Rare-Earth ions spin detected with a microwave photon counter

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Abstract:

We report the spin resonance spectroscopy of rare-earth ions using the newly developed method of spin microwave fluorescence detection at millikelvin temperature [1]. The rare-earth ion is Er^{3+} in a $CaWO_4$ crystal, which behaves as an effective electron spin-½ with high gyromagnetic ratio and long coherence time [2]. The spins are magnetically coupled to a micron-size superconducting microwave resonator deposited on top of the crystal, which enhances their radiative relaxation rate via the Purcell effect [3]. The ions are excited by a resonant microwave pulse, and their radiative relaxation is detected at 10mK using a Single Microwave Photon Counter based on a transmon qubit [4].

Fluorescence detection has proven a complete spectroscopy method able to detect a large variety of spin species at various magnetic field condition. The high sensitivity of this technic allows probing the few ions close to the surface and the resonator. Those spins show a short relaxation time due Purcell effect, and have a specific resonant condition that we attribute to mechanical strain. Additionally, we have proven the possibility to measure the spin coherence with this fluorescence detection by using the appropriate excitation pulses sequence.

References

[1] Albertinale et al., Nature, 600 (2021) 434-438
[2] M. Le Dantec, ScienceAdvances, 51 (2021)
[3] A. Bienfait et al., Nature 531, (2016)
[4] Lescanne et al., Phys.Rev.X 10, 021038 (2020)

Figures

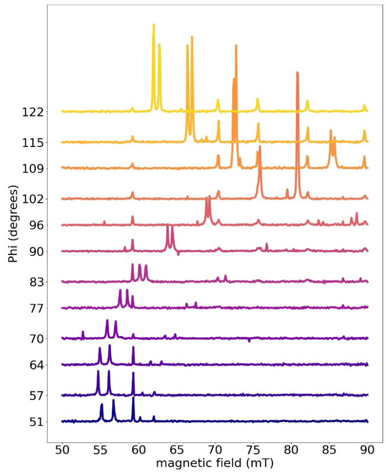

Figure 1: Fluorescence spectroscopy at various magnetic field angle and amplitude, showing many different spin signals

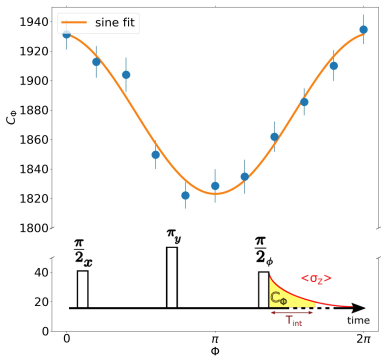

Figure 2: Coherent signal measured with fluorescence detection, with a 3 pulses sequence where we vary the last pulse angle