SiGe spike mono emitter HBT modelling with Hicum

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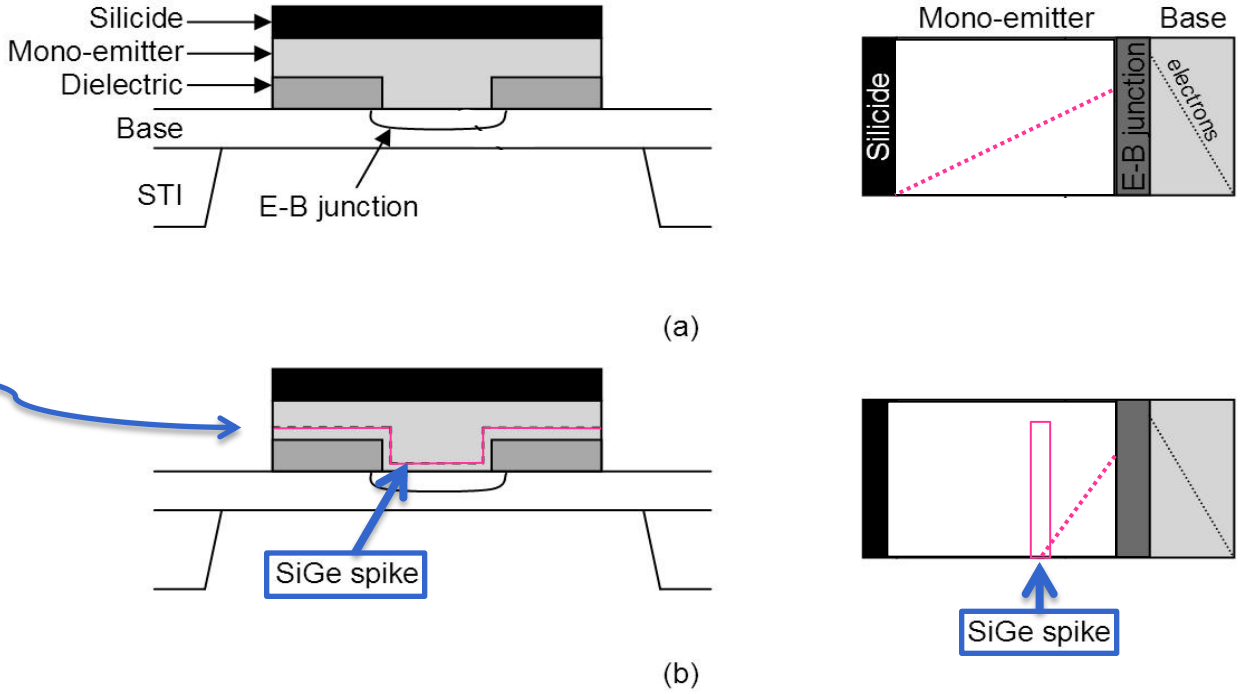
Outline

- **Introduction: SiGe spike emitter**
  - Basic principle
  - structure
- **Device simulation on SiGe spike transistor**
  - Static characteristics
  - Dynamic characteristics
- **Compact modeling results**
  - modeling with HICUML2V24
- **HICUM with an additional base current**
  - Formulation of the model
  - Modeling results
- **Conclusion**

