

# Optoelectronics

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# Exam

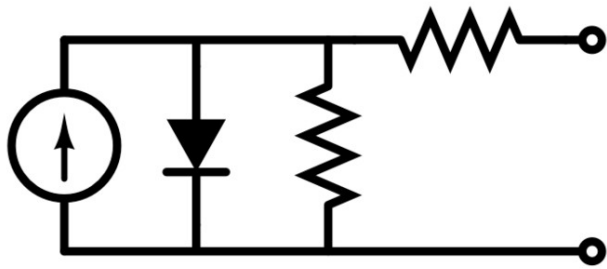
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January 29, 14:00 – 15:00 P2

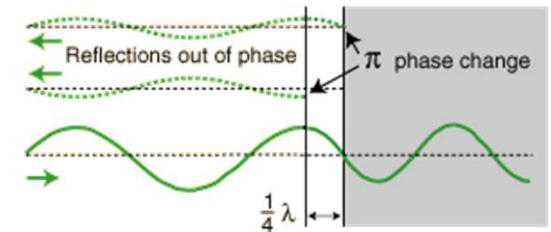
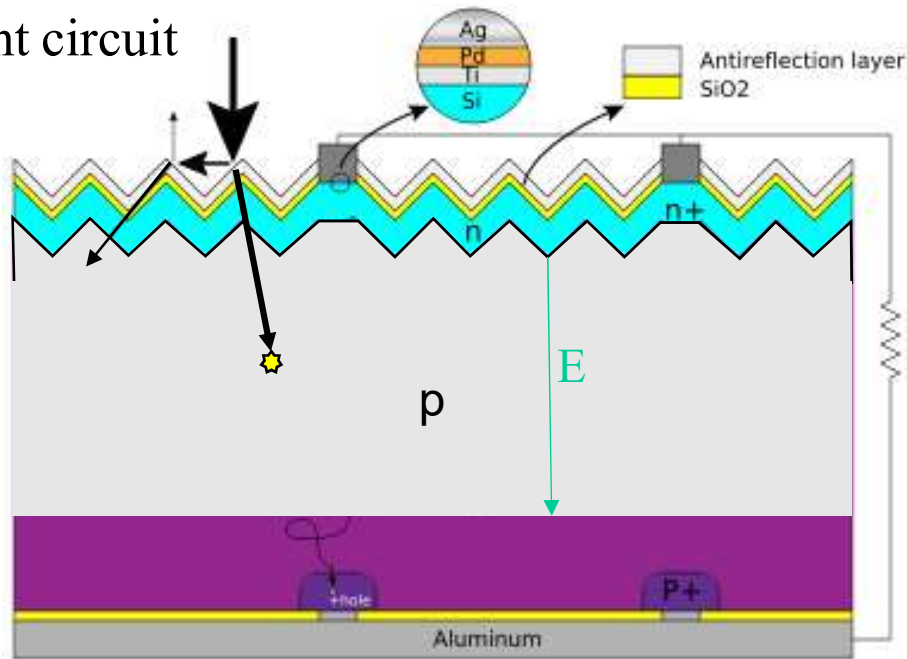
A4 of handwritten notes

