Upgrades to the CSO

A 280-420 GHz Technology Development Receiver (Trex) and beyond....

J. Kooi, A. Kovacs, M. C. Sumner, R. Ceria, D. Miller, T. G. Phillips

J
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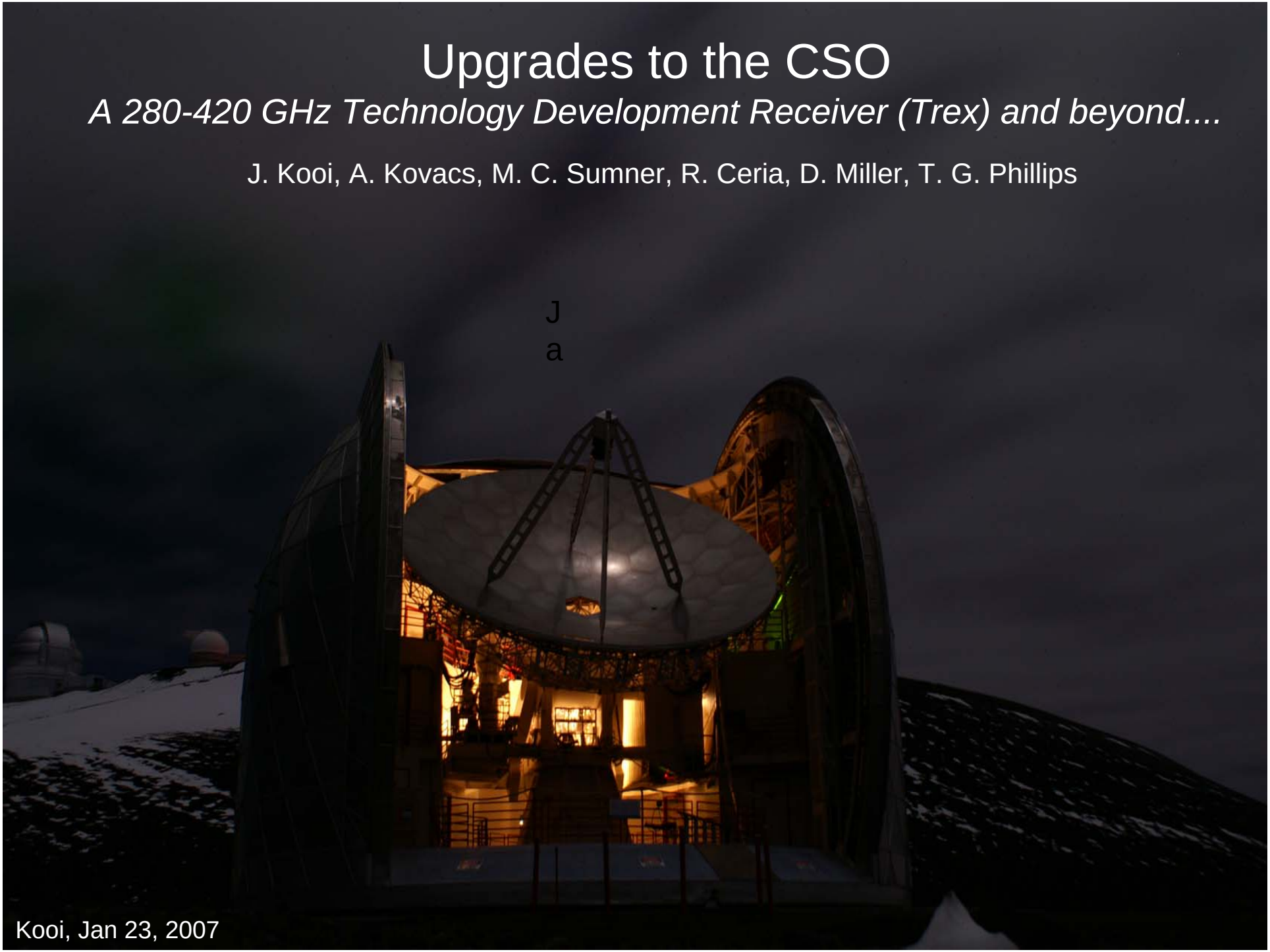


Talk Outline

- **280 - 420 GHz Technology Demonstration Rx (Trex):**
  - Used to demonstrate a Varity of Technologies
  - Allow Extended Baseline Observations with the SMA.
  - 4-8 GHz IF
- **Balanced Receivers:**
  - Dual Frequency Operation (230/460 GHz and 345/650GHz Atmospheric Windows)
  - Tunerless
  - 4-8 GHz IF
- **280 - 420 GHz Tunerless Correlation (high-Z galaxy) Rx:**
  - Single Polarization, Continuous Comparison Rx
  - Tunerless
  - 100 μK (100MHz) in 8 hours Integration
  - 4-8 GHz IF

Science Objectives

- Point Sources:
  Red Shift Confirmation (SCUBA, SHARCII, BOLOCAM…)
  Extra Galactic Molecular Species
  Probing Star Forming Regions
  Interferometry with the SMA
- Spectral Line Surveys

High Sensitivity and Stable Receivers

Balanced Instrumentation:

Advantages of Balanced Receivers:
- Separate LO Port → Much lower LO requirement over traditional DSB and SSB designs.
- Reduced (11-15 dB) Local Oscillator Amplitude Noise →Improved Stability and increased Sensitivity
- Easy to automate over large RF Bandwidth (spectral line surveys)

280-420 GHz Correlation (Galaxy) Rx:

Advantage of a Correlation Receiver:
-Two Pixels; (On Source - Off Source),
-Improved Sky Subtraction
-Deep integrations for Extra Galactic (High z) spectral line work.

Needed: Technology Demonstration Receiver.
- 280 - 420 GHz Single-ended DSB Rx
- Allow for Extended Baseline Observations with the SMA.
- 4-8 GHz IF

Needed Technology

✓**Wide Bandwidth Waveguide to Microstrip Transition (to couple to the mixing device)**

✓Balanced & Correlation Mixer Block Design

✓Optics Design

✓ New Set of SIS Junctions (JPL)

✓4-8 GHz IF Match, Bias Tee, In-phase Power Combining

✓4-8 GHz Low Noise Cryogenic Amplifier (Chalmers Univ).

✓4-8 GHz Warm IF + Stability requirements

✓Synthesized LO + + Balanced Power Amplifiers

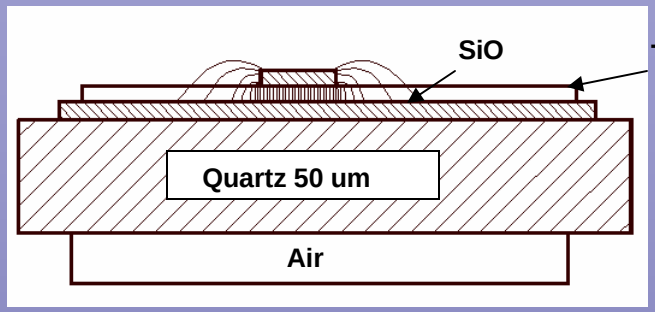
✓4 GHz Hybrid AOS (U. Koln) + 4-8 GHz IF processor (CSO)

✓Complete Computer Control of Bias Electronics

✓ Performance

✓ = Complete
✓= Under Development

Thin Film Radial Probe



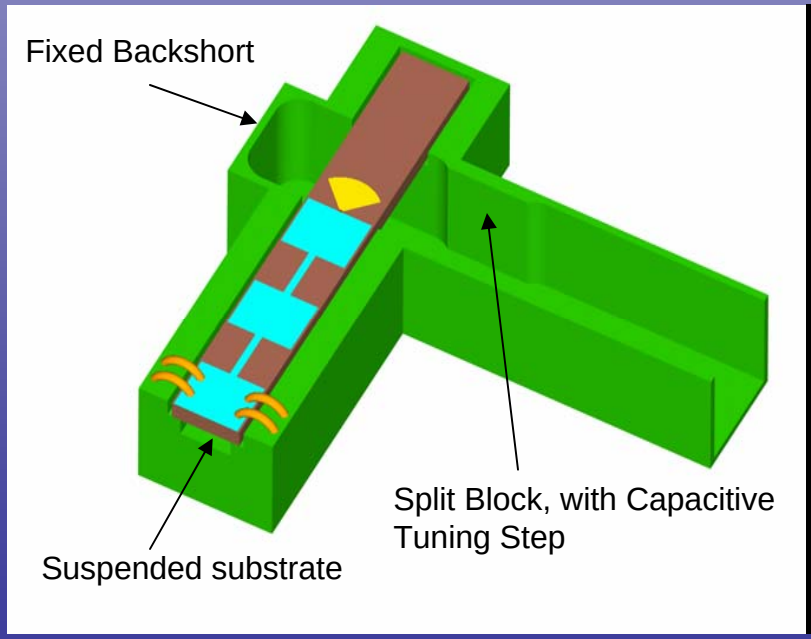
Thin Film Microstrip Mode

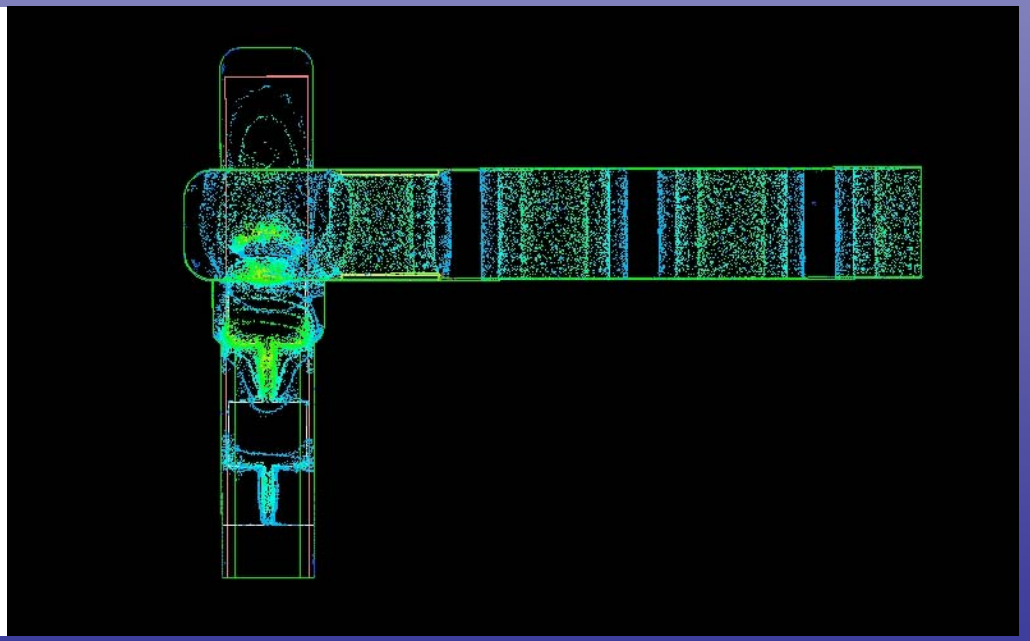
Concept: Stafford Withington, THz Conf, UVa 1999

Advantages:

