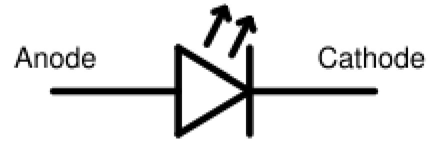
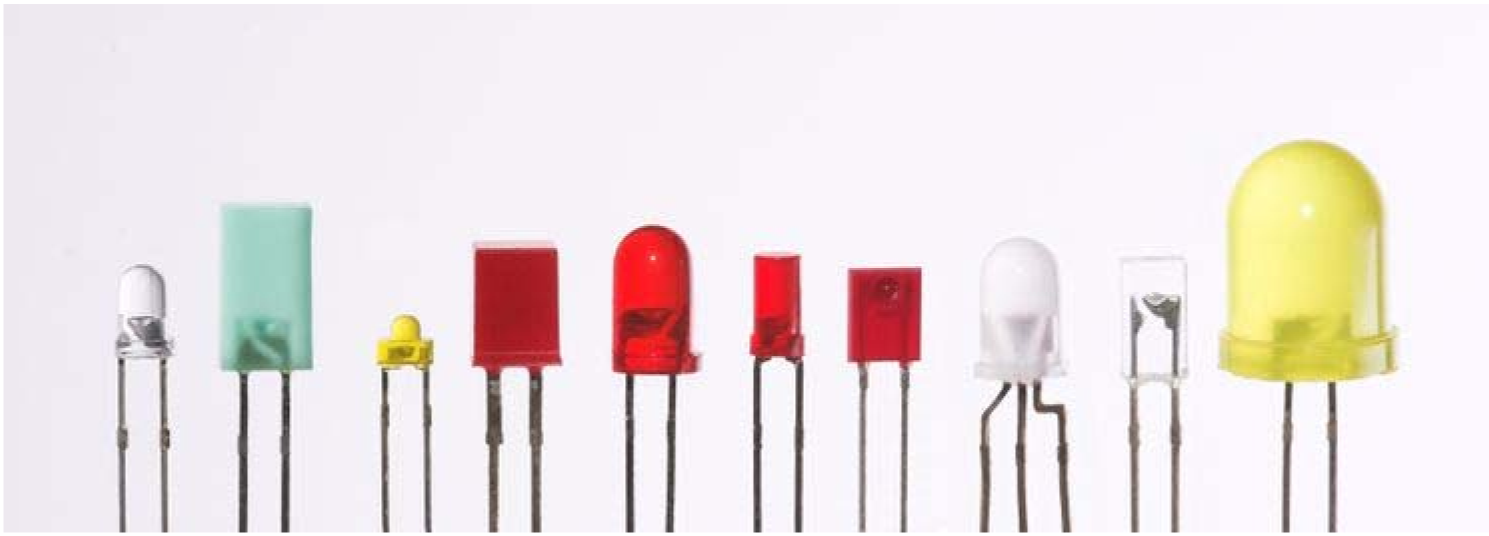
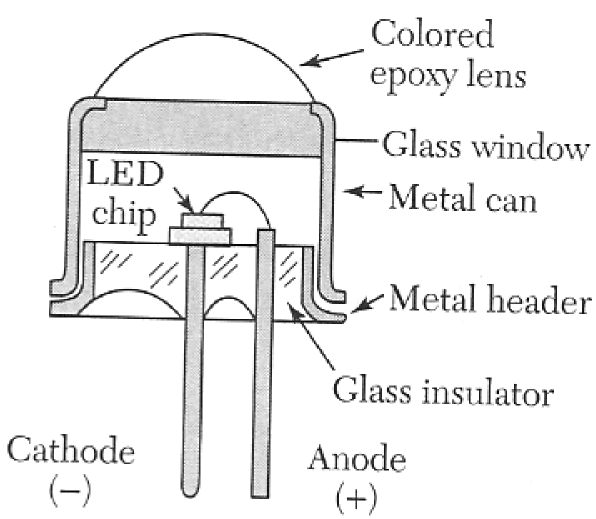
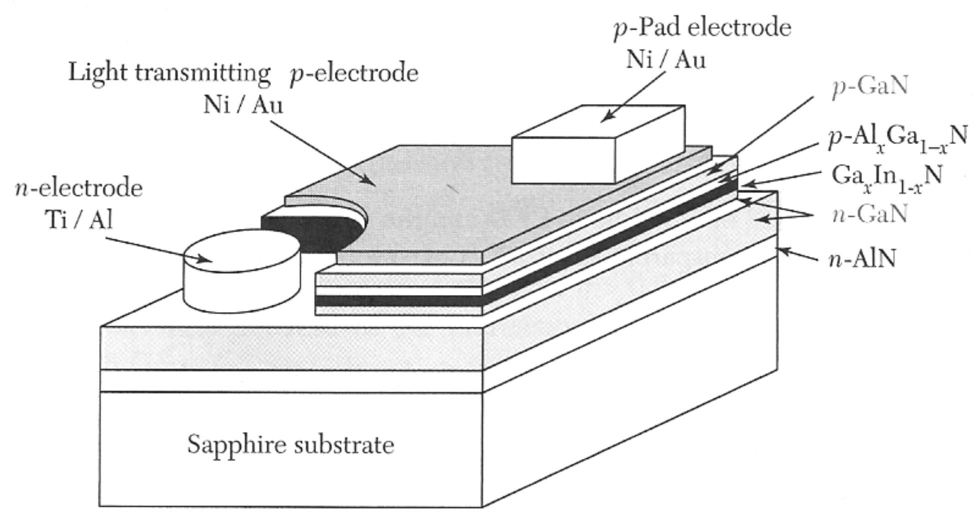
Optoelectronics

Light emitting diodes



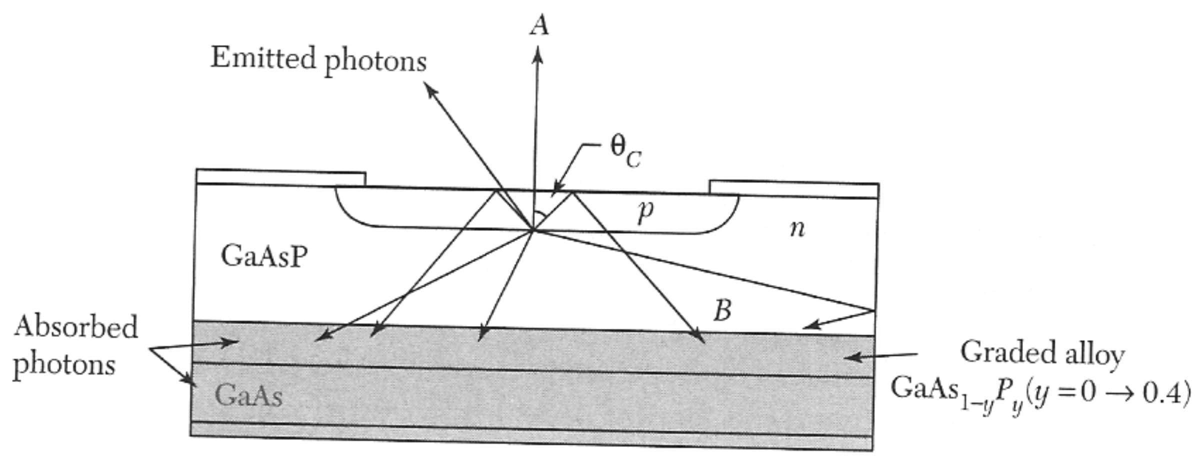




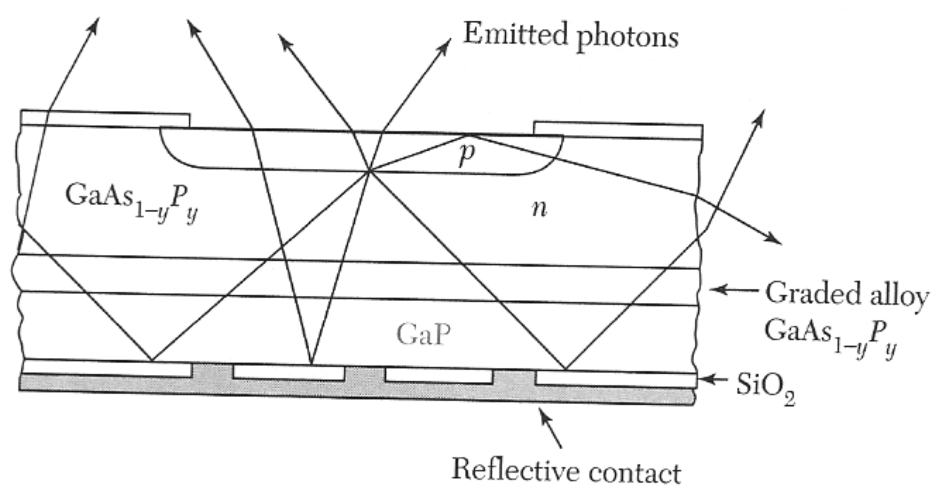


Solid state lighting is efficient.

