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ALMA
ATACAMA LARGE MILLIMETER ARRAY

ALMA Band 1

Charles Cunningham and Stéphane Claude

Canadian Users - ALMA

Canadian LRP 2010

- The Atacama Large Millimetre Array is the top priority in LRP2000
- The Atacama Large Millimetre Array (ALMA) is the first of the great “World Observatories”.

Canadian LRP 2011

- Canada should participate in a bid on the provision of ALMA Band one receivers to take advantage of Canadian skills and experience developed during the design and building of the Band 3 receivers.

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Band 1 Consortium

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HIA, Canada

University of Chile

ASIAA, Taiwan

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HIA Band 1 Design team

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RF design team at HIA:

Stéphane Claude, Charles Cunnigham, Philip Dindo, Doug Henke, Frank Jiang and Filippo Rossi (University of Victoria PhD student)

Millimetre Instrumentation Laboratory: component and cartridge testing

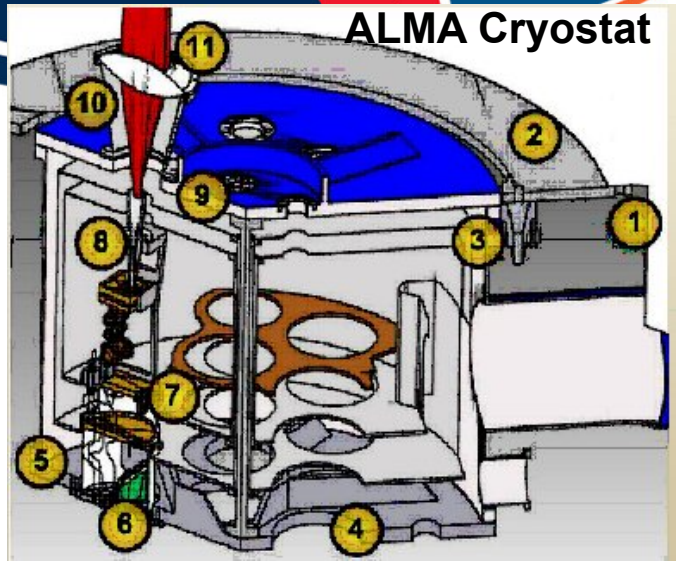
Mechanical design team: Dave Duncan and Ivan Wevers

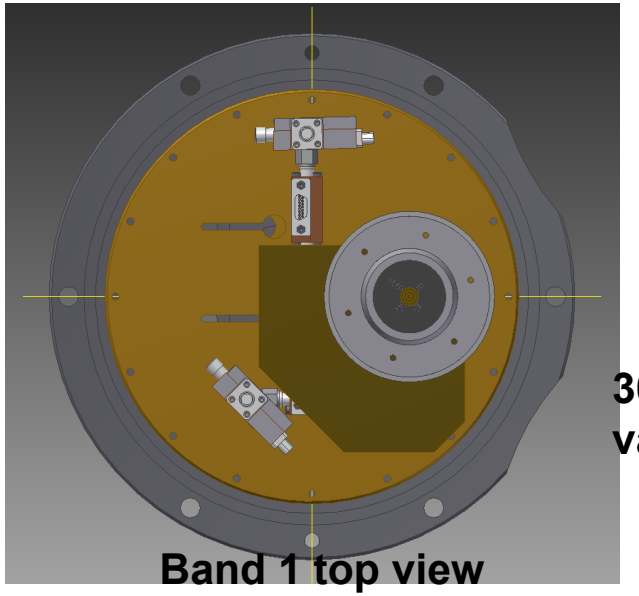
Workshop: Gord Hnylycia and Jim Jennings

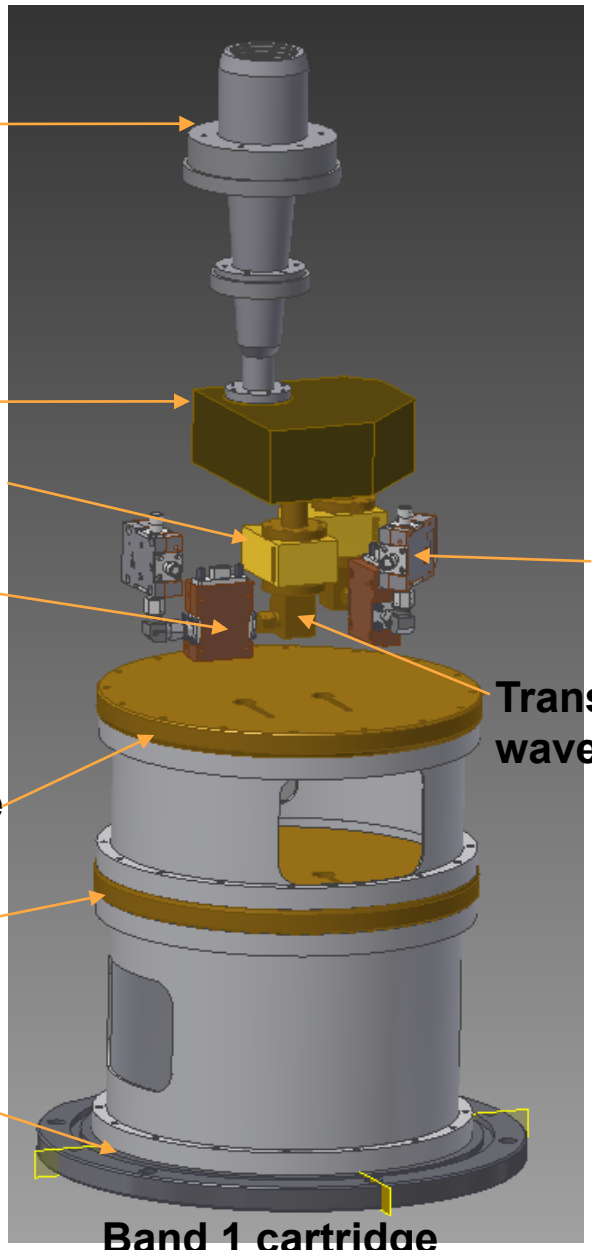
Band 1 Sub-systems and Challenges

- **Sub-systems:**
  - Optics: lens, horn + Orthomode Transducer (OMT)
  - Low Noise Amplifier (LNA)
  - Local Oscillator and down-converter
- **Challenges:**
  - Noise: 17 K Single Side Band (dominated by LNA and optics)
  - RF Bandwidth 36% (31.3 to 45 GHz) – widest of all ALMA bands

