Cue to scatter

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Billiard balls are perfect for demonstrating to students the conservation of energy and momentum during collisions. They are also useful for modelling ultracold atoms and quantum dots. And for more complicated systems with moving boundaries, which give rise to multiple scattering events — such as a microwave cavity — Florian Lenz and co-workers again take their cue from billiards.

Their theoretical study involves an elliptical boundary that can change shape; by harmonically driving the ellipse, they create a dynamical non-equilibrium system of ensembles that undergo multiple scattering off moving targets. The authors calculate the escape rate for an ensemble of 10^5 particles through a small hole in the ellipse, which requires a four-dimensional (three spatial and one temporal) mapping of phase space. Particles can follow two orbits: the 'librator' or 'rotator', and only the rotator orbits lead to escape. Unlike for a static boundary, they find that for the driven system the escape rate does not saturate with time. This behaviour, which they can tune, is due to two fundamental scattering processes that change the librators to rotators, which then escape.

Interference proof

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The concept of interference doesn't stop at the familiar two-slit experiment. A particularly intriguing effect is that of particles that are emitted from completely independent sources but nonetheless interfere — as long as the particles are indistinguishable. Izhar Neder and colleagues demonstrate this effect using pairs of electrons, in an experiment that amounts to an electronic reproduction of the classic experiment of Hanbury Brown and Twiss, where the interference between light from uncorrelated portions of a star is observed (and used to determine the angular diameter of visual stars).

Whereas the Hanbury Brown–Twiss effect, using classical waves, has been known for more than half a century, constructing an experiment where independent single photons interfere has proved difficult — in particular, owing to the challenges of building completely independent sources of single photons that can be appropriately synchronized. As Neder *et al.* show, these problems are more easily addressed with electrons in a conductor that is cooled to the point where the Fermi gas is completely degenerate.

Working doubly well

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Cold atoms trapped in an optical lattice have come a long way as a simulator of quantum many-body effects. But such a system is also a contender for the hardware for a quantum computer. One requirement yet to be met, however, is the ability to manipulate individual atoms in the lattice, and therefore to address single qubits.

Patricia Lee and colleagues have explored an optical lattice whose unit cells can be transformed dynamically — by changing the polarization of the laser beam that makes up the lattice — between a single potential well and a double potential well. In the double-well configuration, the transition frequencies of an atom sitting in, say, the left-hand well is different from that of an atom sitting in the right-hand well. This tag provides a handle for addressing two distinct subsets of atoms, if not every atom individually. Furthermore, the ability to switch between single- and double-well configurations provides the means to control interactions between pairs of atoms.

Graphene junctions

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The relentless march towards building devices to probe, and perhaps ultimately exploit, the exceptional electronic properties of graphene continues apace, with two recent studies into the unusual quantum Hall behaviour of a graphene p-n junction.

In most semiconductors, p–n junctions are formed at the junction between two oppositely doped regions. But, being a pure hexagonal mesh of carbon atoms, graphene cannot be conventionally doped. In the first study, Jim Williams *et al.* overcome this by electrostatically tuning the majority carrier type of adjacent regions of a monolayer graphene sheet with isolated gate electrodes on either side. They find that when the two regions are tuned to be the same type, their device exhibits integral quantum Hall behaviour, but when tuned to be of different types, becomes fractional — consistent with theoretical predictions made in a second study of such junctions by Dmitry Abanin and Leonid Levitov.

Möbius in equilibrium

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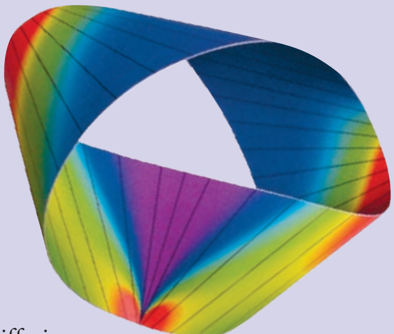
Everyone is familiar with the curious single-sided topology of a Möbius strip. But probably few are aware of how difficult it is to predict mathematically the exact shape of a Möbius strip in equilibrium. The challenge of doing so was first proposed by M. Sadowsky in 1930, but until now has remained unsolved.



To crack the problem, Eugene Starostin and Gert van der Heijden use a so-called invariant variational bicomplex formalism to derive the equations that describe the equilibrium state of a sheet that can bend but not stretch when it is subjected to large deformations. Using these equations, they simulate numerically the structures that arise when sheets of differing widths and lengths are bent to form a Möbius strip. More than simply providing a solution to an outstanding mathematical problem, the authors approach could prove useful in understanding the 3D topologies that form when paper is crumpled or a length of fabric draped.