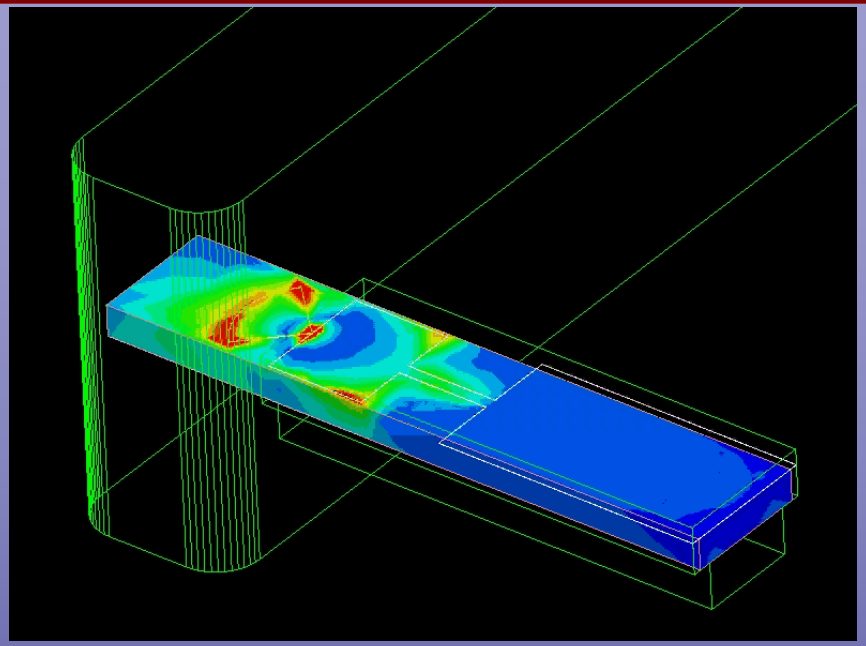
Full Height Waveguide

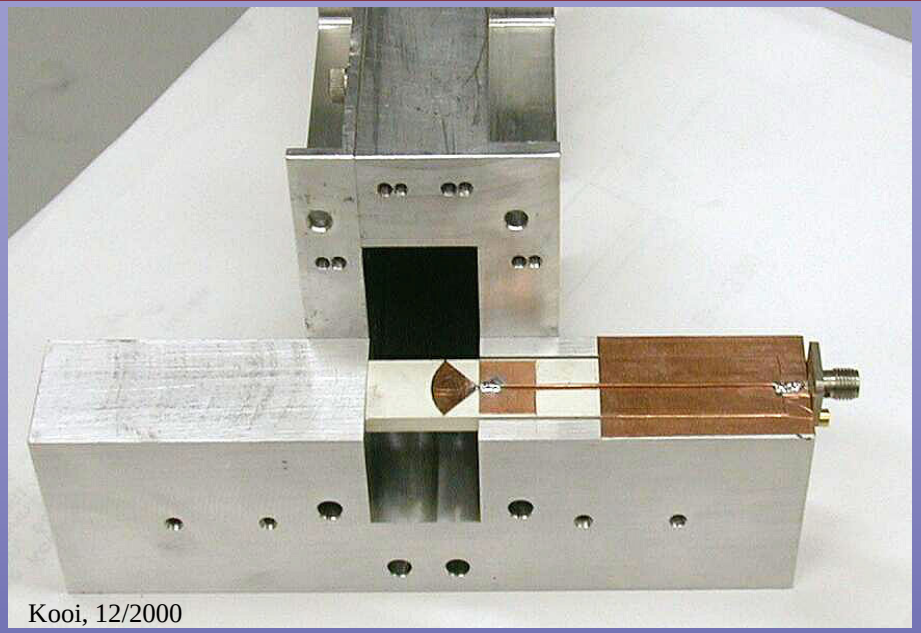
45-50% Fractional BW

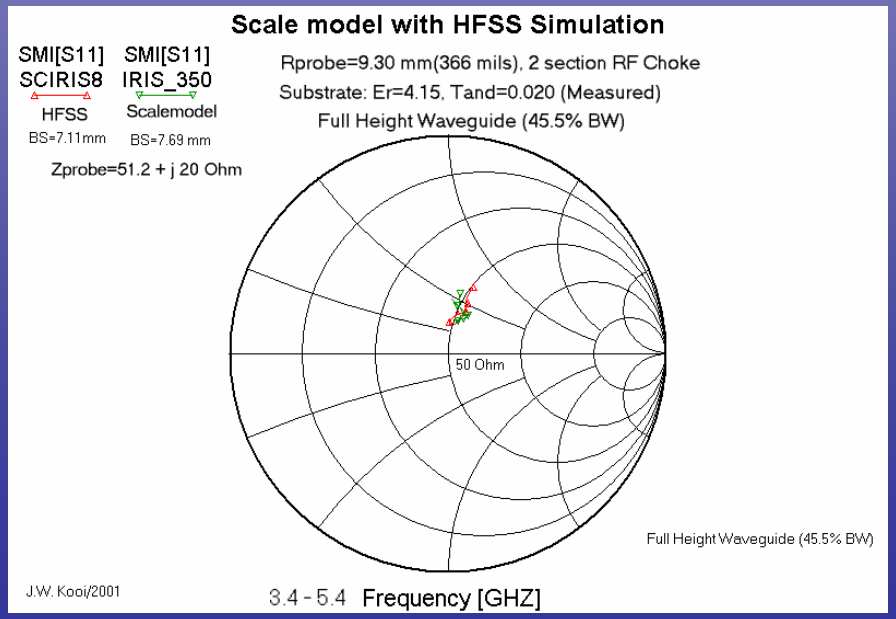


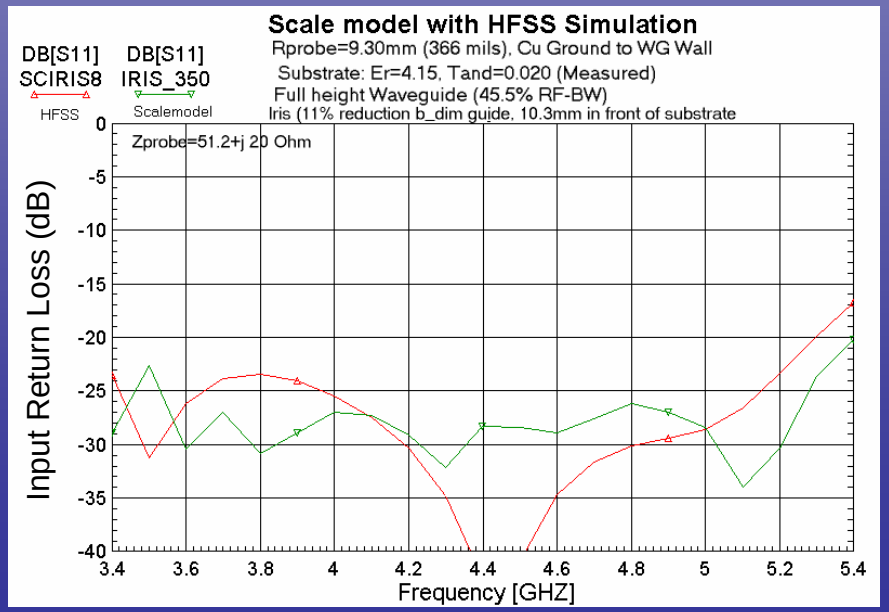


Scalemodel Verification of the E-Plane Radial Probe

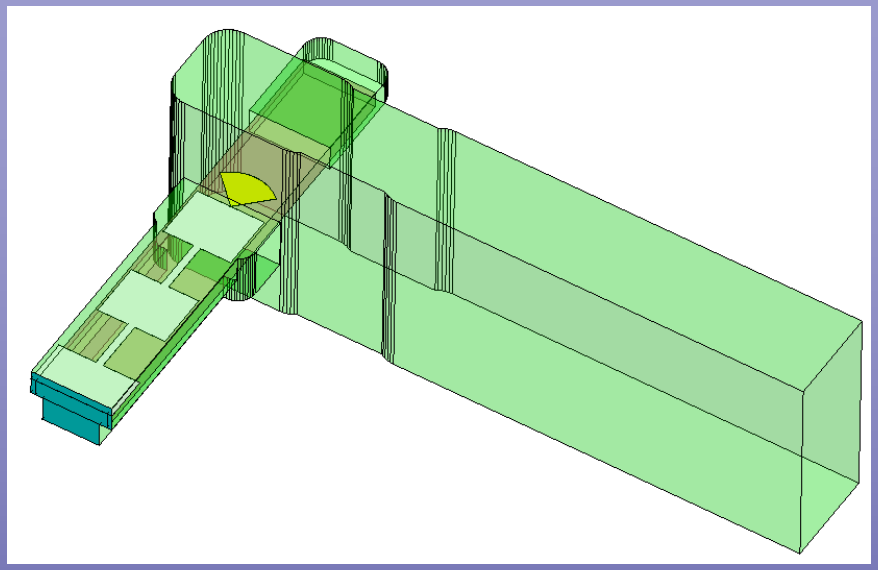


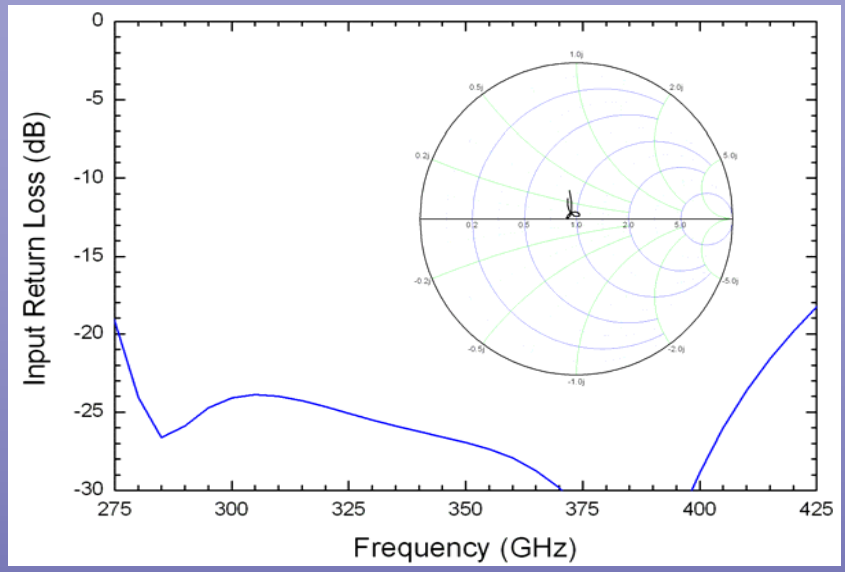




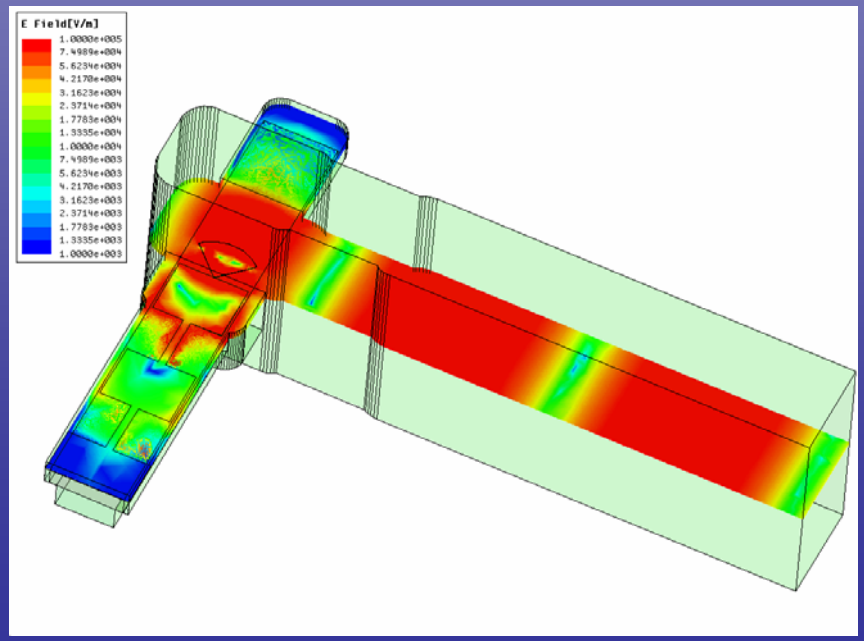


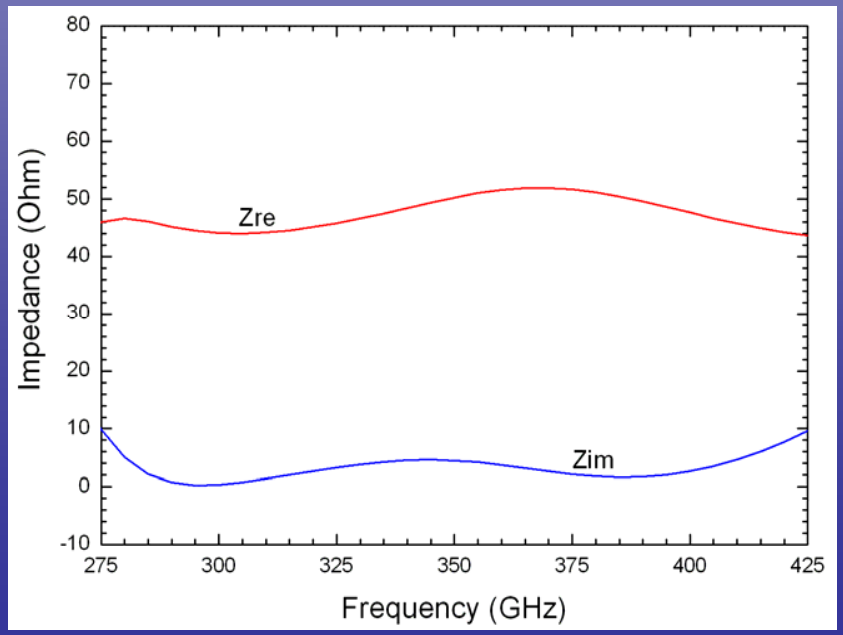
