HICUM - Productization and Support Update

Anjan Chakravorty , Michael Schroter

Dept. of Electrical and Computer Engin.
University of California at San Diego
USA

Chair for Electron Devices and Integrated Circuits (CEDIC)
University of Technology Dresden Germany

mschroter@ieee.org , chakravo@iee.et.tu-dresden.de
http://www.iee.et.tu-dresden.de/iee/eb/hic_new/hic_start.html

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Overview

- HICUM/Level2 Version 2.2 release
- Test results
- Documentation
- Code/implementation related investigations
- Version 2.3 in progress
- HICUM/Level0

HICUM/L2 version 2.2 release

- Version 2.21 released in November' 2005
  - allow variable self heating model via flag FLSH
  - provide flexible flicker noise model
  - version control mechanism fixed
  - focus on v2.2 instead of v2.1
  - downward compatibility issues raised and primarily addressed

- Version 2.22 released in August' 2006
  - minor bugs in v2.21 fixed and code rearranged
  - all compatibility issues addressed and fixed
    - temperature related seven incompatible equations
    - incompatibility of collector current spreading
  - compatibility flag FLCOMP can have values of version number (e.g. 2.1)
  - thermal node set as external : issues with NODE COLLAPSING
  - hyperbolic smoothing in internal base resistance formulation

HICUM/L2 version 2.2 release (contd.)

downward ***compatibility*** issues (with respect to v2.1)

- Temperature related (presented in last CMC meeting)
  - Version 2.21 included
    - BE injection related saturation currents
    - BE recombination related saturation currents
    - equilibrium hole charge
    - emitter transit time
  - Version 2.22 additionally included
    - BC saturation currents
    - Substrate transistor transfer and SC saturation currents
    - Voltage separating ohmic and saturation velocity regime

- Collector minority charge in version 2.22
  - separate routine HICFCT for 2D/3D case like in V2.1

HICUM/L2 version 2.2 release (contd.)

internal base resistance

- equation of conductivity modulation

v2.1: $$r_i = r_{Bi0}\left(\frac{Q_0}{Q_0 + \Delta Q_p}\right) = r_{Bi0}\left(\frac{Q_0}{Q_0 + Q_{jEi} + Q_{jCi} + Q_f}\right)$$

v2.21: $$r_i = r_{Bi0}\left(\frac{Q_0}{Q_0 + \Delta Q_p}\right) = r_{Bi0}\left(\frac{Q_0}{Q_0 + Q_{jEi} + Q_f}\right)$$

ADS2005: $$\Delta Q_{pm} = q_{0lim} + \frac{1}{2}[\Delta Q_p - q_{0lim} + \sqrt{(\Delta Q_p - q_{0lim})^2 + \delta^2}]$$

$$q_{0lim} = -0.75 Q_0 \quad \text{and} \quad \delta = Q_0(T_0) \times 10^{-3}$$

$$r_i = r_{Bi0}\left(\frac{Q_0}{Q_0 + \Delta Q_{pm}}\right)$$

HICUM/L2 version 2.2 release (contd.)

internal base resistance

version 2.22 includes a solution simpler to ADS

- equation of conductivity modulation

v2.22:

$$r_i = r_{Bi0}\left(\frac{Q_0}{Q_0 + \Delta Q_p}\right) = r_{Bi0}\left(\frac{1}{\frac{q_r + \sqrt{q_r^2 + 0.01}}{2}}\right)$$

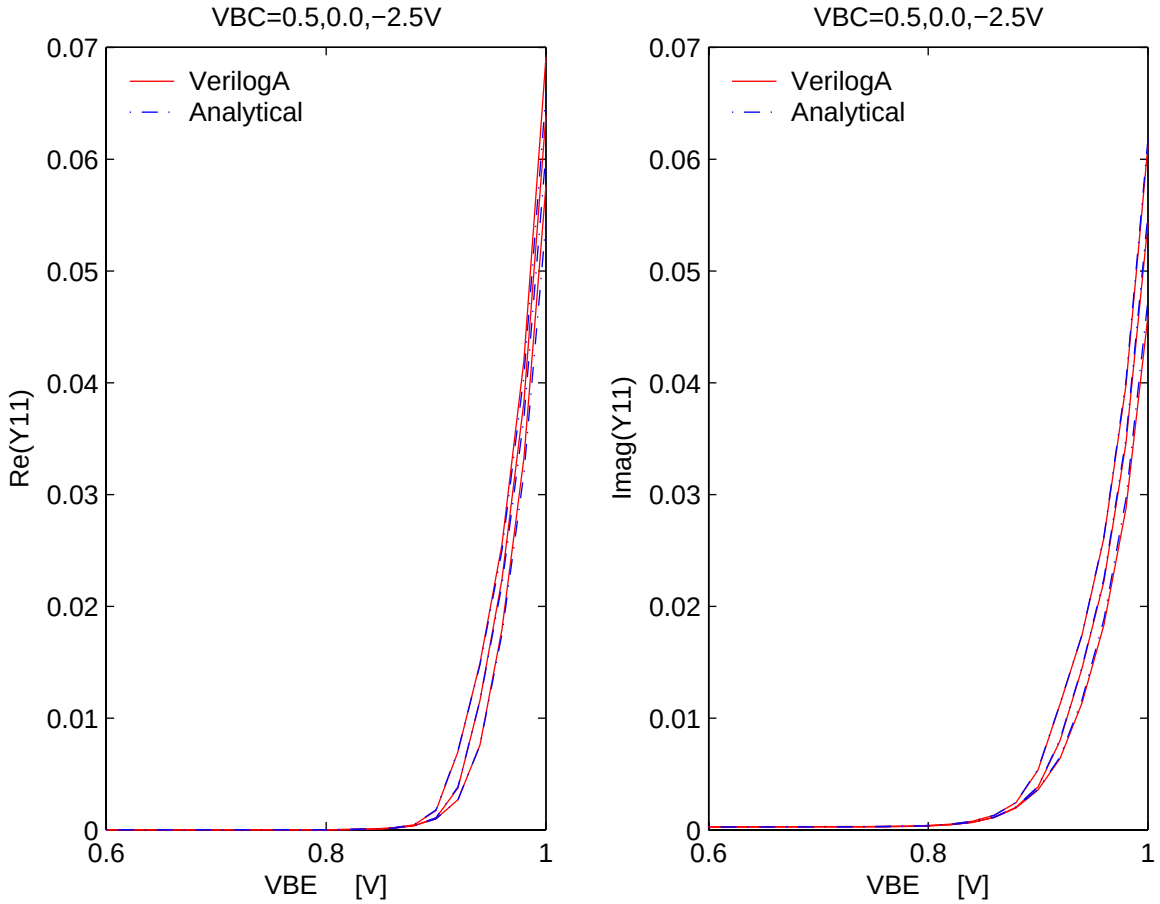
$$q_r = 1 + \frac{\Delta Q_p}{Q_0} = 1 + \frac{Q_{jEi} + Q_{jCi} + Q_f}{Q_0}$$