Calculator

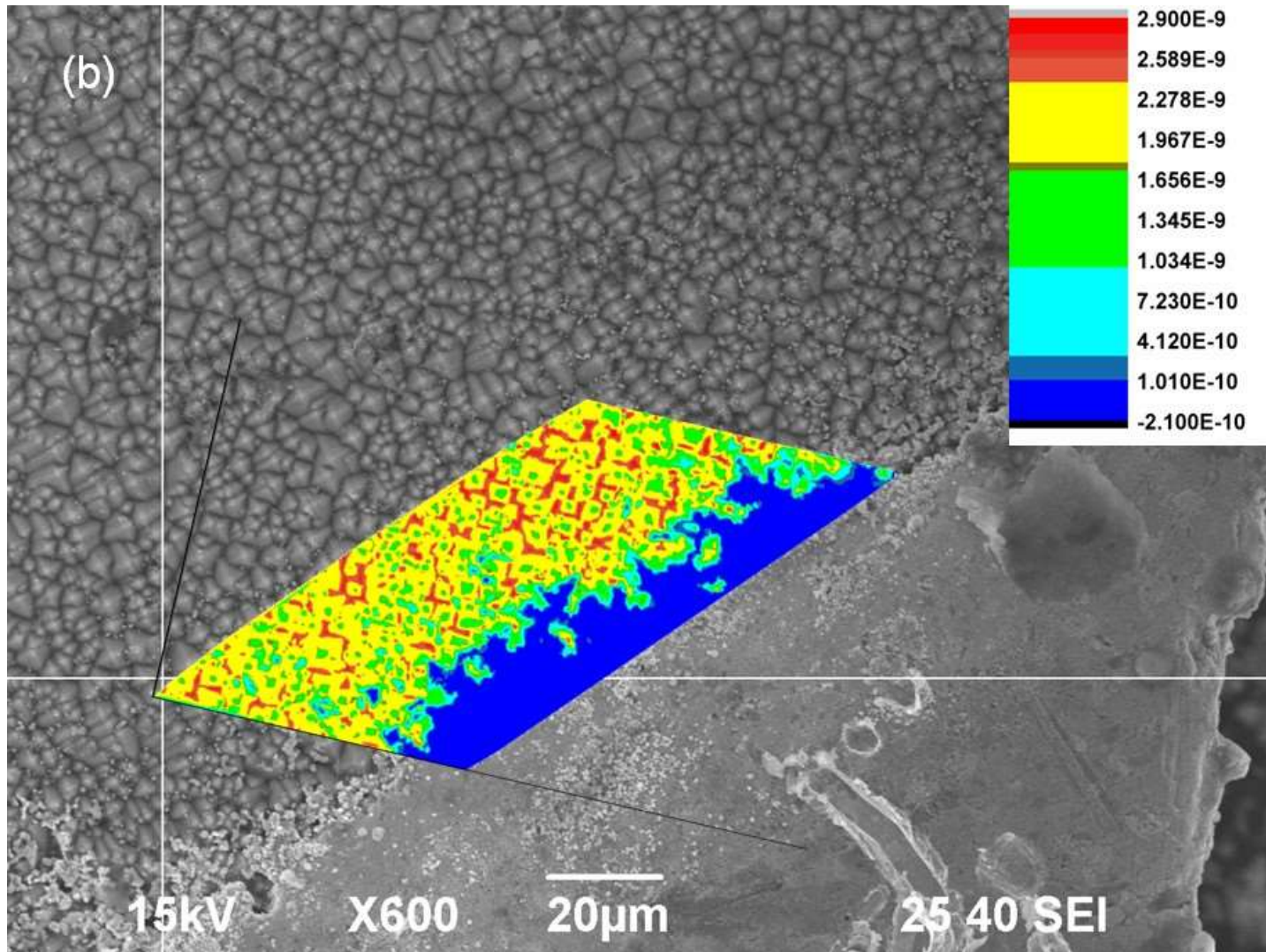
# Solar cell



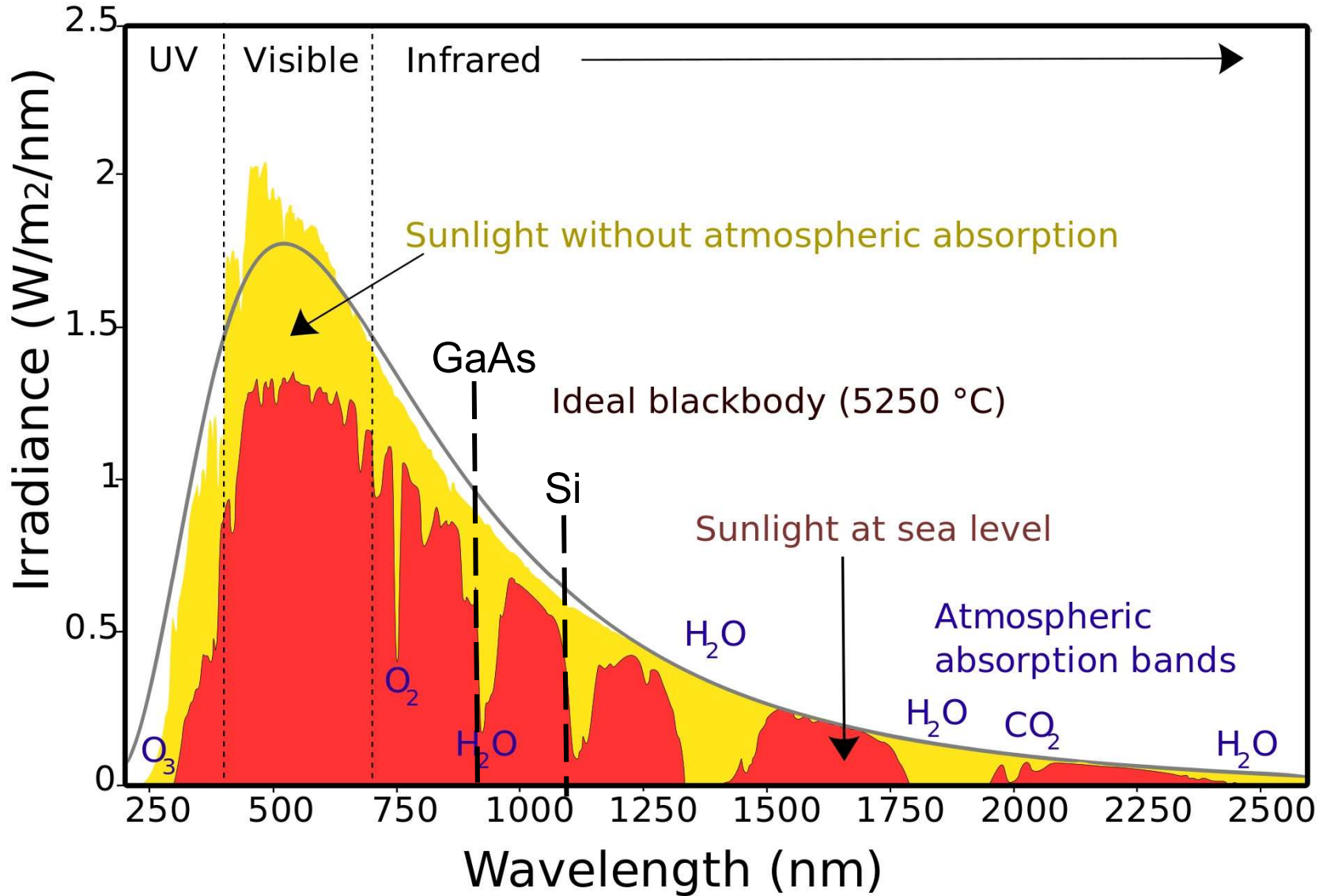
Equivalent circuit



# Polycrystalline films

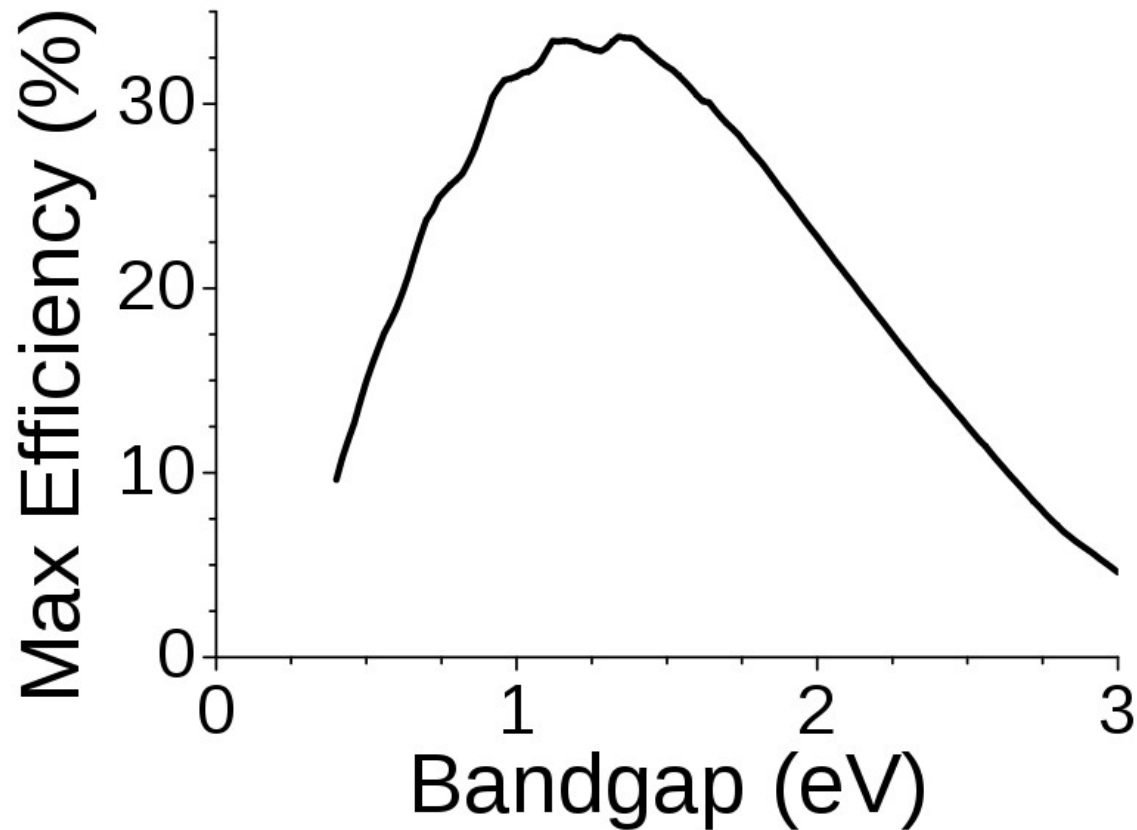


# Spectrum of Solar Radiation (Earth)



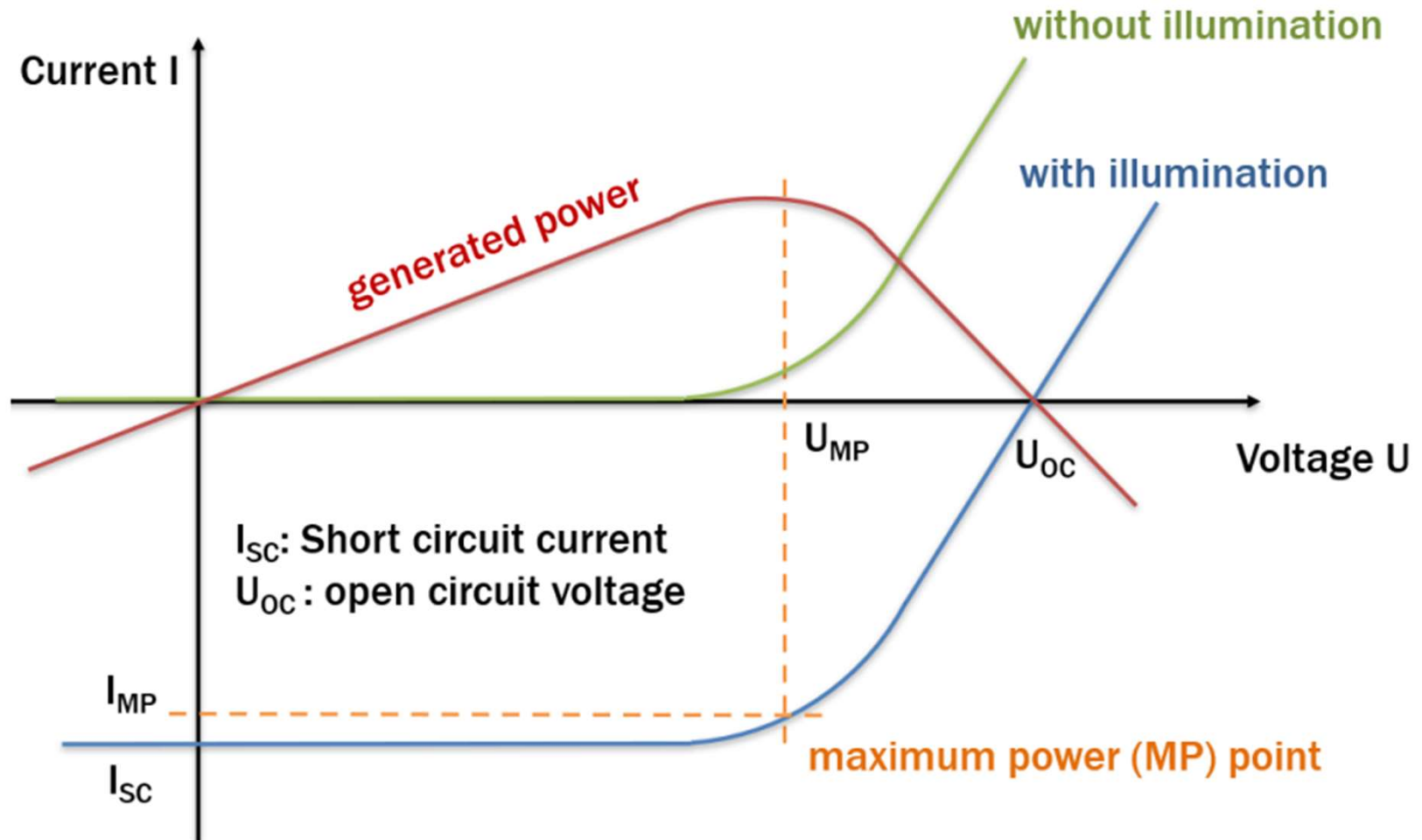
# Shockley-Queisser limit

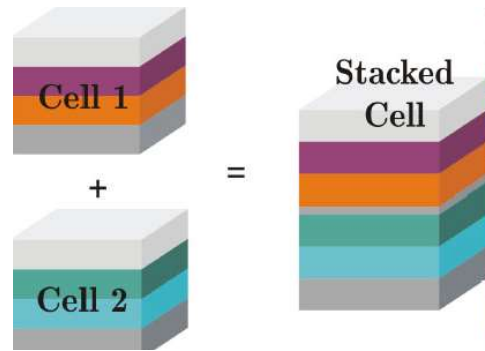
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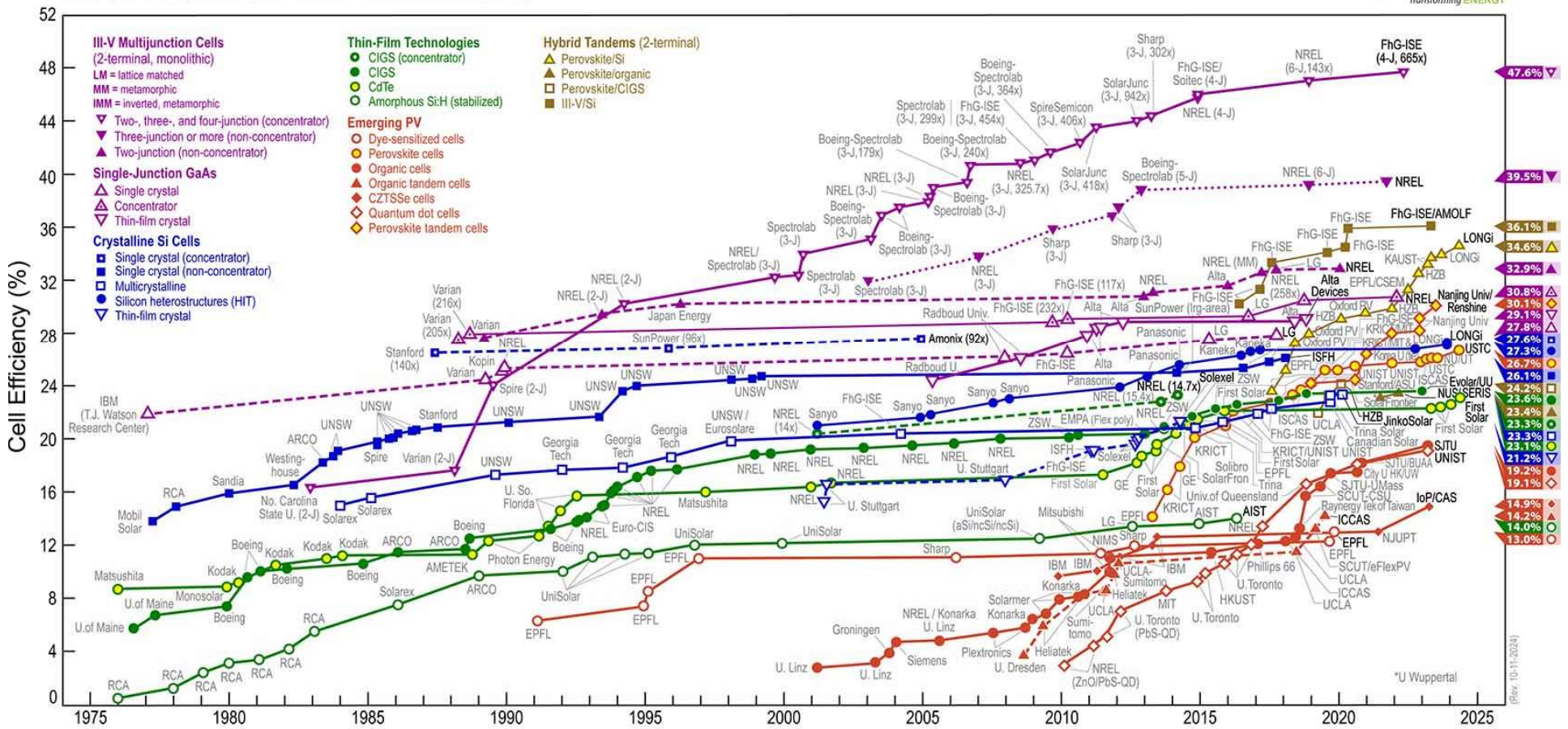
[http://en.wikipedia.org/wiki/Shockley-Queisser\\_limit](http://en.wikipedia.org/wiki/Shockley-Queisser_limit)

# Maximum power point





## Best Research-Cell Efficiencies

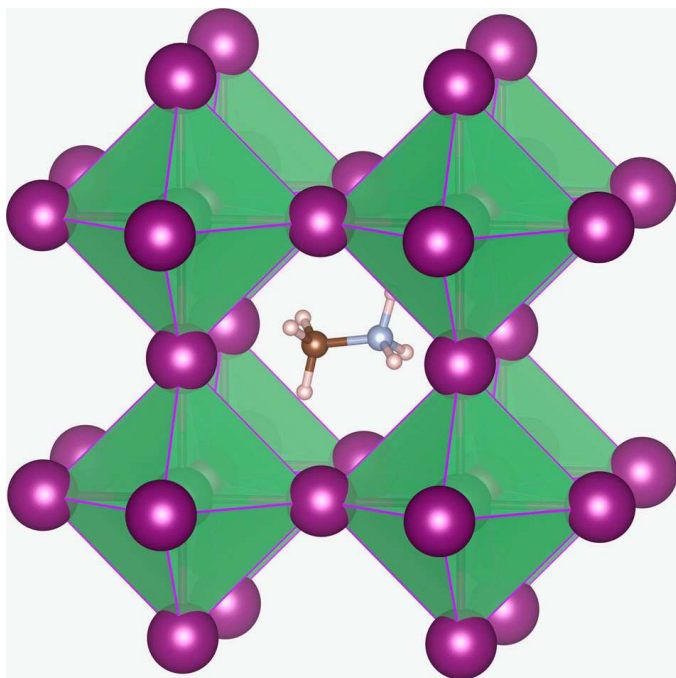


(Ref: 10-11-2024)



# Perovskite solar cells

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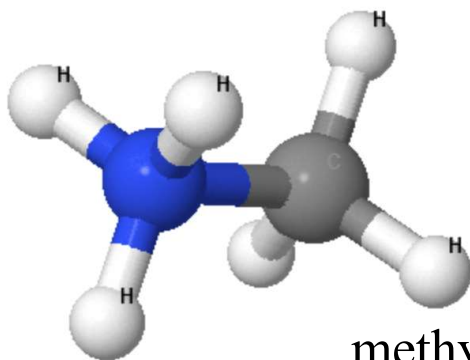


