Measurement and Scalable Model for Parasitic PNP of HV PMOS

B. Senapati

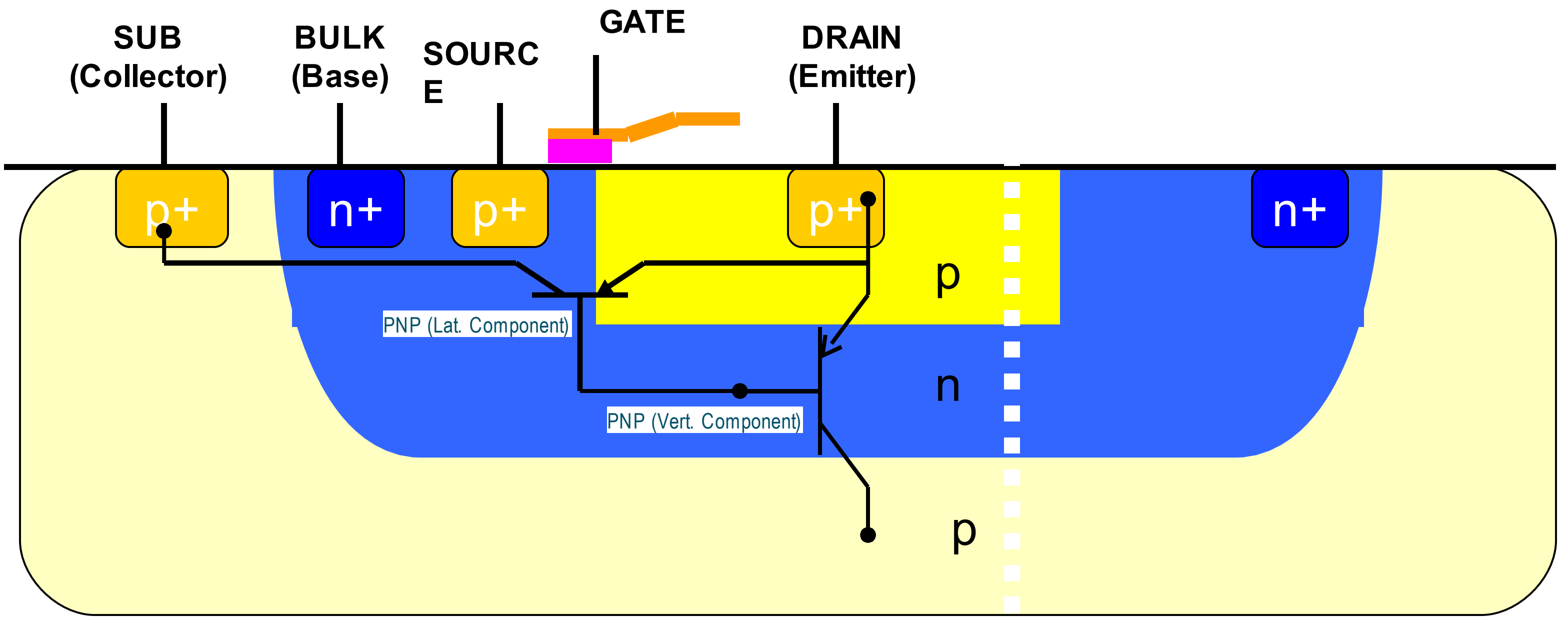
austriamicrosystems AG, Unterpremstaetten, Austria
biswanath.senapati@austriamicrosystems.com

Bipolar Arbeitskreis, 18-19 October 2007, Munich, Germany

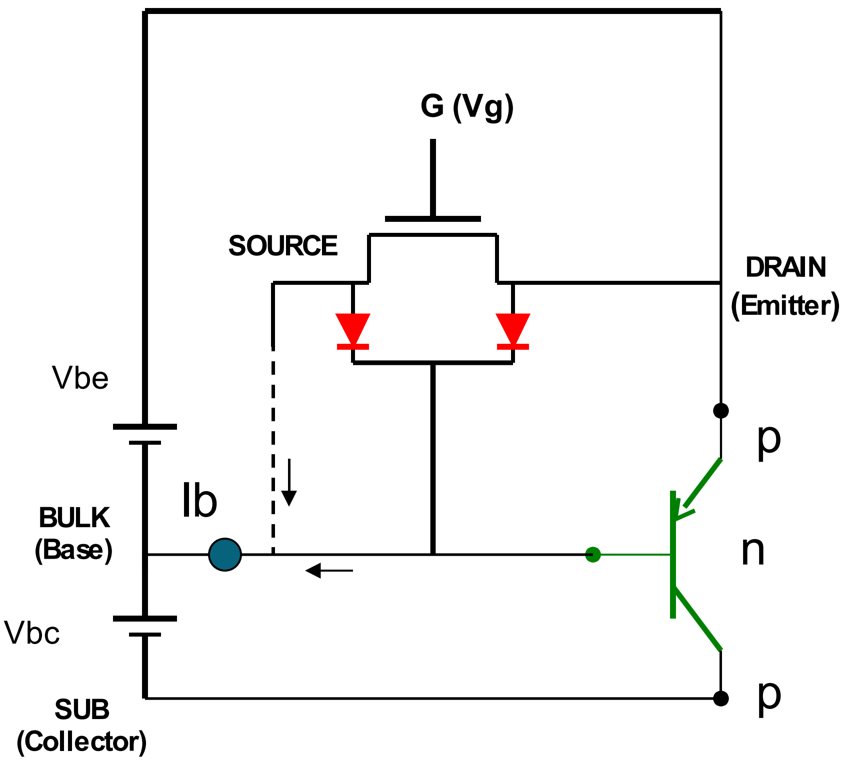
Outline

- Measurement configuration for parasitic PNP
  - Cross-section of HV PMOS device
  - Understanding of parasitic bipolar
  - Measurement results
- Analysis for high current gain
  - Current gain for different devices
  - High current gain
- Investigation on scalable model
  - Details collector current (Ic) and base current (Ib) scaling over width and length
  - Propose scaling equation
- Modeling of reverse operation
  - Reverse current gain < 1
  - Sub-circuit model for reverse operation
- Summary

