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In Tiny Supercooled Clouds, Physicists Exchange Light and Matter

Technique may give scientists a new degree of control over fiber-optic communication and quantum information processing

CAMBRIDGE, Mass. – Physicists have for the first time stopped and extinguished a light pulse in one part of space and then revived it in a completely separate location. They accomplished this feat by completely converting the light pulse into matter that travels between the two locations and is subsequently changed back to light.

Matter, unlike light, can easily be manipulated, and the experiments provide a powerful means to control optical information. The findings, published this week by Harvard University researchers in the journal *Nature*, could present an entirely new way for scientists and engineers to manipulate the light pulses used in fiber-optic communications, the technology at the heart of our highly networked society.

"We demonstrate that we can stop a light pulse in a supercooled sodium cloud, store the data contained within it, and totally extinguish it, only to reincarnate the pulse in another cloud two-tenths of a millimeter away," says Lene Vestergaard Hau, Mallinckrodt Professor of Physics and of Applied Physics in Harvard's Faculty of Arts and Sciences and School of Engineering and Applied Sciences.

Hau and her co-authors, Naomi S. Ginsberg and Sean R. Garner, found that the light pulse can be revived, and its information transferred between the two clouds of sodium atoms, by converting the original optical pulse into a traveling matter wave which is an exact matter copy of the original pulse, traveling at a leisurely 200 meters per hour. The matter pulse is readily converted back into light when it enters the second of the super-

cooled clouds – known as Bose-Einstein condensates – and is illuminated with a control laser.

"The Bose-Einstein condensates are very important to this work because within these clouds atoms become phase-locked, losing their individuality and independence," Hau says. "The lock-step nature of atoms in a Bose-Einstein condensate makes it possible for the information in the initial light pulse to be replicated exactly within the second cloud of sodium atoms, where the atoms collaborate to revive the light pulse."

Within a Bose-Einstein condensate – a cloud of sodium atoms cooled to just billionths of a degree above absolute zero – a light pulse is spatially compressed by a factor of 50 million. The light drives a controllable number of the condensate's roughly 1.8 million sodium atoms to enter into quantum superposition states with a lower-energy component that stays put and a higher-energy component that travels between the two Bose-Einstein condensates. The amplitude and phase of the light pulse stopped and extinguished in the first cloud are imprinted in this traveling component and transferred to the second cloud, where the recaptured information can recreate the original light pulse.

The period of time when the light pulse becomes matter, and the matter pulse is isolated in space between the condensate clouds, could offer scientists and engineers a tantalizing new window for controlling and manipulating optical information; researchers cannot now readily control optical information during its journey, except to amplify the signal to avoid fading. The new work by Hau and her colleagues marks the first successful manipulation of coherent optical information.

"This work could provide a missing link in the control of optical information," Hau says. "While the matter is traveling between the two Bose-Einstein condensates, we can trap it, potentially for minutes, and reshape it – change it – in whatever way we want. This novel form of quantum control could also have applications in the developing fields of quantum information processing and quantum cryptography."

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