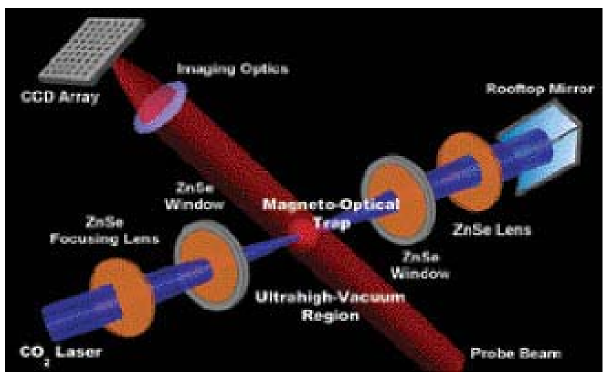
Photonics Research
June 2002 Edition

Send News to photonics@laurin.com or submit online here

Optical Trap Produces Degenerate Fermi Gas

A group of physicists at Duke University in Durham, N.C., has demonstrated an optical trap capable of creating an arbitrary spin-state degenerate Fermi gas. The work promises to offer researchers cold-gas analogs of high-temperature superconductors.



An all-optical trap (facing page) creates an arbitrary spin-state degenerate Fermi gas, a low-temperature atomic ensemble whose behavior is dominated by quantum- mechanical effects. The trap is formed by a CO_2 laser focused to a 47-µm-diameter spot (left), and the trapped fermions are reduced in temperature until they occupy the lowest possible energy states. Courtesy of Stephen R. Granade, Duke University.

As the temperature of an atomic gas is reduced to ultralow levels, the behavior of the atoms can no longer be described with semiclassical rules of thermal distribution, but require fully quantum-mechanical descriptions. Because fermions cannot share both spin quantum number and the same position, identical fermions cannot collide, unlike their bosonic counterparts, which overlap into Bose-Einstein condensates.

Using the fermionic atom ^{6}Li, the researchers, led by professor John E. Thomas, first confined the atoms in a magneto-optical trap. They subjected the gas to Doppler laser cooling, lowering the ensemble temperature to 150 µK. A ZnSe lens then focused the 10.6-µm beam from a CO_2 laser to a diameter of 47 µm, trapping 3.5 million atoms, and the researchers applied a bias magnetic field, which interacted with the 1/2 and -1/2 spin states and enabled them to mix. After six seconds of evaporative cooling, the number of trapped atoms fell to 1.3 million, but the temperature also fell, to 50 µK.

As evaporative cooling proceeded, fewer atoms escaped. To continue cooling, the researchers reduced the laser intensity, increasing the density of occupied quantum states by up to a factor of 400. With an initial phase space density of 8 x 10^{-3}, the final phase space density approached 1. After 60 seconds, approximately 10^5 atoms remained in the trap, the Fermi temperature was 8 μK and the measured temperature was less than 4 μK. At that point, quantum effects dominated the behavior of the gas.

The work is important not only for what it may enable, but because it demonstrates that the trapping can be done at all. Stephen R. Granade, a graduate student on the research team, explained that the 1/2 and -1/2 states of ^{6}Li are predicted to display interactions analogous to a superconductor at half the Fermi temperature, as opposed to the 1/10,000 of ordinary superconductors. But these states are repelled in a magnetic trap, he said. "The optical trap is essential to explore neutral atom analogs of high-temperature superconductivity."

Although the initial trapping experiments were successful, the Duke team plans to improve the apparatus, first to remove asymmetries that are created when the laser intensity is changed and then to increase the magnetic field strength. These changes should improve the efficiency of evaporative cooling, and higher magnetic fields will enable more complete control of the atomic interaction.

"Because of how widely interactions can be tuned in our system," Granade said, "the system may serve as a test bed for new effective field theories of interactions between fundamental particles."Richard Gaughan

by Richard Gaughan

Physical Review Letters, March 25, 2002, 120405.

Return to the previous page

Browse

Accent on Applications | Presstime Bulletin | Article Abstracts
BusinessWorld | Technology World | Photonics Research
Innovative Products | Spectra Contents

top of page

Photonics.com: Optical, Laser and Fiber Optics Resource
[Home | Reference Library | Print Publications | Employment Center | Tech Focus | News & Analysis]
[Innovative Products | Calendar | Advertising | About Laurin | Site Map]

Other Areas and Laurin Web Sites