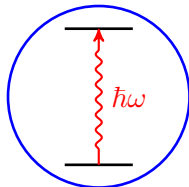# Lamb-Dicke regime/approximation
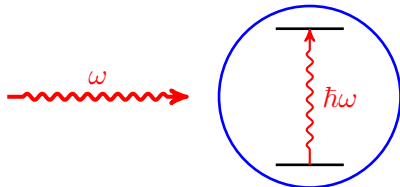
Yichao Yu

Journal Club
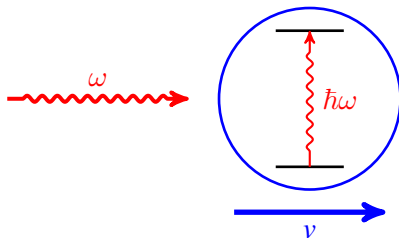
Doppler effect
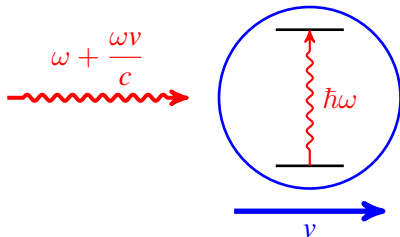
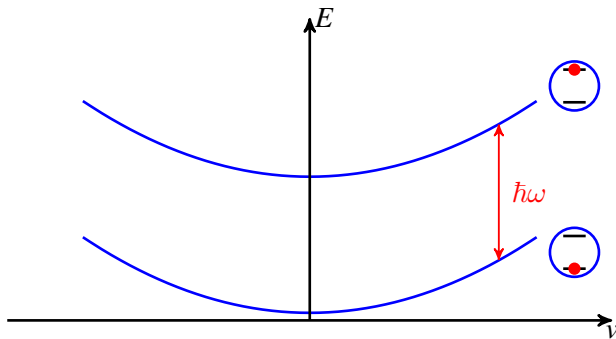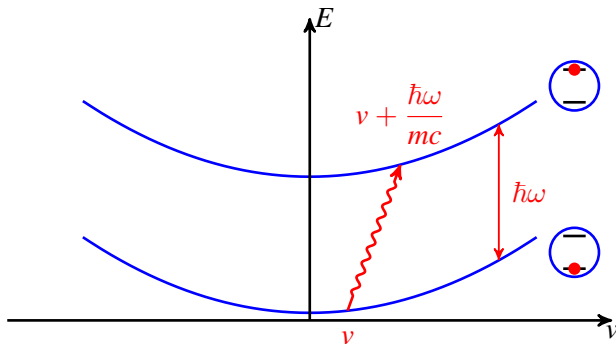# Doppler effect

Doppler effect

Doppler effect

Doppler effect

Doppler effect

Doppler effect
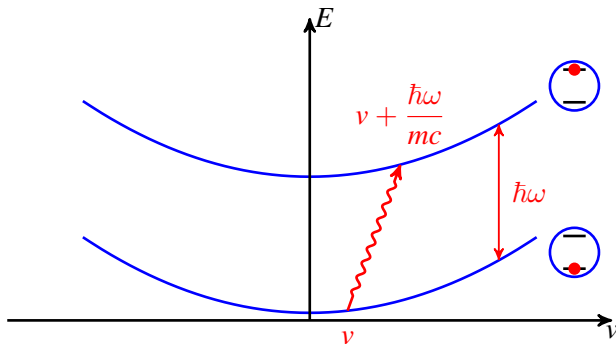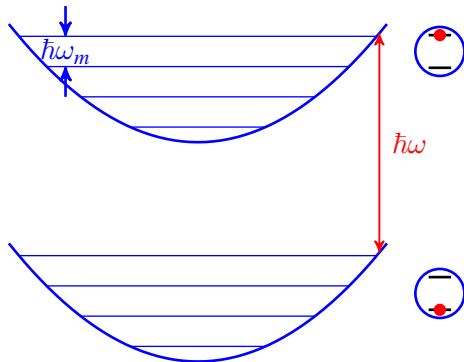

$$\omega + \frac{m}{2\hbar}\left(v + \frac{\hbar\omega}{mc}\right)^2 - \frac{mv^2}{2\hbar} = \omega + \frac{\omega v}{c} + \frac{\hbar\omega^2}{2mc^2}$$

