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MIT Physicists Create New Form of Matter

Online staff -- *Electronic News*, 6/23/2005

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MIT scientists have created a new type of matter, a gas of atoms that shows high-temperature superfluidity.

The work is closely related to the superconductivity of electrons in metals and may help solve questions about high-temperature superconductivity, which has widespread applications for magnets, sensors and energy-efficient transport of electricity, said Wolfgang Ketterle, a Nobel laureate who heads the MIT group and who is the John D. MacArthur Professor of Physics at the school.

According to MIT, research groups around the world have been studying cold gases of so-called fermionic atoms with the ultimate goal of finding new forms of superfluidity. A superfluid gas can flow without resistance and can be clearly distinguished from a normal gas when it is rotated. A normal gas rotates like an ordinary object, but a superfluid can only rotate when it forms vortices similar to mini-tornadoes, MIT explained, adding that this gives a rotating superfluid the appearance of Swiss cheese, where the holes are the cores of the mini-tornadoes.

"When we saw the first picture of the vortices appear on the computer screen, it was simply breathtaking," said graduate student Martin Zwierlein in a statement recalling the evening of April 13, when the team first saw the superfluid gas. For almost a year, the team had been working on making magnetic fields and laser beams very round so the gas could be set in rotation, he reported.

"In superfluids, as well as in superconductors, particles move in lockstep. They form one big quantum-mechanical wave," added Ketterle. Such a movement allows superconductors to carry electrical currents without resistance.

The MIT team was able to view these superfluid vortices at extremely cold temperatures, when the fermionic gas was cooled to about 50 billionths of a degree Kelvin, very close to absolute zero (-273 degrees C or -459 degrees F).

"It may sound strange to call superfluidity at 50 nanokelvin high-temperature superfluidity, but what matters is the temperature normalized by the density of the particles," Ketterle said. "We have now achieved by far the highest temperature ever."

Scaled up to the density of electrons in a metal, the superfluid transition temperature in atomic gases would be higher than room temperature, he added.

Broken down, the MIT team observed fermionic superfluidity in the lithium-6 isotope comprising three protons, three neutrons and three electrons. Because the total number of constituents is odd, lithium-6 is a fermion. Using laser and evaporative cooling techniques, the team cooled the gas close to absolute zero. They then trapped the gas in the focus of an infrared laser beam; the electric and magnetic fields of the infrared light held the atoms in place. The last step was to spin a green laser beam around the gas to set it into rotation. A shadow picture of the cloud showed its superfluid behavior: The cloud was pierced by a regular array of vortices, each about the same size, MIT reported.

The work is based on the group's earlier creation of Bose-Einstein condensates, a form of matter in which particles condense and act as one big wave.

The superfluid Fermi gas created at MIT, said the school, can also serve as an easily controllable model system to study properties of much denser forms of fermionic matter such as solid superconductors, neutron stars or the quark-gluon plasma that existed in the early universe.

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