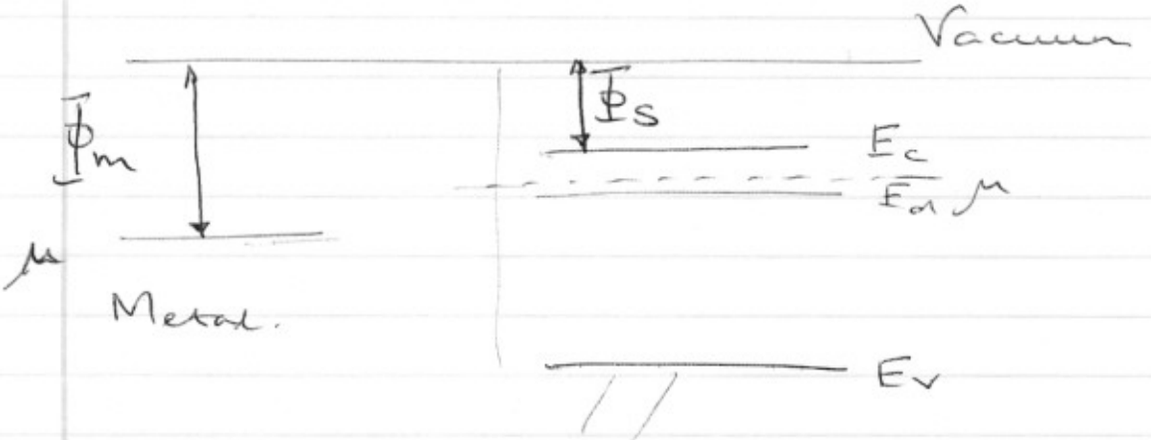
Devices — inhomogeneous.