methylammonium lead trihalide  $ABX_3$   
 $CH_3NH_3PbX_3$ , where X is I, Br or Cl  
Optical bandgap 1.5 - 2.3 eV

+ Cheaper to fabricate than Si solar cells.  
(silicon cells require  $> 1000\text{ C}$ )

- Contains lead  
Also less efficient  $CH_3NH_3SnI_3$  version

- Not stable



methylammonium

# Solar paint

## SOLAR COATING GENERATES ELECTRICAL ENERGY

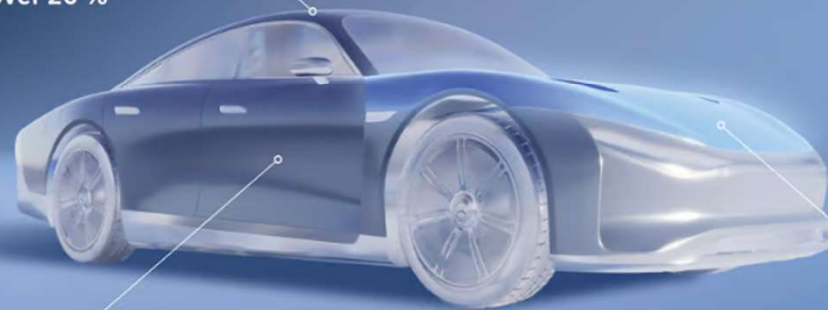
### The principle

The entire car body is coated with **photovoltaic paint** which generates electrical energy. The energy can be used immediately for driving or is stored in the battery when the vehicle is stationary.



A completely new type of nanoparticle-based paint allows **94 % of the sun's energy** to pass through to the solar coating.

