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PERSONALIA

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Yurii Vasil'evich Kopaev (on his 70th birthday)

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Professor Yurii Vasil'evich Kopaev, corresponding member of the Russian Academy of Sciences (RAS), Director of the Solid State Physics Division of the RAS P N Lebedev Physical Institute (FIAN), had his 70th birthday on 21 October 2007.

Yurii Vasil'evich manifested his serious interest in physics while still a student. The paper that the student Yu V Kopaev sent for publication was reviewed by a FIAN young research scientist L V Keldysh who wished to meet the juvenile author. This meeting and subsequent collaboration in research played a decisive role in the career of Yu V Kopaev.

In 1964 Keldysh and Kopaev published the famous paper on the theory of insulator phase transitions (the Keldysh – Kopaev model) in which they showed that the modified formalism of the BCS theory of superconductivity can be effectively used for a description of metal – insulator phase transitions in solids. The phase transition arises in the model no matter how weak the interelectron interaction and, by analogy with the superconducting transition, can be interpreted as the Bose condensation of electron – hole pairs (excitons). The insulator phase in the Keldysh – Kopaev model was subsequently rechristened the 'excitonic insulator' — the term that is now in general use. In fact, the Keldysh – Kopaev excitonic insulator model became a standard way of describing interelectron correlations in the weak interaction limit. The importance of the exciton model of insulators follows largely from the fact that it describes (in a unified framework) an entire family of phase transitions with different types of symmetry of the ordered phase. The order parameter of the model characterizes the contribution of interelectron correlations to the self-consistent crystal potential. This potential has a complicated spin and phase structure that determines the type of ordering. Yu V Kopaev and coworkers showed that the excitonic insulator model describes a wide variety of experimentally observable states: charge and spin (band antiferromagnetism) density waves, weak ferromagnetism of collectivized electrons, and the ferroelectric state in nonionic crystals. Yu V Kopaev and his coworkers also studied various exotic states that arise in this model: states with spin and charge current (orbital antiferromagnetism). This last state is interesting in that under certain conditions it describes a qualitatively new type of ordered state in which the ordering parameter is the density of the toroidal dipole moment (toroidal moments are the third independent family, along with the electric and magnetic moments, of electromagnetic multipoles). It was also shown that microinhomogeneous toroidal orbital antiferromagnets can have anomalously high diamagnetism. Later, the ideas of Yu V Kopaev and his colleagues on ordered states with spontaneous currents were further developed in papers on strongly correlated states in connection with the problem of high-temperature superconductivity, where they are known as 'flux phases'.

Yurii Vasil'evich Kopaev

In 1982 Yu V Kopaev, together with a team that submitted the completed project "Prediction, detection and study of gapless semiconductors and exciton phases," received the USSR State Prize.

A large series of papers written by Yu V Kopaev and coworkers is devoted to studying nonequilibrium phase transitions in semiconductors. In these papers the authors provide a reliable theoretical foundation to popular ideas of the analogy to laser generation phenomena and the phase transitions, and for the first time analyze them with mathematical rigor. Thus, Yu V Kopaev and his colleagues suggested and studied in detail the electron mechanism of laser annealing. The destruction of crystal structure connected with the formation of structural instability in response to the excitation of nonequilibrium charge carriers (nonequilibrium phase transition) is indeed observed in a number of semiconductors. This body of work, "The discovery of the phenomenon of pulse-oriented crystallization in solids (laser annealing)," received the USSR State

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Prize in 1988 (awarded to the team of authors). At the moment the main theoretical results generated in this field have proved immediately useful in connection with the active research effort on nonlinear nonequilibrium effects in microresonators, whose fabrication became possible owing to progress in nanotechnology.

In the field of physical foundations of nanoelectronics, Yu V Kopaev and his colleagues formulated new principles of processing and converting information based on controlled restructuring of coherent states of quantum heterostructures that contain tunneling-linked quantum wells, and proposed new types of functionally integrated quantum logic elements. Yu V Kopaev, in collaboration with V F Elesin, developed a microscopic kinetic theory of a quantum cascade laser and suggested design options that result in lower critical currents and increased operating temperature.

