ALMA Interferometer and Band 7 Cartridge

B7 Cartridge designed, assembled and tested by:
S. Mahieu, D. Maier (mixer team lead), B. Lazareff (now at IPAG)
G. Celestin, J. Chalain, D. Geoffroy, F. Laslaz, Q. Moutote, M. Parioleau, G. Perrin, J. Reverdy.
As well as contributions from SIS, mechanical and administration groups.

ALMA Project, some key parameters

- International collaboration between North America, Europe, East Asia and Chile.
- Manufacturing of a giant interferometer with 54 (12) 12 m (7 m) antennas at 5000m altitude in atacama (Chile) (~1.3 Billion $, 10% Rx, 65% antenna)
- Largest astronomical ground-based observatory on earth that will allow research into the physics of the cold universe (stars and planets formation)
  - Wavelengths between 0.3 and 9.6 mm shared amongst 10 receiver bands.
  - Baseline of 150 m to 16 km
  - Angular resolution ~0.005" at the highest frequencies
  - Should be operational end of 2013.
  - Early science is about to start (end of 2011).

ALMA OSF & AOS

The Operations Support Facility (OSF)

• antenna Assembly-Integration-Verification (AIV) activities. -> center of all scientific activities related to the daily operation of the JAO. -> central location for observatory maintenance and operations aspects.

Array Operation Site:

The AOS Technical Building houses the ALMA Correlator. Digitized signals received from the radio telescopes are processed here and further transmitted to the data storage facilities located at the OSF.

Cryogenic devices for ALMA

- The world-class project that uses the largest amount of cryogenically cooled active and passive devices (Mixer Chips, LNA, Isolators, etc..)

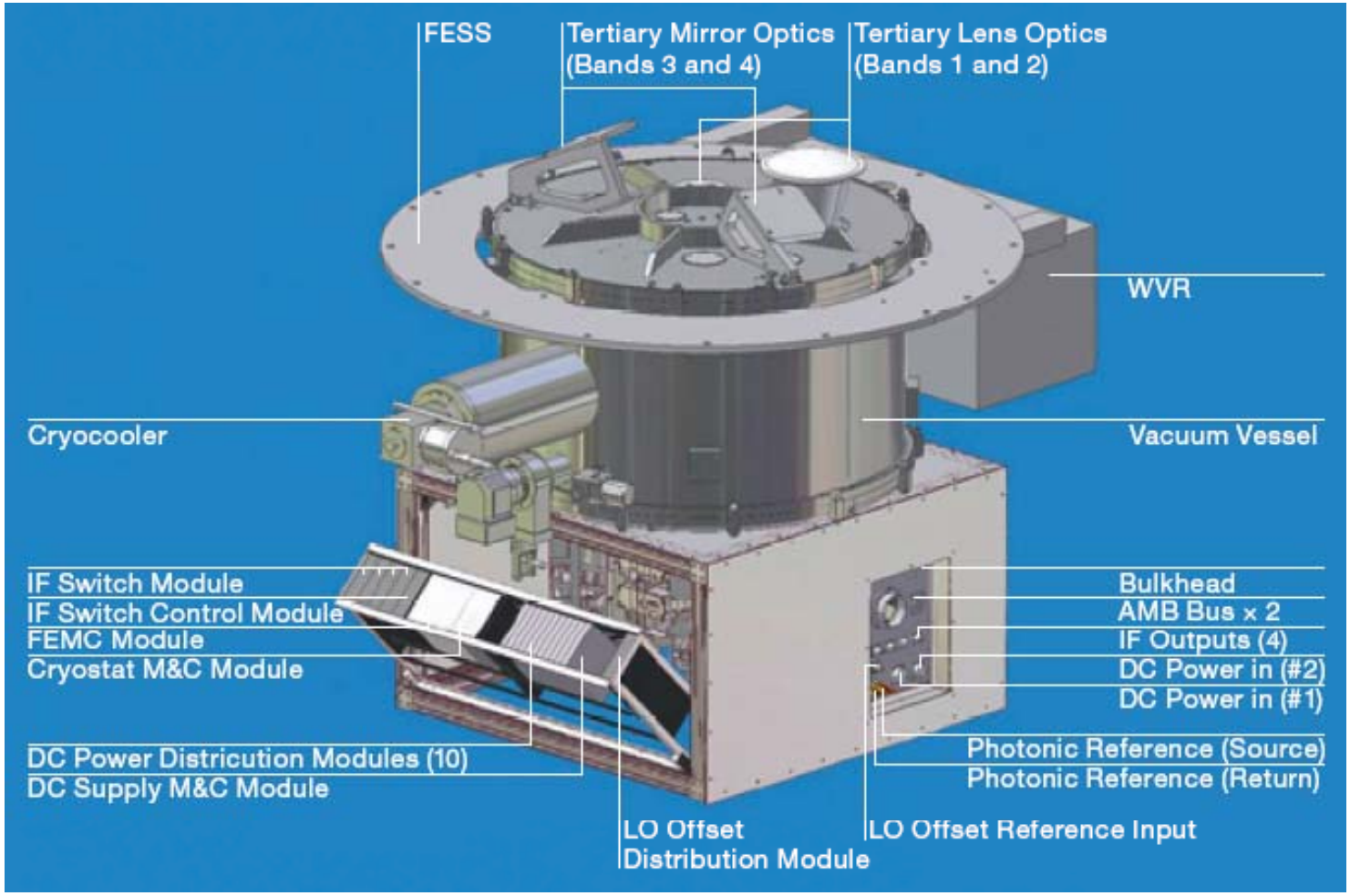
Band	Manufacturer	Frequency	Mixing Scheme	Noise Temperature	Cryo LNA	Technology
1	-	31.3-45 GHz	USB	26 K (SSB)	2	HEMT
2	-	67-90 GHz	LSB	47 K (SSB)	2	HEMT
3	HIA	84-116 GHz	2SB	60 K (SSB)	4	SIS
4	NAOJ	125-163 GHz	2SB	82 K (SSB)	4	SIS
5**	Chalmers	163-211 GHz	2SB	105 K (SSB)	4	SIS
6	NRAO	211-275 GHz	2SB	136 K (SSB)	4	SIS
7*	IRAM	275-373 GHz	2SB	147 K (SSB)	4	SIS
8	NAOJ	385-500 GHz	2SB	292 K (SSB)	4	SIS
9	SRON/NOVA	602-720 GHz	DSB	261 K (DSB)	2	SIS
10	NAOJ	787-950 GHz	DSB	344 K (DSB)	2	SIS
				Total for 65 receivers	1820	

* 370-373 GHz < 300K
** limited to 6 units

- 100% of the components are tested prior to integration at cold temperature (15K or 77K)

ALMA Cryostat (RAL-UK)

One of the core components for the ALMA Front End that cools the inner components < 4K.

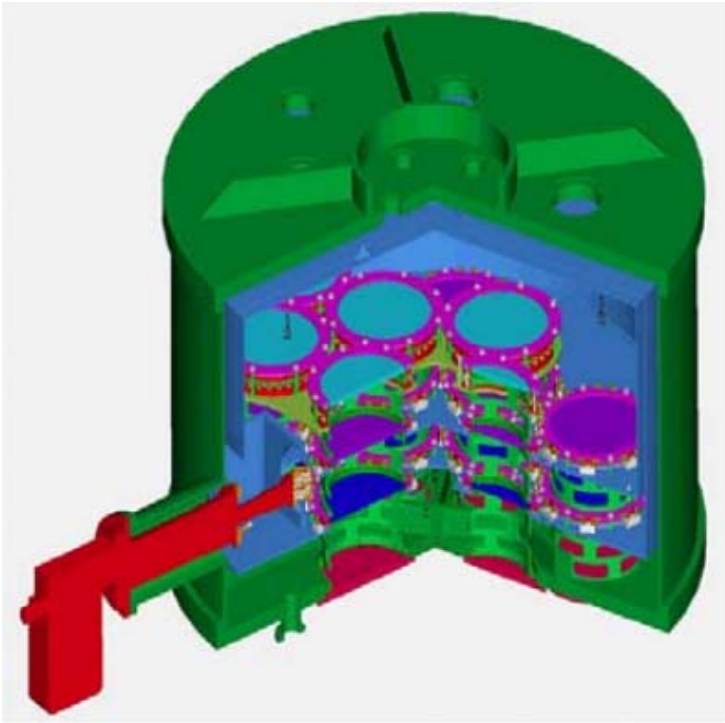


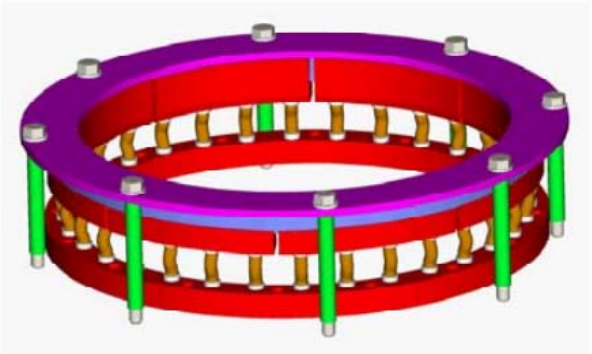
- Necessary for operating mm and sub-mm high sensitivity SIS mixers + cooling of other electronic components .
- Closed cycle cryocooler allows for long term (> 1 year) unattended operation
- Use of 15K and 90K shields to minimize the radiation heat load on the 4 K components.
- Top plate accommodates 10 vacuum windows allowing the incoming radio frequency (RF) signal to reach the cold optic components mounted on each cartridge.
- IR filters are also mounted on the inner shields to prevent IR radiation from entering and warming up the 4K stage.

