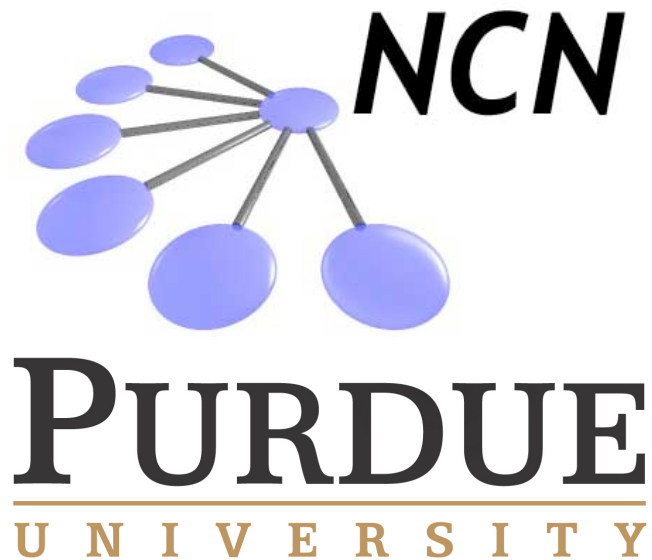


Network for Computational Nanotechnology (NCN)

UC Berkeley, Univ. of Illinois, Norfolk State, Northwestern, Purdue, UTEP

First-Time User Guide BJT Lab V2.0



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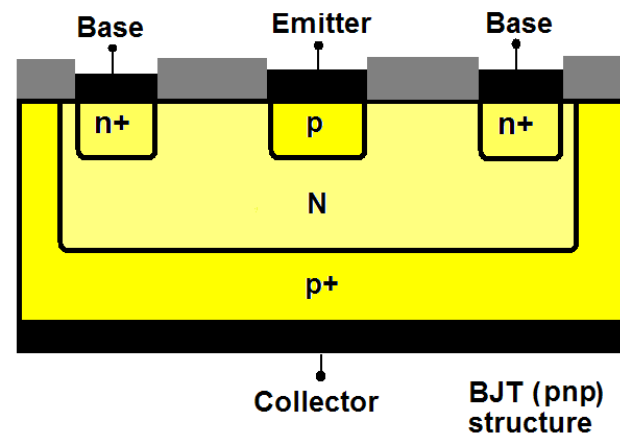
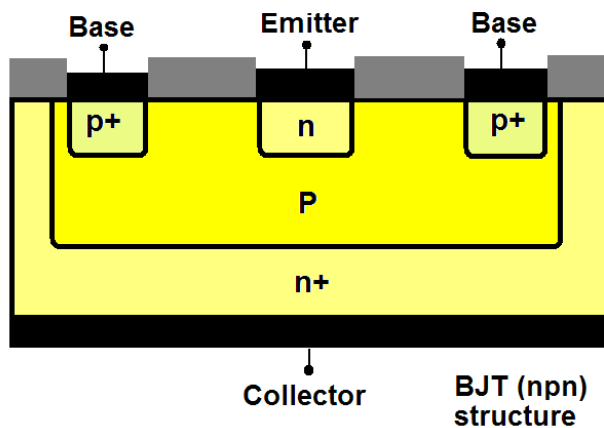
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Introduction: What is a BJT?

- Bipolar Junction Transistor (BJT): Three-terminal device used for amplifying or switching

BJT can be *npn* or *pnp* depending on doping.