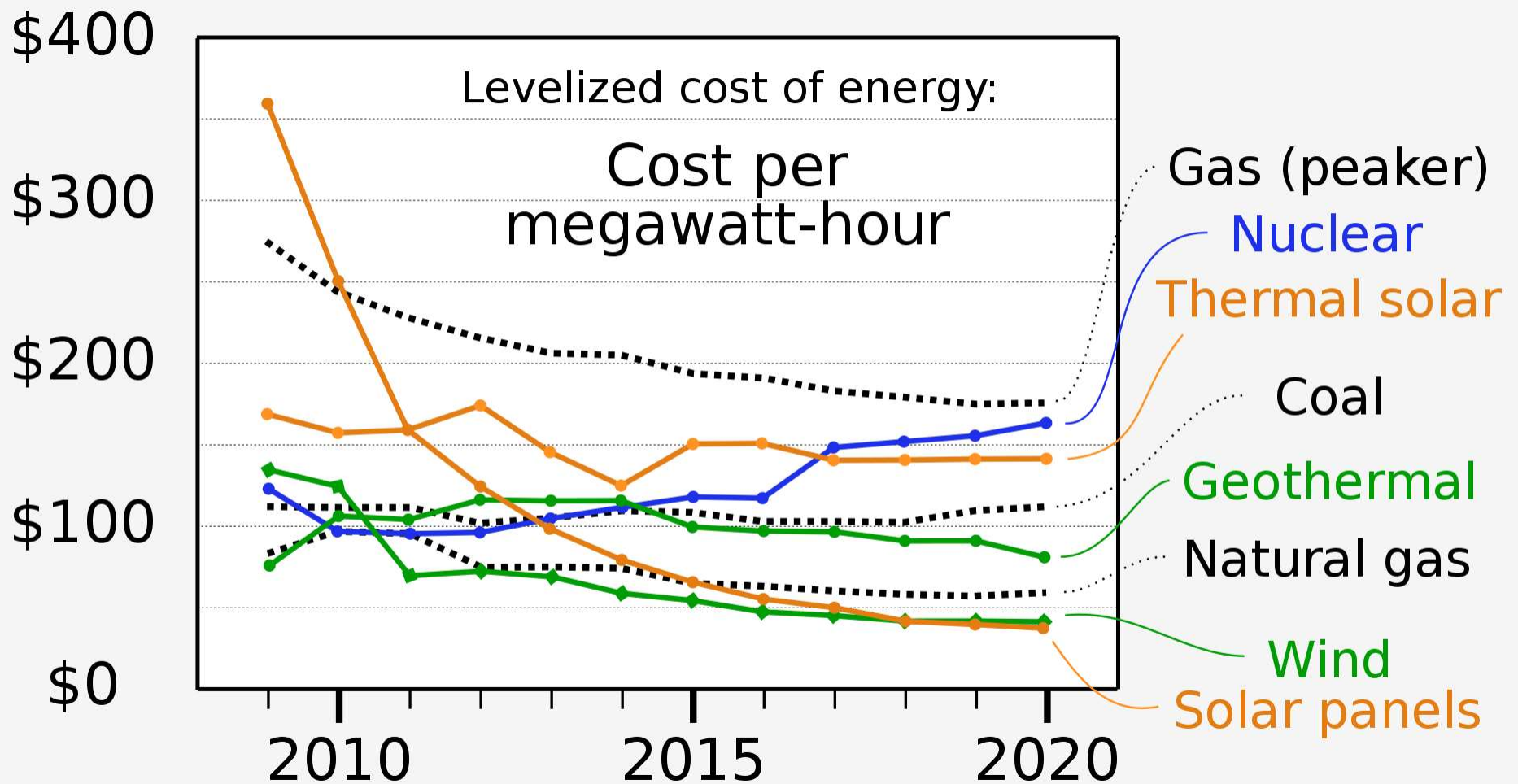
Very effective: **efficiency of over 20 %**



Extremely light: **50 g/m<sup>2</sup>**

The solar coating is located between the body panel and the coloured paint.

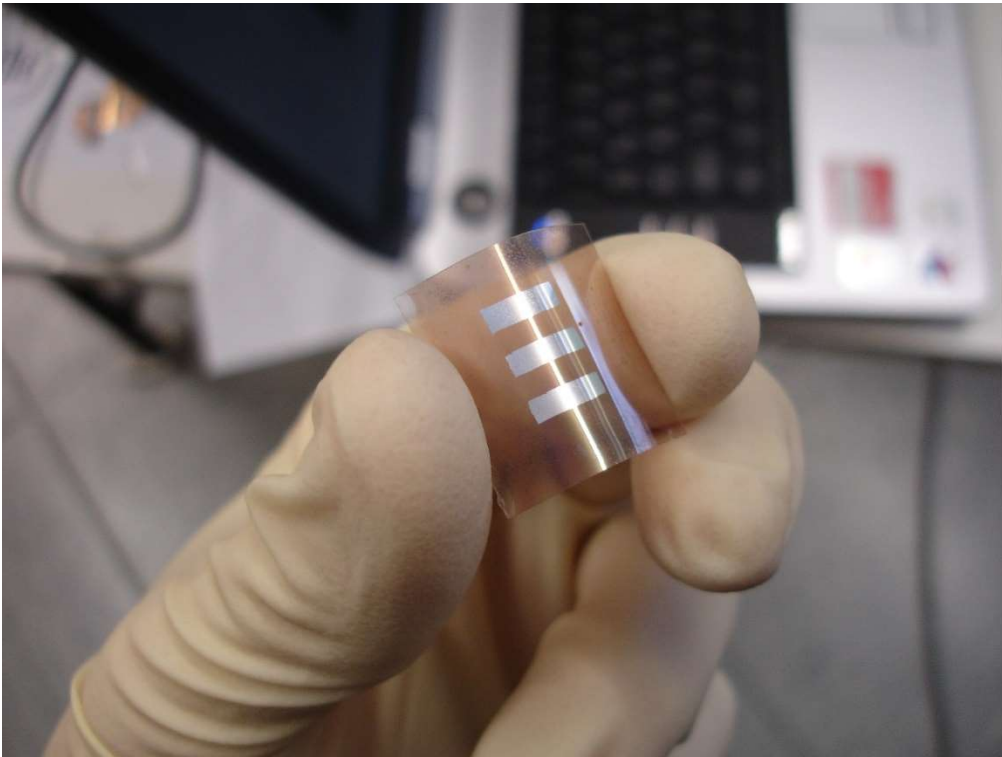
Extremely thin: **5 micrometers**



By RCraig09 - Own work, CC BY-SA 4.0,  
<https://commons.wikimedia.org/w/index.php?curid=99427431>

# Printable solar cells

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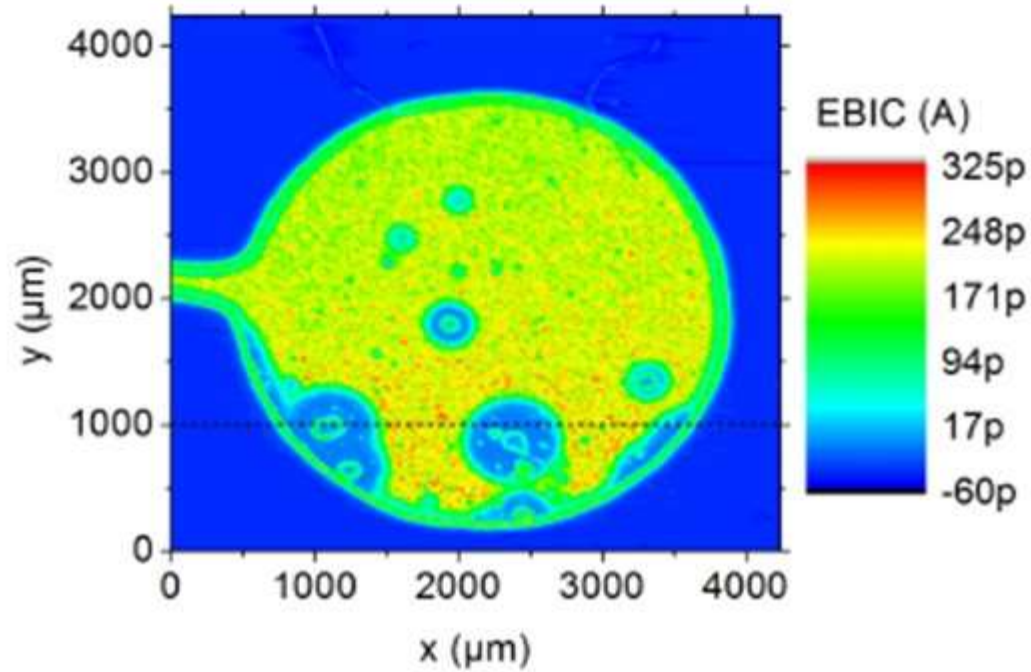


CD labor - TU Graz

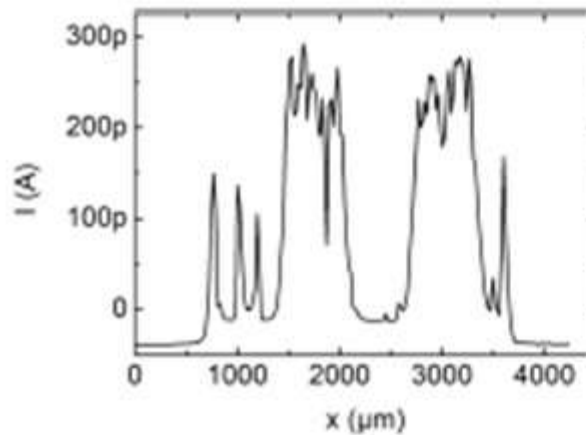


Konarka

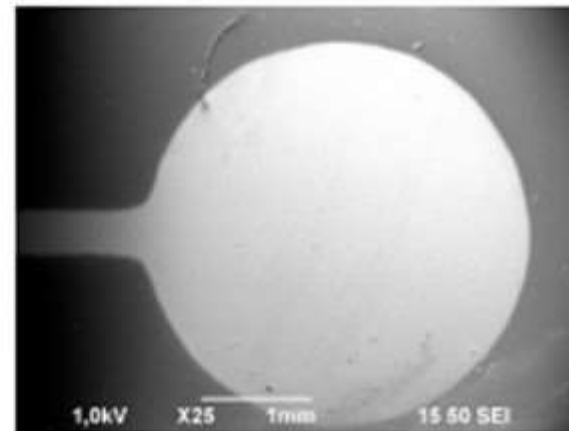
# Printed solar cells



(a)



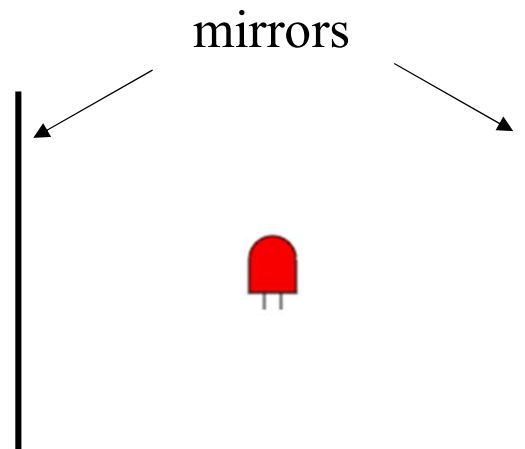
(b)