Basic 280-420 GHz Mixer Block



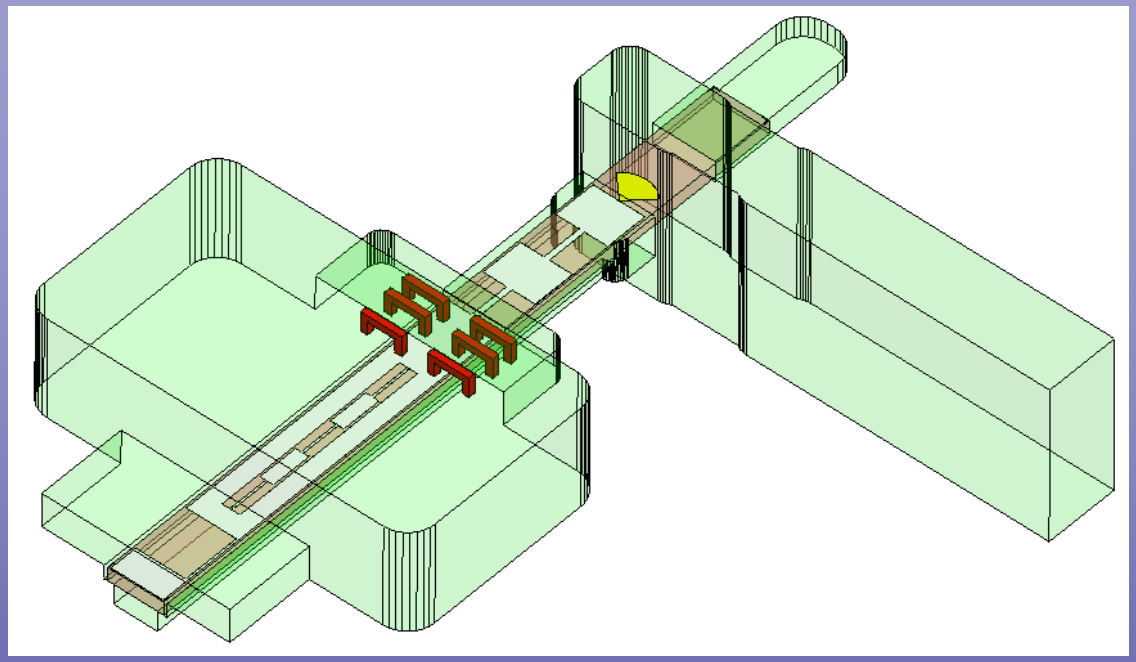


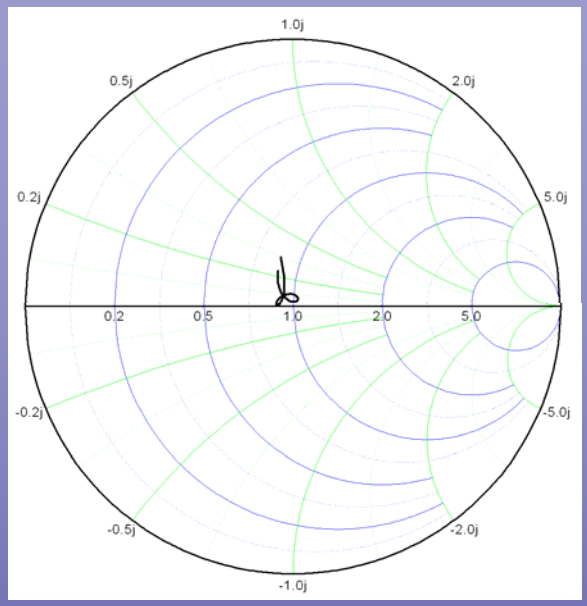
Simulation: 345 GHz





Finalized 280-420 GHz Mixer Block





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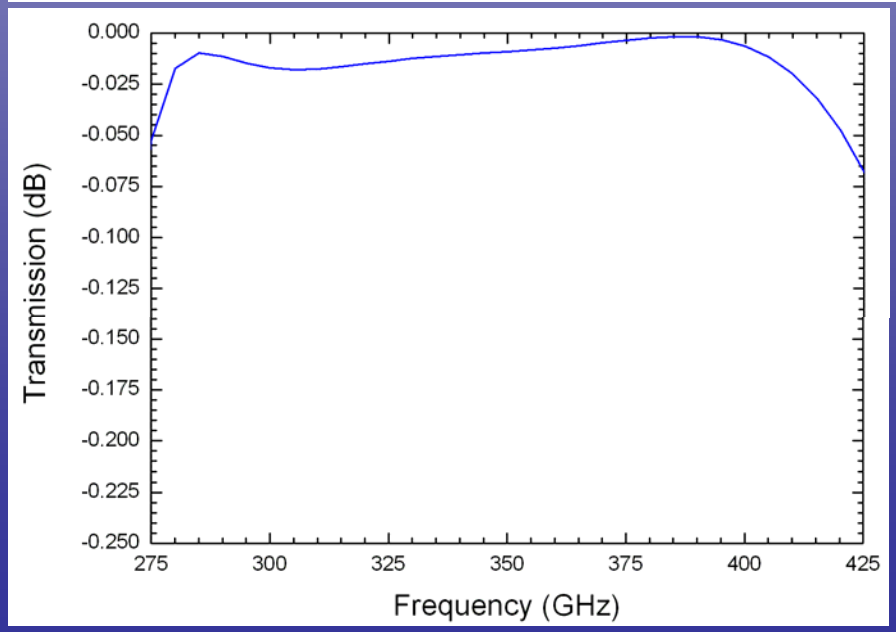
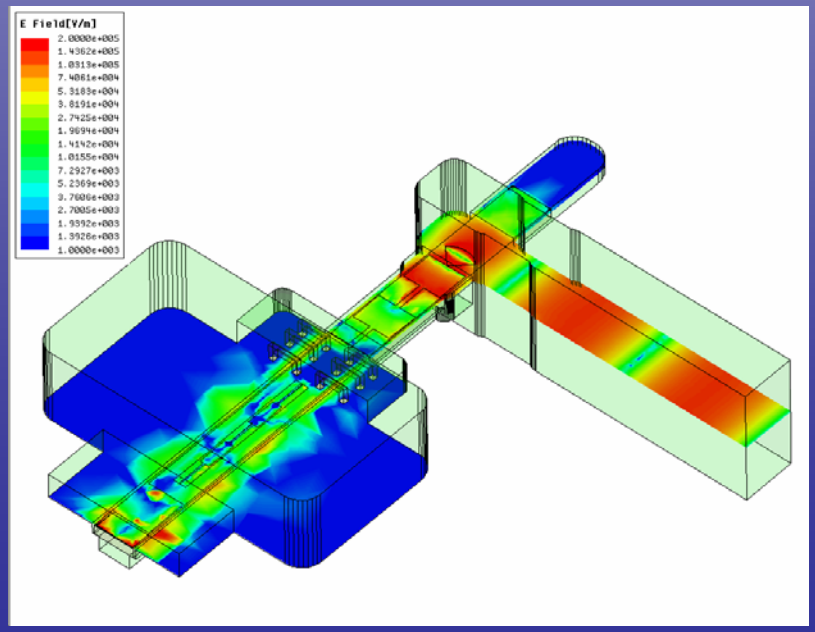
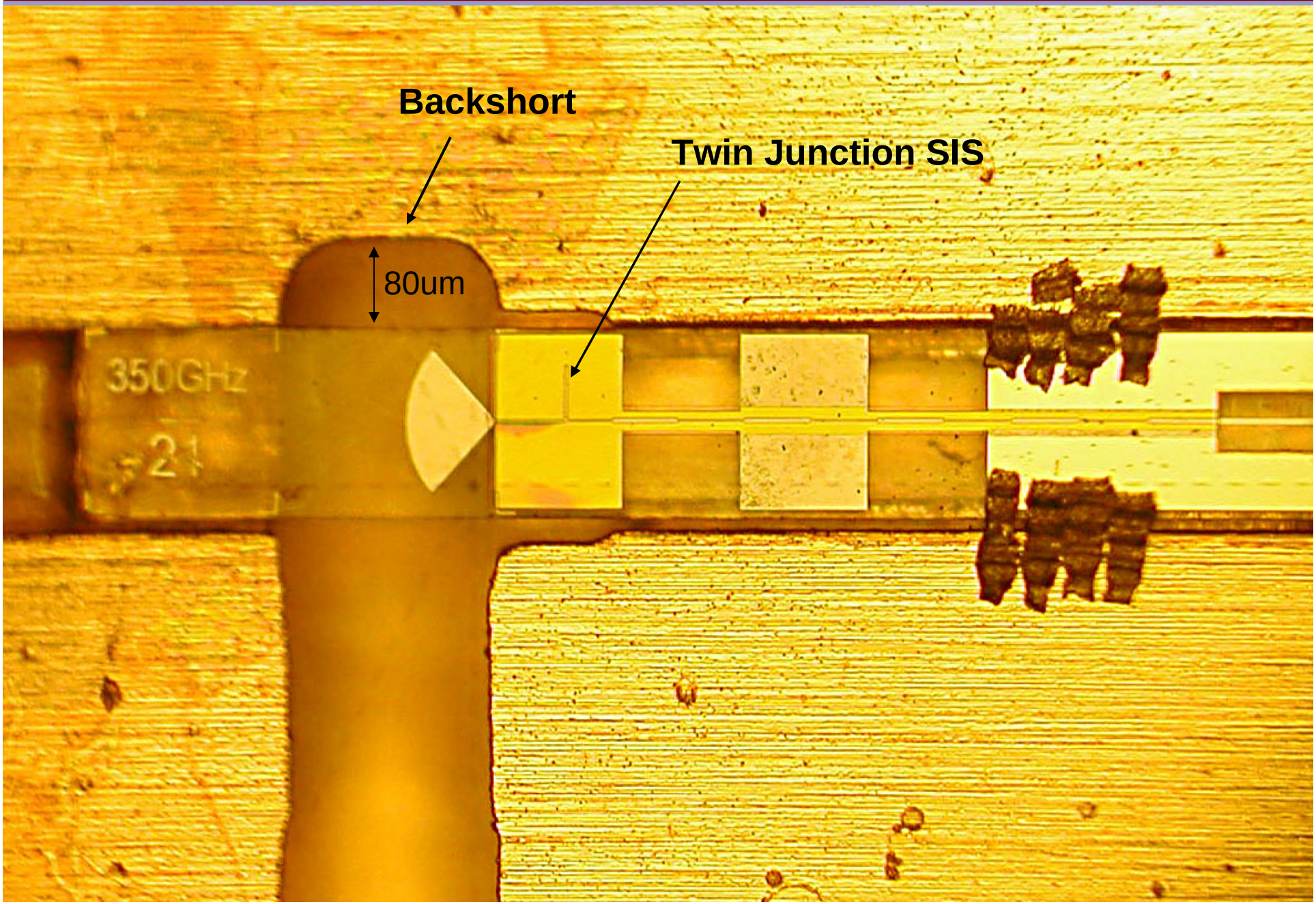
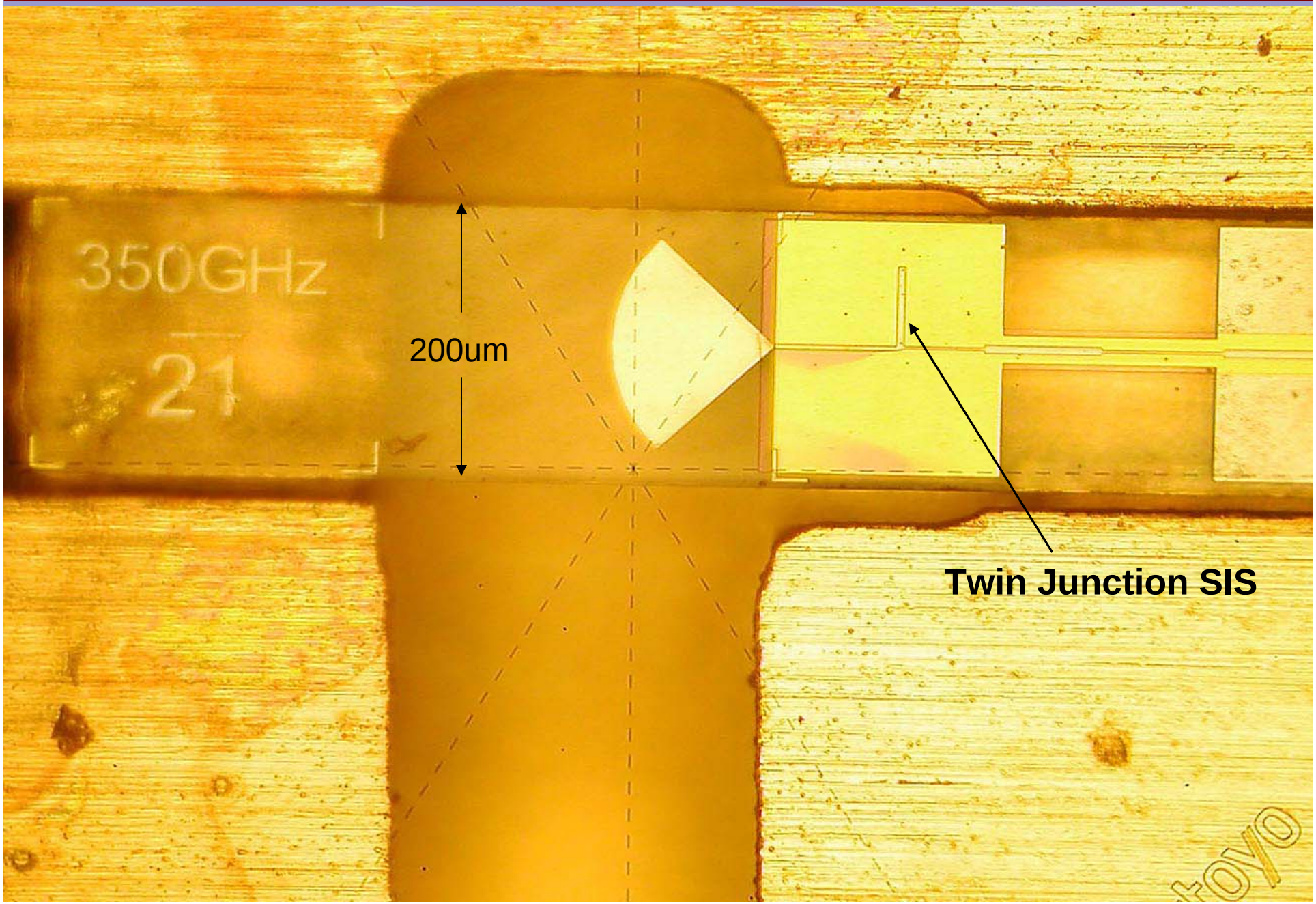


