

hard alloys based on tungsten carbide.

Leonid Fedorovich devoted considerable attention to the training of research manpower in the fields of physics and high pressure technology. He organized and headed special chairs in the Moscow State University and the Moscow Physical-Technical Institute.

An outstanding personality has left us replete with new ideas which he did not have time to realize. His sensitivity, kindness and accessibility earned for him the respect of all who had the good fortune of having worked with him.

For his scientific attainments, L. F. Vereshchagin was in 1960 elected corresponding member of the Academy of Sciences of the USSR, and in 1966 he was elected

to full membership in the Academy of Sciences of the USSR. For his work in high pressure chemistry, he was awarded the State Prize of the USSR, and for his work on the synthesis of diamonds he was awarded the Lenin prize. He was a member of the Engineering Academy of Sweden.

For his meritorious services in the development of Soviet science and for his active participation in social affairs, the Soviet government awarded to L. F. Vereshchagin the title of Hero of Socialist Labor, and rewarded him with orders and medals.

The fond memory of Leonid Fedorovich Vereshchagin will forever live in our hearts.

Translated by G. Volkoff

Rem Viktorovich Khokhlov (Obituary)

S. A. Akhmanov, N. G. Basov, É. S. Voronin, A. V. Gaponov, B. B. Kadomtsev, L. V. Keldysh, A. A. Logunov, V. V. Migulin, A. M. Prokhorov, S. M. Rytov, M. F. Stel'makh, I. M. Ternov, V. S. Fursov, and I. A. Yakovlev

Usp. Fiz. Nauk 124, 355-358 (February 1978)

PACS numbers: 01.60.+q

Soviet and world science has suffered a grievous loss. Academician Rem Viktorovich Khokhlov, a prominent Soviet physicist and organizer of science and of higher education died suddenly on 8 August 1977.

The range of scientific interests of Rem Viktorovich was very wide. To him belong fundamental results in the nonlinear theory of oscillations, in quantum electronics, in optics and in acoustics. World fame was brought to R. V. Khokhlov by his work on the theory of nonlinear wave processes, nonlinear optics, tunable lasers, effect of intense radiation on matter.

Rem Viktorovich Khokhlov was born on 15 July, 1926 in the city of Livna of the Orlov district. On completion of the seventh year of secondary school in 1941, he began work as an auto mechanic. In 1944 having passed the external examinations for the 8-10 years of secondary school, he entered the Moscow Aviation Institute. A year later, he transferred to the physics faculty of the Moscow State University and from that moment the rest of Rem Viktorovich's life was inseparably associated with the Moscow State University.

R. V. Khokhlov published his first scientific paper "On nonstationary processes in wave guides" in 1948 while he was still a student. The theory of nonstationary processes in distributed systems became the subject of his candidate's dissertation defended by Rem Viktorovich in 1952. Subsequent papers of R. V. Khokhlov in mid-fifties were related to nonlinear theory of oscillations. In 1954 Rem Viktorovich published one of his basic papers "On the theory of capture in the case of small am-



REM VIKTOROVICH KHOKHLOV (1926-1977).

plitude of the external force."

In this paper the asymptotic methods of the theory of nonlinear oscillations developed in our country received their further development.

R. V. Khokhlov was the first to direct attention to the

circumstance that in the so-called truncated equations describing the behavior of slowly (compared with the period of oscillation) varying amplitudes and phases one can in turn pick out the rapid and the slow motions. This idea lies at the base of the method worked out in detail by the Rem Viktorovich of the stage-by-stage simplification of the truncated equations—a method which radically extends the number of problems of nonlinear oscillation theory which are susceptible to yielding analytic results.

The “Khokhlov method” turned out to be fruitful to the highest degree. Using it, Rem Viktorovich obtained for the first time results in classical problems of the theory of oscillations concerning the external and mutual synchronization of auto-oscillations, and provided a nonlinear theory for a number of electronic ultrahigh frequency generators. Many other authors also successfully used the Khokhlov method; the general ideas of the method were later widely used by Rem Viktorovich, his pupils and collaborators also in the nonlinear wave theory.

