40 YEARS OF M.M. BOGOLYUBOV INSTITUTE FOR THEORETICAL PHYSICS OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE

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M.M. Bogolyubov Institute for Theoretical Physics was founded according to the decision of the Presidium of the Academy of Sciences of Ukrainian SSR №7 on January 10, 1966, adopted to the implement the decision of the Council of Ministers of Ukrainian SSR on January 5, 1966. The founder and the first Director of the Institute was Mykola Bogolyubov, the prominent Ukrainian mathematician and theoretical physicist, Academician of the Ukrainian and USSR Academies of Sciences. The Institute was created with the purpose to provide a high-level of theoretical researches in the most advanced fields of physics, in particular, nuclear physics, physics of elementary particles, and statistical physics.

The establishment of the new Institute was preceded by a sound preparatory work. A considerable contribution belonged to Correspondent Member of the Academy of Sciences of Ukraine Vitaly Shelest (the first Vice-Director of the Institute) and Prof. Albert Tavkhelidze (now Academician of the Russian Academy of Sciences). The promotion by Petro Shelest, the First Secretary of the Central Committee of the Communist Party of Ukraine, and the active support of Borys Paton, the President of the Academy of Sciences of Ukrainian SSR, has been of crucial importance for obtaining the necessary govermental approvals and adopting the final official decision concerning the creation of the Institute.

The functioning of the newly created Institute owed much to the efforts of the Scientific Secretary Prof. V.P. Gachok, and the management director Z.Sh. Kaplun.

The new Institute consisted of three Departments: Mathematical Methods in Theoretical Physics (headed by Academician Ostap Parasyuk), Nuclear Theory (headed by Academician Alexander Davydov), and Theory of Elementary Particles (headed by Prof. Albert Tavkhelidze, since 1969 – by Correspondent Member of the Academy of Sciences of Ukrainian SSR Vitaly Shelest).

Later on, the structure of the Institute has been modified and improved according to the development of various research fields. The Institute incorporated the Department of Nuclear Theory and Nuclear Reactions (headed by Academician A.G. Sitenko) in 1968, and Department of Gravity Theory (headed by Academician A.Z. Petrov) in 1970. In 1969, the Department of Statistical Theory of Condensed Matter was organized in Lviv (headed by Prof. Ihor Yukhnovsky, now — Academician of the Academy of Sciences of Ukraine). This department was transformed into the Lviv division "Statistical Physics" (1980), then, in 1990, made the basis for the newly founded Institute of Condensed Matter Physics of the Academy of Sciences of Ukraine. In 1982—1985, the Institute has the Department of Solid State Physics headed by Victor Baryakhtar, Academician of the Academy of Sciences of Ukraine.

The first Head of the Institute, Mykola Bogolyubov, belonged to the most brilliant physicists of the twentieth century. His personality to a great extent determined the high level of the research work in the Institute and the high requirements to the researchers. Very soon, the research staff included high-level experts in quantum field theory, theory of elementary particles, gravity theory, theory of nuclei and nuclear reactions, solid state theory, plasma theory. Among them — Academicians of the Academy of Sciences of Ukraine A.S. Davydov, O.S. Parasyuk, A.Z. Petrov, A.G. Sitenko, I.R. Yukhnovsky, Correspondent Members of the Academy of Sciences of Ukraine V.P. Shelest, P.I. Fomin, Professors V.Ya. Antonchenko, I.P. Dzyub, G.F. Filippov, V.P. Gachok, Yu.B. Gaididei, V.F. Kharchenko, A.U. Klimyk, M.A. Kobylinsky, V.M. Loktev, Yu.M. Lomsadze, A.F. Lubchenko, Yu.L. Mentkovsky, V.A. Miransky, V.I. Ovcharenko, E.G. Petrov, D.Ya. Petryna, O.O. Serikov, B.V. Struminsky, I.V. Symenog, I.I. Ukrainsky, I.P. Yakymenko, V.A. Yatsun, G.M. Zinovjev, and many others. The first generation of the researchers of the Institute had been pioneers who discovered new phenomena and effects and developed new theories which have been given their

The Heads of the Institute for Theoretical Physics Academicians (from left to right) A. Davydov (from 1973 to 1988), A. Sitenko (from 1988 to 2002), and M. Bogolyubov (from 1966 to 1973)

names. Among other results, such are the justification of the method of unified field theory renormalization (Bogolyubov–Parasyuk theorem), theory of collective excitations in nonaxial and deformed atomic nuclei (Davydov–Filippov model and Davydov–Chaban model), theory of absorption-band splitting in molecular crystals (Davydov splitting), theory of nonlinear excitations in one-dimensional molecular chains (Davydov solitons), diffraction theory of high-energy nuclear reactions (Sitenko–Glauber theory), classification of gravity fields (Petrov types), prediction of the magnetic structure of hard-oxygen β-phase (Loktev structure), discovery of the instability of physical vacuum that makes it possible to regard vacuum as the initial state of the Universe (Fomin model), etc. These and other results provided the Institute a leading position in various fields of theoretical physics.

