BEC and Lattice Numbers

David Chen

Last update: October 13, 2012

1 BEC

- Number of atoms: $N = 1.5 \cdot 10^5$
- Mean trap frequency: $\omega = 2\pi$ (40) Hz
- Rb^{87} mass: $m = 87$ g/mol
- Rb^{87} s-wave scattering length: $a_s = 5.5$ nm
- Interaction energy: $U_0 = 4\pi\hbar^2 a_s/m = 5.3 \cdot 10^{-51}$ Jm^3 (find better units)
- Characteristic length: $a_{osc} = \sqrt{\hbar/m\omega} = 1.7$ μm
- Cloud radius: $R = 15^{1/5} \left(\frac{Na_s}{a_{osc}}\right)^{1/5} \cdot a_{osc} = 10$ μm
- Cloud density: $n = \frac{N}{4\pi R^3/3} = 3.5 \cdot 10^{13}\ cm^{-3}$
- Inter-particles distance: $d = R/N^{1/3} \sim 0.2$ μm
- Sound modes-quasiparticle modes limit: $q = \sqrt{mnU_0}/\hbar = 2\pi/4\mu$m
- Correlation length: $\xi = \hbar/\sqrt{2mnU_0} = 0.5\ \mu m$
- Transition temperature (non-interactive gas): $T_c = 0.94\hbar\omega N^{1/3}/k_B = 96$ nK
- de Broglie wavelength: $\lambda_T = h/\sqrt{2\pi mkT}$
- Phase-space density: $\varpi = n(2\pi\hbar^2/mk_BT)^{3/2}$
- Condensate fraction: $N_0/N = 1 - (T/T_c)^3$

- Doppler broadening @300 K: $\Gamma_D = \frac{\omega_0}{c}\sqrt{\frac{2k_BT}{m}} \sim 2$ Ghz
- $5S_{1/2} \to 5P_{5/2}$ Natural line-width (FWHM): $\Gamma = 2\pi \cdot 6$ MHz
- $5S_{1/2} \to 5P_{5/2}$ lifetime: $\tau = 26$ ns
- Doppler cooling limit (MOT cooling limit): $k_BT_D = \hbar\Gamma/2 \sim 144\ \mu$K
- Recoil energy @812nm (Sisyphus cooling limit): $E_R = \hbar^2k^2/2m = 167$ nK
- Zero-point energy: $E_0 = 3\hbar\omega/2 \sim 0.1$ kHz ~ 3 nK
- Saturation intensity D_2 transition: $I_{sat} = \pi hc/3\lambda^3\tau = 1.7$ mW/cm^2
- Cross section @780nm $\sim 2\ \mu m^2$

2 Lattice

- Recoil energy @812nm: $E_R = \hbar^2k^2/2m = 3678$ Hz $= 167$ nK
- Recoil energy @790nm: $E_R = \hbar^2k^2/2m = 3481$ Hz $= 176$ nK
- Add table of J and U for different lattice depths

3 BEC apparatus

- MOT $\sim 10^8$ atoms, 300 μK (Doppler limit)
- molasses $\sim 80\ \mu$K (sub-Doppler limit)
- MOT magnetic field ~ 10 G/cm
- before loading to the optical trap (trap depth $\sim 50\ \mu$K), $\sim 10^7$ atoms
- after loading to the optical trap, $\sim 5 \cdot 10^6$ atoms
- after evaporation (trap depth$\sim 5\ \mu$K), ~ 150000 atoms, ~ 70 nK

4 Hyperfine Transition Frequencies

For a 10G field:

- $|1,-1\rangle \rightarrow |2,-2\rangle$, $f = 6827.98$ MHz, $t_\pi = 64\mu$s, $\Omega = 49$ kHz
- $|1,-1\rangle \rightarrow |2,-1\rangle$, $f = 6830.213$ MHz, $t_\pi = 200\mu$s, $\Omega = 16$ kHz
- $|1,-1\rangle \rightarrow |2,0\rangle$, $f = 6832.446$ MHz