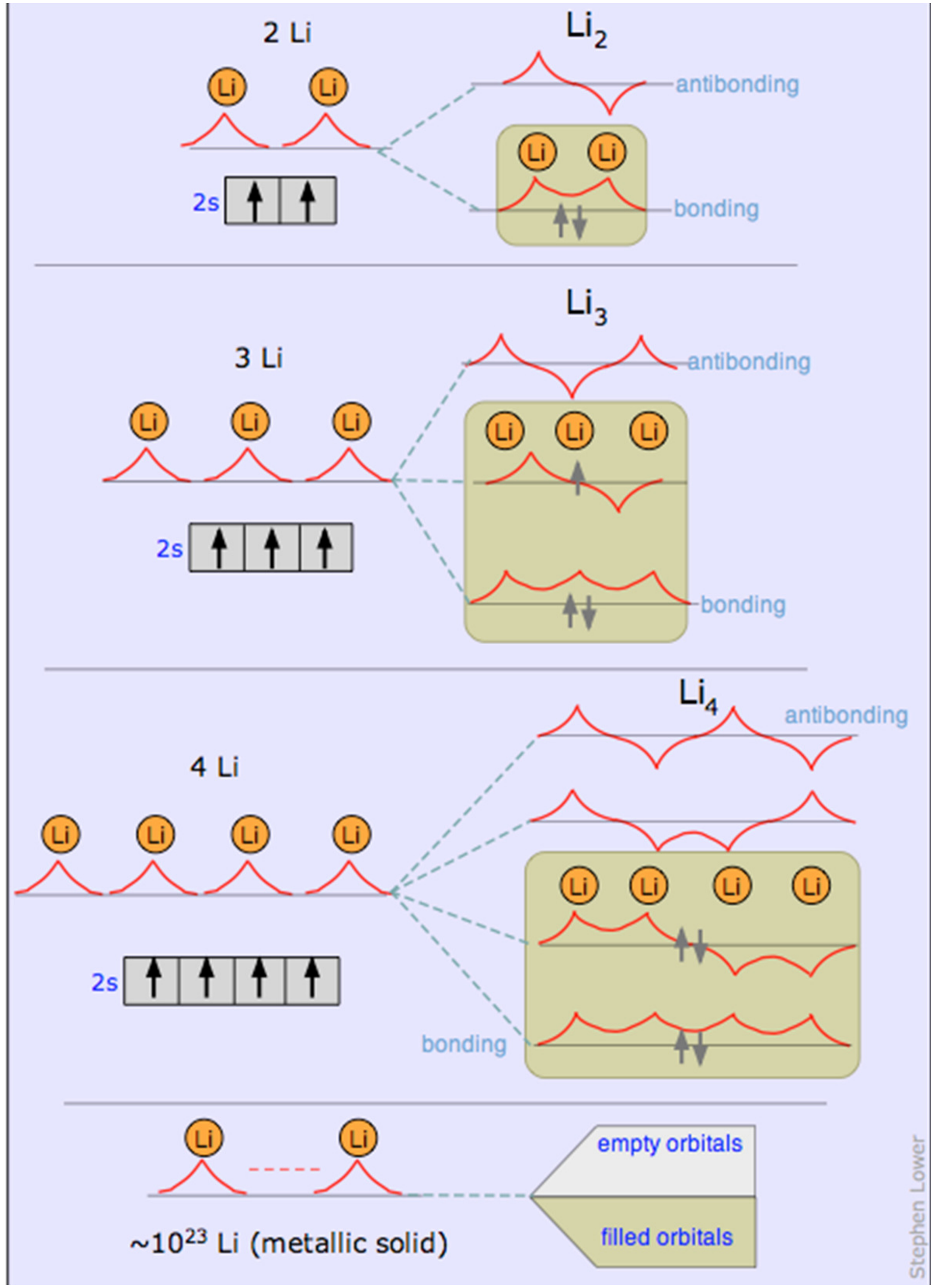
dilithium

trilithium

tetralithium

lithium metal



ParaCon 2016
What went well?

Everyone was able to extract some ***novel*** science, and accepted the challenge

No presentation was a “train-wreck”; even if it were given a national conference

Everyone managed to loose ALL their audience at some point

In 5 min: *you only have time to communicate ONE message*

“the science talk”

- you are not a presenter or a teacher!

your role is “global authority”

