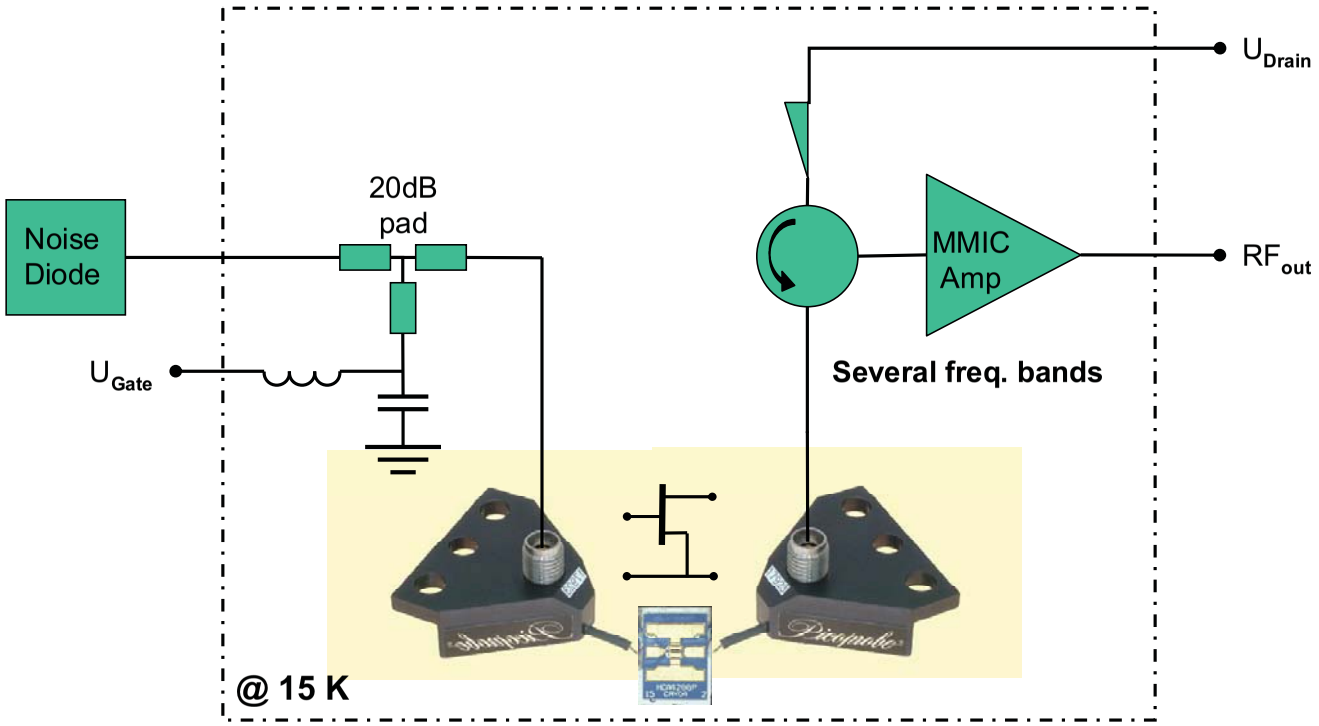
Noise characterization of single HEMTs : Why F50 ?

Several variants possible for measurement of NT at cryogenic temperatures

1. Standard method determines NT parabola from NT-measurements at different source impedances
   - Direct measurement of T_{min} possible
   - Needs automated tuners (mechanical or electronic) and for calibration permanent VNA control of impedances at cryogenic temperature
   - Since (standard) tuners have to be at ambient temperature the important length of (coaxial) cable necessary for the transition from ambient to cryogenic temperatures adds uncertainties especially at higher frequencies

2. F50 method (proposed by Dambrine, Cappy et.al in 1993) measures NT versus frequency in a 50 Ω System
   - Only measurements at a single, rather well controllable impedance level necessary
   - Original F50 exploits circuit properties of standard extrinsic FET model to directly measure R_n and from linear dependency of NF_{50} versus ω^2, additional assumption on correlation coefficient (i.e. Pospieszalski model) then give complete set of noise parameters
   - IAF model uses least squares to fit the channel temperature T_c to measured NF_{50} data, the other access resistances are at physical temperature of device

