Quantum teleportation over 143 kilometers

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The so-called „quantum internet" is envisaged as a revolutionary platform for information processing. It is not based anymore on classical computer networks but on the current developments of modern quantum information, where individual quantum particles are the carriers of information. Quantum networks promise absolutely secure communication and enhanced computation power for decentralized tasks compared to any conceivable classical technology. Due to the intrinsic transmission losses in conventional glass fibers a global quantum network will likely base on the free-space transfer of quantum states, e.g., between satellites and from satellites to ground. The now realized quantum teleportation[1] over a distance of 143 kilometres[2], beating a just one-month old record of 97 kilometers set by a group of physicists from China[3], is a significant step towards this future technology.

On the island of La Palma our team produced entangled pairs of particles of light (photons 2 and 3, see figure 1). Quantum entanglement means that none of the photons taken by itself has a definite polarization but that, if one measures the polarization of one of the photons and obtains a random result, the other photon will always show a perfectly correlated polarization. This type of quantum correlation cannot be described by classical physics and Albert Einstein therefore called it "spooky action at a distance". Photon 3 was then sent through the air to Tenerife, across the Atlantic Ocean at an altitude of about 2400 meters and over a distance of 143 kilometers, where it was caught by a telescope of the European Space Agency. Photon 2 remained in the laboratory at La Palma. There, we created additional particles of light (photon 1) in a freely selectable polarization state which we wanted to teleport.

This was achieved in several steps: First, a special kind of joint measurement, the so-called Bell measurement ("BM"), was performed on photons 1 and 2, which irrevocably destroys both photons. Two possible outcomes of this measurement were discriminated, and the corresponding classical information was sent via a conventional laser pulse (violet in the figure) to Tenerife. There, depending on which of the outcomes of the Bell measurement had been received, the polarization of photon 3 was transformed accordingly. This transformation ("T") completed the teleportation process, and the polarization of photon 3 on Tenerife was now identical with the initial polarization of photon 1 on La Palma.

The complexity of the setup and the environmental conditions (changes of temperature, sand storms, fog, rain, snow) constituted a significant challenge for the experiment. They also demanded a combination of modern quantum optical technologies concerning the source of entangled particles of light, the measurement devices, and the temporal synchronization of the two laboratories (see Figure 2 for the experimenter's view from La Palma to Tenerife). The experiment therefore represents a milestone, which demonstrates the maturity and applicability of these technologies in real-world outdoor conditions and hence paves the way for future global quantum networks. For the next step of satellite-based quantum teleportation an international collaboration of the Austrian and Chinese Academy of Sciences plans to shoot a satellite into space in the foreseeable future.

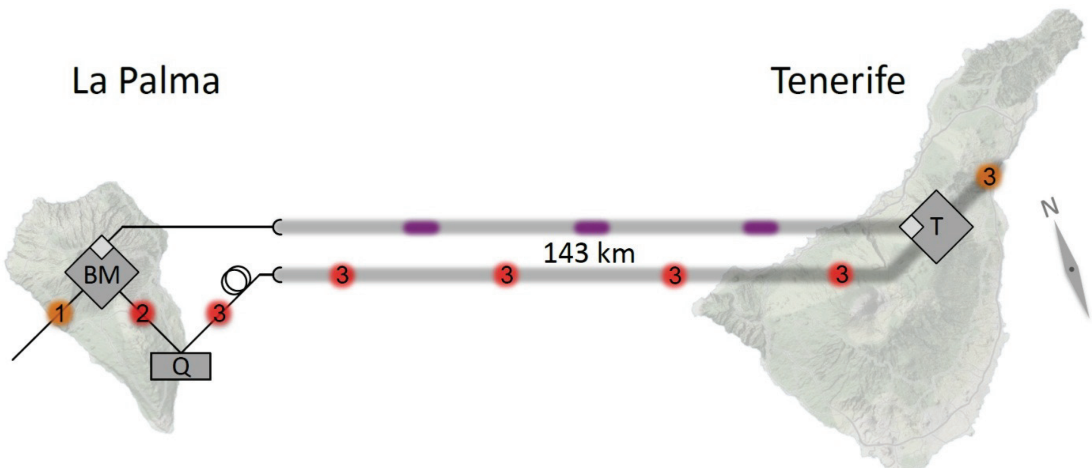

Figure 1: *Schematic illustration of the teleportation experiment. The polarisation state of particles of light was teleported over a distance of 143 kilometres from the Canary Island La Palma to Tenerife. Graphic: IQOQI Vienna & MPQ Garching.*

Figure 2: *Long time exposure photography viewing from La Palma to Tenerife. A green laser beam indicates the free-space link between the two laboratories. Graphic: IQOQI Vienna.*

References

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