

PACS number: **01.90. + g**

Physics news on the Internet (based on electronic preprints)

DOI: https://doi.org/10.3367/UFNe.2017.08.038182

1. Photon–photon scattering

The light-by-light scattering ($\gamma\gamma \to \gamma\gamma$) was first evidenced directly in the CERN LHC experiment with the ATLAS detector. This process is forbidden in the framework of classical electrodynamics because of the linearity of Maxwell's equations, whereas the photon interaction in quantum electrodynamics is carried out through the production of pairs of virtual charged particles in intermediate states, as was predicted by W Heisenberg and H Euler in 1936. The $\gamma\gamma \to \gamma\gamma$ scattering has already been observed but only indirectly in measurements of the anomalous magnetic moment of leptons and in some other processes. The ATLAS Collaboration investigated 'ultra-peripheral' lead nuclear collisions when the impact parameter of nuclei moving towards each other exceeds the diameter of the nucleus. Here, the nuclei fly past each other, transferring to the excited state without breaking down. Near a moving nucleus, a strong electromagnetic field exists which, under ultrarelativistic velocities of the colliding ions is a cloud of 'quasireal' photons located almost on the mass surface. After their interactions between themselves these photons are finally detected as real photons. A total of thirteen candidate events of the $\gamma\gamma \to \gamma\gamma$ process were registered, whereas the predicted value was 7.3 and the expected background value of events was 2.6 ± 0.7, i.e., the statistical significance of the result was 4.4σ. The measured lead ion interaction cross section is highly consistent with the calculations within the Standard Model.

Source: *Nature Physics* **13** 852 (2017)
https://doi.org/10.1038/nphys4208

2. Search for 'subgravitational' forces

M Jaffe (University of California, Berkeley, USA) and colleagues have measured the gravitational attraction of caesium atoms to a miniature (several cm) and small-mass (190 g) tungsten cylinder, whereas in previous experiments the source masses amounted to tens and hundreds of kilograms. The gas was cooled in a trap (a light-induced lattice) to a temperature of $\sim$ 300 nK and was launched upwards into free fall by a shift of the lattice. Laser pulses were used to transfer the atoms to the state of motion along two vertical trajectories, one lagging relative to the other. These trajectories are the atom interferometer arms. Attraction to the cylinder induces an additional atomic phase difference in the trajectories, which was measured by the interference pattern observed using the fluorescent radiation of atoms. The cylinder-induced gravitational acceleration calculated within the Newton theory is 65 ± 5 nm s^{-2}, and the experimentally obtained constrain on the possible additional acceleration was < 49 nm s^{-2}. Thus, the experiment with a small-mass source allowed a search for 'subgravitational' forces, which are weaker than gravitational forces. The existence of such forces on small scales had been predicted by some models of cosmological dark energy. The constrains on the parameters of the theory of a 'chameleon field' obtained in this experiment improved the previous limits by two orders of magnitude and only left a small region of admissible parameters. With improved measuring accuracy, it will be possible either to confirm or to completely 'close down' this theory in the nearest future. The constrains on the self-action parameter of the scalar field in the 'symmetron' theory were also improved by two orders of magnitude. In the future, it is planned to examine the gravitational Aharonov–Bohm effect in a similar experiment and to perform precision measurements of the Newtonian gravitational constant G.

Source: *Nature Physics*, online publication of July 3, 2017.
https://doi.org/10.1038/nphys4189

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DOI: https://doi.org/10.3367/UFNr.2017.08.038182
Translated by M V Tsaplina

3. Quantum radio-frequency magnetometer

The use of quantum effects in measuring devices improves substantially their capability, for quantum coherence is fairly sensitive to external actions. F M Ciurana (Barcelona Institute of Science and Technology, Spain) and his colleagues demonstrated a new technique for measuring the forms of superweak radio-frequency pulses by combining the stroboscopic method and quantum measurements. An ensemble of 1.5×10^6 ^{87}Rb atoms was used at a temperature of 16 μK in an optical trap placed in a constant magnetic field. The examined signal, i.e., a weak variable magnetic field in the radio-frequency range, was applied in the direction perpendicular to the constant magnetic field. Faraday rotation of the polarization plane of laser light passing through a cloud of atoms was registered. These were so-called 'quantum nondemolition measurements,' which do not violate the quantum coherence of the investigated system. At the initial moment, atomic spins were directed along the constant magnetic field and precessed coherently between measurements. A series of successive measurements was conducted by the stroboscope method, which allowed an examination of the waveform. This technique permitted us to examine sinusoidal and linearly chirped waveforms. Since the atoms resided in a quantum-entangled state, the noise was suppressed by 25% and a sensitivity was attained comparable with that of the best magnetometers of the same frequency range but operating according to other principles.

Source: *Phys. Rev. Lett.* **119** 043603 (2017)
https://doi.org/10.1103/PhysRevLett.119.043603

4. Polarizer of terahertz radiation

Radiation in the THz range positioned between microwave and IR ranges has a number of useful applications but requires special equipment. R Mendis (Brown University, USA) and colleagues have fabricated a new material — artificial dielectric medium which enables singling out linearly polarized components from a beam of terahertz radiation. The material consists of a uniformly spaced stack of parallel 30-μm thick metal plates located at a distance of 300 μm from one another. The array of plates is 20×22 mm^2 in size, 2 mm thick, and — from the electromagnetic point of view — equivalent to a stacked array of parallel-plate waveguides. A beam of radiation is directed at an angle of 45° to the stack plane. If the electric field vector of the wave is parallel to the metal plates, the radiation is reflected almost completely, and if perpendicular, the radiation passes almost freely. With the help of two such polarizers, an isolator of terahertz radiation (material with a very low back reflection) was produced with an efficiency exceeding that of ferrite isolators.

Source: *Scientific Reports* **7** 5909 (2017)
https://doi.org/10.1038/s41598-017-06297-7

5. Two-step magnetic reconnection in a solar flare

T Gou (University of Science and Technology of China, and University of Graz, Austria) and colleagues have studied the effect of two-stage reconnection of magnetic lines of force during the solar flare of May 13, 2013. The observations were carried out at the Solar Dynamics Observatory (SDO). The flare exhibited two separate episodes of energy release. The first concerned typical events and was characterized by the eruption of a magnetic flux rope. The second episode, on the contrary, was rather unusual. It was stronger than the first one and exhibited heightened X-ray and even gamma-ray emissions. During the second episode, the long magnetic-loop leg began accelerating sharply to a speed of 130 km s^{-1} and in some time disappeared, which was accompanied by a diffuse plasma eruption in the perpendicular direction. A possible interpretation of these processes centers around magnetic reconnection of the magnetic lines of force of the loop after its eruption.

Source: *Astrophys. J. Lett.* **845** L1 (2017)
https://arXiv.org/abs/1707.06198

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