e is +ve

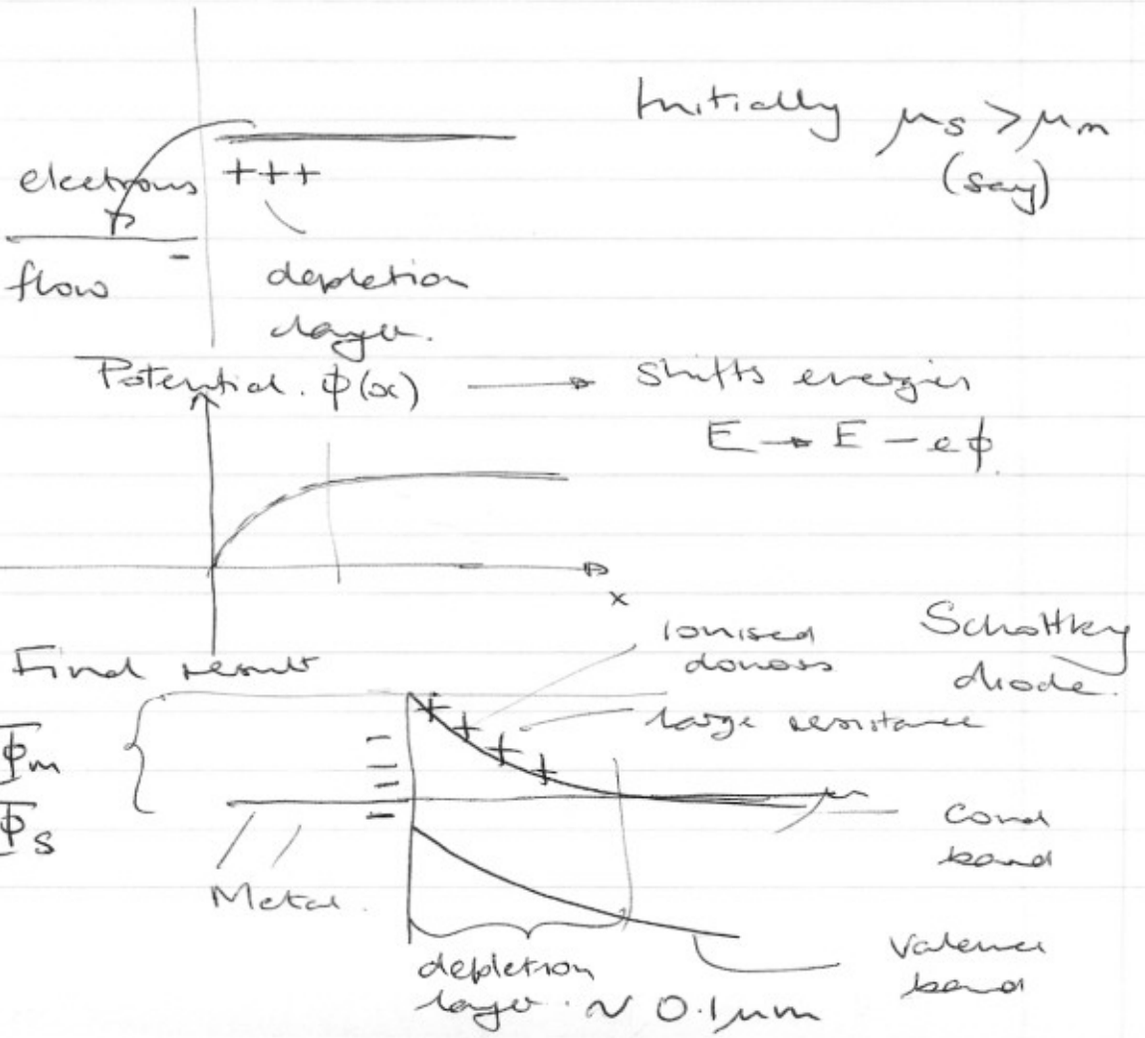
$$\mathcal{H} = E_n(k) - e\phi(r)$$

↑ electric potential.

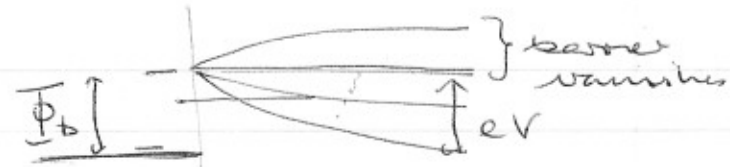
Metal / Semiconductor

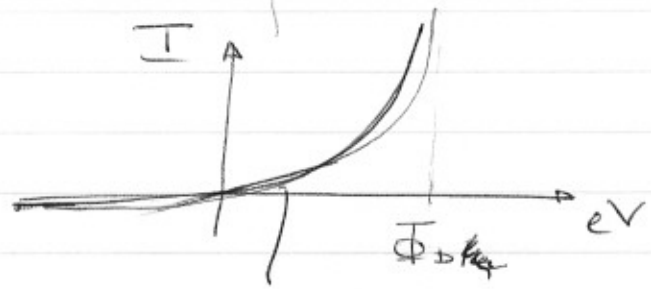


Not in equ^{n} ⟹ different μ



Applying a bias





reducing the barrier

$j \propto e^{-(\Phi - eV)/kT} \propto e^{eV/kT}$.

