

PHYSICS OF ULTRACOLD ATOMS AND THEIR APPLICATIONS

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Physics of ultracold atoms in Russia: topical research

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In the last decade, significant advances have been made in the laser cooling and trapping of atoms and ions. The most widespread schemes are those employing magneto-optical and optical traps for neutral atoms and RF traps for ions, which allow one to reach translational motion temperatures of atoms and ions below 100 μK. The use of ultracold trapped atoms and ions opens up new possibilities for diverse basic and applied studies in atomic spectroscopy owing to the spatial localisation of atoms and ions in a small volume, without transit-time or Doppler broadening. For example, in the case of cold atoms the time of interaction with probe light is determined by the lifetime of an atom in a trap, which reaches tens of seconds. At a low density of atoms, the width of some optical resonances in the atoms can be less than a fraction of a hertz, which allows one to envisage a new generation of atomic frequency standards, with a relative uncertainty less than 10^{-18}. At the same time, at a high density of atoms resonances should broaden and shift as a result of collisions and interatomic interactions, so laser and microwave spectroscopies can be used to follow collisional and collective processes in ensembles of cold atoms. Finally, cold atoms and ions are thought to be promising objects for producing a quantum computer's qubits.

Experimental studies of ultracold atoms were activated in Russia after 2000, when several scientific groups, differing in their research interests, were formed simultaneously. The development and implementation of state-of-the-art ultraprecise optical frequency standards based on ultracold atoms and ions are the main purpose at the Institute of Laser Physics, Siberian Branch (SB), Russian Academy of Sciences (RAS) (Novosibirsk); P.N. Lebedev Physical Institute (LPI), RAS (Moscow); and All-Russia Research Institute of Physical and Radio Engineering Measurements (VNIIFTRI) (Moscow); highly excited ultracold atoms and their applications in quantum information processing are being investigated at the Rzhanov Institute of Semiconductor Physics, SB, RAS (Novosibirsk); researchers at the Institute of Automation and Electrometry, SB, RAS (Novosibirsk) experimentally demonstrated Bose–Einstein condensation; a two-dimensional Fermi gas based on ultracold lithium atoms was produced for the first time at the Institute of Applied Physics, RAS (Nizhnii Novgorod); and researchers at the Joint Institute for High Temperatures, RAS, are investigating the formation of an ultracold plasma of lithium Rydberg atoms. Because of the necessity of sharing experiences and co-ordinating efforts between various research groups, it was decided to held annual working sessions in Novosibirsk on the physics of ultracold atoms, which evolved into full-scale all-Russia conferences.

As a continuation of the previous special issues of *Quantum Electronics* [1,2], this issue presents reports selected by the Conference Organising Committee and the corresponding parts of reports presented at the Physics of Ultracold Atoms 2018 (PUCA 2018) Conference, which was held on 17–19 December 2018. On the whole, the conference programme comprised 32 oral presentations and 6 posters by scientists from 24 Russian institutions (see the Conference website https://www.isp.nsc.ru/quantum18/upload/Program_UltraColdAtoms-2018.doc). The reports were divided into several special sessions: quantum metrology, quantum gases, waves of matter, spectroscopy, quantum computation and laser cooling. In addition, a review report devoted to the 90th birthday of S.G. Rautian, an eminent Russian physicist, was presented. All these directions are represented in this special issue.

References

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