The second and the third Heads of the Institute, world-renowned theoretical physicists Academicians Alexander Davydov (from 1973 to 1988) and Alexej Sitenko (from 1988 to 2002) have considerably contributed to its development. New trends of studies have been initiated, and both the number and the level of the researchers have grown. Several schools on topical problems of theoretical physics have been formed: Bogolyubov–Parasyuk school in mathematical physics and quantum field theory, Davydov school in solid-state theory, Sitenko school in nuclear and plasma theory, Fomin school in relativistic astrophysics, cosmology, and elementary particles.

An important role in the formation of the Institute as a modern center of theoretical physics belonged also to Academicians I.R. Yukhnovsky, V.G. Baryakhtar, and Correspondent Member D.Ya. Petryna who have worked in the Institute for some time and favored its development.

Now the staff of the Institute consists of 245 people, 125 research workers among them. These include two Academicians of the Academy of Sciences of Ukraine (O.S. Parasyuk, V.M. Loktev), three Correspondent Members of the Academy of Sciences of Ukraine (A.G. Zagorodny, E.G. Petrov, P.I. Fomin), 40 doctors, and 60 Candidates of Physics and Mathematics.

The Institute consists of 13 departments dealing with the most topical problems of theoretical physics: nuclear and quantum field theory, astrophysics and theory of elementary particles, nonlinear physics of condensed state, mathematical methods of theoretical physics, theory and simulation of plasma processes, physics of high energy density, quantum electronics, quantum theory of molecules and crystals, synergetics, structure of atomic nuclei, computational methods of theoretical physics, mathematical modelling. The studies are concentrated in the fields substantially concerning advanced trends of the modern theoretical physics — astrophysics and high-energy physics, relativistic and quantum cosmology, theory of nuclear systems, quantum field theory and theory of symmetries, theory of nonlinear processes in macromolecular structures, nanosystems and plasmas, dynamics of open strongly nonequilibrium physical, biological, economic, and information systems. Quite a number of results obtained has been widely recognized by the international physical community.

The studies in relativistic and quantum cosmology have led to the development of the inflational model of the expanding Universe. New cosmological models are proposed which extend the brane theory. The conditions are found for the Dicke superradiance effect to occur for electrons in a magnetic field. The last effect is shown to provide an explanation of the superstrong decametric radiation generated by planetary objects.

The considerable achievements in high-energy physics concern the development and application of phenomenological models of elementary particles. The statistical approaches in dual models are proposed and employed to study the multiple production of secondary particles under high-energy hadron collisions. The analytical dual models of hadron collisions are worked out.

The group-theoretic and symmetry methods of quantum field theory and new nonperturbative approaches to the treatment of quantized fields are extensively developed and applied, in particular, in the study of the dynamic mass generation mechanism in gauge field theories as well as conditions for the manifestation of the instability of the quantum electrodynamic and chromodynamic vacuum of massless phases with respect to the initiation of a violated-symmetry massive phase. A general approach is proposed to the construction of a weak-interaction theory in six- and eight-quark models. A new approach is developed in the instanton model of quantum-chromodynamics vacuum, the effect of the color field on the instanton liquid is considered. A method of experimental study of the state of the strongly interacting matter formed at the initial stage of nucleus-nucleus collisions is proposed; the predicted nonmonotonic energy-dependence of the ratio of the numbers of produced strange to nonstrange hadrons is in full agreement with the experimental results.

The applied aspects of the theory of representations of Lie groups and algebras which are the mathematical basis of studying the symmetries in quantum physics are developed. New chapters of the theory of quantum groups are worked out and applied to construct the solutions of physical problems.

In the field of theoretical nuclear physics, a nonrelativistic theory of three- and four-nucleon systems with binary interactions is developed in terms of integral equations, and the efficient methods are proposed for constructing the solutions thereof. The polarization of few-body nuclear systems in electric fields is described in terms of a new microscopic method and the effect of the nucleus structure on the probability for a charged particle to approach a multiparticle nucleus.

