Cryogenic MMIC Low Noise Amplifiers and Heterodyne Receiver Modules

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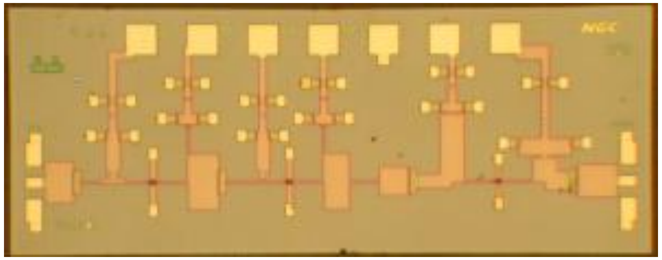
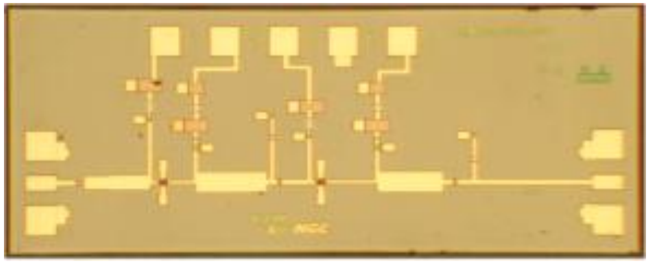
Outline

- MMIC Low Noise Amps (LNAs): Where we are today
- Low Noise Amplifier and Noise Figure results
- Multichip Heterodyne Receiver Modules with MMIC Front-Ends
- Cryogenic Results of G-Band Receiver module

MMIC LNAs - Where we are today: 2011





Major breakthroughs have been accomplished in the past few years in InP high electron mobility transistors (HEMTs) and MMICs, permitting high gain MMIC amplifiers well over 400 GHz [1-3].

A very useful consequence of these high gain transistors are their higher gain, and lower noise, found at lower frequencies.

W-Band LNAs are showing unprecedented cryogenic noise temperatures over wider bandwidths than previously possible, e.g., *Tsys* = 22K at 85 GHz (E. Bryerton, IMS 2008).

[1] Samoska, *et al*., “On-wafer Measurements of S-MMIC amplifiers from 400-500 GHz,” IMS Baltimore, 2011
[2] Deal *et al*., “Scaling of InP HEMT Cascode Integrated Circuits to THz Frequencies,” CSICS, Oct., 2010.
[3] Tessmann *et al*., “A Metamorphic HEMT S-MMIC Amplifier with 16.1 dB gain at 460 GHz,” CSICS, Oct., 2010.

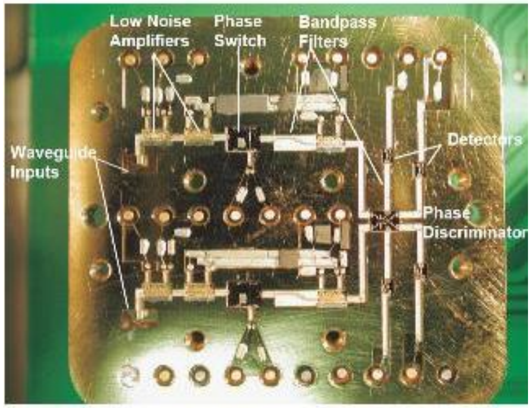
Why MMIC LNAs? Why InP?

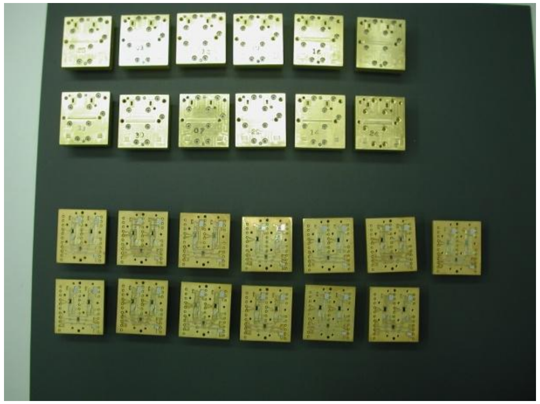
• InP MMIC LNAs have extremely high electron mobilities, particularly when cooled to cryogenic temperatures.

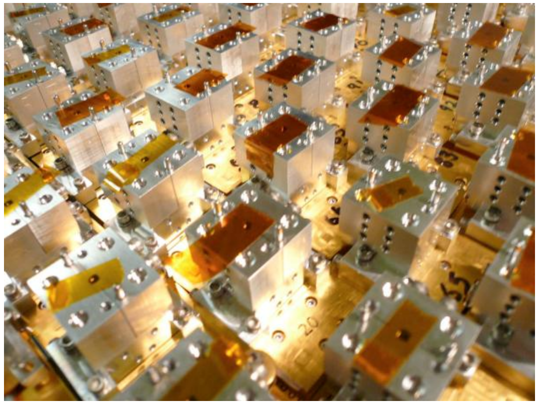
• A factor of 7-10 improvement in noise temperature has been experimentally observed when cooling from 300K to 20K ambient.

• Advantages of MMIC LNA receivers include operation at 20K, well above the temperature required for superconducting detectors. Inexpensive cryocooler options are more readily available for 20K cooling.

