Modeling and scaling of III-V HBTs using HICUM and TRADICA

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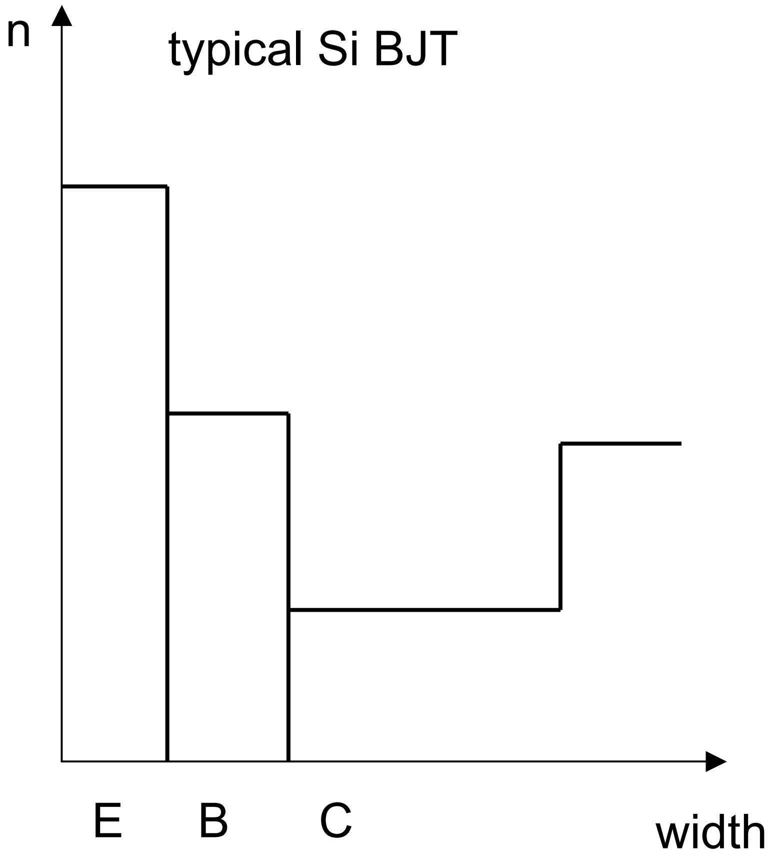
Situation

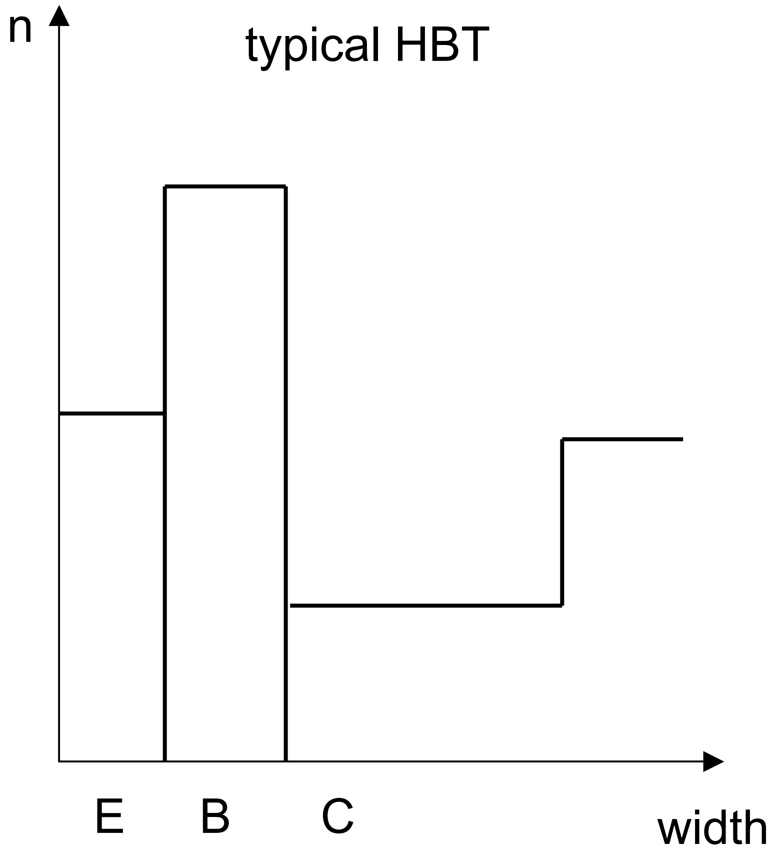
- Increasing demand for power amplification at high speeds
- Pure silicon devices limited by material characteristics and design principles
- Trend goes towards hetero-structure devices (HBTs)
- Introduction of silicon-germanium transistors (already implemented in modern BiCMOS-technologies)
- Search for alternative materials (e.g. gallium-arsenide)
- Silicon technologies covered by the modeling community very well
- Need for accurate models describing differences in physics and geometry of HBTs

Advantages of HBTs

- Higher carrier mobility (Si: ~1.3cm²/Vs GaAs: ~5.0cm²/Vs)
- Different bandgaps of emitter and base material (current gain controlled not only by doping concentration)
- Implementation of a “build-in-field” in the base layer by doping AND compositional grading
- Velocity overshoot effects in the base-collector SCR increase transistor speed
- Well controlled layer growth and composition due to molecular beam epitaxy technology
- Simple geometry of mesa-HBTs compared to typical silicon transistors

