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Fedor Vasil'evich Bunkin (on his 80th birthday)

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Academician Fedor Vasil'evich Bunkin, an outstanding physicist and science administrator in Russia, a brilliant representative of the Russian school of radiophysics and quantum electronics, had his 80th birthday on January 17, 2009. F V Bunkin's fundamental work extended the ideas of this school to new avenues of research in laser physics, nonlinear optics and acoustics, remote sounding of the atmosphere and oceanic waters, and the physics of condensed media.

F V Bunkin was born on 17 January 1929 in the village of Aksin'ino of the Moscow region (nowadays this is the Khovrino district of the city of Moscow). His father, Vasilii Fedorovich Bunkin, was a geodetic engineer, and his mother, Antonina Sergeevna Bunkina (Tselikova), was an accountant. In the hard times of the Great Patriotic War their son graduated from a seven-year school, then the Automobile and Road Construction Technical School, then enrolled in the Moscow Power Engineering Institute. In 1947, he transferred to the second course of the newly organized Physics and Technology Department of Moscow State University, later reorganized into the Moscow Institute of Physics and Technology (MFTI). In 1952, Fedor Bunkin received a diploma as a radiophysics engineer and entered the postgraduate course of the P N Lebedev Physical Institute of the USSR Academy of Sciences (FIAN in *Russ. abbr*.).

F V Bunkin began his research work exactly 60 years ago at the Oscillations Laboratory of FIAN. His subsequent activities were entirely connected with the A M Prokhorov Institute of General Physics of the Russian Academy of Sciences (IOF RAN); here a number of research teams which specialized in a wide variety of fields merged into one body, centered in this legendary laboratory.

F V Bunkin's style in science is characterized by a profoundness of theoretical approaches and mandatory ties to experiment and to possible applications; it grew largely at the time that Bunkin entered science (1949 – 1964). He owed the high level of his theoretical and general physics grounding to the generation of pupils of the L I Mandel'shtam 'oscillatory' school — M A Leontovich, S M Rytov, and G S Gorelik — who worked at the time in the Laboratory. Fedor Vasil'evich began his work on electrodynamics and statistical radiophysics under the guidance of his first teacher S M Rytov by calculating the fluctuation sensitivity of radiometers for measurements of the temperature of astronomical objects. These calculations were later extended to developing the theory of thermal radiation of anisotropic media and to solving general problems of the theory of fluctuations in nonlinear and nonequilibrium physical systems. On the basis of these results, F V Bunkin submitted and defended his CandSc thesis (in 1955) and later his DSc thesis (in 1964).

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Fedor Vasil'evich Bunkin

From the mid-1960s onwards, the priority research field for F V Bunkin became laser physics. This was the beginning of many years of collaboration with A M Prokhorov, whom Fedor Vasil'evich regards as his second teacher. The opening series of his research papers in this area targeted developing a theory of strong optical field-stimulated effects of atomic ionization, molecular dissociation, cold electron emission, and bremsstrahlung. These classic results, obtained with A M Prokhorov and colleagues at the Oscillations Laboratory (his co-authors), were almost immediately confirmed by experiments. Also predicted and experimentally investigated were phenomena in laser discharge under cold combustion conditions and in the low-threshold optical breakdown mode in a gas close to a solid surface; proposals were also made for employing laser-based systems in military applications. The most active stage in F V Bunkin's research of the interaction between matter and laser radiation involved the implementation of these proposals in a huge MOD-commissioned project that was carried out in collaboration with the 'Diamond' Central Design Bureau. In this project Fedor Vasil'evich provided, under A M Prokhorov's general supervision, theoretical support for the coordinated efforts of a large team of experimenters.

At the end of the 1970s, Fedor Vasil'evich greatly extended the scope of his scientific interests and, with the support of A M Prokhorov and A V Gaponov-Grekhov, turned to fields that were new both to himself and to the IOF, including laser and acoustic sounding of the ocean and nonlinear ultrasonics. The path in these directions was prepared by the theoretical and experimental work of F V Bunkin and his colleagues on the laser excitation of sound in liquids.

