Parameter extraction issues in HICUM/L2 for very advanced HBTs

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Würzburg, October 23rd 2009

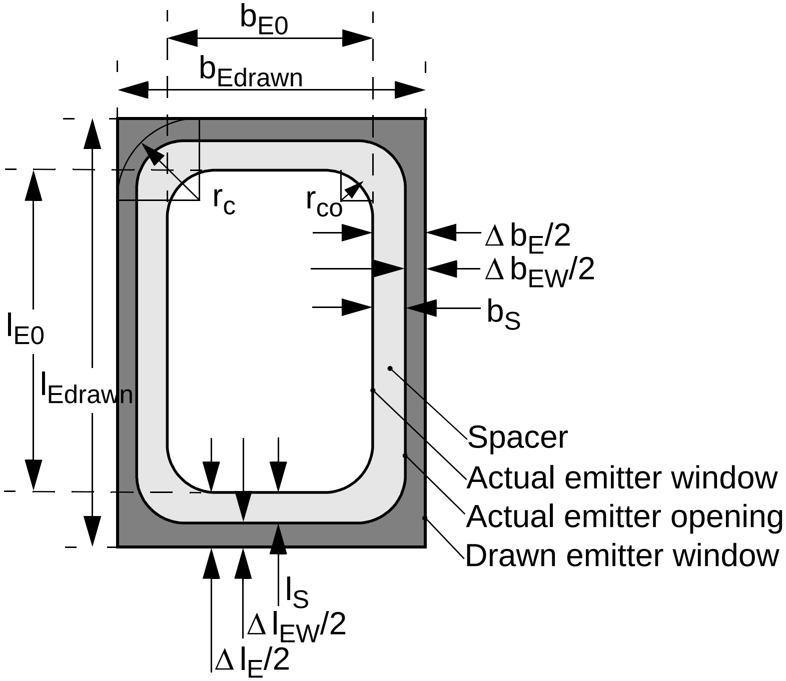
Outline

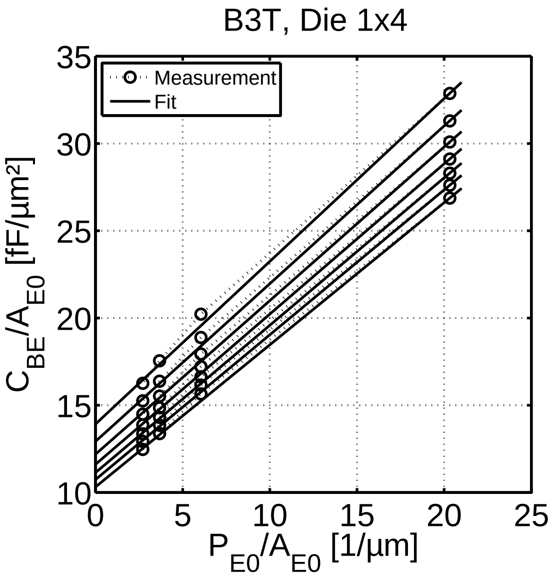
- Introduction
- Extraction issues without regard to model formulation
- Extraction issues with regard to model formulation
- Model comparison
- Summary

1 Introduction

- Observation of model limitations for very advanced HBTs
- Database: ST B3T technology (HBTs with fmax > 0.3THz), developed within the DOTFIVE project (http://www.dot-five.eu)
- Very aggressive device performance, SiGe HBT structure extremely scaled down laterally and vertically, striking self-heating effect
- Extracted models show partially accuracy issues
- Solving some extraction issues makes changes/extensions to certain model formulations inevitable

