Unbreakable quantum entanglement

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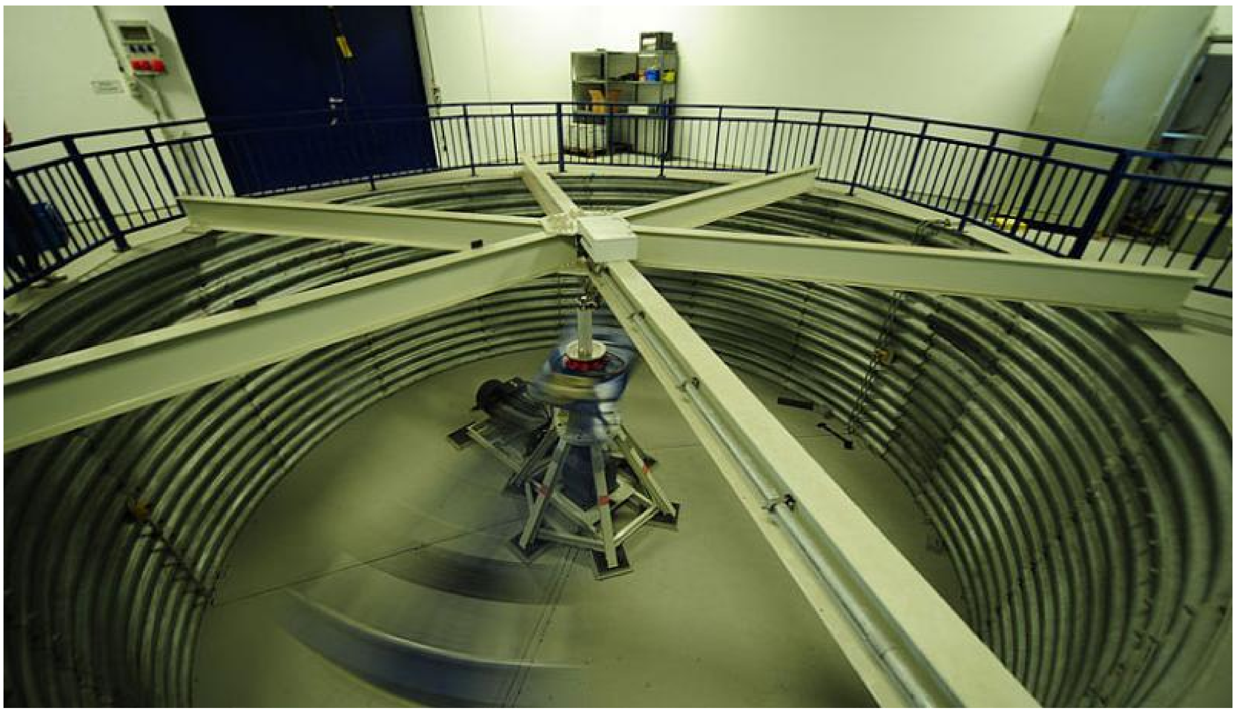


The rotating centrifuge in which the entangled photon source was accelerated to 30 times its weight. Credit: IQOQI/ÖAW

Einstein's "spooky action at a distance" persists even at high accelerations, researchers of the Austrian Academy of Sciences and the University of Vienna were able to show in a new experiment. A source of entangled photon pairs was exposed to massive stress: The photons' entanglement survived the drop in a fall tower as well as 30 times the Earth's gravitational acceleration in a centrifuge. This was reported in the most recent issue of *Nature Communications*. The experiment helps deepen our understanding of quantum mechanics and at the same time gives valuable results for quantum experiments in space.

Einstein's theory of relativity and the theory of quantum mechanics are two important pillars of modern physics. On the way of achieving a "Theory of Everything," these two theories have to be unified. This has not been achieved as of today, since phenomena of both theories can hardly be observed simultaneously. A typical example of a quantum mechanical phenomenon is entanglement: This means that the measurement of one of a pair of light particles, so-called photons, defines the state of the other particle immediately, regardless of their separation. High accelerations on the other hand can best be described by the theory of relativity. Now for the first time, quantum technologies enable us to observe these phenomena at once: The stability of quantum mechanical entanglement of photon pairs can be tested while the photons undergo relativistically relevant acceleration.