ALMA Cryostat thermal links

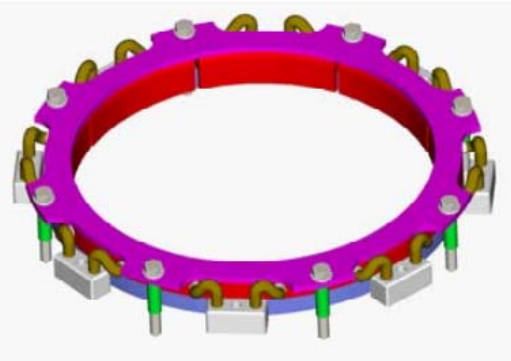
The individual receiver modules are known as cold cartridge assemblies. Thermal connection to each cartridge assembly heat sink stage is provided via a novel resistance thermally activated link arrangement that requires no permanent mechanical attachment.

- No need to open the cryostat to swap receivers
- Easy to maintain
- Possibility to assemble and test receivers in different places





4 K link

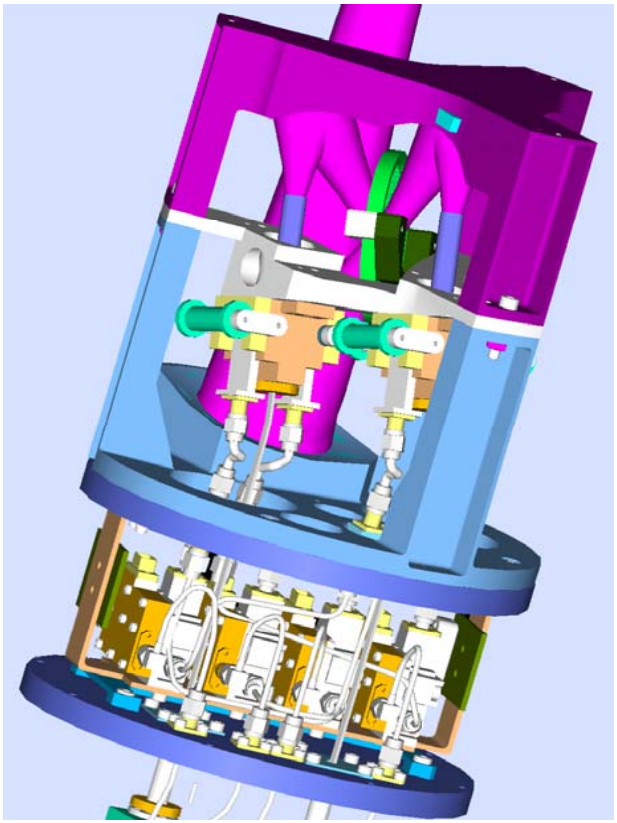


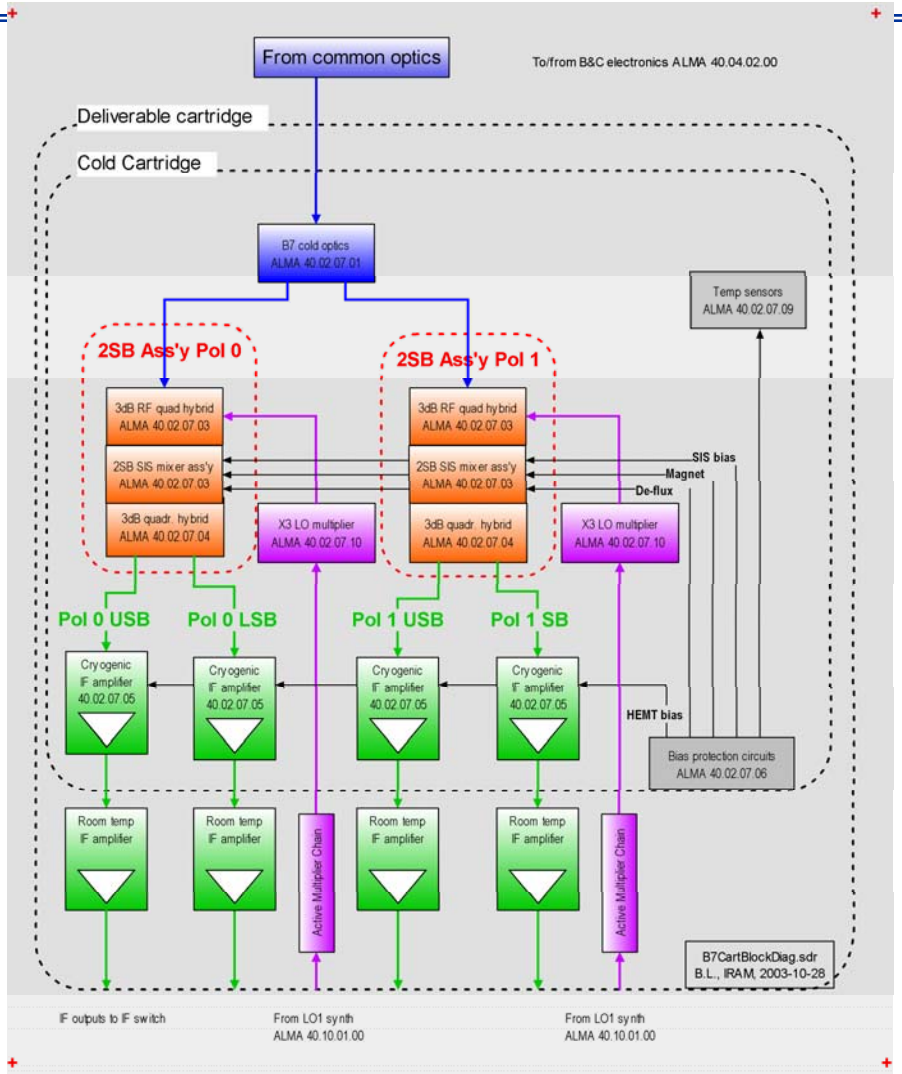
12 and 90 K link

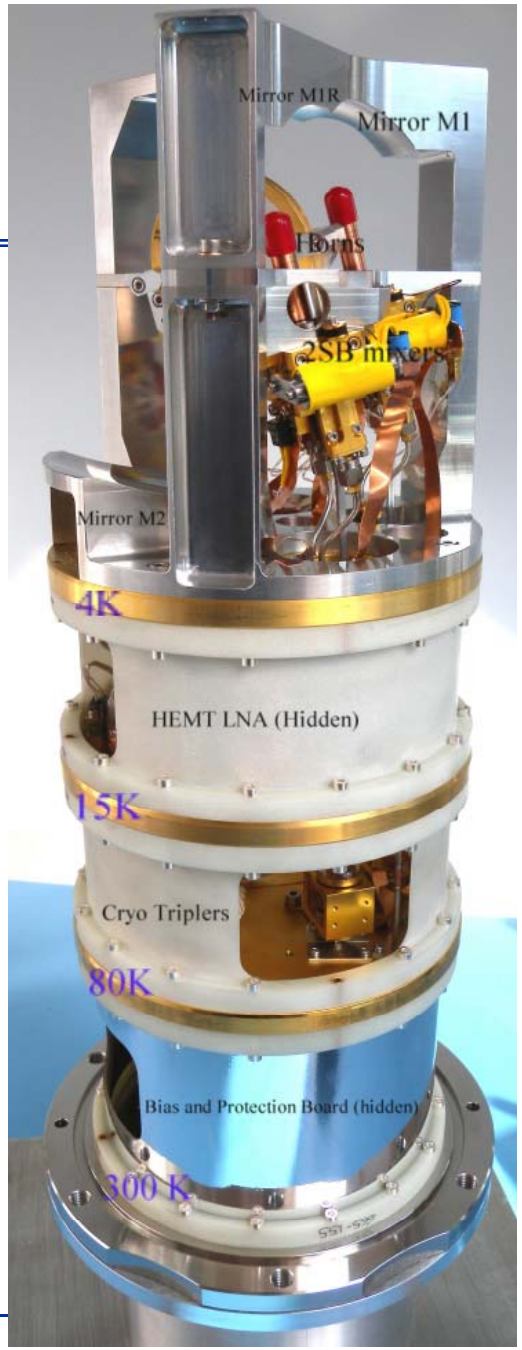
IRAM contribution to ALMA

- IRAM, amongst others is responsible for developing and manufacturing 73 ALMA band 7 (275-373 GHz) receivers
- The specifications that were put in place in the early 2000 have pushed the limits of the state of the art to date.
  - The design challenges were overcome during the pre-production phase.
  - During production phase, emphasis has been put on quality assurance, schedule and cost commitment, thanks to the elaboration of proper test procedures and construction of dedicated automated test set.