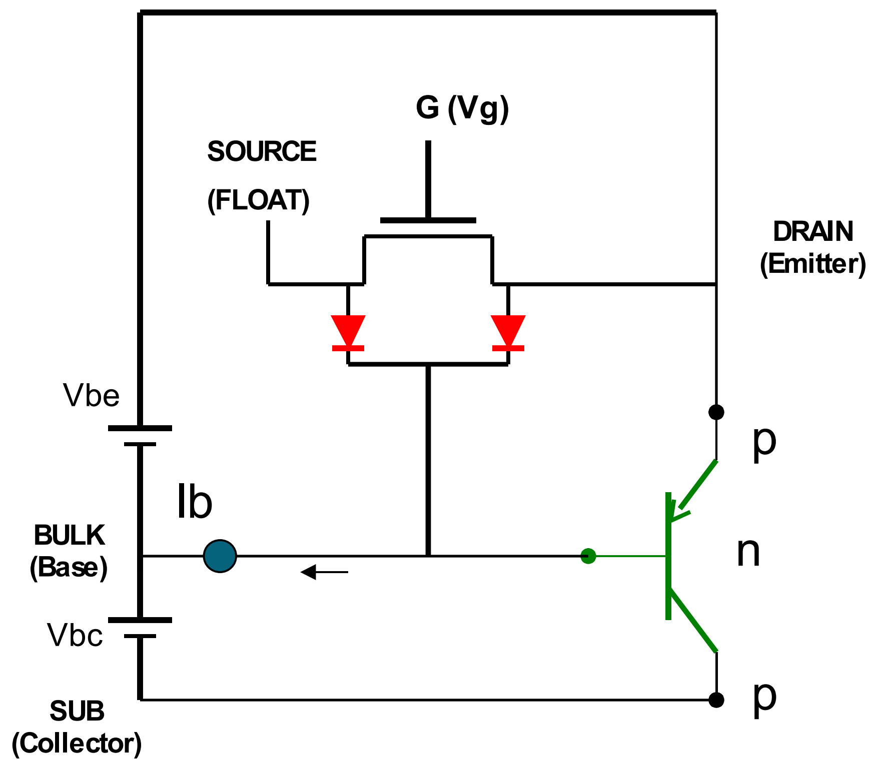
Understanding of Parasitic PNP



Measurement Conditions

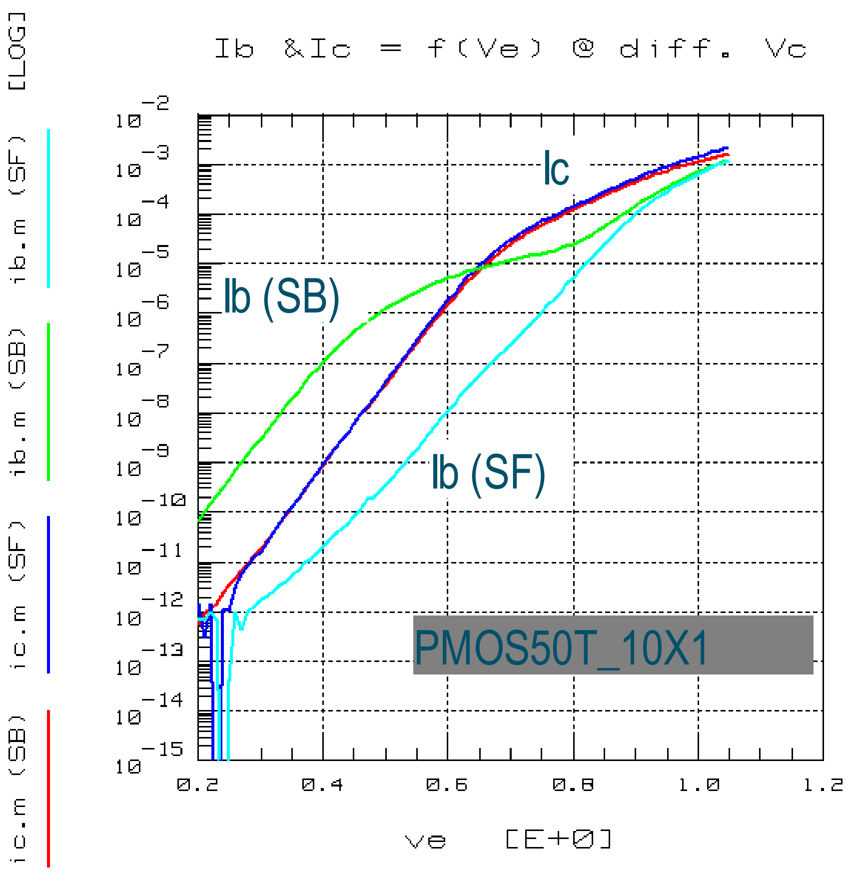


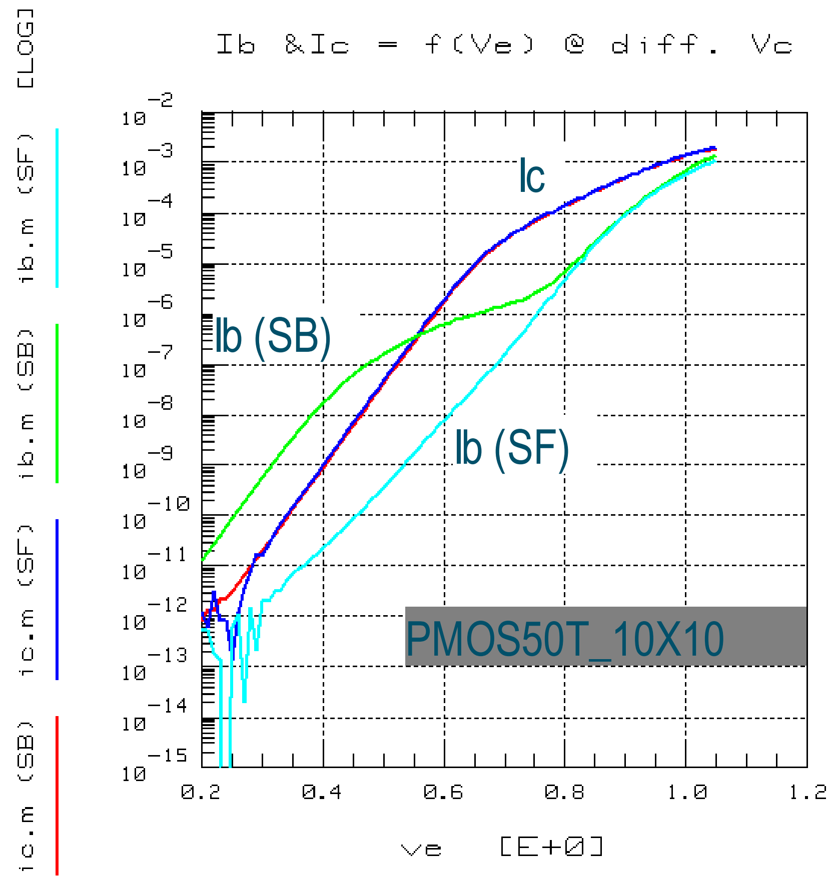
Source is connected with Bulk (SB)



Source is floating (SF)

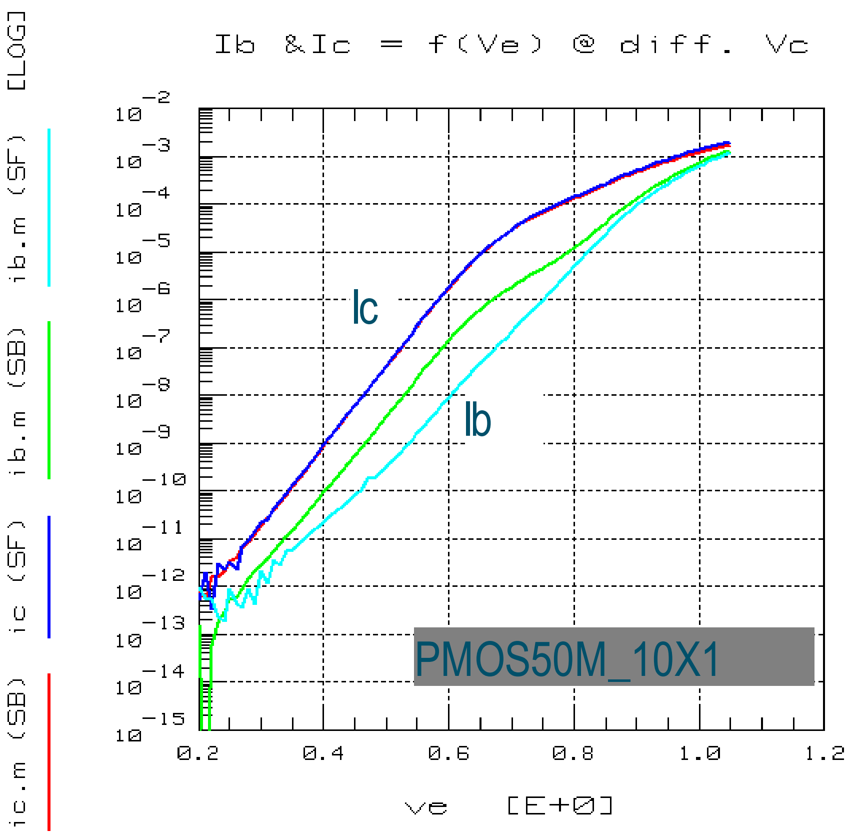
Measurement of PMOS50T (TOX = 7.5 nm)

