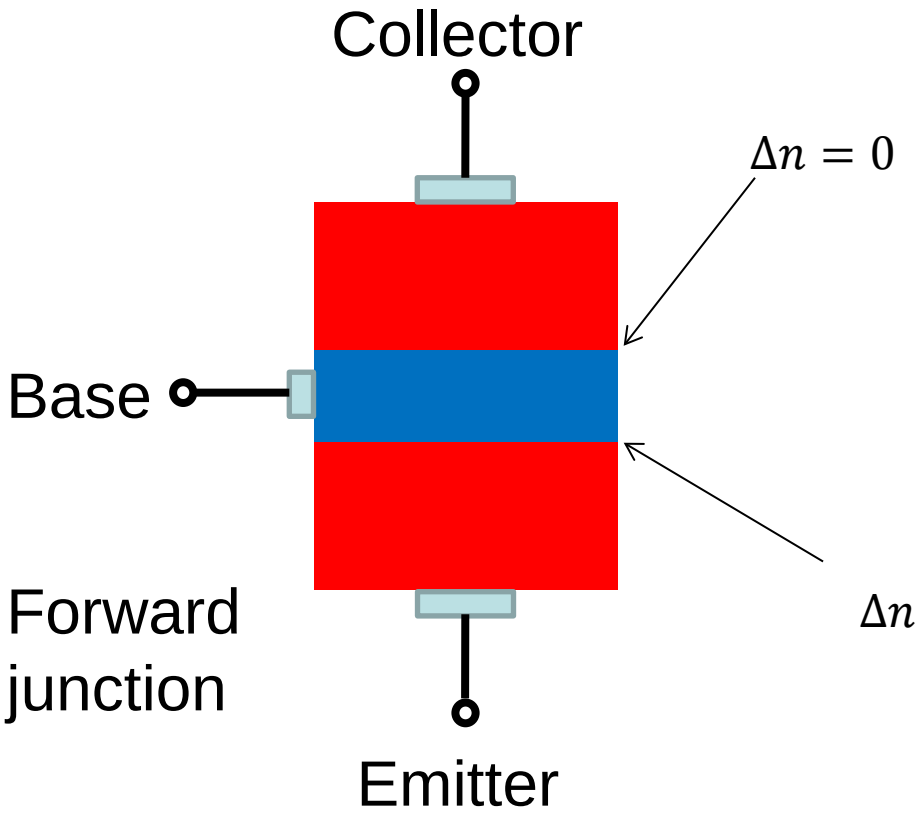
Lecture21: Physics of bipolar transistors (2)

Sung-Min Hong (smhong@gist.ac.kr)

Semiconductor Device Simulation Lab.
School of Information and Communications
Gwangju Institute of Science and Technology

Collector current

- Calculate it using the diffusion current.



