Master 2: *International Centre for Fundamental Physics*

INTERNSHIP PROPOSAL

(One page maximum)

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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: ERC

Laser cooling of circular Rydberg atom of Strontium

Summary
Rydberg atoms are highly excited atomic levels with large principal quantum number n, with a valence electron far away from the nucleus and only seeing the 1/r-potential of the atomic core. The spatial extension of the Rydberg electron wavefunction and the very long lifetime, especially for circular Rydberg levels (with angular momentum l=m=n-1) make them of great interest for quantum metrology and quantum simulation. We have used rubidium Rydberg atoms prepared with one valence electron in non-classical Schrödinger cat states to measure electric or magnetic field with an unprecedented precision, well below the standard quantum limit [1]. Chain of circular Rydberg atom, trapped deterministically, would also open very promising perspectives for quantum simulations of spin systems [2].
We are currently developing a new experiment based on strontium. Being an alkali-earth element, the strontium possesses two valences electrons, leaving an optically active ionic core once one of the electrons is promoted to the Rydberg states. The second electron can thus be used to detect the atom by fluorescence, allowing for instance to obtain a spatial image of the electromagnetic field that the atoms are measuring. The ionic core optical transition also enables to implement standard cold-atom techniques to laser-cool the atoms once in the Rydberg states.

Project:
The master internship will be consisting in setting up a new, room-temperature strontium laser cooling setup for preparing ultracold strontium circular Rydberg atoms.
At room temperature, the lifetime of circular atoms is strongly limited in the range of 100µs timescale by blackbody-induces radiative transitions. The purpose of the proposed PhD work is to develop a new set-up for cooling and trapping ground state strontium atoms in a cryogenic environment. At low-temperature, the lifetime of circular Rydberg states of strontium, in the tens of millisecond range, will be long enough to allow us to manipulate the atomic motion using laser forces, and demonstrate cooling of a cloud of circular Rydberg atom. This opens very exciting perspectives for quantum simulation, where the motion of atom is often the limiting factor that prevent from observing the long-term dynamics of the system.

[1] A. Facon, *et al* , A sensitive electrometer based on a Rydberg atom in a Schrödinger cat state, Nature, **532**, 262 (2016)
[2] T. L. Nguyen *et al*, Towards Quantum Simulation with Circular Rydberg Atoms Phys. Rev. X **8**, 011032. (2018)

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: YES