• MMICs lend themselves easily to large arrays (example: QUIET – 91 elements, 90 GHz)

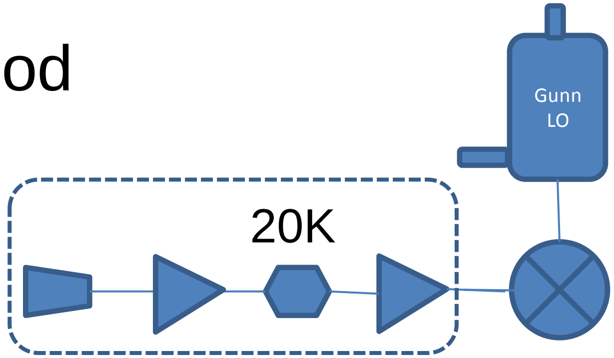




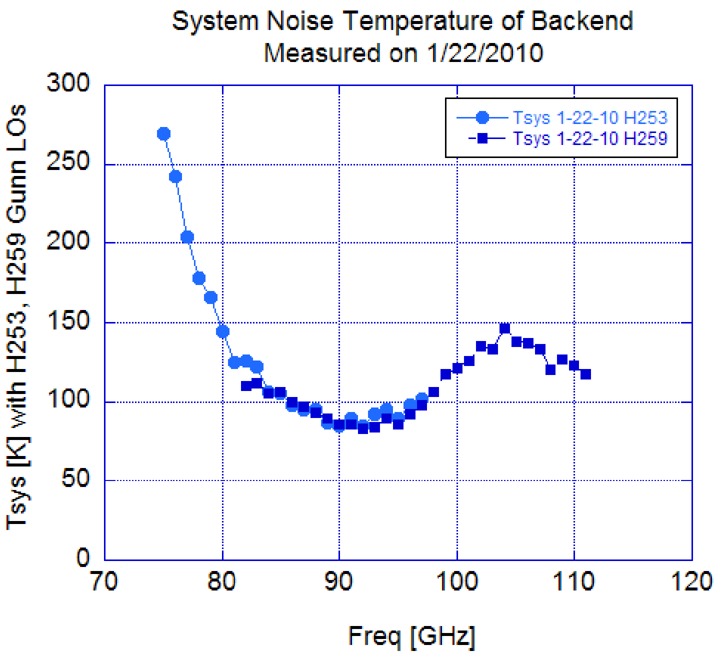


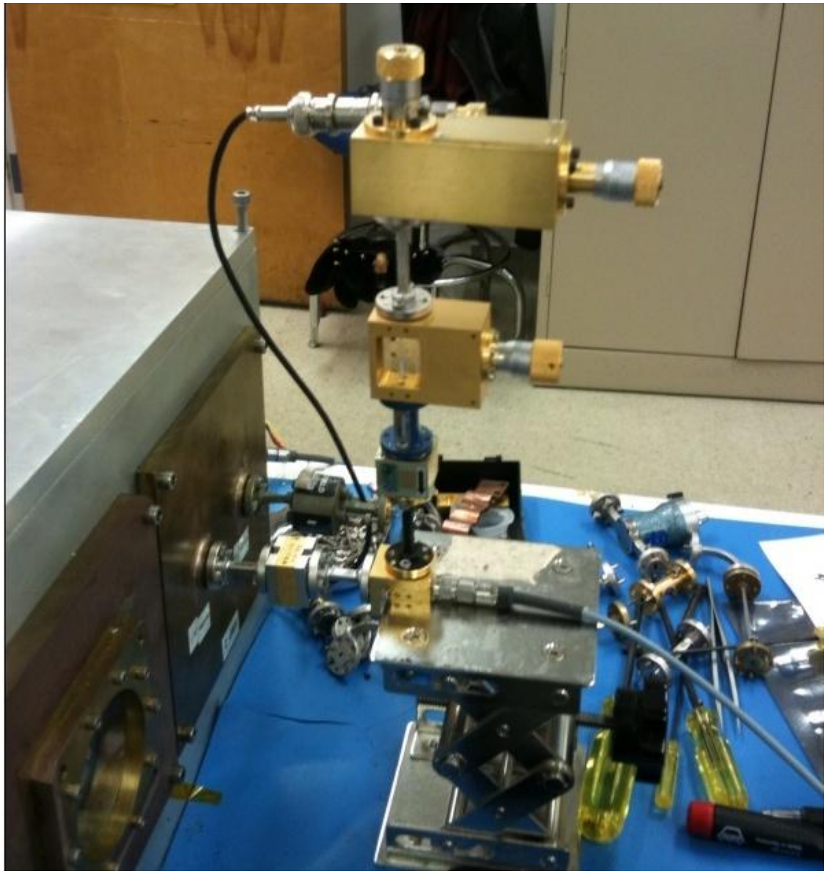
Test Set for Noise Measurements

Y-Factor Method



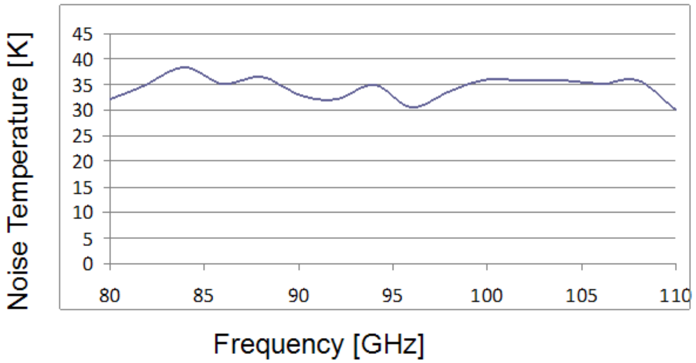
- Two Cold LNAs were inserted in the dewar with an isolator between them.
- WR10 horn and 1 mil mylar window used.
- Isolators used between LO Gunn and Mixer
- Two Gunns used to span 75-110 GHz
- Tamb=21.6K
- IF bandwidth is ~500MHz wide

