Purcell enhancement of single-photon emitters in silicon

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The integration of optically coupled spin qubits into nanophotonic silicon resonators offers unique promise for distributed quantum information processing with devices that can be fabricated at scale. Erbium ions are particularly attractive emitters as their transitions fall within the main band of optical communication, where loss in optical fibers is minimal. In addition, they can exhibit narrow inhomogeneous linewidth and long optical coherence at a temperature of 4 K in nanophotonic waveguides [1]. By integrating Erbium into a photonic nanobeam cavity with a quality factor of ~10^5, we achieve spin-resolved excitation of individual emitters with < 0.1 GHz spectral diffusion linewidth. Upon resonant driving, we observe optical Rabi oscillations and single-photon emission with a 78-fold Purcell enhancement. Our results thus establish a promising new platform for quantum networks.

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Emergence of highly coherent quantum subsystems of a noisy and dense spin system

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Quantum sensors and qubits are usually two-level systems (TLS), quantum analogs of classical bits assuming binary values ‘0' or ‘1'. They are useful to the extent to which superpositions of ‘0' and ‘1’ persist despite a noisy environment. The standard prescription for long persistence (‘decoherence times') of solid-state qubits is their isolation via extreme (≲ppm) dilution in ultra-pure materials. We experimentally demonstrate a different strategy using the rare-earth insulator $LiY_{1-x}Tb_xF_4$ (x=0.001) which realizes a dense random network of TLS. Some TLS belong to strongly interacting Tb^{3+} pairs whose quantum states, thanks to localization effects, form highly coherent qubits with 100-fold longer coherence times than single ions. Our understanding of the underlying decoherence mechanisms - and of their suppression - suggests that coherence in networks of dipolar coupled TLS can be enhanced rather than reduced by the interactions.

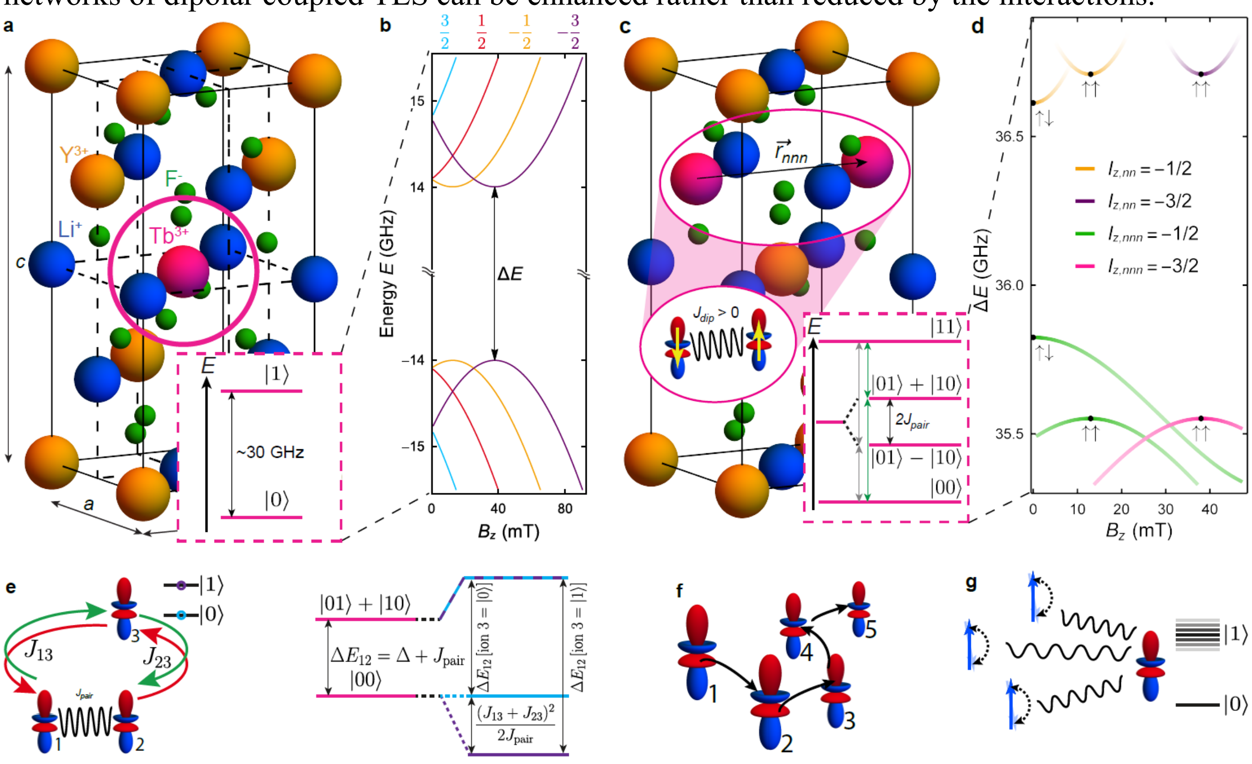

Figure 1:Clock states and decoherence mechanisms of single Tb^{3+} ions and pairs in $LiY_{1-x}Tb_xF_4$.