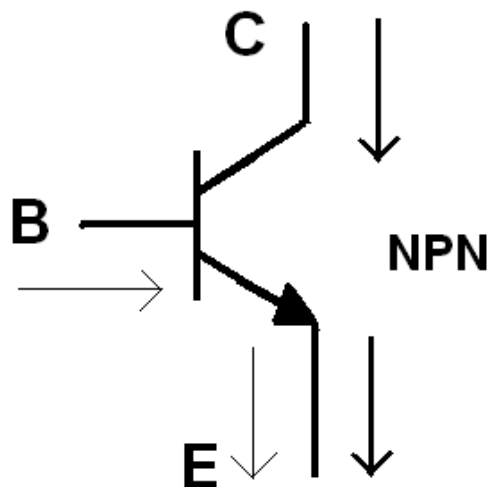


n/N/n+ : donor impurities

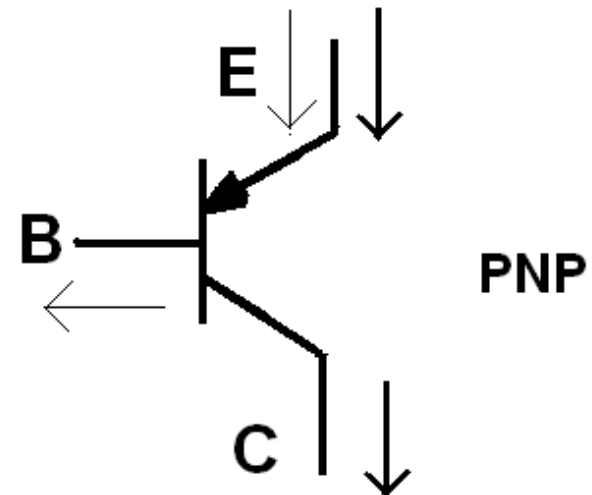
p/P/p+ : acceptor impurities

Introduction: Working of a BJT

- Functioning of BJT: current controlled current regulators
- Base current: controlling current
- Emitter-collector current: controlled current



— small controlling current
 = large controlled current



— small controlling current
 = large controlled current

Refer to [1] <https://nanohub.org/resources/5084/> for detailed information about the operation of BJT.

What Can Be Simulated in BJT Lab?

Structure type: npn

Operation mode: Common emitter

Emitter region length, Y1 (um): 0.05um

Base Region length, Y2 (um): 0.1um

Collector region length, Y3 (um): 1um

Emitter region width, X1 (um): 1um

Base region width, X2 (um): 1um

Emitter contact width, C1 (um): 0.8um

Base contact width, C2 (um): 0.6um

Simulate >

Emitter **Base**

X1(um) X2(um)

C1(um) C2(um)

Y1(um)

Y2(um)

Y3(um)

Collector

n+ P n-

Different structure and operation modes of BJT

Simulate *npn* or *pnp* BJT structure

Simulate BJT in common emitter or common base operation mode

Design the device structure

What Can Be Simulated in a BJT Lab?

Structure | Materials | Gummel Plot | Output Characteristics

Select the material for BJT operation: Si

Emitter region doping (n/p):

Base region doping (P/N):

Collector region doping (n+/p+):

Minority carrier lifetimes

For electrons:

For holes:

Simulate >

Material parameters for BJT simulation

Specify material and minority carrier lifetimes

Specify doping level for Emitter, Collector, and Base regions

What Can Be Simulated in BJT Lab?

Structure | Materials | Gummel Plot | Output Characteristics

Applied Collector Voltage, Vc (for Gummel Plot): $-1^{\text{E}} 3.5\text{V}$

Applied Emitter Voltage start value, Veb: $-1^{\text{E}} 0\text{V}$

Applied Emitter Voltage end value, Veb: $-1^{\text{E}} 1\text{V}$

Applied Base Voltage start value, Vbe: $-1^{\text{E}} 0\text{V}$

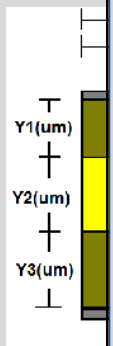
Applied Base Voltage end value, Vbe: $-1^{\text{E}} 1\text{V}$

Number of data points: 12

Output Plots from BJT Lab

Gummel plot input deck

- Gummel plot is useful in extracting beta, β parameter for a BJT device



Structure | Materials | Gummel Plot | Output Characteristics

Injection Current at Emitter electrode start value, Ie: $-1^{\text{E}} 1\text{e-}06\text{A}$

Injection Current at Emitter electrode end value, Ie: $-1^{\text{E}} 4\text{e-}06\text{A}$

Injection current at Base electrode start value, Ib: $-1^{\text{E}} 1\text{e-}06\text{A}$

