Abstract

Control of external and internal degrees of freedom at the level of single quantum states is essential for a series of molecular physics experiments. Heteronuclear dimers feature a large electric dipole moment, which makes them particular interesting candidates for experiments with strongly interacting quantum gases. However efficient cooling schemes such as laser cooling are difficult to realize for molecules. Therefore we create ultracold molecules from already cooled ultracold gases.

This this work presents a series of experiments that has been carried out in order to create the molecules in their lowest internal quantum state. Techniques to create ultracold atoms are readily available. However, the creation of stable mixtures is still a challenge since inter-species scattering plays a role in addition to intra-species scattering physics. This requires us to cool two clouds of ^{87}Rb and ^{133}Cs separately and merge the clouds afterwards. After overlapping the BECs, we produce weakly bound RbCs molecules using the Feshbach-association technique. We transfer the molecules from the weakly bound state to the lowest vibrational and rotational level of the $X^1\Sigma^+$ electronic ground-state potential. For the transfer the initial and the final state are linked with lasers to an intermediate electronically excited state. The transfer is achieved by the Stimulated Raman Adiabatic Passage (STIRAP) technique.

In order to identify a suitable route for STIRAP a variety of electronically excited molecular levels is investigated by high resolution spectroscopy. Two-photon spectroscopy is used in order to determine the binding energy of the lowest ro-vibrational level of the $X^1\Sigma^+$ ground state to be $D_0^X = 3811.5755(16)\,\mathrm{cm}^{-1}$. The vibrational level 29 of the $b^3\Pi_1$ electronic excited potential is determined to feature suitable couplings to both the initial and the final state and the molecules are transfered to the ground state with an efficiency of 89%. In order to determine the hyperfine level of the molecular ground state, the hyperfine splitting is measured and STIRAP transfer to a different vibrational level is carried out. It is found that for RbCs the Feshbach molecules can be directly transferred to the lowest hyperfine level of the ro-vibrational ground state.