Spécialité de Master « Optique, Matière, Paris »

Stage de recherche (4 mois minimum, à partir de début mars)

Proposition de stage (ne pas dépasser 1 page)

Date de la proposition : 14/11/2018

Responsable du stage / *internship supervisor*:

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Nom du Laboratoire / *laboratory name*: Center for Nanoscience and Nanotechnology

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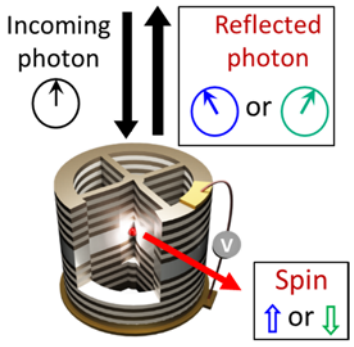
Lieu du stage / *internship place*: Avenue de La Vauve, 91120 Palaiseau

Measuring and entangling a single spin with single photons

This project aims at **controlling the interaction between light and matter at the most fundamental quantum level**: *qubits,* i.e. the elementary systems of quantum physics, which can be in a superposition of two quantum states. To this purpose, we recently developed **an efficient interface between a single material qubit** (the spin of a single charge) and a **single photonic qubit** (the polarization of a single photon). Our interface uses the spin qubit carried by a semiconductor hole, confined in a nanometer-scale InAs quantum dot (QD), inside an optical microcavity. In such a device, a photon reflected by the QD-cavity structure experiences a drastically-enhanced rotation of its polarization, clockwise or counter-clockwise, depending on the spin state (see figure). This allows us to play with the polarization qubit of the reflected photons in the Poincaré sphere. In addition, **we recently demonstrated the non-destructive quantum measurement of a single spin using single photons**. In such experiment every single detected photon leads to a quantum measurement back-action on the spin qubit.



In the proposed internship/thesis offer, we want to interface spins with single photons for various applications:

- **Fundamental quantum measurements.** We aim at controlling the quantum back-action induced on a single spin by a detected photon, up to the strong measurement regime and to the "quantum Zeno" effect. In this framework the spin-photon interface is used as a quantum measurement platform, on which we can control the way photons are "watching" the spin system.
- **From spin-photon to multi-photon entanglement**. We want to demonstrate a new form of spin-photon entanglement, where the spin qubit is entangled with the polarization qubit of a single incoming/reflected photon. By successively entangling several photons to a single spin, we will also be able to engineer highly-entangled "cluster" states which can be used for measurement-based quantum computing.
- **Quantum logic gates.** Finally, we plan to demonstrate deterministic spin-photon gates for quantum computing applications. As an example, the state of a first photon can be coherently transferred to the spin quantum memory, and retrieved at a later time using a second photon.

The proposed work is mostly experimental, involving various quantum optics experiments on single nano-objects. All the expertise exists in the group, on the technological, experimental and theoretical aspects, to successfully lead this project. We welcome excellent students with a solid training in quantum physics, optics and/or solid-state physics.

[1] De Santis et al, **Nature Nanotech. 12**, 663 (2017)
[2] Somaschi et al, **Nature Photonics 10**, 340 (2016)
[3] Arnold et al, **Nature Commun. 6**, 6236 (2015)
[4] Anton et al, **Optica 4**, 1328 (2017)

Ce stage pourra-t-il se prolonger en thèse ? *Possibility of a PhD* **? : Yes**

Si oui, financement de thèse envisagé/ *financial support for the PhD***:** to be discussed

Lumière, Matière, Interactions	**X**	Lasers, Optique, Matière	**X**

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