

PhD Thesis Defense: Quantum memories based on rare-earth doped solids: from spatial multiplexing to new materials

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November 16, 2026

10:00

ICFO Auditorium

Quantum repeaters play a fundamental role in the development of long-distance quantum network. In most architectures, their functional core is constituted by quantum memories. Although many systems have been investigated as potential quantum memory, no single platform yet satisfies all the requirements simultaneously. Solid-state systems, particularly cryogenically cooled rare-earth doped crystals represent one of the most promising routes toward efficient, long-lived and massively multiplexed quantum memories, with great prospects for integration. This thesis addresses two main objectives. The first is to extend the spatial multimode capacity of a rare-earth-doped quantum memory using a

praseodymium-doped yttrium orthosilicate Pr^{3+}:Y_2SiO_5 to increase the entanglement generation rate required for realistic quantum repeater application. The second objective, carried out in collaboration with Corning, investigates the spectroscopic properties of? erbium-doped-chalcogenides to assess their suitability as fiber-integrated quantum memor operating at the telecom wavelength

To achieve spatial multiplexing in the Pr^{3+}:Y$_2SiO_5 crystal, we implement a quantu memory array (QMA) using a pair of acousto-optic deflectors, creating ten individuall controllable spin-wave memory cell featuring on-demand read-out. By combing the spatia multiplexing of the array with the intrinsic temporal multimodality of the atomic frequenc comb (AFC) protocol, we store and retrieve on-demand up to 250 modes using wea coherent pulses at the single-photon level, both surpassing the current state-of-the-art fo solid-state quantum memory. The high signal-to-noise ratio and low cross-talks enable th storage of heralded single-photons. To do so, we use a cavity enhanced spontaneou parametric down conversion source to generate a pair of photons, with the signal photo stored in the QMA and the idler at telecommunication wavelength. We demonstrate th violation of the Cauchy-Schwarz inequality by at least 4.8 standard deviations in all t e memory cells, demonstrating light-matter quantum correlations between the QMA and t e telecom photo

. We further demonstrate the potential use of our system as a random access quant m memory (RAQM) by storing path and time-bin qubits encoded with weak coherent states n the quantum memory array, achieving average fidelities of 95 ± 2% and 91 ± 2%, respectiv ly. We further load sequentially a time-bin qubit in two different memory cells, simultaneo sly store both qubits, and perform a collective read-out. The high fidelities together ith independent control pair represent a significant step toward a solid-state RAQM for qua tum repeaters and photonic quantum process

rs. For the fiber-compatible quantum memory, we study three Er-doped chalcogenide gla ses with a different glass network rigidities quantified by the coordination mean number (M N). We measure their optical coherence time (T_2) through two-pulse photon echo (PE) technique and find that the sample with MCN < 2.4 exhibits the shortest T_2, while the most rigid sample (MNC = 2.9) suffers from internal stress that also limits the coherence time The intermediate rigidity sample (MNC = 2.69) shows a T_2 close to 1 ?s (corresponding to a homegeneous linewidth ? 370 kHz) at 2 K and 0.2 T, which is among the longest co erence times reported for Er-doped glasses under practical cryogenic conditions, reachable with a standard close-cycle cryostat. However, the spectral hole burning measurements reve l hole widths around 50 MHz for two best TPE performing samples, severely restrict ng the achievable comb finesse and therefore constraining the AFC efficiency in these mat

Monday November 16, 10:00 h. ICFO Auditorium

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