The University Of Sheffield.

EEE105 "Electronic Devices"

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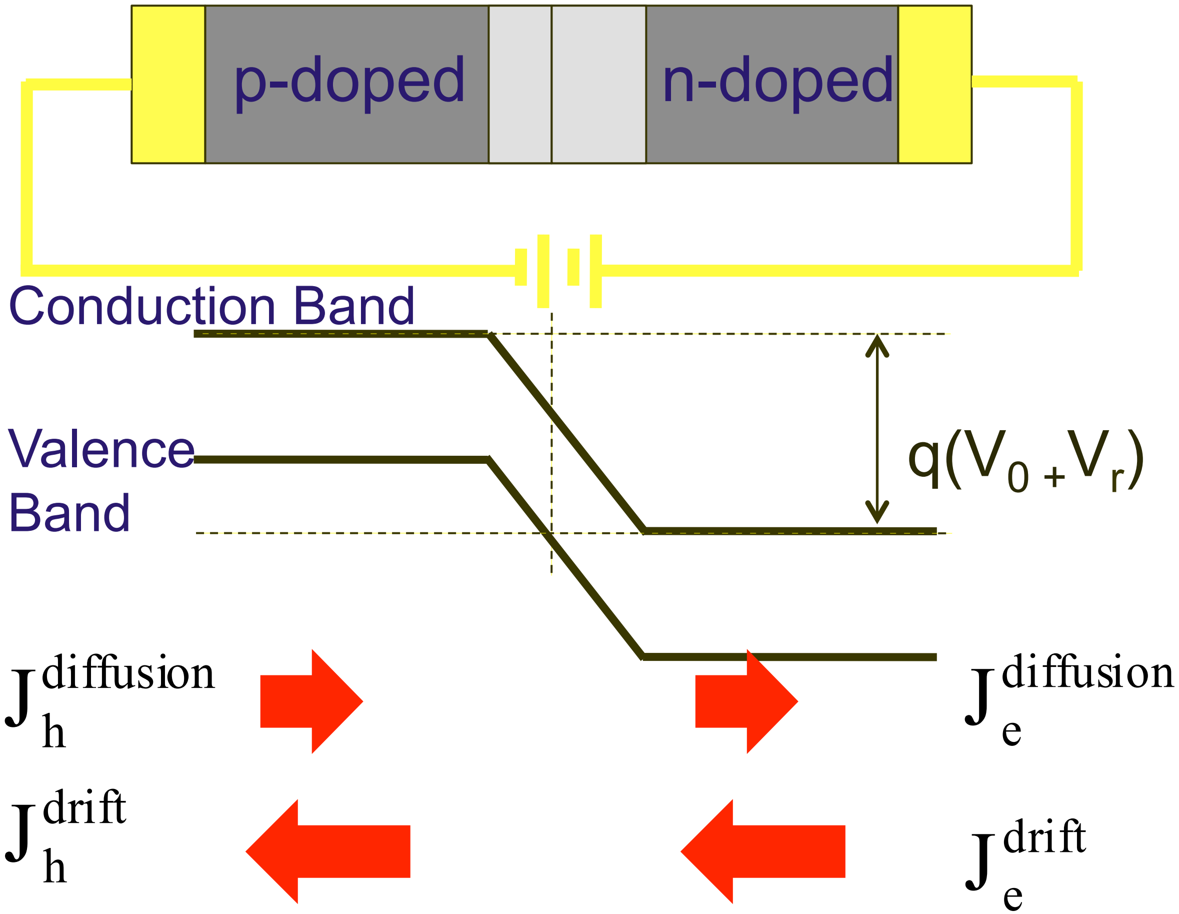
Lecture 17

- p-n junctions under reverse bias – minority carrier injection
- Electronic minority carrier injector?
- Bipolar Junction Transistor (BJT)