Sideband

Sideband
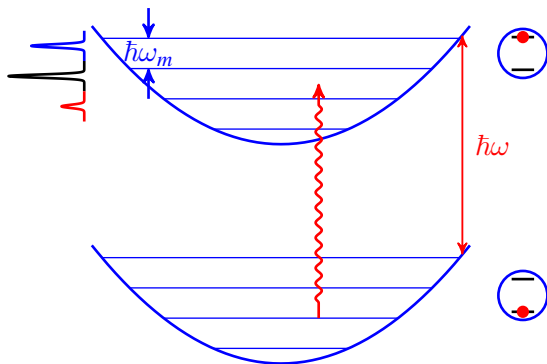
Frequency: $\omega + n\omega_m$

Sideband

Frequency: $\omega + n\omega_m$

Strength: $\langle n|e^{ik\hat{x}}|n + \Delta n\rangle$

Lamb-Dicke parameter

$$\langle n|e^{ik\hat{x}}|n + \Delta n\rangle$$

Lamb-Dicke parameter

$$\langle n|e^{ik\hat{x}}|n + \Delta n\rangle$$

$$\hat{x} = \sqrt{\frac{\hbar}{2m\omega}}\left(a + a^{\dagger}\right) = z_0\left(a + a^{\dagger}\right)$$

Lamb-Dicke parameter

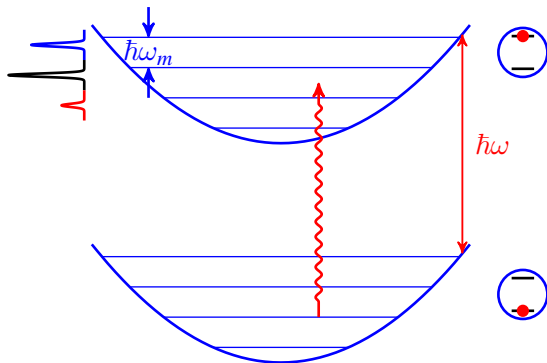$$\langle n | e^{ik\hat{x}} | n + \Delta n \rangle$$

$$\hat{x} = \sqrt{\frac{\hbar}{2m\omega}} \Big(a + a^\dagger \Big) = z_0 \Big(a + a^\dagger \Big)$$

$$k\hat{x} = \eta \Big(a + a^\dagger \Big)$$

$$\eta \equiv kz_0 = k\sqrt{\frac{\hbar}{2m\omega}}$$

Lamb-Dicke parameter

$$\langle n|e^{ik\hat{x}}|n + \Delta n\rangle$$

$$\hat{x} = \sqrt{\frac{\hbar}{2m\omega}}\Big(a + a^\dagger\Big) = z_0\Big(a + a^\dagger\Big) \qquad\qquad \eta = \frac{2\pi z_0}{\lambda}$$

$$k\hat{x} = \eta\Big(a + a^\dagger\Big) \qquad\qquad \eta = \sqrt{\frac{\omega_R}{\omega_m}}$$

$$\eta \equiv kz_0 = k\sqrt{\frac{\hbar}{2m\omega}}$$

Sideband strength
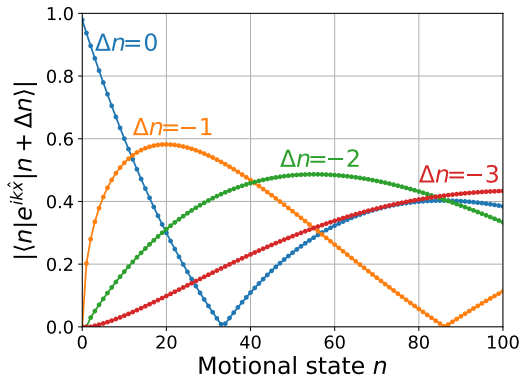
$$\langle n|e^{ik\hat{x}}|n + \Delta n\rangle$$

$$=e^{-\eta^2/2}\eta^{\Delta n}\sqrt{\frac{n_-!}{n_+!}}\,L_{n_-}^{\Delta n}(\eta^2)$$

$$n_- \equiv \min(n, n + \Delta n), \quad n_+ \equiv \max(n, n + \Delta n)$$

Sideband strength

$$\langle n|\mathrm{e}^{\mathrm{i}k\hat{x}}|n + \Delta n\rangle$$

$$=\mathrm{e}^{-\eta^2/2}\eta^{\Delta n}\sqrt{\frac{n_-!}{n_+!}}\,L_{n_-}^{\Delta n}(\eta^2)$$

$$n_- \equiv \min(n, n + \Delta n), \quad n_+ \equiv \max(n, n + \Delta n)$$

Sideband spectrum