Narrow optical and spin linewidths in rare earth
doped nano- and micro-structures

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Rare earth doped nanoparticles are attractive candidates for quantum technologies hardware as they have the potential to combine the narrow optical and spin linewidths found in bulk crystals with the possibility to strongly interact with other quantum systems [1,2].

To investigate this potential, we identify the physical mechanisms responsible for the optical homogeneous broadening in Eu$^{3+}$:Y$_2$O$_3$ nanoparticles. By studying how the homogeneous linewidth depends on temperature, applied magnetic field, and measurement time scale the dominant broadening interactions for various temperature ranges above 3 K were characterized. These results provide strong evidence that for 400 nm diameter nanoparticles the minimum linewidth achieved (45±1 kHz at 1.3 K) is not fundamentally limited. Several strategies for reducing this linewidth to below 10 kHz are discussed. We also studied the ground state hyperfine coherence lifetime in Eu$^{3+}$:Y$_2$O$_3$ transparent ceramics with micron size crystalline domains and found T$_2$ up to 16 ms under a small magnetic field. These coherence lifetimes could be extended to several 100s of ms by using control techniques like dynamical decoupling or clock transitions [3,4].

The observation of narrow homogeneous linewidths for optical and spin transitions in Eu$^{3+}$:Y$_2$O$_3$ crystals suggests that this system is suitable to build long-lived quantum photon-atom-spin interfaces at the nanoscale.

![Optically detected nuclear spin echo decay
in a Eu$^{3+}$:Y$_2$O$_3$ transparent ceramic at 4 K.
Amplitude modulation is attributed to interactions with Y nuclear spins.]

References:

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