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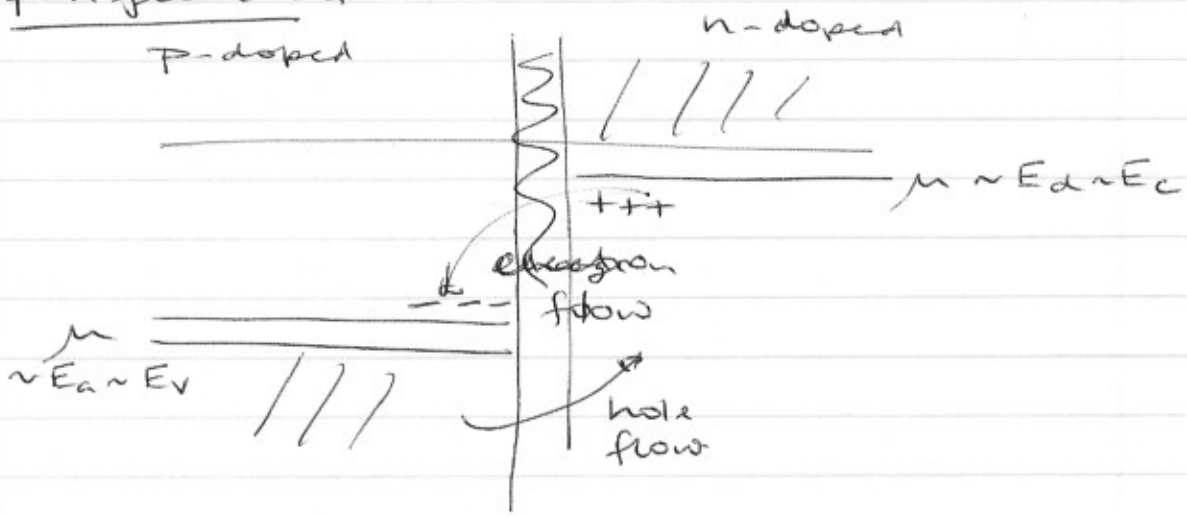
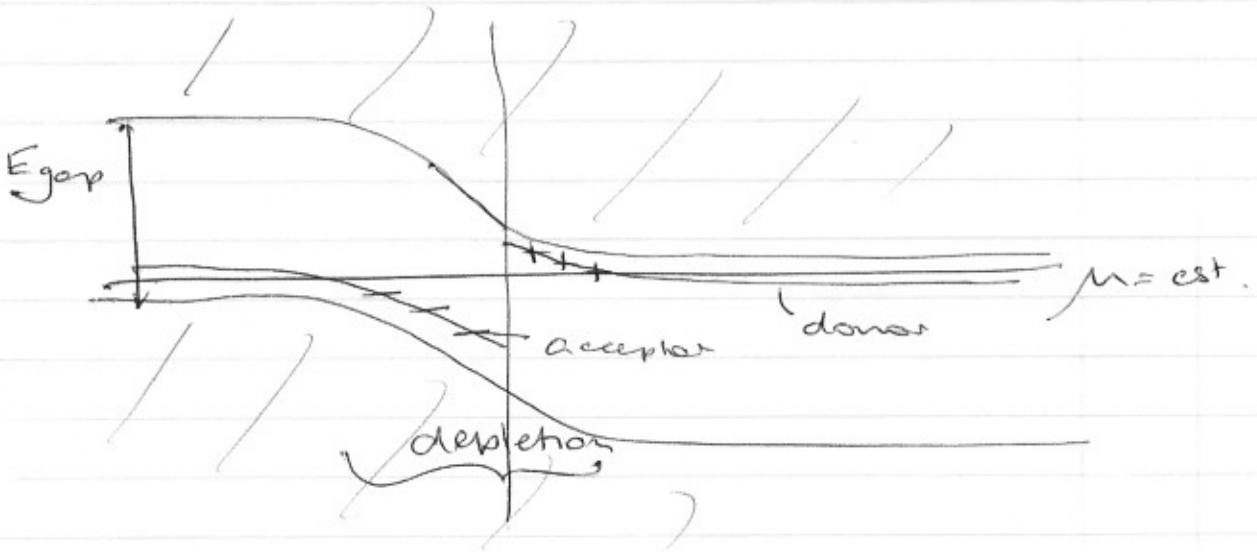
