PhD position

Circular Rydberg atom of Strontium in optical tweezers

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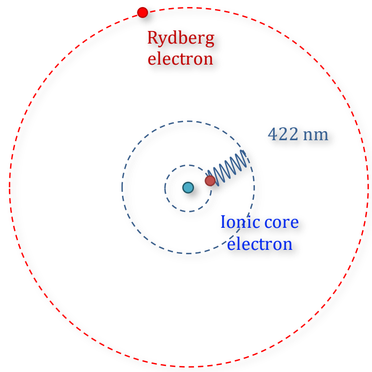
Scientific context:

Rydberg atoms arrays are one of the most promising platforms for quantum simulation. Ground-state atoms, trapped in optical tweezers, are arranged into a well-defined arbitrary geometry before being transferred into low-angular momentum Rydberg states using laser pulses. Once in a Rydberg level, the atoms interact with each other through the dipole-dipole coupling, which enables to simulate the dynamics of arbitrary Hamiltonians. However, the relatively short lifetime (in the 100 µs range) of low-angular momentum Rydberg atoms currently limits either the number of atoms or the duration of the simulation in order to ensure that none of the atom decays during the experiment.



Circular Rydberg states of strontium. Once in the first electron has been promoted to the circular state, the second ionic core electron can be used to optically manipulate the atom with 422 nm light. Due to the electrostatic coupling between the two electrons, it is possible to use one to measure the state of the others, opening the way to an all optical quantum non-demolition measurement of the state of the Rydberg atom.

To overcome this issue, we propose to build a quantum simulator based on circular states of strontium. Circular Rydberg atoms have a much longer lifetime (on the 10 ms range), opening the way to study dynamics on a much longer time scale [1]. 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 ionic core transitions can be used to trap the Rydberg atom, or to cool its motion. This opens very exciting perspectives for quantum simulation, where the motion of atom can be the limiting factor that prevent from observing the long-term dynamics of the system. Furthermore, our group has recently demonstrated that the electrostatic coupling between the two valence electron was inducing an energy shift of the ionic core levels that depends on the state of the Rydberg electron [2]. This opens the way to implement a quantum non-demolition measurement of the circular state using the ionic core fluorescence in order to optically detect a Rydberg atom. This would have very interesting perspective for both quantum simulation and quantum metrology.

Project:

The purpose of the proposed PhD work is to build a new experimental set-up to prepare arrays of circular state atoms of strontium in a cryogenic environment. This requires trapping ground state strontium atom in optical tweezers, transferring them into the circular state, and capturing the circular state again using a tweezers tune close to the optical transition of the ionic core. Then, we will demonstrate that it is possible to measure the state of the Rydberg atom by using the selective fluorescence of the second valence electron.

During master internship, the student will set up the laser system to cool and trap ground state strontium atom in optical tweezers.

[1] T. L. Nguyen *et al*, Towards Quantum Simulation with Circular Rydberg Atoms, Phys. Rev. X **8**, 011032. (2018)

[2] A. Muni *et al*,Optical coherent manipulation of alkaline-earth circular Rydberg states, Nat.Phys.**18**,502(2022)