Persistent spectral hole burning and atomic frequency comb at microwave frequency in Er^{3+} : $CaWO_4$

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The interaction of electron spins with neighboring nuclear spins in a host crystal leads to rich physics and dynamics, as observed in semiconducting quantum dots, color centers in diamond and donors in silicon. Here, we report a new phenomenon, using a crystal of $CaWO_4$ containing Erbium ions, at millikelvin temperature.

Erbium has a doublet ground state with a large magnetic moment behaving as an effective electron spin-1/2. In CaWO4, Er^{3+} couple to the magnetic moment of neighboring ^{183}W nuclear spins (14% abundance). Under a field of 450 mT, the Erbium spin is brought in resonance with a superconducting resonator at 7.8 GHz used for detection. By applying a microwave tone, we observe spectral holes created in the absorption of Er and these holes exist over 20 hours, which is much longer than the Er^{3+}:$CaWO_4$ spin-lattice relaxation time (0.2s). We interpret the holes as being caused by dynamic nuclear polarization of the nearby W nuclear spin leading to an Overhauser field seen by the Er^{3+}, while its persistent existence demonstrates the stability of polarization within W nuclear spins at low temperature. Furthermore, by applying repeated double-pulse sequence, we are able to generate an atomic frequency comb in the spin ensemble, which persists for at least 120 hours at 10mK.

References

[1] Putz, Stefan, et al. "Spectral hole burning and its application in microwave photonics." Nature Photonics 11.1 (2017): 36-39.
[2] Le Dantec, Marianne, et al. "Twenty-three–millisecond electron spin coherence of erbium ions in a natural-abundance crystal." Science advances 7.51 (2021): eabj9786.

Figures

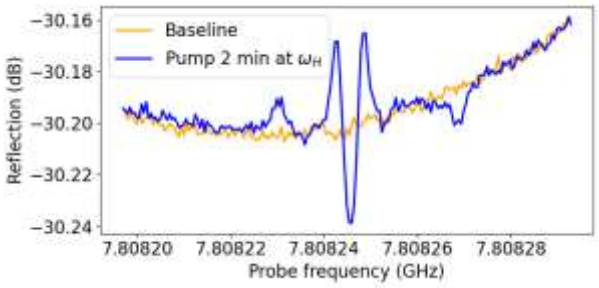

Figure 1: Refection spectrum of spin ensemble before and after applying microwave at the frequency ω_H, where the ω_H is the summation of resonator frequency ω_0 and tungsten nuclear Larmor frequency ω_I

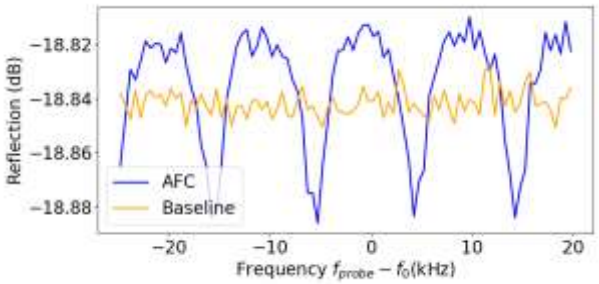

Figure 2: Atomic frequency comb created in the spin ensemble absorption spectrum after applying the following pulse sequence with a repetition of 18000 times: two square pulses separated by 100 µs and waiting time of T_1(Er) 0.2 s