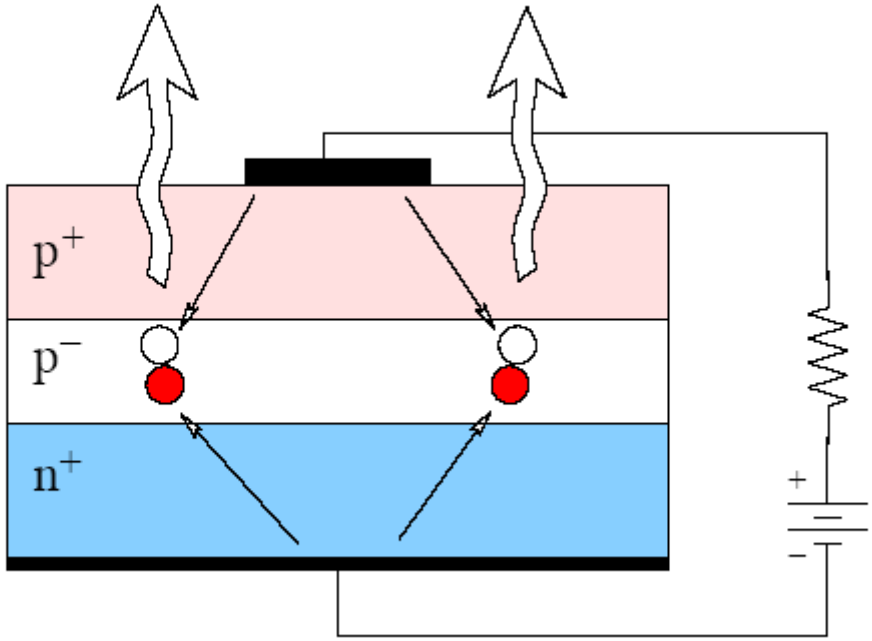
# LEDs

LECTURE 13

- LED basics
- voltage efficiency
- heterojunction band diagrams
- current efficiency

Chap. 8

# Electrical-to-optical energy conversion

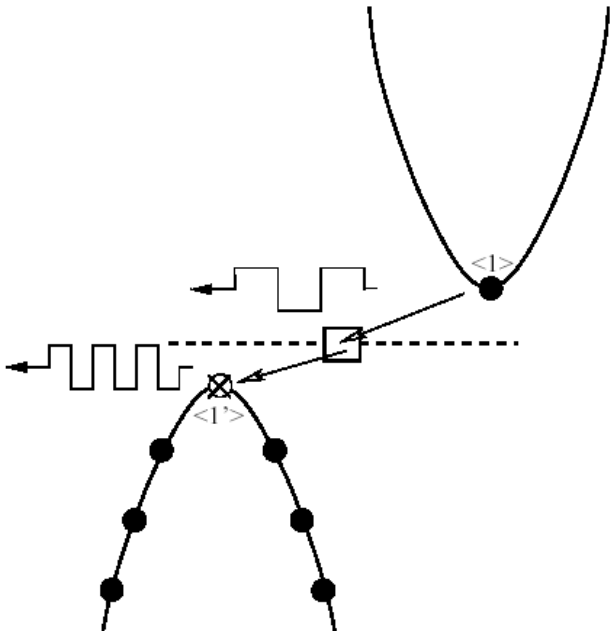


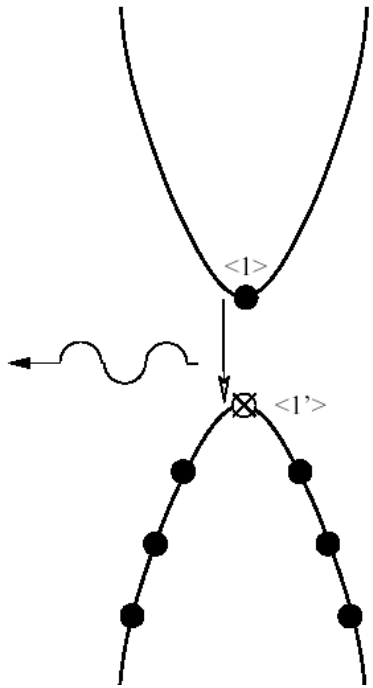

Why *p* on *n*, and not *n* on *p*?