Injection current at Base electrode end value, Ib: $-1^{\text{E}} 4\text{e-}06\text{A}$

Number of output Ic-Vce curves: 6

Applied Collector Voltage from 0V to ,Vce: $-1^{\text{E}} 3.5\text{V}$

Position along x to plot 1D data: **0.5um**

X1(um) X2(um)
C1(um) C2(um)

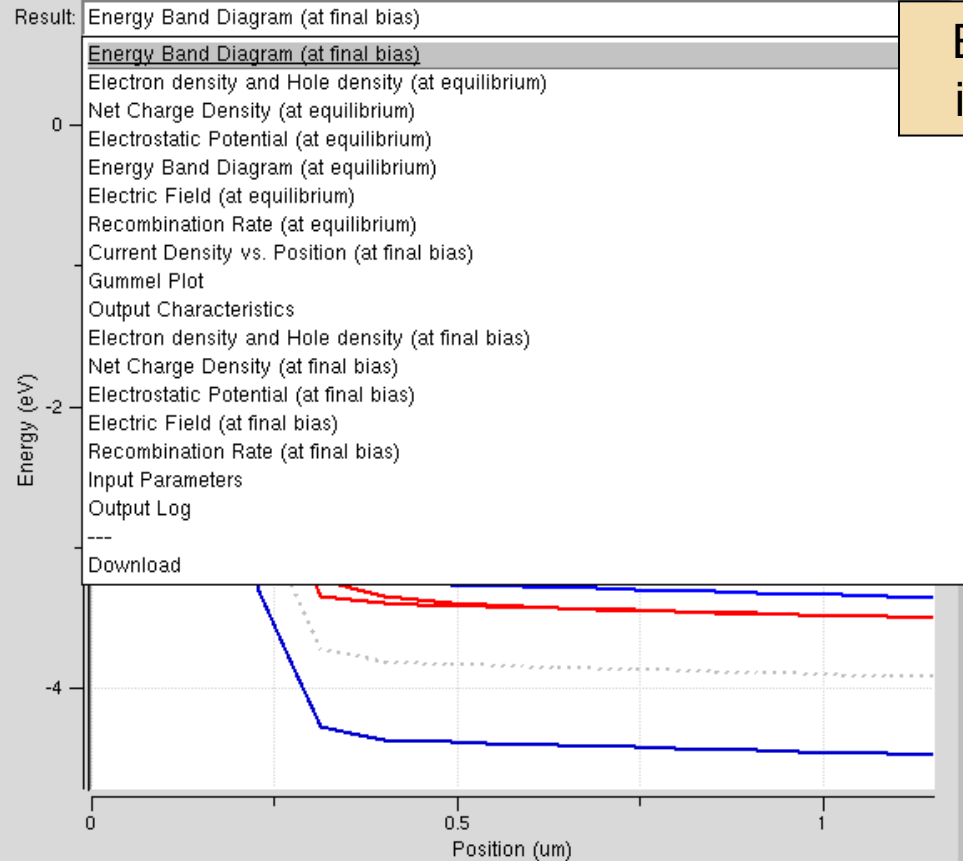
Emitter Base
n+ P n-
Y1(um) Y2(um) Y3(um)
Collector

Output Characteristics

- Useful in determining output resistance, early voltage, etc.

Set position for 1D plot less than X1 to view Emitter profile!

What If You Just Hit “Simulate”?



