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1. New limit on the electron electric dipole moment

The Standard Model of particle physics predicts the asymmetry of the electron charge distribution along the spin direction, i.e., an electric dipole moment (EDM) whose value is much smaller than can be measured in today's experiments. Some theories introducing a 'new physics' beyond the Standard Model give a much larger EDM, and these predictions can already be verified. In the ACME II experiment, a new limit on electron EDM, $|d_e| < 1.1 \times 10^{-29}\, e$ cm, has been established with the sensitivity which is an order of magnitude better than that achieved for the limit obtained five years ago by the ACME Collaboration in a similar experiment with thorium single-oxide molecules. The strong intramolecular electric field in ThO molecules interacts with the EDMs of electrons and induces a precession of their spins. The electron EDM can be found from the difference between precession angles in quantum states with different EDM directions. The measurements were performed through the exposure of molecules to laser light and detection of their fluorescent radiation. The experimental data also suggest new limits on admissible 'new physics' parameters. In particular, the difficulties arise for some versions of the supersymmetry theory, which lowers the chance to discover supersymmetric particles at the Large Hadron Collider.

Source: *Nature* **562** 355 (2018)
https://doi.org/10.1038/s41586-018-0599-8

2. Count of the number of phonons in a micromechanical oscillator

Vibrations of mechanical oscillators near a quantum level (with small occupation numbers of phonons) have already been observed in some experiments. To measure the characteristics of states and to manipulate vibrations, the oscillators were coupled with superconducting qubits, but strong coupling had not been reached earlier. Researchers from the JILA, National Institute of Standards and Technology, and the University of Colorado, Boulder (USA), J J Viennot, X Ma, and K W Lehnert, used for this purpose a charge-sensitive qubit and an oscillator made of an aluminum membrane several μm in size. Positive and negative charges were gathered at different ends of the membrane under an electric field. Mechanical 25 MHz vibrations of a membrane set the charges in motion, and they affected the qubit, leading to a shift of its fundamental frequency at 4 GHz by 0.52 MHz (in terms of one phonon). The information on phonon distribution was contained in the measured spectral function of the qubit. Also investigated was the effect on the system of microwave pulses on the lower sideband of qubit vibrations modulated by the oscillator frequency. This signal allowed managing the oscillator Fock states up to approximately seven phonons, and with its help it was possible to cool the oscillator, thus raising its ground state population by a factor of eight. Such an approach can find application in quantum micromechanics.

Source: *Phys. Rev. Lett.* **121** 183601 (2018)
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3. Dielectric resonant antenna

P Kapitanova (St. Petersburg National Research University of Information Technologies, Mechanics and Optics) and colleagues have designed and implemented a dielectric resonator antenna intended for coherent manipulation over a large ensemble of nitrogen-vacancy (NV) color centers in a diamond. The antenna has the form of a hollow dielectric cylinder 12.5 mm in diameter and 6 mm in height. A diamond with NV centers was placed inside the cylinder on its axis. A resonance electromagnetic mode with a frequency of 2.84 GHz is excited by a conducting loop at the antenna's pedestal, the magnetic field inside the cylinder being homogeneous to a high degree of accuracy. Owing to this fact, the electron spins of NV centers are well synchronized, which strengthens the output optical signal. The average Rabi frequency of 10 MHz was reached in a volume of 7 mm^3, being constant along the sample to an with a standard deviation of less than 1%. Such an antenna can be used in ultrasensitive sensors.

Source: *Pisma Zh. Eksp. Teor. Fiz.* **108** 625 (2018)
http://www.jetpletters.ac.ru/ps/2199/article_32961.shtml

4. Optical gyroscope

The operation of optical gyroscopes is based on the measurement of the phase difference of light beams that pass along a ring waveguide in two directions [for the Sagnac effect, see *Phys. Usp.* **45** 793 (2002) and *Phys. Usp.* **57** 714 (2014)]. Optical gyroscopes have no moving mechanical parts, but their sensitivity is limited by thermal fluctuations, component drift and fabrication mismatches. P P Khial, A D White, and A Hajimiri (California Institute of Technology, USA) have demonstrated a new construction of the optical gyroscope with a sensitivity higher by 1–2 orders of magnitude than that of fibre-optic gyroscopes and being only 2 mm^2 in area. In the new proof-of-concept device driven by the electronic switches, the optical inlets and outlets change places, and a pair of rings is utilized. Slow thermal fluctuations similarly affect the light propagating in both directions, and therefore the switch of directions counterbalances the influence of fluctuations. Being small, the new gyroscope can be integrated into different mobile devices.

Source: *Nature Photonics* **12** 671 (2018)
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5. An assembling galactic cluster in the early Universe

Observed galactic clusters occurred rather recently at redshifts $z \leqslant 1-2.5$. In earlier epochs, galactic clusters were very rare, but they had progenitors, namely, nonvirialized regions (those that have not reached gravitational equilibrium) with a heightened concentration of galaxies, i.e., protoclusters. The properties of protoclusters are of interest, in particular, for inhomogeneous reionization models. L Jiang (Peking University, China) and colleagues have implemented a search for protoclusters at $z > 5$. Chosen were candidates from the Subaru/XMM-Newton survey of galaxies, which were then examined by a spectrograph with the 6.5 m Magellan telescopes in Chili. This method was used to investigate a region on the celestial sphere 4 square degrees in size, and a giant protocluster of galaxies at $z = 5.7$ was revealed. It has a mass of $(3.6 \pm 0.9) \times 10^{15} M_{\odot}$ and occupies a volume of $35 \times 35 \times 35$ co-moving Mpc^3.

Source: *Nature Astronomy* **2** 962 (2018)
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