INTERNSHIP PROPOSAL

Laboratory name: SPEC, CEA Saclay
CNRS identification code: UMR 3680
Internship director'surname: James O'Sullivan/Patrice Bertet/Emmanuel Flurin/
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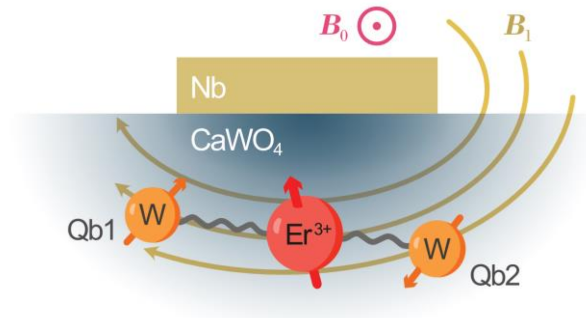
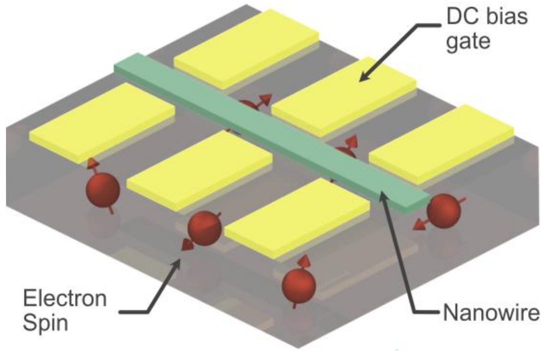
Web page: https://iramis.cea.fr/en/spec/gq/
https://www.youtube.com/watch?v=Pg_dzTcpqi8&t=2s
Internship location: CEA Saclay
Thesis possibility after internship: YES/~~NO~~
Funding: YES/~~NO~~ If YES, which type of funding: ERC

Quantum computing with nuclear spins

Nuclear spins in solids are amongst the quantum systems with the longest coherence times, up to minutes or even hours, and as such are attractive qubit candidates; however, controlling and reading out individual nuclear spins is highly challenging. In our laboratory, we have developed a new way to do so. The nuclear spin qubits are interfaced by an electron spin ancilla (see left figure) to which they are coupled by the hyperfine interaction [1]. The electron spin is then measured by microwave photon counting at millikelvin temperatures [2,3]. Nuclear-spin single-shot readout is performed via the electron spin [4], and coherent control is achieved through the use of microwave Raman transitions. The electron spins are Er^{3+} ions in a $CaWO_4$ crystal, and the nuclear spins are ^{183}W atoms in the matrix, which have spin 1/2.
We recently demonstrated single- and two-qubit gates using two ^{183}W atoms coupled to the same Er^{3+} ion, with coherence times above one second.
As part of the ERC starting grant project 'Nuclear Quantum Information processing Controlled by Hyperfine Interactions with Electrons' (nQUICHE) led by James O'Sullivan, we now want to generate two-qubit gates between ^{183}W atoms coupled to different Er^{3+} ions. To achieve this, we will explore interactions between two Er^{3+} ions. One option is to exploit direct magnetic dipole coupling. Another option is to mediate the coupling through a detuned superconducting resonator to which the two ions are mutually coupled, facilitating coupling via a virtual photon interaction. This also requires local frequency control of each ion, which we will do by applying electric fields via gates patterned on top of the crystal (see right figure). This internship consists of designing, fabricating, and measuring such a device. Experimental techniques include cleanroom work, low-temperature microwave measurements in dilution refrigerators, superconducting circuits and single-spin magnetic resonance spectroscopy. The student will team up with a PhD and postdoc.

[1] J. O'Sullivan et al., Nature Physics (2025)
[2] E. Albertinale et al., Nature 600, 434 (2021)
[3] Z. Wang et al., Nature 619, 276 (2023)
[4] J. Travesedo et al., Science Advances (2025)





Condensed Matter Physics: YES/~~NO~~ Soft Matter and Biological Physics: ~~YES~~/NO
Quantum Physics: YES/~~NO~~ Theoretical Physics: ~~YES~~/NO