BJT Lab simulates the default input deck

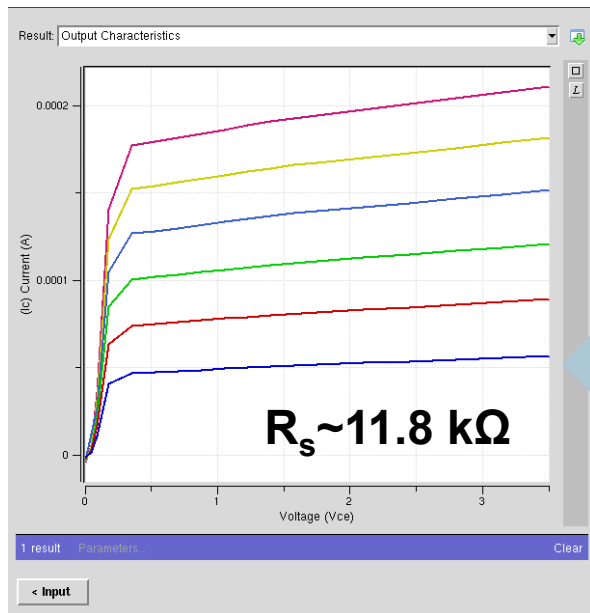
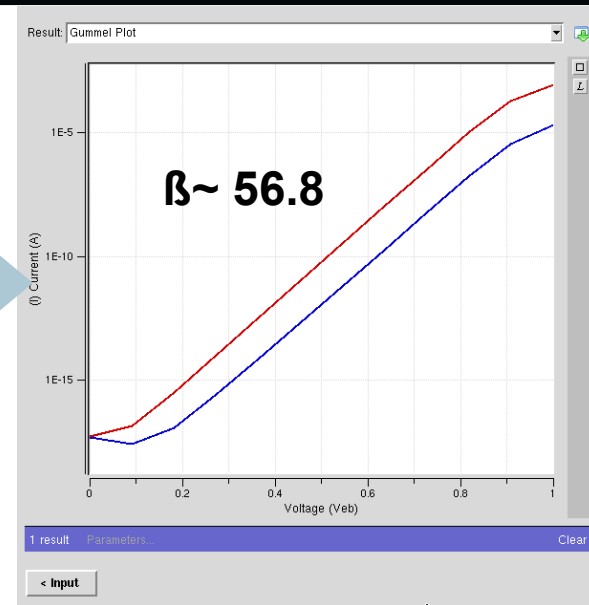
Default device:
NPN type BJT in common emitter mode

	Emitter	Base	Collector
Length (μm)	0.05	0.1	1.0
Doping (/cm ³)	1x10 ¹⁹	1x10 ¹⁸	1x10 ¹⁷

What If You Just Hit “Simulate”?

Gummel Plot

- $I_{\text{collector}}$ and I_{base} vs. V_{eb} .
- Users can extract the beta or h_{fe} parameter $\beta = I_{\text{collector}} / I_{\text{base}}$.