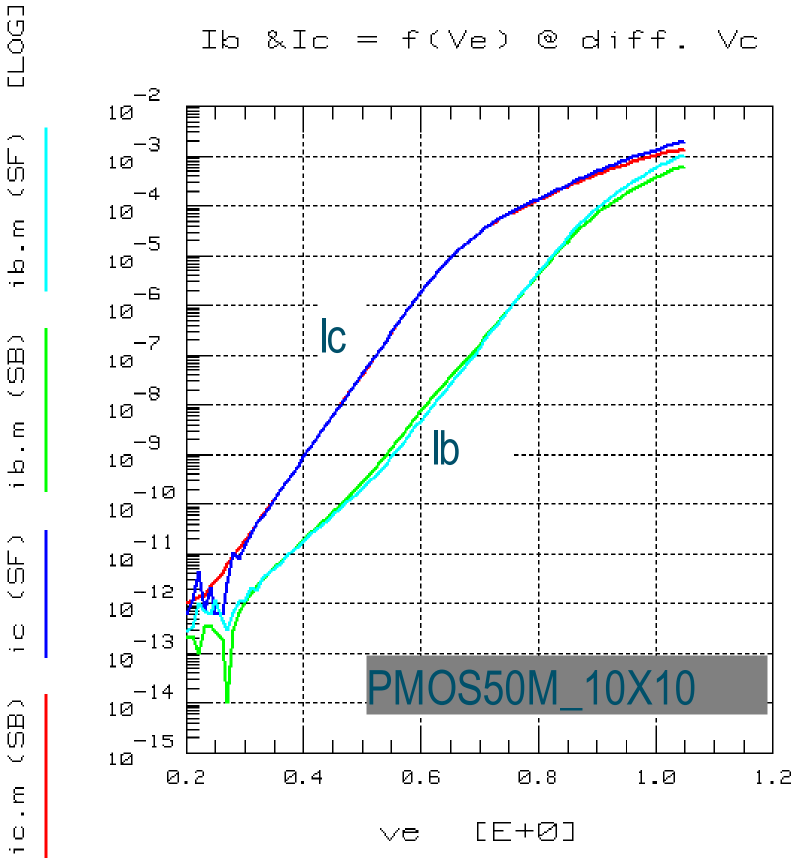




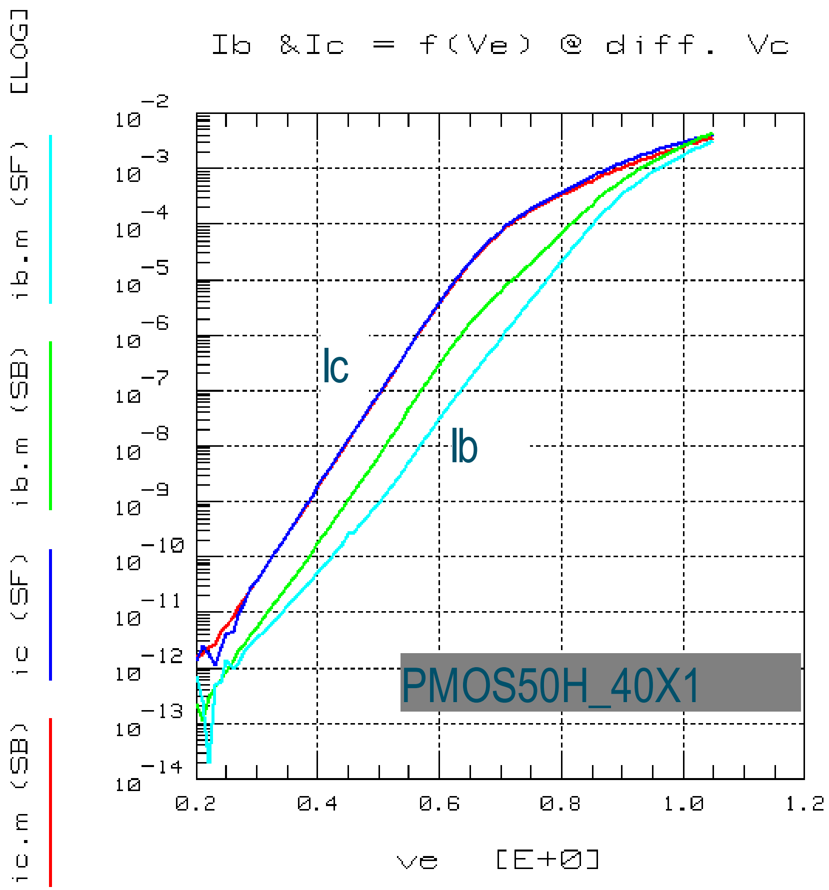
- **Collector current has nearly same value for the both conditions**
- **Base current shows very high value for the SB condition due to leakage current from drain to source**

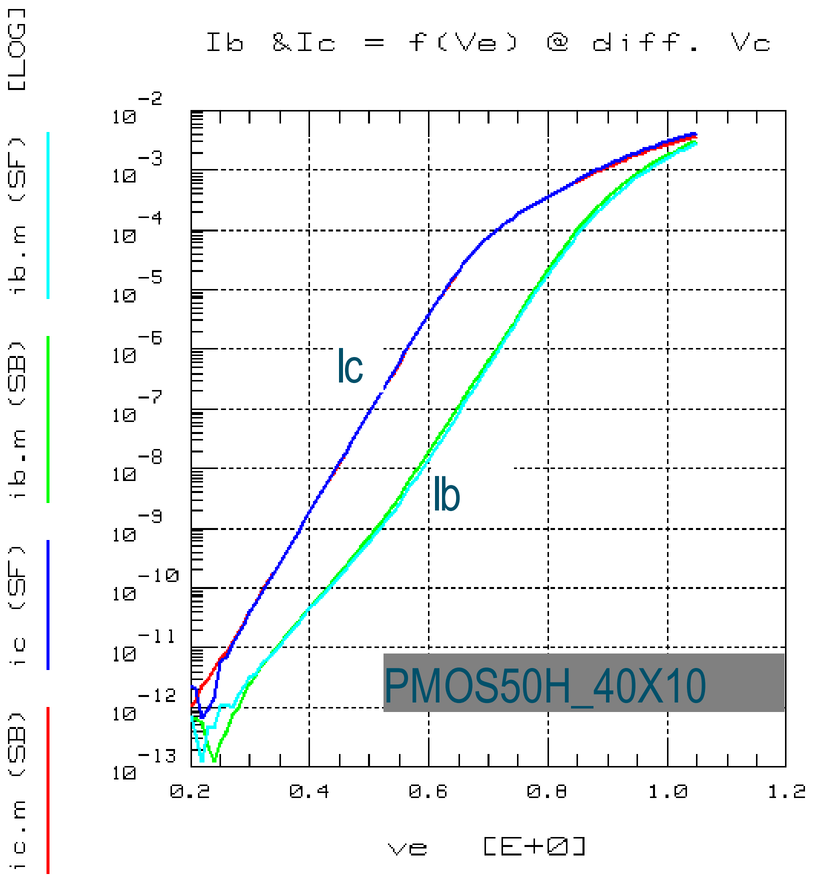
Measurement of PMOS50M (TOX=15nm)





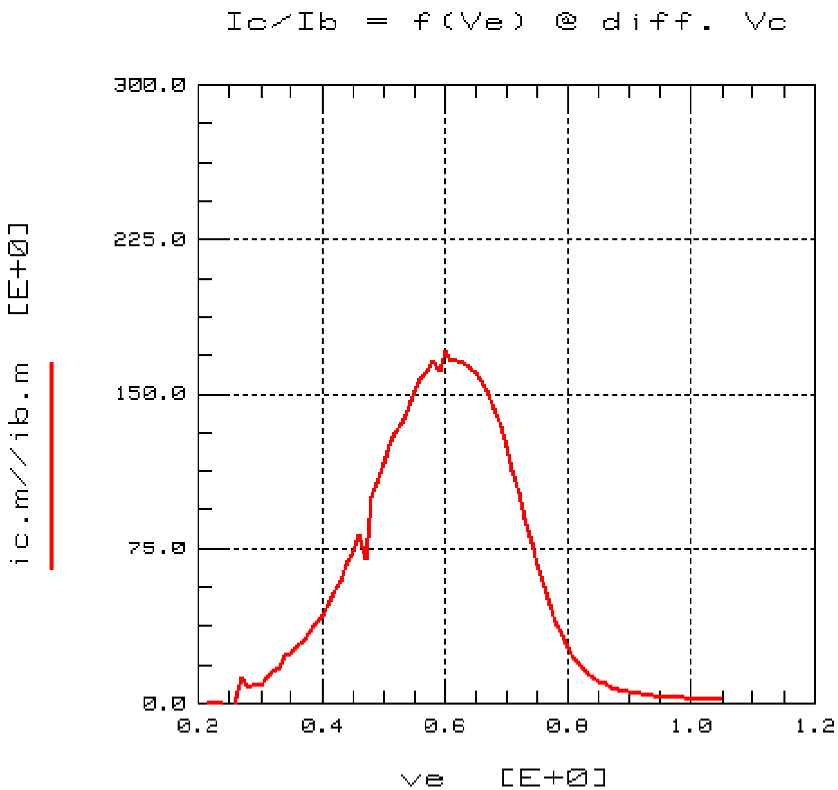
Measurement of PMOS50H (TOX=48 nm)