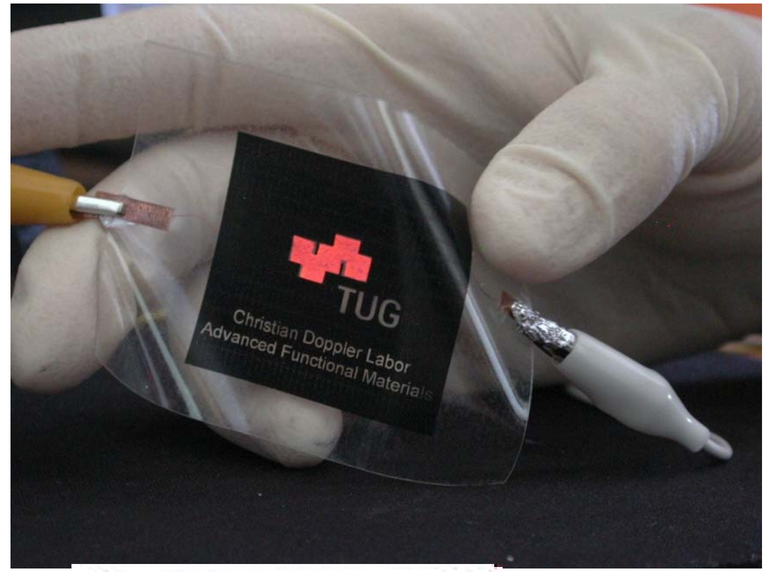
Light emitting diodes

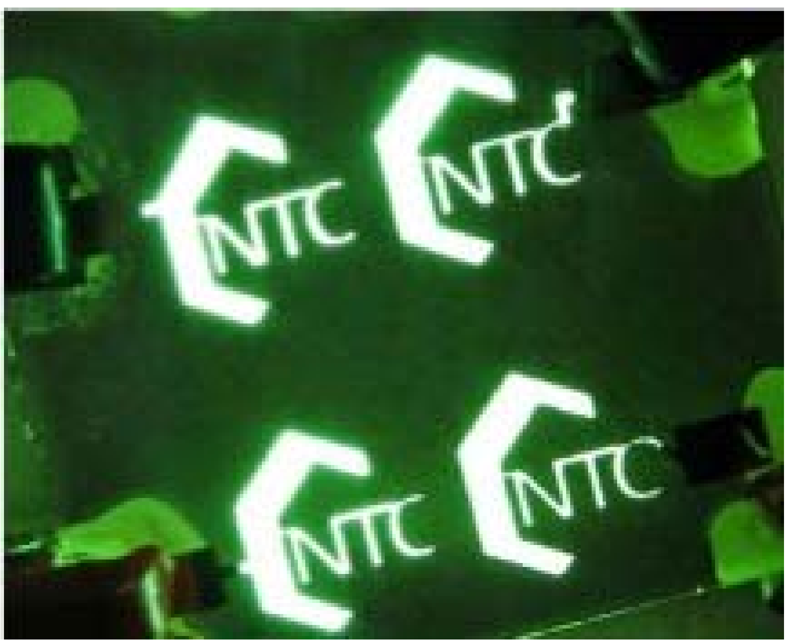


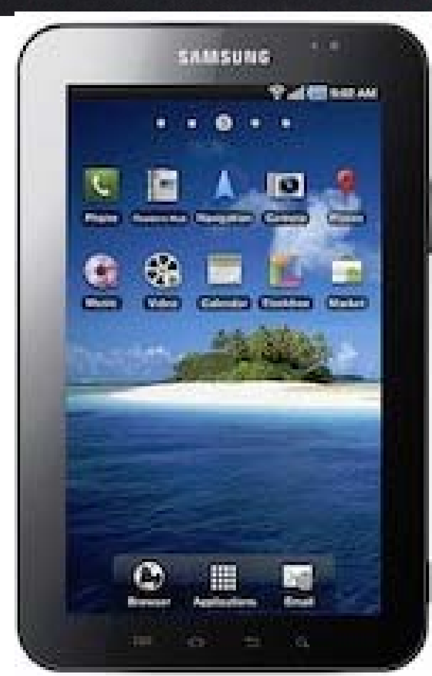
absorption
reflection
total internal reflection



OLEDs







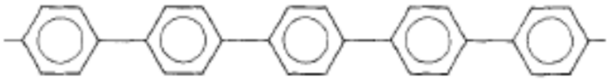
Galaxy Tab

Encapsulation technology

Electroluminescence in poly(p-phenylene)

Prof. Günther Leising

In 1992, Leising et al. for the first time reported on blue electroluminescence from OLEDs containing poly(p-phenylene) (PPP).

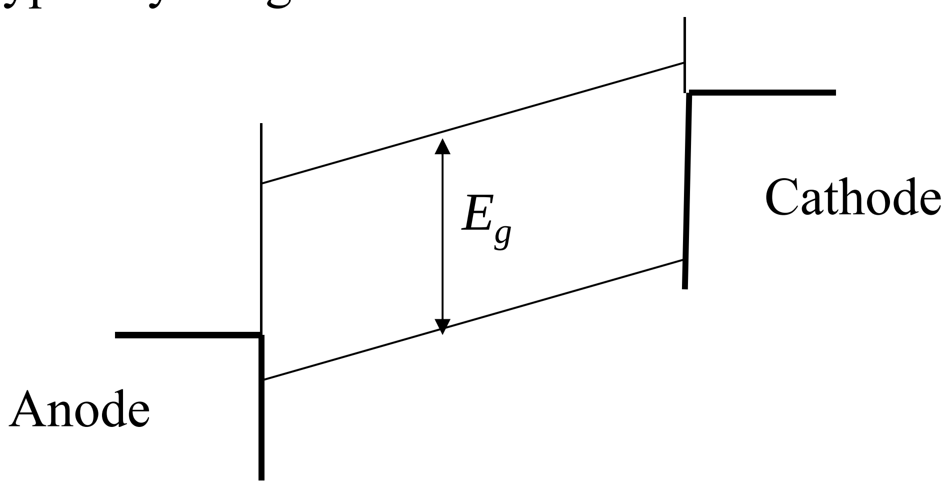


OLEDs

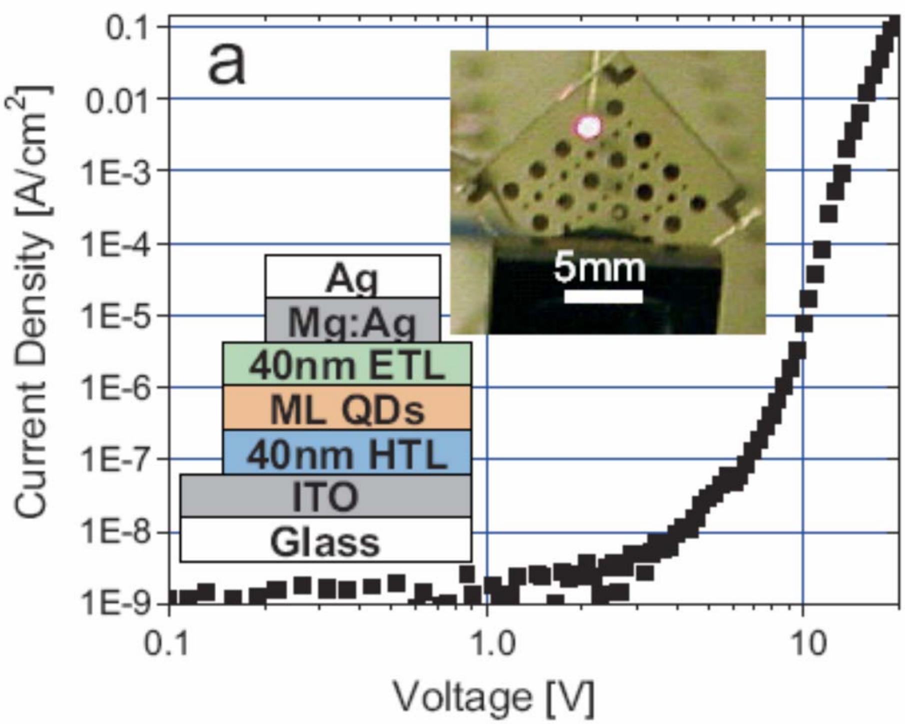
Aluminum cathode
Electron transport layer
Emission layer
Hole transport layer
ITO anode
Glass

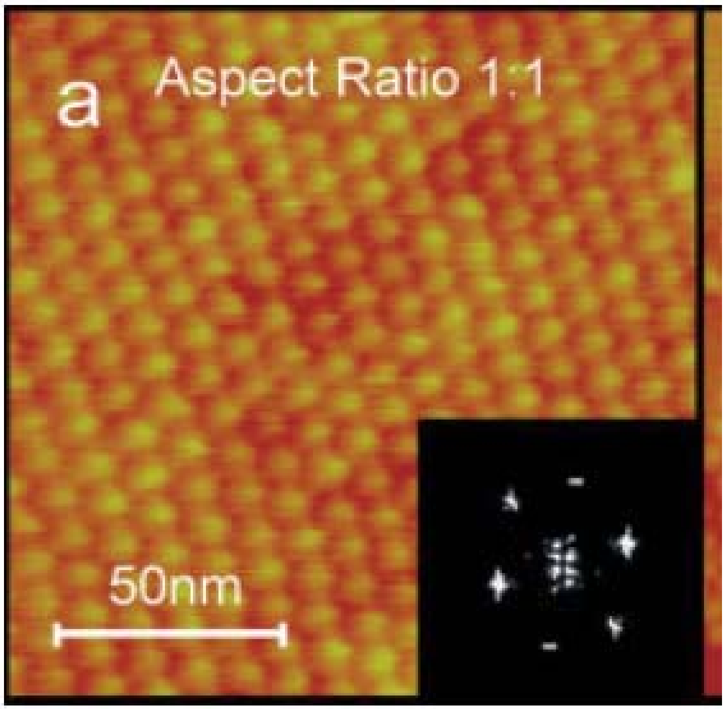
Cathode is typically a low work function material Al, Ca - injects electrons

Anode is typically a high work function material ITO - injects holes



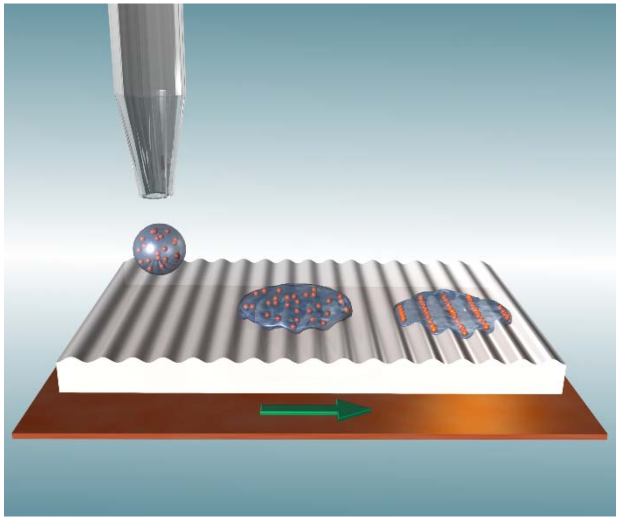
Q-dot LEDs

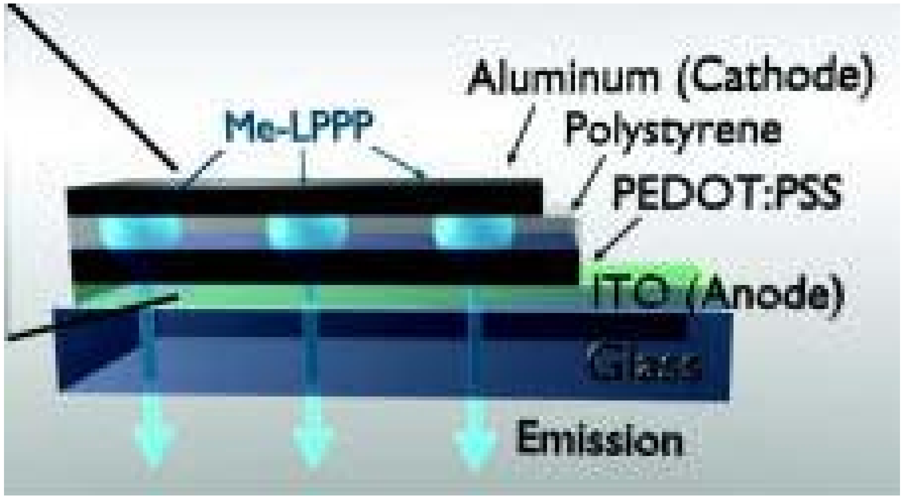




Coe-Sullivan, et al. Advanced Functional Materials, 10.1002/adfm.200400468

Nanoparticle OLEDs





Semiconductor nanosphere (Me-LPPP) OLEDs

Appl. Phys. Lett. 92, 183305 (2008)

Efficient lighting

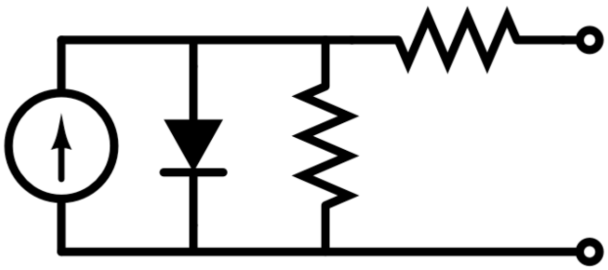
Very efficient
Many colors possible
No toxic chemicals

