Non-equilibrium Relaxation in Many-Body Quantum Systems – student projects

Positions

Bachelor, diploma, and PhD students

Contact

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We aim to study relaxation processes from non-equilibrium states in many-body quantum systems. For this goal an all-optical ultracold atom experiment of fermionic lithium is being developed. Using fermionic lithium atoms, one has the ability to tune the inter-atomic scattering strength precisely over a wide range. One also has the choice of forming lithium molecules or an ultracold Fermi gas.

We envision to significantly enhance the capabilities of non-equilibrium experiments with continuous systems and realize experiments with: (1) precise control over the inter-particle interaction strength, allowing us to take our studies into the strongly interacting regime of the many-body systems; (2) perform experiments with both bosons and fermions; (3) specially designed trapping potentials extending to 2D and more complicated geometries and topologies; and (4) considerably longer lifetimes of the atomic sample even in the strongly interacting regime to allow observation of evolution to study the behaviours of relaxing quantum systems at long times, beyond pre-thermalization.

The new lithium quantum gas lab is currently in the process of construction, and offers a variety of projects for different experiences working with cold atom experiment.

Diplomaarbeit

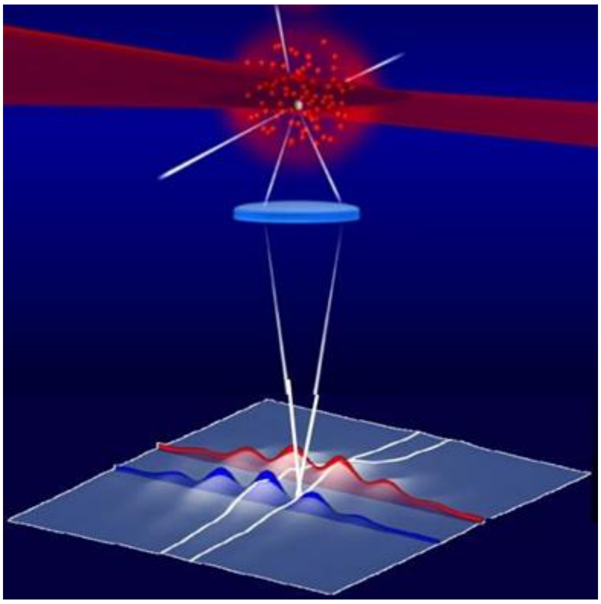
Spatially resolved, free flight fluorescence imaging for quantum degenerate lithium gas

A crucial part of the experiment will be a fluorescence light-sheet imaging system capable of detecting single atoms with extremely high quantum efficiency near 100%. The light-sheet will be the major tool of interrogation in the experiment, being capable of acquiring spatially revolved images and accurately counting atoms.

The major challenge to obtaining spatially resolved images, for atoms with low masses in particular, is the random walk rendered by spontaneous photon scattering. Precise determination of the distribution of particles is crucial. Achieving the fluorescence imaging depends on sufficient photon collection, while limiting the spatial diffusion of atoms. We will design and implement a high numerical aperture optical system for the imaging, collecting up to 10% of the photons

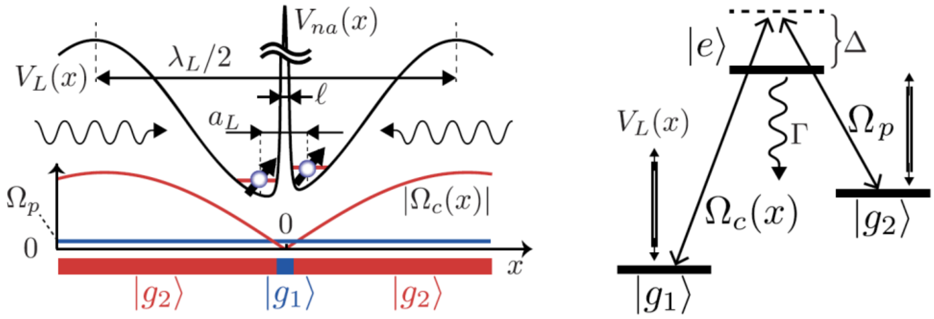
In the ultimate setup, the motion due to photon scatter can be confined with a lattice potential. The distribution of atoms within the cloud is frozen after a certain time-of-flight. By shifting the lattice and making multiple detections, it is even possible to obtain a full three-dimensional mapping of the system of interest.

The student will learn to consider atom-light interaction for a real case scenario, work with diode laser and basic optics components, and in particular learn about lens design. An optical system with high numerical aperture will be designed and collection photons for the imaging. The final imaging performance will be characterized and optimized.



