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Physics news on the Internet (based on electronic preprints)

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1. Testing the isotropy of the speed of light

Ch Eisele, A Yu Nevsky, and S Schiller (Institut fur Experimentalphysik, Heinrich-Heine-Universität Dusseldorf, Germany) conducted a laboratory test of the independence of the speed of light of the direction of its propagation, with record accuracy to date. The layout of the experiment resembled that of the classical Michelson–Morley experiment. The setup included two mutually perpendicular optical waveguides with slightly different resonance frequencies, in which standing electromagnetic waves were excited by a laser. The difference between frequencies in the two waveguides was measured by observing beats of the sum signal as a function of the spatial orientation of the apparatus. In the 13 months that the experiment was run, the apparatus was turned by 90 degrees approximately 175,000 times. Considerable effort was made to exclude external factors of various types that produce systematic errors. No anisotropy of the speed of light was detected at an accuracy of $\sim 10^{-17}$, which confirms the local Lorentz invariance at this level. The measurements conducted are important for testing the suggested approaches to constructing the unified field theory: indeed, the Lorentz invariance holds only approximately in some models.

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2. Ferromagnetism in a Fermi gas

W Ketterle (Massachusetts Institute of Technology, Cambridge) and his colleagues succeeded for the first time in detecting the ferromagnetic properties of an ultracold gas consisting of ^{6}Li atoms. Ferromagnetism was previously observed in gases only in the state of the Bose–Einstein condensate. The possibility of a transition of Fermi gases to the ferromagnetic state, when the interparticle interaction is repulsive, has been discussed in a number of theoretical papers, but no definitive conclusions have been made on the feasibility of such transitions. In the new experiment, a cloud of ultracold gas, which is a mixture of atoms with oppositely oriented spins, was trapped in the focus of an infrared laser beam. The transition to the ferromagnetic state at a temperature of less than 1 μK was identified by an indirect method of recording a drop in the rate of three-particle inelastic collisions that result in the formation of molecules, by detecting the point where the minimal kinetic energy of the particles is reached, and by recognizing certain characteristics of the expansion of the gas cloud after the atoms were released from the trap. These properties were exactly those predicted for the ferromagnetic gas. The gas cloud contained about 100 magnetic domains with volumes of about 5 μm^3, with about 50 atoms of the gas in each. This experiment demonstrated that itinerant ferromagnetism of delocalized-fermions is possible without crystal lattice and band structure.

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Translated by V I Kisin

3. Buffer-gas cooling

S Ch Doret (Massachusetts Institute of Technology) and his colleagues developed a new broadly general method of cooling a gas to the state of a Bose–Einstein condensate — the gas was cooled via collisions of its atoms with atoms of an auxiliary buffer gas. The Bose–Einstein condensate is typically produced by preliminary laser cooling, but this method works with only a few gases. In the experiment by MIT scientists, ^{4}He atoms were evaporated by light pulses from the inner walls of a vessel and a small fraction ($\sim 10^{-5}$) of them was raised by microwave pulses to an excited state ^{4}He*. Atoms of ^{4}He in the ground state acted as a buffer gas; collisions with them cooled ^{4}He* atoms to a temperature of $\sim$ 500 mK. Then in a short time ^{4}He atoms were again absorbed by the vessel walls, so that what was left in the vessel was a cooled gas of ^{4}He* atoms. Further cooling for the transition to the Bose–Einstein condensate used the conventional evaporation technique. The buffer-gas method can cool many atomic and molecular gases for which other methods of cooling are inapplicable.

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4. Improved atomic force microscope

Scientists at the IBM research laboratory in Zurich (Switzerland) and the Institute for Nanomaterials Science (Utrecht, the Netherlands) have improved the resolution of the atomic force microscope (AFM) to a level at which individual atoms composing a molecule can be observed. This became feasible by using a single molecule of carbon monoxide, CO, as a tip of the AFM needle. The factor that limited the resolution of AFMs with a sharp metal tip was the distortion of the structure of the specimen by van der Waals forces when the tip approached the specimen surface, or atoms jumped to the tip off the specimen surface, adsorbed on the needle, and destroyed the observed features. The advantages of a CO tip used as the needle tip lie in the considerable stability of this molecule against outside influences and van der Waals forces. As an illustration, L Gross and his colleagues carried out observations of a carefully scrutinized pentacene molecule, $C_{22}H_{14}$. The improved microscope made it possible to resolve all five carbon rings as well as all constituent carbon and hydrogen atoms in the molecule. It was possible to measure interatomic distances of only 0.14 nm, which is a record resolution of an atomic force microscope.

Source: *Science* **325** 1110 (2009)
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5. Search for gravitational waves

It is assumed that cosmic gamma bursts of short duration (less than two seconds) occur because of a merger of two neutron stars, or a neutron star and a black hole in a binary system, while long-duration gamma bursts with a softer spectrum are generated in supernova explosions. In both cases, gamma radiation must be accompanied with a powerful burst of gravitational waves. The data collected by the detectors LIGO (in the USA) and VIRGO (in Italy) during two years were compared with a catalog of 137 gamma bursts, most of which were observed by the Swift satellite. The study found no statistically significant correlation of signals, which puts a bound on the total energy of gravitational radiation, or (if energy is given) on the distance to the sources of the bursts. Typical gamma bursts occur in other galaxies, at cosmologically large distances. A gamma burst can be recorded by LIGO or VIRGO only if the burst source happens to be relatively near. Preliminary evaluations showed that such events cannot be dismissed as impossible, but that their probability is very low. An earlier search by the LIGO detector of a gravitational signal from a relatively near and extremely bright gamma burst GRB 030329 also failed to find a signal. According to calculations, gravitational waves from gamma bursts should be credibly recorded by future improved detectors with the sensitivity raised by approximately an order of magnitude compared to today's LIGO and VIRGO.

Source: http://arXiv.org/abs/0908.3824

Compiled by *Yu N Eroshenko*