Influence of exact emitter dimensions on scalability

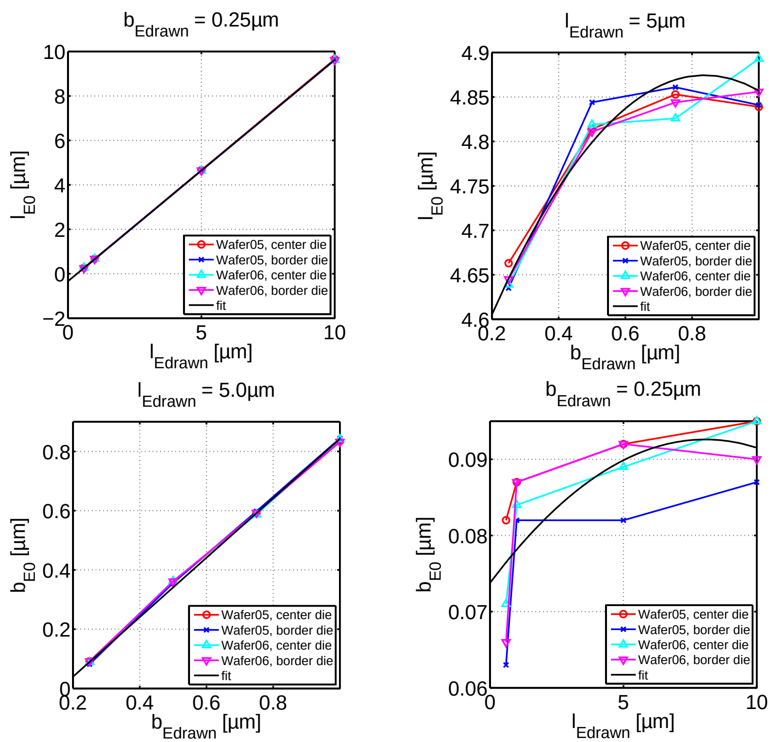




P/A separation of BE capacitance

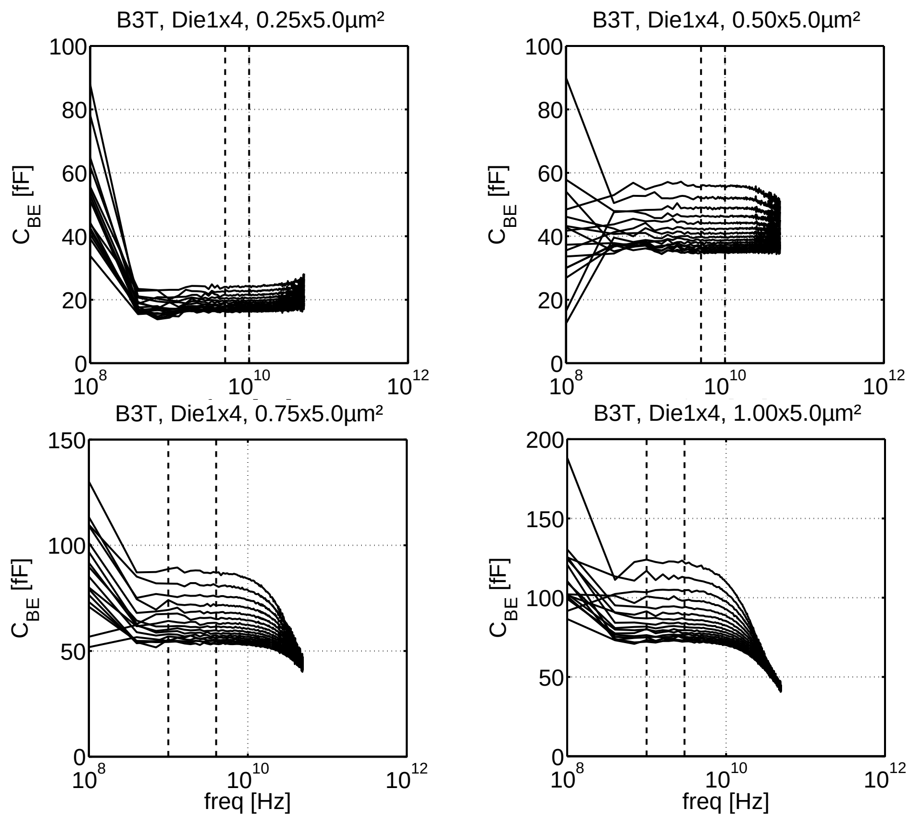
2 Extraction issues w/o regard to model formulation (1)

Analyses across various die sites (based on SEM data)



