MMIC Amplifier Technology State of the Art:

Power Amplifiers and Low Noise Amplifiers

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MMIC Power Amplifiers

- Discuss state-of-the-art published results for output power vs. frequency
- Restrict discussion to technologies and results from W-band and above, with particular emphasis on technologies capable of frequencies > 100 GHz
- Restrict discussion to SINGLE CHIP results (as opposed to power-combined chips)
- Indicate trends as a function of frequency
- Discuss device size and bandwidth of operation for the best published results
- Discuss possible limitations and realizable frequency limits
- Open the discussion to include additional results if any are made available

Most Promising Technologies for Power Amplifiers > 100 GHz

- GaAs PHEMT (pseudomorphic HEMT)

  Gate lengths of 0.1μm, most promising from NGST
- InP HEMT (high electron mobility transistor) –

  Gate lengths 0.1μm, 0.15μm

  Foundries: HRL Laboratories, NGST
- InP HBT (Double Heterostructure Bipolar Transistor)

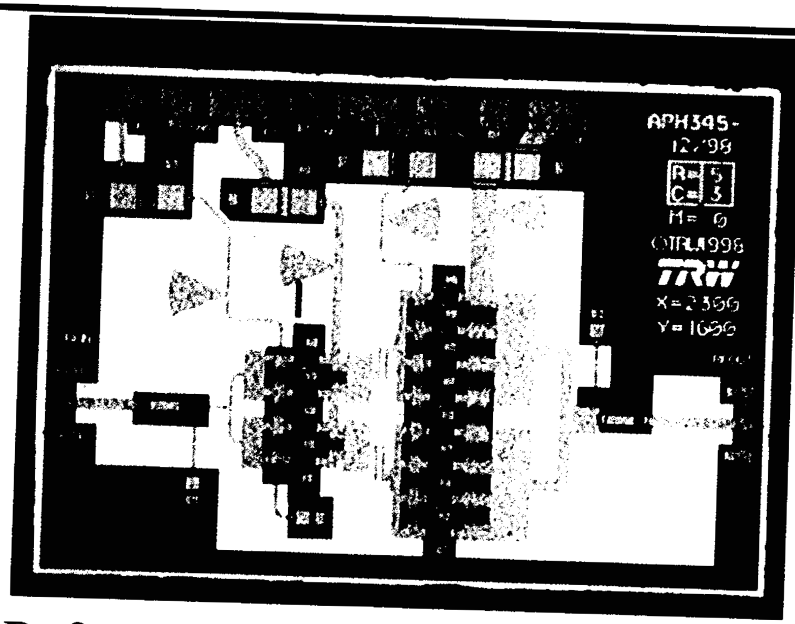
  Include bases of InGaAs or GaAsSb

  Foundries and Universities: HRL, NGST, UC Santa Barbara, GCS, JPL

GaAs PHEMTs: NGST /JPL

- 0.1 µm GaAs PHEMT yields typical power from 200-300 mW with 15% bandwidth in W-Band
- Chip geometry makes use of HEMTS with 8 fingers totaling 160µm of gate periphery per HEMT.
- 8 HEMTS were combined in parallel in the output stage. Total Periphery: 1.28 mm
- Approximate DC power dissipation for 200 mW output power at 95 GHz: 1.5W

•Many designs have been fabricated which work in several bands covering 70-115 GHz



Reference: H. Wang, L. Samoska, *et al.*, IEEE Trans MTT Vol 49 (1), Jan. 2001, pp. 9-16.

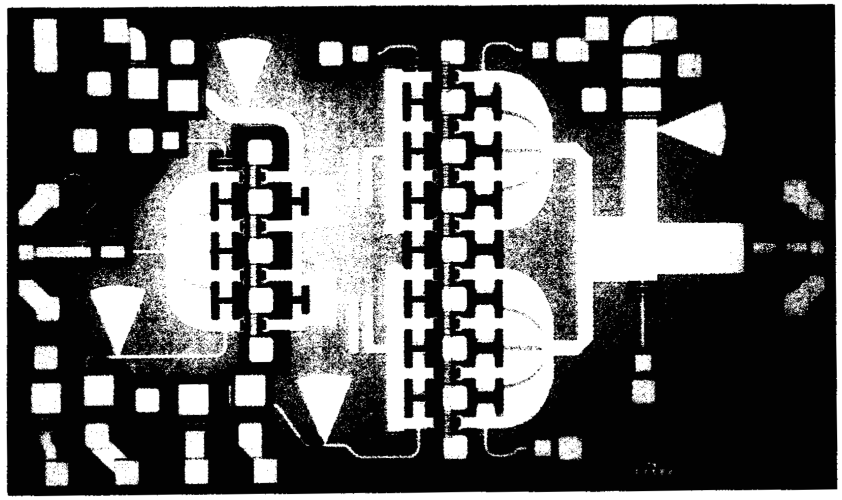
InP Power HEMTs: NGST

- **0.15 μm InP HEMT yielded highest power (427 mW) solid-state W-band (95 GHz) amplifier to date**

- Chip geometry makes use of HEMTS with 8 fingers totaling 160μm of gate periphery per HEMT.