Introduction: SiGe spike emitter

- **Basic principle:**



Inserting SiGe Spike inside mono emitter

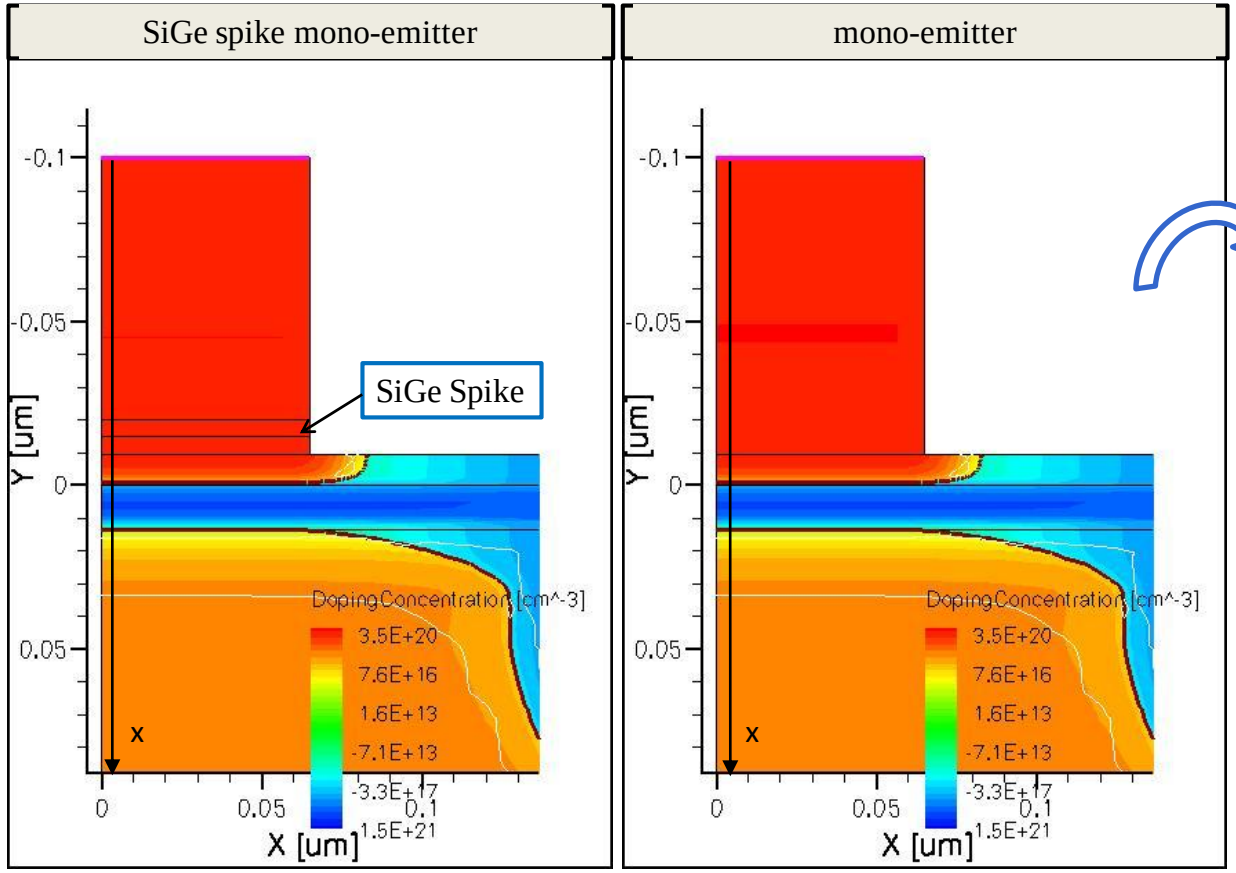
Increases hole recombination

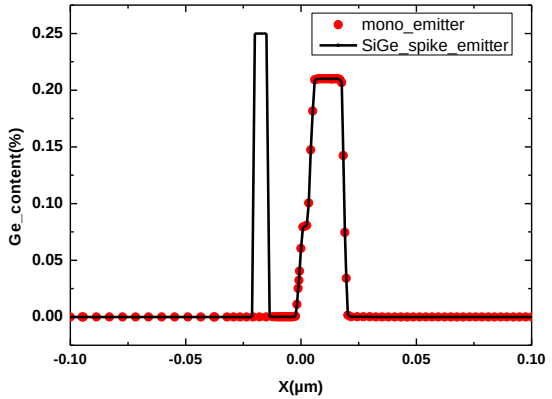
Increases base current

From Choi IEEE EDL 2007

Introduction: SiGe spike emitter

- **SiGe spike emitter is constructed with the help of IMEC device.**



