

Quantum network nodes and quantum repeaters: from experiments to technology

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Abstract: We report on new experimental efforts in Florence toward a telecom-compatible quantum repeater node with ytterbium atoms, and on ARQ Quantum Technologies, a Barcelona-based startup building quantum repeater hardware for a continental-scale quantum internet.

The realization of a large-scale quantum internet — a global network of quantum devices interconnected via light — remains one of the central long-term goals of quantum science. Such a network would enable distributed quantum computation, high-precision clock synchronization, and fundamentally secure long-distance communication. At its core, this vision relies on quantum repeaters: nodes that can reliably store, process, and distribute entanglement over long distances, overcoming the photon losses inherent to optical fibers.

In this talk, I will give a brief overview of the quantum internet landscape and the main architectural approaches. I will then focus on a particularly powerful platform: single neutral atoms coupled to high-finesse optical cavities, which offer a near-deterministic light-matter quantum interface. I will describe two key milestones achieved with this platform: the realization of a rudimentary quantum network link via cavity-mediated quantum logic gates between distant nodes [1], and the demonstration of a highly efficient, multiplexed quantum memory node based on a reconfigurable array of atoms assembled with optical tweezers inside an optical cavity [2,3]. The latter achieved atom-photon entanglement with a source-to-detection efficiency of $\sim 90\%$, a critical step toward practical entanglement distribution.

Building on this foundation, I will present a new experimental platform under development at LENS (Florence), designed to push toward a deployable quantum repeater node. The platform traps single ^{171}Yb atoms in optical tweezers and couples them to a high-finesse optical cavity. Ytterbium offers a unique combination of advantages: a telecom-compatible transition at 1389 nm (requiring no frequency conversion) and an ultra-narrow clock transition ($^3\text{P}_0$, < 1 Hz linewidth), whose nuclear spin ($I = 1/2$) serves as a highly coherent qubit with long coherence times and insensitivity to magnetic fluctuations. By combining cavity-stimulated photon emission with resolved-sideband control enabled by the clock transition, we aim to interface long-lived atomic spin qubits with narrowband telecom photons.

Finally, I will present ARQ Quantum Technologies, a Barcelona-based deep-tech startup spinning out of the group of Hugues de Riedmatten at ICFO, which I co-founded together with Samuele Grandi. ARQ's goal is to translate this class of quantum hardware into commercial repeater infrastructure. The core technology combines solid-state quantum memories based on rare-earth-doped crystals (Praseodymium and Ytterbium) with SPDC-based entanglement sources, and features native multidimensional multiplexing — temporal, spatial, and spectral — making it, to our knowledge, the only telecom-compatible multiplexed quantum repeater hardware with a demonstrated proof of concept [4]. Supported by the Quantum Internet Alliance (QIA) and in collaboration with research institutions and private partners, ARQ aims to realize quantum network testbeds, enabling entanglement distribution across city, national, and continental distances.

References

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