Rice ties in race for atomic-scale breakthrough

November 17 2009

Everybody loves a race to the wire, even when the result is a tie. The great irony is the ultraprecise clocks that could result from this competition could probably break any tie.

The Rice lab of physicist Tom Killian published a paper online this month demonstrating the long-sought creation of a Bose-Einstein condensate (BEC) of strontium atoms. BEC is a state of matter predicted by early 20th-century physicists Satyendra Nath Bose and Albert Einstein. Basically, at extremely cold temperatures, some types of atoms come to almost a complete standstill and enter a state in which they lose their individual identity.

In the same online edition of Physical Review Letters, a paper by the laboratory of Rudolf Grimm at the Universität Innsbruck in Austria reported the same result.

Though it was a scramble to the finish line, in the end a gentlemanly agreement determined the knotty outcome. Killian said he caught wind of the Austrians' work in an online archive where physicists commonly post preprints of upcoming papers.

"We've both been working on this for a long time, but when their paper appeared on the archive, there was still a technical problem keeping us from getting a BEC," said Killian, an associate professor of physics and astronomy. "After three or four all-nighters, we fixed our problem, wrote the paper and submitted it. At that point I discovered the Austrian paper had been fast-tracked and publication was imminent."

Killian got on the phone with the journal's editor. "He called Austria, and they said they'd be happy to wait for us. They were very generous."

Killian said his lab had been working toward a BEC for years and avoiding trial and error in favor of measurements to determine which isotope of strontium was most likely to condense.

To get the atoms to stop in their tracks and form a BEC, the lab had to cool them to near absolute zero (-459.67 degrees Fahrenheit) through a combination of tried-and-true techniques involving lasers and evaporative cooling. That brings the trapped atoms, which are inside an evacuated chamber, to within a millionth of a degree of zero Kelvin. At that point, the atoms collapse into a condensate -- a singular lump that physicists can play with.

A good explanation of BECs and the cooling technique appears at www.colorado.edu/physics/2000/bec/what_is_it.html, courtesy of the University of Colorado at Boulder.

Physicists have been making BECs since 1995, when Eric Cornell, Carl Wieman and Wolfgang Ketterle confirmed Bose and Einstein's theory with ultracold atoms and won the Nobel Prize for their efforts. Randy Hulet of the Rice Physics and Astronomy Department has also made seminal contributions to the field from its beginning. A number of elements have since been used to make BECs, most of them alkali-metal atoms, which have one valence electron. The number of valence electrons, which spin in the outer shell of an atom, determines how it reacts with other atoms.

Strontium has two valence electrons, which really changes the game. "In the lowest energy state they spin in opposite directions and pair up very nicely," said Killian. Applying just the right amount of energy via a laser can flip the spin of one of the electrons. Once they're aligned, in the case of strontium, they stay that way for minutes.

"That long-lived, excited state allows you to lock your laser to just the right energy for spin flipping," he said. "This controls the frequency of the laser, or the rate at which the waves go by. Those waves become the pendulum of the world's most accurate clock." Killian expects the combination of clock technology and BECs can lead to breakthroughs in quantum computing. In 2004, a BEC in ytterbium, another two-valence-electron atom, was observed; but strontium is used in the best clocks, and strontium BECs contain 10 times more atoms, which is important for future experiments.

Killian expects the Austrian lab will pursue quantum computation, but his interests lie elsewhere. "It turns out that, for the same reasons these atoms make a good clock, we can use lasers to manipulate the way the atoms interact with each other.

"Lasers can change interactions on small length scales and very quickly, which opens the study of fundamental phenomena in solid-state physics and materials we don't quite understand," he said.

Killian said manipulating interactions could also lead, someday, to matter-wave "lasers" for very precise sensors. "That has applications for things like navigating airplanes or submarines, detecting oil deposits underground or tunnels where tunnels shouldn't be, like along international borders," he said.

"I do really fundamental physics, but if we work on these techniques, 10 to 15 years from now they could have applications," Killian said. "The specific properties of strontium make it very useful for some of these applications, which is why it's valuable."

Source: Rice University (news : web)

Citation: Rice ties in race for atomic-scale breakthrough (2009, November 17) retrieved 20 April 2024 from https://phys.org/news/2009-11-rice-ties-atomic-scale-breakthrough.html