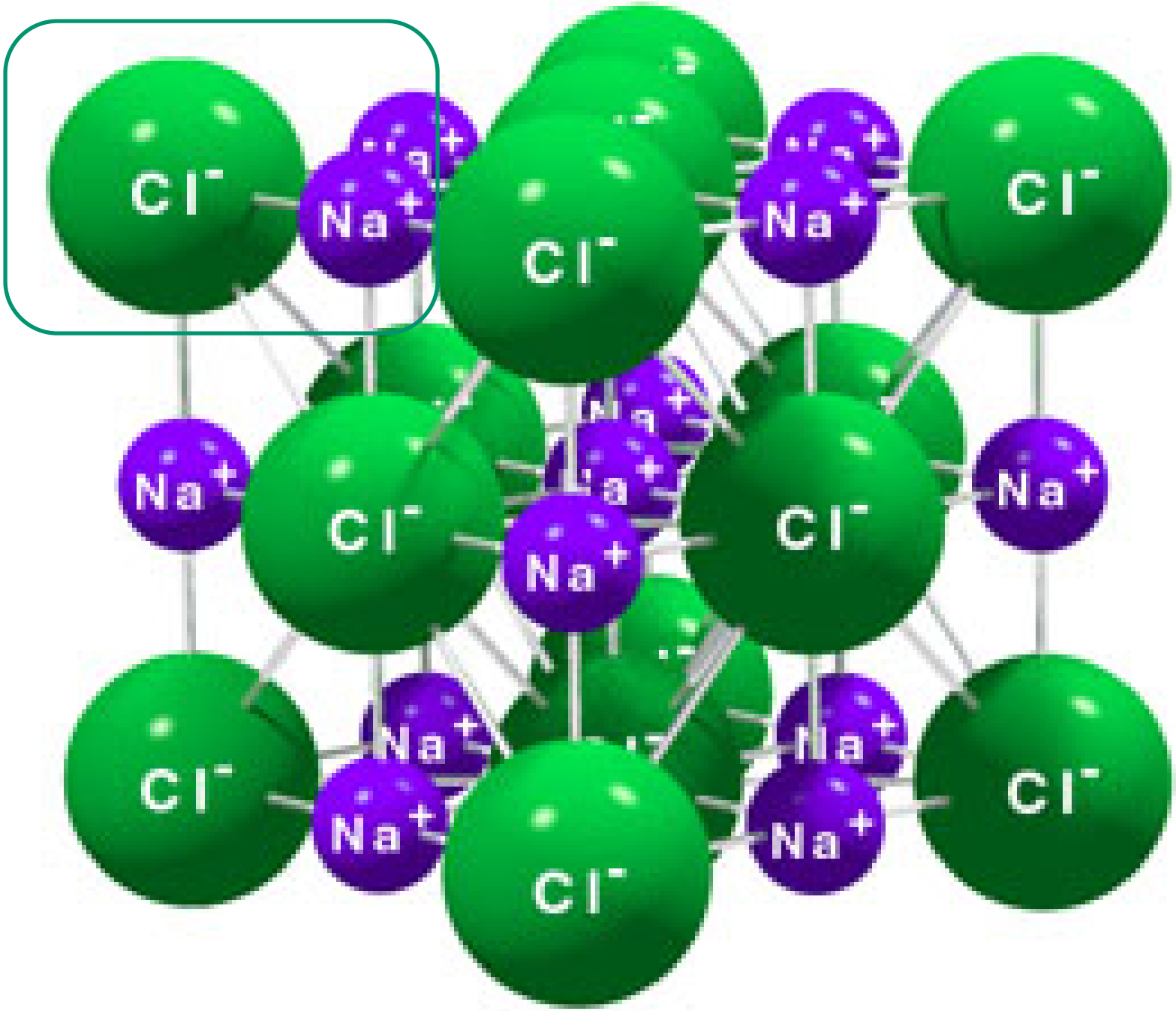
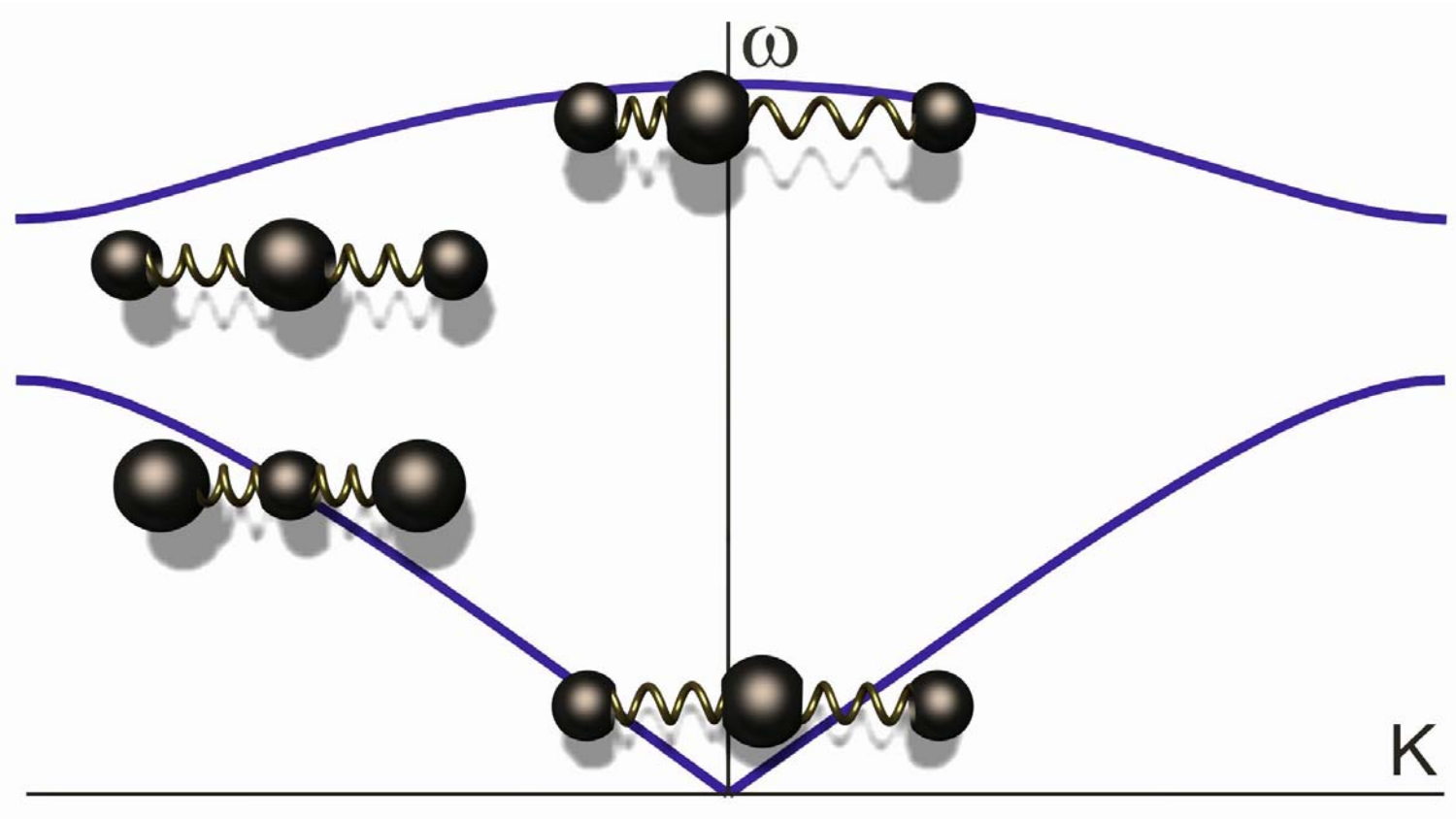