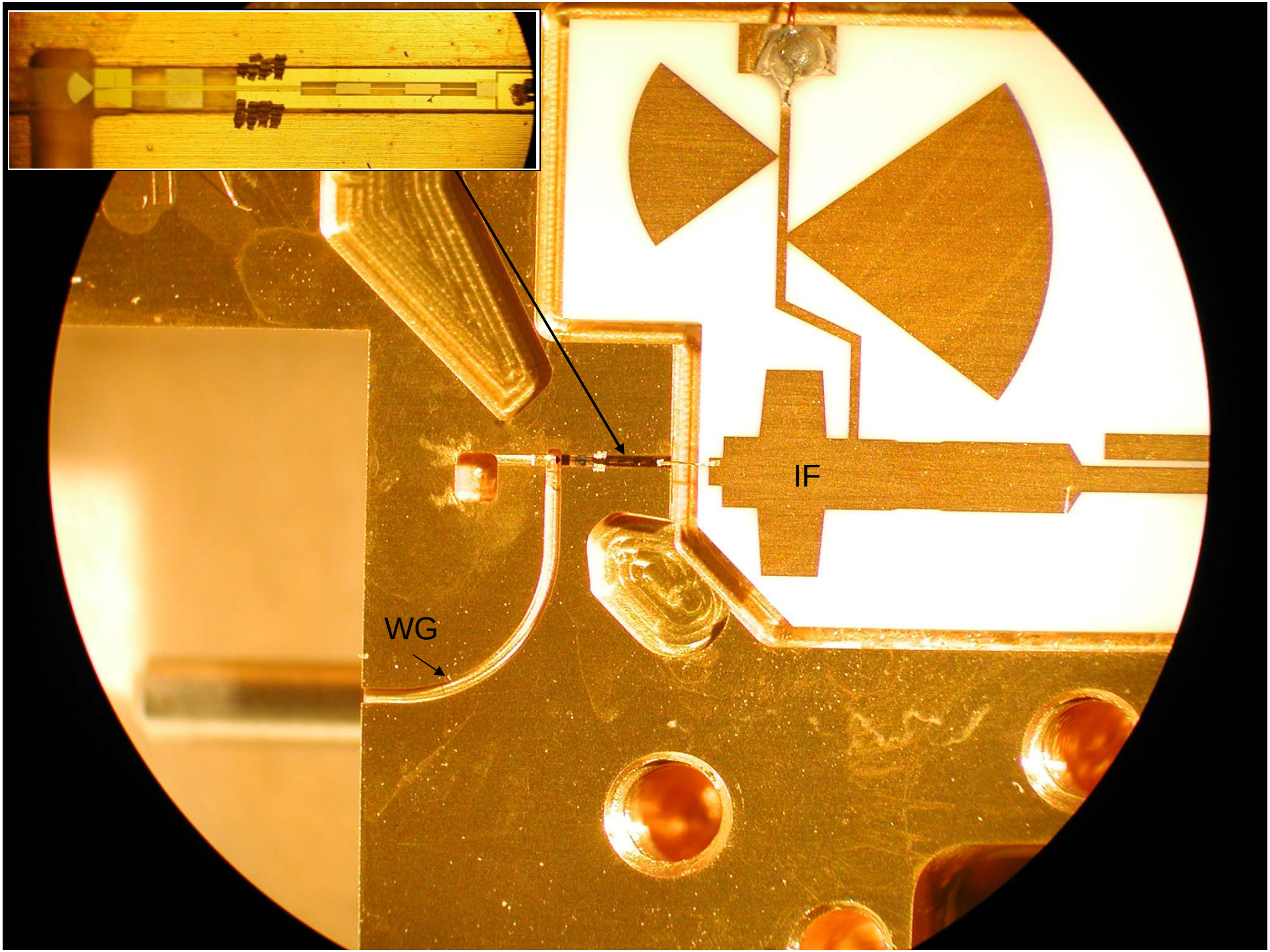


The Mixer's Heart



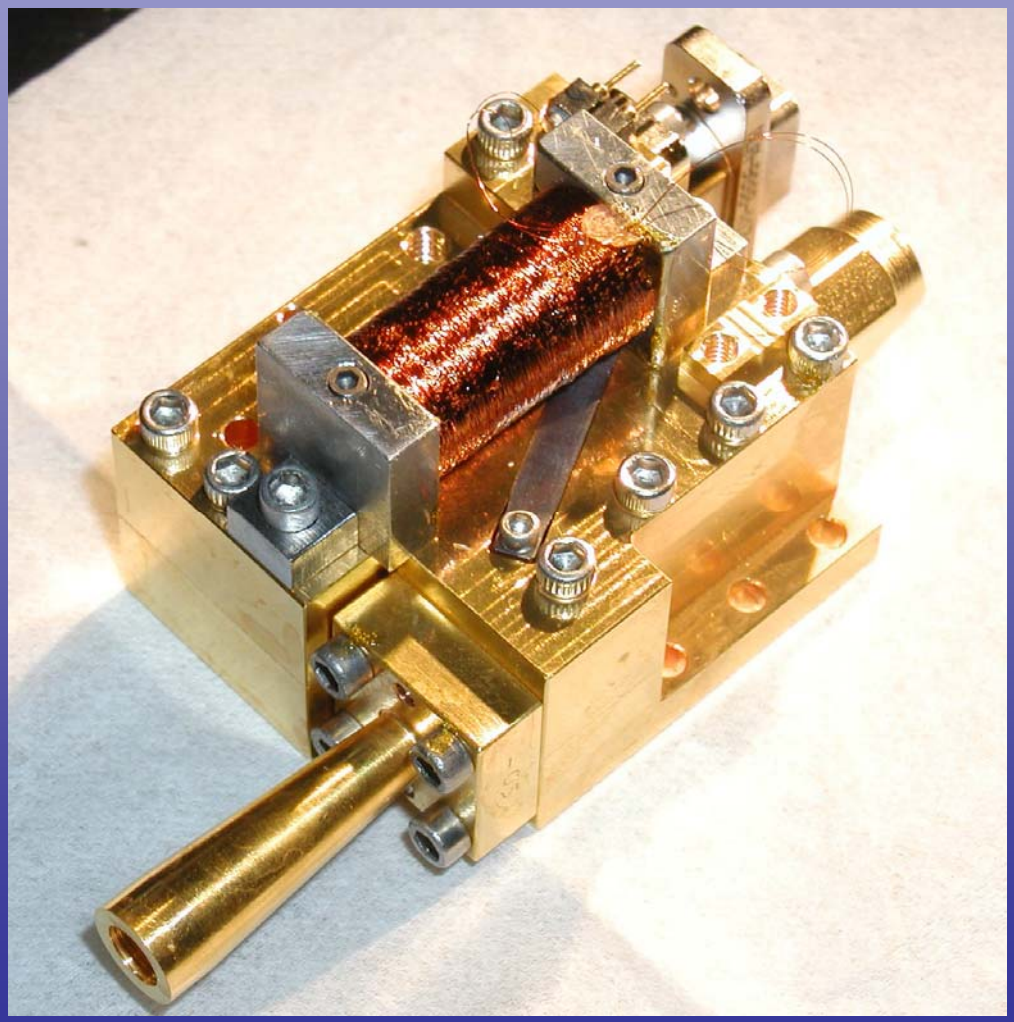
The Mixer's Heart Zoomed in

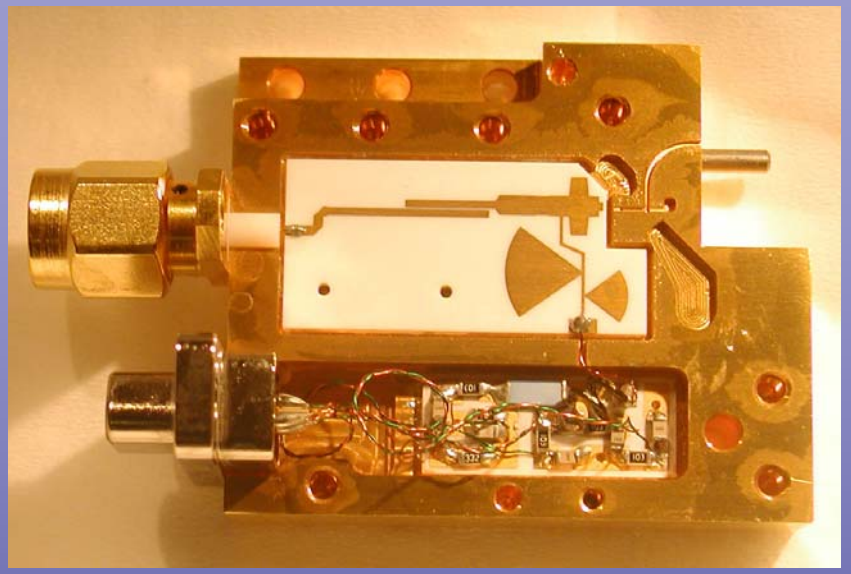


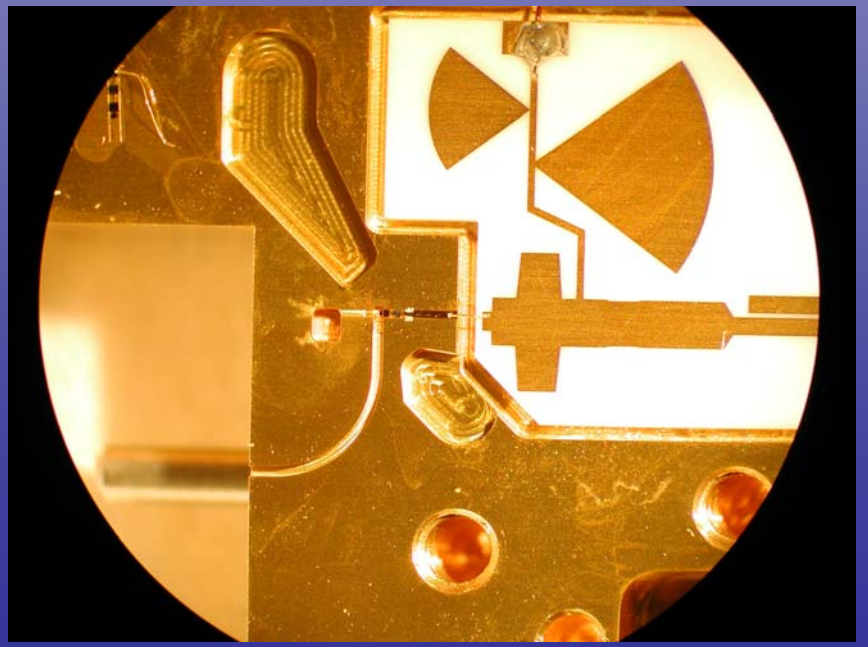

IF
WG

Single Ended Mixer Block

A tunerless 280 -420 GHz mixer based on the radial probe Wg transition and High Current Density AlN SIS junction (JPL).







Needed Technology

✓**Wide RF Bandwidth Tunerless Waveguide Mixers**

✓**Balanced & Correlation Mixer Block Design**

✓ Optics Design

✓ New Set of SIS Junctions (JPL)

✓4-8 GHz IF Match, Bias Tee, In-phase Power Combining

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✓Synthesized LO + + Balanced Power Amplifiers

✓4 GHz Hybrid AOS (U. Koln) + 4-8 GHz IF processor (CSO)

✓Complete Computer Control of Bias Electronics

✓ Performance

✓ = Complete
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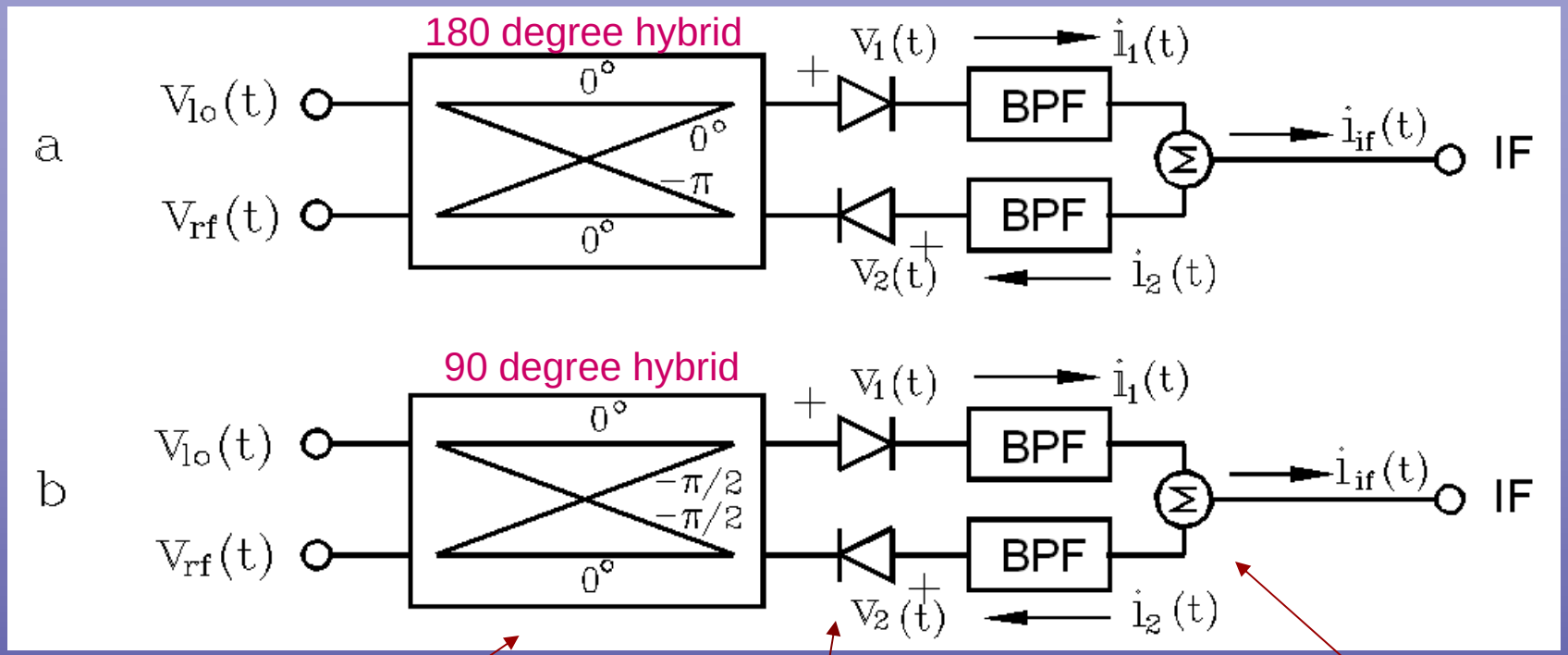
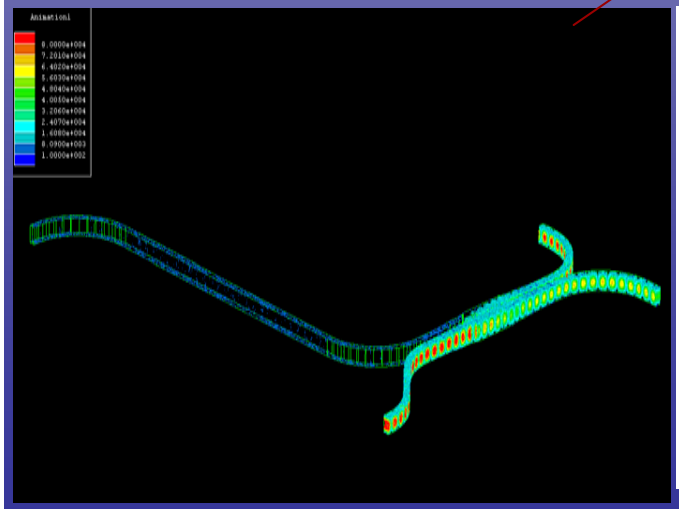
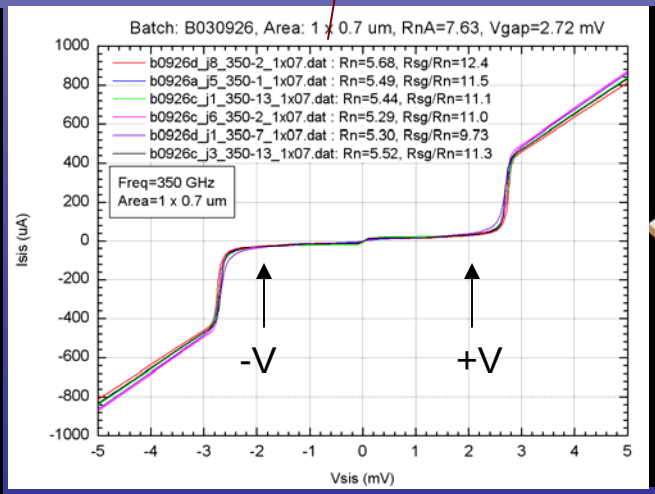
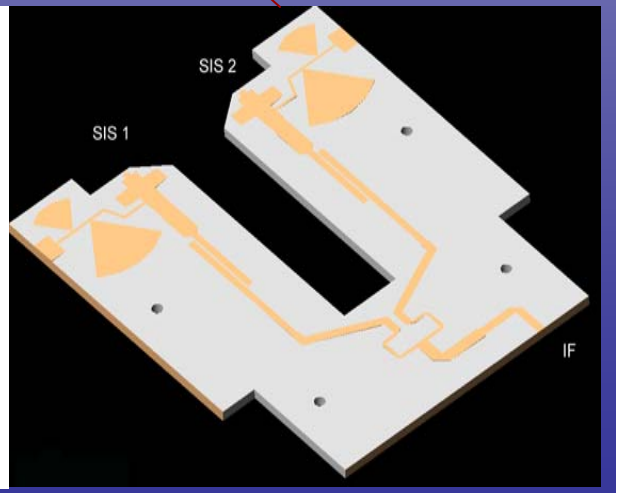
Possible Balanced Mixer Configuration

