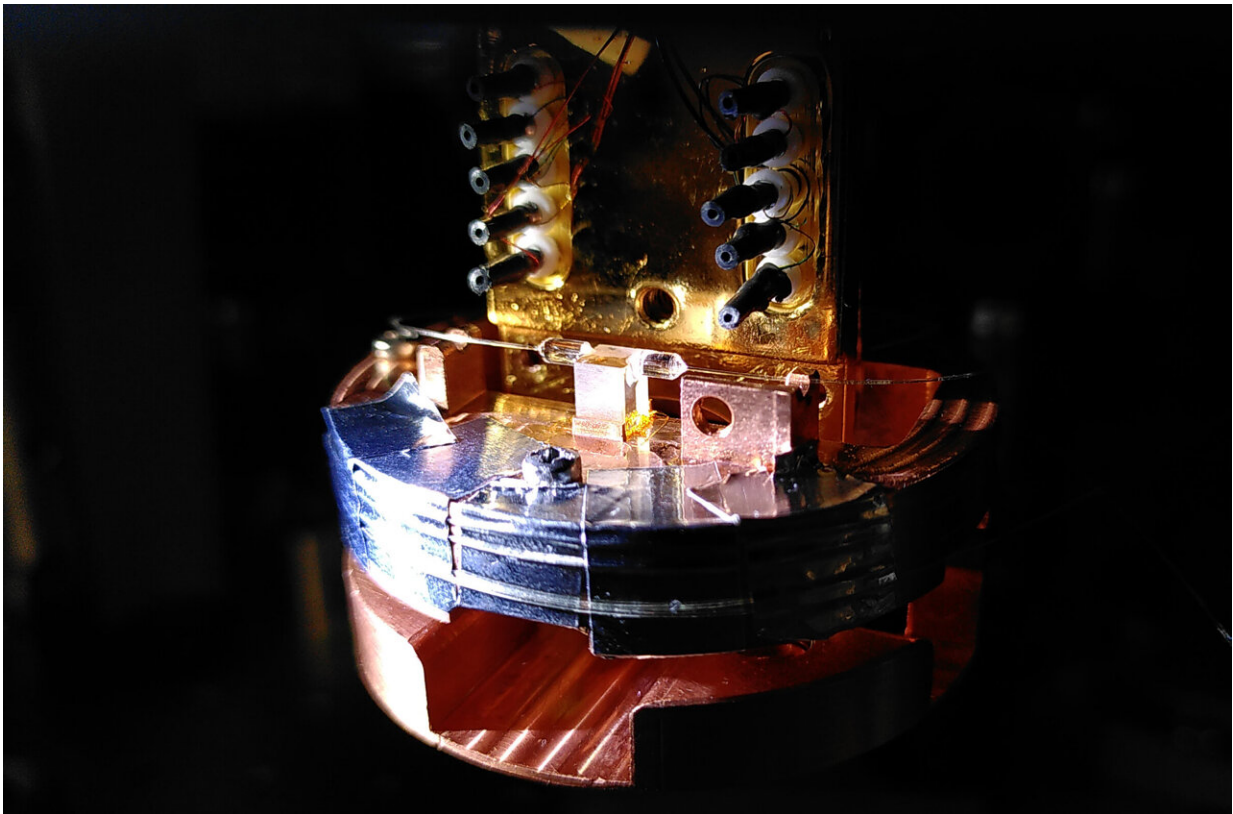


A boost in performance in fiber-integrated quantum memories

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Picture of the quantum memory attached to the optical fiber. Credit: ICFO/ S. Grandi

Quantum memories are one of the building blocks of the future quantum internet. Without them, it would be rather impossible to transmit quantum information over long distances and expand into a real quantum

network. These memories have the mission of receiving the quantum information encoded in a photon in the form of qubits, storing it and then retrieving it. Quantum memories can be realized in different material systems, for example ensembles of cold atoms or doped crystals.

In order to be useful memories, they need to fulfill several requirements, such as the efficiency, duration, and multiplexing of their storage capability, to ensure the quality of the quantum communication that they will support. One other requirement that has become a matter of considerable research is designing [quantum memories](#) that can be directly integrated in the fiber-optic network.

In recent years and with the boom of quantum technologies, there has been a lot of work oriented to improve the scalability of existing quantum memories (make them smaller and/or simpler devices) to facilitate their integration and deployment in a real-work network. Such a fully integrated approach comes with several physical and engineering hurdles, including finding a solution that preserves good coherence properties, providing an efficient and stable system to transfer photons from optical fibers to the quantum memory, as well as the miniaturization of the control system of the quantum memory and its interface with incoming light. All of this should be performed while reaching the same level of performances obtained in "standard" bulk versions of the device. This has so far proved challenging, and current realizations of fiber-integrated quantum memories are far from what can be reached in bulk memories.

With these objectives clear, in a recent work published in *Science Advances*, ICFO researchers Jelena Rakonjac, Dario Lago-Rivera, Alessandro Seri and Samuele Grandi, led by ICREA Prof. at ICFO Hugues de Riedmatten, in collaboration with Giacomo Corrielli and Roberto Osellame from IFN-CNR and Margherita Mazzera from Heriot-

Watt University, have been able to demonstrate entanglement between a fiber-integrated quantum memory and a telecommunications-wavelength photon.

A special quantum memory

In their experiment, the team used a crystal doped with praseodymium as their quantum memory. A waveguide was then laser-written inside the memory. This is a micrometer-scale canal within the crystal which confines and guides the photon in a tight space. Two identical optical fibers were then attached to both sides of the crystal to provide a direct interface between photons carrying [quantum information](#) and the memory. This experimental setup enabled an all fiber connection between the quantum memory and a source of photons.

To prove that this integrated quantum memory can store entanglement, the team used a source of entangled photon pairs where one photon is compatible with the memory, while the other one is at telecom wavelength. With this novel setup, they were able to store photons from 2 μs up to 28 μs and preserve the entanglement of the photon pairs after storage. The result obtained is a major improvement because the entanglement storage time shown by the team is 1,000 times longer (three orders of magnitude) than any other previous fiber-integrated device used until now, approaching the performances observed in bulk quantum memories.

This was possible thanks to the fully integrated nature of the device, which allowed for the use of a more sophisticated control system than previous realizations. Finally, since the entanglement was shared between a visible [photon](#) stored in the quantum memory, and one at telecom wavelengths, the team also proved that the system is entirely compatible with telecommunications infrastructure and suitable for long-distance quantum communication.

The demonstration of this type of integrated quantum memory opens up many new possibilities, particularly regarding multiplexing, scalability and further integration. As Jelena Rakonjac emphasizes, "this experiment has given us great hopes in the sense that we envision that many waveguides can be fabricated in one crystal, which would allow for many photons to be stored simultaneously in a small region and maximize the capability features of the quantum memory. Since the device is already fiber coupled, it can also be more readily interfaced with other fiber-based components."

Hugues de Riedmatten concludes by stating that "we are thrilled with this result which opens many possibilities for fiber integrated memories. What is clear is that this particular material and way of creating waveguides allows us to achieve performances close to bulk memories. In the future, extending the storage to spin states will allow on-demand retrieval of the stored photons and lead to the long storage times that we have been aiming for. This fiber-integrated quantum [memory](#) definitely shows great promise for future use in quantum networks."

More information: Jelena V. Rakonjac et al, Storage and analysis of light-matter entanglement in a fiber-integrated system, *Science Advances* (2022). [DOI: 10.1126/sciadv.abn3919](https://doi.org/10.1126/sciadv.abn3919)

Provided by ICFO

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