Science Talk Advice

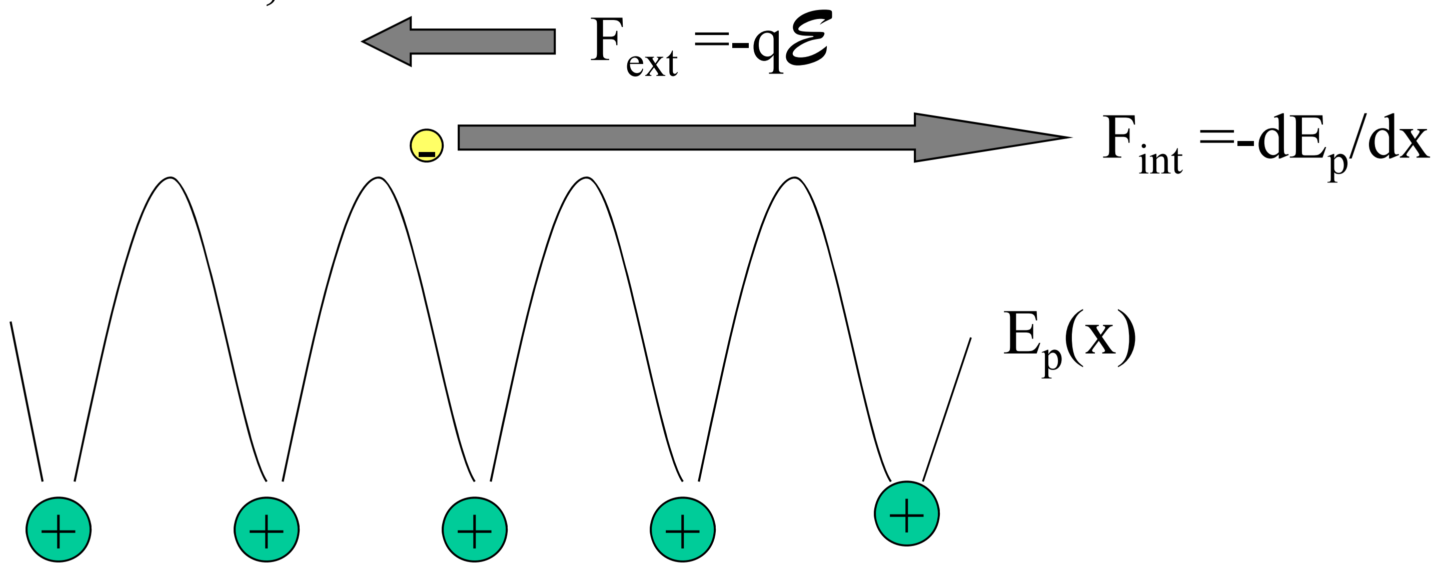
Rule 1: Take care of your audience

Rule 2: Communicate what is new

Rule 3: People will believe you (proofs are for papers)

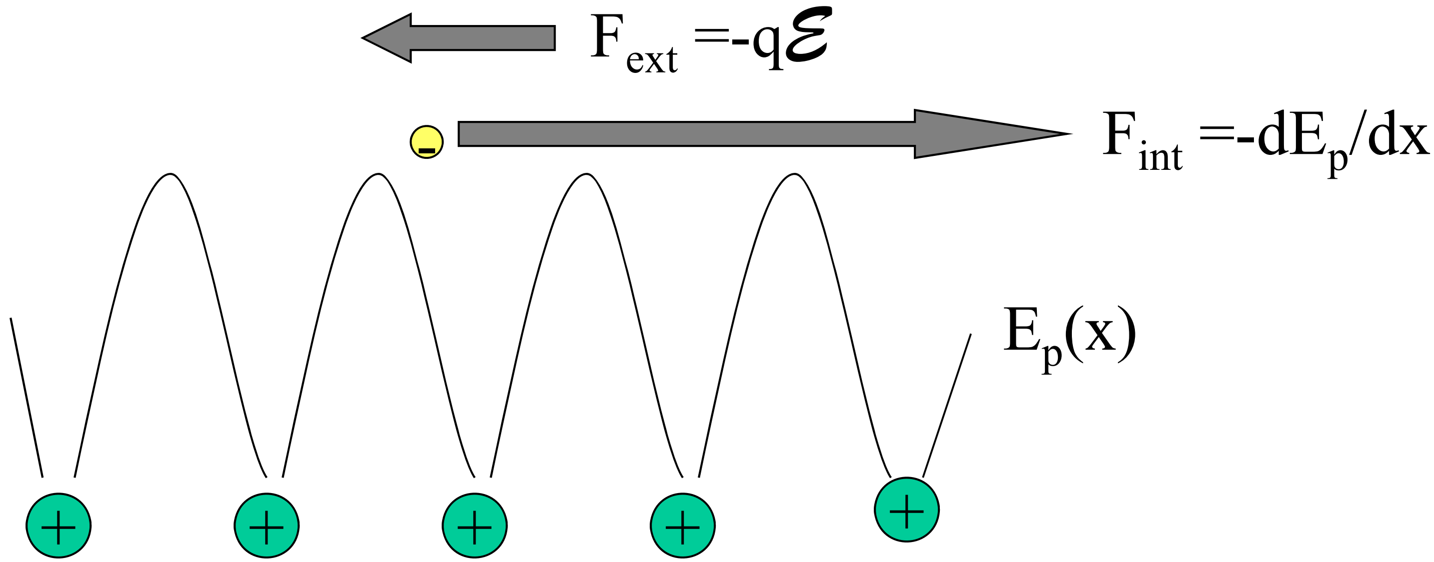
Interpretation

- The electron is subject to internal forces from the lattice (ions and core electrons) AND external forces such as electric fields
- In a crystal lattice, the net force may be opposite the external force, however:



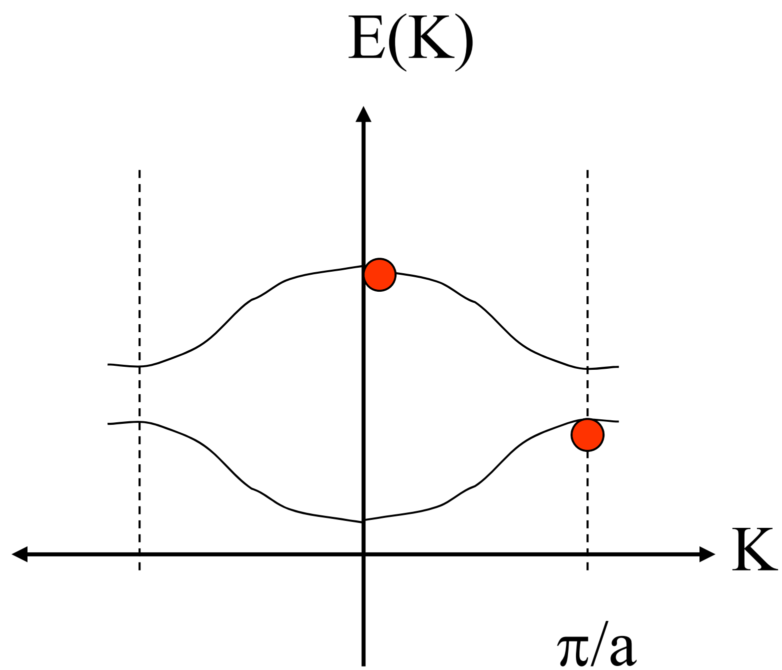
Interpretation

- electron acceleration is not equal to F_{ext}/m_e, but rather…
- $a = (F_{ext} + F_{int})/m_e == F_{ext}/m^*$
- The dispersion relation E(K) compensates for the internal forces due to the crystal and allows us to use *classical* concepts for the electron as long as its mass is taken as m^*



The Hole

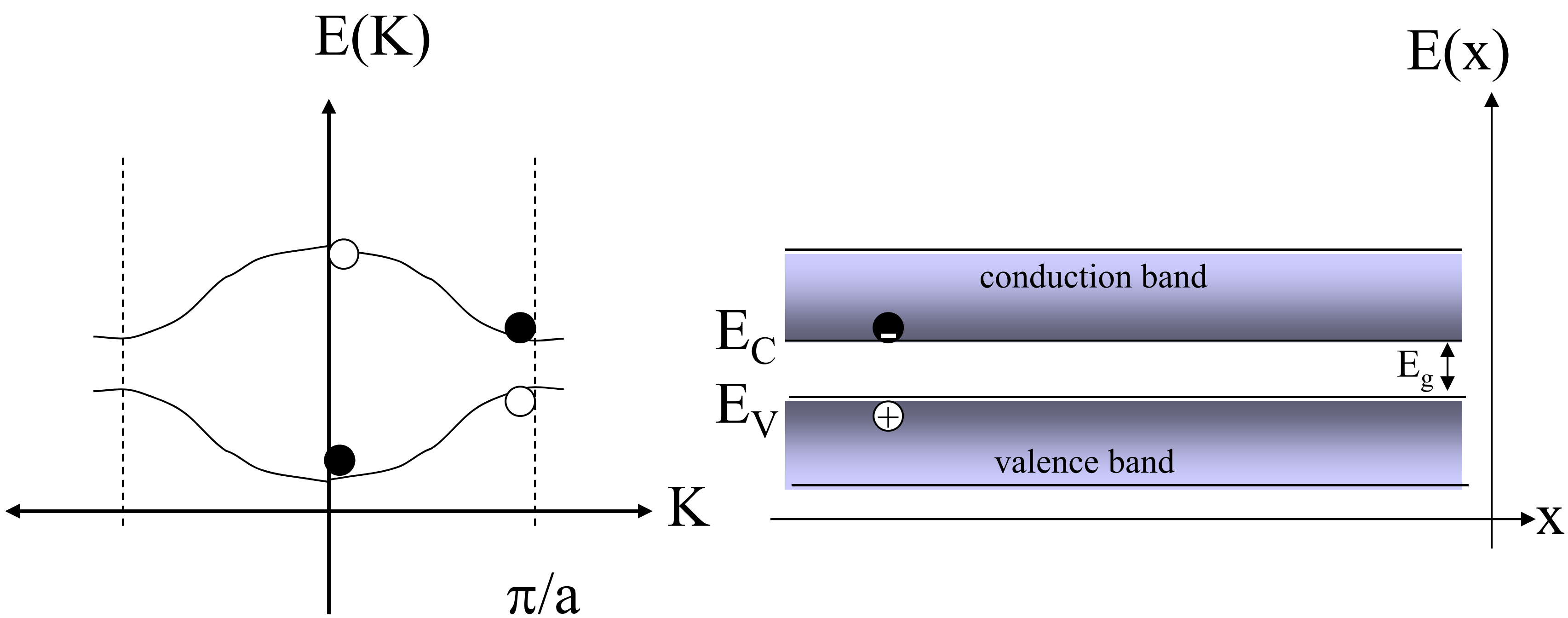
- The hole can be understood as an electron with negative effective mass
- An electron near the top of an energy band will have a negative effective mass
- A negatively charged particle with a negative mass will be accelerated like a positive particle with a positive mass (a hole!)



