INDIUM PHOSPHIDE DOUBLE HETEROJUNCTION BIPOLAR TRANSISTORS WITH T-SHAPED EMITTER METAL FEATURES HAVING CUTOFF FREQUENCIES IN EXCESS OF 200 GHZ

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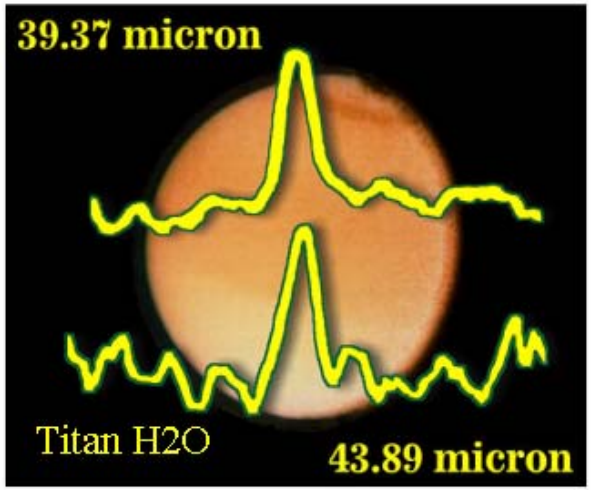
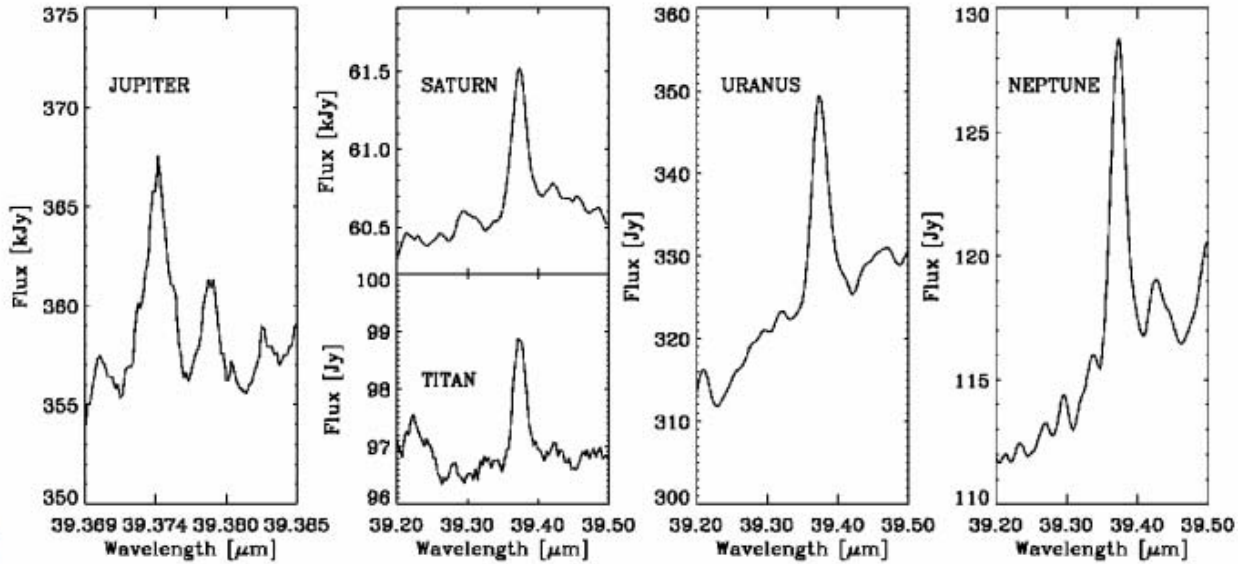
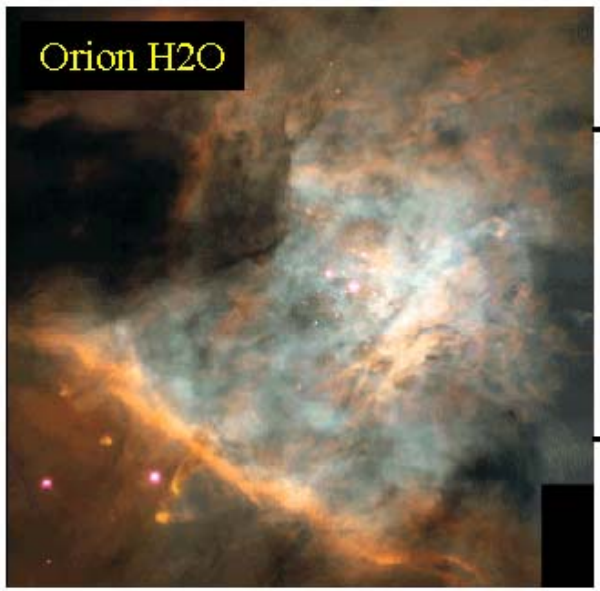
Introduction

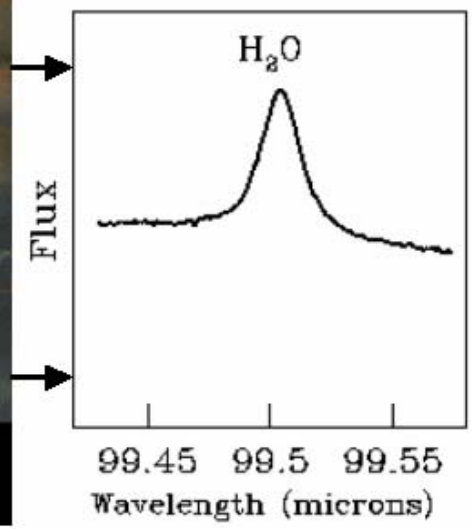
- Motivation
  - Improve electronic instruments for spectroscopy.
  - Develop and utilize the fastest transistors (Heterojunction Bipolar Transistors) for advancing heterodyne receivers.
- Device Development
  - Microfabrication of HBTs
  - T-emitter metal structure
- Results
  - DC and RF HBT characteristics
  - Matched HBT amplifier characteristics
- Summary
- Acknowledgments