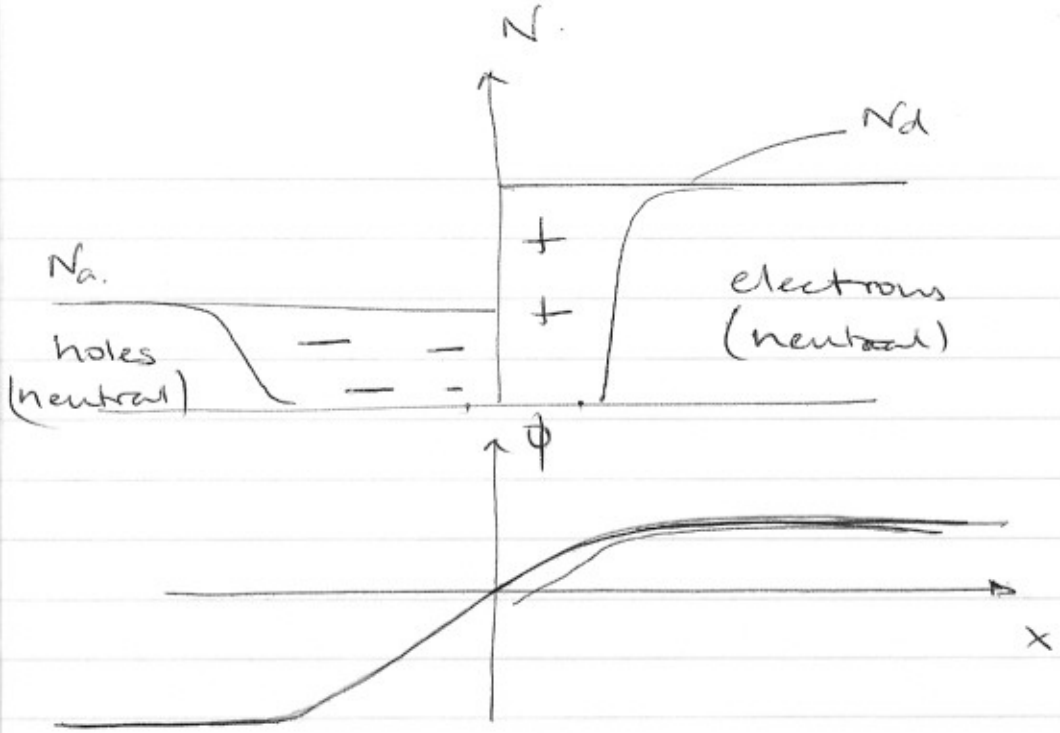
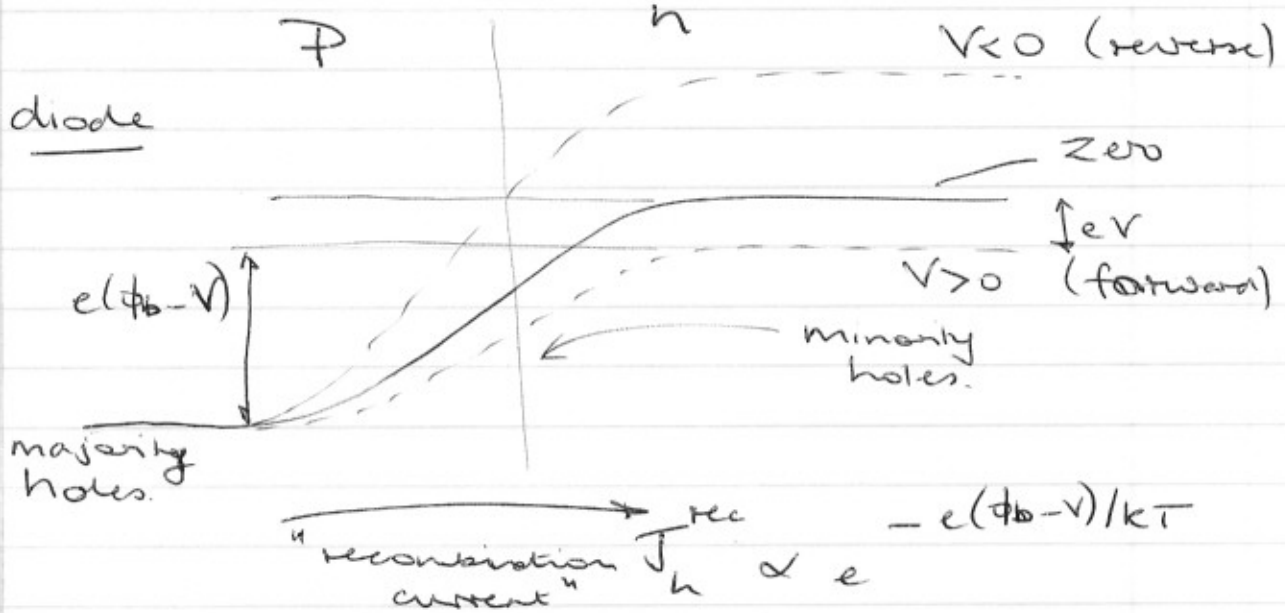
p-n junction