Addressing the electronic spin ensemble via propagating microwaves in broadband regime

Nadezhda Kukharchyk[1,2,3]

Group members with poster presentations: Georg Mair[2,1] and Ana Strinic[1,2,3]

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The rare earth ions are well-known for their long-living coherent spin states with transition frequencies in the microwave range. This frequency range is directly compatible with the superconducting quantum circuits, which nowadays represent the most promising technology for realization of quantum computers. Beyond the quantum computers, however, the quantum microwaves are very promising for short distance quantum communication, classical analogy are WiFi and 5G/6G. With rare-earth spin ensembles, we aim for development of the quantum memory directly compatible with superconducting circuits and propagating microwave signals within united cryogenic environment with minimized microwave losses. Towards this goal, we work on the both, improvement of the coupling of spin ensembles to superconducting circuits and enhancement of the cryogenic setup arrangement. In this talk, I will give the overview of our effort for realization of this aspirational aims, with more technical details presented in the posters of the group members. As well, an outline of our recent project on microwave quantum tokens will be given.

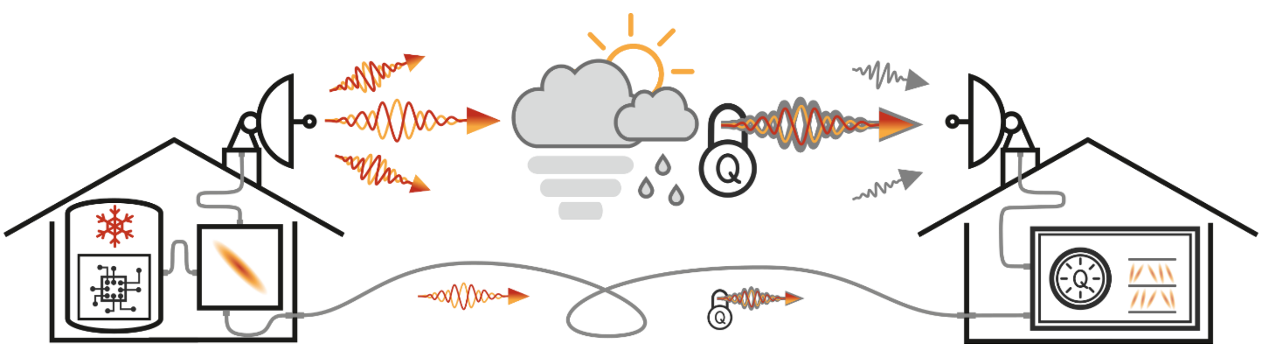

Figure 1. Concept image of near-range quantum microwave communication via free space for thermal-noise robust and weather independent quantum microwaves.

Spectroscopy and cavity-enhanced emission of Europium-based solid-state and molecular systems

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Europium-doped materials are attractive for the realization of quantum registers given their long coherence together with electric dipole interactions that enable quantum gates. However, Eu^{3+} has a long optical lifetime (T_1 ~ms) and a low branching ratio (<1%), limiting single-ion experiments. Both issues can be solved by high-finesse fiber-based microcavities.

We report on cavity-enhanced emission of Eu^{3+} ions in Y_2O_3 nanoparticles at 5 K. We observe fluorescence signals from small ion ensembles and measure a lifetime shortening to half the free-space lifetime, revealing effective Purcell-factors of one and emission enhancement by ~ 100-fold. We observe narrow spectral features that we interpret as first signs of single-ion-level signals.

Furthermore, we study Eu-doped molecular crystal powders, including a Trensal complex that yields 7 min spin lifetime and a homogeneous linewidth of 2.8 MHz at 4.2 K [1]. On a single, macroscopic molecular crystal [Eu(Ba)4(pip)] [see 2], we measure narrow inhomogeneous linewidths, hour-long spin T_1, and photon echoes at < 1K. Steps to integrate molecular crystals into a fiber cavity are reported. The results are important steps towards single ion readout and control necessary for scalable quantum registers.

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[2] Serrano et al., Nature 603 241 (2022)

Frequency tunable, cavity-enhanced single erbium quantum emitter in the telecom band

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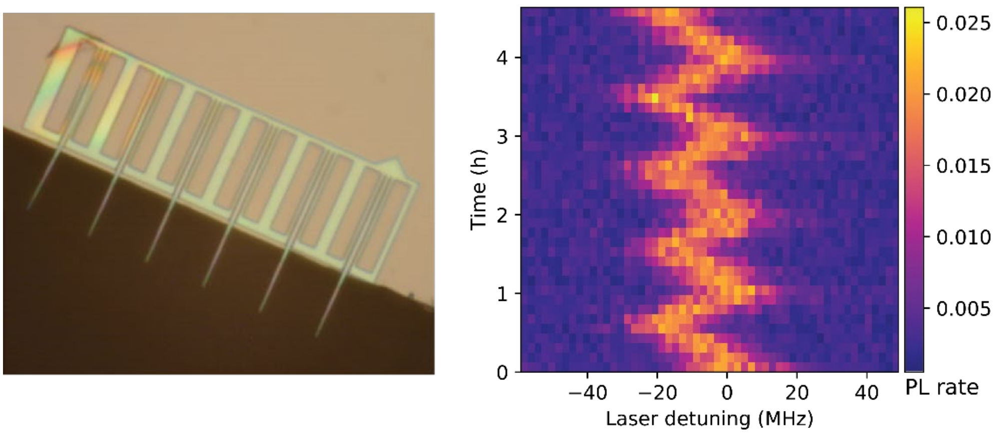
Single solid-state quantum emitters are attractive for quantum information processing and quantum networking. Among various candidates, Er^{3+} ions are appealing due to their telecom C band emission and their long spin coherence times. However, the long lifetimes of their excited state and inhomogeneous broadening of the emission present challenges in networking. Achieving multi-photon interference is difficult due to low photon emission rates and distinct spectra of different emitters. Here we solve this challenge by demonstrating for the first time the linear Stark tuning of the emission frequency of a single Er^{3+} ion. We enhance the ion embedded in a lithium niobate up to 143 increases in decay rate by evanescently coupling it to a silicon nano-photonic cavity. By applying an electric field, we achieve a Stark tuning greater than the ion's linewidth without altering its single-photon emission statistics. Our results are a key step towards rare earth ion-based quantum networks.



