Packaging (and associated) Technologies for Large Arrays

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Overview

- Large Array Requirements
- Accommodating New Technologies
- Packaging Technologies
  - Single function Modules: SEQUOIA, WMAP etc (N=10-50)
  - Multi-function modules: QUIET, MIMRAM, MAS (N=100-500)
  - New Approaches: Wafer level packaging (N=500-5000)

Array Receiver Requirements

Arrays are needed when:

1) Individual detector noise approaches fundamental limits

InP HEMTs, SIS

2) Large areas (compared to resolution) needs to be observed continuum and spectral line surveys, CMB, Earth Science

Receiver Array Requirements:

Large array integration must be facilitated- interconnections, integration, bias and readout

Single pixel performance needs to be maintained- beam integrity, noise performance etc

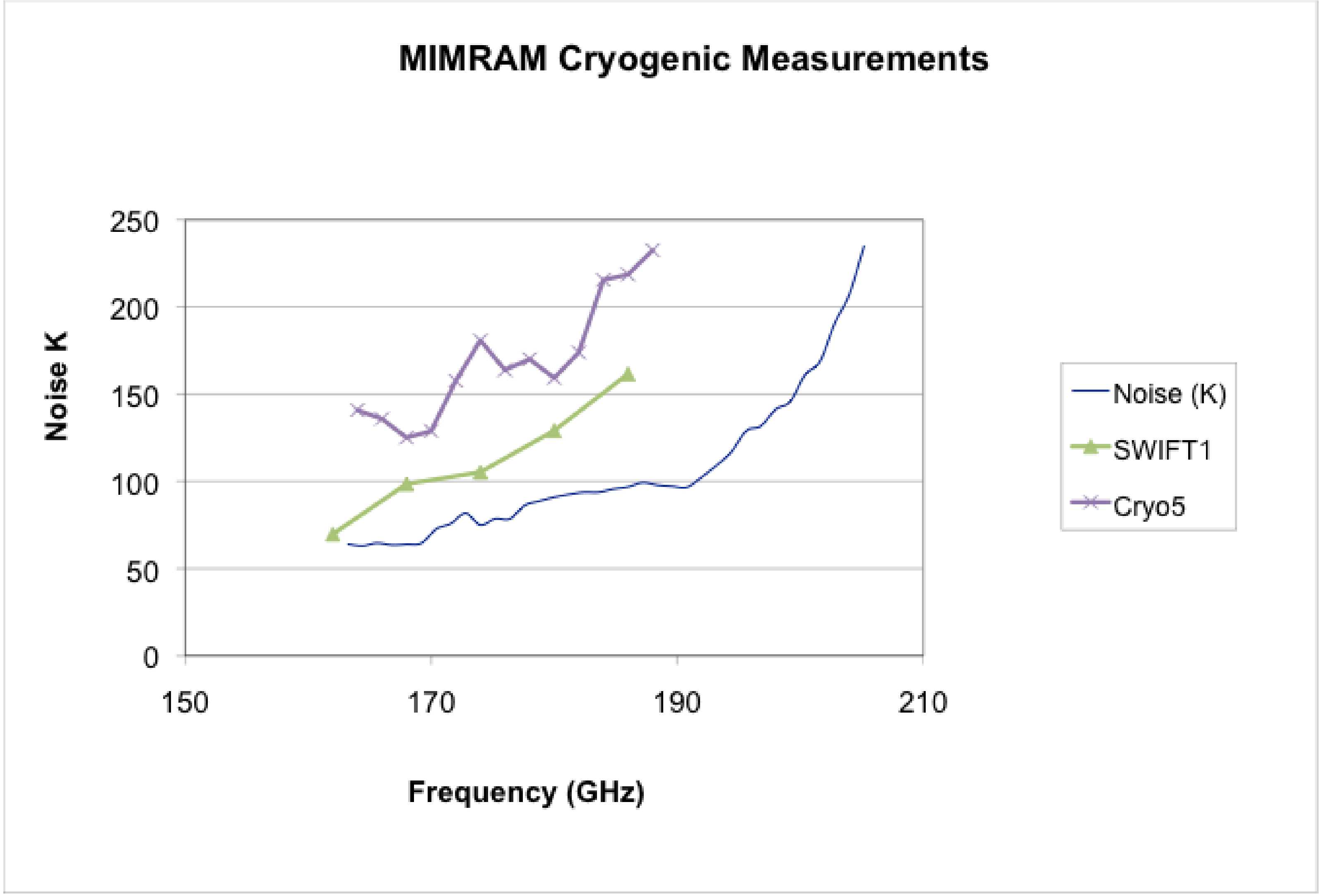
New Technologies need to be accommodated- Incremental improvements need to be accounted for

