

PACS number: 01.90. + g

Physics news on the Internet (based on electronic preprints)

DOI: 10.1070/PU2008v051n05ABEH006481

1. Superconductor in contact with a ferromagnet

Electric current destroys superconductivity because of the dissipation of energy by moving magnetic vortices. The critical current increases in the presence of factors, such as defects in crystalline structure, that lead to vortex pinning. Theorists have predicted that the critical current can also be increased by bringing the superconductor in contact with a layer of the ferromagnet whereby local magnetic fields pin the vortices within the boundaries of magnetic domains at the surface of the ferromagnet. Some evidence of this mechanism have already been examined in experiments. The new experiment by Vitalii Vlasko-Vlasov (Argonne National Laboratory in Illinois, US) and his colleagues studied this effect in more detail and a method was found for controlling the critical current through changing the characteristics of magnetization of the ferromagnet. A 0.8-μm-thick film of ferromagnetic $Ni_{80}Fe_{20}$ was deposited onto a 20-μm-thick superconducting $NbSe_2$ crystal. The magnetic field parallel to the film was applied to create in the ferromagnet an array of elongated magnetic domains with alternating directions of magnetization. This additional magnetic field generated magnetic vortices in the superconductor. The structure of magnetic domains in $Ni_{80}Fe_{20}$ was studied with a superconducting magnetometer and a magnetic-force microscope, while the pattern of magnetic vortices was observed through changes in light polarization. It was found that pinning vortices within magnetic domains increases the critical current flowing parallel to the film surface and across the magnetic domains by a factor of about three, as compared to the critical current in the direction perpendicular to the film surface.

Sources: *Phys. Rev. B* (to be published),
http://focus.aps.org/story/v21/st13,
http://arXiv.org/abs/0705.0555

2. Graphene transistor

The silicon-based electronic components industry has now reached the scale of $\simeq 45$ nm, which is not far from the limiting scale of $\simeq 10$ nm at which silicon is not capable any more of forming stable structures. The promise of further miniaturization in electronics is associated with using carbon in the form of nanotubes or graphene, and experimental transistors have already been created. A K Geim, K S Novoselov (the University of Manchester, UK), and their colleagues created a graphene transistor of record small size — its width is a mere 10 carbon atoms. Furthermore, in contrast to graphene transistors created earlier, which operated at ultralow temperatures, the new transistor can function at room temperature. The transistor constitutes a quantum dot comprising five carbon rings, with a potential well depth of about 0.5 eV. The efficiency of electron capture by the quantum dot and correspondingly the current flowing through the transistor are controlled by a magnetic field.

Source: *Science* **320** 356 (2008),
http://dx.doi.org/10.1126/science.1154663

3. Protons in supercooled water

A Pietropaolo, A Botti and their colleagues in Italy used the method of deep inelastic neutron scattering to study the energy distribution of protons (hydrogen nuclei) in molecules of supercooled water. Compared to water in its ordinary state, a significant excess of high-energy protons was observed, with the measured values of mean kinetic energy not following a simple linear-extrapolated dependence on temperature. The discovered phenomenon may originate with the effect of quantum delocalization of protons between oxygen atoms of two neighboring water molecules. The distance between neighboring oxygen atoms in supercooled water is less than in water in its ordinary state, which results in a changed interaction potential of protons and surrounding atoms.

Source: *Phys. Rev. Lett.* **100** 127802 (2008),
http://dx.doi.org/10.1103/PhysRevLett.100.127802

4. Single-photon ultrashort light pulse

P J Mosley (Oxford University, UK) and his colleagues obtained a record-short light pulse consisting of a single photon. Photons in pure quantum states were obtained by parametric conversion, i.e., by splitting photons in a nonlinear birefringent crystal into pairs of photons at doubled wavelength or with half the energy of the original photon. The high state purity (more than 95%) in pairs of photons was achieved by a special choice of dispersion properties of the crystal, angle of incidence of the light beam, and light wavelength, so that the group velocity of the initial photon was equal to the group velocity of one of the photons produced by splitting the initial photon. It was therefore possible to eliminate quantum correlations between photons of the pair. In the Oxford experiment, the pairs of photons made had a central wavelength of about 830 nm. The wave corresponding to the photons obtained was 65 fs long, which is shorter by a factor of 15 than record-short photons generated previously. In fact, even shorter pulses were reported earlier (see *Usp. Fiz. Nauk* **175** 314 (2005) [*Phys. Usp.* **48** 254 (2005)]), but only in wave packets consisting of many photons.

