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PERSONALIA

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Oleg Vladimirovich Rudenko (on his 60th birthday)

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Oleg Vladimirovich Rudenko, an outstanding physicist and corresponding member of the Russian Academy of Sciences (RAS) had his 60th birthday on 25 September 2007; he has made contributions, highly regarded by the world physics community, to nonlinear physics, acoustics, and a number of applications-oriented fields; he has enriched science with important results in nonlinear wave physics, laser physics, mechanics, geophysics, and biomedical and underwater acoustics.

Oleg Rudenko was a lucky boy. He was born in 1947 in a bright, multinational city — Tbilisi — surrounded by laughter-loving people, people in love with life. His father, Vladimir Grigorievich, was also born in Tbilisi and lived all his life there; he had lost his parents at 2 years of age and was raised in an orphanage, served in World War II and, after it ended, worked until his death at various engineering posts in industry. Oleg's mother, Aleksandra Petrovna, was born in Kharkov, worked as an accountant, and is now retired.

Having graduated from school with gold medal distinction and received a first prize in the Republican Physics Olympiad, Oleg moved to Moscow and enrolled without contest in the Department of Physics of Moscow State University (MGU). His luck was with him again. In his third year at university, he was selected into the group of Professor Rem Viktorovich Khokhlov, corresponding member of the USSR Academy of Sciences (later full member of the Academy and Chancellor of MGU). By the time of his graduation from university in 1971 O V Rudenko had already published 10 papers. His master's thesis won the contest as the best at MGU and then received 1st Prize in the All-USSR Contest and a medal from the Ministry of Higher Education of the USSR.

As a postgraduate, O V Rudenko worked on the theory of nonlinear waves, laser photochemistry, and the problem of creating gamma lasers. He submitted his PhD dissertation work on "Related problems in nonlinear acoustics and hydrodynamics" (supervised by R V Khokhlov) in less than the assigned three years and defended it in 1973.

This thesis, based on the publications of Rudenko's student years, gave results that established the foundations of modern nonlinear acoustics. Among other things, it presented a nonstationary theory of Eckart-type flow. It also proposed a theory of 'acoustic wind' formed and driven by both wave and hydrodynamic nonlinearities. This theory explained the observed dependence of flow velocity on wave intensity, as well as the appearance of a steep flow front at a certain distance from the source. It was shown that Landau's solution for submerged jet flow (with zero discharge of the liquid emerging from a pointlike orifice) is in good agreement with the experiment on exciting the 'wind', in which a liquid is driven by the pressure of radiation. Another result was a prediction of self-reflection: namely, once shock fronts appear, the wave splits into two waves propagating in opposite directions. This effect was later observed experimentally and was used as a basis for a new technique of nonlinear diagnostics. Self-similar solutions of Bürgers-type equations were also obtained for waves with planar and cylindrical symmetries, which are now cited in various handbooks of differential equations.

Oleg Vladimirovich Rudenko

In the same year, O V Rudenko, together with S I Soluyan, wrote a monograph *Theoretical Foundations of Nonlinear Acoustics*, which was published in 1975 in Russian (by Nauka) and in 1977 in the USA (by Plenum). This book appeared at the time when the physics of powerful acoustic waves was fast transforming from a curiosity of academic research to a field of applied physics. It proved to be timely and in demand and was massively cited. It was the first to present systematically the mathematical apparatus of nonlinear acoustics developed by R V Khokhlov and his students, analyzing the principal ideas and results in this field of

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physics. Among other things, it presented a theory of high-intensity diffracting beams using the equation that O V Rudenko suggested calling the Khokhlov – Zabolotskaya equation. Nowadays, the acronym KZ is universally accepted and requires no clarification. A nonlinear integro-differential equation was suggested for waves in media with strain memory whose kernel degenerates to exponential in Mandelshtam – Leontovich-type simple relaxation media. The general concept of interaction between dispersionless waves and waves in artificial media with weak dispersion was formulated. When describing parametric interactions, an approach was used for the first time which was based on a combined frequency-temporal description of wave fields that proved very efficient for strongly distorted waves containing discontinuities. The chapter on statistical phenomena in nonlinear acoustics (whose study O V Rudenko initiated) appeared before related papers could be read in journals.

In 1974 R V Khokhlov managed to find a vacancy at MGU for O V Rudenko as junior research scientist. This led to a surge in his creativity. By the end of the 1970s O V Rudenko was able to build a theory of nonlinear transformation of spectra and probability distribution of random wave fields, to solve a number of problems of laser generation of nonlinear sound, and to develop the theory and principles of designing parametric instruments for underwater applications. This work created the basis for the fields of research now known as 'statistical nonlinear acoustics', 'laser opto-acoustics' and 'nonlinear hydroacoustics'.