Flexible, transparent, wearable displays

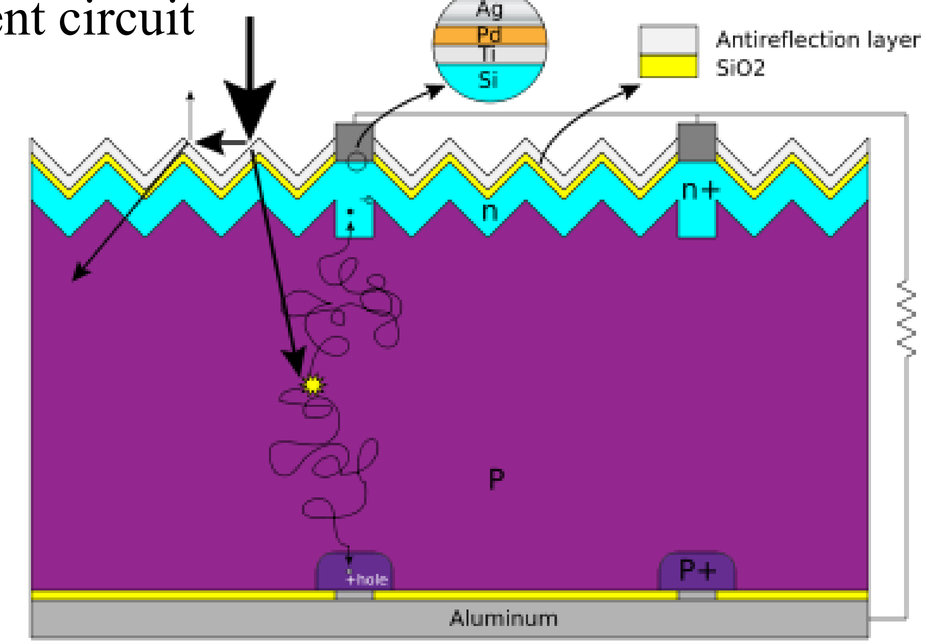
Transparent AMOLED

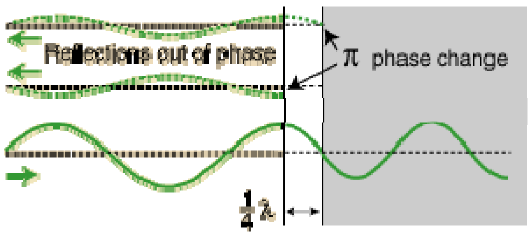
Folding display

Solar cell

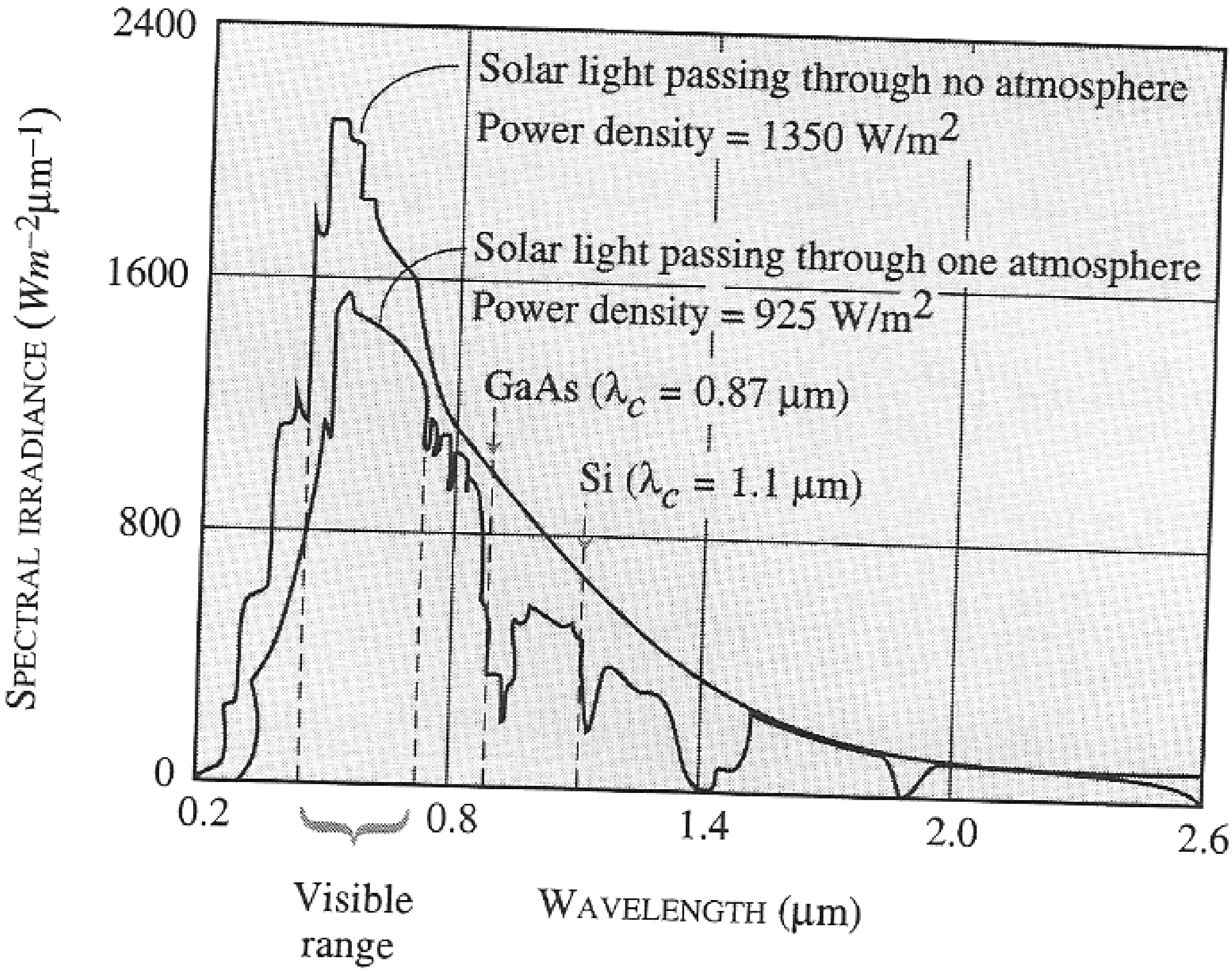


Equivalent circuit

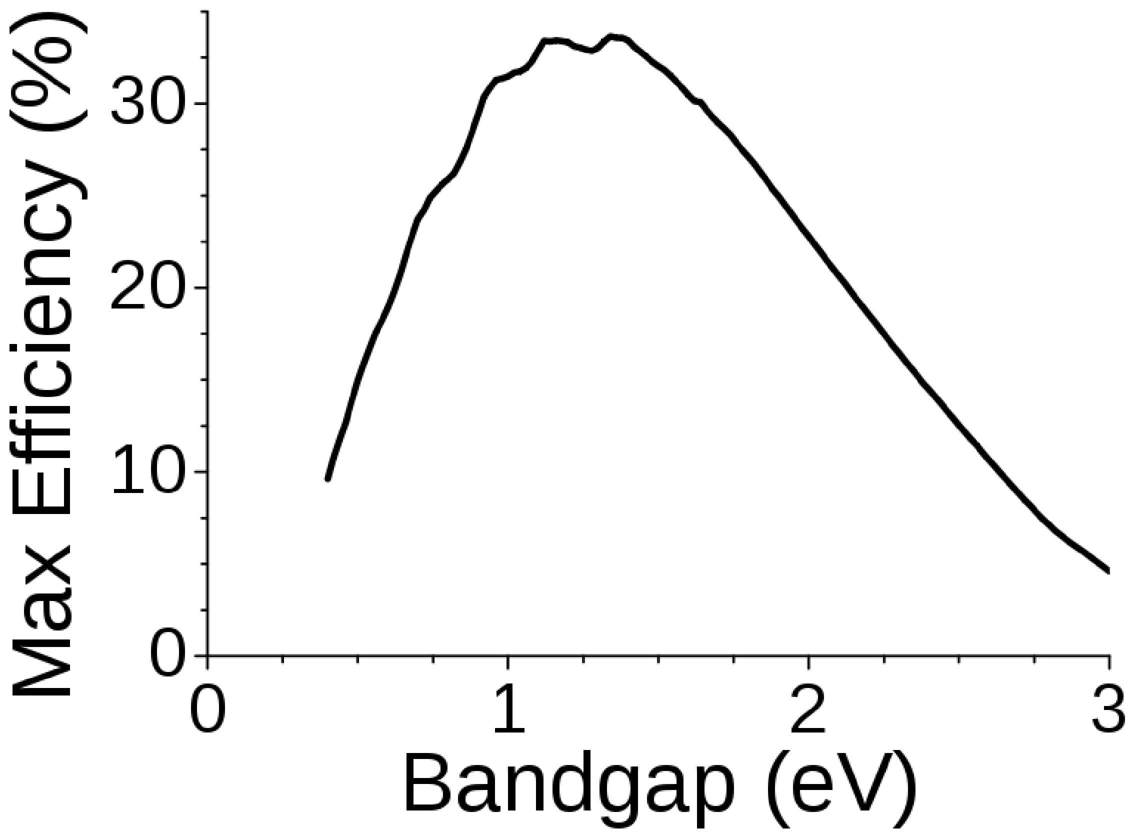




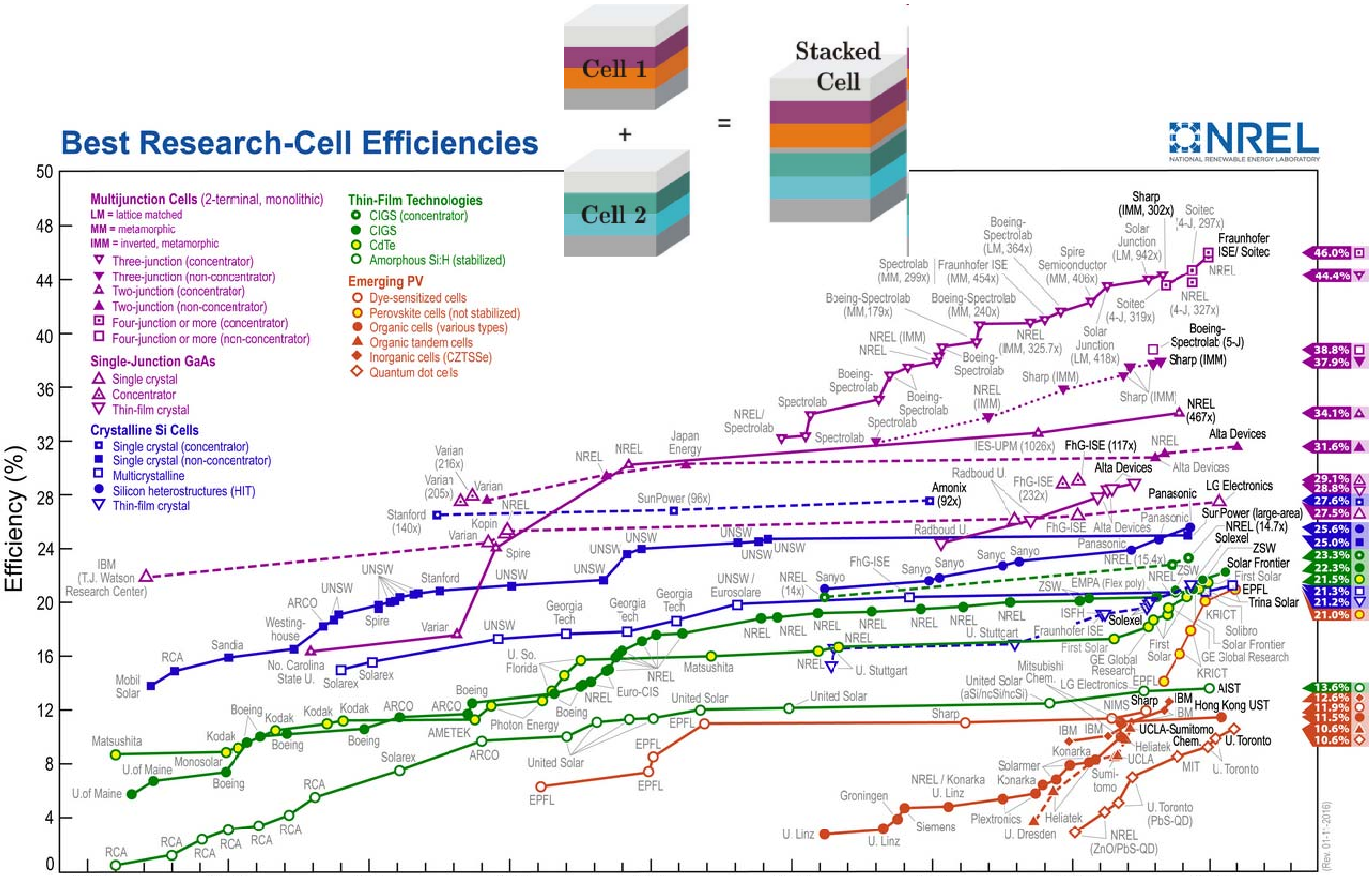
Solar spectrum



Shockley–Queisser limit



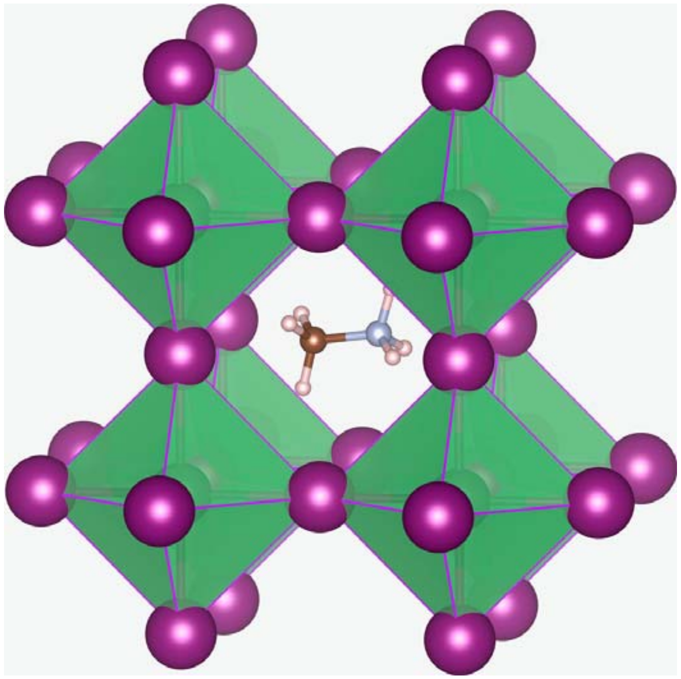
http://en.wikipedia.org/wiki/Shockley-Queisser_limit



Biofuel efficiency ~ 1%

Perovskite solar cells

https://en.wikipedia.org/wiki/Perovskite_solar_cell#/media/File:CH3NH3PbI3_structure.png



