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1. Quantum dot qubits in germanium

N W Hendrickx (Delft University of Technology, Delft, Netherlands) and co-authors have created [1] quantum bits — qubits in germanium that surpass qubits in silicon in a number of characteristics. Instead of electronic states in quantum dots in silicon, hole states were used in germanium. Quantum levels of holes were considerably different in energy, which improved the qubit operation accuracy. Two quantum dots in a flat germanium sample were between the control electrodes. A strong spin-orbit coupling and the Coulomb blockade effect allowed the electric field to control qubits without additional devices. Both a single qubit and a two-qubit logic gate were demonstrated. In the former case, the quantum fidelity was 99.3%, and operations could be performed with a gate time of 20 ns. In the two-qubit case, the tunnel effect was used to couple qubits, and a "controlled NOT logic gate (CNOT)" executed within 75 ns. Thus, quantum dots in germanium proved to be one of the most promising platforms for quantum calculations.

2. Antiferromagnetic topological insulator

An international group of scientists, including Russian researchers from St. Petersburg and Tomsk State Universities, the Institute of Strength Physics and Materials Science SB RAS (Tomsk), and the Institute of Solid State Physics RAS (Chernogolovka), has shown [2] that the compound $MnBi_2Te_4$ is a combination of a topological insulator and antiferromagnet. These properties of $MnBi_2Te_4$ had been predicted by theoretical *ab initio* calculations and then confirmed experimentally by photoemission spectroscopy with angular resolution. A topological insulator is material with an electrically conducting surface and a nonconducting bulk. Magnetization measurements at different temperatures and magnetic field strengths showed the presence in $MnBi_2Te_4$ of three-dimensional antiferromagnetic ordering at a temperature of 24.2(5) K at the Néel point. Earlier, magnetic topological insulators were only obtained through doping of nonmagnetic topological insulators with metals, which resulted in strong inhomogeneity. On the contrary, $MnBi_2Te_4$ has its own magnetic properties even without doping, and so its characteristics are homogeneous. Antiferromagnetic topological insulators can find important applications in both fundamental research and spintronics. For spintronics, see [3], and for topological insulators, see [4–6].

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3. Dissipation-induced instability in a quantum gas

It is a known fact that the mutual influence of the processes of coherent evolution and dissipation can be the cause of nontrivial effects, such as dissipative phase transitions. T Esslinger (Swiss Federal Institute of Technology, Zurich) and colleagues have investigated [7] the interaction of coherent quantum evolution and dissipation in a Bose-Einstein condensate of ^{87}Rb atoms. The condensate atoms could be in two Zeeman states, and two perturbation modes — the atomic number density modulation mode and the spin density modulation mode — could be excited in the condensate. The modes were coupled by the scattering of standing wave photons of laser radiation in a cavity. The system turned out to evolve following a circular path in the phase space of the two modes. This behavior was understood with the help of a mechanical analogy with a position-dependent nonconservative force. A phase transition was observed between the regime in which only one mode was excited and the one with two excited modes. An instability region was revealed in which both modes were synchronized owing to strong dissipative coupling between them. For nonequilibrium dynamics, see [8].

4. Rotation of a superfluid liquid

The rotation of quantum superfluid liquids has been investigated in many studies, both theoretical and experimental (see [9–12]). Of interest is the case where the rotation frequency approaches or exceeds the retentive frequency of the atomic trap potential. Here, according to calculations, circular structures must appear that can be represented by a combination of many quantum vortices in one giant vortex. Such structures were actually observed, but they swiftly decayed or the liquid density in the center was not low. Researchers from the University of Paris 13 and the French National Center for Scientific Research have experimentally obtained [13] for the first time a circular structure that was stable for over one minute. Through rotation of a nonspherical trap potential, angular momentum was imparted to a Bose–Einstein condensate of ^{87}Rb atoms. In the course of selective evaporation, it increased to $350\hbar$ per atom. In the condensate structure, a ring ~ 30 μm in radius with a hole in the center appeared which rotated at a supersonic linear velocity reaching Mach 18. In the ring, a quadrupole deformation mode was excited, for the description of which existing hydrodynamic models appeared to be insufficient, requiring a more detailed theory.

5. Group of distant galaxies and the reionization of the Universe

Hydrogen reionization in the Universe was presumably due to radiation from quasars and the first stars in young galaxies. V Tilvi (University of Arizona, USA) and colleagues have discovered [14] a group of galaxies at the red shift $z \approx 7.7$ surrounded by mutually overlapping ionized gas bubbles. Three galaxies radiating strongly in the Ly_α line were discovered in photometric observations with the 4-meter telescope of the Kitt Peak Observatory, and then a spectroscopic Keck I confirmation was obtained. One of the three galaxies was known from earlier observations. The intergalactic spacing along the line of sight is 0.7 Mpc and in the transverse direction 0.05–0.18 Mpc. The possibility of observing Ly_α radiation lines implies that the galaxies are surrounded by rather lengthy ionized hydrogen bubbles, for in neutral hydrogen the radiation would have been absorbed. During the time of their motion, photons inside the bubbles go beyond the absorption line owing to the cosmological red shift. According to the estimates, the bubble size is 0.55–1.02 Mpc, and therefore they must partly overlap each other. Thus, it has been proved for the first time that the group of galaxies might be responsible for the inhomogeneous reionization of the Universe. It is expected that a substantial advance in the study of the reionization of the Universe will be possible with the now planned IR JWST (James Webb Space Telescope) and SKA-2 radio interferometer.

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