Permanent magnetic lattice on an atom chip

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Periodic optical lattices produced by the interference of intersecting laser beams are widely used for manipulating ultracold atoms and Bose-Einstein condensates and for performing fundamental physics experiments such as studies of low dimensional quantum gases and quantum tunnelling experiments including the superfluid to Mott insulator quantum phase transition. Periodic lattices also have potential application in quantum information since they may provide storage registers for qubits based on single atoms.

An alternative approach for producing periodic lattices for ultracold atoms is to use the magnetic potentials of periodic arrays of magnetic microtraps [1]. We have successfully loaded and trapped ultracold rubidium-87 atoms in a 1D permanent magnetic lattice of period 10 μm on an atom chip [2]. The periodic magnetic field potential is produced by a grooved silicon substrate coated with a multi-layer structure of perpendicularly magnetised TbGdFeCo of thickness 1 μm (Fig. 1). Ultracold rubidium atoms are evaporatively cooled in a Z-wire magnetic trap on the chip and then adiabatically transferred to the magnetic lattice potential by applying an appropriate bias field. Under our experimental conditions up to 2 x 10^6 rubidium atoms are trapped in about 150 lattice sites at less than 5 μm from the chip surface with a measured lifetime of about 450 ms at trap frequencies of up to 90 kHz.

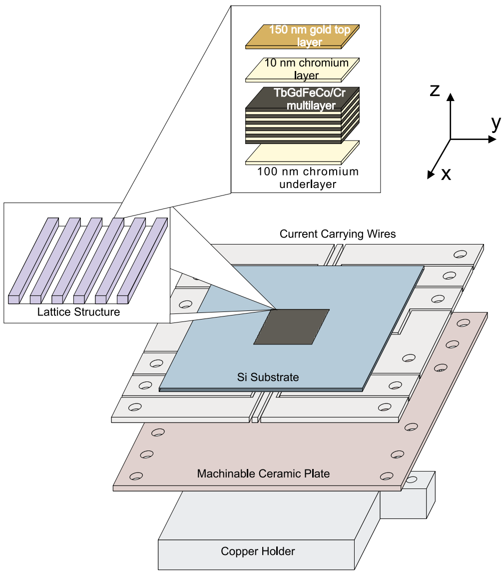

Figure 1: Periodic magnetic microstructure on an atom chip

Magnetic lattices based on permanent magnetic films are highly stable with low technical noise and low heating rates; they can have large and controllable barrier heights and large trap curvature leading to high trap frequencies; and they can be constructed with a wide range of periods, down to about 1 μm. The atoms need to be prepared in low magnetic field-seeking states, allowing RF evaporative cooling in situ and the use of RF spectroscopy. We consider magnetic lattices to be complementary to optical lattices, in much the same way as magnetic traps are complementary to optical dipole traps.

References

[1] S. Ghanbari, T.D. Kieu, A. Sidorov and P. Hannaford, J. Phys. B **39**, 847 (2006).
[2] M. Singh, M. Volk, A. Akulshin, A. Sidorov, R. McLean and P. Hannaford, J. Phys. B **41**, 065301 (2008).