- Q_{jCi} included as in original model formulation
- numerical instability removed with hyperbolic smoothing

Test results

internal transistor model : Y11 plot at T=300K

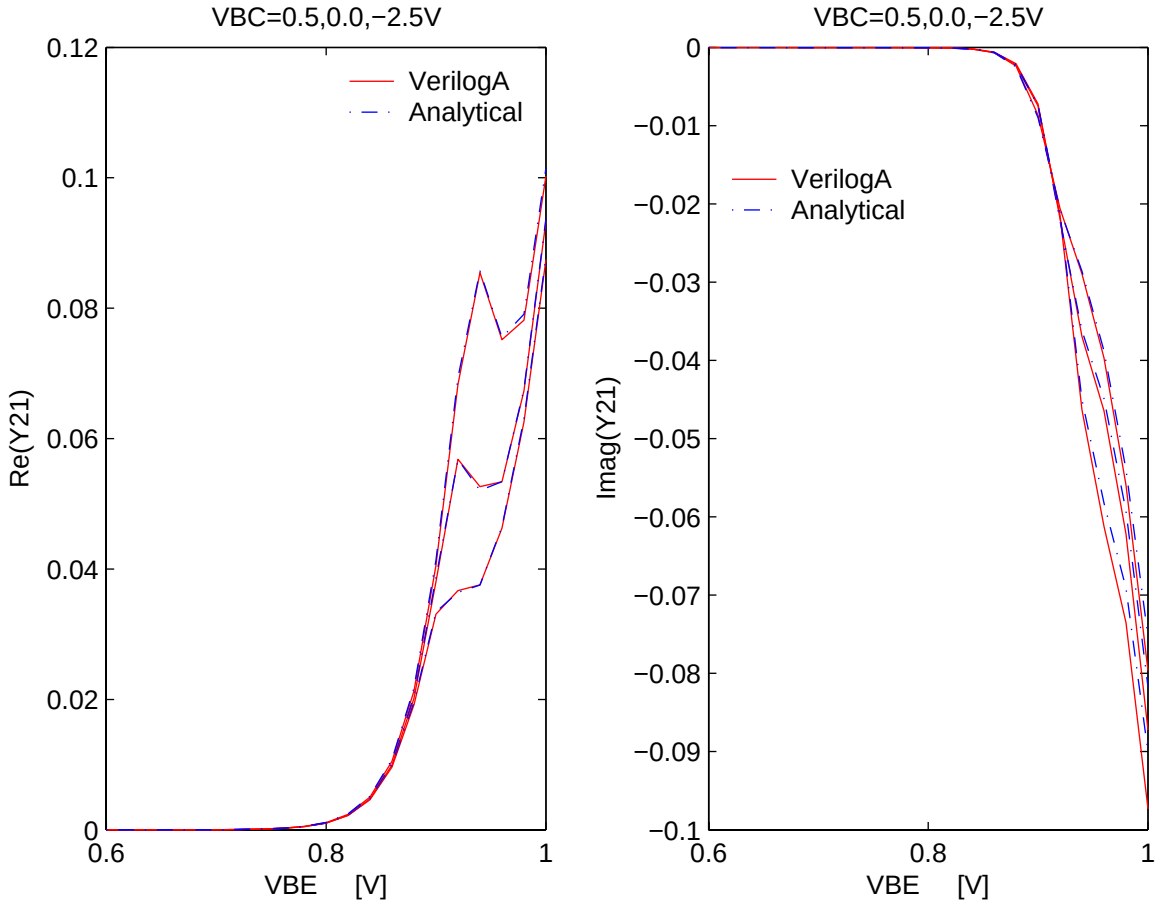
vbc=0.5,0.0,-2.5 V, Verilog-A v2.22: red, analytical: blue



Test results (contd.)

internal transistor model : Y21 plot at T=300K

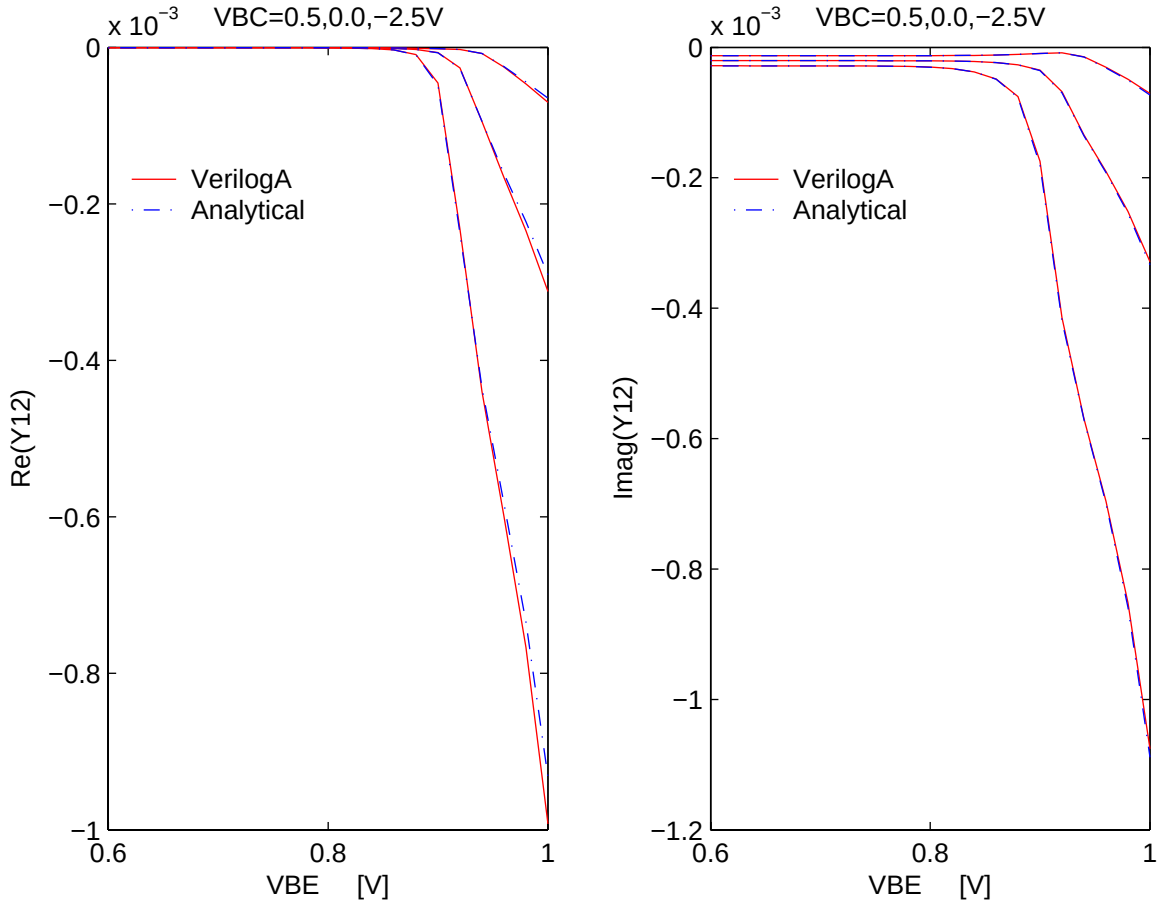
vbc=0.5,0.0,-2.5 V, Verilog-A v2.22: red, analytical: blue



