

PERSONALIA

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Leonid Veniaminovich Keldysh (on his seventieth birthday)

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Leonid Veniaminovich Keldysh, a brilliant theoretical physicist, full member of the Russian Academy of Science, was born on the April 7, 1931. His entire career in research is inseparable from the Division of Theoretical Physics of FIAN (now known as the I E Tamm Division of Theoretical Physics of the P N Lebedev Physics Institute of the Russian Academy of Sciences). This career was launched in 1954 when L V Keldysh, having graduated from Moscow University, enrolled in the postgraduate course at FIAN, where his scientific adviser was V L Ginzburg. The scientific allegiances of Leonid Veniaminovich were formed then and there.

The 1950s and 1960s witnessed rapid progress in semiconductor physics. This field of science attracted the young theorist and to a great extent dictated his life in physics. L V Keldysh developed his *modus operandi*: active collaboration with experimentalists, first of all with those in the semiconductor physics laboratory of FIAN. As a theorist, he immediately rose to the leading position. The work done by L V Keldysh in semiconductor physics always had a profound and transparent physical meaning and was directly related to actual experimental work.

At the end of the 1950s and the beginning of the 1960s L V Keldysh published a series of fundamental papers on band-to-band elastic and inelastic tunneling in semiconductors, which immediately made him world-famous. The strongest resonance resulted from his work on the shift of the edge of interband absorption towards lower energies in response to an external electric field applied to the semiconductor. This phenomenon stems from the tunneling penetration of electron wave functions into the forbidden energy band, which is bent by the electric field. This effect was soon detected experimentally and is known as the Franz – Keldysh effect. It is widely used in various fields of optics and laser technology for high-frequency modulation of light flux.

During the same time (up to the mid-1960s), L V Keldysh published another set of important results. He was the first to suggest the use of the spatially periodic fields to form artificially induced crystal spectra caused by additional Bragg reflections due to these fields. Later this idea was implemented in the creation of artificial superlattices. L V Keldysh developed the theory of deep levels created by multiply charged impurities in semiconductors, which made it possible to interpret the recombinational activity of defects of this type, caused by a charge carrier incident onto the center. The theory developed by L V Keldysh of multi-photon ionization of atoms in the field of high-intensity electromagnetic waves was an important contribution to laser physics.

When these results were published, nearly 10 years had passed since L V Keldysh entered the postgraduate course. It was necessary to think about his thesis. But even in this, Keldysh chose his own path: he refused to present a thesis

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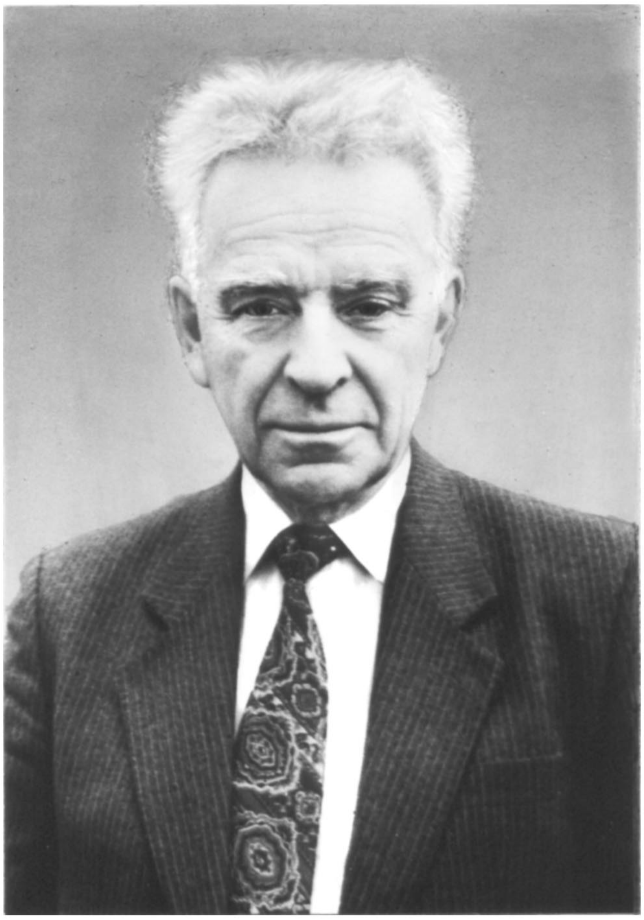

Leonid Veniaminovich Keldysh

composed of already published work. He decided to merge them into a coherent whole by a unifying mathematical technique. Thus was born (in 1964) the Keldysh diagram technique for strongly non-equilibrium steady-state processes. L D Landau had a high opinion of this work. Nowadays Keldysh's method is widely used by theoretical physicists. It was possible to extend it to a non-steady-state case, which led to the introduction of the Keldysh action. L V Keldysh's PhD thesis was unanimously reclassified as a DSc.