Reverse Bias



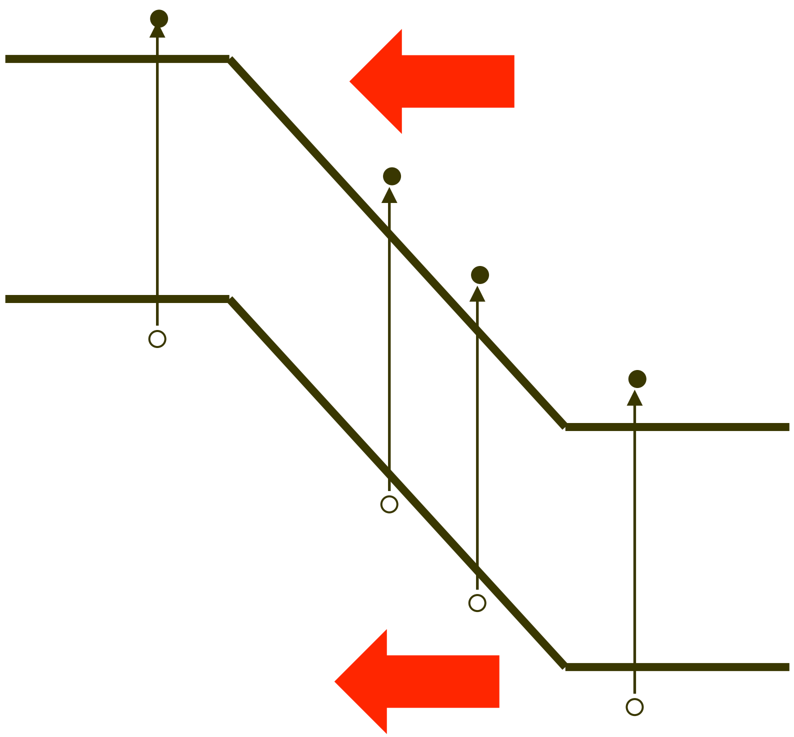
At high V_r

Current is entirely due to drift

This is due to thermally generated minority carriers in n and p-type material

"Generation current"

Photodiode

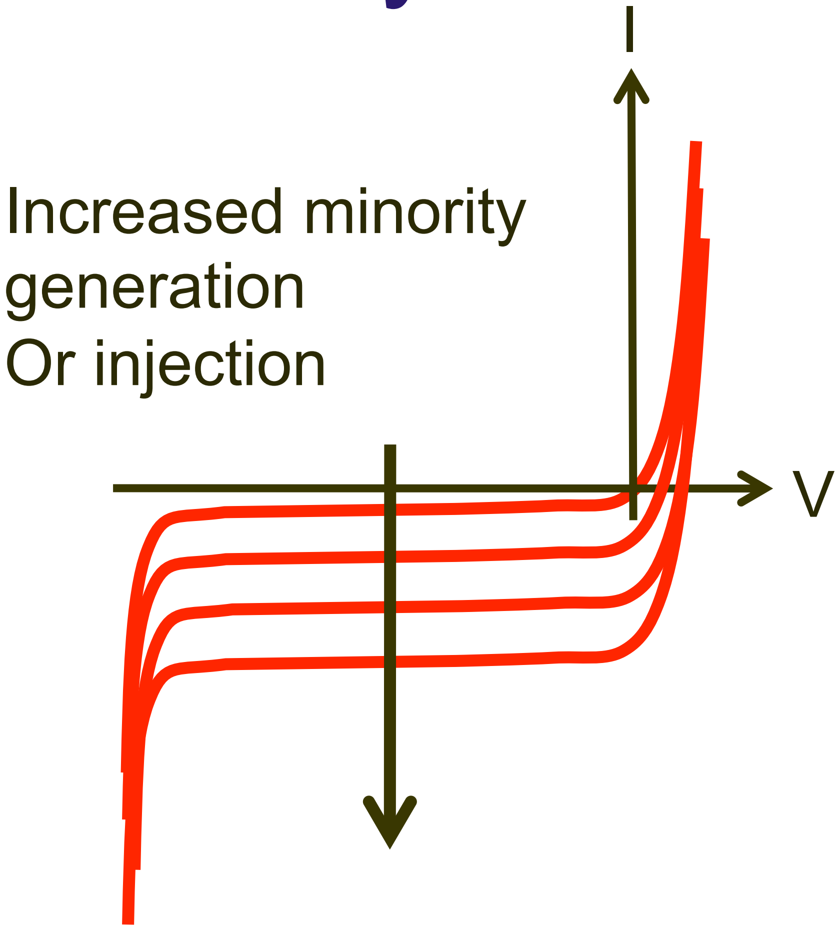


If light of energy greater than the band-gap is shone on the semiconductor electron hole pairs can be created throughout

Electron-hole pairs in the intrinsic region are separated and contribute to drift current

Essentially same as enhancing the minority carrier injection from the p-type and n-type regions

Minority Carrier Injector?