The parts have to be <u>testable or highly repeatable</u>

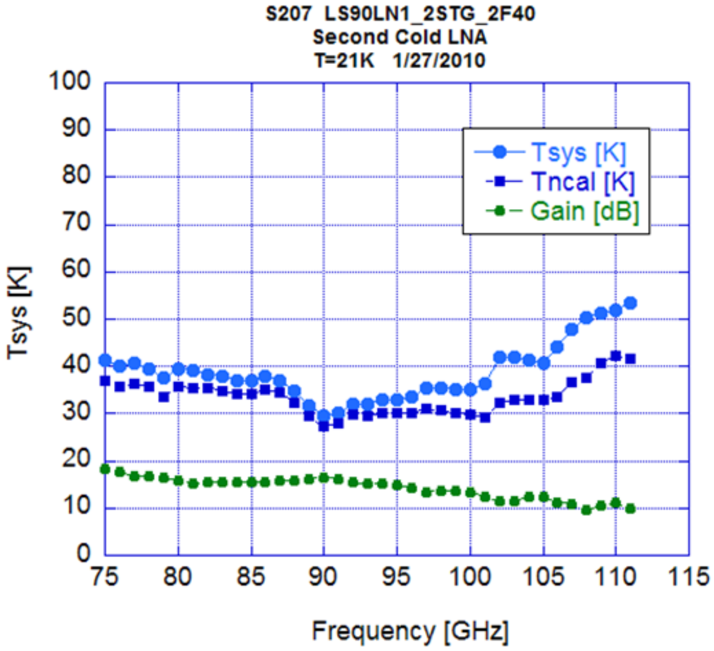
Evolution of Technology

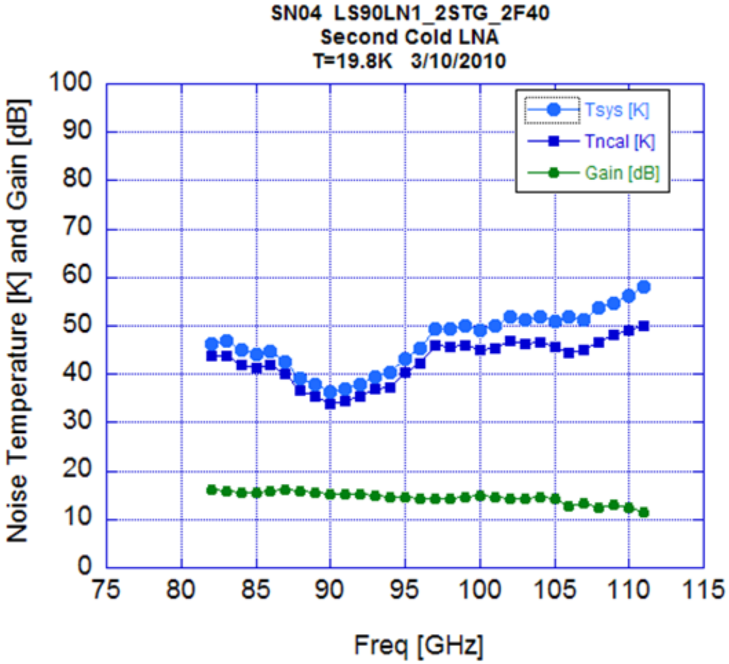
- Evolution has been substantial for high frequency (>100 GHz) devices
  - 1998 Room temp NF =3dB @90 GHz, 6 dB @180 GHz
  - 2010 Room temp NF=2.5 dB @90 GHz, 3 dB @180 GHz