Cartridge Design







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Systems Noise Budget

Components	Component Gain (dB)	Cumulative Gain (dB)	Component Noise (K)	Cumulative Noise (K)	
Optics	-0.3	-0.3	8.0	8.0	
Feedhorn (15 K)	-0.1	-0.4	0.3	8.4	Optics
OMT	0.0	-0.4	0.1	8.5	
Isolator (WG)	-0.4	-0.8	1.4	10.1	
WG to coax adapter	-0.1	-0.9	0.3	10.6	Pre-LNA
LNA	**45.0**	44.1	**15.0**	29.2	LNA
Coax (4-300K)	-2.0	42.1	87.7	29.2	
Amplifier (Warm RF) G=35dB, NF = 4dB	35.0	77.1	446.0	29.2	
Atten Pad	-3.0	74.1	293.6	29.2	
Mixer (Spacek) -8 dB G, 6dB NF	-8.0	66.1	879.4	29.2	
Coax	-4.0	62.1	446.0	29.2	

Working Noise Budget = 29.2 K SSB

Specification from ALMA project book: 17 K over 31.3 GHz to 45 GHz for 80 % of the band and 26 K for any frequency.

D. Henke, S. Claude, F. Jiang, D. Dousset, and F. Rossi,
"Component Development for ALMA Band 1 (31–45 GHz)," at *Proc. SPIE*, San Diego, CA, Jun. 30, 2010

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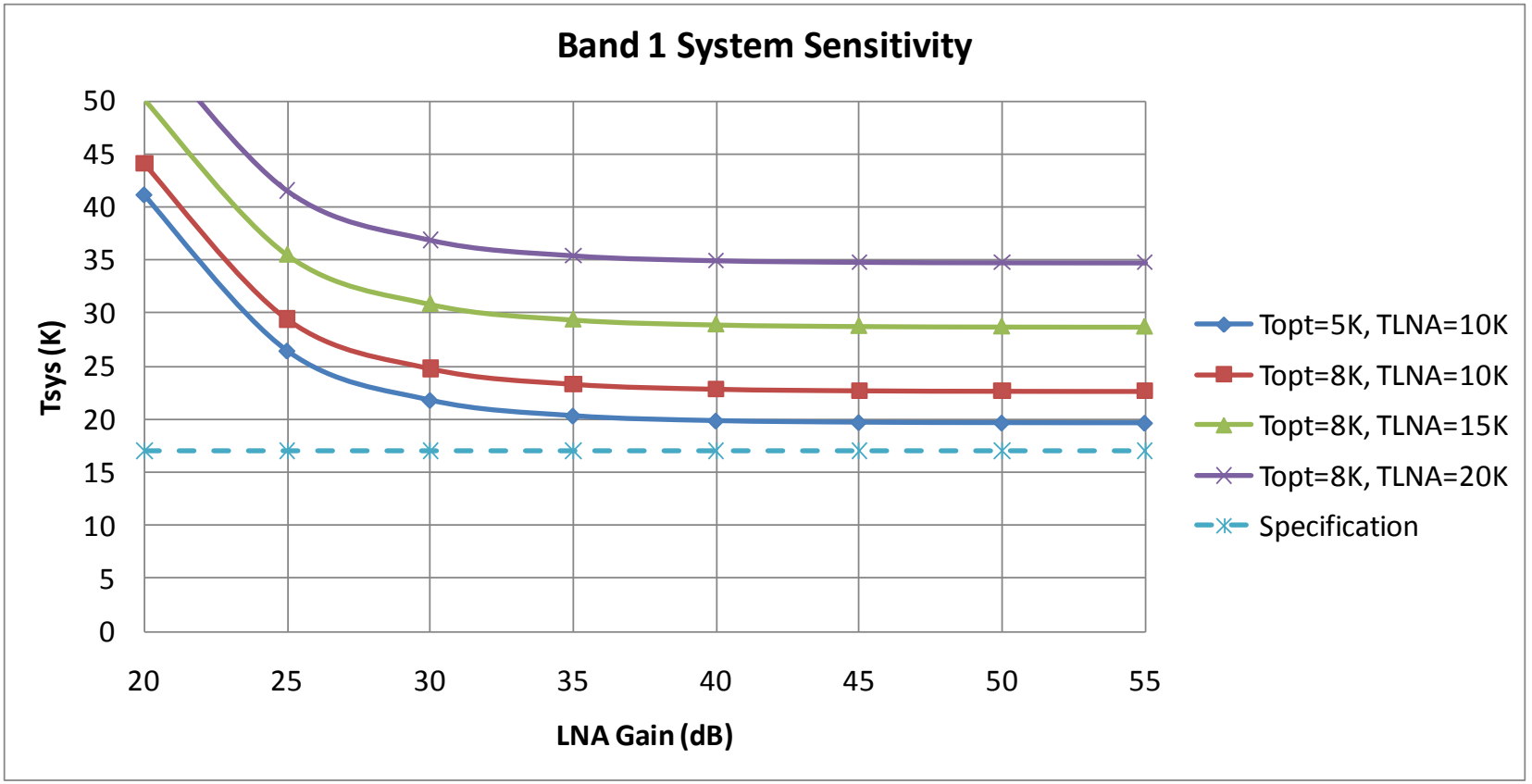
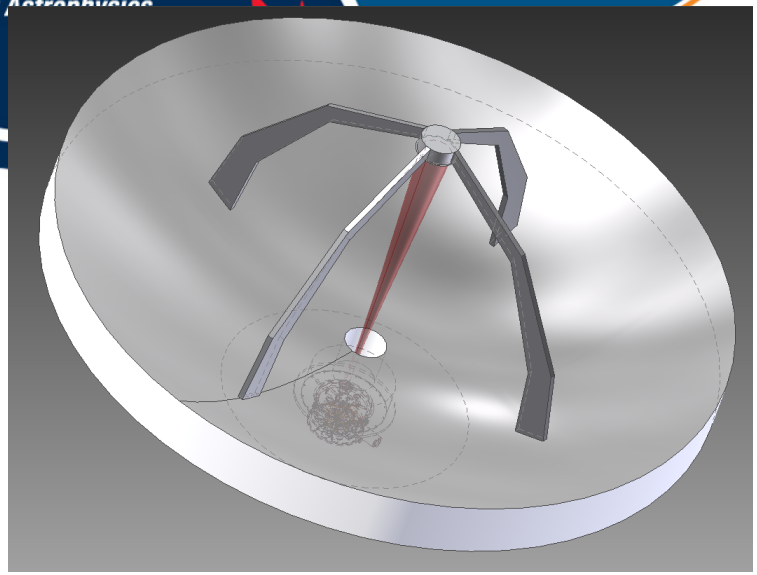
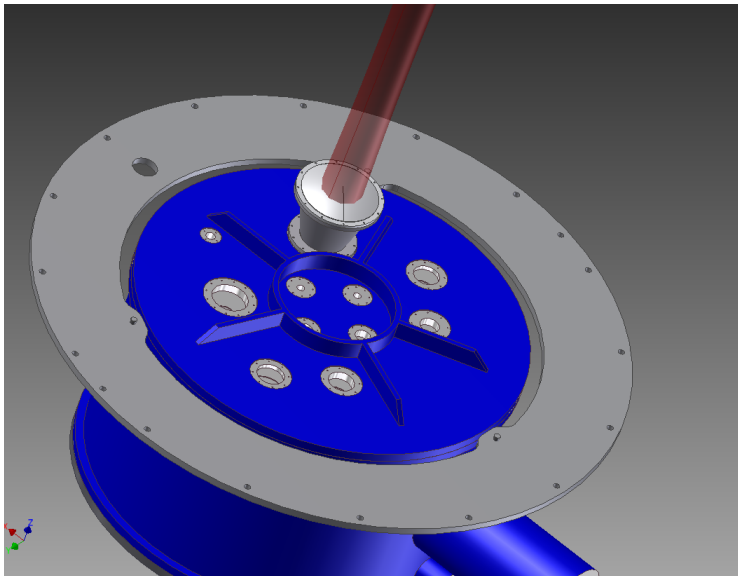
Noise versus gain



