https://arxiv.org/pdf/1110.1361.pdf (mai 2012)

Michèle Leduc is a CNRS Research Director emeritus at laboratory Kastler Brossel at Ecole normale supérieure in Paris. She first focussed on polarized Quantum Fluids at low temperature, where the ma-croscopic properties of gases are modified by the polarization of their nuclear spins, as a consequence of the Pauli principle. She demonstrated the occurrence of spin waves in polarized helium 3 gas. She developed a variety of infrared lasers for this purpose, which she also applied to high density polarized helium 3 targets in use for nuclear and high energy physics and also as neutron spin filters at reactors. At the same time she developed a strong interest for Magnetic Resonance Imaging using spin polarized helium 3 gas, resulting in a new clinical method for studying the human lung ventilation and functionality. She then joined the laser cooling group headed at ENS by C.Cohen Tannoudji. She demonstrated Bose Einstein Condensation of metastable helium atoms. She created giant exotic helium dimers by photoassociation and produced a very accurate measurement of the scattering length for metastable helium.

She is editor of the book series “Savoirs Actuels” for CNRS (60 books) and “Introduction à” for EDP Sciences. For the last 20 years, in parallel she developed various activities directed towards science policy at the French and European level. She is involved in the supervision of research and innovation networks in the Paris area (IFRAF for cold atoms and SIRTEQ for quantum technologies). She is currently deeply involved in reflexion about science and society as a member of the Ethics Committee of CNRS and of the French Office for Scientific Integrity.

BIOMEDICAL PHOTONICS IN PHOTOTHERANOSTICS. NEW STRATEGY

Ivan Shcherbakov, Victor Loschenov, *Prokhorov General Physics Institute of the Russian Academy of Sciences, Moscow, Russia*

Methods of photonics have extensive application in diagnostic and therapy of oncological and other socially significant diseases. There are several fields where these methods play a crucial role: cancer theranostics, eye diseases treatment, noninvasive resection of neoplasms, minimally invasive surgery. One of the rapidly developing areas is fluorescent diagnostic and photodynamic therapy. Devices and methods based on the principles of laser radiation interaction with biological tissue and photosensitizers found their application at almost all fields of clinical medicine. They play an especially important role in neurosurgery as a tool for surgical navigation during brain tumor removal, in urology, where their use leads to a significant decrease in the recurrence rate, in organ sparing surgeries, etc. The strategy for the development of this field is carried out through the solution of several problems that are associated with the most recent, very important discoveries in the field of immunology. The basic idea is that many diseases progress due to macrophages, that are supposed to keep organs vacant from foreign entities and unnecessary metabolic products, switching to the side of neoplasms, protecting them from immunocompetent cells.

These neoplasms can be nascent malignant tumors (cancer), atherosclerotic plaques (heart attacks, strokes), endometrioid heterotopias (endometriosis), proliferating synovial membranes (arthrosis), amyloid plaques (Alzheimer).

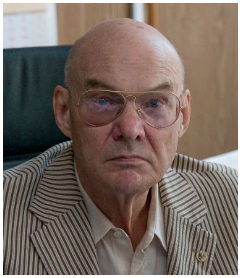
This list might expand. Diabetes, Crohn’s disease and other diseases associated with autoimmune processes may be added in the future.

How can the photodynamic therapy and fluorescent diagnostics be relevant here? It was established that macrophages accumulate photosensitizers in a significantly higher amount (10 times as high) than any other cell types. On the other hand, there are methods based on picosecond fluorescent spectroscopy that allow determining the type of macrophage, whether defender or traitor, that absorbed the photosensitizer and thereby assess the status and dynamics of pathological process. But what would be the course of action in case if the wrong macrophages prevail in the tumor? Here is where photodynamic therapy comes into play. Its use can kill the macrophages, deactivate them, or even reprogram them to fight the neoplasm. It must be noted that other physical methods used in medicine do not provide this opportunity.