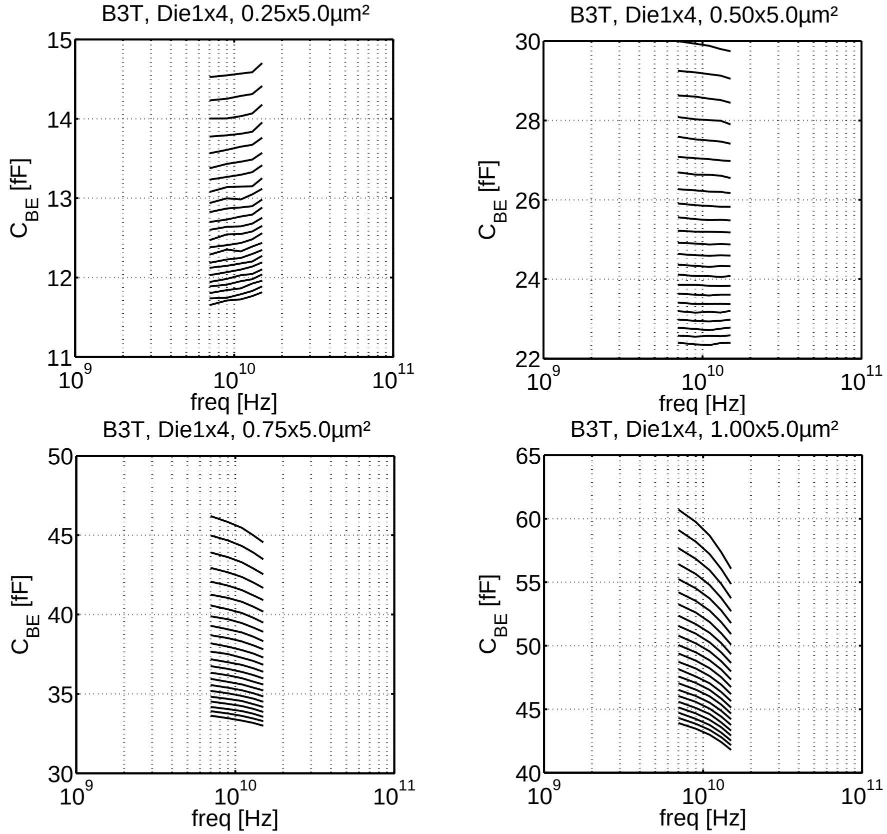
- Information on actual emitter dimensions derived from SEM pictures provided by ST
- Transformation from drawn width and length to actual dimensions using a second-order model

2 Extraction issues w/o regard to model formulation (2)



- TUD data
- C_{BE} vs. frequency
- V_{BE} = (0.65...0.8)V
- Measurements at spot frequency are obviously not sufficient

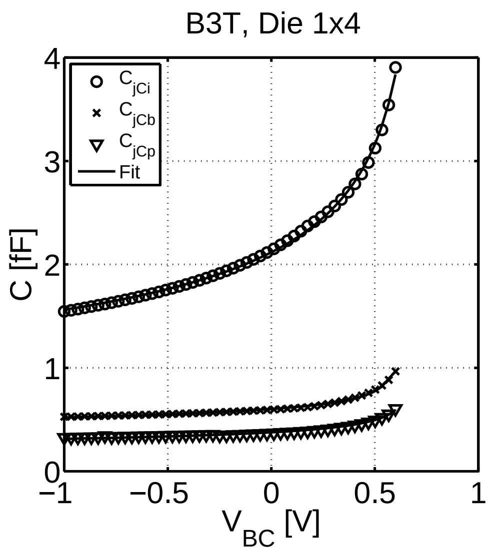
2 Extraction issues w/o regard to model formulation (3)

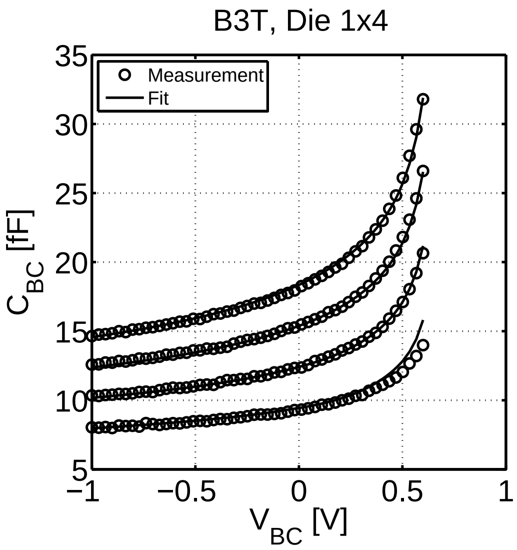


- XMOD data
- C_{BE} vs. frequency
- V_{BE} = (-0.6...0.5)V
- Estimizations of RC-time constants need to be known up-front