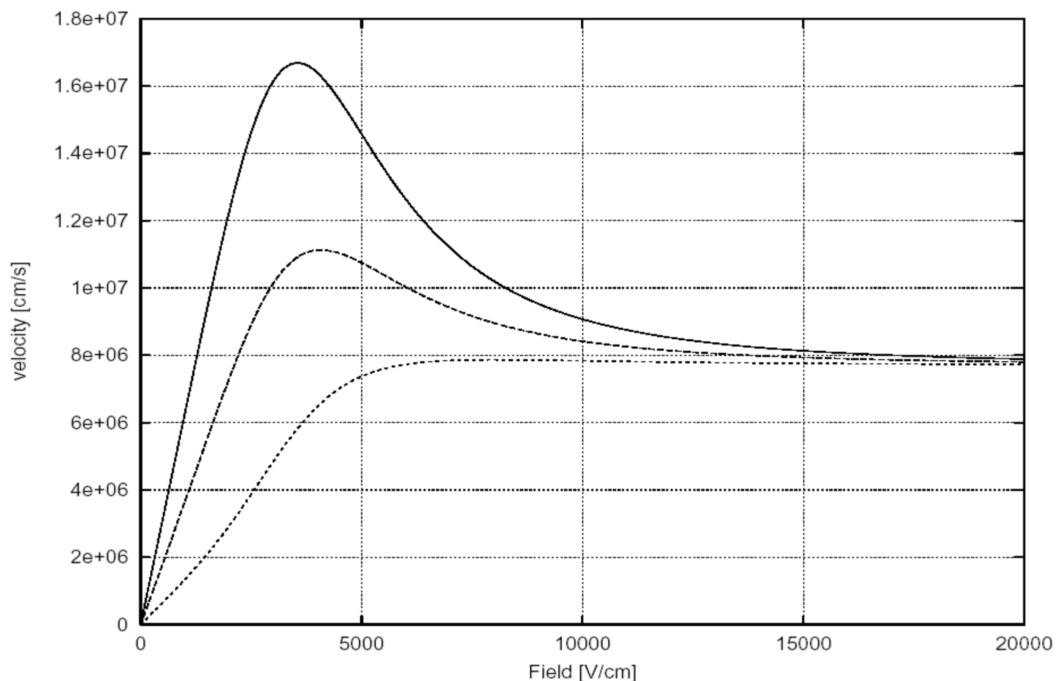
Doping profiles



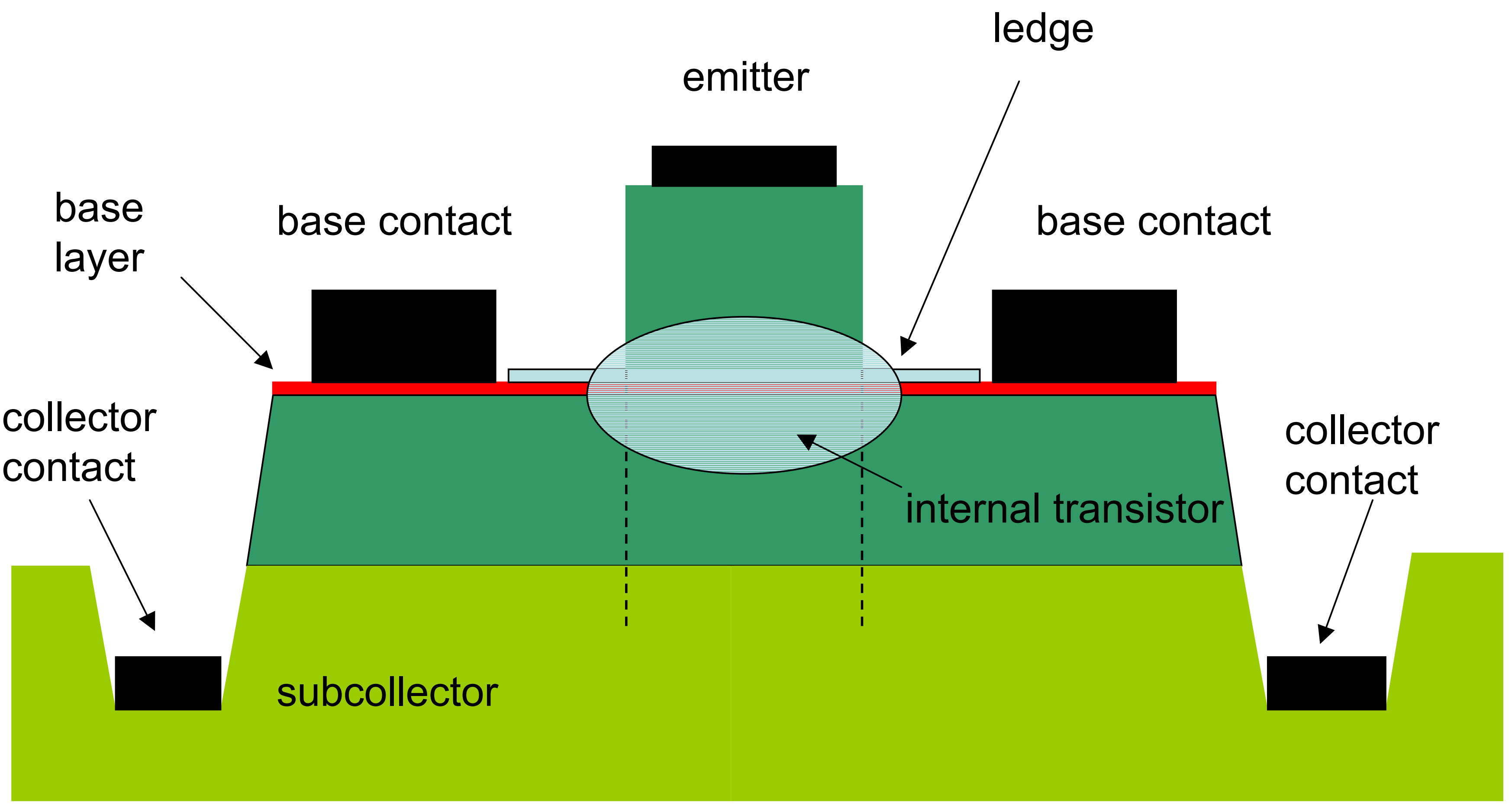


Disadvantages of HBTs

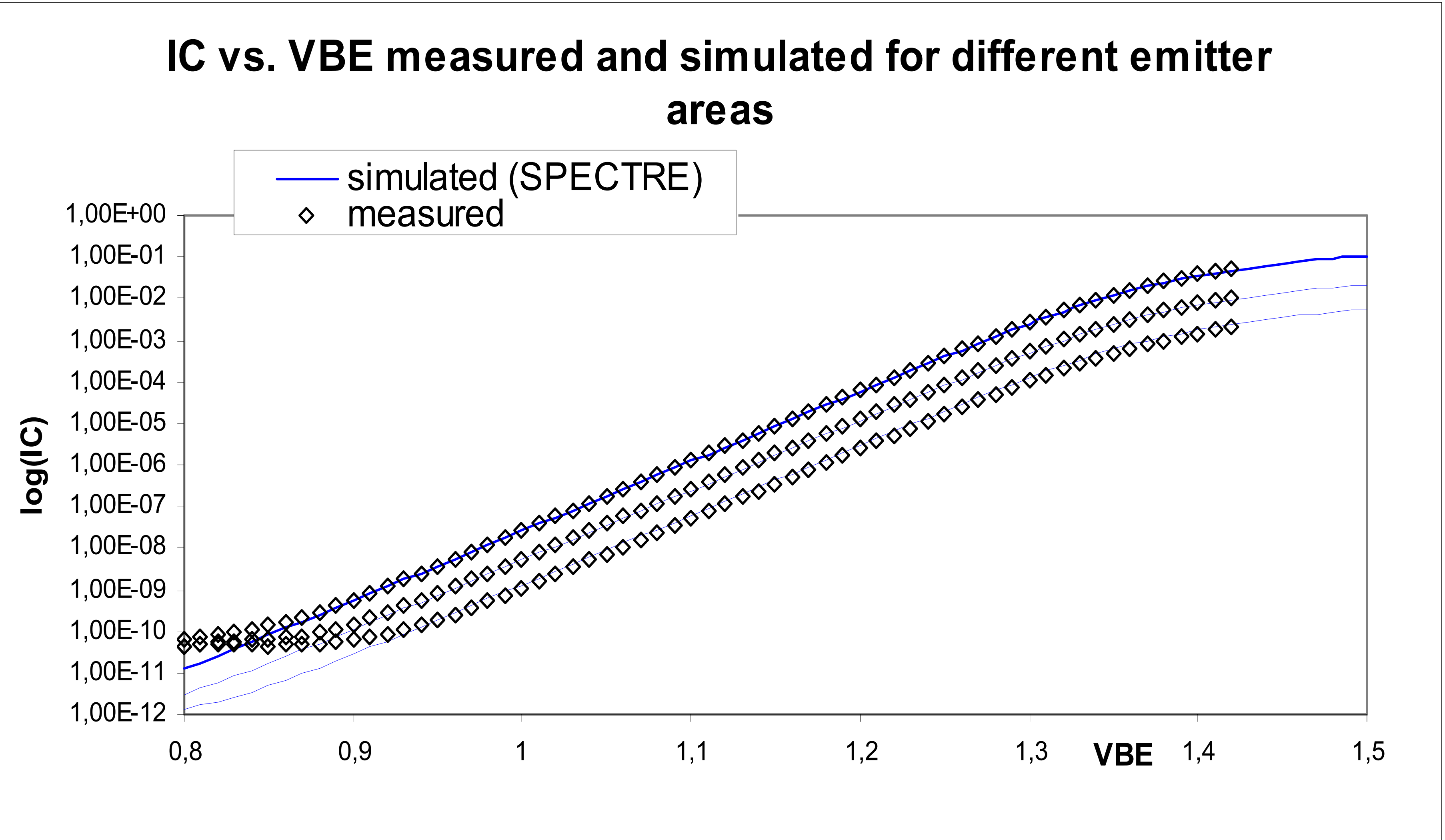
- Lower thermal conductivity
- Lower integration density (technology development far behind silicon)
- Actual wafer sizes 150mm (6”)
- Non-monotonic velocity-field characteristics



