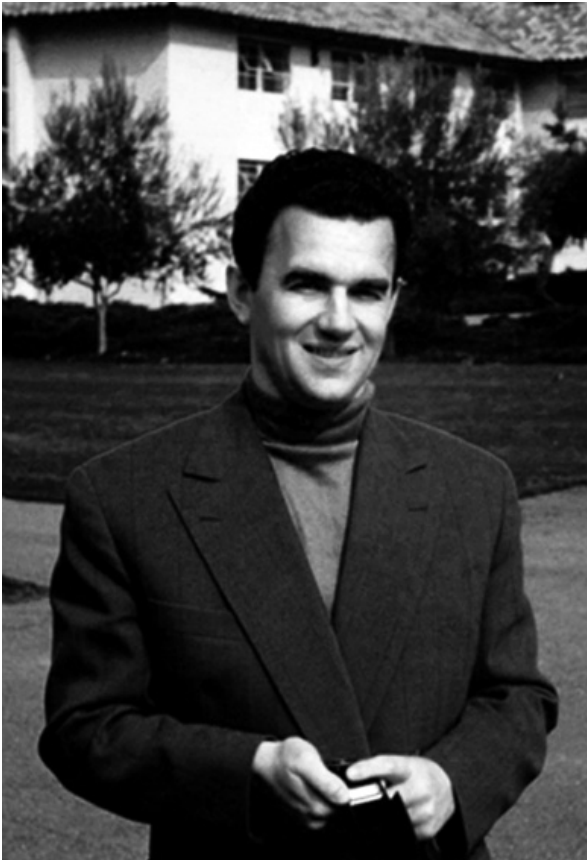


On the 90th Birthday of Rem Viktorovich Khokhlov



July 15th 2016 marked the 90th birthday of Rem Viktorovich Khokhlov, a prominent Russian physicist, talented organiser of national and world science and higher education, rector of Lomonosov Moscow State University, vice-president of the USSR Academy of Sciences, founder and head of the Department of Wave Processes. He tragically died on 8 August 1977 trying to conquer the highest peak of the Pamir Mountains.

The name of Rem Viktorovich is widely known throughout the scientific world. It has become a symbol of such fields of science as nonlinear optics, nonlinear acoustics and laser physics. His ideas, methods and scientific developments have become so classic and so firmly established in our academic community that they seem to have always existed and to be quite commonplace. R.V. Khokhlov was a pioneer and discoverer, generously sharing ideas with numerous disciples. He had an amazing intuition and flair for identifying contemporary challenges in science; he worked a lot and over the years managed to do what others did not even dare to dream. Much is written in articles and books about his goodwill and adherence to principle, sincerity and honesty, charm and tact. He demonstrated these qualities in science and in dealing with people; he showed them always and everywhere.

In difficult situations, he was not afraid to take responsibility. Many people are grateful to him for the fact that in difficult moments of their lives, when words fail, Khokhlov was ready to help, even though many around turned their backs on them. Rem Viktorovich had a phenomenal intuition and keen sense of justice. He could notice and find the most important things among a vast amount of information, journal articles, everyday affairs, papers and phone calls. His ideas were always ahead of time; his working day began very early. At seven o'clock in the morning he was seen doing the exercises, he appointed many meetings at ten and eleven o'clock in the evening.

He climbed the highest mountain peaks, he perfectly drove the car, he liked jogging, he was fond of skiing and swimming and he loved classical music and literature. Like all of us, every year he had to face a severe test in front of new generations of students and post-graduates making their first steps at the university and into the world of science, and his human qualities allowed him from year to year to succeed with this challenge.

Rem Viktorovich was extremely responsible towards administrative and party work, and later towards his duties of Rector of Lomonosov Moscow State University. He was approachable and supportive of university students and colleagues; he was ready to solve problems instead of postponing them, and at the same time he demonstrated the highest professionalism in science, without which creative work is impossible.

R.V. Khokhlov left a rich scientific heritage in nonlinear optics and acoustics, quantum electronics and laser physics, coherent gamma-optics, laser chemistry and biology, theory of nonlinear oscillations and waves. He created a large scientific school in physics of wave processes. His students became well-known scientists, heads of laboratories, departments and institutions. He trained more than fifty doctors and candidates of science, many of whom have been successfully preparing teams to augment the Khokhlov School. While careful over the details of his colleagues and disciples' research work, he left them a wide scope for individual creativeness.

