

Abstract

Our new experiment, which is built at the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences, aims for the generation of heteronuclear Fermi-Fermi mixtures at ultracold temperatures; where heteronuclear Feshbach resonances should exist, with which the interaction strength could be tuned. Due to the Pauli exclusion principle heteronuclear molecules are much more stable than molecules made of bosons. Imbalanced mixtures with respect to atom number, mass difference, Fermi surfaces or confinement allow to test fundamental theories of many-body quantum systems, such as properties of heteronuclear mixtures at the BEC-BCS crossover. We will gain new insights and probably new behavior and new phases will be observed.

The newly designed machine gives us the versatility to generate not only mixtures of the fermionic species ${}^6\text{Li}$, ${}^{40}\text{K}$ and ${}^{87}\text{Sr}$, but of the bosonic isotopes as well. A novel three-species oven provides the atom beams, which are decelerated with a Zeeman slower and trapped within a custom-shaped glasscell in a three-color MOT. Using magnetic fields allows us to tune the interactions by Feshbach resonances while the mixture is held in an optical dipole trap which maintains stable trapping conditions. The first dipole trap used is a resonator enhanced optical dipole trap. It will create a large and deep trapping potential due to the power enhancement of the standing wave. Through evaporative cooling the temperature of ${}^6\text{Li}$ is lowered while the other elements can be sympathetically cooled with ${}^6\text{Li}$. On the repulsive side of the Feshbach resonance heteronuclear molecules will be formed which can Bose condense.

The design of the resonator is the content of this thesis. A laser linewidth reduction to 10 kHz and the measurements of the losses of the resonator are presented. With the knowledge of the losses, the design was optimized. The measurements show that a power enhancement of three orders of magnitude can be reached. The resonator is nearly finished, but it is not yet integrated into the experiment. In a different optical dipole trap we have already created a ${}^6\text{Li}_2$ molecular BEC and have observed sympathetic cooling of ${}^{39,40}\text{K}$ by ${}^6\text{Li}$. The next goal is the generation of a heteronuclear molecular BEC.