



permittivity. According to the theory, the collective plasmon oscillations became increasingly sensitive to the quantum nature of individual electron transitions as particle dimensions diminished. Despite a number of simplifying assumptions, such as infinite potential barriers, the energies of the model's LSPRs closely matched the EELS observations. This initial theory can be applied to other met-

als and geometries by making modifications to the key parameters in the dielectric function.

The research team now anticipates that researchers may be able to exploit the behavior of quantum-sized nanoparticles for a variety of applications. Because of their high-surface-area-to-volume ratios, these nanoparticles are ideal candidates for sensor and catalysis

applications, particularly for events that involve interactions with very few photons or transferred electrons. Quantum-sized nanoparticles may also be of value in biological systems since they should be able to maneuver through cellular environments with greater ease than their larger counterparts.

**Anthony S. Stender**

### Spin-orbital separation observed in a Mott insulator

Electrons in atoms can be described by three quantum numbers: spin, charge, and orbital. In an experiment performed at the Paul Scherrer Institute in Switzerland, these properties have now been separated. In one-dimensional systems, it is predicted that the electrons can separate into independent quasi-particles, which cannot leave the material in which they have been produced. While quasi-particles carrying either spin (spinons) or charge (holons or chargons) have already been identified, an international team of researchers led by experimental physicists from the Paul Scherrer Institute, Switzerland, and theoretical physicists from the IFW Dresden, Germany, have now succeeded in separating quasi-particles carrying the orbital degree of freedom (orbitons). These results are reported in the May 3 issue of *Nature* (DOI: 10.1038/na-

ture10974; p. 82).

The electron's breakup into two new particles—spinons and orbitons—has been gleaned from measurements on the copper-oxide compound  $\text{Sr}_2\text{CuO}_3$ , a one-dimensional Mott insulator. This material has the distinguishing feature that the particles in it are constrained to move in one direction only, either forward or backward. Using x-rays, scientists have lifted some of the electrons belonging to the copper atoms in  $\text{Sr}_2\text{CuO}_3$  to orbitals of higher energy, corresponding to the motion of the electron around the nucleus with higher velocity. By comparing the properties (energy and momentum) of the x-rays before and after the collision with the material, the properties of the newly produced particles can be traced.

“These experiments not only require very intense x-rays, with an extremely well-defined energy, to have an effect on the electrons of the copper atoms,” said Thorsten Schmitt, head of the experimental team, “but also extremely

high-precision x-ray detectors.”

“It had been known for some time that, in particular materials, an electron can in principle be split,” said Jeroen van den Brink, who leads the theory team at the IFW Dresden, “but until now the empirical evidence for this separation into independent *spinons* and *orbitons* was lacking. Now that we know where exactly to look for them, we are bound to find these new particles in many more materials.”

Observation of the electron splitting may also have important implications for high-temperature superconductivity, according to the researchers. Due to the similarities in the behavior of electrons in  $\text{Sr}_2\text{CuO}_3$  and in copper-based superconductors, understanding the way electrons decay into other types of particles in these systems might offer new pathways toward improving the theoretical understanding of high-temperature superconductivity.

### Nano Focus

#### X-ray microscope captures nanoscale structures in 3D

A new x-ray microscope probes the internal structures of materials smaller than human cells and creates unparalleled high-resolution, three-dimensional (3D) images. By integrating unique automatic calibrations, scientists at Brookhaven National Laboratory are able to capture and combine thousands of images with greater speed and precision

than any other microscope. As reported in the April 2 issue of *Applied Physics Letters* (DOI: 10.1063/1.3701579; 143107), this full-field transmission x-ray microscope (TXM) rapidly combines two-dimensional (2D) images taken from every angle to form digital 3D constructs. The direct observation of structures spanning 25 nm will offer fundamental advances in many fields, including energy research, environmental sciences, biology, and national defense, according to the scientists.

“We can actually see the internal 3D structure of materials at the nanoscale,” said Jun Wang, lead author of the article and head of the team that first proposed this TXM.

Wang's team specifically examined a 20- $\mu\text{m}$ -wide sintered  $\text{LiCoO}_2$  electrode from a lithium-ion battery, wherein the energy performance of the battery is related to the internal connectivity of the pores and particles within the electrode. The researchers took 1441 2D pictures of the electrode as the material was rotated