(Left) Silicon nanocavities on the Er:LiNbO3. (Right) Stark tuning of a single Er ion.

Tailoring inhomogeneous profiles for fast light propagation

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Fast light in dispersive materials was described more than hundred years ago. The counter-intuitive result that a pulse of light can propagate faster than the speed of light in vacuum and that the peak of such a pulse can exit the material some time, τ_{adv}, before it enters the material has sparked interest and discussions since it was first described. Various methods have been used to date to generate fast light. However, many of these suffer from very strong attenuation [1], [2] or heavy distortion [3]. It has been suggested that one could achieve fast light without suffering from absorption or distortion in the vicinity of a gain doublet [4]. In the early 2000s, Wang et al. [5] showed that for a pulse with a full width at half maximum, T_{FWHM}, this was indeed possible using a Raman pumped system achieving a relative shift $\tau_{adv}/T_{FWHM} = 1.5\%$ with respect to the pulse width T_{FWHM}. Rare earth crystals are convenient materials for fast light propagation using the inhomogeneous profile, extremely narrow homogeneous linewidth and long hyperfine life times, *e.g.* [6]. Here we demonstrate an approach to achieve a relative advancement $\tau_{adv}/T_{FWHM} > 10\%$, while maintaining both the pulse shape and pulse energy.

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Progress towards high-performance Pr-based quantum memories

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The realization of quantum repeaters is a long-standing goal of the field of quantum communications aimed at the distribution of entangled states over long distances using entanglement sources and quantum memories (QM). In this talk, we report on recent progress on single photon level storage with solid-state Pr^{3+}:YSO QM using the atomic frequency comb (AFC) protocol. In particular we will focus on current efforts towards high efficiency and long storage times, two essential requirements for quantum repeaters.

In the first part, we present results on the implementation of a dynamical decoupling (DD) technique allowing for long-lived storage in the hyperfine ground state of Pr^{3+}:YSO. In the classical regime, bright pulses of light can be stored for up to 6 ms. We then demonstrate storage at the single photon level using weak coherent pulses tailored to match the temporal waveforms of single photons produced by a in-house cavity-enhanced SPDC source. At a storage time of 130 us, we achieve a SNR as high as 12.2 for a mean photon number of 0.64 photon/pulse, leading to $\mu 1$=0.055 (see Figure 1). We also measured storage times of up to 300 us for pulses containing 1 photons on average, the longest storage time achieved so far at the few photon level in a multimode Pr^{3+}:YSO QM.

The second part of the talk is dedicated to the first demonstration of cavity-enhanced on-demand AFC memories at the single photon level. In this experiment, the Pr^{3+}:YSO crystal is placed in a cavity of finesse 6, which was built outside of the vacuum chamber. With a mean input photon number of 0.5 photons/pulse, we reach a device efficiency of about 30% at a signal-to-noise ratio over 10. The transfer pulse efficiency is around 90%. Figure 2 shows a histogram of photon arrival times to compare the input pulse, reflected from the first cavity mirror, scaled to 100%, with the spin-wave AFC echo after 13.5 µs storage time.

The current level of performance of these two experiments should enable the storage of genuine single photons on the short term. Together, these results represent a promising avenue for the realization of metropolitan-scale quantum repeater links with SPDC sources and multimode solid-state QM.

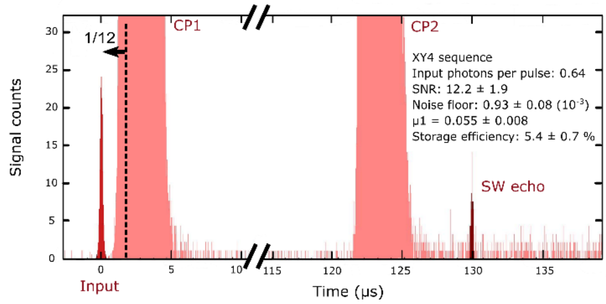

Figure 1 Time-correlation histogram for the spin-wave storage of a weak coherent state using an XY4 DD sequence.

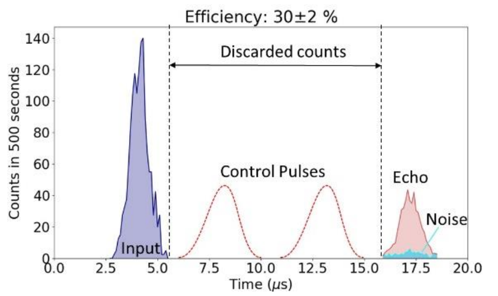

Figure 2 Time-correlation histogram for the spin-wave storage of a weak coherent state in a cavity-enhanced AFC memory.