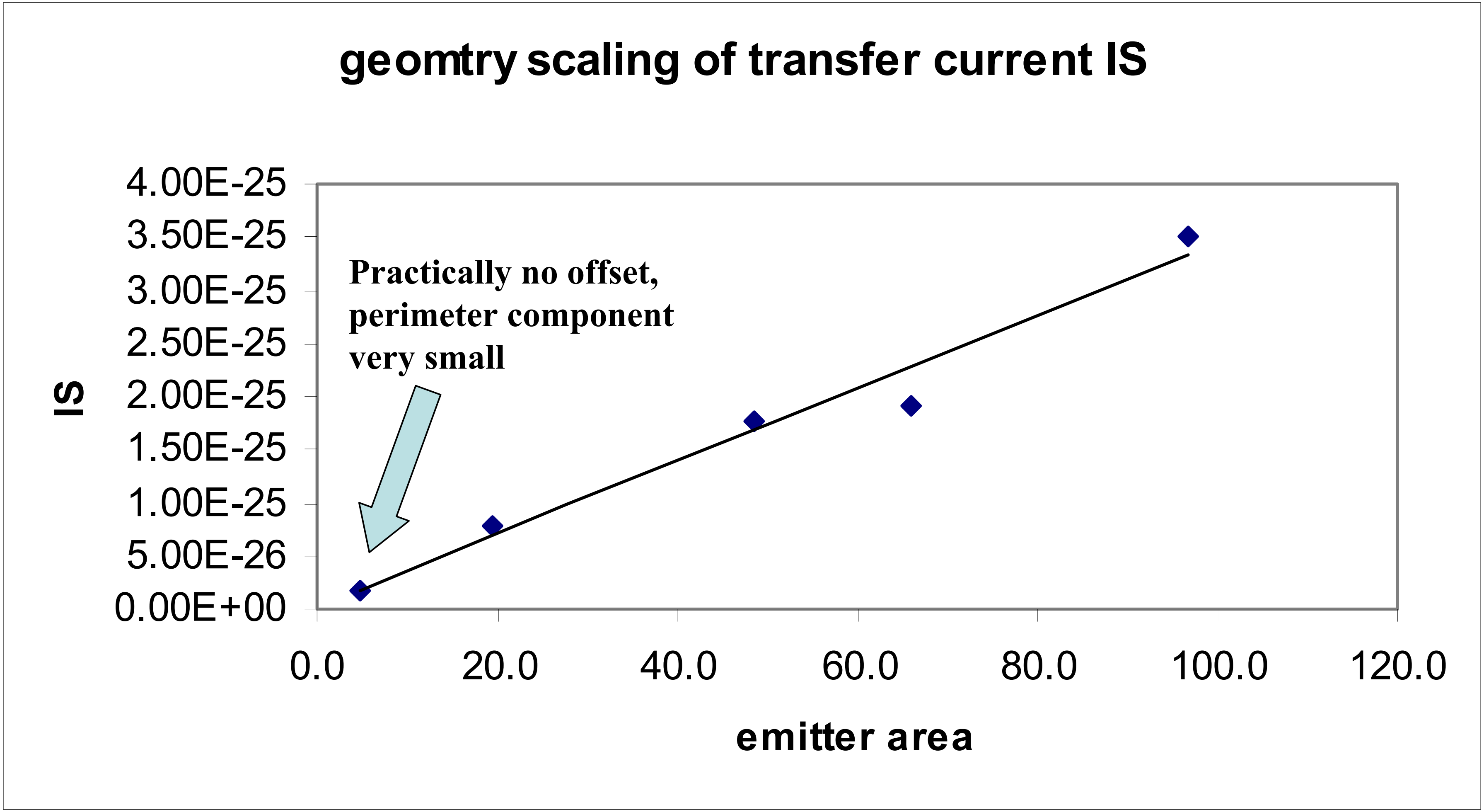
mesa-HBT cross section



Gummel characteristics verification

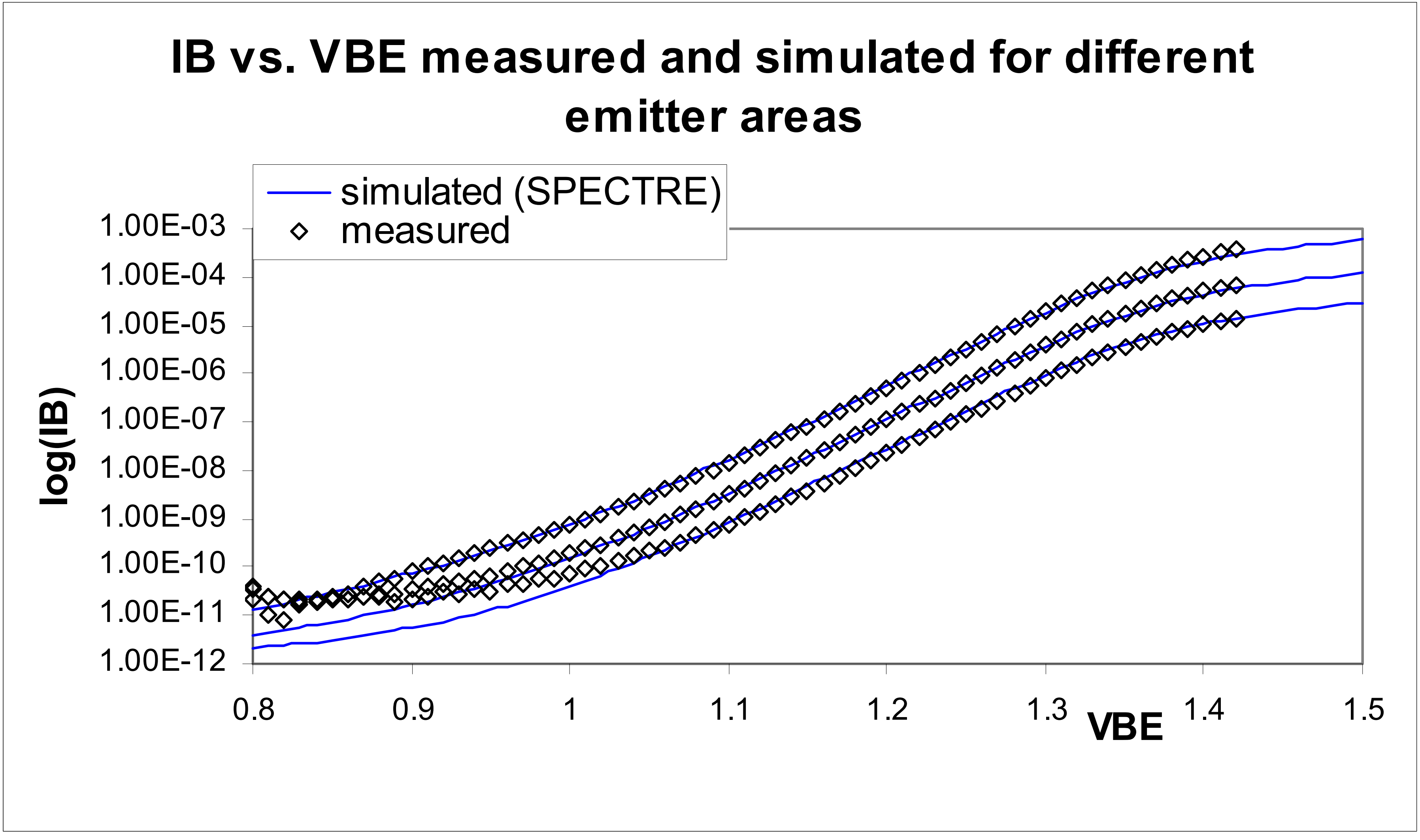