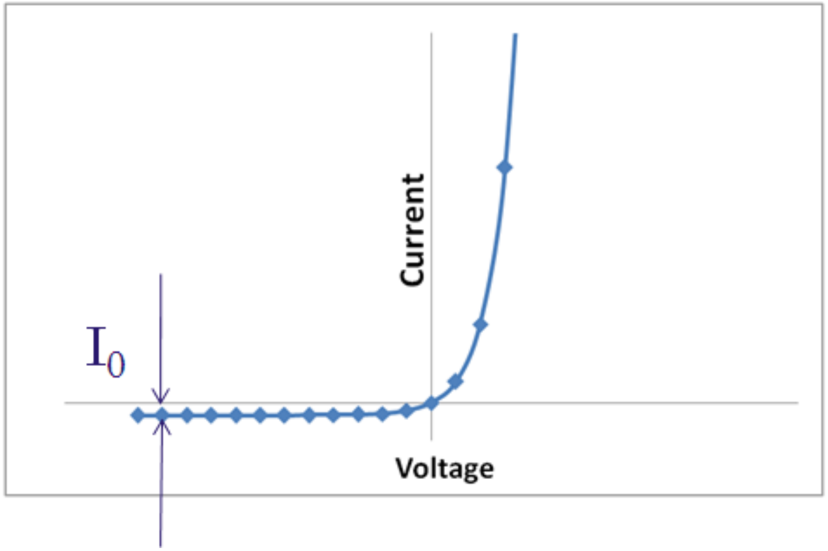
In a photodiode the current is independent of bias (load resistor)

If it is possible to control generation or injection we can control current flow through the junction

Can make a controllable constant current source

Can we create a minority carrier injector ?

Single minority carrier injector



Diode equation for p-n junction

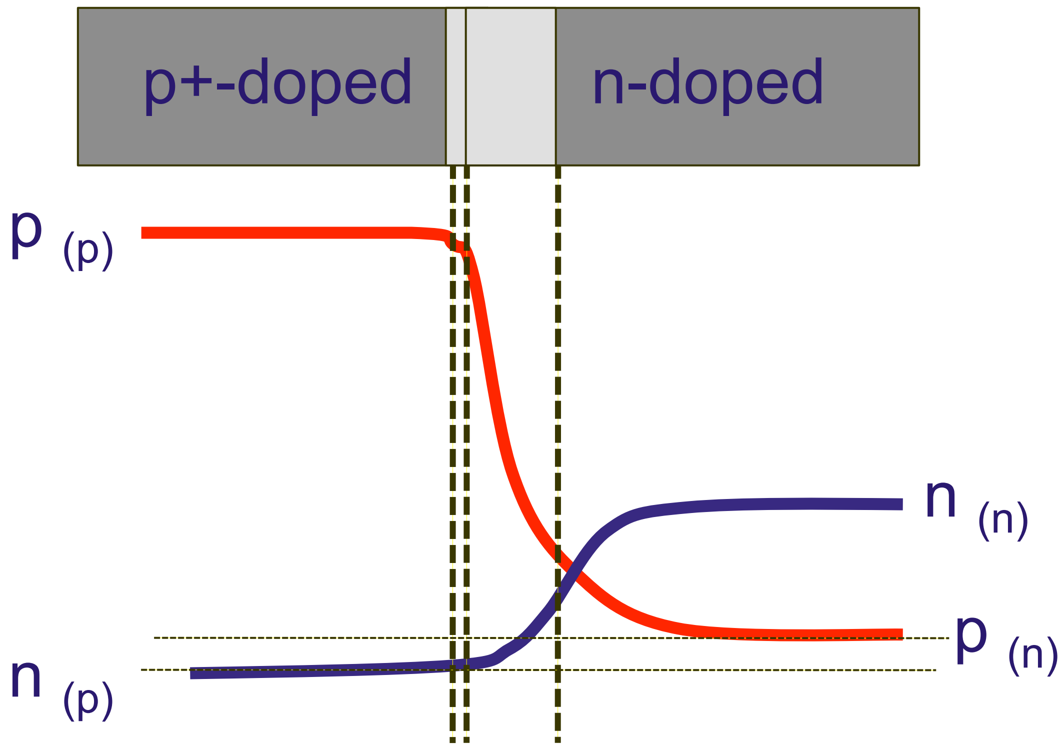
$$I = I_0\left[\exp\left(\frac{qV_f}{k_B T}\right) - 1\right]$$

$$I_0 = I_{e0} + I_{h0} = qA\left[\frac{L_e n_p}{\tau_e} + \frac{L_h p_n}{\tau_h}\right] = qAn_i^2\left[\frac{D_e}{L_e N_A} + \frac{D_h}{L_h N_d}\right]$$

