Lecture 18

Various laser types

Laser pumping processes:

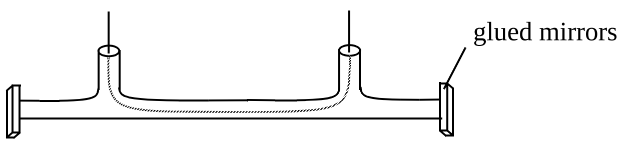
Electrons: Gas discharge or electron beam

Optical: a) incoherent – flashlamp, arc lamp, solar

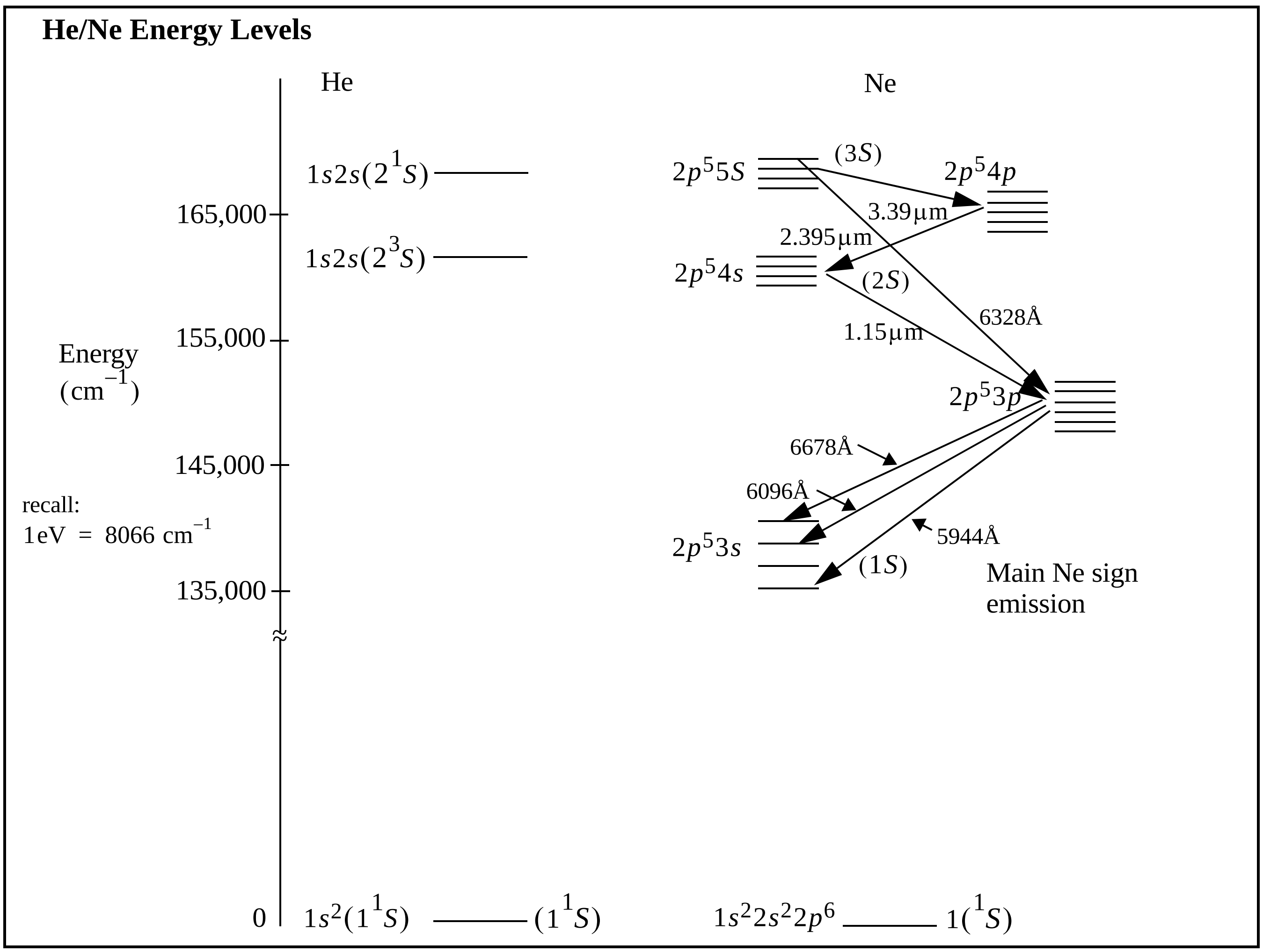
b) coherent – another laser

Electrical current: Semiconductor diode laser

<u>Gas discharge laser construction</u>

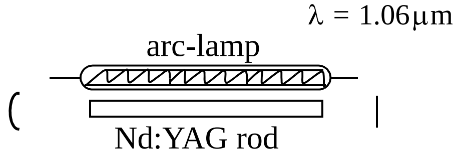


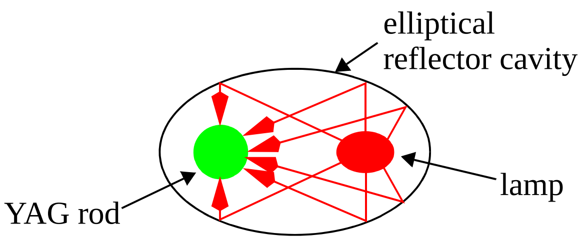
– Ne excited states $1s^2 2s^2 2p^5 3s$, $1s^2 2s^2 2p^5 3p$, $1s^2 2s^2 2p$



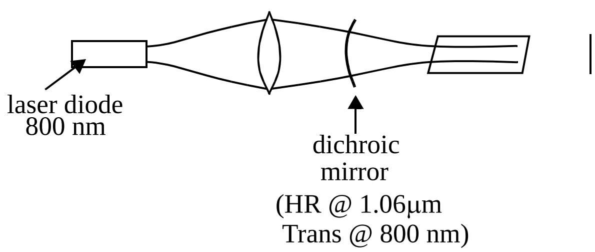
Optically pumped lasers