2 Extraction issues w/o regard to model formulation (4)

Separation of BC capacitance

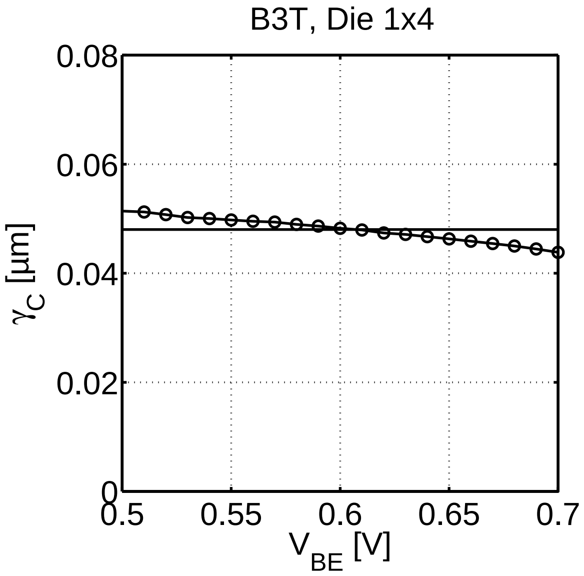




- For proper geometry separation the use of transistor test structures without SIC is desirable.
- Separation here has been done using information from device simulations.

Low current density scaling

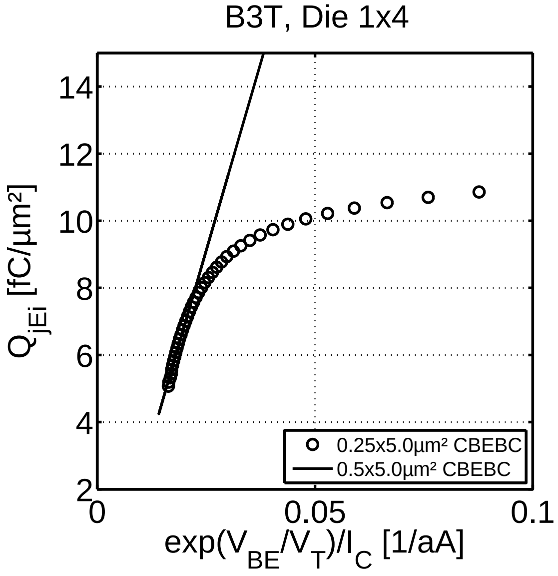
- Decrease of γ_C with V_{BE}, relatively large mean value ($\approx$50nm) compared to emitter window and spacer widths



- Physical cause of bias dependence and large value is already unter investigation
- Bias dependence rather weak -> use of mean value transitionally sufficient

3 Extraction issues w/ regard to model formulation (1)

I_T parameter extraction issue

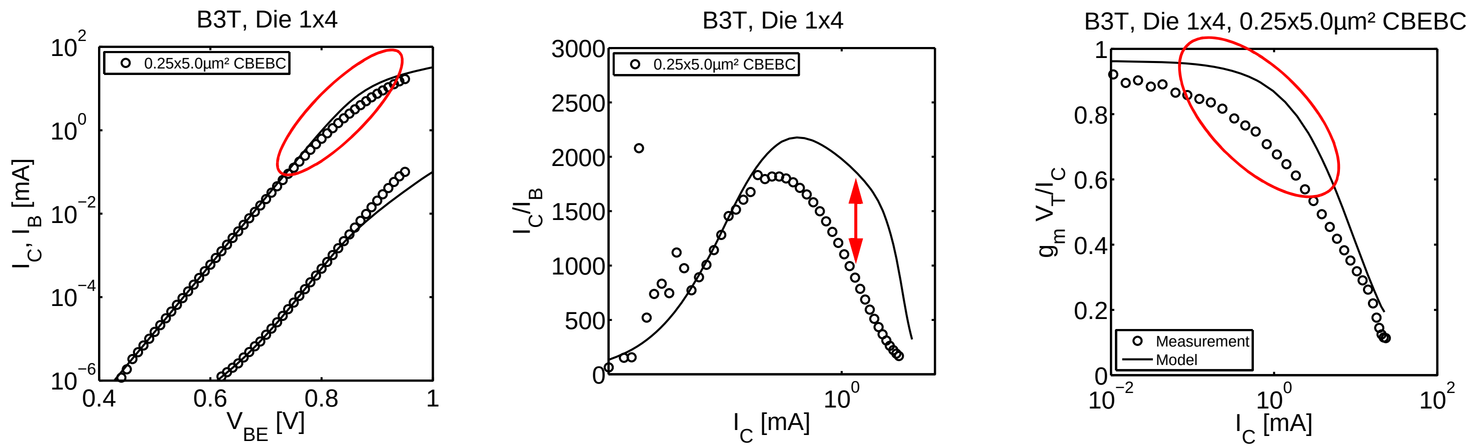


- Standard extraction of Q_{p0}, c_{10} gives negative or too low Q_{p0} values
- Extracting Q_{p0} from I_C may not give accurate results!
- Ignoring the bias dependence of h_{jEi} leads to the observed issue