Test results (contd.)

internal transistor model : Y12 plot at T=300K

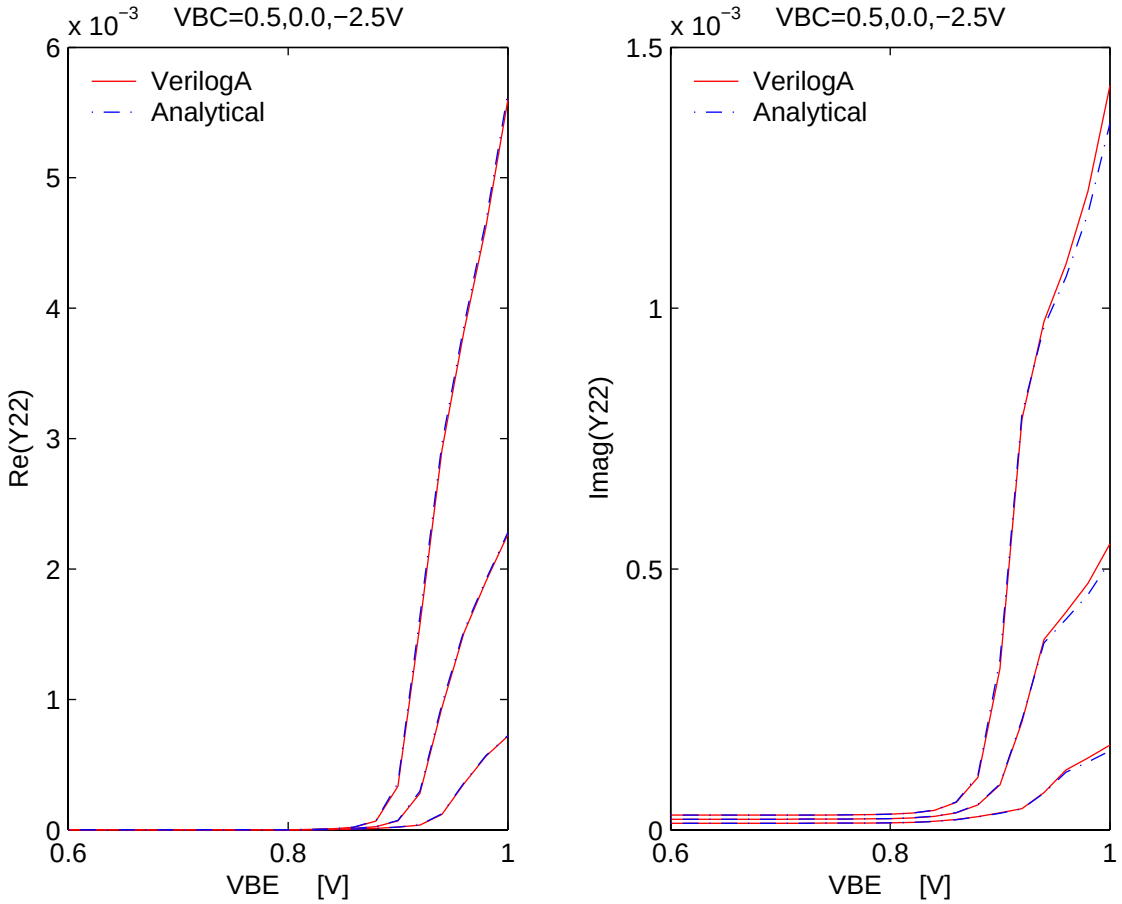
vbc=0.5,0.0,-2.5 V, Verilog-A v2.22: red, analytical: blue



Test results (contd.)

internal transistor model : Y22 plot at T=300K

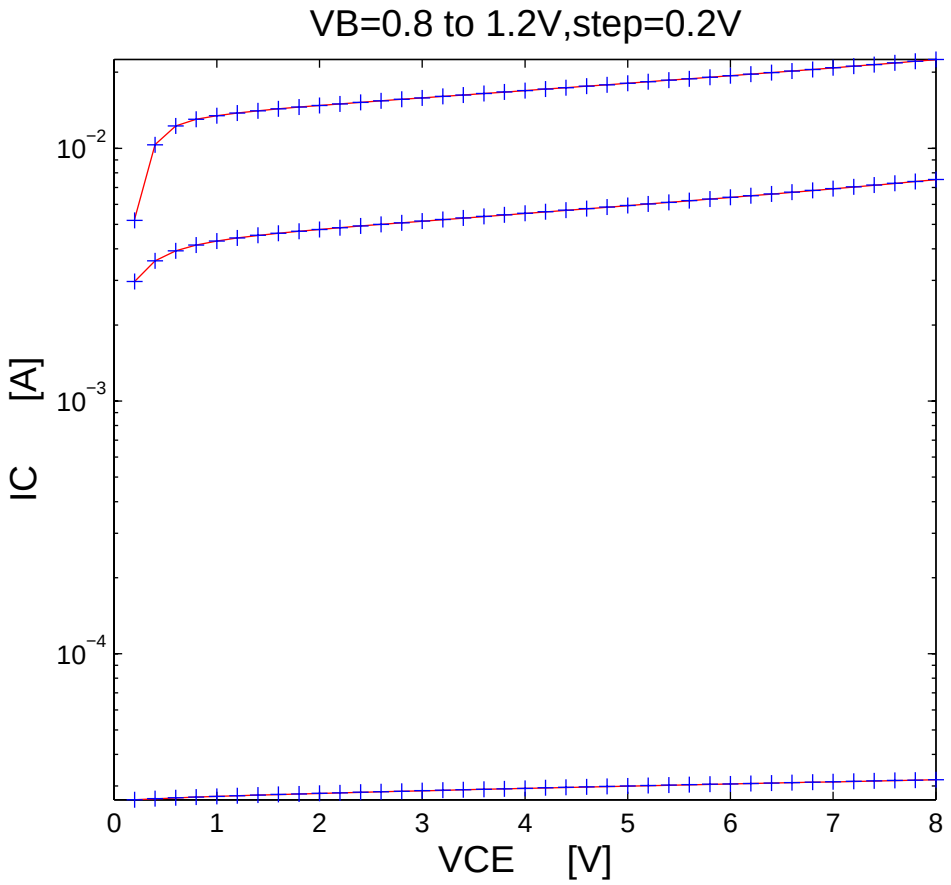
vbc=0.5,0.0,-2.5 V, Verilog-A v2.22: red, analytical: blue