Source: *Phys. Rev. Lett.* **100** 133601 (2008),
http://dx.doi.org/10.1103/PhysRevLett.100.133601

5. Testing of general relativity

The quasar OJ287 is known to generate two powerful optical bursts approximately every 12 years. This quasiperiodic

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DOI: 10.3367/UFNr.0178.200805h.0557
Translated by V I Kisin

activity is a consequence of the presence of a pair of supermassive black holes in the quasar core. A black hole with a mass of 1.8×10^8 solar masses revolves on an elongated orbit around a black hole that is 200 times more massive with a period of about 12 years. The bursts occur when the smaller black hole travels through the gas accretion disk surrounding the larger black hole. In view of the considerable mass and compact size of the binary system under investigation, the effects of general theory of relativity (GTR) must be clearly manifested in the motion of the black holes, namely, rapid precession of the orbit and emission of gravitational waves. Theoretical calculations carried out under the guidance of M Valtonen of Tuorla Observatory in Finland and the next observation due of bursts on September 13, 2007 made it possible to conduct a new successful test of GTR predictions for strong gravitational fields. With precession and gravitational radiation taken into account, it was predicted that bursts should occur on the date above, give or take a day or two. Observations of the quasar OJ287 by several telescopes were started by that time and as expected, two bursts were indeed recorded on September 13, 2007. This has confirmed that OJ287 does indeed contain a system of two supermassive black holes. GTR predictions for gravitational radiation proved correct to within 10%. Without gravitational waves taken into account, the date of the bursts would shift by approximately 20 days. The rate of precession of black hole orbits reaches 39° per period. When these black holes approach, this binary system constitutes the most powerful emitter of gravitational radiation among the sources known in the Universe. There is a prospect, therefore, to observe gravitational waves from the binary system OJ287 in 12 years' time using the Laser Interferometer Space Antenna (LISA), which is planned to be launched before the event.

Source: *Nature* **452** 851 (2008)
http://dx.doi.org/10.1038/nature06896

6. Search for dark matter particles

Possible detection was reported in 2000 of dark matter particles (hidden mass) in the DAMA experiment (the Gran Sasso National Laboratory of the I.N.F.N., Italy). The detector allegedly revealed seasonal variations in the number of recoil nuclei, which could be interpreted as a periodic variation in the velocity of the Earth relative to the galactic halo (for details see *Usp. Fiz. Nauk* **170** 446 (2000) [*Phys. Usp.* **43** 414 (2000)]). However, this result was not confirmed in independent experiments, thus awakening suspicions that it was caused by systematic experimental errors due to, for instance, seasonal temperature variations. In the last several years, the DAMA experiment has been significantly modified. The updated DAMA/LIBRA experiment utilizes as a working substance about 250 kg of NaI(Tl) highly purified of radioactive inclusions that would generate background noise. Exposure of about 530 kg × yr has already been achieved in the measurements. The first DAMA/LIBRA results have completely confirmed the data of the preceding DAMA experiment. Seasonal variations of recoil nuclei were observed, unexplainable by any other known source of systematic errors. It is claimed that taking into account the data of the preceding experiment, the confidence level of registering the dark matter particles is supported at 8.2σ. At the present moment, it is necessary to clarify why other experiments gave negative results for the same range of parameters of dark matter particles, and to study in detail all other possible causes of the observed seasonal variations. The conclusion that the signature of dark matter particles has been successfully recorded can only be made when confirmation is provided by independent experiments.

Source: http://arXiv.org/abs/0804.2741

7. 'Echos' of X-ray flares

Data obtained with X-ray space telescopes Suzaku, XMM-Newton, Chandra, and ASCA indicate that the X-ray luminosity in the Fe K_α line emitted from the large gas cloud Sgr B2 located 300 light years from the supermassive black hole at the center of our Galaxy has been decreasing in recent years. The factor causing this X-ray light was most probably a flare that occurred close to the central black hole when a gas blob fell into it. The radiation of the flare itself reached Earth 300 years ago and the central region of the Galaxy in the X-ray spectrum was brighter for several years than now, by a factor of 10^6. Then, 300 years later the light of the flare reached the object Sgr B2 and excited its iron atoms which reemitted the X-ray 'echo' we observe now. The X-ray flare indicates that the quiet state of the central black hole is sometimes replaced by an active phase involving accretion of matter. A similar but less powerful flare from the galactic center was observed in 2001 (see *Usp. Fiz. Nauk* **171** 576 (2001) [*Phys. Usp.* **44** 546 (2001)]). The echo of flares is observed in other galaxies, too. S Komossa (Max Planck Institute for Extraterrestrial Physics in Garching, Germany) and her colleagues carried out detailed observations of the effect exerted on matter at the center of the galaxy SDSSJ0952 + 2143 which was detected in December 2007 in the Sloan Digital Sky Survey archive. The flare occurred as a result of a tidal disruption of a star near a black hole and the accretion of the generated gas cloud (the debris of the disrupted star) into the black hole. In this case as well, the X-ray and UV radiation caused ionization of the gas and the subsequent echo. The structure of the molecular torus surrounding the black hole and the accretion disk was studied in detail by observing the strength of iron emission lines, the degree of ionization, and the distribution of gas velocities. A very peculiar shape of the hydrogen emission lines emerging from the accretion disk was also noticed.

Sources: http://arXiv.org/abs/0803.1528,
Astrophys. J. Lett. **678** 13 (2008),
http://arXiv.org/abs/0804.2670

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