Recent G-Band Results

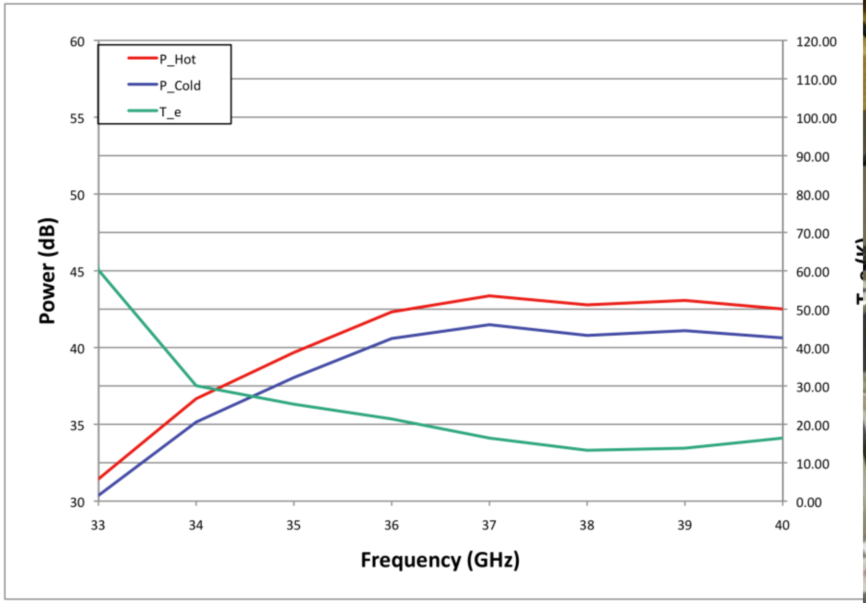


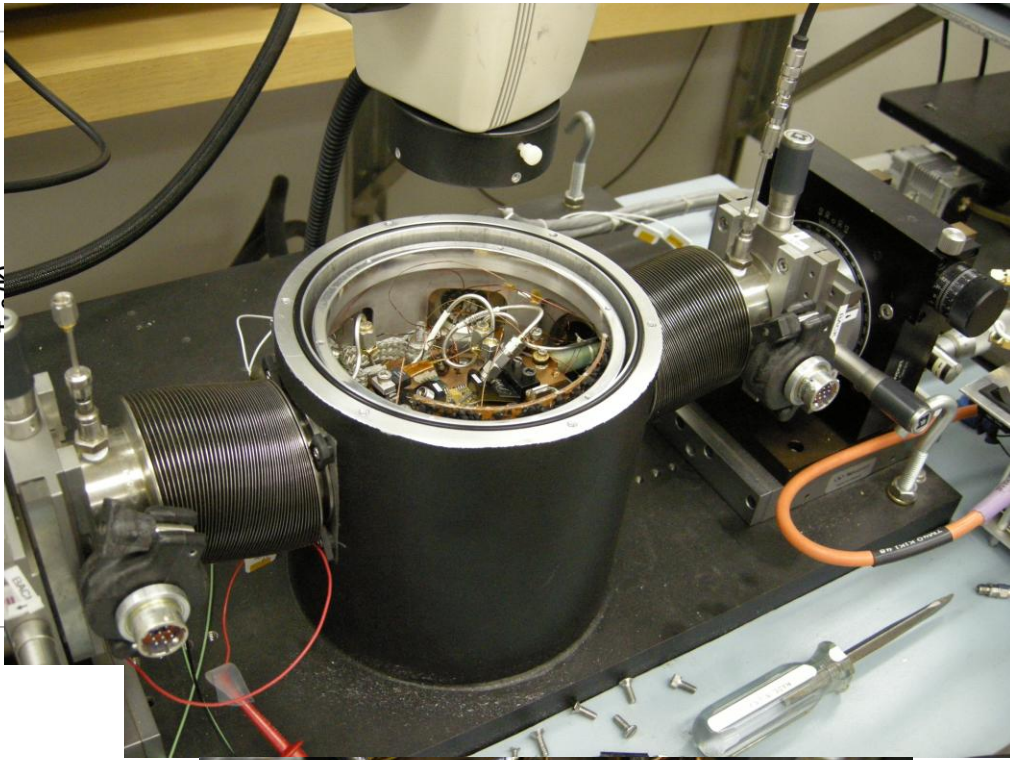
90 GHz 35 nm results

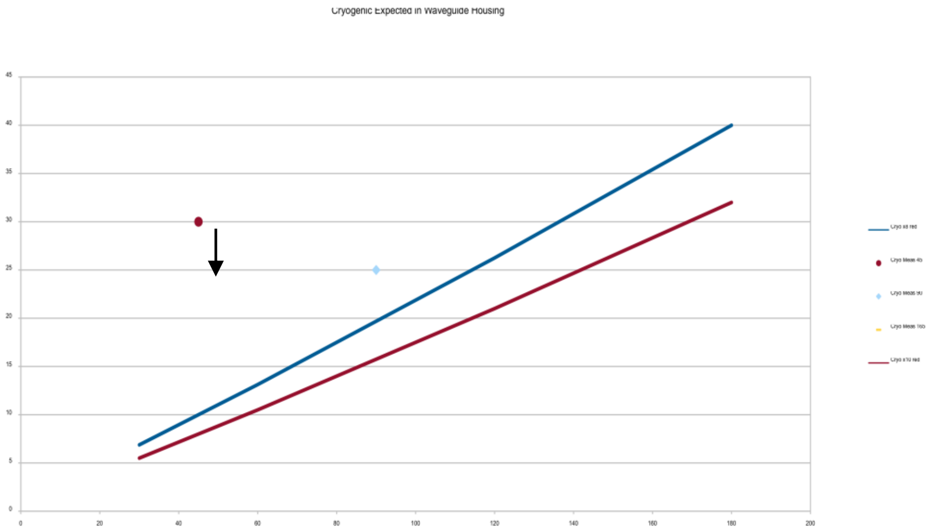


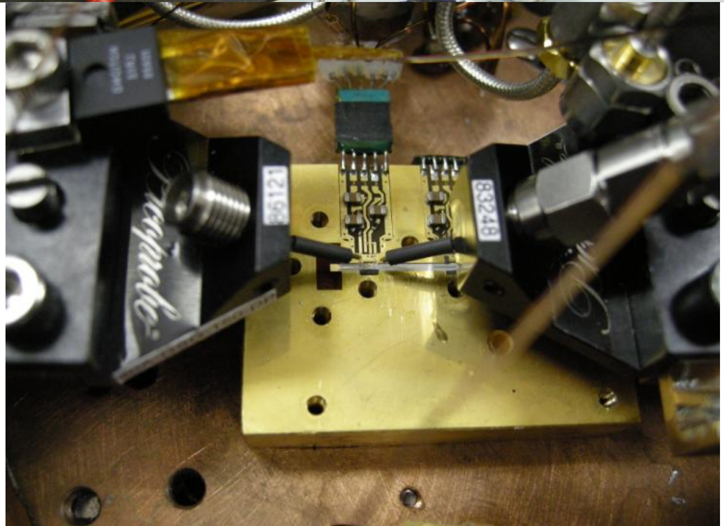


Wafer Probe Noise Measurement-40 GHz



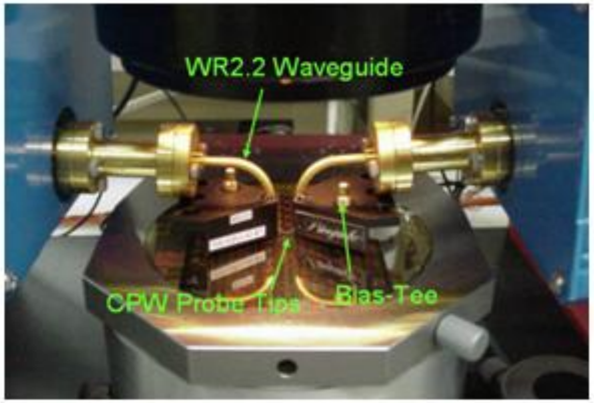


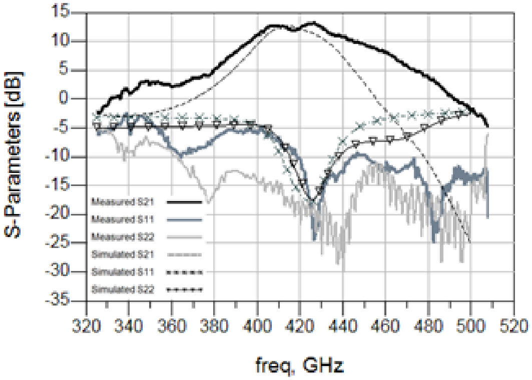




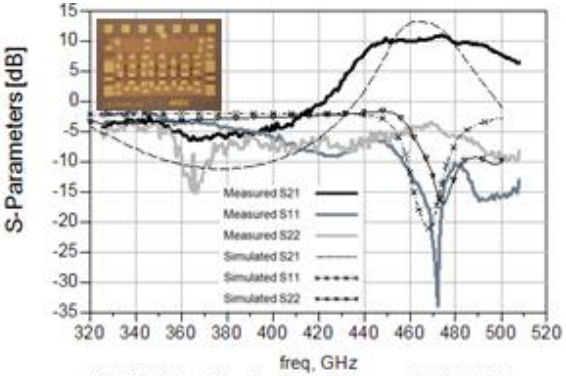
New High Frequency Breakthroughs

- In a Spontaneous Concept RTD from 2007, we designed MMICs in the 400-500 GHz range. At the time, there was no way to test them because the frequency is outside the bandwidth of any wafer probe capability
- Under this program, Andy Fung, together with Greg Boll of GGB, developed and the ***very first*** wafer probe measurements ***up to 500 GHz.***
- We have used the probes to measure the 2007 circuits, and have found very high gain up to 500 GHz (~10 dB at 475 GHz with 40 GHz bandwidth)
- Cryogenic noise testing of these chips is beyond the current scope of this program, due to the need for developing a low loss waveguide package capable of being cooled.
- A new RTD Topic has been submitted (PI Samoska) “MMIC Low Noise Amplifier Modules up to 700 GHz– A World Record Enabling Technology” to package and test these amplifiers cryogenically, by fabricating low loss waveguide transitions in the MDL.