p^+-n diode

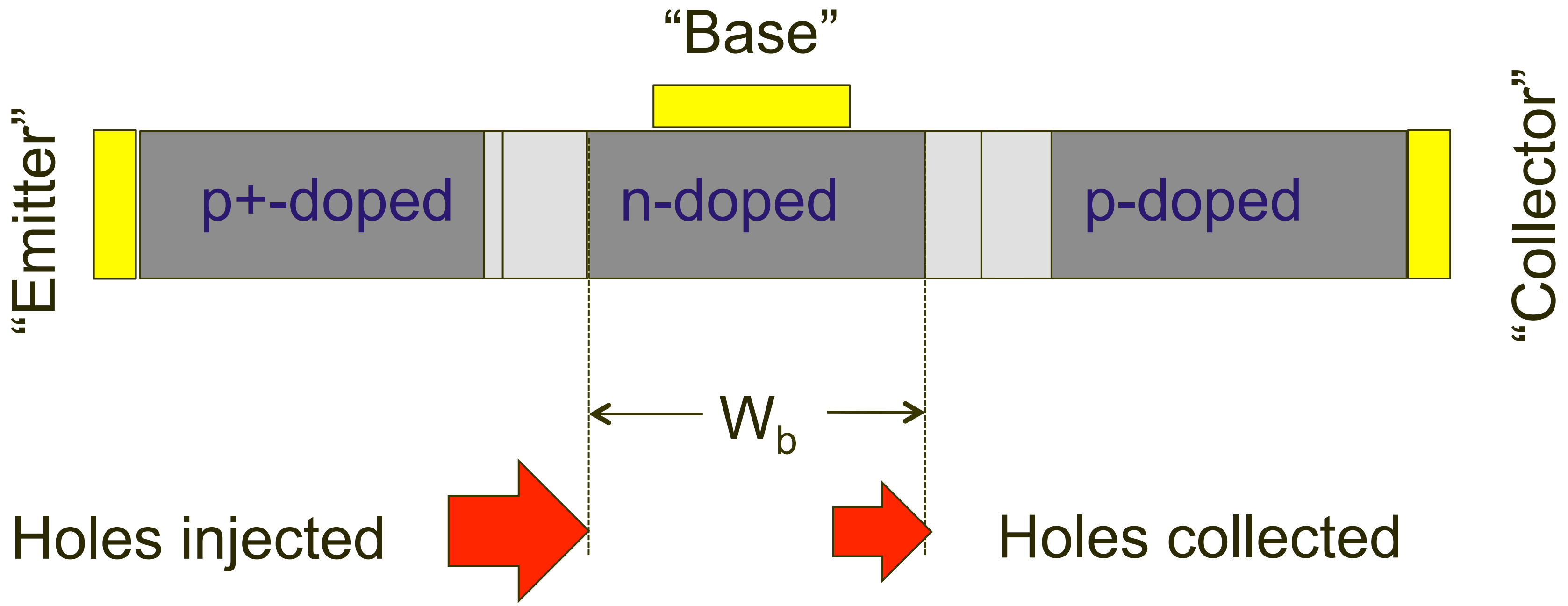
If p-doping is >>n-doping

Majority of diode current is due to holes
(n.b. can make n+-p too for electron dominated current)



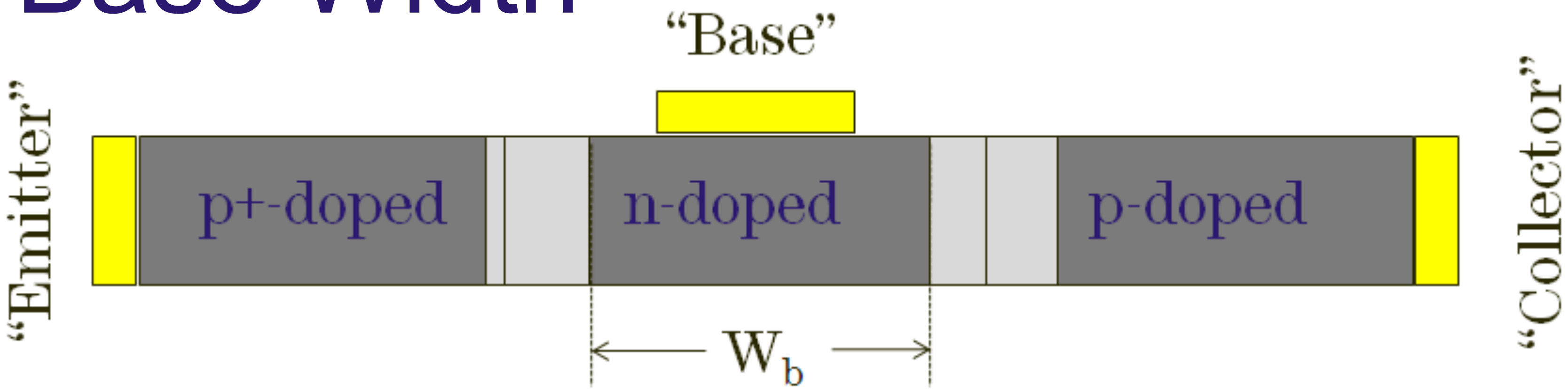
$$I_0 = I_{e0} + I_{h0} = qA\left[\frac{L_e n_p}{\tau_e} + \frac{L_h p_n}{\tau_h}\right] = qAn_i^2\left[\frac{D_e}{L_e N_A} + \frac{D_h}{L_h N_d}\right]$$

