Copper top insulator

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What do you get when you add copper to the topological insulator Bi_2Se_3? A topological superconductor. The answer is by no means obvious, for neither compound is superconducting on its own. Moreover, it only works when the Cu atoms form layers between the Bi_2Se_3 layers, rather than being substituted randomly for Bi atoms. And, as shown by Yew San Hor and co-workers, superconductivity at 3.8 K appears for a narrow range of Cu doping, corresponding to a low electron density of 2×10^{20} cm^{-3}.

Topological insulators are bulk insulators with conducting surface states that are robust against scattering and perturbations, making them ideal candidates for applications in spintronics and fault-tolerant quantum computing. The appearance of superconductivity is an exciting advance. As one example, a proximity effect between a conventional superconductor and a topological insulator — which would induce superconductivity in the surface states of the topological insulator — may finally lead to observation of the elusive Majorana fermion, a particle that is its own antiparticle and has half the degrees of freedom of a normal Dirac particle.

Universal key

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That a laboratory experiment performed at microkelvin temperatures can teach us anything about distant neutron stars and quark–gluon plasma might seem surprising. But two studies, by Sylvain Nascimbene *et al.* and Munekazu Horikoshi *et al.* (published in *Nature* and *Science* respectively) in which they measured the thermodynamical properties of dilute atomic gases, should contribute to a universal basis for the exploration of a broad class of such systems.

Ensembles of strongly interacting particles are notoriously difficult to understand, not least because their behaviour often depends on the details of the interactions between the particles. However, when, in a gas of fermions, these interactions approach the maximum strength allowed by quantum mechanics — known as the unitary limit — then the thermodynamics of the system depends on only particle density and temperature.

An ideal platform for probing the thermodynamics of such 'universal Fermi gases' is provided by trapped clouds of atoms cooled to quantum degeneracy, for which the interactions between the particles can be conveniently tuned. But so far progress has been hindered by the inhomogeneity of the trapping potential. The two groups have overcome this obstacle, and present detailed measurements of universal thermodynamic functions in their systems. Comparison with theoretical models reveals surprises — none of the existing theories agrees with the data over their full range.

Cosmic string theory

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It's 50 years since Yakir Aharonov and David Bohm proposed that a charged particle in a region of zero electric and zero magnetic field would still, through quantum mechanics, be affected by the electromagnetic potential. The effect is typically described in terms of a charged particle moving around a solenoid, and consequently acquiring a phase.

The concept applies on cosmological scales too. Katherine Jones-Smith and colleagues have turned things around and, envisaging a cosmic string as an oscillating solenoid in a vacuum, show that Aharonov–Bohm radiation — pair-creation of charged particles — is possible. Moreover, there should be an analogous gravitational effect that causes the radiation of all types of particle, including photons, and the authors show that the energy radiated as photons would be greatest around a kink in the cosmic string. The energy released is likely to be insufficient to signal the existence of a cosmic string, Jones-Smith *et al.* conclude, but the presence of this photon radiation may aid the identification of a string candidate, should one arise in other observations.

Spin spun

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Using the spin of electrons trapped in quantum dots is an approach to quantum information processing that has the benefit of being in the solid state. Jason Petta and colleagues are now able to control the spin of such electrons in just a matter of nanoseconds.

Quantum dots are often referred to as artificial atoms because they strongly localize electrons, forcing them into one of a discrete set of quantum states. They are appealing because they can be made using the same technologies developed for the semiconductor industry. The dots investigated by Petta *et al.* trap two electrons in the electrical field created by nanometre-scale electrical contacts.

For information-processing applications, it is crucial to rotate the spin state controllably. But managing single electrons with such tiny magnetic influence, particularly one that is confined to a small space, is far from easy. Petta and colleagues show that they can quickly switch between two two-electron spin states by careful tuning of the voltages applied to the quantum-dot device and the external magnetic field. This is done without relying on rapidly oscillating magnetic fields, which have been required in the past.

Economies of nanoscale

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To design an efficient photovoltaic solar cell involves — as with most things — tradeoffs between many competing physical and financial factors. Increasing the thickness of the active layer of a device means it will absorb more light and generate more charge carriers, but will make it more difficult to extract these carriers for electricity; conversely, decreasing this thickness means carriers can be extracted more efficiently, but reduces the amount of light absorbed. Using cheaper materials can bring down the cost of a solar-cell array, but reduces the amount of power generated per unit area or weight of the array.

Yet such factors needn't always be in competition. Michael Kelzenberg and colleagues show that, by building a solar cell whose active region consists of a forest of silicon nanowires, light absorption, carrier transport and material cost can be improved simultaneously.

The nanowires were just a quarter the thickness of the active region of a commercial polycrystalline silicon cell — enabling efficient carrier extraction. But, by depositing alumina particles between the wires to scatter incident light, the authors achieved similar levels of optical absorption. The result is a solar cell with a light-conversion efficiency equivalent to that of a commercial device but using just 1% of the silicon.