In 1959–1960 began a new stage in the scientific activity of R. V. Khokhlov associated with widespread investigations of nonlinear wave processes. In these years radiophysicists acquired the possibility of studying nonlinear waves under laboratory conditions—in travelling-wave tubes, in transmission lines with ferrites and semiconductors. Somewhat earlier, nonlinear distortions of ultrasonic waves in liquids were experimentally recorded. Rem Viktorovich was one of the first to recognize clearly that we were dealing here with the birth of a new large field of physics of wave phenomena extending far beyond the limits of only radiophysics and acoustics.

In 1959–1960 Rem Viktorovich carried out two investigations on the theory of nonlinear waves which played a major role in establishing this field, papers which with complete justification can be called classic. The titles of these papers published in 1961—“On the propagation of waves in nonlinear long lines” and “On the theory of shock radiowaves in nonlinear lines.” In them R. V. Khokhlov gave a clear classification of nonlinear wave processes based on comparing the effects of nonlinearity and dispersion, developed a regular mathematical apparatus which now lies at the base of an overwhelming majority of theoretical papers on nonlinear waves and solved a number of problems fundamental for nonlinear optics and nonlinear acoustics.

Rem Viktorovich clearly distinguished two limiting cases in the theory of nonlinear waves: nonlinear waves in systems with strong dispersion and nonlinear waves in a nondispersive medium.

R. V. Khokhlov proposed two methods, appropriate to these two cases, of simplifying partial differential equations describing propagation of waves in nonlinear media. For strongly dispersive media he developed (in analogy with the almost-sinusoidal oscillations in systems with lumped constants) the method of slowly varying amplitudes in which the truncated equations describe the slow (on the scale of a wavelength) spatial variations in the amplitudes of the waves as a result of their non-

linear interaction and dissipation. In the same paper Rem Viktorovich for the first time developed the theory of generation of the second harmonic in wave systems showing the possibility of a complete transfer of energy into the harmonic under conditions of phase synchronism—a result of fundamental significance for nonlinear optics.

For nonlinear media with weak dispersion Rem Viktorovich proposed a completely novel idea of representing the wave process as a slow distortion of the profile of a traveling wave. The method of a slowly varying profile led to truncated partial differential equations in terms of time and a spatial coordinate. In the latter case R. V. Khokhlov also investigated the possibility of a stage-by-stage simplification of the truncated equations in describing the processes of formation and dissipation of shock waves.

These two papers of Rem Viktorovich Khokhlov anticipated the subsequent publications by several years. They exerted a strong influence on the development of physics and of the theory of nonlinear wave processes. The first of the papers cited above formed the base for investigations in nonlinear optics, the second one in nonlinear acoustics.

The nature of the scientific work of Rem Viktorovich underwent substantial change in the early sixties. Experimental investigations began to play an ever more important role in his own work and in the work of the group directed by him. In 1962 a laboratory of nonlinear optics was organized within the Physics Faculty of the Moscow State University. Within a short time the laboratory became one of the leading world scientific centers in the field of nonlinear optics and quantum electronics.

One of the major achievements of the laboratory of nonlinear optics of the Moscow State University which gained world recognition was the creation of parametric light generators—devices quite novel for optics in which powerful laser radiation of fixed frequency is transformed into coherent radiation smoothly tuneable in frequency.

Experimental work in the laboratory of nonlinear optics of the Moscow State University began in 1962 with the creation of powerful optical frequency multipliers. Here were created powerful generators of the second, third, fourth, and later even fifth harmonics of the radiation of a pulsed neodymium laser the parameters of which remained unsurpassed for a long time. The developed generators of harmonics of light were then successfully utilized by R. V. Khokhlov and his collaborators in a number of physics and applied investigations.

In 1963–64 R. V. Khokhlov and his collaborators carried out a number of investigations devoted to the study of induced Raman scattering of light. Rem Viktorovich was the first to develop a detailed classical theory of the phenomenon; this theory lies in essence at the base of the majority of subsequent papers in this important field of nonlinear optics and nonlinear spectroscopy.

