SCIENTIFIC AMERICAN

News - February 7, 2007

Quantum Quirk: Stopped Laser Pulse Reappears a Short Distance Away

Supercold atoms learn how to play catch with light

By JR Minkel

Harvard University researchers have halted a pulse of laser light in its tracks and revived it a fraction of a millimeter away. Here's the twist: they stopped it in a cloud of supercold sodium atoms, known as a Bose-Einstein condensate (BEC), and then restarted it in a second, distinct BEC as though the pulse had spookily jumped between the two locations.

"It's odd," says atomic physicist Lene Hau, the team's leader. "We can actually revive the light pulse and send it back on its way as if nothing had happened." Besides being a neat quantum game of catch, Hau speculates that the technique may someday be used in optical communications or ultraprecise navigation systems.

BEC clouds are prized because their atoms' delicate quantum states all vibrate in unison, effectively creating one big atom that does things individual atoms cannot. In 1999, for example, Hau's group slowed light inside a condensate to "bicycle speed" (38 mph). For the new experiment, she and her colleagues shined a control laser beam through two independent BECs placed side by side. They struck the first BEC with a laser pulse, which slowed and transferred its energy into a collective shudder of the condensate atoms—a sort of slow-moving ripple of matter that mirrored the laser pulse.

The researchers shut off the control beam long enough to give the wave time to travel the 160 microns between the BECs and then reactivated it. The laser caused the matter wave to coalesce (dump atoms) inside the second BEC, forcing the surrounding atoms to radiate like antennas and reproduce the original pulse.

"It's really playing with quantum mechanics at a lot of different levels," Hau says. The laser pulse and BEC are able to trade energy only because the quantum states of the condensate atoms match up with the frequency of the laser. As a result, the BEC enters a so-called superposition, meaning the matter wave is simultaneously there and not there.

The matter wave cannot distinguish between the BECs, because the superposition of the first BEC means that it is partly in the same pristine, undisturbed condition as the second one, says Michael Fleischhauer of the Technical University of Kaiserslautern in Germany in an editorial accompanying the Harvard team's report, published online February 7 by *Nature*. With a bit of prompting it therefore transfers its energy to the new condensate in an exact reversal of what happened in the first condensate, producing what he calls "a striking and intriguing demonstration of a fundamental aspect of quantum physics."

It might eventually have practical applications, too. By changing where the matter wave coalesced, Hau's group could alter the properties of the restored pulse, suggesting the technology could be used to manipulate optical signals, perhaps helping to realize quantum schemes for ultrasecure communications, Hau says. She adds that it could also be used to produce continuous laserlike streams of supercold atoms, which could enhance navigation systems.

Further Reading

Is the Universe Leaking Energy?
"Twistor" Theory Reignites the Latest Superstring Revolution
Spooky Eyes: Using Human Volunteers to Witness Quantum Entanglement
Is Time an Illusion?

Through Neutrino Eyes: Ghostly Particles Become Astronomical Tools
One for All: Five Entangled Photons Collectively Choose a Path to Follow
"Quantum Microphone" Puts Visible Object in Two Places at Once
Quantum Effects Exploited to Generate Random Numbers