A considerable part of Yu V Kopaev's research activities has been devoted to investigating the physics of the superconducting state. Much of this research was carried out while he worked at the FIAN Theoretical Physics Division, where he had been invited by V L Ginzburg to join the high-temperature superconductivity group. Yu V Kopaev investigated the possibility of constructive interference of insulating and superconducting correlations long before the discovery of high-temperature superconductivity (HTSC) of cuprates that are doped insulators. It was shown for the first time that the partial dielectrization of the electron spectrum can result in a considerable rise in the superconducting transition temperature. Furthermore, the structure of coherence factors changes, so the kinetic characteristics of such a system may differ significantly from the BSC model. The isotopic effect in a superconductor with insulating correlations may be to a large extent suppressed. A characteristic feature of such systems is the phase stratification that should be observable in a wide range of parameters of the system. A main part of this research program was published in the collective monograph *Problems of High-Temperature Superconductivity*, published in 1977 (editors V L Ginzburg and D A Kirzhnits).

Later, Yu V Kopaev and his colleagues applied the diagrammatic technique to nonequilibrium processes and studied in detail nonequilibrium states that are formed in superconductors with an excess of quasiparticles (in comparison with their thermal production). As a result, they discovered a whole new range of phenomena for which certain specific features of the nonequilibrium distribution function of quasiparticles is responsible. It was thus shown that, depending on the sign of the interelectron interaction and the type of paring in nonequilibrium conditions, spatially nonuniform states of various types may be formed in superconductors.

In recent years, Yu V Kopaev et al. have suggested and elaborated a new mechanism of superconductivity that takes into account the specifics of the electron structure of HTSC cuprates that permit superconducting pairing with the large total momentum of each pair under shielded Coulomb repulsion. This mechanism leads in a natural manner to the possibility of the existence of noncoherent superconducting pairs in a very wide temperature range of the pseudogap state immediately above the temperature of superconducting transition. The study of competition and coexistence of the superconducting and dielectric states in HTSC cuprates led to understanding the nontrivial momentum dependence of the superconducting order parameter, as well as to a qualitative interpretation of the phase diagram and key physical properties of cuprates.

Professor Yu V Kopaev has devoted much time to training young scientists and engineers. It has already been 33 years since he started teaching at the Moscow State Institute of Electronic Technology (MIET). He presents courses on Solid state physics, the Physics of semiconductors, the Physical nature of biological fields, Disordered semiconductors, Kinetic processes in semiconductors, and Physics at the foundation of nanoelectronics. Yu V Kopaev's lively, content-rich, and nontrivial lectures were star events for many students, for whom he opened a door to life in science. He was supervisor to 14 PhD students, who successfully defended, of which five later rose to obtain a DSc degree. On Yu V Kopaev's initiative, which preempted many ideas in the Federal "Integration" program, the FIAN and MIET Research & Education Center (REC), Quantum devices and nanotechnologies, was launched in 1994, of which he is Chairman of the Board of Directors. The REC Quantum devices and nanotechnologies merged the research potential of the FIAN Division of Solid State Physics in solid state physics and the physics of semiconductors and the experience of MIET scientists in developing and designing semiconductor devices and integrated circuits based on them for designing and improving quantum devices that can implement new physical principles, and for the joint training of experts in these fields of research. A number of important research programs and design projects have been carried out at the REC in the nanoelectronics domain. It was REC that pioneered in Russia quantum-classical integrated circuits. In 2003 Yu V Kopaev was awarded the Prize of the President of the Russian Federation in Education.

Yu V Kopaev is Deputy Editor-in-Chief of the *Journal of Experimental and Theoretical Physics*, sits on the "Electronics" Editorial Board of the Institute of Higher Education Establishments and on the Learned Council of the RAS P N Lebedev Physical Institute, is a member of the Specialized Learned Councils of FIAN, IOFAN (General Physics Institute), and MIET, and chairs the section of Theory of condensed state of the RAS Science Council on the Physics of condensed media. For many years now Yu V Kopaev has organized and chaired monthly meetings of the scientific sessions of the RAS Division of Physical Sciences on fundamental problems in physics.

For his many years of work and for his research achievements Yu V Kopaev was awarded the Order of Honor.

We wish Yurii Vasil'evich all the best from the bottom of our hearts on his jubilee year and wish him good health and further creative success.

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S N Bagaev, V L Ginzburg, A A Gorbatsevich,
V F Elesin, L V Keldysh, O N Krokhin,
E G Maksimov, G A Mesyats, Yu A Chaplygin