Secs. 3.2.1, 3.2.2

# Choosing the semiconductor

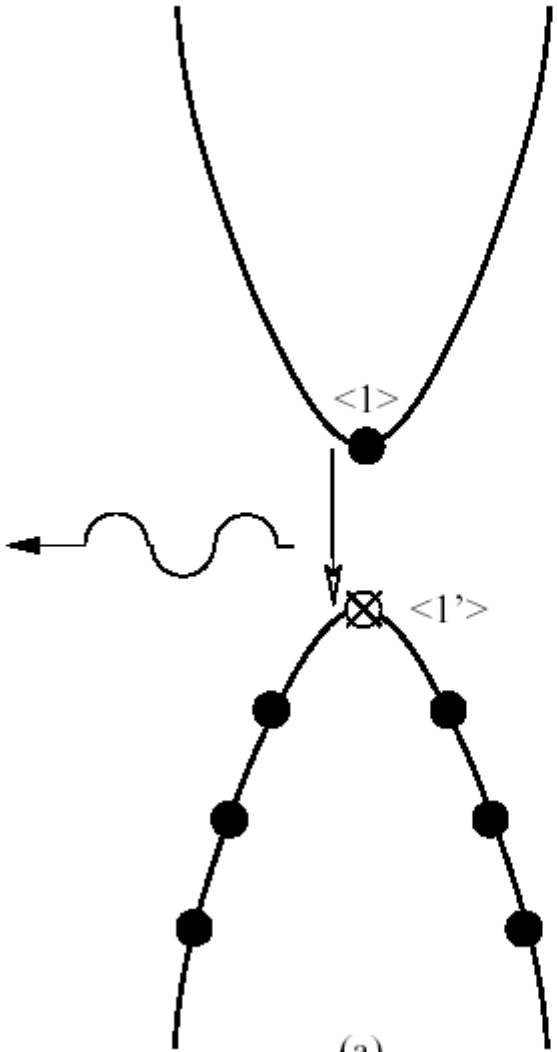
Indirect- or direct-bandgap material ?



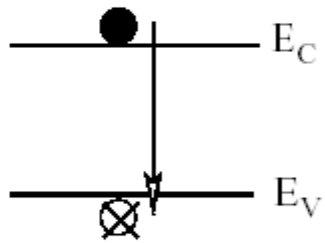



Sec. 8.1

# Voltage efficiency: choosing the colour




(a)

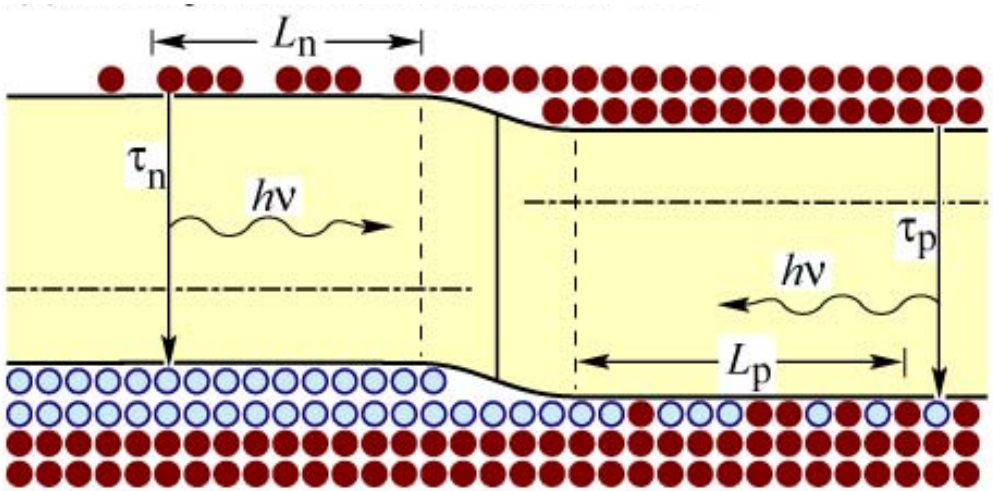



(b)

