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# Physics news on the Internet (based on electronic preprints)

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## 1. Reactor antineutrino oscillations

New, more precisely measured data from the RENO experiment on oscillations of electron antineutrinos $\bar{\nu}_e$ born in atomic reactors have been presented. $\bar{\nu}_e$ from six reactors were registered over 2200 days using identical near and far detectors, and the $\bar{\nu}_e$ flux variation on the way between them was examined. In the detectors, $\bar{\nu}_e$ induced inverse beta decay $\bar{\nu}_e + p \rightarrow e^+n$ on nuclei from a hydrocarbon scintillator containing gadolinium Gd impurity. Registered were gamma-ray photons from positron annihilation and from neutron absorption by Gd nuclei by a time-lagged coincidence circuit. The obtained data show a clear periodic dependence on the ratio $L/E_\nu$ of the $\bar{\nu}_e$ path $L$ to its energy $E_\nu$, as it should be in oscillations. Close to $E_\nu \sim 5$ MeV, both detectors show some difference between the registered $\bar{\nu}_e$ energy spectrum and the calculated one. To explain this discrepancy, models of neutrino generation in reactors should be specified. The values obtained for the neutrino oscillation parameters are as follows: $\sin^2(2\theta_{13}) = 0.0896 \pm 0.0048(\text{stat.}) \pm 0.0047(\text{syst.})$ and $|\Delta m^2_{32}| = (2.63 \pm 0.14) \times 10^{-3}$ eV$^2$ (in the case of normal mass hierarchy).

Source: *Phys. Rev. Lett.* **121** 201801 (2018)
https://doi.org/10.1103/PhysRevLett.121.201801

## 2. Optomechanical Bell test

States of the vibrational modes of macroscopic mechanical oscillators quantum-entangled among themselves and with photons have been experimentally obtained over the past few years. S Groblacher (Delft University of Technology, Netherlands) and colleagues checked for the first time the violation of Bell inequalities for mechanical oscillators consisting of $10^{10}$ atoms each and entangled with a radiation field. Two rod-shaped silicon oscillators 10 μm long were located in two interferometer arms. The photons that passed through the rods induced their mechanical vibration. Then, repeated laser pulses interacting with the vibrating oscillators were let through the interferometer, which resulted in a mixing of the frequencies of phonons and reradiated photons. The detectors registered pulses at the outlet from the interferometer, and the correlations between the pulses with upward or downward frequency shifts were examined. The measured correlation coefficient $S = 2.174^{+0.041}_{-0.042}$ violates the Bell inequality $S \leqslant 2$ at the level of four standard deviations, which refutes the presence of hidden parameters in the quantum-mechanical description of the system.

Source: *Phys. Rev. Lett.* **121** 220404 (2018)
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## 3. Parallel frequency-bin qubits

P Lougovski (Oak Ridge National Laboratory, USA) and his colleagues have developed quantum gates at two parallel frequency-bin entangled qubits in the same optical fiber. The frequency quantum information encoding is rather promising for application in quantum communication and quantum calculations, since it is capable of supporting many qubits in a single optical fiber. Frequency mixing while maintaining a low noise level is difficult. In the experiment with electro-optical phase modulators and two-photon frequency combs, a Hong–Ou–Mandel interference was observed with a visibility of 97%. This allowed different independent operations to be performed simultaneously on two qubits encoded at different frequency-bin photons in an optical fiber.

Source: *Optica* **5** 1455 (2018)
https://doi.org/10.1364/OPTICA.5.001455

## 4. Lens for extreme-UV radiation

Usual lenses of solid materials are inapplicable for focusing light of the extreme-UV range because of strong light absorption in a substance. In this spectral region, reflecting mirrors and diffraction plates are typically used. L Drescher (Max Born Institute, Germany) and colleagues constructed a new lens for the extreme-UV range not consisting of solid material but formed by a gas jet. The light crosses the jet orthogonally with a transverse density gradient. Near atomic resonances, photon reemission by helium atoms changes their phases, and summation of phases of the light waves that pass through the jet induces beam focusing, as would be done by a cylindrical lens. Changing the gas density can control the focal length of the gas lens. The light beam of the extreme-UV range was narrowed from the initial width of 2.7 mm to 410 μm. The minimum scale is limited by geometrical and chromatic aberration and can be diminished through method modification. The application of a second perpendicular gas jet might narrow the light beam in the other direction. The new lens appears to be useful, in particular, for the observation of structural variations of biomolecules on short time scales.

Source: *Nature* **564** 91 (2018)
https://doi.org/10.1038/s41586-018-0737-3

## 5. Cosmological radio recombination lines

Radio-frequency recombination lines in space are due to stimulated transitions between highly excited electron levels of Rydberg atoms. In the rarified cosmic medium, the population of these levels can be rather high. Radio recombination lines have to date only been observed from the gas in our Galaxy and from near galaxies. K L Emig (Leiden Observatory, Netherlands) and colleagues have used the LOFAR telescope-radio interferometer network to register for the first time recombination radio lines at a cosmological distance in the spectrum of quasar 3C 190 at $z = 1.1946$. An array of 13 lines corresponding to transitions with principal quantum numbers $n = 266-301$ was observed. The radio-frequency lines were revealed with a confidence $> 5\sigma$. Different scenarios of the origin of these lines are possible. They can emerge on both hydrogen and carbon atoms in a dwarf galaxy along the line of sight. The carbon must be found in cold neutral gas clouds, and the hydrogen in hot clouds with a high degree of ionization. The lines may also appear in gas currents from the galactic active nucleus, but this model encounters some difficulties due to the high gas velocity. The observation of recombination radio lines is of importance for clarifying the physical state of the gas in far objects.

Source: https://arxiv.org/abs/1811.08104

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