Rapid production of metastable helium BEC using a cross-beam dipole trap

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The experimental realization of Bose-Einstein condensation (BEC) provides the possibilities of demonstrating quantum phenomena on a macroscopic scale. The high internal energy between the ground-state helium and its first excited state 23S1 (the metastable state) enables direct detection of single atom by means of electronic detectors such as multi-channel plate (MCP) and delay-line detectors (DLD). This opens up a wide range of exciting experimental possibilities, for example, the BEC experiments on the Hanbury Brown-Twiss (HBT) effect [1], Wheeler's delayed choice [2], Bell tests [3], ghost imaging [4], fermionic anti-bunching[5], quantum quenching [6], quantum depletion [7] and optical lattice physics [8].

However, many of these experiments crucially rely on the measurement of HBT-style correlation functions. Such correlation measurements require a large amount of data [9, 10]. As a result, a single BEC experiment mentioned above usually requires 10,000 – 100,000 experimental runs. This motives us to create an experimental apparatus and sequence that can produce BEC in a relatively short time frame. With the rapid BEC production apparatus, we plan to investigate some special properties of BEC such as the higher-order correlations, thermal dynamics, hydrodynamics, out-of-equilibrium dynamics, quantum quenching, and superfluity.

Here we demonstrate the laser cooling techniques for rapid production of a metastable helium BEC. The experimental setup features an in-vacuum magnetic trap and a cross-beam optical dipole trap. The magnetic trap is a novel quadrupole-Ioffe configuration (QUIC) trap formed by in-vacuum hollow copper tubes, which provides fast switching times and maximizes optical access for BEC experiments using optical lattices. An in-trap 1-dimensional Doppler cooling is used to maximize the transfer of the atoms from the magnetic trap to the cross-beam dipole trap. Evaporative cooling is then performed in the dipole trap to obtain pure BEC. The duration of experimental sequence is 3.3 seconds, with a pure BEC of about 106 atoms observed after evaporative cooling.

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