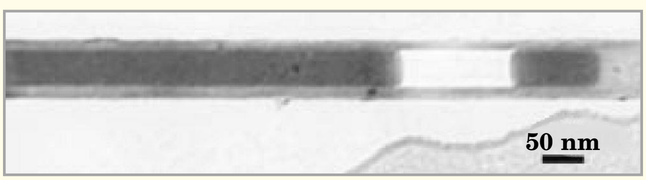
Physics Update

A picosecond-resolution crystallographic movie of a functioning protein has been created by a multinational collaboration. Crystallographers have amassed snapshots of thousands of frozen proteins, but those structure determinations provide only limited information on how a protein actually works. It would be more informative to capture a protein's full collection of motions as it functions (see the article by Eric Galburt and Barry Stoddard in PHYSICS TODAY, July 2001, page 33). Now, using the European Synchrotron Radiation Facility in Grenoble, France, researchers have made picosecond movies of a mutant form of myoglobin—the protein that stores oxygen in muscle tissue—ridding itself of a toxic carbon monoxide molecule. To capture this process, the scientists first hit the protein with a 1-ps pulse of laser light to dislodge the CO, then used an intense 150-ps x-ray pulse with a variable time delay. A CCD camera recorded the diffraction pattern at each time delay; from that recording, the collaborators deduced the sequence of the rapid structural changes. The movie showed the CO migrating to various sites in the protein, with the myoglobin rearranging its shape accordingly. The picosecond time scale of the structural changes is similar to the time scale of many molecular dynamics simulations, and could allow for closer comparison between theory and experiment. (F. Schotte et al., *Science* **300**, 1944, 2003) —BPS

A high-temperature nanotube thermometer has been fabricated. Researchers at the National Institute for Materials Science in Tsukuba, Japan, developed a one-step approach to synthesizing magnesium oxide nanotubes filled with gallium. The several-micron-long tubes have square cross sections, tens of nanometers on a side. Often, the gallium filling has a gap in its midsection, as shown below. The gallium expands linearly as it's heated; the temperature of the thermometer can be read out by measuring changes in the size of the gap using electron microscopy. And because MgO has excellent high-temperature stability, the thermometer can operate from room temperature up to well over 1000°C. Similar carbon-nanotube thermometers—fabricated by the same group last year—degrade above 700°C. The scientists were also able to fill MgO tubes with indium, and thus suggest that their synthesis technique might be used universally to create metal-filled oxide nanotubes. (Y. B. Li et al., *Appl. Phys. Lett.* **83**, 999, 2003.) —JRR



Entangled protons in a solid polymer. In condensed matter systems, adjacent nuclei and their nearby electrons can all, in principle, be in a state of quantum entanglement, but the decoherence time would be exceedingly short—in the subfemtosecond realm. Still, the effect could be observable, according to Aris Chatzidimitriou-Dreismann (Technical University Berlin), because the time scale is roughly the same as the interaction time for Compton scattering. Several years ago, he performed neutron Compton scattering off water molecules and saw an anomalous shortfall of scattering from protons, which he attributed to short-lived nuclear entanglement. Now, he and his collaborators have Compton-scattered both neutrons and electrons off protons in a polymer called formvar. The electron experiments, done at the Australian National University in Canberra, showed precisely the same shortfall as the neutron experiments, done at the ISIS neutron spallation source in the UK. The similarity of the results is striking because the two projectiles interact with protons via fundamentally different forces—electromagnetic and strong. (C. A. Chatzidimitriou-Dreismann et al., *Phys. Rev. Lett.* **91**, 057403, 2003.) —BPS

Tumor holograms. Researchers at Purdue University and Imperial College, London have created a holographic imaging system capable of visualizing structure inside living tissue. The researchers used optical coherence imaging (OCI), a technique that directly records complete images of thin tissue sections with a video camera. Tissue readily reflects image-bearing infrared light, but it also strongly diffuses the light, an effect that would ordinarily overwhelm the coherent pictures. The key to the OCI technique is a dynamic holographic film—a 100-layer photorefractive quantum-well device—that filters out the diffused, incoherent background light but passes the coherent, full-frame images to a camera. By adjusting the relative delay between the image beam and the reference beam in the OCI system's imaging interferometer, the researchers control the depth of the image plane and thereby assemble a slice-by-slice tour through a tumor while leaving the tissue intact. Application of the OCI technique to cultured rat tumors (see image) revealed structures that appeared to be dead tissue and calcifications much like those found in human cancers. The researchers say that holographic OCI could offer a nondestructive alternative to ionizing x rays and microsectioning methods for studying living tissue. (P. Yu et al., *Appl. Phys. Lett.* **83**, 575, 2003.) —JRR