

INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: **YES**
Funding: **YES** If YES, which type of funding: **ANR + RP**

Strong light-matter interactions with intra-cavity 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]. We obtained the first fully deterministically-generated free-propagating states of light with negative Wigner functions [2]. We also developed a deep theoretical understanding of the rich physics and the abilities of the superatoms, validated by experimental results [3,4].

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.

We recently expanded the capabilities of this platform towards the multi-superatom regime. A possible experimental M2 internship will consist in studying the effective interactions between optical pulses reflected from the cavity with two superatoms, leading to a PhD project focused on deterministic multi-photon quantum logic and Wigner-negative light states generation.

The project requires a background in quantum physics, cold atoms and quantum optics, an interest in experimental research and an ability to work in a team.

- [1] J. Vaneecloo, S. Garcia & A. Ourjountsev, [Phys. Rev. X **12**, 021034 \(2022\)](#)
[2] V. Magro, J. Vaneecloo, S. Garcia & A. Ourjountsev, [Nature Photonics **17**, 688 \(2023\)](#)
[3] A. Covolo, V. Magro, M. Girard, S. Garcia & A. Ourjountsev, [Optica **12**, 1427 \(2025\)](#)
[4] V. Magro, S. Garcia & A. Ourjountsev, [Phys. Rev. Lett. **137**, 053605 \(2026\)](#)

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