research highlights

Spinning around

Phys. Rev. D **79,** 103001 (2009)

Some newly formed neutron stars are believed to be magnetars — named for their incredibly strong magnetic fields, which may be as high as 10^{15} gauss. So far, 16 potential magnetars have been identified by astronomers, but the origin of their magnetic fields is not certain: Kohta Murase and colleagues suggest that there could be valuable clues in neutrinos detected on Earth.

If there is a dynamo mechanism at work in generating the magnetar fields, then these neutron stars are likely to be spinning with a rotation period of as little as a millisecond. Such rotation is good for particle acceleration, and Murase *et al.* show that, under such conditions, interactions of the cold nucleons and thermal photons around the magnetar (the remnant of its supernova) with cosmic-ray protons could produce distinctive fluxes of neutrinos — which could be picked up by large-volume neutrino telescopes such as IceCube, a cubic-kilometre detector array buried in the Antarctic ice and due to achieve full operational capability in 2010.

A better connection

Phys. Rev. A **79,** 040304 (2009)

A number of different systems have been investigated as bits for quantum information. Each has their strengths and weaknesses. David Petrosyan and co-workers now propose a technique for combining two of these approaches — atomic ensembles and superconducting circuits — to take advantage of the best aspects of each.

Superconducting qubits enable fast efficient logic processing, but decoherence means that the information is lost very quickly. Atomic ensembles, on the other hand, in which the information is stored as the collective spin excitation of many atoms, are much better for qubit storage. To transfer the quantum information from one system to the other and back again, Petrosyan *et al.* suggest using a microwave transmission line. This structure would strengthen the coupling between an optical field and the qubits. Quick state-transfer could be achieved by a judicious choice of resonant frequency for each part of the system.

The authors admit that the idea is likely to pose a number of challenges to experimentalists, but it is feasible and could enable high-fidelity quantum computing.

Less than wafer thin

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Superconductors are robust. You can pressurize them, freeze them, strain them, subject them to a magnetic field, add dirt to them — up to a limit, of course — but how thin can you make them? From tens of atomic layers downwards, quantum effects such as oscillations in the superconducting order parameter start to appear. Going further, Shengyong Qin and co-workers have made thin films of lead and observe superconductivity down to two atomic layers. Calculations show that one quantum level (or subband) of electronic states remains available for the formation of Cooper pairs.

The samples are grown on silicon substrates, which can affect the metal film. For instance, there are two lattice types: one with an underlying 1×1 atomic structure (similar in lattice parameter to bulk lead) and another that is $\sqrt{3}\times\sqrt{3}$ (similar to the silicon substrate) and rotated by 30°. Clearly, the film–substrate interface is important and could be used as a tuning parameter for the superconductivity, which has a different transition temperature for each type (4.9 K and 3.65 K, respectively).

Useful diversion

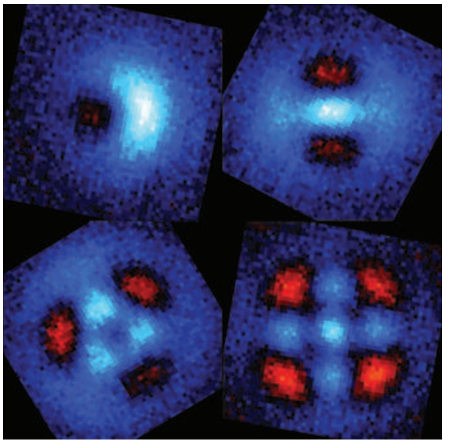
Phys. Plasmas **16,** 056110 (2009)

The key challenge in harnessing nuclear fusion for electricity generation is to confine a dense hydrogen plasma at temperatures of hundreds of millions of kelvin for long enough to extract useful amounts of energy. Progress with tokamaks has been made steadily for decades, and is measured by the product of the density, temperature and confinement time of a plasma. But increasing the power density of a tokamak-confined plasma may be limited by whether its exhaust — known as its divertor — could withstand the extreme temperatures and neutron fluxes generated.

Through redesigning the magnetic geometry of the divertor, Prashant Valanju and colleagues propose a solution. Simulations of their design, which they call a Super-X divertor, show that it increases the area of plasma in contact with the divertor plate two- or threefold, thereby reducing the flux and the temperature. If the allowable power density in the core of a plasma is thus increased, this could enable the construction of more compact fusion devices, to be used in the development of a hybrid fusion–fission reactor for processing nuclear waste (see Commentary on page 370).

Quantum-state synthesizer

Nature **459,** 546–549 (2009)



The superposition principle lies at the heart of quantum physics, and allows the preparation of a quantum system that is simultaneously in several distinct physical states. In practice, however, creating such non-classical states is challenging. But Max Hofheinz and colleagues now demonstrate that, in a superconducting resonator, they can synthesize 'on demand' a wide range of quantum-superposition states.

A resonant circuit possesses an infinite number of quantized energy levels, but accessing these levels is difficult, at least when the resonator is driven by a classical signal whose only adjustable parameters are amplitude and phase. Instead, Hofheinz *et al.* gain more control by using a superconducting qubit — a micrometre-sized circuit that acts as an effective two-level quantum system — which serves as a nonlinear element.

They have used a similar scheme before for creating states with a well-defined number of photons, but, with additional control over the amplitude and phase of the photons pumped into the resonator, they can now create superposition states in a deterministic manner — as shown here in these four Wigner tomograms for two- to five-photon states in superposition with the no-photon state.