A new microscopic treatment of three-cluster configurations in light atomic nuclei is applied to study the bound states of helium-III and helium-IV and the light-nucleus decay dynamics in two- and three-cluster channels.

A model-free description of the three-nucleon nuclear processes is proposed. Few-nucleon systems are described in terms of a new approach that makes no use of the isospin formalism and thus ensures the extremely high accuracy in the treatment of basic structural characteristics of the lightest nuclei.

The Dirac Hamiltonian is employed to derive Schrödinger–Breit-type relativistic equations for two fermions. A quantum three-particle system is considered near the two-particle threshold in the region where the Efimov effect is manifested, and the excited weakly bounded states of this system are studied.

The level of theoretical solid-state physics in the Institute is traditionally high. The exciton theory is employed to explain the peculiar features of vibronic spectra in molecular crystals. The spectra of solid-state oxygen are considered, and the splitting of biexciton absorption bands in the antiferromagnetic phase of oxygen is revealed. Thus, a solution of the problem that had remained unsolved for more that 30 years is derived. A new linear magnetooptical effect is predicted that makes it possible to prove the domain existence in antiferromagnets experimentally. Electron excitations in quasi-one-dimensional systems are studied with regard for the electron-electron interaction. The resonance decay of phonons is predicted. A theory of exciton states in magnetically ordered crystals is developed, and a new phenomenon, “magnetic Davydov splitting”, is predicted.

A new model is proposed to describe the impurity centers in high-temperature superconductors with regard for the influence of copper ions on superconducting particles near the impurity. For the case of symmetric pairing, the crossover from Bose–Einstein to Bardeen–Cooper–Schrieffer superconductivity is shown to occur both under local and indirect interactions. A model is proposed to describe the shape-memory effect in weakly-doped cuprates exposed to an external field.

The dynamical properties of the charging of solitons in low-dimensional discrete molecular systems with the electron-phonon interaction are studied. Electrosolitons are shown to emit an electromagnetic field, whose frequency is determined by the soliton velocity.

The spontaneous generation of a gap in the spectrum of one-particle quasi-excitations in graphite is shown to accompany the metal-dielectric phase transition. This prediction is confirmed experimentally. The theory of de Haas–van Alfven and Shubnikov–de Haas effects is developed for planar graphite systems, and thus new phenomena are predicted and then observed experimentally, in particular such as the phase shift of oscillations of the magnetization and conduction, temperature-sensitive dependence of the oscillation amplitude on the carrier density, unusual quantization of the Hall conduction, etc.

Fullerene-based crystalline structures are described in terms of a new quantum-mechanical model taking into account the correlation specificity of the electron structure of fullerene and its charge modifications in crystals under their chemical and field doping.

Analyzing the experiments on breaking the symmetry in the high-frequency nonlinear resonance responses of consolidated materials, a model of the slow dynamics and hysteresis has been proposed.

Nonlinear magnetic excitations (vortices) in a ferromagnet exposed to an external magnetic field are described in terms of a new dynamical theory taking into account both the dissipation and the intrinsic degrees of freedom of a vortex. A new efficient method is proposed that makes it possible to control the magnetic state of a quantum dot by means of a circularly polarized magnetic field.

In the field of soft-matter physics, a microscopic model of superfluid helium-II is developed by assuming the lattice ordering of helium atoms and a high probability of the band-related tunnel flow of atoms through the lattice they form.

General approaches are worked out to describe the donor-acceptor electron transport in molecular structures. In particular, a model is proposed for the unified treatment of the hopping and superexchange mechanisms of electron transport over linear bridge structures under conditions of the strong relaxation.

The delay of the luminescence in biological systems is shown to be associated with nonlinear effects conditioned by the collective electron states.

A detailed analysis of the electron transport in macronanodevices with fullerene granules, rodaxen molecules, and DNA as active elements is carried out, and the regularities of an external influence on the nonlinear resonance tunneling are studied.

The numerical simulation is employed to study the properties of small volumes of water. The water structuring near the surface is revealed. A soliton model of the proton transport in the chains of water molecules is proposed.

A theory of the hypochromic effect in DNA is worked out, and the conformational mechanisms of the functioning of DNA are studied. A new mechanism of the macroscopic deformation of polymorphic molecules is proposed which implies the structural deformation of a macromolecule to be induced by localized conformation excitations.