$$J_n = qD_n \frac{dn}{dx}$$

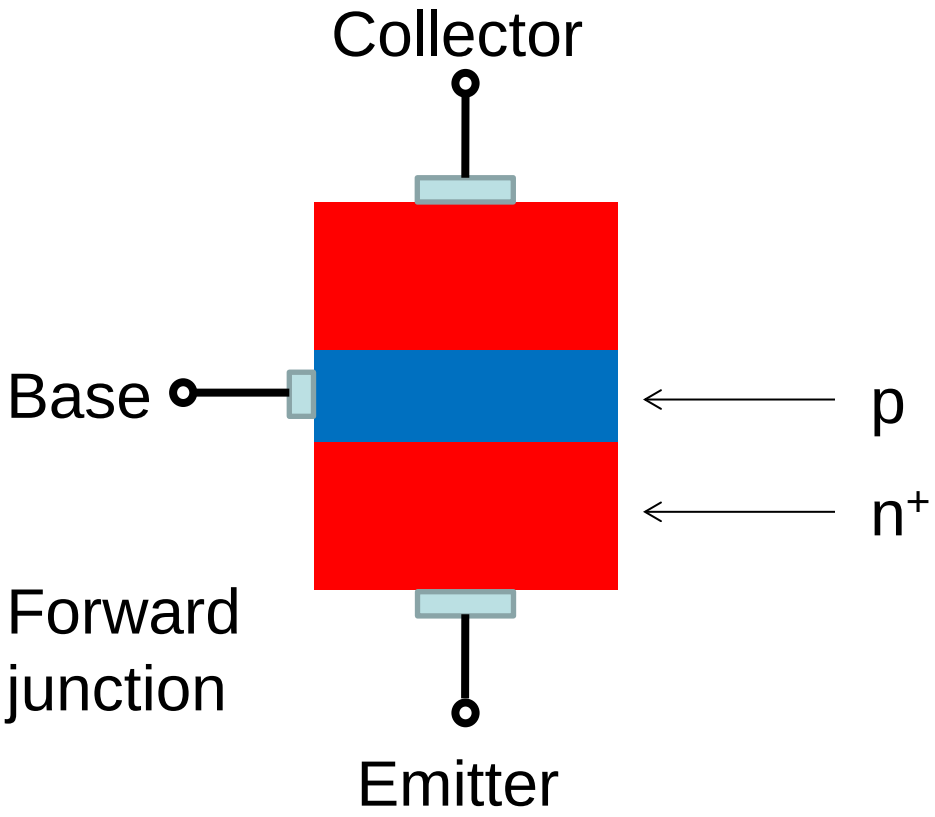
$$I_C = \frac{A_E q D_n n_i^2}{N_B W_B}\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)$$

$$\Delta n = \frac{n_i^2}{N_B}\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)$$

Check your (4.5)!

Base current

- Hole flux of the base-emitter junction
  - Doping levels, diffusion constants, diffusion lengths



$$I_C = \beta I_B$$

Gummel plot

- IV curves for the BJT
  - Collector and base currents

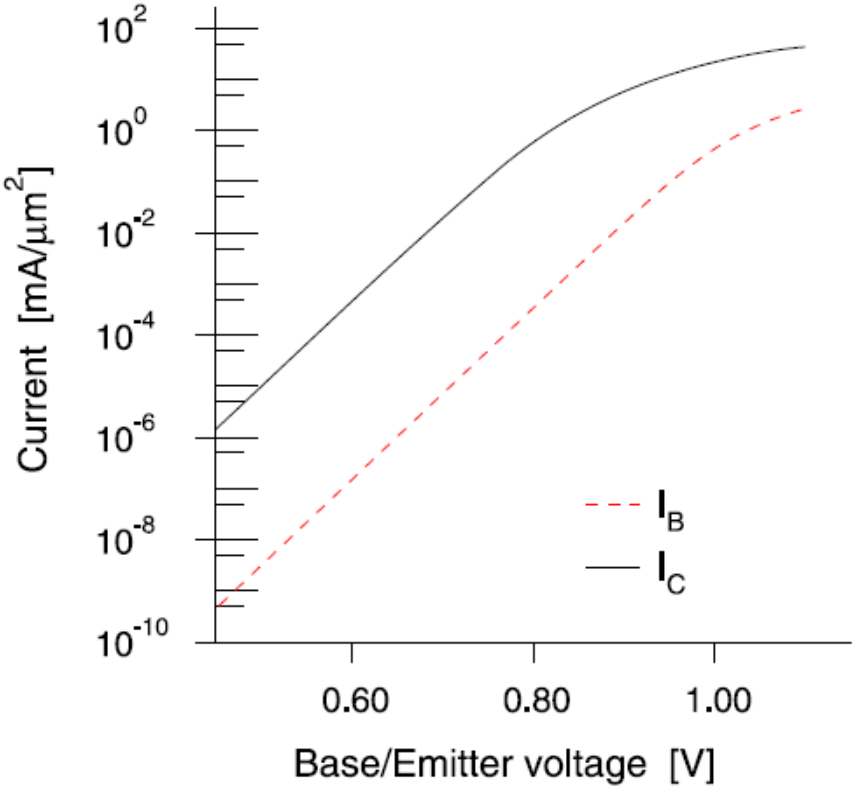


Fig. 19 Gummel plot. $V_{CB} = 0.1$ V

Simulated Gummel plot of a HBT
(Taken from Hong, JCE, vol. 8, p. 225, 2009)

