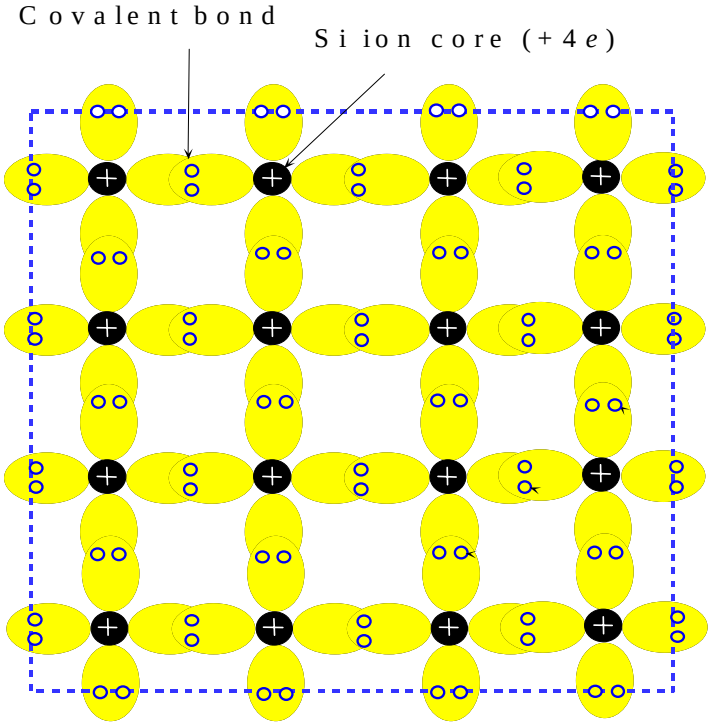
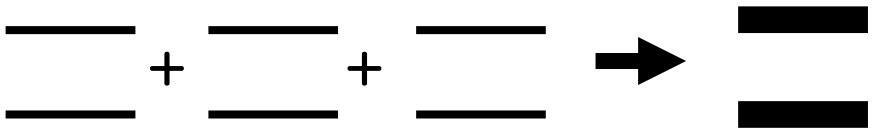
Lect. 18: LED and SOA

Electron energy levels in semiconductors



Electrons in each Si atom have discrete energy levels.

But in Si crystal, energy bands are formed.