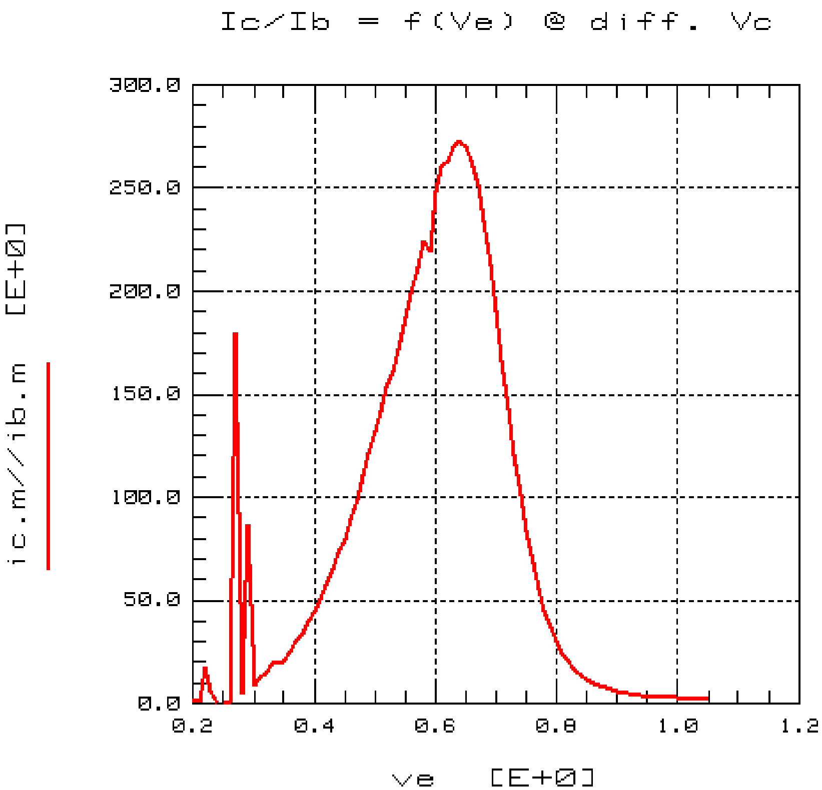


Analysis for high current gain

Current Gain: PMOS50T

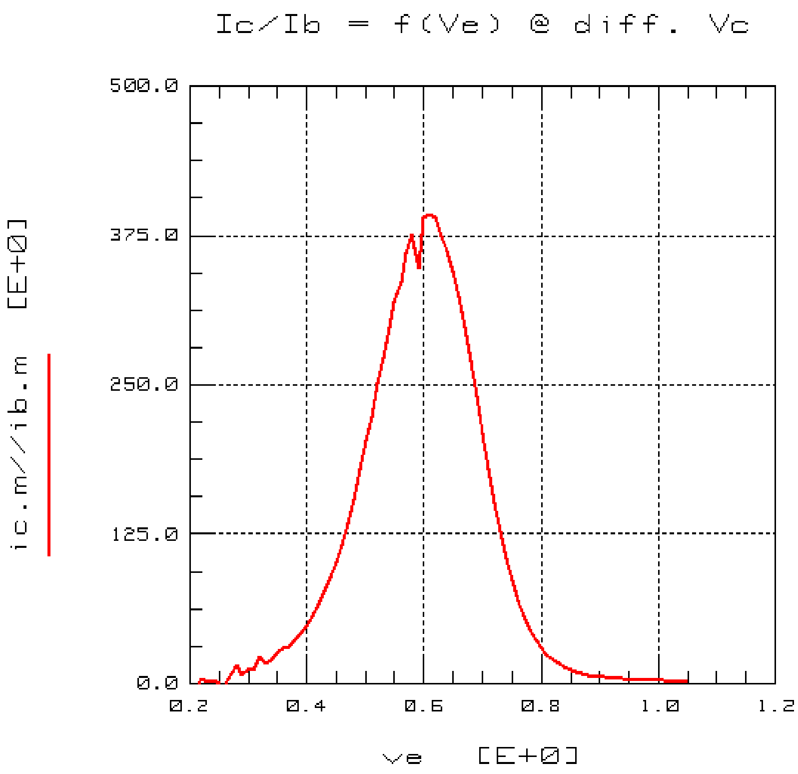


PMOS50T_10X1

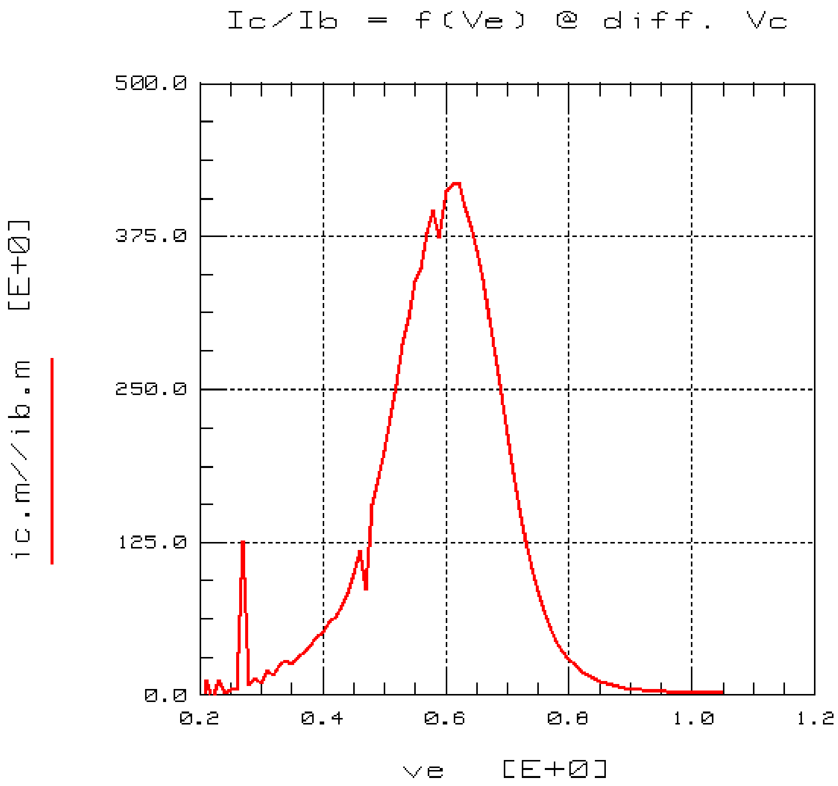


PMOS50T_10X10

Current Gain: PMOS50M and PMOS50H

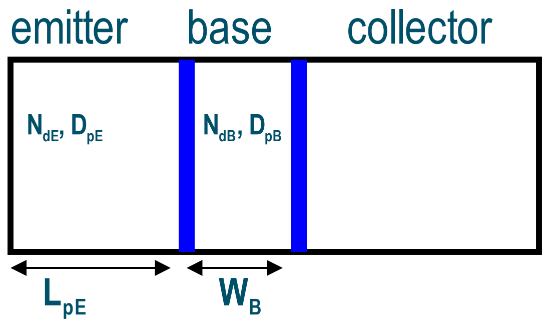


PMOS50M_10X10



PMOS50H_10X10

Bipolar Gain

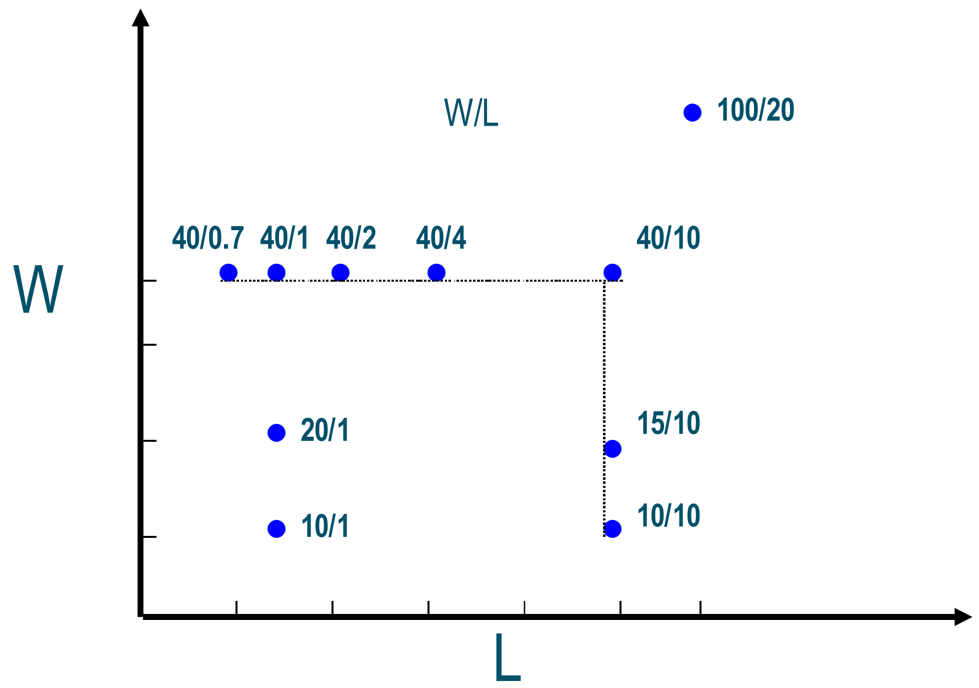


$$\beta_{max} = \frac{N_{dE} * D_{nB} * L_{pE}}{N_{aB} * D_{pE} * W_B}$$

- Y-direction cross-section shows very thin base thickness
- Due to thin base, PNP shows very high current gain (βmax ~ 400)

