In-trap imaging of strongly interacting Rydberg gases

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Application Note

Introduction

The field of Rydberg excitation of neutral atoms has seen large growth in recent years [1-3] due to the strong, controllable interactions inherent between Rydberg atoms. Recent experiments [4] have shown that the excitation of a single Rydberg electron in a Bose-Einstein condensate (BEC) leads to a strong mechanical coupling between the Rydberg electron and the ground state atoms. In our experiment we aim to directly image this coupling.

Experimental setup

Our setup consists of an ultra-high vacuum chamber within which we cool and trap rubidium 87 atoms in a magneto-optical trap. We trap a few billion atoms at a temperature of a few tens of microKelvin. These atoms are then magnetically transported to a quadrupole-Ioffe magnetic trap where they are evaporatively cooled. We reach the BEC phase transition in 15 s with approximately one million atoms.

Inside our vacuum chamber we have high numerical aperture lenses (NA = 0.55) which allow us to achieve 1 μm imaging/focusing resolution. Incorporating these lenses into a 44X telescope permits in-trap imaging of the cold cloud where one micron in the imaging plane is magnified onto three pixels on the camera. After cooling the trapped atoms we resonantly excite them to Rydberg states using short laser pulses.

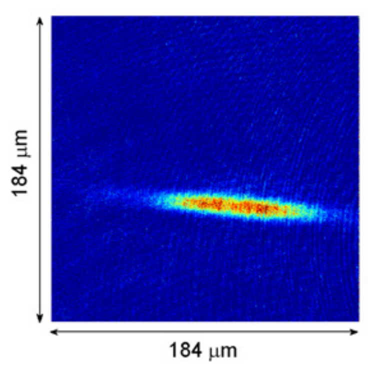

Figure 1: In-trap absorption image of our BEC. Image represents the full chip of the camera. The cloud is approximately 100 nK and is ≈100 μm by 10 μm in size.

Measurements

We employ an absorption imaging technique to image the shadow of the cold atom cloud onto a back-illuminated EMCCD camera (Andor iXon3 DU897 ECS-EXF). The very low noise and high quantum efficiency of the camera at both 420 nm and 780 nm (the two usable imaging wavelengths) are important as the effect we wish to measure is very small. The high magnification in our imaging setup allows us to directly measure the cloud shape and density profile in the magnetic trap. We illuminate the condensate with a thirty microsecond pulse of 420 nm light on resonance with the $5S_{1/2}$ to $6P_{3/2}$ transition. An example image of our BEC is shown in figure 1. As we can take images of the BEC in trap we will now investigate the effect of Rydberg atoms interacting with the ground state atoms with spatial and temporal resolution.

References

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