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Physics news on the Internet (based on electronic preprints)

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1. The average trajectories of photons in the two-slit experiment

A Steinberg (University of Toronto, Canada) and his international team of researchers have determined by way of weak quantum measurements the average trajectories of single photons in an interference experiment similar to Young's two-slit experiment. An experiment is referred to as weak if it yields only partial information about the quantum state of the system in a way that does not destroy this state. For the light source developed at the NIST, Steinberg et al. utilized a quantum dot of low luminosity: only one photon was in the beam at any instant of time. Photons propagated through the optical splitter and entered into two arms of a Brown–Twiss interferometer. A calcite crystal placed in the path of the two beams produced phase shift and rotation of the polarization vector by the amount dependent on the direction of the photon momentum. Therefore, selection of photons with a specific polarization allowed conduction of weak quantum measurements of the photons' transverse momenta at different distances from the screen (the CCD matrix). After a large number of measurements of information on the average momenta and coordinates of interactions between photons and the screen, it was possible to calculate the set of average photon trajectories. The concept of average photon trajectories was introduced operationally; they are not real trajectories, and carry only a limited meaning in quantum mechanics. Compressions and rarefactions of the bunch of average trajectories was found to correspond to maxima and minima of the interference pattern on the screen; the pattern was not destroyed by weak quantum measurements of light pulses. The results of the experiment fully comply with the standard Copenhagen interpretation of quantum mechanics.

Source: *Science* **332** 1170 (2011)
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2. Dynamic Casimir effect

An experiment has been carried out at the Chalmers University of Technology in Gothenburg, Sweden, in which C M Wilson and his colleagues observed for the first time the dynamic Casimir effect, which was theoretically predicted by G Moore in 1970. The dynamic Casimir effect, in contrast to the usual static Casimir effect with two flat mirrors, occurs for a single mirror moving through space at relativistic velocity. It changes the spectral composition of zero-point quantum fluctuations in the vicinity of the mirror, and the pairs of virtual particles arising from the vacuum at sufficiently high velocity can separate and convert into real particles at the expense of energy obtained from the mirror. Wilson and his colleagues built an aluminium waveguide approximately 100 μm long, plugged by a superconducting contact — a SQUID. The SQUID's inductance was modulated within 10% by a microwave field at frequency 11 GHz. The modulation produced periodic changes in boundary conditions at the end of the waveguide, whose effective electric length correspondingly oscillated with the amplitude of about 1 nm. This yielded an analog of a mirror oscillating at a speed of about 5% of the speed of light. Observations recorded emergence of additional microwave photons. This radiation was composed of two correlated modes with different frequencies, which pointed to its quantum origin from split pairs of virtual photons, in agreement with the theoretical calculations for the dynamic Casimir effect.

Source: http://arXiv.org/abs/1105.4714v1

3. 'Friction' between holes and electrons in a semiconductor

Researchers from the University of California, Berkeley, and the Sandia and Lawrence Berkeley National Laboratories investigated the motion of electron–hole excitations in a single quantum wall. Unlike the case with noninteracting electrons and holes, exchange of momentum between them reverses the direction of flow of charge waves, namely, the flow of electrons drags holes in the direction of its motion. A similar but weaker effect had already been observed earlier in multilayer systems in which the interaction occurred between electrons and holes from neighboring layers (parallel quantum walls). In this experiment, the quantum wall was an n-doped 9-nm-wide GaAs/AlGaAs structure. The wave of electron–hole density was excited by laser pulses and created variations of the refractive index in a two-dimensional gas. These variations were recorded through optical measurements using phase-resolved transient grating spectroscopy, which yielded the values of the ambipolar diffusion coefficient and charge mobility, and this data allowed calculation of the characteristic value of the interaction ('friction') between a two-dimensional Fermi liquid of electrons and a dilute gas of holes in charge waves.

Source: *Phys. Rev. Lett.* **106** 247401 (2011)
http://dx.doi.org/10.1103/PhysRevLett.106.247401

4. Helical structures in a magnetized plasma

M Schwabe (Max-Planck-Institute for Extraterrestrial Physics in Garching, Germany) and her colleagues found new ordered structures in the plasma subject to a strong magnetic field. Plasma from neon, argon, krypton, and the air was studied at low pressure and room temperature. A plasma with an ionization level of $10^{-7}-10^{-6}$ was created by radio frequency discharge at the center of a superconducting solenoid whose magnetic field (vertically oriented) was uniform to within 0.65%. To achieve visualization, microscopic dust particles (2.55 μm in diameter) were injected into the plasma and illuminated by a horizontal laser beam; the

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observations were conducted through a transparent top electrode and through the side wall of the chamber. If the solenoid magnetic field was weak, the plasma–dust crystal filling the chamber rotated almost rigidly around its center. As the field grew above ~ 1.3 T at pressures of less than 20 Pa, plasma filaments emerged parallel to the magnetic field and their common rotation separated into individual vortices about 1 mm in radius around the axes of filaments. At the same time, microscopic particles in the plasma formed patterns of spirals and concentric circles in the transverse direction. No detailed theory of filament rotation and pattern formation has been developed so far. The authors of the experiment hypothesize that the phenomenon responsible for this effect is probably due to the motion of positive ions; in contrast to electrons, they are not trapped in the filaments and can travel through the chamber, are deflected by the magnetic field, and affect the motion of dust microparticles.

Source: *Phys. Rev. Lett.* **106** 215004 (2011)
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5. Galactic cluster PLCK G266.6-27.3

Detection with the Planck Space Radio Telescope (based on the Sunyaev–Zeldovich effect) and confirmation by the X-ray Observatory XMM-Newton revealed that the cluster of galaxies PLCK G266.6-27.3 belongs to a rare type of distant massive clusters with high X-ray luminosity. The iron emission line in the spectrum yielded an accurate redshift $z = 0.94 \pm 0.02$. The mass of the cluster, based on its X-ray luminosity of $\approx 1.4 \times 10^{45}$ erg s^{-1} in the range of 0.5–2 keV and on dynamic models, is estimated to be $(7.8 \pm 0.8) \times 10^{14} M_{\odot}$. This cluster is thus a member of the three known clusters at redshift $z > 0.5$ with the largest X-ray luminosity, and has become one of the two most massive clusters at $z \approx 1$. The cluster PLCK G266.6-27.3 is unique in that it appears to be very regular: spherically symmetric with a power-law density cusp at the center and a cold core. In other words, even though PLCK G266.6-27.3 is observed in a fairly early cosmological epoch when most of the clusters are only just beginning to form, it has already undergone dynamic relaxation. One possible explanation of these properties is that this cluster grew out of a very rare large density perturbation.

Source: http://arXiv.org/abs/1106.1376

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