**Double Well Potentials**

![Double Well Potentials Diagram]

**D.C. Octopole**

Closed wells $\rightarrow$ large $\beta$

This tends to imply large $\alpha_{x}$, $\alpha_{y}$, $\alpha_{z}$

But to confine we require small $\alpha_{x}$, $\alpha_{y}$, $\alpha_{z}$

$\rightarrow$ Octopole + D.P. Quadrupole $\rightarrow$ small D.C. Quadrupole

$V(x, y, z) = \frac{\epsilon_{0}}{4\pi}\left(\frac{1}{r_{x}} + \frac{1}{r_{y}} + \frac{1}{r_{z}}\right)$

Geometric factors $\gamma_{x}$, $\gamma_{y}$ defined by

- For $Q_{x} = 0$, $\beta = \gamma_{x} = \frac{\epsilon_{0}}{\epsilon}$
- For $\beta = 0$, $Q_{x} = \frac{\epsilon_{0}}{\epsilon}$

Distance to nearest surface

$\zeta = \left[\frac{2(\alpha_{x} + \alpha_{y} + \alpha_{z})}{\epsilon_{0}}\right]^{|\mu|}$

where $d = \text{separation of the ions}$

**Push & Wobble Gate**

- Dipole force in moving standing wave
- Slow oscillation of force: “push”
- Near resonant oscillation of force: “wobble”

**Geometrical Argument**

- COM: Stretch
- Push vs. Wobble: Phase space

**Fidelity**

- Photon Scattering: $N = \frac{\gamma_{x}^{2} + \gamma_{y}^{2} + \gamma_{z}^{2}}{\gamma_{x}^{2} + \gamma_{y}^{2} + \gamma_{z}^{2}}$

- Push: $F = \frac{1}{1 + \frac{T}{\gamma_{x}^{2} + \gamma_{y}^{2} + \gamma_{z}^{2}}}$

- Wobble: $F = \frac{1}{1 + \frac{T}{\gamma_{x}^{2} + \gamma_{y}^{2} + \gamma_{z}^{2}}}$

**Dynamical Argument**

- Push: Coulomb interaction when ion pushed by distance $x_{p}$

- Wobble: Raman transition causes light shift

**Electrode Configurations**

- Some standard octopole configurations

**Discussion**

- Gate time $= \frac{2\pi}{\omega_{W}}$ or $\frac{2\pi}{\omega_{D}}$

- Wobble uses resonance to displace ions further for a given force $\rightarrow$ requires less laser intensity (for given scattering $\alpha$)

- Laser intensity noise typically falls vs. frequency $\rightarrow$ better to oscillate the force at high freq. to cancel single-bit phases.

- However, for a faster gate require $\beta$ not too small $\rightarrow$ intermediate regime where both modes are excited.

- Fine structure $\rightarrow$ Raman on $\Delta$ $\rightarrow$

- Energy is shifted up by $\Delta$ and down by $\Delta$ $\rightarrow$ net effect independent of $\Delta$

- e.g. Ca 43 vs. Ba 137: factor 30 in speed or 6 in $N$

**Trap frequencies vs $\rho$**

- $\omega_{D}^{(\text{Ca}43)} = \frac{4\pi}{\sqrt{\frac{4}{9}}}$

- $\omega_{D}^{(\text{Ba}137)} = \frac{4\pi}{\sqrt{\frac{1}{9}}}$

- $\Delta = \text{max} \text{ of } i, j, k = \text{maximum }$ parameter

- $\Delta_{\text{max}}$ in $\text{V m}^{-1}$, $\rho$ in $\text{mm}$

- $\rho_{\text{small}} = \omega_{D}^{(\text{Ca}43)} < \omega_{D}^{(\text{Ba}137)}$

- $\rho_{\text{large}} = \omega_{D}^{(\text{Ba}137)} < \omega_{D}^{(\text{Ca}43)}$

- Different $\omega_{D}^{(\text{Ca}43)}$ for $\rho_{\text{small}} = 10^{7} \text{ V m}^{-1}$, $\rho_{\text{large}}$ for $\omega_{D}^{(\text{Ba}137)} = 10^{8} \text{ V m}^{-1}$