NQS modelling with HiCuM: What works, what doesn't

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Outline

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  - Scaling of NQS parameters
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Introduction: NQS basics

- **NQS basics:**

  As the operating frequency approaches the cutoff frequency, the transistor can no longer follows external excitations instantaneously. (Non Quasi Static effect)

- **Transient variation of electron concentration inside the base**

Switch-off

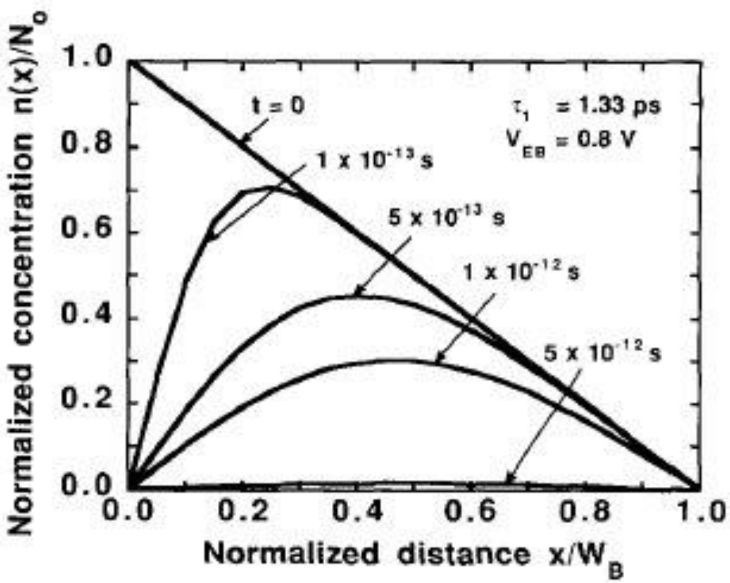


Fig. 5. Transient variation of electron concentration profile when V_{EB} de creases from the switch-on voltage to zero.