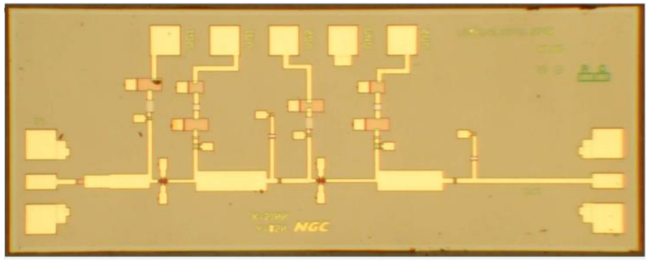


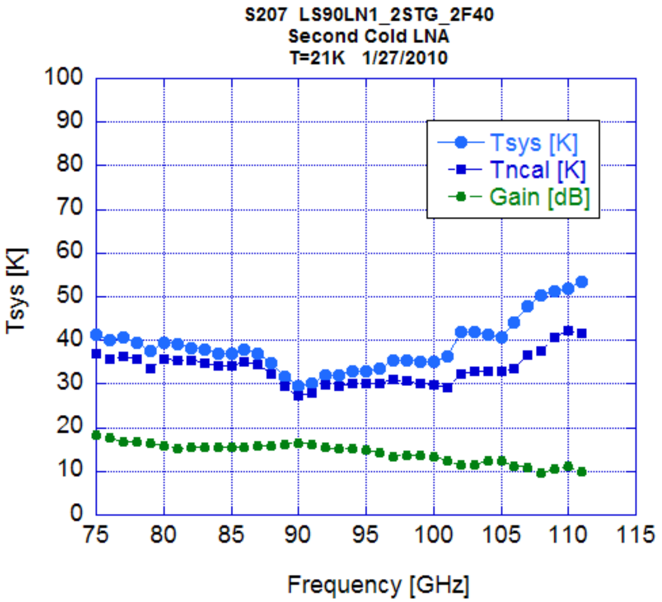


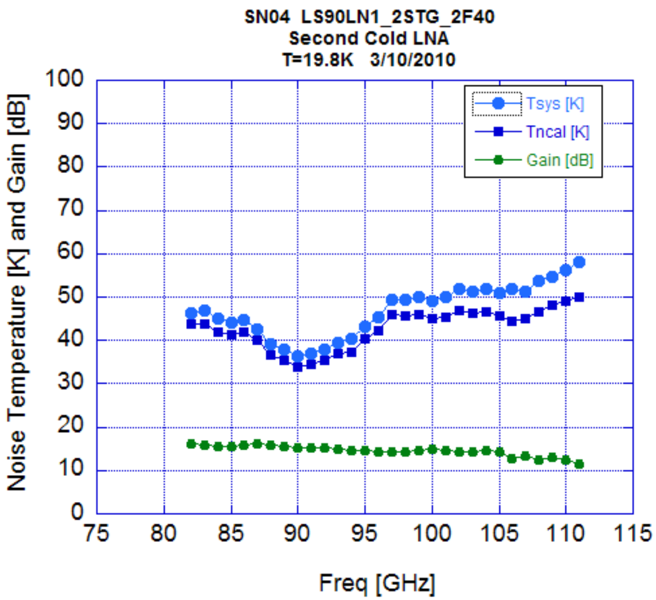
Full W-Band Noise Data of three separate 35 nm chips with 75% InGaAs Channel HEMTs