- Refer to presentation of A. Pawlak: extension of the formulation of the transfer current
- Physics-based solution

3 Extraction issues w/ regard to model formulation (2)

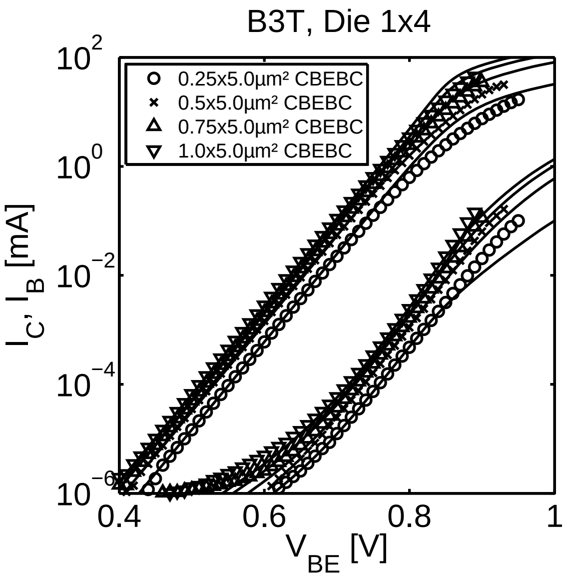
High-current density scaling

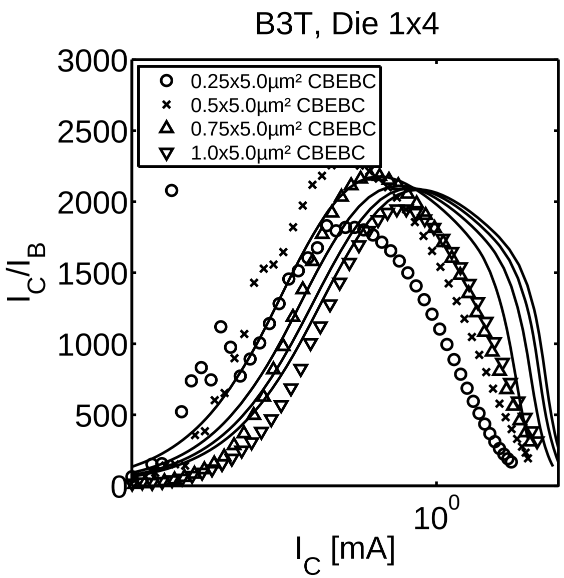


- Weighting factors h_{fe}, h_{fc} have no positive impact
- Deviation is enhanced by self-heating effect
- Caused by bias-independent h_{jei} $\rightarrow$ cf. presentation A. Pawlak, ”A HICUM extension for medium current densities”

4 Model comparison

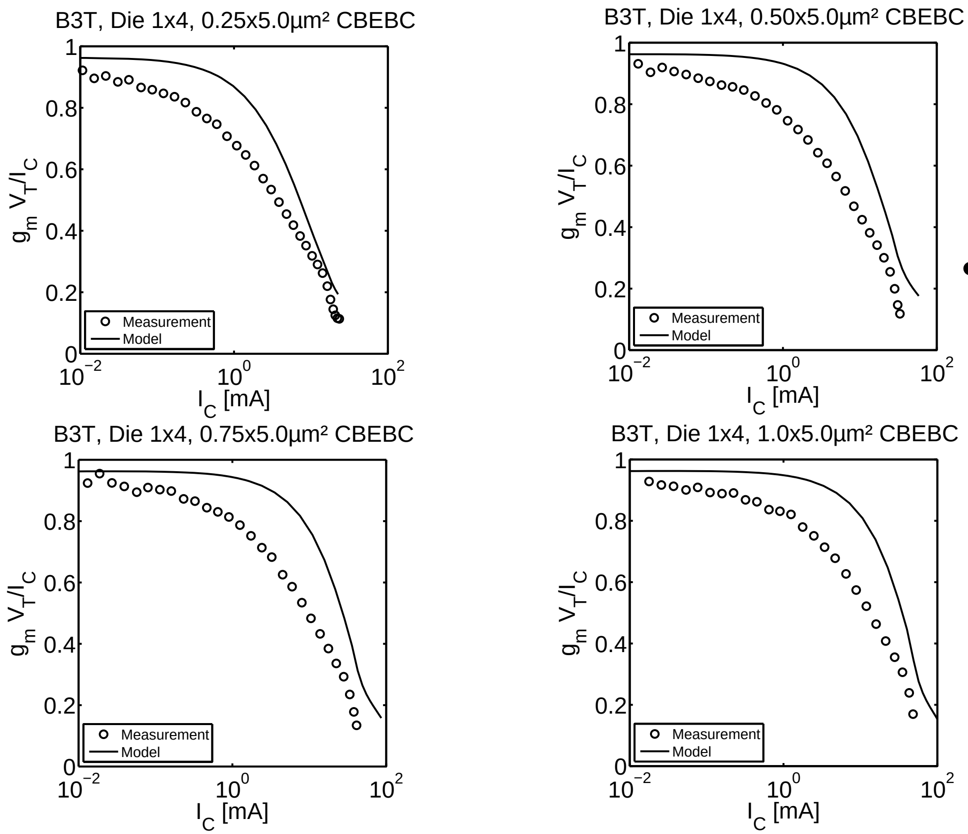
Forward gummel plot and DC current gain at V_{BC} = 0V