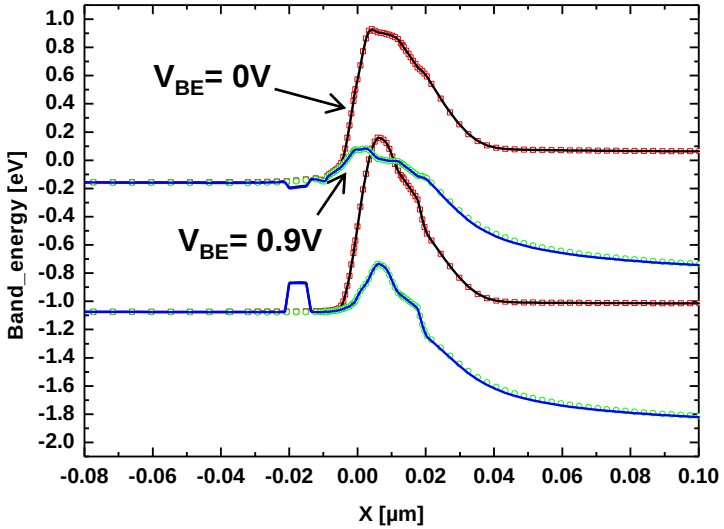


X_mole fraction in both transistors

SIGe spike mono emitter device

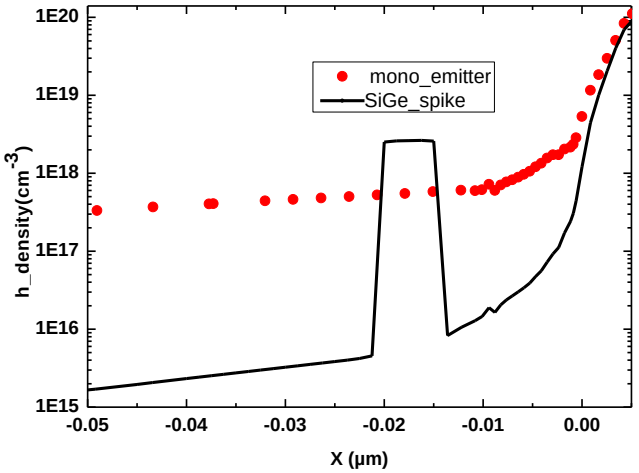
Device simulation on SiGe spike transistor

- **Device is simulated with calibrated parameter file and applying additional recombinatio for SiGe spike**