Dynamical decoupling techniques for long-lived single-photon level storage in Pr-based quantum memories

Félicien Appas, Alberto Rodriguez-Moldes Sebastián, Jelena Rakonjac, Samuele Grandi, Hugues de Riedmatten

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Abstract: The realization of quantum repeaters is a long-standing goal of the field of quantum communications, allowing the distribution of entangled states over long distance using entanglement sources and quantum memories (QM). In this talk, we report on recent progress on long-lived single-photon-level storage in a multimode Pr^{3+}:YSO solid-state quantum memory. We implement a dynamical decoupling (DD) technique that allows us to store bright pulses of light in the hyperfine ground state of Pr^{3+}:YSO using the atomic frequency comb (AFC) protocol for up to 6 ms. We then demonstrate storage at the single photon level using weak coherent pulses tailored to match the temporal waveforms of single photons produced in our lab by cavity-enhanced SPDC source. In this configuration, first measurements show SNR as high 7 for a mean photon number of 1 photon/pulse for 97 us, leading to μ1=0.14 (see Figure 1). We also measured storage time of up to 300 us for pulses containing 10 photons on average, the longest storage time achieved so far at the few photon level in a multimode Pr^{3+}:YSO QM. The current noise level is as low as 2.4e-3 photons/pulse, a promising value for the storage of non-classical light. This value can be further reduced by optimization of the DD pulse sequence and memory preparation. Measurements are ongoing and we will present the latest progress towards the storage of genuine single photons. Together, these results represent a promising avenue for the realization of metropolitan-scale quantum repeater links with SPDC sources and multimode solid-state QM.

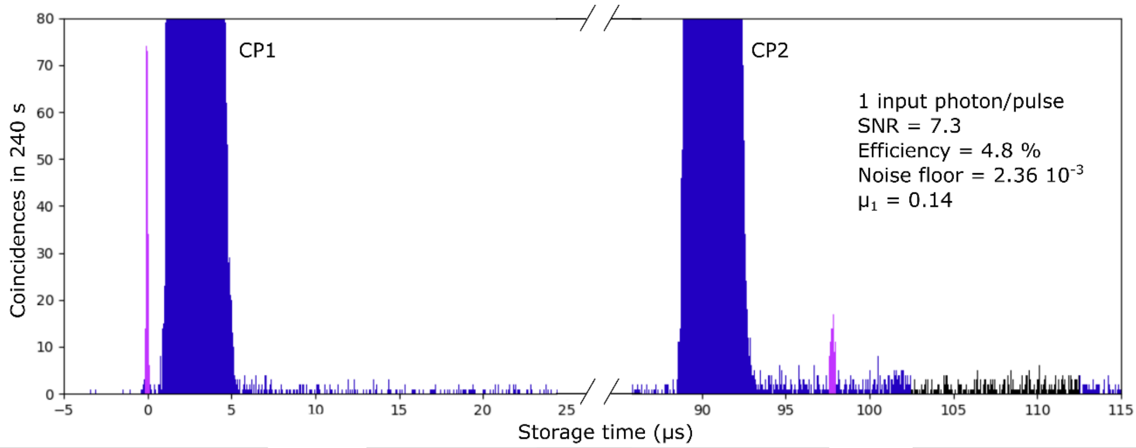

Fig 1- Time histogram of the spin-wave storage of a weak coherent pulse using an XY4 RF sequence. The input pulse transmitted by the AFC is visible at 0 us, while the spin wave echo is visible 97.5 us. CP : Control piulses

Distributed quantum computing over 7 km

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Distributed quantum computing provides a viable approach towards scalable quantum computation However, it has only been realized within single nodes or between nodes separated by a few tens of meters. Here, we demonstrate distributed quantum computing between two nodes separated by 7 km, based on stationary qubits combined with long-lived and multiplexed quantum memories, flying qubits at telecom wavelengths, and active feedforward control based on field-deployed fiber channels. This result lays the foundation for the construction of large-scale quantum computing networks relying on commercial fiber channels.

Site Engineering for Single Erbium Ions in Calcium Fluoride

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Single erbium ions in crystals are compelling candidates for high performance quantum light-matter interfaces [1-7]. A critical part of each demonstration is enhancing the emission rate of single ions by manipulating the local photonic density of states using optical resonators with high quality factors and low mode volume [8,9].

A complementary strategy to achieve high Purcell enhancement is engineering the Crystal Field interaction to increase the optical dipole moment. Towards this goal, we have modified the nanoscopic crystalline environment of erbium in calcium fluoride, modelled its Crystal Field Hamiltonian, and performed an initial experimental characterisation. I will report on the properties of erbium-oxygen complexes including lifetime, linewidths, and dipole moment from these ensemble measurements, and our progress on coupling these sites to high quality factor whispering gallery mode resonators.

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Creation and storage of non-classically correlated light fields in an erbium-based quantum memory

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Department of Quantum Science and Technology,
Research School of Physics,
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Rephased Amplified Spontaneous Emission (RASE) is an atomic ensemble based memory protocol that generates entangled light states. In RASE, an excited population is used to amplify the vacuum state, creating an entanglement between the amplified vacuum state and the atomic ensemble. The entanglement stored on the atomic ensemble is retrieved programmatically as a second light field, resulting in a two-mode squeezed state.

I will present our work on the implementation and characterisation of RASE utilising erbium-doped yttrium orthosilicate ($^{167}Er{:}Y_2SiO_5$) as the solid-state host. Our results demonstrate entanglement between the amplified spontaneous emission (ASE) and RASE fields with a inseparability violation of 3.7σ below the classical boundary. Additionally, we have demonstrated a write time of 150.6μs, storage of 27 temporal modes, spin storage time of 24.5μs, peak RASE recall efficiency of 74%, and a record solid-state memory efficiency of 80% using an inverted four level echo.