Compare g_m

- Transconductance is given by $g_m = \frac{dI_C}{dV_{BE}}$.

$$I_C = I_S \exp \frac{V_{BE}}{V_T}$$

$$g_m = \frac{I_C}{V_T}$$

- How about the MOSFET?

$$I_D = ???$$

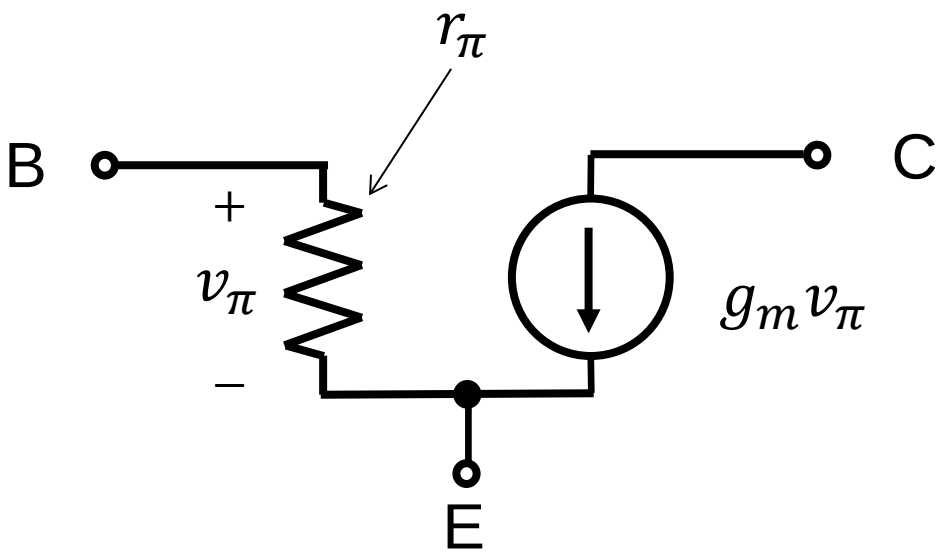
$$g_m = ???$$

- For a given current, which one has higher g_m?

