Abstract

In this thesis about »*Ultracold paired atoms in coherent light fields*« I report about several experiments which I performed during my PhD studies. Ultracold paired atoms appear in several varieties: In terms of molecules, in terms of a coherent superposition state of atoms and molecules as well as in terms of so-called repulsively bound atom pairs. In all cases coherent light fields play a key role for the creation and investigation of these pairs.

In one of these experiments we use light to directly couple unbound atoms of a Bose-Einstein condensate (BEC) to a molecular state by means of a two-color photoassociation transition. Thereby we create a novel atom-molecule dark state which is a coherent superposition state of a BEC of Rubidium (Rb) atoms and a quantum degenerate gas of Rb_2 molecules.

I further report on the creation of long-lived ultracold molecules in an optical lattice using a magnetic Feshbach resonance. Ramping the magnetic field we efficiently associate pairs of bosonic atoms which are located on the same lattice site into molecules. This process benefits from the optical lattice in several ways. A deep lattice leads to high atomic densities which allows fast conversion speeds and high stability. With two atoms per lattice site the system is precisely defined and allows for a simple quantum mechanical description. In addition the optical lattice protects the formed molecules from detrimental collisions with other atoms or molecules. In this way we achieve nearly unit conversion efficiency between pairs of atoms into molecules together with a long lifetime. This presents a substantial improvement compared to previous experiments without an optical lattice.

During the study of the properties of atom pairs in an optical lattice we discovered a novel bound state which is caused by the *repulsive* interaction of the atoms. The decay of such a pair is suppressed since in the periodic potential of the optical lattice the allowed energy states are severely restricted and hence a conversion of the interaction energy into kinetic energy is not possible. For the study of these so-called repulsively bound pairs we used as essential tools the methods we developed for creating molecules in an optical lattice.

The experiments we performed enable new possibilities for the chemistry of ultracold atoms and molecules, for condensed matter physics as well as for quantum information.