Minority Injector + p-n



This is known as a Bipolar Junction Transistor (BJT)
(n.b. this is p+-n-p junction – similarly for n+-p-n)

Base Width

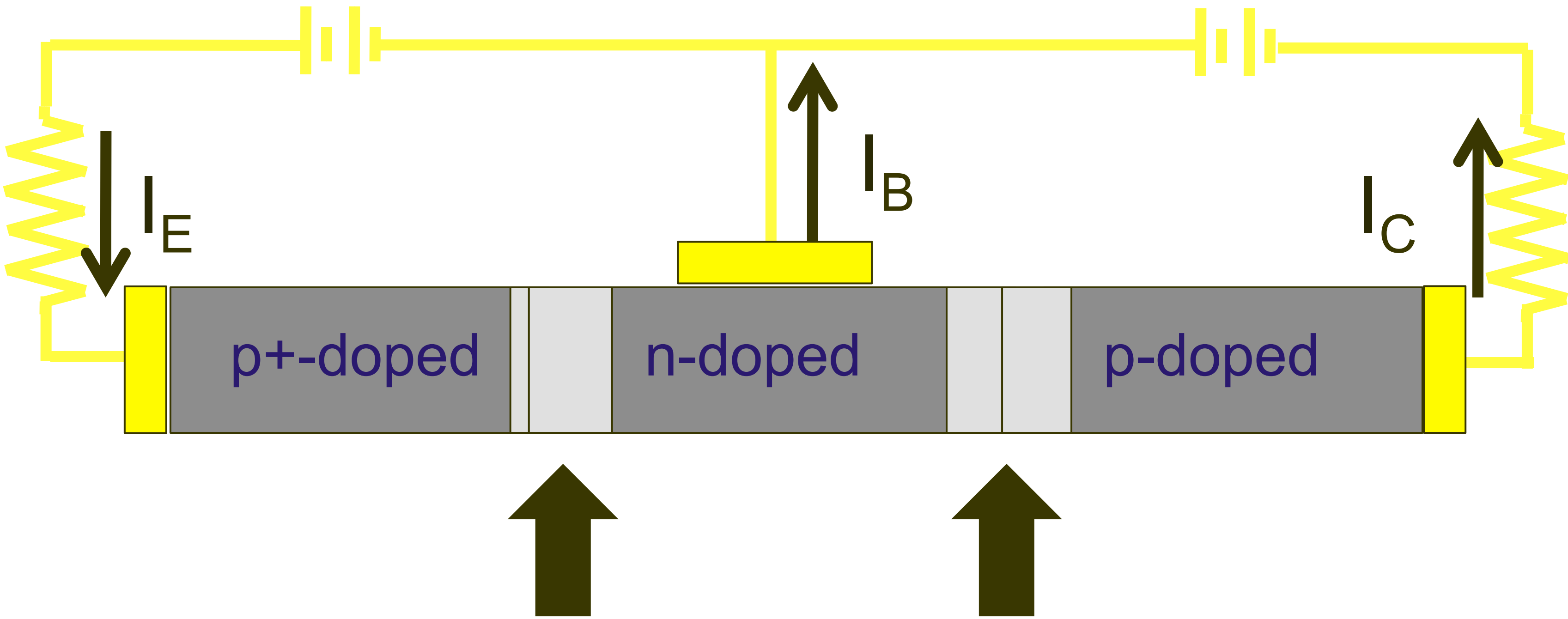


We would like holes injected to experience a long minority lifetime in the n-type base. n-type material should be thin.
In such a case most injected holes transit to the collector