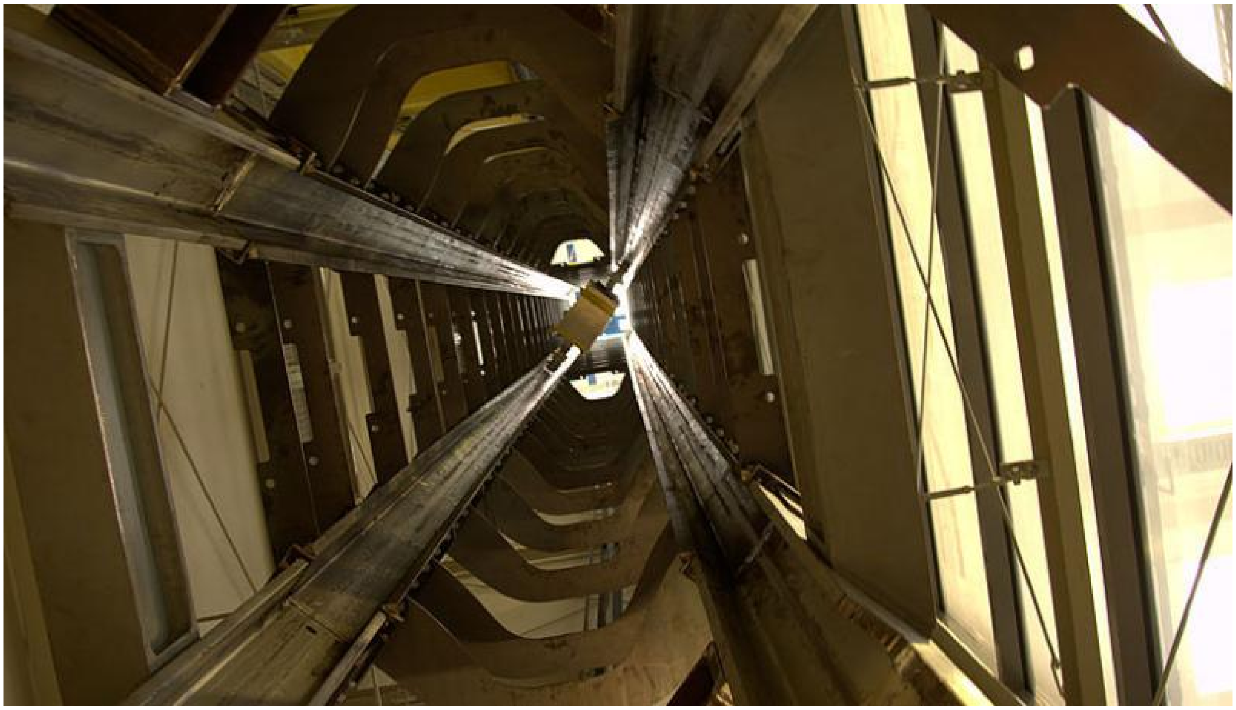
Quantum entanglement proves to be highly robust

Researchers of the Viennese Institute of Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences (OeAW) and of the University of Vienna have now investigated this area of research experimentally for the first time. They could show in their experiment that entanglement between photons survives even when the source of entangled photon pairs including the detectors are experiencing free fall or are being accelerated with 30g, that is, 30 times the Earth's acceleration. Doing so, the Viennese researchers have experimentally established an upper bound below which there is no degradation of entanglement quality.

The frame in the fall tower at the Institute of Automotive Engineering of the TU Dresden with the quantum-optical design. Credit: IQOQI/ÖAW

Important for quantum experiments with satellites

"These experiments shall help to unify the theories of quantum mechanics and relativity," says Rupert Ursin, group leader at IQOQI Vienna. The sturdiness of quantum entanglement even for strongly accelerated systems is crucial also for quantum experiments in space. "If entanglement were too fragile, quantum experiments could not be carried out on a satellite or an accelerated spacecraft or only in a very limited range," exemplifies Matthias Fink, first author of the publication.

