Physics Update

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Particle mass predicted with lattice quantum chromodynamics, then confirmed at Fermilab. Lattice QCD has come far in recent years (for a primer, see the article by Carleton DeTar and Steven Gottlieb, PHYSICS TODAY, February 2004, page 45), and it has now joined other theoretical methods of predicting the mass of a hadron—in this case the charmed B meson, B_c. A reliable treatment of the heavy quarks allowed a team of theoretical physicists to capitalize on earlier improvements in lattice QCD. Those earlier developments provided a realistic treatment of the light "sea quarks," the virtual quarks whose ephemeral presence influences the "valence" quarks—the anti-bottom and charmed quarks for the B_c—that are considered the nominal constituents of a hadron. The remarkably precise predicted value was 6304 ± 20 MeV. Shortly after the theorists submitted their paper for publication, the first good experimental measurement of the same particle was announced: 6287 ± 5 MeV. The confirmation bolsters confidence that lattice QCD can be used to calculate many other properties of hadrons. (I. F. Allison et al., *Phys. Rev. Lett.* **94**, 172001, 2005; CDF collaboration, http://arxiv.org/abs/hep-ex/0505076.) —PFS

Single-atom photon recoil momentum in a dispersive medium has been measured. Photons have no mass, but they do carry momentum, h/λ, where h is Planck's constant and λ is the wavelength of the light in vacuum. In a dispersive medium, light's momentum separates into electromagnetic momentum and mechanical momentum of the medium. Therefore, there has been some confusion concerning the medium's recoil when a photon is absorbed. A group at MIT has now verified that the momentum transferred to the absorbing atom is nh/λ, with n the index of refraction. The physicists used two identical laser beams sent into a dilute Bose–Einstein condensate of rubidium atoms. The first beam placed a small fraction of the atoms into a particular momentum state within the BEC. After a delay, the second beam created more identically moving atoms that interfered with the initial batch. The resulting beat note provided the momentum recoil measurement. That the recoil momentum is actually proportional to the index of refraction provides an important correction for high-precision measurements using cold atoms. (G. K. Campbell et al., *Phys. Rev. Lett.* **94**, 170403, 2005) —PFS

Room-temperature liquid sodium can exist at high pressure. Melting generally occurs when the thermal agitation of atoms or molecules in a solid overpowers the attractive interactions among them. Pressure applied to a solid sample usually helps negate thermal agitation: The melting temperature customarily goes up with pressure. However, in a few materials, such as water, the melting temperature can drop on compression. The most dramatic such negative melting curve yet seen has been studied by scientists at the Carnegie Institution of Washington who looked at one of the simplest metals known—sodium. At atmospheric pressure (0.1 MPa), sodium melts at 371 K. As pressure goes up, so does the melting temperature, as high as 1000 K at a pressure of 30 GPa. Then strange things begin to happen. As the pressure rises further, the melting temperature starts to drop, and reaches a low of 300 K at 118 GPa. Between 65 and 80 GPa, the solid changes structure, from bcc to fcc. At those pressures, the sodium's liquid phase is denser than the solid, like water and ice. Above 100 GPa, sodium begins to crystallize in denser and unexpectedly complex structures. (E. Gregoryanz et al., *Phys. Rev. Lett.* **94**, 185502, 2005.) —PFS

An optical conveyor belt for transporting submicron objects has been devised by collaborating physicists from the Institute of Scientific Instruments in Brno, Czech Republic, and the University of St. Andrews in Scotland. Rather than using a laser beam with a Gaussian profile, their setup had two counter-propagating nondiffracting beams with profiles described by a zero-order Bessel function. The beams established a standing-wave pattern in which steep changes in optical intensity could confine small particles. Unlike in an optical tweezer, however, the relative phases of the beams could be controlled to march the particles along the length of the beam while keeping them not only confined laterally but also trapped longitudinally in intensity maxima or minima. The "self-healing" property of the nondiffracting beams means that many particles can be confined simultaneously in the standing-wave structure because their presence does not degrade the beam. The figure shows a pair of 410-nm-diameter polystyrene spheres transported over a distance of a quarter of a millimeter in under three seconds. (The stacked images were acquired in 0.25 s increments.) The positioning accuracy—currently at the micron level—is related to the precision of the phase shift and the optical trap depth and will get better, according to Pavel Zemánek, the group's leader. (T. Čižmár et al., *Appl. Phys. Lett.* **86**, 174101, 2005.) —PFS