

INTERNSHIP PROPOSAL

Laboratory name: Quantronics group, SPEC, CEA Saclay	
CNRS identification code: UMR 3680	
Internship director's surname: O'Sullivan	
e-mail: james.osullivan@cea.fr	Phone number: +33 (0)1 69 08 60 00
Web page: https://iramis.cea.fr/en/spec/gq/	
Internship location: SPEC, L'orme des merisiers, 91191 Cedex, 91190 Gif-sur-Yvette, France	
Thesis possibility after internship:	YES/NO
Funding: YES /NO	If YES, which type of funding: To be acquired

Towards an error-detected spin quantum memory protocol

Electron spins in solids can have coherence times exceeding seconds [1], and as such are attractive qubit candidates; however, creating a coherent interface between single electron spins and other quantum systems, such as superconducting qubits, is challenging. In the Quantronics group at CEA Saclay, we are investigating a novel platform for this purpose: Tb spin defects in a CaWO₄ crystal [2] coupled to a superconducting resonator.

We recently realised a device exhibiting high-cooperativity coupling between a terbium spin defect and a superconducting resonator, meaning the spin interacts coherently with the resonator's electromagnetic field, which has never been demonstrated before in such systems. This is enabled

by a so-called 'clock transition' – a magnetic-field-insensitive optimal working point of one of the Tb spin transitions which has been measured in the Quantronics lab to have a T₂* dephasing time longer than 10 ms. This transition also has an effective gyromagnetic ratio more than 8× larger than a free electron, meaning that it couples particularly strongly to resonant microwave-frequency magnetic fields, such as the field of a superconducting resonator. This combination of long coherence and large coupling is key to reaching the high cooperativity regime.

The long-term goal of this project is to realise a deterministic error-detected quantum memory protocol, in which a quantum state is transferred from a superconducting transmon qutrit to a single Tb spin and back again (see Fig.1). This will require coherent photon emission from the transmon via a parametric process. This photon will be transferred and absorbed by a Tb spin via a tunable coupling between a single Tb spin and an ultra-low impedance (ULI) resonator [3]. This internship will involve design, simulation and optimisation of the ULI resonator including tuning electrodes to control one or more Tb spins via electric fields.

This project combines superconducting devices with spin physics, microwave quantum optics and quantum information processing. Experimental techniques include cleanroom work, low-temperature microwave measurements in dilution refrigerators and single-spin magnetic resonance spectroscopy. The student will team up with a PhD student and postdoc. The student will be jointly supervised by James O'Sullivan, Emmanuel Flurin and Patrice Bertet.

- [1] Nature Nanotechnology 8, 561–564 (2013) [2] Physical Review 126, 923–930 (1962)
 [3] arXiv:2603.25258 (2026)

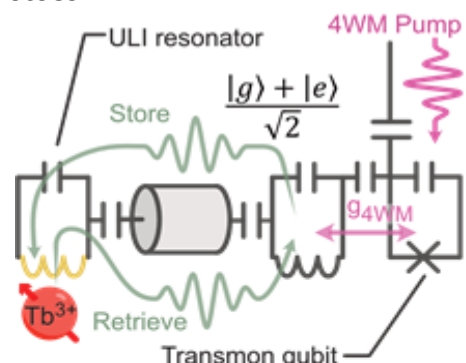


Fig.1 | Schematic of the Tb spin memory setup. The Tb couples to the superconducting circuits via the inductive element (yellow) of an Ultra-Low Impedance (ULI) resonator.

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

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