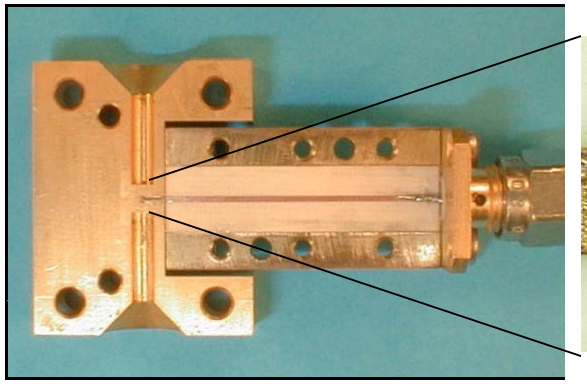
Band 7 Cartridge overview



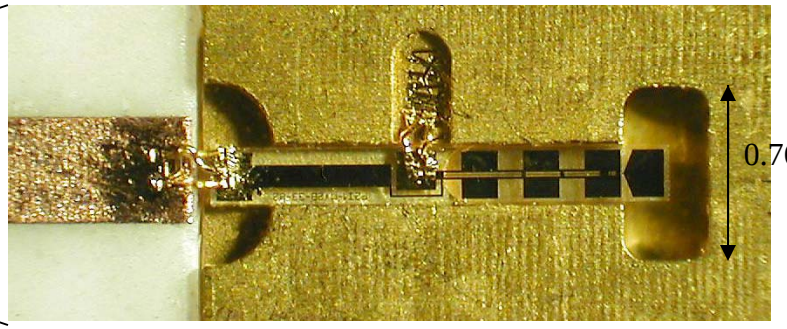




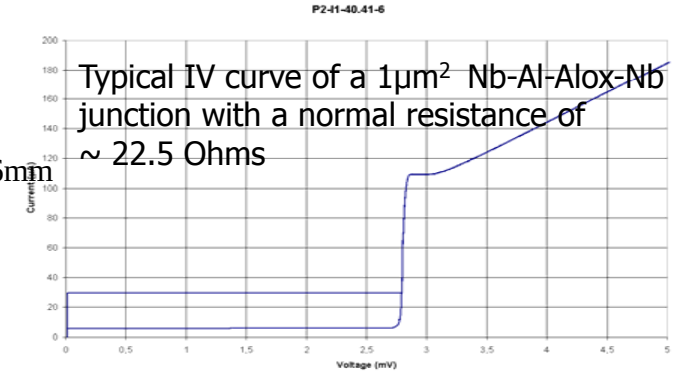
B7 Cartridge Sideband Separating Mixer



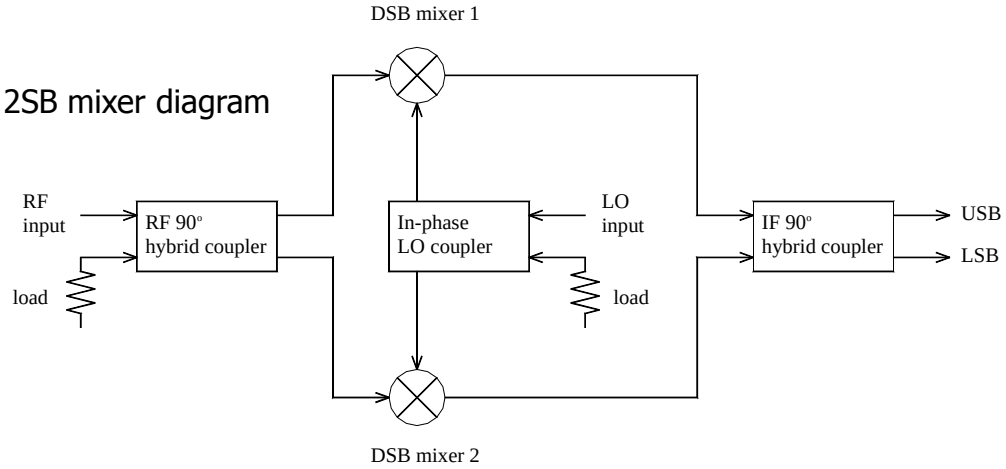
Double Side Band mixer (DSB) with its IF circuit

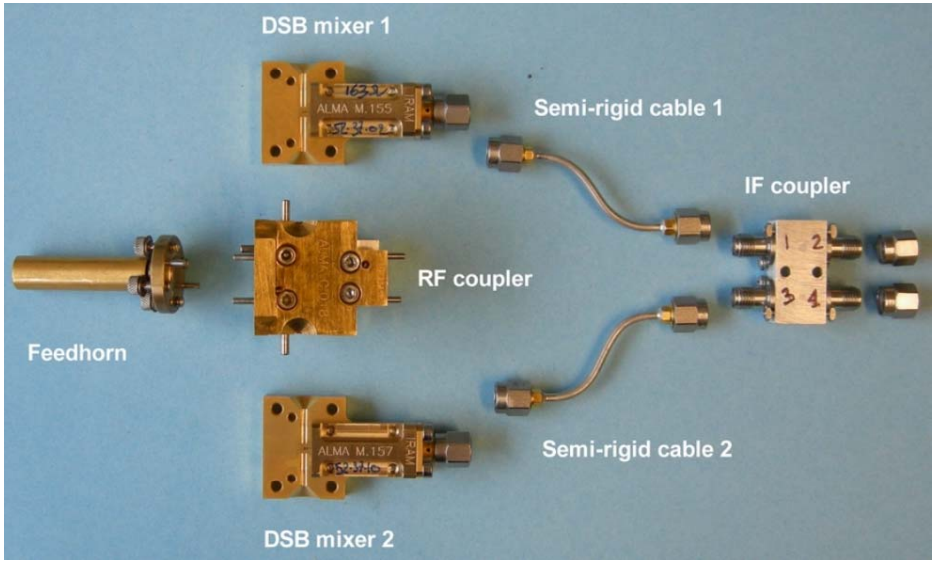


Close view of the mixer chip mounted on 80 µm thick quartz



2SB mixer diagram





Thermal Analysis 1

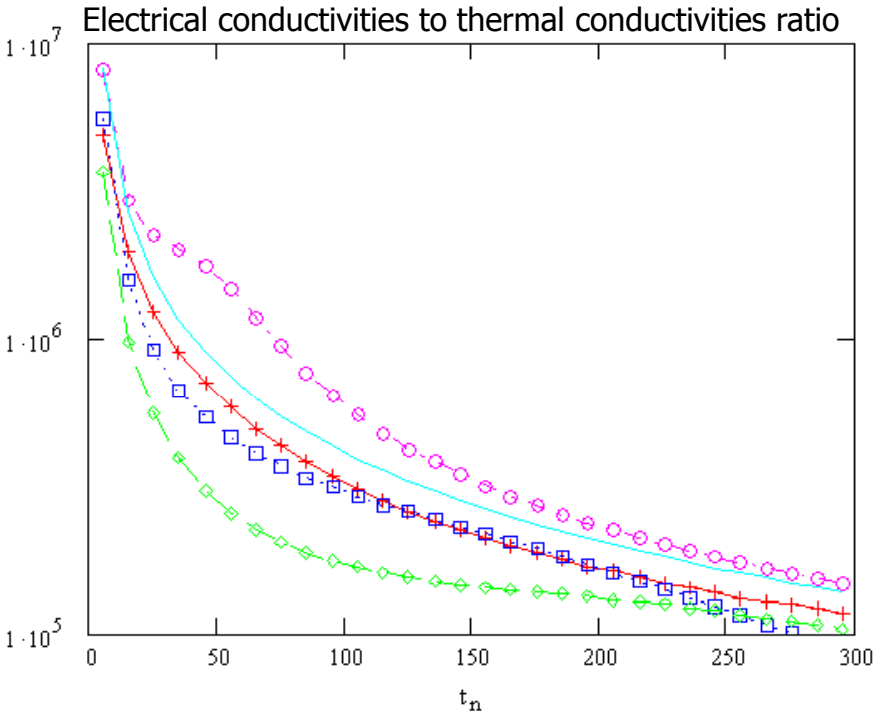
Thermal budget had to be met, therefore contributions were calculated for:

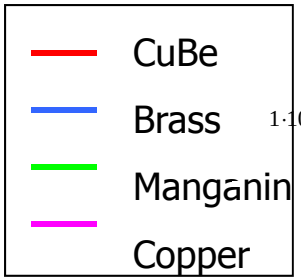
- Wiring
- Local Oscillator waveguides
- HEMTs
- triplers
- IF coax

Theoretical analysis and experiments on thermal shunts were also performed.

