

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

DOI: 10.3367/UFNe.0183.201312f.1366

1. Nondestructive detection of a photon

A method of the so-called 'weak quantum measurements' has been implemented in a number of experiments; the quantum state of the system in the configuration under study was not destroyed because only a part of the quantum information was extracted. Thus, by taking weak measurements, S Haroche and his colleagues detected in the 1990s photons of microwave radiation in a resonator. Researchers from the Max Planck Institute of Quantum Optics (Garching), A Reiserer, S Ritter, and G Rempe, were the first to implement such a nondestructive method of detection relevant to photons of the optical range. The experiment was carried out with the ^{87}Rb atom placed in an optical cavity between two semitransparent mirrors. The atom resided in the superposition of two states, one of which was coupled to a cavity and the other of which was not. With the atom in the former of these states, photons could not penetrate the optical cavity, as they were immediately reflected. In the latter state of the atom, photons penetrated the cavity and were reflected by the second mirror. The phase of two indicated atomic states changed therewith by 180 degrees. The phase difference of the atom placed into a preliminarily prepared superposition of two states was measured from the properties of the fluorescent photons emitted by the atom, and it was concluded whether or not the atom underwent a phase shift after transmitting a photon. It is important that the establishment of an instance of a photon flying through the optical cavity failed to destroy the quantum state of the qubit (quantum bit), the state which this photon could code, for instance, with its polarization state.

Source: *Science* **342** 1349 (2013)
http://dx.doi.org/10.1126/science.1246164

2. Levitons

D C Glattli (Institute of Matter and Radiation, Saclay, France) and his colleagues have managed to generate for the first time in their experiments quasiparticles which were predicted nearly 20 years ago by L S Levitov, D A Ivanov, G B Lesovik, and H W Lee [Landau Institute of Theoretical Physics of the Russian Academy of Sciences (RAS), Institute of Solid State Physics of the RAS, and Massachusetts Institute of Technology (USA)]. The quasiparticles, which the authors of the experiment gave the name 'levitons' (Levitov's solitons), transfer the electron density wave; it is important that no hole (electron vacancy) is created simultaneously with the electron excitation. In the above experiment, levitons moved through a conducting heterostructure between two electrodes, being born owing to a time-dependant potential. As predicted by the theory, if the potential varies following the form of the Lorentz distribution, levitons are born at maximum efficiency, because the Lorentz curve corresponds to an integer-valued quantity of charge transferred by the excitation. Checking demonstrated that levitons were born less efficiently in the case of a different shape of the potential pulse (rectangular or sinusoidal), and the contribution from holes was high enough. Levitons were detected using two techniques. In the first of them, electron noise in the sample was measured. In the case of levitons, the noise was considerably weaker when the electron and hole pairs were born. The second technique was based on generating two levitons by potential pulses shifted in time, and on measuring their anti-correlation (Hong – Ou – Mandel interference effect) at the center of the conductor. The measurement data demonstrated that levitons are indeed quantum quasiparticles obeying the Fermi statistics. Levitons may find applications as agents for the translation of quantum information in solid-state quantum computers.

Source: *Nature* **502** 659 (2013)
http://dx.doi.org/10.1038/nature12713

Uspekhi Fizicheskikh Nauk **183** (12) 1366 (2013)
DOI: 10.3367/UFNr.0183.201312f.1366
Translated by V I Kisin

3. Dissociation of hydrogen molecules

J Robert (University of Paris-Sud, France) and his colleagues from France and Brazil have observed for the first time the channel of H_2 molecule dissociation into a pair of hydrogen atoms in metastable states 2^2S. Even though the dissociation of H_2 into H(2^2S) atoms has already been studied in detail, twin metastable H(2^2S) atoms have not been detected in experiments when originating from the same molecule. The reason for this is the small dissociation cross section for this channel. In the new experiment, a cold beam of H_2 molecules intersected a beam of electrons, and collisions between them led to the molecular dissociation. At distances of about several centimeters from the collision center, two photodetectors were installed underneath and above the cross-over plane in which the two beams lay. These detectors recorded the Ly_α photons emitted when atoms indirectly transferred to the ground energy level through a 2^2P level. The study leaned upon the coincidence technique made it possible to detect several thousand H(2^2S) – H(2^2S) pairs of atoms. When the detectors were placed at different distances from the collision point, a simultaneous time shift was observed between the signals; it was explainable by the atoms traversing an additional distance until the atomic metastable level decayed.

Source: *Phys. Rev. Lett.* **111** 183203 (2013)
http://dx.doi.org/10.1103/PhysRevLett.111.183203

4. Brownian motion of nonsymmetrical particles

A Chakrabarty (Kent State University, USA) and his colleagues have studied the Brownian motion of boomerang colloidal microparticles confined between two glass plates, and established that, at the beginning of the observation, the particles move predominantly along the symmetry line, in the direction of expansion of the boomerang shoulders, while later on the motion of particles changes to chaotic. Boomerang-shaped particles with shoulder lengths of 2.1 μm placed at right angles were manufactured by a photolithographic technique from a polymer material. They form in water a suspension between two glass plates, and their quasi-two-dimensional motion allows one to observe that this behavior differs from that of spherical or ellipsoidal particles which move chaotically from the very beginning. The properties of the boomerang-shaped particle suspension and its quasi-two-dimensional motion could be observed through a glass using a microscope and a video camera. If one starts tracing a particle, then, at the beginning, as predicted theoretically, it moves along the symmetry axis with a nonzero mean displacement $\langle \Delta x \rangle$ in the direction of the total force exerted on it by molecules. However, the motion looks chaotic over large time intervals, $\langle \Delta x \rangle = 0$ and $\langle (\Delta x)^2 \rangle \propto t$, as in the case of the Brownian motion of symmetric particles. This is explained by the fact that, with time, the particle is turned, and its predominant direction of motion changes. Clarification of the properties of Brownian motion of nonsymmetric particles may prove useful for sorting and ordering large organic molecules.

Source: *Phys. Rev. Lett.* **111** 160603 (2013)
http://dx.doi.org/10.1103/PhysRevLett.111.160603

5. A remote galaxy

A galaxy characterized by a high rate of star formation at red shift $z = 7.5078 \pm 0.0004$ has been discovered using the MOSFIRE infrared spectrograph of the 10-m Keck I telescope. The galaxy is observable during the epoch when the age of the Universe was 700,000,000 years, and is the farthest away of those galaxies for which spectroscopic confirmation of the z value has been obtained. S L Finkelstein (University of Texas at Austin, USA) and his collaborators studied 43 galaxies at $z > 6.5$ among the candidate galaxies selected earlier with the NASA's Hubble Space Telescope. The spectral line, which can be interpreted as an Ly_α with a high confidence, was detectable only in the case of this one galaxy mentioned above. It appears that some effects at $z > 6.5$ make the registration of Ly_α difficult. This could be due to a high fraction of neutral hydrogen in the intergalactic medium, or a large amount of gas in galaxies themselves. The color of the above galaxy corresponds to a relatively high content of heavy elements in it. Owing to high z, the enrichment in metals should have been completed very fast: the estimate of the star formation rate should be $\sim 330 M_\odot$ year^{-1}, which exceeds the current rate of star formation in our Galaxy by 2 orders of magnitude.

Source: http://arXiv.org/abs/1310.6031

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