Test results (contd.)

compatibility test with self-heating: output characteristics

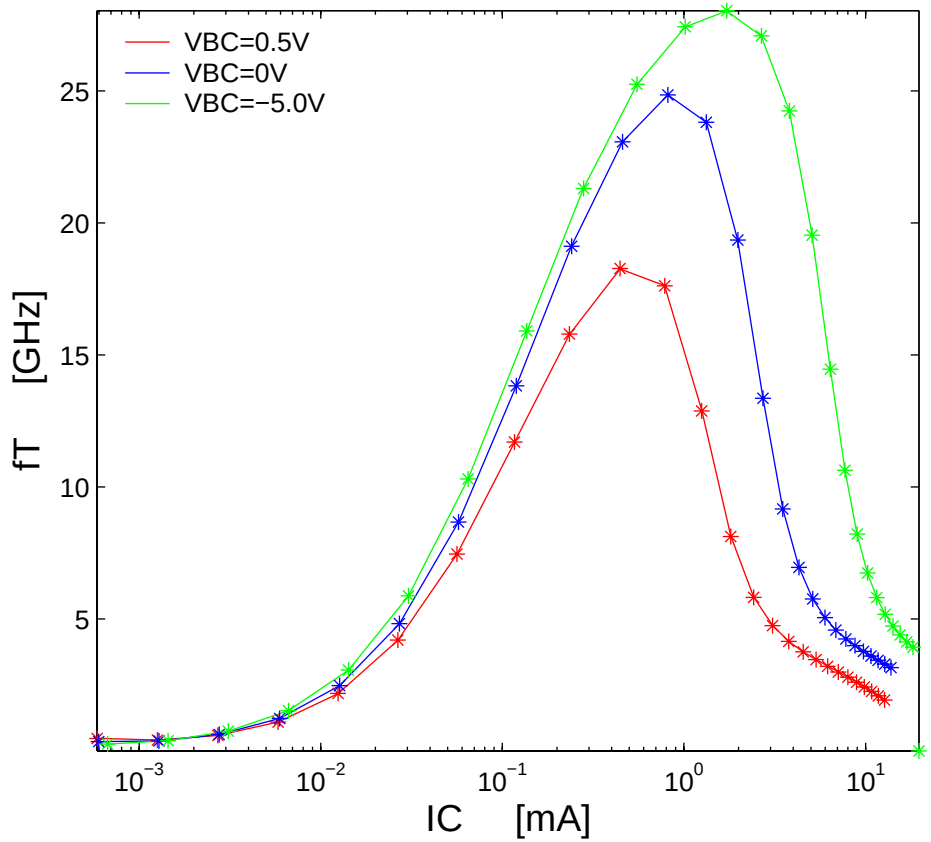
T=300K, FLSH=1, v2.22: continuous line, v2.11: symbols



Test results (contd.)

compatibility test with self-heating: transit frequency (@0.5GHz)

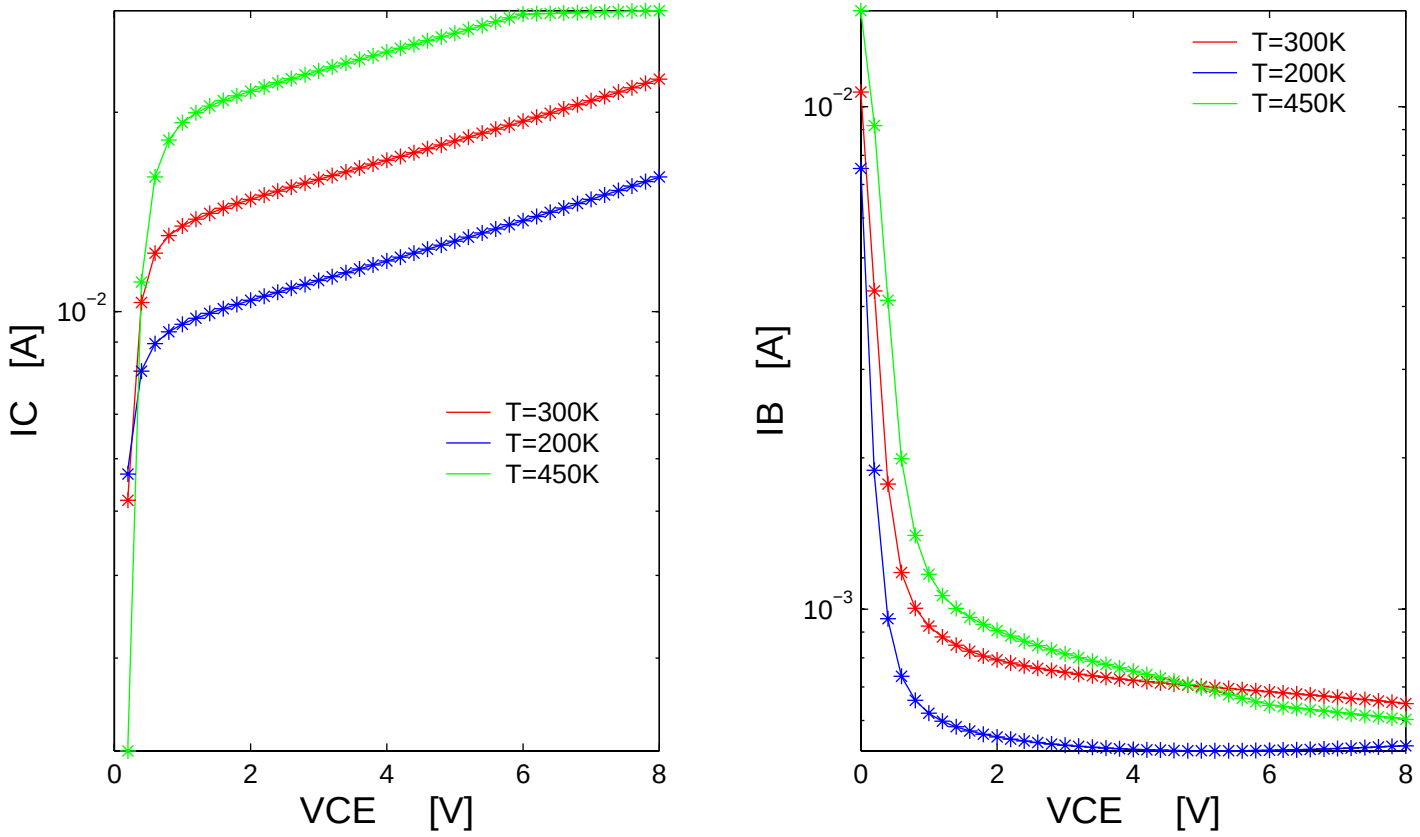
T=300K, FLSH=1, v2.22: continuous line, v2.11: symbols