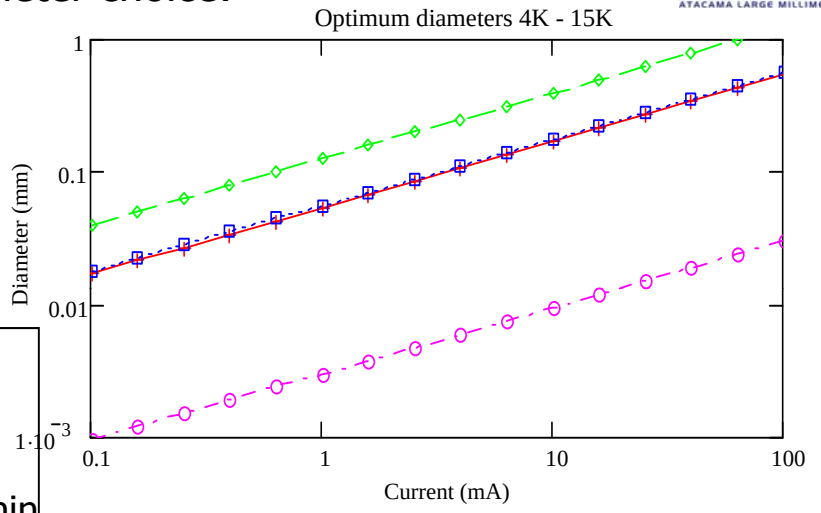
Thermal Analysis 2

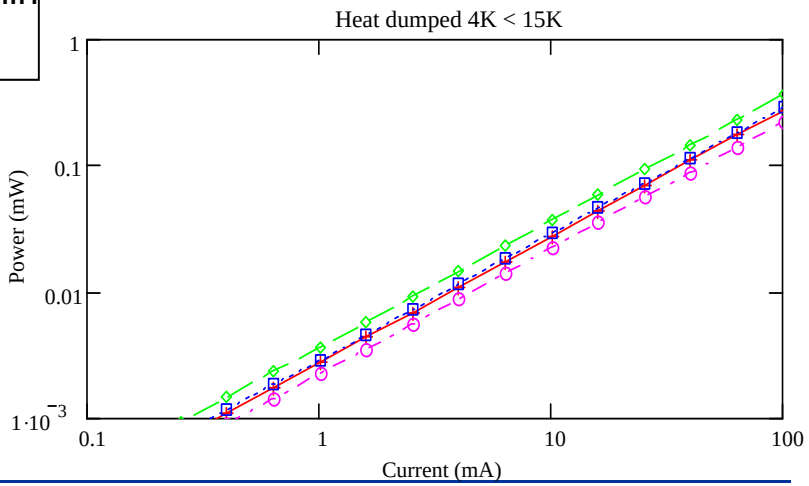
- Material choice:



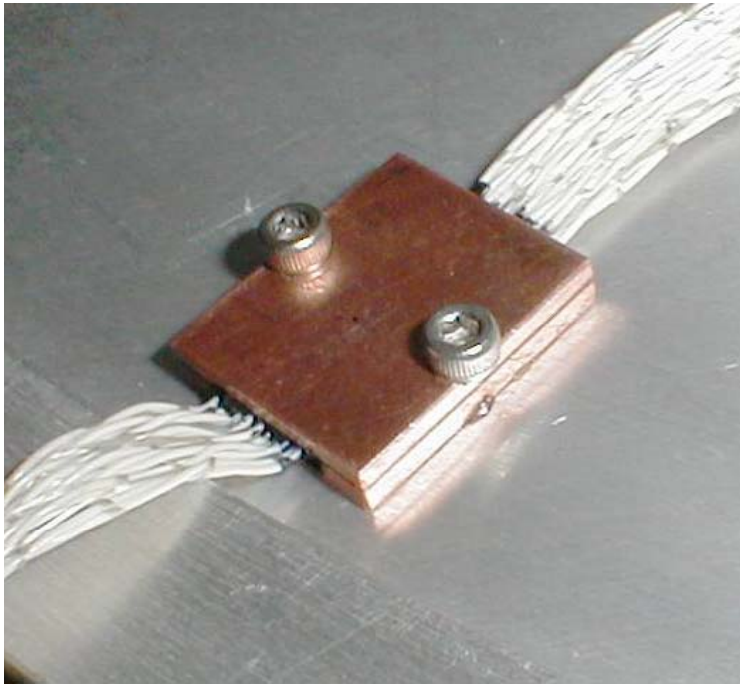


- Diameter choice:

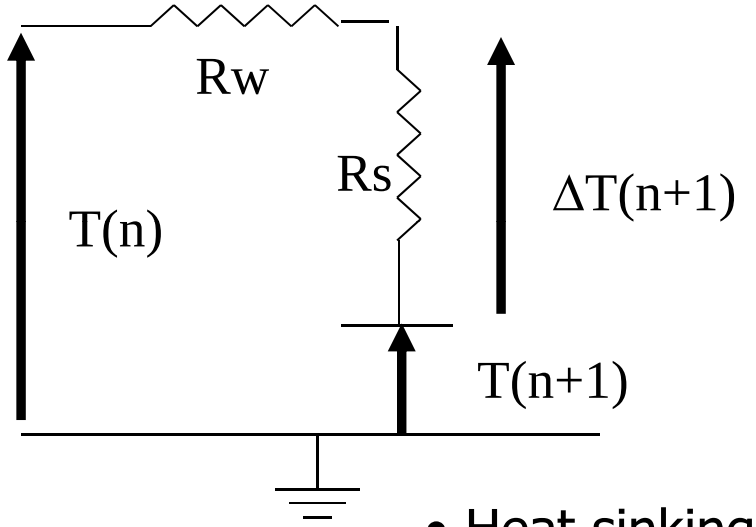




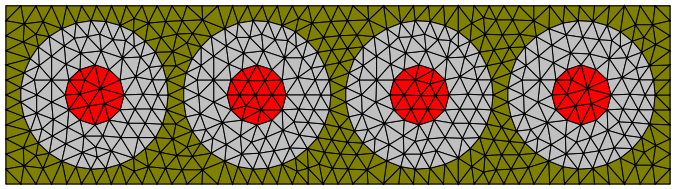
Thermal Shunts, Structure and Role



Equivalent circuit



Cross Section:

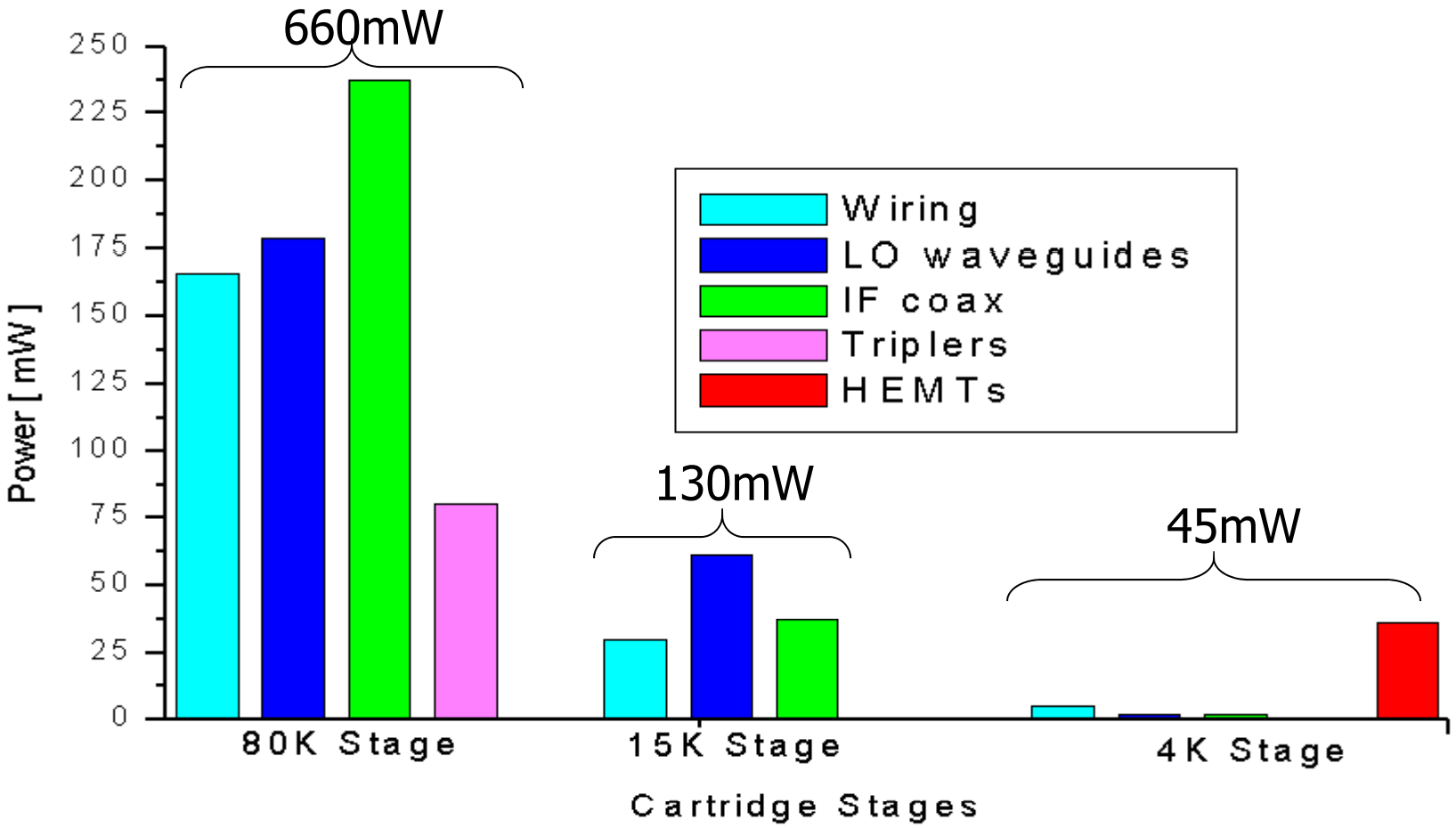


- Heat sinking on each cartridge stage using OFHC copper shunts
- Simple working up
- Reliable Technique

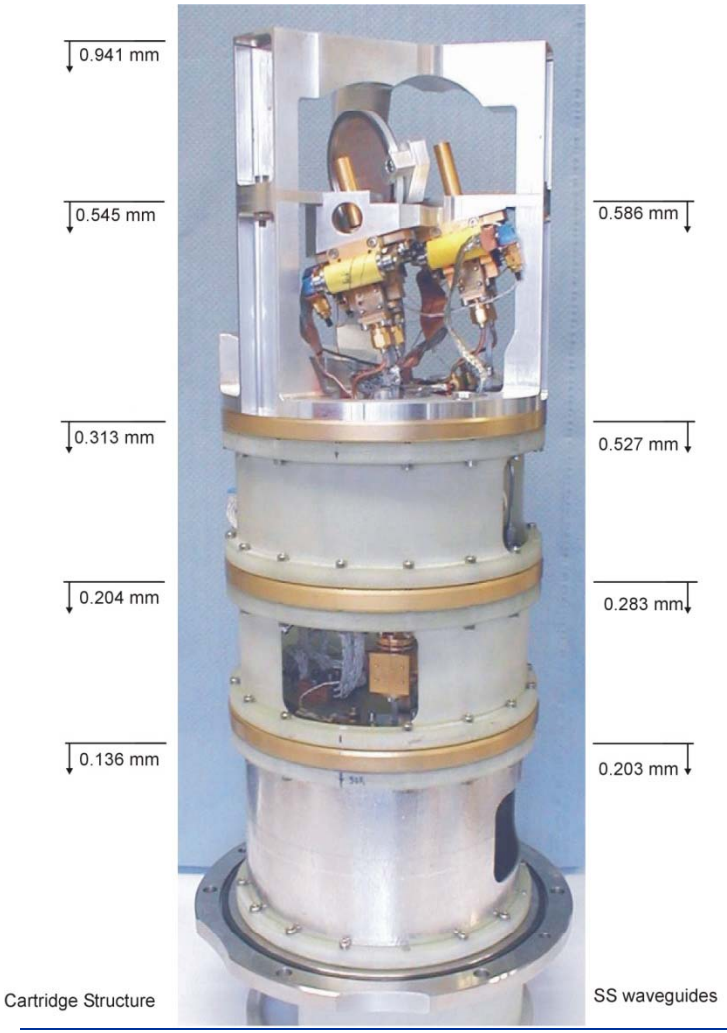
Technical Choices

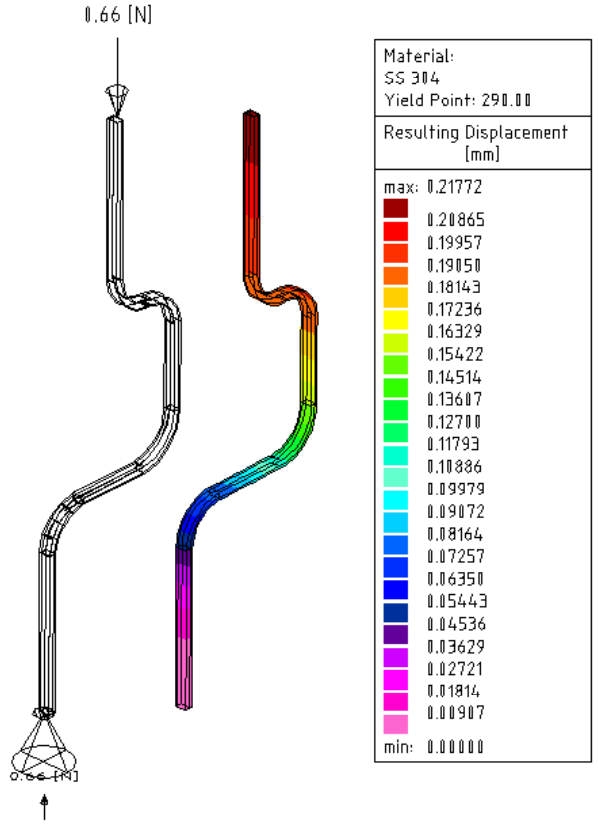
- Manganin wires for low power transport, shunted at each stage
- Brass wires for high power transport, shunted at each stage
- Wires diameter: 0.2mm
- LO waveguides: WR10 waveguides plated with 4μm gold
- IF coax: outer conductor in stainless steel, inner conductor in CuBe
- HEMTs on 4K stage

