Hybrid cavity quantum electrodynamic with Rydberg atoms and superconducting qubits

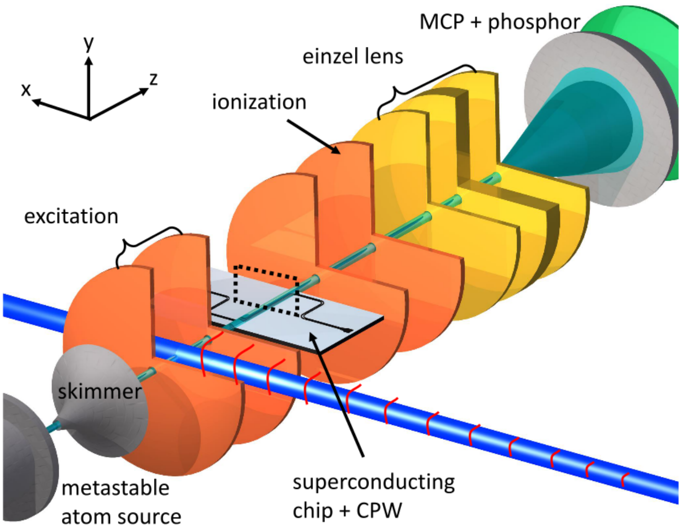
M1 internship proposal

at Quantum device lab of Prof. Dr. Andreas Wallraff
contact : Dr. Sébastien Garcia (sgarcia@phys.ethz.ch)

Light-matter enhancement in cavity quantum electrodynamics systems is a powerful resource for quantum information processing. Superconducting qubits coupled to microwave resonators are among the most promising systems to build a quantum computer. Indeed, as solid state micron-scale devices they offer excellent scalability, and their strong coupling allows to perform fast entanglement and measurement operations in a few tens of nanoseconds. However, these devices suffer from relatively low coherence times on the order of ten microseconds and they are limited to interactions with microwave photons. In contrast, atoms have very long coherence times which can reach minute scale and also provide optical transitions. Moreover, when they are excited to Rydberg states, they also couple strongly to microwave electromagnetic modes.

In our lab, we aim to combine the advantages of both systems by coupling Rydberg atoms to superconducting qubits in a hybrid cavity quantum electrodynamics experiment. Superconducting qubits can be coupled to 2D stripline microwave resonators or 3D cavities, that we both investigate in a cryogenic environment to limit black body radiation. So far, we have achieved coupling of Rydberg atoms to a microwave 2D transmission line and to a 3D cavity.

The experiment combines top of the art technologies in very different fields including ultra-high vacuum, cryogenics, electronics, low noise detection, microwave and laser technologies. We have several possible projects for an experimental M1 internship in particular including : design and realization of an intra-cavity Rydberg-Stark decelerator and trap; optimization of an optical cooling system and design of an upgrade to a magneto-optical version; realization and measurement of high frequency fast tunable superconducting qubits in 3D cavities; design of a system combining optical and microwave cavities. The specific project will depend on experimental progress at beginning of the internship and on student research interests. The student will join an international research team, where weekly group seminar and journal club will expand his knowledge on current research in quantum physics.



Sketch of the main experimental setup: helium atoms propagate through the cryogenic setup along the z axis. They are excited to a Rydberg level by a combination of optical and microwave pulses. They interact with a sample (2D or 3D cavity) and are ionized. The resulting electrons are detected on a micro-channel plate (MCP).