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Quantum technologies in Russia

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Quantum technology today is in the focus of attention of the scientific community. There has even been put forward such a notion as 'the second quantum revolution'. If the first quantum revolution led to the advent of lasers, transistors and GPS at the beginning of the 20th century, today we are talking about the development of quantum computers, quantum simulators and quantum communication systems. It is believed that the main results of the development of quantum technology will be an unprecedented increase in the performance of computing devices and a qualitatively new level of protection for communication systems. In the first case, we need to solve problems that are inaccessible to classical supercomputers, which is of fundamental importance for producing new materials and preparations, as well as for processing large amounts of data and optimising complex systems. In the second case, the goal is to increase the security of information processing and transmitting to a level that does not depend on the capabilities of eavesdroppers and is determined only by the fundamental laws of physics.

In this regard, fundamental and applied scientific research aimed at the development of the element base of quantum optical and spin technologies is very important. The main lines of research are the development of quantum logic devices, quantum memory devices, sources of nonclassical states of light, single-photon detectors and quantum sensors. To date, the most impressive success has been achieved in the field of quantum computers based on superconducting qubits, as well as basic devices of quantum cryptography.

Multi-qubit quantum memory is considered as a platform for developing a universal quantum computer, and devices of multimode optical quantum memory and sources of single-photon light states are supposed to be used in systems of long-range quantum communication through optical fibre channels. At the same time, the fundamental point is the search and study of new materials and structures, which allow the quantum information processing protocols to be effectively implemented. In this regard, much attention is paid to the study of crystals doped with rare-earth ions and defects in diamond. Finally, the implementation of quantum interfaces, which allow optical and microwave quantum circuits to be integrated into a single system, as well as the development of hybrid devices combining the advantages of optical and spin quantum systems, is of great practical importance.

This issue of Quantum Electronics publishes papers on the development of quantum technology in Russia. They largely, though not completely, reflect the scientific directions in which Russian scientists are actively involved and characterise the vector of the development of this field in our country. The developments in the field of quantum technology correspond to the directions of the strategy of scientific and technological development of the Russian Federation, as well as through technologies in the framework of the National Technology Initiative (NTI) and digital economy. An important organisational event was the formation of a consortium to establish the M.V. Lomonosov Moscow State University's Quantum Technologies Centre in accordance with the NTI tasks.

The issue opens with a paper by V.V. Ryazanov and his colleagues, who describe the results obtained so far as part of the implementation of the first Russian project to produce superconducting qubits and a quantum computer based on them. Currently, this project of the Russian Foundation for Advanced Research Projects (the state contractor of the works is Dukhov Research Institute of Automatics) united almost all teams with experimental experience in developing superconducting quantum structures from such institutions as National University of Science and Technology MISIS, Moscow Institute of Physics and Technology, Novosibirsk State Technical University, Institute of Solid State Physics (ISSP) of the Russian Academy of Sciences (RAS), Russian Quantum centre and Bauman Moscow State Technical University. Topical issues related to the study of Rydberg atoms and the development of methods for quantum computations based on them are discussed in the work of I.I. Ryabtsev with co-authors (ISSP RAS). The works of S.A. Moiseev and colleagues present the latest experimental results on the development of optical and microwave quantum memory, which are carried out at the Kazan Quantum Centre of the Kazan National Research Technical University in collaboration with the Kazan Federal University and E.K. Zavoisky Physical-Technical Institute (KPhTI) of the Kazan Scientific Centre (KSC) RAS. The development of single-photon light sources based on spontaneous parametric scattering is discussed in the work of D.O. Akat'eva et al. (KPhTI KSC RAS), and the generation of clustered states of light for the implementation of unidirectional quantum computing is investigated in the work of T.Yu. Golubeva and Yu.M. Golubev with co-authors (St. Petersburg State University). The issue ends with the work of R.A. Akhmedzhanov and his colleagues on the development of magnetometers based on NV centres in diamond, which are conducted at the Institute of Applied Physics RAS.

The papers presented the issue may be of interest to specialists in the field of quantum technology, quantum optics and spectroscopy, as well as to students and postgraduates who want to get an idea of the most challenging problems in these fields of science.

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