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1. Observation of β-phase of superfluid helium-3

V V Dmitriev (P L Kapitza IPP RAS) and his co-authors have become the first to carry out the observation of β-phase of superfluid ^{3}He in nematic aerogel in a strong magnetic field [1]. Under ordinary conditions, superfluid ^{3}He has only two phases (A and B). In a strong magnetic field, however, it splits into new phases with different spin compositions of an ensemble of Cooper pairs. If, in addition, ^{3}He is confined in nematic aerogel (a loose medium of siliceous filaments or another substance) with co-directed filaments, then a strong anisotropy and a polar phase may appear. E V Surovtsev (IPP RAS and MIPT) predicted in [2, 3] that, under such conditions, ^{3}He, when cooled, will transfer to the so-called β-phase instead of the purely polar phase, and then to a deformed β-phase with further cooling. Used in the new experiment was nematic aerogel of mullite (a mineral of the silicate class) with elongated pores, in which solid ^{3}He layers on the filament surface were replaced by ^{4}He. The aerogel was fixed in a mechanical cavity, and the resonance properties of this system as a function of temperature were examined. The transition of ^{3}He into one phase or another was accompanied by a change in the superfluid component density and thus affected the resonant frequency and the shape of the resonance curve. This method was used to register the predicted transitions to a superfluid β-phase and a deformed β-phase. The temperature range of the β-phase was found to be proportional to the magnetic field value. For superfluid ^{3}He phases in aerogel, see also [4].

2. Casimir effect and nonreciprocal energy transfer

Z Xu (Purdue University, USA) and her co-authors have performed an experiment demonstrating for the first time a nonreciprocal energy transfer from one micromechanical oscillator to another [6] via the Casimir effect (see [5]). The oscillators were made of two rods with different resonant frequencies of elastic mechanical vibrations. In the region between the rods, zero electromagnetic-field vacuum fluctuations (the Casimir effect) took place, which generated rod-affecting forces. An alternating electric field excited parametric modulations of the distance between the rods and the Casimir forces, thus favoring rod vibration coupling. Additional energy dissipation was artificially induced in one of the rods (energy receiver), thus leading to the occurrence of an exceptional point in the parameter space. This point is the boundary of the presence of real values in the spectrum of the Hamiltonian containing non-Hermitian terms. In bypassing the loop in the parameter space, more energy was transferred from one rod to the other than in the reverse direction, as in the case of electric current running through a diode. This effect may find useful applications in micromechanical systems.

3. Quantum teleportation of microwaves

An important role in constructing quantum computers is played by quantum coherent transmission of states between spaced facilities such as quantum processors. It is desirable to transmit unknown quantum states through quantum teleportation. However, as distinct from the optical range, propagating quantum states were not earlier transmitted between superconducting cells in the microwave frequency range. K G Fedorov (Walter Meissner Institute of the Bavarian Academy of Sciences and Technical University of Munich, Germany) has experimentally demonstrated quantum teleportation of propagating microwave states at a distance of 42 cm through a coaxial cable at a carrier frequency of 5.435 GHz by a preliminary squeezing and entanglement of photon states in two Josephson parametric amplifiers [7]. An analogous pair of amplifiers was employed for measurements on the recipient side using Wigner quantum tomography of states. Quantum fidelity of teleportation $F = 0.689 \pm 0.004$ was reached, exceeding the asymptotic quantum-state no-cloning threshold of $2/3$.

Teleportation of subsequent states (alphabet) was also demonstrated in the experiment. This result opens new possibilities of creating quantum microwave circuits for quantum communication and distributed quantum calculations. For quantum computers, see [8–10].

4. Twisted NOON states of photons

NOON states are a superposition of N photons in two orthogonal modes $(|N,0\rangle + |0,N\rangle)/\sqrt{2}$. A change in the NOON phase under external action is N times larger than in one-photon states, and therefore such states are interesting in metrological and other applications. A group of scientists from Finland and Canada have performed a new experiment [11] combining the advantage of NOON states and the potential of 'twisted' states with orbital angular momenta. This allowed obtaining, along with sensitivity to phase

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variations, a high sensitivity in angular measurements. First, two quantum entangled photons passed through different regions of a spatial modulator. Then, the structured photons met again in a splitter and got into a second modulator, which imitated the measured system. Finally, the photons were transmitted through a Mach–Zehnder interferometer and were registered. Photon states with $N = 1$ and 2 and with orbital angular momenta up to $100\hbar$ were used. Measurements have shown that an increase in N and the orbital angular momentum heightens the precision of angular measurements and detector sensitivity as was theoretically predicted.

5. Double pulsar and a test of the General Relativity Theory

Long-term observations of the double radio pulsar PSR J0737-3039A/B with several telescopes made it possible to perform a new test of General Relativity Theory (GRT) predictions in the strong field region [12]. Neutron stars form a pair with a sufficiently short orbital period of 2.45 h, their orbit has a nonzero eccentricity $e = 0.088$, and the orbit plane is optimally oriented with respect to the line of sight. This makes the double pulsar PSR J0737-3039A/B a convenient system for testing some relativistic effects. The pulse arrival time containing information about the properties of pulsars and their gravitational field was measured using an atomic clock. Seven relativistic post-Keplerian corrections were measured. Some relativistic effects were revealed for the first time. The deviation of pulses in the gravitational field of the companion was registered, which allowed the pulsar rotation direction to be determined. Observed was orbit variation owing to an effective pulsar mass loss due to pulsar rotation retardation. The angular velocity of periastron rotation was measured. The current accuracy already makes it possible to see the influence of the equation of state of the neutron star on the spin-orbital coupling in the binary system. The orbit period variation rate due to gravitational wave radiation corresponds to the formulas for quadrupole approximation to an accuracy of 1.3×10^{-4}. Thus, GRT predictions have been confirmed once again and some alternative gravitational theories constrained. For radio pulsars, see [13, 14].

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