During the same years, R. V. Khokhlov together with

his collaborators continued to carry out intensive work in the further development of the mathematical apparatus of nonlinear optics and the application of this apparatus to the description of different nonlinear optical phenomena. The results of investigations in nonlinear optics obtained by R. V. Khokhlov and coauthors during the first stage of these investigations were summarized in the first monograph in the world literature "Problemy nelineĭnoi optiki" (Problems of Nonlinear Optics) published in 1964. This book to a large extent aided the rapid development in investigations in nonlinear optics in the USSR.

The laboratory of nonlinear optics of the Physics Faculty quickly gained recognition. It exerted a great influence on the development of nonlinear optics not only in our country but also abroad. The laboratory itself also grew. In 1965 using it as a base a Chair of Wave Processes was organized which was headed by Rem Viktorovich.

In 1965 R. V. Khokhlov and coauthors created a parametric light generator which enabled them to obtain infrared radiation tuneable in frequency. Subsequently similar generators were created also in other ranges of the optical spectrum. Tuneable generators revolutionized optical spectroscopy, opened up new possibilities in the study of the effect of optical radiation on matter.

The study of the nature of noise in optical parametric amplifiers carried out on the initiative of and under the guidance of R. V. Khokhlov led to the discovery of a new type of scattering of light-parametric scattering.

The mathematical apparatus of nonlinear optics received further development in 1965-1966. In a series of papers of R. V. Khokhlov and collaborators the method of slowly varying amplitudes was extended to a new range of wave problems. The equations obtained in these papers which take into account the diffraction of interacting beams formed the basis of modern quasi-optics of nonlinear dispersive anisotropic media.

An extensive series of investigations was carried out by R. V. Khokhlov and coauthors involving the study of selfinteraction of intense light beams. In 1965 at the First All-Union Symposium on Nonlinear Optics Rem Viktorovich presented arguments concerning the instability of an intense plane wave in a nonlinear medium. At the present time this instability is one of the most important factors limiting the output intensity of the radiation from lasers and laser amplifiers. In 1966 an effective method for analyzing the effect of self-focussing was developed. In a series of papers belonging to the same period an exhaustive treatment was presented of the phenomenon of thermal selfinteraction of light beams which in particular plays an important role in the propagation of laser beams in the atmosphere.

It must be stated that even during the period of the most active investigations in nonlinear optics the problems of nonlinear acoustics continually remained within the circle of scientific interests of Rem Viktorovich. Utilizing and developing the asymptotic method proposed by him in his classical paper of 1961 for weakly disper-

sive media R. V. Khokhlov together with collaborators created in essence the mathematical apparatus of modern nonlinear acoustics. He investigated such phenomena as shock waves, parametric amplification and generation of sound, nonlinear diffraction of limited acoustic beams, problems concerning parametric antennas, acoustic flows, etc.

In the late sixties Rem Viktorovich began a series of investigations associated with the selective effect of intense laser radiation on matter. The experimental basis for these papers already existed; by that time parametric generators of light of tuneable frequencies and dye-based lasers had already been constructed. In 1967 R. V. Khokhlov presented the idea of the possibility of attaining essentially nonequilibrium states in molecules undergoing selective interaction with intense resonance laser radiation. In subsequent papers an analysis was given of the possibility of regulating the rate and direction of chemical reactions with the aid of selective laser excitation of one of the vibrational degrees of freedom of molecules. This pioneering paper played an important role in establishing selective laser photophysics and photochemistry. Subsequently R. V. Khokhlov with coauthors carried out work on the photochemistry of heterogeneous processes.

Intensive work covering the infrared range was carried out in the laboratory of Rem Viktorovich. Different types of gas-dynamic, electric discharge and solid state lasers were developed and perfected. R. V. Khokhlov turned his attention to the promising possibility of utilizing the nonlinear effect of addition of frequencies for visualization of infrared images. The work of R. V. Khokhlov and collaborators "Infrakrasnaya golografiya metodami nelineĭnoi optiki" (Infrared Holography by the Methods of Nonlinear Optics) published in 1969 gave rise to a long series of practically important investigations.

In 1972 Rem Viktorovich began work on gamma-lasers. In a paper published in 1972 R. V. Khokhlov presented a number of novel possibilities of creating a gamma-laser using longlived isomers. These papers stimulated similar investigations in the USSR, in a number of leading scientific centers of the USA and formed the beginning of a new and promising direction in gamma optics.