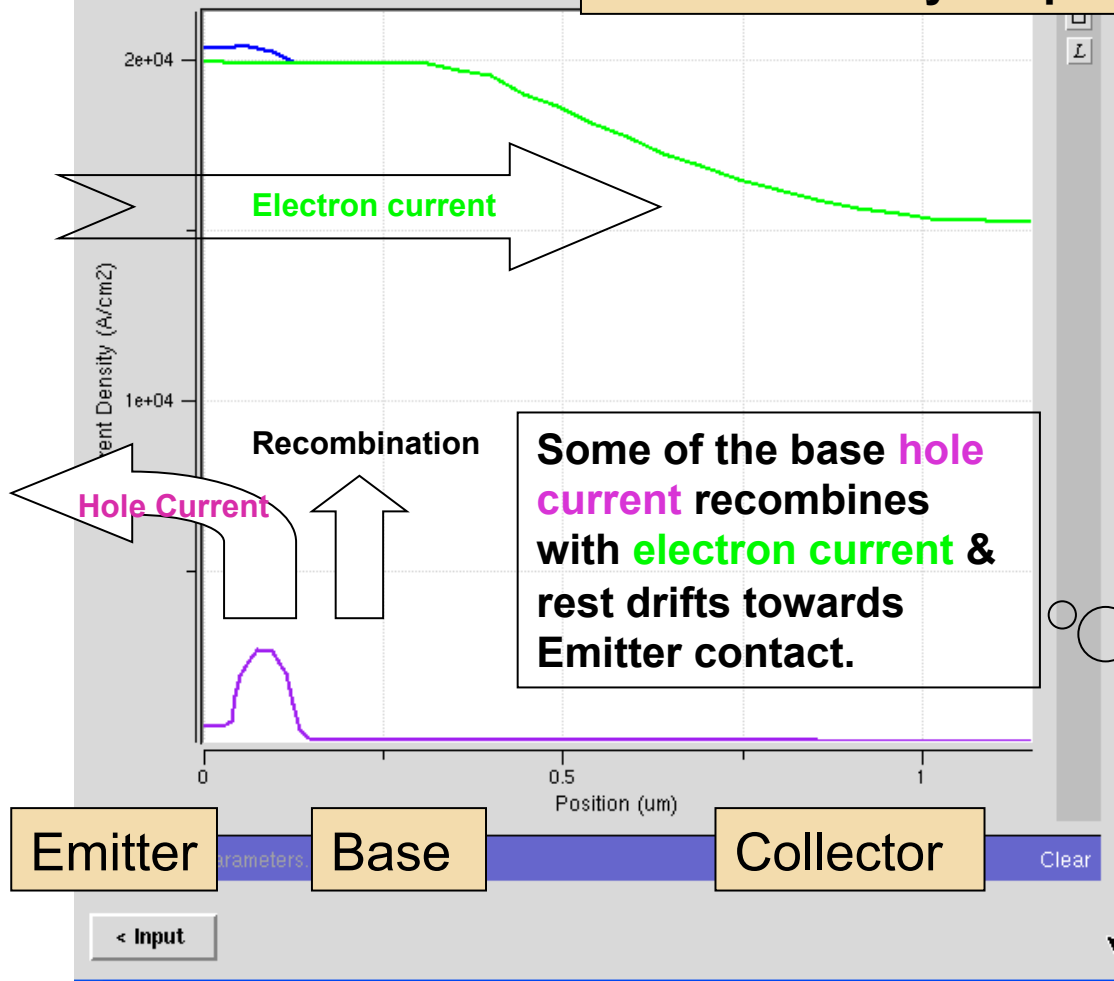
Output Characteristics ($I_{\text{collector}}$ Vs $V_{\text{collector-emitter}}$)

- The relatively flat region is the active region.
- The slope of I_c vs. V_{ce} is output (or collector) resistance, R_s .

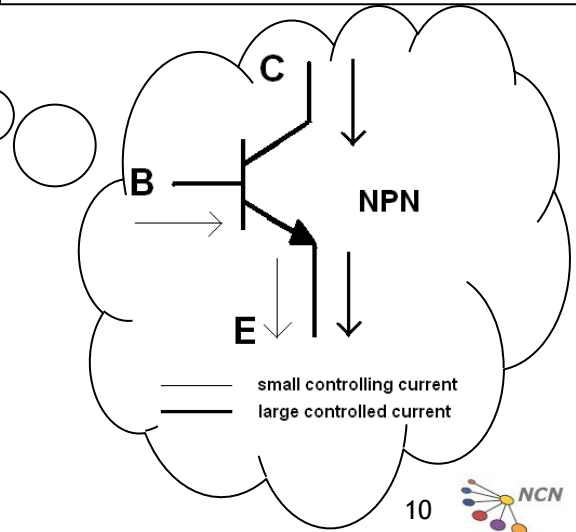
What If You Just Hit "Simulate"?

Result: Current Density vs. Position (at final bias)