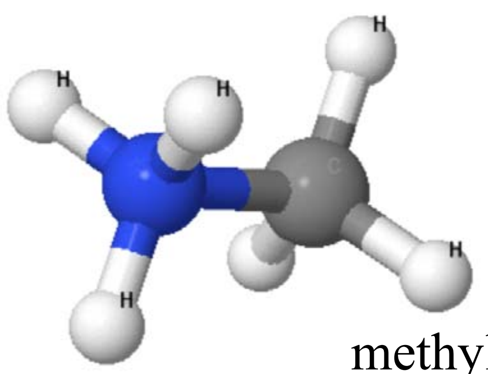
methylammonium lead trihalide ABX_3
$CH_3NH_3PbX_3$, where X is I, Br or Cl
Optical bandgap 1.5 - 2.3 eV

+ Cheaper to fabricate than Si solar cells.
(silicon cells require > 1000 C)

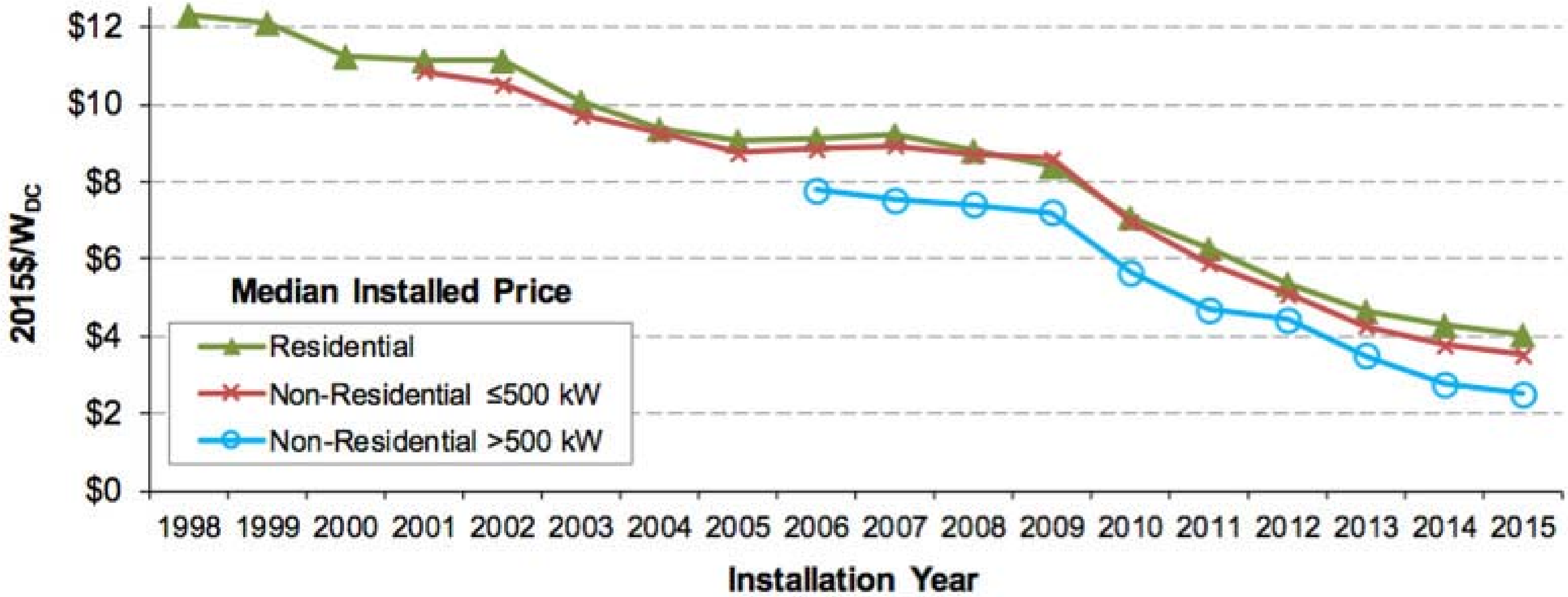
- Contains lead

Also less efficient $CH_3NH_3SnI_3$ version

- Not stable



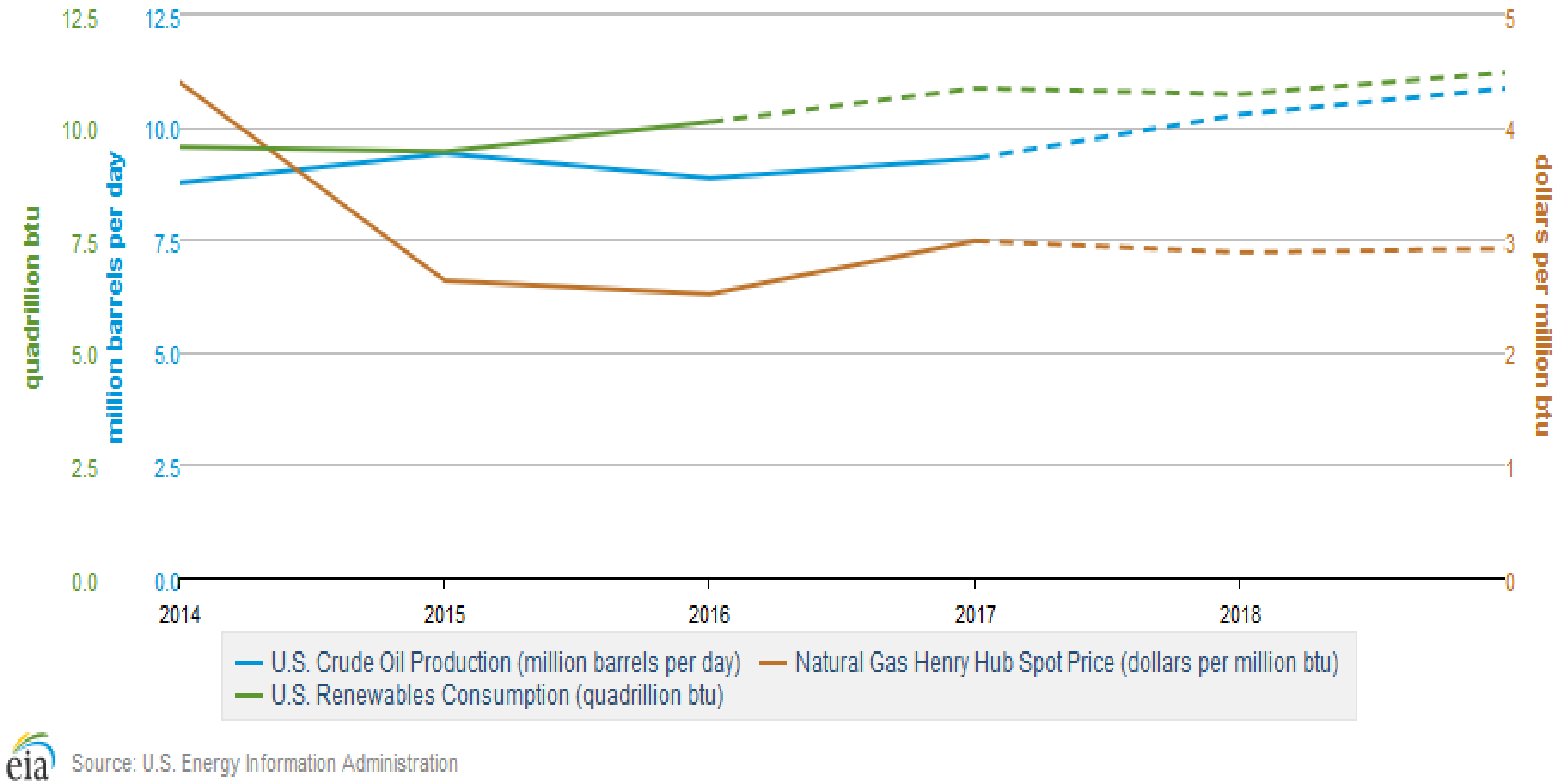
methylammonium



Notes: See Table 1 for sample sizes by installation year. Median installed prices are shown only if 20 or more observations are available for a given year and customer segment.