He organized integrated research expeditions for studying the long-distance propagation of low-frequency sound in the Barents Sea over distances of hundreds of kilometers. Experiments were conducted along fixed acoustic trajectories using data processing with modernized theoretical models, which allowed the team to measure the effects of tidal flows and internal waves on the fluctuation characteristics of sounding signals. Experiments on radar and laser sounding of the surface layer of ocean water from aircraft and ships were carried out in this sea and in a number of other sea water areas. New efficient instruments — laser wavegraphs, bathymeters, and fluorimeters — for the diagnostics of the parameters of sea waves and the impurity composition of aqueous medium were developed and tested during these experiments.

To extend this work on solving the general problem of large-scale sea monitoring, F V Bunkin organized by the end of the 1990s a research and design team of hydroacoustic specialists as part of the Scientific Center of Wave Studies of the IOF RAN). This team is engaged in developing technical equipment for acoustic diagnostics of sea water areas in broad cooperation with a number of industrial plants and research organizations; the aim was to ensure the state orders be carried out. The decision of the Russian Academy of Sciences Presidium and of Navy Main Headquarters to make the Scientific Center of Wave Studies responsible as of the year 2000 for supervising and guiding one of the basic areas of specialized work to guard the interests of the Russian Navy is a measure of the fundamental and application-oriented importance of hydrophysics research conducted at the Center.

Using nonlinear-optical analogies, F V Bunkin and his coworkers were able to predict and then experimentally find new effects of physical acoustics. First, it was the parametric wavefront reversal of ultrasound beams. The study of a wide range of experimental implementations of phase conjugation, including some stemming from nonlinear acoustics, and the development of magnetic materials with optimum modulation parameters resulted in designing a unique technology for ultrasound wavefront reversal at giant amplification. Theoretical and experimental studies of the propagation of high-power ultrasound in viscous liquids revealed, second, the novel effects of the spatial and temporal self-compression of wave packages. They are complemented by the 'self-bleaching' effect — absorption of ultrasound decreases with increasing its energy. A detailed investigation of the physical mechanisms of these effects created the foundation for developing new applications in high-contrast acoustoscopy and biomedical ultrasound technologies.

Beginning in the mid-1970s and especially in the last several years, F V Bunkin has been working on the ideas of using the optical action effects on substance in physics of condensed media. His first publications on this topic formulated and substantiated the theoretical basis for a novel — optothermodynamical — approach to the problems of laser control of the phase state. F V Bunkin and his coworkers theoretically predicted in this field and experimentally studied the effects of light-induced critical opalescence, the concentration self-action of light, and light-induced spinodal decay in stratifying liquid solutions. The results of these experiments revealed new possibilities for measuring thermodynamic material bucklings in a wide temperature range and for identifying which mechanisms dominate in phase transitions. The development of the principles of selective laser control of chemical reactions served as a basis for a new avenue of research — laser thermochemistry, in which many physics, chemistry and materials science laboratories are now working. One of the laboratories of the IOF Scientific Center continues researching in the spirit of this ideology; here, possible technological applications stem from the effect of the ablation-assisted formation of metallic nanoparticles and surface nanostructures exposed to optimized laser irradiation.

In the mid-1990s, F V Bunkin's scientific interests focused on the physics of water and aqueous solutions. He enlisted the cooperation of researchers from several teams of the Scientific Center and Oscillations Laboratory in a search for new methods and for ways to implement them so as to ensure progress in solving problems of principal importance in this difficult field of physics. His own approaches to studying dynamical short-range order structure so typical of water and formed by intermolecular hydrogen bonds with picosecond lifetimes were outlined, on the one hand, in his work on the optothermodynamics of solutions and, on the other hand, in lidar diagnostics of the impurity composition of sea water.