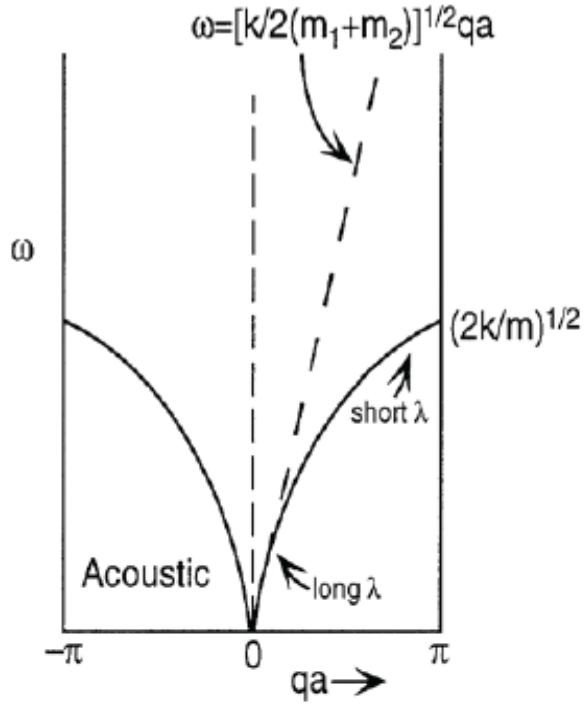