S. Xenos' data (2008)

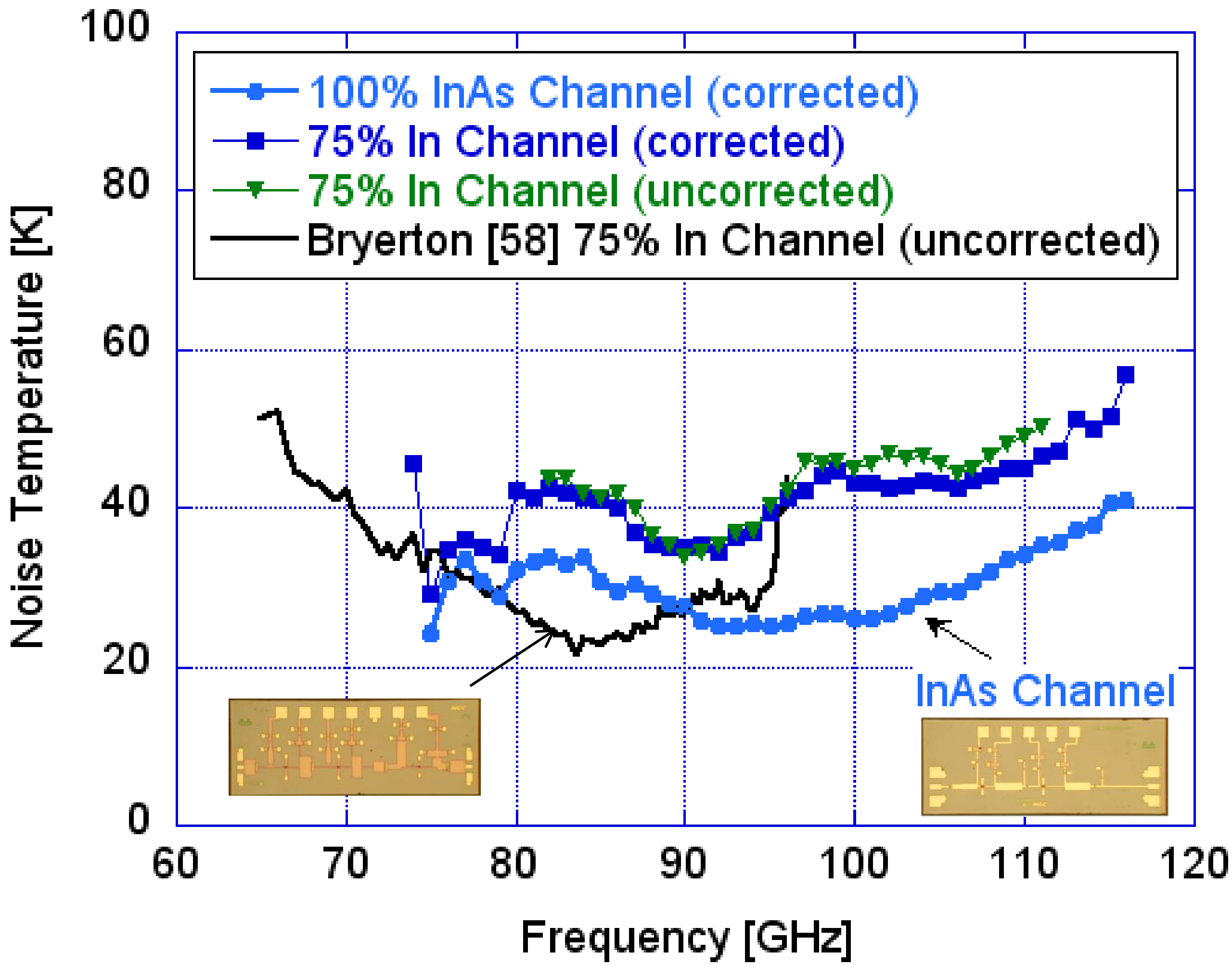






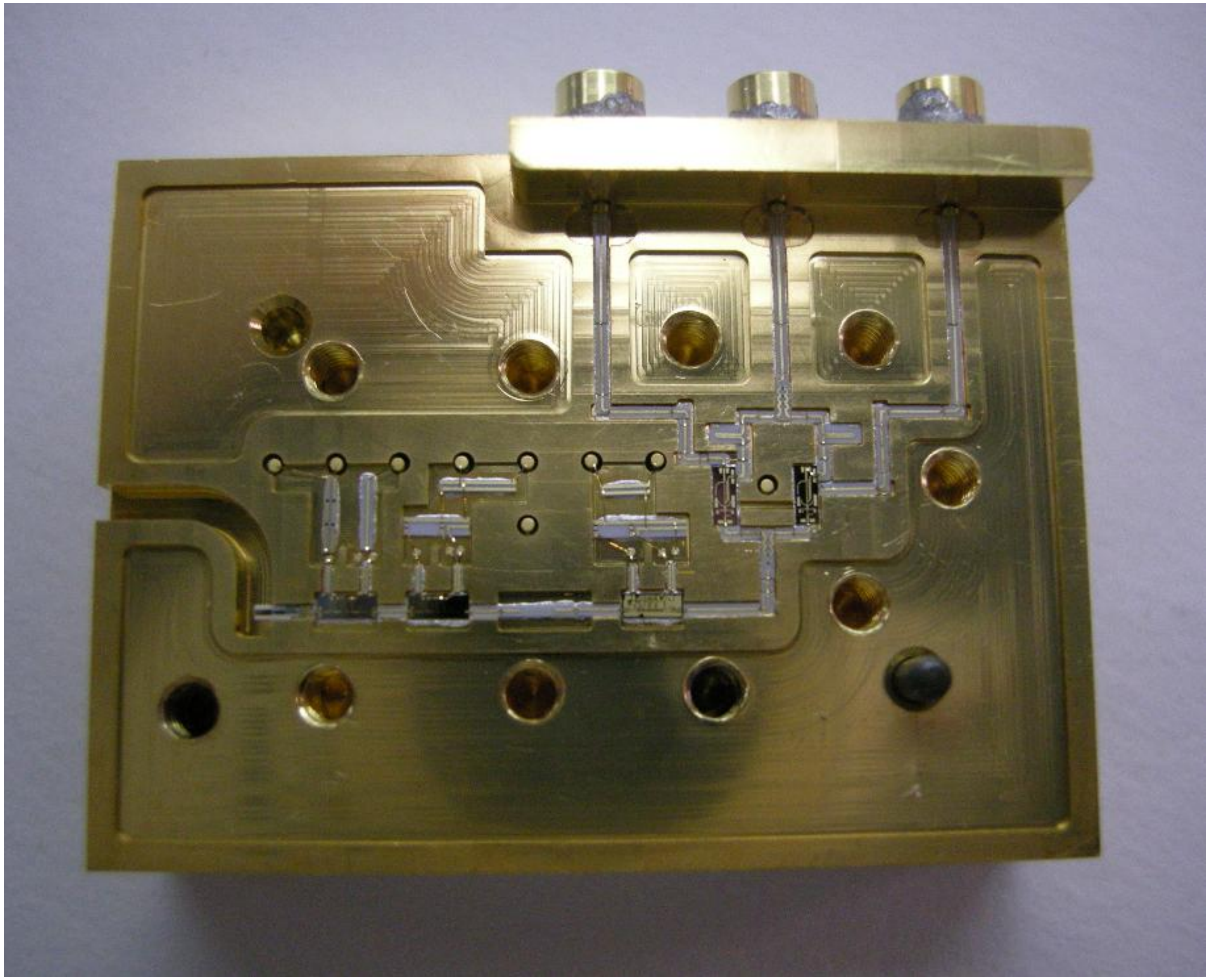


W-Band Noise Results



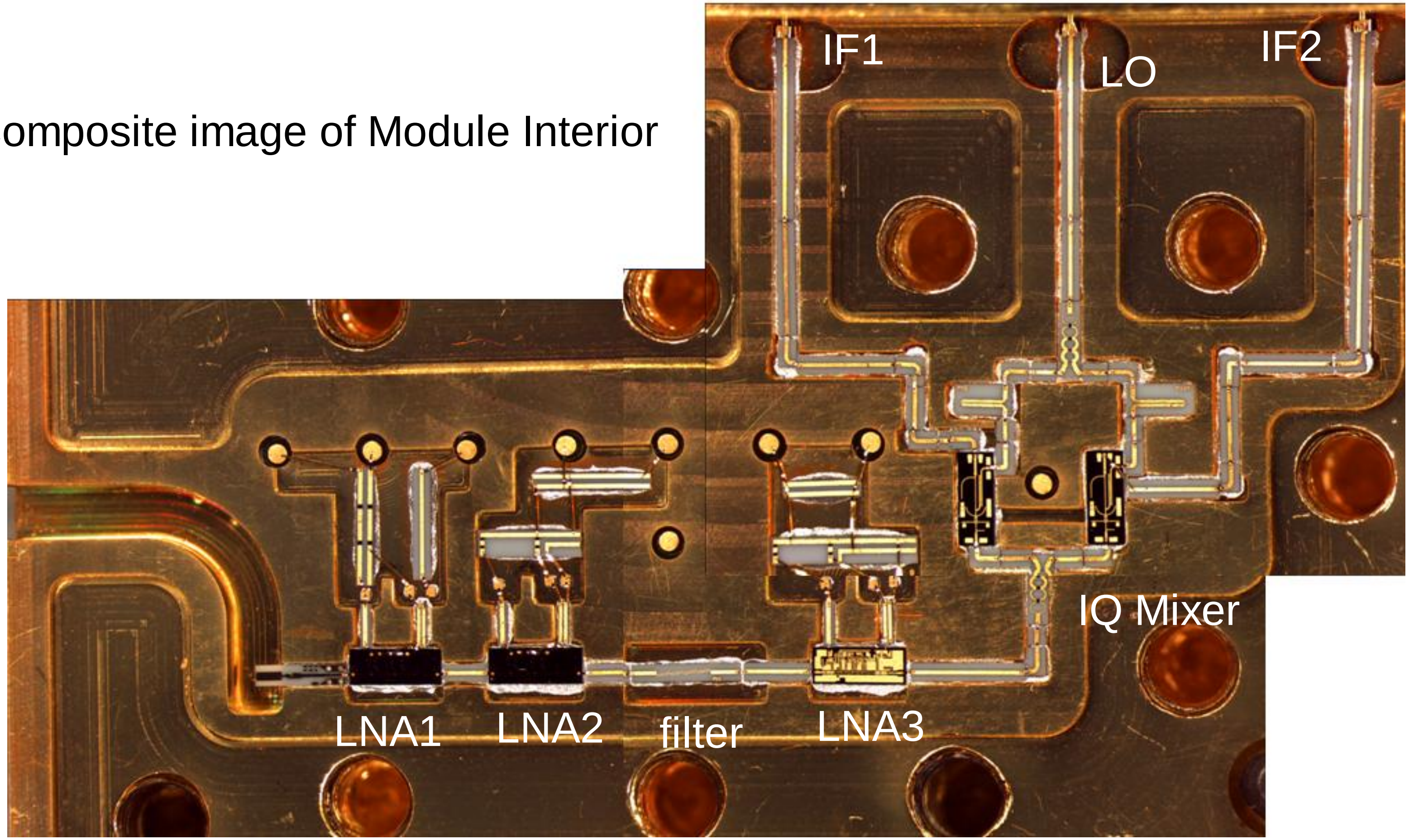
W-Band Heterodyne Module

- We have begun work on a heterodyne module for W-Band, shown below