Energy band diagram comparing

SiGe spike emitter and mono emitter

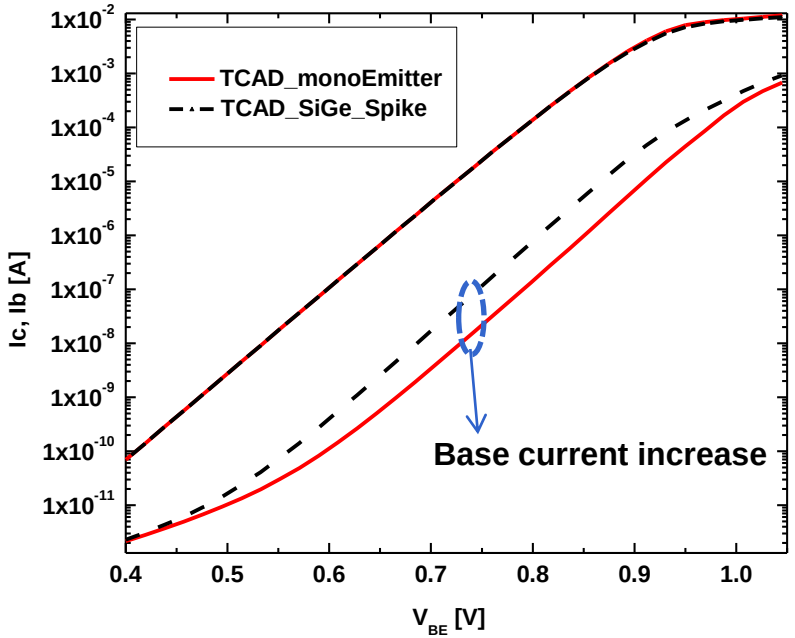


h carrier density at V_{BE}= 0.9V

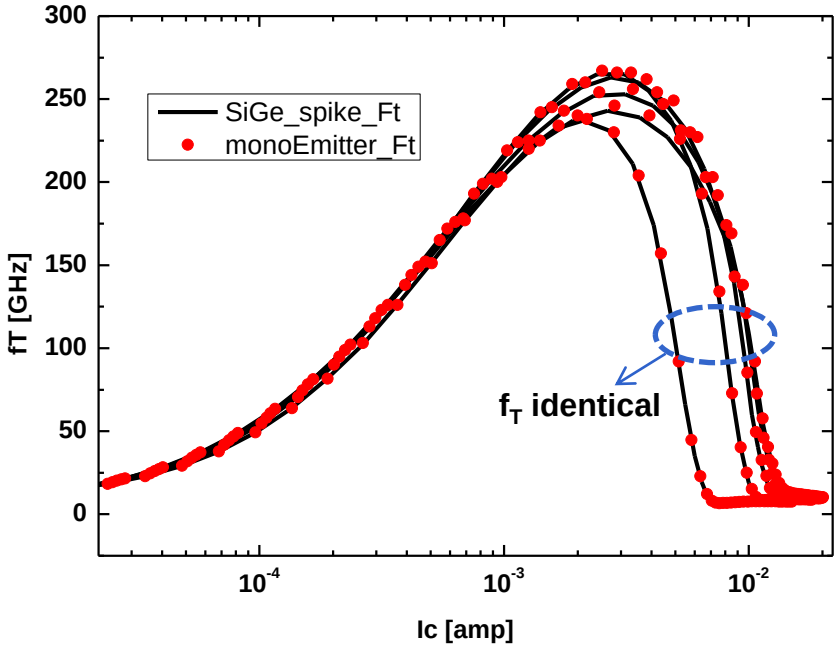
h carrier density slope increses near BE junction.

Device simulation on SiGe spike transistor

- DC and AC Simulaton results with SiGe spike emitter are compared with the mono emitter



