

*Séminaire AXE 1 - Sciences et Matériaux Quantiques*



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***Probing Landau–Zener transitions of a single Ho atom qudit with spin-polarized STM***

Nuclear spins are promising candidates for quantum bits owing to their long lifetimes and robustness against environmental noise [1-3]. However, reliable initialization and readout of individual nuclear spins in solid-state systems remain challenging [2,3]. Using spin-polarized scanning tunnelling microscope, we demonstrate all-electrical initialization, single-shot readout and long-lived storage of the nuclear spin state of a single Ho atom on MgO. Strong hyperfine coupling between the electron and nuclear spins enables high-fidelity state preparation (> 95% polarization) at 50 mK and allows nuclear spin populations to be detected through Landau–Zener transitions at avoided crossings of the electronic spin states [4]. We resolve an unprecedented avoided-crossing gap of 10 peV—the smallest ever measured for spins on surfaces—and observe nuclear spin polarization exceeding 90 % at 50 mK. Using a pump–probe protocol based on double magnetic-field sweeps across an avoided level crossing, we extract a nuclear spin relaxation time ( $T_1$ ) of approximately 60 s for Ho on 2 ML MgO, increasing to several minutes on 3 ML MgO. These results establish controllable and long-lived nuclear spin states at the single-atom limit and provide a pathway toward atomically engineered nuclear-spin qudits.

**References**

- [1] R. Vincent et al., *Nature* **488**, 357–360 (2012)
- [2] J. P. Jarryd et al., *Nature* **496**, 334–338 (2013)
- [3] E. W. Stolte et al., *Nat. Commun.* **16**, 7785 (2025)
- [4] P. R. Forrester et al., *Phys. Rev. B* **100**, 180405(R) (2019)

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