$$W_B << L_h = \left(D_h \tau_h\right)^{1/2}$$

$$\left(D_h = \frac{k_B T \mu_h}{q}\right)$$

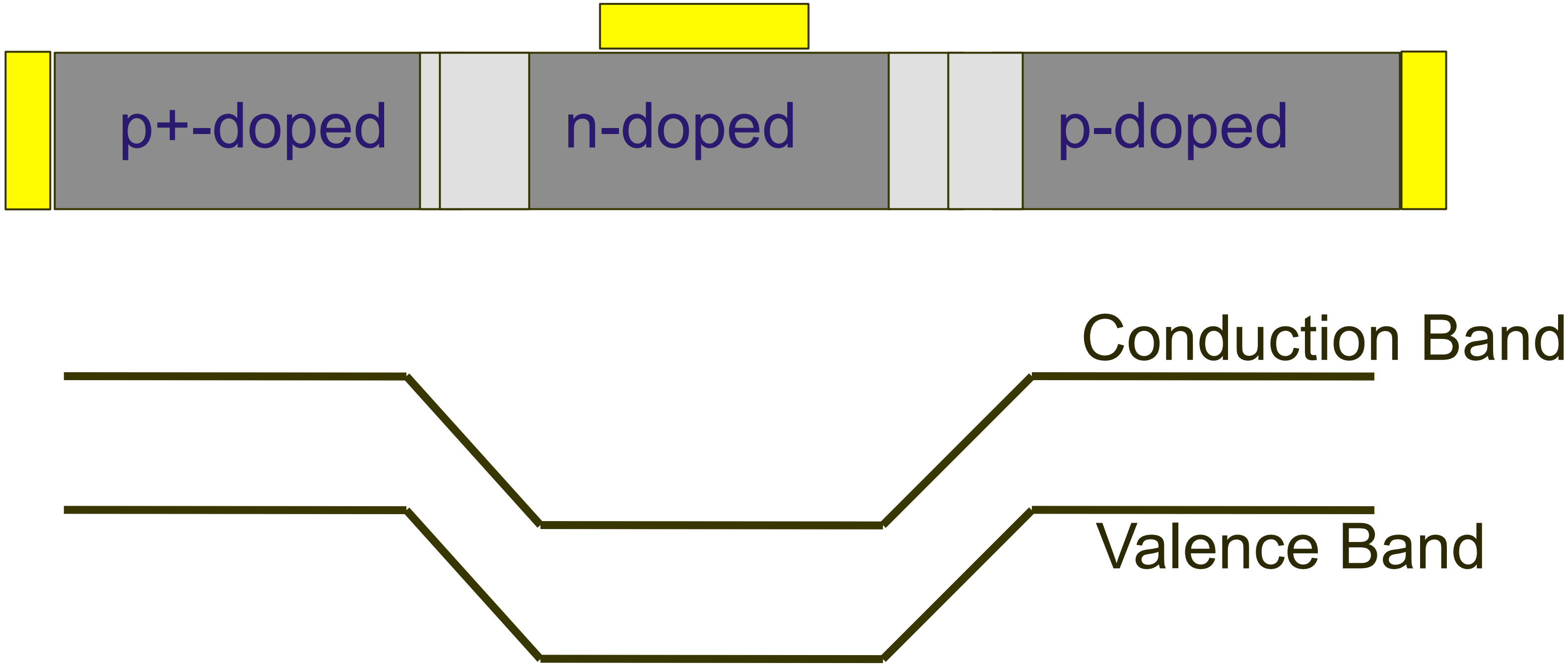