Optics





Key Issues for Band 1 Optics

- Lens:
  - Dissipative loss
  - Scattering/Reflection
  - Material control and manufacture
- System design verfication and modeling
  - Aperture efficiency
  - Cross-polarisation
  - Spill-over/Truncation
- Feedhorn
- Polarisation splitter (OMT)

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Modeling of Optics

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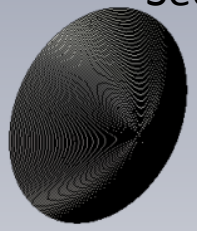
Secondary



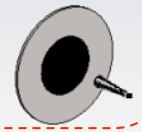
System Modeling

- Overall model extremely large
- Detailed features of feedhorn + lens

EM Solver (CST)

Feedhorn + Lens

Farfield response of lens + FH

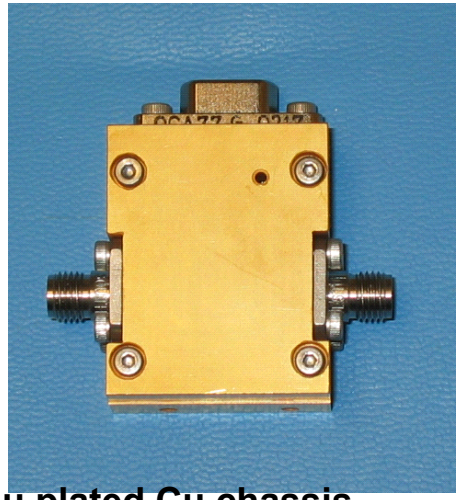


Physical Optics (Grasp)

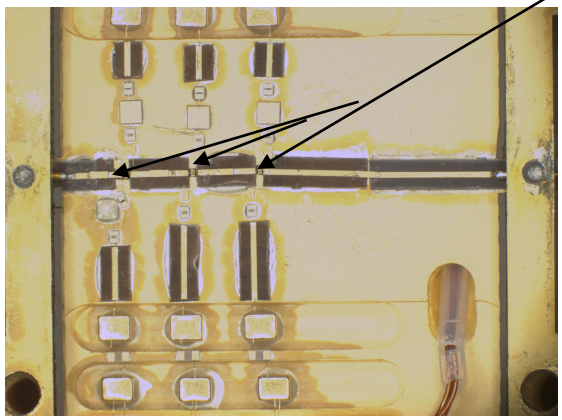
With existing feedhorn, changed lens focal length and position to match a 12.3 dB edge taper on the secondary

LNA Prototype program

- Building on the Band 3 LNA expertise
- Prototype has 3 InP transistor stages from HRL
- Design is hybrid and includes discrete components and wire bonding for tuning gain, noise and input match
- InP technology based transistors have low power dissipation for cryogenic operation
- Layout is optimized for automated assembly for medium size production volume
- Band 1 LNA will have to be 5 stage to provide 40 dB of gain