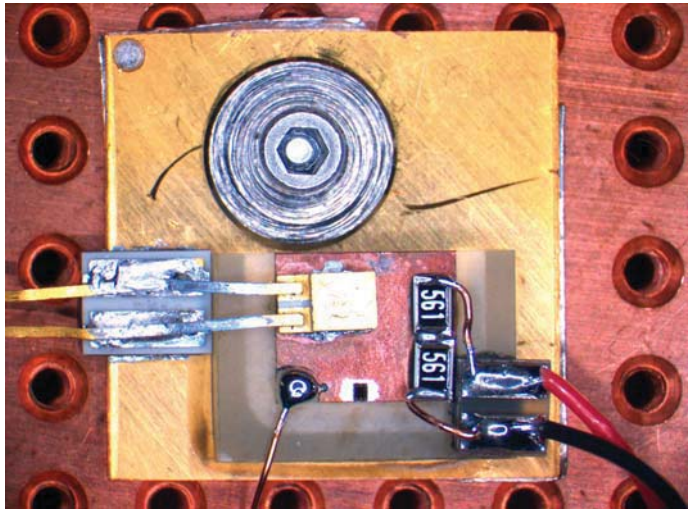
A possible cryogenic F50 setup

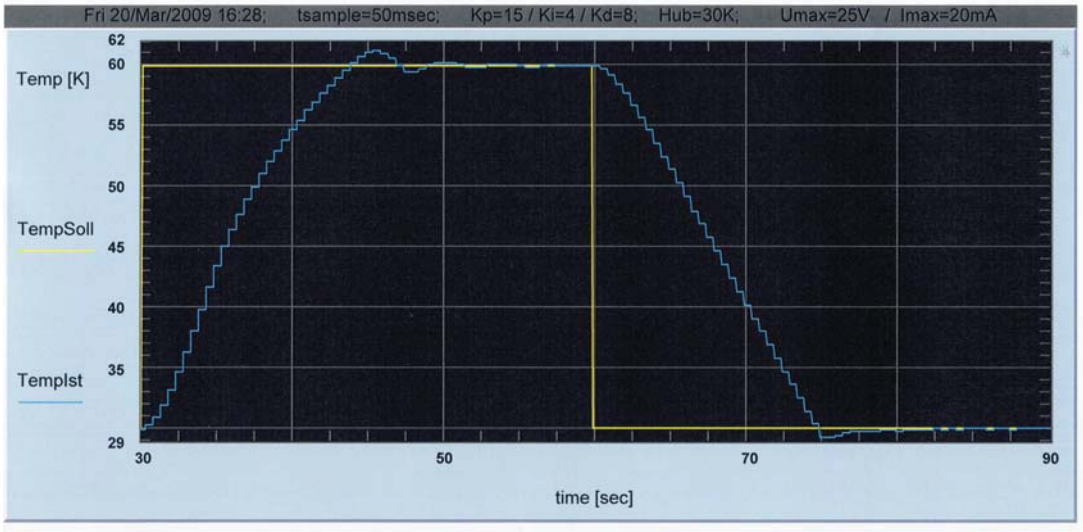


- Uses cold-attenuator method for good match and adequate source temperatures
- Still needs additional VNA to calibrate source temperature at probe tip reference plane, calibration prone to errors due to different media (coaxial/coplanar) and assumptions for temperature distribution on input line to cold pad

Internal CAL load for F50

Solution of calibration problem at 15K using a well matched internal heated load
@ known absolute temperature:





