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Quantum teleporter creates laser beam clones

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Quantum physicists have moved beyond teleporting individual photons to imitating a classic science-fiction scenario – a teleportation machine that generates two near-identical copies of the original.

In the fifth episode of the original Star Trek series, the transporter malfunctioned and beamed up to the Starship Enterprise two copies of Captain Kirk, which looked identical but behaved differently. A new experiment has now demonstrated "quantum telecloning" – transporting a whole laser beam to two separate places.

However, the two new beams differed slightly from each other and the original – an inherent difference arising from quantum mechanics, says Sam Braunstein at the University of York, UK, one of the researchers.

Photons generated simultaneously by the same light source can display a peculiar entanglement if the two photons are sent in different directions. Quantum teleportation takes advantage of this entangled state.

Quantum mechanics dictates that the entangled photons' properties remain unknown until they are measured – but observing one photon instantaneously determines the properties of its "entangled" partner, no matter how far apart the two are.

Photon destruction

In conventional quantum teleportation, the sender combines the photon to be teleported with one of a pair of entangled photons, then measures their combined quantum state. The second entangled photon instantaneously takes on a set of quantum properties that includes information on the quantum state of the input photon, as well as on the original entangled photon in their mingled state. The process actually destroys the original input photon.

Quantum telecloning takes advantage of a different type of entanglement which can be extended to multiple locations. Laser beams can be entangled to connect three points – one sender, and two receivers.

As in quantum teleportation, the input signal is combined with the entangled beam at the send point, then measured, and information on its quantum state is transmitted to two receivers, each of which recreates the input beam.

But there is a catch. Quantum mechanics also dictates that just measuring the position of a particle disturbs it and so limits the accuracy to which it can be reliably replicated – a concept known as the uncertainty principle. This makes producing an exact clone of the beam impossible.

High fidelity

The experiment, led by Akira Furusawa at the University of Tokyo, Japan, recreated the properties of the laser beam, such as amplitude and phase, within a range of uncertainty. The "fidelity", or degree of overlap between the uncertainty ranges of the two beams the team copied from the original, was 58%. Because of the uncertainty principle the maximum possible fidelity would have been 66%.

Although that fraction sounds low, the copies actually were pretty good because the ranges of uncertainty of the two beams overlapped closely. Thus the differences were much smaller than those between the two Captain Kirks, one of whom had all the original's good traits, while the other had all the bad.

Quantum telecloning would have changed only a few of the original Kirk's traits, and would not have dramatically altered his character, says Braunstein. But neither, he notes, would it have been able to resolve the plot complications by recombining the two Kirks at the end of the story.

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