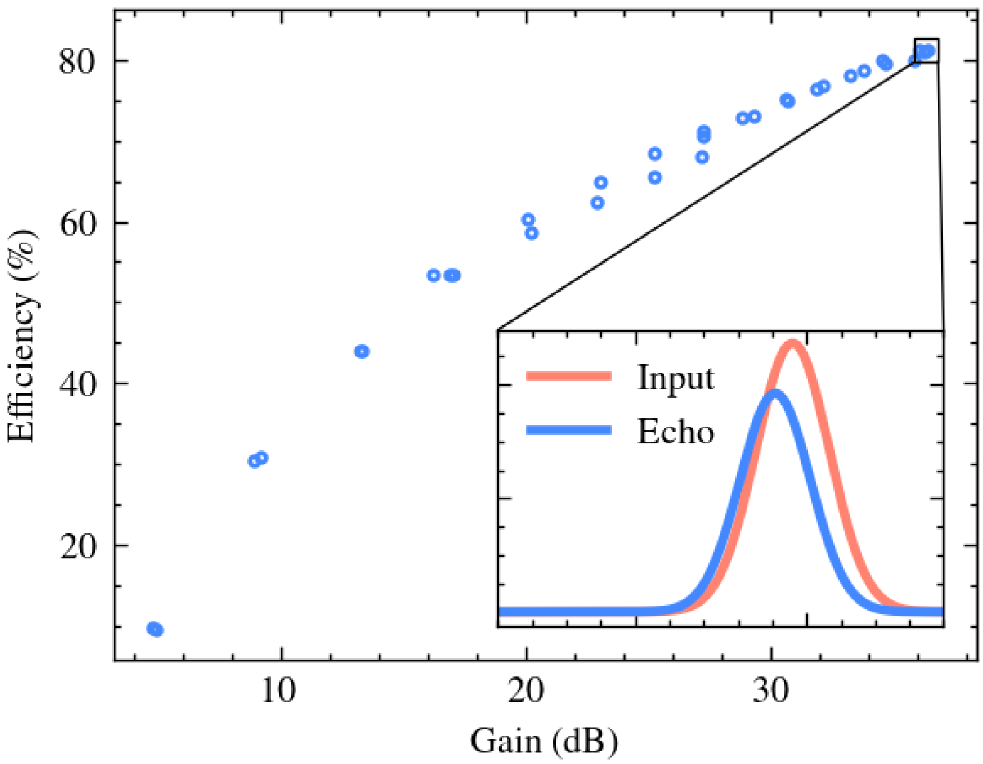

Figure 1: Inverted four level echo gain dependent recall efficiency with a 24μs delay. (Insert) Single shot input and echo power spectrum at maximum gain.

Title: Indistinguishable telecom band photons from a single erbium ion in the solid state

Authors: Mehmet T. Uysal*, Salim Ourari*, Łukasz Dusanowski*, Sebastian P. Horvath*, Christopher M. Phenicie, Paul Stevenson, Mouktik Raha, Songtao Chen, Robert J. Cava, Nathalie P. de Leon, Jeff D. Thompson

Affiliation: Princeton University

Abstract: Atomic defects in the solid state are a key component of quantum repeater networks for long-distance quantum communication. Recently, there has been significant interest in REIs, in particular Er^{3+} for its telecom-band optical transition. However, the development of repeater nodes based on REIs has been hampered by optical spectral diffusion. Here, we implant Er^{3+} into $CaWO_4$, a material that combines a non-polar site symmetry, low decoherence from nuclear spins, and is free of background REIs, to realize significantly reduced spectral diffusion for ions coupled to nanophotonic cavities. This enables the observation of Hong-Ou-Mandel interference with a visibility of 80(4)%, measured after a 36 km delay line. We also observe spin relaxation times $T_1 = 3.7$ s and $T_2 > 200$ µs, with the latter limited by paramagnetic impurities in the crystal instead of nuclear spins. This represents a significant step towards the construction of telecom-band quantum repeater networks with single Er^{3+} ions.

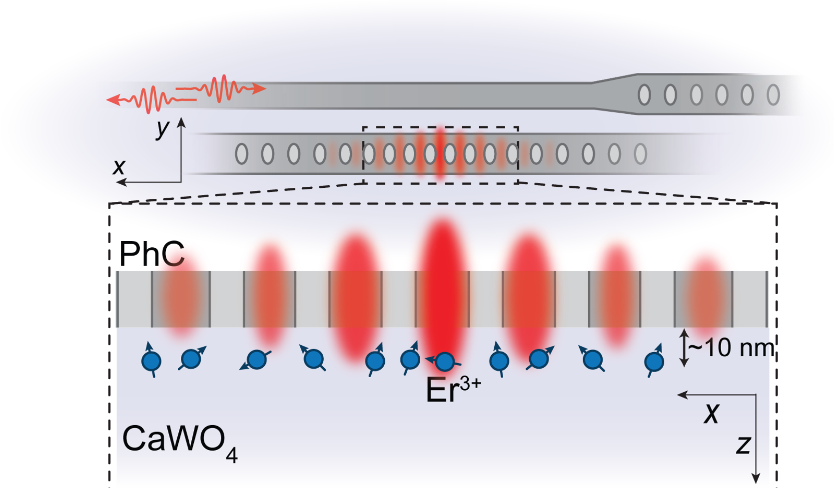

Figure 1: Sketch of implanted Erbium ions in $CaWO_4$ coupled to a nanophotonic cavity.

