

PACS numbers: **01.10. – m**, **01.30. – y**, **01.90. + g**

Physics news on the Internet (based on electronic preprints)

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DOI: https://doi.org/10.3367/UFNe.2021.08.039040

1. Breit–Wheeler process

In 1934, soon after the founding of quantum electrodynamics, G Breit and J A Wheeler analyzed theoretically the process of electron-positron pair (e^+e^-) production upon the collision of two real (not virtual) photons. They noticed that the condition for e^+e^- production might be attained in a collision of highly charged relativistic ions. In this case, an ion field, which is Coulomb in the rest system, can be imagined as if consisting of real photons. The Breit–Wheeler process could not have been registered because of the difficult ion focusing. The Breit–Wheeler process in Au + Au collisions with a CMS energy of 200 GeV has been observed for the first time in the STAR experiment, carried out at the relativistic heavy ion collider (RHIC) at Brookhaven National Laboratory (USA) [1]. Almost tangent (ultrarelativistic) collisions of nuclei were singled out [2] in which strong interaction is not involved in scattering. In the experiment, 6085 produced e^+e^- pairs were detected, the process cross section $\gamma\gamma \to e^+e^-$ was measured, and the characteristic angular modulation predicted for the Breit–Wheeler process was observed. It confirms that it is real photons with transverse linear polarization that collide. One can hope that in a similar experiment vacuum birefringence will also be observed for photons in a magnetic field.

2. High-frequency signals in gravitational wave antennas

Gravitational waves from collisions of two black holes were detected by the LIGO detector in 2015 for the first time. It should not be ruled out that gravitational waves are also generated in other processes in the Universe at other frequencies. A new high frequency gravitational wave detector has started operating in the Australian city of Perth [3]. Its base is a quartz plate 1 mm thick and 30 mm in diameter; different modes of its volume acoustic oscillations are registered by a superconducting quantum interferometer (SQUID). The detector is thoroughly isolated from sources of acoustic and other environmental noises — its sensitivity is limited to internal thermal noises and SQUID readout noise. Two amplifiers, tuned to overtones of different oscillation modes, can conduct monitoring simultaneously at two frequencies. During the first 153 days of observation, M Goryachev (University of Western Australia) and his co-authors registered two statistically significant events. The first occurred on May 12, 2019 at a frequency of 5.506 MHz, whereas no event was observed at the other examined frequency of 8.392 MHz. The second event was noticed on November 27, 2019 at frequencies of 5.506 MHz and 4.993 MHz. Oscillations lasted 1–2 seconds; in view of the known plate quality factor, this is consistent with the time of damping from a short interaction. According to estimates, an energy of the order of hundredths of a fraction of eV was released in the detector. It is still unclear what may have been responsible for these events. During the events, no lightning or earthquakes occurred, and LIGO/Virgo detected no gravitational-wave bursts. No meteors or fast radio bursts were registered either. This may have been caused by stress relaxation in the quartz plate, the action of radioactivity, or cosmic rays. This may also have been a high-frequency gravitational-wave signal of unknown origin with a characteristic amplitude $h \simeq 2.5 \times 10^{-16}$. Other possible explanations concern domain walls or the interaction of dark matter particles with the crystal lattice. The nature of the registered signals will perhaps clear up with increasing detector sensitivity and the acquisition of statistics.

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Uspekhi Fizicheskikh Nauk **191** (9) 1116 (2021)
Translated by M V Tsaplina

3. Dissipative time crystals

Time crystals, predicted theoretically by F Wilczek in 2012, are characterized by the fact that their properties repeat in time like atoms settled periodically in solid crystals. Time crystals have already been observed in experiments. H Keβler (University of Hamburg, Germany) and his co-authors have become the first to realize time crystals stabilized by dissipation [4]. The experiment employed Bose-Einstein condensate of ^{87}Rb atoms in an optical cavity, to which laser pumping radiation was directed perpendicularly to the optical axis. As the pumping intensity increased above some threshold value, a density wave phase, described by the Dicke model, arose in the cavity. Time crystal oscillations occurred between even and odd states of density waves. Crystals were stabilized by balancing the periodical driving force, cavity-mediated interactions, and controlled cavity dissipation.

4. Directly measuring a multiparticle wave function

As distinct from the indirect measurement of a quantum wave function, realized in quantum tomography, direct measurements using a single observable make it possible to find a real or imaginary part of a wave function. The direct method has already been employed to measure the wave function of only one particle. M-C Chen (University of Science and Technology of China) and their co-authors proposed theoretically a new method of direct measurement of a multiparticle quantum wave function and have realized it experimentally for the first time [5]. It is based on quantum teleportation of an individual multiparticle density matrix element to a unit logical qubit, where the real or imaginary part of the element is measured through a quantum readout depending on the chosen measuring basis. The experiment with photons entangled in polarization states confirmed the efficiency of this method in the case of a two-photon wave function. In many cases, the new method may provide considerable advantages over the usual quantum tomography. For quantum effects, see [6–10].

5. Periodicity in fast radio burst profiles

The CHIME/FRB program for observing fast radio bursts (FRB) at frequencies of 400–800 MHz is being implemented with a Canadian radio telescope-interferometer. Some FRB profiles observed in CHIME/FRB show several peaks. The peaks of three FRBs are separated by about equal time intervals, which is indicative of FRB generation periodicity. Periodicity with a period of 216.8 ms and a significance of 6.5σ was found in the nine-peak burst FRB 20191221A. Some indications (1.3σ and 2.4σ) of periodicity with periods of 2.8 ms and 10.7 ms are shown by two more FRBs [11]. These observations favor neutron-star FRB origination: on magnetars and interacting neutron stars in binary systems. In view of the discovered millisecond periodicity, the emission region must lie in a neutron star magnetosphere rather than at a distance from it, as presupposed in some models. For FRBs, see [12].

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