INTERNSHIP PROPOSAL

Laboratory name: **Jeunes Equipes de l'Institut de Physique du Collège de France**
CNRS identification code: **UAR 3573**
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Web page: https://jeipcdf.cnrs.fr/quantum-photonics/
Internship location: **Collège de France, 11 Place Marcelin Berthelot, 75005 Paris, France**
Thesis possibility after internship: YES Funding: Applied (ANR)

Quantum engineering of light with intracavity Rydberg superatoms

Optical photons are excellent carriers of quantum information, but their lack of mutual interactions is a major roadblock for quantum technologies. Our new setup enables such interactions by transiently injecting the photons into an intra-cavity cold atomic gas and converting them into strongly interacting Rydberg polaritons. The Rydberg-blockaded cloud then acts as an effective two-level superatom with an enhanced coupling to light. We can coherently manipulate its state, efficiently detect it, and observe state-dependent π phase flips on the light reflected from the cavity as required for many quantum engineering tasks [1]. Recently, we obtained the first fully deterministically-generated free-propagating states of light with negative Wigner functions [2]. This platform opens many perspectives for developing deterministic multi-photon gates, performing quantum measurements impossible with current techniques, generating non-classical free-propagating resource states, and studying strongly correlated quantum fluids of light.

Currently, we are expanding the capabilities of this platform towards the multi-superatom / multi-mode regime. A possible experimental M2 internship will consist in demonstrating a cavity-mediated entanglement between two superatoms, leading to a PhD project focused on deterministic multi-photon quantum logic and Wigner-negative light states generation.

Another internship topic, more oriented towards theory and experimental design, will be to study the possibility to trap and control a single atom next to a superatom. The following experimental PhD thesis will aim at developing quantum interconnects between static and flying qubits, in a collaboration with the quantum tech company Pasqal.

Both projects require a background in quantum physics, cold atoms and quantum optics, as well as an ability to work in a team.

[1] J. Vaneecloo, S. Garcia & A. Ourjoumtsev, Phys. Rev. X **12**, 021034 (2022)
[2] V. Magro, J. Vaneecloo, S. Garcia & A. Ourjoumtsev, Nature Photonics 17, 688 (2023)

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:	NO