Time-Dependent Loading of Conservative Atom Traps

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The field of laser cooling and trapping of neutral atoms has achieved staggering progress during the last two decades. Magneto-optical traps (MOTs) can now be used to trap $\sim 10^{10}$ atoms at a phase space density of $n\lambda_{dB}^3 \sim 10^{-5}$ (where n is the atom number density and λ_{dB} is the de Broglie wavelength of the atom). However, the limits on both number and phase space density are set by processes involving near-resonant light. In many experiments, e.g. precision measurements or Bose-Einstein condensation, far larger atom numbers would be desirable. Both limits can, in principle, be exceeded in a conservative trap, e.g. a magnetic trap or a far-off-resonant dipole trap.

Accumulating a large number of atoms requires a trap loading technique that is not limited by near-resonant light. One possibility, evaporative loading involving a cryogenically cooled buffer gas, has been developed by Doyle *et al* [1], achieving larger atom numbers but lower phase space densities than characteristic of laser cooling. Cornell *et al* [2] have previously demonstrated multiple loading of an ac-magnetic trap with atoms delivered from a MOT. Optical pumping was used to transfer between untrapped and trapped states. Alternatively one can consider multiple loading of a time-dependent trap. In the work presented here, we investigate loading atoms into a conservative potential which is spatially separated from the laser cooling region. To minimise the loss of phase space density during transfer we deliver the cold atoms using a far-off-resonant optical guide [3]. A schematic of the set-up is shown in figure 1. The guide is a 12 W, Nd:YAG focused laser beam, detuned 284 nm to the red of the ^{85}Rb resonance. A fountain geometry facilitates loading of the conservative trap since at the apex the atoms are nearly at rest. A cloud of atoms optically guided over 7 cm has a phase space density comparable to that obtained in a MOT. The phase space density decrease in a similar unguided transfer is $\sim 10^3$.

For the time-dependent conservative potential we have investigated an all-optical trap and a quadrupole magnetic trap. In the all-optical trap, the guiding beam forms the walls of the trap and an additional blue-detuned light sheet, or 'trap door', is used to form the floor. The trap door beam is positioned 1 cm below the apex of the guided atomic fountain and can be switched off to allow atoms to enter the trap from below. It is then switched back on so that atoms fall onto the trap door potential and bounce. We have studied the lifetime and dynamics of the atoms in the trap for a trap door beam with a power of 40 mW, 20 GHz blue-detuned and focused to 10 μm by 200 μm. We have also investigated the conditions under which multiple loading of the trap would be possible. A quadrupole magnetic trap can provide a deeper trapping potential. In this case, better mode-matching of the atomic cloud and the trapping potential is obtained by focusing the cloud using a short magnetic pulse, before switching on the quadrupole field.

The lifetime of the atoms in both traps is sensitive to scattered light from the laser cooling region. This effect can be reduced by trapping in a 'dark state' and by shielding the trap along all directions except the transfer direction. If the effect of scattered light is minimised atom numbers in excess of those achieved in a MOT should become feasible.

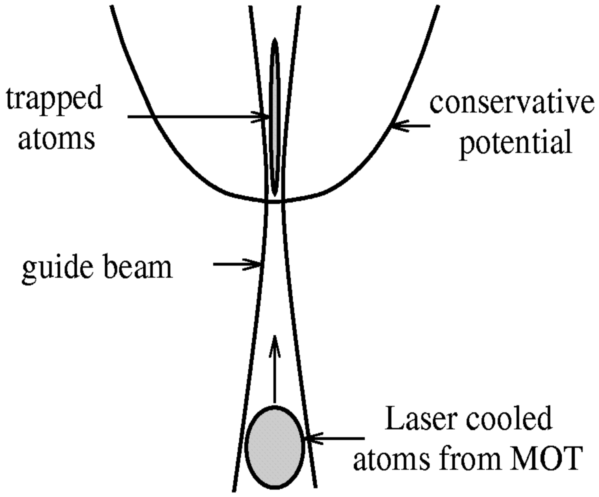

Figure 1: Schematic of loading a conservative trap using an optically guided atomic fountain. Cold atoms are launched from a MOT and guided by a red-detuned, far-off resonant dipole guide beam. When they reach the apex of the fountain a conservative trapping potential is switched on.

[1] J. M. Doyle, B. Friedrich, J. H. Kim and D. Patterson *Phys. Rev. A* **52** 4 (1995).
[2] E. A. Cornell, C. Monroe and C. E. Wieman *Phys. Rev. Lett.* **67** 2439 (1991).
[3] K. Szymaniec, H. J. Davies and C. S. Adams *Europhys. Lett.* **45** 450 (1999).