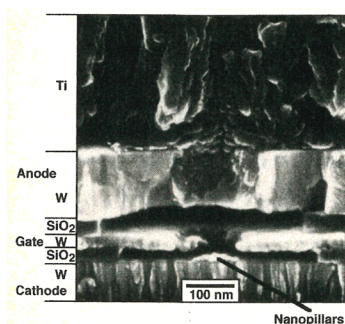


PHYSICS UPDATE

VACUUM TUBES ATTEMPT A COMEBACK. Vacuum tubes were the backbone of the electronics industry until the 1960s, when their large size, excessive power dissipation, and lack of small-scale integrability allowed solid-state technology to win out. Now, dense arrays of tiny nanotriodes might bring vacuum designs back, at least for niche applications. Researchers at the University of Cambridge (UK) have made a 100-nm sized anode-gate-cathode device (shown here in cross section) in which



the cathode consists of multiple metal pillars, which are each only about 1 nm in radius and crowded together in a dense forest. The one nanopillar with the greatest electric field at its tip is most likely the source of the

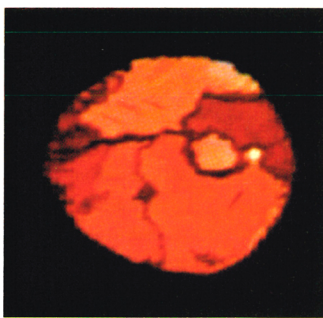
ballistic, field-emitted electrons in the triode. Shooting electrons through a vacuum makes not only for fast switching, but also for a few advantages over semiconductor technology: The nanotriodes are radiation resistant and operate well at both high and low temperatures; also, because they are vertically oriented, integration in the third dimension is possible. Electrons issuing from the nanopillars are coherent and highly focused, and might be useful for doing holography or nanolithography. Remaining problems with this vacuum design include a relatively high operating voltage (8–10 V) for large-scale integration applications, and the reproducibility and longevity of the devices. (A. A. G. Driskill-Smith *et al.*, *Appl. Phys. Lett.* **75**, 2845, 1999.) —PFS

WAVE PROPERTIES OF BUCKYBALLS have been observed. Anton Zeilinger (University of Vienna) and his colleagues sent a beam of the soccerball-shaped C_{60} molecules (also known as fullerenes) through a system of baffles and a grating (having slits 50 nm wide and 100 nm apart), and detected a characteristic quantum interference pattern. With velocities of around 220 m/s, the deduced de Broglie wavelength for the molecules is about 0.025 nm. They also saw the interference with C_{70} . The researchers suggest that, because they have shown that the large and complex buckyballs retain their quantum coherence, fullerenes provide an ideal system for further explorations of the boundary between quantum and classical physics. (M. Arndt *et al.*, *Nature* **401**, 680, 1999.) —PFS

AN ALTERNATIVE TO COMPACTIFICATION has been proposed for dealing with extra dimensions. Invisible dimensions are for particle theo-

rists what they are for Star Trek captains: a device for covering a lot of ground quickly and explaining anomalous behavior. In physics, they might help make peace between quantum mechanics and general relativity, but they don't explain the hierarchy problem—the great disparity between the energy at which the weak and electromagnetic forces fuse together (10^2 GeV) and that at which gravity joins up with the other forces (10^{18} GeV). Some theories contend that we are unaware of the extra dimensions because they are “compact,” extending only across distances far smaller than the size of an atom. But now, Lisa Randall and Raman Sundrum have proposed that additional dimensions can be essentially infinite in extent, as long as gravitons are locked up in localized regions, at least in the extra dimensions. They show that, with a particular non-factorizable metric, the 3-brane on which we live is just part of a five-dimensional space, the equations of general relativity are solved and its tests met, the unification energy scale comes down to about 1 TeV, and spin-2 resonances are predicted that will be experimentally verifiable at the Large Hadron Collider. Sundrum emphasizes that localized gravity, not infinite extra dimensions, is what brings down the gravity scale. (L. Randall, R. Sundrum, *Phys. Rev. Lett.* **83**, 3370, 1999; and **83**, in press, 1999.) —PFS

A LATTICE OF O_4 MOLECULES may exist in high-pressure experiments. At pressures less than 10 GPa, solid oxygen behaves much like other molecular crystals, such as nitrogen: A series of different structures appear as the pressure increases, although the molecular bonds are not greatly altered. At 96 GPa, oxygen becomes metallic. Throughout the large pressure range in between, the molecule is in its mysterious ϵ , or “red,” phase. The transition to the ϵ phase is characterized by a greatly reduced volume, a dramatic color change (to a deep red, as shown here), and very strong infrared absorption. Now, a group of researchers at the University of Florence (Italy) have studied the IR spectrum in detail, including the far IR region, and concluded that the



charge transfer mechanism becomes extremely efficient between 10 and 20 GPa, and leads to chemical bonding between neighboring molecules. No theory exists for an O_4 molecule, but calculations done for an O_2-O_2 dimer provided a qualitative guide for interpreting the spectra. The association into O_4 units could be the first stage in oxygen's metallization process. (F. A. Gorelli *et al.*, *Phys. Rev. Lett.* **83**, 15 November 1999.) —PFS ■