Thus, the following three problems stand in front of laser physics and biomedical photonics:

1. Development of photosensitizers, in addition to universal ones, specific to certain nosologies;
2. Development of laser video-fluorescent endoscopic devices with picosecond time resolution;
3. Development of medical technologies for photodynamic therapy “from within” based on the use of Cherenkov radiation generated by radiopharmaceuticals used in nuclear medicine.

The report will present developments in these three areas implemented jointly by GPI RAS and National Medical Research Radiology Center, N.N. Burdenko National Scientific and Practical Center for Neurosurgery, and others.



I.A. Shcherbakov was born in Moscow in 1944. He graduated from Moscow Power Engineering Institute in 1967. Later, an engineer, junior and senior researcher at Lebedev Physical Institute of USSR Academy of Sciences. In 1976-1977 – Visiting Professor at the University of Southern California, in 1979 – at the University of Hamburg. From 1998 and until 2018 – Director of A.M. Prokhorov General Physics Institute, RAS. Currently he is the scientific director of the institute, Academician-Secretary of the Physical Sciences Division of RAS. Chairholder of laser systems and structured materials in Moscow Institute of Physics and Technology. Corresponding Member of the Russian Academy of Sciences since 1991, Academician of RAS since 2011 in the Department of Physical Sciences. Member of the RAS Presidium. Specialist in the field of spectroscopy of laser materials.

I.A. Shcherbakov is the successor of work on the application of optical and laser methods in medicine that was started at the General Physics Institute under the initiative of its founder, Academician A.M. Prokhorov. He is actively engaged in the implementation of the results of the institute activities in medical practice. On the basis of deep fundamental research under his leadership, real practical results were obtained at the General Physics Institute - unique medical devices continue to be developed as a product of modern nanotechnology, lasers that exhibit non-standard original solutions.

Among his students are 8 doctors of science, 20 people under his leadership defended their dissertations. He is an author more than 400 scientific works. Laureate of USSR Council of Ministers Prize and Lenin Komsomol Prize. Awarded the Gold Medal of A.M. Prokhorov for the series of works «The processes of excitation energy transformation in active media of lasers».

V.B. Loschenov, head of laboratory of laser biospectroscopy in GPI RAS, chair of laser micro and nanotechnologies in NRNU MEPhI, PhD, Professor. Born in the village Yurty, Taishet District, Irkutsk Region, in 1953. In 1976 graduated from the Moscow Power Engineering Institute. In 1981 successfully defended his thesis for the Candidate's degree, and in 2006 – Doctorate Thesis: «Photodynamic therapy and fluorescent diagnostic of oncological diseases: development and implementation in clinical practice». In 2007 he was awarded the title of professor in laser physics. Loschenov V.B. has been working in the field of creation of new methods and devices for use in medical diagnostic since 1982, actively promoting introduction of new physical technologies in medical practice. Devices based on laser-spectroscopic and video-fluorescent methods for diagnostic and treatment of oncological diseases were created. These devices are used in more than 60 leading scientific centers and clinics in 25 cities of Russian Federation and in clinics of 18 other countries. 20 dissertations have been defended under the leadership of Loschenov V.B. He has more than 400 scientific publications including more than 70 patents. In 1982 he was awarded Lenin Komsomol Prize in science.

HIGH-QUALITY RESONANCES IN NANOPARTICLES OF DIFFERENT SHAPES AND MATERIALS: ANALYTICAL MATERIAL-INDEPENDENT APPROACH

Vasily Klimov,
Lebedev Physical Institute,
Leninskij Prospect 53, Moscow, 119991 Russia

The confinement of light in localized modes is extremely important for modern applications in nanophotonics including lasing, sensing, harmonic generation, Raman scattering, computer interconnects. and photovoltaics. For many optical devices, it becomes critical to localize electromagnetic fields in sub-wavelength volumes. The physics and description of high-quality resonant modes are very complicated, and usually the numerical approaches with frequency as a complex eigenvalue are used. However, these approaches are not satisfactory from the mathematical and physical points of view because eigenmodes with complex frequency are not decreasing at infinity.