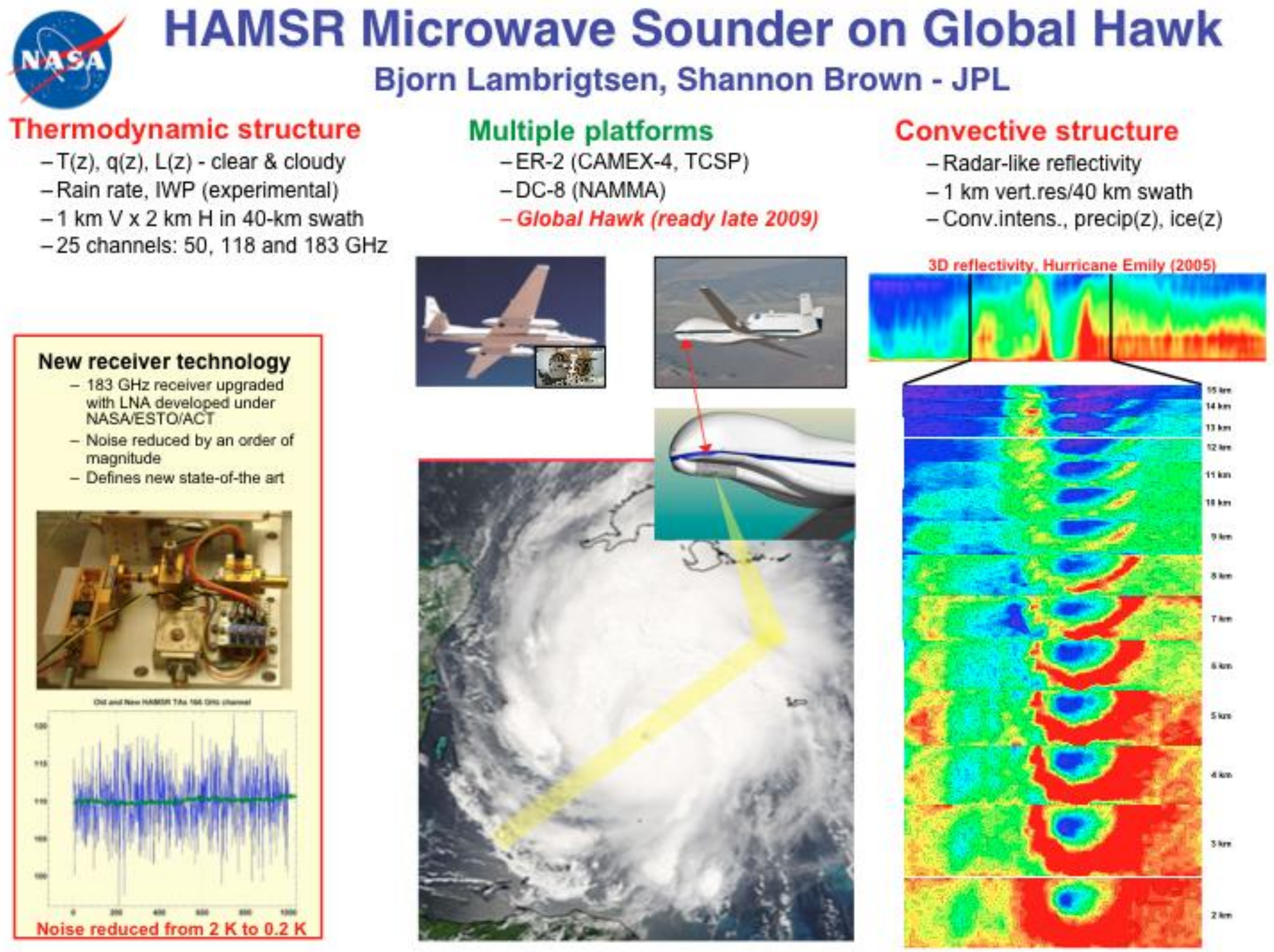


MMIC LNA with > 10 dB from 400-445 GHz



MMIC LNA with 10 dB gain from 445-490 GHz

Progress in 10 years?



HAMSR Microwave Sounder on Global Hawk

Bjorn Lambrigtsen, Shannon Brown - JPL

Thermodynamic structure

- T(z), q(z), L(z) - clear & cloudy
- Rain rate, IWP (experimental)
- 1 km V x 2 km H in 40-km swath
- 25 channels: 50, 118 and 183 GHz

Multiple platforms

- ER-2 (CAMEX-4, TCSP)
- DC-8 (NAMMA)
- *Global Hawk (ready late 2009)*

Convective structure

- Radar-like reflectivity
- 1 km vert.res/40 km swath
- Conv.intens., precip(z), ice(z)

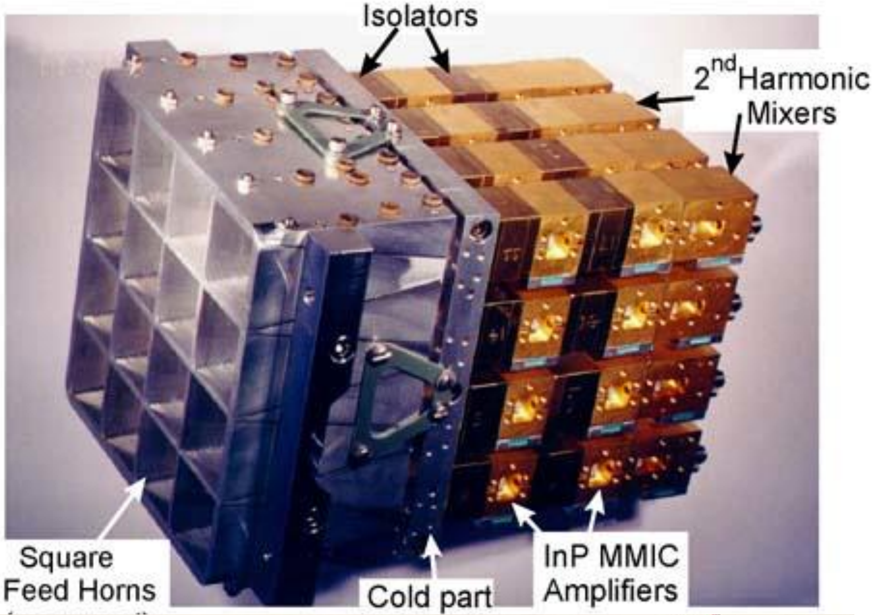
New receiver technology

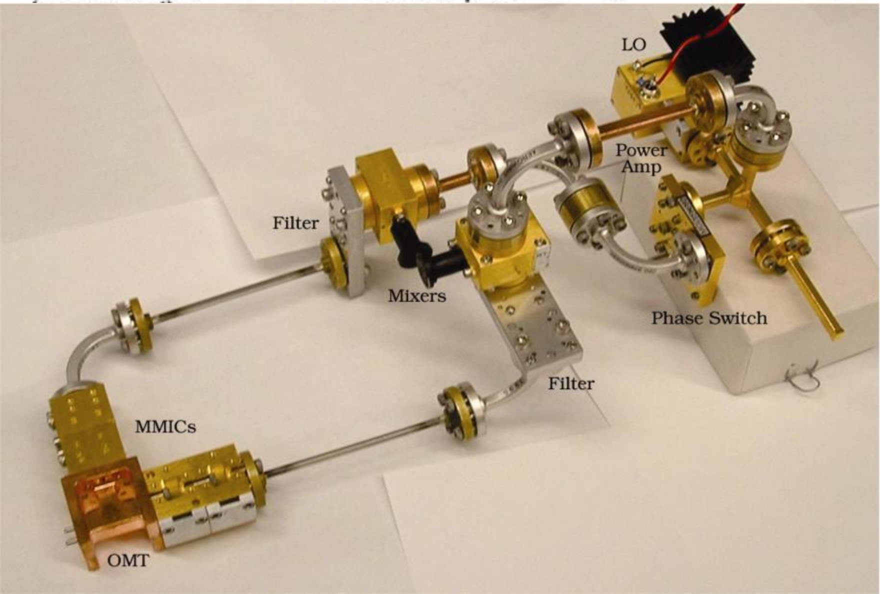
- 183 GHz receiver upgraded with LNA developed under NASA/ESTO/ACT
- Noise reduced by an order of magnitude
- Defines new state-of-the art

Noise reduced from 2 K to 0.2 K

3D reflectivity, Hurricane Emily (2005)

Single-function modules





Systems are built from individual blocks, typically serving a single function.