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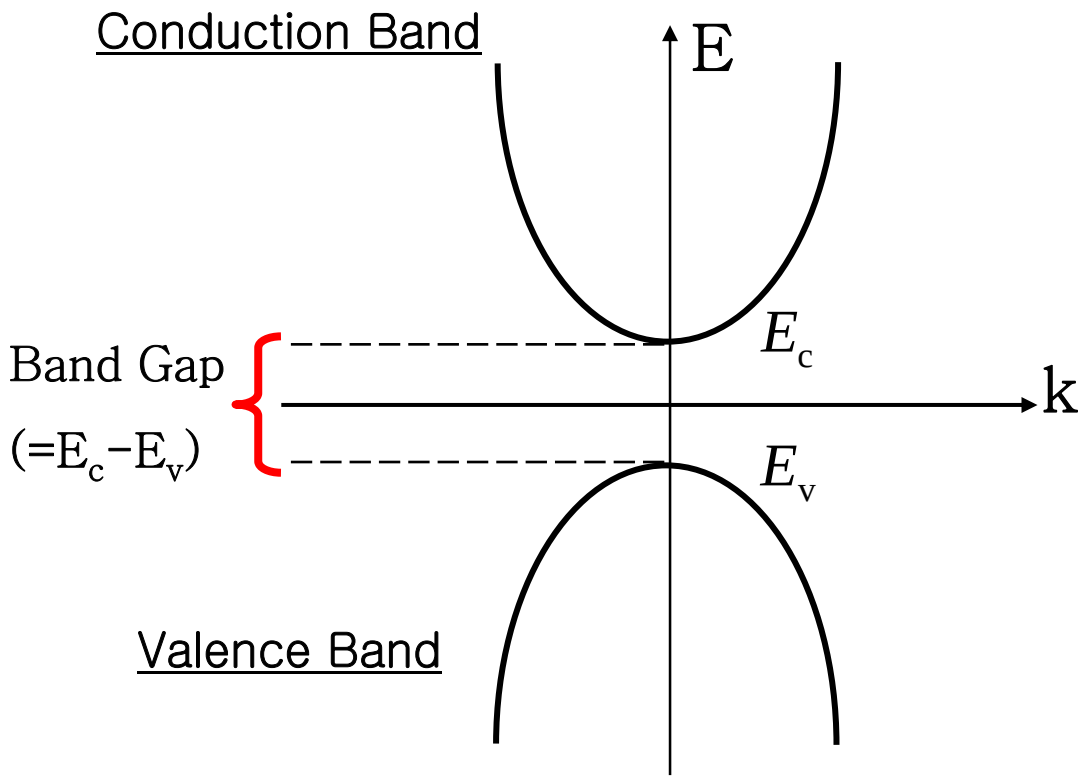
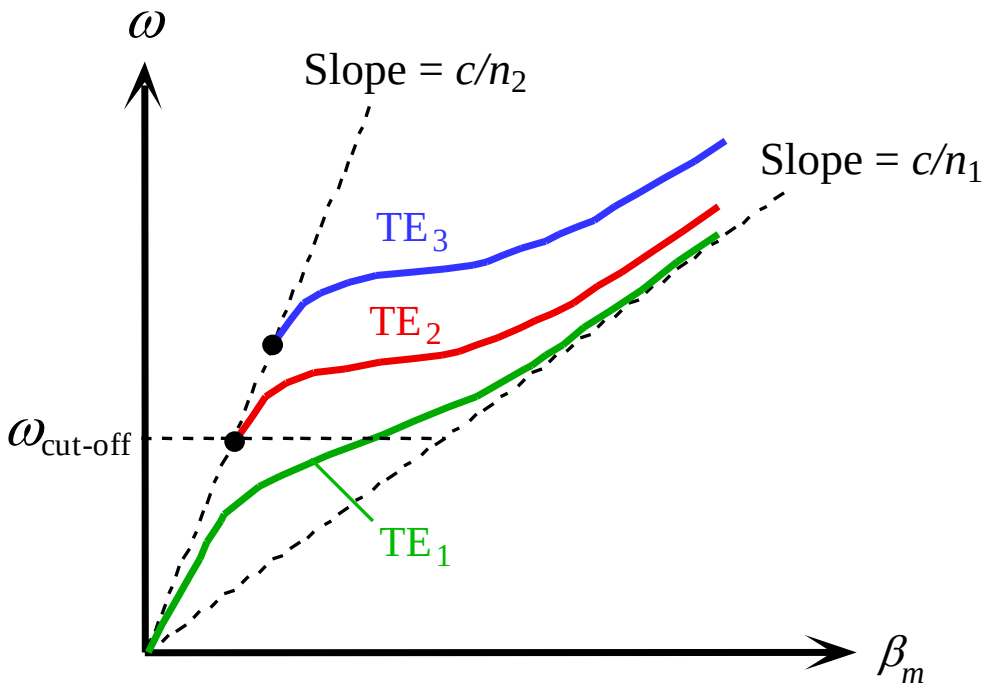


