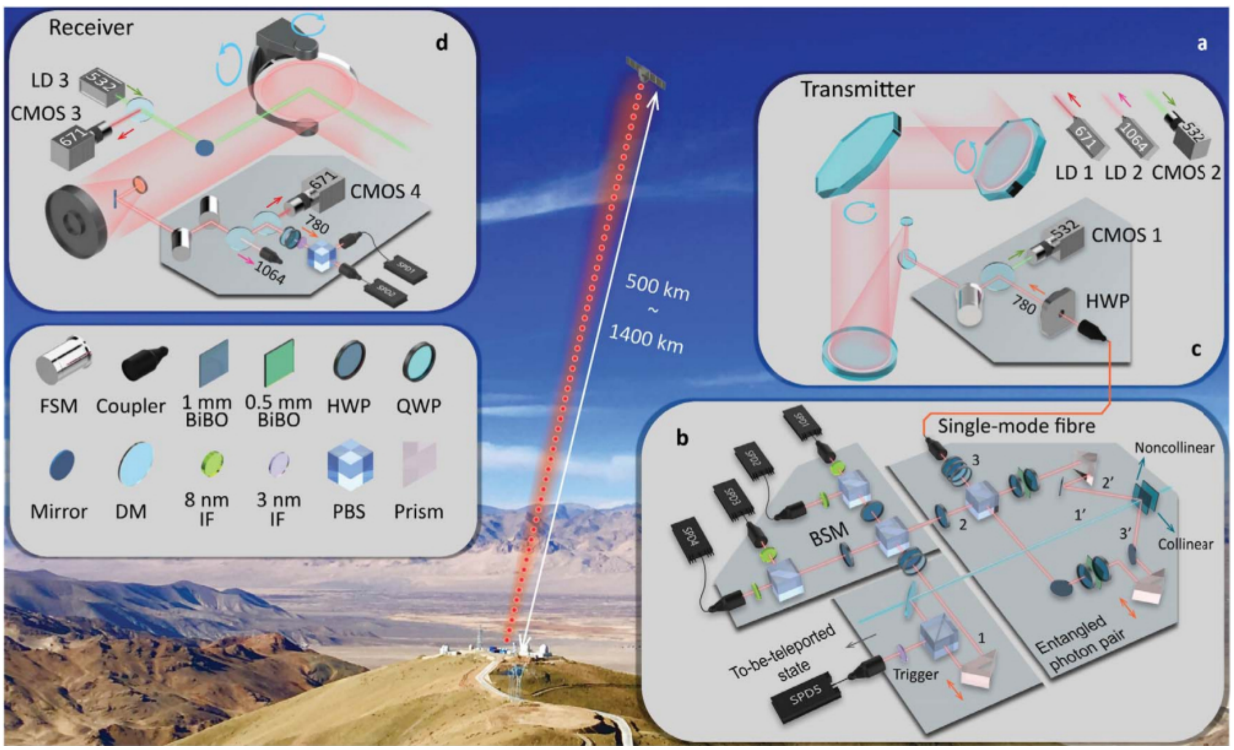
Physicists transmit data via Earth-to-space quantum entanglement

July 11 2017, by Bob Yirka



Overview of the set-up for ground-to-satellite quantum teleportation of a single photon with a distance up to 1400 km. Credit: arXiv:1707.00934 [quant-ph]

(Phys.org)—Two teams of researchers in China have advanced the distance that entangled particles can be used to send information, including encryption keys. In their papers, both uploaded to the *arXiv* preprint sever, the two groups outline their work and suggest their achievement represents an essential step toward the development of a global-scale quantum internet.

Quantum entanglement is the shared state of two separate particles—what happens to one happens to the other. Scientists have not yet figured out how this occurs, but they have learned how to create entangled particles on demand, typically by firing a laser through a crystal. As physicists learn more about entangled particles, they've designed more experiments to take advantage of their unique properties. One such area of research involves using them to build quantum networks. Such networks would be much faster than anything we have now, and they would also be much more secure because of the nature of entangled particles—disruptions to encryption keys, for example, could be instantly noted, allowing for prevention of hacking. In this new effort, the researchers have extended the entanglement distance of two particles—one on the surface of the Earth and the other in space, courtesy of a satellite. They have also shown that it is possible to send entangled encryption keys from a satellite to an Earth-based receiving station.

In the first experiment, the research team transferred the properties of an entangled particle housed in a facility in Tibet to its partner, which was beamed to a satellite passing overhead, far surpassing the distance record by other researchers. In this case, the information transfer occurred with photons that were approximately 500 to 1,400 kilometers apart, depending on the location of the satellite.

In the second experiment, equipment aboard a satellite created a random string of numbers to represent an encryption key. The key was then beamed to an Earth station as part of an entangled photon stream that used polarization as a means of transmission security.