- 8 HEMTS were combined in parallel in the output stage to yield the high power result. Total Periphery: 1.28 mm

- Approximate small-signal bandwidth is 83-97GHz (~ 15%)

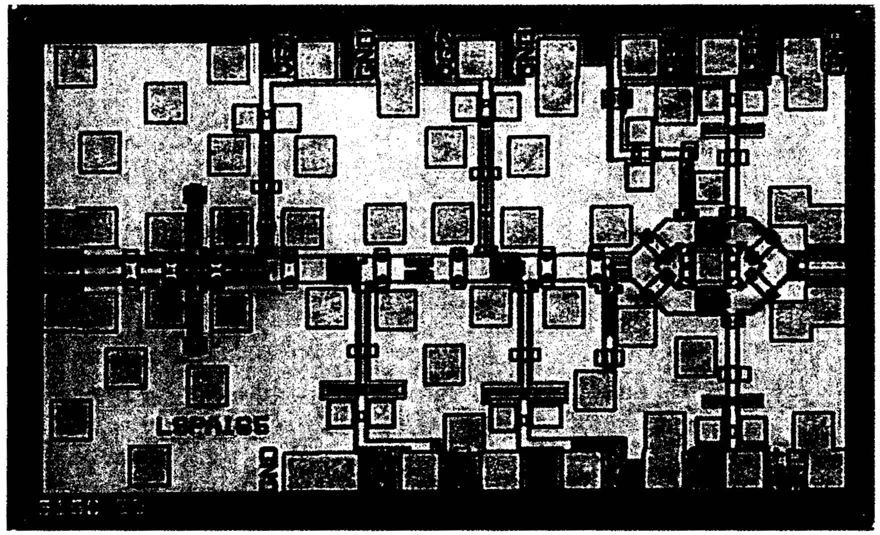


- Approximate DC power dissipation for 427 mW output power at 95 GHz: 1.8W (Better efficiency with InP)

Reference: D. L. Ingram, et. al, 1999 RFIC Symposium Digest, pp. 95-98

InP HEMTs: HRL/JPL

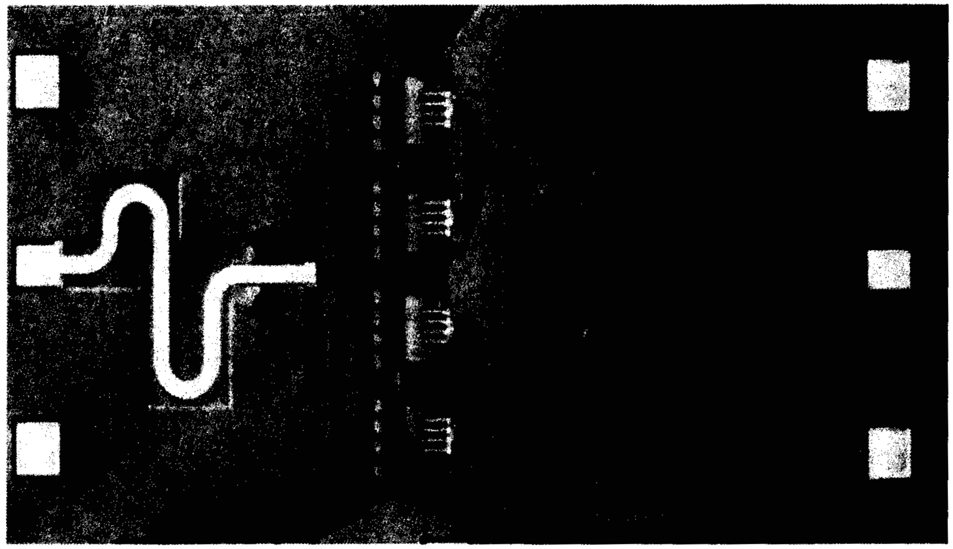
- 0.1 μm InP HEMT
- Typical power device consists of 4 gate fingers, with 2 devices combined in parallel for 300 μm total output stage periphery.
- Existing results cover bandwidths between **65-170 GHz**
- Grounded cpw topology used for the high frequency results
- 20-50 mW has been achieved for very wideband amplifiers (up to 80% bandwidth)
- DC dissipation ~0.5W



Reference: L. Samoska, IEEE MTT IMS Digest 2001, pp. 1805-1808.