Small-signal model

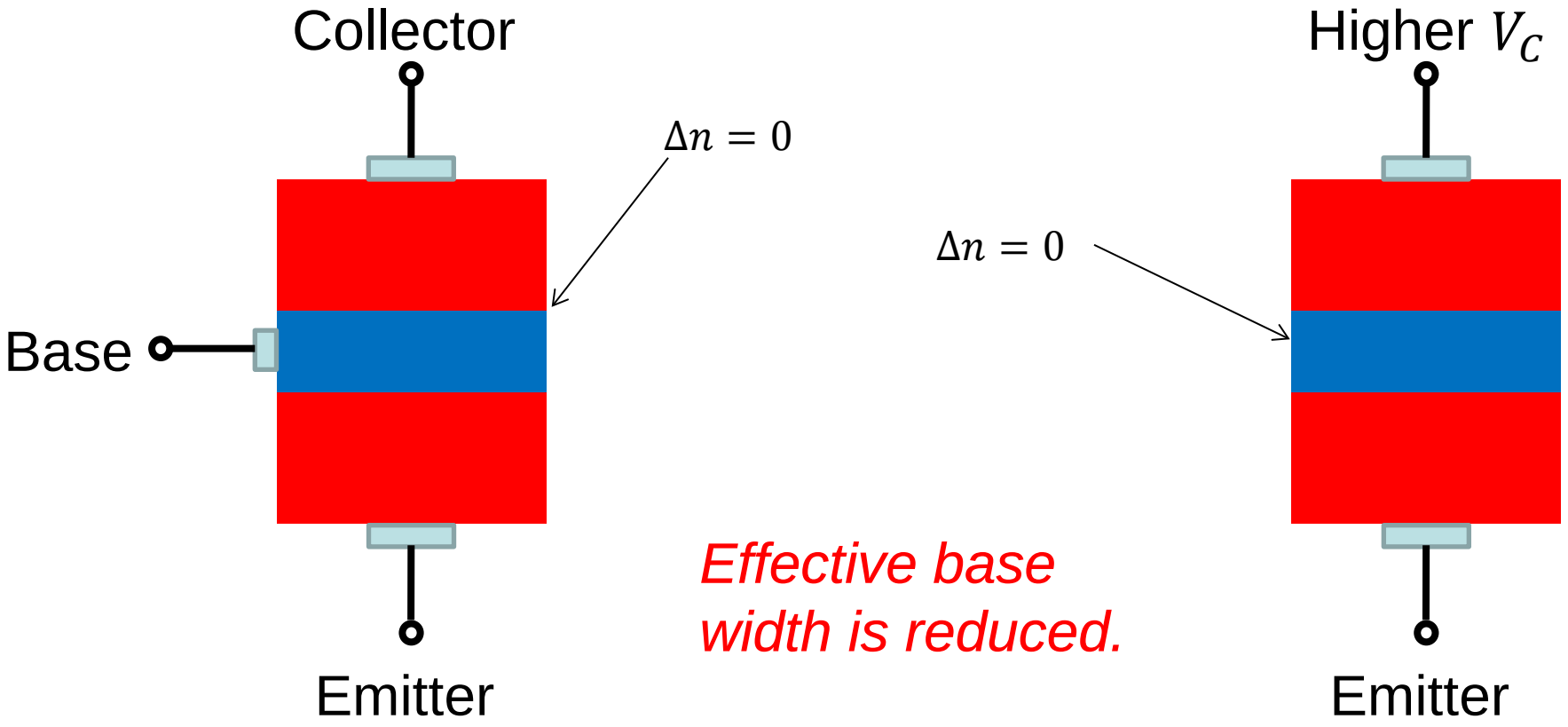
- Quite similar with the MOSFET model
  - Finite resistance between the base and emitter

$$r_\pi = \frac{\beta}{g_m}$$



Early effect (1/2)

- For higher V_{CE},
  - The depletion region between the base and collector is widened.