Lect. 18: LED and SOA

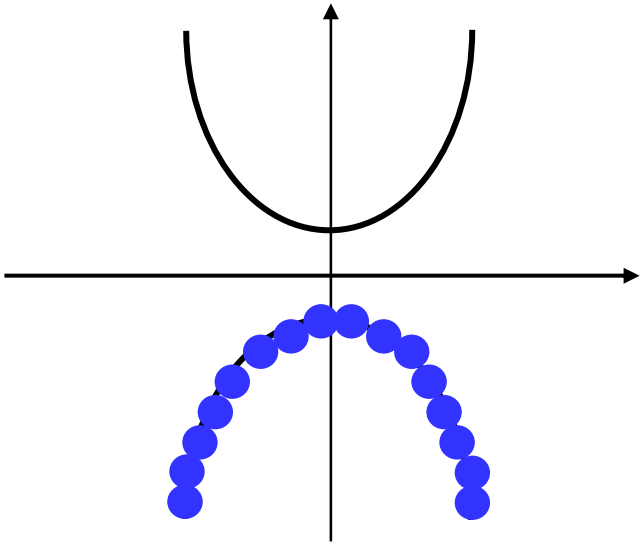


Example for E vs k diagram: EM waves in a dielectric waveguide

Lect. 18: LED and SOA

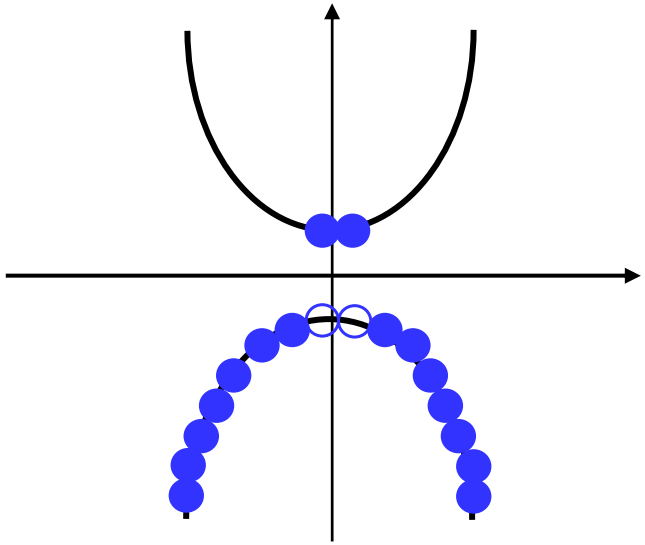
Where are electrons?

T=0 K



no electrons in conduction band and no holes in valence band

T > 0 K

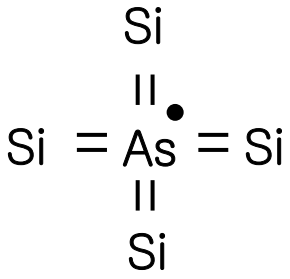


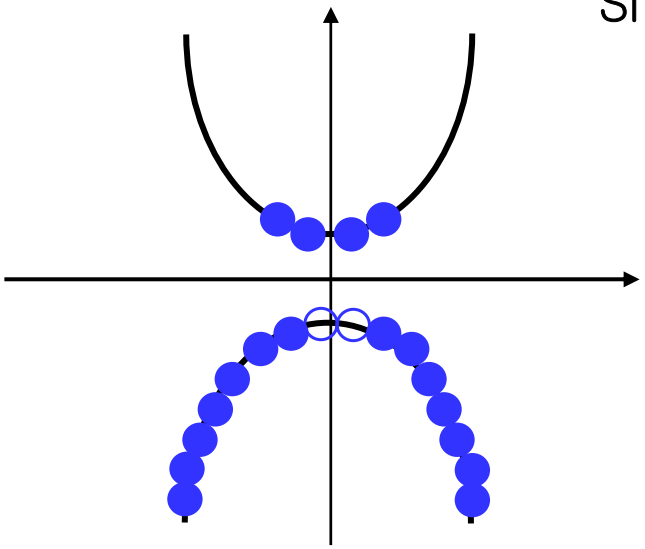
same number of electrons in conduction band as holes in valence band