Au plated Cu chassis for good thermal dissipassion



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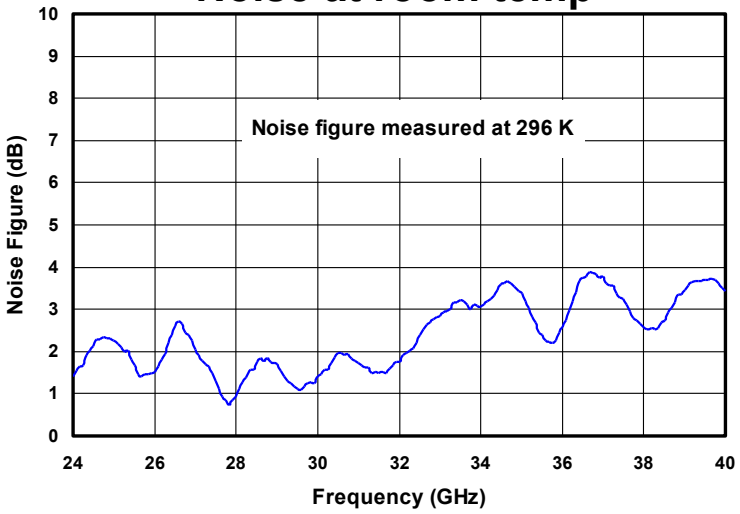
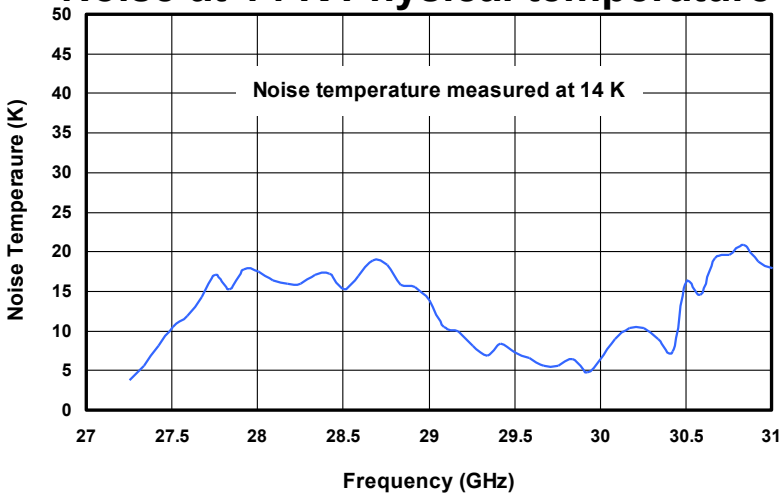
LNA Prototyping

LNA SN1

Noise at room temp

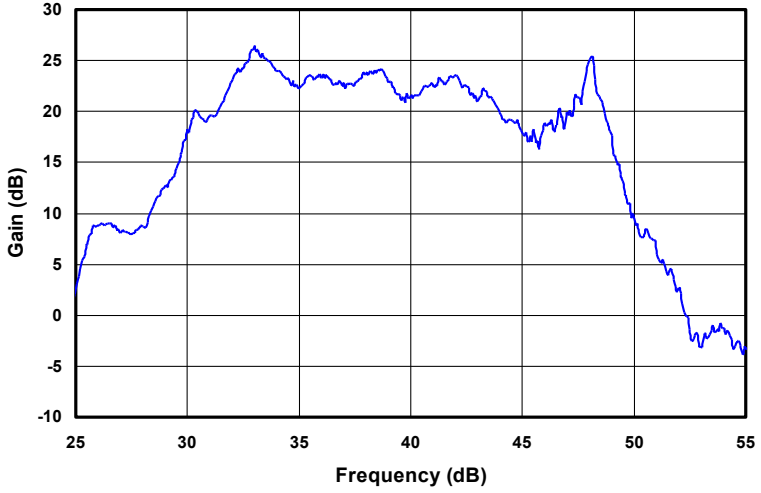


Noise at 14 K Physical temperature

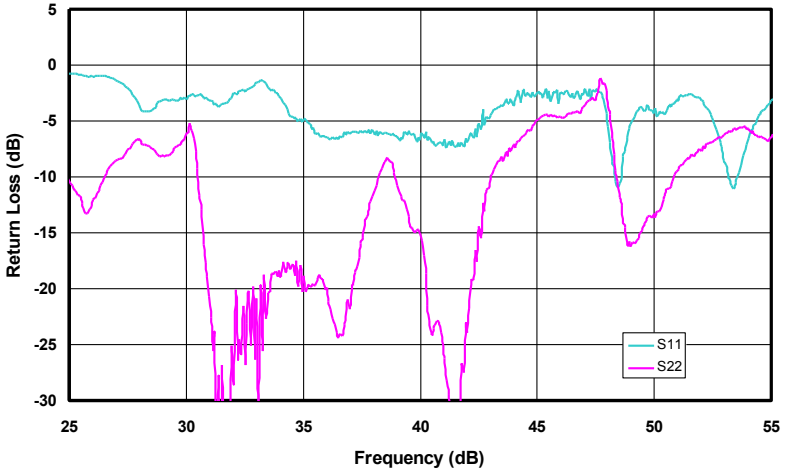


LNA SN3

Gain



Input and output match

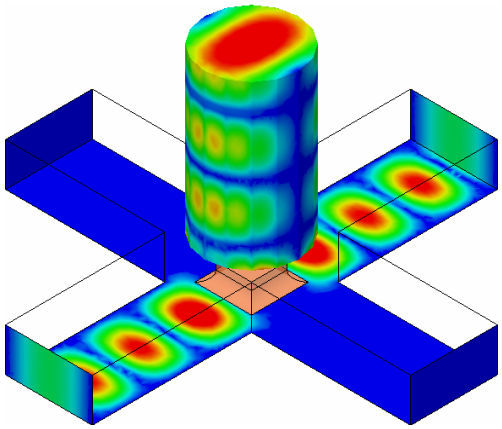


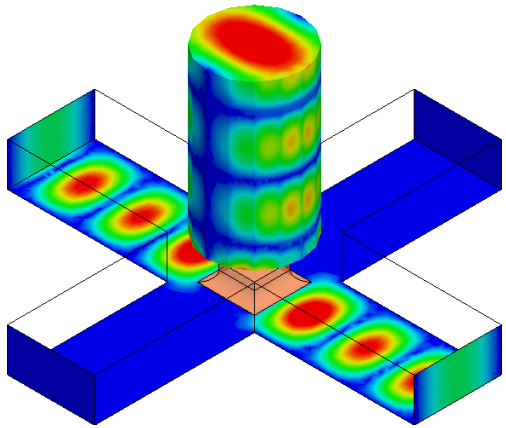
OMT

- Design is based on a turnstile with circular waveguide input matching feedhorn for optimum cross-polarisation

- Simple and accurate machining of the turnstile in one block using CNC in aluminum

- OMT is made of three blocks.