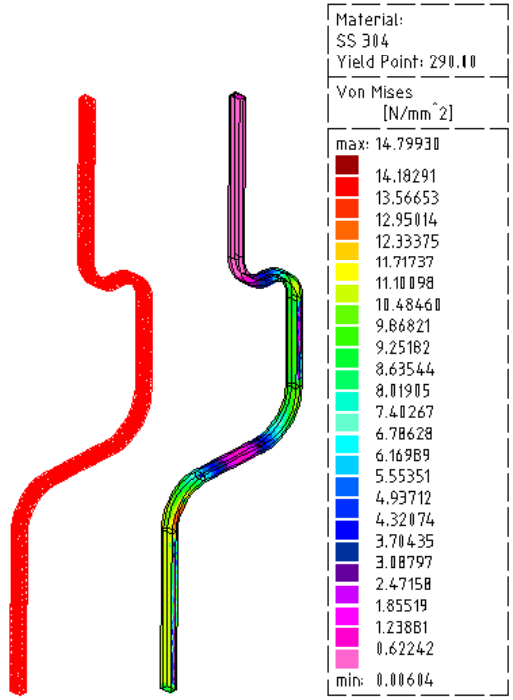
Thermal Budget



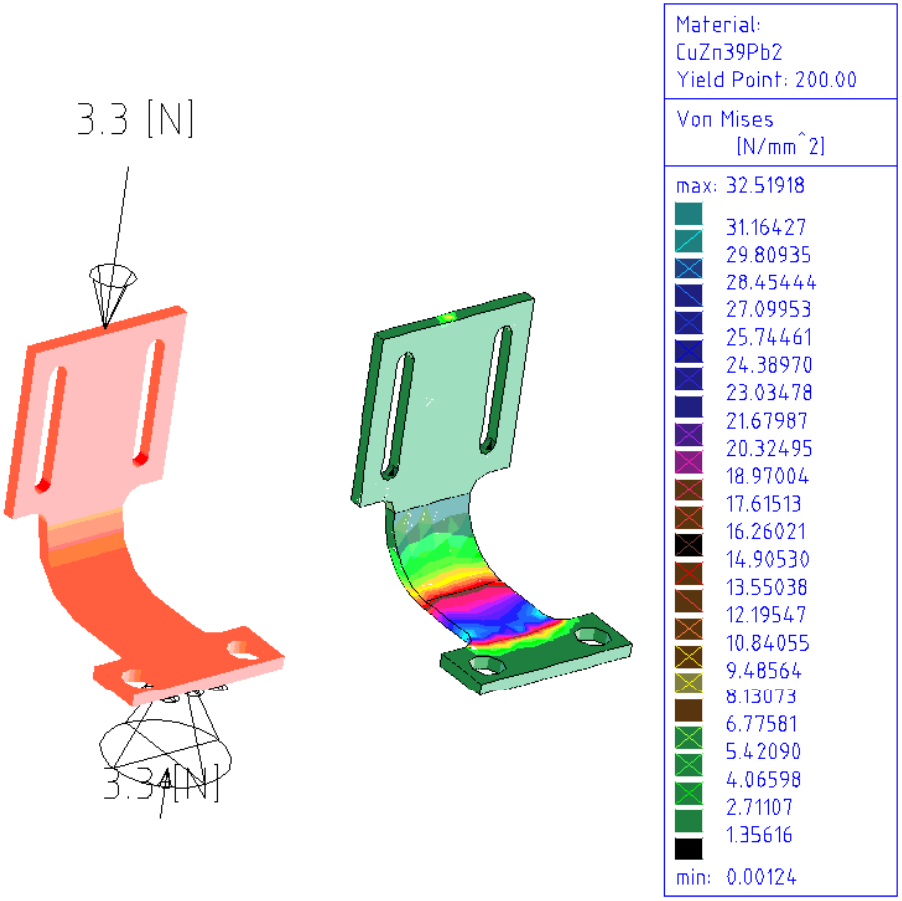
Thermal Stress Relief, WG Compliance







Tripler Brackets

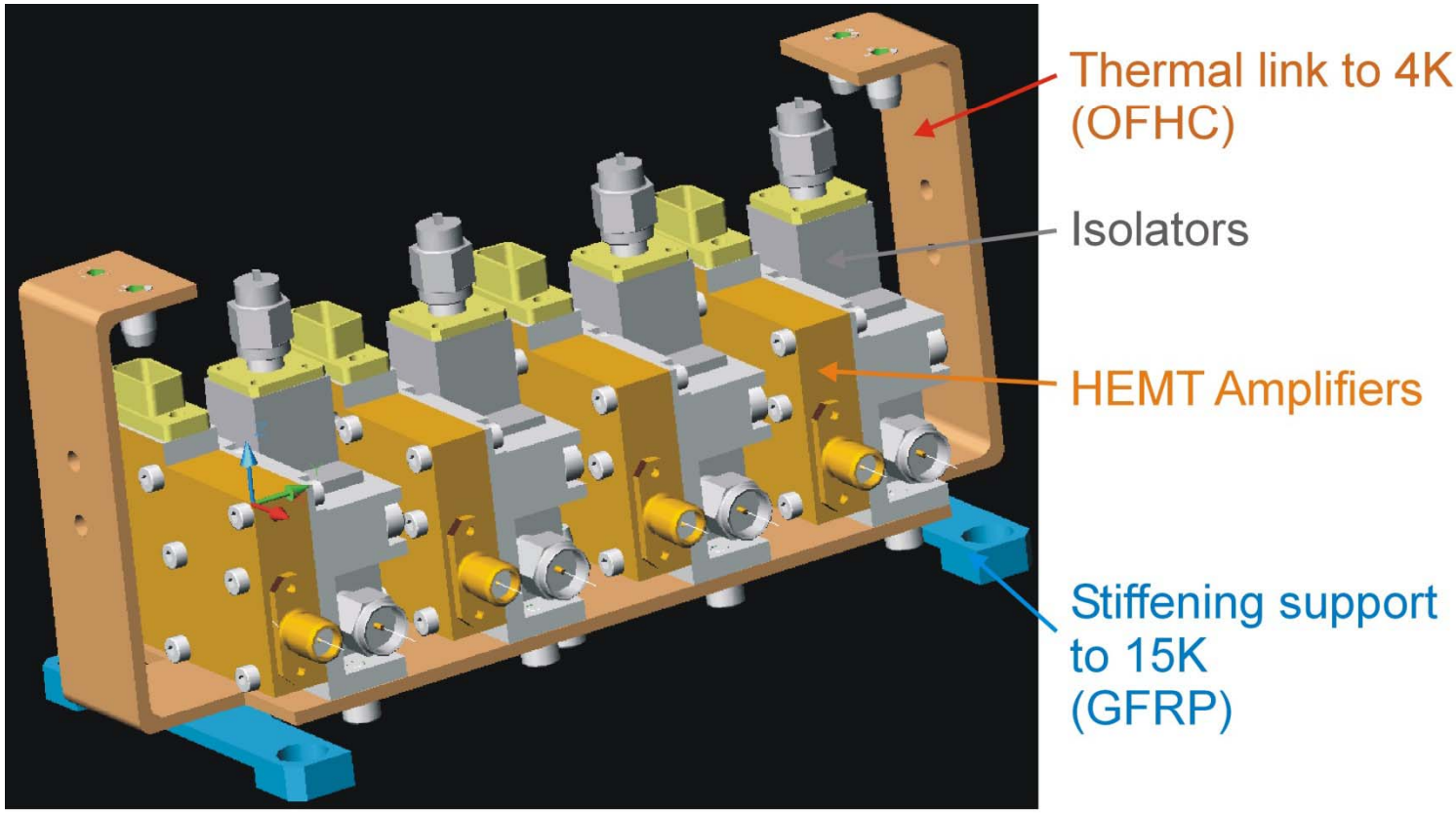


More Flexible for thermal diff. contraction + oblong holes

The tripler brackets could be made even more flexible to minimize the axial force applied to the waveguide between 4K and tripler output.

The maximum stress applied onto the guide is about 1/3 of the WG yield point.