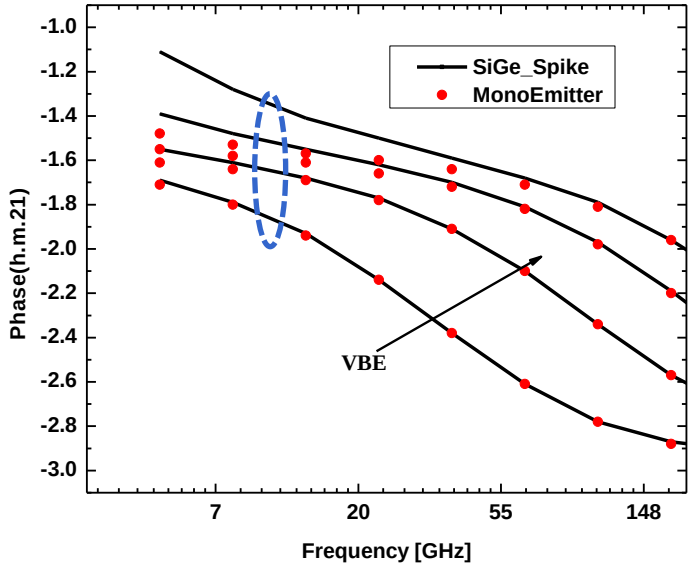
Gummel plot at V_{CB}= 0V



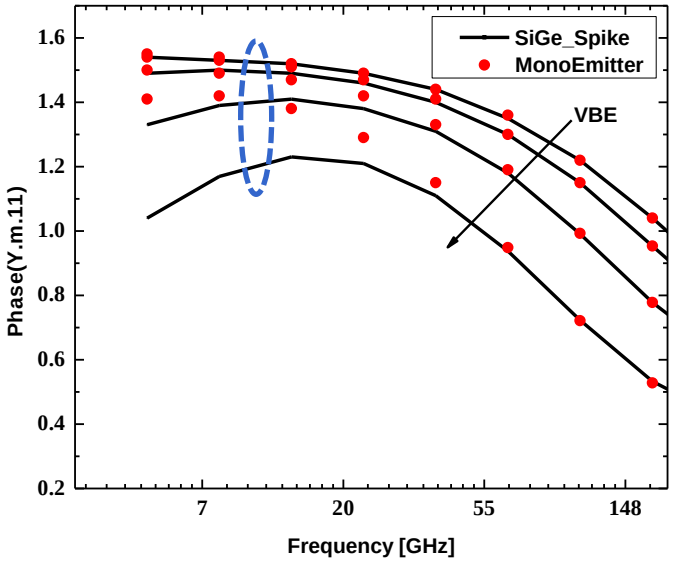
f_T vs Ic plot at different V_{CE}

Device simulation on SiGe spike transistor

- **Excess recombination charge affects the phase of dynamic parameters at low frequency**



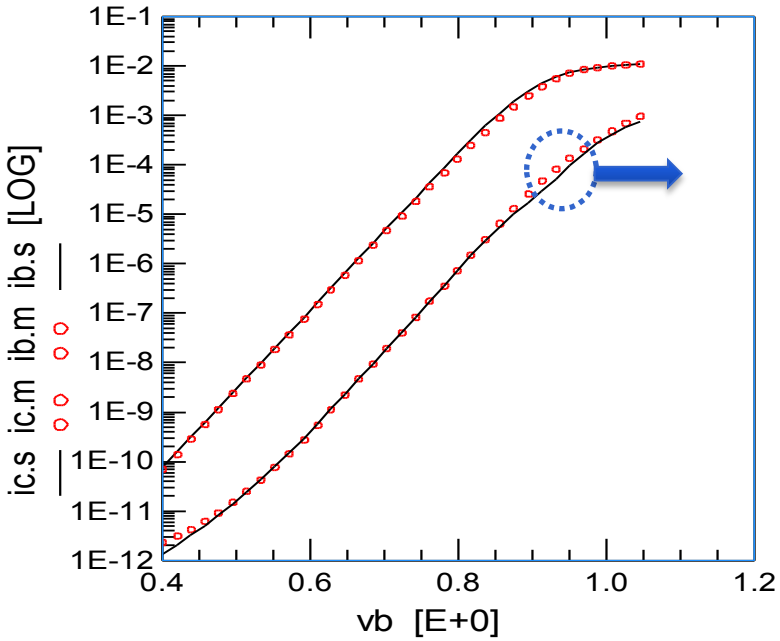
Phase of h_{21} at V_{CE}= 0.5V and V_{BE}= 0.75V, 0.79V, 0.83V, 0.87V



Phase of Y_{11} at V_{CE}= 0.5V and V_{BE}= 0.75V, 0.79V, 0.83V, 0.87V

Compact modeling on SiGe spike transistor

- SiGe spike mono emitter device simulation data are exported to ICCAP to perform compact modeling with HICUML2