Established as the most promising among spectroscopic diagnostic techniques was the method of four-photon polarization spectroscopy with high sensitivity in the range from the Mandel'shtam – Brillouin to Raman frequency shifts, i.e., from several tenths to several hundred inverse centimeters. An original integrated system devised at the Center for four-photon spectroscopy made it possible to detect for the first time a reliably resolved multipeak excitation spectrum of liquid water and aqueous solutions at frequencies below one hundred inverse centimeters, precisely in the range of characteristic rotational motions of light molecules and molecular complexes. This result served as a sufficient justification for extending research on aqueous solutions using the new elaborated method. The scope of investigation is growing wider through varying the thermodynamic parameters of the state of water and its isotopic and impurity compositions, applying external fields, and utilizing specific solutions as objects of study. Working with the solutions of biomolecules has already revealed spectroscopic features caused by localized changes in the phase state of water in the vicinity of hydrophobic segments of protein molecules; this result appears promising from the standpoint of biomedical technologies.

At the same time, during this period Fedor Vasil'evich began to build on his earlier theoretical studies of laser discharges in gases and started to work on the theory of light-induced electrical breakdown in liquids transparent in the optical range; this was accompanied by arranging experiments with weakly absorbing aqueous solutions. Consistently taking account of the effect of ionic composition, the concentration of dissolved gases, and the thermodynamic parameters on the phase state and structure of the solutions allowed him not only to suggest a well-supported mechanism of electrical breakdown but also to generate more general results. They constitute the fundamental theory of a liquid in contact with an atmosphere. The theory predicts that under certain conditions (in water, under normal conditions) bubbstons (abbreviation of bubbles stabilized by ions) are formed in the liquid — bubbles of dissolved gas whose stability is maintained by the adsorption of ions on their surface. The formation of a bubbston structure proceeds as a quasiequilibrium first-order phase transition and its existence is sustained by the competing kinetics of the effects of flotation and spontaneous nucleation. In terms of this theory, the laser-induced breakdown in liquids is initiated inside bubbstons, i.e., due to a local action of the mechanism of electron avalanche in the gas. The theoretical predictions are supported by direct observations using interference microscopy. This study allowed F V Bunkin and his coworkers to propose, and work on, technical and biomechanical applications, first and foremost those connected with the possibility of raising the optical and electric strength of liquid materials.

F V Bunkin considers efforts to further improve the organization of research in this country as very important. In the 1980s and 1990s, as Deputy Director of the IOF RAN and Professor at MFTI, he assembled and trained a highly skilled team of researchers for the Scientific Center of Wave Studies at IOF RAN that he organized and has headed since 1998. Using the Center of Wave Studies at IOF RAN as the base, he created there in cooperation with French colleagues the European Laboratory of Nonlinear Magnetoacoustics of Condensed Media.

In 1977 – 1992, F V Bunkin headed the Russian Academy of Sciences (RAS) Learned Council on Coherent and Nonlinear Optics. In 1988, he became deputy chairman of the RAS Learned Council on the Hydrophysics complex problem, which was working out a scientific strategy of development for the Russian Navy. He was recently appointed to the RAS Learned Council on Defense Studies.

For many years F V Bunkin was editor-in-chief of the Physics Section of the *Russian Abstracts Journal* and of the journal he founded, *The Physics of Wave Phenomena*, also a deputy editor-in-chief of the journal *RAS Izvestiya, Physics Series*, and was a member of editorial boards of a number of authoritative physics journals.

F V Bunkin's contribution to the solution of problems in fundamental and application-oriented fields was highly regarded by the government and the scientific community. He received the USSR and Russian Federation State Prizes (1982 and 1999), was elected Corresponding Member of the USSR Academy of Sciences (1976) and Full Member of the RAS (1992), was decorated with the Order of the Red Banner of Labor (1979), Order of Friendship between Peoples (1985), Order of Services to the Fatherland of the Fourth Class (2000), and the Badge of Honor (2004). Colleagues abroad marked F V Bunkin's achievements in science with the distinctions of Honoris Causa of Szeged University (Hungary) and docteur Honoris Causa of Valencienne University (France).

F V Bunkin, one of the most cited Russian physicists, who was published more than 300 research papers and several monographs, actively continues his multifaceted work. His disciples and followers of the scientific school of laser physics, acoustics, and hydrophysics that he created carry on the efficient scientific work in many laboratories in Russia and abroad. Some of them have gone on to head research teams and innovative organizations in their own right.

Being fully certain that the future will bring him new successes in the best of professional fields, we wish Fedor Vasil'evich Bunkin happy birthday and send him our wishes for many years of good health.

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