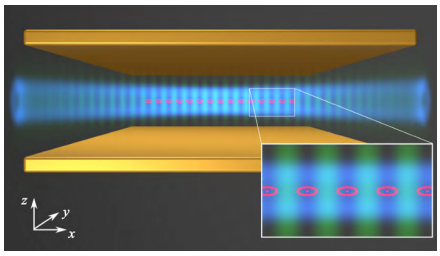
M2 INTERNSHIP and THESIS PROPOSAL

Laboratory name: **Laboratoire Collisions Agrégats Réactivité (LCAR, Toulouse)**
CNRS identification code: UMR5589
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Keywords: *cold atoms, Rydberg atoms, quantum tomography, quantum simulation*
Thesis possibility after internship: yes

Long-lived trapped circular Rydberg atoms

Scientific context:

The current ultimate goal of the group is the realization of a novel quantum simulator platform based on a chain of circular Rydberg atoms and its benchmarking by the exploration of the phase diagram of a 1D spin chain. The corresponding proposal is presented in details in Phys. Rev. X 8, 011032 (2018). Circular Rydberg levels have a large principal and maximum orbital and magnetic quantum numbers. Despite their very long intrinsic lifetime T of several tens of milliseconds, the lifetime of a chain of N atoms scales as T/N, significantly limiting the possible use of these atoms in chains for long and sophisticated quantum simulation protocols. The atomic lifetime can be increased by passing two basic milestones: the realization of a Rydberg atom chain trapped at laser intensity minima by the ponderomotive energy of the atoms' nearly-free electron and the enhancement of the atom lifetime (inhibition of their spontaneous relaxation) by placing the atoms in a plane-parallel capacitor with millimeter spacing, as schematically shown in the figure.



Artist's view of a laser-trapped circular Rydberg atom chain inside a spontaneous-emission inhibiting capacitor.

Current status:

As of October 2026, the group has assembled the main components of the experimental setup inside the cryostat and realized the cooling and the deterministic transport of cold ground-state atoms by means of an "atomic conveyor belt" towards the capacitor. Besides, we have first evidence of the 10x increase in the atomic lifetime in the inhibition zone.

Internship:

The goal of the internship is the realisation and optimisation of trapping of individual circular Rydberg atoms inside the protective zone. During his/her internship in the group, the intern student will participate in the building and testing of different components of the experimental system. Under the guidance of senior colleagues, he/she will learn various experimental technics, like optical systems for laser control (frequency, power, polarization, beam shape), electronics (fast control, high-current applications, superconducting elements, etc), high frequency generation (radio-frequency, microwaves), cryogenics and ultra-high vacuum, as well as programming and computer control of the experimental system.

Future PhD thesis:

The main task of the future PhD project is to study atomic interactions in trapped chains of circular Rydberg atoms. This is a necessary and important step on the way to full-fledged quantum simulations on arrays of long-lived atomic qubits.