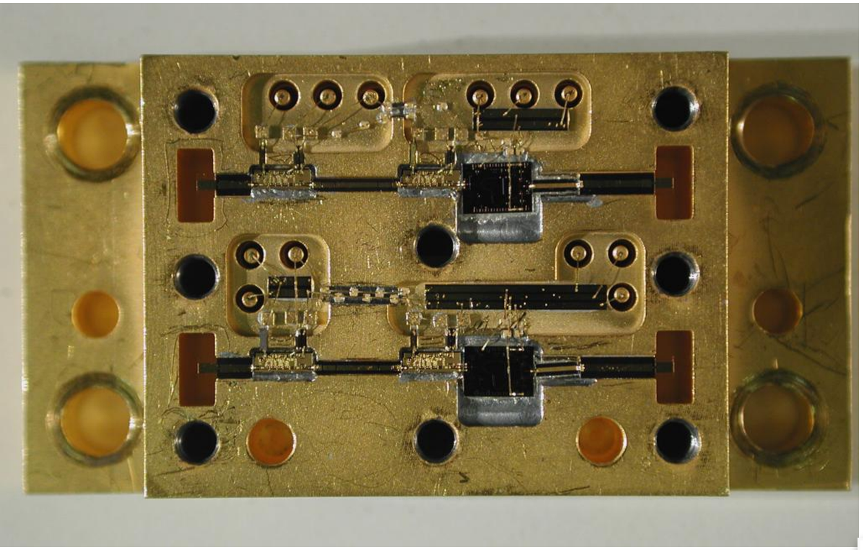
Advantages: simple design, easy testing, cryogenic components can be limited to those requiring cooling, less subject to yield issues since rework is inexpensive.
Disadvantages: complex integration, larger chains, more interconnects

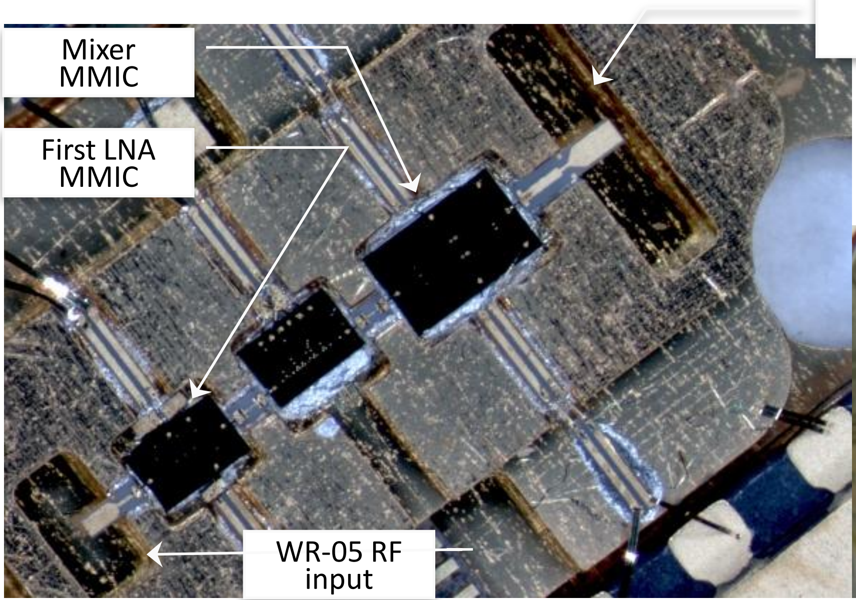
Multi-function multi-chip packaging

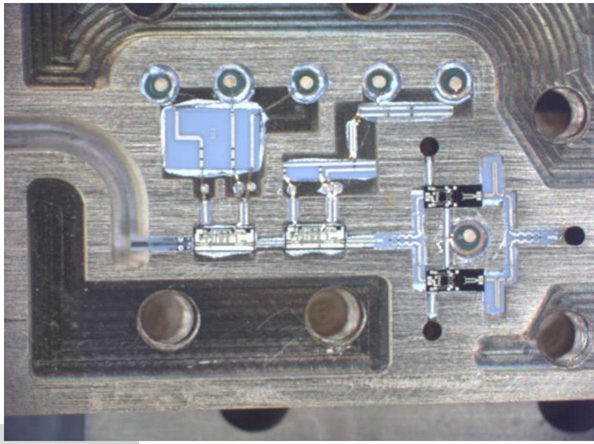
Moderate integration:

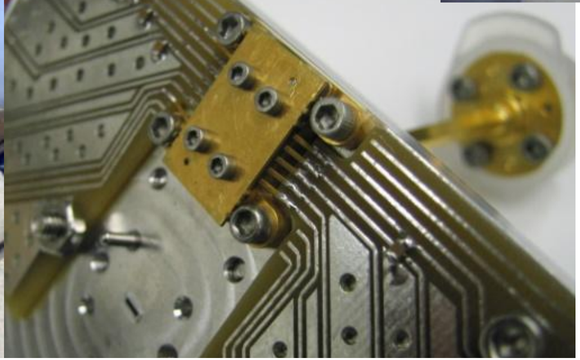
Systems are still complicated to integrate but have fewer connections.

Components retain a large degree of RF testability. RF gain is typically limited, making design for stability easier



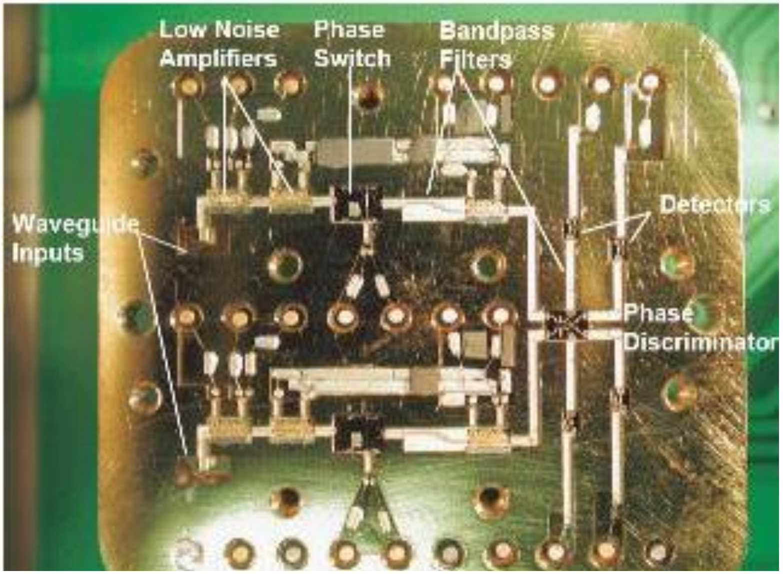






Multi-function multi-chip packaging

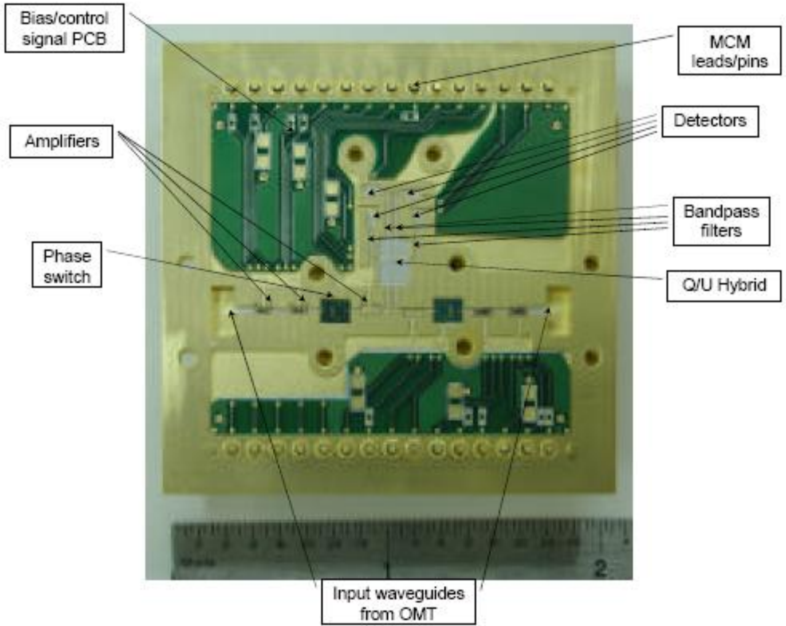
Highly integrated:

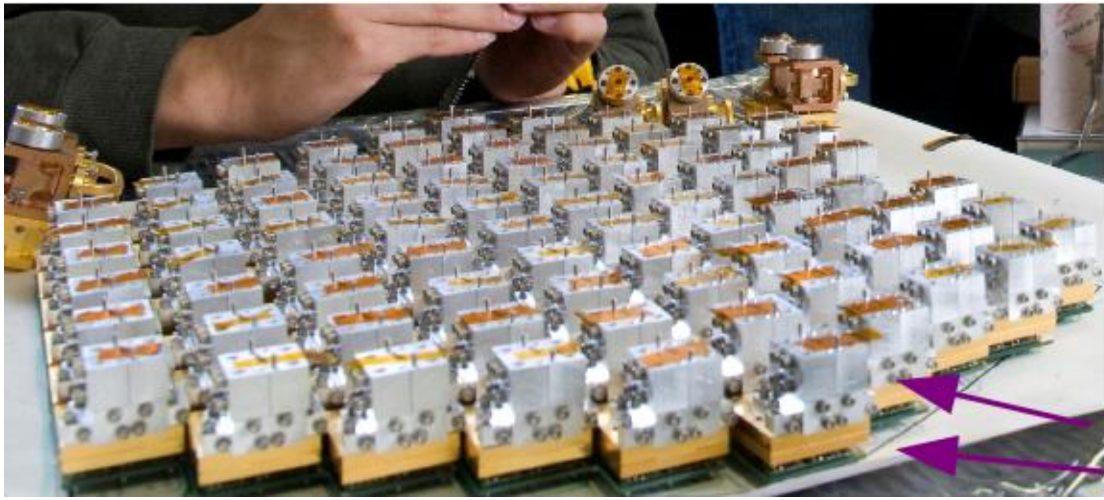


Large systems are easier to integrate.

Components retain minimal RF testability. RF gain is typically high.

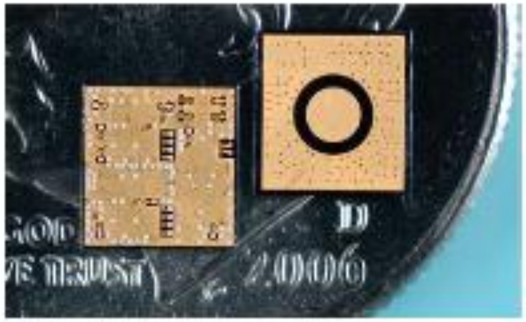
Highly dependent upon device yield and repeatability.



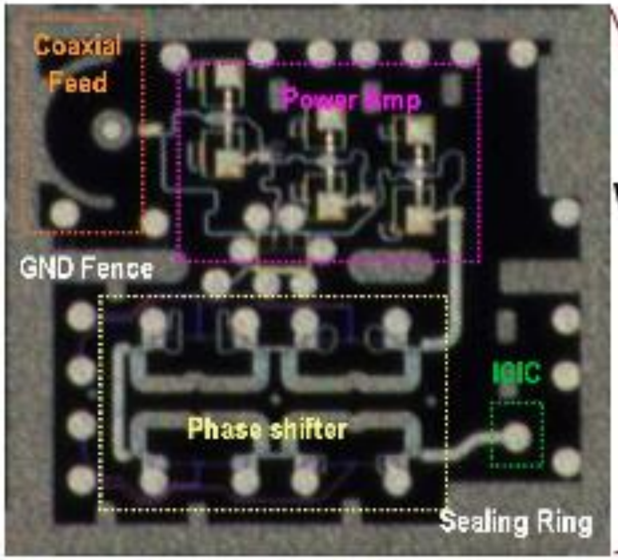


Heterogeneous Integration Example

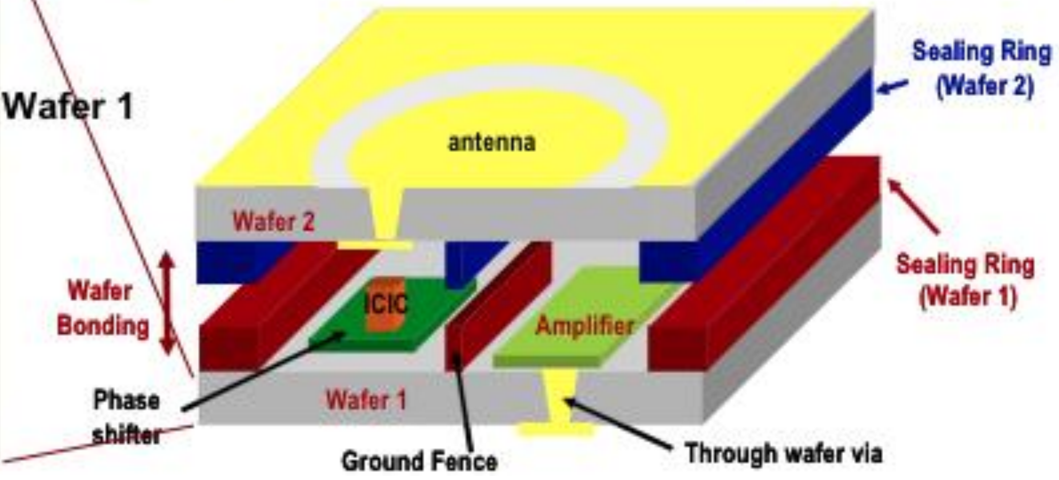
- Integrated RF front end module with antenna
  - PA (GaAs HEMT)
  - 3 bit phase shifter (GaAs HEMT)
  - Interconnections (ICICs)
  - Antenna