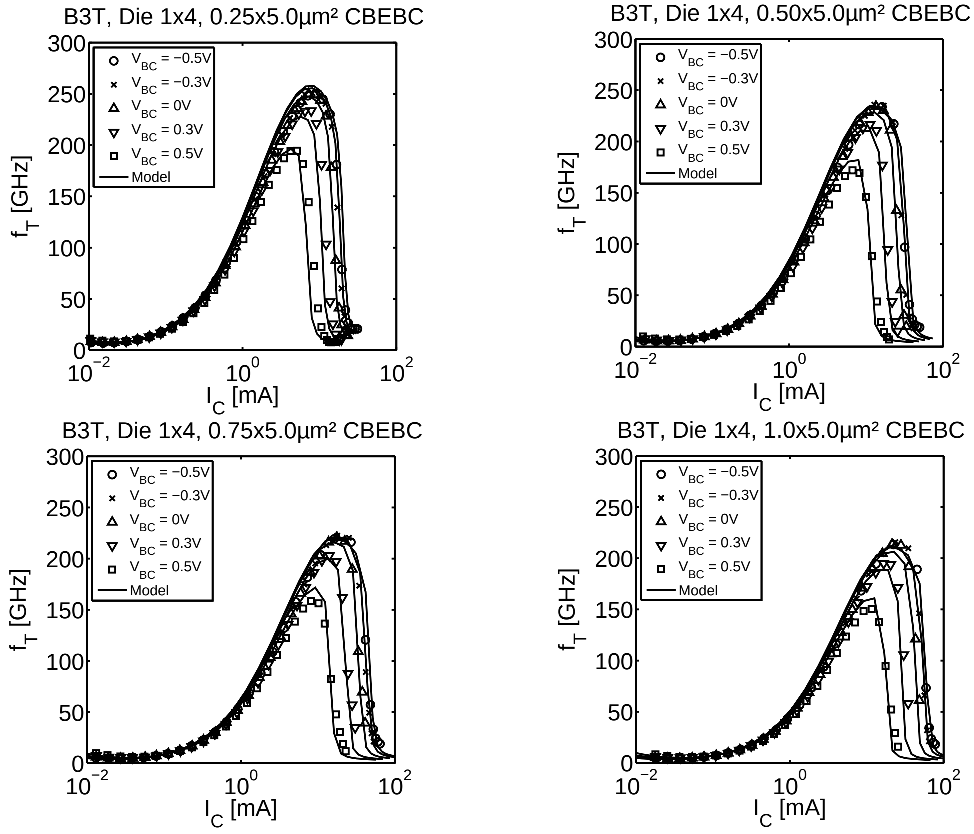
- Expected deviations in high-current region.

Model comparison (cont'd)



