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1. Conductivity of graphene

In experiments carried out to date, the conductivity of graphene (a one-atom thick carbon layer) has been measured on a substrate and no data has been available on graphene conductivity in a vacuum — that is, when the electronic structure of graphene is not disturbed by the influence of substrate charges (see, e.g., *Usp. Fiz. Nauk* **178** 776 (2008) [*Phys. Usp.* **51** 744 (2008)]). Theoretical investigation of this characteristic is not easy since the effective electrodynamic coupling constant α_g of electrons in graphene is approximately 300 times greater than the fine-structure constant $\alpha = 1/137$, so the methods of perturbation theory cannot be applied. J E Drut of Ohio State University in Columbus and T A Lähde of the University of Washington in Seattle have developed a new theoretical approach to calculating the electronic properties of graphene. They applied a numerical 'lattice' computation technique resembling methods used in quantum chromodynamics where the coupling constant is also large. Computations revealed how the energy gap in the graphene electronic spectrum changes depending on where the graphene is placed. It was shown that conductivity changes correspondingly and it is affected by the coupling constant α_g. For graphene on an SiO_2 substrate, the authors obtained $\alpha_g \approx 0.79$, so the graphene is conducting. As α_g increases beyond the critical value $\alpha_g = 1.11 \pm 0.06$, graphene becomes insulating. For instance, in a vacuum $\alpha_g \approx 2.16$ and graphene is an insulator. The validity of the formulated theoretical predictions can be tested in future experiments.

Sources: *Phys. Rev. Lett.* **102** 026802 (2009)
http://dx.doi.org/10.1103/PhysRevLett.102.026802
Nature **457** 638 (2009)
http://dx.doi.org/10.1038/457638b

2. Type-1.5 superconductors

V V Moshchalkov and his colleagues in Leuven (Belgium) and Zürich (Switzerland) have confirmed experimentally that the two-component superconductor MgB_2 possesses superconducting properties of both type-1 and type-2, and consequently proposed referring to it as a superconductor of intermediate type-1.5. They studied the spatial distribution of superconducting vortices in a single-crystal MgB_2 as it was cooled and went into a superconducting state in an external magnetic field perpendicular to the specimen surface. It was found that vortices are not uniformly spread but form denser patterns of a spider web or ribbon-like shape. This implies that at small distances vortices repel one another as they do in type-2 superconductors, but attract one another at larger distances as they do in type-1 superconductors. This phenomenon is theoretically explained in terms of two weakly coupled order parameters in superconducting MgB_2, so that MgB_2 manifests a combination of the properties of two superconductors with different ratios ξ/λ (coherence length to penetration length) typical of type-1 and type-2 superconductors. The measurement results are in good agreement with the predictions of numerical modeling of vortex dynamics and calculations in terms of the Ginzburg – Landau two-component theory.

Source: http://arXiv.org/abs/0902.0997

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3. Entangled state of mechanical oscillators

J D Jost and his colleagues at the US National Institute of Standards and Technology (NIST) in Boulder, Colorado have for the first time entangled two mechanical systems — two oscillators consisting of ion pairs $^9Be^+ - ^{24}Mg^+$ in a potential well. First, all four ions were trapped in a single potential well of a multizone linear Paul trap in which the internal degrees of freedom of two $^9Be^+$ ions got entangled. Then, two laser beams were used to modify the shape of the potential well and the ions were separated into two pairs of $^9Be^+ - ^{24}Mg^+ \sim 4$ μm in size; the separation between the pairs was 0.24 mm. These pairs of ions resemble microscopic springs with weights at their ends. Laser pulses forced the internal state of entanglement in each pair to transfer to the mechanical oscillations of ions in the pair relative to one another. This resulted in the formation of two pairs of ions entangled over mechanical vibrational degrees of freedom.

Source: http://arXiv.org/abs/0901.4779v1

4. Powerful gamma-ray burst

NASA's Fermi Gamma-ray Space Telescope has recorded a space gamma-ray burst of extraordinary power, designated GRB 080916C. The optical afterglow of the burst was observed with the GROND detector of the 2.2-m telescope at the European Southern Observatory in La Silla, Chile, as well as with other telescopes. The source of the burst was probably a supernova explosion in a remote galaxy with a red shift of $z = 4.35 \pm 0.15$; consequently, GRB 080916C belongs to the 5% of the remotest-recorded gamma-ray bursts. It is assumed that violent energy releases resulting in gamma-ray bursts take the form of narrow jets. It was established from the variability of gamma emission that the Lorentz factor of a burst exceeds 1090. If we assume for the sake of comparison that the emission is isotropic, the energy released in the explosion comes to 6.5×10^{54} erg, or roughly 9000 times the energy of ordinary supernovas. This allows classifying gamma-ray burst GRB 080916C as having record-high energy. As observed with some other bursts, high-energy photons arrive with a certain time delay relative to photons from the low-energy part of the spectrum. This may indicate that emission from different parts of the spectrum is generated in different conditions at different stages of the explosion, or in different regions of the jet-carried ejecta.

Source: http://arXiv.org/abs/0902.0761

5. Coherence of electrons in photosynthesis

It was earlier assumed that the energy transfer between electrons of different molecules in protein complexes responsible for photosynthesis proceeds classically (via Coulomb collisions). However, data were obtained in 2007 that electrons in protein molecules are quantum-coherent, so energy is transferred by a wave mechanism. The 2007 experiment required prolonged irradiation of molecules by laser light, which resulted in their degradation and destruction; furthermore, the spectra could be obtained only at select points of protein complexes. I Mercer of University College, Dublin, Ireland and his colleagues at Imperial College, London, UK worked out a new and perfected technique which made it possible to clarify details of energy transfer in photosynthesis. By using photosynthetic protein irradiation with a series of short laser pulses with different wavelengths, Mercer et al. obtained a two-dimensional spectrum of protein complexes and were able to build a spatio-temporal picture of the processes. Thus, the new experiment has confirmed that electrons transfer energy in a coherent manner.

Sources: *Phys. Rev. Lett.* **102** 057402 (2009)
http://dx.doi.org/10.1103/PhysRevLett.102.057402
http://focus.aps.org/story/v23/st5

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