Expansion of 1d Quasicondensates in an Atom Chip Trap

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Application Note

Ultracold atom experiments allow precise control over external and internal degrees of freedom in a quantum many body system. In the group of Prof. Schmiedmayer, the properties of Rubidium atoms trapped in elongated magnetic potentials generated by wire structures on an Atom Chip are studied. Cooled down to temperatures in the nanokelvin regime, the atoms accumulate in the quantum mechanical ground state of the transversal trapping potential, but still occupy a spectrum of states along the elongated trap axis. Such a system allows the investigation of a quantum many body system confined to one dimension, and features a unique phase diagram.

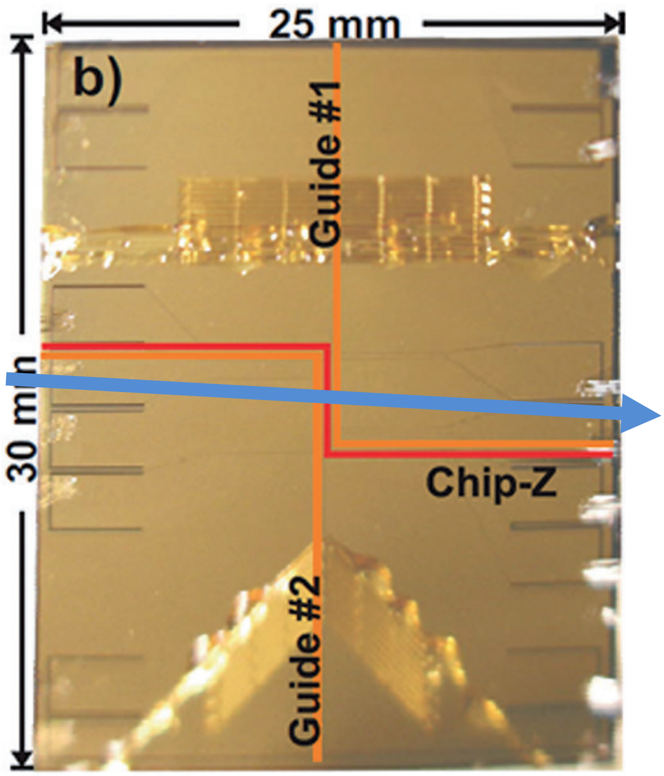

Figure 1: Image of the Atom Chip. The red highlighted wire structure in the chip center is used to trap an atom cloud and cool it down into the quasicondensate regime. The orange structures are used as magnetic waveguide, allowing 1d expansion and transport to different fiber optical elements used to manipulate and detect atoms. The blue arrow indicates the direction of the beam imaging the atoms on the CCD.

Part of this phase diagram ist the so-called quasicondensate phase. As opposed to a 3d Bose-Einstein condensate, which features full phase coherence along all trap axes, the atoms form several domains with phase coherence lengths according to a temperature-dependent distribution. In free expansion, this phase distribution is converted into a density distribution, which can be imaged on a CCD chip by illuminating the atoms with resonant laser light [1].

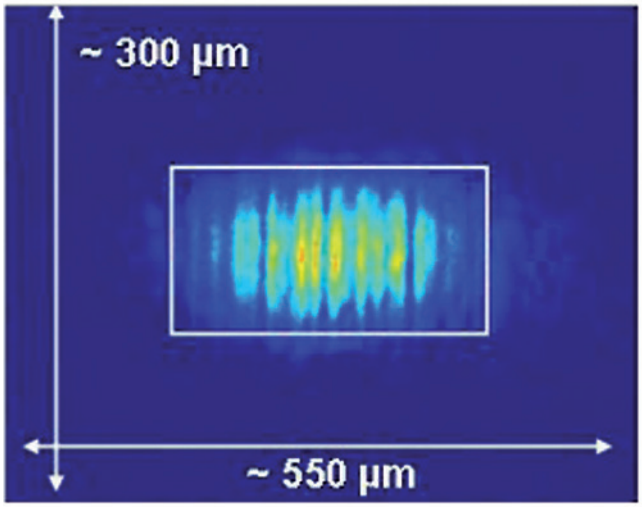

Figure 2: Absorption image of a typical quasicondensate with approximately 15000 atoms after 12 ms of free expansion. The inhomogeneous density distribution can be interpreted in terms of interference between different phase domains during time-of-flight expansion.

The spatial distribution of this density pattern can be analyzed to extract the temperature as well as to gain information about dynamics in the atom cloud. In our experiment, after preparing the quasicondensate, we can transfer the atoms into a magnetic waveguide where they can freely expand along the longitudinal direction [2]. In order to study these dilute expanded clouds reliably, we recently set up a new imaging system based on an Andor iKon-M Back Illuminated Deep Depletion CCD detector (DU934N-BR-DD). It offers high quantum efficiency combined with low noise levels, both of which are critical properties in order to gain sufficient contrast at densities of only a few atoms per pixel.

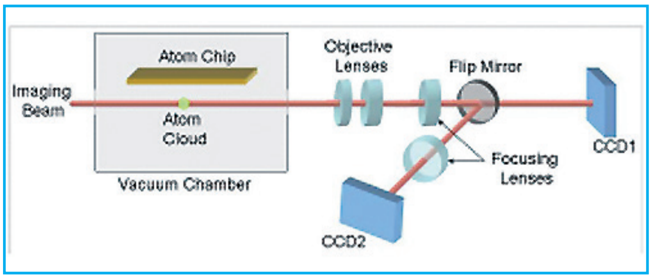

Figure 3: Schematics of the imaging setup.

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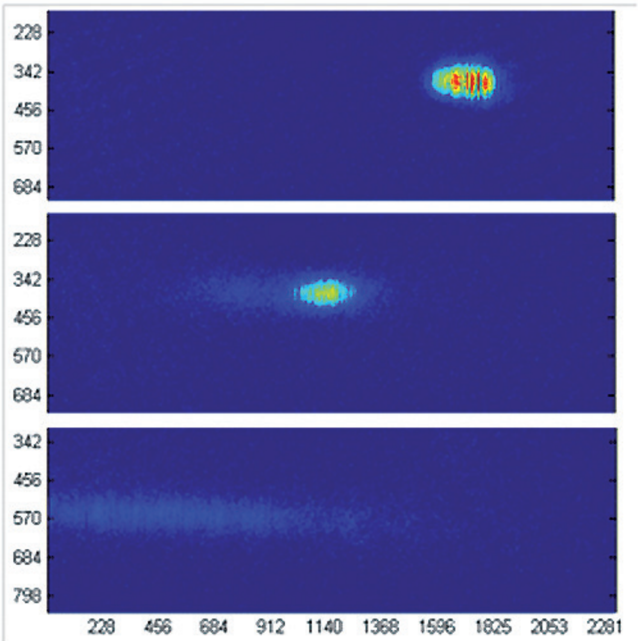

Figure 4: 1d expansion of a quasicondensate. Panel 1 shows the atom cloud after 12 ms 3d expansion from the chip trap. Panel 2 and 3 show a cloud after 50 and 100 ms of 1d expansion within the waveguide respectively, and at additional 12 ms 3d expansion. The inhomogeneity in the density distribution is clearly visible even in the dilute cloud of Panel 3. Axes are given in µm.

References

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[2] D. Heine, W. Rohringer, D. Fischer, M. Wilzbach, T. Raub, S. Loziczky, XiYuan Liu, S. Groth, B. Hessmo and J. Schmiedmayer: A single atom detector integrated on an atom chip: fabrication, characterization and application; New J. Phys. 12, 095005 (2010)

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