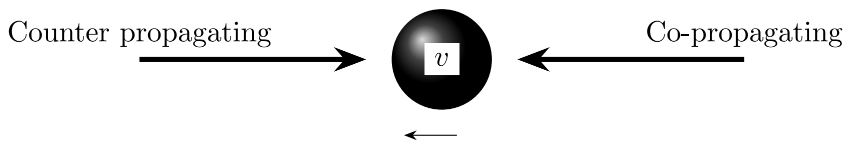
Optical Molasses

Force in Optical Molasses is given by,

$$\vec{F}_{net} = \vec{F}_{counter} + \vec{F}_{coprop} \tag{1}$$



Doppler effect

Doppler formula for counter propagation beam given by,

$$\nu'_L = \nu_L \left(1 + \frac{v}{c}\right) \tag{2}$$

$$\therefore \nu'_L = \left(\nu_L + \frac{\nu_L v}{c}\right)$$

Multiply 2π and using $\lambda_L = c/\nu_L$

$$2\pi\nu'_L = 2\pi\nu_L + 2\pi v/\lambda_L$$

But $k = 2\pi/\lambda_L$,

$$\omega'_L = \omega_L + kv \tag{3}$$

Force calculation for Counter propagating beam

Detuning for counter propagating beam is given by,

$$\Delta = \omega_L - \omega_0 \tag{4}$$

$$\Delta' = \omega_L + kv - \omega_0 = \Delta + kv \tag{5}$$

$$\vec{F}_{counter} = \frac{\hbar \vec{k} \Gamma_{sp} \Omega^2}{4(\Delta + kv)^2 + \Gamma_{sp}^2} \tag{6}$$

Consider,

$$\frac{1}{4(\Delta+kv)^2+\Gamma_{sp}^2} = \frac{1}{4\Delta^2+\Gamma_{sp}^2}\left[1-\frac{8\Delta kv}{4\Delta^2+\Gamma_{sp}^2}\right]$$

Force of counter propagating beam is given by

$$\vec{F}_{counter} = \frac{\hbar\vec{k}\Gamma_{sp}^2\Omega^2}{4\Delta^2+\Gamma_{sp}^2} - \frac{\hbar\vec{k}\Gamma_{sp}^2\Omega^2}{4\Delta^2+\Gamma_{sp}^2}(8\Delta kv) \tag{7}$$

$$\vec{F}_{counter} = \vec{F}_0 - \frac{\alpha}{2}\vec{k}v \tag{8}$$

Force calculation for Co-propagating beam

Detuning for co-propagating beam is given by,

$$\Delta = \omega_L - \omega_0 \tag{9}$$

$$\Delta' = \omega_L - kv - \omega_0 = \Delta - kv \tag{10}$$

$$\vec{F}_{counter} = \frac{\hbar\vec{k}\Gamma_{sp}\Omega^2}{4(\Delta-kv)^2+\Gamma_{sp}^2} \tag{11}$$

$$\vec{F}_{counter} = \frac{\hbar\vec{k}\Gamma_{sp}\Omega^2}{4\Delta^2+\Gamma_{sp}^2}\left[1+\frac{8\Delta kv}{4\Delta^2+\Gamma_{sp}^2}\right] \tag{12}$$

For Co-propagating beam, the wave vector condition is $\vec{k} = -\vec{k}$

$$\vec{F}_{coprop} = -\vec{F}_0 - \frac{\alpha}{2}\vec{k}v \tag{13}$$

Net force is given by adding equation (8) and (13).

$$\vec{F}_{net} = \vec{F}_0 - \frac{\alpha}{2}\vec{k}v - \vec{F}_0 - \frac{\alpha}{2}\vec{k}v \tag{14}$$

Along x-direction, Force is given by,

$$F_x = -\alpha k_x v \tag{15}$$