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Scientists Bring Light to Full Stop, Hold It, Then Send It on Its Way

By JAMES GLANZ

Researchers say they have slowed light to a dead stop, stored it and then released it as if it were an ordinary material particle.

The achievement is a landmark feat that, by reining in nature's swiftest and most ethereal form of energy for the first time, could help realize what are now theoretical concepts for vastly increasing the speed of computers and the security of communications.

Two independent teams of physicists have achieved the result, one led by Dr. Lene Vestergaard Hau of Harvard University and the Rowland Institute for Science in Cambridge, Mass., and the other by Dr. Ronald L. Walsworth and Dr. Mikhail D. Lukin of the Harvard-Smithsonian Center for Astrophysics, also in Cambridge.

Light normally moves through space at 186,000 miles a second. Ordinary transparent media like water, glass and crystal slow light slightly, an effect that causes the bending of light rays that allows lenses to focus images and prisms to produce spectra.

Using a distantly related but much more powerful effect, the Walsworth-Lukin team first slowed and then stopped the light in a medium that consisted of specially prepared containers of gas. In this medium, the light became fainter and fainter as it slowed and then stopped. By flashing a second light through the gas, the team could essentially revive the original beam.

The beam then left the chamber carrying nearly the same shape, intensity and other properties it had when it entered. The experiments led by Dr. Hau achieved similar results with closely related techniques.

"Essentially, the light becomes stuck in the medium, and it can't get out until the experimenters say so," said Dr. Seth Lloyd, an associate professor of mechanical engineering at the Massachusetts Institute of Technology who is familiar with the work.

Dr. Lloyd added, "Who ever thought that you could make light stand still?"

He said the work's biggest impact could come in futuristic technologies called quantum computing and quantum communication. Both concepts rely heavily on the ability of light to carry so-called quantum information, involving particles that can exist in many places or states at once.

Quantum computers could crank through certain operations vastly faster than existing machines; quantum commmunications could never be eavesdropped upon. For both these systems, light is needed to form large networks of computers. But those connections are difficult without temporary storage of light, a problem that the new work could help solve.

A paper by Dr. Walsworth, Dr. Lukin and three collaborators — Dr. David Phillips, Annet Fleischhauer and Dr. Alois Mair, all at Harvard- Smithsonian — is scheduled to appear in the Jan. 29 issue of Physical Review Letters.

Citing restrictions imposed by the journal Nature, where her report is to appear, Dr. Hau refused to discuss her work in detail.

Two years ago, however, Nature published Dr. Hau's description of work in which she slowed light to about 38 miles an hour in a system involving beams of light shone through a chilled sodium gas.

Dr. Walsworth and Dr. Lukin mentioned Dr. Hau's new work in their paper, saying she achieved her latest results using a similarly chilled gas. Dr. Lukin cited her earlier work, which Dr. Hau produced in collaboration with Dr. Stephen Harris of Stanford University, as the inspiration for the new experiments.

Those experiments take the next step, stopping the light's propagation completely.

"We've been able to hold it there and just let it go, and what comes out is the same as what we sent in," Dr. Walsworth said. "So it's like a freeze frame."

Dr. Walsworth, Dr. Lukin and their team slowed light in a gas form of rubidium, an alkaline metal element.

The deceleration of the light in the rubidium differed in several ways from how light slows through an ordinary lens. For one thing, the light dimmed as it slowed through the rubidium.

Another change involved the behavior of atoms in the gas, which developed a sort of impression of the slowing wave.

This impression, actually consisting of patterns in a property of the atoms called their spin, was a kind of record of the light's passing and was enough to allow the experimenters to revive or reconstitute the original beam.

Both Dr. Hau's original experiments on slowing light, and the new ones on stopping it, rely on a complex phenomenon in certain gases called electromagnetically induced transparency, or E.I.T.

This property allows certain gases, like rubidium, that are normally opaque to become transparent when specially treated.

For example, rubidium would normally absorb the dark red laser light used by Dr. Walsworth and his colleagues, because rubidium atoms are easily excited by the frequency of that light.

But by shining a second laser, with a slightly different frequency, through the gas, the researchers rendered it transparent.

The reason is that the two lasers create the sort of "beat frequency" that occurs when two tuning forks simultaneously sound slightly different notes.

The gas does not easily absorb that frequency, so it allows the light to pass through it; that is, the gas becomes transparent.

But another property of the atoms, called their spin, is still sensitive to the new frequency. Atoms do not actually spin but the property is a quantum-mechanical effect analagous to a tiny bar magnet that can be twisted by the light.

As the light passes through, it alters those spins, in effect flipping them. Though the gas remains transparent, the interaction serves as a friction or weight on the light, slowing it.

Using that technique, Dr. Hau and Dr. Harris in the earlier experiment slowed light to a crawl. But they could not stop it, because the transparent "window" in the gas became increasingly narrower, and more difficult to pass through, as the light moved slower and slower.

In a recent theoretical advance, Dr. Lukin, with Dr. Suzanne Yelin of Harvard-Smithsonian and Dr. Michael Fleischhauer of the University of Kaiserslautern in Germany, discovered a way around this constraint.

They suggested waiting for the beam to enter the gas container, then smoothly reducing the intensity of the second beam.

The three physicists calculated that this procedure would narrow the window, slowing the first beam, but also "tune" the system so that the beam always passes through.

The first beam, they theorized, should slow to an infinitesimally slow speed, finally present only as an imprint on the spins, with no visible light remaining. Turning the second beam back on, they speculated, should reconstitute the first beam.

The new experiments bore those ideas out.

"The light is actually brought to a stop and stored completely in the atoms," Dr. Harris said. "There's no other way to do that. It's been done — done very convincingly, and beautifully."