Nd:YAG laser

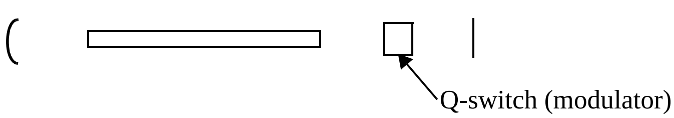




Diode pumping



Q-switching



Upper-level lifetime in Nd:YAG is ~ 100 μsec

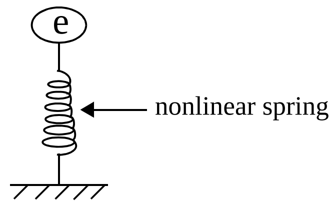
1. Modulator has low transmission
2. Population builds up in upper state
3. Inversion density >> threshold, but no lasing
4. Modulator switches to high transmission
5. Laser action builds up rapidly, energy stored is released in a giant pulse

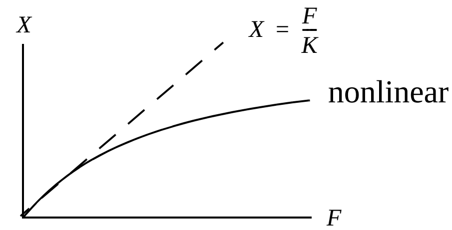
Second harmonic generation SHG

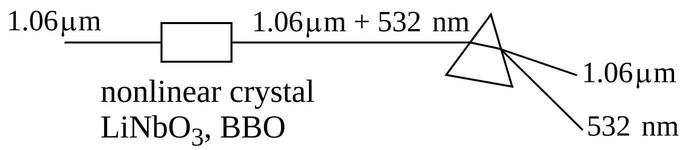
"Nonlinear" crystal – Electron binding is *nonlinear*

