JANUARY 2006

PHYSICS TODAY

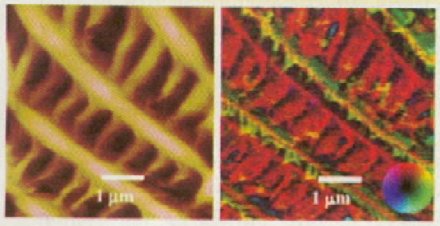
********** *****FIRM CAR-RT LOT ** C-021
0957022478 AVS PT 059-01 X S DOM
PT
SERGEI V KALININ
OAK RIDGE NATIONAL LAB
BLDG 3025 M/S 6030
1 BETHEL VALLEY ROAD
OAK RIDGE TN 37830-8050
P0040

Special focus:
Benjamin Franklin turns 300

Physics Update

Supplementary material related to these items can be found at www.physicstoday.org.

A nanoscale Galvani experiment provides a new way to image and characterize biological tissue. In the 18th century, Italian physician and physicist Luigi Galvani caused a frog's muscle to contract when he touched it with an electrically charged metal scalpel, and thereby made perhaps the first observation of electromechanical coupling in biological systems. The simplest of such couplings is piezoelectricity, in which voltage induces mechanical deformation and vice versa. Cellulose, collagen, and keratin are among the many biopolymers that exhibit piezoelectric behavior. At the November 2005 AVS meeting in Boston, Sergei Kalinin of Oak Ridge National Laboratory and his colleagues reported results from a technique named piezoresponse force microscopy (PFM), in which a voltage applied to the tip of a scanning probe microscope induces an electromechanical response that is determined by local molecular orientation. The researchers have imaged various tissues—including cartilage, the enamel and dentin of teeth, and deer antler—with better than 10-nm resolution. The images here show a portion of a butterfly wing; topography is on the left and the piezoresponse is on the right, where the colors indicate the orientation of chitin molecules. (S. Kalinin, B. Rodriguez, A. Gruverman, AVS meeting paper NS-WeM3. Also see J. Shin et al., *J. Vac. Sci. Technol. B* **23**, 2102, 2005; S. V. Kalinin et al., *Appl. Phys. Lett.* **87**, 053901, 2005.) —BPS



Optical vortex coronagraph. Astronomers would like to view extrasolar planets directly without any annoying glare from the parent star, in much the same way that the Sun's faint corona is best seen during an eclipse. A typical star looks like a fuzzy blob of light—an Airy disk—due to the various optical elements in the telescope. A nulling coronagraph uses an occulting mask in an intermediate focal plane to remove starlight by shifting its phase over some part of the Airy disk. Grover Swartzlander and his colleagues at the University of Arizona propose to replace such a mask with a "vortex phase mask" to produce a helical phase front. Light passing through the thicker central part of the mask is slowed down and, because of the graduated shape of the glass, an "optical vortex" is created: The light coming along the axis of the mask is, in effect, spun out of the image. The Arizona optical scientists have shown that in the absence of scattering or aberrations, such a device can extinguish any magnitude of starlight while letting the light from a resolved companion planet through, even if the two objects differ in brightness by a factor of 10 million. (G. Foo et al., *Opt. Lett.* **30**, 3308, 2005.) —PFS

Hyper-entangled photon pairs. Entanglement is the quantum connection between or among particles (such as atoms or photons) because of which the measurement of some property for one particle automatically and instantaneously determines the corresponding property of the other particle. One of the chief hopes of entanglement researchers is to exploit the phenomenon for quantum computation. (See PHYSICS TODAY, April 2003, page 46.) Paul Kwiat and his colleagues at the University of Illinois have now demonstrated the entanglement of two photons in all possible degrees of freedom. The physicists sent light to be "down-converted" in two adjacent nonlinear crystals, producing daughter photons that were simultaneously entangled in polarization, orbital angular momentum, and energy–time. The uncertainty of the precise production details of each photon in each crystal is what permitted the hyper-entanglement to occur. The setup was also used to produce an unusual state in which photon pairs simultaneously displayed classical correlations in polarization and quantum correlations in orbital angular momentum. (J. T. Barreiro et al., *Phys. Rev. Lett.*, in press.) —PFS

Gravity map of tides under Antarctica. Scientists have known for decades about tidal flows along the Antarctic Ocean's floor that can lift an entire coastline by as much as 3 meters and simultaneously erode or melt the underside of the ice sheet. The availability of only a few in situ measurements, however, has made the large-scale process difficult to model. Geoscientists from the Ohio State University and the National Astronomical Observatory of Japan have now mapped the tides using GRACE—a pair of satellites with known separation whose minute differences in orbital acceleration are used to repeatedly measure Earth's entire gravity field. As shown here, the large moving mass of water in the tides could be extracted from GRACE's data. The top map shows the height fluctuations resulting from the twice-daily lunar tides; the result of the solar tides appears on the bottom. (S.-C. Han, C. K. Shum, K. Matsumoto, *Geophys. Res. Lett.* **32**, L20311, 2005.) —SGB