Laser setup for formation of sub-wavelength barrier in optical lattice

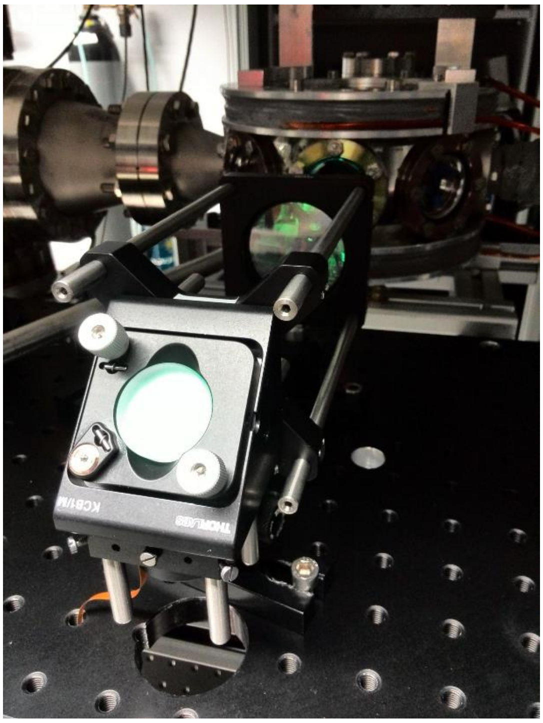
Based on the work of Łącki et al. (PRL 117, 233001 (2016)), and experimental demonstration by Wang et al. (PRL 120, 083601 (2018)), it is know that sub-wavelength barrier can be produced in optical lattice for the formation of double wells and atomic Josephson junction. This provides access to tunnel coupling and matter wave interferometry. We will investigate the feasibility of such technique for hyperfine states of ^{6}Li and its Feshbach molecules, and implement it for double-well setup for 1D quantum gases in optical lattice.



Bachelor projects

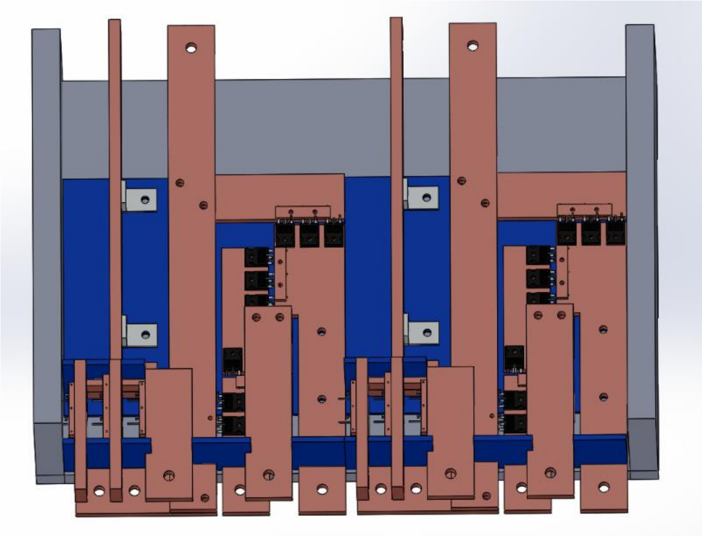
Optical transport of quantum degenerate gas

After standard laser cooling, the lithium cloud is further cooled with a narrow-line transition to reach a temperature of order 10 µK. The cold cloud can then be efficiently transferred to an optical dipole trap, in which the atomic cloud will be evaporatively cooled and subsequently transferred to the science chamber. Techniques to be applied in this sub-project allow transport of ultracold atomic clouds over macroscopic distances. The student will work to accomplish efficient transfer from a magneto-optical trap into an optical potential, with appropriate mechanical setup and feedback control to perform transportation with minimal loss or heating effects.



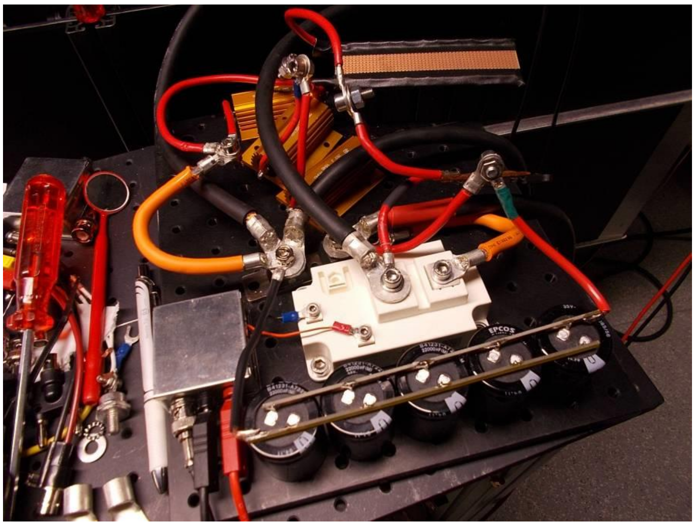
Current switch box

The current switch box will allow one current supply to be switched between multiple tasks. The box is also to allow the change of polarity of a magnetic coil. We will achieve the switching with a simple network made of copper structure, with connections controlled by MOSFETS. The inversion of polarity is to be achieved with a so called H-bridge. A control PCB processes the TTL command inputs through logic gates, and converts the commanded setting into the voltage from MOSFET drivers.



Field jump circuit

To control the interatomic interaction, we will adjust magnetic field values. Some experiments require strong interaction, while for acquiring the momentum distribution weak or null interaction is needed during expansion. For quench operations we require changing the interaction rapidly. Both cases require jumping the field coil current. The inductance of the coil and high current set the challenges for such tasks. Rapid ramp of the fields for quenching experiments, levitation, or imaging demand precise control and suppressing inductive response due to the high energy stored in the fields. Such tasks are to be achieved with power electronics techniques and standard PI control schemes combined in the system.



Magnetic field coil design for atom manipulation

For various purposes, different magnetic field coils are used for manipulate the atoms. The mount allows swapping different field coils. Modelling and making of the coils will carried out for the purposes of controlling Feshbach resonances, applying levitation against gravity, spin state separation, focusing during time-of-flight.