INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: **Jeunes Equipes de l'Institut de Physique du Collège de France**
CNRS identification code: **UAR 3573**
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Internship location:
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Thesis possibility after internship: **YES**
Funding: **YES** If YES, which type of funding: ANR

Efficient atom-photon interface via an intracavity Rydberg superatom

Arrays of neutral atoms, trapped and imaged via high-resolution optics and interacting via Rydberg blockade, are a leading platform in quantum simulations and quantum computing. Their performance scales with the number of individually addressed atoms, currently of a few thousands, close to ultimate constraints set by optics and geometry.

Optically connecting atomic arrays could lift this roadblock. For this, a currently missing piece of technology is an efficient and Rydberg-compatible system for entangling neutral atoms with optical photons. Indeed, strong atom-photon coupling usually relies on high-finesse optical cavities or nanophotonic structures, which both pose significant challenges in terms of optical losses and coupling stability, exacerbated by the sensitivity of Rydberg atoms to the presence of nearby surfaces.

In our lab, we recently demonstrated an efficient and strong interaction between a single photon in a running-wave optical cavity and a Rydberg-blockaded cloud, that acts as an effective two-level superatom [1]. The collective enhancement of the coupling between the superatom and the photon allows us to use a cavity with (i) a centimeter scale compatible with Rydberg atoms with high principal quantum numbers and (ii) a medium finesse, enabling highly efficient (low-loss) quantum optics, demonstrated by the first deterministic generation of photonics qubits with negative Wigner functions [2].

Leveraging the efficiency of this approach, we are building a new experimental setup combining high-numerical-aperture optics with a centimeter-scale running-wave medium-finesse cavity, to create a highly efficient interface between single atom arrays and single photons mediated by Rydberg superatoms.

We offer an internship position dedicated on one side to the experimental construction of the laser system and on another side to numerical simulations of single atom trapping and transport. This internship could continue with a PhD position, aiming at a highly-efficient atom-photon entanglement, a building block for future interconnections between atomic processors.

[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