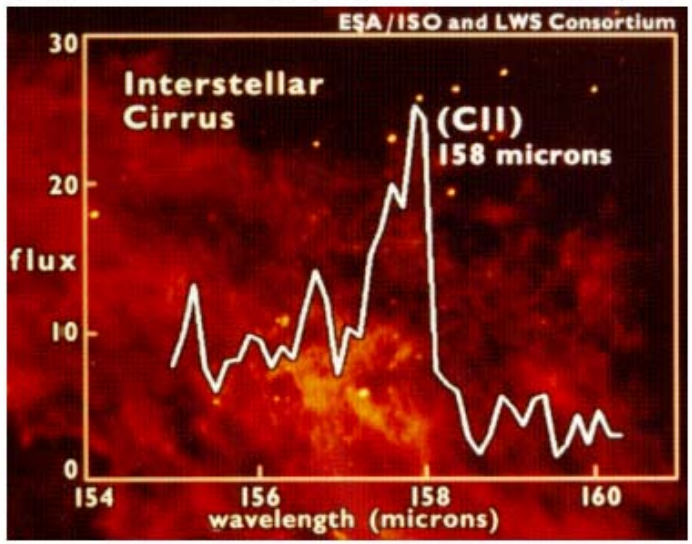
Motivation





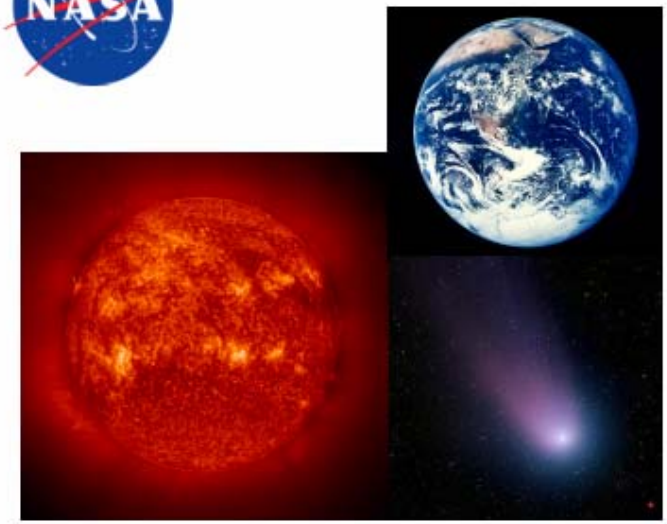


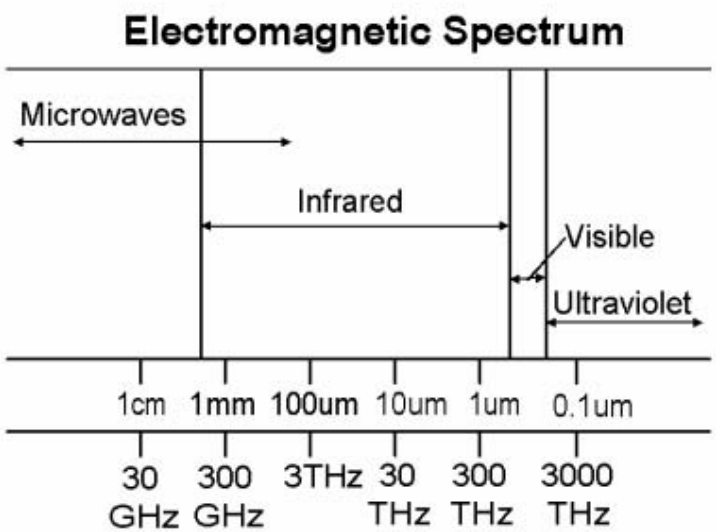




Source: http://www.iso.vilspa.esa.es

Motivation

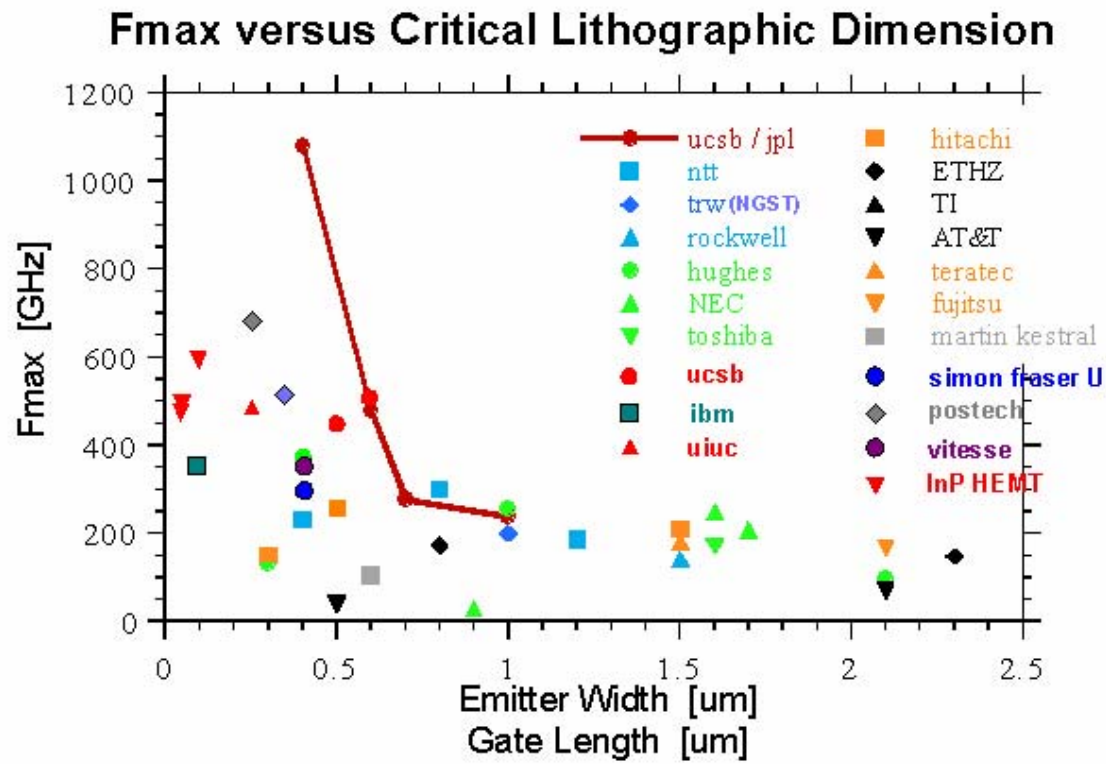




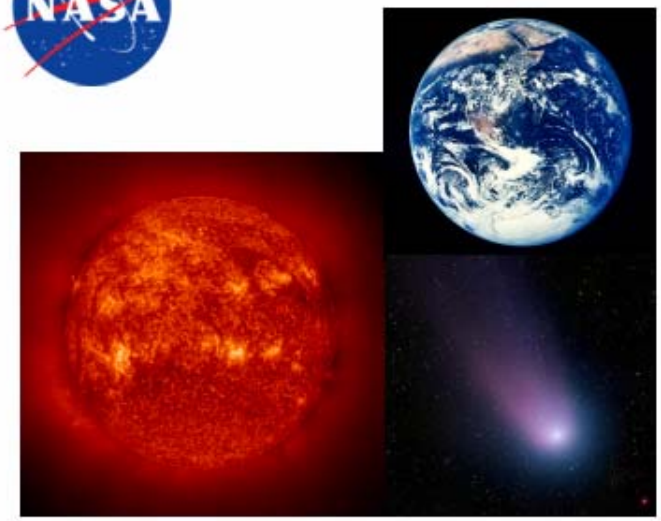
Microwave/Infrared Spectroscopy

Carbon II - 1.9 THz, H20 - 7.6 THz (Organic Life)