Bias



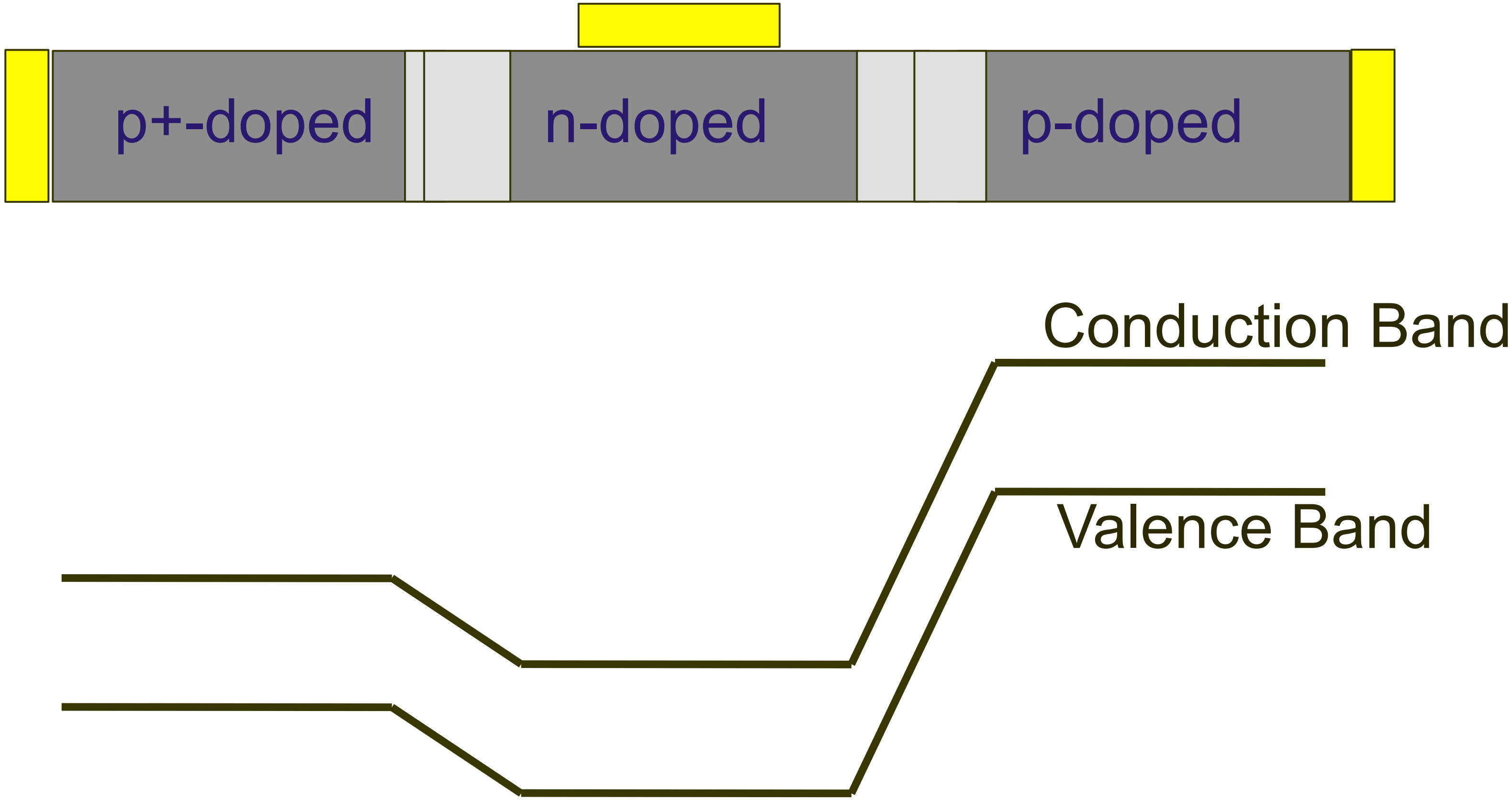
Forward Biased diode – hole injector as heavier p-doping than n-doping

