INTERNSHIP PROPOSAL

(One page maximum)

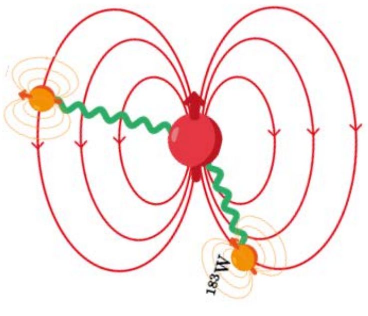
Laboratory name: SPEC, CEA Saclay
CNRS identification code: UMR 3680
Internship director'surname: Patrice Bertet/Emmanuel Flurin
e-mail: Patrice.bertet@cea.fr/emmanuel.flurin@cea.fr Phone number: 0169084567
Web page: https://iramis.cea.fr/en/spec/gq/
Internship location: CEA Saclay
Thesis possibility after internship: YES/~~NO~~
Funding: YES/~~NO~~ If YES, which type of funding: ANR

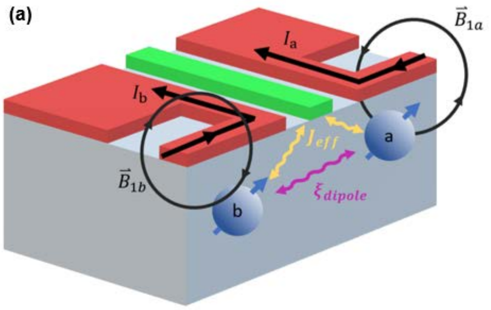
Quantum computing with nuclear spins

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. The electron spin is then measured by microwave photon counting at millikelvin temperatures [1,2]. Nuclear-spin single-shot readout is performed via the electron spin [3], 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 a spin 1/2. We recently demonstrated single- and two-qubit gates with two ^{183}W atoms coupled to the same Er^{3+} ion (see left figure), with coherence times above one second. In order to scale to multi-qubit processors, it is necessary to generate two-qubit gates between ^{183}W atoms coupled to different Er^{3+} ions. For that, we will explore interactions between two Er^{3+} ions (see figure, right). One option is magnetic dipole coupling (in purple); another option is to mediate the coupling through a superconducting resonator (green) to which the two ions are mutually coupled (yellow arrows). This also requires to locally control the resonant frequency of each ion, which we will do by passing current through wires placed on top of the crystal (in red in the figure). The internship consists in designing, fabricating, and measuring such a device.

Experimental techniques include cleanroom work, low-temperature microwave measurements in dilution refrigerators, single-spin magnetic resonance spectroscopy. The student will team up with a PhD and postdoc.

[1] E. Albertinale et al., Nature 600, 434 (2021)
[2] Z. Wang et al., Nature 619, 276 (2023)
[3] J. Travesedo, arxiv (2024)





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