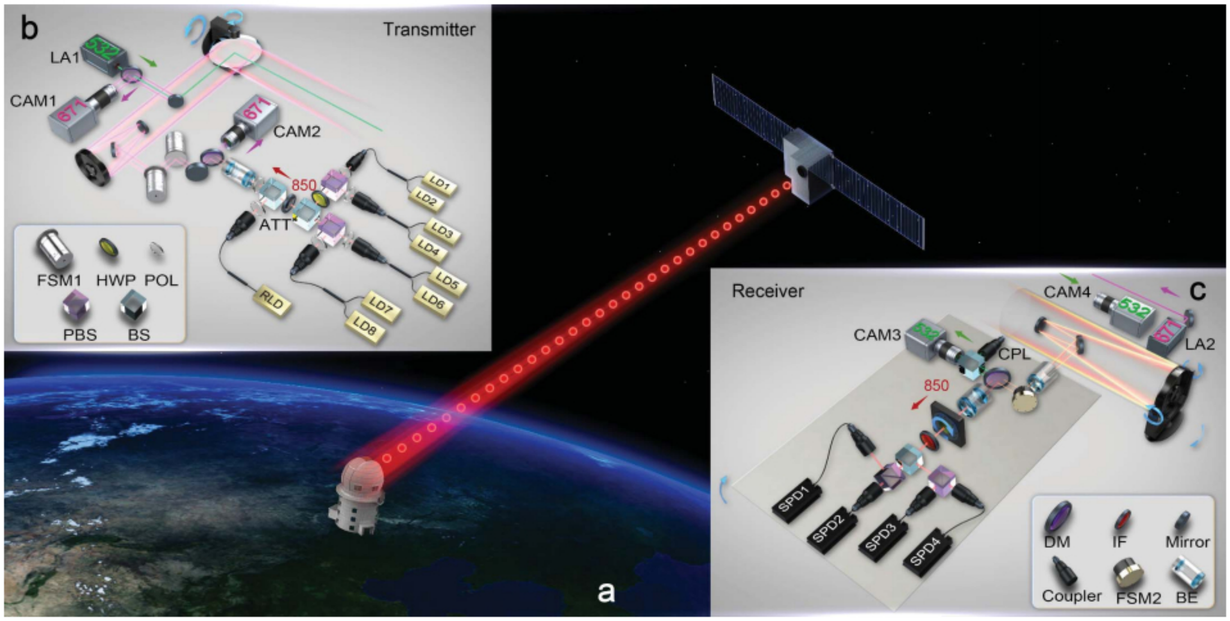


Illustration of the experimental set-up from "Satellite-to-ground quantum key distribution" arXiv:1707.00542 [quant-ph]

More information: * Ground-to-satellite quantum teleportation, arXiv:1707.00934 [quant-ph] arxiv.org/abs/1707.00934

Abstract
An arbitrary unknown quantum state cannot be precisely measured or perfectly replicated. However, quantum teleportation allows faithful transfer of unknown quantum states from one object to another over long distance, without physical travelling of the object itself. Long-distance teleportation has been recognized as a fundamental element in protocols such as large-scale quantum networks and distributed quantum computation. However, the previous teleportation experiments between distant locations were limited to a distance on the order of 100 kilometers, due to photon loss in optical fibres or terrestrial free-space

channels. An outstanding open challenge for a global-scale "quantum internet" is to significantly extend the range for teleportation. A promising solution to this problem is exploiting satellite platform and space-based link, which can conveniently connect two remote points on the Earth with greatly reduced channel loss because most of the photons' propagation path is in empty space. Here, we report the first quantum teleportation of independent single-photon qubits from a ground observatory to a low Earth orbit satellite - through an up-link channel - with a distance up to 1400 km. To optimize the link efficiency and overcome the atmospheric turbulence in the up-link, a series of techniques are developed, including a compact ultra-bright source of multi-photon entanglement, narrow beam divergence, high-bandwidth and high-accuracy acquiring, pointing, and tracking (APT). We demonstrate successful quantum teleportation for six input states in mutually unbiased bases with an average fidelity of 0.80+/-0.01, well above the classical limit. This work establishes the first ground-to-satellite up-link for faithful and ultra-long-distance quantum teleportation, an essential step toward global-scale quantum internet.

* Satellite-to-ground quantum key distribution, arXiv:1707.00542 [quant-ph] arxiv.org/abs/1707.00542

Abstract
Quantum key distribution (QKD) uses individual light quanta in quantum superposition states to guarantee unconditional communication security between distant parties. In practice, the achievable distance for QKD has been limited to a few hundred kilometers, due to the channel loss of fibers or terrestrial free space that exponentially reduced the photon rate. Satellite-based QKD promises to establish a global-scale quantum network by exploiting the negligible photon loss and decoherence in the empty out space. Here, we develop and launch a low-Earth-orbit satellite to implement decoy-state QKD with over kHz key rate from the satellite to ground over a distance up to 1200 km, which is

up to 20 orders of magnitudes more efficient than that expected using an optical fiber (with 0.2 dB/km loss) of the same length. The establishment of a reliable and efficient space-to-ground link for faithful quantum state transmission constitutes a key milestone for global-scale quantum networks.

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