Switch-on

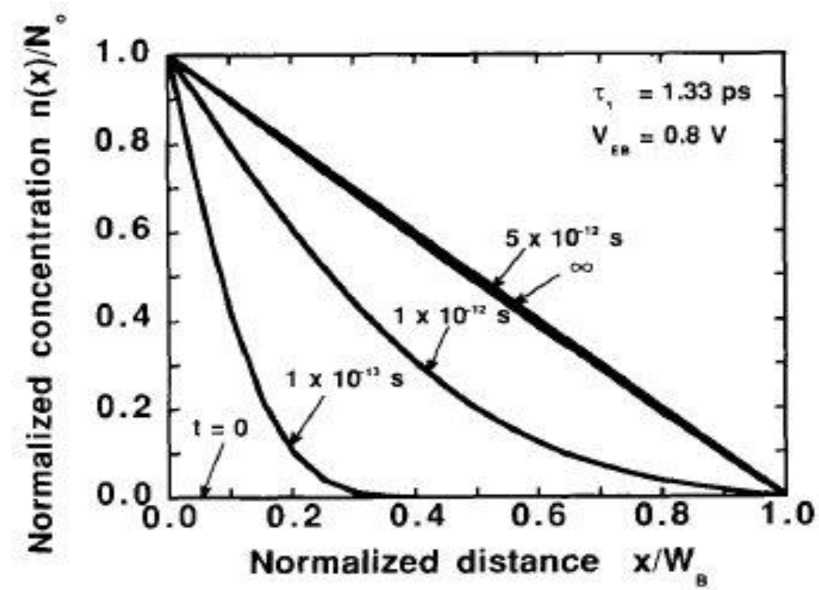


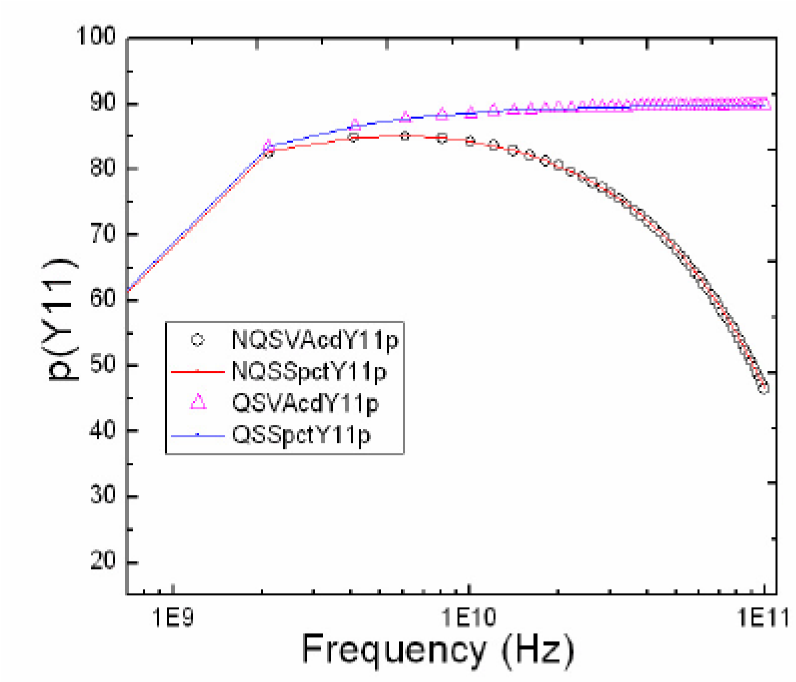
Fig. 8. Transient variation of electron concentration profile when V_{EB} increases from zero to the switch-on voltage.

From Suzuki IEEE TED 1992

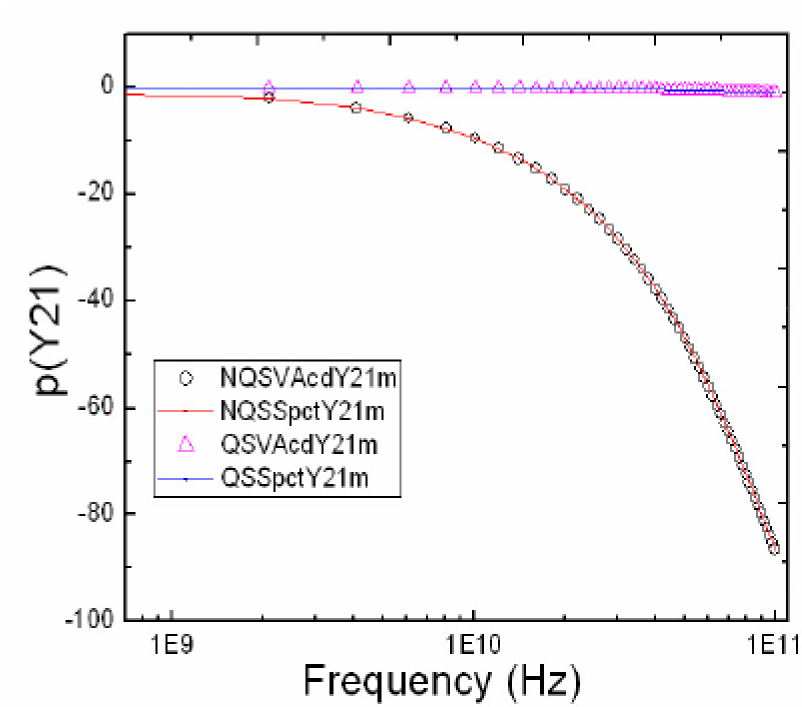
Introduction: high frequency Y parameters

- Phase of admittance parameters show NQS effect.

Phase(y.11)



Phase(y.21)

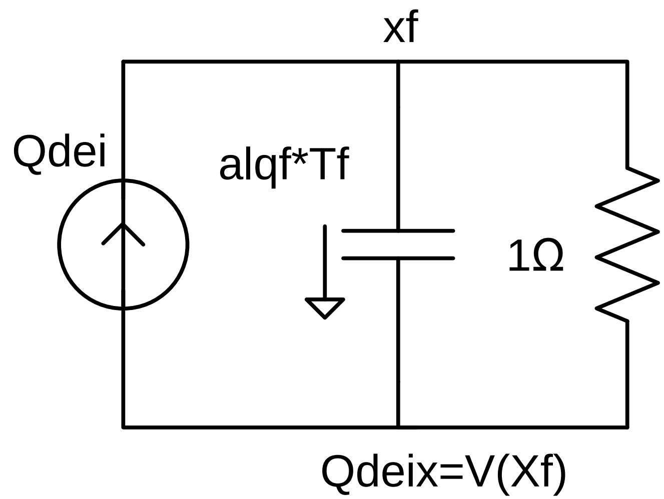


HICUM- Productization and Support Update, Oct 2007.