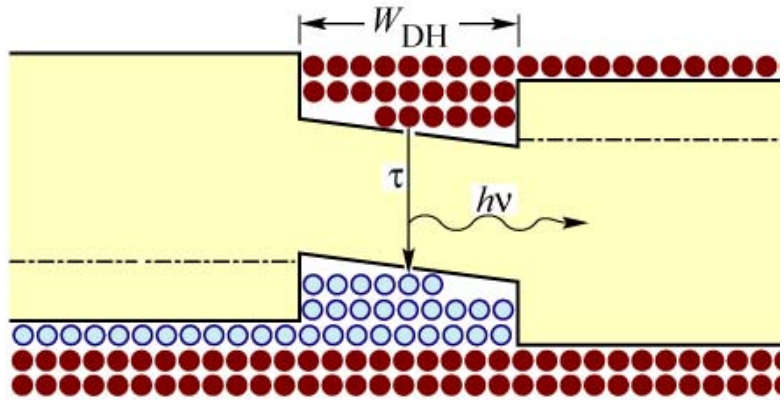
$$\eta_V \equiv \frac{\hbar\omega}{qV_a} \approx \frac{E_g}{qV_a}$$

Sec. 8.2

# Current efficiency: choosing the structure




Homojunction




Heterojunction

For high-brightness LEDs it is necessary to concentrate the recombination into a small volume.

The example shown has an [ ] of [ ] bandgap,

and [ ] layers of higher bandgap.

Schubert, Ref. 8.2

# Examples of colour lighting

## Automotive, Traffic Signals, Signage & Contour Solutions




LUMILEDS

Regensburg bridge

Schubert, Ref. 8.2

18 million LEDs in New York city

# Lattice mismatch

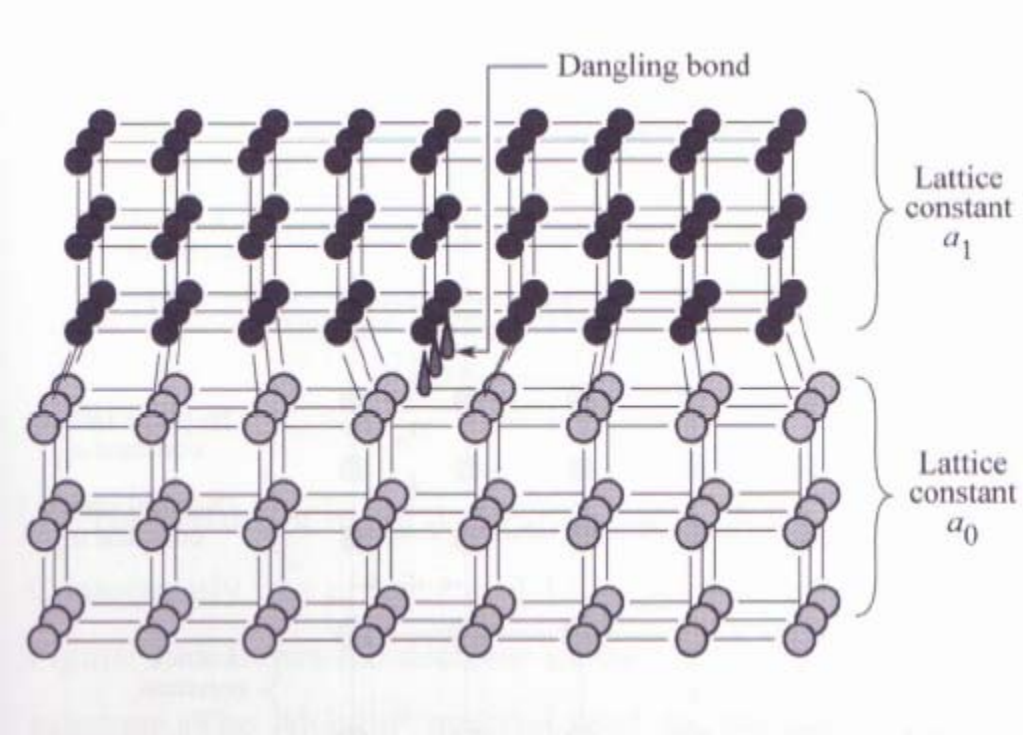
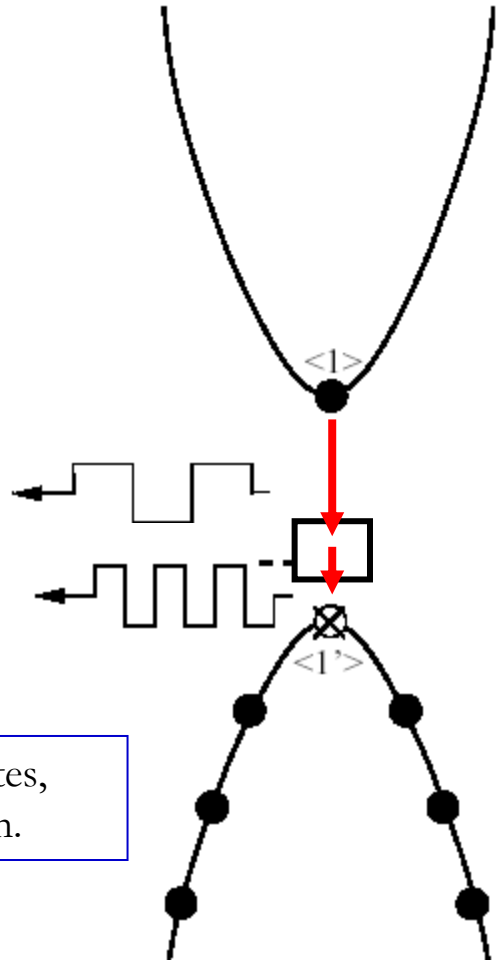