Reverse Biased – needs injecting with carriers

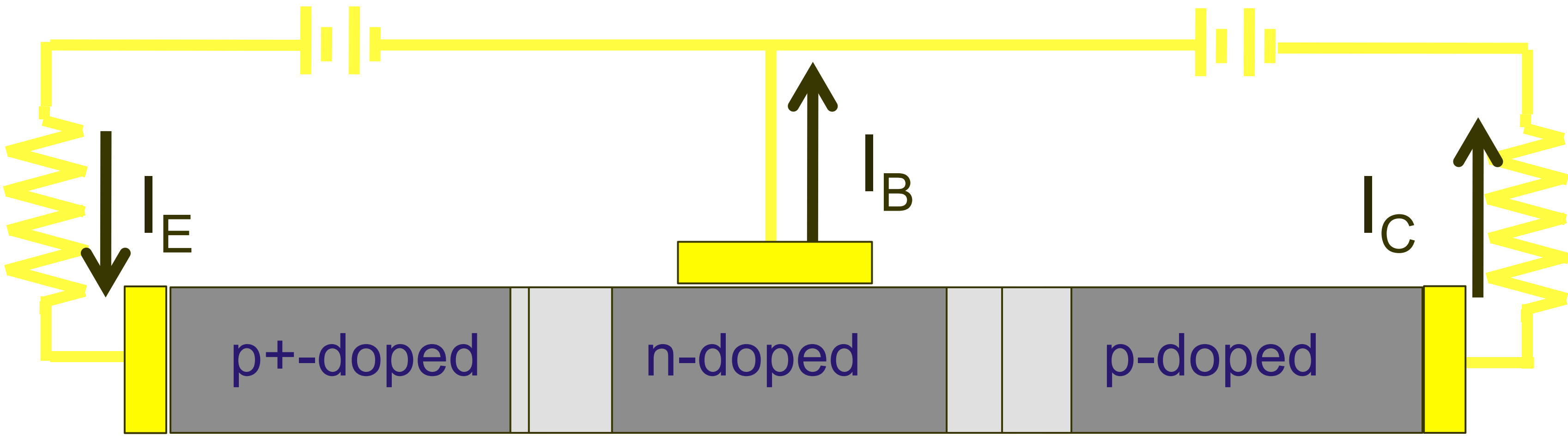
Zero Bias – p+-n-p



Operational Bias – p+-n-p

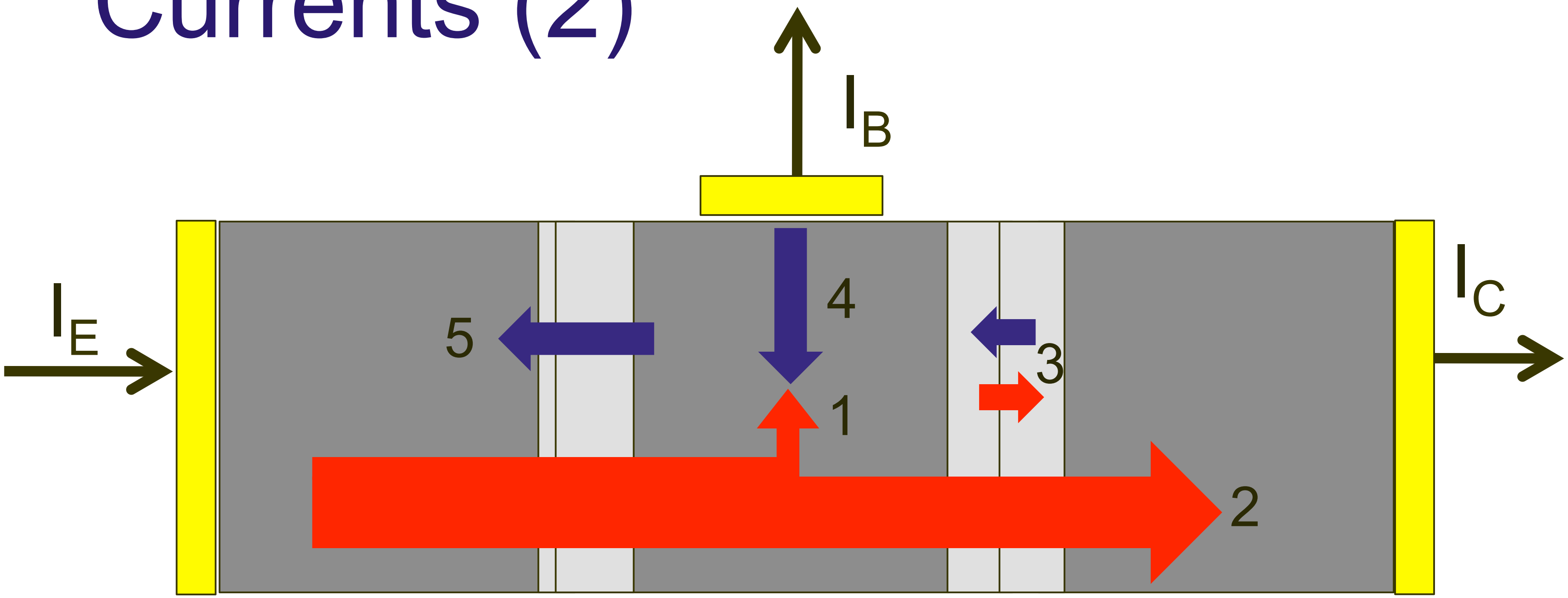


Currents



Ideally $I_E=I_C$ and $I_B = 0$. If all the current through the "injector" is hole current and width is small so there is no recombination in the base.

Currents (2)



p+-doped n-doped p-doped

Currents (3)

(1) Injected holes lost to recombination in n-type base

(2) Injected holes whish reach the reverse biased collector junction

(3) Thermally generated electrons and holes (saturation current for this junction)

(4)Electrons supplied due to recombination of holes in the base

(5)Electrons injected across the forward biased emitter junction

Summary

- The saturation current is due to the thermal generation of minority carriers which diffuse into the intrinsic region and contribute to drift current
- A device which injects minority carriers would be useful as the current through a diode can be controlled
- A diode with strongly asymmetric doping is a candidate – the current is dominated by one carrier
- A bipolar junction transistor is introduced – a thin base is required to ensure all the minority carriers injected by the emitter arrive at the collector
- Composition of currents in the transistor have been discussed