Investigation on scalable model

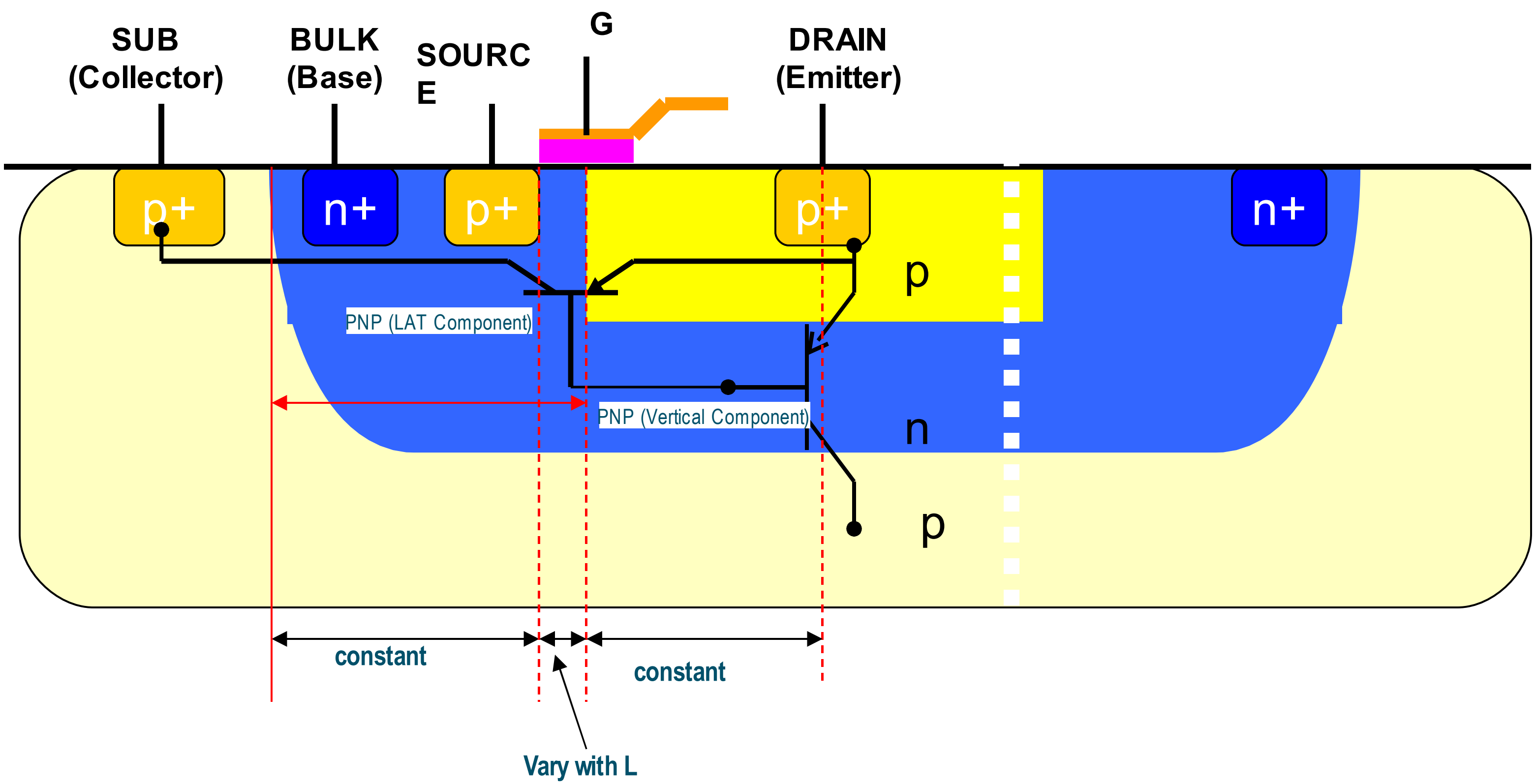
Geometry of 50V PMOSM



- Different geometries are available for the measurement

Scaling of Parasitic PNP

• PNP (both Vertical component and Lateral component) are scaled with W

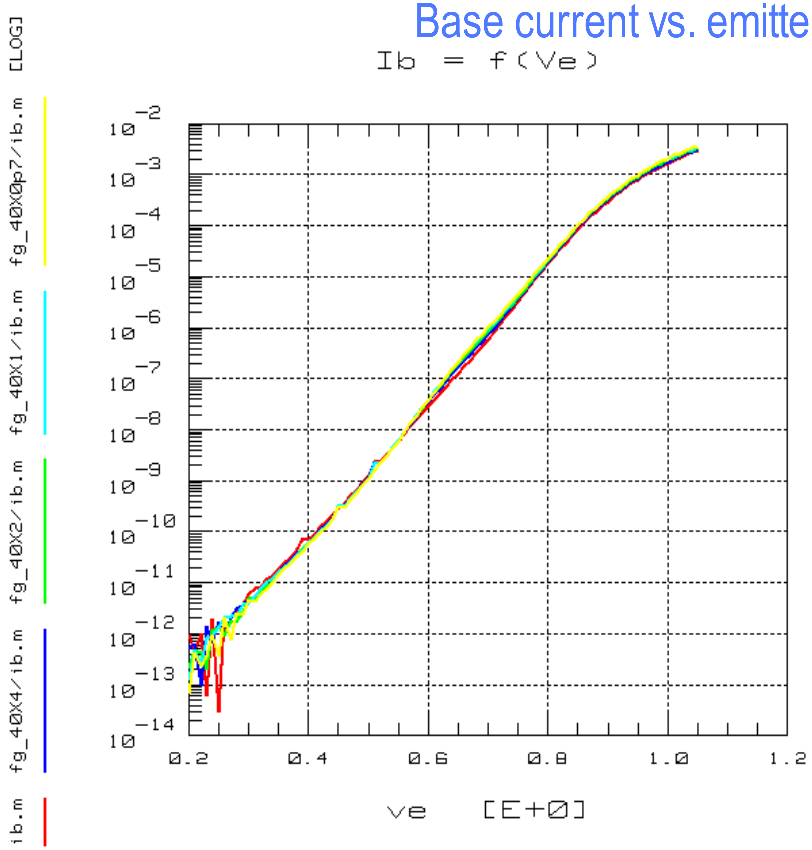


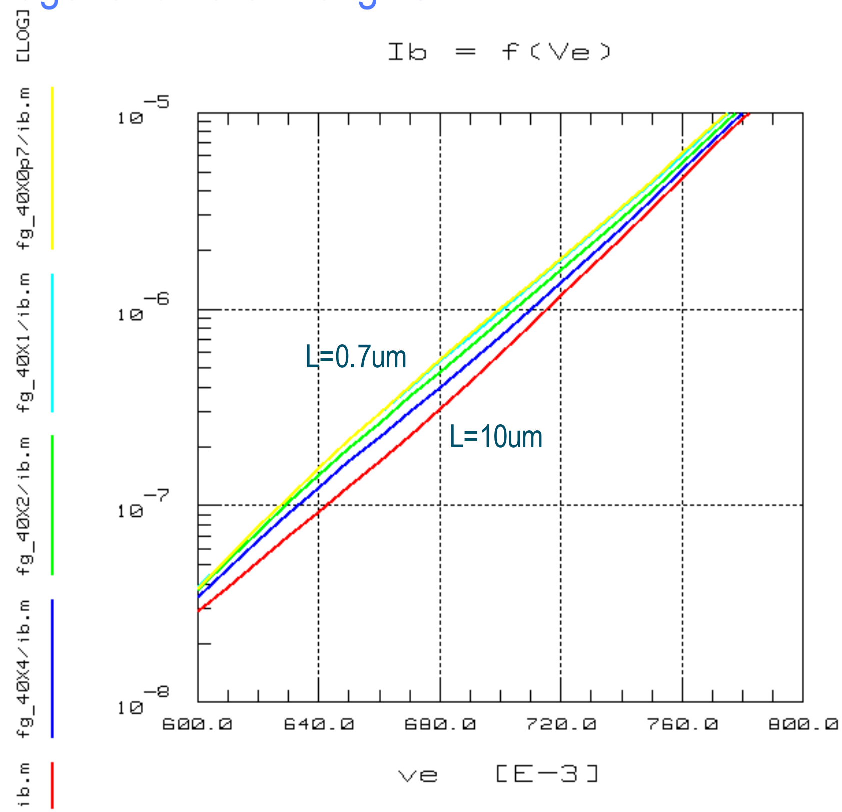
• PNP (Vertical component) does not vary with L