Optical coherence and spin population dynamics in $^{171}Yb^{3+}:Y_2SiO_5$ single crystals

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Department of Applied Physics, University of Geneva, Geneva 4, Switzerland

$^{171}Yb:Y_2SiO_5$ (YSO) crystals are a promising platform for optical quantum memories in long-distance quantum communications. The relevance of this material lies in ^{171}Yb long optical and spin coherence times, along with a large hyperfine splitting, enabling long quantum storage over broad bandwidths. Mechanisms affecting the optical decoherence are however not precisely known, especially since low-temperature measurements have so far focused on the 2 to 4 K range. In this work, we report on two- and three-pulse photon echoes and spectral hole burning (SHB) to determine optical homogeneous linewidths in two ^{171}Yb:YSO crystals doped at 2 and 10 ppm. Experiments were performed in the 40 mK to 18 K temperature range, leading to values between 320 Hz - among the narrowest reported for rare-earth ions - and several MHz. Our results show in particular that the direct effect of spin and excited state lifetime is a minor contribution to optical decoherence in the whole temperature range studied.

Strain-mediated ion-ion interaction in rare-earth-doped solids

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It was recently shown that the optical excitation of rare-earth ions produces a local change of the host matrix shape, attributed to a change of the rare-earth ion's electronic orbital geometry [1]. In this work we investigate the consequences of this piezo-orbital backaction and show how it leads to a specific ion-ion interaction mediated by mechanical strain. This interaction, intimately connected to the piezospectroscopic effect, scales as $1/r^3$, similarly to the other archetypal ion-ion interactions, namely electric and magnetic dipole-dipole interactions.

We quantitatively assess and compare the magnitude of these three interactions from the angle of the instantaneous spectral diffusion mechanism, and reexamine the scientific literature in a range of rare-earth doped systems in the light of this generally underestimated contribution [2].

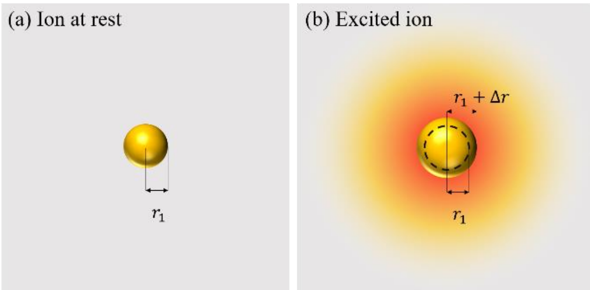

Figure : Simplified view of the piezo-orbital backaction around a spherical rare-earth ion. The excitation-induced stress field, symbolized by a radial color gradient around the ion, perturbs the surrounding ions via the piezospectroscopic effect.

References

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Title: Decoherence Protection of Nuclear-spin Ensembles in $^{171}Yb:YVO_4$

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Nuclear spins are ubiquitous and useful resources in solid-state technologies. The vanadium (V) nuclear spin ensemble surrounding single ^{171}Yb ions in YVO_4 comprises a confined, isolated many-body central spin system with deterministic positioning and interactions. In this talk, I will highlight how the unique aspects of this platform can be leveraged for quantum information and networking applications.
Due to the proximity of Yb to V, V nuclear spins experience, and are limited by, common mode noise generated by a randomly induced Yb dipole moment. We engineer GHZ states that leverage our system symmetry to intrinsically protect coherence from this correlated noise. The robustness of the decoherence-protected subspace is verified with artificially generated noise fields. Finally, we develop a scheme that enables quantum state storage in this decoherence protected basis.
This paves the way for utilizing dense nuclear spin ensembles as a deterministic quantum resource.

Dual Er qubits and correlated noise spectroscopy in epitaxial thin film crystals

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We report dual Er qubits in two distinct symmetry sites of an epitaxially grown single crystal Y_2O_3 thin film. Coupling of Er spins to a superconducting microwave resonator and a fiber micro-cavity enables simultaneous optical-spin coherence spectroscopy at millikelvin temperature. Field-angle dependent micro ESR reveals expected Er qubit anisotropy in a single crystal Y_2O_3 host matrix. At optimal field orientations, over millisecond spin coherence times are observed for Er qubits in both C_2 and C_{3i} symmetry sites. These long spin coherences are consistently measured throughout a 3 inch wafer on which a sub-micron Y_2O_3 thin film is grown using molecular beam epitaxy. Single Er ions in both C_2 and C_{3i} sites are addressed optically, respectively at the field configuration where their millisecond spin coherence times are measured. While C_2 site Er qubits show an optical linewidth of 1 MHz without significant spectral diffusion, Er qubits in C_{3i} sites shows much narrower linewidth, as low as 160 kHz thanks to their pure magnetic dipole allowed transitions and resulting immunity to electric noise. By correlating the spin spectral diffusion and optical dephasing rate of C_{3i} Er qubits, we report a magnetic noise limited spin-optical dephasing rate of only 2.5 kHz, demonstrating significant prospect of Er in epitaxial Y_2O_3 thin film as a highly coherent spin-photon interface for quantum network application. In addition, we also report our spectroscopic measurements on the tunneling-TLS and oxygen vacancy centers in this thin film matrix, and discuss potential use of these unique defect systems for mediating long-range Er-Er interactions and charged-controlled Er qubits.