When such a system is driven by a sinusoidal signal $\sin(\omega t)$, the response contains harmonics: $\sin(2\omega t)$, … . These can radiate under suitable conditions

Conversion efficiency:



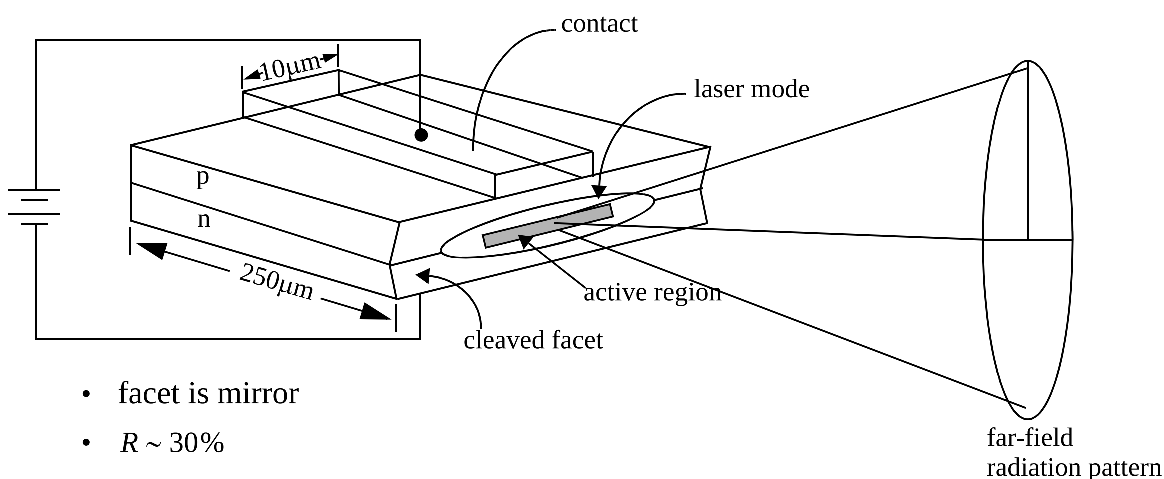




$$\eta = \frac{P_o(532\ \text{nm})}{P_i(1.06\mu\text{m})}$$

$\eta > 70\%$ can be obtained.

Diode Lasers

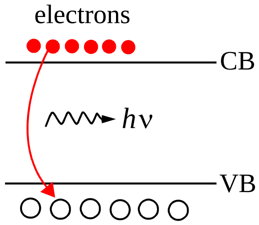


- facet is mirror
- $R \sim 30\%$
- short length → large α_m needed

- Forward-biased pn diode
  - Active area $\sim 40\mu\text{m} \times 250\mu\text{m} \times \sim 1\ \mu\text{m}$
  - Typical current drive: 15 mA → Current density across junction ~ 1 KA/cm^2 !
  - Typical voltage ~ 2 V → 30mW input power
  - Typical overall efficiency ~ 50%, 15mW output!
  - Because of the small size, the electrical capacitance is small and the device can be modulated at frequencies > 10 GHz

Atoms? – Electrons and holes

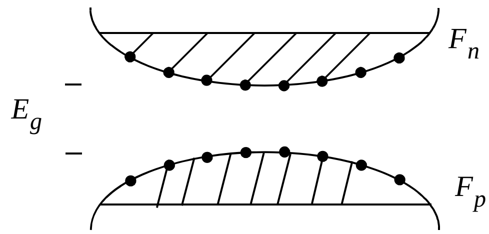
This is the big difference with all other lasers. Electrons and holes are spread out over the whole crystal:



$e + h \rightarrow h\nu$

Optical transitions in semiconductors

Conservation of momentum $\boxed{k_e = k_h}$ – not possible in indirect gap semiconductor



Pauli exclusion principle: Only 2 electrons can occupy each $k-$ state. This gives rise to "band-filling."

