Manipulation of ultracold atoms using magnetic and optical fields

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Abstract

The loading and guiding of a launched cloud of cold atoms with the optical dipole force are theoretically and numerically modelled. A far-off resonance trap can be realised using a high power Gaussian mode laser, red-detuned with respect to the principal atomic resonance (Rb 5s-5p). The optimum strategy for loading typically 30% of the atoms from a Magneto optical trap and guiding them vertically through 22 cm is discussed. During the transport the radial size of the cloud is confined to a few hundred microns, whereas the unconfined axial size grows to be approximately 1 cm. It is proposed that the cloud can be focused in three dimensions at the apex of the motion by using a single magnetic impulse to achieve axial focusing.

A theoretical study of six current-carrying coil and bar arrangements that generate magnetic lenses is made. An investigation of focusing aberrations show that, for typical experimental parameters, the widely used assumption of a purely harmonic lens is often inaccurate. A new focusing regime is discussed: isotropic 3D focusing of atoms with a single magnetic lens. The baseball lens offers the best possibility for isotropically focusing a cloud of weak-field-seeking atoms in 3D.

A pair of magnetic lens pulses can also be used to create a 3D focus (the alternate-gradient method). The two possible pulse sequences are discussed and it is found that they are ideal for loading both ‘pancake’ and ‘sausage’ shaped magnetic/optical microtraps. It is shown that focusing aberrations are considerably smaller for double-impulse magnetic lenses compared to single-impulse magnetic lenses.

The thesis concludes by describing the steps taken towards creating a 3D quasi-electrostatic lattice for ^{85}Rb, using a CO_2 laser. The resulting lattice of trapped atoms will have a low decoherence, and with resolvable lattice sites, it therefore provides a useful system to implement quantum information processing.

Declaration

I confirm that no part of the material offered has previously been submitted by myself for a degree in this or any other University. Where material has been generated through joint work, the work of others has been indicated.

Matthew J. Pritchard
Durham, 21st September 2006

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“The fear of the LORD is the beginning of knowledge, but fools despise wisdom and discipline.”

Proverbs 1v7

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