‘Giant’ toroidal Bose-Einstein condensates

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The experimental realisation of gaseous Bose-Einstein condensation (BEC) in 1995 [1] sparked considerable interest in this intriguing quantum fluid [2]. Here we propose the development of a new ^{87}Rb BEC experiment, based on a toroidal magnetic trap. A large (≈ 10 cm diameter) BEC will be formed in the trap, using an ‘open’ geometry well-suited to condensate investigation. The benefits of the system are many-fold, as it should readily enable detailed investigations of persistent currents, Josephson effects and high-precision Sagnac interferometry.

A high-flux ($\approx 10^{10}$ atoms/s) magneto-optical trap (MOT) [3] will be used to multiply load an elongated, forced dark [4] MOT in a differentially-pumped XHV vacuum chamber [5]. The form of this second MOT should decrease light-assisted losses. This will lead to a large trapped atom population by efficiently exploiting the high product of the MOT loading rate and lifetime. Both in-vacuo and ex-vacuo coils are under consideration for subsequent magnetic trapping, however the final geometry will be similar to that of Fig. 1.

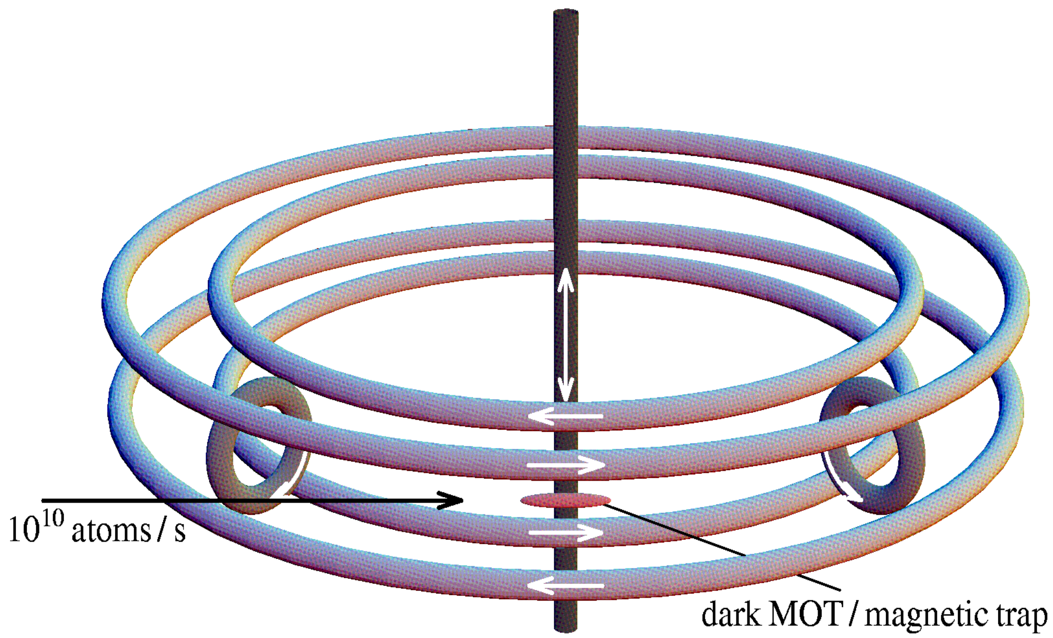

Figure 1: The toroidal magnetic trap. White arrows indicate the direction of currents in the various coils.

The approximately Ioffe-Pritchard [6] type magnetic trap which captures atoms from the elongated dark MOT is comprised of three main magnetic elements (identified by the three shades in Fig. 1). The black straight wire creates a variable azimuthal bias field at the centre of the toroidal quadrupole field generated by the four circular light grey coils. The initial magnetic trap is completed by the dark grey circular 'pinch' coils. The trapped atoms will then be compressed by ramping up the currents in the magnetic coils. This increases the inter-atomic elastic collision rate to facilitate efficient radio-frequency evaporation.

After implementing a suitable evaporation trajectory, condensation will occur in the Ioffe-Pritchard trap in essentially the same manner as most alkali BEC experiments to date. However, by adiabatically ramping down the current in the magnetic trap's pinch coils, atoms can then access the entire torus and a large toroidal BEC will be formed.

The experimental geometry is particularly amenable to imaging the atoms. This high degree of optical access will also facilitate the application of dipole force laser beams for manipulating the BEC in persistent current/Josephson effect experiments. The Sagnac rotational effect is proportional to the enclosed area of the beams in an interferometer. The enclosed area of the toroidal BEC is comparable to existing thermal atomic beam interferometers. Notably, however, it is hoped that the minimum detectable phase shift ($\delta\phi \approx 1/\sqrt{N}$) decreases to $\delta\phi \approx 1/N$ [7] when coherent atoms such as BECs are used. Higher precision Sagnac effect measurement should therefore be possible.

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