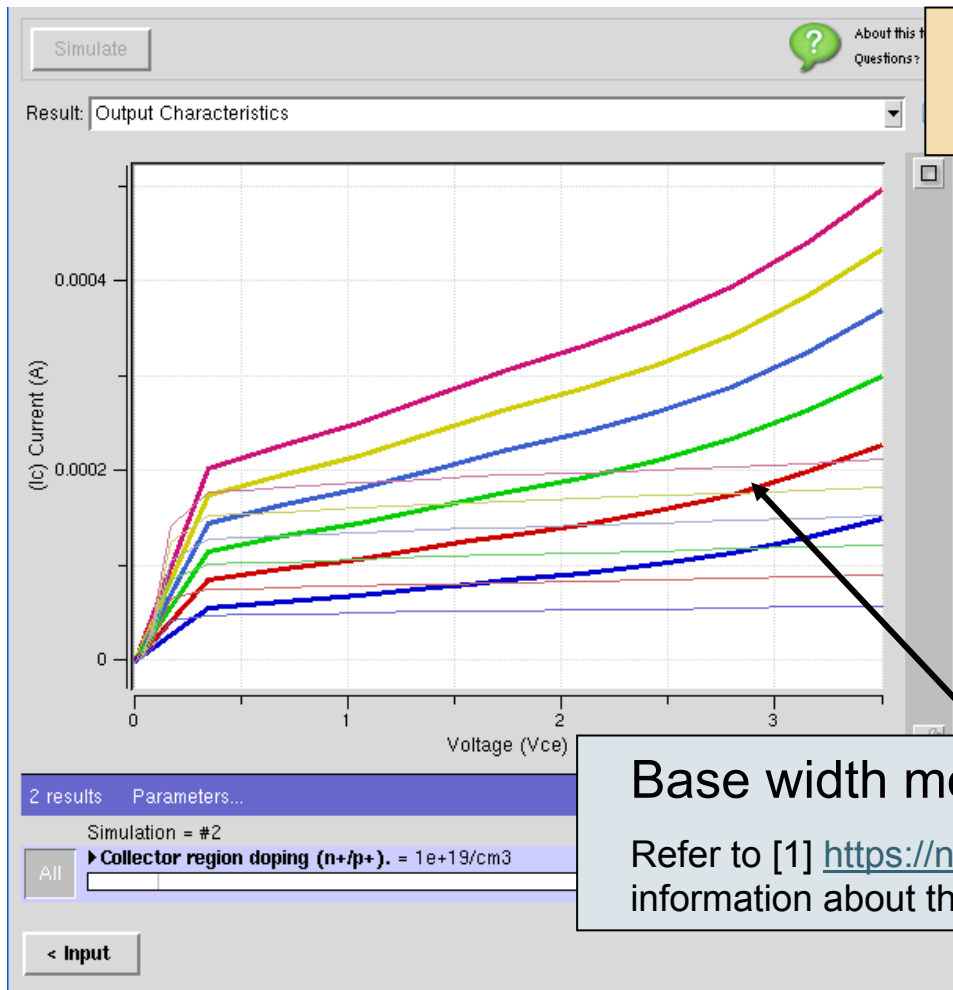
Current density vs. position 1D plot



- Emitter: $x=0-0.05\mu\text{m}$
- Base: $x=0.05-0.15\mu\text{m}$
- Collector: $x=0.15-1.15\mu\text{m}$
- Reduction in current density due to flaring out of collector current into larger region



Examples: What if the Collector Doping is Changed?



Changing collector doping to $1e19 / \text{cm}^3$

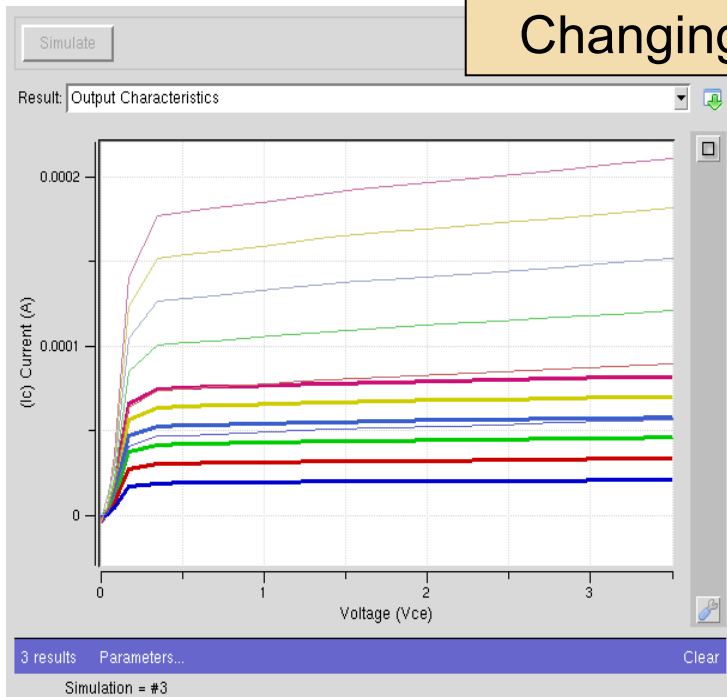
	Emitter	Base	Collector
Length (μm)	0.05	0.1	1.0
Doping ($/\text{cm}^3$)	1×10^{19}	1×10^{18}	1×10^{19}