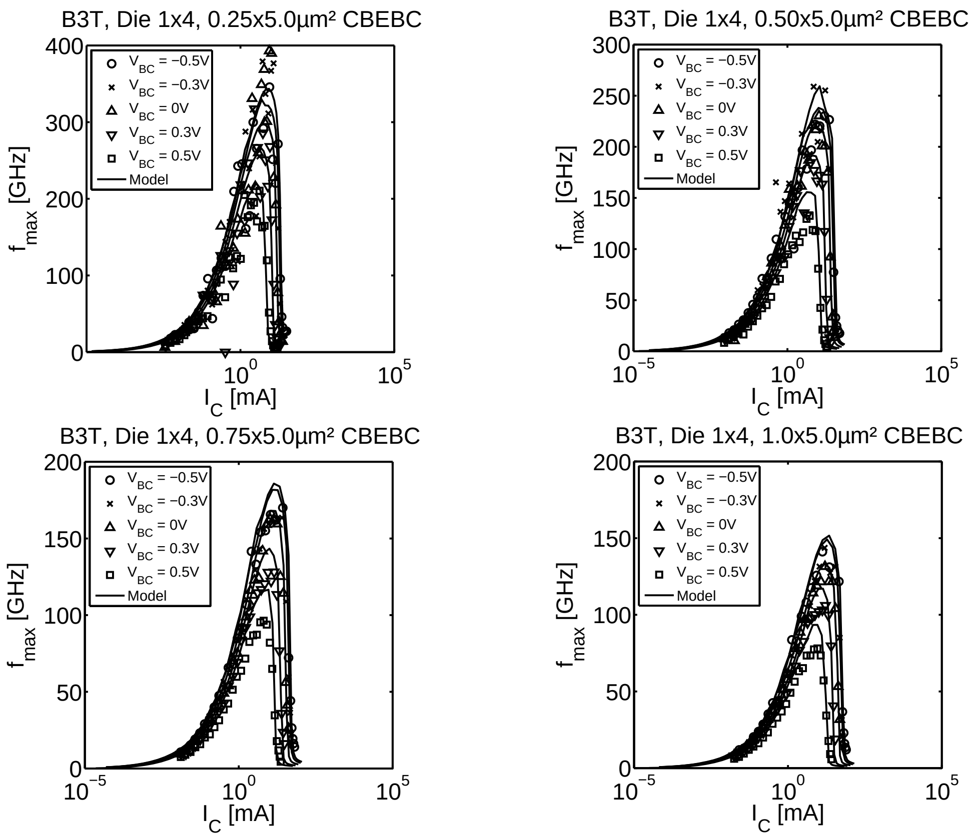
- Normalized transconductance $g_m\ V_T/I_C$ vs. I_C
- ($g_m \approx \mathrm{Real}\{Y_{21}\}$ @ f = 1GHz)
- V_{BC} = 0V

4 Model comparison (cont'd)



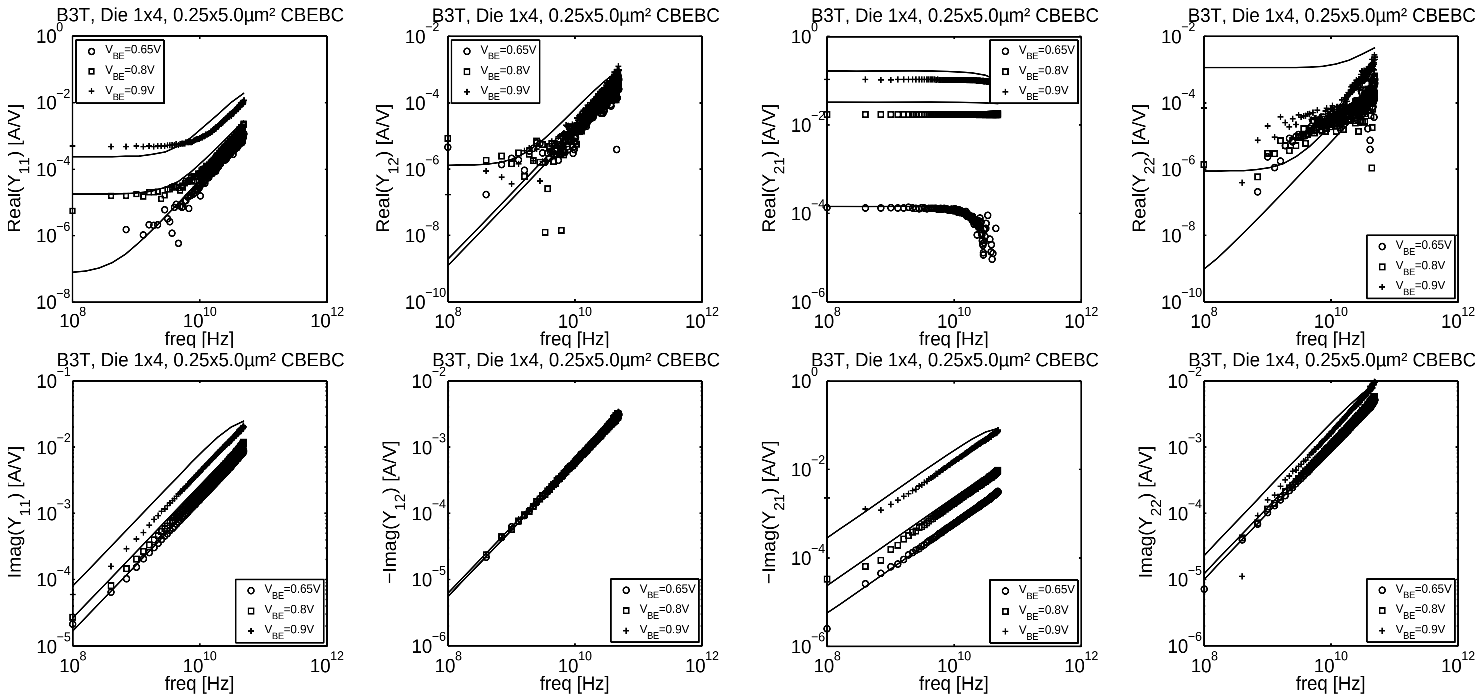
- Transit frequency vs. collector current @ constant V_{BC} = (-0.5, -0.3, 0.0, 0.3 0.5)V
- Good agreement across bias and several widths.

