

Rare-Earth based quantum memory

A system able to store several quantum states, with the ability to absorb and retrieve a given state on demand, is dubbed a Random-Access Quantum Memory [1]. Such devices are critical for applications such as quantum repeaters, parallel quantum processing, and high-precision measurements. While various platforms —such as atomic ensembles, superconducting circuits, and mechanical oscillators—have demonstrated quantum memory capabilities, they often face trade-offs between coherence time, capacity, and coupling strength.

Ensembles of electron spins for microwave quantum state storage combines three advantages. 1) They can offer storage times longer by two orders of magnitude compared to superconducting qubits [2]. 2) They have a small footprint, and are compatible with superconducting qubits. 3) Protocols exist for storing multiple states into the same device, and can be used to reduce the number of required qubits for quantum algorithm [3]. However, current spin ensemble memories suffer from low storage efficiency (<10%) due to a fundamental trade-off: high spin concentration enhances coupling to microwave circuits but reduces coherence.

To overcome this, we propose exploring a novel spin system—ytterbium atoms embedded in CaWO_4 —which maintains state-of-the-art coherence at much higher concentrations than previously studied systems [4]. Additionally, this system can operate at zero magnetic field, making it highly compatible with superconducting qubits. This compatibility opens the door to on-chip integration of spin ensembles and superconducting qubits, similar to early proof-of-concept demonstrations [5].

The project will center around two milestones. We will first test a new deposition technique to strengthen the spin-resonator coupling, and benchmark the storage of classical and then quantum fields inside the spin ensemble.

The PhD project will take place in collaboration with a team in ChimieTech synthesizing the CaWO_4 crystals, and PStash, a nascent start-up company based in Paris. The PhD will be funded through a CIFRE fellowship, and will be realized in Lyon at the beginning with an option to join the experimental effort in Paris at a later stage.

[1] H. J. Kimble, Nature 2008 ; D. Thaker et al., ISCA 2006 ; Zaiser et al., Nature Comm 2016
[2] G. Wolfowicz et al., Nature nano (2013).

[3] V. Damon et al., New J. Phys. 13 (2011).
[4] A. Tiranov, arXiv:2504.01592
[5] Kubo et al., PRL 2011