Ytterbium Quantum Gases in Optical Lattices

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Institute of Laser Physics, University of Hamburg, Germany (September 2013)

Application Note

Introduction

The research group "Quantum gases and spectroscopy" around Prof. Klaus Sengstock (Institute of Laser Physics and Center for Optical Quantum Technologies, University of Hamburg) focuses on the study of ultracold atoms in so called optical lattices. These ultracold samples allow for the creation of model systems in regimes currently not accessible by other experimental methods.

Experiment

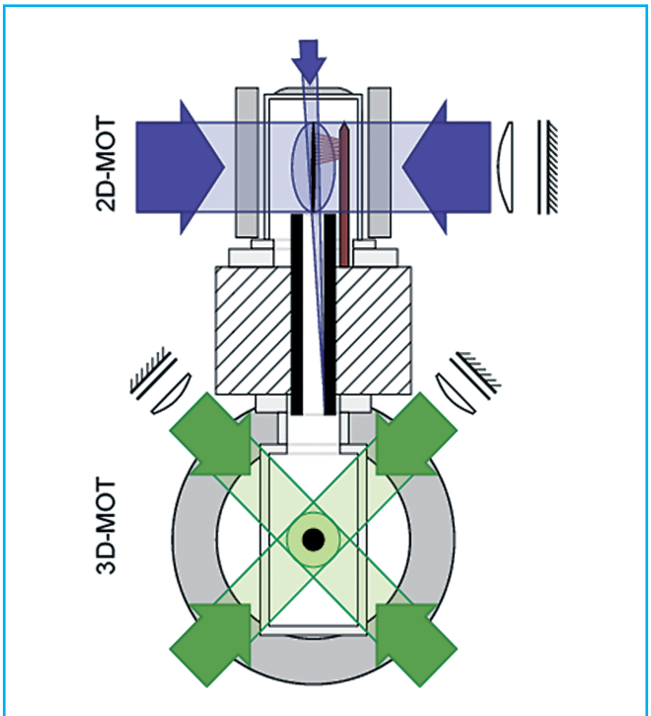

Figure 1 Experimental setup used for the creation of ultracold Ytterbium samples. The atoms are first captured and pre-cooled in a two-dimensional magneto-optical-trap (MOT) and are afterwards transferred to a three-dimensional MOT for further cooling.

For the experiments the optical lattice is created via laser beams which trap the atoms in the resulting standing wave, resembling a lattice structure. We use Ytterbium atoms which offer us new and until now unused features. With its special energy level structure, Ytterbium offers us a so called optical "clock" transition with ultra-narrow line width (some tens of mHz). This transition will allow us to probe the atomic sample with unprecedented precision and exercise a great amount of control allowing us to address specific classes of atoms in the lattice.

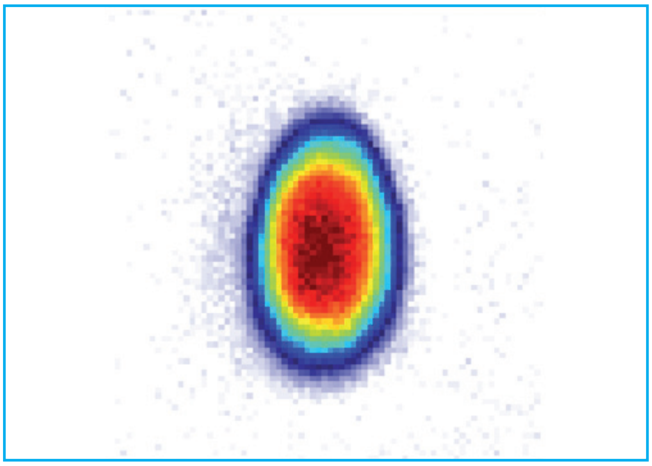

Figure 2 Typical time-of-flight image taken by the Andor iXon. The image shows about 200.000 Ytterbium atoms at temperatures of some tens of nK.

To detect and analyze the ultracold sample we use a technique called time-of-flight (TOF) imaging. For this the atoms are released from the trap and allowed to expand freely. Typically after about 20 ms of free expansion we create an image of the ultracold atoms using a resonant laser beam.

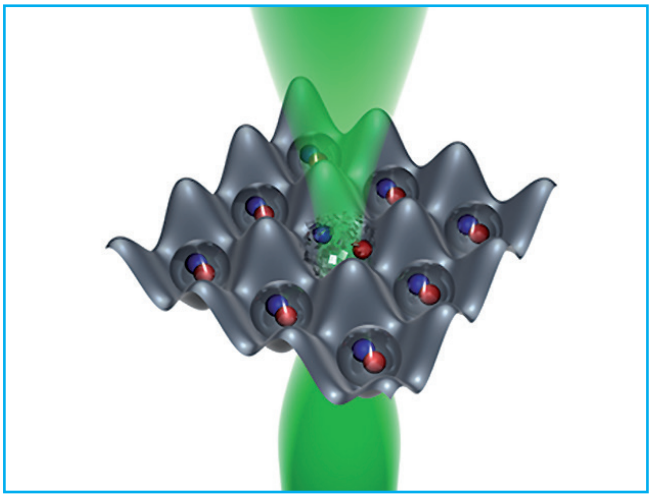

Figure 3 The ultra-narrow optical clock transition allows local, high resolution detection and manipulation of the quantum many body system in the optical lattice.

The current experimental setup uses the Andor iXon3 DU888-DC-QBB with a quantum efficiency of about 70% at 399 nm to image the atomic cloud. The detection sequence consists of capturing three individual images. The first image is called the absorption image. Here, the resonant beam is partly absorbed by the atoms and the resulting shadow is imaged onto the EMCCD chip.

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To correct for the inhomogeneous shape of the imaging laser we need to take a second image (called "reference image"). During acquisition of this image the atoms moved out of the field of view of the camera chip so essentially the profile of the laser is imaged onto the chip. The third image is taken without any laser light to compensate for dark counts and stray light. In order to minimize disturbing interference fringes the first two images have to be taken in rapid succession. For this we make use of the "Fast-Kinetics" mode of the Andor iXon3. In this mode we capture the absorption image onto one half of the EMCCD chip while the other half is masked with a razor blade. The image is then shifted to the darkened area while the reference image is saved to the open part of the chip. For future experiments where we need to detect the very weak fluorescence signal of the atoms we will make use of the electron multiplying capabilities of the iXon. The camera is controlled via a self-written LabView program which in turn uses the software development kit provided by Andor.

References

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