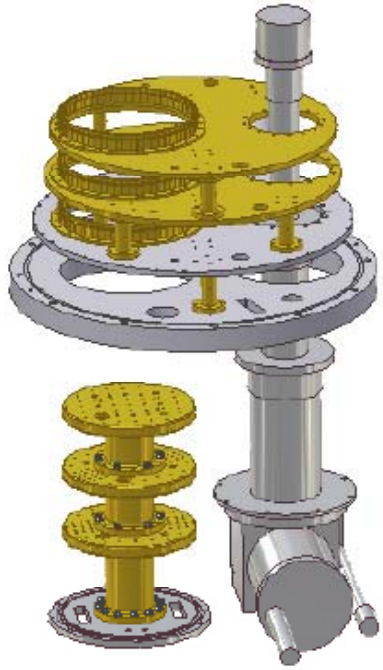
HEMT Amplifier Support



Thermalised at 4K to meet the amplitude stability specification

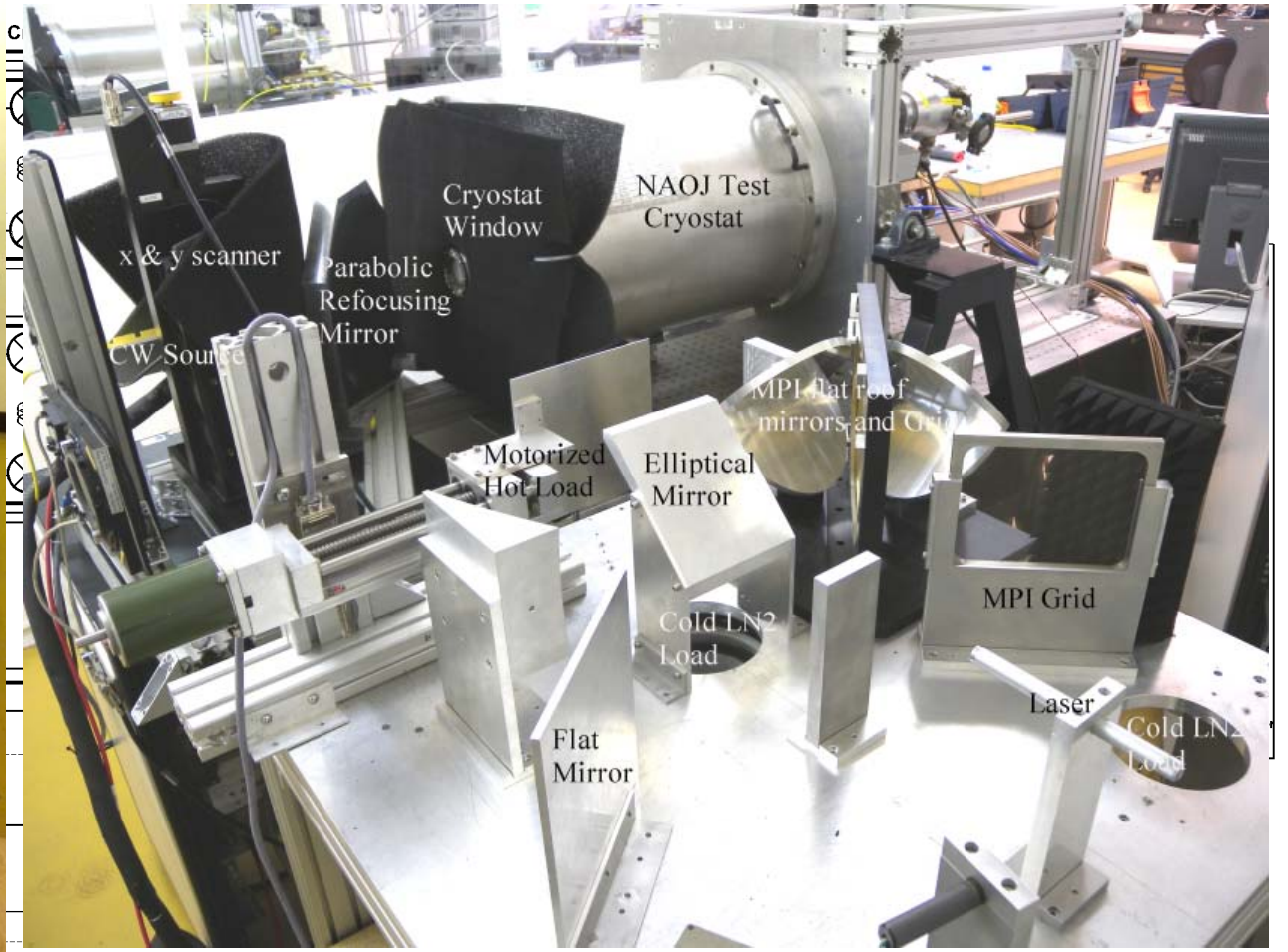
NAOJ (Japan) Test Cryostat

To support developments of state-of-art cartridge-type receivers, NAOJ has fabricated cartridge test cryostats by modifying the ALMA cartridge-type cryostat. reliability, short cooling time and easy handling. The cryostat is cooled by a 3 stage GM cryocooler (Sumitomo RDK 3ST).

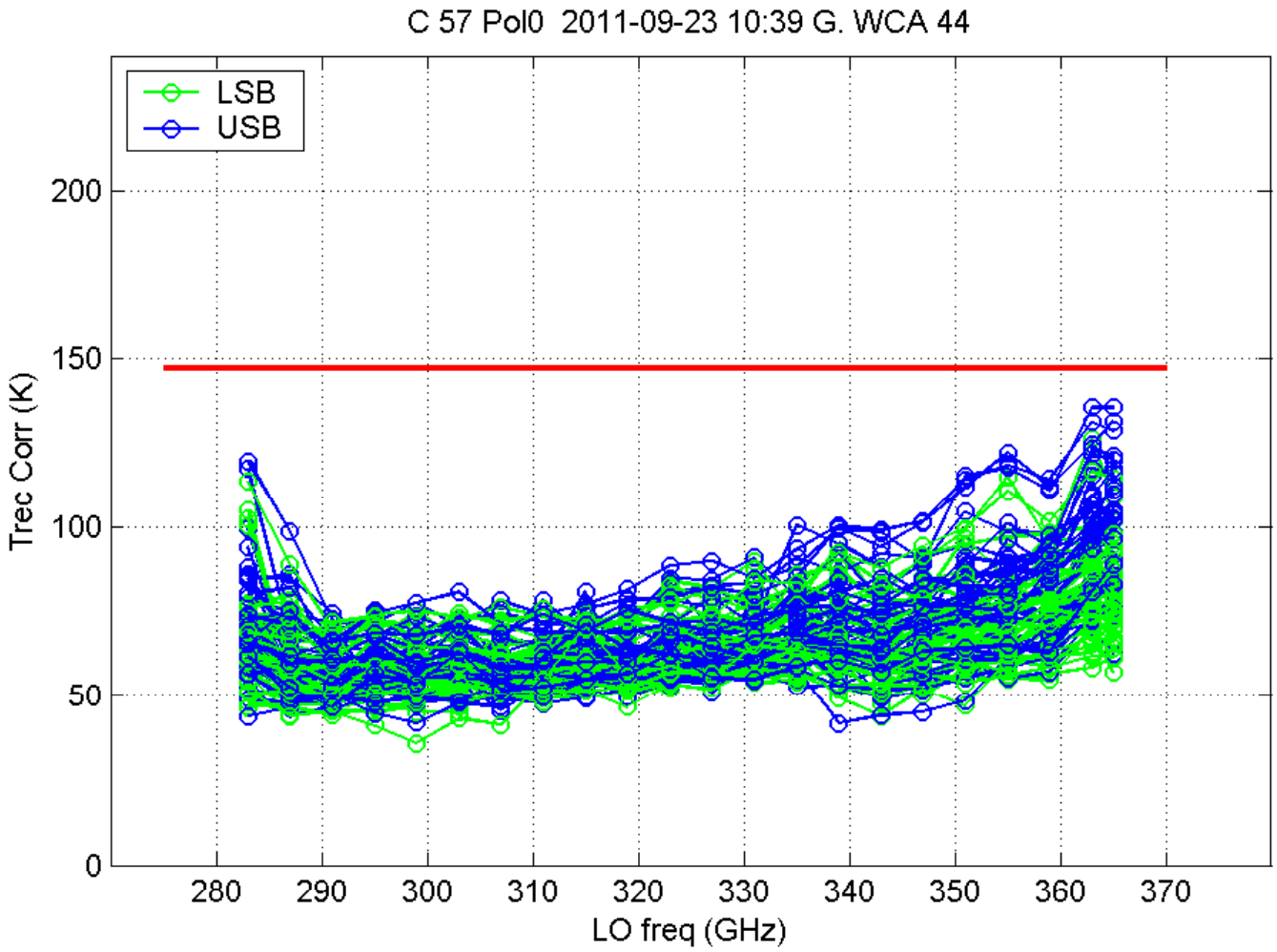


Validation

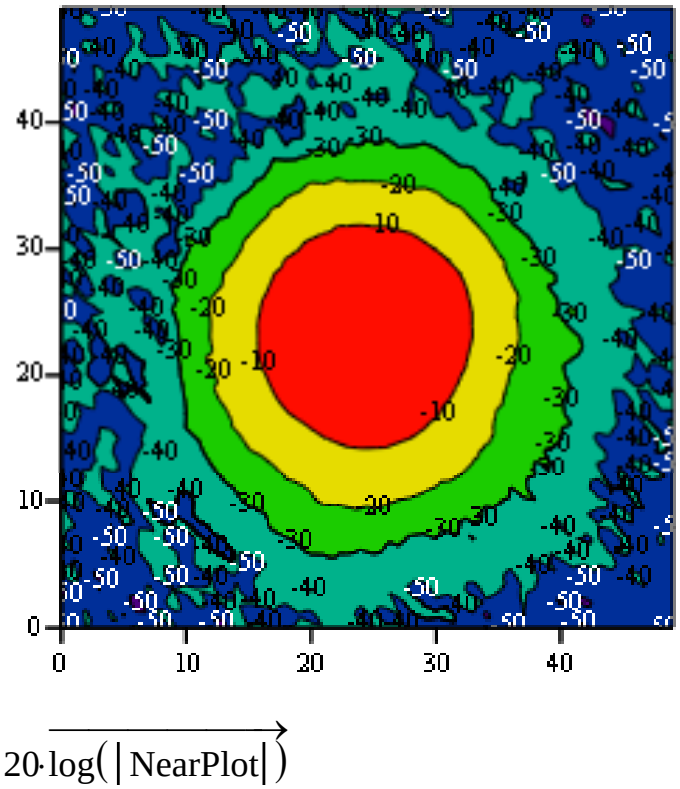
Following test procedures on two dedicated automated test sets.

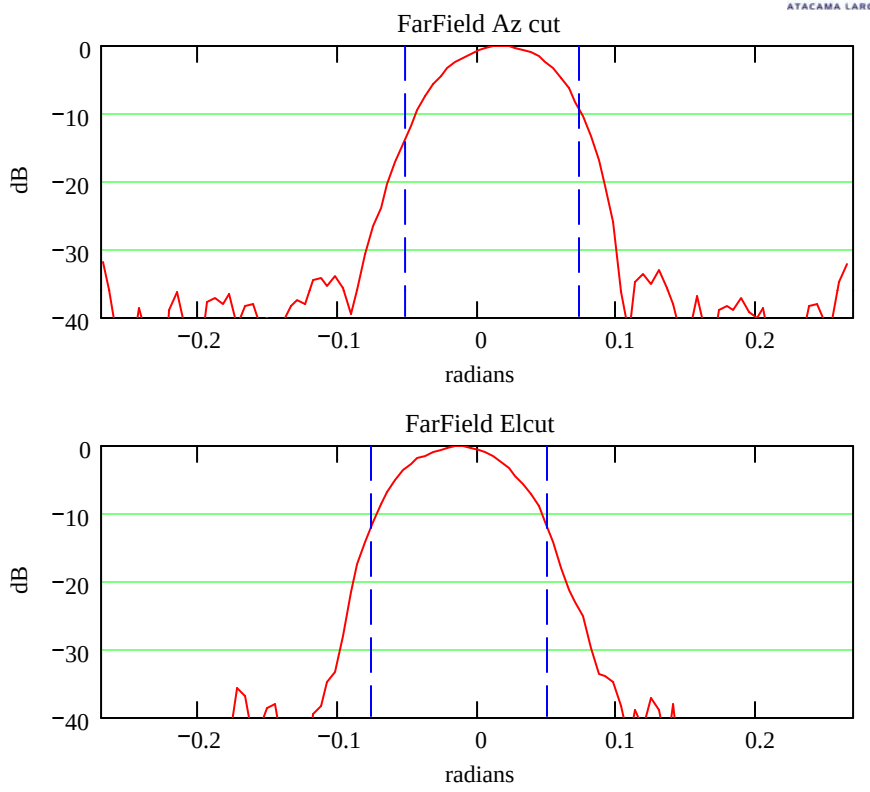


Integrated noise temperature over 4-8 GHz for 48 production cartridges (P0)



