

PACS number: **01.90.+g**

Physics news on the Internet (based on electronic preprints)

DOI: https://doi.org/10.3367/UFNe.2017.04.038123

1. Experimental realization of the discrete time crystal

Mikhail D Lukin (Harvard University, USA) and his colleagues have become the first to demonstrate experimentally a discrete time crystal whose characteristics recur at regular time intervals, just as the properties of ordinary crystals exhibit periodicity in space. Time crystals had been predicted theoretically by Frank Wilczek, although the original idea referring to thermally equilibrium systems turned out to be physically forbidden. But it was later shown that a discrete time crystal can be formed in a nonequilibrium Floquet system which is subject to a periodic drive. It was precisely such a system that M D Lukin and colleagues examined in their experiment. A discrete time crystal was realized at room temperature in a system of nitrogen-substituted vacancies in a diamond crystal. Observed were collective vacancy spin oscillations with periods equal to integer multiples (2 and 3) of the repetition interval of microwave pumping pulses. A discrete time crystal was obtained as well independently by another research group — J Zhang (University of Maryland, and the National Institute of Standards and Technology, USA) and colleagues — in an interacting spin chain of trapped atomic ions.

Sources: *Nature* **543** 217, 221 (2017)
https://doi.org/10.1038/nature21413
https://doi.org/10.1038/nature21426

2. Bose–Einstein condensate with a negative effective mass

The effective mass of a quasiparticle or another subsystem is expressed in terms of the second momentum derivative of its energy: $m_{\rm eff} = (\mathrm{d}^2\varepsilon/\mathrm{d}p^2)^{-1}$, and in some parts of the dispersion relation $\varepsilon(p)$ the effective mass $m_{\rm eff}$ can be negative, whereas the substance density remains positive. A negative $m_{\rm eff}$ has already been realized in some systems with a spin–orbit-coupled atoms. An experiment by M A Khamehchi (Washington State University, USA) and his colleagues has shown that some regions of Bose–Einstein condensate of ^{87}Rb atoms can also have $m_{\rm eff} < 0$. The spin–orbit coupling was generated by lasing which coherently bound the atomic levels $|F, m_{\rm F}\rangle = |1, -1\rangle$ and $|1, 0\rangle$. In the range of negative $m_{\rm eff}$, the Galilean covariance was broken, i.e., the acceleration direction of part of the condensate was opposite to the action of force created by the trapping potential. Such an asymmetric dispersion induced self-trapping, i.e., compression prevailed over general expansion. The experimental data are well described by the Gross–Pitaevskii equation, whose solution was helpful in clarifying the role of negative $m_{\rm eff}$ in the observed phenomena. In particular, it is responsible for emerging the shock waves and the soliton trains carrying away the energy through the condensate boundary.

Source: *Phys. Rev. Lett.* **118** 155301 (2017)
https://arXiv.org/abs/1612.04055

Uspekhi Fizicheskikh Nauk **187** (5) 546 (2017)
DOI: https://doi.org/10.3367/UFNr.2017.04.038123
Translated by M V Tsaplina

3. Homogeneous atomic Fermi gas in an optical trap

Gas inhomogeneity in atomic traps obstructs observation of a number of subtle effects that must take place in the homogeneous case. B Mukherjee (Massachusetts Institute of Technology, USA) and colleagues have created a homogeneous Fermi gas of ultracold ^{6}Li atoms utilizing a special shape of the trapping potential. The trap walls were created by a laser beam in the shape of a hollow tube bound by two transverse cross sections formed by additional beams. The gravitational force was compensated for by the magnetic field, so that the atoms might freely levitate. In such a hybrid potential, the trapped gas was homogeneous to a high accuracy. This made it possible to observe phenomena inaccessible to examination in inhomogeneous systems. Thus, in the momentum distribution of a spin-polarized gas, an emergence of the Fermi surface and a saturation of occupation of one particle per momentum state, i.e., Pauli blocking, were observed. The measurement of compressibility revealed a superfluid transition in a spin-balanced Fermi gas and strong attraction in the polaronic regime.

Source: *Phys. Rev. Lett.* **118** 123401 (2017)
https://doi.org/10.1103/PhysRevLett.118.123401

4. Nano-optical antenna in an X-ray detector

Designing small-sized X-ray scintillation detectors is difficult because of the low photon yield. In a new device demonstrated by T Grosjean (University of Bourgogne–Franche–Comte, France) and his colleagues, this difficulty has been overcome by coupling the scintillator to the optical fiber and the photodetector not directly but through a microscopic antenna operating in the optical range. A horn dielectric antenna was fastened to the end of a single-mode optical fiber through photopolymerization. The antenna mouthpiece faced an optical fiber 125 μm in diameter, and on the other side of the antenna a piece of scintillator was fixed. From the outside, the device was covered by a thin aluminum layer which transmits X-rays but reflects well photons from the optical range. Owing to such a construction, the majority of optical photons generated by X-rays in the scintillator get into the optical fiber and are then registered by a photodetector. The minimum X-ray flux that could be registered was $\sim 10^3$ photons s^{-1} μm^{-2}. The new detector may find important practical applications. For example, it can be assembled on an endoscope and may play the role of an ultracompact X-ray dosimeter in radio-therapy. Nano-optical antennas are described in the review by A E Krasnok et al. in *Phys. Usp.* **56** 539 (2013) [*Usp. Fiz. Nauk* **183** 561 (2013)]

Source: *Optics Letters* **42** 1361 (2017)

https://doi.org/10.1364/OL.42.001361

5. Excess of gamma rays from the Galactic center

In a number of works, the gamma-ray flux from the center of our Galaxy measured by the cosmic gamma-ray Fermi Large Area Telescope (LAT) at energies of a few GeV was noticed to exceed the flux expected in conventional models of gamma-ray generation by cosmic rays interacting with the interstellar gas and radiation. One of the explanations for the excess of gamma-ray emission is dark-matter particle annihilation. Fermi-LAT continues surveying the galactic center, and in a new analysis of data gathered over the course of 6.5 years takes into account the uncertainty in background radiation intensity, in cosmic ray fluxes, and in models of their propagation. Moreover, a possible contribution from Fermi bubbles, i.e., giant diffusive gamma-ray sources located on both sides of the galactic disc, was taken into account. Even with allowance for these uncertainties, the excess of gamma-ray emission from the center of the Milky Way remains statistically significant. The signal from control regions along the galactic disc in which the dark-matter density is low was also found to show an excess of gamma-ray emission, and therefore the annihilation of weakly interacting massive dark matter particle may not be the only source of the excess. Using the available data as the upper limit of the possible annihilation signal, the Fermi-LAT Collaboration has obtained new restrictions on the dark-matter particle annihilation cross section.

Source: https://arXiv.org/abs/1704.03910

Compiled by *Yu N Eroshenko*
(e-mail: erosh@ufn.ru)