Detection of Spin Squeezing on an Atom Chip

Pascal Böhi, LMU Munich (January 2010)

Application Note

The group of Prof. Hänsch is located at the Ludwig-Maximilians-Universität in Munich. In our experiments, we study interactions in many-particle systems on atom chips. Starting point is a Bose-Einstein condensate of about 1000 atoms, which is in a coherent superposition of two internal hyperfine states. During a well-chosen time, we split and recombine the wave functions of the atoms in the different hyperfine states in a coherent way. This leads to spin squeezing, which could be used to improve future atom clocks or interferometers.

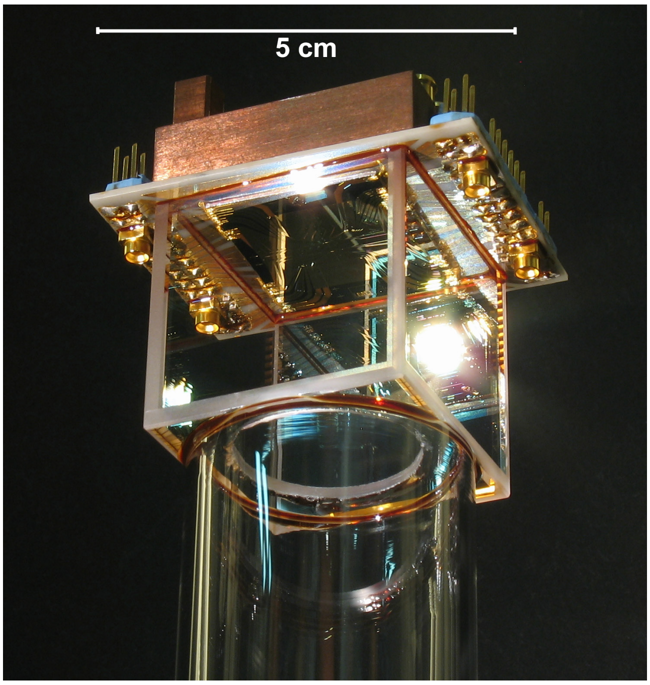

Fig. 1 Picture of our atom chip. The chip is an integral part of an UHV glass cell. Through the contacts at the left and right end of the atom chip, dc as well as microwave currents are fed onto the chip. The magnetic fields of those currents create the trapping potential for the atoms.

For the detection of spin squeezing, we use hyperfine state selective absorption imaging, where a laser illuminates the atom cloud, which leads to a shadow of the atoms in the resonant hyperfine state on a CCD chip.

The spin squeezing cannot be extracted from a single picture, but it is extracted from the fluctuations in the number of atoms in different hyperfine states, measured over many experimental runs. Therefore, to take out fluctuations arising from a variation in the total atom number prepared it is very important to image the atoms in both hyperfine states separately in each shot of the experiment.

Furthermore it is crucial to detect with high quantum efficiency while having very low background noise on the camera.

We achieve this by using the iKon-M DU934N-BR-DD back-illuminated deep depletion camera (Andor Technology, Belfast). The camera has got a quantum efficiency of 90% at 780 nm and is cooled to -80°C using air-cooling only.
Two thirds of the CCD are shadowed and only used as a storage area. We start with two laser pulses which uncover the different hyperfine states. The illuminated area of the CCD is moved behind the aperture after each exposure using Fast Kinetics line shifts. This takes only 1.6 ms. With a third laser pulse we take an image without atoms, which acts as a reference to determine the number of atoms on the first two pictures.

From these three images we are then able to measure the difference in the number of atoms in both hyperfine states with an uncertainty below 7 atoms rms.

