Teleportation moves on

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When physicists teleported photons for the first time in 1997 they had to destroy the photons to be sure that the teleportation had been successful. Now a team at the University of Vienna has managed to teleport photons without destroying them. Jian-Wei Pan and colleagues believe that their method could be the next step towards long-distance quantum communication (J-W Pan et al. 2003 Nature 421 721).

In quantum teleportation the sender, normally called Alice, instantaneously transfers the quantum state of a particle to a receiver, called Bob. In most experiments so far Alice has teleported the quantum state of a photon - defined in terms of its polarization - to Bob. The photon itself is not transferred: rather Bob’s photon acquires exactly the same polarization as Alice’s. The uncertainty principle means that Alice cannot know the exact state of her photon, but another feature of quantum mechanics called “entanglement” means that this is not an obstacle to teleporting the state to Bob.

Quantum entanglement essentially allows two particles to behave as one, regardless of how far apart they are. Photons can be entangled so that if one is vertically polarized, for instance, then the other photon in the pair is always horizontally polarized.

In a standard teleportation experiment a laser is directed at a crystal with nonlinear optical properties. Occasionally the photon will be “down-converted” into two lower energy photons, and sometimes these photons will have their polarizations entangled. In a teleportation experiment the beam is reflected back through the crystal to sometimes produce a second pair of entangled photons. By convention the photons in the first pair are labelled 2 and 3 (for mode 2 and mode 3), and those in the second pair are 1 and 4. Photons 1 and 2 are directed to Alice, photon 3 is sent to Bob and photon 4 is used as a trigger. A variety of mirrors, beamsplitters and polarizers are used to direct the photons to four detectors labelled D1, D2, D3 and T (for trigger).

The aim of the experiment is to transfer, or teleport, the polarization of photon 1 to photon 3. This is normally done by making a joint measurement on photons 1 and 2 which changes the polarization of the latter in such a way that photon 3 - which is entangled with it - always acquires the same polarization as the first photon. In other words the quantum state of photon 1 - which was unknown to Alice - has been teleported to photon 3.

The experiment was set up such that detectors D1, D2 and T all register photons at the same time when teleportation takes place. However, under certain circumstances - the emission of two photons each into modes 1 and 4 - it is possible for the same three detectors to register events even though there is no photon in mode 3 to teleport to. These spurious events mean that the D3 detector must also register - and destroy - a photon to be sure that teleportation has taken place.

By using a filter to reduce the intensity of the photons that are going to be teleported the researchers were able to significantly reduce the number of spurious detection events. The Vienna team could be 97% certain that the state had been teleported to photon 3 without actually having to detect it. Such a high accuracy means that the teleported photons could be used in “quantum repeaters” for long distance communication. The team now hopes to combine these results with a technique known as “entanglement purification” to further develop quantum communication over long distances.

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