• PNP (Lateral component) base width vary with L

Length Scaling of PMOS50T (Ib)

Base current vs. emitter voltage for different lengths



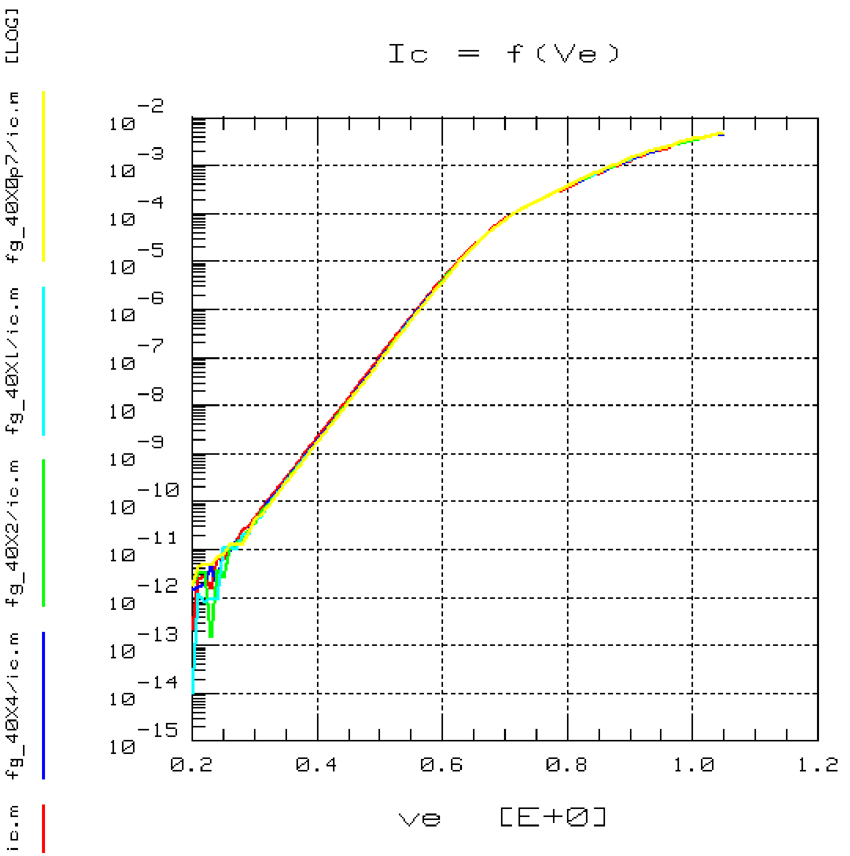


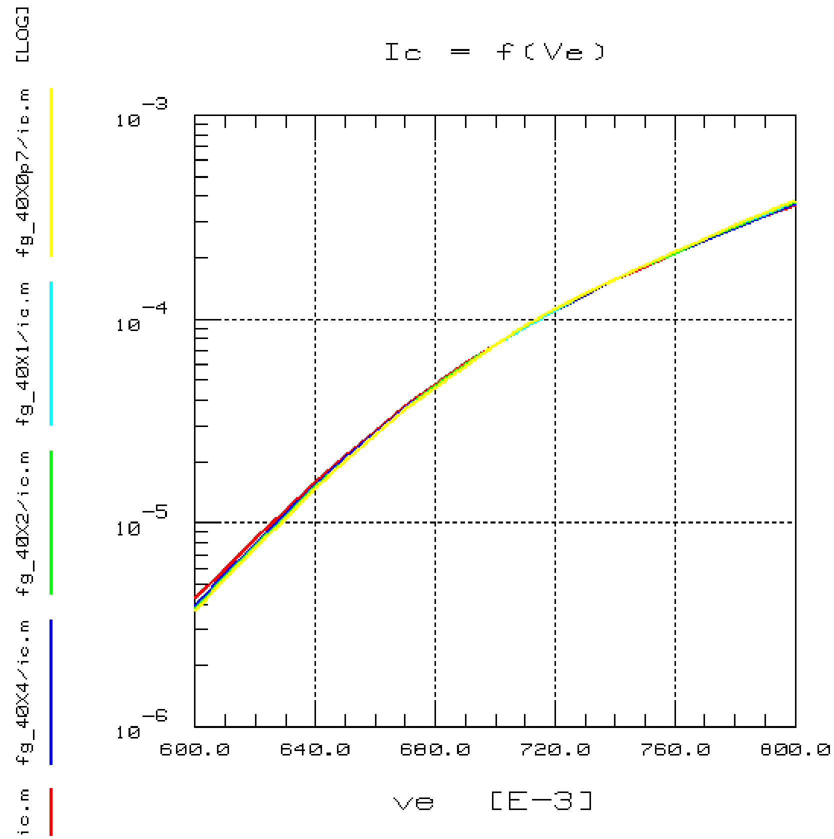
L= 10, 4, 2, 1, 0.7 um; W = 40 um

- As the L decreases base current increases, due to surface leakage current from drain to bulk

Length Scaling of PMOS50T (Ic)