"Pump" high density of electrons and holes into same region.

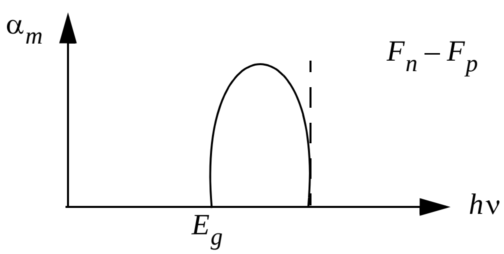
F_n, F_p :quasi-Fermi levels

F_n :energy of highest occupied electron state

F_p :energy of lowest hole state

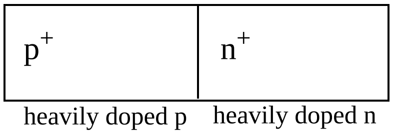
Inversion condition: $\boxed{F_n - F_p > E_g}$

Equilibrium: $F_n = F_p \cong E_g/2$

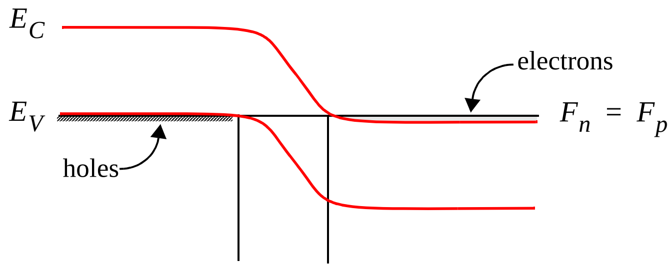


How to achieve inversion:

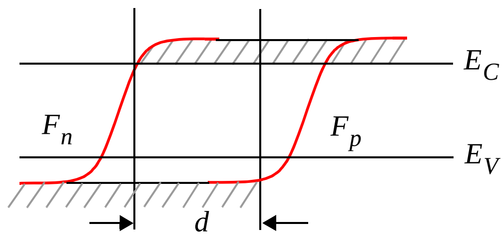
p-n Junction



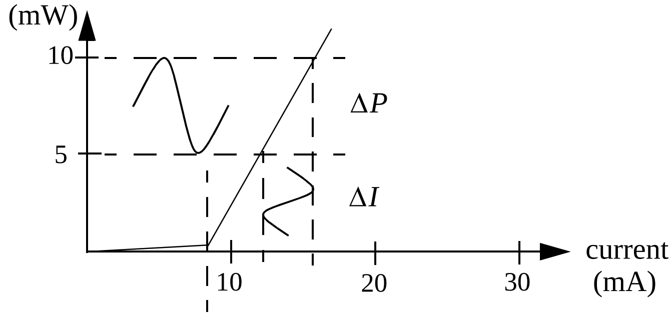
Equilibrium:



Forward bias:

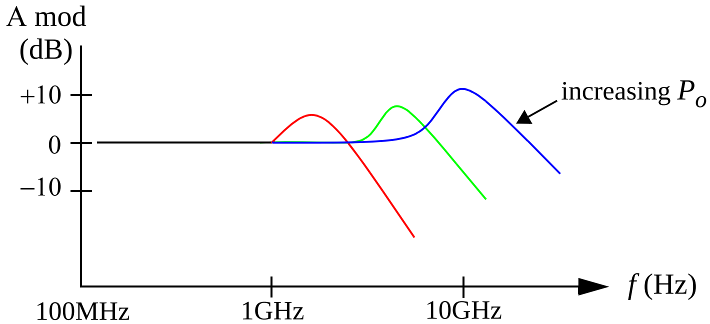


d ~ 1μm controlled by carrier diffusion



Modulate current → modulate output

Frequency response $\frac{\Delta P_m(f)}{\Delta I_m(f)} \equiv A \text{ mod } (f)$



Increasing P_o → increasing stimulus emission rate → faster discharge of jn capacitance