Chapter 1

MOTs

https://journals.aps.org/pra/pdf/10.1103/PhysRevA.70.063413 narrow line cooling and momentum space crystals

https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.93.073003 previous paper narrow line cooling finite photon recoil dynamics For the 689 line in strontium, the ratio of the recoil frequency $\omega_r = \frac{\hbar k^2}{2m} = 2\pi \times 4.8$ kHz to the natural linewidth $\Gamma = 2\pi \times 7.4$ kHz the transition is on the order of unity. this is what defines a narrow line MOT.

1.1 Finite photon recoil dynamics

The 1s0-3p1 transition has its single photon recoil is of comparable sixe to the natural linewidth. When an atom of mass m emits or absorbs a photon γ of frequency ω, then momentum of the photon $p_\gamma = h/\lambda = \hbar k$ is transfered to the atom giving it some velocity $v_{rec} = \hbar k/m$

1.2 Regimes of red-detuned MOT

Three regimes of behavior depend on the relative magnitudes of $|\Delta|$, Γ, and $\Gamma_E = \Gamma\sqrt{1+s}$ where Γ is the natural linewidth $s = I/I_{sat}$ is the saturation intensity which may broaden the line. The three regimes are (I) $\Gamma \lll \Gamma_E \lll |\Delta|$, (II), $|\Delta| < \Gamma_E$ and $\Gamma \lll \Gamma_E$ so $\Gamma < |\Delta| < \Gamma_e$ (but perhaps $\Gamma \not\lll |\Delta|$?), and (III), when $s \simeq 1$. and so $\Gamma \not\lll \Gamma_E$.

1.2.1 Red-detuned MOT Regime (I)

In the first regime, $\Gamma \lll \Gamma_E \lll |\Delta|$. For the 689 line in strontium, the ratio of the recoil frequency $\omega_r = \frac{\hbar k^2}{2m} = 2\pi \times 4.8$ kHz to the natural linewidth $\Gamma = 2\pi \times 7.4$ kHz the transition is on the order of unity. In this regime,

1.2.2 regime 2

$|\Delta| \lesssim \Gamma_E$ and $\Gamma \lll \Gamma_E$

this is more typical and thermodynamics remicent of ordinary doppler cooling. δ and s dependent teperature minima

1.2.3 regime 3

s approces unit, photon-tecoil-driven impulsive force dominates and temperature below photon-recoil limit $T_r = 2\hbar\omega_r/k_b$

$$\Gamma \simeq \Gamma_E$$

1.2.4 other regimes?

sing $\Gamma \sim \omega_r$ you get momentum packets. explained by analytic solution to the 1D semiclassical radiative force equation. for $\delta > 0$, and $\Gamma \sim \omega_r$ allow direct visualization of positive feedback acceleration that effeciently bunches the atoms into discrete, well-defined momentum packets. the gravity ratio R directly influences the blue detuned thermodynamics, enabling cooling around a velocyt where radiation pressure and gravity balance. aparently the underlying physics here is the same as regime I but manifest bvery differently.

1.2.5 method

uses frequency modulate redMOT, start at 3G/cm and go to 10 G/cm. Then transition to singlefrequency