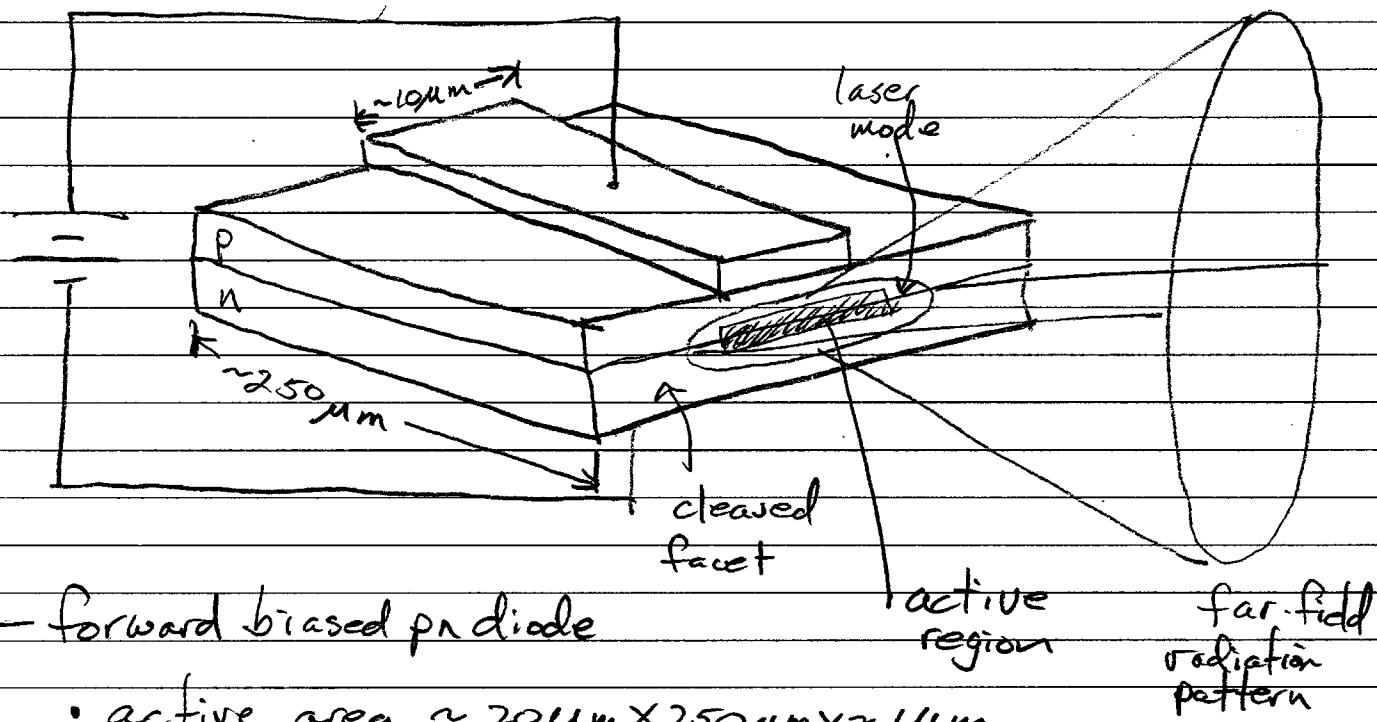
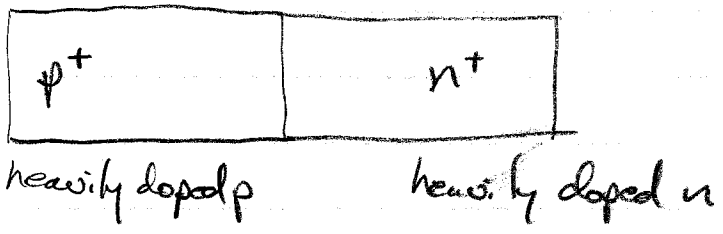
Semiconductor lasers [read Svelto 9.4]