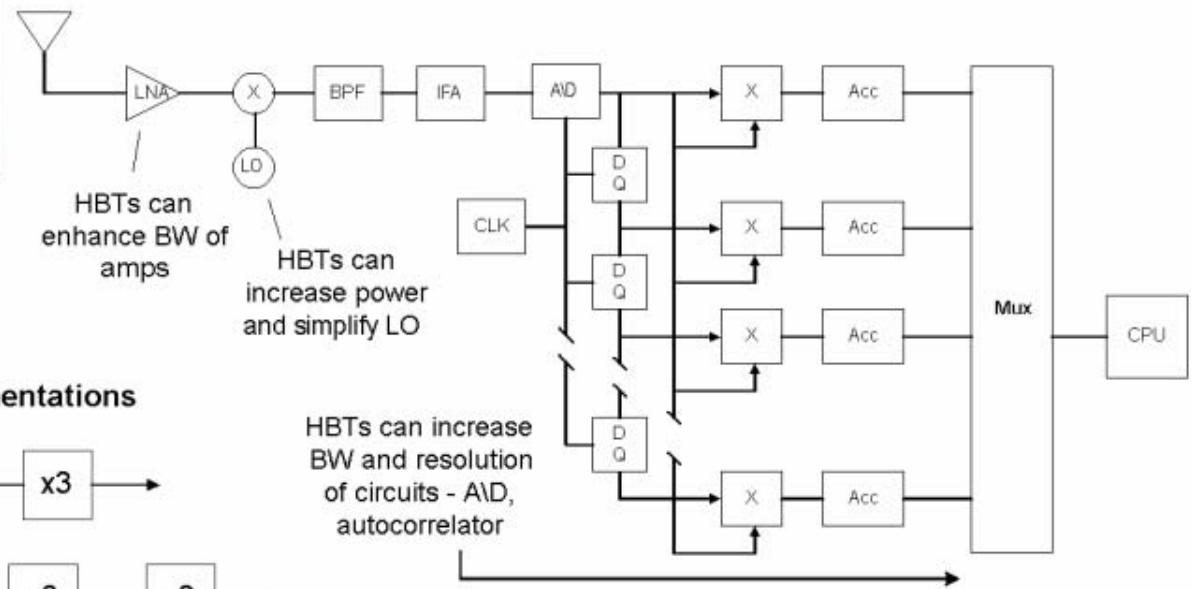
Hydrogen deuteride - 2.7 THz (Big Crunch)



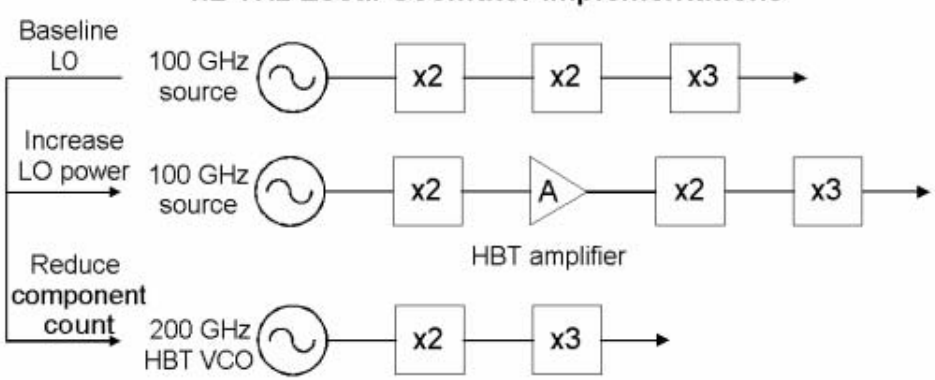
Motivation



Receiver Schematic

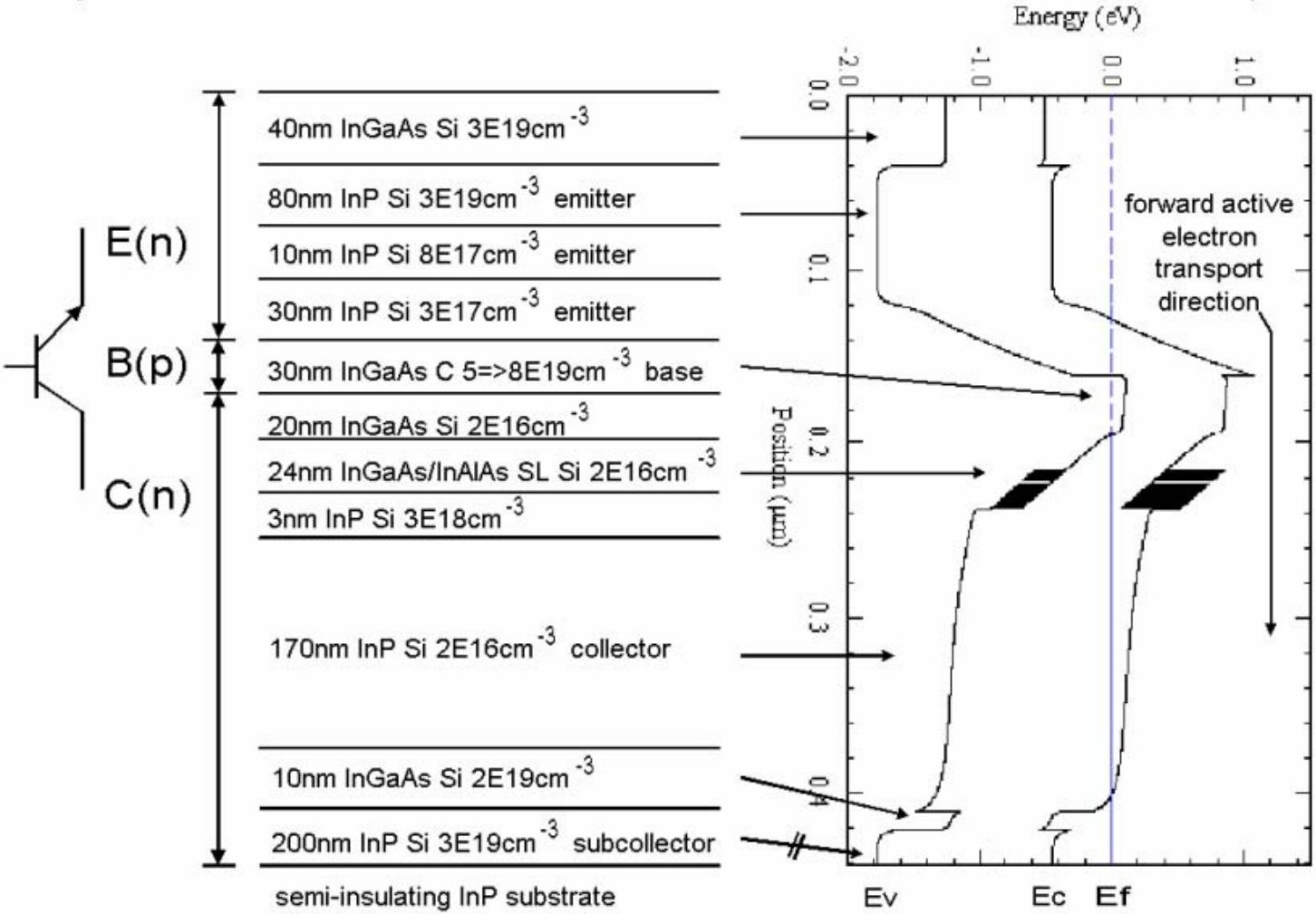


1.2 THz Local Oscillator Implementations



Device Development

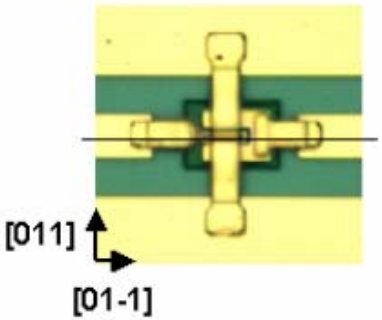
- Epitaxial Structure - InP/InGaAs/InP Double HBT (DHBT)

