Abstract

This thesis reports on the first Bose-Einstein condensation (BEC) of molecules starting from optically trapped fermionic ^{6}Li atoms. The control of the interaction properties by means of a Feshbach resonance allowed us to pair the fermionic atoms to bosonic $^6Li_2$ molecules that were Bose condensed by evaporative cooling.

To load a large number of ^{6}Li atoms from a magneto-optical trap, a novel optical dipole trap was developed that employs the resonant enhancement in an optical resonator to achieve a very large trap depth and trapping volume from moderate two Watts of laser power.

A broad Feshbach resonance for a mixture of the two lowest spin states of the ^{6}Li ground state leads to resonant quantum mechanical scattering at magnetic fields near 800 G. The elastic collision properties in magnetic fields up to 1500 G were initially observed through evaporative loss of atoms from our dipole trap. In that way we could observe a zero crossing in the scattering length at 530(3) G that manifested itself through the absence of evaporative loss.

In subsequent experiments, the tunability of the interactions in the vicinity of the Feshbach resonance proved to be ideal to form stable weakly bound $^6Li_2$-molecules through three-body recombination. The high collisional stability of these molecules together with an expected very large elastic collision rate allowed us to evaporatively cool the molecules into a molecular BEC in a second focused beam optical dipole trap. Two independent manifestations of the presence of the condensate were the excitation of a characteristic collective oscillation mode, and the tunability of the mean field of the condensate using the magnetic field. The phase transition to the BEC was observed by imaging the characteristic bimodal spatial distribution of our cloud that represents a narrow condensed fraction and a broader thermal distribution.

The molecular condensate that was the final achievement of this thesis represents the strong-coupling limit of the so-called BEC-BCS crossover. Subsequent experiments showed that by tuning the magnetic field, the coupling strength can be adiabatically reduced and a crossover to a weakly interacting highly degenerate Fermi gas can be realized. This tunable quantum gas is an ideal model for such diverse systems as neutron stars, high-T_c superconductors, and heavy nuclei.