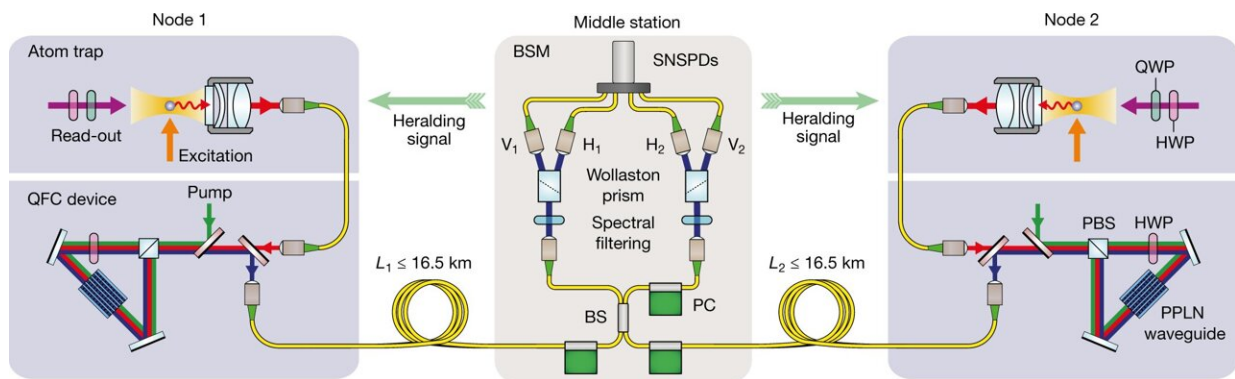


# Researchers achieve record entanglement of quantum memories

July 7 2022



Schematic of the experimental setup. In each node, located in buildings 400 m apart, a single  $^{87}\text{Rb}$  atom is loaded in an optical dipole trap. Both atoms are synchronously excited to the state  $5^2\text{P}_{3/2}|F'=0, m_F=0\rangle$  to generate atom–photon entanglement in the subsequent spontaneous decay. The single photons emitted at a wavelength of 780 nm are collected using high-numerical aperture objectives and coupled into single-mode fibers leading to the QFC devices. There, they are converted to telecom wavelength ( $\lambda = 1,517$  nm) by difference frequency generation in a periodically poled lithium niobate (PPLN) waveguide located in a Sagnac interferometer type setup, such a configuration fully maintains the polarization quantum state of the photon. The converted photons are guided to a middle station by fiber links with lengths up to 16.5 km, where the entanglement is swapped to the atoms by a BSM. After successfully generating atom–atom entanglement, the atoms are analyzed independently by a readout pulse of which the polarization, set by a half-wave plate (HWP) and quarter-wave plate (QWP), defines the measurement setting. PC, polarization controllers. Credit: *Nature* (2022). DOI: 10.1038/s41586-022-04764-4

A network in which data transmission is perfectly secure against hacking? If physicists have their way, this will become reality one day with the help of the quantum mechanical phenomenon known as entanglement. For entangled particles, the rule is: If you measure the state of one of the particles, then you automatically know the state of the other. It makes no difference how far away the entangled particles are from each other. This is an ideal state of affairs for transmitting information over long distances in a way that renders eavesdropping impossible.