Test results (contd.)

compatibility test with self-heating: output characteristics

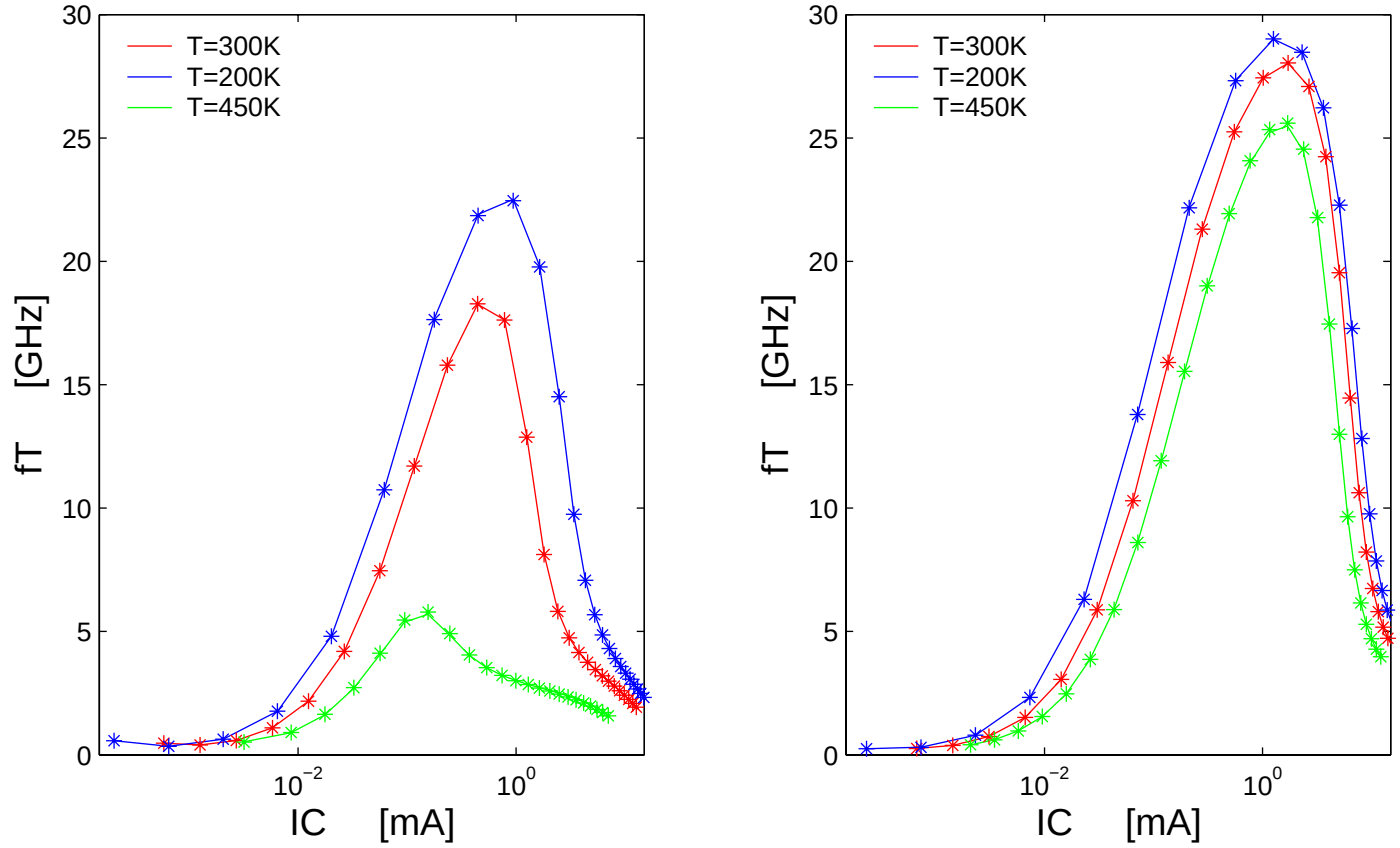
FLSH=1, vbe=1.2V, v2.22: continuous line, v2.11: symbols



Test results (contd.)

compatibility test with self-heating: transit frequency (@0.5GHz)