In my talk, I will present a material-independent approach which is based on permittivity as a spectral parameter. Within this approach, I will present an analytical description of high-quality oscillations in plasmonic and dielectric nanoparticles with high permittivity. Nanoparticles made of metamaterials with chirality and negative refractive index will also be discussed. The analytical results are obtained for nanoparticles in the shape of a sphere, a spheroid, an ellipsoid, a cylinder, a hexahedron, a dimer of 2 nanoparticles, and even more complicated shapes. Good agreement with numerical and experimental results is demonstrated. Our results show that for nanoparticles of the same volume, the spherical one has the highest Q factor. Our analytical results also shed light on possible problems with numerical calculations of resonant features of nanoparticles with sharp edges.

Prof. **Vasily Klimov** received both his M.S. (with honours) and PhD degrees in Physics from Moscow State University in 1978 and 1981 respectively. In 1981-1990, he was a Senior Researcher at Naval Research Laboratory (Russia). From 1990 to date, he is a Principal Scientist at Lebedev Physical Institute of Russian Academy of Sciences. In 2001 he received his Doctor of Sciences degree in Physics from Lebedev Physical Institute. In 2014 – 2018, he headed a mega project “Quantum Plasmonics”, which was funded by Russian Foundation for Advanced Research Projects.

Prof. Klimov is an author of more than 150 research publications and 6 book chapters. In 2009, he published a book “Nanoplasmonics” in Russian and international editions. His fields of interest includes quantum electrodynamics and field theory, nano-optics, metamaterials and metasurfaces, wave propagation, particle physics, quantum and classical optics, etc. His main research achievements include: 1) theory of QCD at high temperatures and densities, 2) theory of coherent emission from carbon nanotubes, 3) theory of spontaneous emission of atoms and molecules near nanoparticles of different shapes, 4) theory of plasmonic properties of nanoparticles of complex shapes, 5) theory of focusing light and matter waves by negative refraction, 6) theory of radiation by fast decaying currents.

ATTOSECOND X-RAYS FOR ULTRAFAST CONDENSED PHASE PHYSICS

Jens Biegert,
The Institute of Photonics Sciences,
The Barcelona Institute of Science and Technology,
Castelldefels (Barcelona), Spain

The development of intense mid-IR sources led to the generation of isolated attosecond pulses in the soft X-ray water window across the oxygen edge at 543 eV. These table top sources of coherent x-rays are powerful new tools that combine ultrafast temporal resolution with the soft X-ray's element specificity to investigate electronic dynamics and their coupling with nuclei/lattice in real time. I will describe some of our sources that enable such resource and show first results in which we resolve the carrier dynamics in a quantum material in real time. These results provide first comprehensive insight into the dynamics in condensed matter, with the future possibility to address fundamental and long-standing questions such as phase transitions and superconductivity.

Jens Biegert is ICREA professor for Attoscience and Ultrafast Optics at ICFO – The Institute of Photonic Sciences in Barcelona. He received his PhD in 2001 with distinction on “Polychromatic Multi-Photon Coherent Excitation of Sodium” from the Technical University Munich with Profs. Alfred Laubereau and Jean-Claude Diels, for which he was awarded the Allen Prize of the Optical Society (OSA). He then went on to head a research group on ultrafast pulse generation and strong field physics during his Habilitation at ETH Zurich from 2001 until 2006. Since 2007 as tenured Professor at ICFO and ICREA professor of the Catalan Institution for Research and Advanced Studies, his research focus lies on the investigation of the real-time quantum dynamics of electrons and nuclei in atoms, molecules and solids. This research employs home-built cutting-edge laser technology, attosecond soft x-ray pulses and electron diffraction for atomic-scale imaging of molecular dynamics and to unravel the interplay between carriers and the lattice in quantum solids. Jens Biegert is actively involved in the scientific community as author of the whitebook leading to the European Extreme Light Infrastructure (ELI), is elected member of the management board of Laserlab-Europe and Laserlab-Europe AISBL, chair elect of the Board of Meetings of the Optical Society (OSA), panel member of the European Research Council and the Volkswagen Foundation, and traveling lecturer of the Optical Society (OSA). He holds an appointment as Adjunct Professor at the University of New Mexico in the USA, is Associate Editor of APL Photonics, a fellow of the German Academic Scholarship Foundation and the Optical Society of America, and he is ERC Advanced Grant holder and was awarded the Bessel Prize of the Alexander von Humboldt Foundation.

