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Yu N Eroshenko

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1. Brown–Zak fermions in graphene

J Barrier (University of Manchester, Great Britain) and his co-authors have discovered a new type of quasiparticles, referred to as the Brown–Zak fermion, in a graphene layer placed between two layers of insulator — hexagonal boron nitride [1]. The arising superlattice has the form of a moire pattern with a period of ~ 14 nm. According to the calculations, for some magnetic field values the translational symmetry is recovered and the fermions must move rectilinearly (as in a zero field). The fermion electron spectrum was examined in detail by measuring the longitudinal and Hall conductivity of the sample. The spectrum shows multiple Landau levels that fan out. The predicted ballistic propagation of Brown–Zak fermions with a mobility exceeding 10^6 cm^2 V^{-1} s^{-1} was revealed. In a zero magnetic field, the free path of charge carriers exceeds 20 μm and is limited by the channel width. These data testify that Brown–Zak fermions are Bloch quasiparticles. However, at a low temperature, some mini-fans show anomalous behavior that has not yet been explained theoretically. Brown–Zak fermions may become the basis for the creation of ultrafast transistors and other electronic components. For graphene and graphene electronics, see [2, 3].

2. Quantum gravity scattering amplitude

Formulating the quantum gravity theory encounters problems with nonrenormalizability. In their theoretical paper [4], T Draper (Radboud University Nijmegen, Netherlands) and his colleagues have proposed a new type of effective quantum action in which the scattering amplitude of two different high-energy scalar particles scattered by means of a gravitational field remains finite. The action includes special propagators, and an infinite array of interacting spin zero states and spin 2 poles occurs in the amplitude. The formulated theory meets the unitarity and microcausality requirements and becomes scale-invariant upon approaching the Planck energy. It does not require the introduction of nonlocalities typical of string theory. The high-energy scattering region alone has hitherto been examined, whereas the infrared divergences due to the massless character of gravitons have not been considered. The proposed new type of action may underlie the construction of the theory of various elementary processes in quantum gravity. For the history of the development of quantum gravity theory, see [5], and for unsolved problems, see [6].

3. Equivalence principle violation for quantum particles

The weak equivalence principle asserts that free particle motion in a gravitational field is independent of its mass. The validity of the assertion in the quantum realm was doubted because of quantum uncertainties that exclude mentioning particle trajectories. The violation of the equivalence principle may also be due to the differences among the evolution of a wave packet of particles with different masses. J Q Quach (University of Adelaide, Australia) has investigated this aspect of the equivalence principle [7] using R Fischer's theory in which information is expressed in an integral way in terms of the particle wave function constituting the wave packet. In the static Schwarzschild metric, the quantum equivalence principle turned out not to be violated. However, in the variable field of a gravitational wave, the Fischer information depends on the particle mass, which means violation of the weak equivalence principle for a quantum particle. Gravitational waves are emitted, for instance, in the merger of two black holes. For single particles, it is now impossible to reveal the violation experimentally. J Q Quach emphasized that the effect can be stronger for Cooper pair condensate in superconductors.

4. Metalens

Metalenses consisting of a periodic array of elements on a flat base can in many cases substitute successfully for ordinary convex lenses. B Xu (Nanjing University, China) and co-authors assembled a metalens directly on a radiation sensor (on a light sensitive CMOS matrix in this case) to show that such a construction possesses a number of unique properties [8]. It can exceed substantially other analogs in resolution, signal-to-noise ratio, and width of the field of vision. A resolution of ~ 1.74 μm was attained for a centimeter lens. A two-phase matrix of metalenses with an extensive field of view was also investigated. Since the metalens was made of silicon, it can be readily integrated with CMOS matrices. The new method of exploiting metalenses can be used, in particular, in broad-field microscopy. For optical metamaterials, see [9, 10, 11].

5. Gas in cosmic filaments

On the scale of galaxy superclusters, matter is distributed in the form of walls, filaments, and nodes separated by extensive empty space regions. These structures are thought to contain

Yu N Eroshenko Institute for Nuclear Research,
Russian Academy of Sciences,
prosp. 60-letiya Oktyabrya 7a, 117312 Moscow, Russian Federation
E-mail: erosh@ufn.ru

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a considerable part of the hot gas in the Universe. This gas has already been registered by the thermal Zel'dovich–Sunyaev effect, but the data obtained did not allow its density and temperature to be independently determined because of degeneracy in the observed parameters. Some evidence of the presence of gas has also been obtained from X-ray observations. H Tanimura (Paris-Saclay University, France) and his colleagues have registered gas in filaments [12] for the first time with high confidence by its X-ray emission. The statistical sampling from the SDSS optical survey includes 15,165 30–100-Mpc filaments at redshifts $0.2 < z < 0.6$. They investigated the correlation of these filaments with ROSAT X-ray observations. X-ray point sources and massive galactic clusters were excluded. This was how gas emission in the range of 0.56–1.21 keV was discovered with a 4.2σ statistical significance. The gas density at filament cores exceeds 30 ± 15 times the average cosmological gas density, which is consistent with the data on the Zel'dovich–Sunyaev thermal effect. However, the measured gas temperature of $0.9^{+1.0}_{-0.6}$ keV is several times higher. Further examination is needed to reveal the reason for this difference. For the intergalactic gas, see [13].

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