(c)

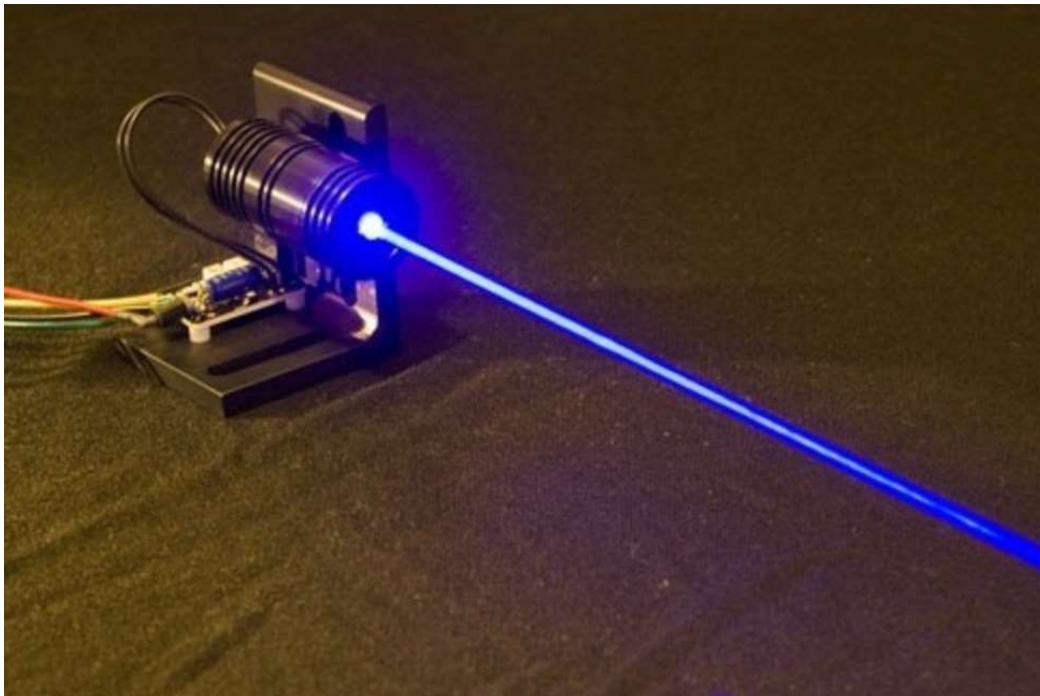
# Laser Diodes

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# laser diodes

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<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



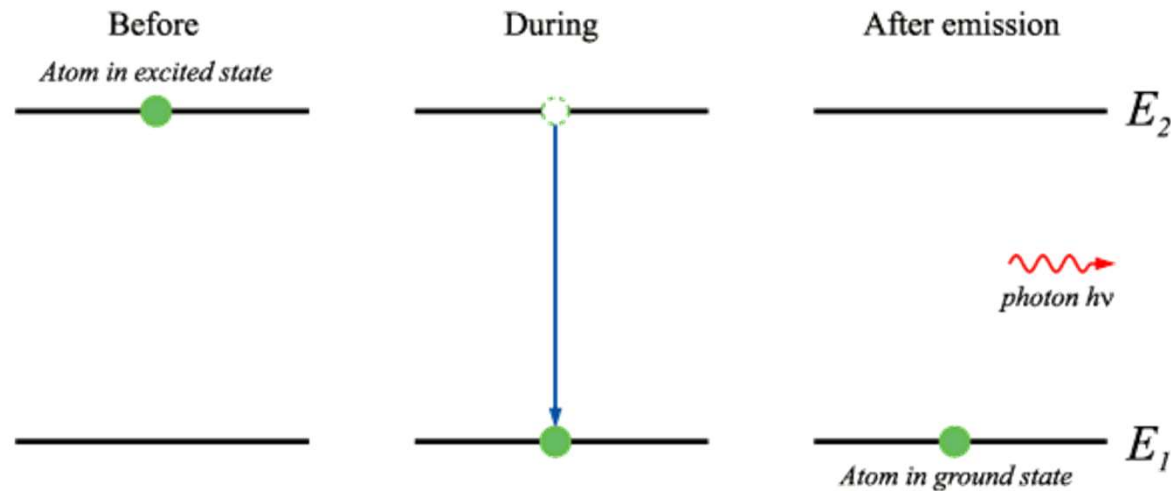
Laser Components  
- ...

**€30,72**

Distrelec Österrei...

# Spontaneous emission

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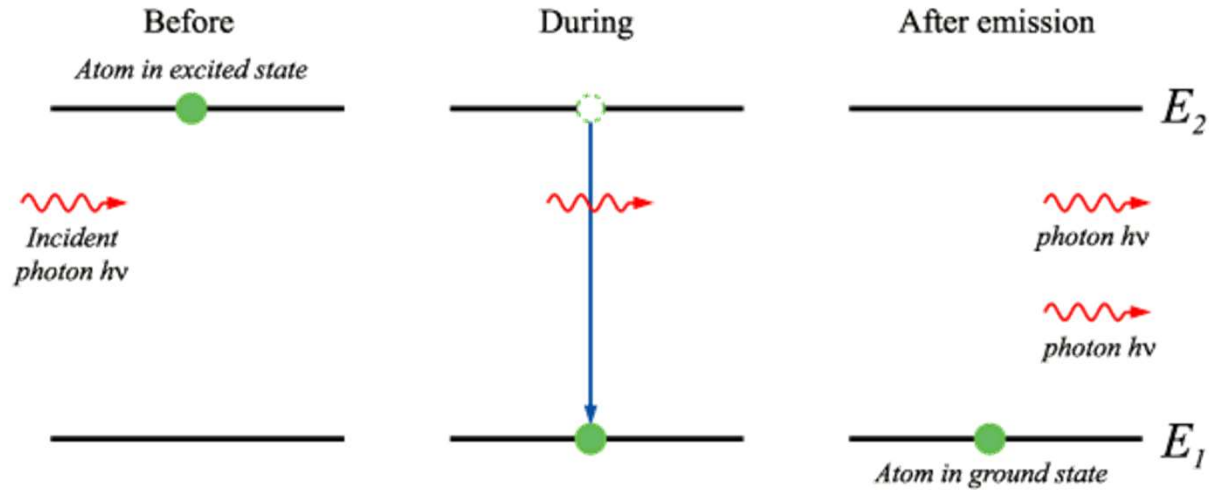


$$h\nu = E_2 - E_1$$

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

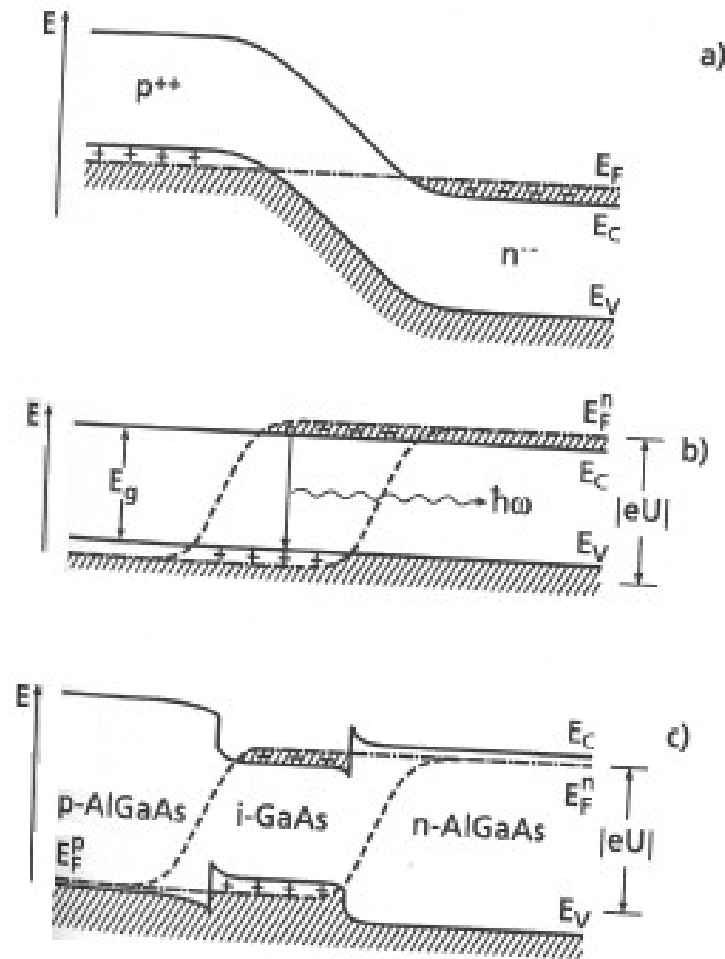
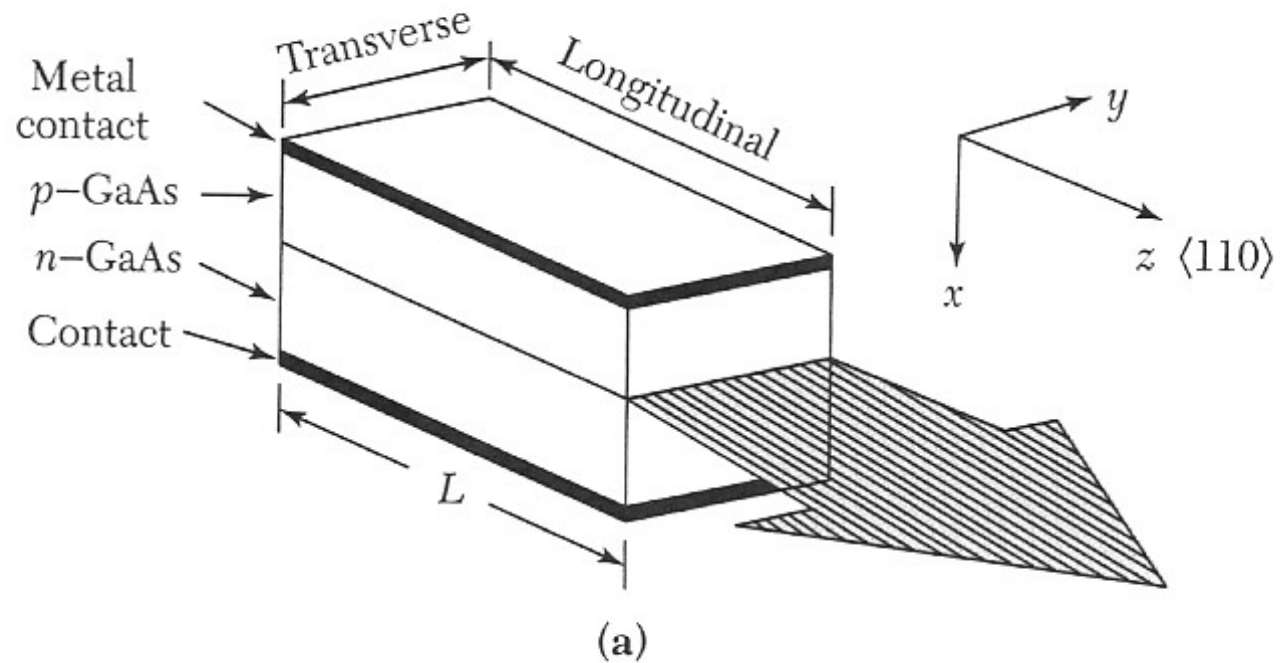


