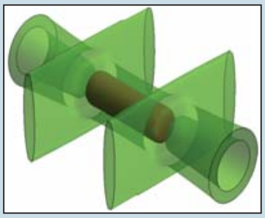
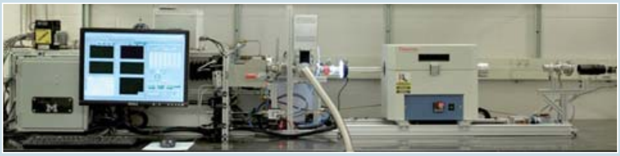
cool when diluted, even if the gas molecules don't interact. Now Joule–Thomson cooling of such a gas has finally been observed, by Zoran Hadzibabic and colleagues at the University of Cambridge, thanks to a novel trap. Conventional traps



hold gases in harmonic potentials whose confining forces strongly amplify the effect of any interparticle interactions, thereby obscuring the "ideal" quantum Joule–Thomson effect. The researchers created a nearly uniform confining potential by intersecting a tube-like green laser beam with two sheet-like beams, as shown in the figure. They then filled their trap with a 45-nK Bose gas of very weakly interacting rubidium-87 atoms. The gas became diluted, not because the team expanded it but because atoms were naturally ejected via collisions with the background gas in the trap's vacuum chamber. The rate of exodus is independent of energy, so just as for free expansion, the dilution does not change the energy per particle in the system. In time, 80% of the initial Rb atoms exited, and the temperature dropped to 23 nK, in agreement with theory. (T. F. Schmidutz et al., *Phys. Rev. Lett.*, in press.) —SKB

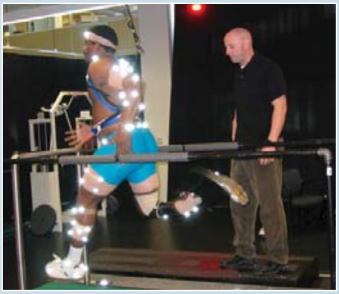
A phase-change alloy that crystallizes without shrinking. In the race to become the next technology for computer memory, phase-change memory (PCM) is among the leading contenders. The basis of PCM is a reversible, temperature-induced change between a shiny, low-resistance crystalline phase and a dull, high-resistance amorphous phase. In prototype devices, either the change in reflectivity or the change in resistance is exploited to write and store data. Unfortunately, in most PCM materials, the phase change is accompanied by a change in density that's large enough to create performance-sapping voids beneath electrodes. And the materials that exhibit the biggest change in reflectivity or resistance also exhibit the biggest change in density. Magali Putero of Aix-Marseille University in France and her colleagues from CNRS and IBM have been systematically investigating the phase-change behavior of a wide range of PCM materials. Most of them shrink when they crystallize, but others swell. Using a beamline at the European Synchrotron Radiation Facility, Putero and her colleagues found that 50-nm-thick films of one PCM material, a gallium–antimony alloy, can do both, depending on the composition ratio. Films of the lowest Sb composition that they studied, 55%, expanded in thickness by 3%, and films of the highest Sb composition, 95%, shrank by 4%. At 70% Sb, the thickness remained the same. That desirable property came with another: The change in resistance at that composition was large enough to qualify the alloy as a good PCM material. The researchers are now looking for other PCM materials that behave in the same way. (M. Putero et al., *APL Mat.* **1**, 062101, 2013.) —CD

High-speed nanomaterial synthesis and discovery. Researchers working to develop nanomaterials with novel properties often rely on educated guesses and one-off experiments to gradually improve, but not always optimize, the fabrication process. Consider thin films made with chemical vapor deposition (CVD): A sample substrate is placed in a tube in which the pressure is adjusted and suitable gases are introduced; the tube is inserted into a furnace for heating and cooling, then the sample is removed and analyzed, and the next experiment is set up. In a typical workday, 2–4 experiments can be done. John Hart of MIT and his group have created Robofurnace, shown here, which can execute up to 16 CVD experiments in 24 hours. Built mostly using off-the-shelf components, the robotic system incorporates a magazine that can hold up to 10 sample substrates, a transfer arm that loads each sample into the furnace tube, several different gas lines, pressure- and humidity-control systems, and a furnace (the box on the right) that slides along the tube. Each sample can be processed using a different "recipe." Rapid heating to a given temperature of up to 1100 °C, and subsequent rapid cooling, can be accomplished by precisely posi-



tioning the furnace around the sample, then sliding the furnace away. In an early demonstration of Robofurnace's capabilities, the researchers used a sequence of experiments to find a new recipe to grow carbon-nanotube forests—films of vertically aligned CNTs used in myriad commercial applications—that are an order of magnitude more dense than they had grown in a static tube furnace. (C. R. Oliver et al., *Rev. Sci. Instrum.* **84**, 115105, 2013.) —SGB

Capturing the chaos of running. None of us are perfect—and neither are our gaits. In any given stride, we might extend a knee a bit further, swing a leg a bit wider, or raise a foot a bit higher than in the stride before. In nonlinear dynamics, such deviations from perfect periodicity are often characterized by the Lyapunov exponent, a measure of the rate at which small perturbations grow into big ones. A large Lyapunov exponent indicates an unstable, chaotic system prone to large fluctuations; a small exponent indicates a stable system that's nearly periodic. (See the article by Adilson Motter and David Campbell, PHYSICS TODAY, May 2013, page 27.) Now Nicole Look, her advisers Elizabeth Bradley and Rodger Kram, and their colleagues at the University of Colorado Boulder have used motion-capture technology to determine Lyapunov exponents associated with human running. The researchers tracked the movements of 17 subjects—six of



whom had below-knee amputations and were fitted with prostheses—as they ran at paces varying from a trot to a sprint. (One test subject is pictured here.) As expected, the amputees' knee and hip motions were less stable than those of nonamputees. But surprisingly, amputees had, on average, a slightly more stable center of mass. Moreover, the center-of-mass dynamics of all subjects tended to grow more stable with increased running speed, even as knee and hip movements grew more chaotic. One proposed explanation: Runners may instinctively compensate for diminished lower-body control by exerting more control over their core. (N. Look et al., *Chaos* **23**, 043131, 2013.) —AGS ■