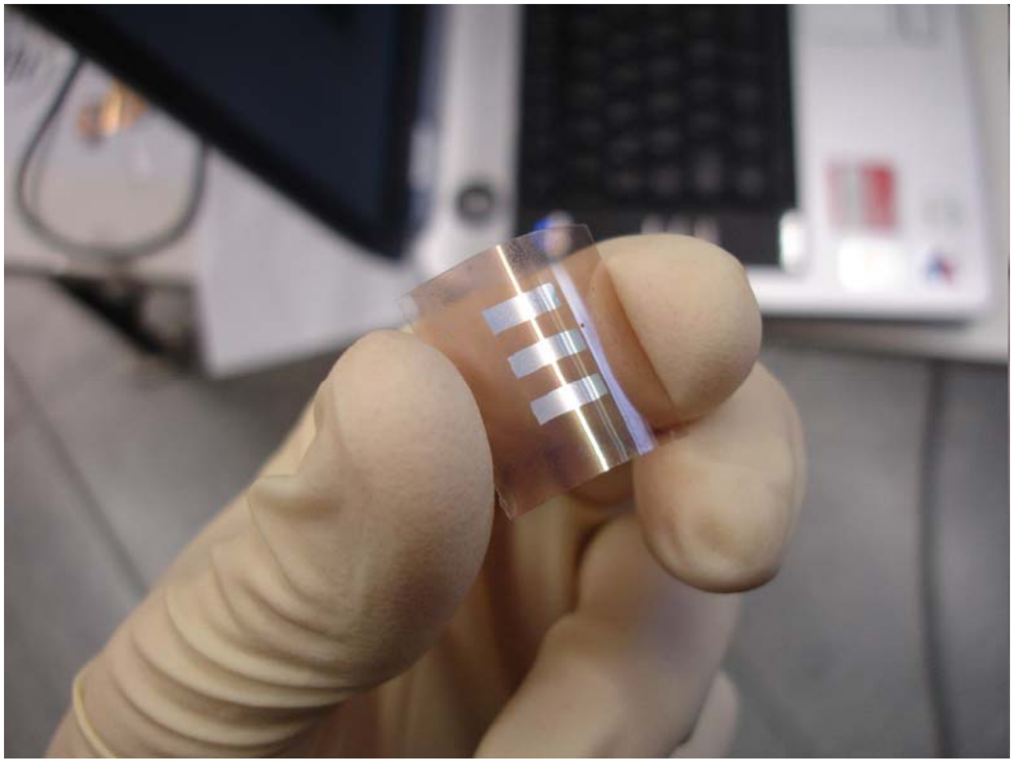
Figure 6. Median Installed Price Trends over Time

https://www.vox.com/2016/8/24/12620920/us-solar-power-costs-falling



Grid parity is achieved when the prices are equal

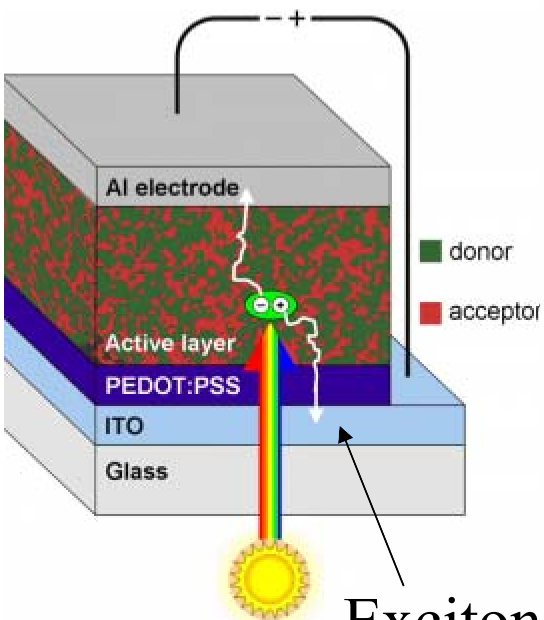
Printable solar cells



CD labor - TU Graz

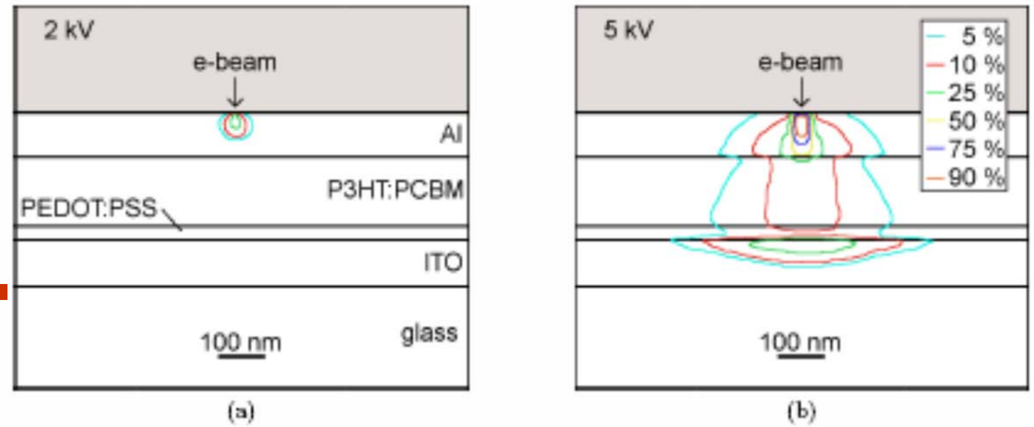
Konarka

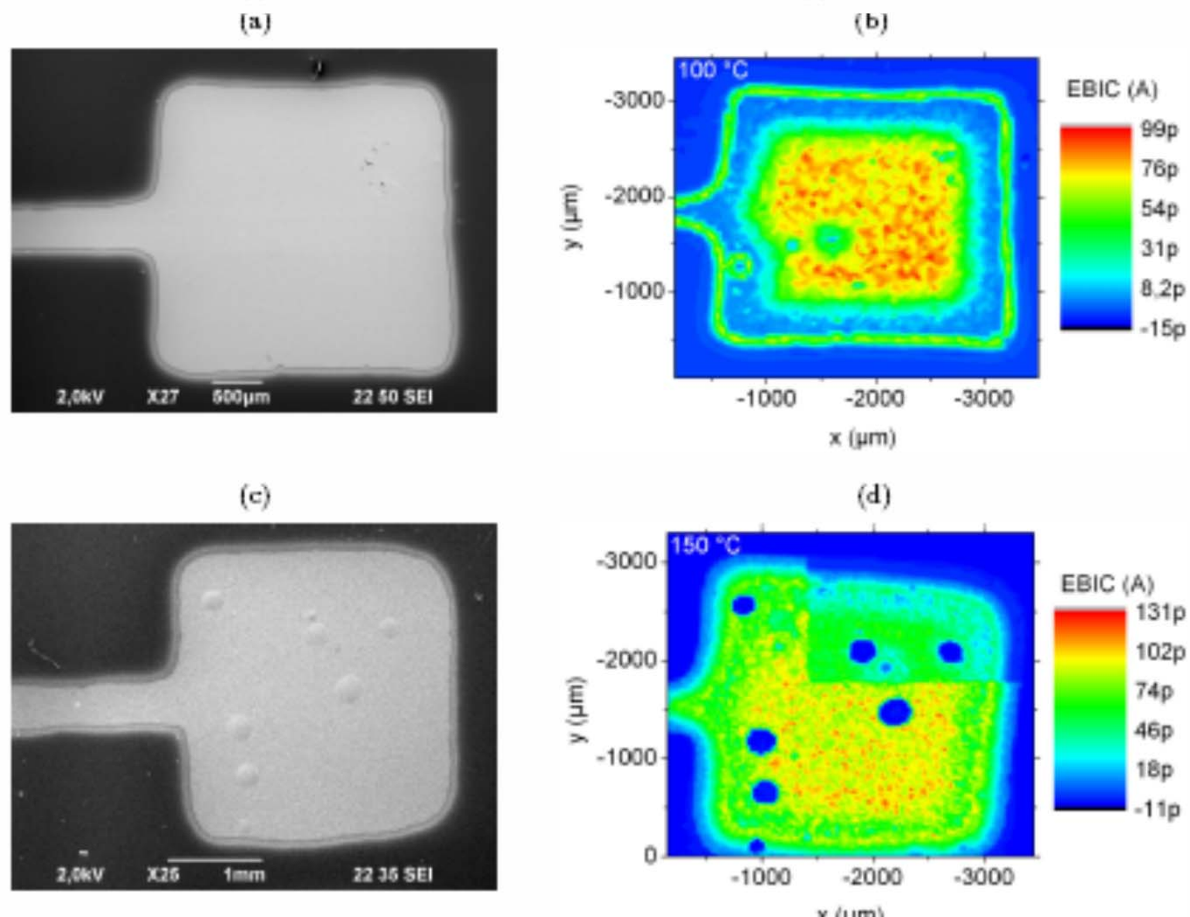
organic solar cells



Excitons

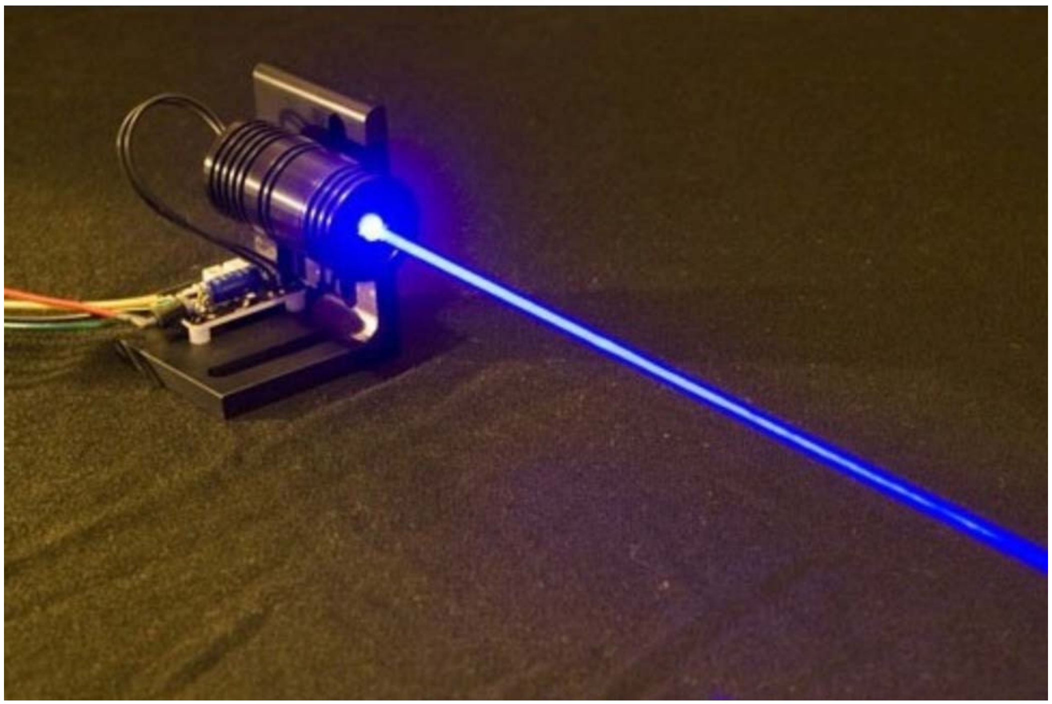
Bulk heterojunction





http://www-ssrl.slac.stanford.edu/science-highlight/2011/january/effects-thermal-annealing-morphology-polymer%E2%80%93fullerene-blends-organic