Fig. 12.37. Electronic band schemes  $E(x)$  of  $pn$ -semiconductor laser structures along a direction  $x$  perpendicular to the layer structure: (a) Degenerately doped  $p^{++}n^{--}$  junction without external bias (thermal equilibrium); (b) same  $p^{++}n^{--}$  junction with maximum bias  $U$  in forward direction; (c) double-heterostructure pin junction of  $p\text{-AlGaAs}/i\text{-GaAs}/n\text{-AlGaAs}$  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

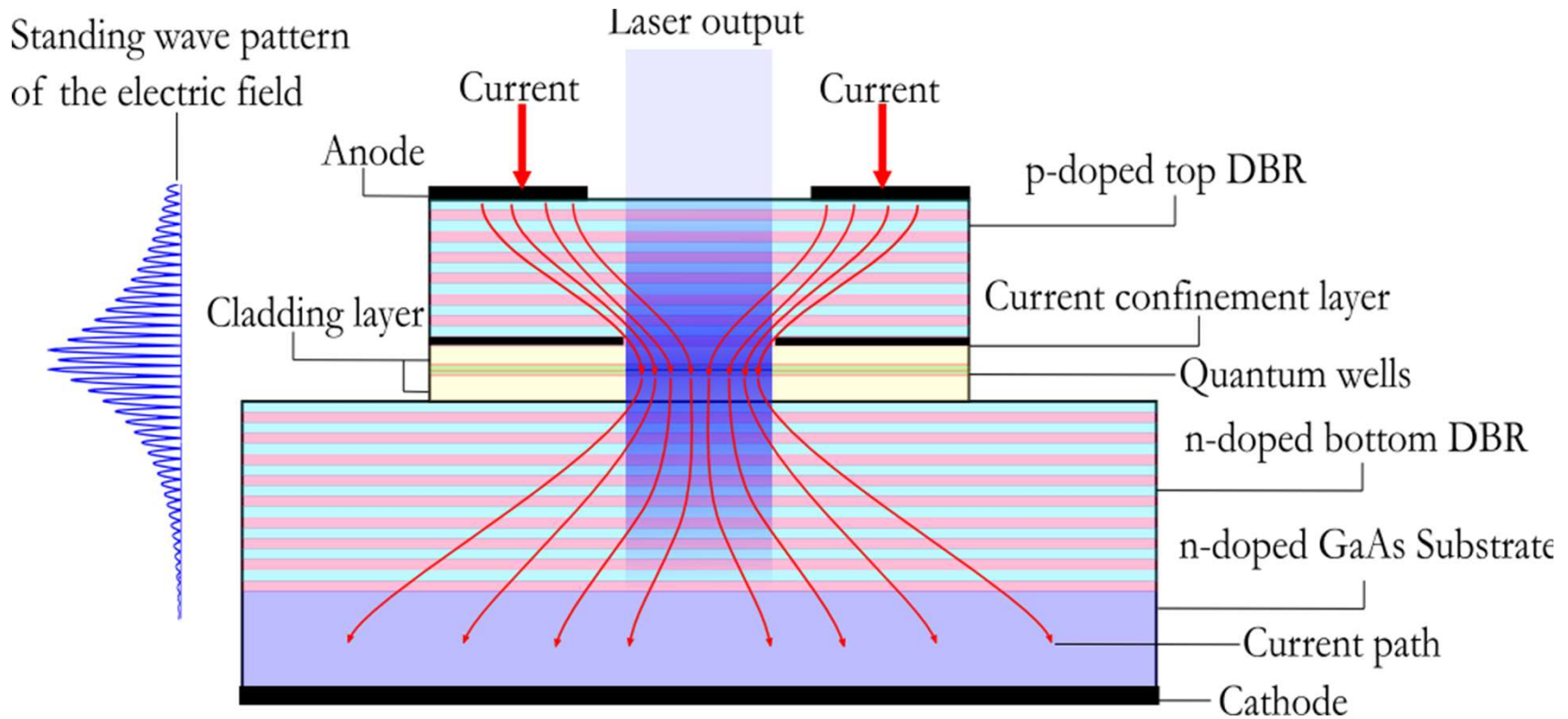
# Laser diode

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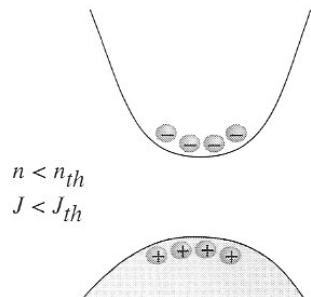


The faces of the crystal are cleaved to make mirrors.

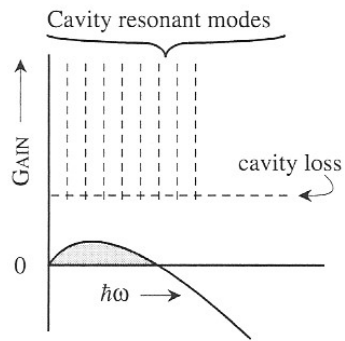
# Vertical-cavity surface-emitting laser (VCSEL)



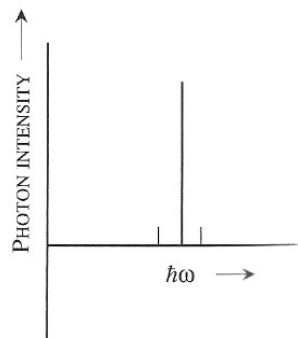
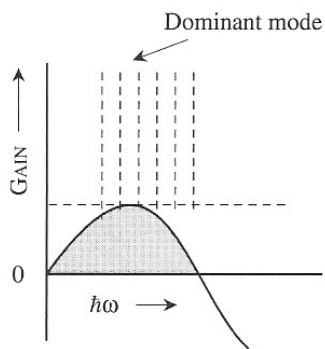
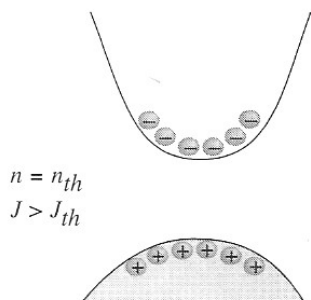
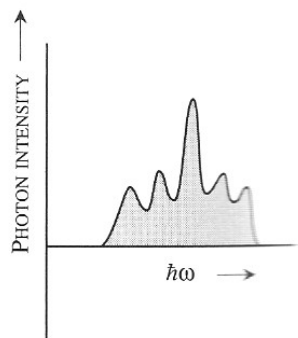
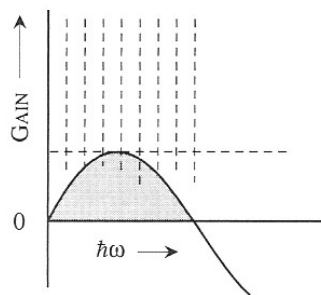
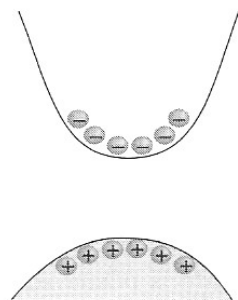
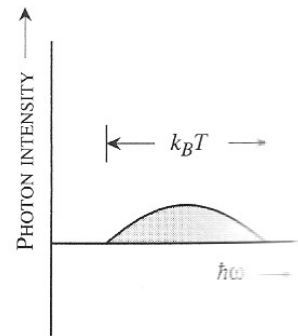
e-h in bands