LASER OPTOACOUSTIC SPECTROSCOPY IN BIOMEDICINE: FROM IDEA TO DIAGNOSTICS, THERAPY, AND THERANOSTICS

Rinat Esenaliev,
Department of Neuroscience and Cell Biology,
Biomedical Engineering and Imaging Sciences Group,
UTMB Cancer Center,
University of Texas Medical Branch, Galveston, Texas

In late 80s – early 90s under supervision of Prof. Vladilen S. Letokhov at the Department of Laser Spectroscopy of the Institute of Spectroscopy of Russian Academy of Sciences we proposed biomedical optoacoustics. At present, optoacoustic (photoacoustic) technique is an emerging diagnostic modality which combines high optical contrast and ultrasound spatial resolution [1–4]. This technique is based on generation of optoacoustic waves in tissues using short optical pulses and allows for imaging with high (optical) contrast and high (ultrasound) resolution. Moreover, optoacoustic spectra provide clinically important information on molecular content in tissues [2]. We proposed to use the optoacoustic technique for a number of important clinical applications including cancer detection, monitoring of thermotherapy (hyperthermia, coagulation, freezing), monitoring of cerebral blood oxygenation in patients with traumatic brain injury, neonatal patients, fetuses during late stage labor, central venous oxygenation monitoring, total hemoglobin concentration monitoring, as well as for hematoma detection and characterization. We developed and built tunable OPO-based systems and multi-wavelength, fiber-coupled, highly-compact, laser diode systems for optoacoustic imaging, monitoring, and sensing. Ultra-sensitive, wide-band optoacoustic probes were developed by our group for different clinical applications. We performed pre-clinical and clinical tests of the systems and the optoacoustic probes in backward mode for most of the applications and in forward mode for the breast cancer detection and cerebral applications. The high pulse energy and repetition rate allowed for rapid data acquisition with high signal-to-noise ratio from cerebral blood vessels, central veins, peripheral veins and arteries, as well as from intracranial hematomas. Recently, we proposed to use optoacoustics for noninvasive therapy and theranostics and demonstrated efficacy of this method in vivo [3 – 4].

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4. Esenaliev R.O. 25 years of biomedical optoacoustics: From idea to optoacoustic imaging and thera-nostics (Invited Review). Proc. SPIE 2019.

Rinat Esenaliev, PhD, is a Professor at the Department of Neuroscience and Cell Biology, Director of Laboratory for Optical Sensing and Monitoring, and Director of High-resolution Ultrasound Imaging Core at the University of Texas Medical Branch at Galveston, Texas, USA. He is an SPIE Fellow and OSA Fellow. Dr. Esenaliev graduated in 1987 from Moscow Institute of Physics and Technology (Quantum Optics division at the Institute of Spectroscopy Russian Academy of Sciences). He received PhD degree (PhD dissertation supervisor: Prof. Vladilen Letokhov) from the Institute of Spectroscopy of Russian Academy of Sciences in 1992. He was working at Rice University and MD Anderson Cancer Center in Houston (Texas) from 1993 to 1997. Since 1997 he has been working at the University of Texas Medical Branch. Dr. Esenaiev is a pioneer in biomedical optoacoutics and has more than 30 years of experience in biomedical optoacoustics, optoacoustic instrumentation, and optoacoustic applications in imaging, monitoring, and sensing. Recently, Dr. Esenaliev proposed optoacoustic therapy and theranostics. His research interests include also nanotechnology, laser-based therapies of cancer and other diseases, anti-cancer drug delivery, OCT, and high-resolution ultrasound. Dr. Esenaliev is an author of more than 170 publications (excuding abstracts), 20 patents, and 250 conference presentations, most of them on biomedical optoacoustics. In 2010 he was a winner of the University of Texas System Chancellor’s Innovation and Entrepreneurship Award for “Multiple Therapeutic and Diagnostic Methods and Devices”. He received more than 30 grants for development of novel optical and spectroscopic methods and devices

