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1. Theory of high-temperature superconductivity

The Bardeen–Cooper–Schrieffer (BCS) theory successfully explains superconductivity of simple metals, but it fails to describe high-temperature superconductors-cuprates. P W Phillips, L Yeo, and E W Huang (University of Illinois at Urbana Champaign, USA) have formulated a new theory [1] explaining cuprate superconductivity at the microlevel. Cuprates are doped Mott insulators. The authors described them using the Hatsugai–Kohmoto model, which is a modification of the Hubbard model, and found new exact solutions. The mechanism playing the role of Cooper pairing in BCS theory was identified and an instability corresponding to the superconducting state was found. The ratio of the transition temperature to the energy gap is shown to be higher and the superfluid component density to be lower than in BCS theory. The model also explains the enhanced low-frequency radiation absorption by cuprates observed in the experiment. For a discussion of some models of high-temperature superconductors, see [2–4].

2. Magnetic solitons

G Lamporesi (University of Trento and Trento Institute for Fundamental Physics and Applications, Italy) and his colleagues have investigated magnetic solitons in Bose–Einstein condensate [5]. ^{23}Na atoms in a hybrid trap were transferred to a mixture of components with opposite spin directions using microwave pulses. Moving magnetic solitons in which the magnetization phase changed twice by π were created at the trap edge through potential perturbation. The dissipationless soliton dynamics, including their oscillations, were investigated. Pair collisions of solitons with the same or opposite magnetization were observed. The results of measurements are consistent with the theoretical description presented in paper [6]. An independent observation of magnetic solitons was also reported in [7]. For solitons in ultracold gases, see [8].

3. Local character of Aharonov–Bohm effect

The Aharonov–Bohm effect is typically considered to be an example of a nonlocal phenomenon: the charge acquires phase by enclosing a solenoid, where the solenoid's electromagnetic field is zero. However, C Marletto and V Verdal (University of Oxford (Great Britain), National University of Singapore, and Institute for Scientific Exchange (Italy)) have found [9] that in a self-consistent quantum-mechanical consideration the phase gain has a local character, that is, the phase is gained as the particle moves from point to point. Developing the approach proposed in [10], they showed that both the charge motion and the electromagnetic field of the solenoid should be quantized. A quantized field is no longer zero outside the solenoid (its expectation mean alone is zero), and therefore the charge interacts with photons and gains the quantum phase gradually. The idea is suggested to experimentally verify the conclusion drawn in the work through quantum tomography of the charge state.

4. Reverse quantum evolution

Time reversal of quantum evolution has already been demonstrated in an experiment with a simple quantum computer [11]. In their theoretical work [12], A V Lebedev (Moscow Institute of Physics and Technology) and V M Vinokur (Argonne National Laboratory and the University of Chicago, USA) describe a method for bringing on a reverse time evolution of the system even without knowing its initial state, which can be a mixed quantum state. To this end, a second system described by the same Hamiltonian should be created and certain operations on the auxiliary system should be performed simultaneously with quantum operations on the investigated system. System thermalization at the end of the evolution induces a reverse sequence of quantum transitions and transfers the system to a state with the same density matrix as the one at the outset.

5. Recovery of quantum information

The researchers B Yan and N A Sinitsyn (Los Alamos National Laboratory, USA) have developed a new method for recovery of quantum information damaged by measuring [13]. To this end, one should know certain correlators taken at different instants of time and provoke a reverse evolution of the system. A partial simulation of this algorithm on a 5-qubit quantum IBM processor showed that, when it is implemented, decoherence remains at a low level. Owing to the fact that local damage to quantum information does not lead to a catastrophic increase in damage (in the quantum region, the 'butterfly effect' is absent), the damaged quantum information is to a great extent accessible for recovery.

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6. Is there a primordial black hole in the Solar System?

In the motion of icy bodies, anomalies have recently been noticed at a distance of 300–1000 au from the Sun that can be explained by the presence of a 9th planet with a mass of 5 to 15 Earth masses. The OGLE telescope simultaneously observes microlensing events that may have been caused by compact objects with masses of 0.5 to 20 Earth masses. These objects may be free floating planets in interstellar space. J Scholtz (Durham University, Great Britain) and J Unwin (University of Illinois at Chicago, USA) have suggested an alternative hypothesis [14]: in both cases, the objects are primordial black holes (PBHs) rather than planets. The authors showed that the capture of PBHs in the Solar System, if they exist in the numbers given by OGLE, is as probable as the capture of a planet. In this case, at the edge of the Solar System there may be a black hole rather than a 9th planet. Such a PBH can be revealed by annihilation of dark matter particles that must form a dense cluster around a PBH. For PBHs, see [15].

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