

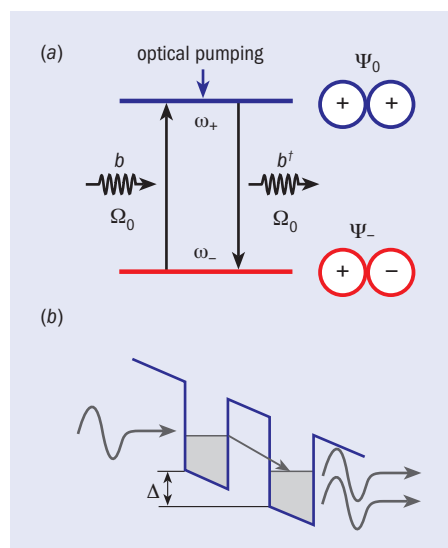
Phonon lasers produce coherent beams of sound

The acoustic equivalent of a laser – a device that produces a coherent beam of phonons – has recently been realized in two distinct ways. Ivan Grudin and colleagues at Caltech have used two coupled optical resonators to make a photonic analogue of a molecule with states differing by an energy corresponding to that of a phonon (figure a). The resonators are microtoroids 63 μm in diameter, operating in “whispering-gallery mode”. Coupling of the whispering-gallery modes occurs through evanescent waves in the air gap between the cavities. Optical pumping of the system with enough energy leads to coherent production of phonons at around 21 and 41 MHz, with the emission of lower-energy photons produced as “waste”.

In independent work, Ryan Beardsley and colleagues at the University of Nottingham have demonstrated coherent sound amplification in the terahertz range. They used a 50-layer n-doped superlattice of GaAs/AlAs to make the phononic analogue of a quantum-cascade laser, in which electrons tunnel down a staircase of quantum wells emitting phonons by stimulated emission as they go (figure b). Interestingly, the same sort of phonon-electron coupling that normally gives rise to electrical resistance with incoherent phonon emission here gives rise to a coherent beam of sound.

Making Majorana fermions in the lab

Majorana fermions, which – like photons – are their own antiparticles, have yet to be observed as fundamental particles. They could, however, be made as quasiparticles in the laboratory. The details are quite sophisticated but the basic idea is that Majorana fermions have half the number of degrees of freedom compared with normal fermions. In the Bardeen-Cooper-Schrieffer theory for superconductivity there is a mixing of electron and hole degrees of freedom with positive and negative energy respectively. Normally only half of the degrees



(a) Two-level phonon laser energy-level diagram including schematics of the symmetric and antisymmetric orbitals of the photonic molecule formed by coupled microtoroids. (b) Schematic representation of phonon-assisted tunnelling between neighbouring quantum wells in a superlattice by stimulated emission.

Further reading

Ivan S Grudin et al. 2010 *Phys. Rev. Lett.* **104** 083901.

RP Beardsley et al. 2010 *Phys. Rev. Lett.* **104** 085501.

of freedom – the positive energy ones – are considered, but there are situations when a zero-energy state appears. Taking half of the degrees of freedom of that state is then effectively a Majorana fermion.

Jason Alicea of Caltech has now shown that a rather simple set-up of a semiconductor coupled to a conventional superconductor (s-wave) in a strong magnetic field should work. This is interesting for quantum computing because Majorana fermions should display non-Abelian exchange statistics and could be used to manipulate quantum information without decoherence.

Further reading

J Alicea 2010 *Phys. Rev.* **B81** 125318.

Hydrocarbon superconductors

The first of a new class of high-temperature superconductors is a hydrocarbon. Ryoji Mitsuhashi of Okayama University in Japan and colleagues have shown that planar molecules of picene – essentially five benzene rings fused together – will superconduct at 18 K if doped with potassium or rubidium ions.

This is the first molecular superconductor whose organic component is made of only carbon and hydrogen. Interestingly, pentacene, which is isomeric with picene but with the benzene rings laid out a little differently, does not display the same superconducting behaviour. There remains plenty that is still not understood about exactly how this new material works.

Further reading

R Mitsuhashi et al. 2010 *Nature* **464** 76.

Qubit memories made of erbium

Photons are good candidates for qubits because they can easily be prepared in a superposition of two (polarization) states, but how might a memory device for such qubits be made without effectively making a measurement on them and destroying the quantum information?

Björn Lauritzen and colleagues of the University of Geneva shone a weak pulse of infrared light on a crystal containing erbium atoms that had previously been excited by a different pulse of light. Via a process called controlled reversible-inhomogeneous broadening, the infrared photons were effectively absorbed over many atoms and could be coaxed back out unchanged by a suitable electric-field gradient. The storage time was several hundred nanoseconds, and while the efficiency was under 1%, this is clearly an important advance in the storage of quantum information.

Further reading

B Lauritzen 2010 *Phys. Rev. Lett.* **104** 080502.