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1. Quantum arrow of time

In spite of the fact that the Schrödinger equation is time reversible, measurements make quantum processes irreversible, and this irreversibility has not yet been explained exhaustively in the quantum theory. One of the approaches is the introduction of quantum entropy. R W Murch (Institute of Materials Science and Engineering and Washington University, St. Louis, USA) and his colleagues have performed an experiment showing the existence of the quantum time arrow for an open system that experiences a backreaction of measurements. The system was a superconducting transmon qubit coupled to an electromagnetic mode in a microwave waveguide. The quantum states of the qubit were measured by the phase shift of a reflected signal, and a pulse with an opposite phase shift led to a backward evolution of the qubit state. The series of successive measurements determined the qubit quantum trajectory. Two hundred eighty thousand quantum trajectories were measured, and the entropy due to the trajectory probability was calculated. This allowed the arrow of time to be characterized as the direction of most probable processes, namely, the prevalence of forward trajectories over backward ones. With increasing duration of the chain of measurements, the irreversibility (prevalence of forward trajectories) increased, which also confirmed in favor of the existence of the quantum time arrow. For classical and quantum irreversibility, see the book *Dynamics and Information* by B B Kadomtsev and also his reviews and papers in *Usp. Fiz. Nauk* **173** 1221 (2003) [*Phys. Usp.* **46** 1183 (2003)]; **166** 651 (1996) [*Phys. Usp.* **39** 609 (1996)]; **165** 967 (1995) [*Phys. Usp.* **38** 923 (1995)] and **164** 449 (1994) [*Phys. Usp.* **37** 425 (1994)].

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2. Qutrit teleportation

Many experiments have been performed on the quantum teleportation of states of particles without transporting the particles themselves. However, the experiments were only performed with two-dimensional subspace of quantized levels represented by qubits. Y-H Luo et al. (University of Science and Technology of China and CAS Center for Excellence in Quantum Information and Quantum Physics, China) have proposed a scheme of teleportation of photon quantum states of any dimension and demonstrated it experimentally using the example of the teleportation of a qutrit corresponding to a three-dimensional subspace. In this scheme, the sender and the receiver first exchange photons in a three-dimensional entangled state. Then, the sender performs measurements inducing interference of the previously distributed state of photons, the state of teleported photon, and the state of auxiliary photon. The receiver receives information on the results of measurements through the classical channel and then, having performed a unitary transformation of his part of the entangled state, reproduces the teleported quantum state. In the experiment, the three-dimensional states of path-entangled photon pairs were obtained using lasers, splitters, and nonlinear crystals. A quantum fidelity of 0.75 was reached and the existence of three-dimensional teleportation was confirmed. Teleportation with high dimensions is more noise resistant in the transmission line than qubit communication.

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3. Highly selective bandpass filter

Microwave bandpass filters are widely applied in communication facilities, radio measurements, and other fields of radio electronics. Bandpass filters are constantly being upgraded. One of the areas is elaboration of high-efficiency filters based on conducting strips of different configurations. Researchers from the L V Kirensky Institute of Physics SB RAS and the Siberian Federal University (Krasnoyarsk) have designed a filter with unique characteristics and demonstrated its operation. The filter was assembled on a dielectric substrate. A stripline conductor with a stub was placed on one side of the substrate and stripline conductors connected to a screen were on the other side. Two of the first three oscillation modes participated in the formation of a narrow passband, while the third mode formed a minimum of the transmission coefficient near the passband. B A Belyaev et al. used computer simulation to select optimal sizes and positions of stripline conductors. Then, a prototype device was made of four such filters. The device has the characteristics of a highly selective eighth-order bandpass filter with $f_0 = 0.52$ GHz central frequency and a relative bandwidth of 14%, while the attenuation band lasted up to $\sim 5 f_0$. Thus, the new filter surpasses the available analogues in its selective properties.

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4. Askaryan effect and the search for ultra-high energy neutrinos

In 1961, the outstanding Soviet physicist G A Askaryan predicted theoretically the effect of the generation of bursts of coherent Vavilov–Cherenkov radio emission upon passage of high-energy photons through matter (*Zh. Eksp. Teor. Fiz.*

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41 616 (1961) [*JETP* **14** 441 (1962)]; *Usp. Fiz. Nauk* **144** 523 (1984) [*Phys. Usp.* **27** 885 (1984)]). Photons generate electromagnetic showers that ionize atoms on their way, knocking out additional electrons from them in the direction of the shower. Simultaneously, positrons leave the shower through annihilation. As a result, the excess of negative charge in the shower can reach $\sim 10\%$, and the uncompensated charges generate Vavilov–Cherenkov radiation. Short-wave (compared to shower size) radiation is attenuated by interference, while long-wave radiation forms a coherent pulse. This effect was first observed experimentally in the SLAC accelerator. The Askaryan effect is a promising method of cosmic ray particle registration in the high-energy range. Ultra-high energy neutrinos ν are being sought now using the Askaryan method by ARA (Askaryan Radio Array) detectors on the South Pole. The idea of using Antarctic ice for this purpose was proposed by V A Gusev, I M Zheleznykh, and M A Markov (INR RAS). The ARA array includes five radio antennas located 200 m deep in the ice. According to calculations, ultra-high energy ν can either be generated directly in astrophysical objects or be cosmogenic, i.e., can occur in the interaction of cosmic rays with background radiation (cosmogenic ν were predicted by V S Berezinskii and G T Zatsepin in 1969). At the Cosmic Ray Conference in Madison, ARA collaboration presented the results of the 2013–2016 search for ν-produced showers. Signals above the background level were not registered, but the limitations from above on the diffuse ν flux obtained earlier by the ARA were improved by a factor of two. In its sensitivity, the ARA has already begun competing with other neutrino telescopes at energies above $> 10^{10}$ GeV, and during the next three years the ARA can either provide the best limitations or register ultra-high energy ν. G A Askaryan also considered Moon matter as a target for radio pulse generation (see *Usp. Fiz. Nauk* **182** 793 (2012) [*Phys. Usp.* **55** 741 (2012)]).

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