Lect. 18: LED and SOA

Doping with impurities

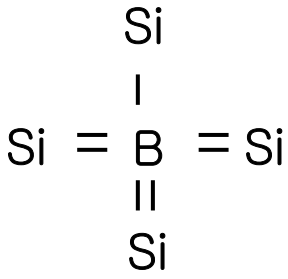
N-type

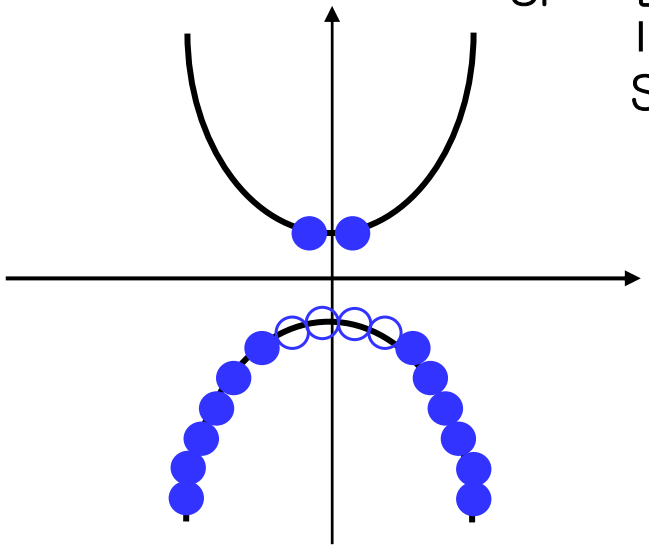




More electrons in conduction band
than holes in valence band

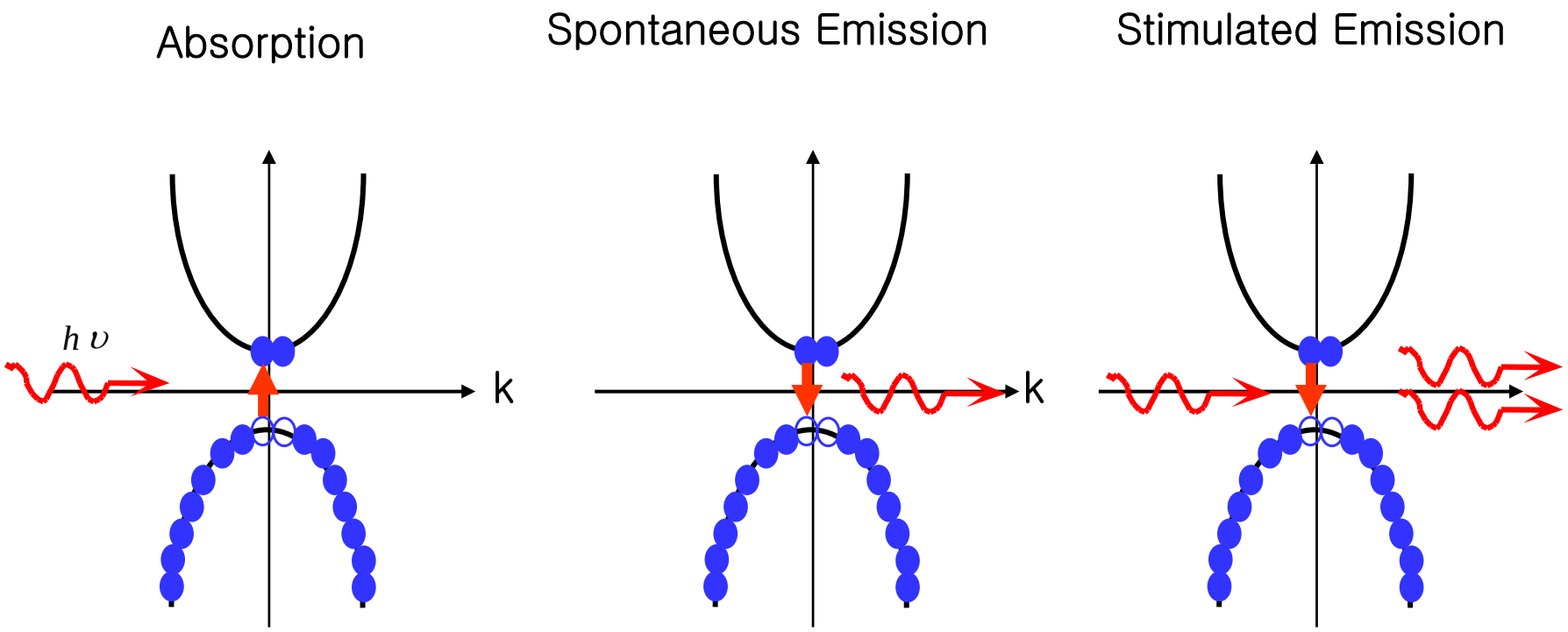
P-type





More holes in valence band
than electrons in conduction band

Lect. 18: LED and SOA



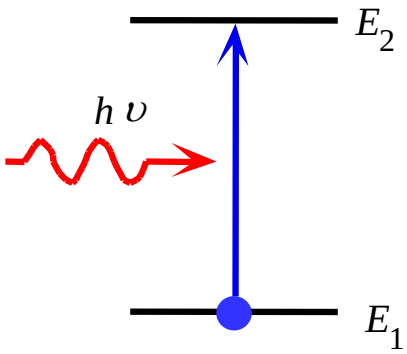