InP Power HBTs: UCSB

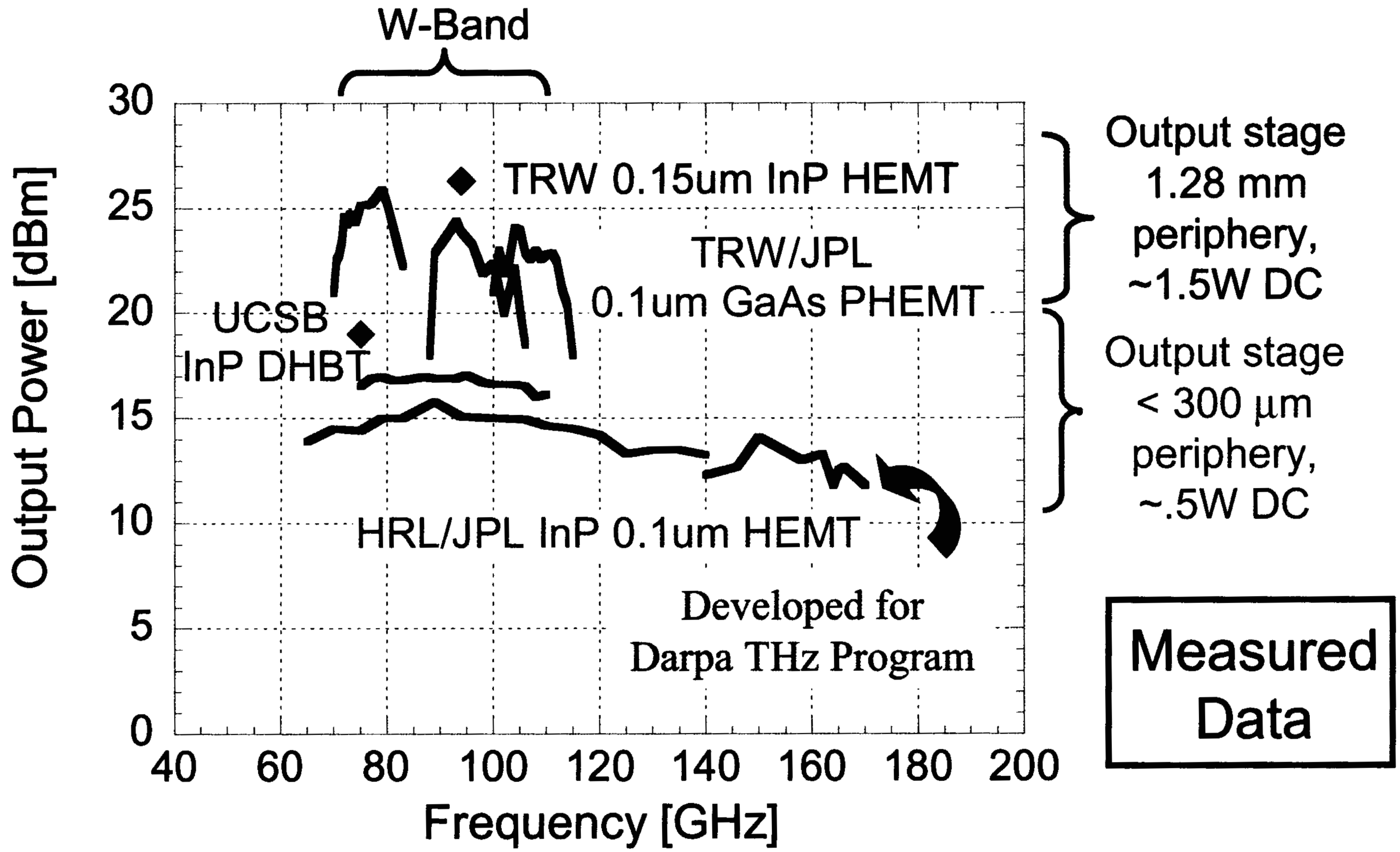
- 1 μm InP transferred-substrate DHBT
- Typical power device consists of 4 emitter/collector fingers, with 4 devices combined in parallel for 256 μm^2 total output stage area.
- Existing result at **75 GHz** .
- Microstrip line topology used for the high frequency results
- ~80 mW has been achieved for 1 dB gain compression
- DC dissipation ~0.6W
- Die size: 0.38 mm × 0.89 mm



Reference: Y. Wei, IEEE MTT IMS Digest 2003, pp. 919-921.