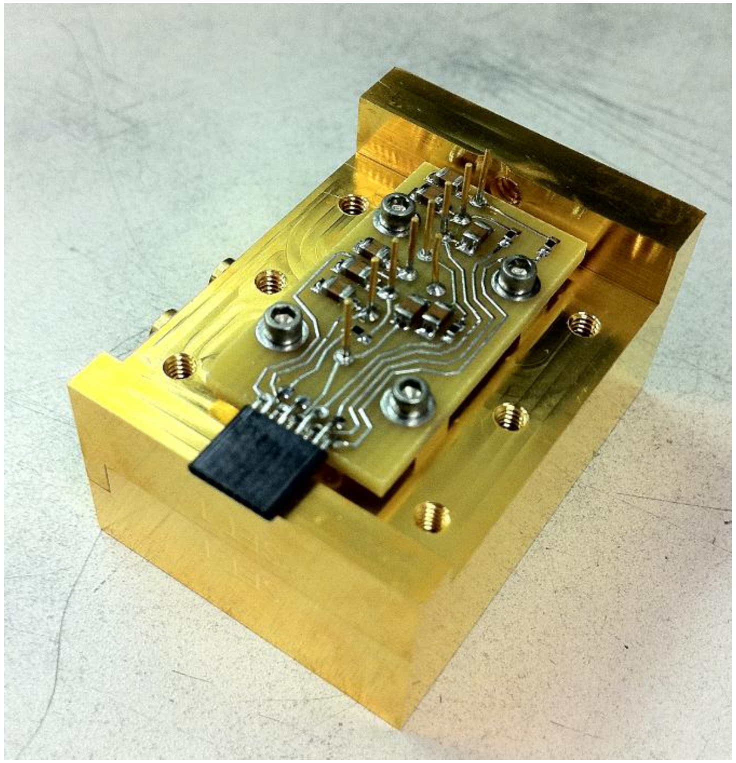
W-Band Heterodyne Module

Composite image of Module Interior

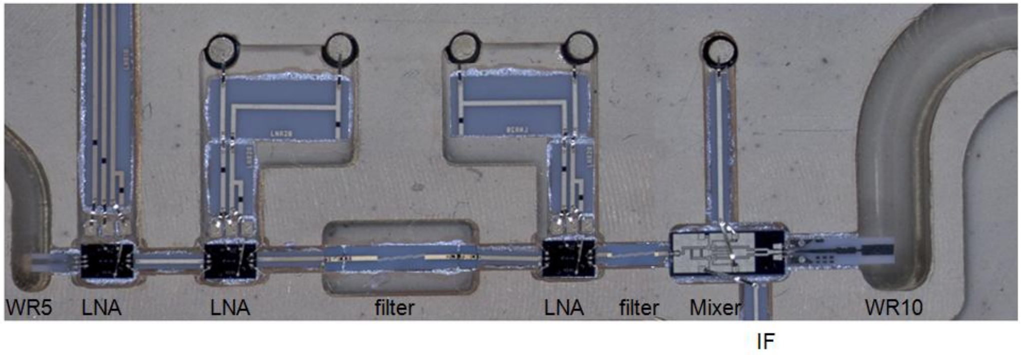


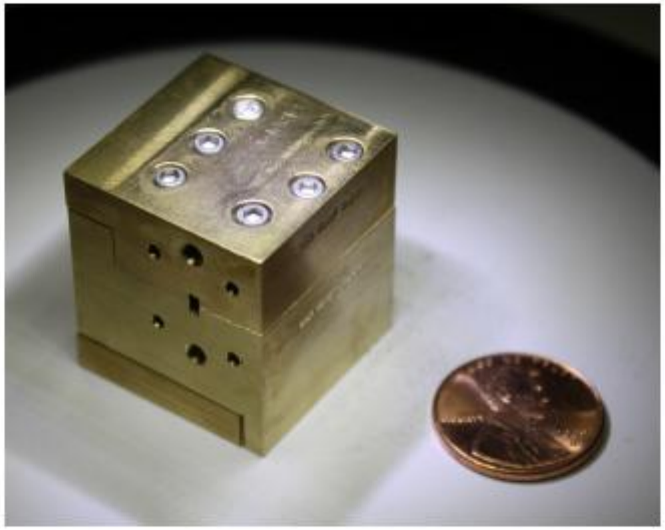
W-Band Heterodyne Module

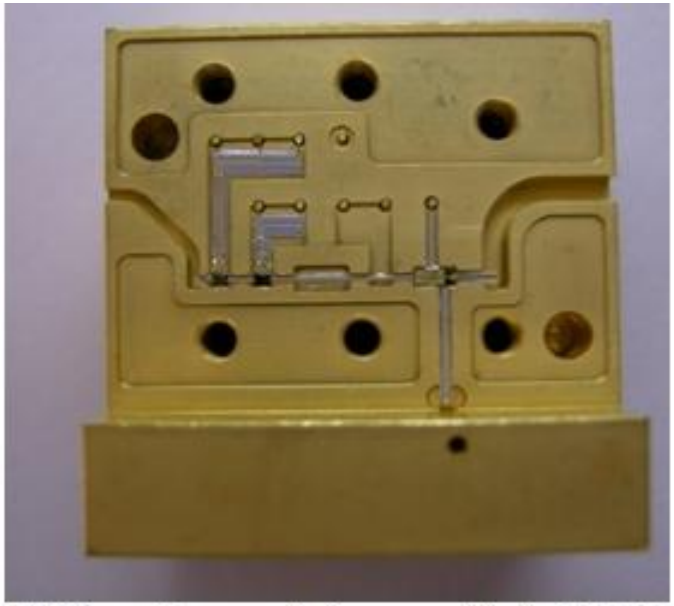
- DC bias board was designed for the module and is shown below.
- Final assembly is taking place now.
- A similar heterodyne module having 100 nm gate length HEMT MMICs had ~50K noise performance, and will be described by M. Sieth, “Technology Developments for a Scalable Heterodyne MMIC Array at W-band,” at *European Microwave*, 2011.