The kinetics of two-level systems in a slowly relaxing protein surrounding is studied, and the kinetic modes of donor-acceptor and sorption reactions which provide evidence for the existence of structural self-organization and memory effects in repeated reaction cycles of a protein macromolecule are described.

The kinetic models of biochemical processes are constructed, in particular, the models of a nanobiosensor and a bioselective membrane. Autocatalytic and chaotic modes are discovered, and the initiation conditions of these modes are revealed.

The considerable results are obtained in plasma theory. A theory of electromagnetic fluctuations and the nonlinear wave interaction in nonequilibrium plasmas is worked out. Microscopic and phenomenological approaches to the description of fluctuations in a plasma with large-scale perturbations (turbulent plasma) are proposed. A kinetic theory of plasma-molecular systems is developed.

The theoretical grounds are formulated for a consistent kinetic description of electromagnetic processes in dusty plasmas with regard for the charging of grains by plasma currents. The diffusion of the grain charging in random potential fields with given statistical properties is analyzed in terms of a non-Markovian generalization of the Fokker-Planck equation, and thus a new theory of time-nonlocal transport processes is proposed.

The Monte Carlo simulation is applied to study the thermodynamic and structural properties of a one-component strongly coupled plasma in a quasi-one-dimensional geometry near the point of the liquid-crystal phase transition.

The growth of a grain introduced into a plasma is studied in terms of the Brownian dynamics, and the correlation functions of charge fluctuations are found. A noticeable weakening of the charge screening is revealed and shown to be associated with plasma flows.

During the last decade, the fundamental studies in financial mathematics and mathematical economics have been initiated and developed in the Institute. A mathematical model of the business cycle is proposed and employed to show that the supply-and-demand system leads to a continuous chaotic regulation through the inflation mechanism.

A model of the economic balance under indeterminacy conditions and a model of economic transformations are worked out and employed to analyze the state of Ukraine's economy and to propose the means to remove the economic deformations and to maintain the level of the economic development.

The above-presented enumeration of the results obtained is far from being complete since the size of this paper is restricted. The author hopes to be kindly understood by the colleagues, whose results are not mentioned.

The researches of the Institute publish yearly about 250 papers in Ukrainian and international scientific journals and present about 100 talks at various conferences. Over 80 books and about 40 proceedings of scientific conferences have been published during 40 years of Institute's history.

The Institute has initiated quite a number of international and national conferences. The most representative of these are the XI Rochester Conference on High-Energy Physics (1970), a series of international conferences "Nonlinear World" (1973, 1979, 1987, 1989), International Conference on Quantum Chemistry, Biology, and Pharmacology (1977), International Conference on the Properties of Liquids in Small Volumes (1990), 23th European Conference on Controlled Fusion and Plasma Physics (1996), international conference "Modern Problems of Theoretical Physics" dedicated to the ninetieth anniversary of the birthday of Academician A.S. Davydov (2002).

In 1993, the Institute held the International Conference "Physics in Ukraine" which was rather important for the integration of physicists of the independent Ukraine's state. The Institute also contributed to the organization of the Ukrainian Congress "Physics in Ukraine" (2005).

Scientists from many countries have regarded as remarkable events the Moscow–Dubna–Kyiv Bogolyubov Conference (1999) and Kyiv Bogolyubov Conference (2004).

The Institute has initiated and considerably contributed to the organization of a series of International Conferences on Plasma Theory, in particular those held in Kyiv (1971, 1974, 1987). The conferences on plasma theory are called "Kyiv Conferences", with this name they are held in many countries since 1976. The Institute is proud to organize the next conference of the series in 2006, again in Kyiv.

More than 30 international and domestic conferences have been held in the Institute during the last five years.

The Institute works in close cooperation with the institutions of higher education. The researchers of the Institute give over 20 lecture courses for the students of Taras Shevchenko Kyiv National University, National Technical University "Kyiv Polytechnical Institute", National University "Kyiv Mohyla Academy", etc.

The international scientific contacts of the Institute are traditionally extensive. The foreign partners of the Institute are The Joint Institute of Nuclear Research (Dubna, Russia), CERN — European Organization for Nuclear Research (Geneva, Switzerland), Chalmers Technical University (Göteborg, Sweden), Theoretical Physics Institute of Bern University (Switzerland), Physical Institute of Bonn University, Brookhaven National Laboratory (USA), Henri Poincaré Université (Nancy, France), York University (Toronto, Canada), West Ontario University (London, Canada), Massachusetts Institute of Technology (USA), and many others. The results of mutual researches are published in about 25 papers yearly.