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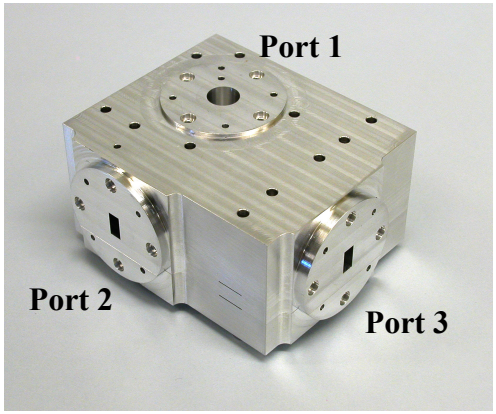
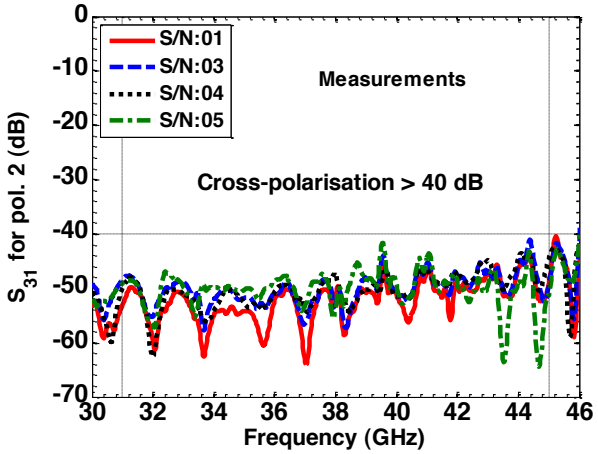
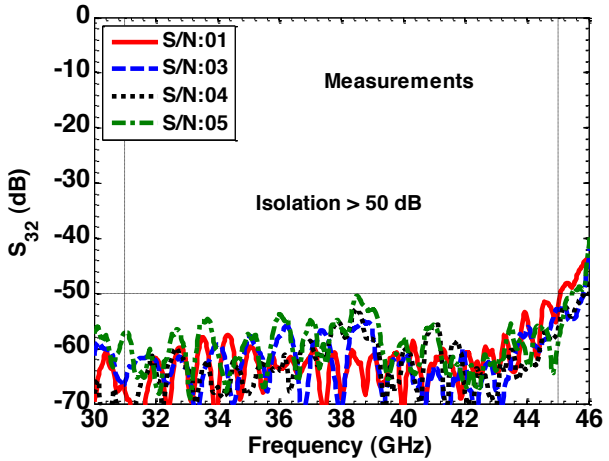
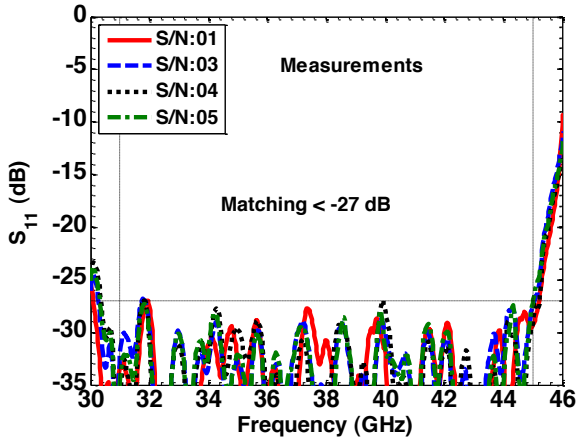
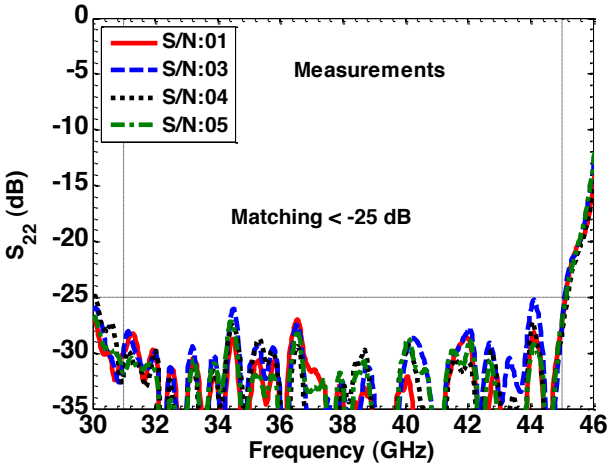
OMT Measurements



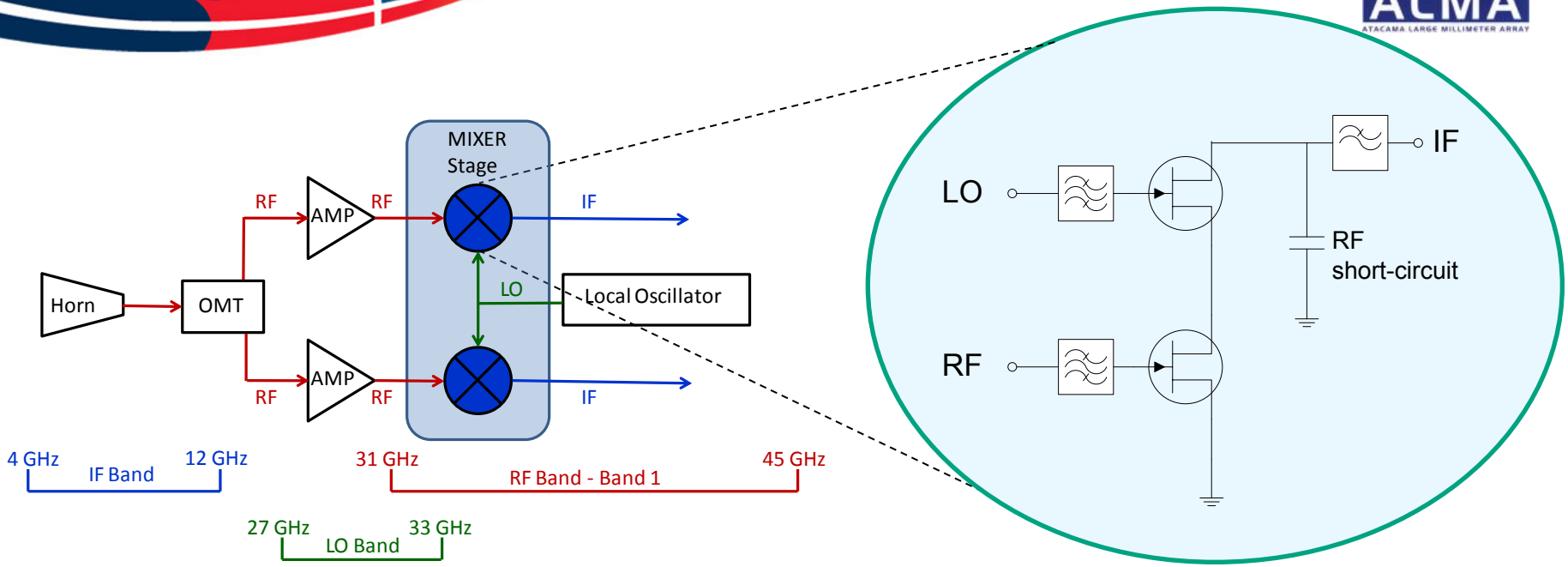








Mixer design



- Dual FET design
  - Inherent isolation between ports
  - Modest gain possible
- Modeling fitting indicates promising simulation
- Capable of cryogenic operation