NQS model implementation : vertical NQS

- **Phase shift network with excess charge.**

HBT HICUML2V24

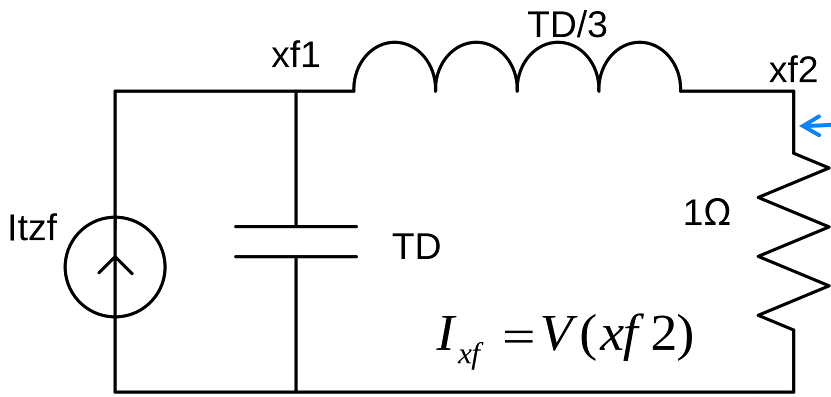


$$Q_{deix} = \frac{Q_{dei}}{1 + sT_D}$$

$$T_D = alqf.T_f$$

NQS model implementation: vertical NQS

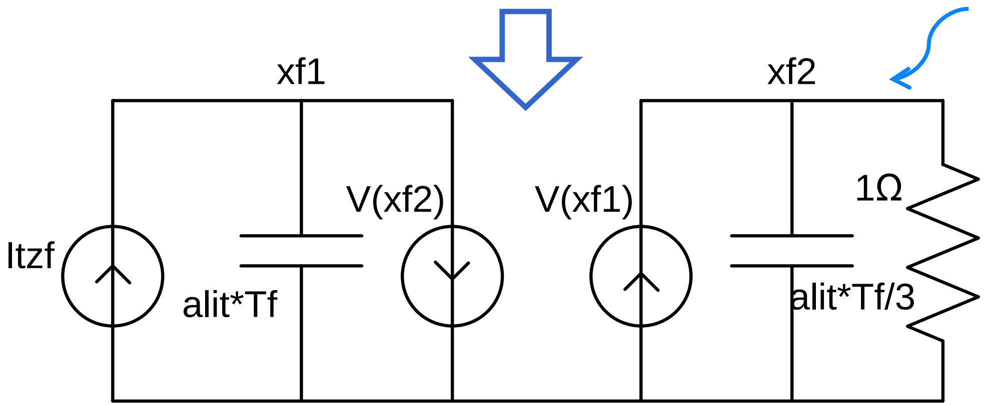
- Phase shift network with transfer current (HICUML2).



$$I_{xf} = V(xf2)$$

Weil-McNamee formulation

$$I_{txf} = \frac{I_{tzf}}{1 + sT_D + (sT_D^{'})^2}$$



$$I_{xf} = V(xf2)$$

Gyrator equivalent formulation (L. Lemaitre)