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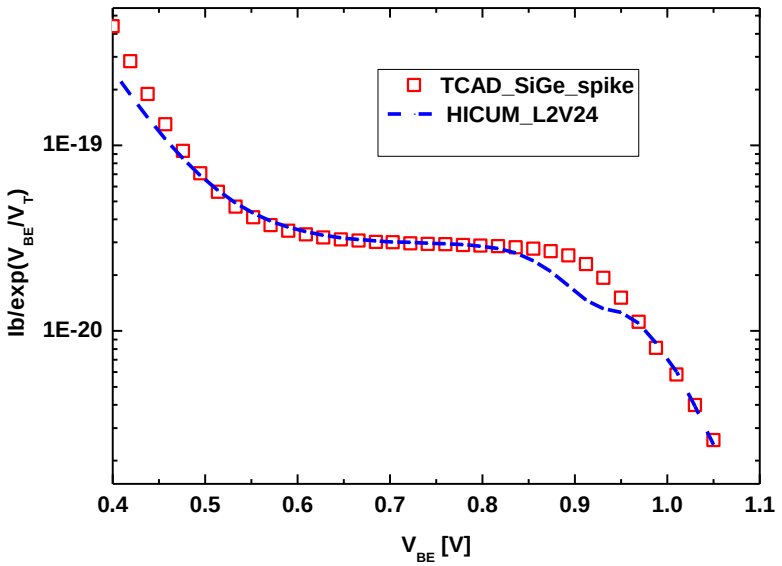
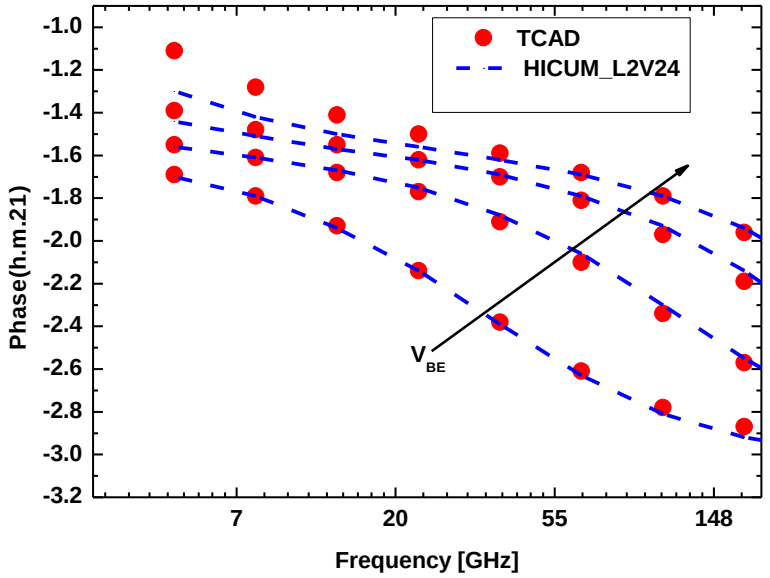


Ib/exp(V_{BE}/V_T) at V_{CB}= 0V

Base current is not perfect with the existing HICUM

Compact modeling on SiGe spike transistor

- Modeling results of phase of h_{21} and Y_{11} also show some inconsistency at low frequency



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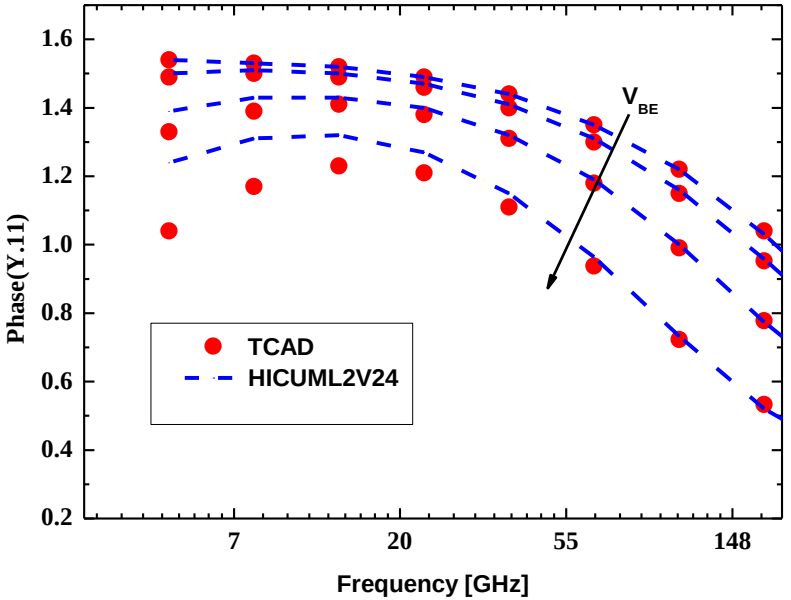