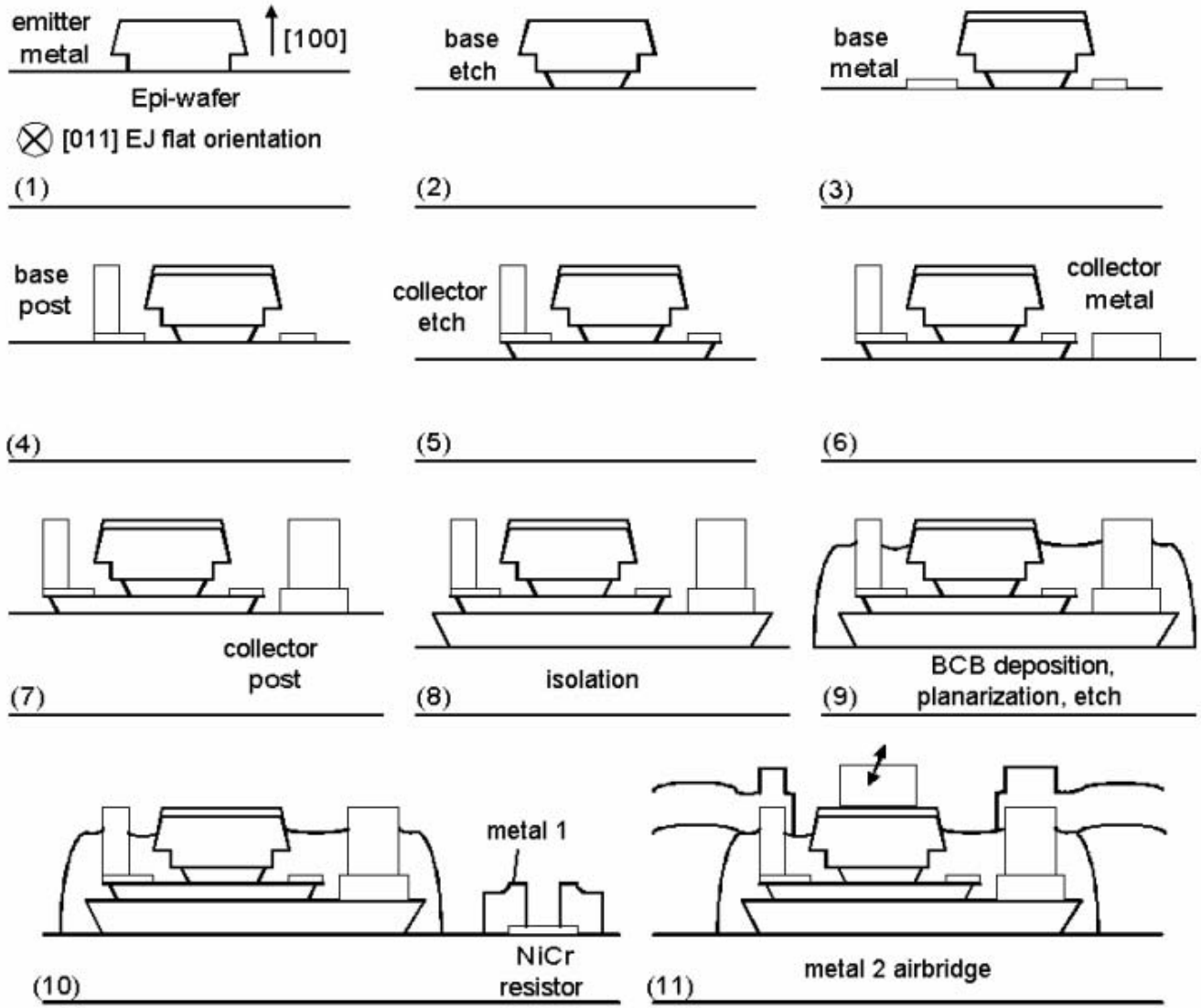


* Energy level versus position diagram generated with Bandprofiler of W. Frensley UTDallas