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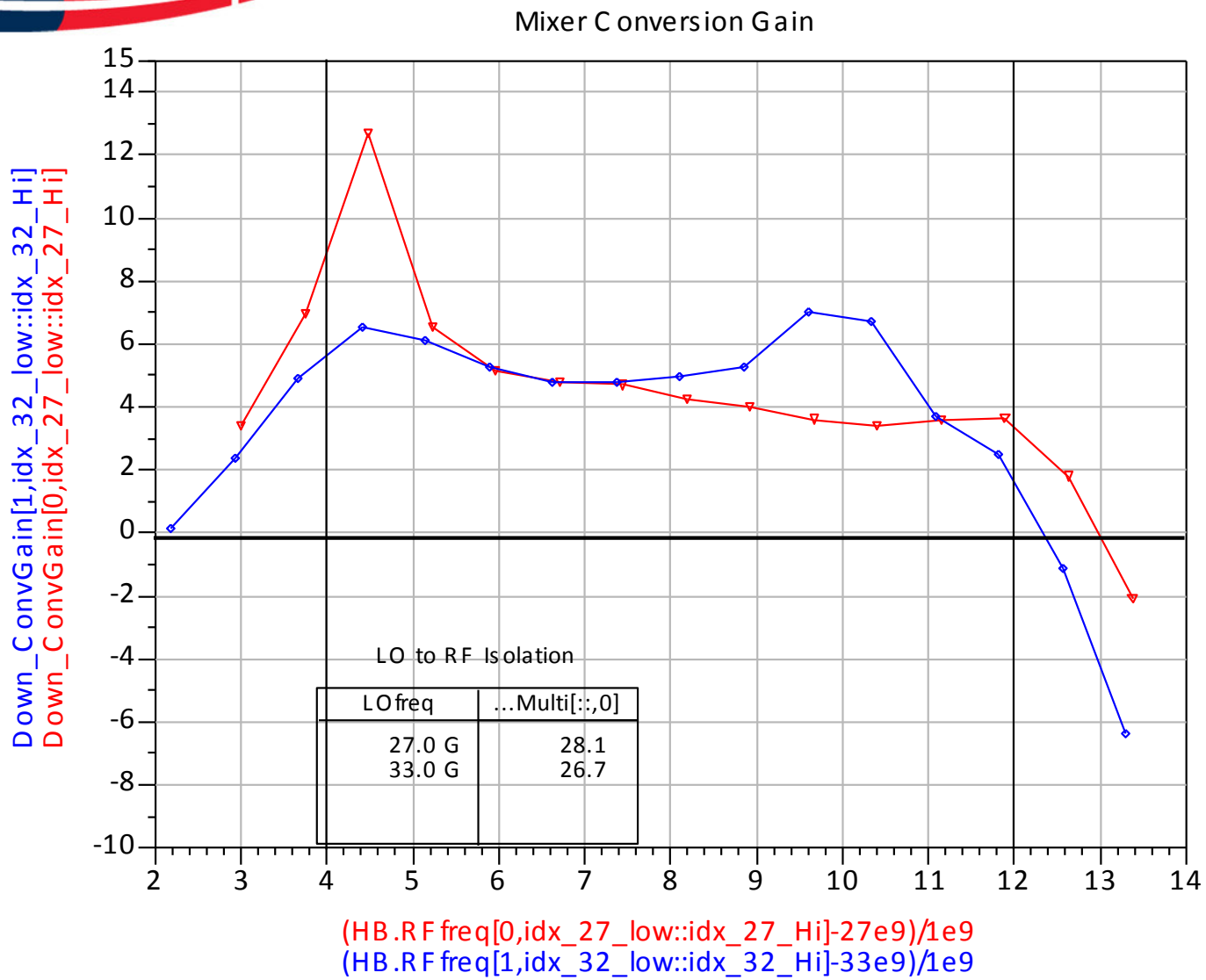
Mixer Conversion Gain