$$F = m^{*}a = Q\mathcal{E}$$

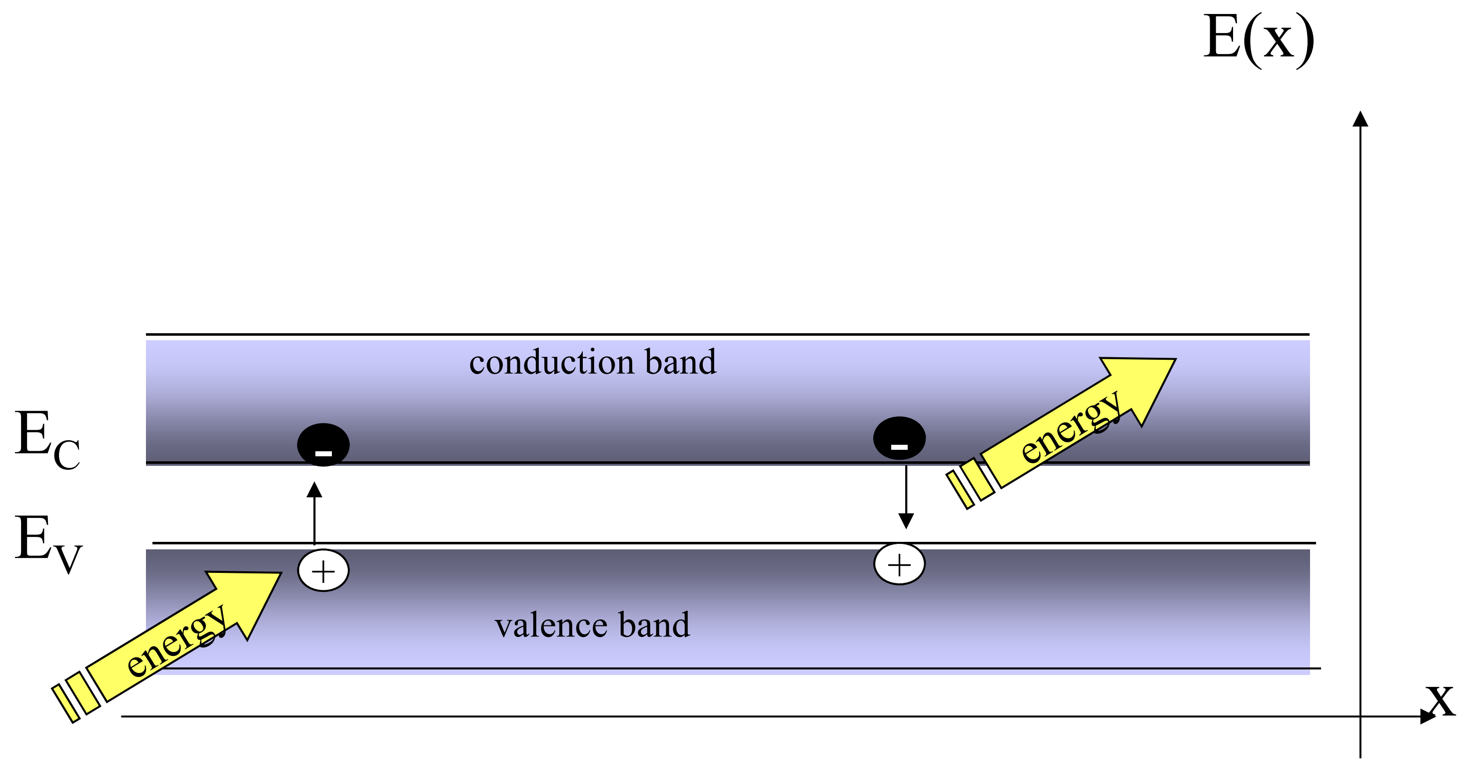
Without the crystal lattice, the hole cannot exist. It is an artifact of the periodic potential (E_p) created by the crystal.