Over twenty-five years of active scientific work he did so much. After his post-graduate studies at the Physics Faculty of the Department of Oscillation Physics, he defended his candidate's thesis on the theory of transient phenomena in waveguides. Since 1954, Rem Viktorovich developed a method of gradual simplification of truncated equations, based on the separation of fast and slow oscillations, with reference to some problems of radiophysics. These studies formed the basis for his doctoral dissertation, which he brilliantly defended in 1961. R.V. Khokhlov was interested in the problems of propagation of nonlinear waves. For highly dispersive media he developed a method of slowly varying amplitudes, which describes synchronous interaction of a small number of harmonic waves. With a weak dispersion, when the number of interacting spectral components is very large, he offered an elegant method of a slowly varying wave profile. These two works had and continue to have a huge impact on the development of physics and the theory of nonlinear wave

processes. Khokhlov clearly understood that various nonlinear wave phenomena can fully manifest themselves in optics. In 1962, he and S.A. Akhmanov set up the first Nonlinear Optics Laboratory in the USSR at the Physics Faculty of Lomonosov Moscow State University, which brought together a team of young talented experimentalists and theorists.

Joining forces of radiophysicist and optometrists led to outstanding results in the first years of the laboratory's work. In 1962, R.V. Khokhlov and S.A. Akhmanov proposed schemes of continuously frequency-tunable optical parametric amplifiers and oscillators. The same year, Rem Viktorovich and A.I. Kovrighin obtained optical second-harmonic generation, and later constructed high-power generators of higher optical harmonics (from the second to the fifth). In a long series of theoretical works under Khokhlov's guidance, reported were basic properties of generation of harmonics, difference and sum frequencies, parametric amplification at various levels of initial intensities with allowance for phase mismatch. R.V. Khokhlov together with V.T. Platonenko developed a classical theory of stimulated Raman scattering.

Summing up the results of the research, R.V. Khokhlov and S.A. Akhmanov published in 1964 the first world's monograph on the subject, 'Problems of Nonlinear Optics'. This book contributed to the rapid development of work on nonlinear optics in the USSR. The Nonlinear Optics Laboratory soon became renowned, and in 1965 it became the nucleus of the Department of Wave Processes. It has greatly expanded the range of the studied problems.

Workshops of the Department, held under the chairmanship of R.V. Khokhlov, became a forum for discussion of all new ideas, which attracted scientists from different laboratories and institutions. In 1965, R.V. Khokhlov, S.A. Akhmanov, A.I. Kovrighin, V.V. Fadeev and A.S. Piskarskas experimentally implemented an optical parametric oscillator, in which the second harmonic of a neodymium laser was converted into frequency-tunable IR radiation. R.V. Khokhlov and A.P. Sukhorukov developed the mathematical formalism of nonlinear optics as applied to real laser beams and pulses. They derived equations that take into account the diffraction of interacting beams, which now constitute the basis of quasi-optical dispersive anisotropic nonlinear media.

The developed approach was used, in particular, to study self-interaction and interaction of high-power light beams and pulses. The results obtained made it possible to formulate the principle of optimal focusing in frequency doublers, to understand the phenomenon of diffraction incoherence and to predict three-wave mutual focusing and parametrically coupled solitons in a quadratically nonlinear medium. In 1967, S.A. Akhmanov, A.P. Sukhorukov and R.V. Khokhlov published in *Soviet Physics Uspekhi* a review on nonlinear self-focusing and diffraction. They developed a universal method of aberration-free description of self-focusing, which was included in textbooks and monographs. At the end of the 1960s, R.V. Khokhlov initiated a series of investigations related to the resonantly selective action of high-power laser radiation on matter. These works, performed in collaboration with V.T. Platonenko, played a major role in the development of laser photochemistry.

For laser applications in photobiology, Khokhlov and his colleagues devised tunable UV lasers, developed and perfected various types of gas-dynamic, electric-discharge and solid-state lasers. A series of pioneering research on visualisation of IR radiation was initiated in his paper 'Infrared holog-

raphy by methods of nonlinear optics', written in collaboration with E.S. Voronin, V.S. Solomatin and Yu.A. Il'inskii. R.V. Khokhlov together with Yu.A. Il'inskii started research on coherent gamma-optics. They identified new possibilities for designing gamma-ray lasers using long-lived isomers. These works stimulated research in our country and abroad and laid the foundations for a new promising direction.

In 1960–1970, he, together with S.I. Soluyan and later with O.V. Rudenko, A.S. Chirkin and E.A. Zabolotskaya, actually developed the mathematical formalism of modern nonlinear acoustics. They derived and analysed now classical equations for plane, spherical and cylindrical finite-amplitude waves propagating in dissipative and dispersive media, and obtained a number of important physical results. R.V. Khokhlov and his colleagues proposed a number of specific schemes of ultrasonic parametric amplifiers. Approaches used in optics for the description of self-interaction of laser beams were generalised in a nontrivial way to the problem of nonlinear acoustics. The resulting equation for acoustic beams (which is now called the Khokhlov–Zabolotskaya equation) turned out to be a versatile tool for solving a wide range of practically important problems, including the development of the theory of parametric sonars.

