A Nobel for New State of Matter

Physics: Prize honors three U.S. scientists who cooled atoms to create a condition that was predicted by Einstein.

By USHA LEE McFARLING and ROBERT LEE HOTZ, Times Staff Writers

Three scientists won the Nobel Prize in physics Tuesday for creating and probing an entirely new state of matter—neither solid, liquid nor precisely gas—that in only a few years has paved the way for broad advances in high-speed computing, nano-technology and exquisitely precise systems for timekeeping and navigation.

"It is a very special form of matter," one of the winners, 43-year-old Wolfgang Ketterle of the Massachusetts Institute of Technology, said of the discovery. "It is a cloud of almost nothing . . . a deep look into the beauty of nature."

The other winners are Eric A. Cornell, 39, of the National Institute of Standards and Technology, or NIST, in Boulder, Colo., and Carl E. Wieman, 50, of the University of Colorado. The three will share the $943,000 prize.

To create their discovery, the three scientists had to cool atoms to temperatures colder than even the deepest reaches of outer space—a few billionths of a degree above absolute zero, minus 459 degrees Fahrenheit. (Background radiation left over from the Big Bang heats intergalactic space to 3 degrees above absolute zero.)

At that ultra-cold temperature, the atoms that make up an ordinary gas slow their normal movement dramatically. They also begin to act as if they were waves, rather than particles, following the rules of quantum mechanics, the physics of the ultra-small. When drastically chilled, the wavelengths of atoms grow to huge sizes. They then begin to overlap and can merge into "superatoms."

At that point, the atoms form a new state of matter in which they are so coordinated they cannot be distinguished as individual atoms; instead, they act as a giant matter wave.

The Nobel citation described the scientists as getting atoms to "sing in unison."

"You get the atoms together in lock step, like marchers in a parade," said Nick Bigelow, a professor of physics at the University of Rochester who has been studying the new form of matter in earnest since its existence was proved.

"The achievement is to matter what the laser beam is to light: the ability to direct and control atoms for a variety of uses that could become very powerful."

It took decades for lasers to pervade daily life, but now they are ubiquitous, cheap and often indispensable. "The implications took time," said Bigelow, "but lasers are now in supermarket scanners, in eye surgery and in communications systems."

In analogous fashion, atomic lasers could one day be used to deposit atoms precisely to etch tiny patterns onto computer chips. Controlling atoms so carefully could also result in highly accurate atomic clocks that use the regular oscillations of atoms for timekeeping or new navigational systems that rely on atomic gyroscopes.

This almost magical state of matter had been predicted in 1924 by Albert Einstein based on a suggestion from the Indian physicist Satyendra Nath Bose. But for 70 years, the so-called Bose-Einstein condensate had been impossible to observe in the real world.

Scientists had tried for decades to observe the condensate, but had simply not been able to get atoms cold enough. Most physicists believed the feat was impossible.

"A lot of famous people stood up to explain to me that I was crazy or wrong," Wieman said Tuesday. "Making it was a big uncertainty. When it showed up, that was awfully exciting."

The condensate was first created by Cornell and Wieman in 1995 by chilling rubidium gas.

Ketterle created a condensate using sodium in his lab just three months after Cornell and Wieman's discovery. Ketterle was praised by the Nobel committee for conducting a wide range of experiments almost immediately to prove that the condensates were indeed extremely coordinated atoms.

In 1997, he generated a stream of small Bose-Einstein condensate drops that fell under the force of gravity and are considered to be the first atomic laser beam.

"It represents the ultimate degree of control we can exercise over matter," said Charles Clark, who heads the electron and optical physics division at NIST and also works on the condensates.

Cornell and Wieman used two techniques to cool, or slow, the atoms. The first was laser cooling, a Nobel prize-winning technique that cools atoms by slowing them with blasts from a laser. But that did not cool the atoms enough. To get the gas even colder, Cornell perfected a clever magnetic atom trap that allowed the hottest atoms to escape, in essentially the same way a cup of coffee cools through evaporation.

"We blended several ideas that were out there," Cornell said. Wieman had been using laser cooling in his lab. Cornell, who joined Wieman's lab after earning his doctorate at MIT, brought the idea of evaporative cooling from Boston, where it had been used by physicists Dan Kleppner, Tom Greytak and Harold Hess.

The race to be first to get the condensate was intense; it included the Kleppner and Ketterle labs at MIT, Steve Chu's lab at Stanford; and the lab of Randy Hulet at Rice University, who also created a condensate in 1995.

Cornell and Wieman had worked on the project for five years. When it finally worked, they had their condensate within hours. "It was very sudden," recalled Cornell. "It was like a snowball effect."

The experiments were so sensitive to temperature fluctuations that they had to be carefully shielded from random atoms or particles of light; they were conducted in an ultra-high vacuum chamber and in the dark.

"These were very, very difficult experiments," said Murray Holland, a fellow at JILA, a physics research institute in Boulder where two of the Nobelists also work. The winners are "absolutely superb scientists."

From the moment the scientists unveiled their findings in a 1995 paper, Nobel talk has surrounded them. Bose-Einstein condensates were named "Molecule of the Year" by
Science magazine when they were discovered in 1995.

So the phone calls from relatives and academic colleagues that awakened Cornell and Wieman early Tuesday did not come as a complete surprise. But they were surprised to be rewarded so soon. "I thought 20 years would go by," said Cornell.

The Nobel prize often recognizes the impact of work done many years earlier. In this case, the early work on Bose-Einstein condensates rapidly sparked more than 30 labs around the world to join the endeavor; about 2,000 papers have already been written on the topic.

In addition to its potential practical implications, the Bose-Einstein condensate intrigues physicists because it is not affected by friction, meaning that it can remain in motion without slowing down.

In this way, the condensate is like "superliquids" that can flow upward or spin forever when stirred just once and superconductors, which allow electricity to flow freely and are used in today's MRI machines.

"Now we have a chance to see the science lurking behind many of these 'super' effects," Bigelow said.

Added Cornell, who planned to have dinner with wife to celebrate and then return to his lab in the morning: "We can really get down to the nitty-gritty."

On the Internet: www.amo.phy.gasou.edu/bec.html

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