Phase of Y_{11} at V_{CE}= 0.5V and V_{BE}= 0.75V, 0.79V, 0.83V, 0.87V

Additional recombination parameter necessary to model the phase

HICUM with an additional base current: formulation

- **Base current components in HICUML2**

$$i_{jBEi} = i_{BEiS}\left[\exp\left(\frac{V_{B'E'}}{m_{BEi}V_T}\right)-1\right] + i_{REiS}\left[\exp\left(\frac{V_{B'E'}}{m_{REi}V_T}\right)-1\right] + I_{Bhrec}$$

Recombination current due to Ge drop in BC junction

$$I_{Bhrec} = \frac{\Delta Q_{Bf}}{\tau_{bhrec}}$$

model parameter

Where,

$$Q_f = Q_{f0} + \Delta Q_{Ef} + \Delta Q_{Bf} + \Delta Q_{Cf}$$

$$\Delta Q_{Ef} = \Delta\tau_{Ef}\,\frac{i_{Tf}}{1+g_{\tau fE}}$$

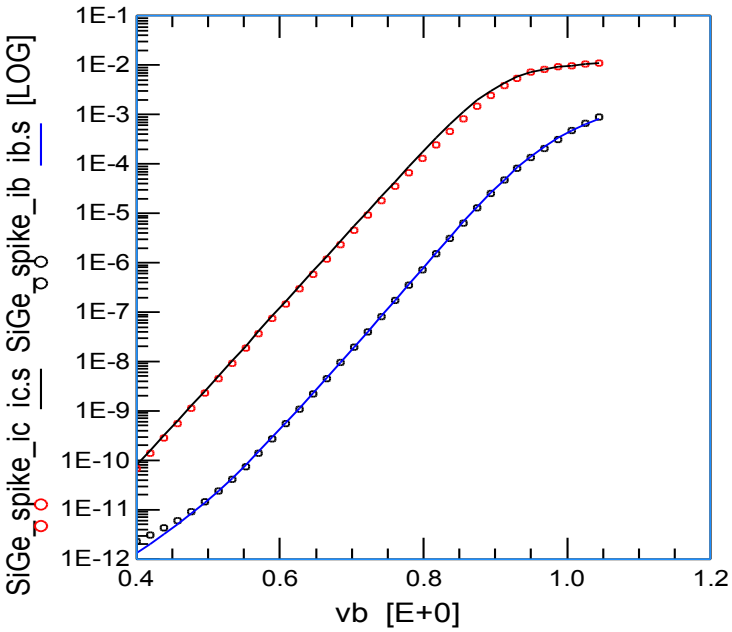
Introducing an additional recombination current due to the excess hole charge