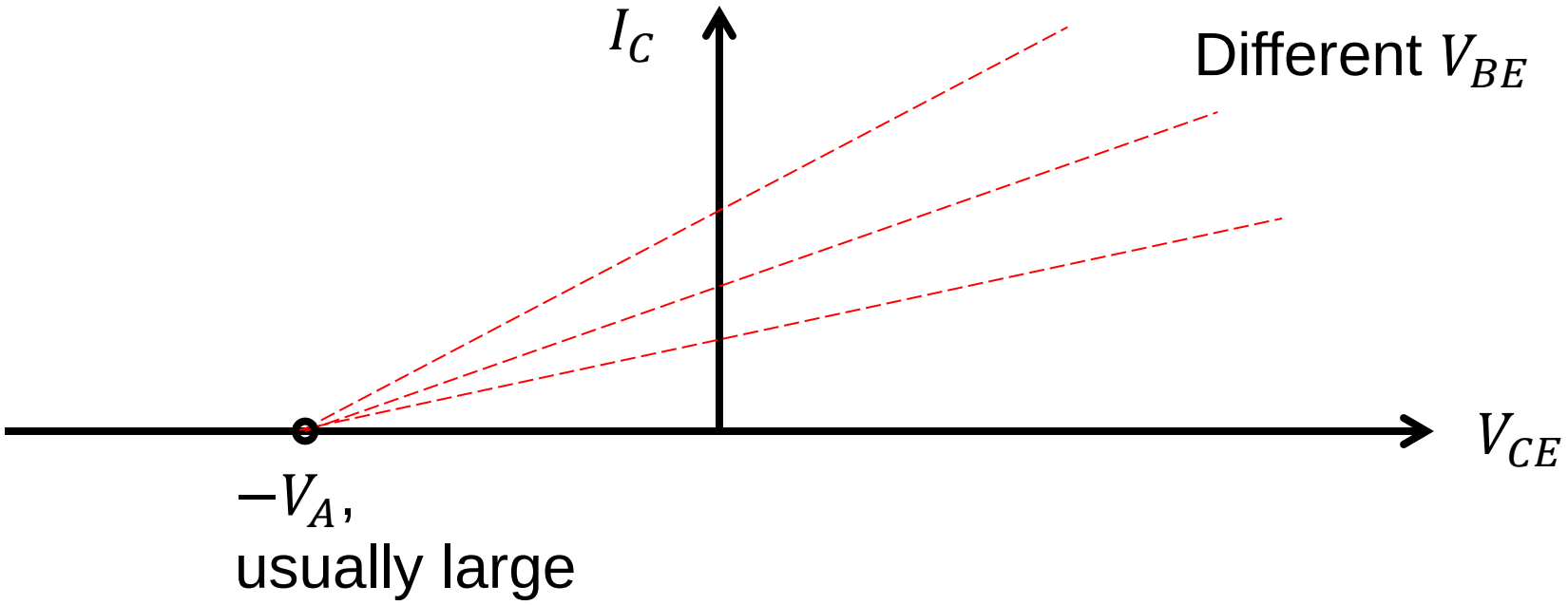


Effective base width is reduced.

Early effect (2/2)

- Its modeling
  - The IV characteristics is now modified:

$$I_C = \left(I_S \exp \frac{V_{BE}}{V_T} \right) \left(1 + \frac{V_{CE}}{V_A} \right)$$