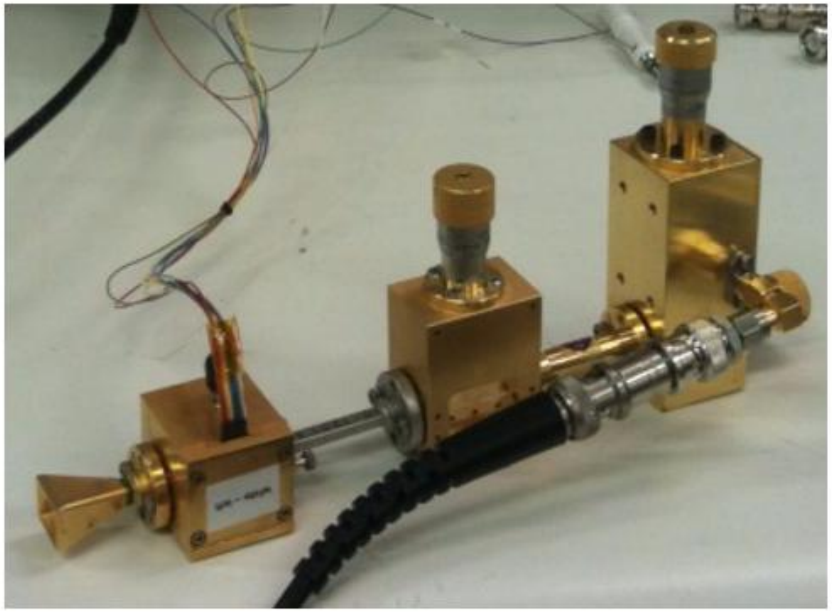
G-Band 150 GHz MMIC Receiver Module





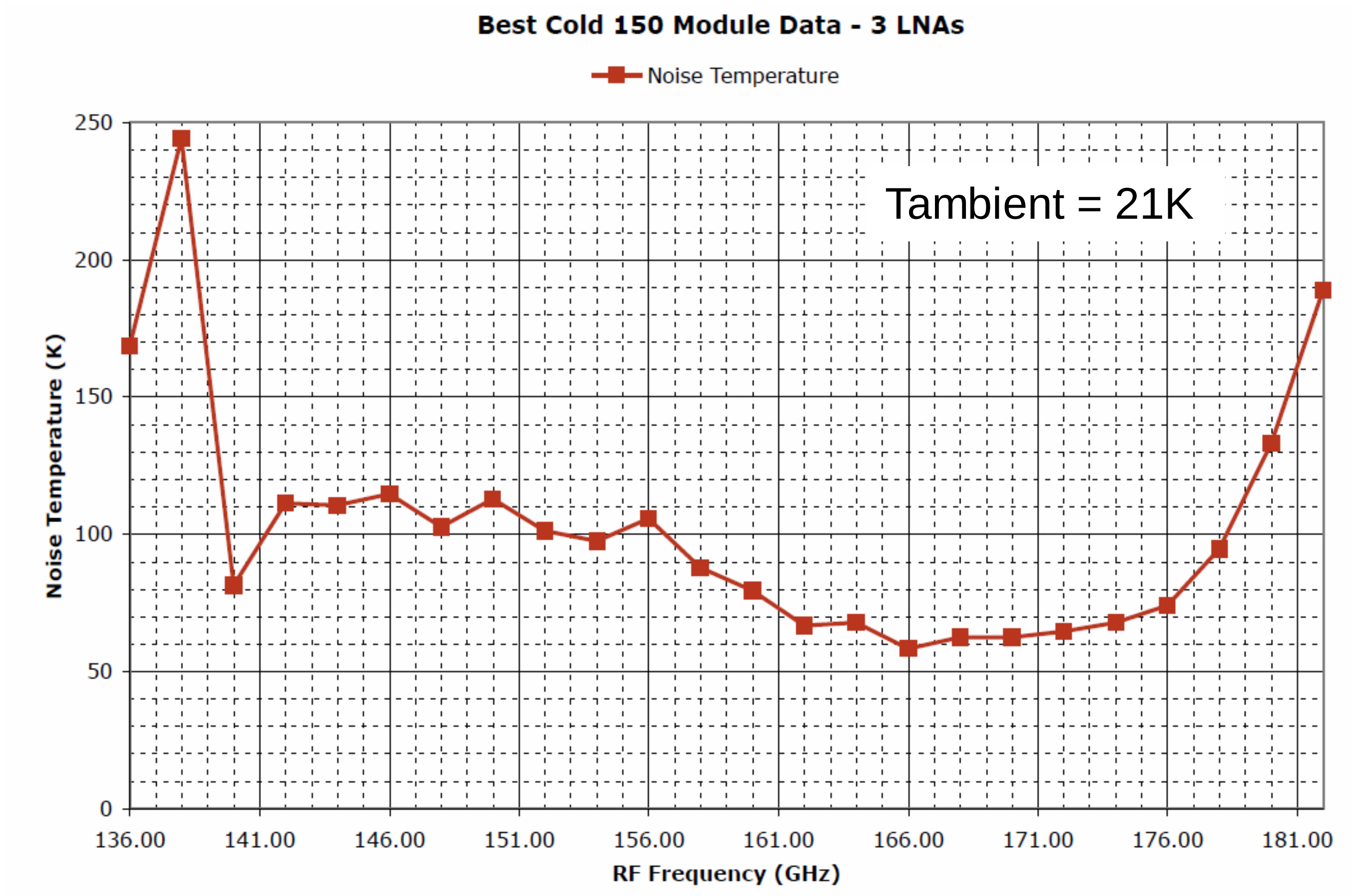


150 GHz MMIC receiver module, assembled with lid open.



150 GHz MMIC receiver module, with local oscillator applied.

G-Band Noise Results: 60K Noise at 166 GHz



Cryogenic Measurements obtained with 3 LNAs in the module, using Horn and 1 mil mylar window. There is no attempt at backend correction or correction for the window. Trec of 60K is obtained at 166 GHz. *(Voll & Samoska)*