Fig. 7.12. Illustration of two crystals with mismatched lattice constant resulting in dislocations at or near the interface between the two semiconductors.

Dislocations cause intra-gap states, and non-radiative recombination.

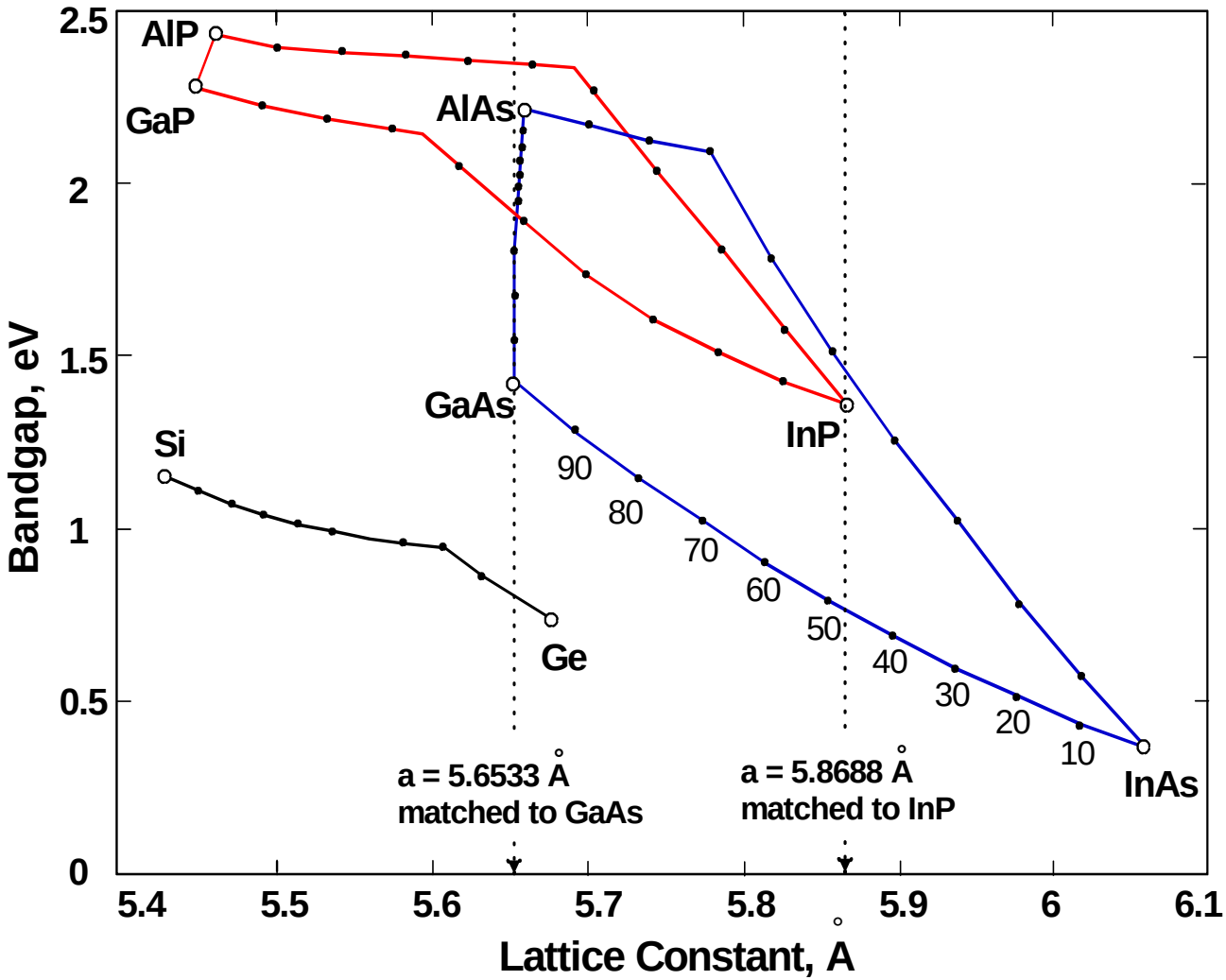



RG-centre (SRH)