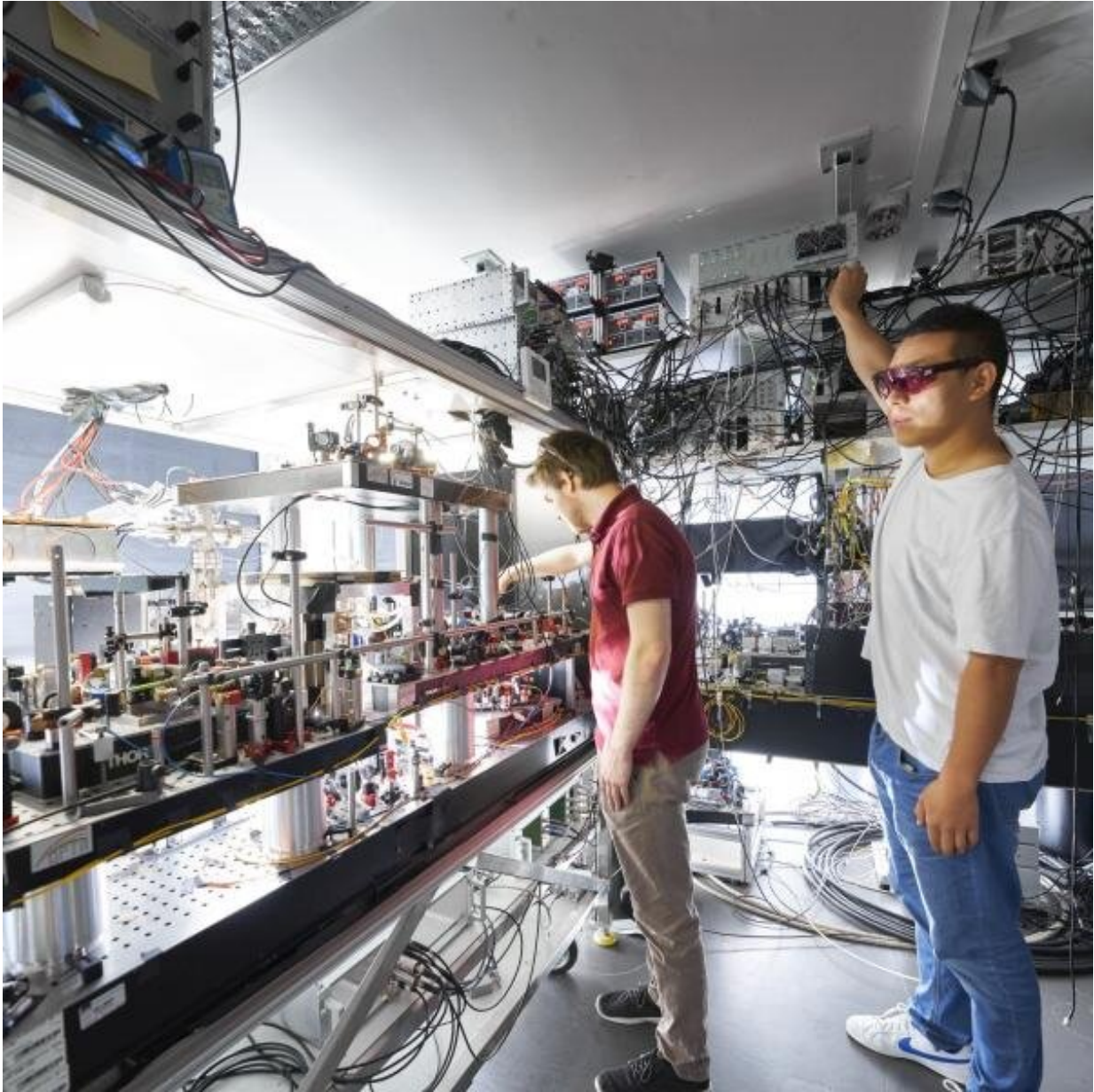
A team led by physicists Prof. Harald Weinfurter from LMU and Prof. Christoph Becher from Saarland University have now coupled two atomic [quantum memories](#) over a 33-kilometer-long fiber optic connection. This is the longest distance so far that anyone has ever managed entanglement via a telecom fiber.

The quantum mechanical entanglement is mediated via photons emitted by the two quantum memories. A decisive step was the researchers' shifting of the wavelength of the emitted light particles to a value that is used for conventional telecommunications. "By doing this, we were able to significantly reduce the loss of photons and create entangled quantum memories even over long distances of fiber optic cable," says Weinfurter.

Generally speaking, quantum networks consist of nodes of individual quantum memories—such as atoms, ions, or defects in crystal lattices. These nodes are able to receive, store, and transmit quantum states. Mediation between the nodes can be accomplished using light particles that are exchanged either over the air or in a targeted manner via fiber optic connection. For their experiment, the researchers use a system comprised of two optically trapped rubidium atoms in two laboratories on the LMU campus. The two locations are connected via a 700-meter-long fiber optic cable, which runs underneath Geschwister Scholl Square

in front of the main building of the university. By adding extra fibers on coils, connections of up to 33 kilometers in length can be achieved.

A laser pulse excites the atoms, after which they spontaneously fall back into their ground state, each thereby emitting a photon. Due to the conservation of angular momentum, the spin of the atom is entangled with the polarization of its emitted [photon](#). These light particles can then be used to create a quantum mechanical coupling of the two atoms. To do this, the scientists sent them through the fiber [optic cable](#) to a receiver station, where a joint measurement of the photons indicates an entanglement of the quantum memories.



Credit: Jan Greune

However, most quantum memories emit light with wavelengths in the visible or near-infrared range. "In fiber optics, these photons make it just a few kilometers before they are lost," explains Christoph Becher. For this reason, the physicist from Saarbrücken and his team optimized the

wavelength of the photons for their journey in the cable. Using two quantum frequency converters, they increased the original wavelength from 780 nanometers to a wavelength of 1,517 nanometers.

"This is close to the so-called telecom wavelength of around 1,550 nanometers," says Becher. The telecom band is the frequency range in which the transmission of light in fiber optics has the lowest losses. Becher's team accomplished the conversion with an unprecedented efficiency of 57%. At the same time, they managed to preserve the quality of the information stored in the photons to a high degree, which is a condition of quantum coupling.

"The significance of our experiment is that we actually entangle two stationary particles—that is to say, atoms that function as quantum memories," says Tim van Leent, lead author of the paper published in *Nature*. "This is much more difficult than entangling photons, but it opens up many more application possibilities."

The researchers think that the system they developed could be used to construct large-scale quantum networks and for the implementation of secure quantum communication protocols. "The experiment is an important step on the path to the quantum internet based on existing fiber optic infrastructure," says Harald Weinfurter.

**More information:** Tim van Leent et al, Entangling single atoms over 33 km telecom fibre, *Nature* (2022). [DOI: 10.1038/s41586-022-04764-4](https://doi.org/10.1038/s41586-022-04764-4)

Provided by Ludwig Maximilian University of Munich

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