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Mixer Matching

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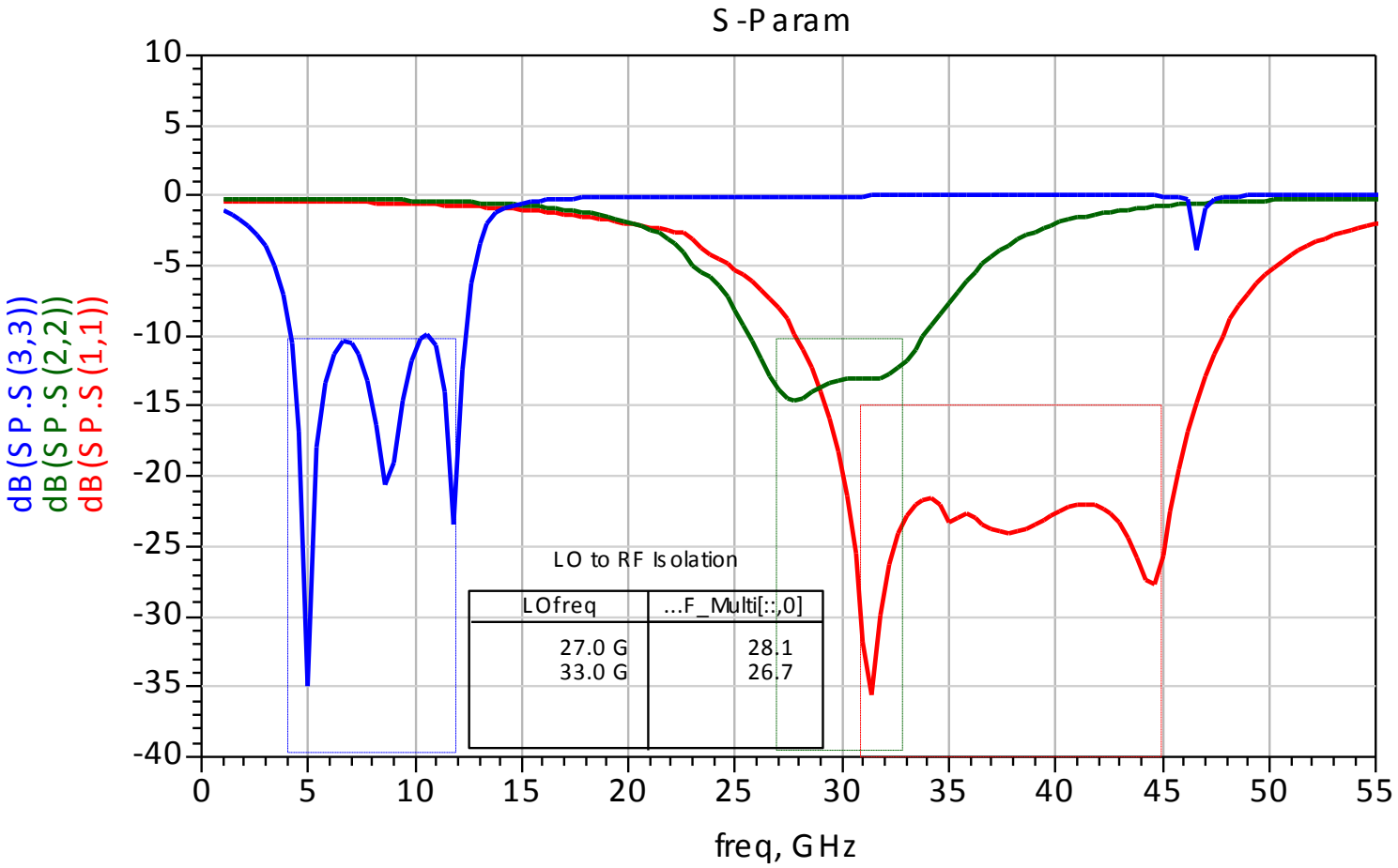

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Feedhorn fabrication

•Design study on machining the feedhorn.

•Difficulties: narrow opening angle, long feed and deep grooves at throat.

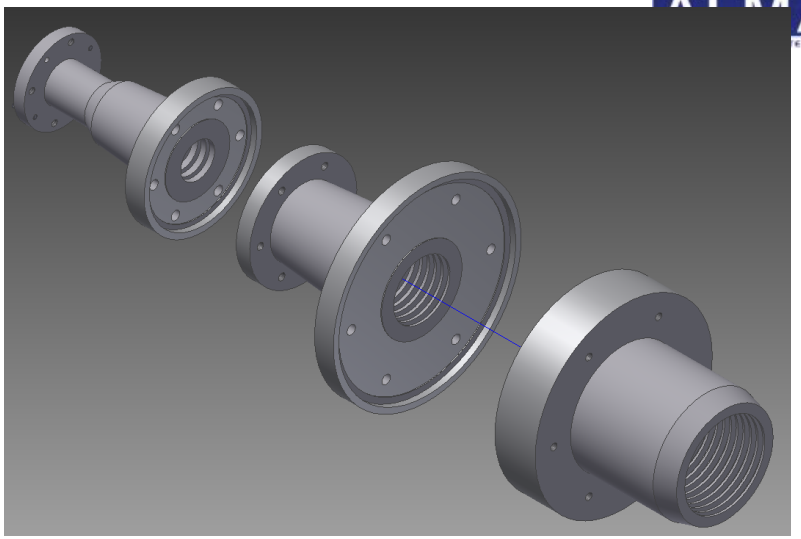
•Proposed fabrication at HIA:

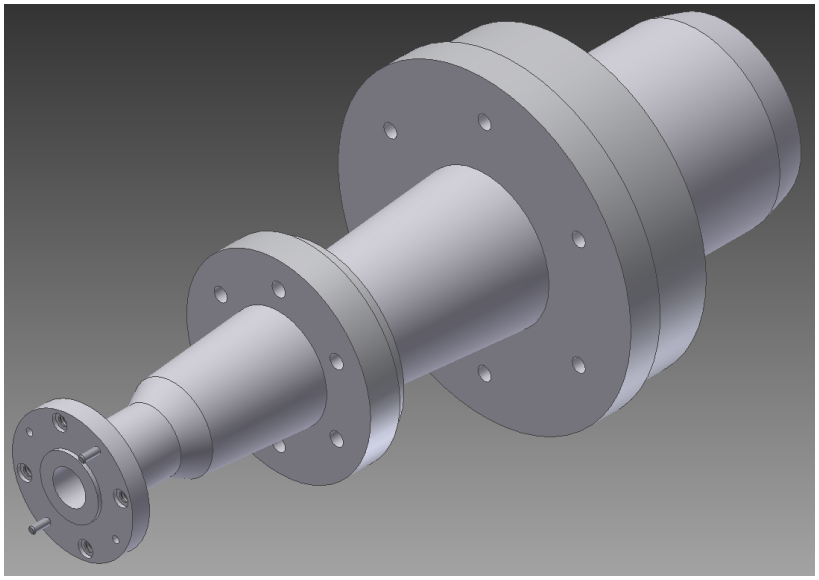
Split horn in three with the first 10 grooves machined in one piece on a lathe.