diode

"recombination current" $J_h^{rec} \propto e^{-e(\phi_b - V)/kT}$

Balanced by hole "generation current"
from minority holes

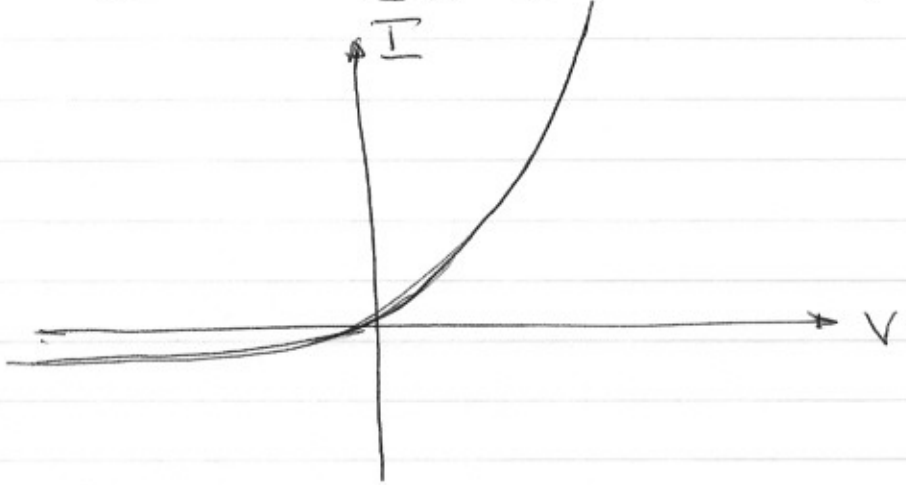
J_h^{gen} (indep of V)

at V=0 $J_h^{rec} + J_h^{gen} = 0$

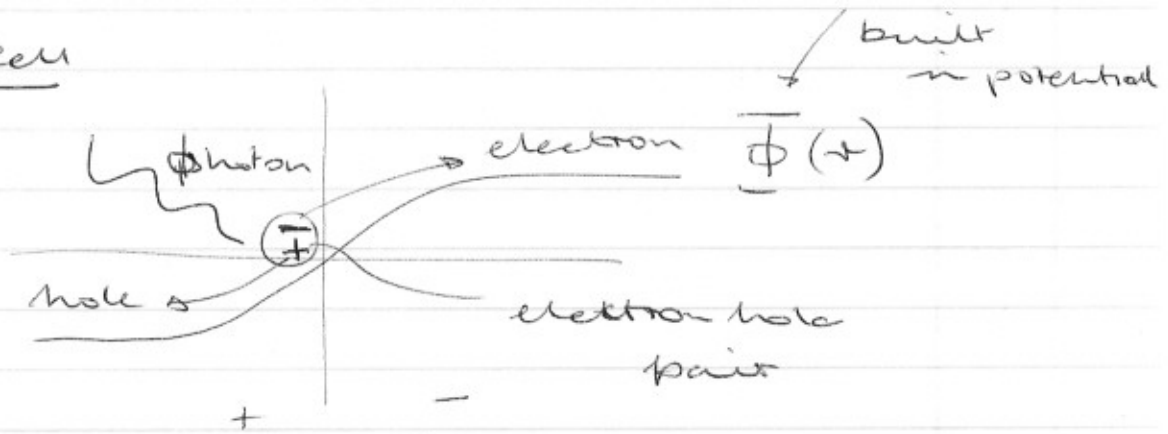
$$J_h^{tot} = J_h^{gen}\left(e^{eV/kT} - 1\right)$$

