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1. Search for axions

Ultralight axion-like particles (axions) could behave like a classical field filling the Universe and interacting with the spins of ordinary particles. Such interaction must be coherent and have a characteristic time dependence associated with Earth's motion. I M Bloch (University of California, Berkeley and Lawrence Berkeley National Laboratory, USA) and his co-authors have performed a new experiment searching for axions on the basis of the indicated signs [1]. Compared in a comagnetometer were the spin precession frequencies of ^{3}He and ^{39}K atoms. The influence of the new interaction on spins has not been revealed yet, but new constraints have been obtained on the value of the coupling constant of axions with protons and neutrons for axion masses of 1.4×10^{-12} to 2×10^{-10} eV. These constraints are stronger than the earlier astrophysical ones (on the SNO cycle in the Sun and neutron star cooling) and improve the previous laboratory constraints by two orders of magnitude. Axions were originally proposed to explain the strong *CP* violation in the Standard Model. Although the composition of dark matter in the Universe is not yet known, axions remain one of the probable candidates for the role of dark matter particles.

2. New quasiparticles — spinarons

In an experiment by F Friedrich (University of Wurzburg, Germany) and his co-authors, spinaron quasiparticles predicted by S Lounis et al. have been identified for the first time [2]. They are magnetic polarons resulting from the interaction of spin excitations with conduction electrons. Previously, interesting spectroscopic tunneling current zero-bias anomalies were observed for separate Co and Ce atoms on flat metal surfaces. Although an explanation was found for Ce atoms for such anomalies as vibrational excitations of hydrogen atoms attached to Ce atoms, for Co, this explanation turned out to be inapplicable. In the case of Co atoms, the anomalies were interpreted as the Kondo effect (collective scattering of impurity spins by conduction electrons) and Fano resonance. The new theoretical calculations by the density functional method and the experiment of F Friedrich et al. testify that a more probable explanation of the anomalies for Co is the formation of spinarons. Co atoms were placed on a copper surface at a temperature of 1.4 K in a magnetic field up to 12 T, and the tunneling current running through them was measured with both spin averaging and polarization. In the latter case, magnetic clusters of iron atoms were used at the tip of a microscope needle. In the tunneling current spectrum, signs of several spinor states were detected, and the magnetic field dependence appeared to be opposite to what it would have been for the Kondo effect. Possibly, many other phenomena which were earlier interpreted on the basis of the Kondo effect can actually be explained by spinarons. Spinarons may find useful applications in nanoelectronics.

3. Optical Stark effect in a pair of quantum entangled photons

The generation of photon pairs in an entangled quantum state is important for application in quantum information devices. In quantum dots, polarization entangled photons are produced in the process of two-photon resonant excitation in a biexciton-exciton cascade, but the efficiency of the described method remains lower than in the parametric down-conversion method. F Basso Basset (Sapienza University of Rome, Italy) and his co-authors have analyzed the influence of the laser-induced Stark effect on the emission spectra of quantum dots and on the quantum entanglement of emitted photon pairs [3]. A quantum dot in GaAs was irradiated with femtosecond laser pulses. The efficiency of entanglement turned out to depend on the ratio of laser pulse duration to the lifetime of the upper excited state of the point responsible for cascade generation. In the new experiment, the pulse duration was adjusted to the lifetime of the indicated level, and the prospects of using photon pairs from quantum dots at frequencies above GHz was shown, although there is still a wide field for further research and improvements.

4. Spectroscopy based on Tamm plasmons

K V Sreekanth (Institute of Materials Research and Engineering (IMRE), Singapore) et al. have demonstrated in their experiment a new spectrograph for surface-enhanced resonant Raman spectroscopy in the near-IR spectrum [4]. This device can be used to identify molecules based on the frequencies of their vibrational lines. A tunable Bragg reflector was used, which was made of alternating low-loss stibnite Sb_2S_3 layers, SiO_2 layers, and a thin metal film. It generated Tamm plasmons with wavelengths of 738 to 1504 nm. Continuous frequency tuning was achieved by changing the Sb_2S_3 layer structure from amorphous to crystalline upon electric heating. A laser beam was focused onto the sample by a lens, and the Roman scattering response was observed through the same lens. The experiment has shown the prospects of this device as a scaled biosensor platform for various applications in clinical diagnostics. In particular, the device can detect chromophore molecules at a wavelength of 385 nm, and it

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has been demonstrated to detect one of the biomarker proteins important in cardiology.

5. Supermassive black holes in the early Universe

The gravitational field of massive objects located on the line of sight focuses light like a lens, the effect being helpful in the observation of small galaxies at a considerable distance. The gravitational lens created by the galactic cluster Abell 2744 at redshift $z = 0.308$ allowed the James Webb telescope to observe 11 galaxies at redshifts $z > 9$ estimated photometrically. The X-rays coming from one of these galaxies at $z \approx 10.3$ were then measured by the Chandra X-ray Observatory, and the galaxy was found to contain a supermassive black hole (BH) with a mass of $\sim 10^7 - 10^8 M_\odot$, generating powerful radiation upon gas accretion [5]. The mass of such a BH is comparable to the total mass of all the stars in the galaxy, while in modern galaxies the masses of central black holes make up $\sim 0.1\%$ of the star mass. Furthermore, it is difficult to explain the very presence of such a massive BH in the epoch when the Universe was only 500 mln years old. BHs of stellar origin would not have had time to increase their mass to the indicated value, and models with a direct gravitational collapse of a massive gas cloud have not yet been ruled out, but also face the problem of a lack of dynamic time. Possibly, early black holes with masses of $\sim 10^4 - 10^5 M_\odot$ already existed and could have increased masses to $z \sim 10$ due to accretion. One of the versions of massive seed BHs are primordial BHs predicted by Ya B Zel'dovich and I D Novikov in 1966 [6] and discussed later by Stephen Hawking [7].

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