Collector current scaling

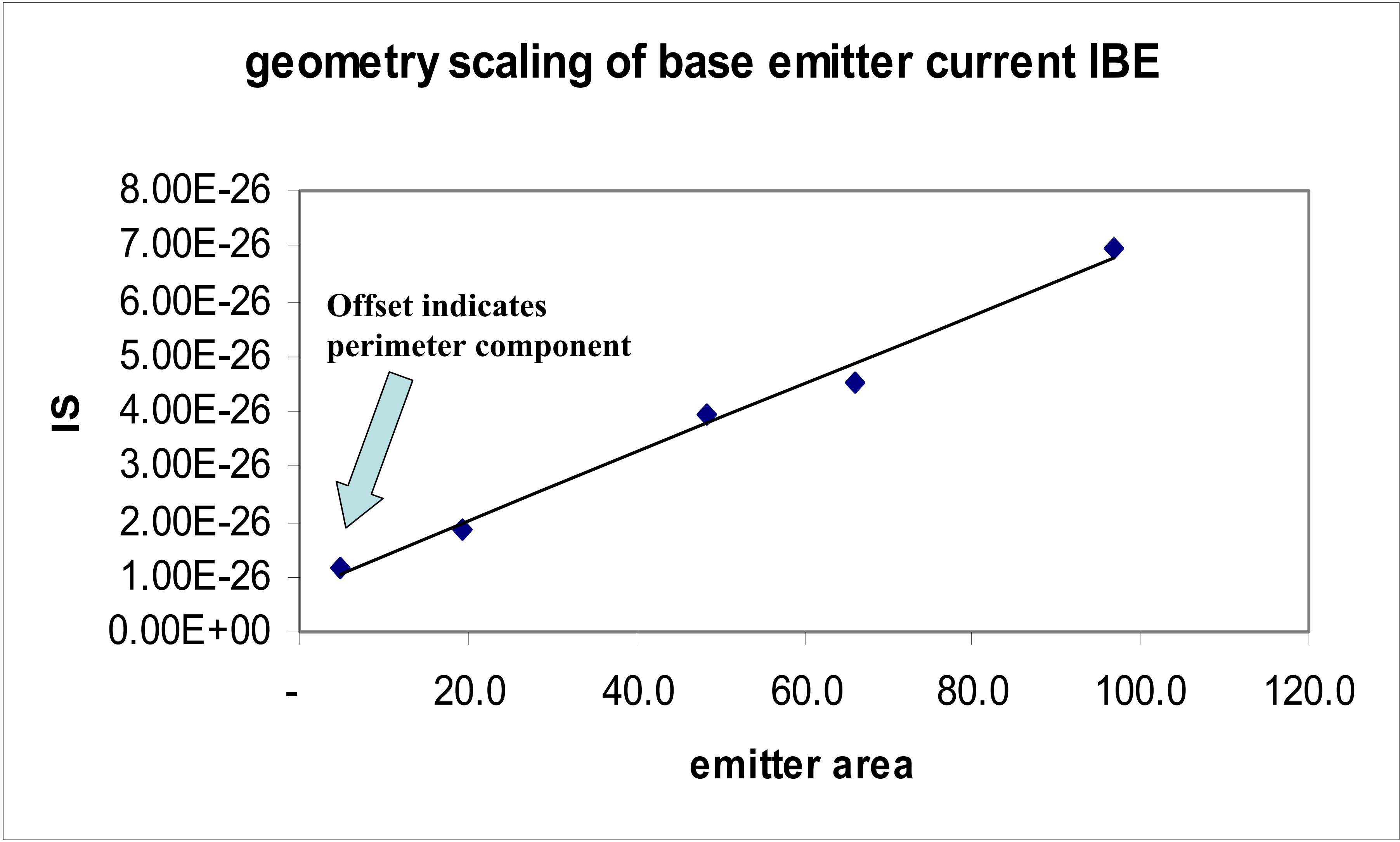


Gummel characteristics verification

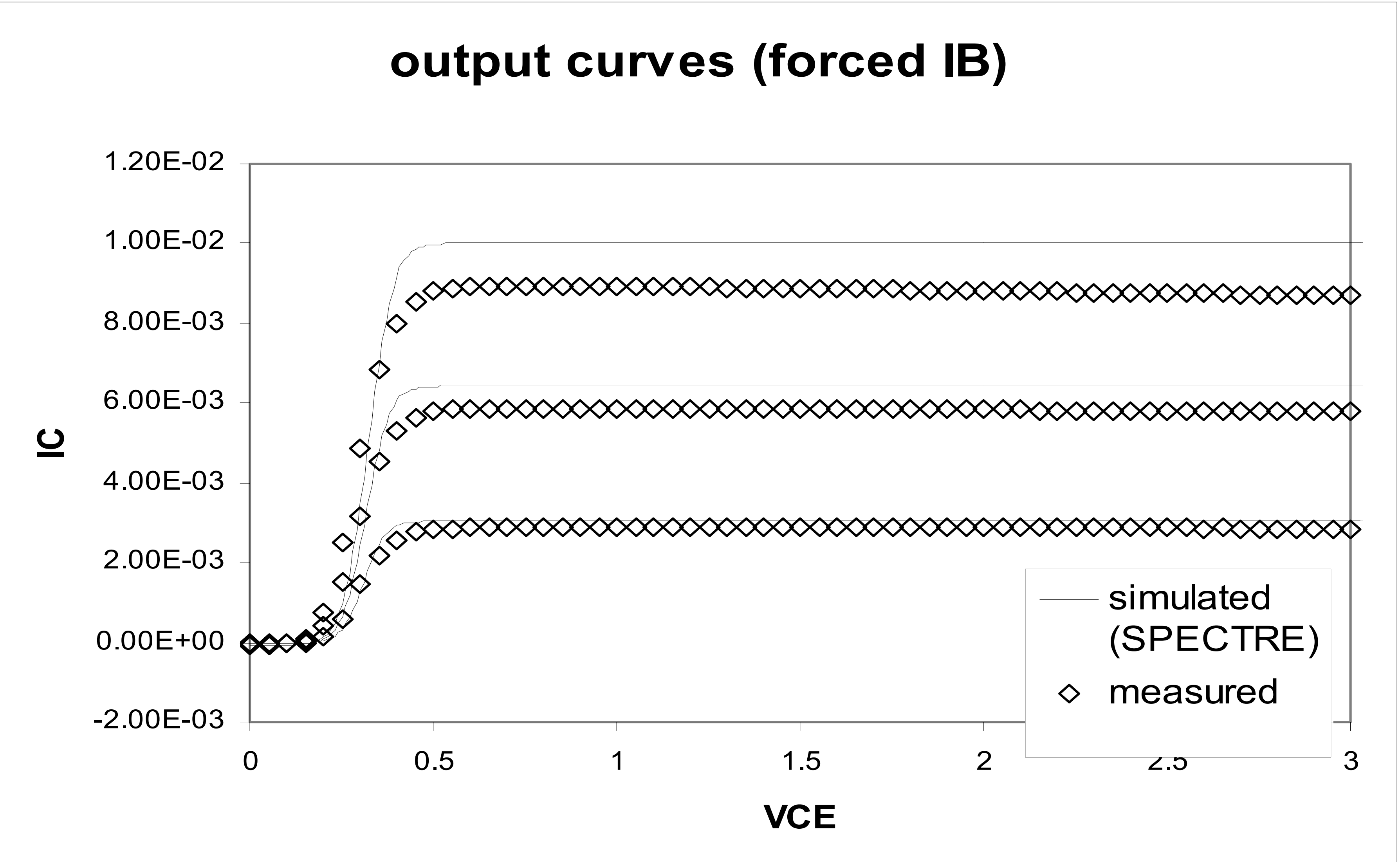
(rectangular devices)