Khokhlov's scientific school is not only a community of scientists, trained in their time at the Department of Wave Processes, and then at the Departments of General Physics and Wave Processes and Quantum Electronics and now successfully working in research centres around the world. Many scientists, who were influenced by Rem Viktorovich in person, by scientific seminars of his department and by his well-known conferences on coherent and nonlinear optics, associate themselves with this community. Khokhlov's scientific school is also a unique platform for dialogue, ensured by his impeccable scientific ethics, genuine friendliness and willingness to listen and understand. A truly scientific and welcoming atmosphere always accompanied R.V. Khokhlov and permeated all of his activities. For outstanding scientific achievements he was awarded the Lenin, State and Lomonosov prizes, orders of Lenin and the Red Banner of Labour, as well as high academic titles.

The strongest influence of Rem Viktorovich on national and world science is felt even today, despite the fact that almost forty years have passed since his death. Scientific directions pioneered by R.V. Khokhlov are now being intensively developed in the works of several generations of his students and colleagues. On his initiative, workshops and later conferences on coherent and nonlinear optics have been held in our country since 1965. All those involved in their work remember well his brilliant review reports on the latest developments and trends in nonlinear optics and laser physics. In 2013, the ICONO/LAT conference, this is how it is now called, took place in Moscow and gathered more than a thousand participants. The next ICONO/LAT conference will be held in Minsk in September 2016.

The Building of Nonlinear Optics, which was constructed according to Khokhlov's plans and bears his name, with his bust in the lobby is a man-made monument to which the path will be kept well trodden. For more than thirty-five years its doors have been open every day to dozens of students, professors, researchers, engineers, foreign visitors and members of the government. The Building of Nonlinear Optics houses the Department of General Physics and Wave Processes. That is how Khokhlov's department is now called after its merger in 1978 with the Department of General Physics headed by



highest,” wrote N. Bloembergen, a Nobel Laureate and an Honorary Professor of the MSU. “R.V. Khokhlov was an outstanding pupil of the Physics Faculty, and all his life was totally devoted to Lomonosov Moscow State University,” said V.S. Fursov, a dean of the Physics Faculty of Lomonosov Moscow State University. One of Khokhlov’s students, Valery Kaner, wrote:

*How many a time will we remember
Not to forget to change the present for the past,
His name’s inscribed in history forever,
But does it make a truly smile on faces last?
His photos on the highest tops of mountains,
The stories and the legends of his life,
They all will pass like circles on the water
But nonetheless we’ll keep his charm in our hearts.
And at a time when sun starts rising,
When darkness ends and gloom is gone,
His farewell smile will rest upon us,
And we’ll continue doing what he hasn’t done...*

Head of the Department of General Physics and Wave
Processes at M.V. Lomonosov Moscow State University,
Director of the ILC MSU
V.A. Makarov

S.A. Akhmanov. The building is also a home to the Department of Quantum Radiophysics (now Quantum Electronics), which was also organised during the merger. Both departments have not only common ‘parents’ and scientific interests, but also long-term sincere friendship and scientific rivalry. Rem Viktorovich dreamt of an Institute of Nonlinear Optics. The International Laser Centre (ILC) of Lomonosov Moscow State University is, of course, not the Institute, which Khokhlov dreamt of. But this small centre has been successfully working for more than twenty-five years, and its scientific achievements are known in the world.

R.V. Khokhlov died early: He was only 51 when a tragic set of circumstances, while climbing one of the highest peaks of the Pamir Mountains, led to his untimely death. His name is forever inscribed in the history of Lomonosov Moscow State University. He left behind a huge legacy as a scientist, as a teacher, as a person, as a real man. If he were alive, he would be proud of his students who continue his work and of his children who are widely known in the scientific community. “The world has lost a truly splendid scholar and educator,” wrote Charles Townes, a Nobel Prize winner in physics. “His scientific contribution was the milestone that marked the formation of the whole field in quantum electronics,” said J.A. Giordmaine, the author of classic works on nonlinear optics, about R.V. Khokhlov. “The rapid development of nonlinear optics and significant progress in this field in the Soviet Union are associated, to a great extent, with the name of R.V. Khokhlov. His personal and professional qualities have contributed to the development of deeper international understanding. He died as he lived, striving for the