4 Model comparison (cont'd)



- Maximum oscillation frequency (extrapolated from Mason's unilateral power gain) vs. collector current @ constant V_{BC}
- Sufficient agreement across bias and several widths.

4 Model comparison (cont'd)



- Frequency dependence of Y-parameters for device 0.25x5.0µm², V_{BE} = (0.65, 0.8, 0.9)V, V_{BC} = 0V.

5 Summary

- Parameter extraction issues could be observed in HICUM/L2 for very advanced HBTs
- Observation of non-standard scaling effects for C_{BE} and I_C
  - Caused by choice of inproper frequency range
  - Might be due to emitter dimensions that are not precisely known
- Some issues involve an extension of the model formulation $\rightarrow$ cf. presentation A. Pawlak

Acknowledgements

This work was supported by:

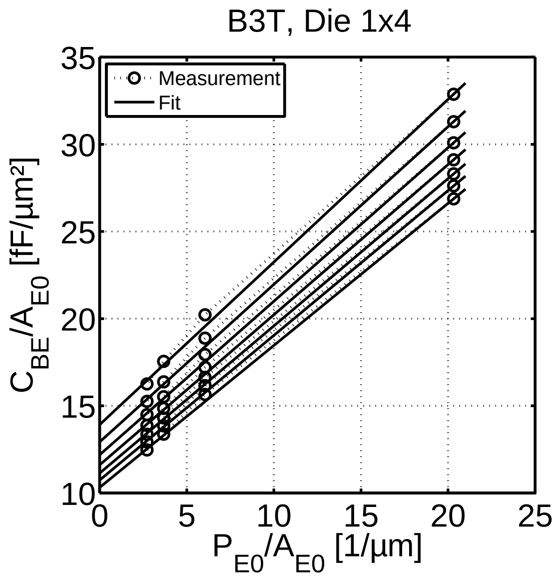
- The European Commision within the framework of the DOTFIVE project (http://www.dotfive.eu).

Thanks to:

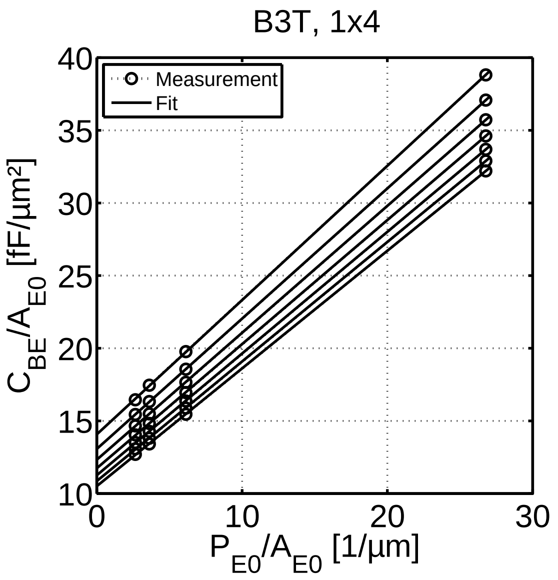
- Bertrand Ardouin for providing model cards and advice
- Didier Céli for his constant support and his help

P/A separation

constant spacer width



optimized spacer widths



Optimization result CBE

	0.25x5.00µm	*0.50x5.00µm*	*0.75x5.00µm*	*1.00x5.00µm*
b_{E0}	0.0756	0.3441	0.6127	0.8812
l_{E0}	5.3851	5.0101	4.7516	4.6093
b_s	0.1744	0.1559	0.1373	0.1188
l_s	-0.3851	-0.0101	0.2484	0.3907

Optimization results