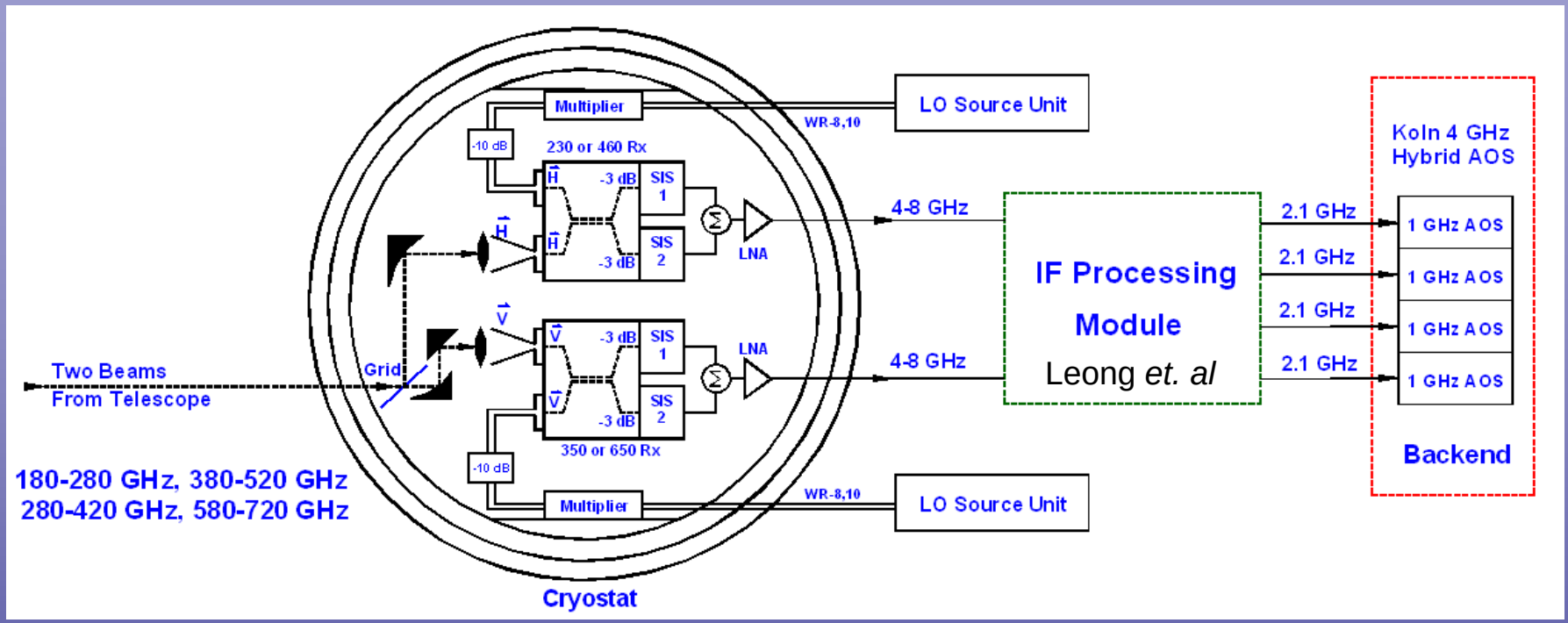








Balanced Instrumentation Layout for the CSO

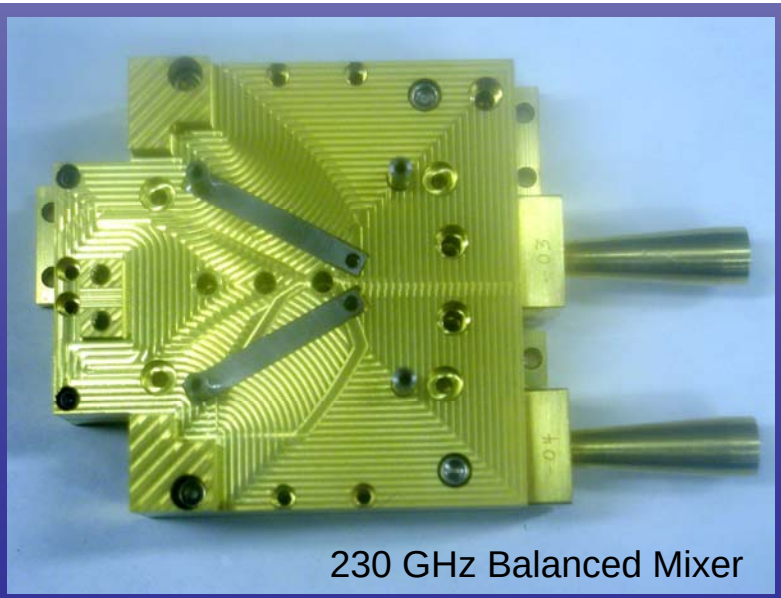


Key Features:

- Dual Frequency (2 Color) Observations

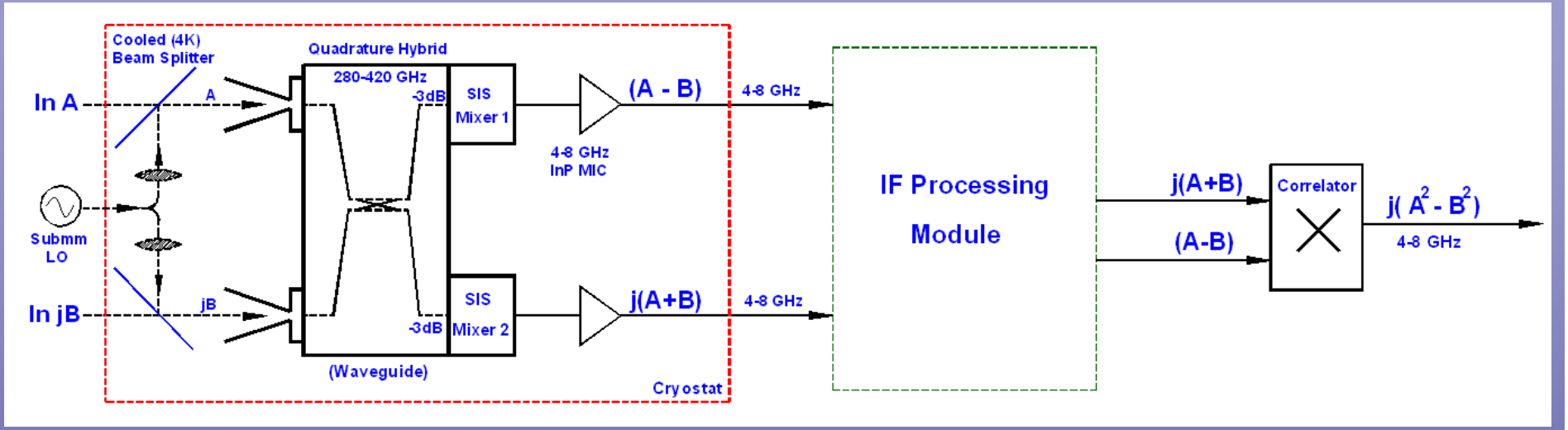
180-280 GHz & 380-520 GHz
280-420 GHz & 580-720 GHz

- **Advantages**: Scientific & Pointing
- Cooled (15K) LO
- LO Noise Cancellation (10-15 dB)



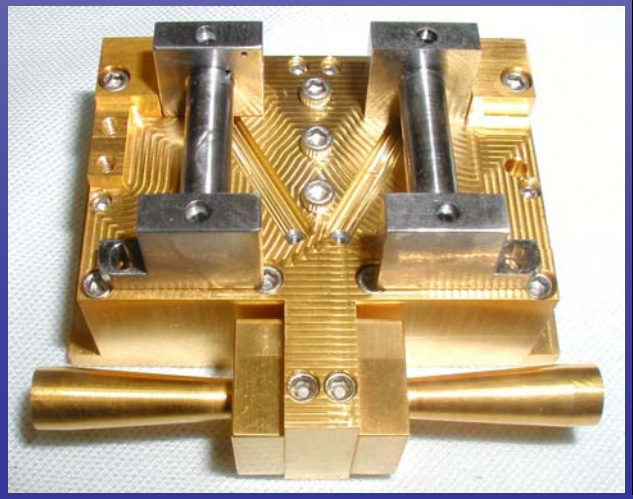
230 GHz Balanced Mixer

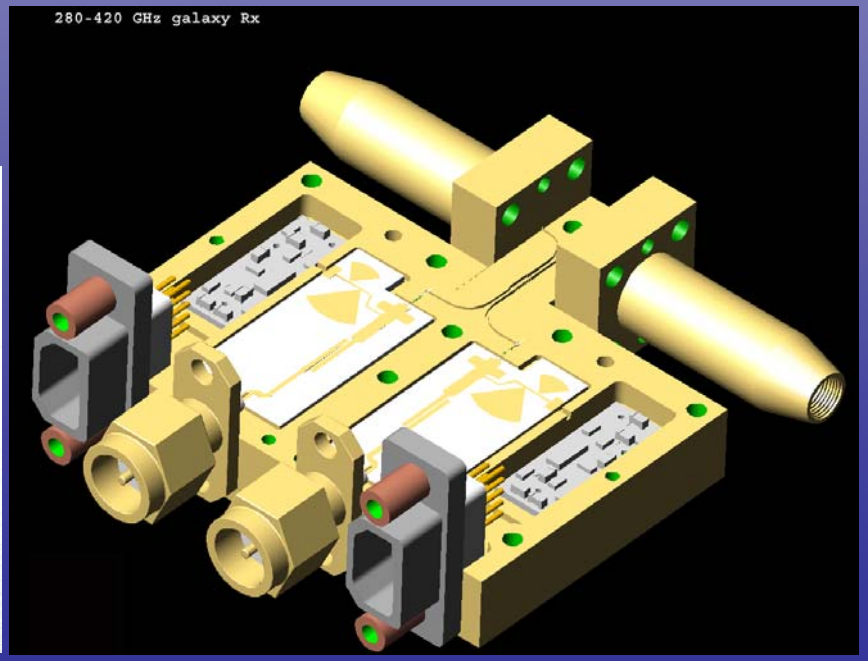
Continuous Comparison (Correlation) Receiver Layout



Specifications:

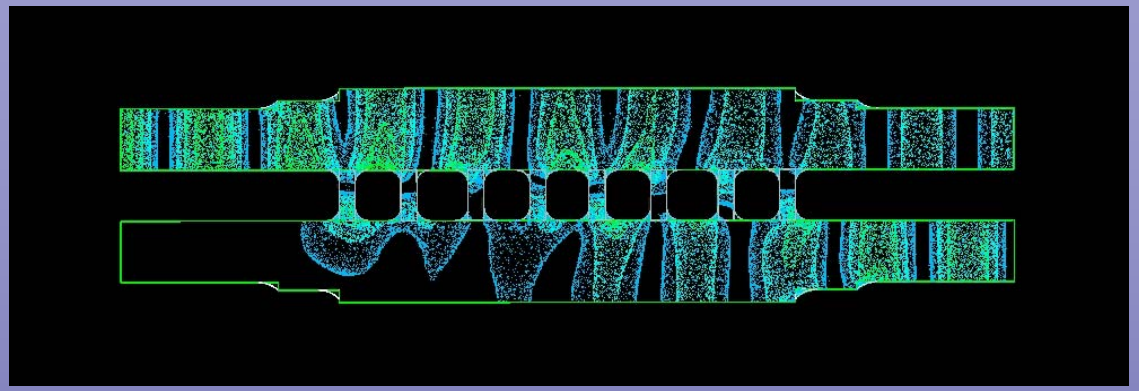
- 100μK (100 MHz) in 8 hours Integration
- 280-420 GHz Tunerless mixer operation
- 4-8 GHz IF





