

advantage is that the hardest part—constructing the entangled state—is all done in advance and is the same for every computation. The single-qubit measurements are comparatively easy.

Basic elements of the scheme are illustrated in figure 1. The cluster state is a square lattice of qubits in which each nearest-neighbor pair is directly entangled. The qubits are measured sequentially, from left to right, in the directions shown by the black arrows. (The $\otimes$ symbols are arrows pointing out of the plane of the page.) A chain of in-plane measurements serves to either propagate the state of a qubit (vertical arrows) or rotate it (tilted arrows) along the chain. The conjunction of two chains forms a simple quantum gate, which

can be combined to construct the quantum analogues of classical logic gates. The out-of-plane measurements serve to clean up the extraneous sites and keep the information chains separate.

One can also design a scheme for a one-way quantum computer based not on qubits but on continuously valued quumodes, such as squeezed optical modes.³ A coherent light beam has an inherent quantum uncertainty in its electric field; in a squeezed optical state, the uncertainty in one part of the wave cycle is reduced at the expense of another. Two optical beams are entangled if their correlations—uncertainty in their sum or difference, for example—display the characteristics of a squeezed state.

To create entangled states of light,

researchers typically use an optical parametric oscillator (OPO), a combination of an optical cavity and nonlinear crystals that split input photons into pairs of lower-energy output photons, subject to conservation of energy and momentum. The quantum fluctuations of the input, or pump, mode are transferred onto both of the output modes, which are thereby entangled.

Most efforts to entangle optical modes into a cluster state suitable for quantum computing involve building up the state bit by bit. Making a larger cluster state thus requires more hardware and effort. But, as Pfister and theorists Steven Flammia and Nicolas Menicucci determined, the equipment and effort might be greatly reduced by

physics update

These items, with supplementary material, first appeared at <http://www.physicstoday.org>.

A sound strategy for pollination. Plants gain an advantage in attracting pollinators if they stand out from the crowd. And so, many plants have evolved flowers with spectacular coloration or enticing scents. Ralph Simon (University of Ulm) and colleagues now report that the Cuban vine *Marcgravia evenia* uses a novel trick—based on acoustics rather than visual or olfactory effects—to attract its pollinating bats. Just above its purple flowers, *M. evenia* presents specialized concave leaves, shown here,

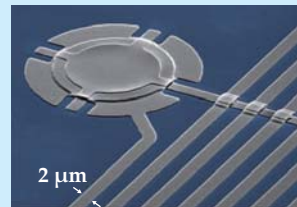


to the foraging bat. The leaf's spherical-cap geometry enables it to return a strong and consistent echolocation reflection over a wide angular range. Thus, as the bat flies around in the vicinity, the plant's steady signal is prominent amongst the random din of echoes from surrounding foliage. To check the effectiveness of the specialized leaf, Simon and colleagues hid a sugar-water feeder in artificial foliage and, in various trials, accompanied it with a replica of *M. evenia*'s concave leaf, a replica of the vine's nonspecialized leaf, or nothing at all. Bats

consistently found the feeder more quickly when the concave leaf was present. It's hard to imagine, write the authors, that the specialized leaves can have any evolutionary advantage other than attracting pollinators. (R. Simon et al., *Science* **333**, 631, 2011; image courtesy of Corinna U. Koch.) —SKB

Sidebands get to the mechanical quantum ground state. Last year researchers at the University of California, Santa Barbara, demonstrated quantum effects in the motion of a macroscopic object. They achieved control of phonon energy states in a high-frequency (6-GHz) micromechanical oscillator after cryogenically cooling it to its ground state. Now, researchers at NIST, JILA, and the University of Colorado at Boulder have employed photon-phonon coupling to reduce the vibrational energy of a low-frequency (10-MHz) micromechanical oscillator to the ground state. Their setup consisted of a flexible 15- μ m-diameter alu-

minum membrane (the gray disk in the image) coupled to a superconducting microwave resonant circuit. After cooling their system to 15 mK, the researchers applied a microwave field at a frequency just below resonance, generating so-called sideband photons that effectively steal energy from the membrane's phonons. For applied photon numbers on the order of 10^4 , the oscillator's motion enters the quantum regime, possessing on average less than one phonon. The researchers also detected the oscillator's displacement with a precision that comes closest to date to the theoretical Heisenberg limit. The low-frequency system's relatively longer phonon lifetimes and larger displacements could pave the way to storage of quantum information and generation of entangled states in mechanical systems. (J. D. Teufel et al., *Nature* **475**, 359, 2011.) —JNAM



The chaotic orbits of asteroids and Earth. Ever since Isaac Newton, astronomers and mathematicians have sought to understand the dynamics of the solar system, but even the seemingly simple case of the three-body Sun-Earth-Moon system eludes an analytical solution (see *PHYSICS TODAY*, January 2010, page 27). Obtaining accurate results for Earth's motion requires numerical calculations that include not only the Sun, Moon, and other planets but also the larger asteroids such as Ceres (now considered a dwarf planet), whose mass is 1/6000 of Earth's, and Vesta, less massive still by a factor of 4. Long-term knowledge of Earth's position is useful for paleoclimate studies, since the changes in incident sunlight allow calibration of geological records (see *PHYSICS TODAY*, December 2002, page 32). In 2004 Jacques Laskar and colleagues at the Paris Observatory calculated Earth's position back 40 million years, allowing calibration of the Neogene period, which began 23 Myr ago. But Earth's orbit is chaotic, with uncertainties increasing by an order of magnitude every 10 Myr, and it was not known how far the numerical solutions could be extended and still be valid. Laskar and coworkers have now established that the limit is 60 Myr. The researchers found that the motions of the five large asteroids they included were much more chaotic than previously thought. Furthermore, the effects of close encounters between asteroids—particularly Ceres and Vesta—on planetary motion are the limiting factor for establishing a longer-term history of Earth's orbit. (J. Laskar et al., *Astron. Astrophys.* **532**, L4, 2011.) —RJF