A rotating-beam optical dipole trap for cold atoms

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In the last few years, several optical dipole traps for cold atoms were demonstrated and used to study cold atomic collisions, long atomic coherence times and quantum collective effects [1]. Blue-detuned dipole traps, where repulsive light forces confines atoms mostly in dark, offer long storage, and photon-scattering times, combined with strong confinement forces [2]. Unfortunately, such blue-detuend dipole traps involve complicated light intensity distributions that require either multiple laser beams [3] or complicated phase elements [2]. Here, we propose and demonstrate a novel configuration for a single-beam blue-detuned dipole trap, which enables larger trapping volume, and fast temporal changes in the trap size and shape.

Our trap consists of a tightly-focused laser beam which is rapidly rotated (with rotation frequency up to 400 kHz) with two orthogonal acousto optical scanners. For very high rotation frequencies the atoms feel a time-averaged static dipole potential. Therefore, when the radius of rotation is larger than the beam size, a dark volume which is completely surrounded by light is obtained around the focal region. By changing the rotation radius and the trapping laser intensity and detuning, the trap dimensions and oscillation frequency could be changed over a large parameter range. In particular trap diameters were changed between 50 to 220 microns and trap length was changed between 3.5 to 16 mm.

$\tilde{}10^6$ atoms were loaded into the rotating-beam dipole trap from a magneto optical trap. The density of the trapped atoms was $\tilde{}4 * 10^{10}$ atoms/cm^3 ,their temperature was $\tilde{}6$ μK. and the trap (1/e) lifetime was 0.65 sec, limited by collisions with background atoms. When the rotation frequency was decreased below the oscillation frequency of the atoms in the trap, the trap became unstable, and a sharp reduction of the trap lifetime was observed, in agreement with our theoretical analysis. Finally, we demonstrated adiabatic compression of atoms in the trap by decreasing the rotation radius and hence the trapping volume. A density increased by an order of magnitude was obtained.

[1] C. S. Adams and E. Riis, Prog. Quant. Electr., **21**, 1, (1997).
[2] R. Ozeri, L. Khaykovich, N. Davidson, Phys. Rev. A., in press (1999).
[3] T. Kuga, et. al., Phys. Rev. Lett., **21**, 4713 (1997); Yu. B. Ovchinnikov, et. al., *ibid.*, **79**, 2225 (1997)