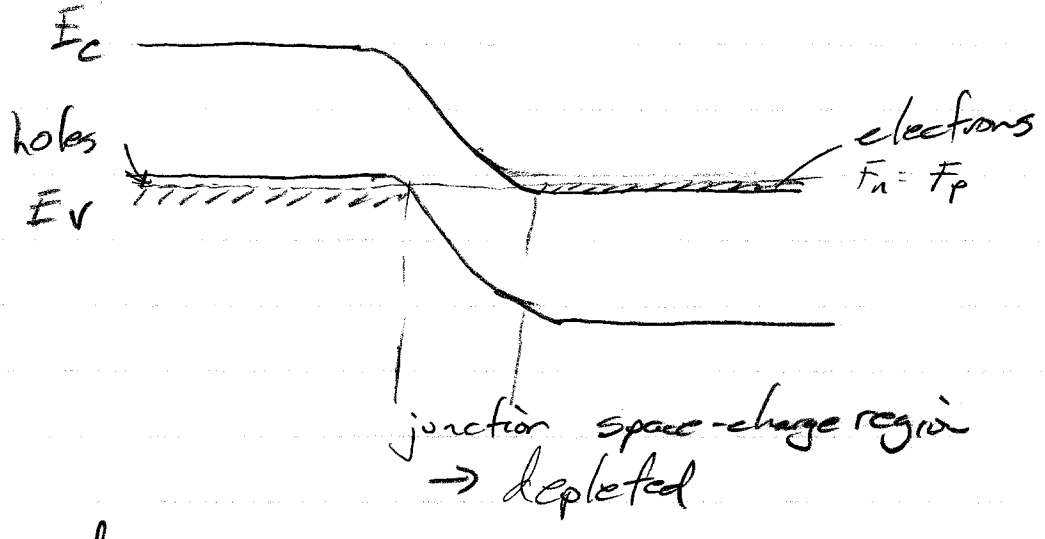
- forward biased pn diode
  - active area ~ 20μm × 250μm × ~1μm
  - typical current ~ 15 mA
    → current density ~ 300 – 1000 A/cm²
  - typ voltage ~ 2V
    → input power ~ 30 mW

λ: AlGaAs/GaAs – 720 – 850 nm
InGaAsP/InP – 1.15 – 1.67 μm
InGaAs/GaAs – 900 – 1100 nm
InGaP/InGaAlP/GaAs 630 – 700 nm
InGaN/sapphire 405 – 450 nm

