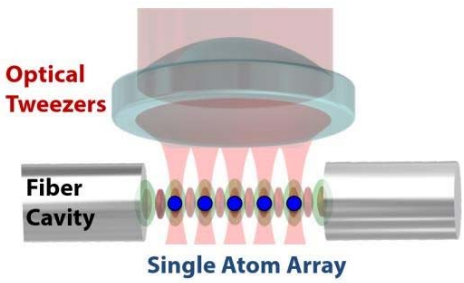
PhD project

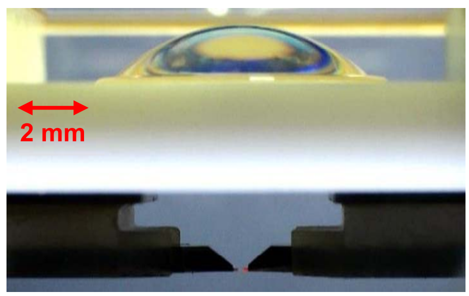
Supervisor: Jakob Reichel (Professeur SU)
Co-Supervisor: Romain Long (Maître de Conférences SU)
Atom Chips Group, Laboratoire Kastler Brossel

Quantum simulation with an atom-tweezer array in an optical microcavity

Exploiting entanglement in many-body quantum systems is at the core of quantum technologies. One of the most exciting challenges is to increase the number of qubits while controlling them at the single particle level. Cold atom platforms offer high-fidelity control, large system size and metrological precision. In this context, cavity quantum electrodynamics (CQED) has been demonstrated to be a powerful tool to produce entangled states with large atom number. However, until now these systems still lack single particle control capability.

At LKB, we have just completed an experimental setup combining a high-finesse optical microcavity, allowing us to work in the strong regime of cavity QED, and a high-numerical aperture lens enabling single particle control by generating an array of tweezers individually controllable (see figure).





Left: Principle of the experimental setup: An array of optical trap and control a register of single atoms inside an optical micro-cavity. Right: an image of the actual experiment.

The cavity-mediated long-range interaction between atoms and the local control offered by the lens open the way for engineering spatial correlations of entangled states. This will lead to new potential applications, for example in quantum simulations to study transport phenomena in disordered spin systems or in quantum metrology where spatially delocalized entangled states are a resource to perform multi-parameters quantum-enhanced estimation.

The PhD project will start with the deployment and test of an entanglement scheme involving Raman transitions within the experimental setup described above. After first tests with a minimal system consisting of two atoms in two separately controlled tweezers, atom numbers will be increased, confirming the scalability to several tens of qubit atoms. At this stage, all elements will be in place to study the transport of a single spin excitation in a chain of atoms where disorder can be added in a controlled way thanks to the tweezers. Depending on the progress, a wealth of problems in entanglement dynamics can then be investigated with the same experiment, leveraging the single-atom control in the tweezers and switchable, nonlocal interactions offered by the cavity.

The student will be part of a small and highly motivated team in an inspiring research environment and will have the opportunity to gain experiences in optics, lasers, cold atoms and cavity QED physics.