90 Degree Hybrid Branch-Line Coupler

Input Side

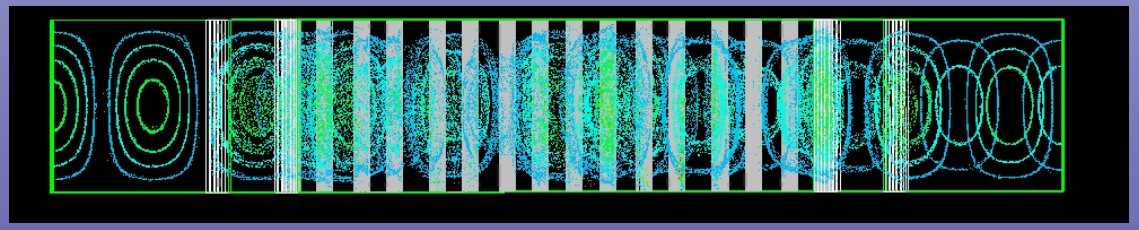


Output Side

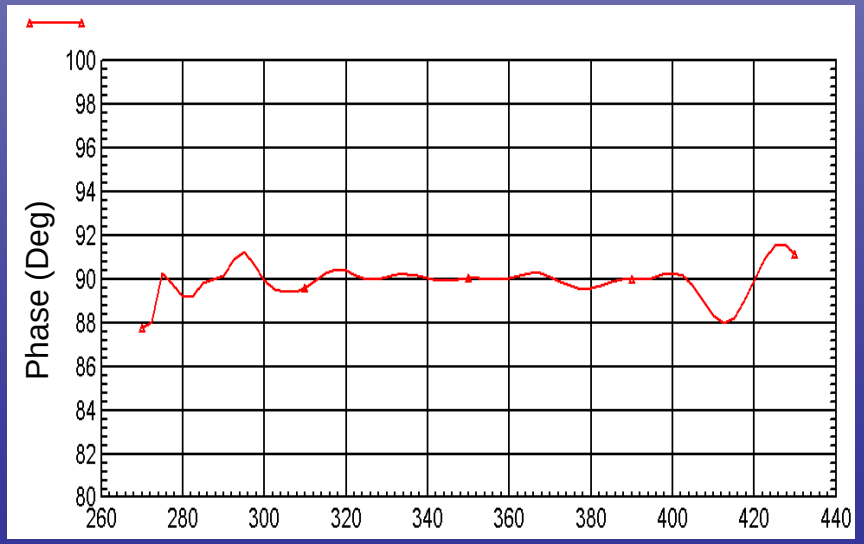
-3dB

-3dB

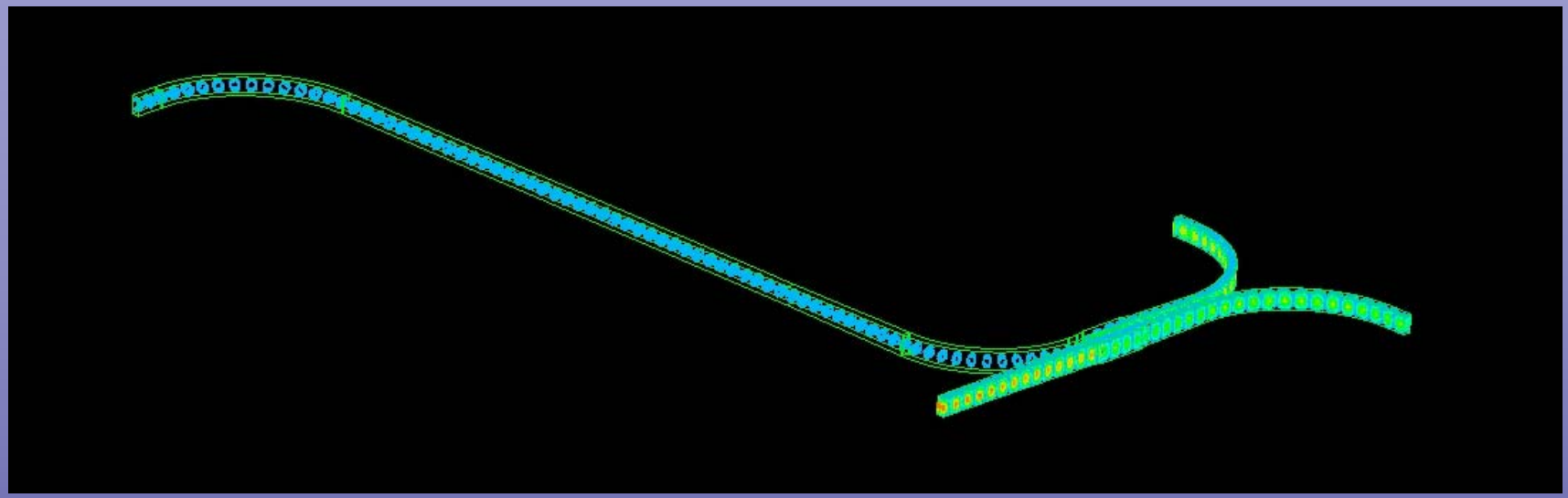
In Phase

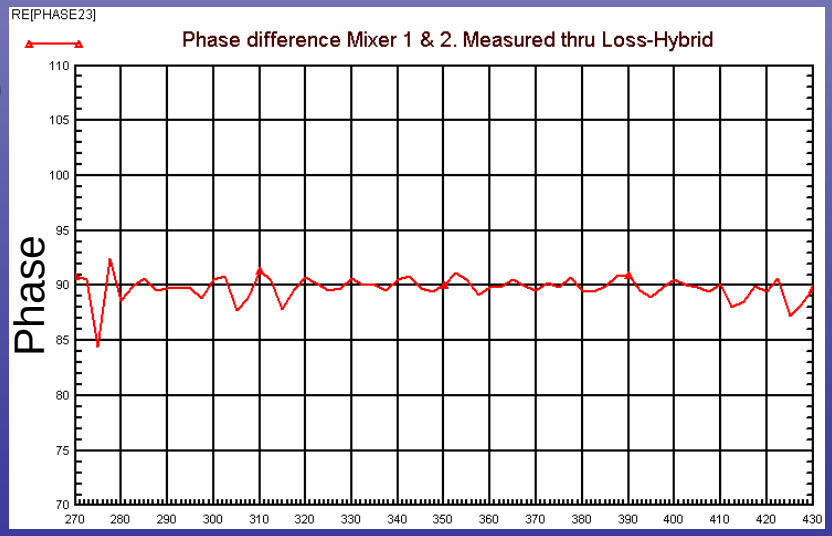


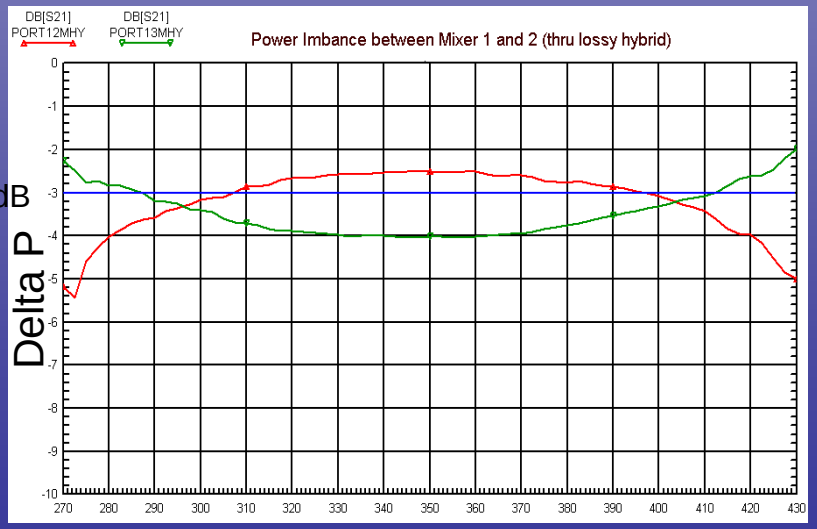
90 degrees Out of Phase



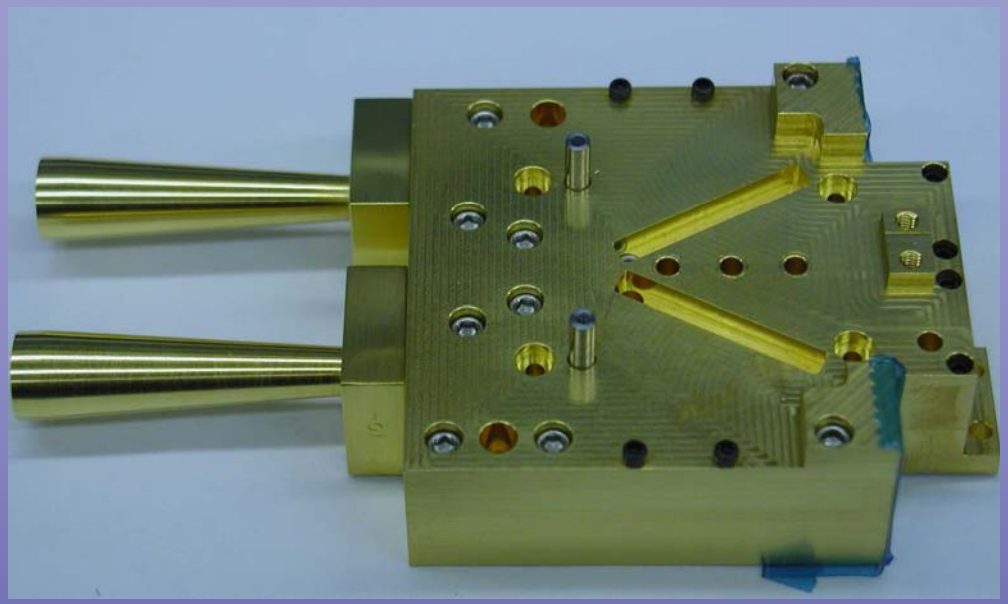
Branch-line Coupler /Mixer for Balanced Rx

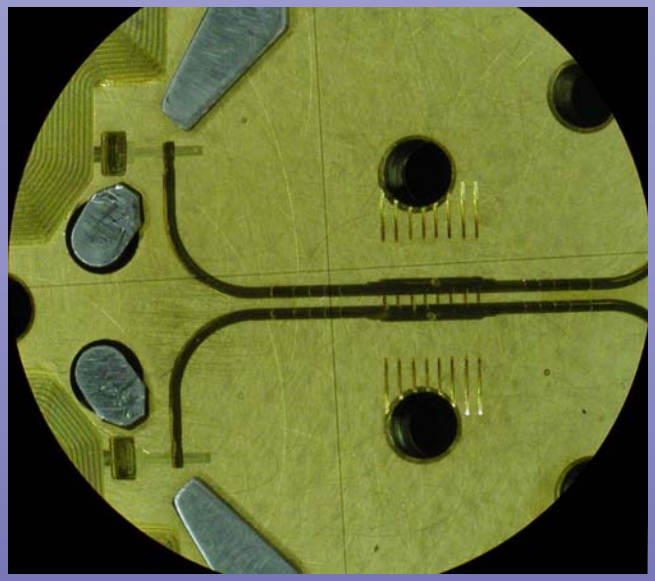


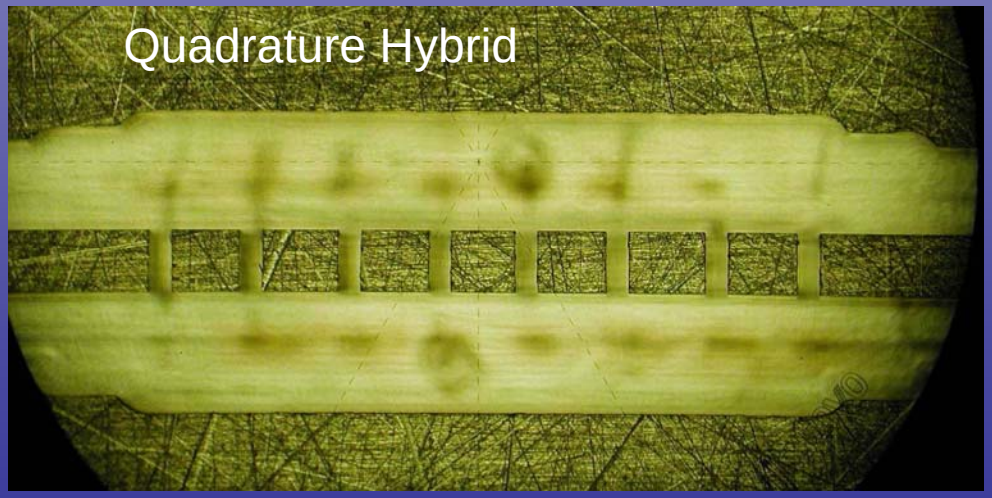




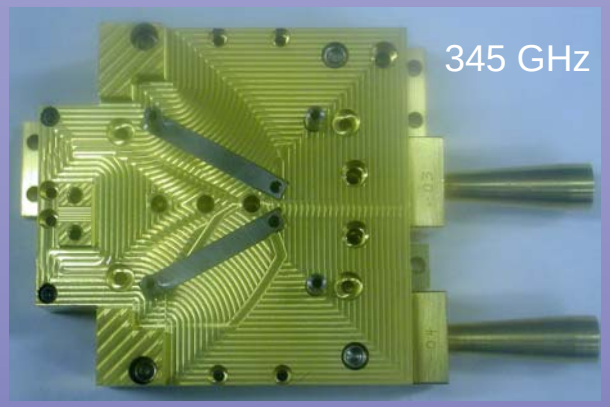
230 Balanced Mixer Hardware

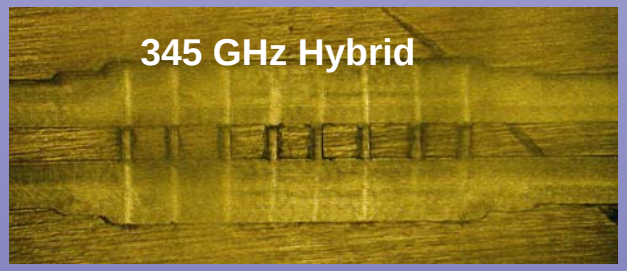


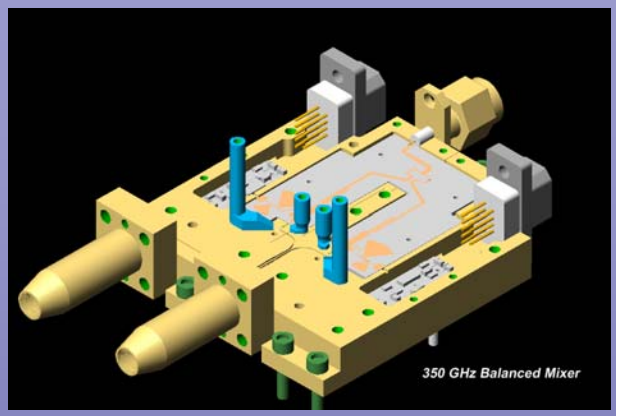


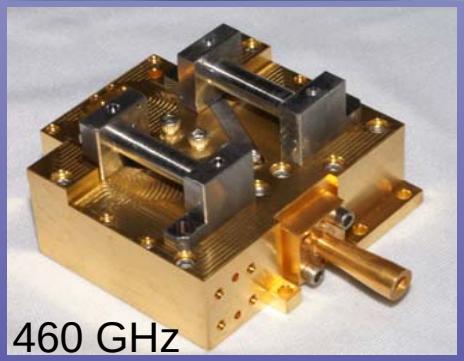


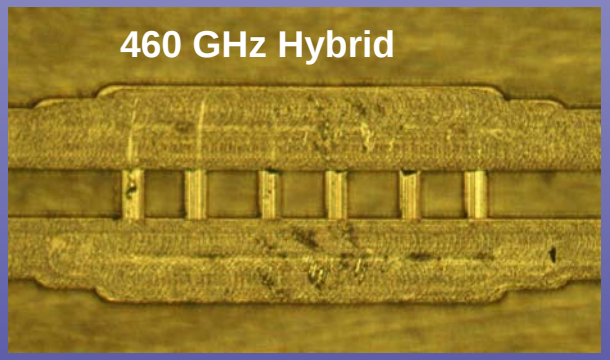
345, 460, 660 GHz Balanced Mixer Hardware