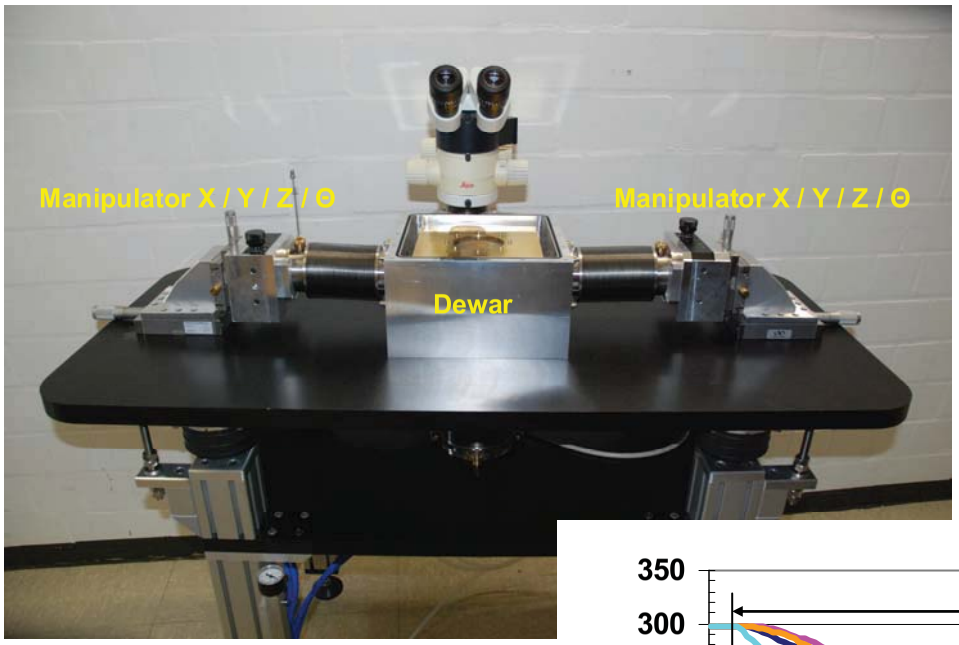
Test load

Profile of 30K temperature step

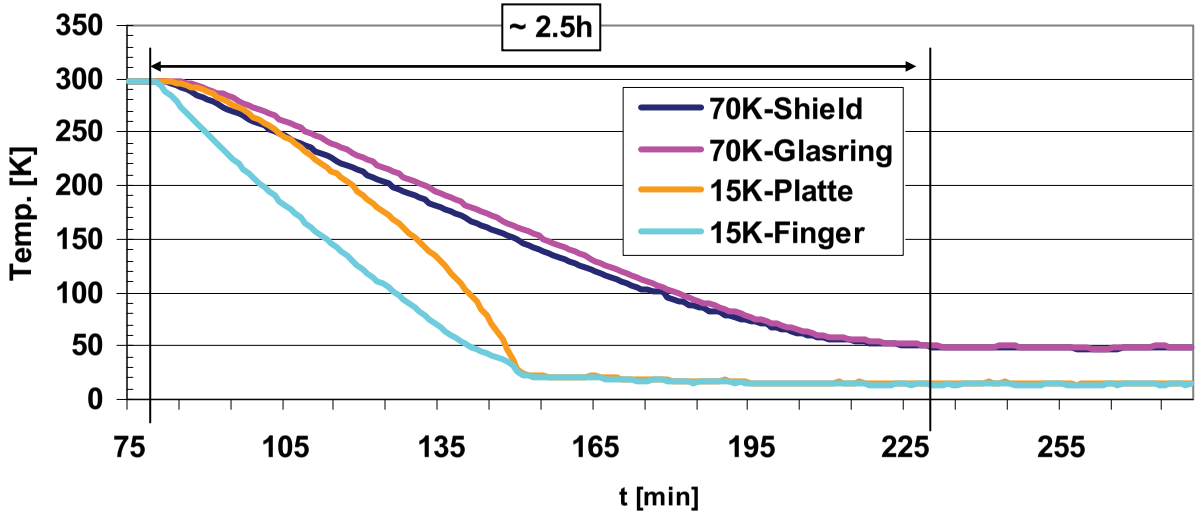
Heated load must have short time constant to minimize errors from NFA gain drifts :

- low thermal mass of heated parts
- + software PID for heater control gives t ~15sec for this test load