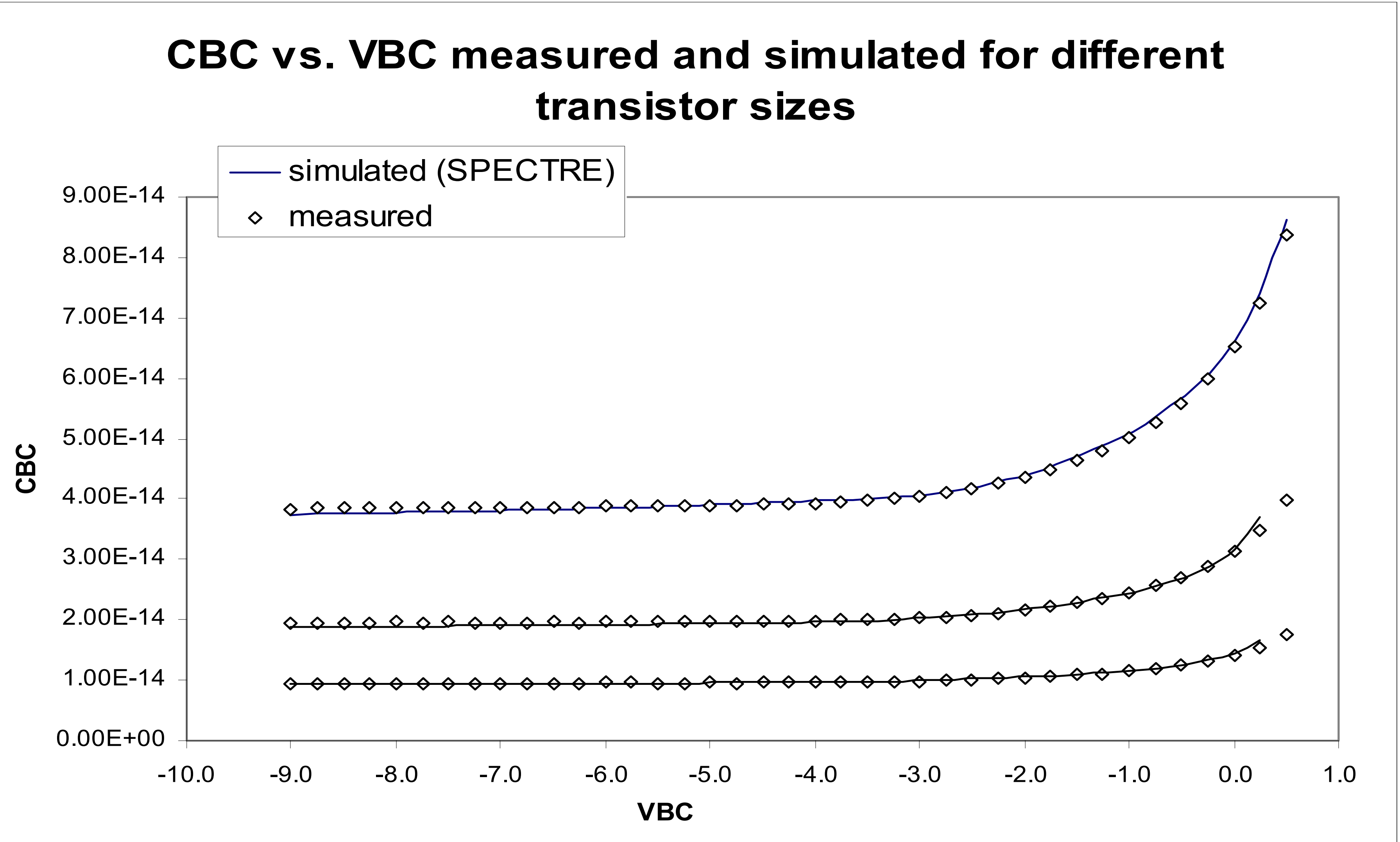
Base emitter current scaling



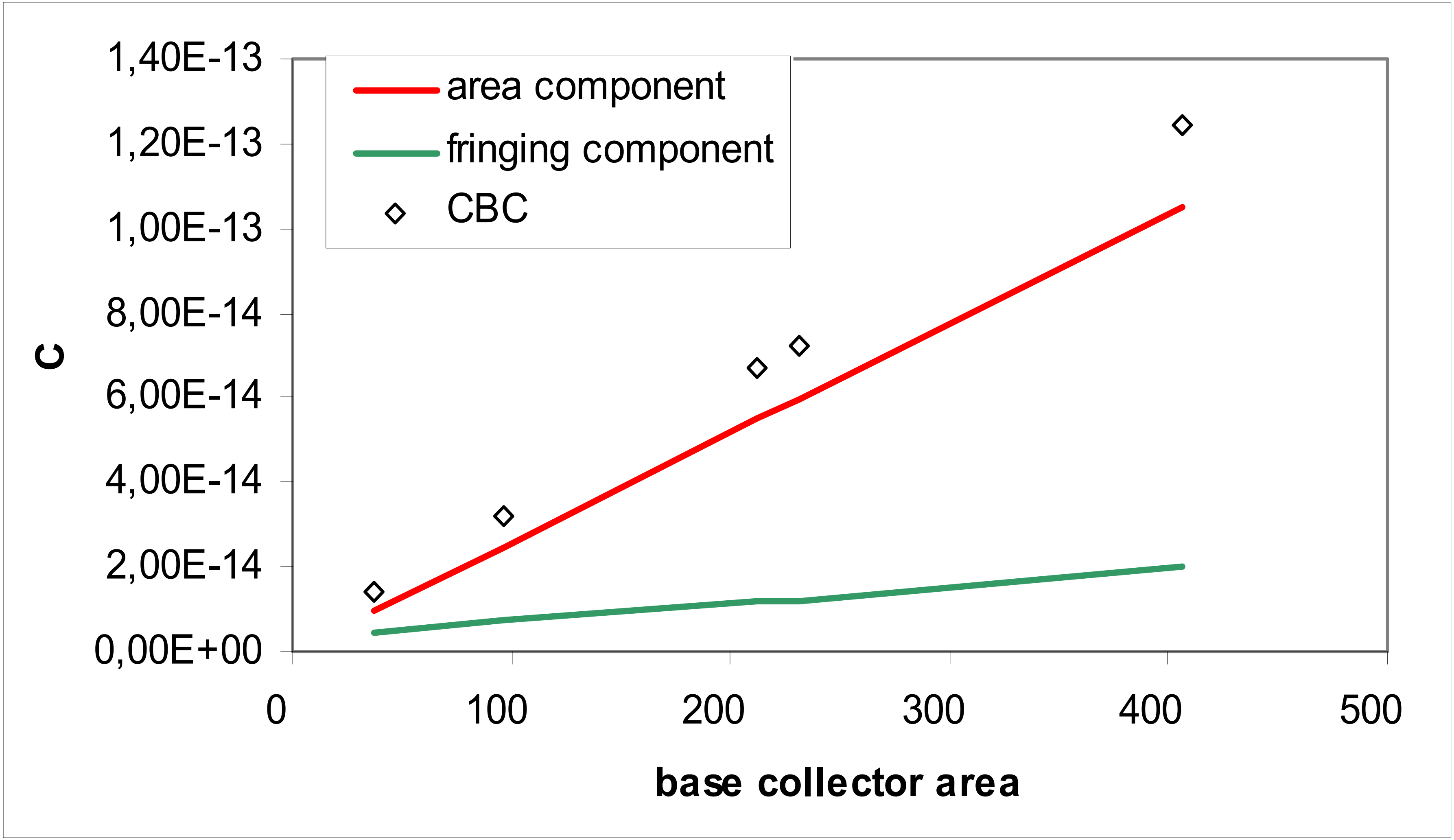
