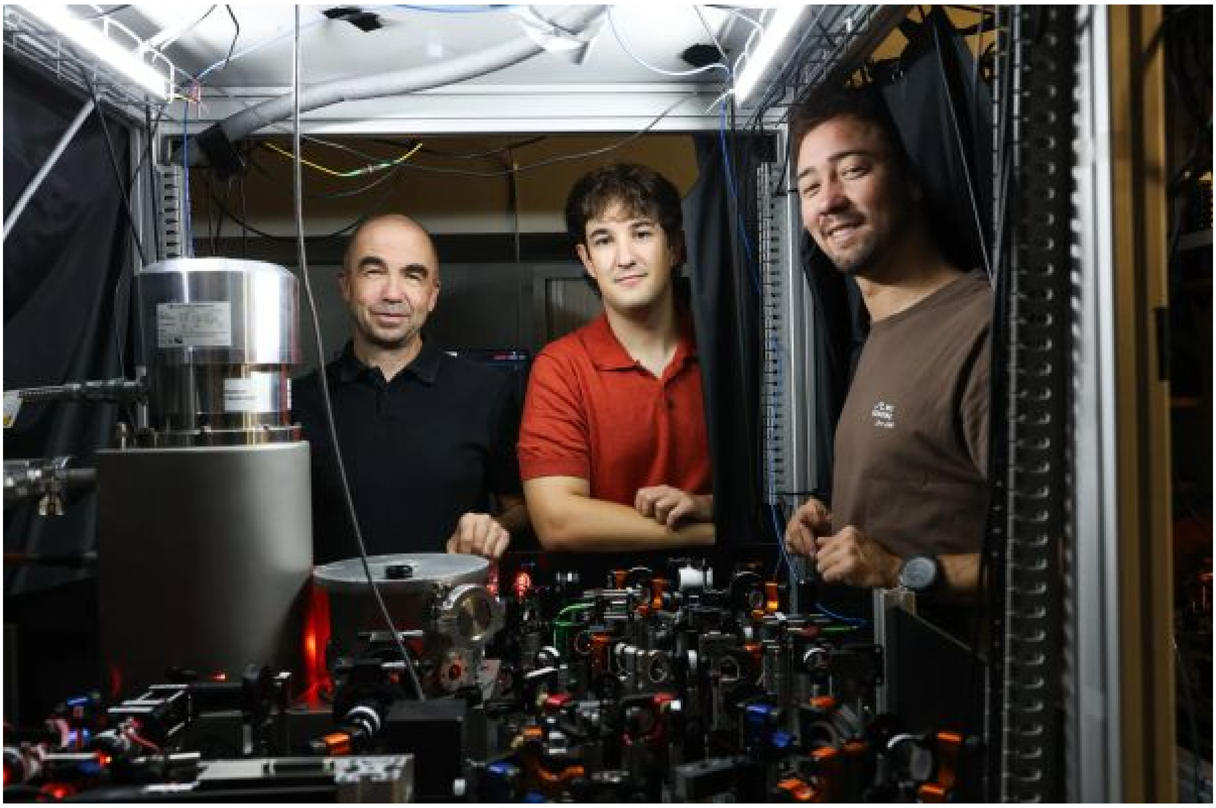

A spin rephased quantum memory for single photons

ICFO researchers have applied a spin rephasing mechanism to store quantum light in a solid-state quantum memory. The work, published in Physical Review Letters, achieves the longest storage time to date for single photons in this kind of memory, marking a significant enabling step towards the quantum internet.

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We are continuously sending information to each other, transmitting zeros and ones through a giant network of connected computers and devices. Scientists are now trying to extend this familiar concept of the internet to the quantum realm, looking for an efficient way to exchange quantum rather than classical information, qubits instead of bits. The motivation behind this is not just genuine scientific curiosity. Qubits open new possibilities for processing information, as they can be either a 0, a 1, or any superposition of the two. They can also become entangled, showing a degree of correlation that is simply out of reach for classical bits.

A key element in enabling the quantum internet is the quantum repeater, an architecture aimed at distributing entanglement over long distances. Quantum repeaters, in turn, require quantum memories that can hold a quantum state for a long period of time, long enough to synchronize measurements across different network segments and successfully establish entanglement.

ICFO researchers **Alberto Rodriguez Moldes**, **Dr. Felicien Appas**, **Jonathan Hanni**, **Dr. Jelena Rakonjac**, and **Dr. Samuele Grandi**, led by **ICREA Prof. Hugues de Riedmatten**, have now taken a significant step in this direction. By implementing the so-called **spin rephasing protocol**, they have demonstrated that **solid-state quantum memories** -promising candidates for building quantum networks due to their already proven high efficiency, capacity to store entanglement, and multiplexing features- **can store single photons for longer times than previously possible**. These results, published in Physical Review Letters and obtained within the Quantum Internet Alliance (QIA), bring us closer to the quantum internet.