Since 2003, the Institute honors Ukrainian and foreign colleagues by the degree of Doctor Philosophiae Honoris Causa of the Bogolyubov Institue for Theoretical Physics for the world-distinguished contribution to theoretical results and the contribution to the scientific cooperation. This title has been conferred on the Foreign Member of the Academy of Sciences of Ukraine R. Jackiw (USA), Prof. W. Greiner (Germany), Academicians of the Academy of Sciences of Ukraine V.G. Baryakhtar and I.R. Yukhnovsky, Correspondent Member of the Academy of Sciences of Ukraine V.P. Shelest, Academicians of the Russian Academy of Sciences V.G. Kadyshevsky and A.N. Tavkhelidze. For the remarkable contribution and support of theoretical physics in Ukraine, the degree of Doctor Philosophiae Honoris Causa of the Bogolyubov Institue for Theoretical Physics is conferred on the President of the Academy of Sciences of Ukraine B.E. Paton.

In view of the pressing need to involve young researchers (unfortunately, for the known reasons, the mean age of the Institute's staff has increased similarly to other scientific institutions of Ukraine), the Institute takes all possible measures to attract talented young people. For this purpose, the Institute supports the Scientific and Educational Center that provides the continuous physical and mathematical education for the pupils of physical and mathematical schools and university students dealing with physics and mathematics. The main task of the Center is to provide talented students with extensive knowledge beyond the scholar programs and to show that the level of physical education in Ukraine in not lower, and in any cases higher that the relevant level in Europe and USA. The Center is rather popular among Kyiv young people, more than 50 students take part in its activity. A much interest is attracted by the international conferences on theoretical and mathematical physics for young scientists (pupils, students, and postgraduates) held each year together with the Institute of Theoretical and Experimental Physics (Moscow).

The Institute works much to implement advanced informational and computational, in particular GRID, technologies to scientific studies. A computational cluster is created and is made use of in the

ALIEN-GRID project aimed to provide the future ALICE experiment on the Large Hadron Collider in CERN. Thus, the Institute is the first Ukrainian participant of the European CRID collaboration. The Institute makes efforts to extend the network and the application of GRID technologies in Ukraine and to create the first Ukrainian GRID-segment including the Bogolyubov Institute for Theoretical Physics, Main Astronomical Observatory, Institute of Molecular Biology and Genetics, Institute of Cell Biology and Genetic Engineering, and Taras Shevchenko Kyiv National University.

The achievements of the researchers of the Institute are widely known both in our country and abroad. They have been awarded two Lenin Prizes (Academicians A.S. Davydov, A.Z. Petrov, Prof. A.F. Lubchenko); eight State Prizes of Ukraine in Science and Technology (Academicians A.S. Davydov, A.G. Sitenko, V.M. Loktev (twice); Correspondent Members of the Academy of Sciences of Ukraine A.G. Zagorodny, E.G. Petrov; Professors I.P. Dzyub, Yu.B. Gaididei, Z.A. Gursky, A.U. Klimyk, V.I. Zasenko); ten prizes bearing the names of outstanding Ukrainian scientists (Academicians A.G. Sitenko (twice), O.S. Parasyuk (twice), V.M. Loktev; Correspondent Members of the Academy of Sciences of Ukraine A.G. Zagorodny, E.G. Petrov, P.I. Fomin; Professors O.O. Yeremko, V.A. Miransky, V.I. Ovcharenko, Yu.A. Sitenko, G.F. Filippov, I.P. Yakimenko); two international awards of the Humboldt Foundation (Correspondent Member E.G. Petrov, Prof. M.I. Gorenstein); the Award of the President of Ukraine for young scientists (Ph.D. Ya. Zolotaryuk, S. Mingaleev, Yu. Khalak).

I am sure, however, that the main achievement is that the Institute has preserved and enlarged its scientific potential that enables the research workers to be sensitive to the newest trends of modern theoretical physics, to understand the essence of the most advanced ideas, and to take part in the studies which form the frontiers of physics. Together with other centers and departments (rather few now) dealing with the fundamental studies in theoretical physics, the Institute maintains the highest education level in physics. No doubt, the Institute has to preserve an appropriate position in the world theoretical physics, which is one of its main tasks for the future. The researchers of the Institute face the fortieth anniversary of the Institute with the will to fulfil this task and to be worthy of their outstanding predecessors.