Device Development

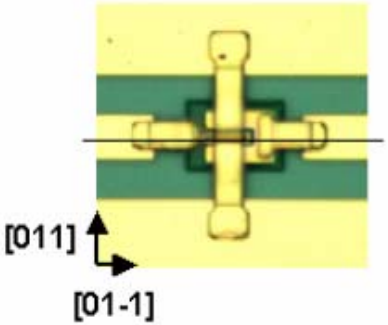
- Triple Mesa DHBT Microfabrication

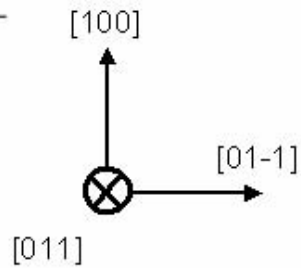


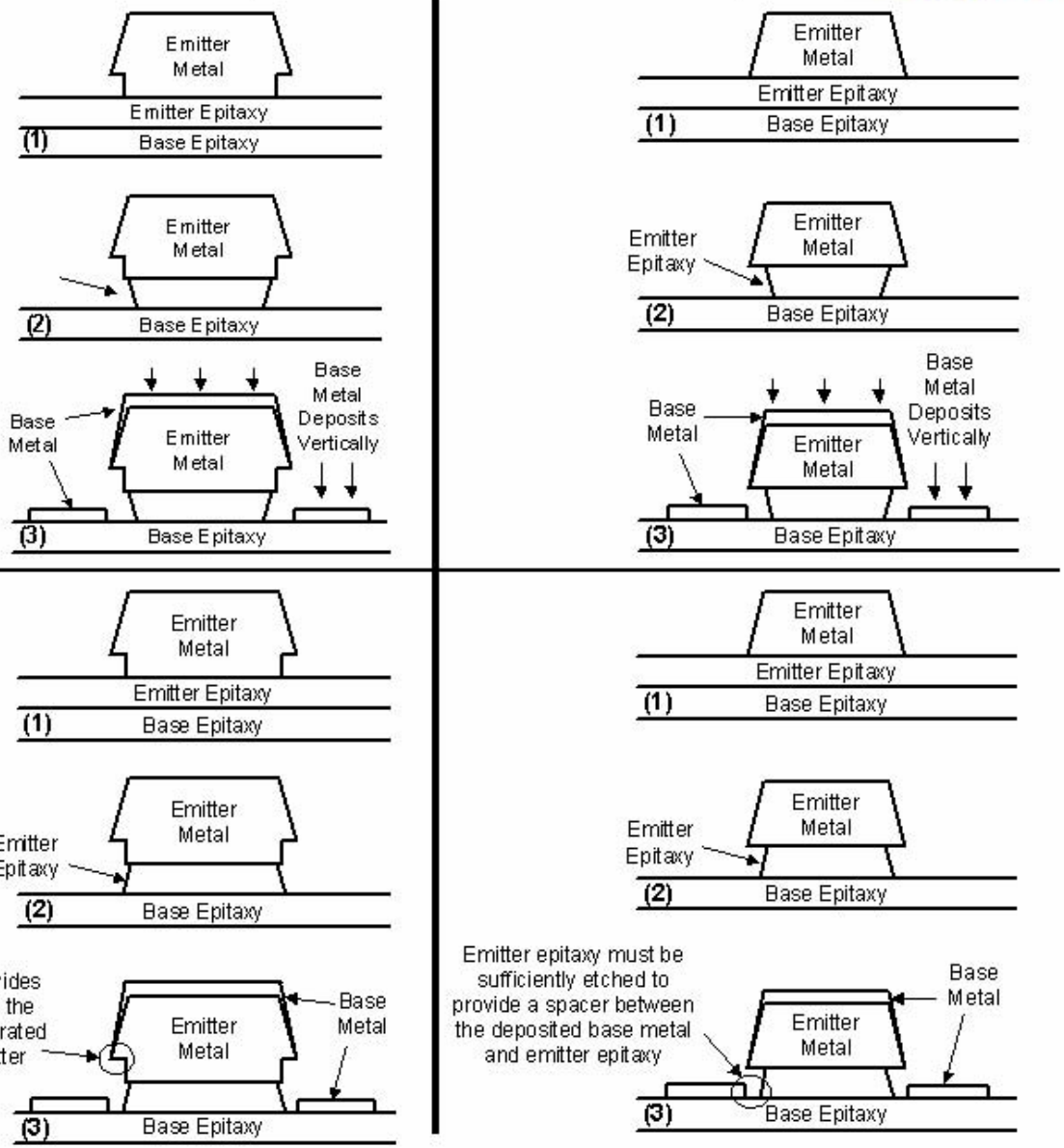


Device Development

- T-Shaped Emitter Metal





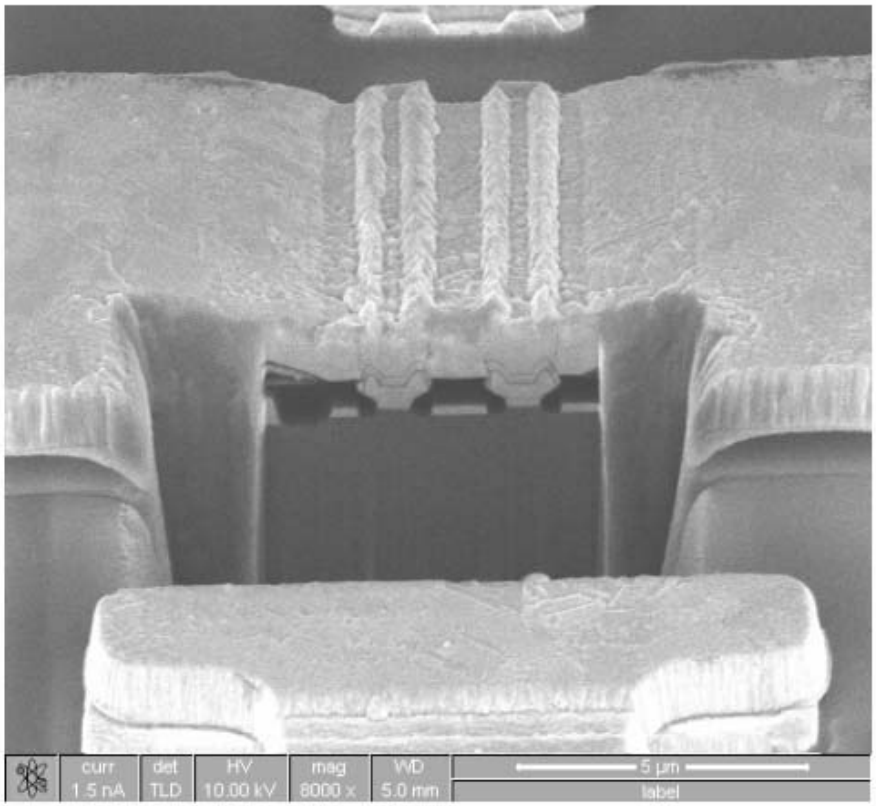


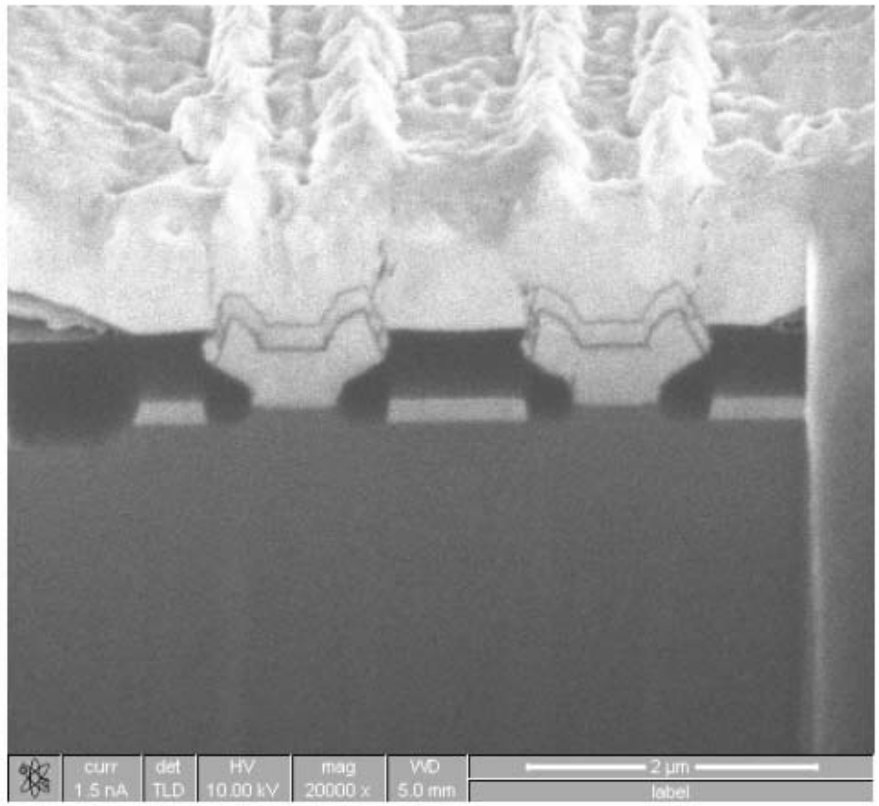
(H. Masuda, et al. '95)
(H. Nakajima, et al. '99)