P. Voll, details to be presented at European Microwave Conference, 2011

30 GHz LNA Designs – 100 nm InP HEMT, 35 nm InP HEMT

From Y. Tang and S. Weinreb

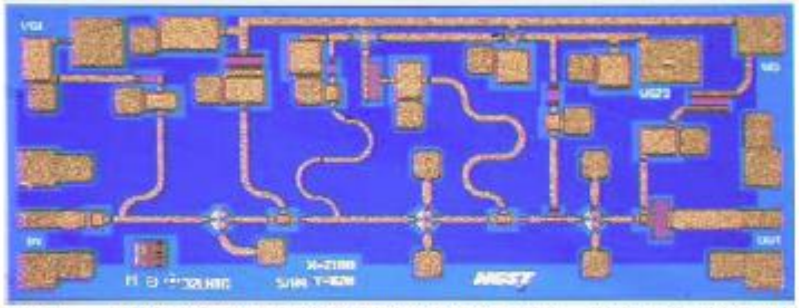


Fig. 2. Photograph of Ka-band MMIC LNA. The compact die measures 2.1 mm by 0.82 mm with a thickness of 75 μm.

10K noise was obtained over a wide bandwidth for a design using 100 nm HEMT process.

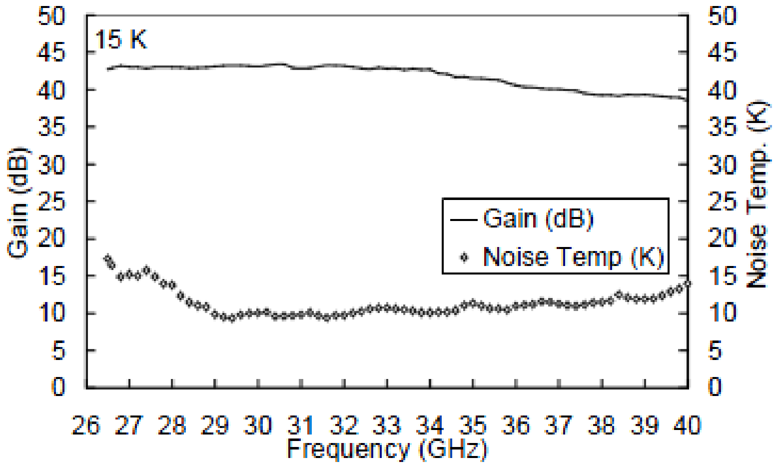


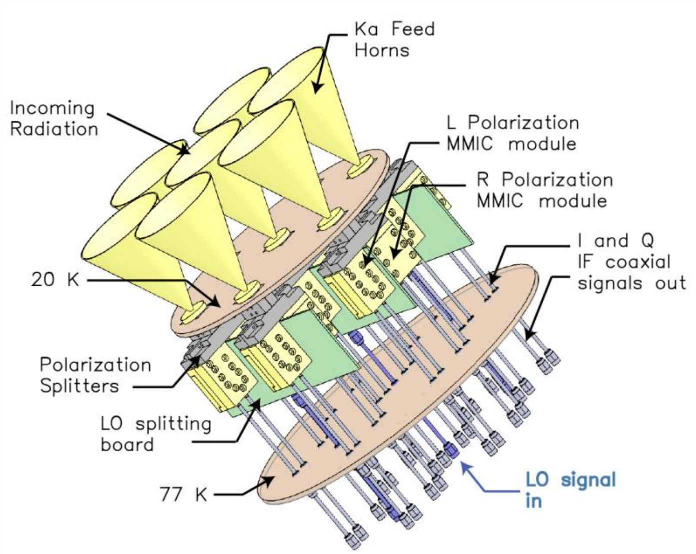
Fig. 10. Measured noise temperature and associated gain of the LNA module, from 26 GHz to 40 GHz, at 15 K.

A ~5 K improvement in noise is predicted for the 35 nm process.

We presently have some of these chips in the 35 nm process, and have the ability to test them for cryogenic gain and noise at JPL.

30 GHz Components

LNAs – could obtain (and/or design) these from NGC for prototype studies. Some chips (small quantities for testing, prototype modules) are available already through JPL/NGC/Caltech collaboration. 35 nm LNAs at 30 GHz are untested.



Mixers – may be GaAs mixer chips commercially available, or GaAs Schottky mixers custom designed for this application. Could also be InP HEMT mixer. (TBD)

IF amplifiers – some of these already exist (designs by S. Weinreb).

Components would need to be selected if available, and/or designed & fabricated for the particular bandwidth needed.

Prototype MMIC receiver module for 30 GHz could be designed for a scalable large array using some of the concepts we have already investigated for 90 GHz and 160 GHz.

Acknowledgments

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- We would like to thank the Keck Institute for Space Studies for support.
- We would like to acknowledge the expertise of Mary Soria and Heather Owen for micro-assembly work.