hν > Eg

Momentum (k) conservation required

Lect. 18: LED and SOA

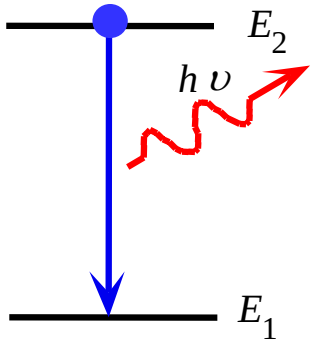
Remember

Absorption



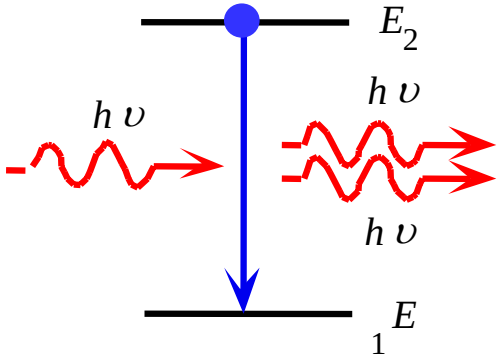
$$R_{12} = B_{12} \cdot N_1 \cdot \rho$$

Spontaneous Emission



$$R_{sp} = A_{21} \cdot N_2$$

Stimulated Emission



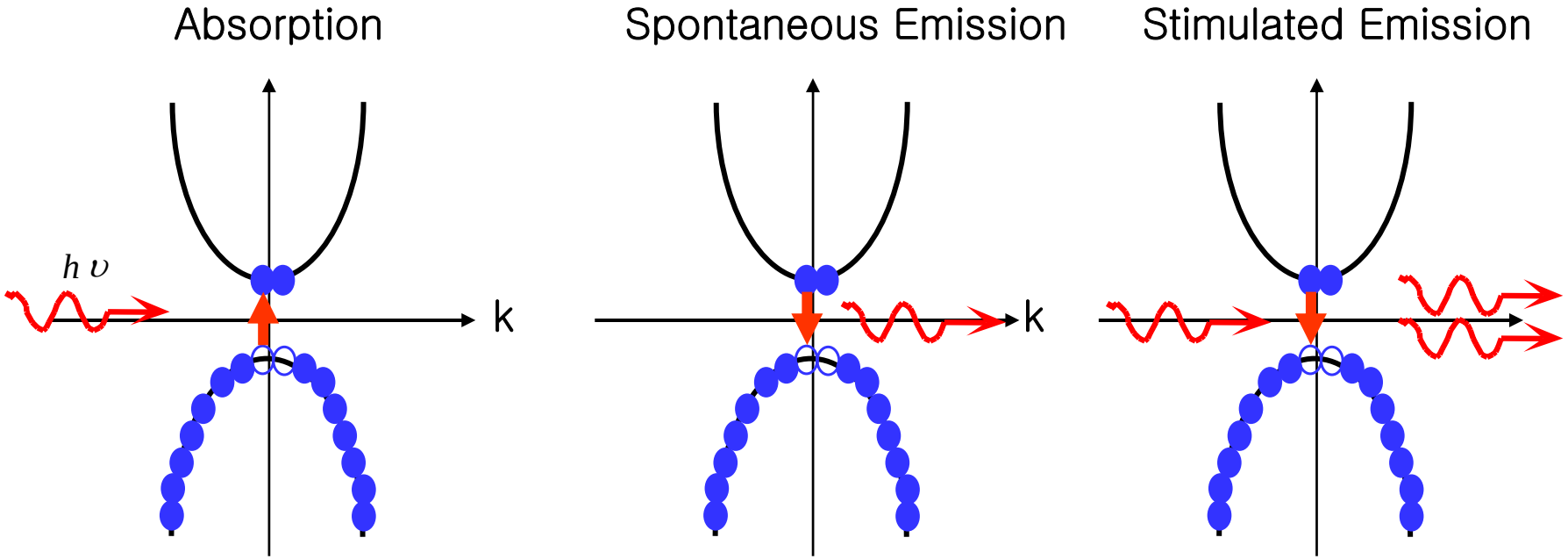
$$R_{21} = B_{21} \cdot N_2 \cdot \rho$$

