# Superconducting and mesoscopic structures: in honor of A. N. Omelyanchuk's 70th birthday

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July 28th, 2017 marked the 70th birthday of Professor Alexander Nikolaevich Omelyanchuk, Corresponding Member of the National Academy of Sciences of Ukraine, a well-known physicist and an organizing force in science. His scientific work is inextricably linked with the B.I. Verkin Institute for Low Temperature Physics and Engineering, where he advanced from being a graduate student to being the head of department—A. N. Omelyanchuk has led the Department of Superconducting and Mesoscopic Structures for 16 years. Alexander Nikolaevich is a member of several scientific councils and is a member of the editorial board of FNT. A. N. Omelyanchuk's students include both Candidates and Doctors of Sciences. He is a laureate of the State Prize of Ukraine in Science and Technology (2006) for the cycle of scientific studies on the "Effects of Spontaneous Symmetry Breaking and Phase Transformations in Elementary Particle Physics and Condensed Matter Physics." In 2008 A. N. Omelyanchuk was awarded the honorary badge by the MES of Ukraine. He was awarded the prize of B. I. Verkin of the NAS of Ukraine in 2016.

Alexander Nikolayevich's interests include a broad range of scientific problems: weak superconductivity, non-equilibrium phenomena in superconductors, excitable discrete quantum systems. The global scientific community is well acquainted with the Kulik-Omelyanchuk theory, which describes the current states in bridge junctions with direct conductivity between superconducting shores. A. N. Omelyanchuk and his colleagues created the theory of microcontact spectroscopy, which was designated as a discovery in 1988.

This special issue of FNT includes articles from prominent scientists from around the world whose scientific interests coincide with the interests of Alexander Nikolaevich.

In his conceptual article, A. Zagoskin outlines the current state of studies pertaining to structures based on Josephson qubits and the prospects of their development. The potential for modern prototypes of quantum computers and other quantum technologies is critically analyzed; open questions related to using the theory of multiple artificial atoms to describe metamaterials and quantum processes are acknowledged. An article from the authors of the well-known firm D-Wave Systems, A. Yu. Smirnov and M. H. Amin, with whom A. N. Omelyanchuk published a number of papers on the theory and experimental studies pertaining to Josephson qubit systems, is dedicated to the theory of measuring the states of multi-qubit systems. In this study the authors discuss using qubit tunneling spectroscopy in order to implement the quantum state tomography. The group led by E. Ilyichev from the Institute of Photonic Technologies (Jena, Germany), with which A. N. Omelyanchuk has worked successfully for many years, presents on the technological aspect of working with Josephson junctions. The article by G. Olsner and his co-authors describes the methods for creating small-size contacts, which are important for the realization of qubits, microwave detectors, SQUID magnetometers and superconducting digital electronics. The study authored by J. Kunert and co-authors from the Institute of Photonic Technologies discusses the technological aspects of preparing low-temperature and high-temperature Josephson junctions for applied purposes and the development of microwave photon detectors with sensitivity close to the quantum limit. The article by N. V. Klenov and co-workers from Moscow and Nizhny Novgorod examines the use of qubits in rapid single flux quantum logic circuits and also presents and develops a theoretical apparatus for describing the dynamic behavior of such hybrid systems that involve both classical and quantum subsystems. A work authored by A. N. Omelyanchuk's students and coworkers from Novisibirsk (A. N. Sultanov *et al.*) describes the passage of photons through a structure consisting of two qubits and two resonators. It is shown that even in the absence of direct interaction between qubits the photon passage leads to effective coupling of the states in the system.

The work by M. A. Belogolovsky *et al.* is a review of the possible implementations of internally shunted Josephson junctions that are required for superconducting logic circuits, and the original experimental results related to this dilemma are discussed. The study by A. G. Semenov and A. D. Zaikin presents the development of quantum fluctuation theory for the case of magnetic flux tunneling though a superconducting nanowire; a theory based on the Keldysh path integral approach is presented consistently and methodically, and a number of original results are presented. The study by D. Massarotti and co-authors classifies the behavior of Josephson junctions in unconventional hybrid compounds, based on the CVC features of such systems; a phenomenological approach to describing the compounds, which are characterized by relatively high critical current $J_c$ densities, is proposed. The physical processes that occur in high-temperature transitions are discussed. I. R. Rahmonov and co-authors present the results of calculating the characteristics of dc-SQUIDs with topologically nontrivial barriers. Formulating the problem in this manner makes it possible to study not only the Cooper pairs, but also the Majorana fermions, as well as the ratio between these two components. Superconducting quantum arrays produced using niobium technology are discussed as a means of linearizing the response to a magnetic signal and significantly increasing the dynamic range of its measurement in the study by V. K. Kornev *et al*. The cells of such arrays are so-called bi-SQUIDs, which are SQUIDs with additional nonlinear inductive elements in the form of a Josephson junction shunting the main inductance of the quantization loop, and are examined in detail.

The study by A. Sidorenko is a revelation of the scientific appetite for new quantum phenomena in layered superconductor/ferromagnet hybrid nanostructures and the detection of multi-period reentrant superconductivity and spin-valve effect in such structures, as well as the possibility of their practical application to high-speed superconducting spin valves. The article by Yu. Gaidukov and co-authors from the Max Planck Institute develops new methods for studying such hybrid nanostructures using spin-polarized neutron diffraction. The article from groups led by A. L. Solovjov and R. V. Vovk from Kharkov, with co-authors, is dedicated to studying how praseodymium doping affects the pseudogap and fluctuation conductivity in the YPrBaCuO single crystal. Emphasis is placed on the mutual influence between superconductivity and magnetism. A number of new experimental results are interpreted as the enhancement of the impact the PrBCO intrinsic magnetism has on the properties of single crystals. S. S. Apostolov *et al*. theoretically describe the passage of an electromagnetic wave through a photonic crystal that consists of dielectric layers and one superconducting layer. The latter plays the role of a defect in the photonic crystal, and its presence can lead to an increase in the crystal's transparency. I. V. Kozlov and Yu. A. Kolesnichenko studied the effects the magnetic defect has on the density of states and magnetization of a two-dimensional electron gas. The authors demonstrate the impact spin-orbit interaction has on the Friedel oscillations of the electron density of states near the impurity. M. Moskalets presents a detailed theoretical analysis of single electron emission in his paper. The author accounts for the non-zero temperature and demonstrates that at a certain symmetry of the electron source the effect that temperature has on emission is suppressed. The study by V. E. Shaternik and colleagues is a discussion of the creation and experimental study of thin-film heterostructures that consist of superconducting molybdenum-rhenium alloy electrodes and a hybrid semiconducting tunnel barrier from a nanosized silicon layer with tungsten nanoclusters. It is suggested that the Coulomb blockade, resonant tunneling, and resonant-percolation transport mechanism can be realized in such systems. In his study, B. Ivlev discusses using the solutions to the Schrödinger and Dirac equations to describe the interactions between nuclei in molecules, which could be useful to the description of unusual chemical bonds and similar mesoscopic systems. This volume is concluded by the work of prof. Ouboter from the K. Onnes Laboratory in Leiden, which is co-authored by our honoree. In this study, the authors demonstrate that the electromagnetic field in a superconductor can be described by introducing the concept of photons having nonzero mass.

The editors and authors of this issue of FNT congratulate Alexander Nikolaevich on reaching his jubilee and wish him health and further creative successes!

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