Dephasing, the main obstacle when storing photons

In the reported experiment, the team first generated a pair of entangled photons. One had a telecom wavelength, compatible with the optical fiber for long-distance distribution; the other was compatible with the quantum memory, a crystal doped with praseodymium ions and cooled to 3 kelvin in a cryostat. There, the well-established Atomic Frequency Comb (AFC) protocol took place.

In AFC, the atoms in the crystal collectively absorb the incoming photon and one of them is excited to a higher energy level, creating an atomic excitation delocalized between all atoms. Before they can naturally re-emit the photon, an optical control pulse transfers the collectiv excitation into the spin state, a level that does not emit light, effectively pausing the emissio and storing the photon. A second control pulse later returns the ensemble to the excite state, triggering the emission of a photon carrying the same information as the original The problem is that, in practice, the collective excitation cannot remain in the spin stat indefinitely. Because the crystal environment is slightly different for each ion, the initia superposition dephases, losing its coherence. If the storage time is too long, the quantu properties of the emitted photon are degraded and information gets lost along the way

Spin rephasing protocol for storing quantum-correlated single photons

This is where spin rephasing, a mechanism that counteracts such decoherence effects, comes into play. It consists of sending a series of radiofrequency pulses that flip the phase each ion has accumulated after a certain amount of time. Then, one just has to wait for the same period, so that the newly accumulated phase compensates the one that was flipped, effectively restoring the collective spin excitation.

The team thus sent multiple radiofrequency pulses to precisely control when this ï¿½flippingï¿½ and ï¿½waitingï¿½ would actually rephase the collective excitation.

At that point, they sent the second control pulse and performed the readout of the quantum memory. ICFO researchers thus managed to store single photons up to **180 microseconds** (**the longest time reported for this kind of memory**), which corresponds to an equivalent fiber-link distance of over **30 km**. ï¿½In the future, longer storage times will be available y applying small magnetic fields to the quantum memory,ï¿½ says Alberto Rodriguez Mol es, first author of the arti le. Importantly, the researchers performed the experiment using quantum light, and demonstrated that **quantum correlations were present** between the spin-rephased quantum memory and the telecom photon. ï¿½Spin rephasing had been demonstrated in the past wi h classical input states, but our results show that it can be extended to quantum light,i ?½ explains ICREA Prof. Hugues de Riedmatten, senior researcher of the study. ï¿½**Our scheme thus establishes praseodymium-doped quantum memories as a major candidate for the scalable implementation of quantum networks.**ï¿

Reference:

Rodriguez-Moldes, A. E., et. al., Long-lived telecom-heralded single-photon storage in an absorptive spin-rephased quantum memory, Phys. Rev. Lett. (2026)
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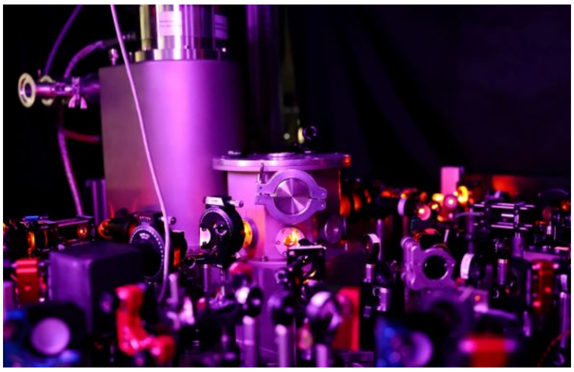
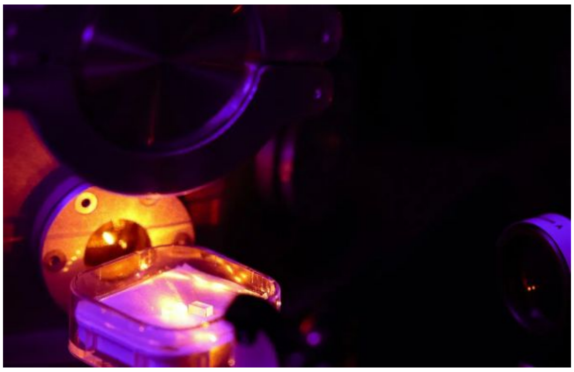


Image of the experimental set-up. Credit: ICFO.



Close-up of the quantum memories. Credit: ICFO.