The next stage in L V Keldysh's research was tightly bound to the concept of exciton and various kinds of phase transitions in equilibrium and non-equilibrium systems. He began to write with co-authors and started forming a semiconductor science school. We will not list all his co-authors and students here: this text is devoted to the anniversary of Leonid Veniaminovich himself.

The same year, 1954, saw the publication of his work on the Bose condensation of equilibrium excitons under conditions when the binding energy exceeds the band gap of the semiconductor. A favorite candidate for this type of phase transition is a semi-metal with electron and hole Fermi surfaces that are congruent in momentum space in the translation to a fixed unit vector of the reciprocal lattice. The theory resembled that of superconductivity but had a number of essential distinguishing features. First, the electron-hole pairing occurs for a fixed momentum, not energy as in the BCS model; secondly, the order parameter is found to be fixed owing to the allowed annihilation of the electron-hole pair. This forbids such super-phenomena as super-thermal-conductance. This model is known as the exciton insulator. Extended further, this model was able to describe a very wide range of phase transitions: structural transitions, charge and magnetic phase transitions in the approximation of a small binding constant, which is responsible for its mathematical reliability.

Later L V Keldysh tackled the problem of collective properties of electron-hole systems. In 1968 he investigated the conditions of Bose condensation of non-equilibrium excitons, caused by their internal structure. It proved possible to develop a consistent microscopic derivation of Ginzburg – Landau-type equations that describe this condensate. It was shown that dissipationless energy transfer is possible in such systems, despite their finite lifetime.

However, it was found in the course of this work that non-equilibrium electrons and holes in semiconductors show a tendency rather to coalesce into metallic droplets than to form a Bose condensate. L V Keldysh explained this phenomenon in terms of the exchange electron – electron and hole – hole interaction. Then, together with a large group of colleagues, he was able to prove this statement rigorously for a hypothetical semiconductor with an infinite number of valleys. Numerous experiments were conducted which confirmed Keldysh's hypothesis. Among these, we need to specifically mention the anomalous diffusion of droplets through non-uniformly deformed semiconductor, and the observation of the phonon wind.

At the time of writing of this text, L V Keldysh continues vigorous research in one of the hottest fields in today's theory of condensed media: the collective properties of light-generated excitons exited by a powerful femtosecond laser pulse.

L V Keldysh's research achievements enjoy the highest standing both in this country and abroad. He received both the Lomonosov and the Lenin Prizes, as well as the Prize of the European Physical Society: he is a full member of the Russian Academy of Sciences, a member of the National Academy of Sciences of the USA and of the American Physical Society, and President of the Russian Physical Society. The outstanding pedagogical effort of L V Keldysh in training the new generations of physicists must definitely be mentioned. He became a professor of the Moscow Physico-Technical Institute in 1962, a professor of Moscow University in 1965, and has headed the chair of quantum radiophysics of the physics faculty of the university since 1988. Regardless of whether his collaborators be doctors of sciences or young students, L V Keldysh treats them with invariable attention, kindness and tact. One unfortunate result of this is that sometimes he has to bear listening to the long-winded, half-baked ideas of his interlocutors. However, L V Keldysh leads his students first and foremost by the personal example of serving physics above everything.

Several words need to be said about the stages in the career of L V Keldysh as a science manager. Already heading the chair of theoretical physics of FIAN, he was elected in 1989 to the directorship of FIAN, and in 1991 to the position of the Secretary Academician of the Division of General Physics and Astronomy of the Russian Academy of Sciences. This was certainly not the best period in the history of the country. Science was simply sidelined during the onslaught of the raging crisis. Many research institutes chose to sell out or to rent out their primary assets; this, in the long run, lead to their complete demise. L V Keldysh was able under these dramatic circumstances to keep the ship of FIAN afloat with minimum losses, displaying the highest sense of responsibility and administrative brilliance.

We wish to congratulate Leonid Veniaminovich Keldysh from the bottom of our hearts on his 70th anniversary, wish him robust health and new achievements that will glorify theoretical physics.

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V P Silin, V Ya Faĭnberg,
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