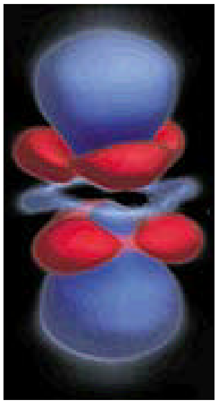
PHYSICS TODAY on the Web

Physics Update

Site Index



Visualizing electronic orbitals. The image of an atom is really the image of the averaged likelihood that the electrons will be at various places. Physicists at Arizona State University have now imaged the cloud of bonding electrons in copper oxide and shown that they look just the drawings used for decades in quantum physics textbooks. Using a combination of x-ray diffraction and electron diffraction (to avoid multiple x-ray scattering problems), the scientists produced a three-dimensional map (shown here) of the hybridized "orbital hole" bonding copper with neighboring oxygen atoms in cuprite (Cu_2O). They also found unexpected metal-metal covalent bonding, not clearly predicted by calculations. The researchers would like to apply their technique to the more complicated CuO_2 superconductors and colossal magnetoresistance manganates. (J. M. Zuo, M. Kim, M. O'Keefe, J. C. H. Spence, ***Nature*** 401, 49, 1999.)

Liquid crystal acoustics. Liquid crystals (LCs) are structures that consist of rod-shaped molecules with the ability to polarize light. They are regularly employed in electronic displays; an applied voltage reorients the rods and thereby changes the optical properties of the LCs. It came as a big surprise to Jay Patel (Pennsylvania State University) that LCs emit faint but audible sound during the electrical switching, while undergoing their choreographed movements. Further, the intensity of the sound increases as the driving frequency approaches the natural resonant frequency of the cavity that contains the LCs. Patel and his colleagues are not yet sure of the implications of this discovery, but expect that it will lead to a fruitful new research area. (Y. J. Kim, J. S. Patel, ***Appl. Phys. Lett.*** 75, 1985, 1999.)

Enriching chemical isotopes with a tabletop terawatt laser has been demonstrated. A group at the University of Michigan used 150-200-femtosecond laser pulses to deliver between 10^{13} and 10^{15} W/cm^2 to a target inside a vacuum chamber. The pulse vaporized some of the isotopes, which escaped in the form of ions, but with ratios of boron-10 to boron-11 and of gallium-69 to gallium-71 that exceeded the natural abundances in the targets by roughly a factor of two. In addition, they were able to deposit thin films that were enriched in the lighter isotopes. Because photoinduced nuclear reactions were unlikely, the researchers suspect that intense magnetic fields associated with the pulses set up a "plasma centrifuge," which separated the ions by mass. If that proves to be the case, then the physicists have also found a way to measure the internal magnetic fields of laser-ablated plasmas. (P. P. Pronko et al., ***Phys. Rev. Lett.*** 83, 2596, 1999.)

Recurring patterns in mixing fluids. In general, when two fluids are stirred together, the fluid elements are stretched and folded as they interpenetrate; diffusion into the surroundings governs the minimum thickness of the striations. Now, Jerry Gollub (Haverford College) and his coworkers have shown that, in a certain kind of periodically forced two-dimensional mixing known as chaotic advection, the structure of the two-fluid concentration field persists. They used electromagnetic forces to mix a 1 mm thick layer of viscous fluid having a fluorescent dye on one half (originally on the right side in this pseudocolor image). After about ten drive cycles, a pattern developed that recurred--even in its finest details--at the same phase of every drive cycle. The persistent pattern, like the one shown here, returned for up to a hundred cycles, merely fading in overall contrast like the grin of the Cheshire cat as diffusion took its toll. However, when the flow became even weakly turbulent--for example, by reducing the viscosity-the mixing occurred much more rapidly, with no pattern recurrence and with the thinnest striations being lost first. This phenomenon was first predicted by Raymond Pierrehumbert in 1994. (D. Rothstein, E. Henry, J. P. Gollub, ***Nature*** , 21 October 1999.)

A quantum capacitance standard is under development at the National Institute of Standards and Technology facility in Boulder, Colorado. Metrology has been moving away from standards based on artifacts such as a meter stick and toward standards using quantum phenomena to provide reliable, accurate, and, if possible, portable calibrations for researchers in the field. Consider capacitance, the measure of how well a tiny reservoir can store electrical charge. NIST's current standard is cumbersome and, more important, its accuracy is frequency dependent; within a certain frequency range, it is accurate to 0.02 parts per million, but outside that range, the standard is no better than 2 ppm. But now, Mark Keller and his colleagues have combined a single-electron transistor (SET) with a cryogenic capacitor to create a standard based on the quantization of electric charge. The charges arriving at the capacitor can be counted one at a time, all the way up to 10^8 or more. Combining that exquisite knowledge of the charge with an accurate voltage measurement then leads to the capacitance standard ($C = Q/V$). The SET approach has now achieved an accuracy of about 2 ppm, and the NIST researchers see the potential of reaching 0.01 ppm. The setup is relatively portable and its output is largely independent of frequency. (M. W. Keller et al., ***Science*** 285, 1706, 1999.)

October 99 Physics Update