NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2024-2025

Spin-photon interface for individual magnetic atoms in semiconductors

General Scope:
Individual spins in semiconductors hold great promise for the development of quantum information technologies. Thanks to their long-expected coherence times, localized spins on individual defects are a medium of choice for quantum information storage, and the semiconductor platform offers interesting integration prospects. For long-range coupling of localized spins acting as quantum nodes, a spin-photon interface is required. These interfaces are generally based on specific optical selection rules. For non-optically active magnetic impurities, an optical interface can be realized through their exchange interaction with semiconductor carriers. This has been demonstrated for transition metal elements (Mn, Cr, Co, Fe, ...) inserted in a semiconductor quantum dot (QD). These magnetic elements offer a wide choice of localized electron spins, nuclear spins and orbital moments.

Research topic and facilities available:
We aim to exploit the optical properties of a QD to probe and control the coherent dynamics of the spin of an embedded magnetic atom. In the case of Mn, we will combine radio frequency (RF) excitation and resonant fluorescence for the coherent control of coupled electronic and nuclear spins. The internship will focus on developing a resonant fluorescence experiment for the detection of the magnetic resonance of a Mn atom in a strain free QD. We will also model the spin-induced fluctuations of optical signals from a resonantly driven magnetic QD in a micro-pillar cavity, a necessary step for the dimensioning of future spin-photonic devices under development. We will analyze the quantum dynamics under continuous resonant optical readout to show how the quantum Zeno effect can contribute to increasing the storage time of the quantum information in such a system. In collaboration with our partners, we will also investigate magnetic ions with a large spin to strain coupling (Ni, Co, Cr), that could be coherently controlled with the strain field of surface acoustic waves. We will first work on modeling the influence of local strain distribution on the magneto-optic spectra of such dots to estimate the spin to strain coupling of the embedded magnetic atom.
Experiments will be carried out on a micro-spectroscopy facility equipped with a magneto-optical cryostat (1.5 K, 9T/2T magnet, optical and RF access), tunable single mode and pulsed (ps) lasers for resonant optical excitation and high-resolution spectrograph for the detection.

References: L. Besombes *et al.* Phys. Rev. B. 109, 235302 (2024) ; L. Besombes *et al.,* Phys. Rev. B 107, 235305 (2023); V. Tiwari *et al.*, Phys. Rev. B 106, 045308 (2022); V. Tiwari *et al.*, Phys. Rev. B Letter 104, L041301 (2021).

Possible collaboration and networking:
This work will be realized in the NanoPhysique et Semi-Conducteurs group (NPSC, CNRS/Institut Néel & CEA/IRIG) in collaboration with the University of Warsaw and the University of Tsukuba for the growth of some of the samples.
Possible extension as a PhD: Yes
Required skills: Master 2 (or equivalent) with good knowledge in solid state physics (electrical, optical, magnetic properties), quantum mechanics, optics, light matter interaction.
Starting date: March 2025 (flexible)
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More information: http://neel.cnrs.fr