Collector current vs. emitter voltage for different lengths



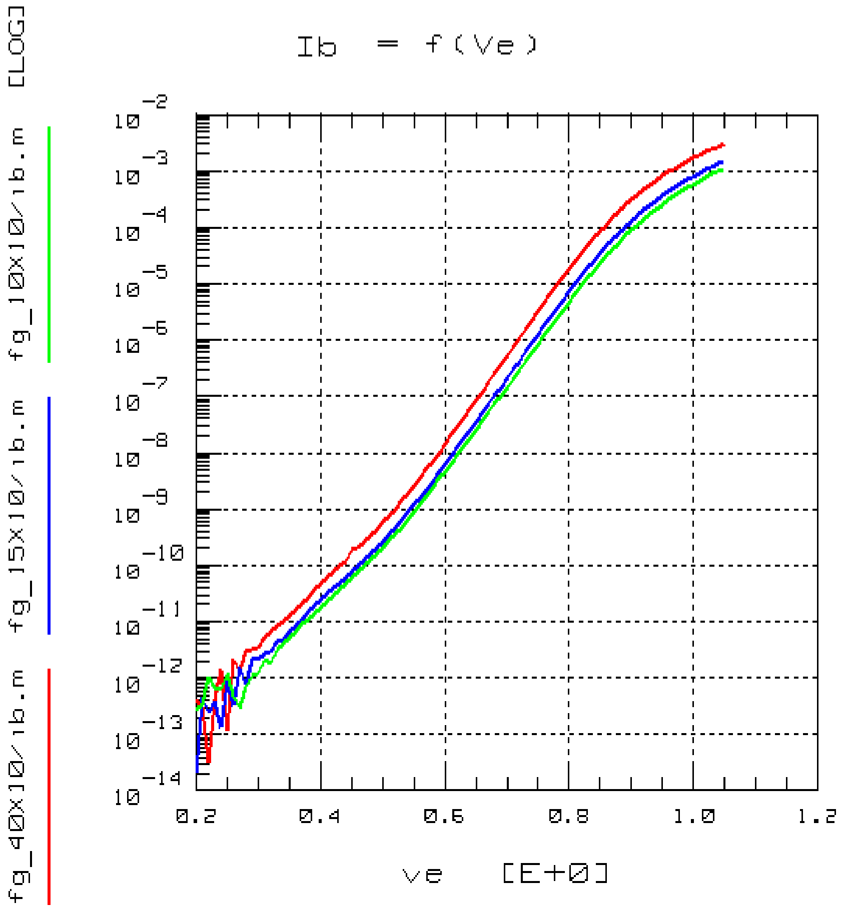


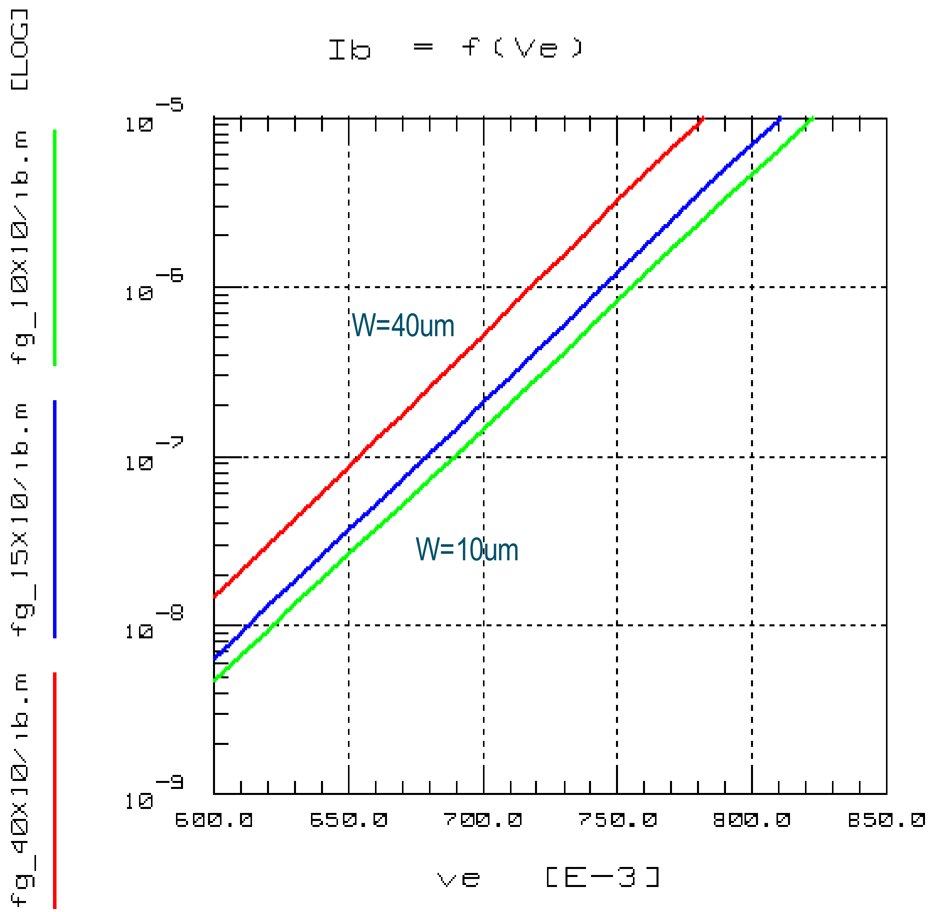
L= 10, 4, 2, 1, 0.7 um; W = 40 um

- No significant change on the collector current over L

Width Scaling of PMOS50T (Ib)

Base current vs. emitter voltage for different lengths



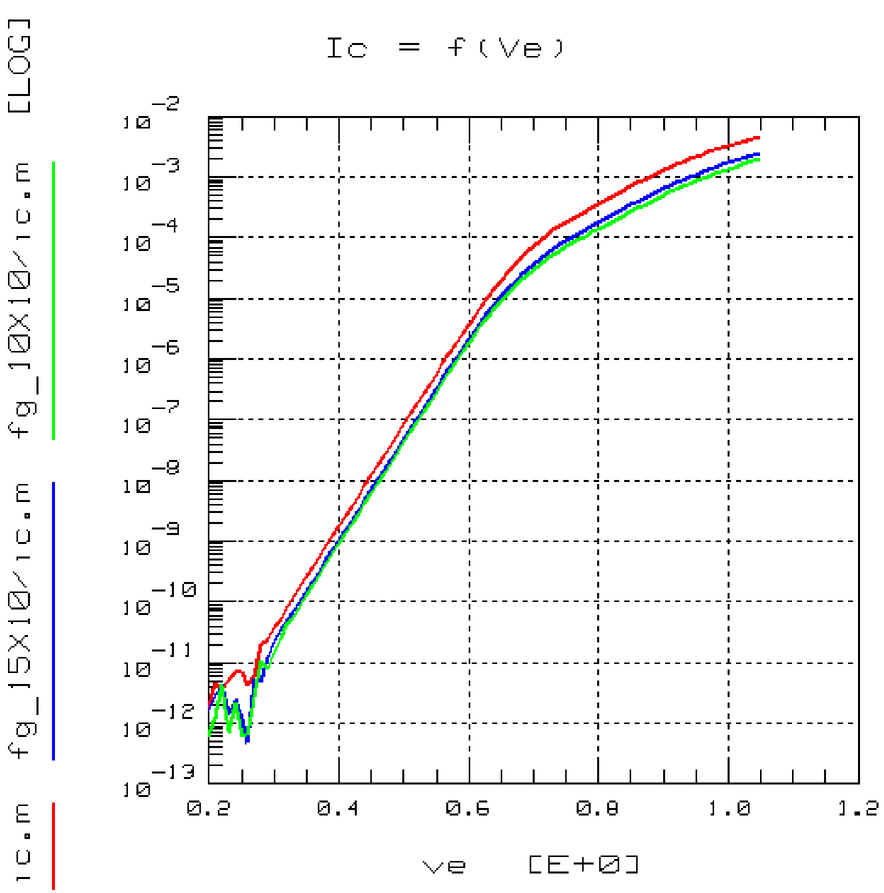


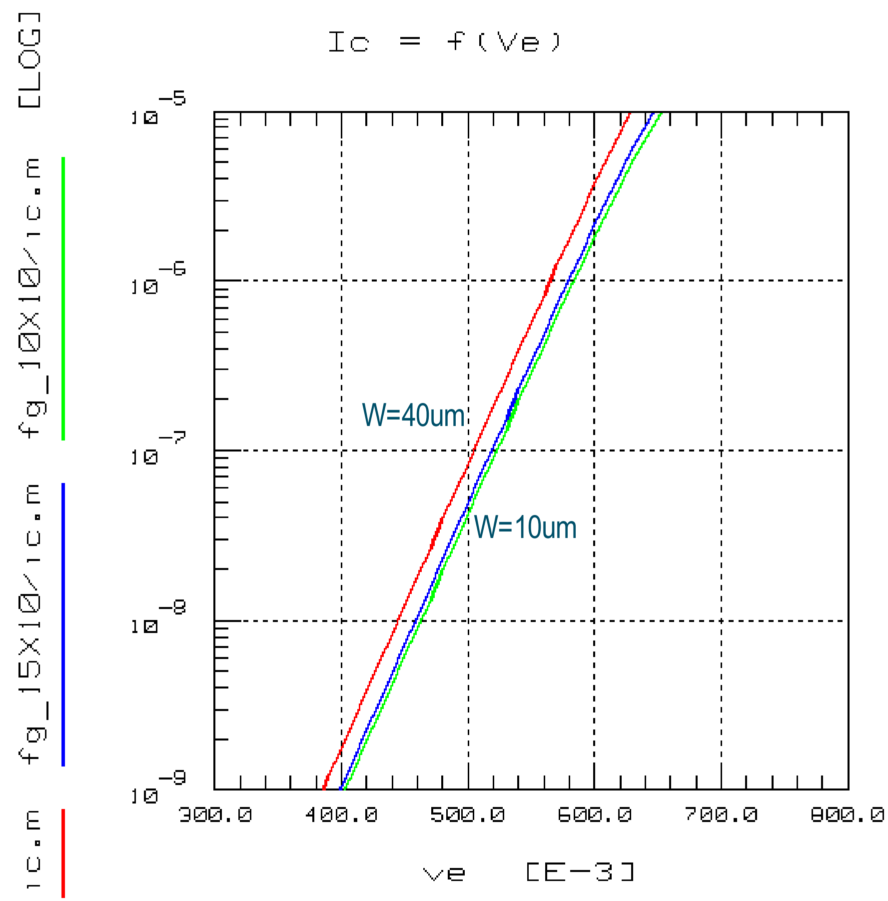
L= 10um; W = 40, 15, 10 um

austriamicrosystems

Width Scaling of PMOS50T (Ic)