E(K) and E(x)



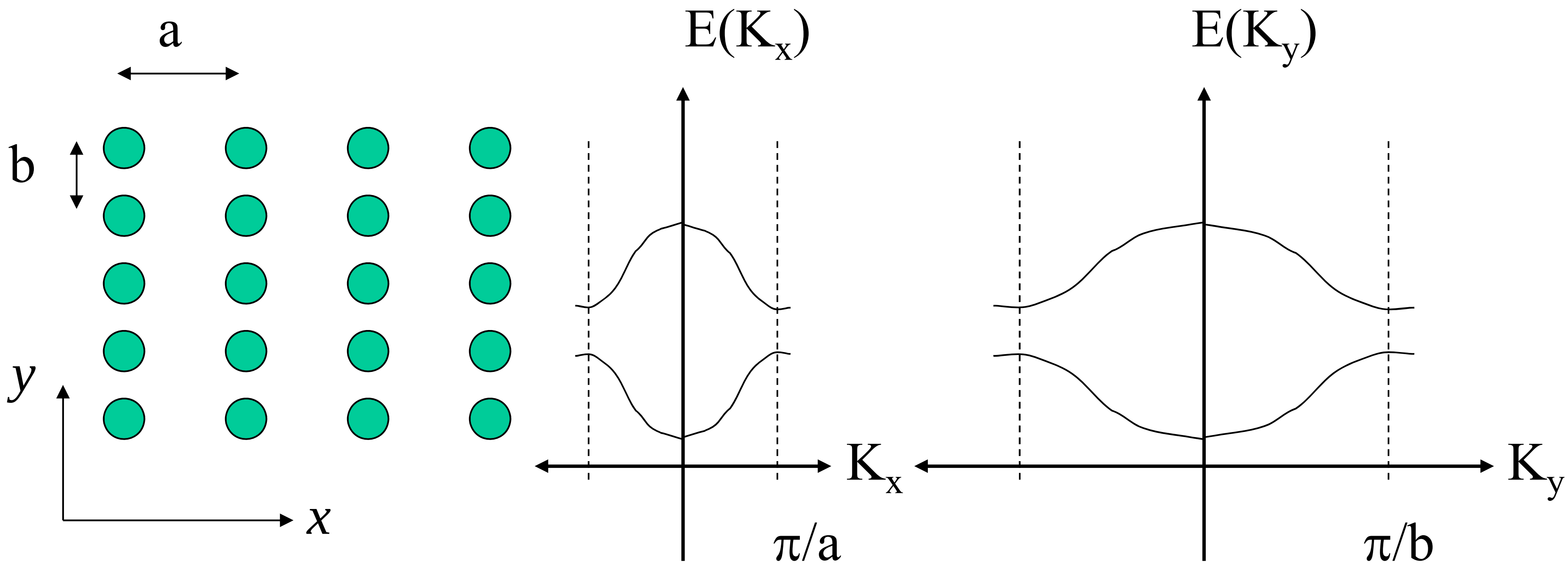
Generation and Recombination

of electron-hole pairs



Non-cubic lattices:

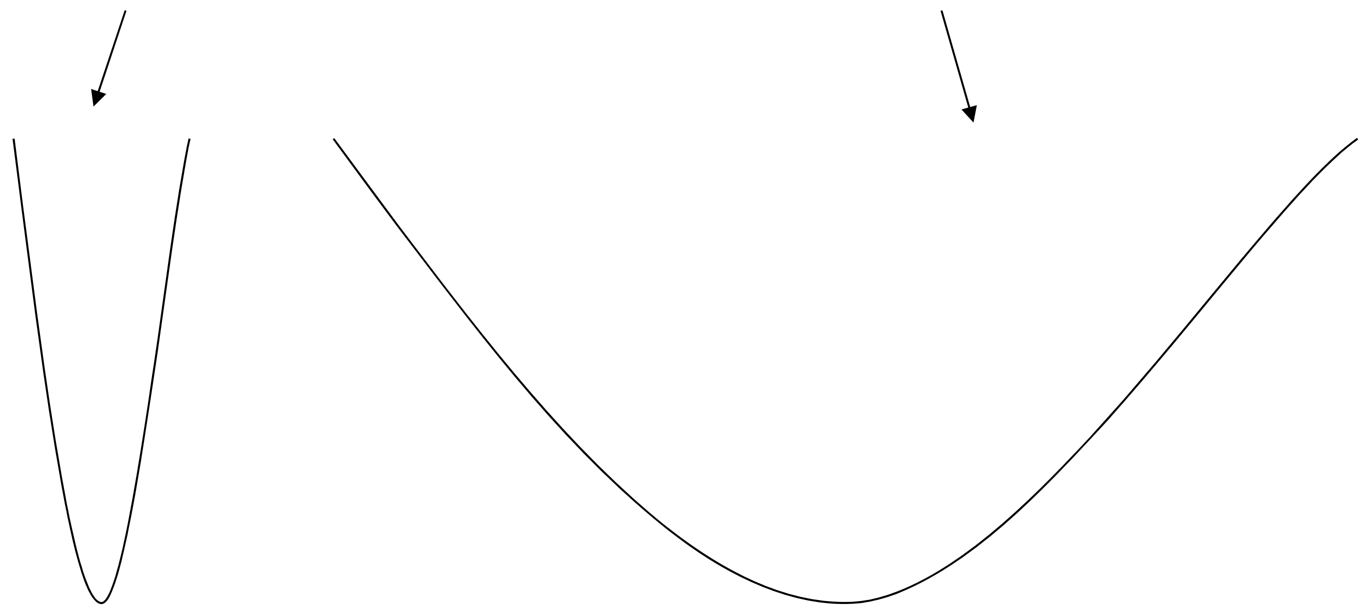
(FCC, BCC, diamond, etc.)



Different lattice spacings lead to different curvatures for E(K) and effective masses that depend on the direction of motion.

Memory Aid

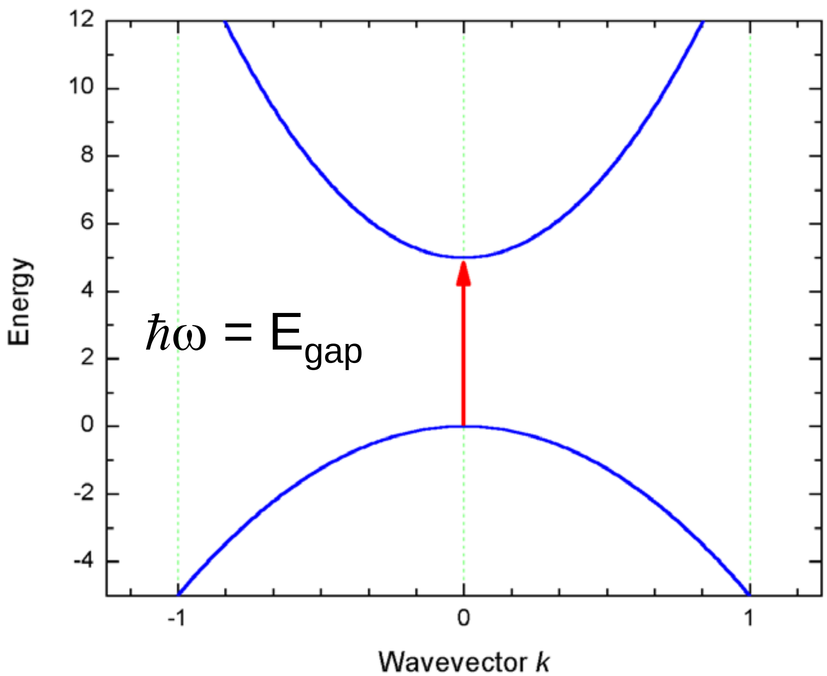
"a hairpin is lighter than a frying pan"



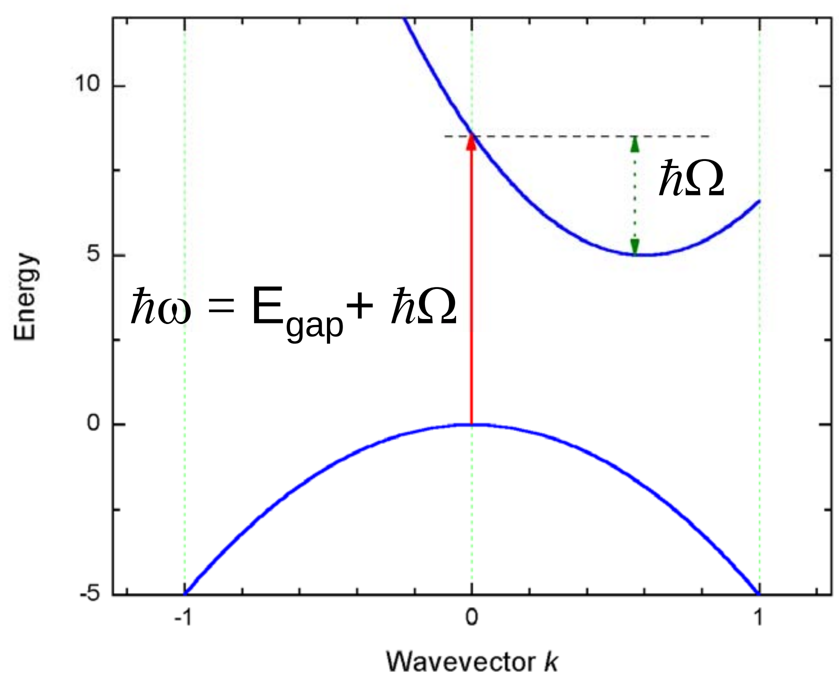
light m^*
(larger d^2E/dK^2)

heavy m^*
(smaller d^2E/dK^2)