Output curves verification



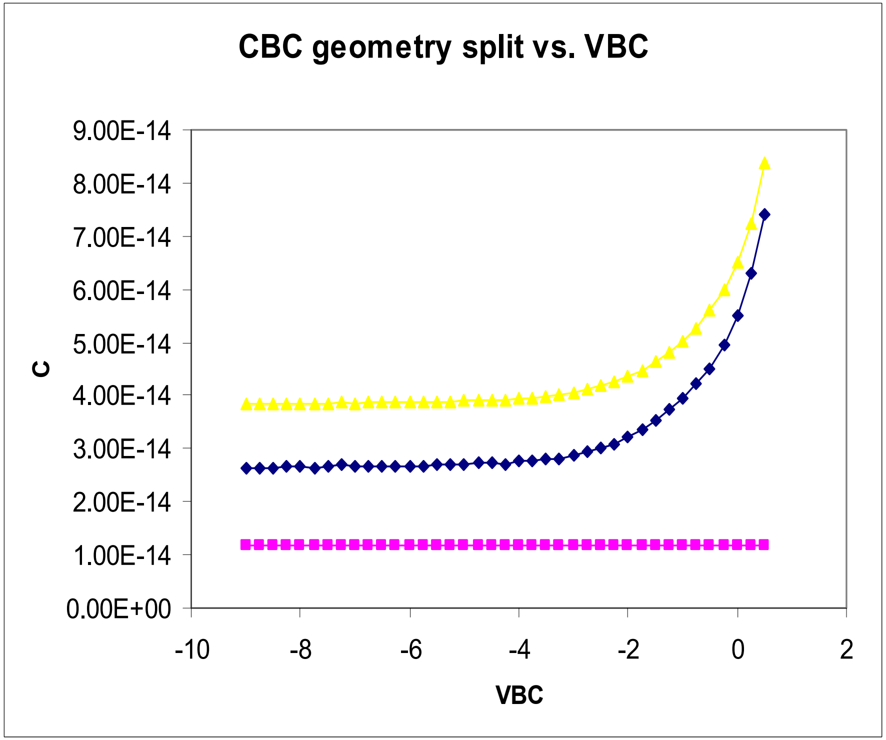
Base collector depletion cap.

