Abstract

A Bose-Einstein condensate (BEC) of cesium atoms features extraordinary possibilities to control interatomic interactions. These outstanding properties result from various couplings to molecular states, which occur at easily accessible magnetic fields and show up in a rich spectrum of low-field Feshbach resonances. In the frame of this thesis, we create a BEC of cesium and exploit its tunability for new experiments on Cs atoms and in the creation of Cs_2 molecules.

To produce the BEC we employ an optical trapping approach to take full advantage of the tunability of cesium. With a sequence of two optical traps we realize good loading conditions as well as efficient evaporation. For the first optical trap, two crossed CO_2 lasers form a large volume trapping potential suited for loading a large number of pre-cooled atoms. This trap serves as a reservoir for the next step: A tightly focussed laser beam creates a "dimple" in the optical potential. In the dimple trap efficient evaporation can be performed by lowering the optical potential. With this strategy we were able to create the first BEC of cesium. Optimization of the loading and evaporation process yields a pure BEC with more than 10^5 atoms, which serves as a starting point for several experiments. We demonstrate the tunability of the mean-field interaction in the condensate by measuring the release energy as a function of the scattering lengths. By switching the scattering length to zero, we realize a non-expanding "frozen condensate" with an extremely low release energy corresponding to 50 pK.

We use the BEC to create ultracold Cs_2 molecules by applying a magnetic field ramp over a Feshbach resonance. The ramp transfers two colliding atoms into the molecular bound state that causes the resonance. We separate atoms from molecules in a Stern-Gerlach type scheme by applying a vertical magnetic field gradient. A reversed magnetic field ramp dissociates the molecules into atoms and allows to image the density distribution of the molecular sample. We precisely determine the molecular magnetic moment by matching the gradient field to exactly cancel the gravitational force for the molecules. We can thus monitor the dynamics of the molecular sample on extended time scales and observe ultra low expansion energies, consistent with the presence of a macroscopic molecular matter wave. A further investigation of the molecular creation process results in a novel magnetic field ramping scheme. The achieved conversion efficiency of 30% is a factor of three higher than obtained by conventional magnetic field ramps. In first experiments we transfer molecules to different internal molecular states using avoided level crossings. In this way we can populate a molecular state with high orbital angular momentum. Finally, we demonstrate trapping of molecules in the CO_2-laser trap, which offers a prospect for a trapped molecular BEC.