Abstract

This thesis reports on the first observation of optical tuning of interactions in an ultracold atomic gas. To control the elastic interactions, we use optically induced scattering resonances. They are realized by coupling pairs of atoms to a bound molecular state with the help of laser light. In comparison to the well-known magnetic Feshbach resonances, these optical Feshbach resonances allow a very fast switching of interactions in a spatially resolved way. This is because laser light can be switched on and off much faster than magnetic fields and because the light intensity can be spatially structured.

Our experiments are performed with a Bose-Einstein condensate (BEC) of ^{87}Rb atoms, which we produce in our new BEC setup. This apparatus has been constructed in the framework of this thesis and offers excellent optical access to the ultracold atom cloud.

To investigate the tunability of atomic interactions with single-frequency laser light, we optically couple pairs of free atoms to an electronically excited molecular state. The coupling is achieved with a laser that is tuned close to the respective free-bound photoassociation transition. By changing the laser detuning we are able to adjust the atomic scattering length to any value between $10\,a_0$ and $190\,a_0$, where a_0 denotes the Bohr radius. The atomic scattering length is a single quantity that fully describes ultracold elastic interactions. Since laser induced atom losses restrict the duration of our experiments, Bragg spectroscopy is employed as a fast method to measure the scattering length.

We also demonstrate that optical Feshbach resonances can be realized with a two-color Raman coupling scheme. To implement this scheme, a second laser is added that couples the excited molecular state to a weakly bound molecular level in a ground state potential. Tuning the second laser results in a modification of the atomic scattering length similar to the one observed with a single laser. In addition, this scheme allows to control the width of the resonance via the detuning of the first laser.

For the one-color and two-color coupling schemes, we investigate how the elastic scattering properties depend on the different available parameters, i.e. the laser detunings and intensities. Our experimental findings can successfully be described with an available theoretical model, which treats ultracold collisions in the presence of laser light.

Optical Feshbach resonances have the possibility of becoming a valuable tool for fast switching of interactions. This is of special interest in quantum computation schemes with neutral atoms, where interactions between different atomic qubits need to be controlled.