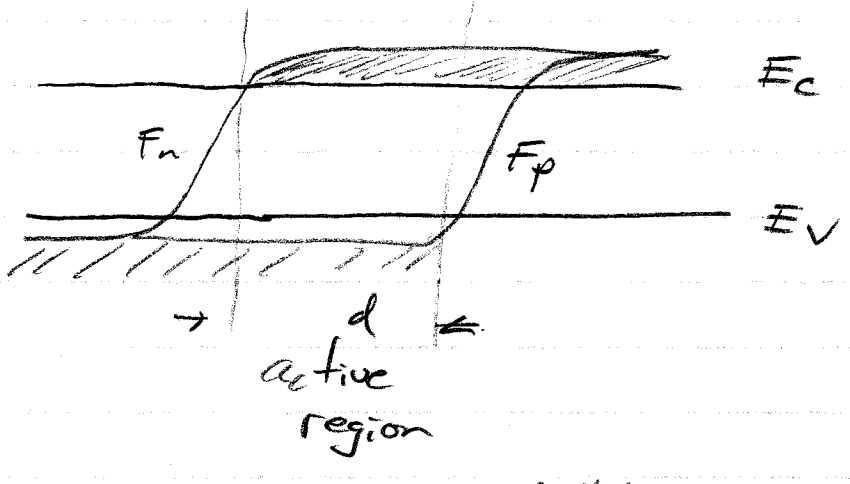
How to achieve inversion
pn junction



equilibrium



forward bias

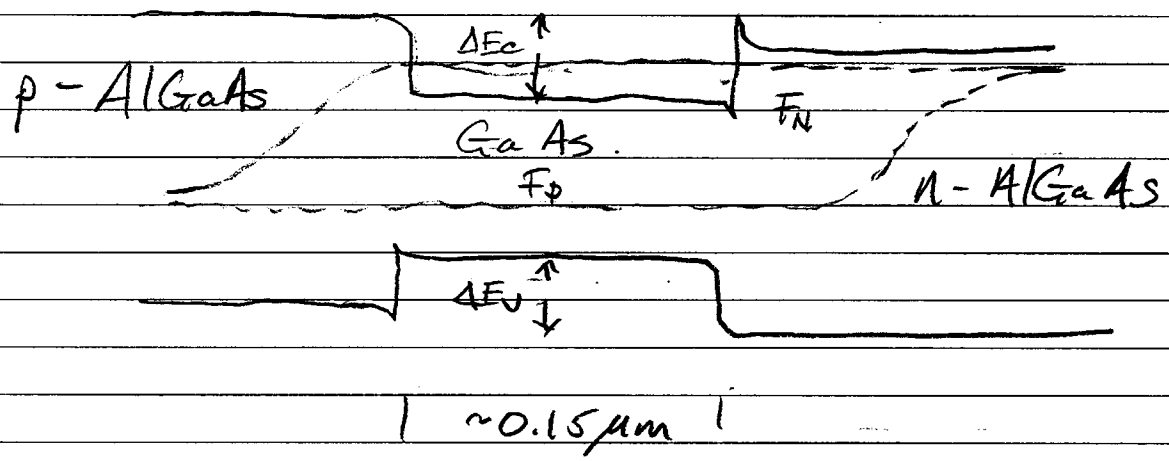


dr/dem controlled by carrier diffusion

Homojunction laser threshold high because carriers spread out by diffusion - larger volume → lower carrier density

— Double Heterostructure Laser

Confine carriers using heterostructure techniques.



- Carriers build up and confined in the GaAs layer
- Thickness is only ~0.15 μm. For same current density, carrier density is increased X6 compared to 1 μm diffusion thickness
- Much lower threshold current - room temp cw operation possible

$In_{1-x}Ga_xAs_yP_{1-y}$ can be lattice matched to InP for the right y/x ratio. Bandgap of alloy is lower than InP gap - so the active region is InGaAsP.

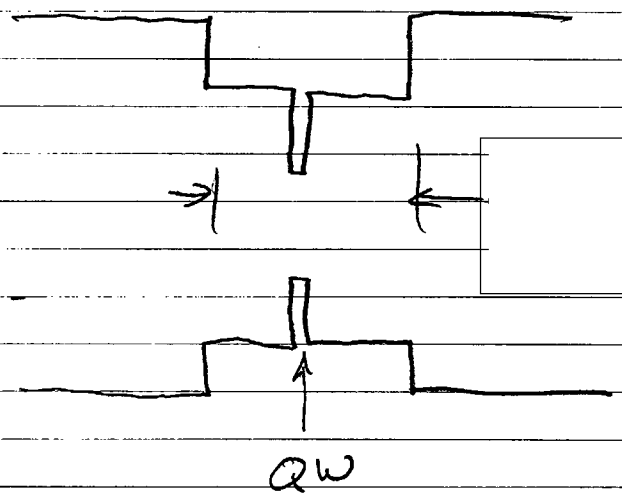
- Active region also has higher index of refraction
  $n = 3.6$ (GaAs)
  $\simeq 3.4$ (AlGaAs)
  so light is guided in the active layer

Quantum Well lasers.

- Insert one or more quantum wells into the active region.
- Modified DOS increases gain as discussed earlier in semester

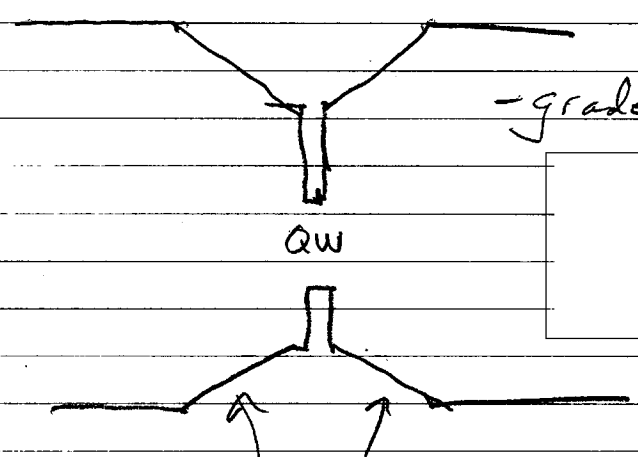
Band diagram

step-index



"GRINSCH"