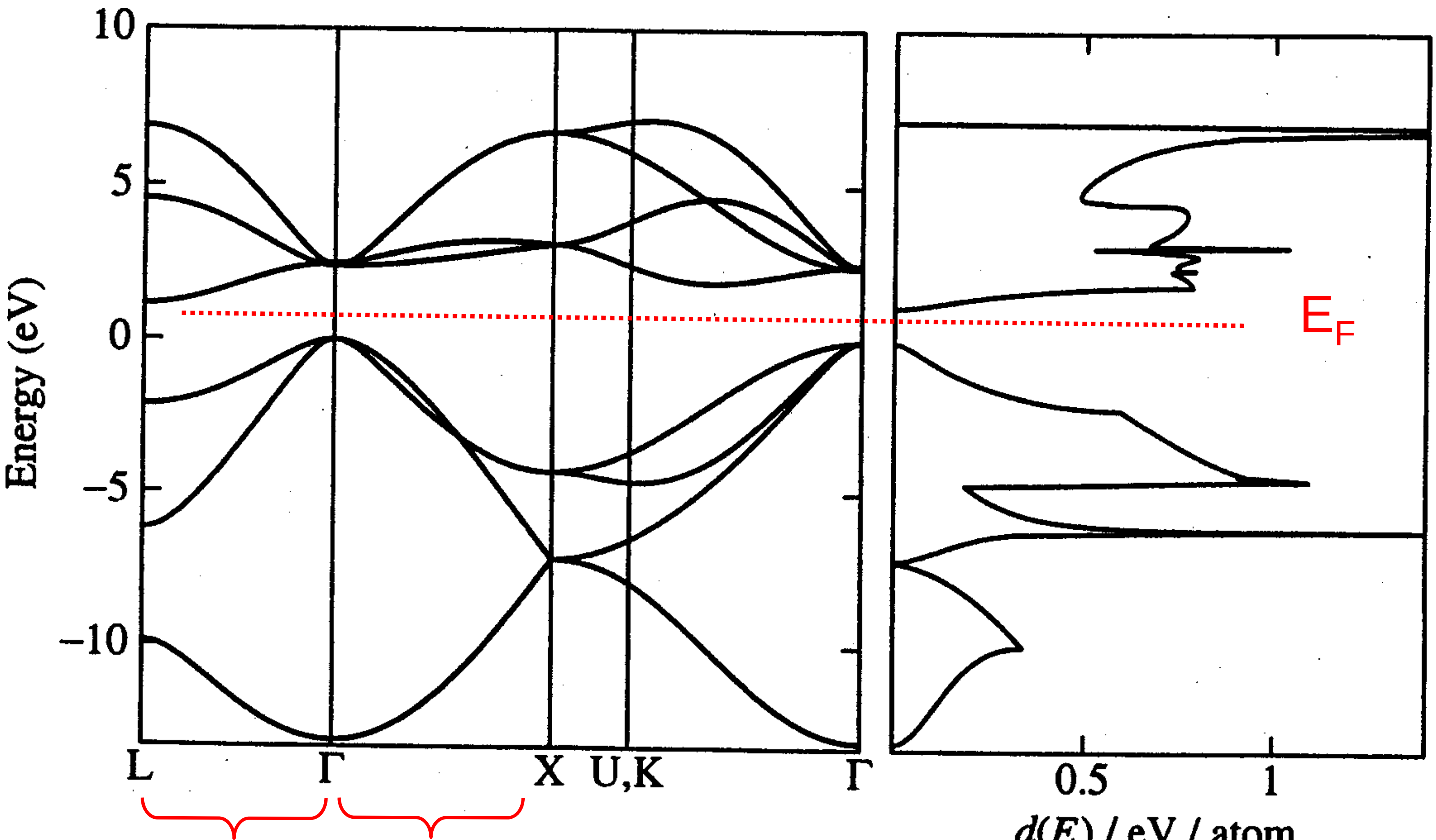
Direct Energy Gap



Indirect Energy Gap



Silicon



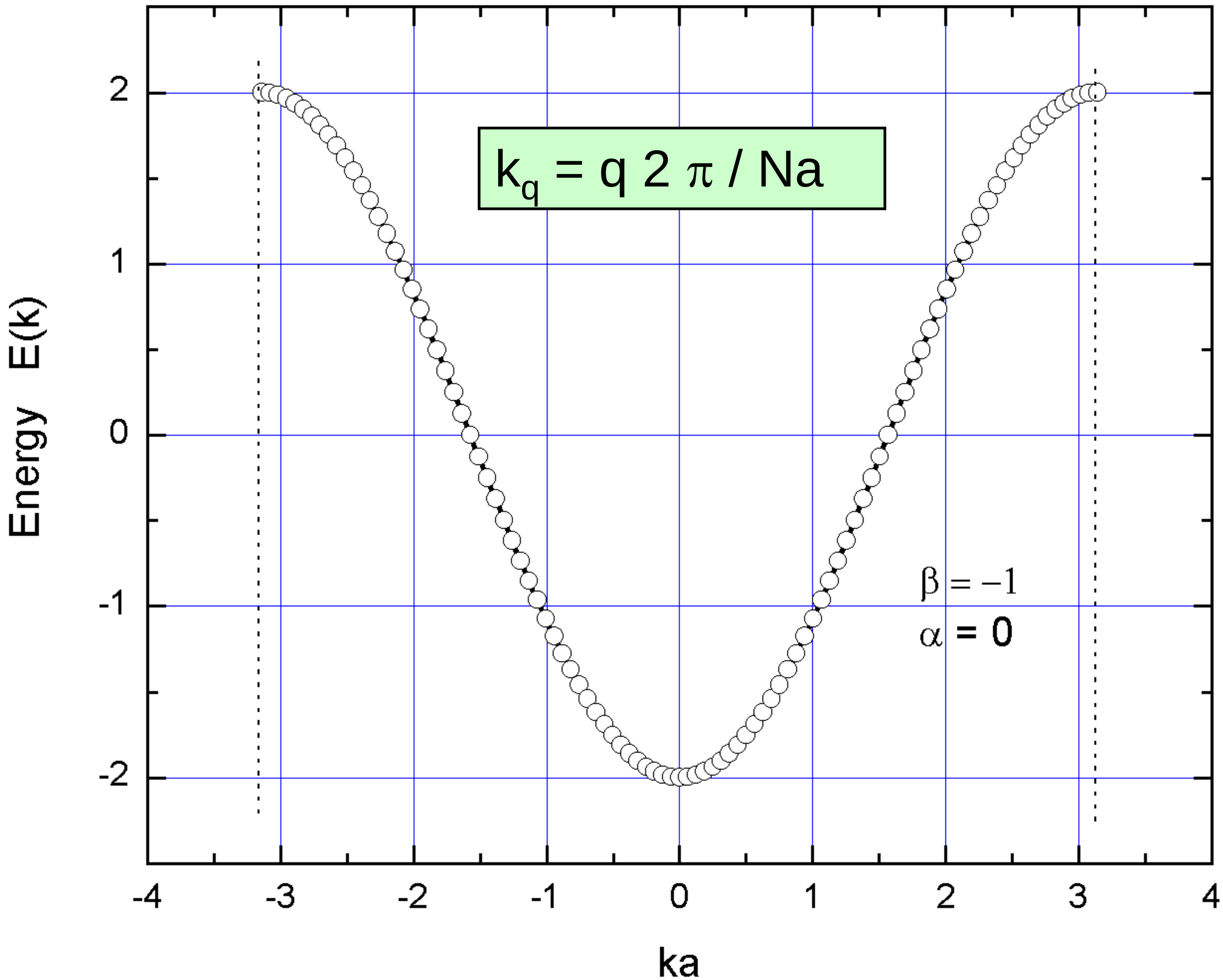
$$\vec{k}=\left[\frac{k}{\sqrt{3}},\frac{k}{\sqrt{3}},\frac{k}{\sqrt{3}}\right] \qquad \vec{k}=[k,0,0]$$

Light Emission

- energy (E) and momentum ($\hbar K$) must be conserved
- energy is released when a quasi-free electron recombines with a hole in the valence band:

$$\Delta E = E_g$$

  - does this energy produce light (photon) or heat (phonon)?
- indirect bandgap: ΔK is large
  - but for a direct bandgap: $\Delta K=0$
- photons have very low momentum
  - but lattice vibrations (heat, phonons) have large momentum
- Conclusion: recombination (e^-+h^+) creates
  - *light* in direct bandgap materials (GaAs, GaN, etc)
  - *heat* in indirect bandgap materials (Si, Ge)



$k_q = q\ 2\ \pi\ /\ Na$
$\beta = -1$
$\alpha = 0$
Energy E(k)
ka
2
1
0
-1
-2
-4
-3
-2
-1
0
1
2
3
4