laser diodes



http://www.aliexpress.com/item/445nm-laser-diode/767127021.html

Shop on Google   Sponsored

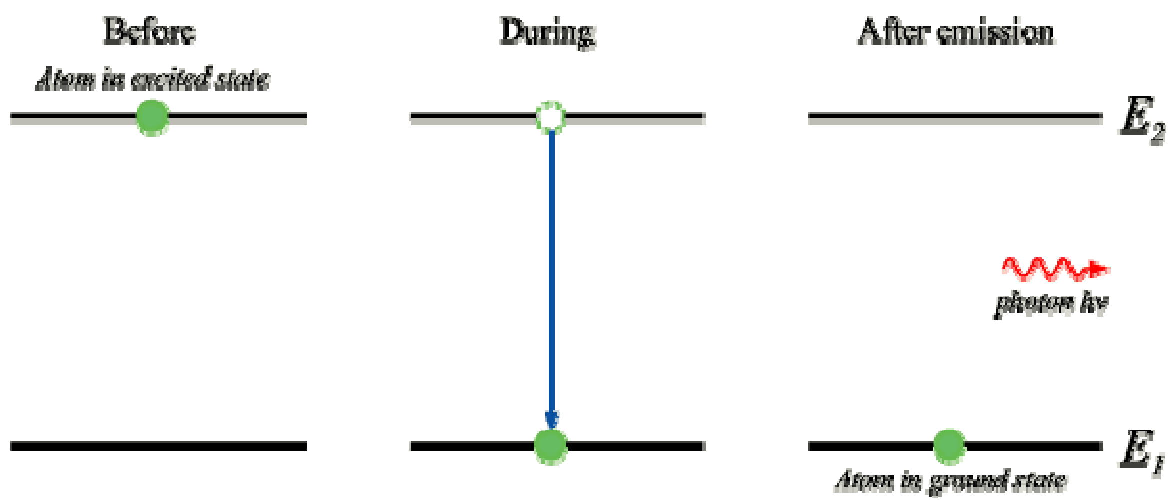
Laserdiode Rot 650 nm 2 mW ...
€23,99
Conrad.at

Laserdiode Rot 670 nm 5 mW U- ...
€9,19
Conrad.at

3V 6mm 5mW 650nm rote Laser-
€2,43
DX.com

Laser Components - ...
€30,72
Distrelec Österrei...

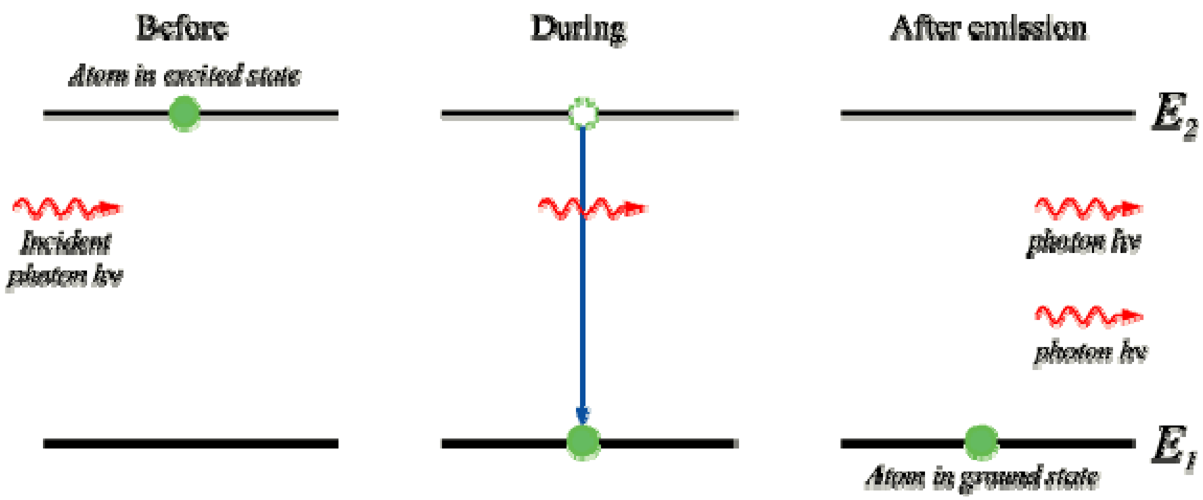
Spontaneous emission



$$h\nu = E_2 - E_1$$

Spontaneous emission dominates in fluorescent lighting and light emitting diodes. In a gas, the conservation of momentum is easily maintained. For a semiconductor, a direct bandgap material is necessary.

Stimulated emission



Stimulated emission is responsible for the coherent light of lasers.

$$W_{\text{stimulated}}(\omega) = W_{\text{spontaneous}}(\omega) \cdot n_{ph}(\omega)$$

laser diodes

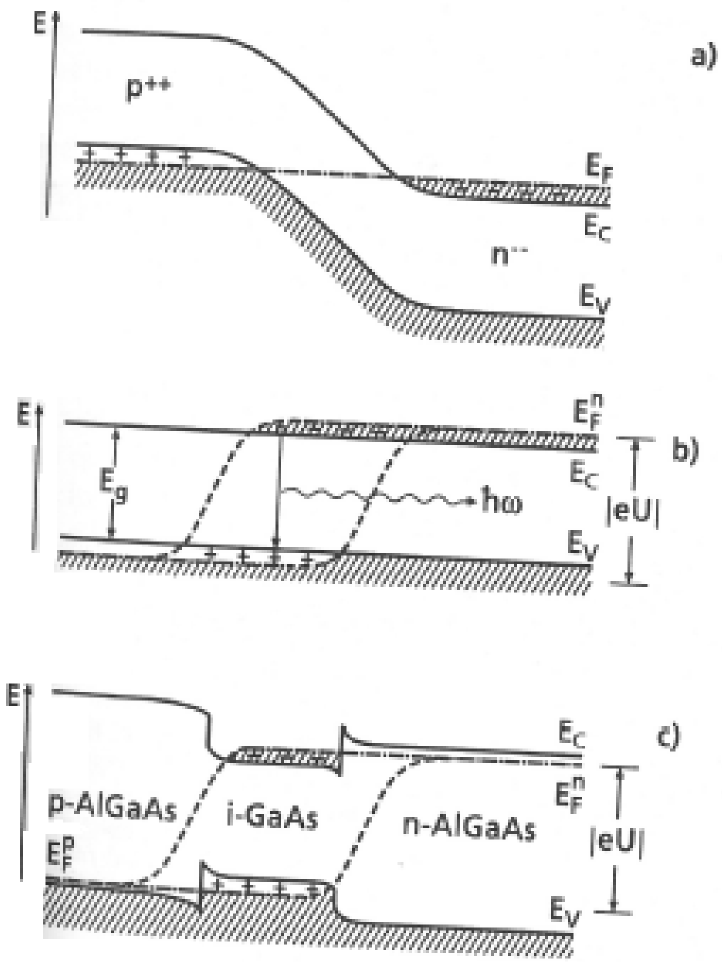
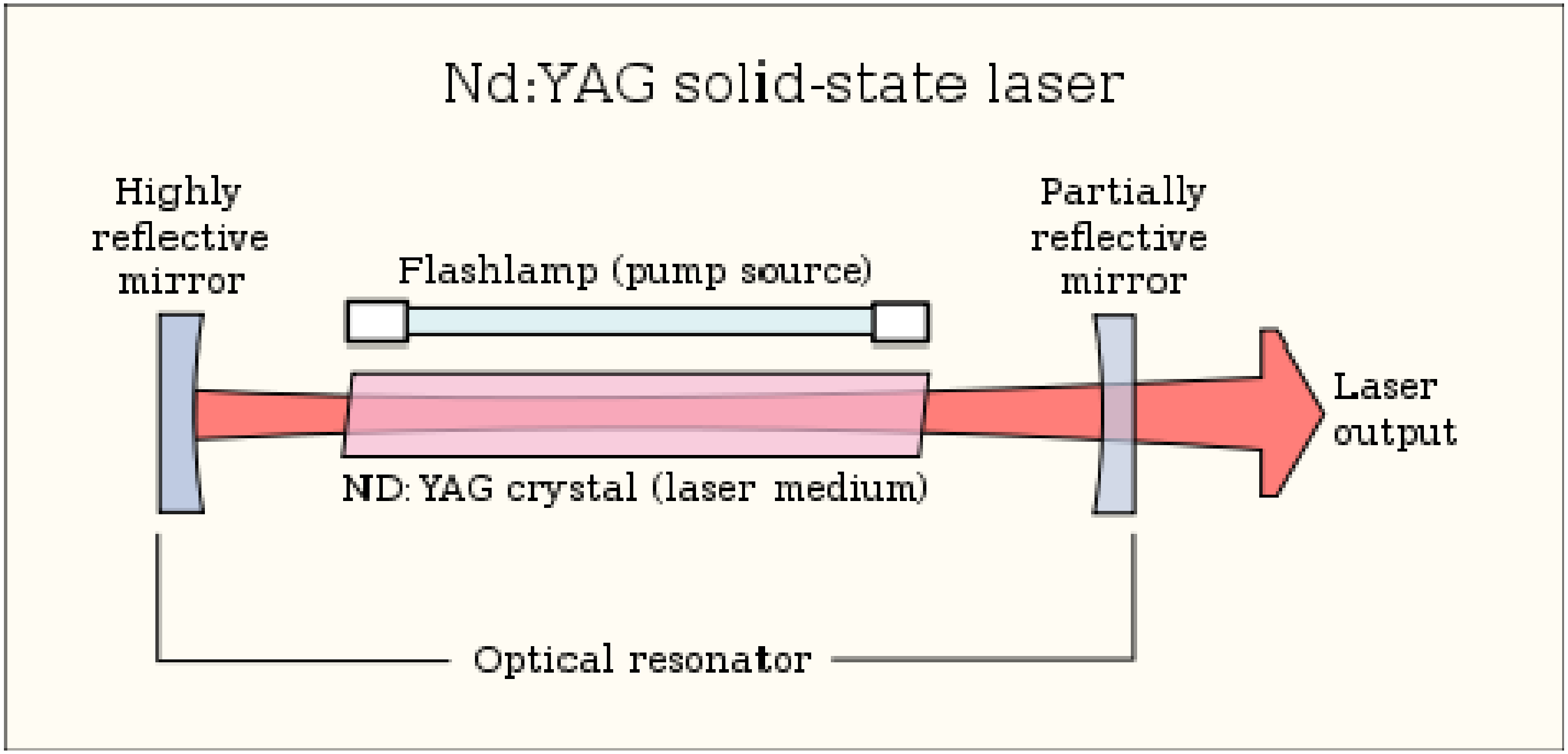


Fig. 12.37. Electronic band schemes $E(x)$ of *pn*-semiconductor laser structures along a direction x perpendicular to the layer structure: **(a)** Degenerately doped $p^{++}n^{--}$ junction without external bias (thermal equilibrium); **(b)** same $p^{++}n^{--}$ junction with maximum bias U in forward direction; **(c)** double-heterostructure pin junction of *p*-AlGaAs/*i*-GaAs/*n*-AlGaAs with maximum bias U in forward direction. E_F^n, E_F^p are the quasi-Fermi levels in the *n*- and *p*-region, respectively; E_C and E_V are conduction and valence band edges

