Bose Einstein Condensation of Metastable Helium

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The main goal of our research is to study the evolution of relative phase between two Bose Einstein condensates (BEC). In particular, we would like to answer some fundamental questions about the phase of a BEC. Do two well separated BECs have an intrinsic relative phase? Or does the act of measuring atoms released from the condensates impose a relative phase on them? At what stage in the measurement of the phase is the interference pattern established?

To answer these questions our group aims to build a double well metastable helium (He*) BEC. He* can be readily detected atom by atom, by virtue of the 20 eV energy stored in the 2^3S_1 excited state [1]. He* atoms will be condensed into both wells, and atoms will then be output coupled onto a micro-channel plate (MCP) detector. The statistics of the arrival times and positions of these atoms can be analysed to yield phase information of the two condensates. Theorists [2] predict that the ”build-up” of relative phase should be seen after a measurement of only $\sim$ 50 atoms, making such an experiment extremely difficult with alkali BECs for which efficient single atom detection is virtually impossible.

In December 2005 we were able to condense He* for the first time in our laboratory. In our experiment we load around 5x10^8 atoms into a high vacuum magneto-optic trap (MOT) from a low velocity intense atomic beam (LVIS) of He* [3]. To transfer atoms into our magnetic trap we first spatially compress the MOT, by tuning the MOT laser frequency closer to resonance. Following compression the atoms are further cooled to around 200 μK by applying a 3-D Doppler molasses stage at which point the magnetic trap is energised with a bias field of 20 Gauss. In such a configuration the trap has very weak trapping frequencies, typically $f_r = 84Hz$ and $f_a = 75Hz$, which minimises heating of the atomic cloud. At transfer we have around 3x10^8 atoms at a temperature of 600 μK. Immediately after transfer we apply a laser beam along the bias field of the magnetic trap, polarised such that atoms cycle back to the low field seeking trapping state. This laser beam is detuned $\sim -\Gamma/2$ from the $m_f = 1 \rightarrow m_f = 2$ transition and cools the atoms down to $\sim$ 150 μK. The bias field of the trap is then reduced to 5 Gauss, increasing confinement and subsequently increasing the temperature of the gas. To remove this heat we apply a second Doppler cooling stage, once again achieving a temperature around $\sim$ 150 μK. At this point, we have excellent starting conditions to achieve runaway evaporation. We evaporate in six seconds using a trajectory comprising seven linear stages. We reach the transition temperature at $\sim$ 1 μK with around one million atoms.

In the coming year we plan to probe the quantum statistical nature of our BEC.

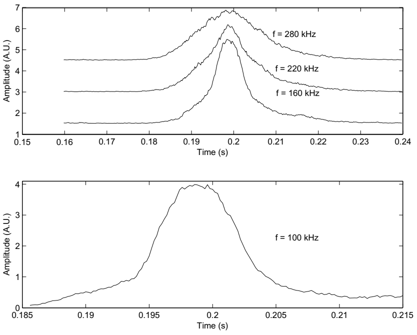

Figure 1: Demonstration of BEC. Time of flight traces taken from an electron multiplier located directly under our magnetic trap. Traces are shown for runs of the experiment with different final evaporation frequencies. As the cloud is cooled down, a bimodal distribution is seen indicating the presence of a BEC.

References

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