Beyond T^4 behavour of spectral hole frequencies in Eu:YSO at dilution temperatures

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The next generation of atomic clocks uses ultra-high purity lasers in the optics domain with an oscillation frequency of hundreds of terahertz. Traditional laser systems use analog servo-loops to match the frequency of the laser with that of an ultra-high finesse Fabry-Perot cavity's resonant mode, resulting in a fractional frequency stability at a low 10^{-16} near 1 s measurement time for standard cavities at room temperature, limited by the fundamental thermal Brownian noise. Further improvements are possible down to 4×10^{-17} for integration times between 1 and 10 s though technically challenging. We explore a novel paradigm by referencing the laser frequency onto spectral holes in a Eu^{3+}:Y_2SiO_5 crystal under dilution temperatures. To quantitatively evaluate thermal related noise, it is then necessary to characterize the sensitivity of the spectral frequency to temperature fluctuations. We measure the temperature-dependent frequency shift of the spectral hole burned in a Eu^{3+}:Y_2SiO_5 crystal from 100 to 900 mK. While the $f \sim T^4$ scaling law is well reproduced for substution site 2, site 1 exhibits an inflexion point where the sensitivity to temperature change is second order. We project an equivalent fractional frequency noise at 3×10^{-21} at 1 s with an achievable temperature fluctuation of 10^{-4} K at 1 s, which makes our system a promising candidate for the next generation ultra-stable oscillator for optical frequency metrology.

Original analog architecture for time-reversal of broadband radiofrequency signals based on 3 pulse photon echo

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Time reversal (TR) is a signal processing operation notably used to focus a wave to improve the signal transmission. We propose an original purely analog TR architecture based on modified 3 pulse photon echo [1] thereby avoiding an analog-to-digital conversion that would exhibit latency and bandwidth limitations.

We use a Distributed Bragg Reflector laser (DBR) able to realize GHz/µs. To correct the chirp distorsion we build a multi-stage correction scheme, originally combining various methods, including a Phase-Lock-Loop (PLL) [2] and a feed-forward correction [3]. We test our correction with two 750 MHz/2.5 µs chirps of opposite signs 20 µs apart. We reach a ~1 MHz RMS error with the complete multistage correction, 93 MHz without (Fig 1.a).

This technique is used to time-reverse 30 MHz BW signals with a good fidelity (Fig 1.b) and will be soon applied to GHz BW signals.

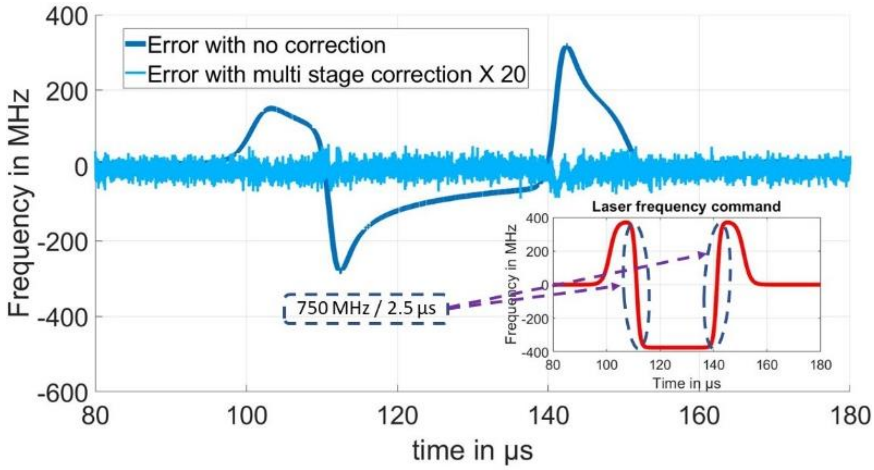

Figure 1.a : Laser frequency error for 750 MHz/ 2.5 µs laser chirps of opposite signs 20 µs apart with and without multistage correction

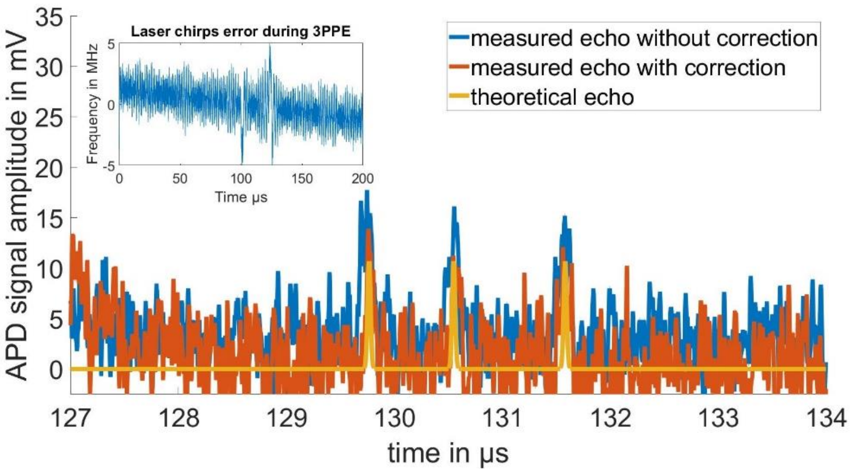

Figure 1.b : Single shot 3 pulse photon echo of 30 MHz bandwidth signal using 50 MHz/ 2.5 µs laser chirps of opposite signs 20 µs apart

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Consequences of the mixed dipole moment of the 1540 nm transition of Er seen in Stark-modulated photon echo measurements

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The 1540 nm transition of Er is well known to have both electric- and magnetic-dipole transition moments, but the full consequences of this unusual hybrid moment are not well studied. We investigated the interesting effects of the hybrid moment for crystals containing a point of inversion. Two inversion-related subsites contribute to spectra in these materials, but electric and magnetic dipoles are respectively odd and even under inversion symmetry, and the subsites have, in general, different interactions with light, which can be clearly seen in Stark-modulated photon echo measurements. We studied the mixed moment of $^{167}Er:Y_2SiO_5$ for both site 1 and site 2 for all possible combinations of electric field direction, light propagation, and light polarisation along the optical extinction axes. We also extracted the optical Stark shifts for both sites and saw evidence for an electron-spin electric field g-shift which may enable electrical control of the Er spin state.