ρ : photon density

$N_{1,2}$: electron density at $E_{1,2}$

B_{12}, B_{sp}, B_{21} : constants

Lect. 18: LED and SOA



$$R_{12}(h\nu) = B_{12} \cdot N_1(E_1) \cdot P_2(E_2) \cdot \rho(h\nu)$$

$$R_{sp}(h\nu) = A_{21} \cdot N_2(E_2) \cdot P_1(E_1)$$

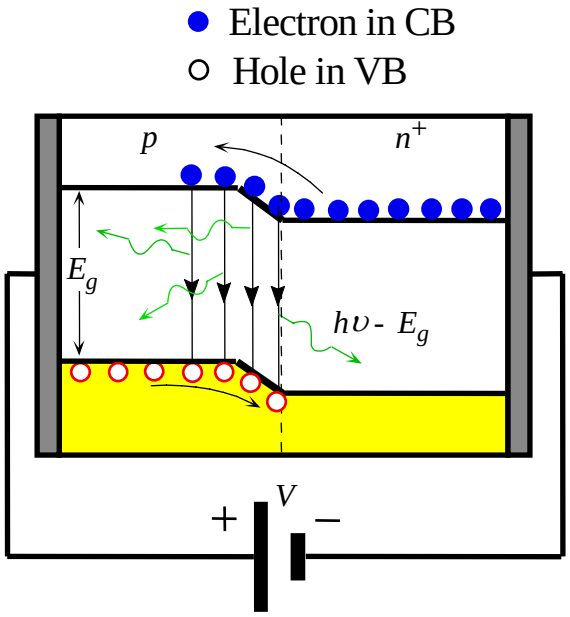
$$R_{21}(h\nu) = B_{21} \cdot N_2(E_2) \cdot P_1(E_1) \cdot \rho(h\nu)$$

For population inversion, $\dfrac{N_2 \cdot P_1}{N_1 \cdot P_2} > 1$ Electron and hole injection needed.

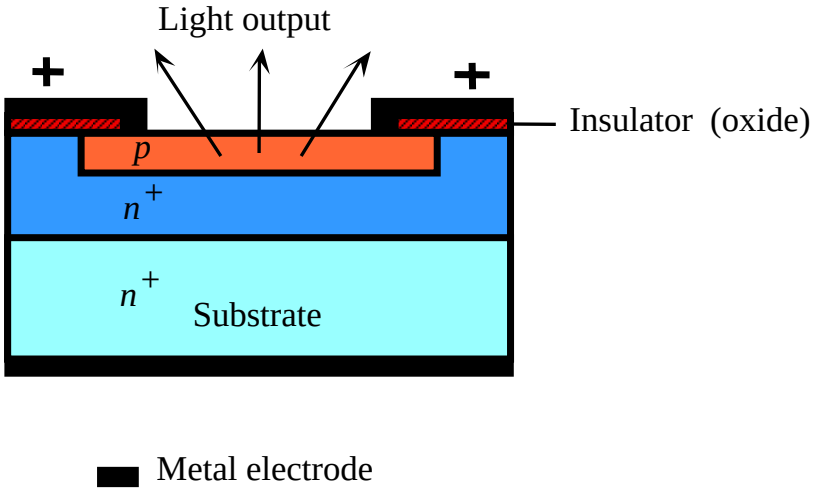
Lect. 18: LED and SOA

How to inject electrons and holes into a semiconductor? PN junction

Current flow in PN junction



Light emitting diode (LED)