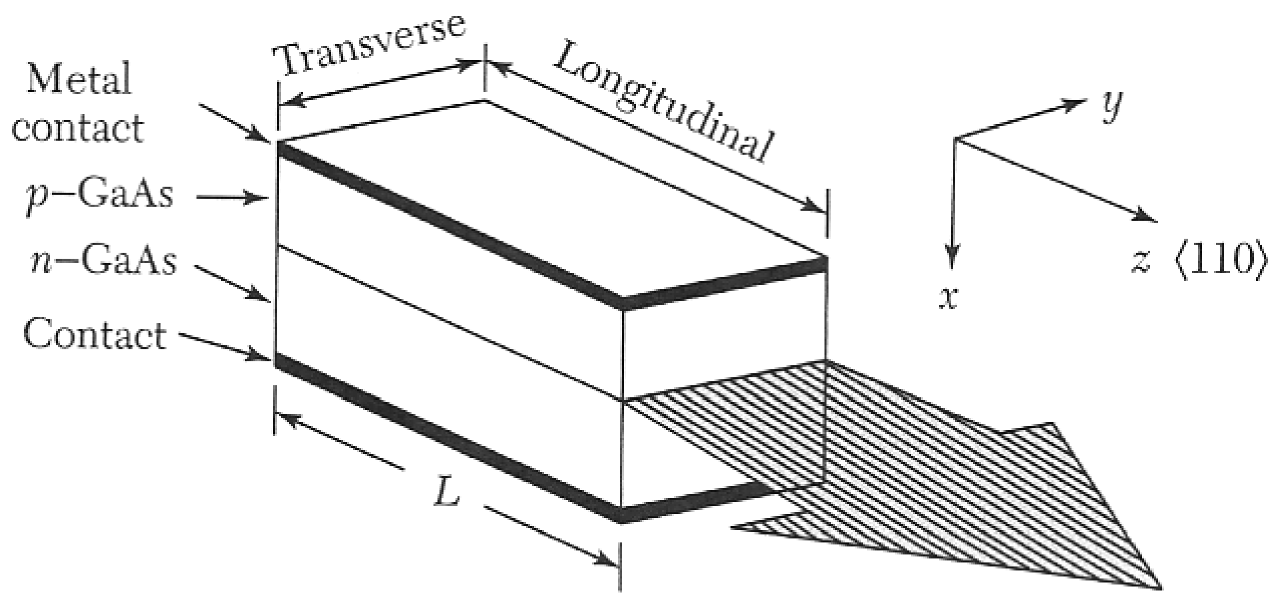
Ibach & Lueth, *Solid-State Physics*

Optical cavity



https://en.wikipedia.org/wiki/Laser_construction#/media/File:Lasercons.svg

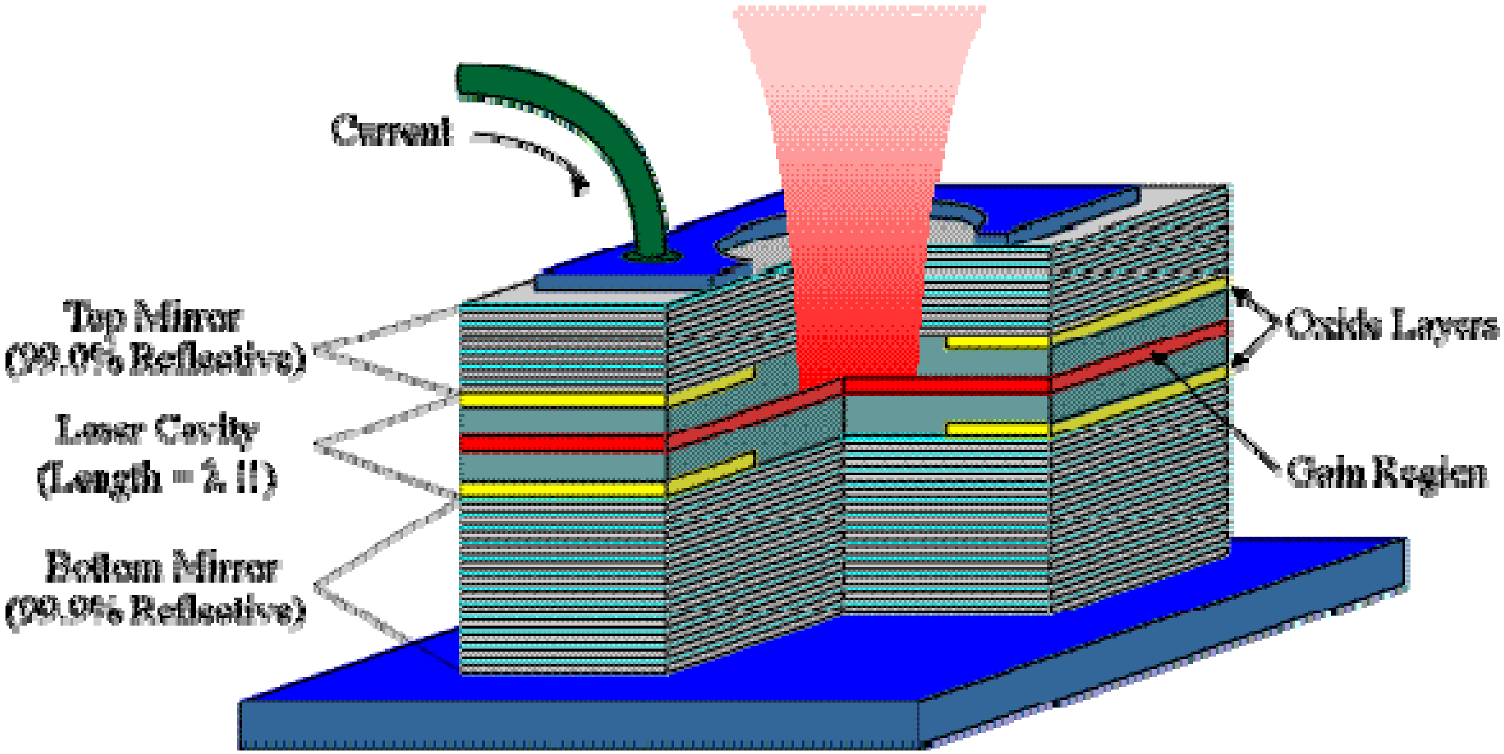
Laser diode



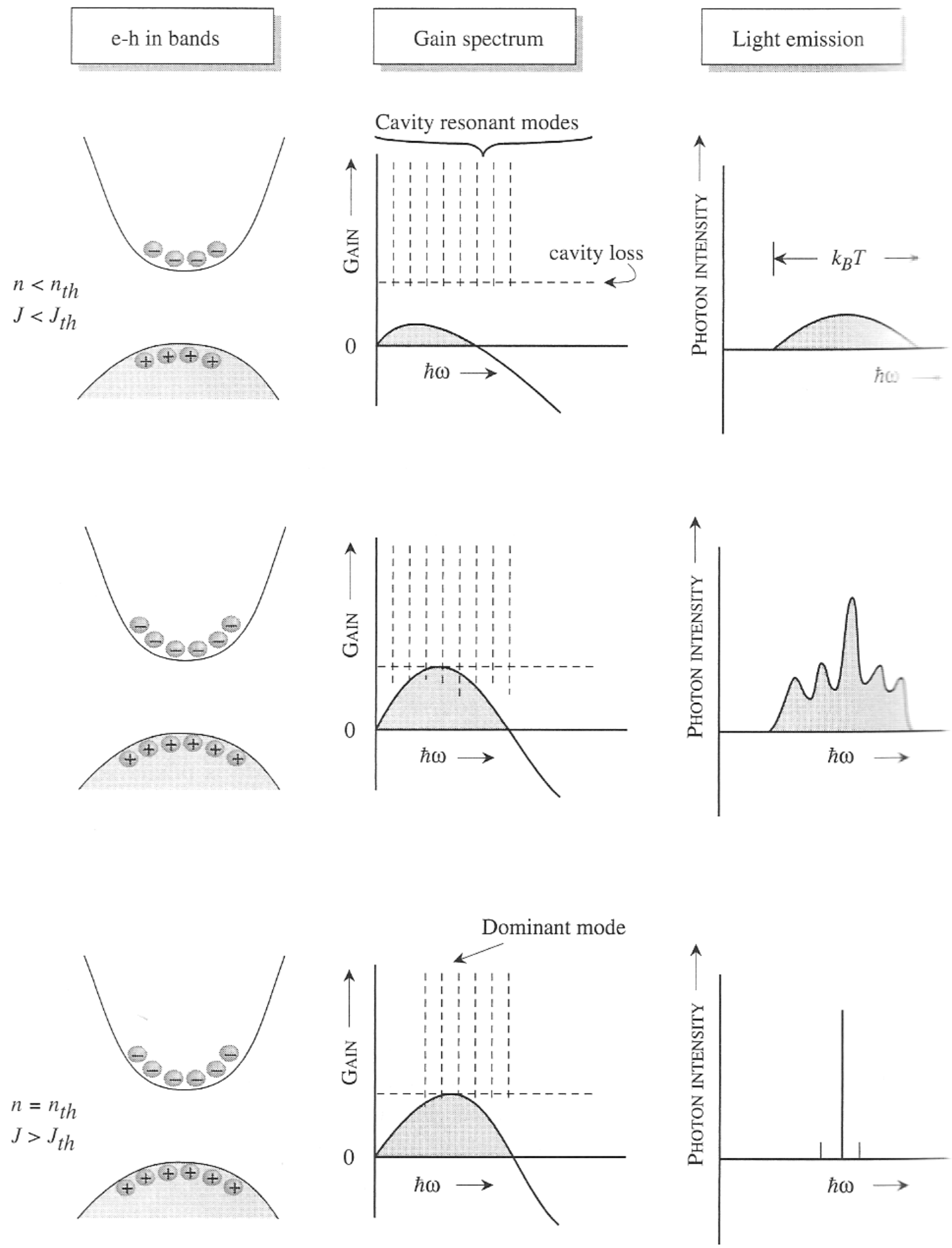
(a)

The faces of the crystal are cleaved to make mirrors.

