Physics News Update

The AIP Bulletin of Physics News

Number 652, September 4, 2003 by Phillip F. Schewe, Ben Stein, and James Riordon

A Spinless BEC

A spinless BEC, a Bose-Einstein condensate that is insensitive to any external magnetic field, has been created by researchers at Kyoto University (contact Yosuke Takasu or Yoshiro Takahashi), potentially offering a route to improved atomic clocks, more precise atom interferometry, and more highly controlled means of depositing atoms on surfaces. In all previous Bose-Einstein condensates, the raw ingredients have either been alkali metals (such as rubidium and cesium) or helium, all of which have been sensitive to magnetic fields. In contrast, the researchers decided to make a BEC of ytterbium (Yb), a rare-earth element that has two outer (valence) electrons, whose "spins" determine the atom's response to a magnetic field. When the spins of Yb's two electrons are in opposite directions, the total spin is zero and the atom assumes a "singlet" state, in which it is unresponsive to a magnetic field. In their setup, the researchers trap approximately 1 million Yb atoms in the singlet state with light beams. The hotter atoms evaporate away, leaving a chilly gas cloud of about 5000 atoms that form a BEC at temperatures of below 790 nanokelvins. Since the Yb BEC is insensitive to stray magnetic fields in its surroundings, it may allow for more precise atomic deposition and atom interferometry. Moreover, the very heavy mass of Yb compared to other BEC atoms means that certain fundamental physics effects, such as atomic parity violation and time symmetry violation, are more pronounced, making a Yb BEC desirable for such studies. Furthermore, lasers interacting with the Yb atoms can be tuned to a very narrow frequency range, potentially enabling a Yb BEC to be the basis of an atomic clock with unprecedented precision. Finally, the many stable isotopes of Yb (5 are bosons, 2 are fermions) facilitates the possibility of creating a BEC and a Fermi degenerate gas in the same cloud. (Takasu *et al.*, *Physical Review Letters*, 25 July 2003)

Pressing Forward from Teeth to Superconductors

Found in teeth and bones as well as fertilizers and DNA, phosphorus is an insulator at room temperature. However, exerting a large amount of pressure on a stable specimen of phosphorus changes its crystalline structure, enabling it to superconduct at temperatures of around 10 K. Exerting even more pressure (2.5 Mbar, about 30,000 times greater than the pressure of clenching your teeth) can transform it again, to a body-centered-cubic (bcc) crystal structure (Akahama *et al.*, *Phys Rev B*, 1 Feb 2000). Now, Sergey Ostanin of the University of Warwick in the UK and his colleagues have shown that bcc phosphorus crystals achieve superconductivity at higher temperatures, somewhere between 14-22 K. This is still much lower than the temperature of your mouth, even after an ice-cream headache. But such phosphorus superconductors might be very useful in spintronics. For example, they could be help in the construction of a superconducting spin switch, specifically one in which the phosphorus layer would lie in between a pair of ferromagnets, an arrangement that could alter its identity from superconductor to regular conductor (L. R. Tagirov, *Phys. Rev. Lett*, 6 September 1999). Furthermore, high pressures might not even be needed to make bcc phosphorus crystals: they could possibly be grown by depositing the atoms onto a substrate of iron, which itself organizes into a bcc structure. (Ostanin *et al.*, *Physical Review Letters*, 22 August 2003)

Non-Contact Friction

Non-contact friction can be artificially enhanced. Usually for two bodies in relative motion to feel friction the respective surface atoms have to be in contact. There is a type of friction, however, which can act between two surfaces not actually in contact. This dilute friction is attributed to the van der Waals force, a common but weak attractive force which arises when an atom or molecule spontaneously develops a dipole moment (that is, although it is neutral, a small region of net negative charge can develop, offset slightly from a comparable positive region) owing to a thermal fluctuation (related to the random motion of the electrons and ions) or a quantum fluctuation (the very positions of the particles varies from moment to moment owing to the uncertainty relations built into quantum reality). This short-lived polarity can in turn induce a dipole moment in a neighboring atom or molecule, some distance away. A new study of van der Waals friction by Alexander Volokitin and Bo Persson at the Institut fur Festkorperforschung (Julich, Germany) accounts for recent odd friction experiments conducted with STM probes. The theory holds that van der Waals friction can be greatly enhanced (by up to a factor of ten million at a separation of 10 angstroms in comparison with the case of good conductors with clean surfaces) by adsorbing certain molecules onto one or both of the surfaces. This increases the resonant electromagnetic force (which can be viewed as the tunneling of photons) between the objects, especially if they are made of the same material. The adsorbate atoms can be thought of as tiny antennas, one acting as an emitter and one as a receiver; when the two antennas are in tune the electromagnetic interaction between them will be greatly enhanced (see figure).

A better understanding of this kind of non-contact friction will, at the fundamental level, help physicists to study the quantum behavior of atoms at surfaces and, at the level of applications, to prepare "brakes" for micromachines where large friction is not needed. (Volokitin and Persson, *Physical Review Letters*, 5 September 2003)

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