LECTURE 13

- LED basics
- voltage efficiency
- heterojunction band diagrams
- current efficiency
Electrical-to-optical energy conversion

Why $p$ on $n$, and not $n$ on $p$?
Choosing the semiconductor

Indirect- or direct-bandgap material?
Voltage efficiency: choosing the colour

Sec. 8.1

\[ \eta_V \equiv \frac{\hbar \omega}{qV_a} \approx \frac{E_g}{qV_a} \]
Current efficiency: choosing the structure

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

The example shown has an active layer of low-bandgap, and confinement layers of higher bandgap.

Schubert, Ref. 8.2
Examples of colour lighting

Automotive, Traffic Signals, Signage & Contour Solutions

Regensburg bridge  
Schubert, Ref. 8.2

18 million LEDs in New York city

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Lattice mismatch

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

E. F. Schubert, LEDs, CUP, 2007
Choosing materials for heterostructures
Heterojunction band diagrams

Sec. 8.2

e.g., \( n\)-Al\(_{0.3}\)Ga\(_{0.7}\)As (\( E_g = 1.80\)eV, \( \chi = 3.83\)eV) on \( p\)-GaAs (\( E_g = 1.42\)eV, \( \chi = 4.07\)eV)

\[
E_g(x) = 1.424 + 1.247x \quad \text{eV}
\]

\[
\chi(x) = 4.07 - 0.79x \quad \text{eV}.
\]

Separated system

\( E_0, E_1 \)

\( \chi \)

\( E_C \)

\( E_F \)

\( E_V \)

Joined system

\( \bullet \) e-barrier < h-barrier
Example of P⁺pN⁺ heterostructure LED

Note notation!

Schubert, Ref. 8.2
Sec. 8.2

Current efficiency

From our toolbox

\[ \frac{1}{q} \frac{dJ_e}{dx} - \frac{\Delta n}{\tau_e} = 0 \]

\[ \int_0^H \frac{\Delta n}{\tau_e} \, dx = \int_0^H \frac{1}{q} \frac{dJ_e}{dx} \, dx \]

Current efficiency

\[ \eta_C = \]