Shortly before his tragic death in 1977 R V Khokhlov involved O V Rudenko in teaching at MGU. From that time on, Oleg Vladimirovich was reading lecture courses on Electrodynamics, Wave theory, and Dynamics of continuous media, as well as a number of original special courses of lectures, and conducting seminar sessions in all main subjects for students of radiophysics chairs. This experience proved useful for preparing study guides for *Wave Theory* (Nauka, publications of 1979 and 1990, together with M B Vinogradova and A P Sukhorukov), *Acoustics through Problems* (Nauka, 1996 together with S N Gurbatov et al.), and *Nonlinear Acoustics through Problems and Examples* (Fizmatlit, 2007, together with S N Gurbatov and K M Hedberg).

In the same year, 1977, R V Khokhlov suggested that O V Rudenko set up an experimental laboratory of nonlinear and laser acoustics. The partners — industrial plants — helped with equipping the laboratory, situated in the Building of Nonlinear Optics of MGU. In the lab, a team of highly talented young students grew around O V Rudenko. They were able to observe, for the first time, the thermal self-action of ultrasound in viscous liquids, suppression of nonlinear absorption by introducing artificial linear losses, bistability of resonators, and asymmetrical distortion of shockwave profiles in diffracted beams. Methods of laser-acoustic diagnostics were developed. Distortion of the wave profile and the formation of a shockwave front in solids were observed for the first time. Four of O V Rudenko's post-graduates received Lenin Komsomol Prizes for this work in 1983 – 1985.

In 1981 the results of work on applied underwater acoustics conducted in collaboration with the Taganrog Radiotechnical Institute were written up as a monograph, *Nonlinear Underwater Acoustics* (Leningrad: Sudosctroenie) (co-authored by B K Novikov and V I Timoshenko); in 1987 this book was published in the USA. The book, dealing with the fundamentals of designing hydrolocators and a new type of receiver, continues to be popular in the world scientific community and is widely cited, regardless of its 'engineering design' orientation.

In the same year, 1981, O V Rudenko submitted his DSc thesis "Interactions between modulated weekly dispersing high-intensity waves" and received the DSc degree; two years later he became Associate Professor of the department.

In 1985 a team of scientists, including O V Rudenko, was awarded the USSR State Prize. The list of publications in this research project, "Creation of the foundations of nonlinear acoustics and its applications", included the work done by O V Rudenko on developing the mathematical apparatus of nonlinear acoustics.

In 1987 O V Rudenko had to leave his laboratory and his team at the chair that now, after R V Khokhlov's death, was headed by S A Akhmanov, and become chair of acoustics. From 1990 to 1997 O V Rudenko combined this post with heading the Division of Radiophysics and Electronics at MGU.

In 1990 a new experimental group was organized within the acoustics chair out of postgraduates who had defended their PhD theses; the group discovered a phenomenon of principal significance for nonlinear waves: thermal self-focusing of sawtooth waves in nonabsorbing media. The physical limitation of pulse fields in the focal area of high-power concentrators was established. The first laser-acoustics lithotripter was developed — a tool for contactless destruction of kidney stones and gallstones. In 1991 this work was awarded the M V Lomonosov Prize.

By that time work was completed on the creation of NACSI applied software packages. This was a result of many years of collaboration of physicists and mathematicians in the field of numerical solution of wave physics that was started in 1974 on the initiative of academicians N S Bakhvalov and R V Khokhlov. The asymptotic and numerical methods developed in the process were partly described by O V Rudenko (co-authored by O A Vasil'eva, A A Karabutov, E A Lapshin) in the monograph *Interaction between one-dimensional waves in dispersionless media* (Moscow: MGU, 1983). This software made it possible to solve numerically — in minutes — a wide range of nonlinear problems even with first-generations PCs.

In 1991 – 1995, on O V Rudenko's initiative, a range of theoretical and experimental projects were completed (in collaboration with mathematicians, biologists, and industries) that were devoted to the problem of the prediction of the levels of acoustic shock over aircraft flight trajectories and of the ecological impact of commercial flights of the anticipated new-generation supersonic passenger aircraft.

In 1997 O V Rudenko was elected an RAS corresponding member. In the same year he and his colleagues received the State Prize of the Russian Federation for the series "Dynamics of high-intensity noise waves and nonlinear structures in dispersionless media" that included O V Rudenko's work on statistical physics of nonlinear waves.