Results

- Focus Ion Beam Cross Sections and SEMs

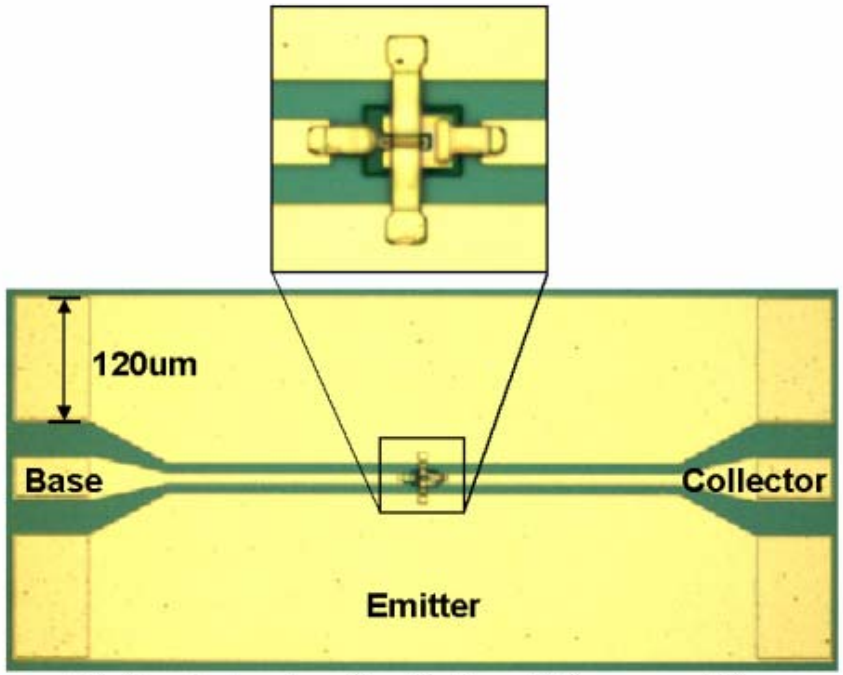
Dual 0.5umx12um Emitter DHBT



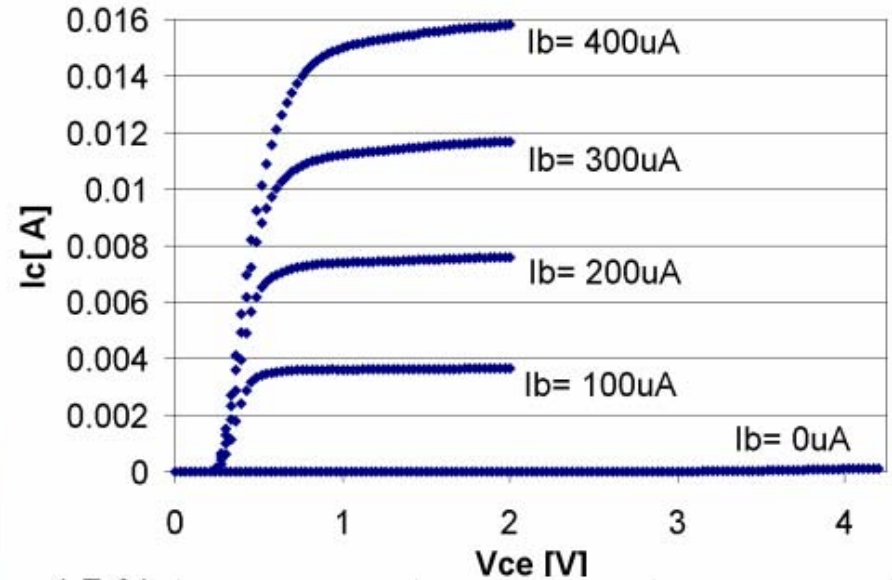


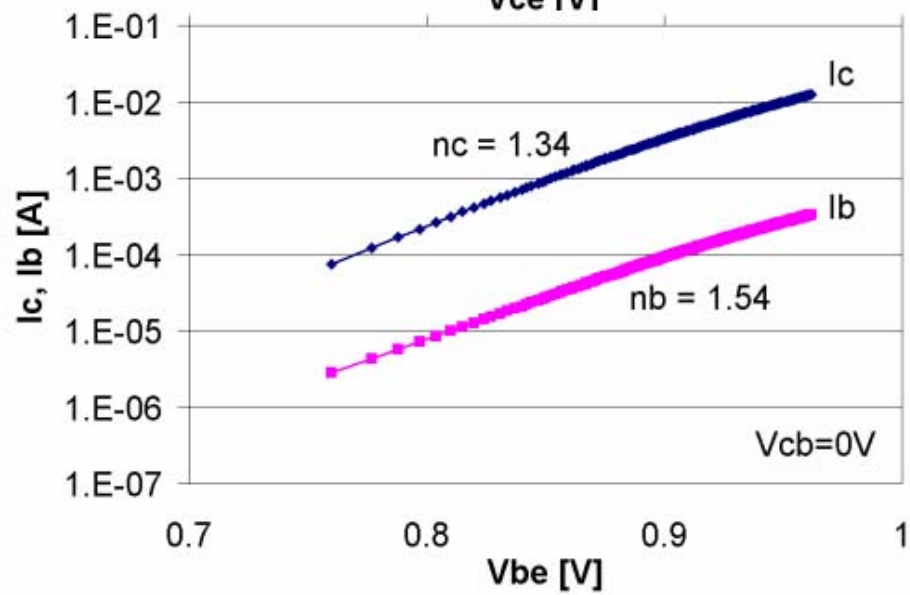
Results

- DC Current – Voltage Characteristics



Optical photo of a 0.3umX9um emitter DHBT in coplanar waveguide.





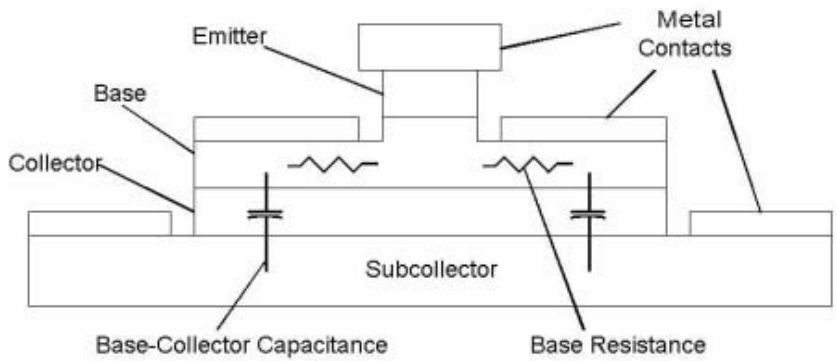
Results

- The figures of merit of high speed transistors are the current gain cutoff frequency (F_t) and maximum frequency of oscillation (F_{max}).

$$F_t = \frac{1}{2 \cdot \pi \cdot \tau_{ec}} \qquad \tau_{ec} = \tau_e + \tau_b + \tau_{bc} + \tau_c$$