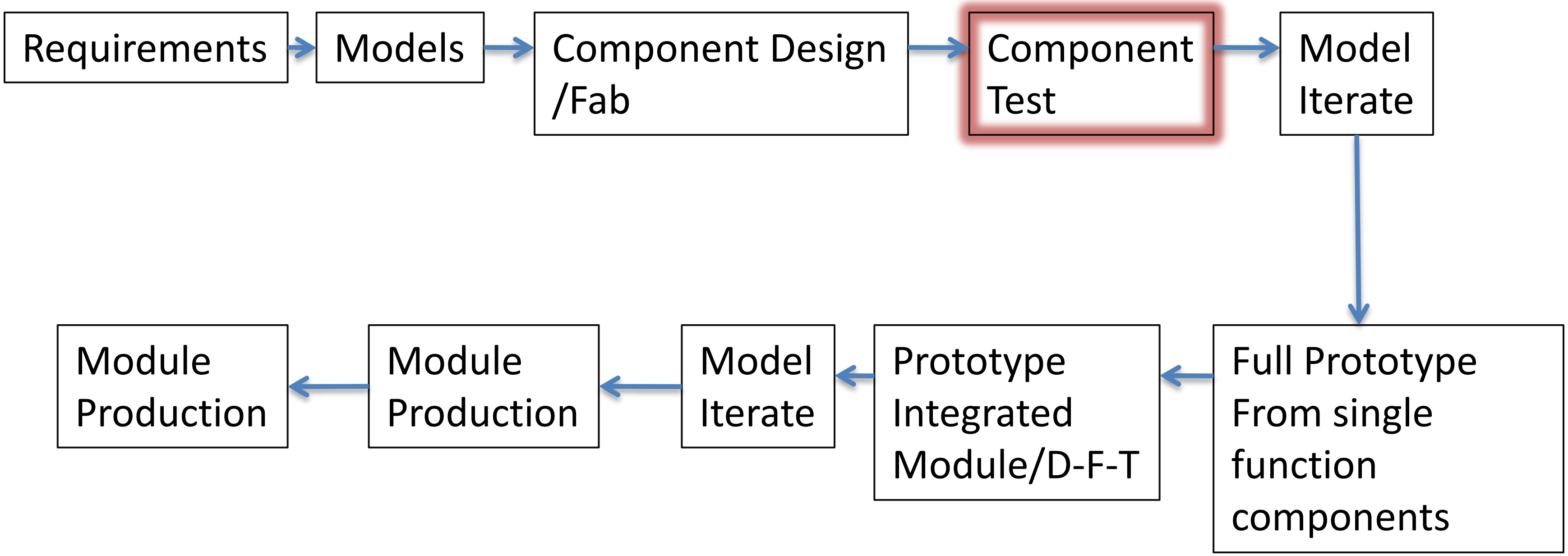
WLP bottom side **WLP top side (antenna)**



