

### Experimental measurement of spin-phonon interactions using acoustic wave resonators in the quantum regime

**General Scope:** Solid-state spins are conventionally controlled and detected using optical or microwave photons [1, 2]. Phonons (acoustic excitations of the spin's solid-state environment) have historically been regarded only as a source of relaxation for spins. But the recent development of quantum acoustics has brought new perspectives: phonons can now be controlled and detected efficiently at the quantum scale. Phonons are therefore no longer considered as a perturbation for spins, but rather as a valuable resource for coherent control and readout of spin qubits.

In our lab we use piezoelectric devices to control and detect acoustic waves efficiently at microwave frequencies [3]. Based on this idea, we have developed a new platform in which bulk acoustic wave resonators interact with spin ensembles. So far, we have used this platform to measure spin-phonon interactions for half-integer spins. We are now investigating integer spins, they are expected to have some of the largest spin-phonon couplings.

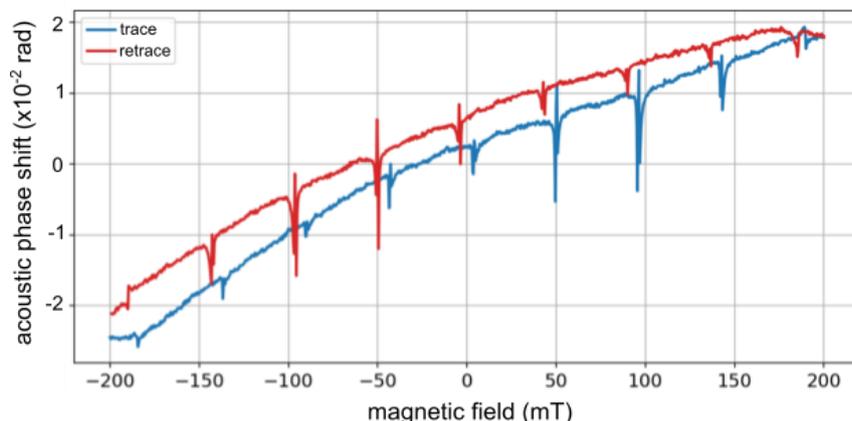


Figure 1 : Acoustically detected electron spin transitions in Holmium ( $\text{CaWO}_4$ ). There are several resonances, at different magnetic fields, corresponding to the non-degenerate nuclear spin states ( $I=7/2$ ) of Holmium ions.

**Research topic and facilities available:** We have samples with ensembles of Holmium ions (integer spins) coupled to bulk acoustic wave resonators at 5 GHz and at 60 mK (see Fig. 1). The student will learn how to carry on these acoustic measurements of spins at 60 mK, with a vector magnetic field. Together, we will characterize the dynamics of these spin states, which is dominated by nuclear spin relaxation/polarization. The aim of the internship is to understand this dynamics and to measure the spin-phonon coupling of Holmium ions.

#### References

- [1] C. E. Bradley et al., A Ten-Qubit Solid-State Spin Register with Quantum Memory up to One Minute, *Physical Review X* (2019)
- [2] J. O'Sullivan et al., Individual solid-state nuclear spin qubits with coherence exceeding seconds, *Nature Physics* (2025)
- [3] A. Hugot et al., Approaching optimal microwave–acoustic transduction on lithium niobate using SQUID arrays, *Nature Electronics* (2026)

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