Base width modulation or early effect

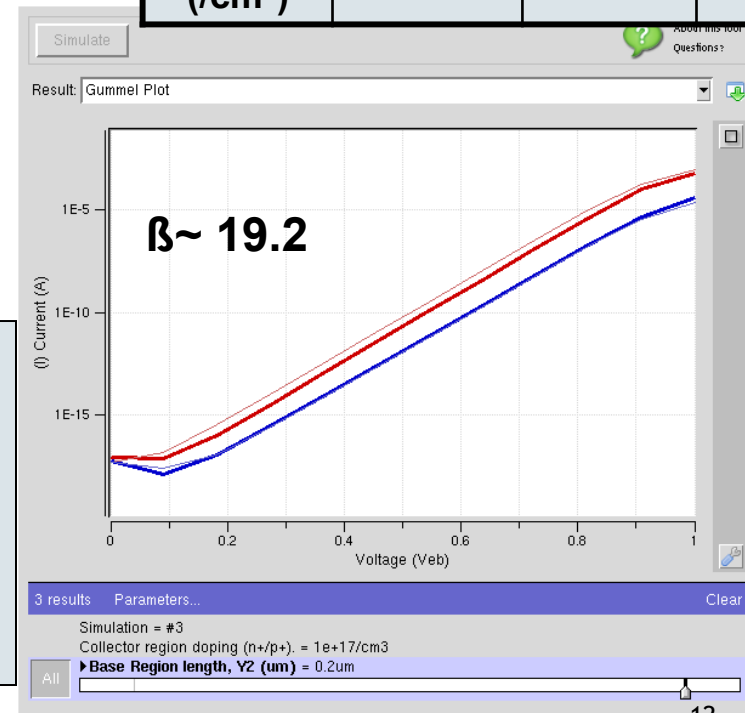
Refer to [1] <https://nanohub.org/resources/5084/> for detailed information about the operation of BJT.

Examples: What if the Base Width is Changed?

Changing base width to 0.2 μm



	Emitter	Base	Collector
Length (μm)	0.05	0.2	1.0
Doping ($/\text{cm}^3$)	1×10^{19}	1×10^{18}	1×10^{17}



Increasing base width leads to smaller current gain factor

Refer to [1]

<https://nanohub.org/resources/5084/> for detailed information about the operation of BJT.

Tool Limitations and Comments

- Large physical dimensions ($>10 \mu\text{m}$) might lead to non convergence or large compute time.
- Take note that while plotting the 1D plot, the distance needs to be smaller than X1 (defined in Structure tab) to view the emitter region profile.
- Take note of the applied voltage values signs, while working with npn and pnp type.

References

BJT Theory

- [1] BJT OPERATION : <https://nanohub.org/resources/5084/>
 - [2] "Semiconductor Device Fundamentals," by R.F. Pierret
 - PADRE
 - [3] Dragica Vasileska; Gerhard Klimeck (2006), "Padre," [DOI: 10254/ nanohub-r941.3](https://doi.org/10.254/nanohub-r941.3).
 - [4] PADRE MANUAL : http://nanohub.org/resource_files/tools/padre/doc/index.html
-

If you reference this work in a publication, please cite as follows:

Saumitra Raj Mehrotra; Abhijeet Paul; Gerhard Klimeck; Dragica Vasileska (2008), "BJT Lab," [DOI: 10254/nanohub-r3984.7](https://doi.org/10.254/nanohub-r3984.7).

We welcome comments about this tool, including those about problems using the tool. Please submit via the following link:
<https://nanohub.org/resources/3984/reviews?action=addreview#reviewform>