# Ultracold Fermi-Fermi Mixtures of $^6$Li and $^{40}$K

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## Application Note

### Introduction

Ultracold Fermi gases with tunable interactions are a rich test-bed for studying the many-body physics of strongly interacting quantum systems. These systems play an important role in the understanding of condensed matter as well as nuclear physics. In our experiments, we prepare an ultracold Fermi-Fermi mixture of $^6$Li and $^{40}$K atoms in order to investigate the physics of a $^{40}$K impurity in a Fermi sea of $^6$Li [1]. The interactions between the two species can be varied in situ with the aid of a magnetically tunable Feshbach resonance.

### Experiments

In our experiments, the measurements are based on absorption imaging of clouds of $10^3$–$10^9$ atoms. From the absorption image we extract the density distribution of the clouds after release from an atom trap. Absorption imaging relies on shining a resonant laser beam onto the atoms and detecting the shadow cast by the absorption of the photons onto the EMCCD chip. Three sequential images are taken in order to do this: a background image without imaging light and two images with imaging light and with/without atoms. By comparing these images, we determine the amount of light absorbed by the atoms. Using Beer's law, we calculate the optical depth (OD) and determine the density of the atomic cloud. By taking the image a variable time after release from the atomic trap, we can also obtain the temperature of the cloud.

We recently integrated the EMCCD camera (Andor Luca-r DL604M) into our setup for diagnostics of cold and ultracold atoms. This camera enables us to image the atomic clouds right after we released them from a magneto-optical trap (MOT). To optimize the MOT cooling stage, we took absorption images 300 µs after switching off the MOT beams. Since the stray light from the MOT beams blinds the EMCCD chip, a fast read-out of the sensor is required to clean the saturated pixel lines before the image is taken. Typical images of the OD of the $^6$Li and $^{40}$K MOT are shown in Figure 1.

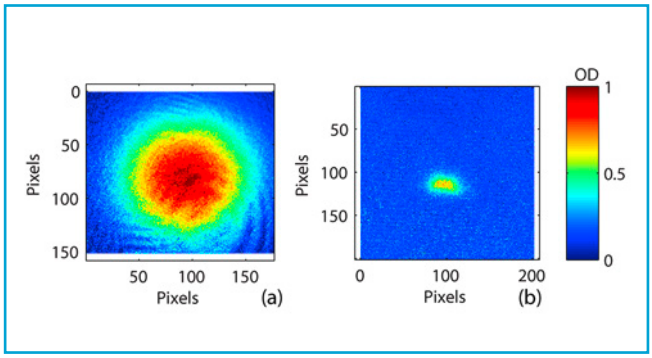


Figure 1. Typical optical depth (OD) images from the lithium (a) and potassium (b) atom cloud taken 0.3 ms after release from the magneto-optical trap. The magnifications and regions of interest differ.

The lithium image had an exposure time of 0.1 ms to the resonant laser beam and shows ~$10^9$ Li atoms at ~300 µK. The potassium image shows ~$10^5$ K atoms at ~200 µK with an exposure time of 0.05 ms. Images of this type are used to optimize the MOT settings in preparation of further cooling and trapping of the gas clouds for measurements in the degenerate quantum regime.

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### References

[1] C. Kohstall et al., Nature 485, 615 (2012)

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