Physics – Uspekhi **63** (4) 414 – 415 (2020)

PACS number: **01.10. – m**, **01.30. – y**, **01.90. + g**

Physics news on the Internet (based on electronic preprints)

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DOI: https://doi.org/10.3367/UFNe.2020.03.038737

1. Nuclear interaction of nucleons

In the Jefferson Lab experiment [1], pair interactions of nucleons (neutrons and protons) in ^{12}C, ^{27}Al, ^{56}Fe, and ^{208}Pb atomic nuclei have been investigated in the region of short inter-nucleon distances not studied earlier. The protons knocked out of nuclei in quasi-elastic scatterings of electrons by nuclei were registered. The ratio of the number of events with two emitted protons to the number of events with one emitted proton first increases linearly in the interval of 400 to 650 MeV$/c$ with increasing relative momentum of two interacting nucleons (that is, with decreasing distance between them) and then remains unchanged up to 1000 MeV$/c$. The inter-nucleon interaction is due to quark-gluon interactions within quantum chromodynamics. But because of complexity of its equations, simplified models are often used. The present experiment confirmed that a good approximation for the electron scattering by nuclei under a large momentum transfer is the model where the nucleons are considered to be point-like particles with a certain effective interaction force between them, and the momentum transfer from the electron is due to one virtual photon. The above-mentioned attainment of a plateau corresponds to the transition from attracting spin-dependent (tensor) pair interaction of nucleons to spin-independent (scalar) interaction with repulsion. This theoretical approach may turn out to be useful, in particular, for calculating the neutron star structure.

2. Cooling of levitated nanoparticles

U Delic (University of Vienna, Austria) and co-authors have managed to cool a solid-state nanoparticle containing 10^8 atoms to the lowest quantum state when on the average less than one phonon (quantum of thermal motion) was excited in a nanoparticle [2]. Feedback cooling was applied when the influence of cooling laser pulses depended on the particle motion. This method was used earlier to cool macroscopic particles only to a state with four phonons. In the present experiment, spherical quantum nanoparticles 143 ± 4 nm in diameter were trapped by 'optical tweezers' (levitated) in an optical field between two concave mirrors in a vacuum chamber linked by a cavity. The photons scattered by a particle carried away thermal energy, thus resulting in cooling. The average number of phonons was 0.43 ± 0.03, which corresponds to a temperature of 12.2 ± 0.5 μK and to a probability of $70 \pm 2\%$ of a particle being in the ground quantum state. Cooling of nanoparticles is important for verification of the basic elements of quantum mechanics in the 'macro-quantum' region and can also turn out to be useful in the design of new ultrasensitive sensors.

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Uspekhi Fizicheskikh Nauk **190** 446 (2020)
Translated by M V Tsaplina

3. Nondemolition readout of the spin state

In quantum calculations, it is sometimes necessary to apply the so-called nondemolition readout of the qubit (quantum bit) state when, after readout, the qubit remains in the initial state. J Yoneda (Institute of Physical and Chemical Research (RIKEN), Japan) and co-authors have experimentally demonstrated [3] a method of nondemolition single-shot readout of the electron spin state in a quantum dot in the magnetic field in silicon. A second auxiliary quantum dot was placed near this dot. The electron in this dot was coupled by an exchange interaction with the electron in the first dot, which allowed the state of the first electron to be determined from the state of the second electron. The states of qubits were prepared using microwave radiation pulses, and the state of the second qubit was measured using a charge sensor, i.e., a one-electron transistor. Over 30 successive non-demolition readouts of the spin state were implemented that yielded similar results with a quantum fidelity of nearly 99%, and the overall measurement fidelity was 95% within 1.2 ms.

4. Kondo screening cloud

The Kondo effect consists of screening the spin located in a metal of a magnetic impurity atom by a coherent spin cloud formed by conduction electrons, which causes an increase in electric resistance with lowering temperature. Although the Kondo effect was experimentally detected long ago, the screening cloud itself has not been observed. I V Borzenets (City University of Hong Kong) and co-authors have been the first to register the Kondo cloud and to measure its length [4]. To this end, a quasi-one-dimensional channel was created with three electric gates at different distances from impurity atoms in a quantum dot. By heightening the voltage at a certain gate, one could form barriers and observe the conductivity changes in the channel. The characteristic scale of the Kondo cloud measured by this method was several μm. The measurement results are very consistent with the theoretical calculations of the Kondo effect, thus confirming the conclusion concerning the existence of the screening spin cloud. The Kondo effect is supposed to play an important role in spin glasses, in high-temperature superconductivity, and in other processes, and therefore a direct recording of a Kondo cloud can help in the corresponding investigation. For the Kondo problem, see [5].

5. Record distance for a blazar

Blazars are radio bright active galactic nuclei with relativistic jets directed towards Earth. The jets are formed along the rotation axis of accretion discs around supermassive black holes in galactic centers. Only seven blazars at red shifts $z = 5.0 - 5.5$ (with the maximum $z = 5.47$) were known till recently. Radio bright galaxies and quasars have also been observed at still larger z, but not blazars. When investigating several radio surveys of galaxies, S Belladitta (Brera Astronomical Observatory and University of Insubria, Italy) and co-authors discovered a new blazar [6], PSO J030947.49 + 271757.31 at the red shift $z \approx 6$. This blazar shows a record brightness in the radio frequency band. The Swift (X-ray Observatory) observation of PSO J030947.49 + 271757.31 also showed that it possesses the highest X-ray luminosity among all known active galaxies at $z \geqslant 6$. The observation statistics imply the presence of $\sim 10^{-2}$ such blazars at $z \sim 6$ in a cubic Mpc. The red shift $z \sim 6$ corresponds to the age of the Universe of 900 mln years. The study of active objects in this epoch is important for understanding the formation and growth of supermassive black holes. Blazars can be sources of neutrinos and high-energy cosmic rays (see [7]).

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