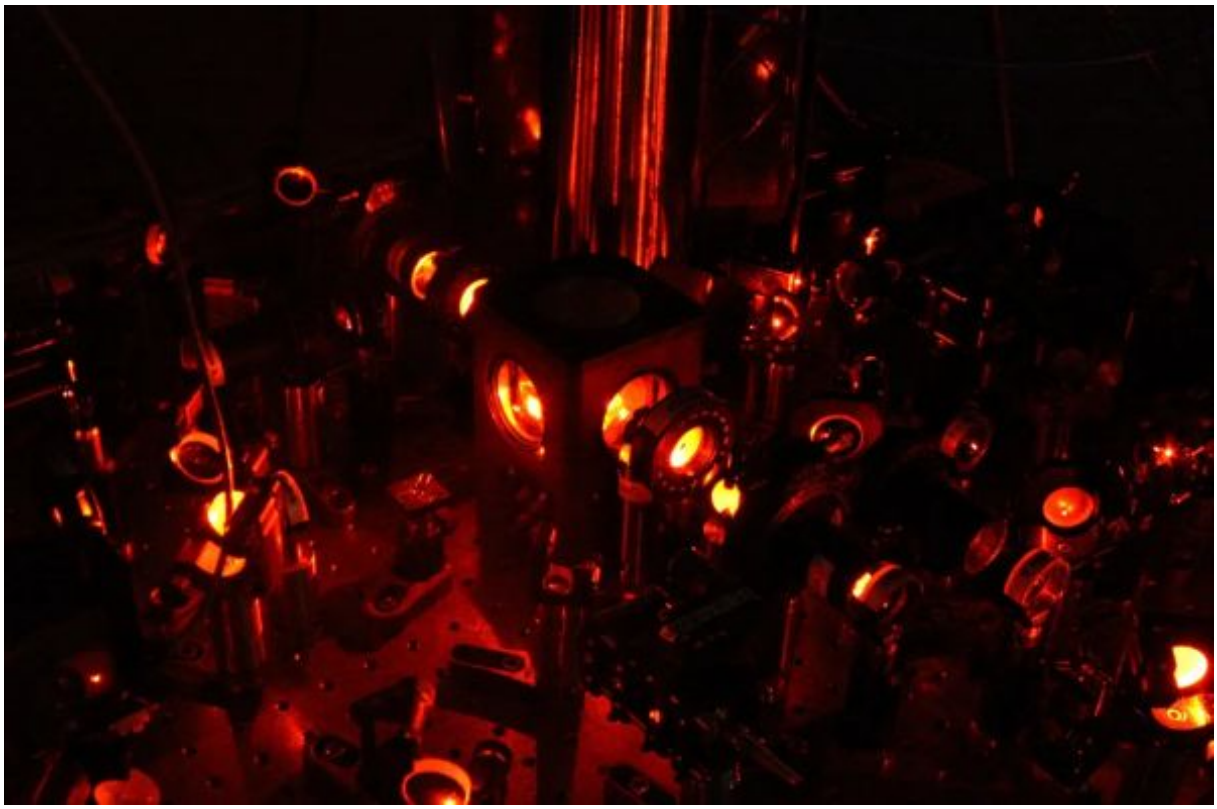


Interconnecting quantum memories for the quantum internet

Quantum entanglement is not only one of the most fascinating features of quantum mechanics but also the cornerstone of many exciting future applications such as interconnecting distant quantum computers or sensors, and ensuring ultra-secure communications. Researchers at ICFO have recently achieved a milestone towards the distribution of entanglement over long distances, which could serve as one of the building blocks of a worldwide quantum internet. The results are presented in Physical Review X.

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Entanglement is transmitted by individual particles of light, or photons, traveling through optical channel such as optical fibers, which are subject to inevitable losses. To mitigate this, quantum analogs of classical repeaters that are ubiquitous in optical telecommunications have been proposed several decades ago. Specifically, quantum repeaters aim to extend quantum communication over vast distances by distributing the quantum resource of

entanglement across successive shorter segments with smaller losses, and by storing it in each segment in a device called a quantum memory.

Researchers at ICFO, **Jonathan Hanni, Alberto Rodriguez-Moldes, Dr. Felicien Appas, Dr. Soeren Wengerowsky, Dr. Dario Lago-Rivera, Dr. Markus Teller, Dr. Samuele Grandi**, led by **ICREA Prof. Hugues de Riedmatten** have now **implemented a proof-of-principle entangled link between two on-demand solid-state quantum memories**, a key resource for the realization of **quantum repeaters.**

The entanglement is created by using sources of photon pairs at each node, storing one photon in the quantum memories while the other photon -at telecommunication wavelength- is sent to a central station where it is detected in a way that erases the information about its origin. This detection heralds the presence of entanglement in the quantum memories, which is then stored and retrieved on-demand with adjustable recall times.

This ability to **store and retrieve entanglement on-demand** is a crucial feature for the temporal synchronization of the different sections of a quantum repeater, and represents one of the main achievements of the work, which has been recently published in Physical Review X. The type of memories used by the researchers -a rare-earth doped crystal- allows the distribution of entanglement in a time multiplexed fashion, meaning that multiple time i¿½slotsi¿½ within the same quantum memory can be used to attempt entangle ent generation. This, in turn, increases the entanglement distribution rate, as demonstrated in the stu y. With the current performance of the system, a quantum link of a few kilometers could al eady be implemented. In fact, the researchers expect that further improvements could push this distance to several tens of kilometer, eventually allowing for connecting distant ci ies. According to Dr. Felicien Appas, one of the first co-authors of the study: i¿½These esults establish our architecture as a prime candidate for the implementation of the future uantum internet -something we eagerly look forward to contribute

Reference:

J. Hanni, A. E. Rodriguez-Moldes, F. Appas, S. Wengerowsky, D. Lago-Rivera, M. Teller, S. Grandi, H. de Riedmatten, Heralded entanglement of on-demand spin-wave solid-state quantum memories for multiplexed quantum network links, PRX **15**, 041003 (2025).
DOI: https://doi.org/10.1103/wvv1-6lg8

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