For electrons same, but with oppositely directed flow & opp sign carried
⟹ Same current

$$\therefore I = I_{Sat}\left(e^{eV/kT} - 1\right)$$



Solar cell



— photovoltaic effect

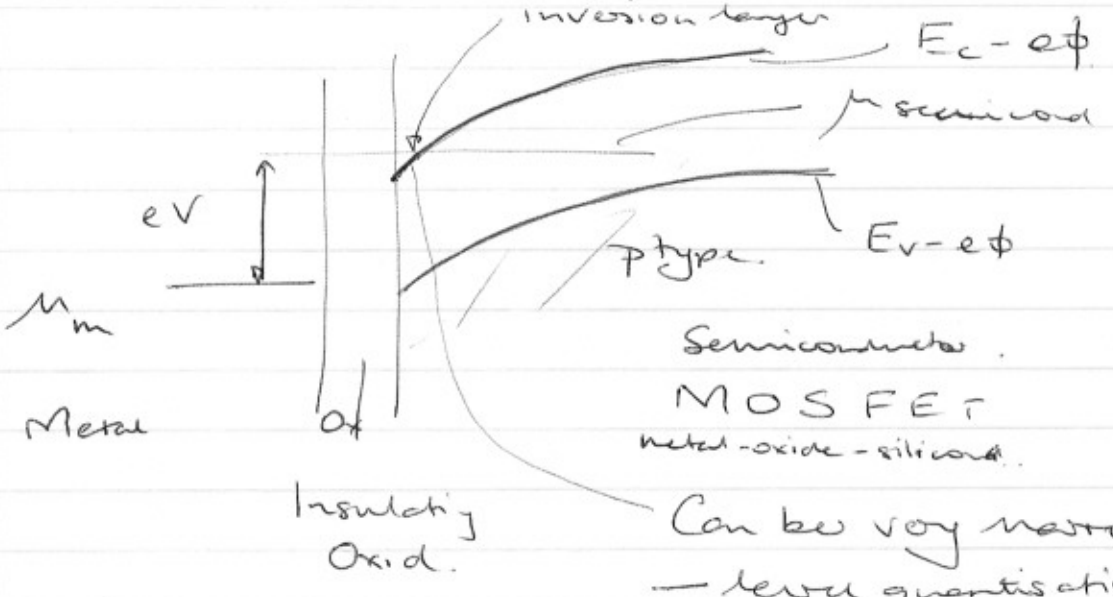
— deliver power to external circuit

Light-emitting diode

— inject e-h pair → photon of energy near band gap.

Field Effect Transistor

— Shift bands by electrostatic potential.