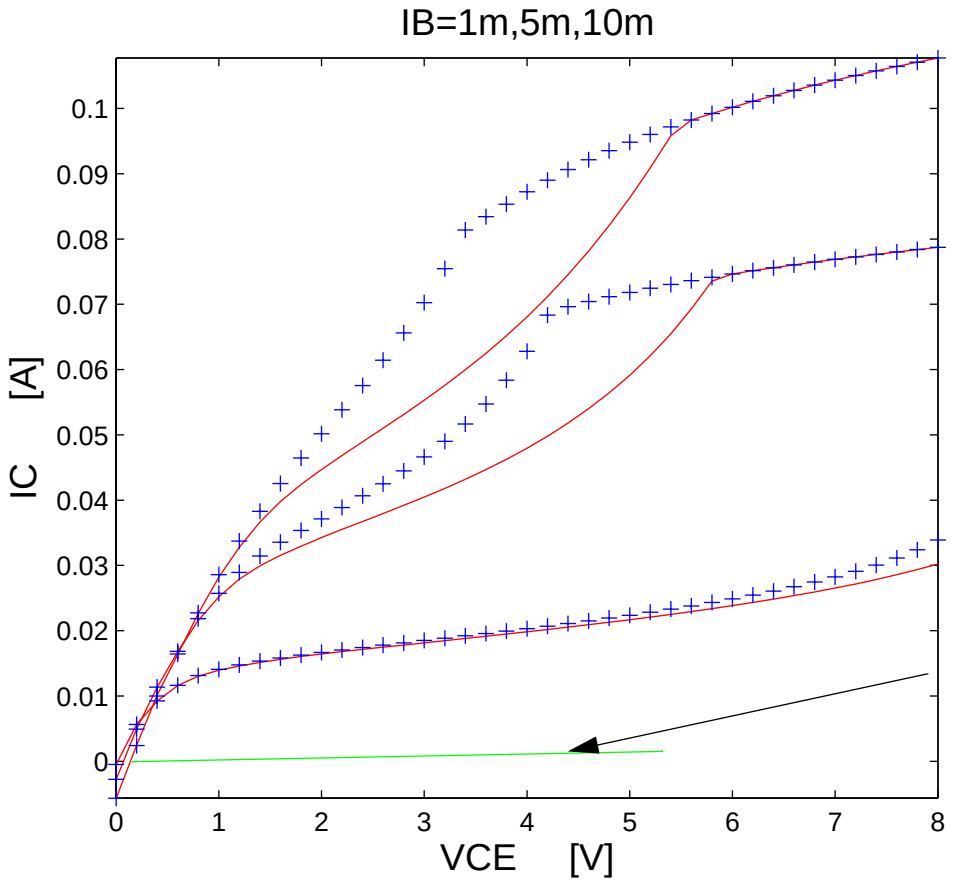
FLSH=1, vbc=0.5,-5.0V, v2.22: continuous line, v2.11: symbols



Test results (contd.)

comparison with self-heating: output characteristics

v2.22, T=300K, FLSH=1: continuous line, FLSH=2: symbols

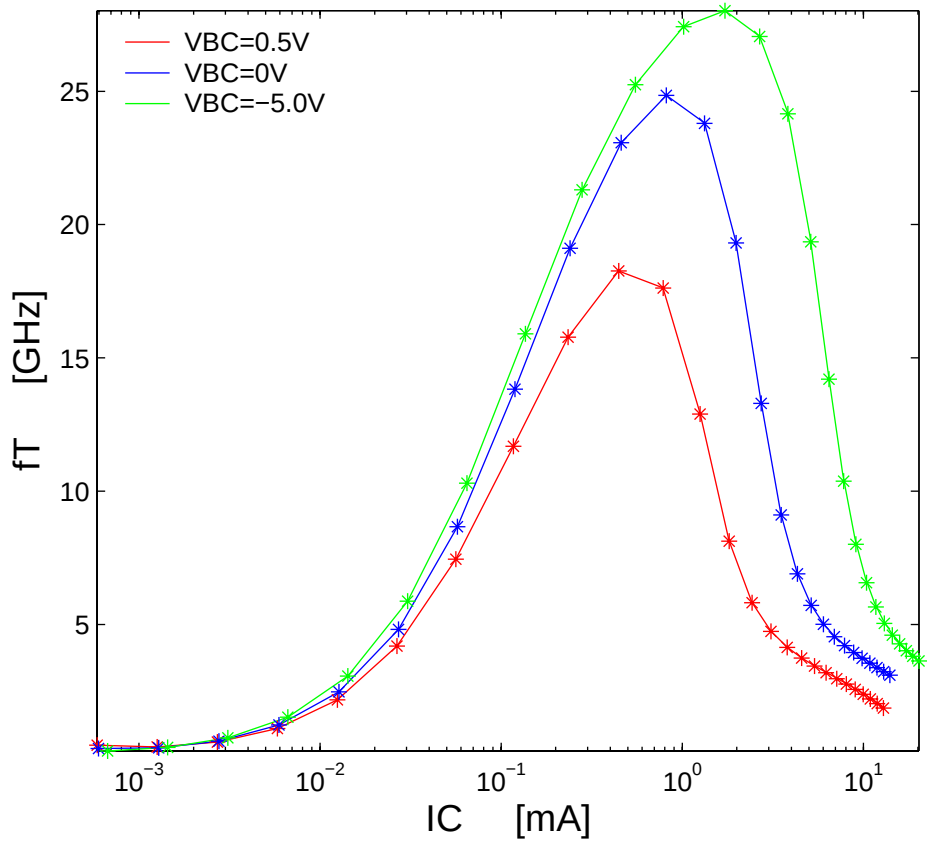


current level at peak f_T

Test results (contd.)

comparison with self-heating: transit frequency (@0.5GHz)

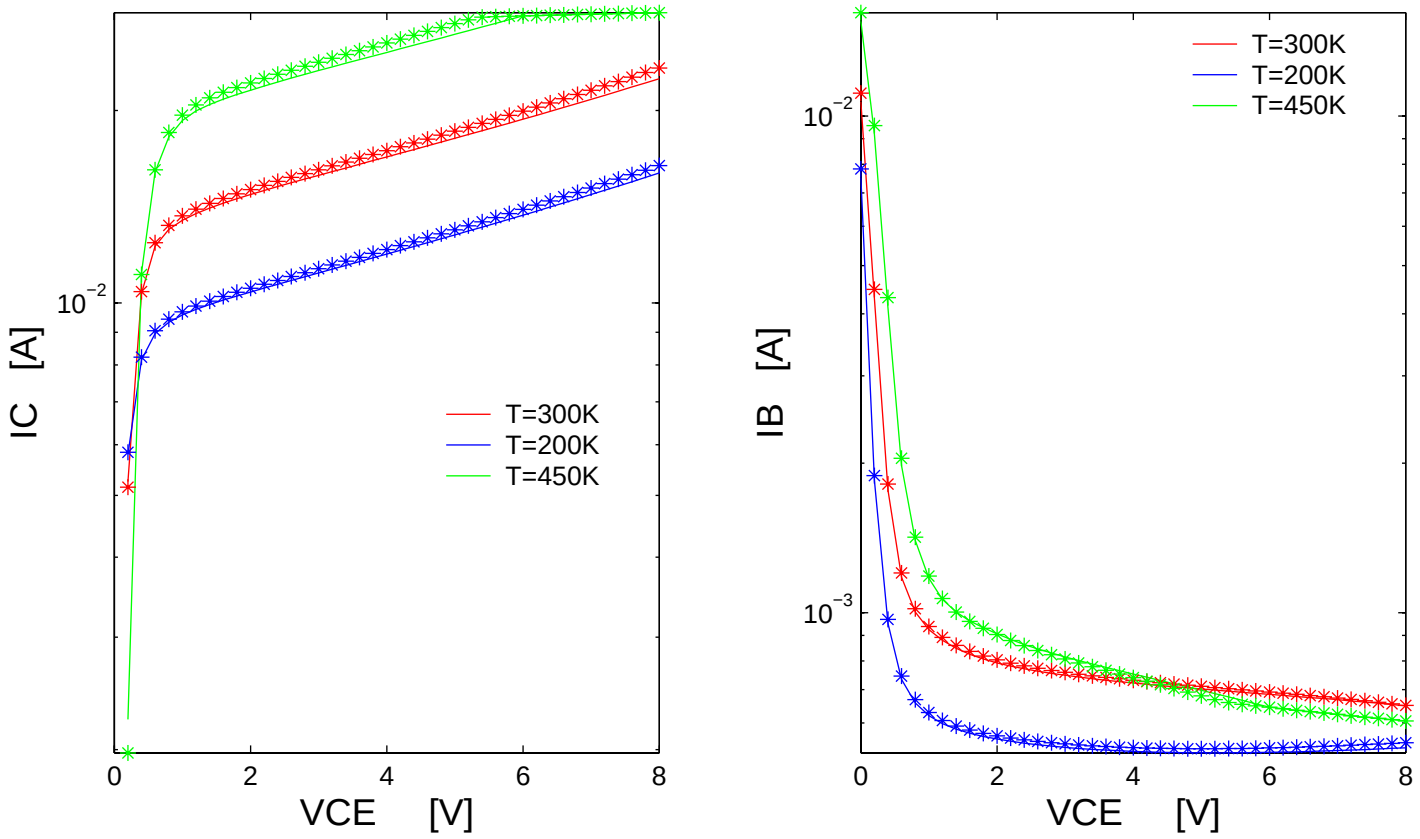
v2.22, T=300K, FLSH=1: continuous line, FLSH=2: symbols



