Imaging of ultracold Bose-Fermi mixtures

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Application Note

Introduction

In the group of Prof. Dr. Matthias Weidemüller at the University of Heidelberg few- and many-body effects of quantum systems as well as dipolar quantum gases are studied with Bose-Fermi mixtures of Cesium and Lithium atoms at nanokelvin temperatures.

Experiments

For the sample preparation in the experiment, a slow atomic beam of Cesium and Lithium atoms is leaving a Zeeman slower and is captured and cooled by standard laser cooling techniques. Forced evaporation out of an optical dipole trap, confining the atoms inside two crossed light beams with high intensity, cools the gas to ultracold temperatures in the nanokelvin regime. The interaction of the Lithium and Cesium atoms can be manipulated via Feshbach resonances using magnetic fields. In this environment, we observe density and momentum distributions of the atomic clouds by absorption imaging.

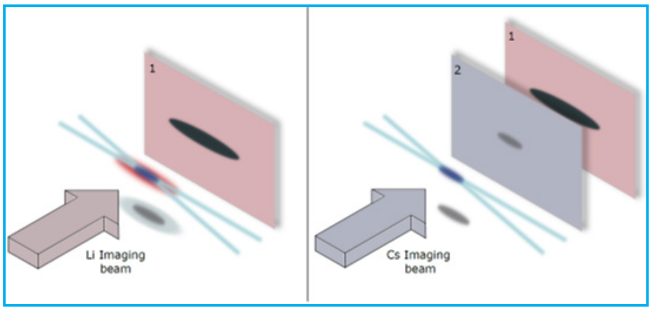

Figure 1: Sequential absorption imaging of a combined cloud of ultracold Cesium and Lithium atoms. First, light resonant to Lithium (red) images the Lithium cloud (red). The image is shifted to the dark region of the CCD chip and stored. The right image shows absorption imaging of Cesium with resonant light (blue) of the Cesium cloud (blue). Both images are stored on the chip and read out simultaneously.

Absorption imaging

For absorption imaging an almost homogeneous, resonant laser beam is illuminating the atomic cloud and is partially absorbed. The remaining light, holding information of the atomic cloud, is then registered on a CCD chip. By comparison with a reference image without atoms the column density of the atoms can be reconstructed.

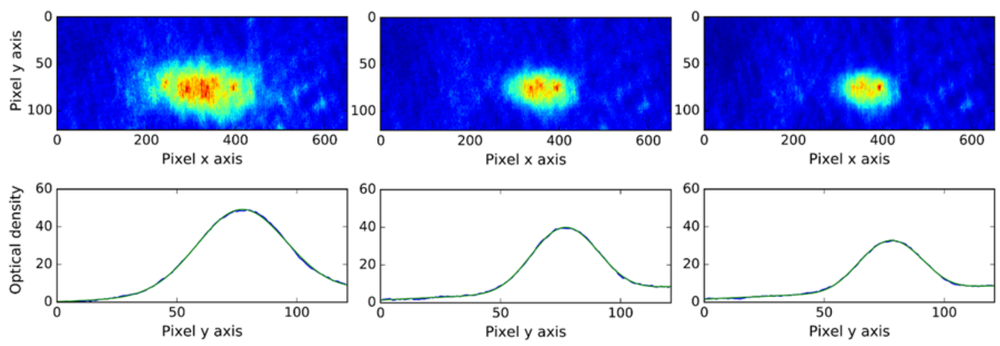

Figure 2: The top row shows absorption images of a degenerate Lithium-6 cloud in an optical dipole trap for temperatures of around 500 nK, 120 nK and 60 nK for the images from left to right taken with the iKon-M camera. The bottom row shows the doubly-integrated atomic density distribution. A theoretical function is fitted to the distribution to extract the temperature and the grade of degeneracy.

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When taking images with different waiting times after release out of the trap (time-of-flight), information about the momentum destitution of the atomic cloud can be extracted. Short time delays between absorption and reference image are beneficial to reduce fluctuations and noise due to changes in the profile and intensity of the imaging beam. Since two different atomic species are used in the experiment we need to take four different images in order to characterize the whole system, one pair for Lithium and one for Cesium.

Recently we have set up a new imaging system, which allows for imaging of both atomic species on an Andor iKon-M Back Illuminated Deep Depletion CCD sensor (DU934P-BEX2-DD) within a short time frame of 2 ms. The camera offers low noise levels and high quantum efficiencies at both resonant wavelengths, which could be confirmed by our measurements. To minimize the time delay between consecutive images we make use of Andor's fast kinetics mode: we mask three quarters of the chip by a razor blade. The imaging beams only illuminates the top part of the chip. After exposure each image is quickly shifted down and stored in the non-illuminated part of the chip. Finally, the whole chip is read out and we obtain the four images. This allows us to take four images with a minimal time delay of less than 0.5 ms between consecutive images. Figure 2 shows absorption images of a Lithium cloud at temperatures between 500 and 60 nanokelvin taken with the Andor iKon-M camera. From the density profiles of the clouds the temperature as well as the degree of quantum degeneracy was extracted.

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