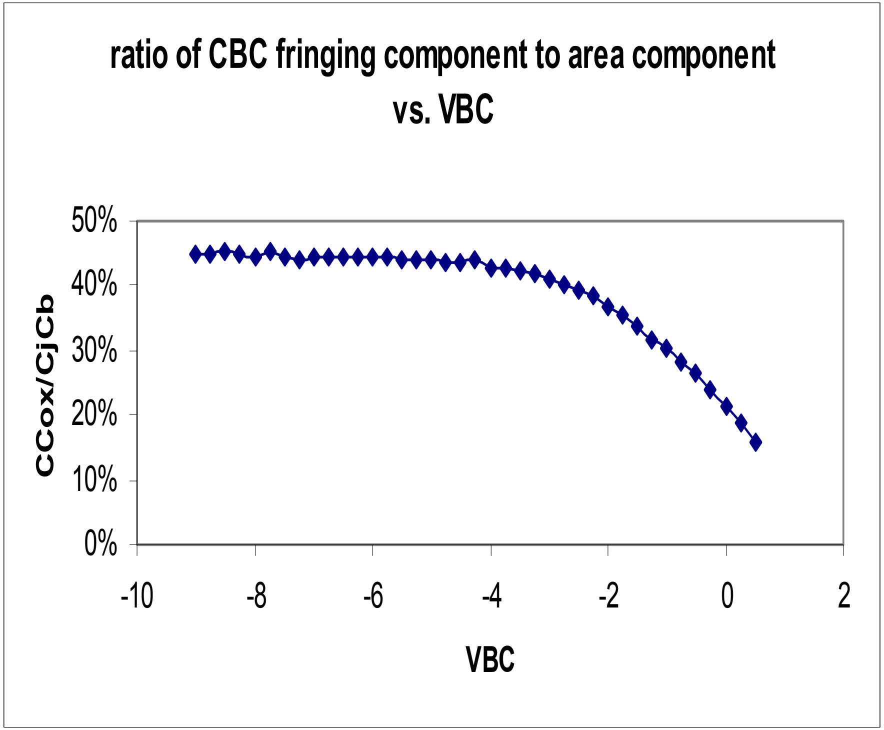


CBC geometry separation and scaling

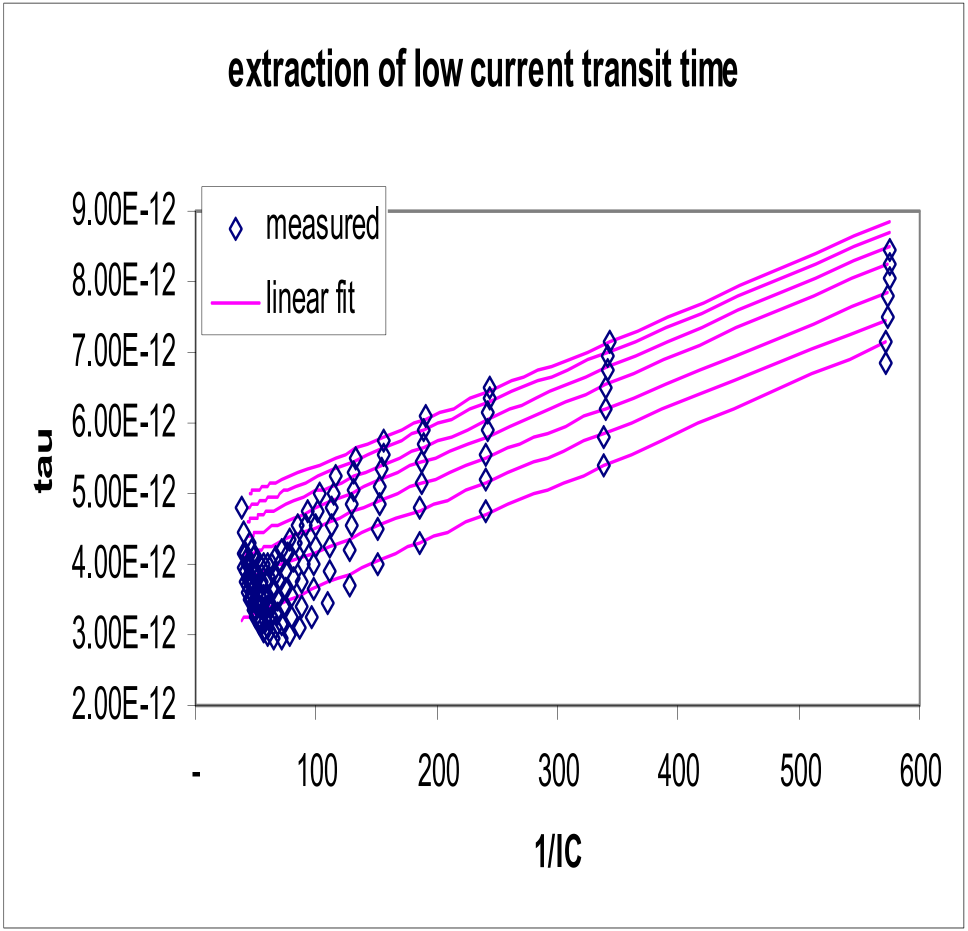


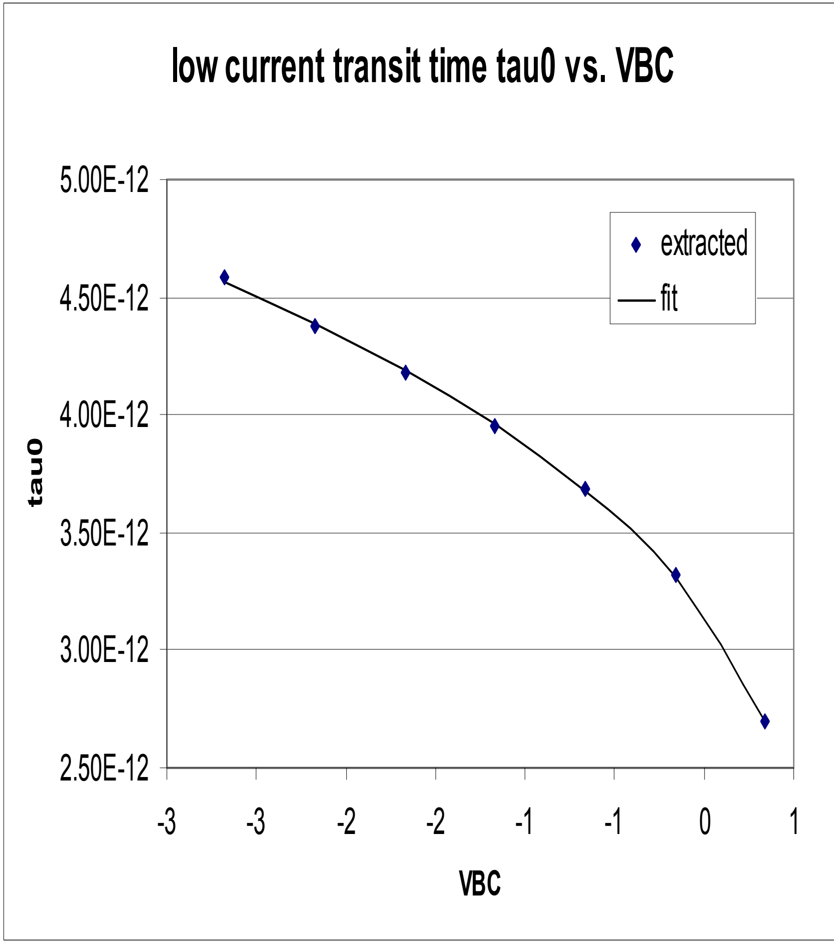
BC fringing capacitance





Low current transit time





Summary

- HICUM model well suited for modeling DC characteristics
- Transit time model in HICUM has to be enhanced (velocity overshoot)
- Scaling equations in TRADICA well suited for mesa-HBTs
- Model parameter generation with TRADICA possible for low IC applications

CONEXANT's HBT-3 process

layer	material	dopants
substrate	GaAs	semi insulating
subcollector	n GaAs	Si
collector	n GaAs	Si
base	p GaAs	C
ledge (emitter)	n AlGaAs	Te
emitter 1	n GaAs	Te, Si
emitter 2	n InGaAs	Te, Si

Importance of accurate measurements