For his outstanding scientific services Rem Viktorovich was elected in 1966 a corresponding member of the Academy of Sciences of the USSR and in 1974 a full member of the Academy of Sciences of the USSR. R. V. Khokhlov was awarded the honorary doctorate by a number of foreign universities.

The scientist-communist Rem Viktorovich was always at the leading edge of the most important party and social affairs. R. V. Khokhlov was a member of the city of Moscow committee of the Communist Party of the Soviet Union, and at the XXV Congress of the Soviet Union he was elected a member of the central revision committee of the Communist Party of the Soviet Union. Rem Viktorovich Khokhlov was elected a deputy of the Supreme Soviet of the USSR.

R. V. Khokhlov participated actively in the work of the

Academy of Sciences of the USSR being a member of the executive of the Division of General Physics and Astronomy, a member of the Presidium of the Academy of Sciences of the USSR, and lately the acting vice-president of the Academy of Sciences of the USSR. Rem Viktorovich worked actively on the editorial boards of leading physics journals—"Uspekhi fizicheskikh nauk," "Zhurnal experimental'noi i teoreticheskoi fiziki," "Kvantovaya elektronika."

Still another page of the scientific biography of R. V. Khokhlov is associated with the organization and coordination of work on nonlinear optics in the USSR. The Council of the Academy of Sciences of the USSR on the topic of "Coherent and nonlinear optics" formed on his initiative united the leading scientists from the different centers of our country. Due to the organizing talent and unchallenged scientific authority of Rem Viktorovich this Scientific Council became one of the most active ones in the Academy. One of the forms of its direction of science are regular symposia, and then conferences on nonlinear optics. These conferences took place regularly and exerted a considerable influence on the development of work in nonlinear optics in our country. R. V. Khokhlov devoted much effort to the concrete organization of these conferences and tried to increase their effectiveness in every possible manner. He proposed the idea of the Vavilov conferences which have now gained widespread international recognition.

The conferences usually began with a paper by Rem Viktorovich which contained a concentrated analysis of the state and of the most vivid achievements of nonlinear optics and predictions of its future development. These reports demonstrated the feeling for what was new and the deep physical intuition characteristic of R. V. Khokhlov.

To R. V. Khokhlov belongs the initiative of starting a number of important investigations in quantum electronics and nonlinear optics. Many of them were carried out by the group of colleagues in the laboratory directed by him together with industrial enterprises under his direct guidance.

Rem Viktorovich devoted much effort and attention to scientific-pedagogic work. Having traversed in the Moscow State University the path from Assistant to Rector, R. V. Khokhlov supervised the theses of over 50 doctors and candidates of science many of whom by now have become well known scientists and in their turn successfully train scientific manpower aiding the growth of the Khokhlov school. The style of interrelationships in this school was developed by its founder—the highly organized, exceptionally modest, always even tempered and kind Rem Viktorovich knew how to hold back gently the excessively impatient, and how to give kindly support to one who stumbled. Painstakingly entering into the details of the scientific work of his collaborators, he left them extensive opportunity for independent creativity. These characteristics of R. V. Khokhlov both as an educator and as an organizer of science were manifested to the full extent in his activity as the Rector of Moscow State University.

The Soviet government highly valued the services of R. V. Khokhlov. He was awarded the orders of Lenin and of the Red Banner of Labor; in 1970 he was awarded the Lenin Prize.

Rem Viktorovich was a many-sided and harmonious man. He had a deep interest in literature, art, and with great sensitivity detected new directions in these fields. Rem Viktorovich knew well and understood sport, and had an undying love for mountains. People were attracted to Rem Viktorovich by his remarkable human qualities, his real kindness, his sincere desire to hear people out and to help them. In science he was remarkably objective in evaluating the work of others; he was quite free of bias.

Rem Viktorovich Khokhlov parted from life in the full bloom of his creative abilities, full of new plans. His was a short but unusually full vivid life. The fond memory of Rem Viktorovich Khokhlov, a remarkable scientist and human being, will forever remain in our hearts.

Translated by G. Volkoff