Other solutions:

• machined in multiple pieces with washers for the first grooves (Cloema, Italy);

• Electroforming; cons: process reproducibility and cost





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Feedhorn Fabrication

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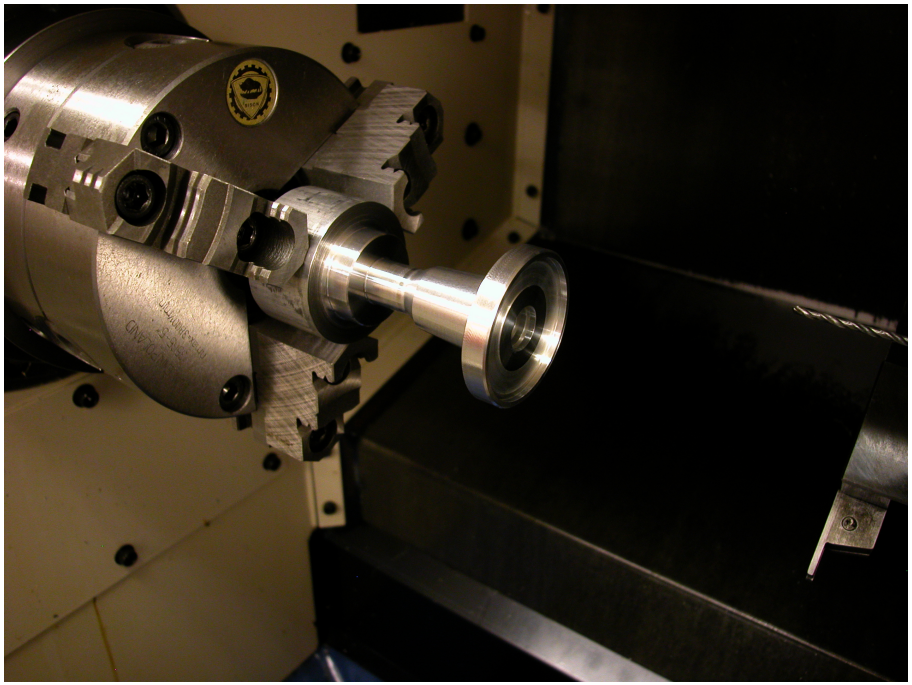

First section in the lathe

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Test Cryostat at HIA

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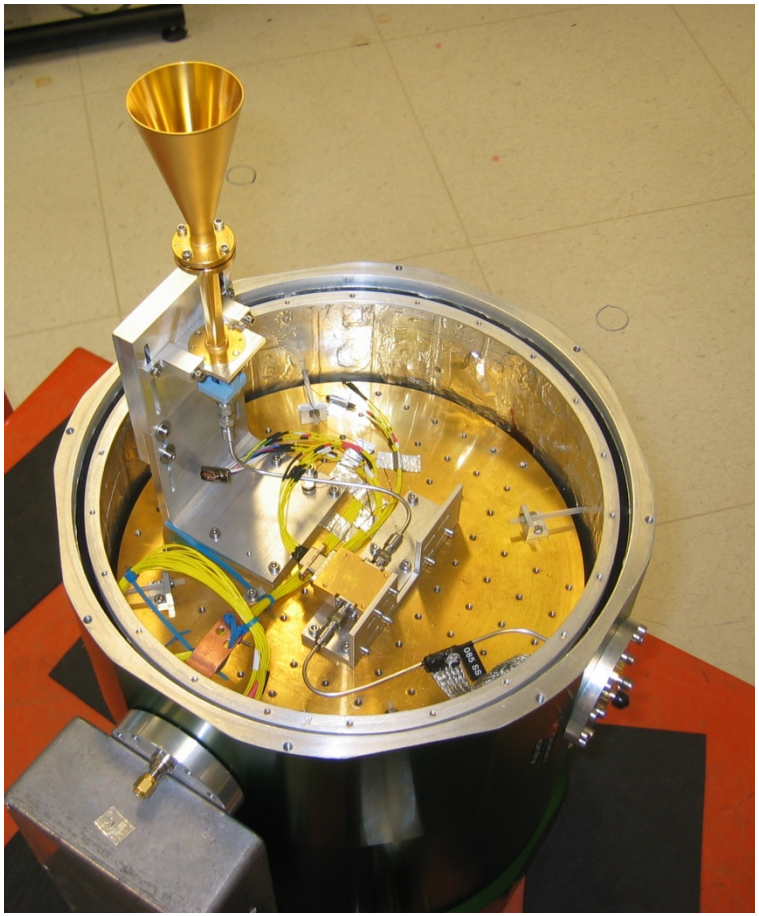

Completed initial noise measurements of simple system

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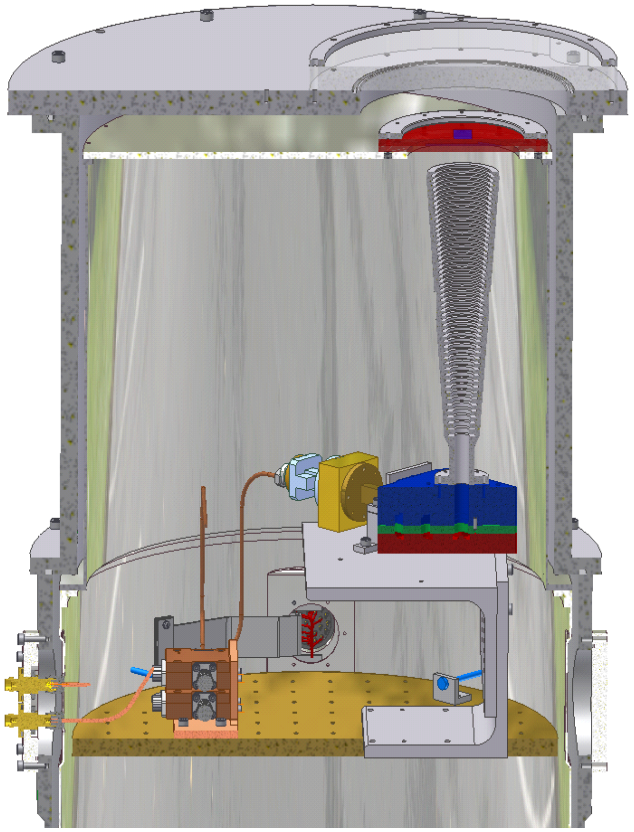
Test configuration with Band 1 feedhorn



Conclusion and future work

- Optics design re-evaluated: complete end to end simulation underway.
- Test cryostat operational for evaluating individual components:
- OMT prototype completed, final design to be manufactured
- New LNA prototype currently under fabrication
- Mixer design completed and ready for prototyping
- Feedhorn fabrication underway