Abstract

The successful realisation of Bose-Einstein condensates in alkali metal atoms in 1995 led to an almost exponential growth of this research area. Although multiple phenomena have already been explored theoretically and experimentally there is still an undiminished activity in the exploration of new fundamental problems in the field of ultra-cold quantum gases.

Multi-component Bose-Einstein condensates extend the spectrum of phenomena in various ways. Here the condensate consists of multiple condensed and interacting components. The thermal atoms also exist in these different states and therefore offer a variety of systems and configurations for the exploration of multi-component quantum systems at finite temperature.

If the components correspond to the alignment of the spin vector, these systems are termed 'spinor condensates'. The spin degree of freedom additionally offers the possibility of conversion between components due to spin dynamics. Although the exploration of spinor condensates promises a variety of new results, only a few experiments have been done so far. In this context spinor condensates in an effective spin-1/2 system in ^{87}Rb have been studied at JILA and in the F=1 - manifold of sodium at MIT. Concurrent to this thesis spinor condensates in ^{87}Rb have been explored at Georgia-Tec.

As main part of this thesis an experiment for the generation and investigation of spinor condensates of ^{87}Rb atoms has been designed and assembled. In addition to the vacuum and laser systems a dipole trap for spin-independent trapping of atoms as well as methods for manipulation and detection of spin states had to be implemented and optimised. These techniques are discussed in detail and compared to theoretical models. Furthermore the phase-contrast detection of spinor condensates, the non-destructive measurement of the time evolution of spin dynamics and the energetic modification of atomic levels by laser light is presented in consideration of the experimental parameters.

The experiment allowed for the first studies world wide of five-component spinor condensates in F=2. The F=1 spinor condensates have been explored in the thermodynamical regime at finite temperatures. A novel experimental approach to 'Bose-Einstein condensation at constant temperature' and 'thermodynamically driven spin alignment' have been demonstrated. The comparison of experimental results to solutions of a rate equation model is used to identify and quantify the seperate processes. Furthermore a mixed-spin-channel Feshbach resonance between different hyperfine levels has been measured for the first time. The loss rate due to this resonance is analysed in the context of theoretical solutions of different loss models.