Physical Review Focus

Ultrastable $CO_2$ Laser Trapping of Lithium Fermions
K. M. O'Hara, S. R. Granade, M. E. Gehm, T. A. Savard, S. Bali, C. Freed, and J. E. Thomas
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# Atoms Trapped by the Light

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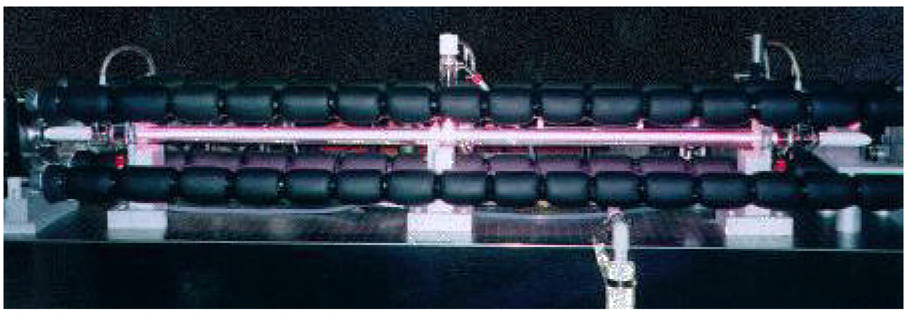
Like children chasing soap bubbles, physicists often find that once they corral a few atoms in one place, they don't last long. So trapping clouds of atoms for long times has been essential for such recent advances as the creation of the quantum state known as a Bose-Einstein condensate (BEC). The longest-lived traps for neutral atoms have always used magnetic fields, but they are limited to specific types of atoms and phenomena. A report in the 24 May *PRL* describes a trap made from a single laser beam that can hold atoms for more than 5 minutes--almost a hundred times longer than previous all-optical traps--putting it within striking distance of magnetic traps and allowing physicists to study new classes of atomic phenomena.



John Thomas and Stephen Granade/Duke University

**Steady as she goes.** This extremely stable $CO_2$ laser allows atoms to be trapped for more than 5 minutes, a lifetime previously only achieved with magnetic field-based traps. All-optical traps work on any type of atom and can be used to study more complex phenomena.

Magnetic traps confine atoms based on their magnetic properties, so the most cooperative atoms have a strong magnetic moment, which comes from an unpaired electron. The trap fixes the spin state of that electron, which limits the number of atomic spin states that can be trapped in a single cloud of atoms. John Thomas and his colleagues at Duke University in Durham, NC, would like to create a "degenerate gas of interacting fermions," a quantum state that so far has been studied only in liquids and solids. These experiments will require atomic states that cannot be trapped magnetically.

Atoms trapped with lasers can normally be held for only a few seconds, according to Randy Hulet of Rice University in Houston, and "there has been a lot of confusion" in the field regarding the cause of the short lifetime. In 1997 Thomas and his colleagues published a theoretical paper (Phys. Rev. A **56**, R1095) that blamed the unsteadiness of the trapping lasers for heating up the atoms and causing them to leave the trap. Now they have built an extremely stable $CO_2$ laser that holds $^6$Li atoms for more than 5 minutes, much longer than previous laser traps.

The trap works by attracting atoms to the focal point in the beam, where the laser's oscillating electric field is strongest. The field polarizes the atoms, causing their energy to be minimized at the focus. Thomas and his colleagues focused their beam down to a 100 µm-diameter region containing about 20,000 atoms, according to team member Ken O'Hara.

In addition to laser stability, the team's success came from obtaining a good vacuum ($10^{-11}$ Torr) and from choosing a laser wavelength (10.6 µm) very far away from any of the electronic transitions in $^6$Li. Atom trappers have known for years that photon scattering heats the atoms if the wavelength isn't far enough "off resonance," but Thomas and his colleagues were the first to combine that approach with such a stable laser.

Hulet says that the freedom to trap a variety of spin states at once will allow many more complex phenomena to be studied, such as the atom gas equivalent of ferromagnetism and other states normally observed only by condensed matter physicists. "It really opens up a lot of possibilities," he says.

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