research highlights

Four pairs good

Nature Nanotech. **5,** 261–265 (2010)

Elemental superconductors have demonstrated superconductivity down to a single monolayer on a substrate, and now the superconducting state in organic superconductors is revealed to be similarly robust.

Specifically, Kendal Clark and co-workers have grown submonolayers of λ-(BETS)$_2$GaCl$_4$ on a silver substrate. There are two BETS, or *bis*(ethylenedithio) tetraselenafulvalene, molecules to one of GaCl$_4$, which form a sandwich structure with GaCl$_4$ as the filling, accepting half an electron charge from each BETS.

Using scanning tunnelling microscopy, the authors measured the superconducting gap of islands of a single layer of λ-(BETS)$_2$GaCl$_4$ — and the gap is significantly larger than the value expected for a weak-coupling conventional superconductor with *s*-wave symmetry. Their data fit best a d_{xy} gap, although other probes have yielded results consistent with both *s*- and *d*-wave symmetries.

The size of the gap decreases as the island area decreases, remaining finite down to four pairs of molecules, where the BETS chains measure only 3.5 nm. Based on the spectroscopic data, the superconductivity originates in these BETS chains.

Weighty issue

Phys. Rev. Lett. (in the press)

It's hard to get hold of a quark. Confinement by the strong force means that only bundles of quarks — as two-quark mesons or three-quark baryons, which are collectively 'hadrons' — are detectable or measurable in particle-physics experiments. Hence deducing the mass of each of the six flavours of quark has proved to be tricky.

Lattice QCD, which is a means of making fundamental calculations of such quantities as hadron masses using quantum chromodynamics (QCD), has however made great strides recently: more sophisticated calculations and increasing computing power have produced a mass value for the relatively heavy charm quark to an accuracy of 1%. The lightest quarks — up, down and strange — were still a problem.

But the latest round of calculations from Christine Davies and colleagues (the HPQCD collaboration) uses a single formalism for the masses of quarks and thus exploits the accuracy already achieved for heavy quarks to produce the most accurate measurements yet of light-quark masses. With the analysis tuned for consistency with experimental data on hadron masses, their value for the strange-quark mass in particular represents an order-of-magnitude improvement in the error, to better than 2%.

Algae, interrupted

Nano Lett. doi:10.1021/nl903141j (2010)

The humble plant is way ahead of scientists trying to eek a few more per cent from solar-cell efficiency, and has been for a very long time. WonHyoung Ryu and colleagues now show that it might be possible to tap, quite literally, into the highly evolved plant process by extracting the electrons generated during photosynthesis.

The chlorophyll in plants absorbs light, and the released energy splits water into oxygen and hydrogen with a few high-energy electrons left over. In the natural photosynthesis process, these electrons have a key role in the chemical reaction that converts carbon dioxide into organic compounds. Ryu *et al.* interrupted this process by inserting nanoscale electrodes into a single-cell alga, *Chlamydomonas reinhardtii*.

The probe consisted of an ultrasharp gold needle attached to the end of an atomic force microscope cantilever. The team slowly increased the pressure until the tip penetrated the membrane of an alga cell. They measured a picoamp current when the alga was illuminated, but nothing in the dark. The current is tiny, but the experiment shows that the idea is possible in principle.

Combing entanglement

Phys. Rev. Lett. (in the press)

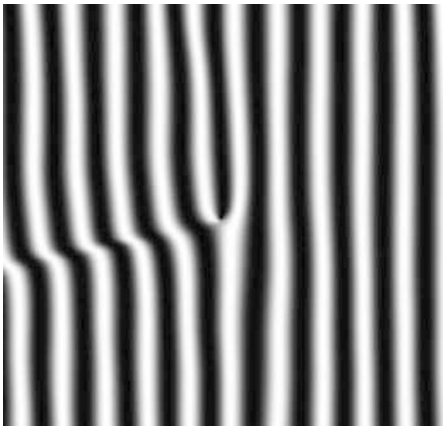
When a mode-locked laser fires off a train of short light pulses, it will generate a spectrum consisting of a series of sharp lines, separated by the repetition rate of the laser. Such spectra are known as frequency combs, and since their invention in 1998 they have been used extensively in optical-frequency metrology and high-resolution spectroscopy.

David Hayes and colleagues now bring optical frequency combs into the context of quantum information science. They make use of their large bandwidth (which is determined by the length of the individual pulses) and high spectral quality to control atomic qubits and generate entangled states.

To manipulate their qubits — encoded in the states of trapped ytterbium ions — Hayes *et al.* had to coherently control both internal electronic and external motional states of the ions. Usually this is done either by using two separate, phase-locked lasers or by modulating a single laser. However, those approaches are limited, respectively, by how well the phases of two lasers can be locked, or by the bandwidth of the modulator — exactly the areas in which the optical frequency comb has its strengths.

Electrons with a twist

Nature **464,** 737–739 (2010)



M. UCHIDA & A. TONOMURA

Waves with a spiralling wavefront, as opposed to a planar one, have created a great stir over the past couple of decades. In the field of optics, for example, they have found application in optical tweezers. Now, twisted beams of electron 'waves' have been created, and bring with them the promise of even more sensitive electron microscopy.

Spiralling photons are generated when a ray of light passes through a phase plate that has a surface shaped into a single twist. It is difficult to apply the same idea to electrons because of the length scales involved: the much shorter de Broglie wavelength of electrons means that the phase plate must have dimensions of less than 100 nm. However, Masaya Uchida and Akira Tonomura approximated a full spiral with a phase plate that simply consisted of four linear steps of graphite thin film.

When a plane-wave electron beam passes through this graphite structure it inherits the corkscrew-like shape and picks up orbital angular momentum. The interference pattern created by mixing the spiralling electrons with a planar wave has a distinctive kink (pictured) that marks it out from the stripy pattern expected when two plane waves interfere.

Correction

In *Nature Physics* **6,** 78 (2010), the Research Highlight 'Above the gap' incorrectly referred to Seung-Yeul Yang as Sanyuan Yang.