Vertical-cavity surface-emitting laser (VCSEL)

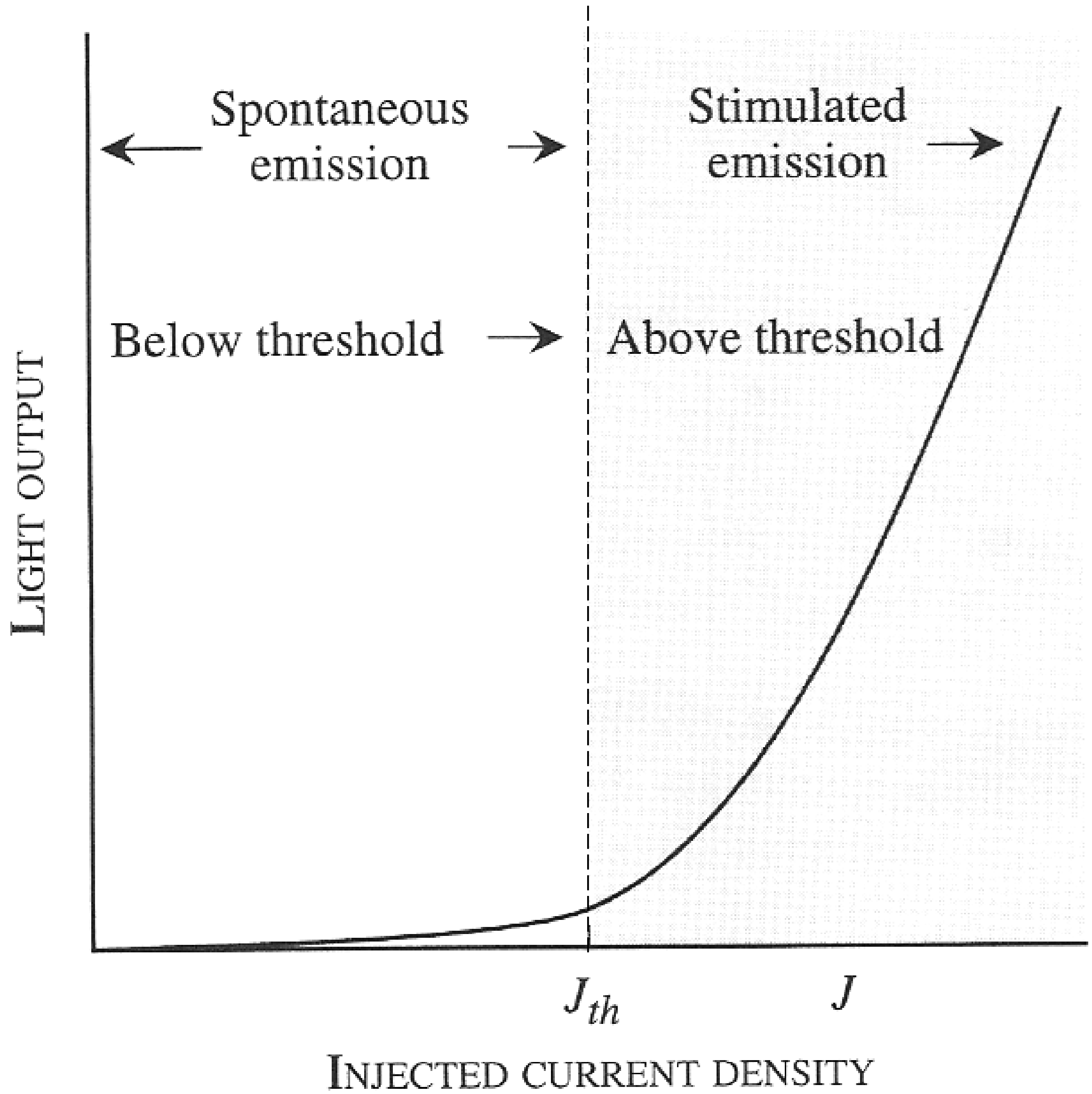


http://wwwold.fi.isc.cnr.it/users/giovanni.giacomelli/Semic/Samples/samples.html

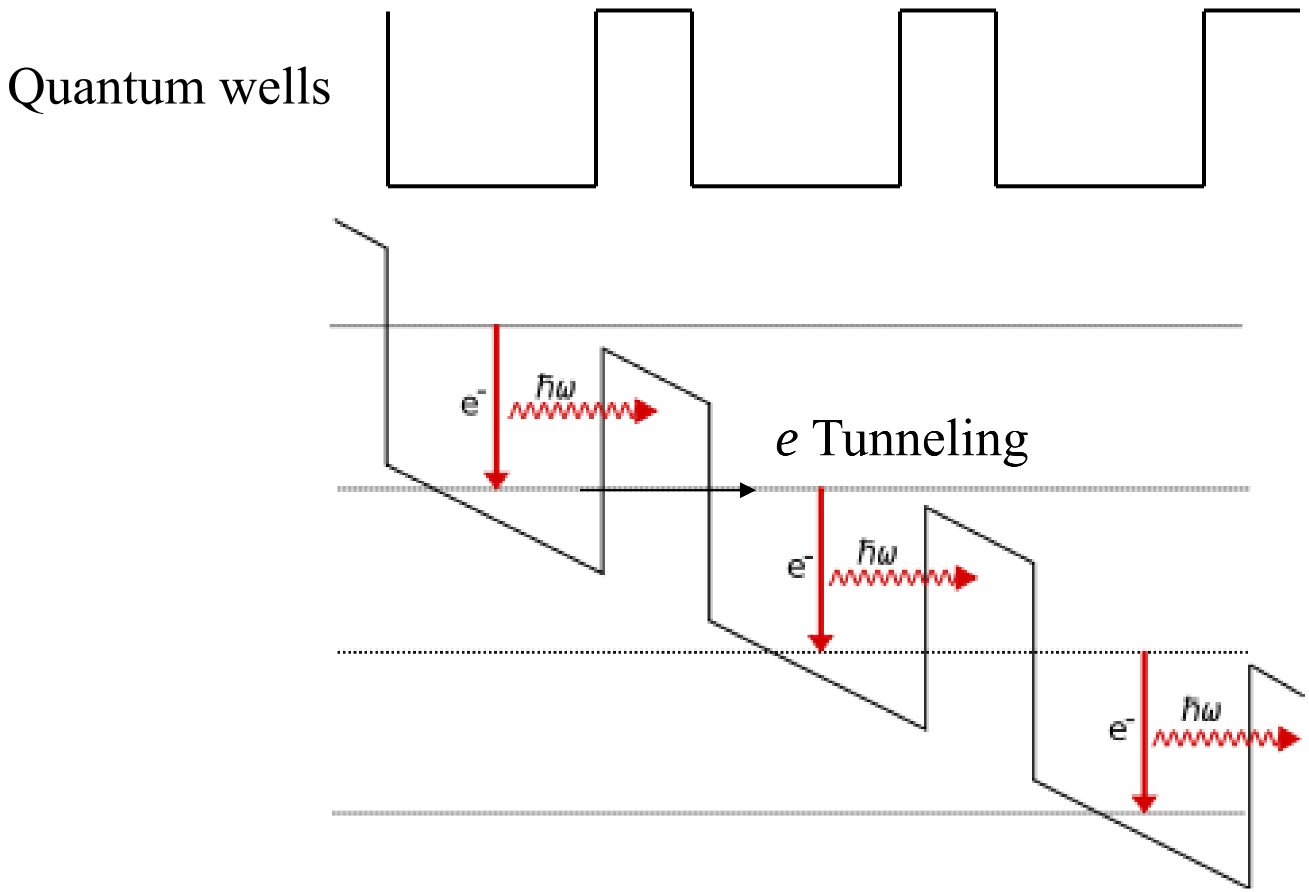


e-h in bands
Gain spectrum
Light emission
Cavity resonant modes
cavity loss
$n < n_{th}$
$J < J_{th}$
GAIN
0
$\hbar\omega$
PHOTON INTENSITY
k_BT
Dominant mode
$n = n_{th}$
$J > J_{th}$

Stimulated emission

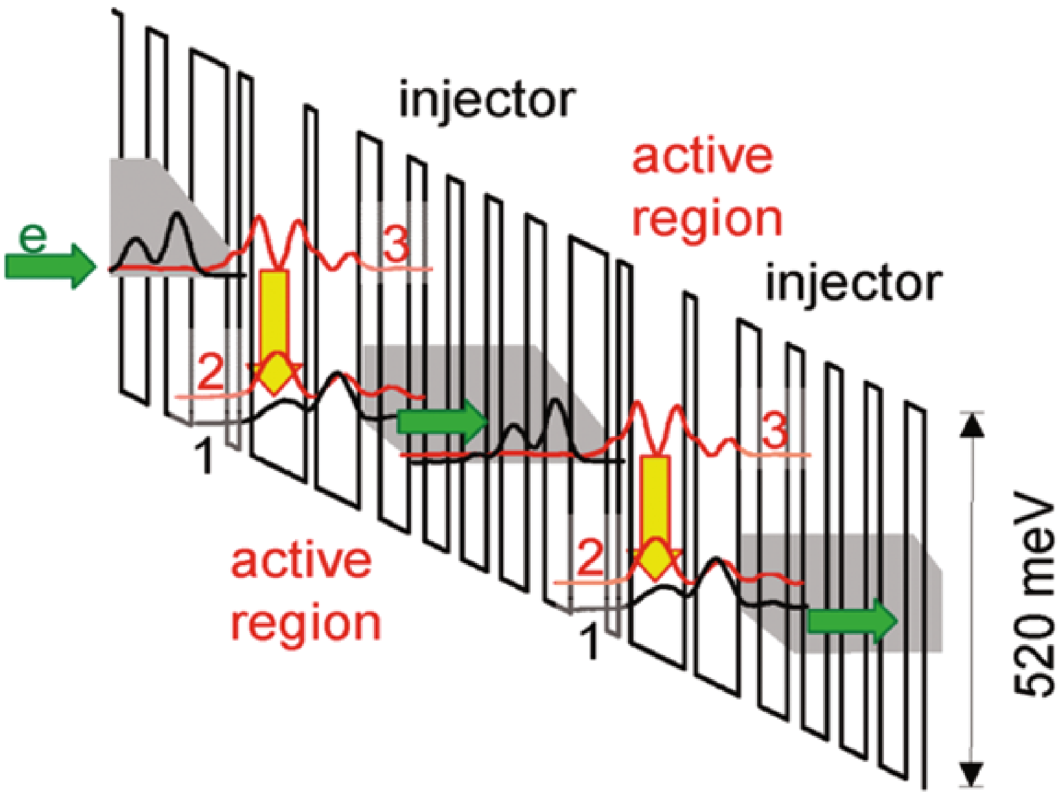


Quantum cascade lasers

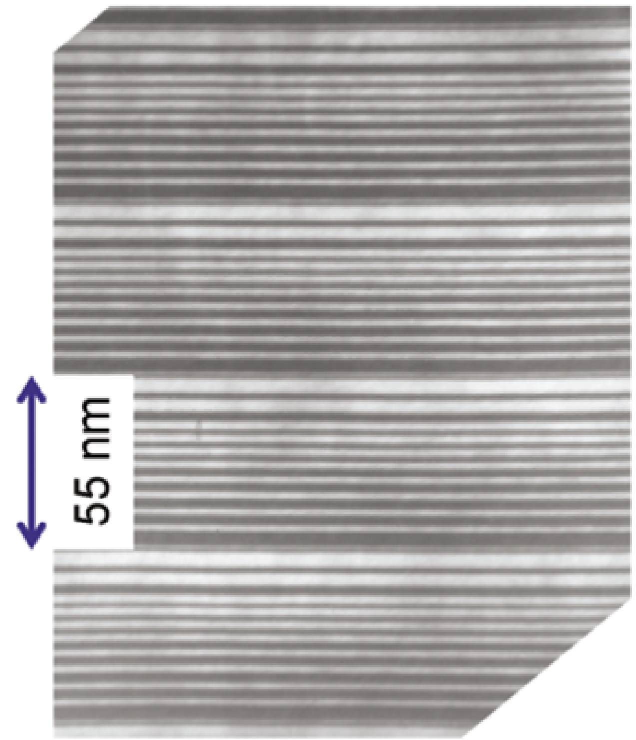


Energy levels depend on the width of the wells so lasers can be made at many frequencies (mid to far infrared 2.75 - 250 μm).
Many colors can be made with one materials system.
Window in atmosphere at 5 μm used for point-to-point communications.

Quantum cascade lasers



(a)



(b)

http://opticalengineering.spiedigitallibrary.org/article.aspx?articleid=1096486