* Comparable output power/mm to .15μm InP HEMT

Roadmap of Best Power Amp MMICs vs. Frequency



Measured Data

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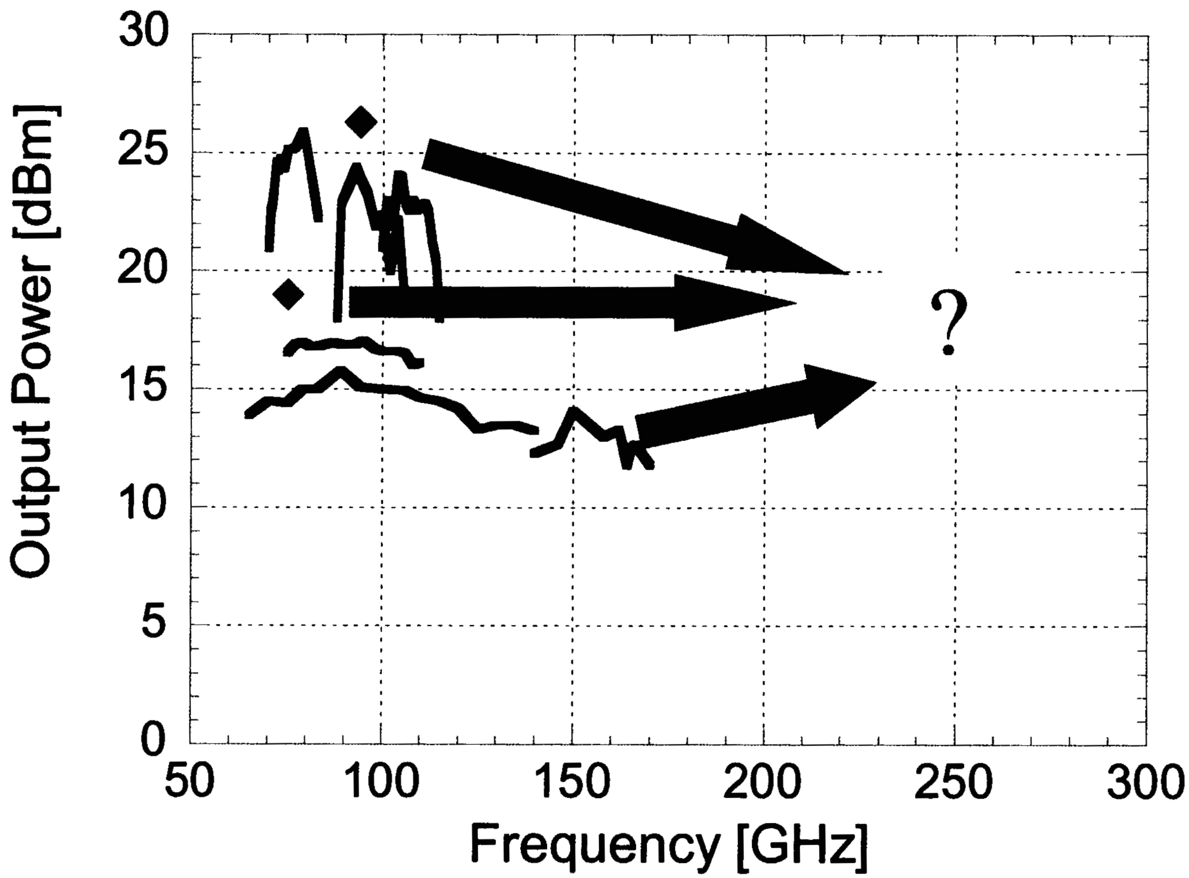
Trends in Frequency



Where will they converge?

The best indicators are from existing data and models:

10 mW @ 200GHz in the short term

50 mW @200 GHz over the next several years

Probable gain up to 300 GHz in the InP devices

PA Summary

- Highest power W-band result: 427 mW (26 dBm) at 95 GHz:
  Using NGST InP .15um HEMT
- Highest frequency chip with usable power: 20 mW @ 150 GHz (in waveguide module): Using HRL InP 0.1um HEMT (with JPL)
- Most linear, highest power amplifier chip: UCSB InP 1μm emitter DHBT, with P1dB=19 dBm (80 mW at 75 GHz)

Trends: More output stage gate/emitter periphery yields more output power (and DC dissipation), but only if the layout can accommodate higher (>>W-band) frequency designs.

Microstrip is convenient for simplicity of simulation and design, but vias will hurt performance at >> W-band and CPWG may become the preferred technology for ~200 GHz+ power amplifiers

Possibilities look good for PAs up to 300 GHz, with ~10 mW estimated at 200 GHz in the next few years