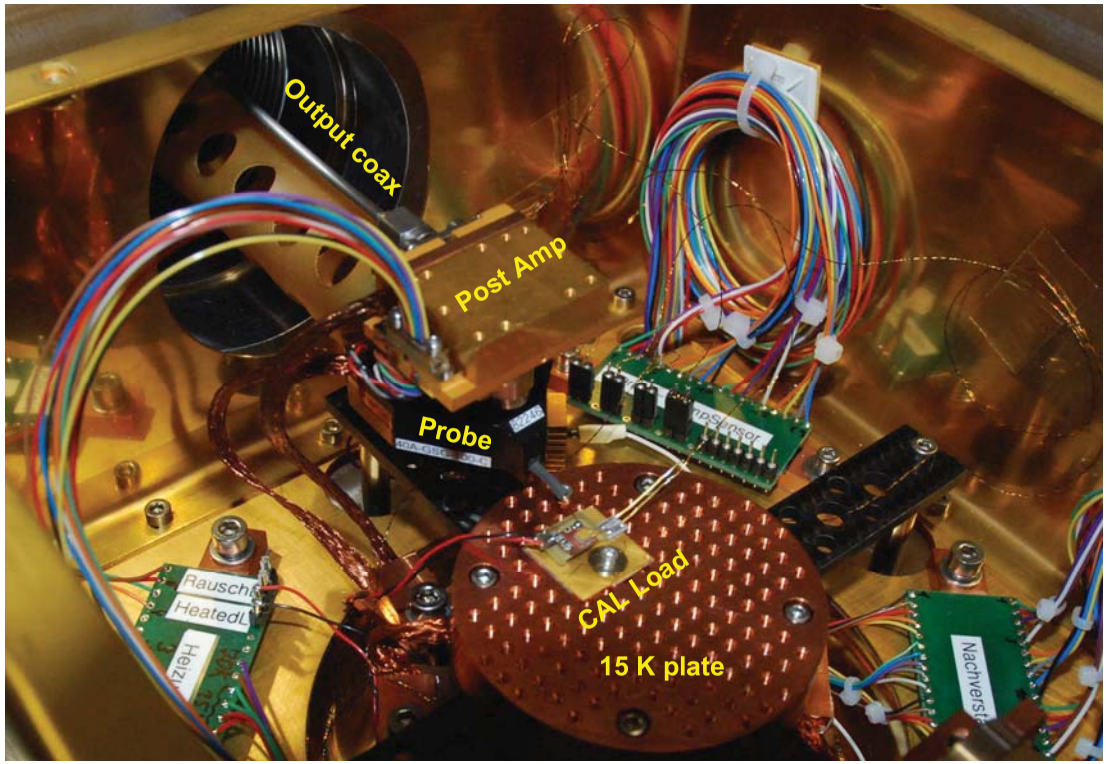
New MPIfR F50-Prober



Cooldown
(standard CTI 350
refrigerator)



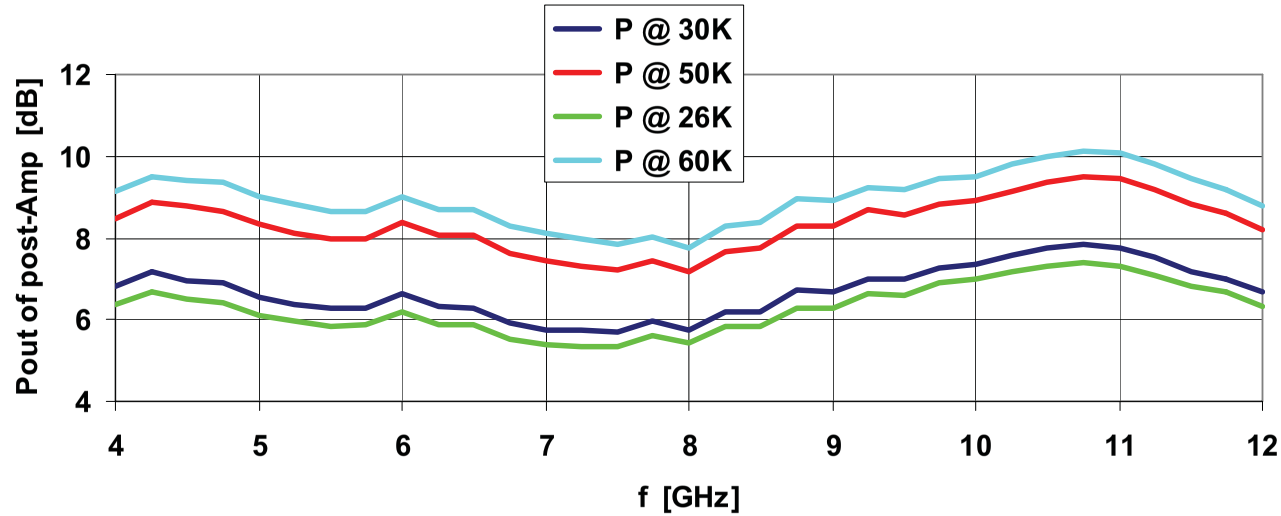
New F50-Prober : Close-up of output probe arm