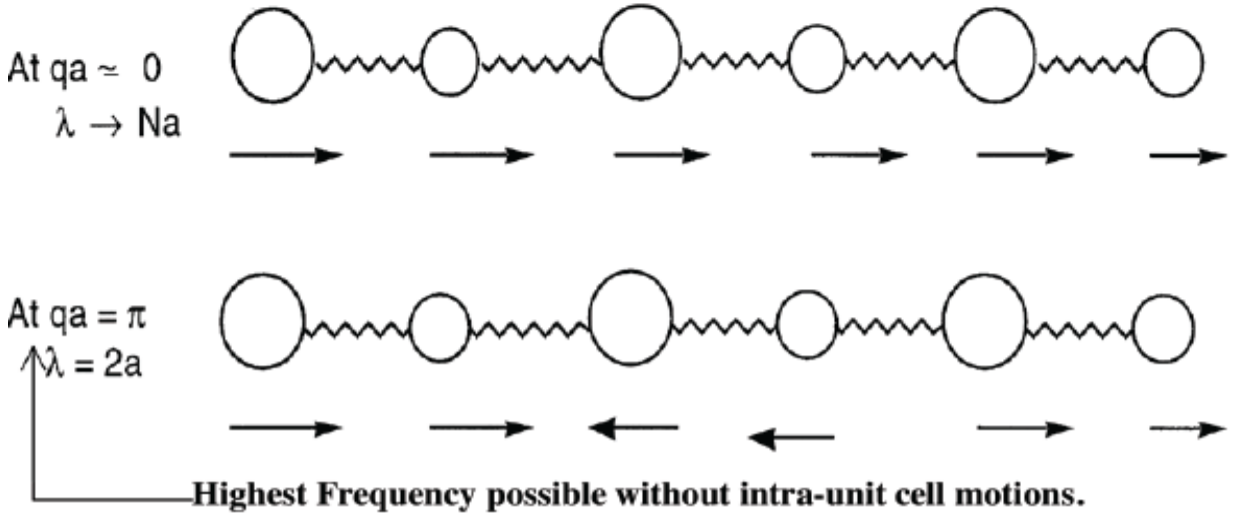
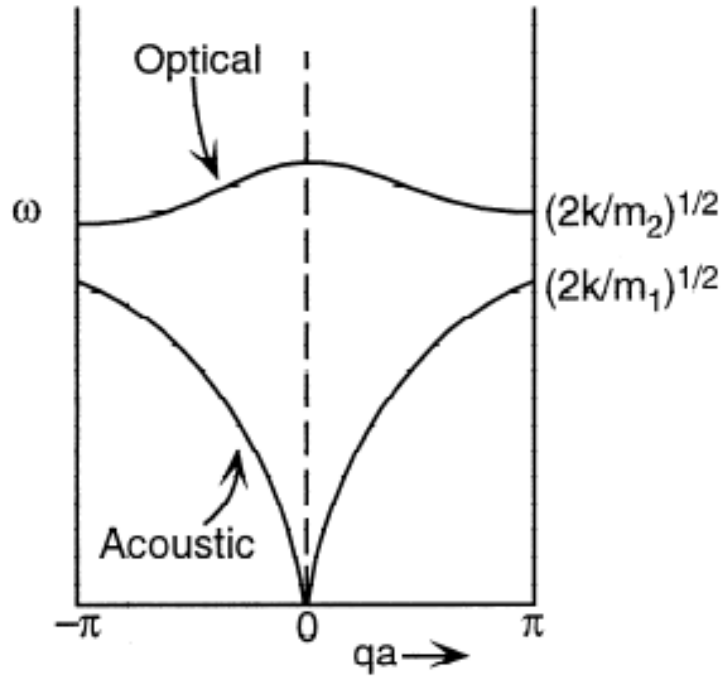

Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻
Na⁺
Cl⁻


ω
K

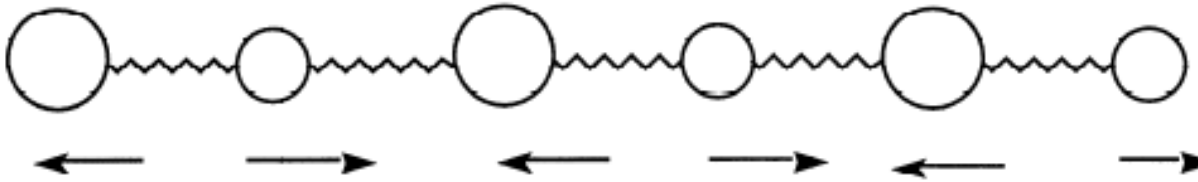




Highest Frequency possible without intra-unit cell motions.

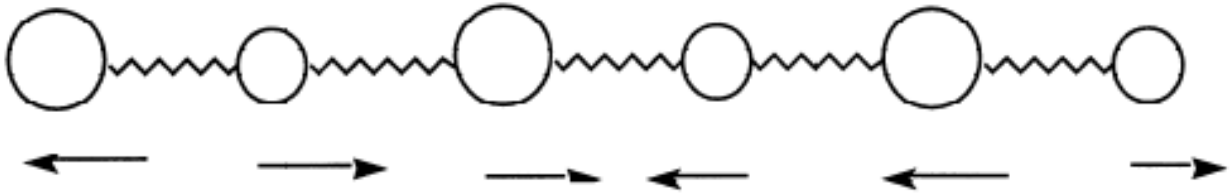


At qa = 0



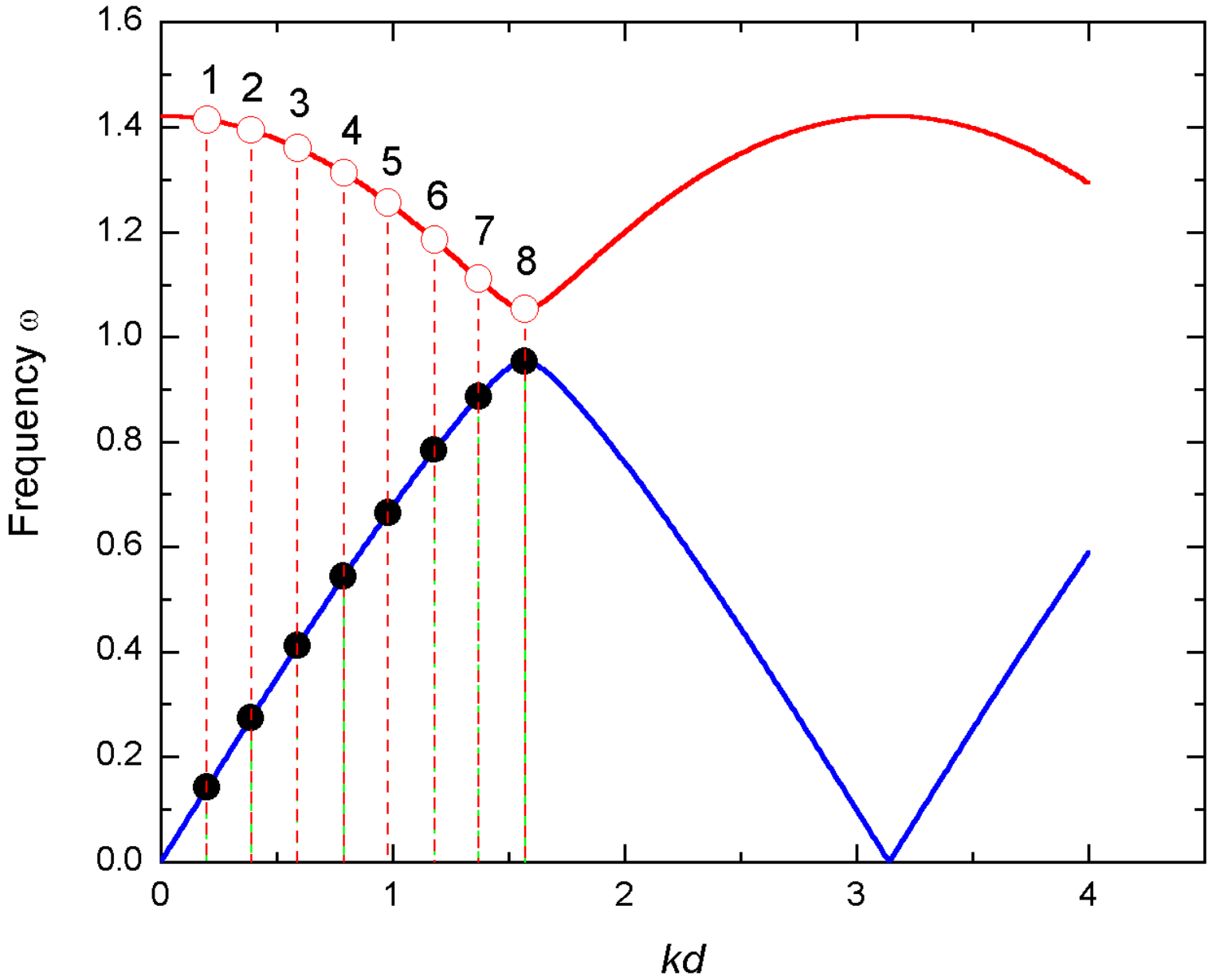
Atoms within each unit cell move out of phase but phases within each cell are identical