*E.F. Schubert, LEDs, CUP, 2007*

Sec. 8.2.1

# Choosing materials for heterostructures



Sec. 8.2

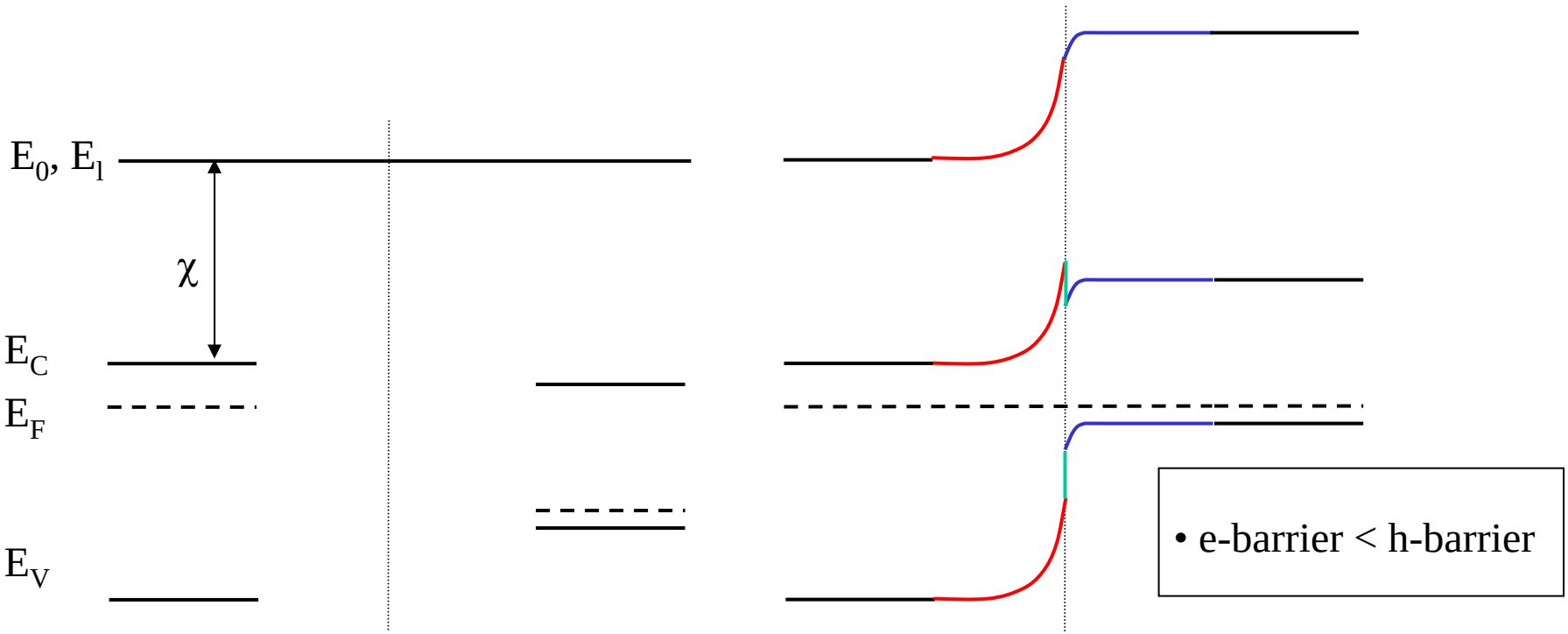
# Heterojunction band diagrams

e.g., *n*-$Al_{0.3}Ga_{0.7}As$ ($E_g$=1.80eV, $\chi$=3.83eV) on *p*-GaAs ($E_g$=1.42eV, $\chi$=4.07eV)

$$E_g(x) = 1.424 + 1.247x \quad \text{eV}$$
$$\chi(x) = 4.07 - 0.79x \quad \text{eV}\,.$$

