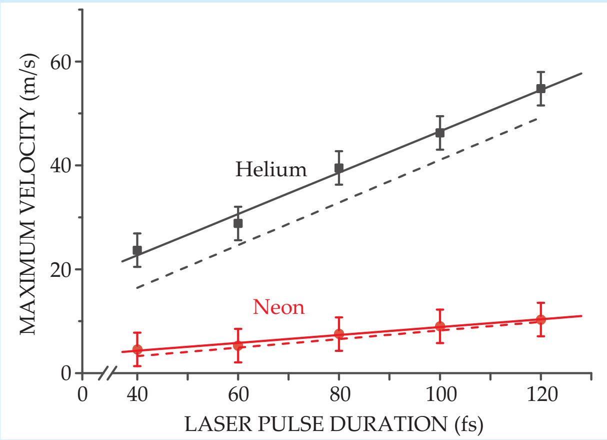
physics update

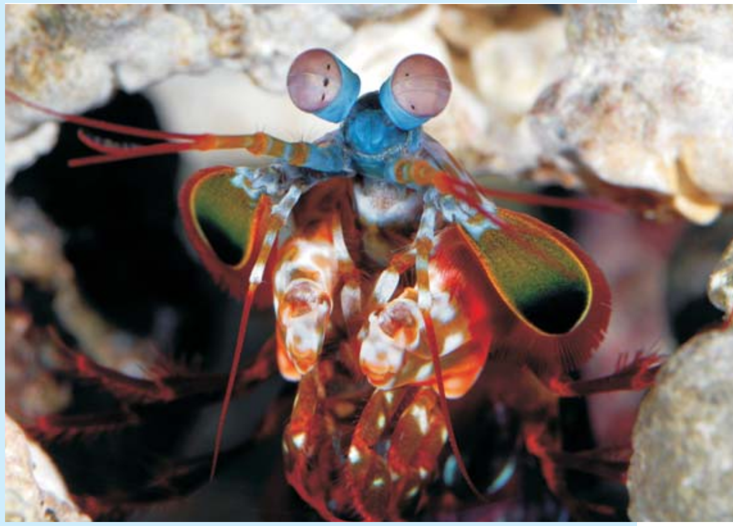
These items, with supplementary material, first appeared at http://www.physicstoday.org.

Accelerating neutral atoms. The intensity gradients of inhomogeneous laser-light fields impose ponderomotive forces on charged particles. Such forces—proportional to the square of the particle's charge and inversely proportional to its mass—push the particle toward lower light intensity and have been used to trap and manipulate ions, diffract electrons, and generate charge waves in plasmas. But they were thought to act only very weakly on neutral atoms—having to rely on the polarizability of an atom's charge distribution. Now, however, a group at the Max Born Institute in Berlin has reported the use of intense ultrashort laser pulses to accelerate neutral helium atoms for about 100 femtoseconds at 10^{15} m/s^2. That's eight orders of magnitude greater than the acceleration (or deceleration) one can get with the continuous-wave techniques used in laser cooling of neutral atoms. The Berlin group argues that the strong laser pulse excites an electron to the outer reaches of the helium atom where it "quivers" in the oscillating light field and experiences the



ponderomotive force almost as a free electron would. But still bound to the atom's ionic core, it tugs the much heavier core with it away from the laser beam's focus. The figure shows how the maximum velocity thus acquired by neutral atoms in the Berlin experiment increases with pulse duration. The dashed curves show the theoretical expectation for the group's model of electron excitation and the consequent ponderomotive force. Such "ultrastrong" acceleration of neutral atoms, they suggest, could be exploited for atomic-beam optics, atom deposition, and controlled chemical reactions. (U. Eichmann et al., *Nature* **461**, 1261, 2009.) —BMS

A mantis shrimp's extraordinary eyes. Photonic devices that can detect and control the polarization of light across a range of wavelengths are rare. More common are materials such as quartz that can be made into monochromatic optical retarders. Through their intrinsic birefringence, those devices retard the phases of a specific wavelength of incident light, converting the light from linearly to circularly polarized or vice versa. Some multilayered thin films exhibit achromatic retardation through fabricated periodic nanoscale structures that effectively combine the dispersive properties of each layer to achieve wavelength-independent birefringence. But engineering on the nanoscale is tricky, and even the best synthetic achromatic retarders perform poorly across the full visible range, straying from the expected retarda-



tion by as much as 2.5%. Nature, though, has already solved the puzzle in animals that have evolved biophotonic structures for signaling, vision, and coloration (see PHYSICS TODAY, January 2004, page 18). An international team of researchers from the UK, Australia, and the US has discovered a near-ideal achromatic retarder in the eyes of the colorful peacock mantis shrimp, *Odontodactylus scyllarus*, shown in the image. The mantis shrimp's biophotonic retarder is the R8 photoreceptor cell—a UV-photopigment-filled lipid bundle with critical radii of 26 nm and 40 nm, which are subwavelength for visible light. When subjected to linearly polarized light, the R8 cell acts as a quarter-wave retarder, converting the incident light to circularly polarized light, as confirmed by close experimental agreement with theoretically determined Stokes parameter values. Moreover, the retardation varied by only 0.8% from ideal values across the visible spectrum. (N. W. Roberts et al., *Nat. Photonics* **3**, 641, 2009. Image courtesy of Roy Caldwell, University of California, Berkeley.) —JNAM

Yoctosecond light pulses from quark–gluon plasmas. In recent years, photon pulses in the attosecond (10^{-18} s) regime have been precisely engineered and are being increasingly put to work—for example, in experimental quantum control and chemical dynamics (see PHYSICS TODAY, March 2005, page 39). But can much shorter pulses be generated and put to use? Three physicists at the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, have proposed some answers. They modeled the photon emission in the early expansion of a quark–gluon plasma, a hot dense stew of fundamental particles created when heavy nuclei smash into each other at relativistic speeds. Prompt gamma rays in the GeV range, produced primarily by quark–gluon Compton scattering and quark–antiquark annihilation, would exit the expanding QGP in at most a few yoctoseconds (10^{-24} s). With certain collision parameters and with detectors nearly aligned with the collision axis, the model predicts a double-peaked pulse before the QGP disappears. One peak is blueshifted, arising from the approaching side of the QGP, the other is redshifted from the receding side; the peaks are separated roughly by the light-travel time across the hot soup. The dip between the peaks occurs during an intermediate time at which the stew acquires an anisotropy and emits nothing along that axis. If the model proves correct, such a double pulse could enable pump–probe experiments at the nuclear scale, though new detection schemes would first need to be invented. (A. Ipp, C. H. Keitel, J. Evers, *Phys. Rev. Lett.* **103**, 152301, 2009.) —SGB