Test results (contd.)

comparison with self-heating: output characteristics

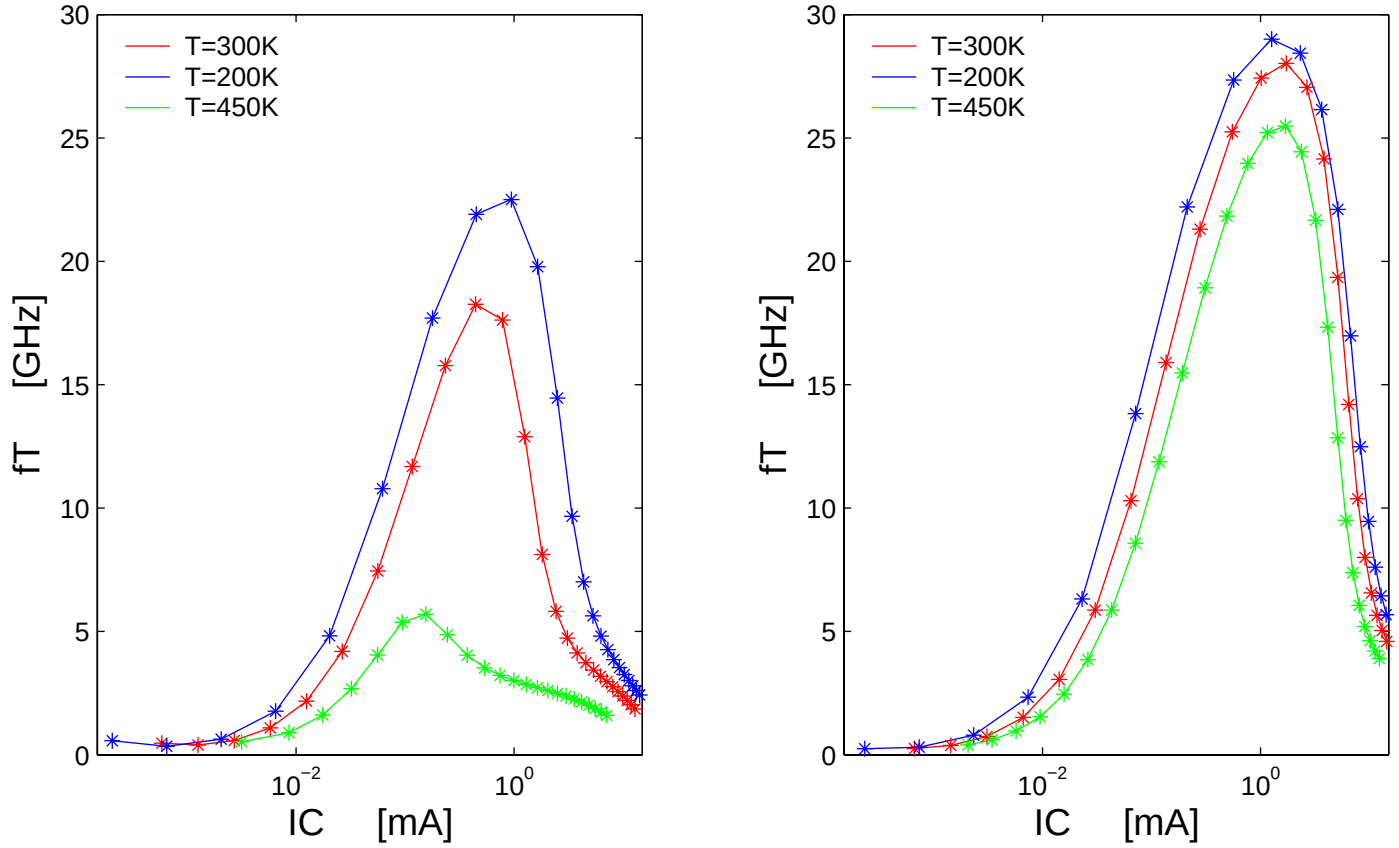
v2.22, vbe=1.2V, FLSH=1: continuous line, FLSH=2: symbols



Test results (contd.)

comparison with self-heating: transit frequency (@0.5GHz)

