Molecular BEC of ^{6}Li$_2$

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Laser and evaporative cooling of atoms has opened the way to studies of quantum degenerate bosonic and fermionic systems. Bose-Einstein condensates of molecules and resonant superfluids, comprised of pairs of fermionic atoms, with long lifetimes can now be routinely prepared [1]. Such systems are the subject of intense investigation and may advance our understanding of other degenerate Fermi systems such as neutron stars and high temperature superconductors. In April 2007 we produced our first highly degenerate Fermi gases (DFGs) and molecular Bose-Einstein condensates (BECs) using a versatile low power crossed optical dipole trap (CDT) [2].

The starting point of our experiments is an isotopically enriched beam of fermionic ^{6}Li atoms which are Zeeman slowed and collected in a magneto-optical trap (MOT). Once around 10^8 atoms are collected in the MOT, the CDT beams, generated from an ELS VersaDisk laser (25 W, 1030 nm), are switched on and the MOT lasers are extinguished. Approximately 4×10^5 atoms are trapped in the CDT in a mixture of the $|F = 1/2, m_F = +1/2\rangle$ and $|F = 1/2, m_F = -1/2\rangle$ ground states. Next, a magnetic field close to the broad s-wave Feshbach resonance at 834 G is turned on to increase the elastic scattering length, a, between atoms in these two states so that $|a| \gtrsim 2500\, a_0$. The intensity of the CDT laser is then lowered by a factor of about 1000 over 3 seconds to achieve forced evaporative cooling. On the low field side of the resonance, where $a > 0$, a bound molecular state associated with the Feshbach resonance exists. As the temperature of the cloud drops below the binding energy of the molecular state, stable dimers are formed and remain trapped in the CDT. These molecules, consisting of two fermions, are bosonic and can undergo Bose-Einstein condensation below a critical temperature (Fig. 1a). Alternatively, on the other side of the resonance, $a < 0$, no bound molecular state exists and a strongly interacting degenerate Fermi gas is produced (Fig. 1b). These two clouds were obtained with identical experimental conditions except using different magnetic fields. The distribution of the trapped Fermi gas is broader and less dense than on the BEC side of the resonance due to Fermi pressure.

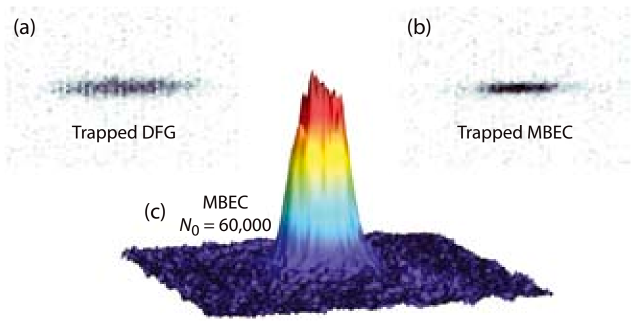

Figure 1: Absorption images of (a) a trapped degenerate Fermi gas and (b) a trapped molecular BEC. (c) A 3D plot of a near pure BEC of 60,000 molecules

We have now replaced the ELS laser with a 100 W IPG fibre laser operating at 1075 nm. We have set up a crossed optical dipole trap with the two lasers beams intersecting at an angle of $14°$, forming a cigar shaped trap with a peak depth of 2.5 mK and oscillation frequencies of 11 kHz and 1.2 kHz in the radial and axial directions, respectively. This increase in trapping power means we now collect more atoms from the MOT resulting in a larger number of atoms/molecules at degeneracy. The colour image (Fig. 1c) shows a near pure BEC of approximately 60,000 molecules prepared in this trap.

References

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