Instant Transport

Achieving quantum teleportation in the laboratory

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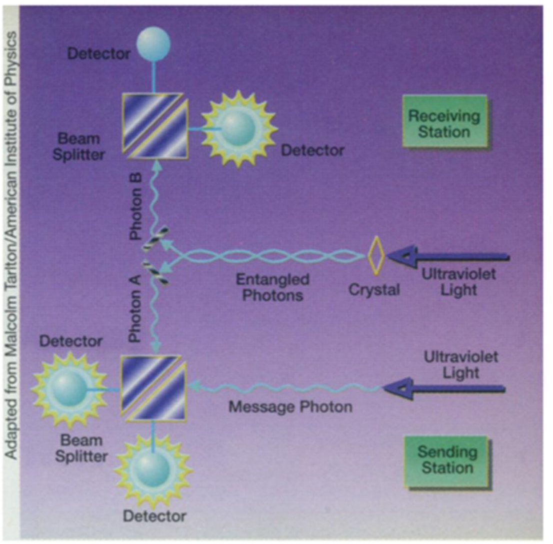

The University of Innsbruck's experimental setup for achieving quantum teleportation.

With a glittery shudder, a figure vanishes from view. At the same instant, a perfect replica shimmers into existence at a distant locality.

In science fiction thrillers, teleportation provides a convenient shortcut across time and space. In the real world, teleporting a person, a mouse, or even a coffee mug remains very much a dream.

In 1993, however, Charles H. Bennett of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y., and his collaborators proposed that, in principle, it should be possible to take advantage of certain quirks of quantum behavior to teleport a specific characteristic of a photon, electron, or other quantum particle, though not the particle itself. The process would accomplish the instantaneous transfer of the quantum state of one particle to another, which could be at the other end of a room or across the galaxy (SN: 4/10/93, p. 229). In effect, that quantum state could be thought of as a message.

Two groups now report having successfully teleported photon characteristics in the laboratory.

Dik Bouwmeester, Anton Zeilinger, and their coworkers at the University of Innsbruck in Austria described the feat in the Dec. 11, 1997 NATURE. Francesco De Martini and his team at the University of Rome "La Sapienza" in Italy are slated to report their results in PHYSICAL REVIEW LETTERS.

"The methods developed for this experiment will be of great importance, both for exploring the field of quantum communication and for future experiments on the foundations of quantum mechanics," the Innsbruck group remarks.

Indeed, teleportation of the quantum states of particles is likely to become an important tool in efforts to design, build, and operate quantum computers (SN: 1/14/95, p. 30) and quantum information systems, Bennett says.

Teleportation of a quantum state depends on a peculiar phenomenon known as entanglement. The idea is to create a pair of particles that, because of their common origin, remain part of a single quantum system.

For example, shining a photon of a particular wavelength into the right sort of crystal converts it into a pair of photons with a special relationship, and they are said to be entangled.

According to quantum theory, neither photon has a particular polarization, or electric field orientation, until it's measured at a detector. Such a measurement transforms a photon's polarization from a range of possibilities into a specific, randomly chosen value. Surprisingly, measuring one photon's polarization causes the other photon of the pair to acquire the opposite polarization at the same instant, no matter how far away it is.

In general, practically anything done to one particle immediately affects the other in a predictable way. The entanglement is quite delicate, however, and the particles must be kept isolated from their environments to preserve their relationship.

In the Innsbruck experiment, to teleport a quantum state, the sender used ultraviolet light to prepare an additional photon. Its polarization state constituted a message to be communicated.

The message photon was brought together with one of the photons of an entangled pair in an optical device known as a beam splitter. These two photons were now entangled. They were then measured jointly to determine the resulting polarization.

"We learned how to entangle independently created photons," Zeilinger says. "This opens up a whole new class of experiments not previously possible."

When the measurement was made, the second, remote photon of the original entangled pair also acquired a polarization. A beam splitter and detectors measured its state. In effect, the message photon's state was transferred to the remote photon without the two ever coming into contact, and the original copy of the message was destroyed.

The sender then used conventional means to report to the recipient how the detectors were set when they measured the joint polarization. This determined what sort of measurement to make on the remote photon in order to retrieve the original polarization state that constituted the message. Because of the need for this conventional communication, the information required to detect that state must travel at the speed of light or slower, even if the polarization state is transferred instantly.

A tricky part of the experiment was proving that an unknown quantum state had actually been teleported. That required careful synchronization of the several polarization detectors used in the experiment.

Instead of having a separate message photon as well as an entangled pair, De Martini and his coworkers used two aspects of each particle of the entangled pair—the polarization and direction of motion. "These enter in the theory just like two separate particles, and they can be used just as well to demonstrate teleportation," says Tony Sudbery of York University in England.

With the success of quantum teleportation using photons as vehicles, researchers are considering the possibility of trying other combinations of particles, including electrons, atoms, and ions. They can envision transferring a fragile quantum state from a short-lived particle to a more stable quantum system.

"This opens the possibility of quantum memories, where the information of incoming photons is stored on trapped ions carefully shielded from the environment," Bouwmeester and his colleagues note.

Quantum teleportation with the addition of special strategies also facilitates the reliable transmission of information in noisy environments, where messages would otherwise be degraded. "The feasibility of preserving quantum states in a hostile environment will have great advantages in the realm of quantum computation," the researchers add. "The teleportation scheme could also be used to provide links between quantum computers."

The researchers have done a remarkable job, Bennett says. "We can now use quantum teleportation in tests of a variety of theoretical concepts." □