$$I_{tzf} = \frac{d}{dt}(alit * T_f * V(xf1)) + V(xf2)$$

$$V(xf1) = \frac{d}{dt}(alit * T_f / 3 * V(xf2)) + V(xf2)$$

$$I_{txf} = \frac{I_{tzf}}{1 + sT_D + (sT_D^{'})^2}$$

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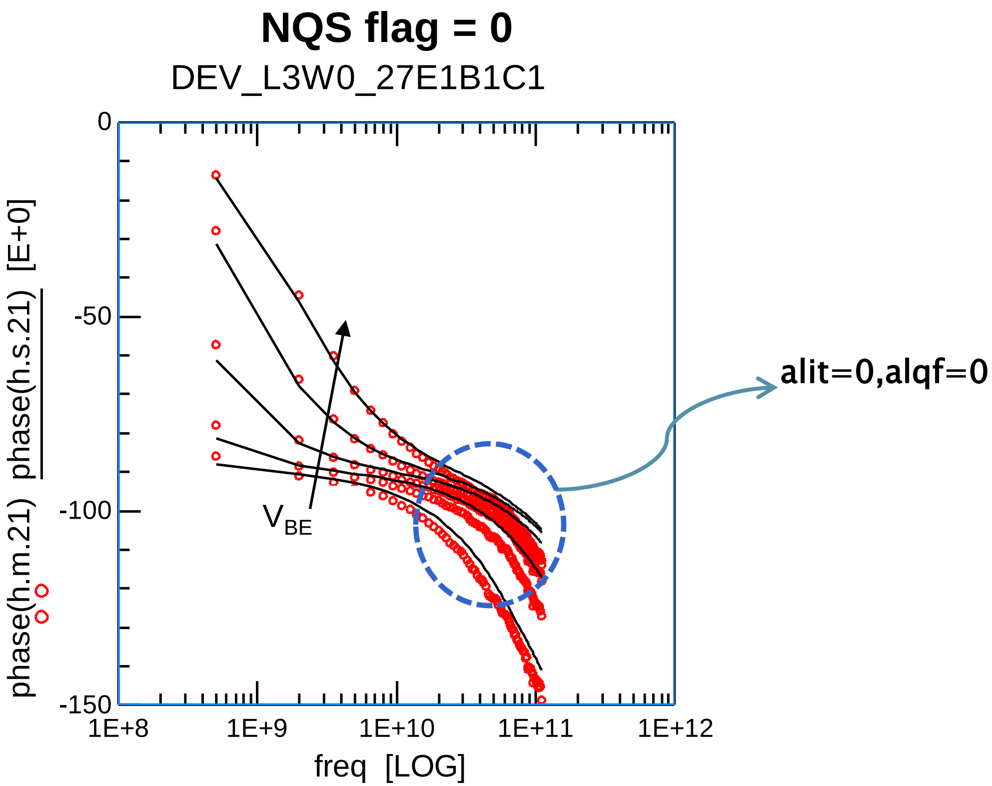
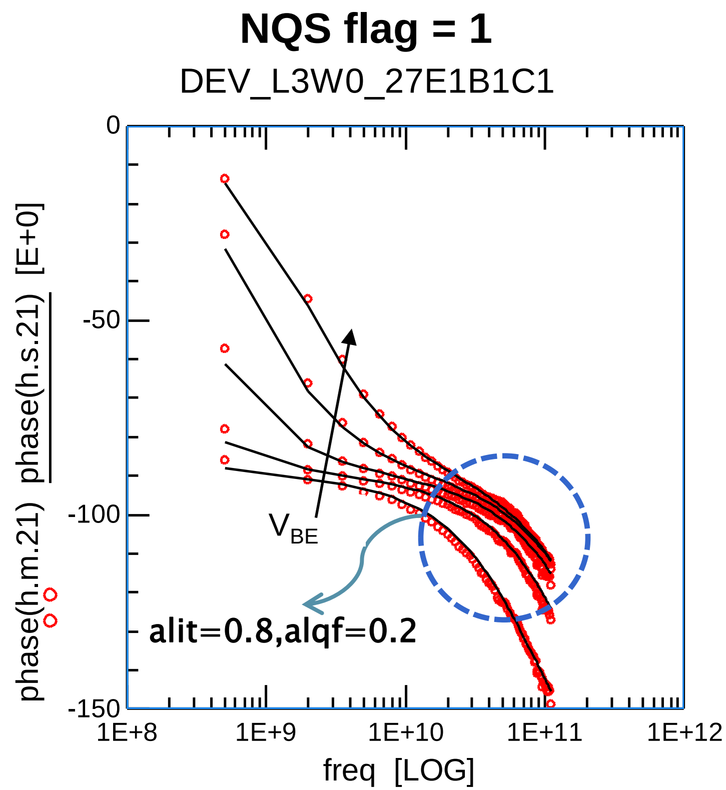
Modeling results: NQS modeling with HICUM L2

- Compact modeling of transistor having B3T technology and BiCMOS9MW layout. (f_T peak =240GHz)
- h_{21}: phase (current gain) V_{BE}=0.76V -> 0.92V, V_{CE}=1.2V





NQS effect in h_{21} phase and modeled using HICUM L2V24 model in a transistor of L_E = 3µm and W_E = 0.27µm.