Collector current vs. emitter voltage for different lengths





L= 10um; W = 40, 15, 10 um

Scaling Equation for Model Parameters

- Standard SPICE Gummel-Poon model is used for the parasitic PNP

- Parameters scaling apply with *W and L separately:*

  parSCALE = parWSCALE + parLSCALE

- Width scaling (*parWSCALE)* equation is used after fitting of each parameter with

  equation

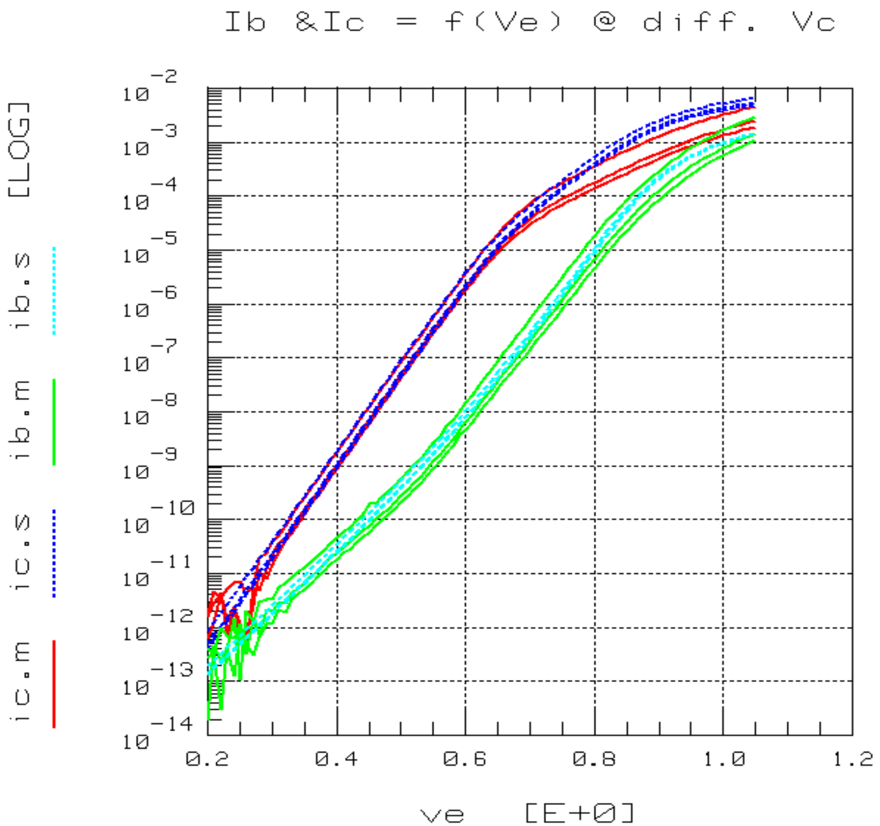
$$parWSCALE = \exp\left[parw0 + \frac{parw}{W + wpar0} \right]$$

- Length scaling (*parLSCALE)* equation is used after fitting of each parameter with

  equation

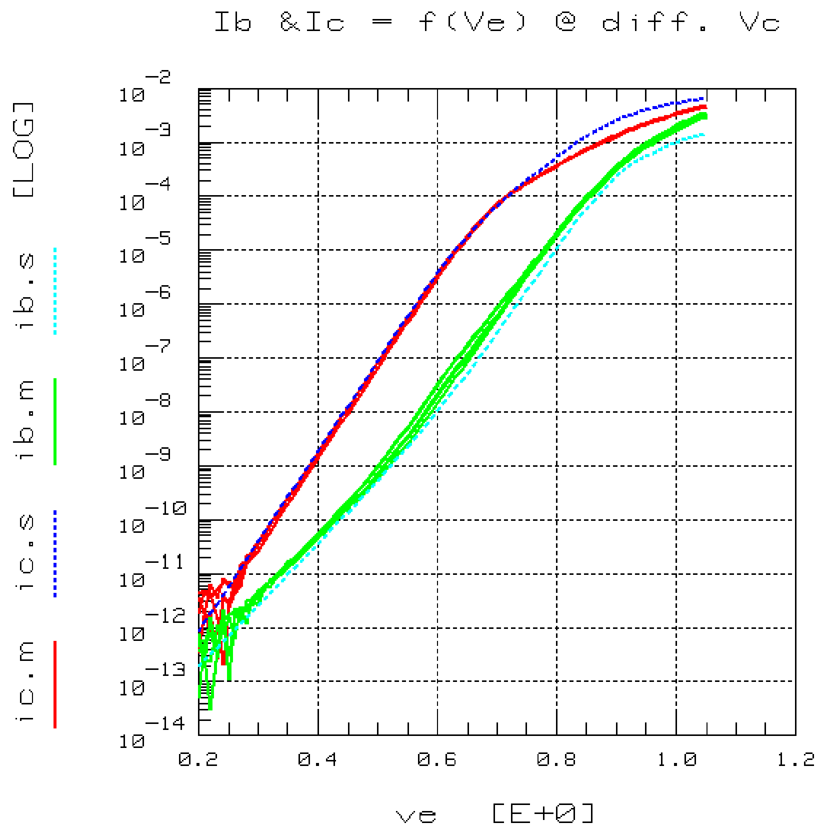
$$parLSCALE = parl0 * L$$

Scalable Model Results: Gummel Plot



Width Scaling

L= 10um; W = 40, 15, 10 um



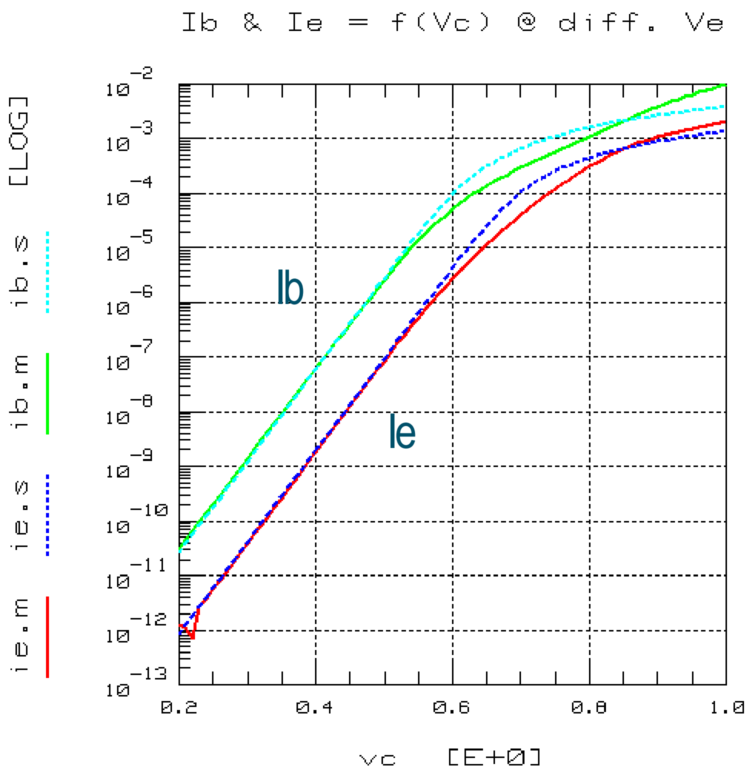
Length Scaling

L= 10, 4, 2, 1, 0.7 um; W = 40 um

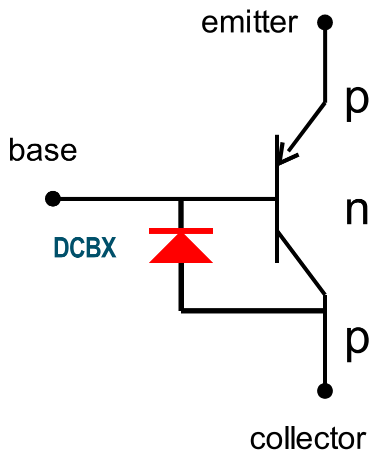
Modeling of Reverse Operation

Reverse Gummel Model

- Reverse current gain shows <1
- After adjusting reverse current gain parameter (BR), it is possible to model reverse Gummel (RG), but impossible to model reverse output (RO)
- For simultaneously fitting both the RG and RO, need to an extra diode between collector and base



Sub-Circuits for modeling surface current



- Due to large area of substrate ring, large current flowing through the surface
- So need extra diode (DCBX) to model the surface current

Summary

- Source floating conditions shows more accurate way to measure the parasitic PNP
- Due to thin base width, PNP shows very high current gain
- Scalable model is now sufficient for all geometries (W and L)
- Reverse mode operation can be modeled with extra diode