τ_{ec} is the total emitter to collector delay time of the HBT.

$$F_{max} \gtrsim \left[\frac{F_t}{8 \cdot \pi \cdot R_b \cdot C_{cb}} \right]^{1/2}$$

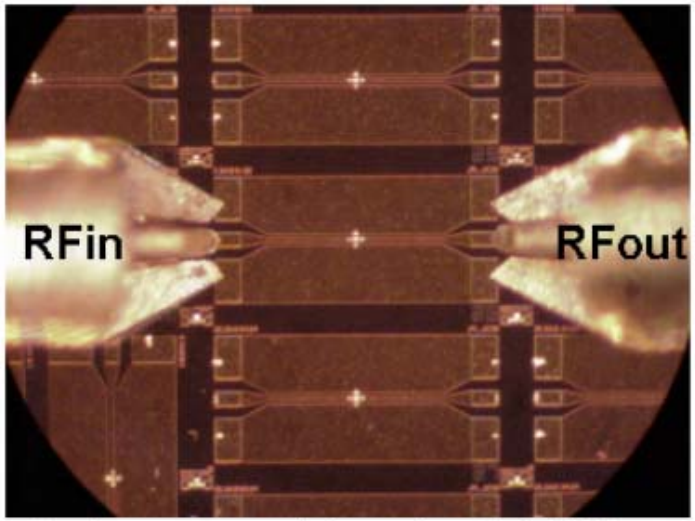


R_b is the effective HBT base resistance,

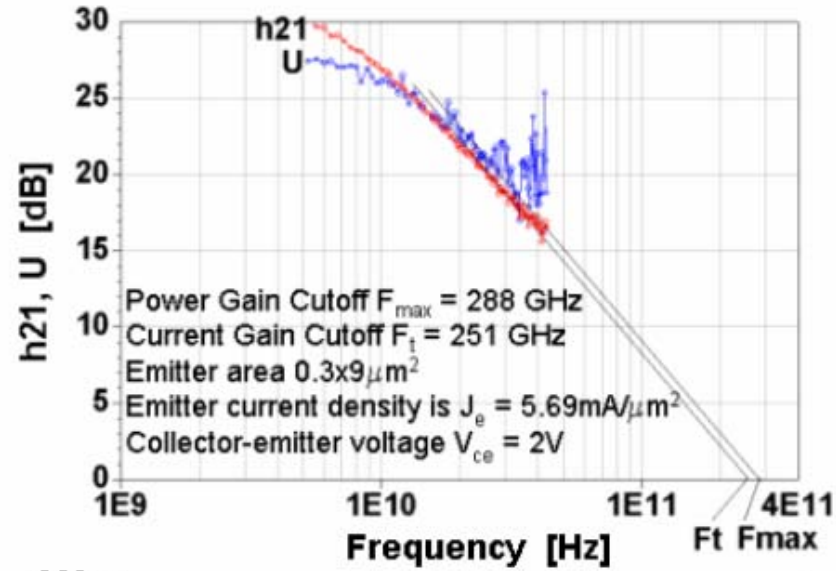
C_{cb} is the base to collector capacitance.

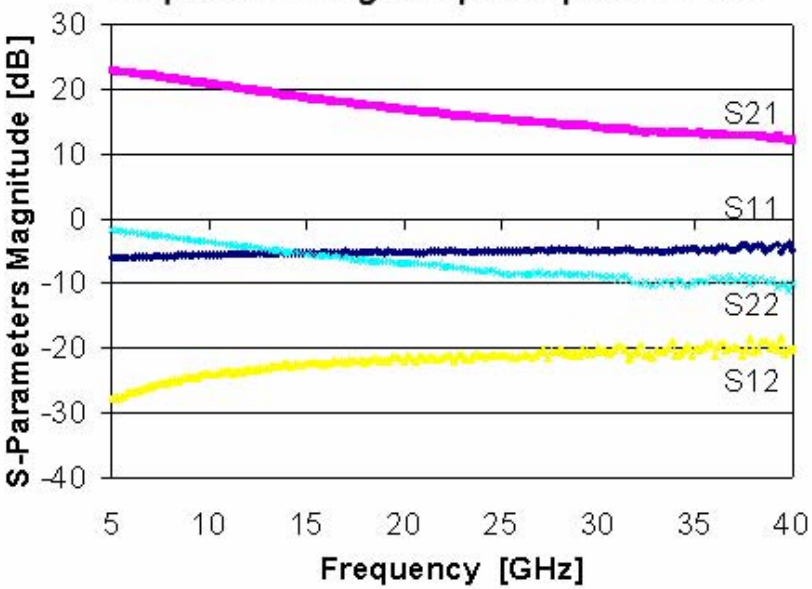
Results

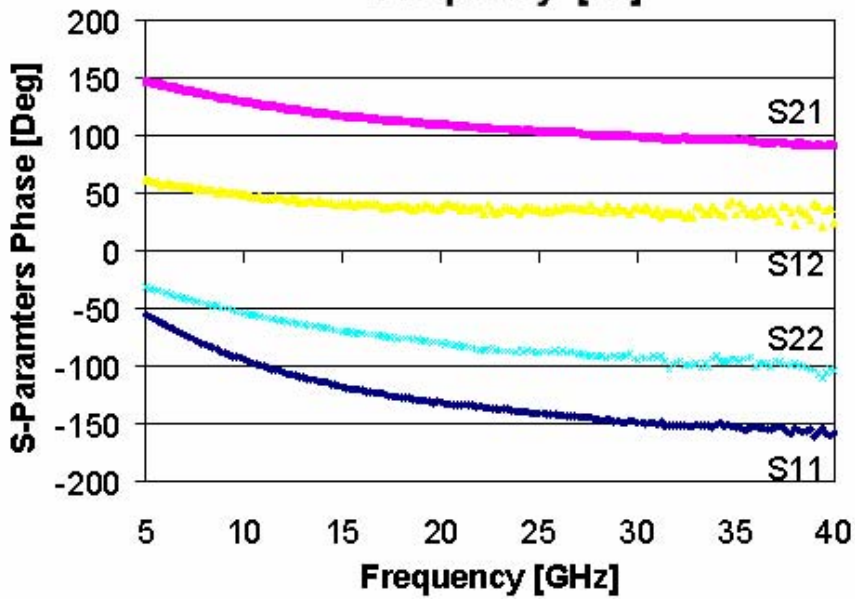
- RF Vector Network Analyzer Measurements of DHBTs