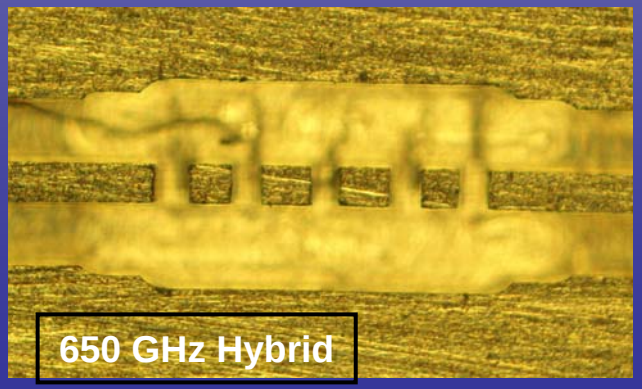




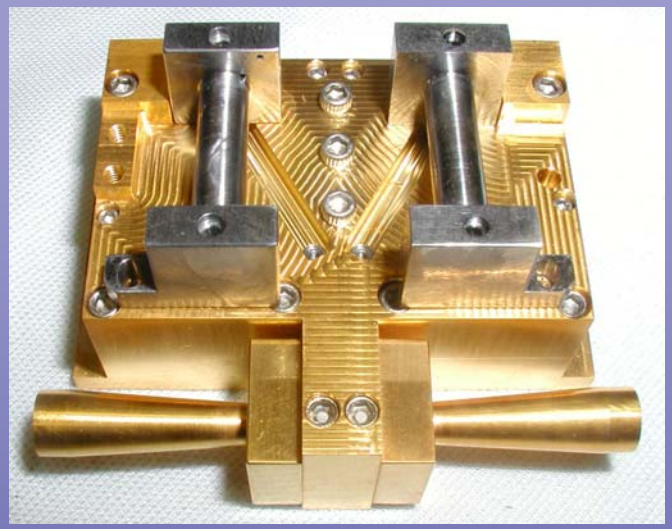


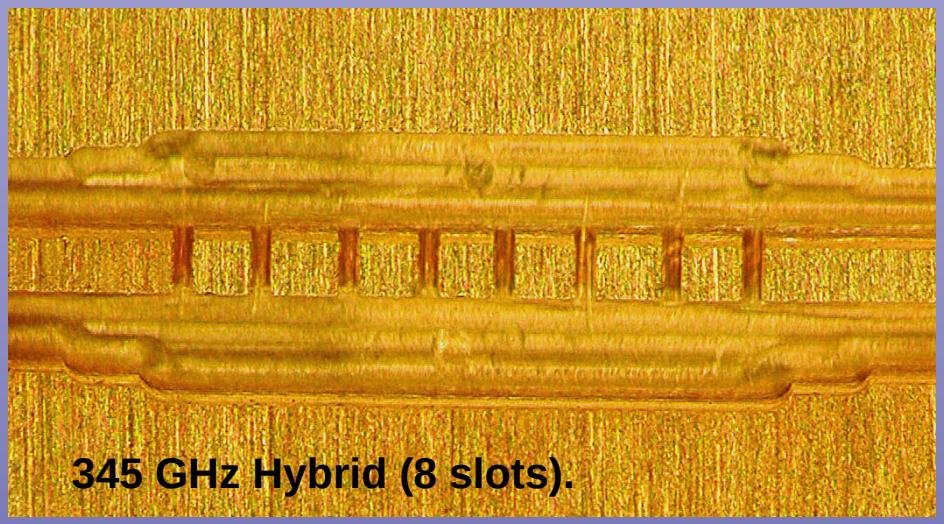




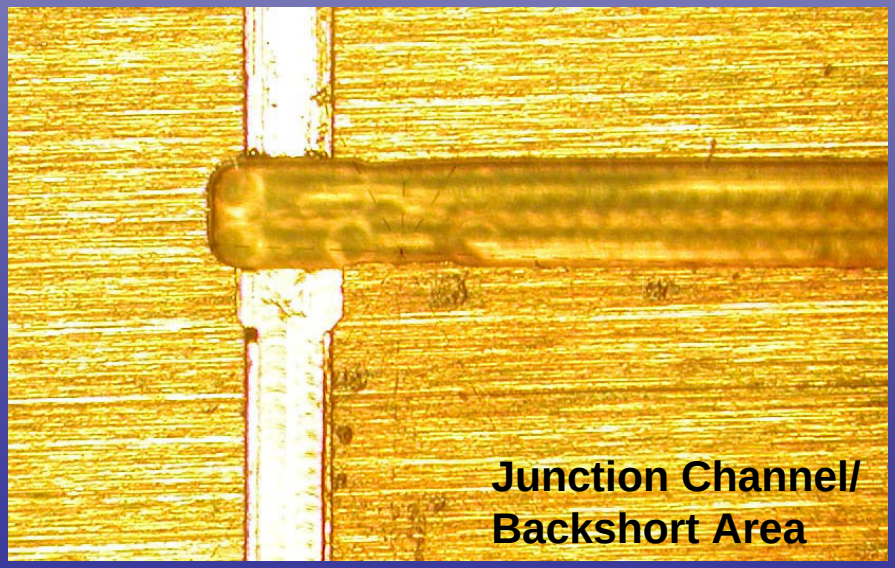


345 GHz Correlation Mixer

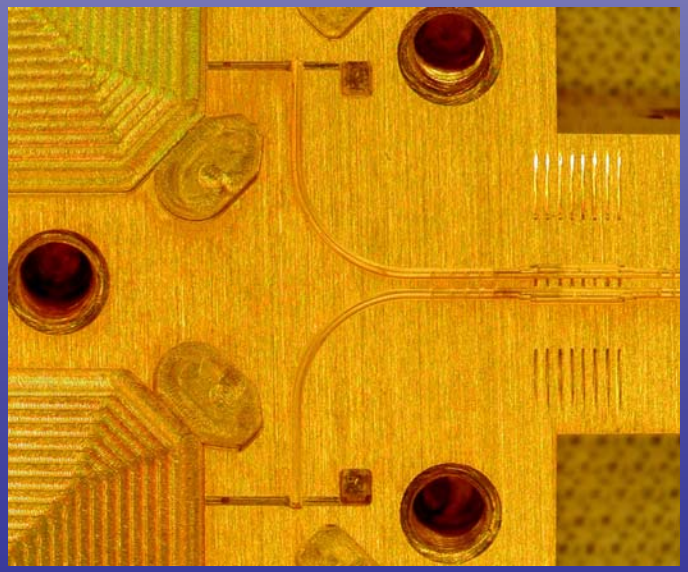




345 GHz Hybrid (8 slots).



Junction Channel/
Backshort Area



Needed Technology

✓Wide RF Bandwidth Tunerless Waveguide Mixers

✓Balanced & Correlation Mixer Block Design

✓**Optics Design:** **- Single-Ended Mixer**
- Balanced Mixers
- Correlation Mixer

✓ New Set of SIS Junctions (JPL)

✓4-8 GHz IF Match, Bias Tee, In-phase Power Combining

✓4-8 GHz Low Noise Cryogenic Amplifier (Chalmers Univ).

✓4-8 GHz Warm IF + Stability requirements

✓Synthesized LO + + Balanced Power Amplifiers

✓4 GHz Hybrid AOS (U. Koln) + 4-8 GHz IF processor (CSO)

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✓ = Complete
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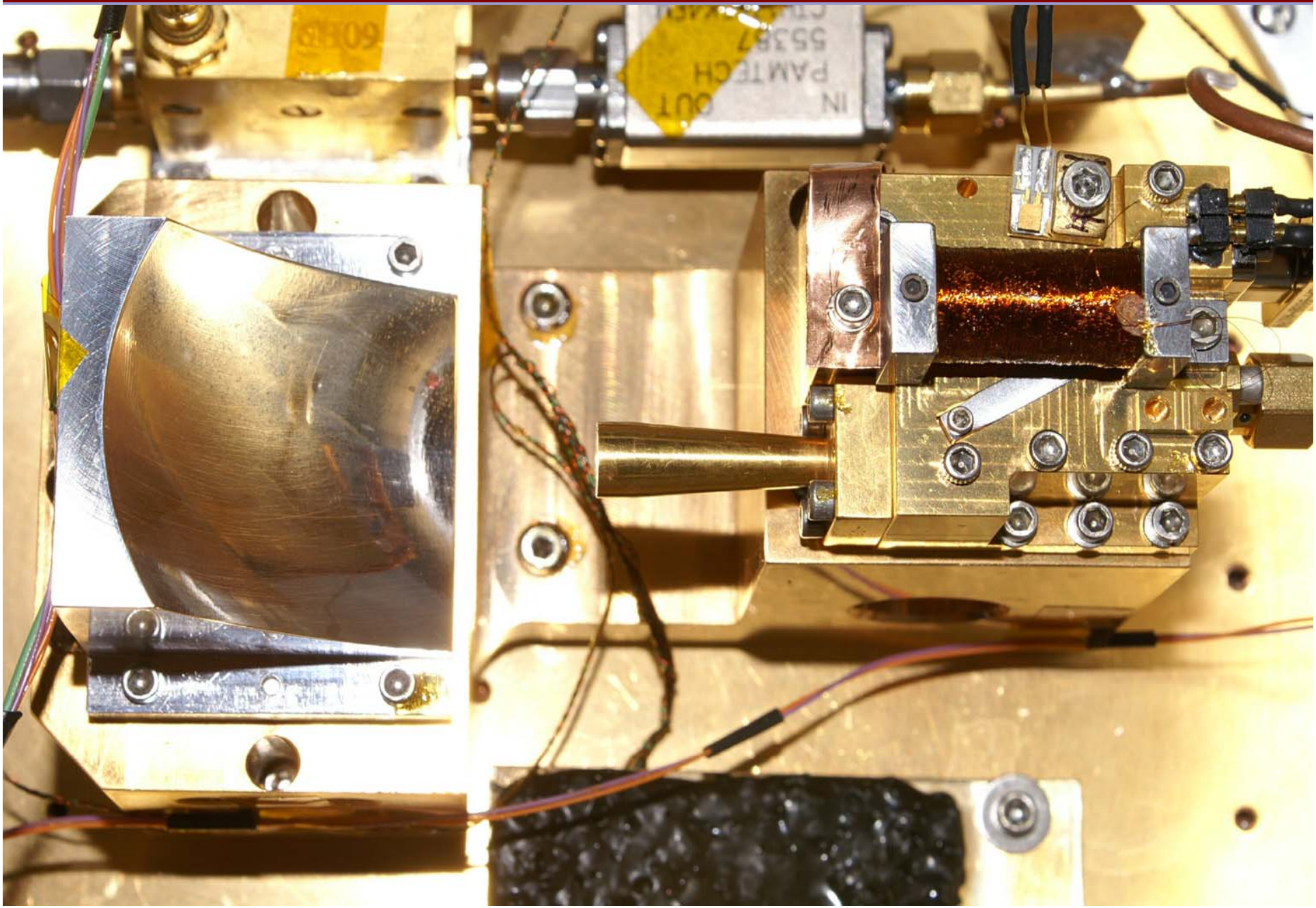
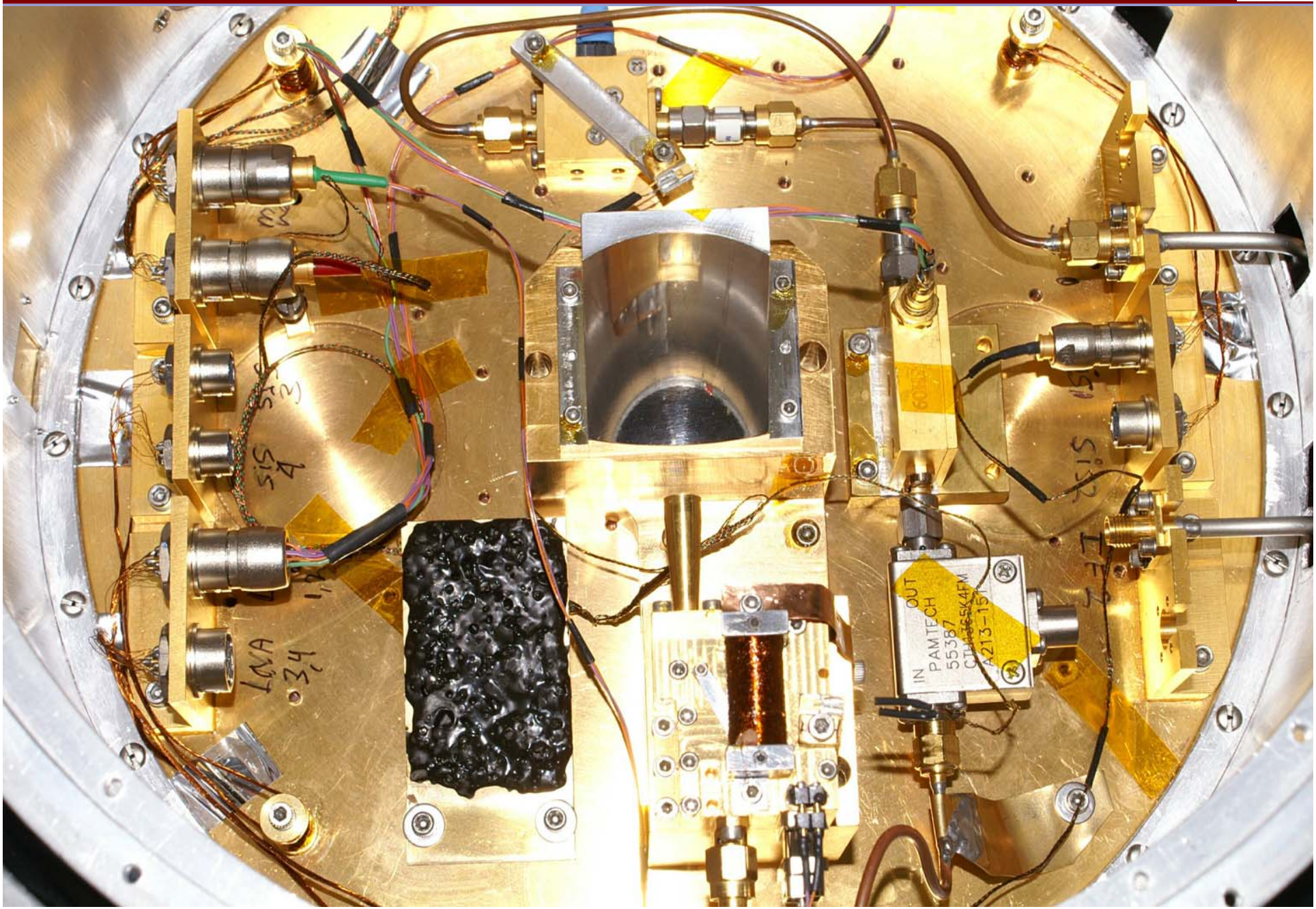
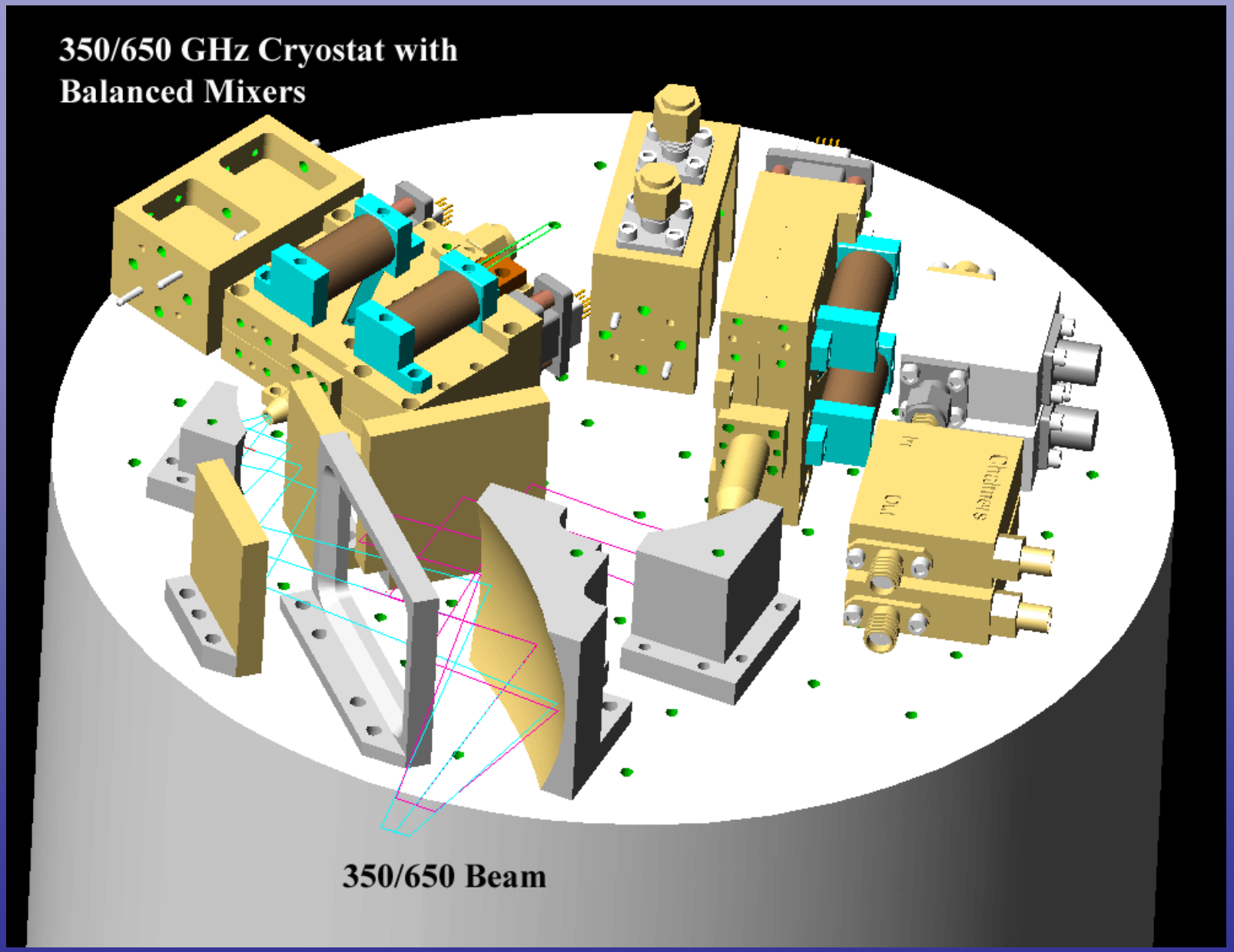
TRex (280-420 GHz) Optics I