Probing local temperature distribution in a Tm:YAG crystal during large band optical programming

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Spectral hole burning properties of RE ions in solids allow to tailor the optical absorption. Some applications, such as frequency multiplexed quantum memories [1] or large band radiofrequency processing [2], require to program over a large portion of the inhomogeneous linewidth. This programming involves the excitation of a large number of atoms, which can create heat through non-radiative relaxations.

Here we study the local temperature gradients in a Tm:YAG crystal when a large number of ions are repeatedly pumped into the optically excited state. The decay from $^3H_4$ (excited state) to $^3F_4$ (metastable state) to known to be highly non-radiative [3]. We estimate that ~60% of the absorbed optical power is transferred into heat during the process. Under magnetic field, the spectral hole lifetime is highly dependent on the temperature through spin-phonon processes. By locally measuring the hole lifetime, we extract the temperature distribution in the sample, and develop a simple heat diffusion model.

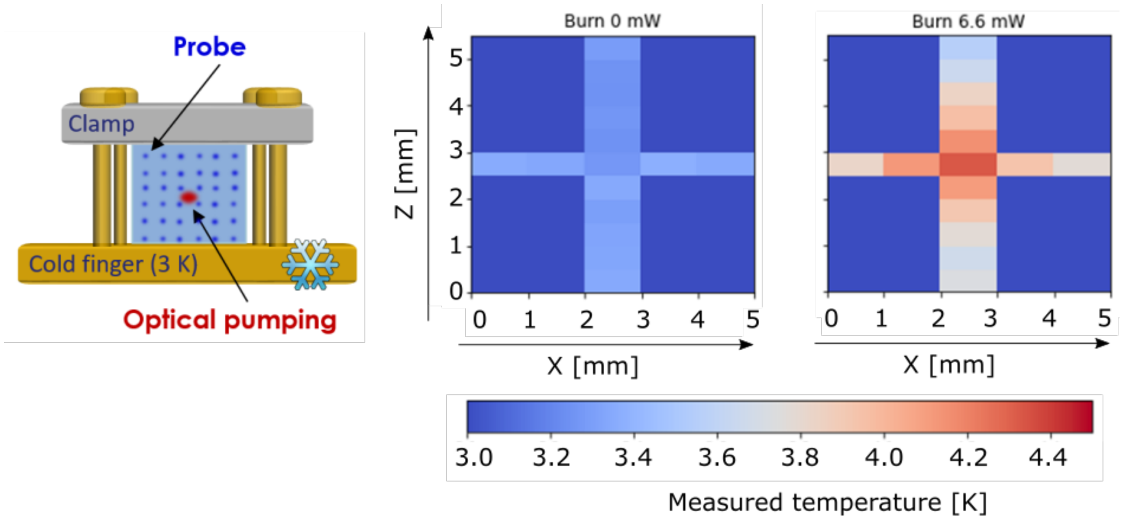

Figure 1. Left : Tm :YAG sample. The optical pumping is performed in the center. The probe beam position is scanned over the sample. Right : Local temperature measured by spectral hole decay when optical pumping in OFF (left) and ON (right).

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Title: Realization of coherence time longer than the state of the art record in Eu:YSO

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Abstract: Eu:YSO is a good candidate of long time quantum memory. In this talk, I will present our recent experimental result of extending the coherence time in Eu:YSO. By applying ZEFOZ method and dynamical decoupling at a sub-Kelvin temperature, we achieved a coherence time longer than the state of the art record. We also studied the magnetic field and temperature dependent decoherence, and observed the "exchange-narrowing" like behavior when approaching the ZEFOZ point.

Title

Deterministic entanglement sources compatible with absorptive quantum memories

Authors

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Abstract

Constructing a large-scale quantum network based on the quantum repeater is essential in the quantum field. Using absorptive quantum memory, the quantum repeater scheme can support external deterministic quantum sources and multi-mode storage simultaneously, which can effectively increase the communication rate. For quantum sources, the deterministic entanglement source can increase the success rate of establishing entanglement between nodes and further increase the communication rate. However, due to the difference in wavelength and bandwidth, the interface between deterministic entanglement sources and quantum memories is still challenging. This work intends to develop a suitable deterministic entanglement source based on quantum dots. Such quantum dots potentially serve as an entanglement source for absorptive quantum memories by optimizing the fidelity and tuning the wavelength. This work will lay a solid foundation for applying quantum repeaters and a large-scale quantum network.

Probing the spin environment of single erbium dopants

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We investigate erbium ions in a 10-micrometer-thin YSO crystal with europium doping. As in our previous experiments [1, 2], a Fabry-Perot resonator enables a ~100-fold Purcell enhancement and thus the efficient manipulation and readout of individual dopants. While the optical coherence can achieve the lifetime limit, a spectral diffusion of ~200 kHz makes emitted single photons distinguishable, preventing remote entanglement by their interference. We thus investigate the yttrium spin bath as source of this diffusion. In echo measurements at a variable magnetic field, we can probe the interaction of individual erbium ions with surrounding yttrium spins. Based on a quantitative description of the observed envelope modulation [3], our measurements not only improve the understanding of spectral diffusion dynamics in Er:YSO, but also provide a first step towards coherent and controlled interactions between erbium dopants and individual spins of the host material.

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