Separated system

Joined system

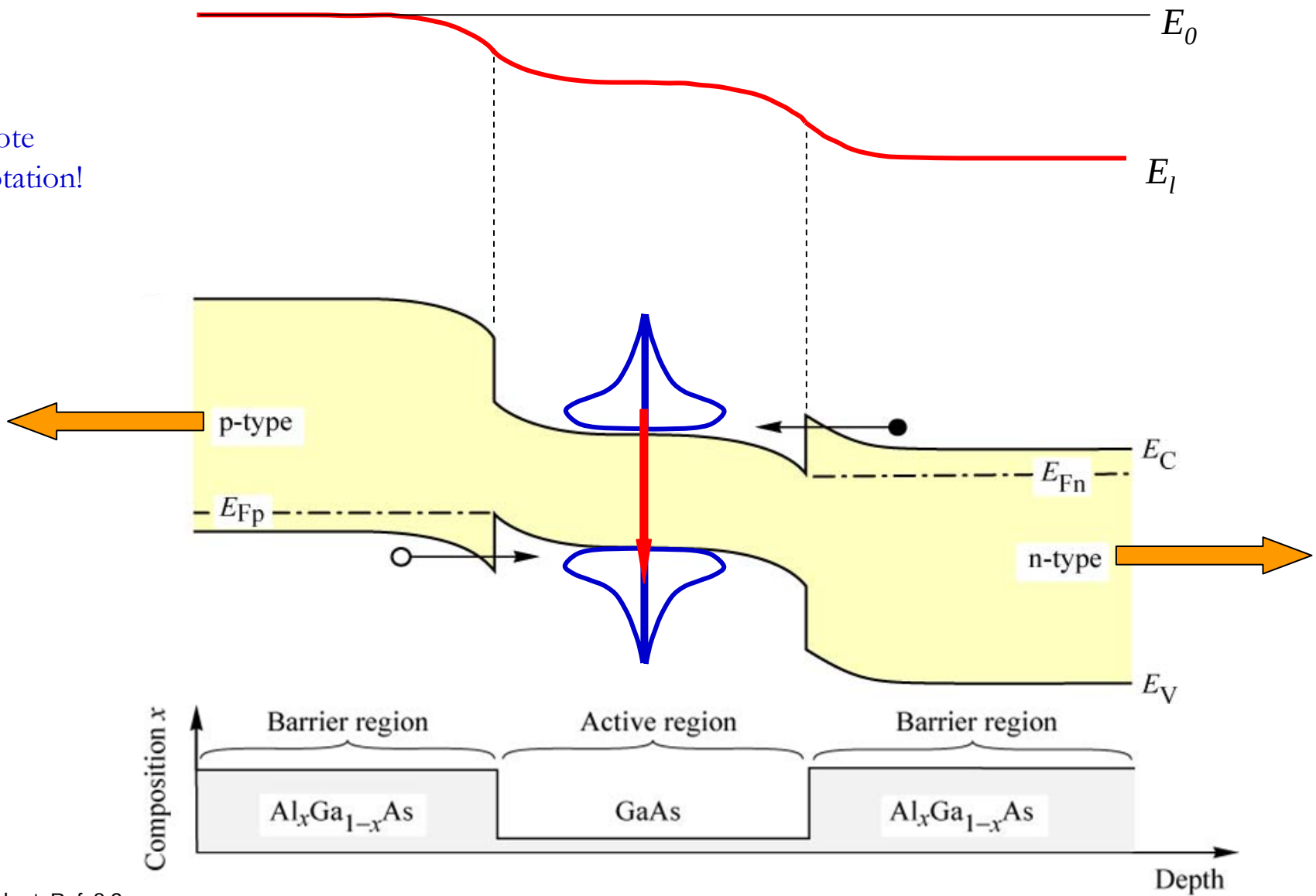



• e-barrier < h-barrier

Sec. 8.2

# Example of P⁺pN⁺ heterostructure LED

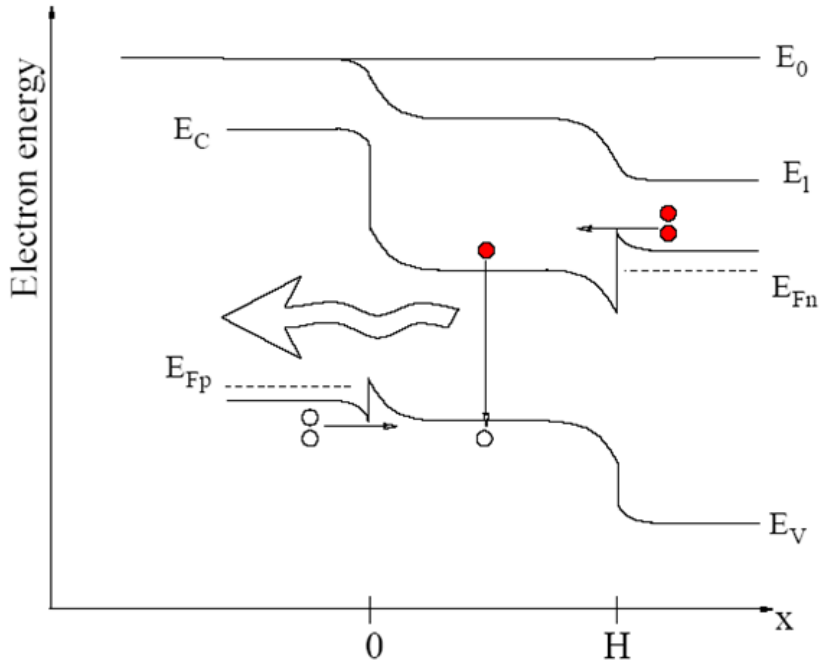
Note notation!




Schubert, Ref. 8.2

Sec. 8.2

# Current efficiency




From our toolbox

$$\frac{1}{q}\frac{dJ_e}{dx} - \frac{\Delta n}{\tau_e} = 0 \quad \Rightarrow \quad \int_0^H \frac{\Delta n}{\tau_e}\,dx = \int_0^H \frac{1}{q}\frac{dJ_e}{dx}\,dx$$

Current efficiency

$$\eta_C =$$