VLADILEN LETOKHOV
AT THE LEBEDEV PHYSICAL INSTITUTE

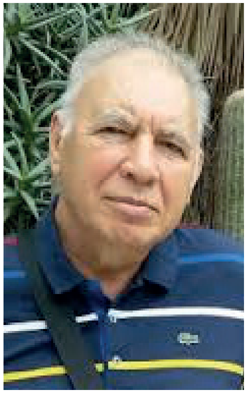
Oleg N. Krokhin,
Lebedev Physical Institute,
Russian Academy of Sciences,
Moscow, Russia

Prof. **Oleg N. Krokhin** — Russian physicist, head of the Quantum Radiophysics division of the Lebedev Physical Institute of the Russian Academy of Sciences, head of the Chair of Semiconductor Quantum Electronics, Professor of the Chair of Solid State Physics, Moscow Nuclear Engineering Institute. He is a Dr. of Sci., Academician of the Russian Academy of Sciences, was awarded with the Demidov award (2005). Editor-in-Chief of Rapid Communications in Physics, Physical Education at the Universities, Quantum Electronics and Journal of Russian Laser Research.

LASER THERMOCHEMISTRY VS IR-LASER PHOTOCHEMISTRY

Boris S. Luk'yanchuk,
Data Storage Institute,
*A*STAR (Agency for Science, Technology and Research),*
2 Fusionopolis Way, Innovis, 138634, Singapore;
Division of Physics and Applied Physics,
School of Physical and Mathematical Sciences,
Nanyang Technological University, 637371 Singapore;
Faculty of Physics, Lomonosov Moscow State Univ., Moscow, Russia

Among the phenomena associated with laser-matter interactions a special role refers to phenomena related to chemical transformations of matter in the field of laser light. Chemical processes which kinetics depend on the laser excitation of internal degrees of freedom of atoms and molecules, are called photochemical. In a number of works, an analysis was made of the conditions were the "separation" of the vibrational temperature from the translational temperature can be realized. The direction associated with thermal laser initiation of chemical reactions (the so-called "laser thermochemistry") looked as "the most trivial possible in chemistry". However, the dynamic features of thermochemical processes in laser thermochemistry are dictated by the combined effect of the chemical state of the medium and the space-time distribution of the thermal energy introduced into the medium. Chemically active media in the field of laser radiation obtain a high ability to different self-organization phenomena. Some of such phenomena are shown in the given presentation.



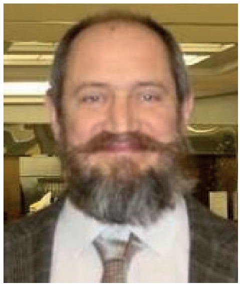
Boris Lukiyanchuk graduated from M.V. Lomonosov Moscow State University in 1967. He got his PhD (Physics and Mathematics) from P. N. Lebedev Physical Institute, Academy of Sciences of USSR, 1979 and Doctor of Sciences (Physics and Mathematics) — Second Doctorate in General Physics Institute, Academy of Sciences of USSR, 1991. He got his State Professor's Degree (Physics and Mathematics) from the State Highest Certifying Committee of Russian Federation, 1992. Since 1980 to 1983 he was working as a Senior Scientist at P.N. Lebedev Physical Institute, Academy of Sciences of USSR, Moscow and since 1983 to 1999 he was a Head of the Laboratory at General Physics Institute, Russian Academy of Sciences, Moscow. Since 1999 to now he was Professor and Scientific Advisor at the Institute of Agency for Science, Technology and Research, Singapore and Professor at Nanyang Technological University, Singapore. Lukiyanchuk was a visiting Professor and invited Professor in Austria, Italy, France, Sweden, Japan and Australia. He is a Honorary Professor at Johannes Kepler University, Linz, Austria, since 1991. He also got an IES Prestigious Engineering Achievement Awards 2004, Singapore, President's Science Award, Singapore 2013 and Institute of Physics, World Scientific Physics Research Award and Gold Medal, Singapore 2016. He is a Fellow of the Optical Society of America since 2011. He published 5 monographs and above 300 original papers. He was a Guest Editor of Appl. Phys. A and Appl. Phys. Lett., Topical Editor of "Optics Letters" and "Journal of Optics".