At qa = π

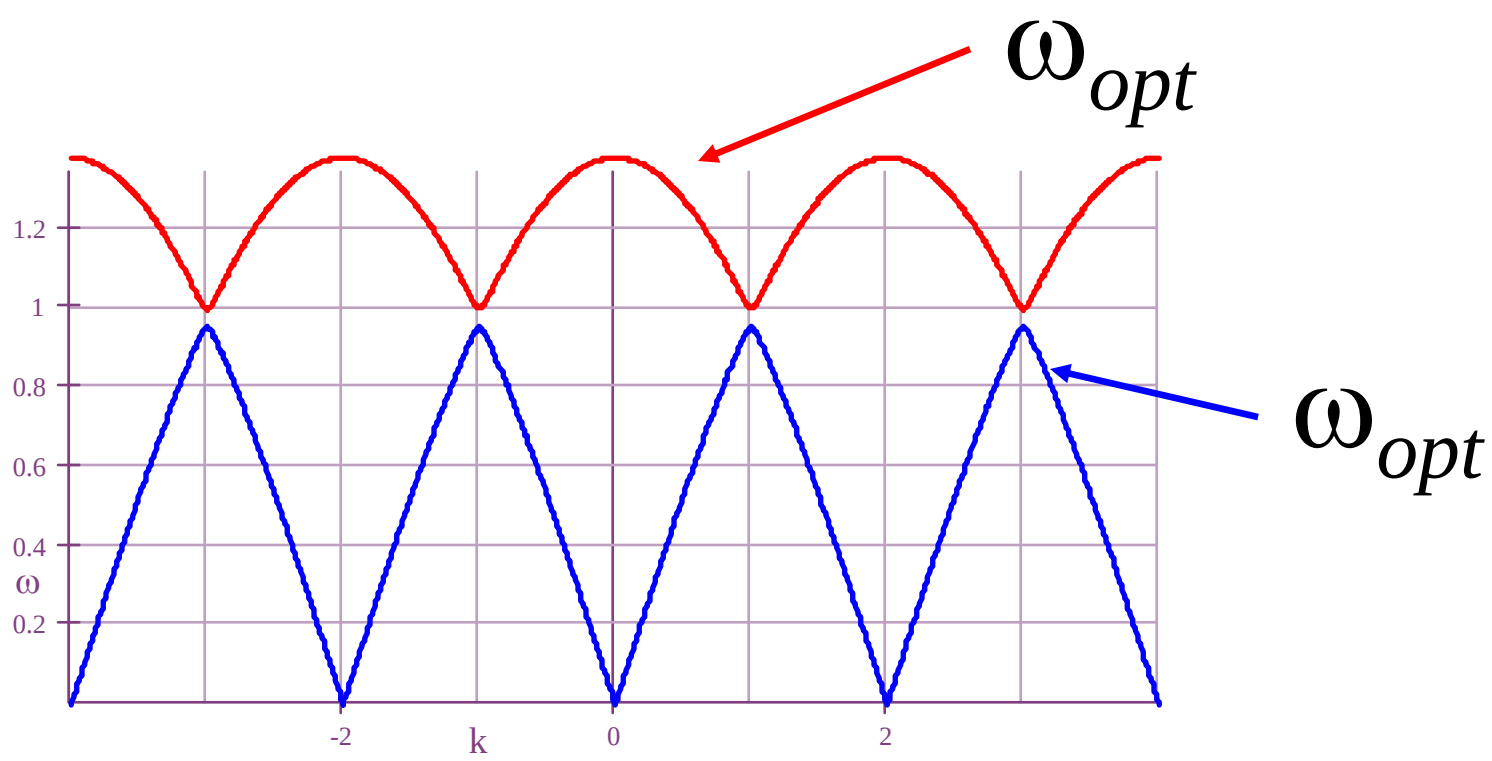


Atoms in each cell are out of phase and phase changes from cell to cell

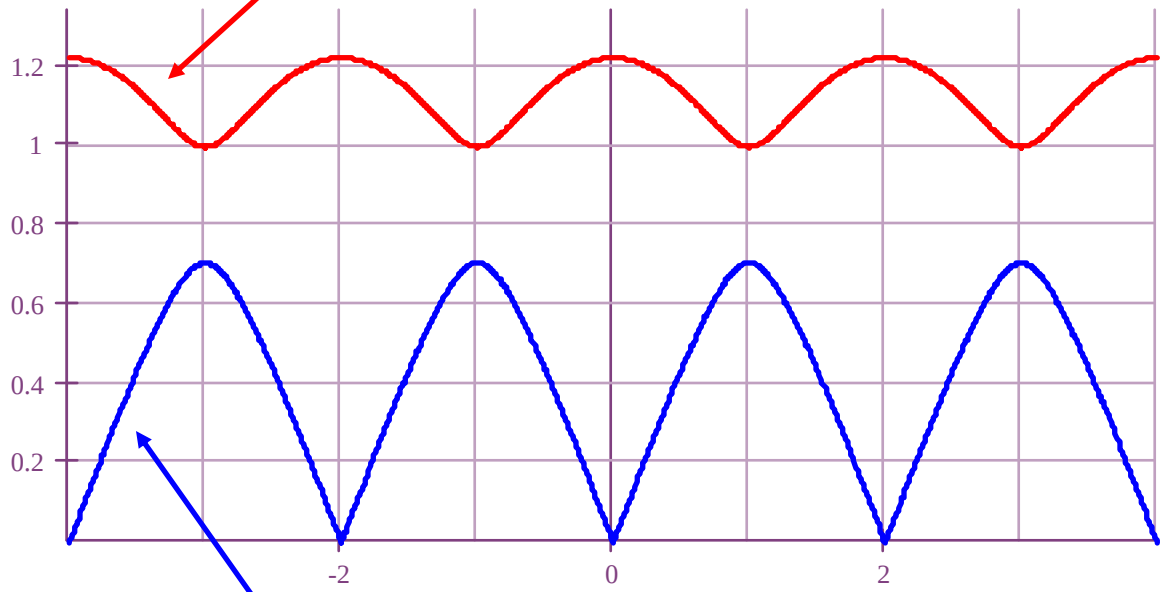
Diatomic chain, 16 masses, 8 unit cells



Dispersion Relation: diatomic

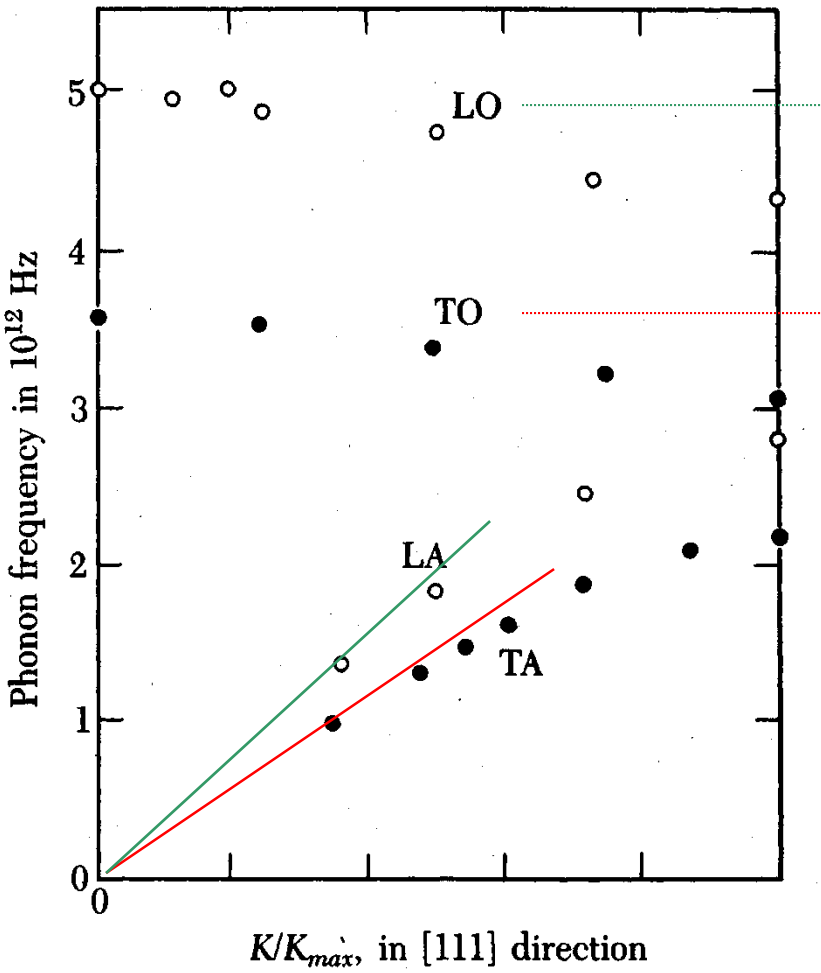


$$\omega_{opt} = \sqrt{\kappa\left(\frac{1}{M}+\frac{1}{m}\right)+\kappa\sqrt{\left(\frac{1}{M}+\frac{1}{m}\right)^2-\frac{4}{Mm}\left(\sin\left[k\frac{a}{2}\right]\right)2}}$$



$$\omega_{ac} = \sqrt{\kappa\left(\frac{1}{M}+\frac{1}{m}\right)-\kappa\sqrt{\left(\frac{1}{M}+\frac{1}{m}\right)^2-\frac{4}{Mm}\left(\sin\left[k\frac{a}{2}\right]\right)2}}$$

Dispersion Relation for KBr (measured by neutron scattering)



$\omega_{opt}/2\pi$ (longitudinal)

$\omega_{opt}/2\pi$ (transverse)

From C. Kittel, *Solid State Physics* after Woods, Brockhouse, Cowley and Cochran, Phys. Rev. **131**, 1025-1029 (1963)

Classical vibrations of atoms in a crystal	**Quantum wavefunctions of e electrons in a crystal**
Normal modes involve ***every*** atom is the crystal	eigenstate wavefunctions spread the probability density over the entire crystal
One natural frequency is associated with each normal mode	Each normal mode has a discrete vibrational frequency ω_κ
each $k=2\pi/\lambda$ describes the normal mode	each k describes the eigenstate wavefunction