$$I_{Berec} = \frac{\Delta Q_{Ef}}{\tau_{berec}}$$

New model parameter

HICUM with an additional base current: modeling results

- **Modeling results with the extended model,**



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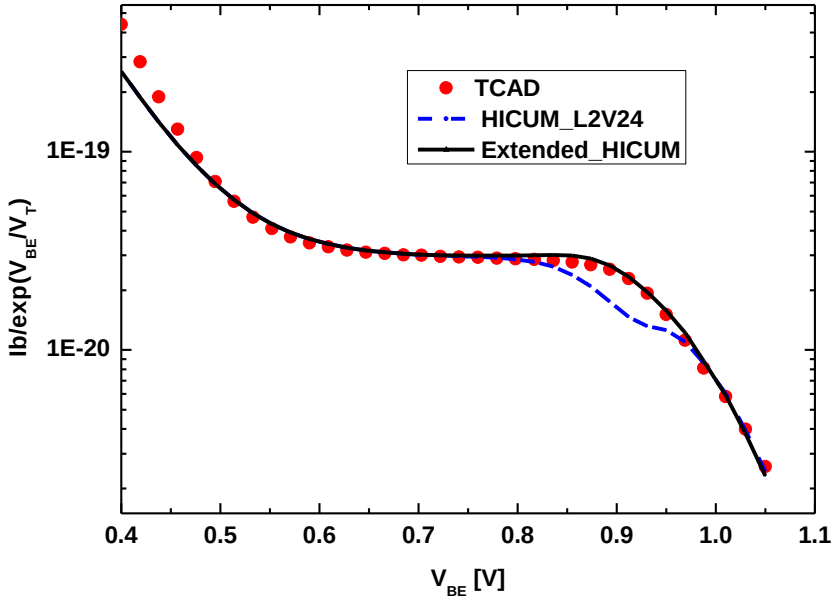
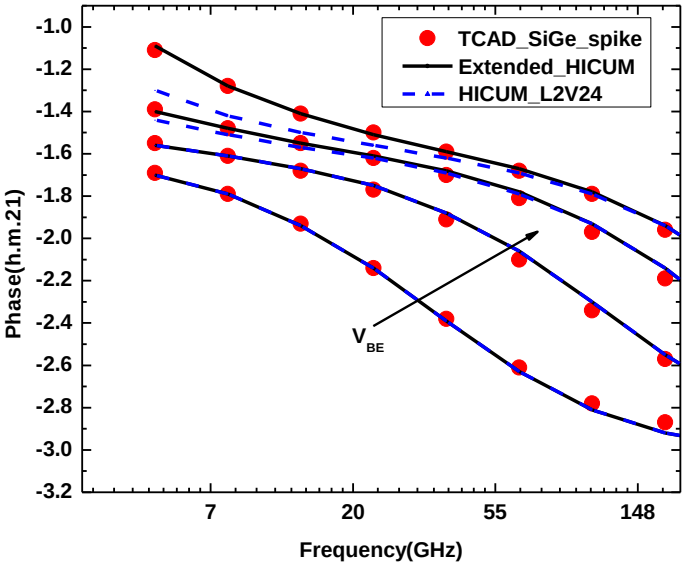


Ib/exp(V_{BE}/V_T) at V_{CB}= 0V

Base current is perfect with the extended model

HICUM with an additional base current: modeling results

- **Modeling results with the extended model,**



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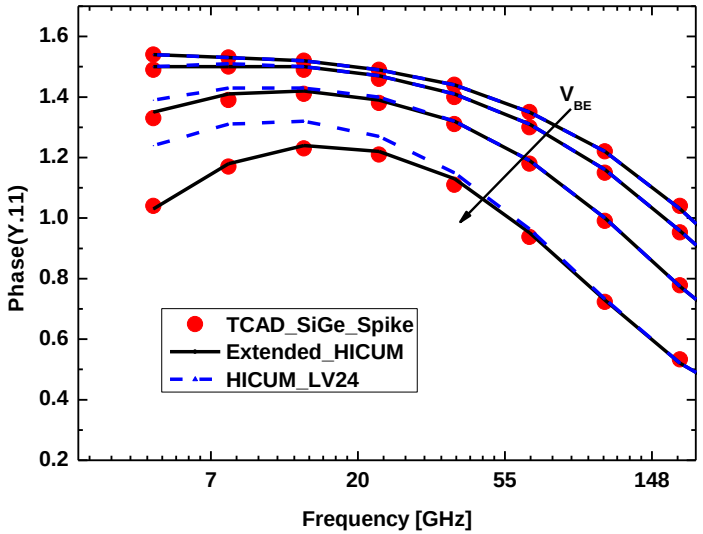

Phase of Y_{11} at V_{CE}= 0.5V and V_{BE}= 0.75V, 0.79V, 0.83V, 0.87V

Excess phase shift is modeled perfectly with the extended model

Conclusion

- A SiGe spike mono emitter device is considered for physical device simulation (TCAD).
- TCAD simulations show an increase in base current without affecting the transit frequency.
- Simulated results are modeled with HICUML2V24 model.
- A small extension of HICUM with an additional recombination current is formulated.
- Base current and Y_{11}, h_{21} phase are accurately modeled with the new model.

Acknowledgment

- **This work is part of the:**
  - **DOTFIVE project supported by the European Commission through the Seventh Framework Programme for Research and Technological Development.**
- **Acknowledgements also to the MEDEA+ “SIAM” project.**
- **We want to thank Arturo.Sibaja-Hernandez from IMEC for fruitful discussions and process information supply.**