OPTICAL CLOCKS:
HISTORY AND NOWADAYS

Sergey Bagayev and Alexey Taichenachev,
Institute of Laser Physics, Siberian mBranch
of the Russian Academy of Sciences, Novosibirsk, Russia

Sergey Bagayev was born on September 9, 1941. He graduated from Novosibirsk State University in 1964 and now is a Scientific Director of the Institute of Laser Physics, Russian Academy of Siences, Novosibirsk, Russia. He is a full Member of the Russian Academy of Sciences since 1994.

Prof. **Alexey Taichenachev**



ROLE OF NON-RADIATIVE CHARGE RECOMBINATION IN NANO-SCALE SEMICONDUCTORS

Arkady Yartsev,
Department of Chemistry, Lund University, Sweden

Resolving charge carrier recombination pathways is essential for understanding properties of various semiconductor materials. Traditionally, radiative recombination of charge carriers was of a primary interest. Yet, non-radiative recombination could be an important factor that affects the carrier evolution and device performance. Thus, thorough characterization of non-radiative carrier recombination channels is of significant fundamental and applied interest.

Non-radiative recombination in semiconductor is often associated with their surface. Apparently, nano-scale semiconductors with very large surface-to-volume ratio are at risk. Therefore, various at-tempts to reduce surface-related non-radiative recombination, namely, surface passivation, have been undertaken for improvement of various applications based on nano-scale semiconductor materials as well as for bulk semiconductors.

In our study, we aim at characterization of non-radiative recombination processes and at optimization of the surface passivation procedure. As the main research tool, we apply a combination of time-resolved and steady state spectroscopy techniques to characterize charge carrier dynamics in III-V semi-conductor nanowires and bulk materials. The methods used build a complimentary and ample approach to understand dynamics of photogenerated charges in semiconductors. We have thoroughly characte-rized charge carrier dynamics in a large set of semiconductor III-V nanowires, in particular regarding the effect of semiconductor doping; (1) the content of the III-elements in InGaP;(2) in relation to the surface HCl etching and (3) in bulk GaAs.

Further studies are required to fully identify the nature of the trap states that is important for further optimization of semiconductor materials especially at nanometer characteristic scale.

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ArkadiyYartsev received bachelor (1981) and master (1984) degrees in Experimental Physics from Moscow Institute of Physics and Technology, Moscow and in 1991 a PhD degree in Physics and Mathematics from the Institute of Spectroscopy of Russian Academy of Sciences. After postdoc studies at the Institute for Molecular Sciences (IMS), Okazaki, Japan, Umeå University, Sweden and Lund University, Sweden at 1996, he has joined the Division of Chemical Physics at Lund University, where he is employed since that time. In 2001, Dr. Yartsev received a docent degree (equivalent to "habilitation") and in 2017 has been promoted to a professor position. Prof. Yartsev is an author of more than 150 research publications and 6 book chapters altogether cited for more than 10000 times.

During his entire scientific carrier, A. Yartsev used time-resolved spectroscopy to address processes in various matters. Among others, he has studied reactions of change and energy transfer, isomerization; energy relaxation and dissipation; processes of charge generation, separation, recombination and transport in organic, inorganic and hybrid photovoltaic materials.

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E-mail:print@trovant.ru http: www.trovant.ru