Coplanar waveguide probe pitch 100um

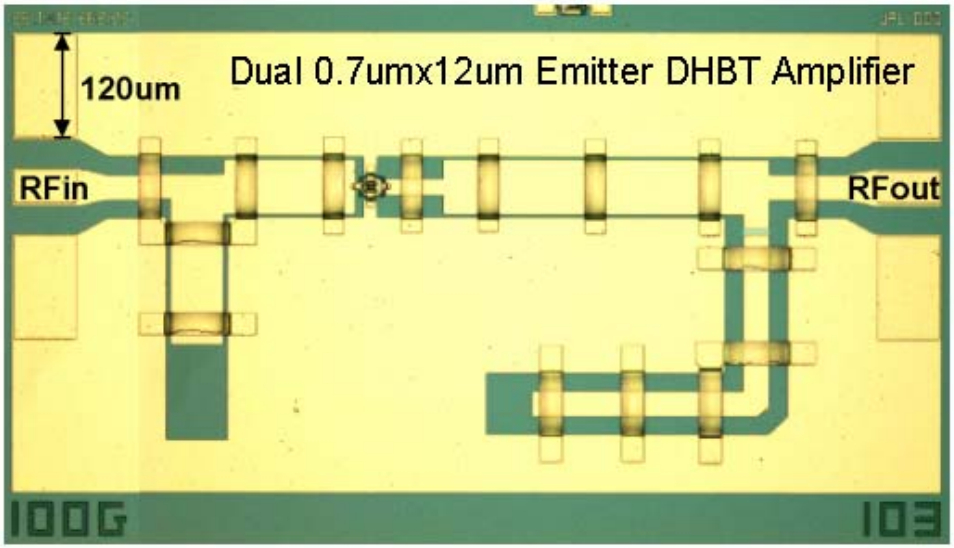


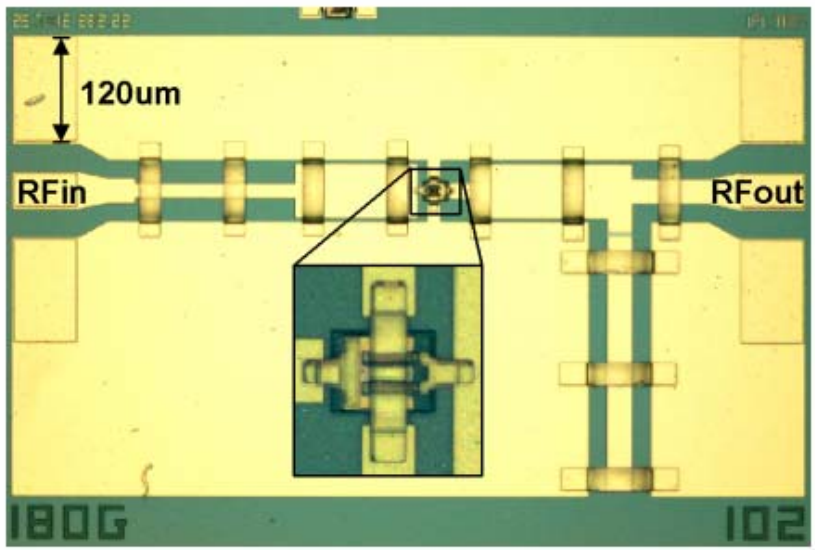


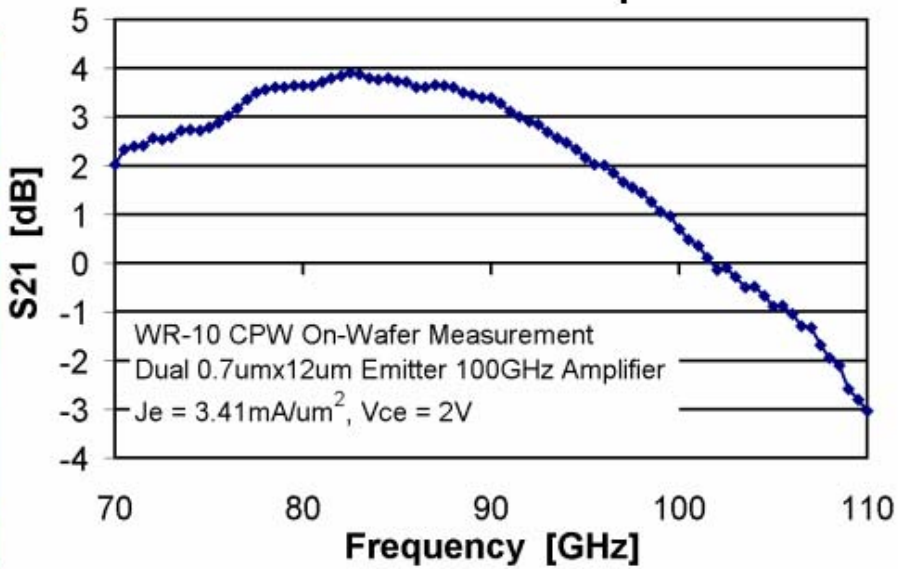


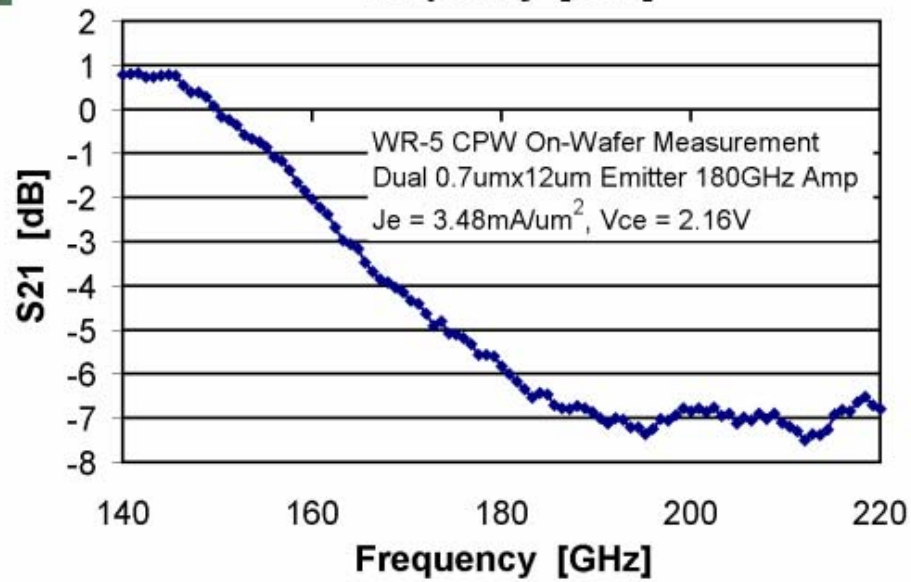
Results

- RF Vector Network Analyzer Measurements of Amplifiers









Summary

- We are motivated to improve electronic components for advancing heterodyne receiver technology for future astrophysics, planetary and Earth science spectroscopy missions.
- We have demonstrated,
  - T-shaped emitter metal DHBTs with the goal of improving yield and performance.
  - Third generation emitter mesa HBTs with Ft = 251 GHz, Fmax = 288 GHz (Second generation had Ft = 142 GHz, Fmax = 160 GHz. First generation had Ft = 126 GHz and Fmax = 120 GHz).
  - DHBT tuned amplifier with 3.9dB gain at 82.5GHz.
- Performance of the HBTs will improve with the minimization of parasitics (base contact and series resistances, reduction of the base metal width) and scaling of epitaxial layers.

Acknowledgments

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