INTERNSHIP PROPOSAL

Laboratory name: Laboratoire de Physique de l'ENS (LPENS)
CNRS identification code: UMR 8023
Internship director'surname: Matthieu Delbecq
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Web page: https://www.lpens.ens.psl.eu/recherche/quant/equipe-21/
Internship location: Hybrid Quantum Circuit Group (LPENS)

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

Mesoscopic quantum electrodynamics with spins in carbon nanotubes

Electron spins in quantum dots represent an attractive path towards the realization of quantum processors due to the high spin resilience to environmental noise. A promising architecture consists in coupling spin qubits to microwave photons in a circuit Quantum Electrodynamics (cQED) architecture to manipulate, read and couple spin qubits. It relies on an engineered spin-photon coupling. The HQC group pioneered the field, with carbon nanotube (CNT) as the host material for the spin qubit[1,2]. CNT offer very interesting aspect for spin qubits as they have a very low natural abundance of nuclear spins, can be grown ultra-clean and be suspended, offering the only qubit platform free of oxide, which host charge fluctuators that are the main source of decoherence in other solid-state qubits. The technology to achieve these last two aspects was developed in the HQC group[3]. Thanks to the high quality of the devices obtained with this nano-assembly technique, we recently demonstrated the manipulation, with cavity photons, of quantum states in a CNT with coherence time of the order of 1.3µs[4]. This is 2 orders of magnitude larger than any previous implementation of spin qubits with CNT and 1 order of magnitude larger than similar device using silicon.
The proposed internship, and following PhD, aims at pushing these recent results further to demonstrate a high single-qubit gate fidelity above the fault-tolerant threshold for quantum error correction codes (and go to two-qubit gates). The strategy will rely on electrically tuning the spin qubit to further improve its coherence time (expected to be between 5µs and 25µs), boosting the spin-photon coupling with high-kinetic inductance microwave resonators and exploiting novel electron-photon coupling schemes that are currently being demonstrated in the group. The candidate will benefit from the interaction with all members of the group and of the fruitful partnership we have with the startup C12 which can then offer a CIFRE PhD funding.

The candidate should have a strong theoretical background in quantum and condensed matter physics, a strong interest in nano-devices and complex microwave techniques to manipulate a quantum system in the time domain.

1. J. J. Viennot *et al.*, Science, **349**, 408–411, (2015).
2. Cubaynes, T. *et al.*, npj Quantum Inf. **5**, 47 (2019).
3. Cubaynes, T. *et al.*, Appl. Phys. Lett. **117**, 114001 (2020).
4. Neukelmance, B., Hue, B. *et al.*, Submitted (2024)

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