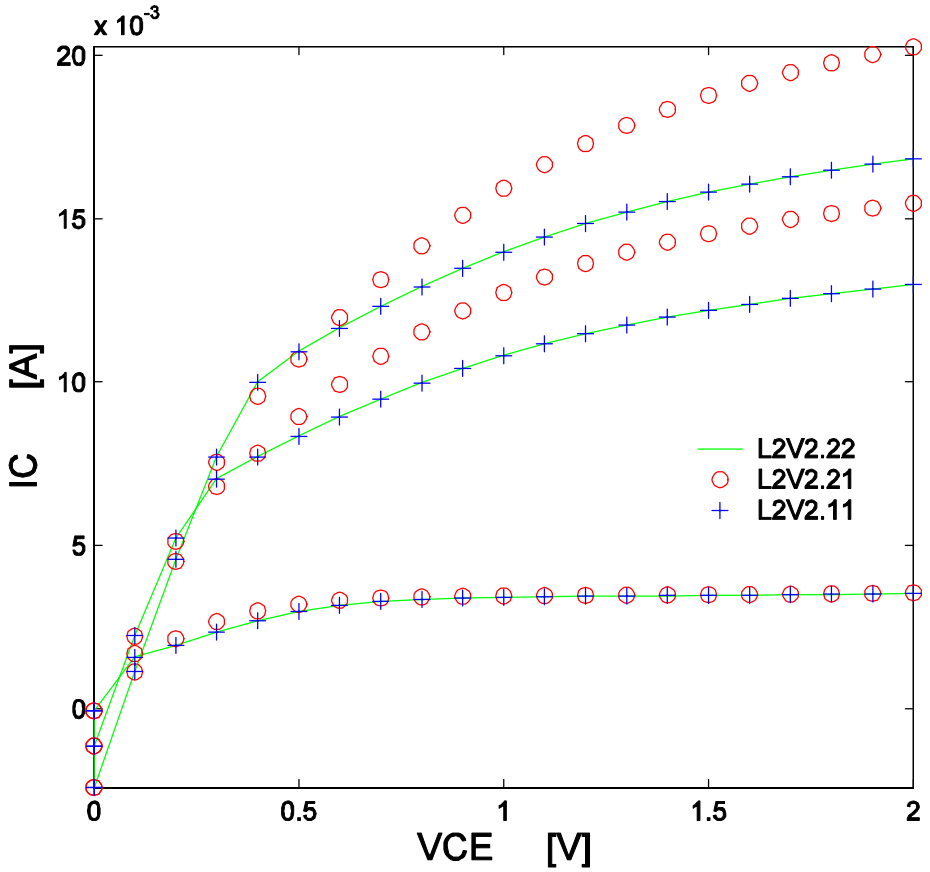
v2.22, vbc=0.5,-5V, FLSH=1: continuous line, FLSH=2: symbols



Test results (contd.)

compatibility with current spreading: output characteristics

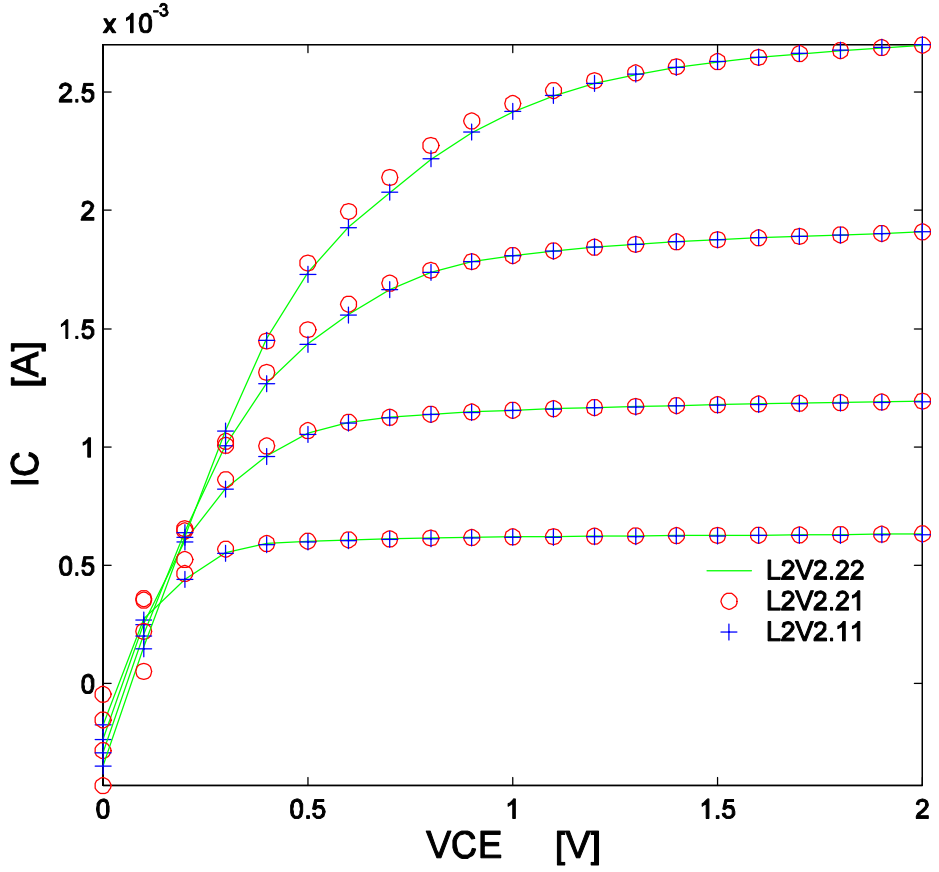
vbe=1,1.5,2V, T=27 ^{0}C



Test results (contd.)

compatibility with current spreading: output characteristics

T=-75,-25,25,75 ^{0}C, vbe=1V



Other activities

- Documentation
  - version 2.22 release notes available on web-site
  - latest documentation update: August ’06
  - most recent results/development/information:
    see website under "Events" => HICUM Workshop

- Code/implementation related investigations
  - correlated noise between base and collector current reported at BCTM06
  - Verilog-AMS specific coding: use of ddx()
  - compiler related information exchange (Freescale, Tiburon)

Version 2.3 in progress

funded by research grants

- NQS effect
  - investigating efficient way for implementing NQS effects
- Correlated Noise
  - investigating efficient option for implementation of proposed solution
- Field based model investigation
  - B-C depletion charge and capacitance as function of current *and* voltage
  - non-local B-C breakdown
  - improved physics-based model for base and collector related minority charge and transit time

HICUM/Level0

funded by research grants

- version 1.11 released in November'05
  - parameters given proper ranges
  - temperature related equations like in L2v2.22: including non-ideal base currents
  - diode currents limited to avoid convergence problem
  - thermal, shot and flicker noise included
  - implemented for NPN and PNP

v1.11:

$$I_{RES}(T) = I_{RES}(T_0)\left(\frac{T}{T_0}\right)^{m_g/2} \exp\left[\frac{V_{gBE}(0)}{2V_T}\left(\frac{T}{T_0}-1\right)\right]$$

- version 1.12 to be released
  - five-terminal model : thermal node set as external
  - introduction of flag FLSH (0,1,2): control of SH calculations
  - all series resistors and RTH will be limited to a minimum value : convergence
  - increase of code clarity
  - substrate transistor current added
  - hyperbolic smoothing in base resistance formulation to avoid divide-by-zero error (s. L2)
  - under test

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