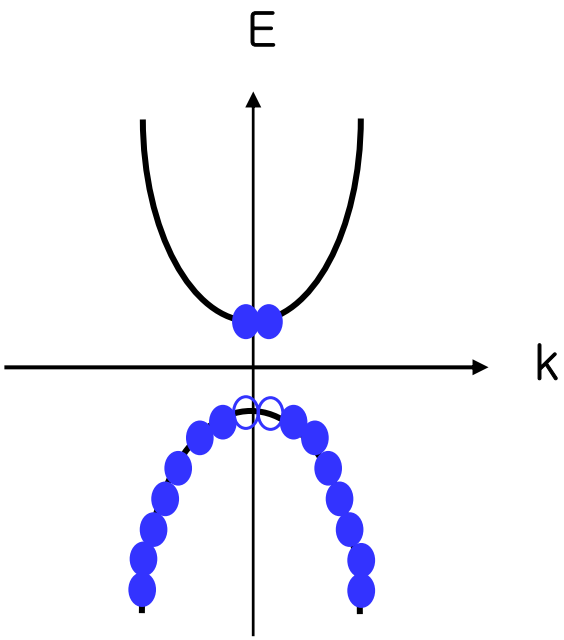


Does any semiconductor emit light?

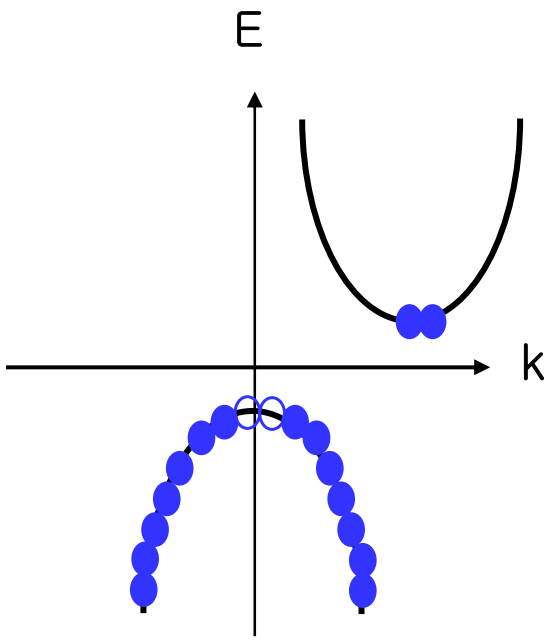
What determines the color of LED?