-graded index QW laser



Graded composition confinement region

- Distributed Feedback (DFB) laser

need for single mode lasers:

- For high speed communication lasers >1GHz
- Fiber dispersion causes pulse broadening
- Need to limit the bandwidth
- DFB laser gives single mode selection

Simple Fabry-Perot GaAs laser, $L = 250\mu m$

mode spacing:

Typical laser gain bandwith $\cong 6$ meV

→ ~10 modes oscillate

Introduce a periodic index variation along the laser gain length

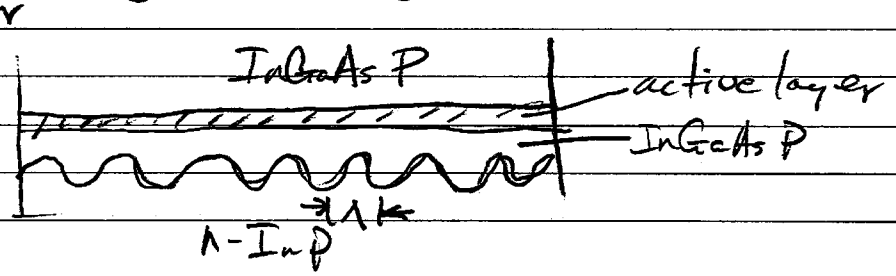
This gives a resonant Bragg refection for

$$\lambda_B = 2 n_{eff} \Lambda$$

→ enhance feedback for selected wavelength

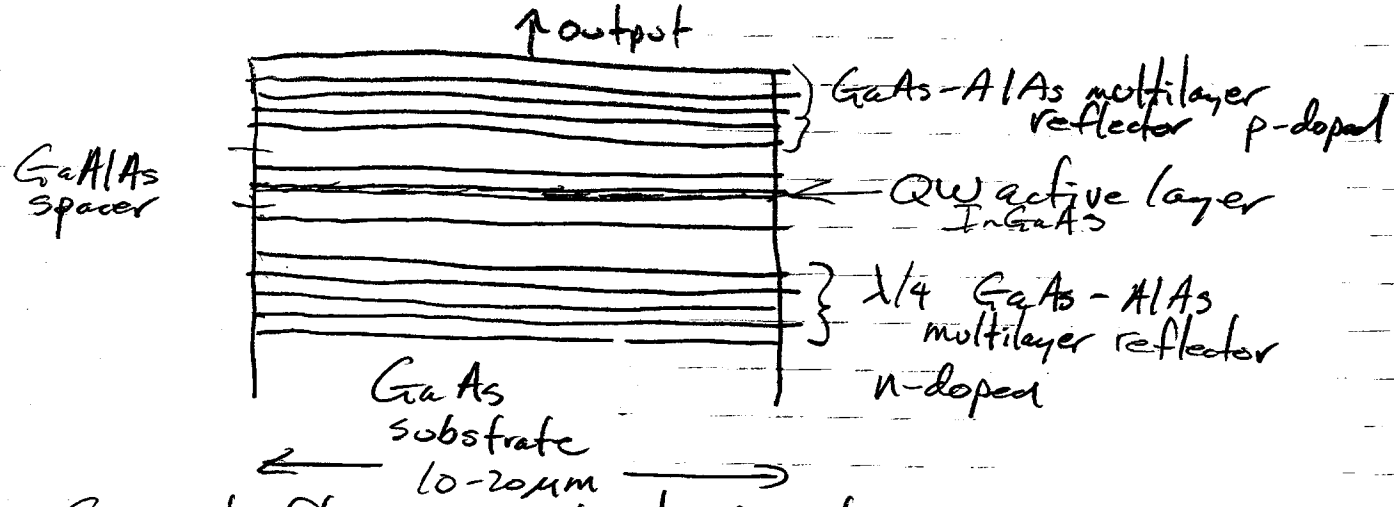
- Single mode operation
- need short period Λ

- This is done by building and burying a corrugation structure into the laser



– Vertical cavity surface emitting laser (VCSEL)

- Similar to the Semiconductor Fabry-Perot Saturable absorber structure



Current flows in vertical direction.
Structure is etched to 20μm circular diameter

Can be built into arrays