

ment on the second photon. The twin beams, which exit the crystal at an angle to their original path, are reflected back toward the crystal by mirrors, but now they pass through it toward detectors.

However, not all the laser light gets converted on the first pass: Some goes straight through the crystal to another mirror and is reflected back into the crystal, giving it another crack at making photon pairs, which then follow the same path as the other beams to the detectors (dotted red and blue lines in lower diagram). The result is two different beams heading toward each detector along two different paths. Each pair of beams corresponds to a double-slit experiment. And providing there is no way to distinguish photons that might be created on the laser light's first pass through the crystal from those that might be created on the second pass, both detectors register an interference pattern.

To make one red path distinguishable from

the other, the researchers put a polarization rotator in the solid red path, converting the vertically polarized light to horizontal. And sure enough, inserting the rotator makes the interference pattern in the upper detector vanish. However, the interference pattern also disappears from the bottom detector. Why? The photons are created as pairs, so when the red-path photons become labeled with which-path information, the same information becomes available for the blue-path photons. This is nonlocality at work.

To erase the which-path information, the Innsbruck team then added a 45° filter to the red path, just in front of the detector. The interference pattern then reappeared in that detector. An interference pattern did not reappear in the other detector, because analyzing the red-path photons does not erase any information from the blue path. But when the experimenters combined the readouts from both detectors, they were able to show that interference actually had been resur-

rected along both paths. Inserting or removing the which-path information transforms the behavior of light throughout the system, simultaneously demonstrating Scully's quantum eraser and dramatizing nonlocality.

For quantum theorists, the Innsbruck experiments offer a fine demonstration that the world really is as weird as quantum mechanics would have us believe. Leonard Mandel of the University of Rochester in New York state, who reported results of a similar experiment at a conference last June, says, "It is nice to be able to demonstrate that distinguishability is the key to determining whether you have interference." And Scully is pleased with the progress of his eraser concept: "These experiments are getting closer and closer all the time to what I had hoped we would do."

—Andrew Watson

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OPTICS

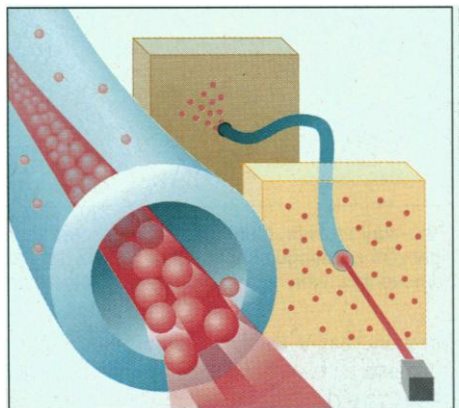
Laser Is a Guiding Light for Atoms

Laser beams have proven faithful guides for everything from smart weapons to teams of surveyors. In last week's *Physical Review Letters* (PRL), their path-finding abilities are on display again, but on a much smaller scale. There, a team of Colorado researchers reports using a laser to guide streams of rubidium atoms through a hollow optical fiber—a feat of control, other physicists believe, that could provide researchers in areas from quantum mechanics to nanotechnology with streams of atoms on tap wherever they are needed.

"It's a new technique that certainly has a lot of promise," says William Phillips, a physicist at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland. Such controllable streams of atoms, explains Phillips, could give nanotechnologists a new way to deliver atoms to precise positions on surfaces. They might also find uses in the new field of atom optics, where physicists split and recombine beams of atoms to explore the wave nature of matter. In the past, it took a series of magnetic or electric fields to bend the path of an atomic beam, explains Phillips. "Now you just bend the tube and make all of the atoms follow the same path," he says.

In creating their atomic guides, the Colorado researchers, led by Dana Z. Anderson and Carl Wieman at the University of Colorado and JILA, both in Boulder, and Eric Cornell at JILA and the Boulder branch of NIST, faced a sticky problem. They needed to ensure that an atom sent down a hollow fiber would faithfully follow any twists and turns without colliding with the walls, where it would stick.

To keep the atoms away from the fiber's walls, the researchers fired a laser beam along it. Laser light effortlessly follows the twists and turns of the optical fiber, because it's reflected off the walls. The light, in turn, guides the atoms. It can do so because, like all light, a laser beam creates an oscillating elec-



Drawn to the light. A laser beam channels atoms along the center of a hollow optical fiber.

tric field. This oscillation causes the atoms' electrons to vibrate. If the frequency of the oscillating field of the laser light is just below the atoms' resonance frequency—a frequency at which their electrons jump from the ground state to an excited state—the atoms and the light oscillate in synchrony, and the atom is drawn to the beam. The tuning is critical: If the frequency of the laser light is above resonance, the atoms oscillate out of synch with the light and get kicked out of the beam.

In their laser guiding scheme, the Colo-

rado researchers not only tuned their laser to just the right frequency; they also tailored the beam so it was most intense down the center. As a result, atoms were attracted to the very center of the fiber, where they could slip safely past the walls. Connected to a container of rubidium gas, a 5-centimeter atomic hose of this design carried about 10,000 atoms a second, the group reported in the PRL paper.

To boost the precision of their atomic delivery system—and thereby make it more useful for atom interferometry and nanotechnology experiments—the researchers now hope to limit the lateral movements of the atoms even further, forcing them to travel through the hoses along just a single path. Fibers with channels even smaller than the 10-micrometer diameter of the current setup will help focus the atoms. At the same time, by taking advantage of the wave nature of matter, the researchers will make the atoms very large. "By cooling the temperature, you increase the wavelength of the atoms," says Anderson. Chilling the rubidium atoms to 100 billionths of a kelvin should fatten them up until they can just barely fit through the fiber, providing even tighter control over their path.

As a bonus, the need for a close match between the laser's own frequency and the atoms' resonance frequency means that the setup acts as a filter that accepts only one kind of atom. Others, with different resonance frequencies, are oblivious to the guiding light. By giving researchers just the type of atoms they want right where they want them, says Anderson, "this might make life a whole lot easier for doing atom experiments."

—Robert F. Service