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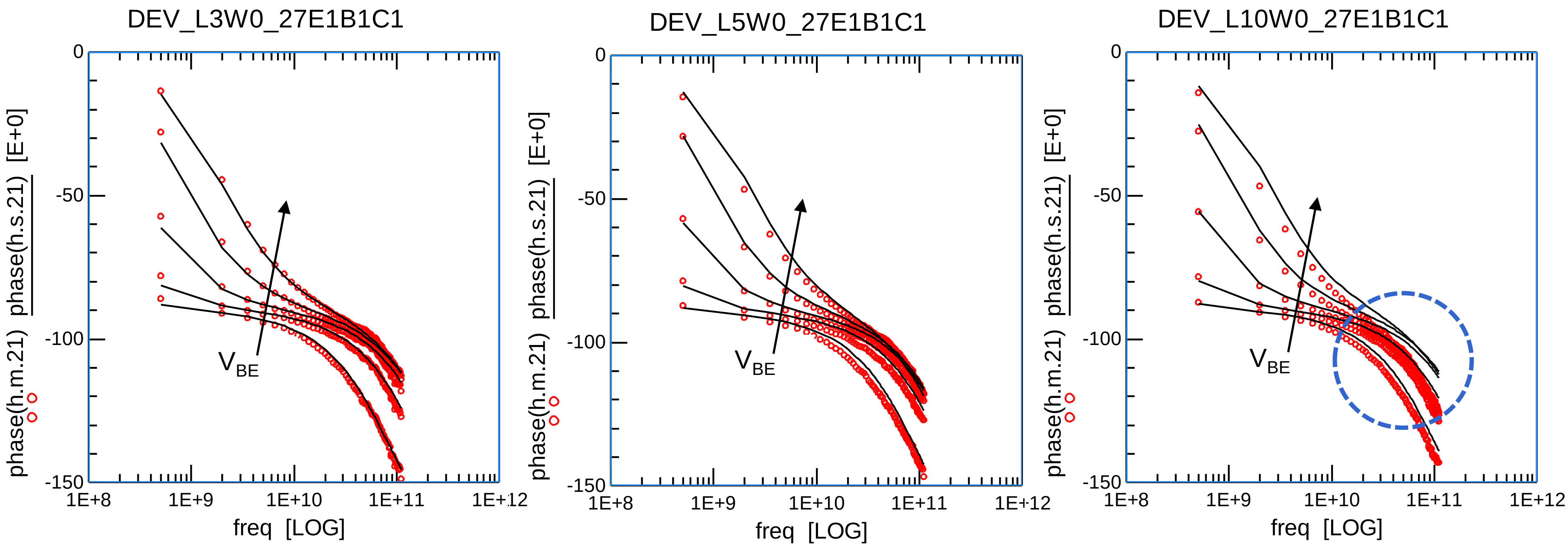
Modeling results: NQS modeling with HICUM L2

- Parameter optimization in different devices V_{BE}=0.76V -> 0.92V, V_{CE}=1.2V



NQS effect in h_{21} phase and modeled using HICUM L2.24 model for transistors having emitter Lengths (L_E) = 3µm, 5µm, 10µm and emitter width (W_E) = 0.27µm.

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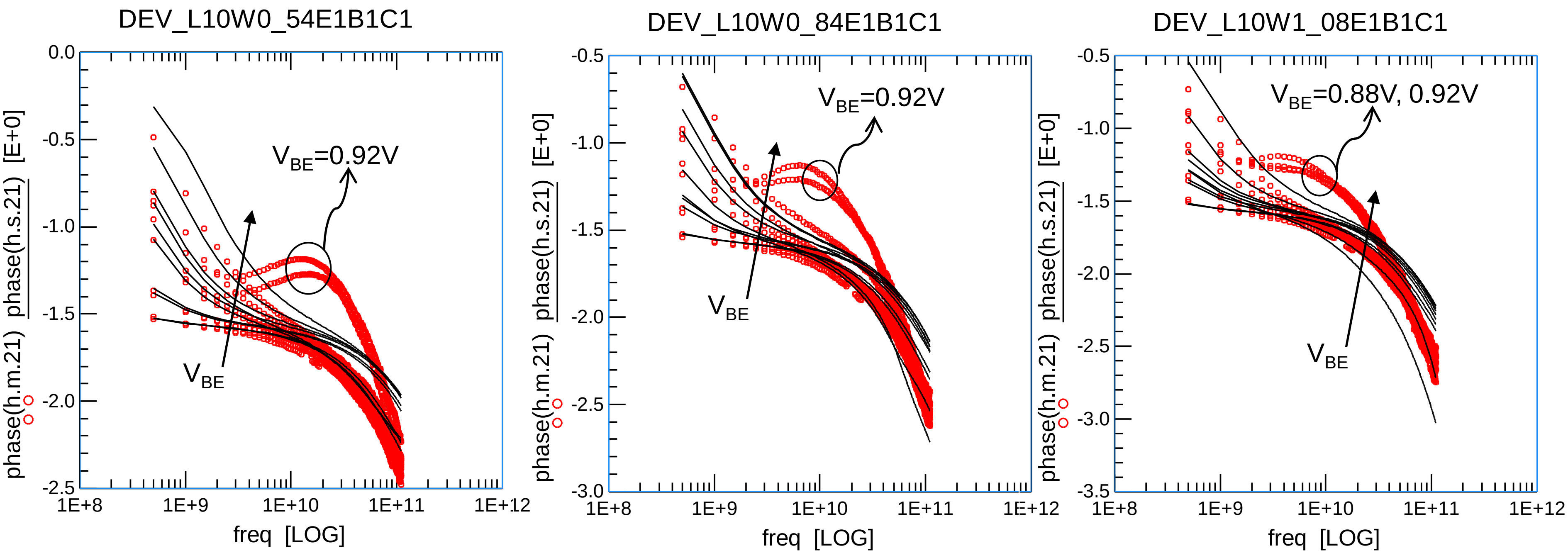
Modeling results: NQS modeling with HICUM L2