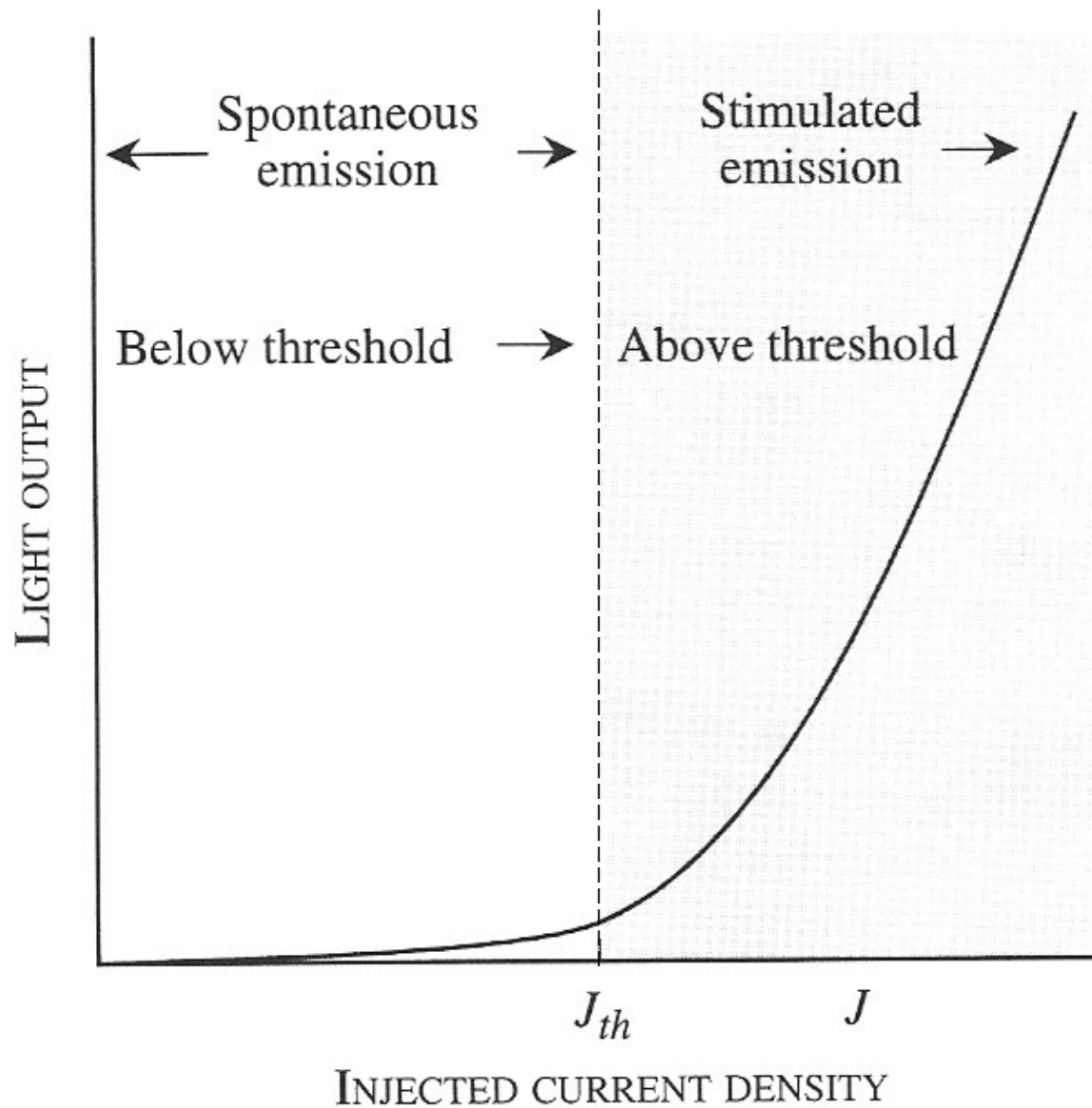
Gain spectrum



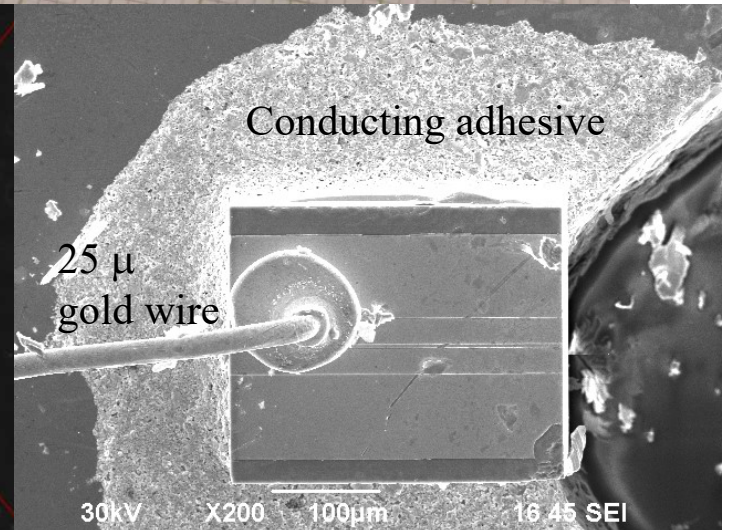
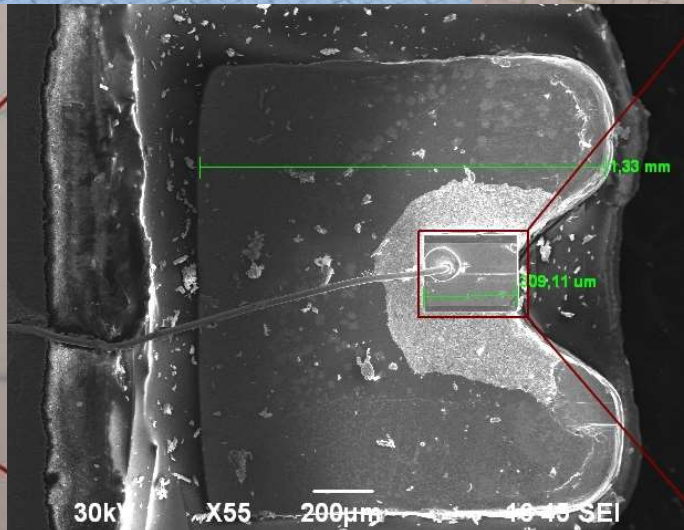
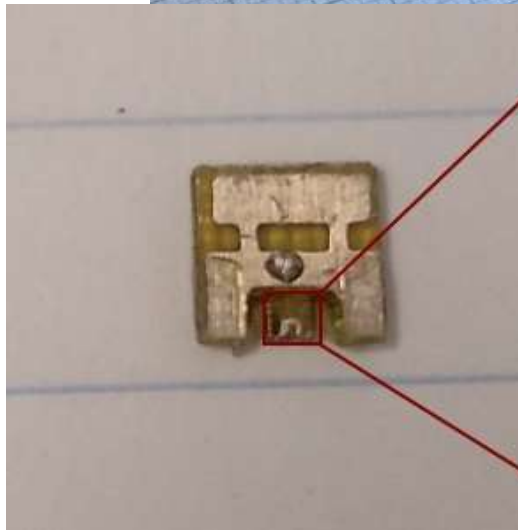
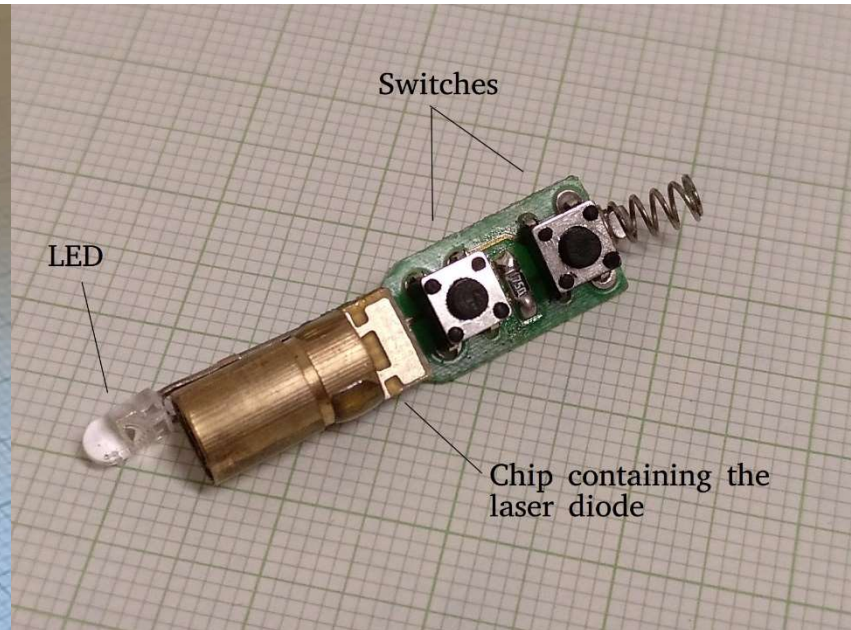
Light emission