Lect. 18: LED and SOA

Direct semiconductor



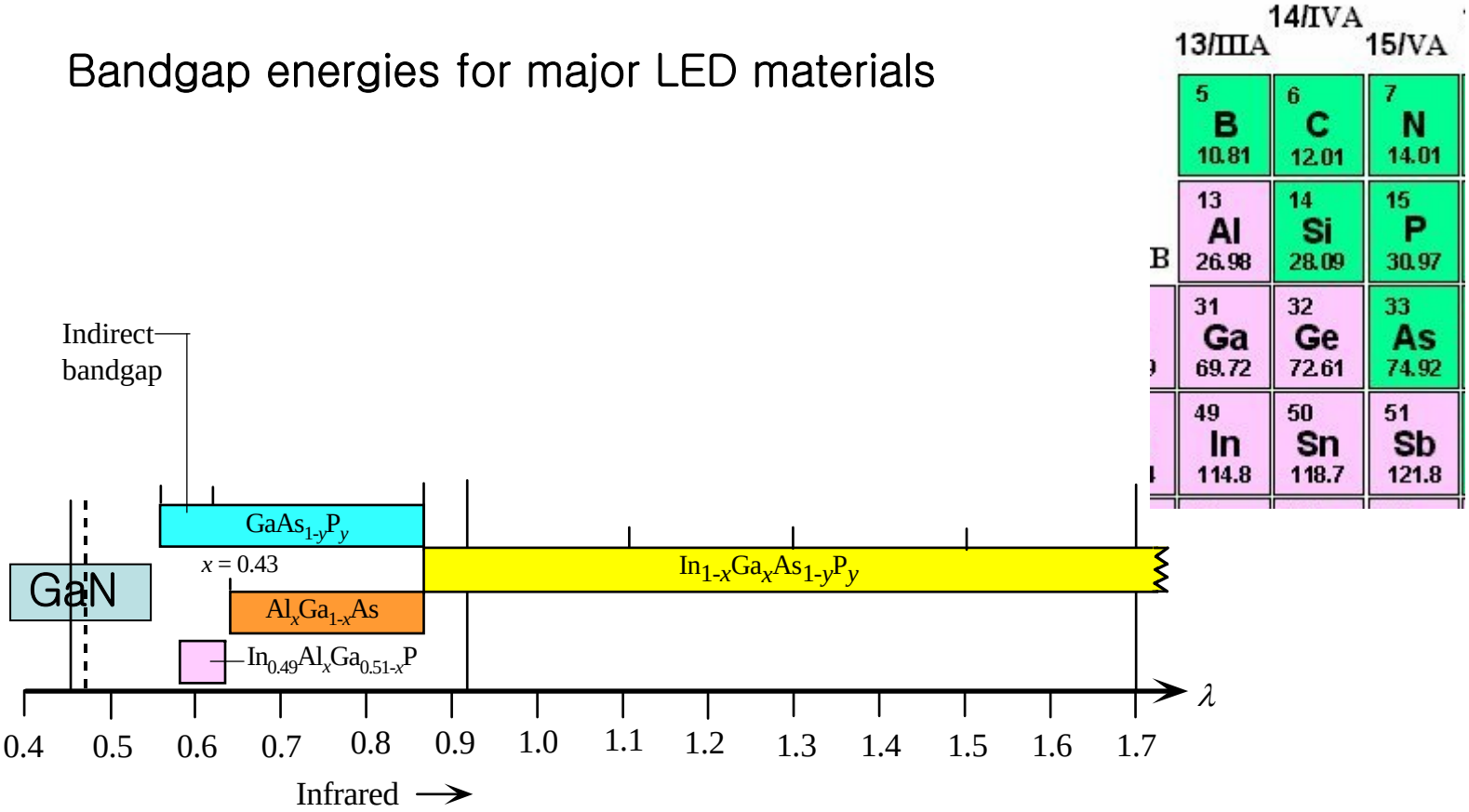
Indirect Semiconductor



Momentum conservation not possible
by photon emission
=> No emission (Examaple: Si)

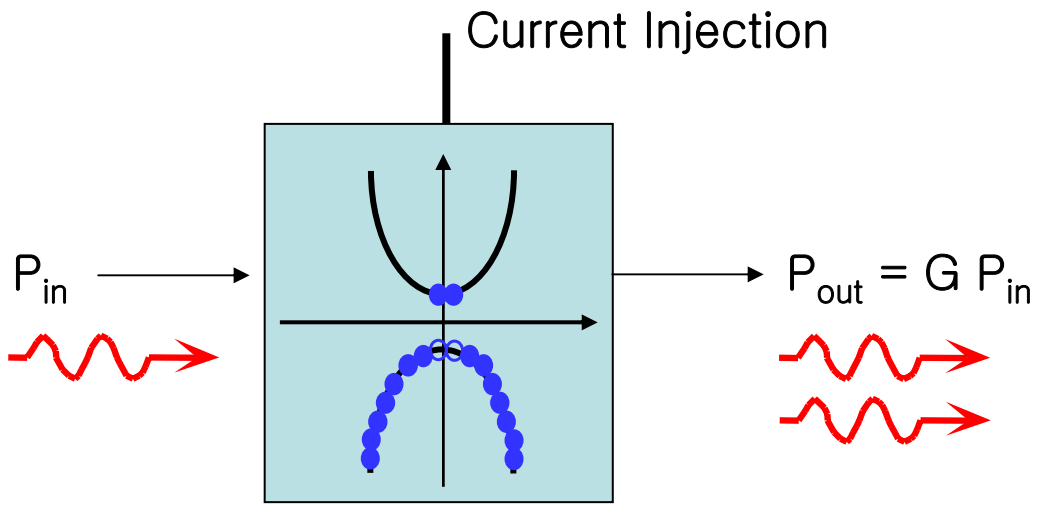
Lect. 18: LED and SOA

Bandgap energies for major LED materials



Lect. 18: LED and SOA

Current injection into PN Junction can be used for SOA
(Semiconductor Optical Amplifier)



Lect. 18: LED and SOA

Gain spectrum for SOA