Integrated RF Front-End Module



(Nearly) Idealized Lifecycle



Requirements

Models

Component Design /Fab

Component Test

Model Iterate

Full Prototype From single function components

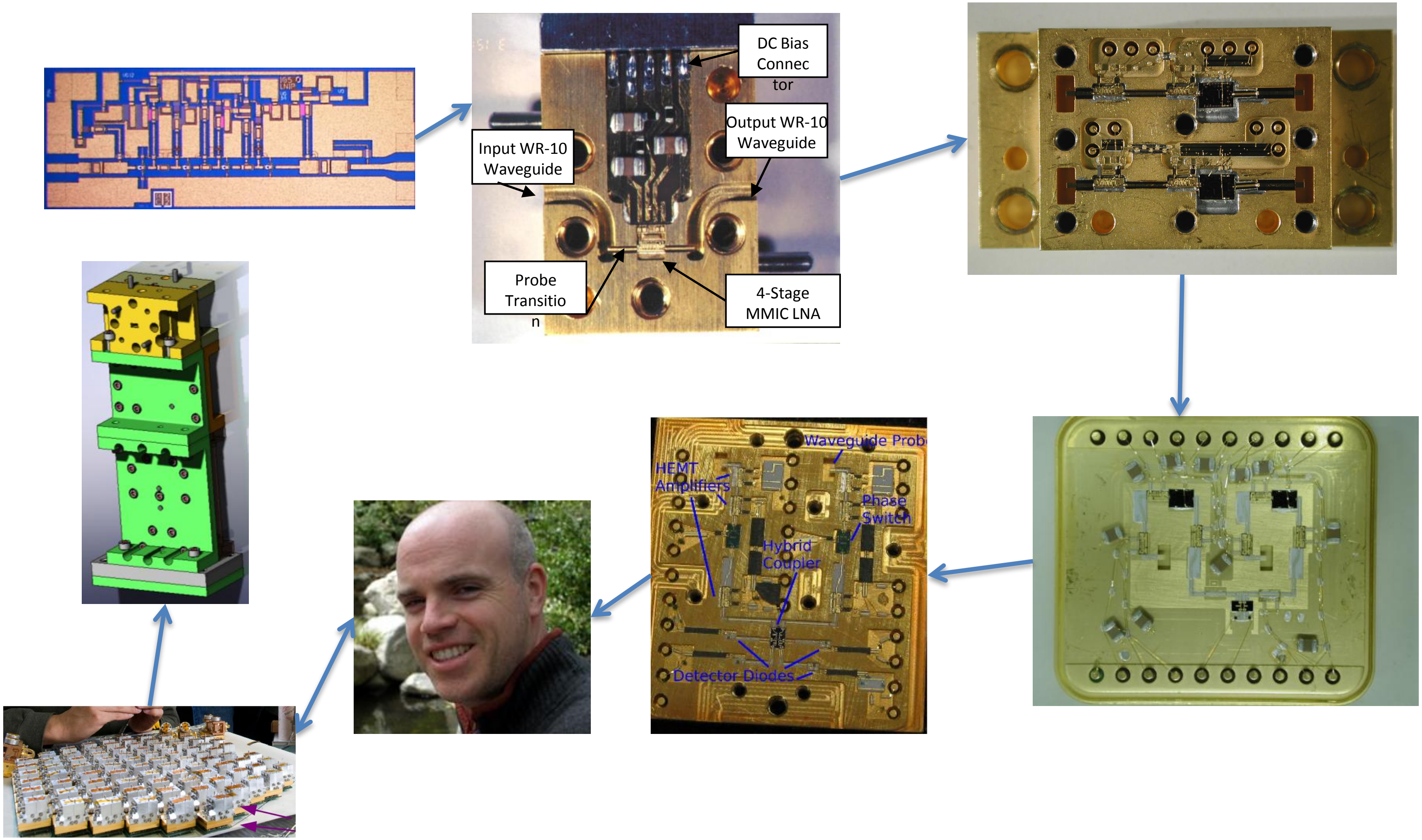
Prototype Integrated Module/D-F-T

Model Iterate

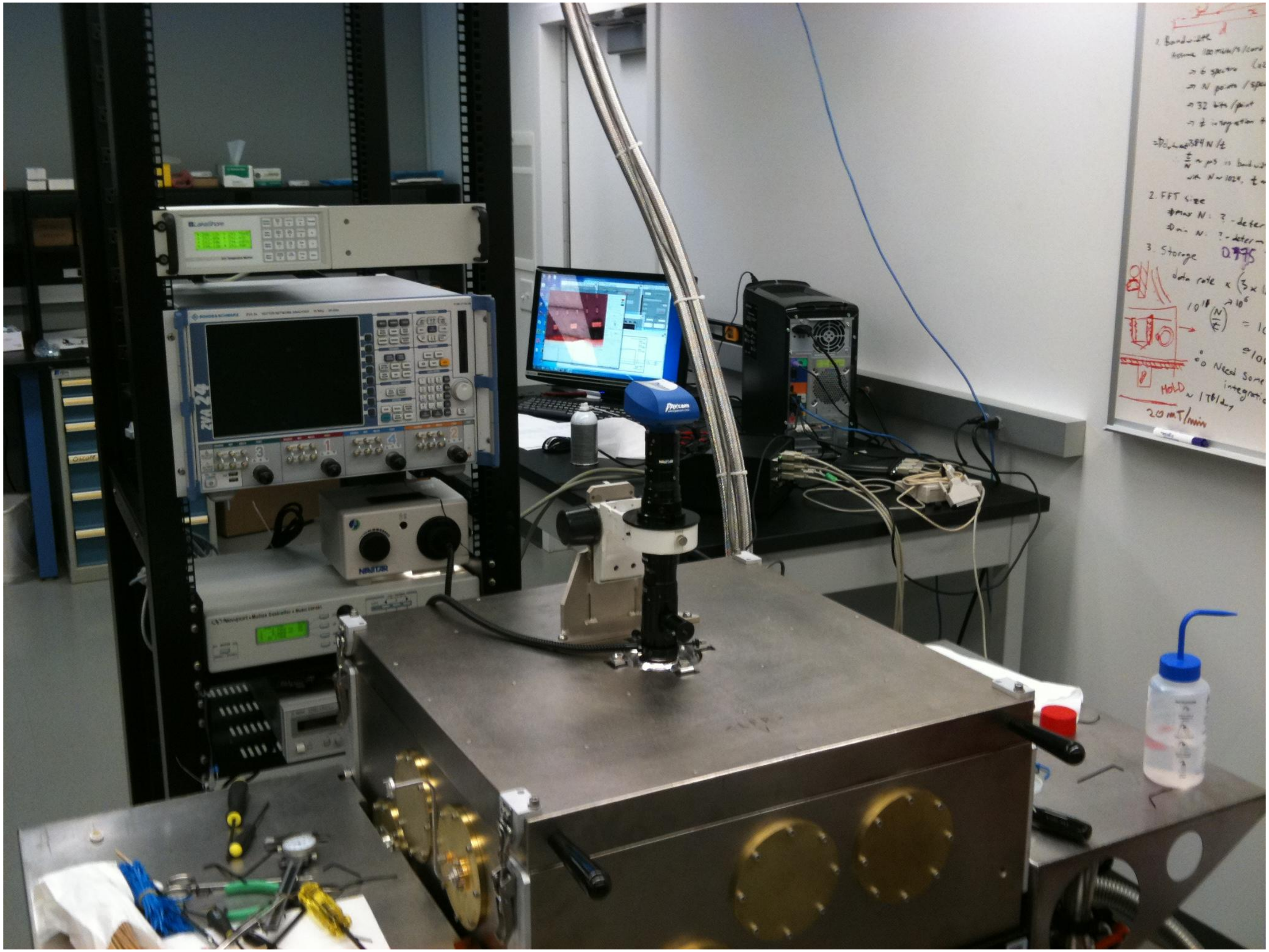
Module Production

Module Production

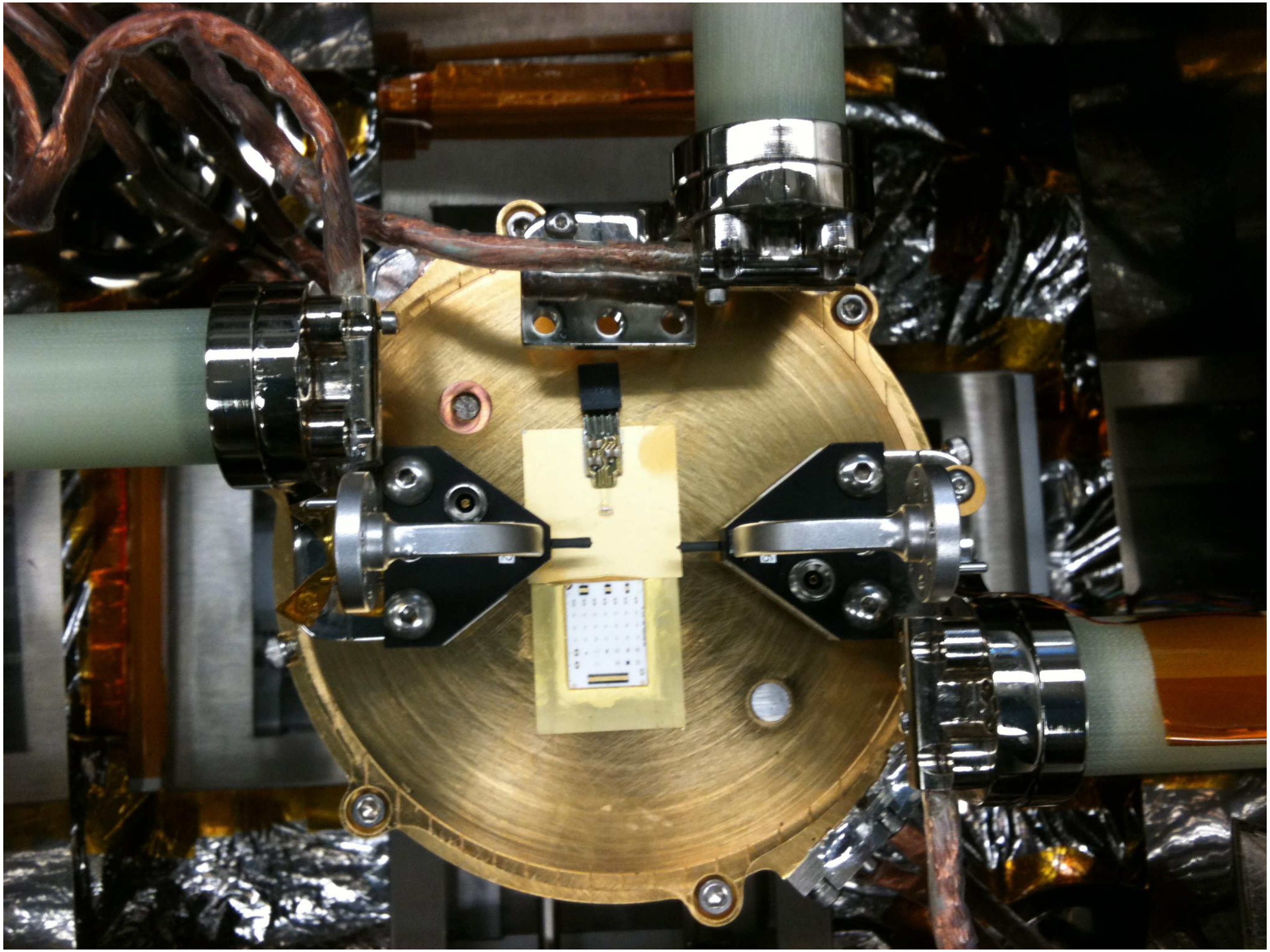
QUIET W-Band Lifecycle



Cryogenic Testing-CIT Probe Station



Cryogenic Probe Station



Cryogenic Probe Station