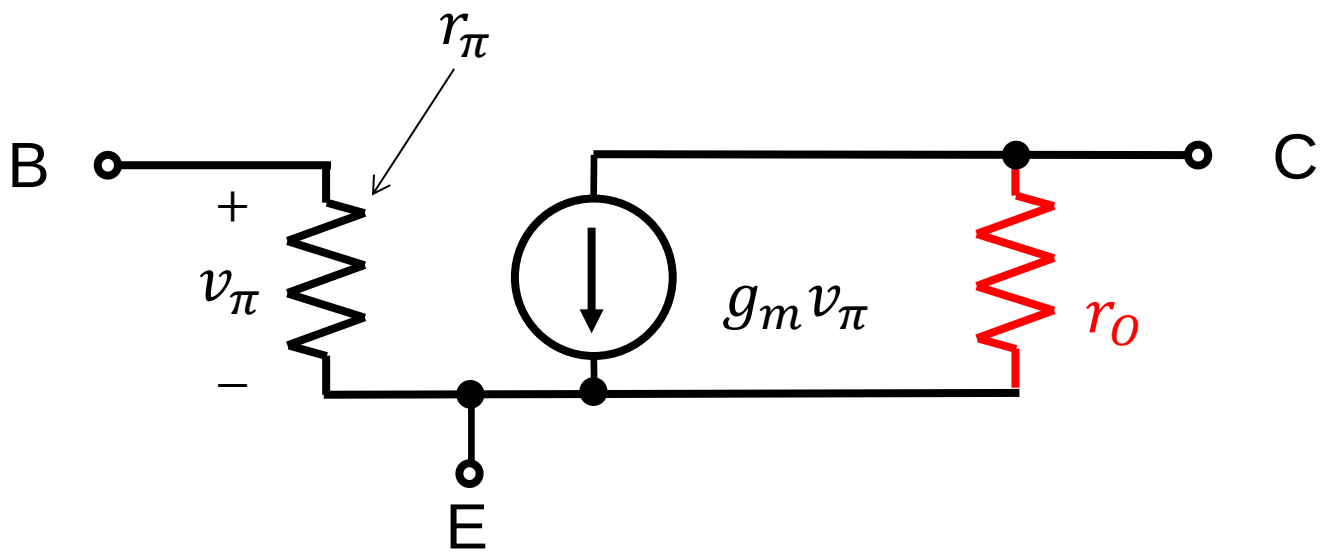


Output resistance

- It is easy to show that

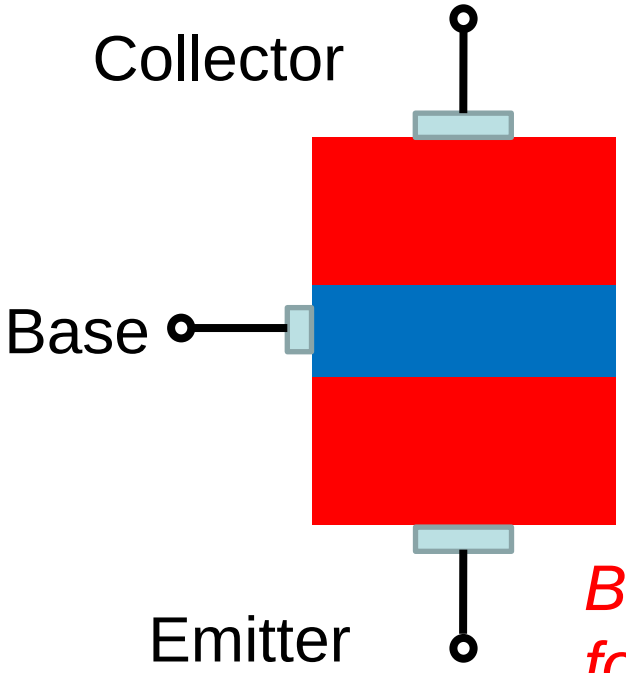
$$\frac{dI_C}{dV_{CE}} = \left(I_S \exp\frac{V_{BE}}{V_T}\right)\frac{1}{V_A}$$

$$r_O \approx \frac{V_A}{I_C}$$

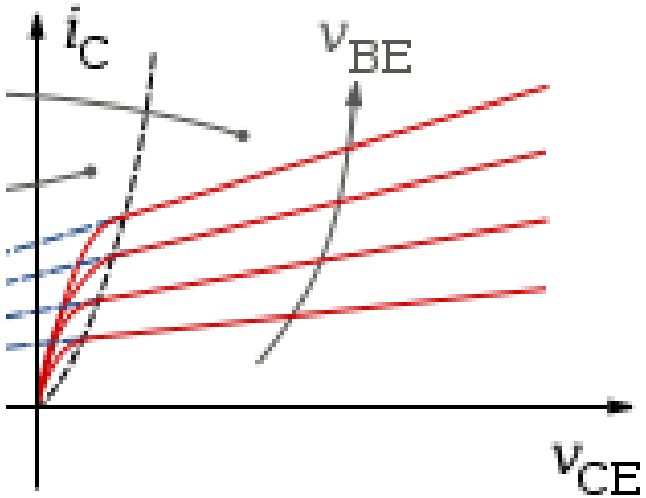


Saturation?

- What was the saturation in the MOSFET?
  - Saturation of the drain current, as the drain voltage increases.
- What is the saturation in the BJT?
  - Saturation of the collector current, as the base current increases.



Both junctions are forward biased.



Typical output characteristics (Taken from Wikipedia)

Read your textbook.

- We have quickly covered the Ch. 4.
  - Many pages, but basically all covered in the lecture.

- On Wednesday, bipolar amplifiers will be studied.