

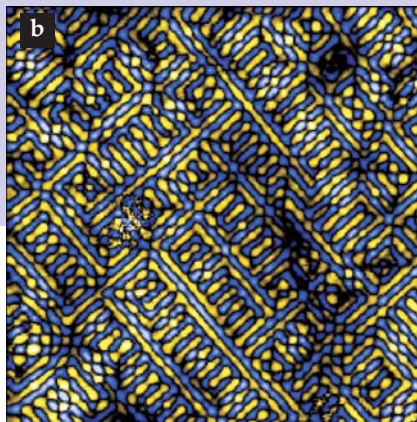
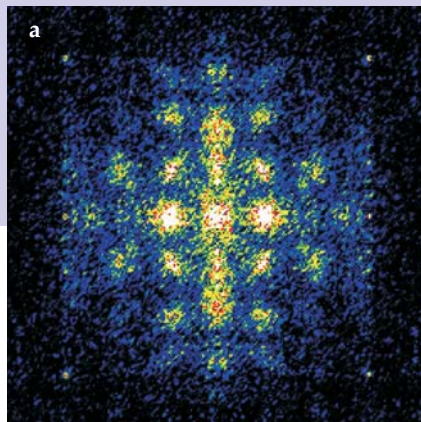


Figure 3. Schizophrenic behavior. Measurements on underdoped Bi-2212 samples reveal, at low excitation energy, quasiparticle interference patterns, suggestive of superconducting electrons (**a**) and, at higher energy, striplike stationary patterns (**b**). (Courtesy of Séamus Davis, Cornell University.)

The results from Hudson's group echo the findings from some angle-resolved photoemission spectroscopy (ARPES) experiments^{8,9} and from Raman scattering measurements,¹⁰ all of which have reported evidence for a second gap below T_c that's smaller than the pseudogap. At the same time, other ARPES groups claim to see just one gap.^{11,12}

Looking in momentum space

A third STM group, led by Davis, has been studying the behavior of underdoped cuprates well below T_c in both real⁴ and momentum space.¹³ At recent

conferences, Davis has reported finding different behavior depending on the energy of the tunneling electrons. For low excitation energies (corresponding to low voltage bias), Davis and his collaborators find evidence for a superconducting condensate. For excitation energies of 35 mV and higher, they find only static spatial patterns, indicating that the electrons are partially localized.

Davis's collaborators hail from Cornell, Brookhaven National Laboratory, the University of Colorado in Boulder, the University of Sherbrooke in Canada, and, in Japan, the University of Tokyo,

RIKEN's Discovery Research Institute in Wako, Kyoto University, and the National Institute of Advanced Industrial Science and Technology in Tsukuba.

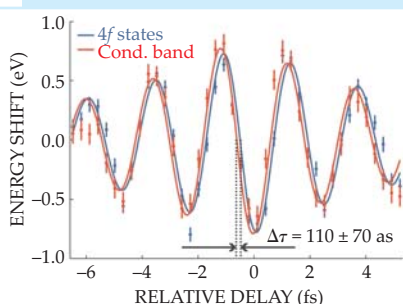
Traditionally, STM has complemented ARPES, with STM peering into real space and ARPES probing k space. A number of years ago, theorists noted that one can infer k -space information from STM. Scanning tunneling microscopes can measure the spatial interference patterns, such as that seen in figure 3a, made by long-lived quasiparticles—electrons from broken Cooper pairs—as they scatter off impurities or other defects. Fourier transforming such patterns yields the k -space scattering vectors.

Last year, Davis and his colleagues explored a new way to look at STM data in real space, exploiting an asymmetry of the tunneling spectrum of high- T_c superconductors¹⁴ that was noted back in

physics update

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Solid-state attosecond metrology. Chemistry takes place at the femtosecond speed of atomic motions. In contrast, electrons within atoms, or traveling between neighboring atoms in a molecule or solid, zip along at an attosecond pace (1 as = 10^{-18} s). A European collaboration of physicists, led by Ferenc Krausz at the Max Planck Institute for Quantum Optics in Munich, Germany, has now timed the transport of photoelectrons prior to their emission from tungsten. To do that, the researchers sent through a tube of neon gas an intense femtosecond laser pulse of near-IR light comprising a few well-controlled field oscillations (see PHYSICS TODAY, April 2003, page 27). Through the magic of high-harmonic generation, a single, isolated 300-as coherent extreme UV pulse in a selected spectral band (90–100 eV) was produced. Next, the XUV pulse was directed at a tungsten target where it energized electrons lying close to the sample's surface.



Affected electrons included both the delocalized conduction-band variety and those tightly bound in the tungsten atoms' 4f orbital. Electrons from those two populations were cleverly distinguished: Part of the original NIR laser beam remained coher-

ently linked to the XUV pulse and was engineered to selectively accelerate the conduction-band electrons as they sprang out of the sample's surface ahead of the 4f electrons. The detected time delay of 110 ± 70 as (see the figure) between the two types of photoelectrons was due entirely to propagation differences of the electron wavepackets in the sample. (A. L. Cavalieri et al., *Nature* **449**, 1029, 2007.) —PFS

Energy-dissipation nanoprobe. Scanning probe microscopy translates the interaction between a flexible cantilever's super-sharp tip and a sample material into topographical images and force measurements at the nanoscale. However, standard single-frequency SPM cannot reveal certain information, such as the local energy dissipation at a single structural defect—that information is embodied in the quality factor Q of the vibrating cantilever. Frequency sweeps using standard lock-in techniques can determine Q , but those techniques are too slow for practical imaging. Now Stephen Jesse and Sergei Kalinin and their collaborators at Oak Ridge National Laboratory, working with Roger Proksch of Asylum Research, have devised a way to excite the cantilever and measure the response over a band of frequencies simultaneously. Known as band excitation (BE), the method is useful for energy-dissipation measurements since the Q factor can be measured directly, even for low Q -factor environments such as liquids. In just about 1 second, the researchers produced force-distance curves of the tip interactions with cleaved mica; a comparable lock-in scan would take around 30 minutes. The team also showed that Q decreased sharply when ferroelectric domains nucleated. In addition, the BE SPM imaged in both amplitude (left image) and phase (right image) the flower-like patterns associated with magnetic domains of yttrium-iron garnet, and detected ring-like energy