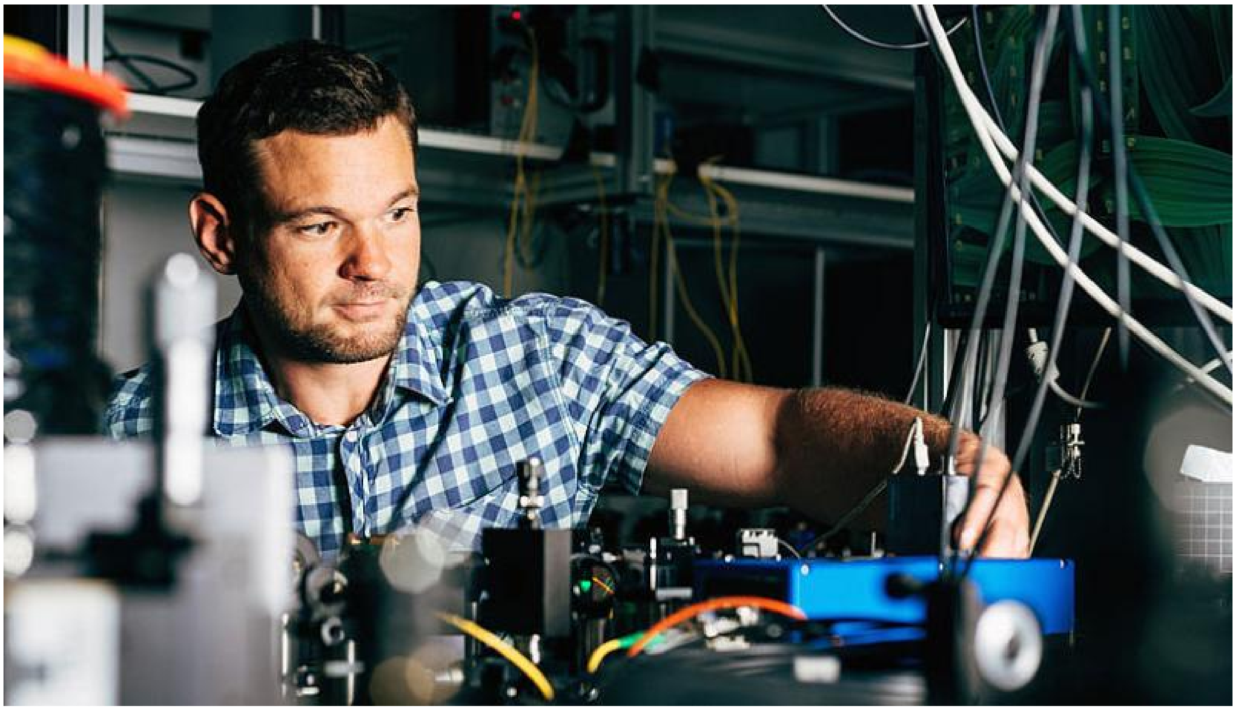


In this tower the experiments of the Viennese quantum physicists were carried out in weightlessness. Credit: IQOQI/ÖAW

12 meters falling height and 30g

In order to prove the robustness of quantum entanglement, quantum physicist Matthias Fink and his colleagues mounted a source of polarization-entangled photon pairs in a crate which was firstly dropped from a height of 12 meters to achieve zero gravity during the fall. In the second part of the experiment, the crate was fixed to the arm of a centrifuge and then accelerated up to 30g. As a comparison for the reader: A roller coaster ride exerts maximally 6g on the passengers.

Detectors mounted on the crate monitored the photons' entanglement during the experiments. Analysing the data, the physicists could calculate an upper bound of disadvantageous effects of acceleration on entanglement. The data showed that entanglement quality did not significantly exceed the expected contribution of background noise. "Our next challenge will be to stabilize the setup even more in order for it to withstand much higher accelerations. This would enhance the explanatory power of the experiment even further," says Matthias Fink.



First author Matthias Fink in the quantum laboratory at the Institute for Quantum Optics and Quantum Information at the Austrian Academy of Sciences. Credit: ÖAW/Klaus Pichler

More information: Experimental test of photonic entanglement in accelerated reference frames, *Nature Communications*, 2017. DOI: 10.1038/NCOMMS15304

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