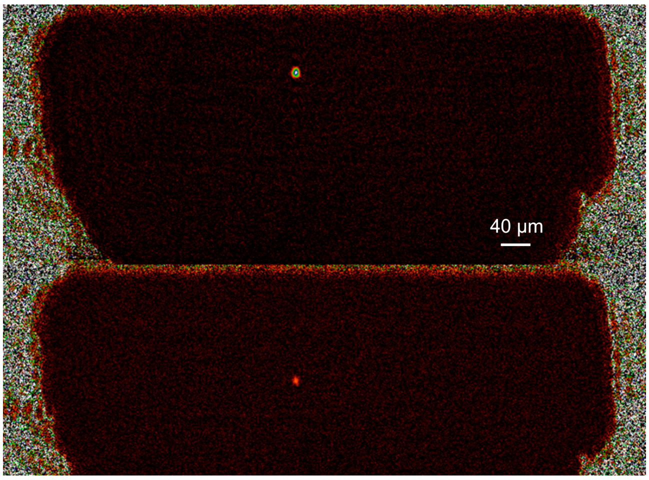

Fig 2 Picture of atom number densities in the different hyperfine states (top F=2/ bottom F=1). There are in total about 1000 atoms. We detect the difference in the number of atoms in the two hyperfine states with a noise of less than 7 atoms rms.

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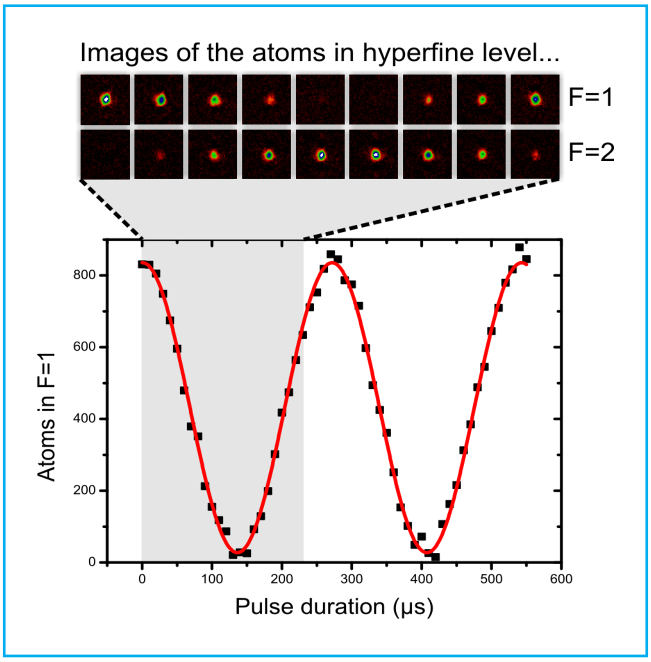

Fig 3 Rabi oscillations in the population of F=1 as a function of the microwave pulse duration which drives the transition between F=1 and F=2. On top, the individual images are shown from which we extract the shown oscillations.

The spin squeezing experiments would not have been possible without a camera that is capable of imaging both hyperfine states in each shot individually.

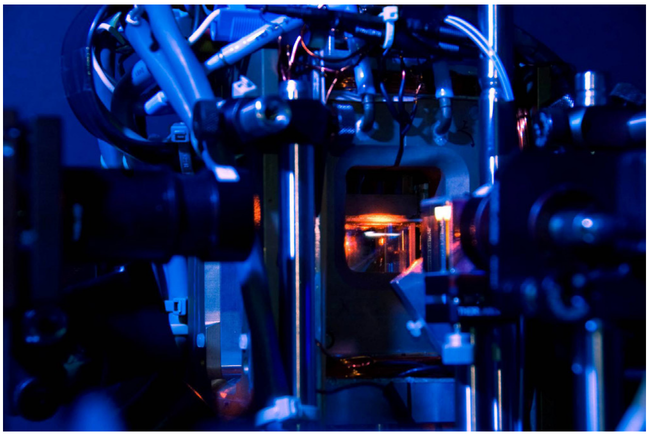

Fig 4 Image of the setup, including the atom chip in the center. The red glowing is due to scattering of the lasers for the MOT.

Application Note

For data processing we use a self-written program for which we have written camera drivers for various models and vendors. Using the Andor SDK (Windows) it was fairly easy to integrate the camera in the existing software environment.

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