- Large transistors show abnormality in h_{21} phase at high injection level



h_{21} phase for different W_E (0.54, 0.84, 1.08µm) with same L_E (10µm) at V_{BE}=0.76V -> 0.92V, V_{CE}= 0.8V, 1.2V

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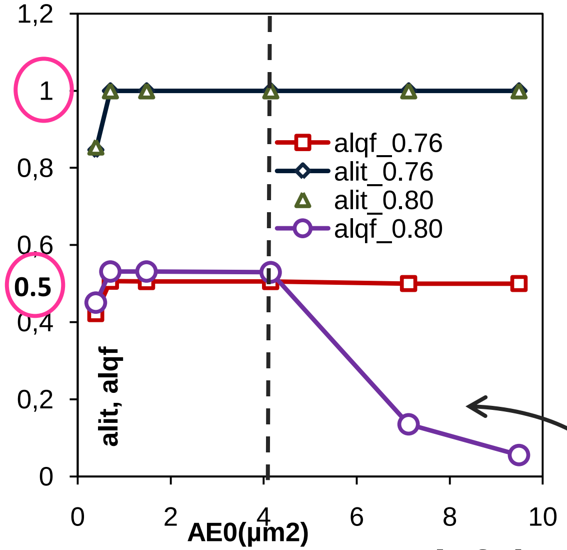
Modeling results: : Scaling of NQS parameters

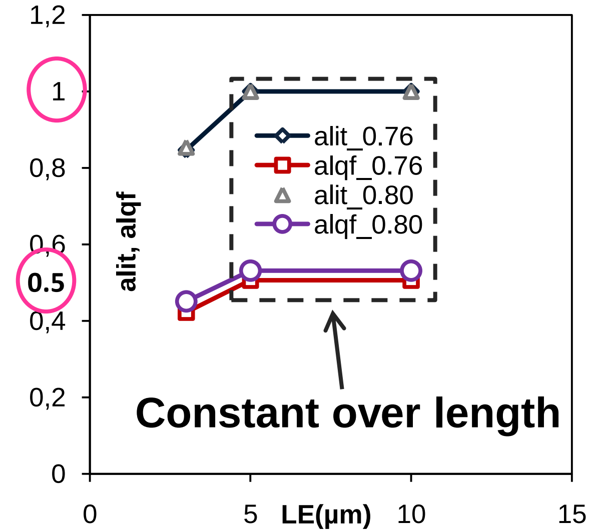
- NQS parameters are optimized for low injection level and plotted against emitter length (L_E) and real emitter area (considering the spacer width of 55 nm).

NQS parameters at V_{BE}=0.76V and 0.80V and V_{CE}=1.2V



alit= 1.0

alqf= 0.5



alqf decreases at higher emitter area

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Conclusion

- NQS basic is presented is presented while showing the HICUM implementation.
- HBT Modeling results with HICUM L2V24 model are presented.
- HICUM provides good results but at high frequency and long devices there is scope for modification (essderc paper 2011, submitted).
- Transistors with higher emitter widths show abnormality in h_{21} phase at high injection.
- Scaling of two NQS parameters show that constant value of NQS parameters (alit=1, alqf=0.5) provide a good modeling accuracy.

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