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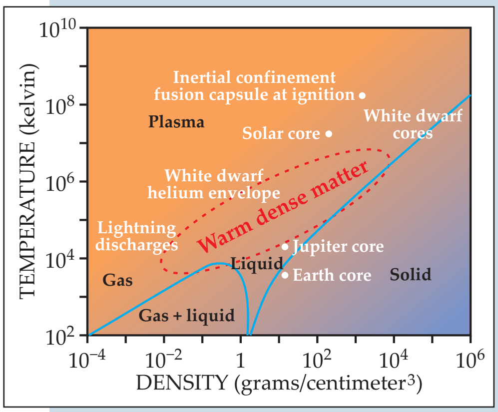
physics update

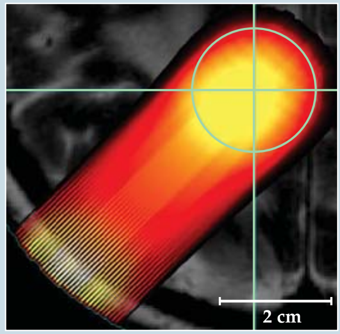
These items, with supplementary material, first appeared at http://www.physicstoday.org.

Ultrafast 4D core-loss spectroscopy meets graphite. Electron energy-loss spectroscopy (EELS) uses an electron beam shot through a sample to knock a resident atom's electron into an unoccupied outer shell or out of the atom entirely. In the process, the probing electrons lose energy. When the target is a tightly bound core electron, the beam's energy losses can easily exceed 100 eV; by analyzing the resultant "core-loss" spectra, researchers can glean information about a sample's chemical and structural properties much as they could using soft x rays. Unlike x rays, however, electrons interact strongly with the light elements that are prevalent in organic materials. A group at Caltech led by Ahmed Zewail has now incorporated nano- and femtosecond time resolution into EELS to study the chemical and structural dynamics of a 50-nm-thick film of graphite. The researchers first use a laser to excite electronic and lattice motions in a small spot of the sample; after the desired time delay, they probe the spot with ultrashort focused electron pulses from a transmission electron microscope (for more on TEMs, see PHYSICS TODAY, April 2015, page 32). Combining the electron energy-loss spectra with molecular dynamics simulations—to account for vibrations and other thermal disorder in the film—the Caltech group deduced that the transient laser heating caused the in-plane bonds of the carbon lattice to contract even as the carbon–carbon bonds between the planes elongated. Additionally, they found that laser-induced phonons caused the overall energy gap between filled and empty electronic bands to shrink significantly on a subpicosecond time scale. (R. M. van der Veen et al., *Struct. Dyn.*, in press.) —SGB

Extreme heating with an x-ray free-electron laser. The border between condensed-matter physics and plasma physics, illustrated by the phase diagram below, is home to a little-understood state called warm dense matter (WDM), in which thermal and Coulomb energies become comparable. (See the article by Paul Drake, PHYSICS TODAY, June 2010, page 28.) Such matter is thought to inhabit the inner cores of giant planets and is formed during the compression stage of inertial confinement fusion experiments. To study WDM, researchers want to controllably create the stuff with uniform temperature and density in the lab. But of the usual heating techniques, optical lasers lack sufficient penetration depth, ion beam pulses last too long, and laser-induced shocks are limited to a narrow slice through temperature-density space. Now, Anna Lévy of Marie and Pierre Curie University, Patrick Audebert of École Polytechnique, and their collaborators have shown that x-ray free-electron lasers (XFELs) are just the tool for the job. At SLAC's Linac Coherent Light Source, the group used a focused XFEL pulse to heat a 0.5-µm-thick silver foil to temperatures greater than 100 000 K. Then they simultaneously probed the foil's front and back surfaces with IR pulses. The results showed that temperature and density profiles were nearly uniform throughout the foil. Next on the agenda is to investigate other WDM properties such as ionic structure and electrical and thermal conductivities. (A. Lévy et al., *Phys. Plasmas* **22**, 030703, 2015; figure adapted from *Basic Research Needs for High Energy Density Laboratory Physics*, US Department of Energy, Office of Science and National Nuclear Security Administration, 2010.) —SC



Minibeams may minimize damage in cancer treatment. The goal of radiation therapy is to deliver a fatal dose to a tumor while sparing the surrounding tissue. One advantage of using high-energy x rays is that they spare the first couple of centimeters of tissue they pass through, a region that is often clinically significant but radiosensitive. But then the dose—the energy deposited per unit mass—rapidly builds, and it can damage healthy regions both upstream and downstream of the target. Proton beams, in contrast, deliver most of their dose in a confined region, at a depth that depends on the beam energy (see the article by Michael Goitein, Tony Lomax, and Eros Pedroni, PHYSICS TODAY, September 2002, page 45). Attaining full coverage of the tumor, though, can cause excess exposure of shallow tissues. That damage is of particular concern for pediatric brain tumors, since it can affect neurological and cognitive development. Now Avraham Dilmanian (Stony Brook University), John Eley (now at the University of Maryland), and Sunil Krishnan (MD Anderson Cancer Center) show that using a collimator to break up a particle beam into multiple parallel planar or pencil-shaped "minibeams," only 0.3 mm in size, can significantly spare shallow tissue: Because of the small irradiated volume, the tissue can both tolerate high doses and begin repairs promptly. As the minibeams penetrate, they gradually broaden and reunite, as seen in this simulated dose map. Through simulation and experiments on tissue surrogates, the researchers find that proton minibeams can stay safely small to depths of about 25 mm; helium and lithium minibeams, even further. Those depths suffice to spare much of the cerebral cortex. Moreover, say the researchers, the collimation is straightforward to implement in current treatment facilities. (F. A. Dilmanian, J. G. Eley, S. Krishnan, *Int. J. Radiation Oncol. Biol. Phys.*, in press.) —RJF



Artificial chameleon. The colors we see usually arise from the chemistry of materials, dyes, or pigments: A surface might reflect only some wavelengths of light; a filter might transmit only a narrow range of colors. Less common than chemistry, structural materials sometimes come along to split white light into some of its constituent colors (see PHYSICS TODAY, October 2006, page 82). But that is a very low-efficiency process. Now Connie Chang-Hasnain and a team of researchers at the University of California, Berkeley, have made a carefully tailored metastructured surface that can harness almost all of