in real space

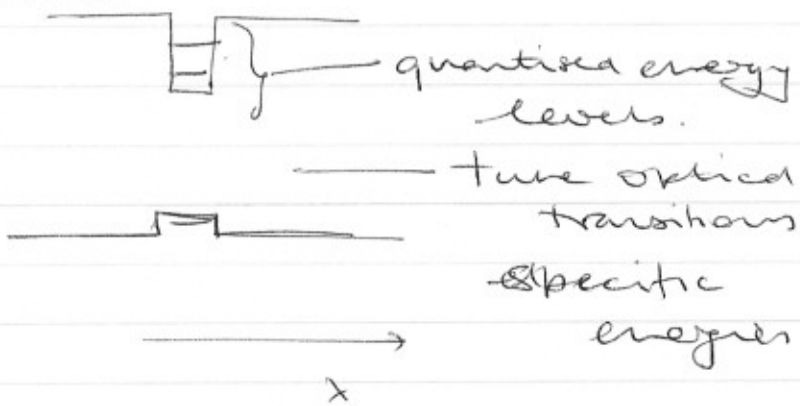
Semiconductor Heterostructures

⟹ Smooth variation of chemical composition

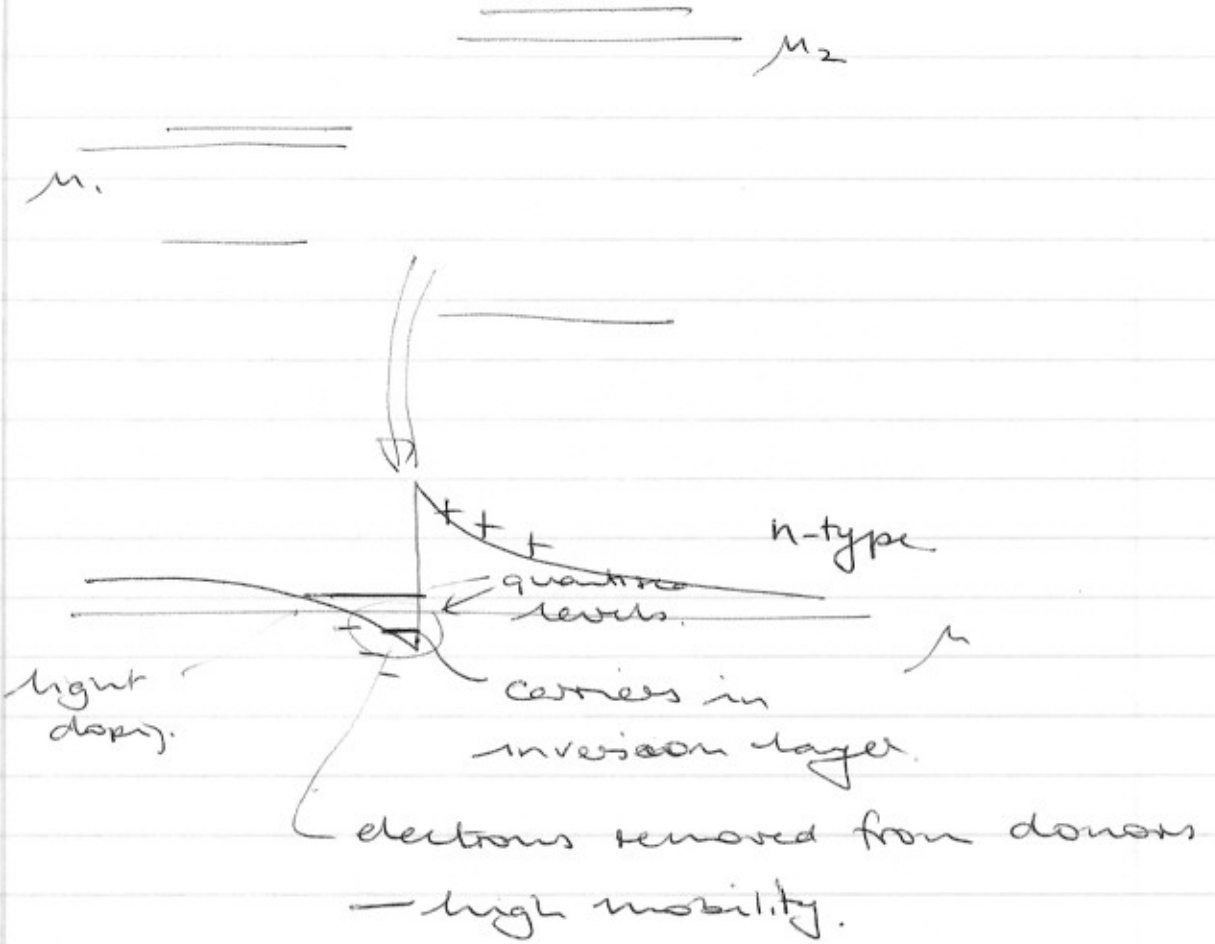
AlAs GaAs — different E_{gap}.

$Al_{1-x}Ga_xAs$

AlGaAs GaAs AlGaAs



2DEG



Quantum well laser