INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: CEA Grenoble/IRIG/MEM/L_Sim
CNRS identification code: UMR 9001
Internship director'surname: Yann-Michel Niquet
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Internship location: Grenoble, France

Thesis possibility after internship: YES
Funding: Pending If YES, which type of funding: Pending

Many-body effects in silicon & germanium spin qubits

Silicon & Germanium spin qubits have made outstanding progress in the past few years [1, 2]. In these devices, the elementary information is stored as a coherent superposition of the spin states of an electron or hole in a quantum dot. These spins can be manipulated electrically owing to spin-orbit coupling, and are entangled through exchange interactions, allowing for a variety of one- and two-qubit gates required for quantum computing and simulation. Grenoble is developing original spin qubit platforms on Si and Ge, and holds various records in spin lifetimes [3] and spin-photon interactions [4].
At IRIG/MEM, we support the progress of these advanced quantum technologies with state-of-the-art modelling [3, 4]. In particular, we are developing the TB_Sim code, able to describe very realistic qubit structures down to the atomic scale.
The role of Coulomb interactions in spin qubits remains poorly understood. Quantum dots with 3 to 5 electrons or holes are expected to screen noise & disorder better than singly-occupied ones; yet Coulomb interactions can dramatically reshape the spectrum and dynamics of the system (Wigner localization [5]…). The aim of this master training is, therefore, to model the effects of Coulomb interactions on spin qubits using "configuration interaction" methods for the many-body wave functions, in relation with ongoing experiments at IRIG.
This Master thesis may be followed by a PhD project on spin manipulation and entanglement in arrays of spin qubits. The Master/PhD candidate will have the opportunity to interact with a lively community of experimentalists working on spin qubits at CEA and CNRS.

Candidates should send a short motivation letter, a CV and transcripts of grades up to M1 to Yann-Michel Niquet (yniquet@cea.fr).

[1] *A four-qubit germanium quantum processor*, N. W. Hendrickx *et al.*, Nature **591**, 580 (2021) [arXiv:2009.04268].
[2] *Universal control of a six-qubit quantum processor in silicon*, S. G J. Philips *et al.*, Nature **609**, 919 (2022) [arXiv:2202.09252].
[3] *A single hole spin with enhanced coherence in natural silicon*, N. Piot *et al.*, Nature Nanotechnology **17**, 1072 (2022) [arXiv:2201.08637].
[4] *Strong coupling between a photon and a hole spin in silicon*, C. X. Yu *et al.*, Nature Nanotechnology **18**, 741 (2023) [arXiv:2201.08637].
[5] *Two-body Wigner molecularization in asymmetric quantum dot spin qubits*, J.-C. Abadillo-Uriel *et al.*, Physical Review B **104**, 195305 (2021) [arXiv:2107.11117].

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

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