In 1998 O V Rudenko and coworkers published an article (which received the Prize of the MAIK-Nauka publisher) on remote generation of shear waves by the radiation pressure caused by modulated ultrasound. This phenomenon was used to develop, and obtain patents for, instruments for soft tissue diagnostics, including tumor visualization. Later, O V Rudenko paid serious attention to other biomedical applications. For instance, an analysis of previously unknown results of 1952 – 1957 on the effects of

high-intensity ultrasound on malignant tumors (USSR Academy of Sciences Laboratory of anisotropic structures, A K Burov) and of the data of clinical testing (Institute of experimental cancer pathology and cancer therapy, N N Blokhin), made it possible to understand the mechanism of stimulation of the immune response to malignant cells that results in regression of metastases. Recently, it became possible to explain the unique ability of skeletal muscles to 'slow down' and cushion a hit.

O V Rudenko's contribution to applied geophysics is also considerable. He explained the mechanism of formation of high-Q resonances observed when recording the response of the Elbrus volcano to seismic signals from remote sources. It was shown that the resonances are only possible if the magma chamber contains gas-carrying molten rock, which is a sign of an approaching eruption. A theory was developed of nonlinearity of grainy media saturated with fluids, and resonance excitation and waveguide propagation of sound along the ocean floor was predicted. The results on the diagnostics of drilled (Armco) piles used to construct the third ring road around Moscow provided the database for advancing the wave theory for plastically deformable media. A theory of relaxation of hysteretic nonlinearity was developed. Also created was the theory of 'giant' nonlinearities in structurally inhomogeneous media, and upper bounds on nonlinearity values were found.

O V Rudenko continues to return to his work in mathematical physics and wave theory. He proposed a new principle of analysis for nonlinear problems based on a reasonable increase in complexity of a mathematical model. This approach (stemming, in a sense, from N H Ibragimov's theorem on projections of equivalence groups) carries a meaning opposite to conventional methods of simplification, but it reveals new symmetries which generate point solutions. A nonlinear equation of fourth order for waves in scattering media was proposed and solved; it extends the 'famous chain' of Bürgers (2nd order) and Korteveg – de Vries (3rd order) equations. Some mathematicians regard O V Rudenko as one of the leaders in finding exact solutions to nonlinear problems, part of which are listed in handbooks and on the relevant sites on the Internet [see e.g. the book *Nonlinear Waves-2006* (Published by IPF RAS, 2007)].

The experience of the past proved to be useful for creating 'parametric amplifiers' — high-power emitters of directed ultrasound through the air capable of 'fooling' the diffraction. Phase diffraction gratings were applied to format fields in the focal zone at levels up to 160 dB that allowed one to observe strong nonlinear effects: acoustic levitation, selective transmission of signals (including transmission through solid obstacles), and remote diagnostics of defects. This experience was also used to offer valuable consulting to a number of well-known companies in Germany, France, the USA, South Korea, and Sweden.

Nevertheless, O V Rudenko continues to devote a significant part of his time to his social and managerial functions. On academician A M Dykhne's recommendation, he worked for ten years in the Russian Foundation for Basic Research (RFBR), recently acting there as Chairman of the Experts' Board on Physics and as deputy chairman of the RFBR. From 2002 on, O V Rudenko has chaired the Experts Board on Physics at the Supreme Qualification Commission of Russia. He is Editor-in-Chief of *Akusticheskii Zhurnal* (*Acoustical Physics* journal). Being one of the deputies of *Uspekhi Fizicheskikh Nauk* (*Physics – Uspekhi*) journal Editor-in-Chief — V L Ginzburg, Rudenko helps him in important ways by supervising on his behalf various aspects of the journal's activities, informally devoting to *Uspekhi Fizicheskikh Nauk* journal much of his time, energy, and effort.

O V Rudenko has received a number of decorations from the government and honorary degrees from Russian and foreign science societies and universities. Many a time he has attracted large audiences when lecturing abroad. He has authored or coauthored 350 publications, among them 12 monographs and textbooks published in this country and abroad. O V Rudenko has supervised seven DSc theses and about 15 PhD theses. Among his students we see professors, heads of chairs, winners of the M V Lomonosov, I I Shuvalov, and Lenin Komsomol Prizes and prizes awarded by the European Community, the Humboldt Foundation, and the Acoustical Society of America, and authors of monographs printed in this country and abroad.

It is a difficult task to cover in a brief jubilee publication the entire range of O V Rudenko's achievements in the 40 years of his creative activities, so we will simply wish Oleg Vladimirovich good health, inspiration in all his undertakings, and a good measure of luck and happiness, but also many pleasant years of life and success in his many new initiatives!

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V L Ginzburg, Yu V Gulyaev, V V Kozlov,
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