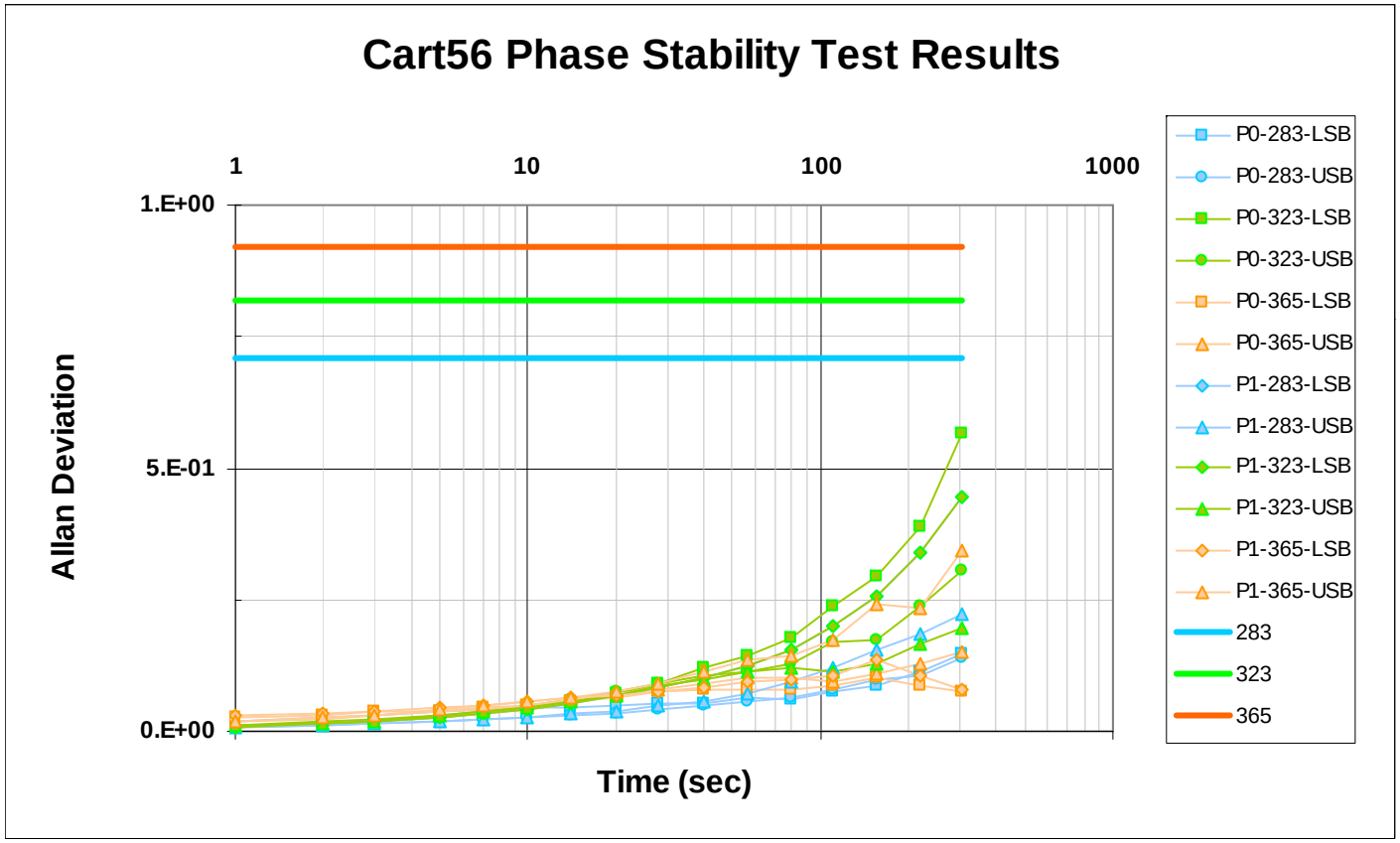
2D Scans





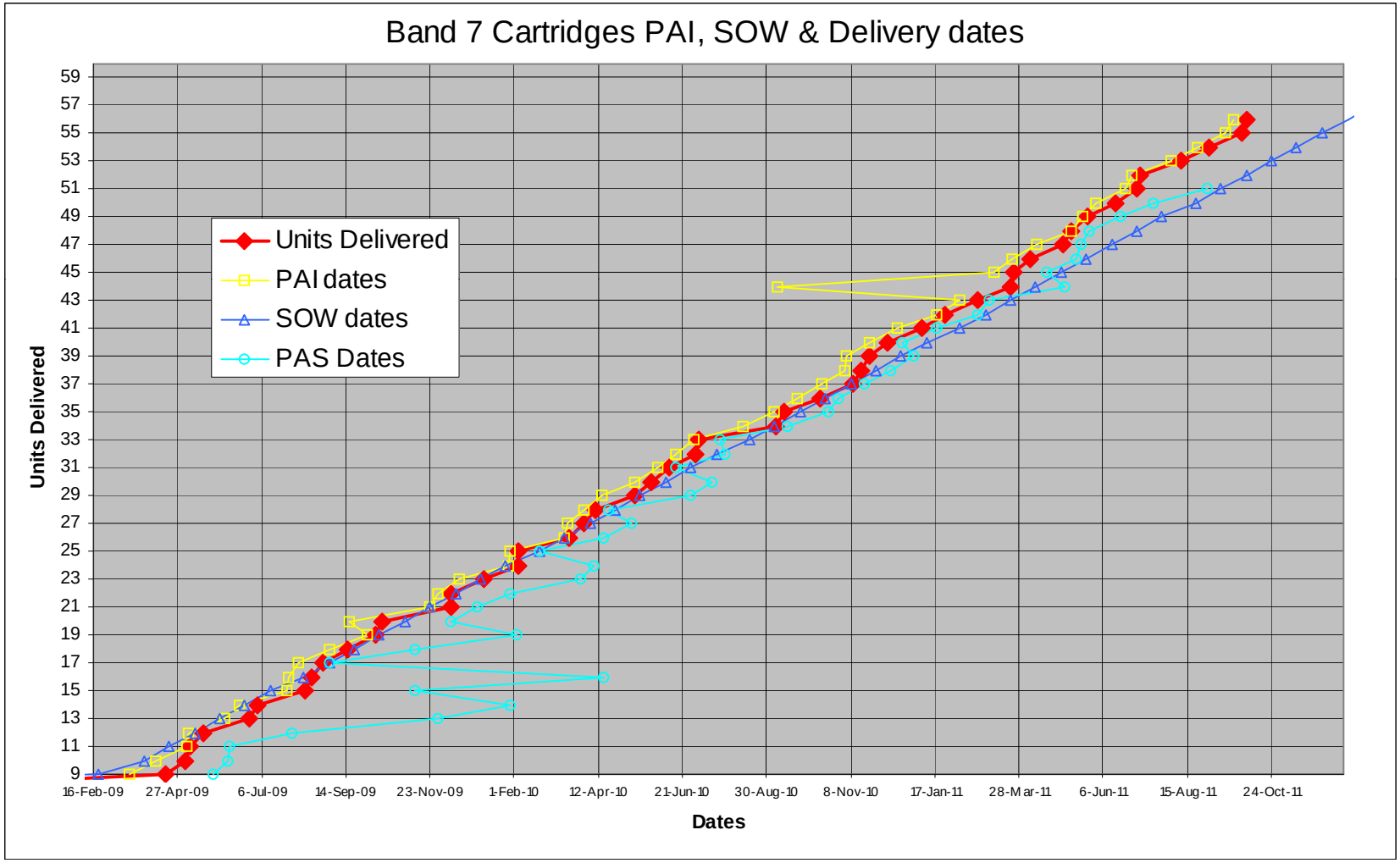
B7 Production Cartridge #47 Near Field (left) and Far Field Azimuth and Elevation beam pattern Crosscuts (right) at 279 GHz.

Phase Stability



B7 Cartridge #56 Phase Stability Test Results.

56 B7 cartridges have been delivered



Conclusion

- IRAM is being involved in a unique project with great success
- Significant effort has been dedicated to the study of cryogenic aspects within the ALMA project by the RAL/NAOJ colleagues and the different cartridge manufacturers
- The band 7 cartridge production is well under control, within schedule and cost. ¾ of the cartridges have been assembled, tested and delivered to the project ahead of schedule and within cost.