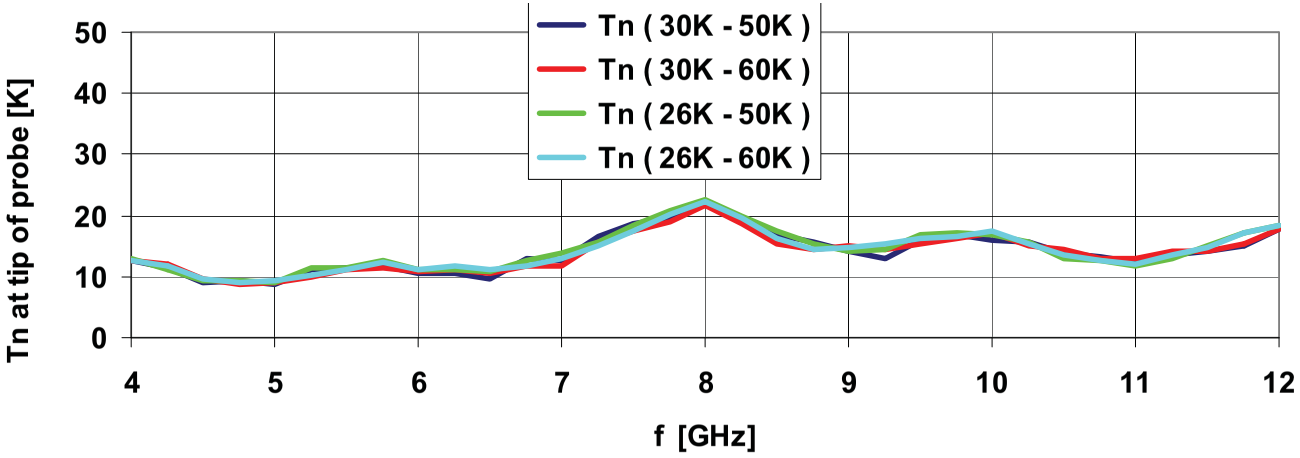
Cryogenic post–amp module for this test :

- WBA13 4-12GHz MMIC LNA from Caltech / NGST (Cryo-11 run, larger noise)
- includes drain bias-tee and 90° coax to MS transition
- single ended input matching designed for power match (IRL ~ -15dB)
- further bands could also use balanced designs to achieve necessary matching

New F50-Prober - First Tests : post-Amp Calibration



Output power of cryogenic post amplifier for different temperatures of internal heated load



Calculated noise temperature at the probe-tip including bias tee for diffferent temperature pairs :

No systematic effects with temperature

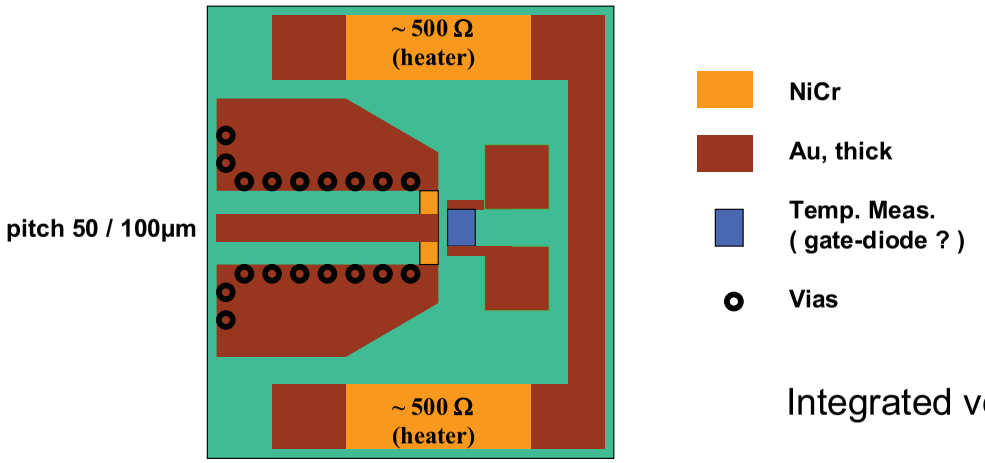
Further plans for cryogenic NT measurements 1

1. Production of absolute temperature calibration standards on wafer is underway, will give faster time constant due to lower thermal mass as compared to hybrid approach used so far

2. Test of two ideas for electronically switched sources that are inherently fast but need to be calibrated repeatedly against absolute temperature standard :

   - Commercial avalanche noise diodes in chip-form + cold attenuator
     (operability at cryogenic temperatures ?)

   - Gate-diode or HEMT at switched bias + cold attenuator as noise source:
     would give on wafer electronically switchable noise source @ 15K using IAF process



Integrated version of coplanar heated load

What's next

- Need more cryogenic measurements on LNA-MMICs (1-4 / 4-12 / 10-18 / 20-25GHz) and single HEMTs in order to improve cryogenic model (F50 > noise) and to have better statistics for stability issues (50 / 100nm). [MPIfR/IAF/CAY/IRAM]
- In parallel more standard (non-cryogenic) W-band -LNAs from IAF will be tested at cryogenic temperatures. [IRAM/MPIfR/CAY?]
- Start design of cryogenic W-band LNA. [IAF]
- From the good results CAY has seen from IAF single HEMTs it seems promising to make a hybrid LNA design at Q-band in collaboration with the APRICOT JRA.
- A design for an OMT providing proper orientation of WG's needs to be done [INAF Cagliari]
- Decision on level of integration of prototype pixel should be taken in next meeting.