Abstract

This thesis describes an experiment capable to study ultracold mixtures with Li, K, and Sr, all having fermionic isotopes. We present the creation of an ultracold mixture of the two fermionic species ^{6}Li and ^{40}K. As the main scientific results of first experiments with this mixture, we present 13 heteronuclear magnetic Feshbach resonances in different stable spin mixtures. The positions of the resonances allow to determine the overall scattering properties for an ultracold ^{6}Li-^{40}K mixture in dependence of an external magnetic field.

Ultracold atomic Fermi gases are a unique experimental system to study the fundamental physics of Fermi many-body systems. Experiments with a single atomic species led to ground breaking results during the last few years. Heteronuclear mixtures of atoms are opening up new possibilities to study new kinds of fermionic quantum systems. Feshbach resonances are essential tools to vary the interaction properties of the atoms and for producing pairs like diatomic molecules or Cooper pairs.

The experimental setup is described in detail with a special emphasis on the new or improved technologies we had to develop in order to simultaneously work with Li, K, and Sr. The design of the machine provides a large variety of state-of-the-art techniques to trap, manipulate, and observe ultracold atomic mixtures.

Different isotopic combinations of Li, K, and Sr can be loaded into a multi-species magneto-optical trap (MOT), using a multi-species oven and a single Zeeman slower. Various magnetic and optical traps can be used for evaporative cooling and the creation of different potentials. A sophisticated coil system is used to control the magnetic field and its derivatives in different directions. Simultaneous imaging of the different atoms species can done by using fluorescence or absorption imaging techniques from different directions. Due to the complexity of an experiment with three different elements, special care was taken during design and construction in order to minimize the daily maintenance work.

The experiments presented in this thesis concentrate on the fermionic mixture with ^{6}Li and ^{40}K. From the MOT, both elements are loaded into a high-power optical dipole trap. We demonstrate the sympathetic cooling of ^{40}K by the evaporation of a ^{6}Li mixture in the lowest two spin states. Using the well-known ^{6}Li Feshbach resonance around 834 G, the ^{6}Li atoms provide an efficient coolant. At temperatures close to quantum degeneracy, we prepare different spin mixtures of ^{6}Li and ^{40}K to perform inelastic loss spectroscopy in dependence of the magnetic field. We observe 13 heteronuclear Feshbach resonances for different spin combinations. Our experimental findings were used in theoretical models by collaborating groups to characterize the Feshbach resonances and gain a full understanding of the scattering properties. The knowledge of the scattering properties now allows us to plan future studies with the newly available ^{6}Li-^{40}K Fermi gas mixture.