Bose-Einstein Condensation in a Permanent Magnetic Microtrap on a Chip

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Microfabricated circuits on a surface produce tightly confining, purpose-tailored, magnetic potentials that can be used as networks of microtraps, waveguides and beamsplitters for ultracold atoms (atom chips). The miniaturisation of components greatly simplifies the creation of Bose-Einstein Condensates (BECs). The Swinburne atom chip combines a perpendicularly magnetised film (TbGdFeCo) with current-carrying wires for the production and manipulation of BECs. The two technologies allow greater flexibility in the quantum control of matter waves.

Fig. 1. A combination of a magnetic field from a perpendicularly magnetised film and a bias field produces a radially symmetric two-dimensional waveguide above the surface. The strength of the radial confinement and the location of the waveguide are determined by the value of the bias magnetic field.

A current-carrying conductor on the chip is initially used for laser cooling and compression of the atomic cloud. A magnetic trap located 560 μm from the surface is also employed for preliminary RF cooling of rubidium-87 atoms to a temperature of ~5 μK. The atoms are then transferred to a magnetic film microtrap 90 μm from the surface (Fig. 1) and evaporatively cooled for 1 s to the BEC phase transition (Fig. 2). The atom chip creates a new condensate of around 10^5 atoms in the magnetic film trap every 50 s [1].

Fig. 2. Absorption images of an atomic cloud, released from a magnetic film trap, after 30 ms of ballistic expansion. The images were taken at different stages of evaporative cooling and correspond to: (a) a thermal cloud (Gaussian distribution), (b) a partially condensed cloud (bi-modal distribution corresponding to the onset of BEC), (c) a pure condensate.

The radial potential of the magnetic film trap has been characterised by observing centre of mass oscillations of the trapped atoms. Harmonic oscillations with small amplitude were monitored over many periods. By exciting centre of mass motion the frequency of the radial oscillations (~1 kHz) can be measured to better than 1 Hz accuracy due to low damping rates and small spatial extent. The value of the trap frequency in combination with the trap bottom potential unambiguously determines the local magnetic field gradient. The frequency and the position have been measured against different values of an applied bias magnetic field. The data are consistent with the prediction of a simple model of a perpendicularly magnetised film (Fig. 1).

References