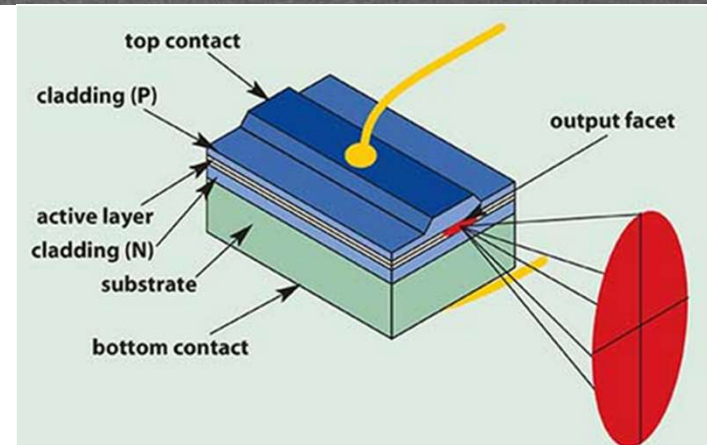
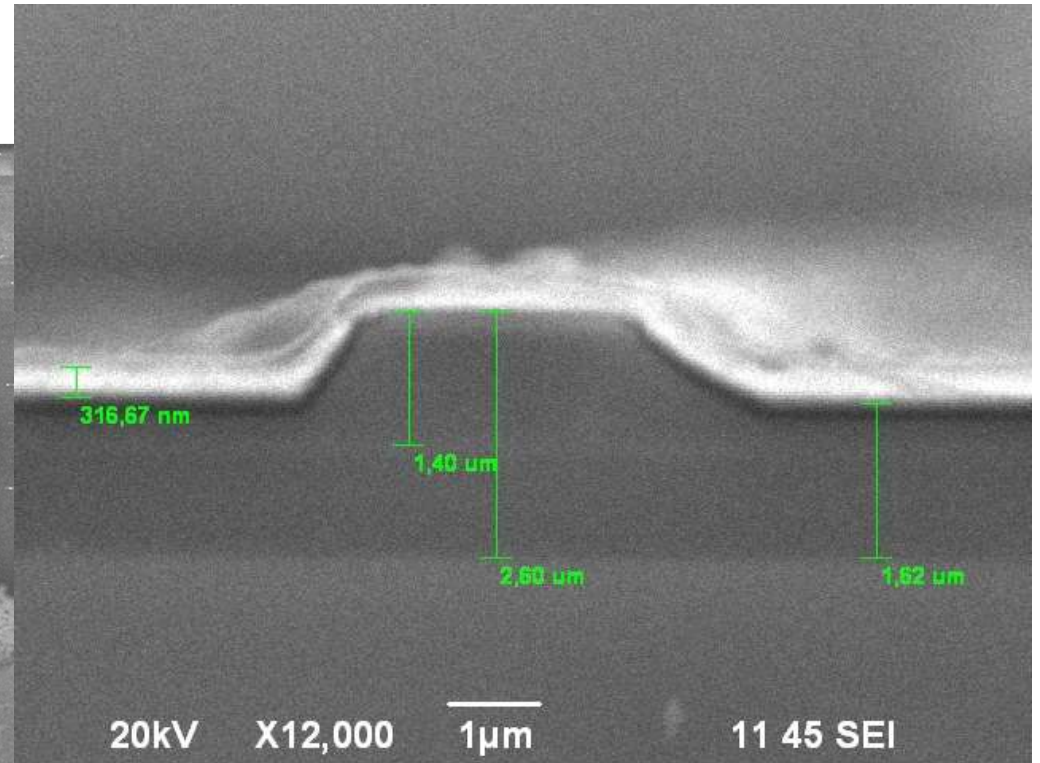
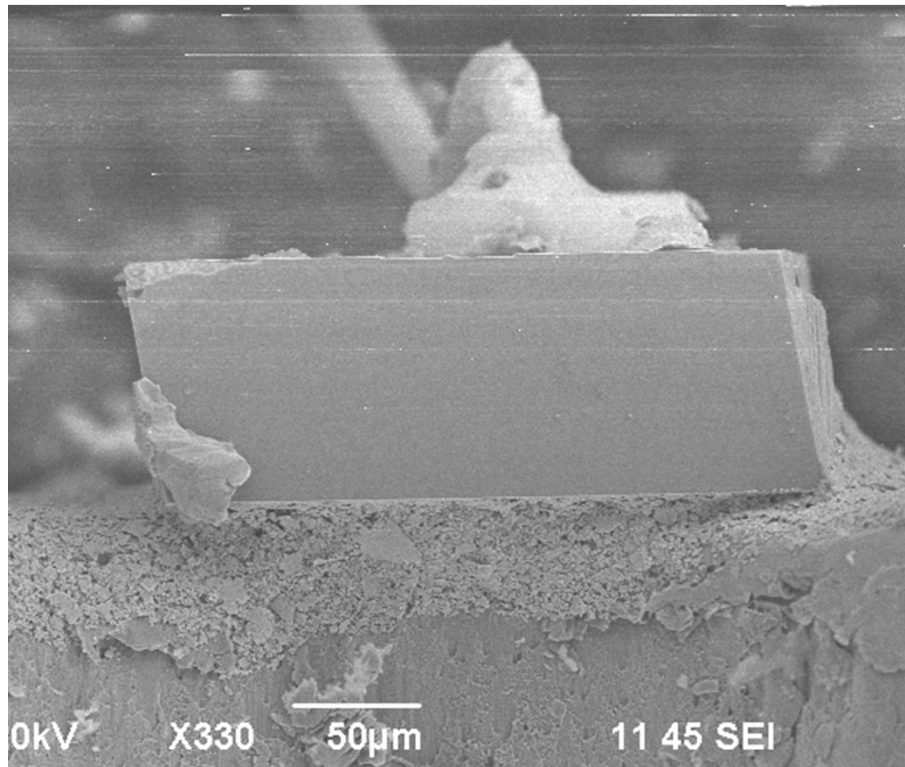
# Stimulated emission



# Laser pointer



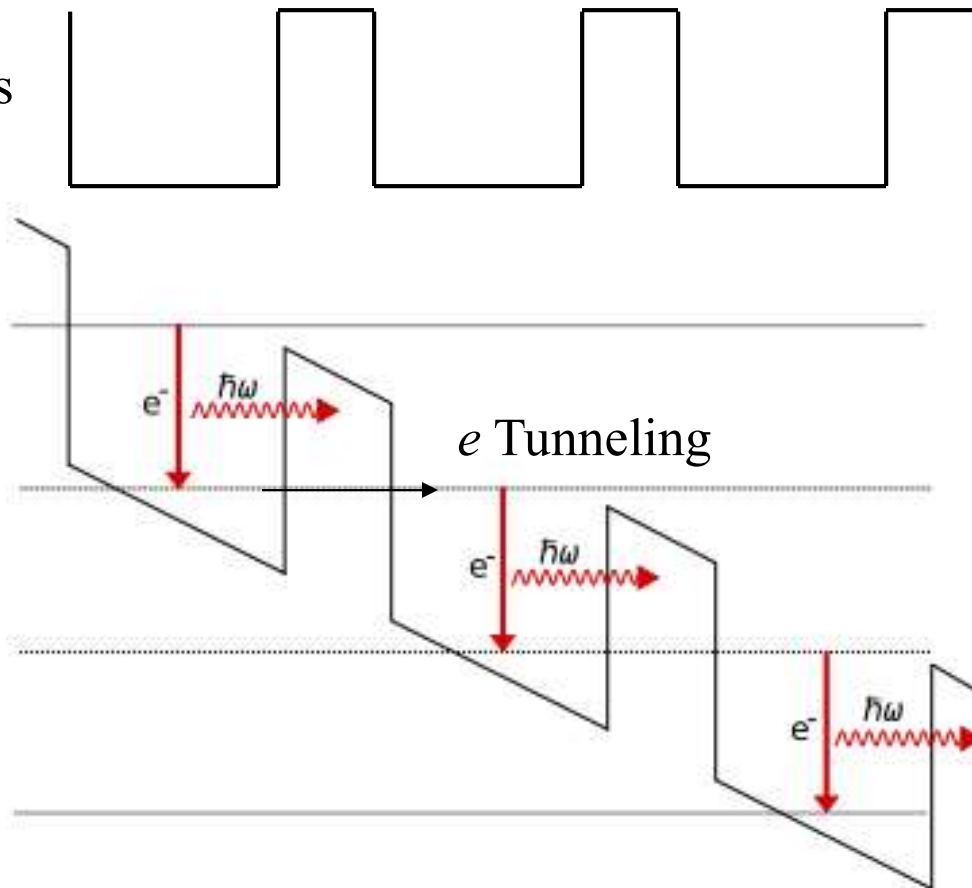
# Laser pointer





# Quantum cascade lasers

Quantum wells



Energy levels depend on the width of the wells so lasers can be made at many frequencies (mid to far infrared 2.75 - 250  $\mu\text{m}$ ).

Many colors can be made with one materials system.

Window in atmosphere at 5  $\mu\text{m}$  used for point-to-point communications.

# Quantum cascade lasers