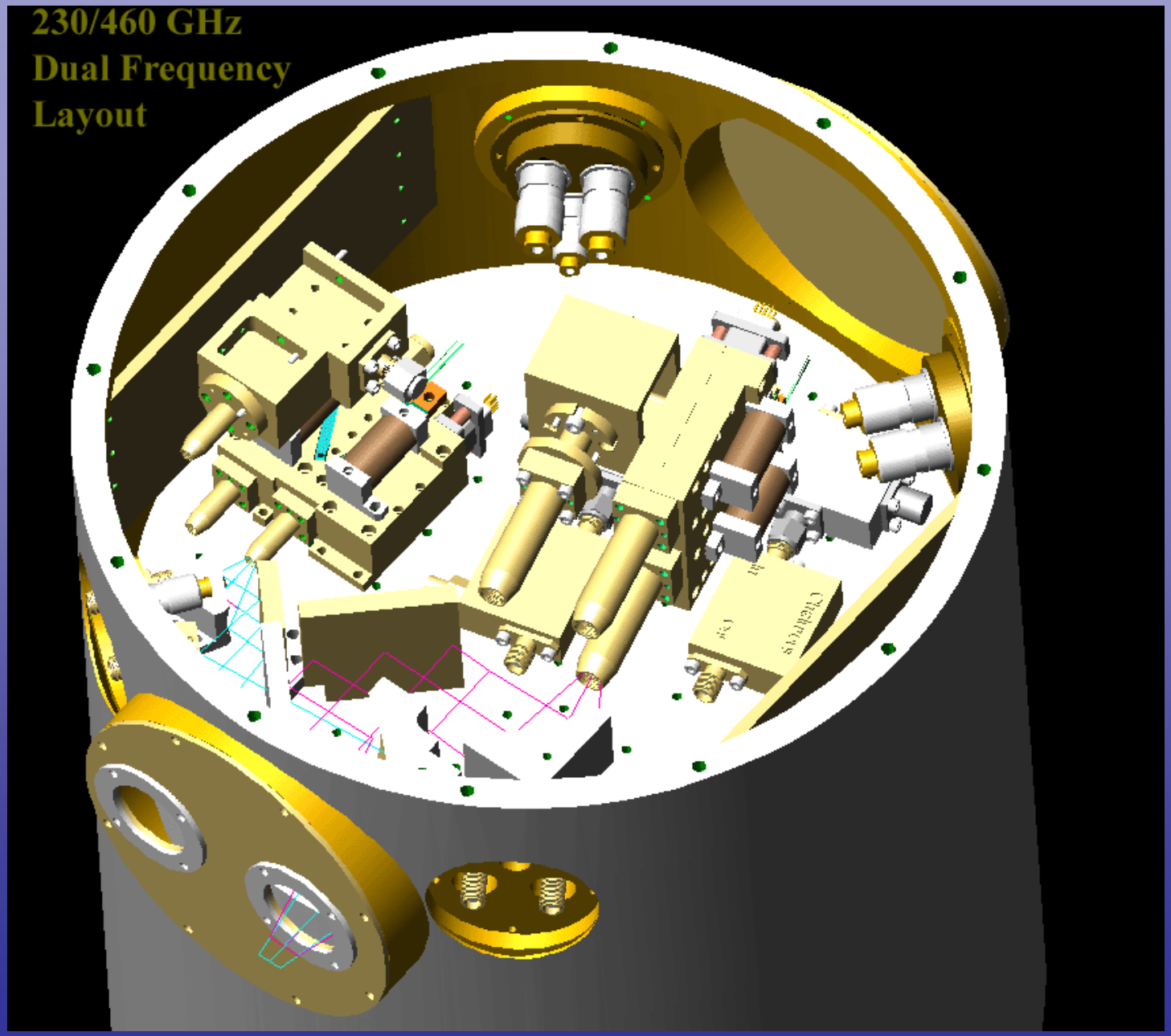
Trex (280-420 GHz) Optics II



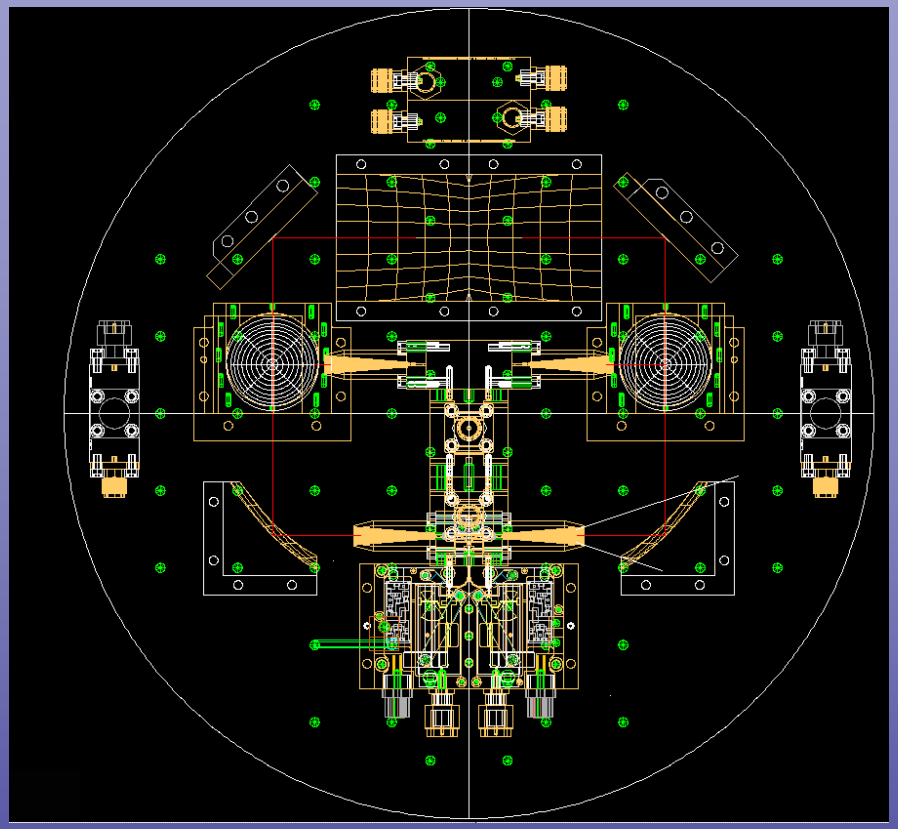
350 GHz and 650 GHz Balanced Mixer Optical Configuration

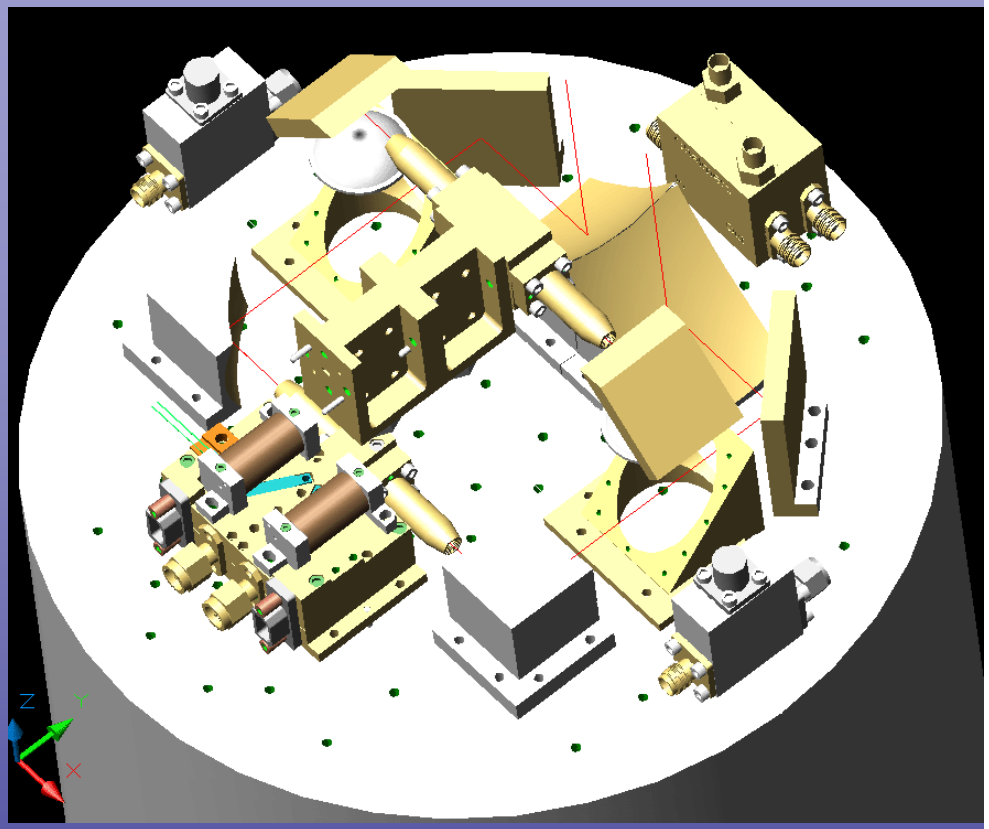


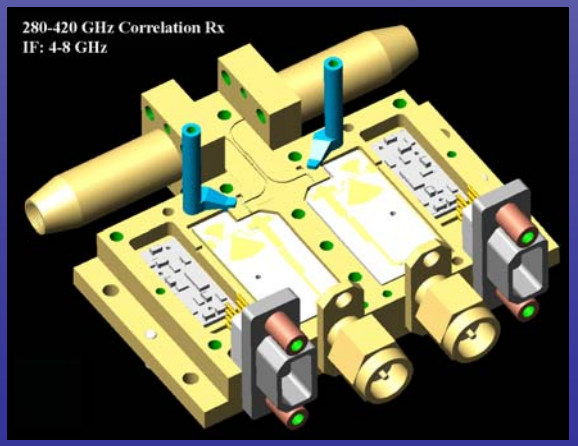
230 GHz and 460 GHz Balanced Mixer Optical Configuration

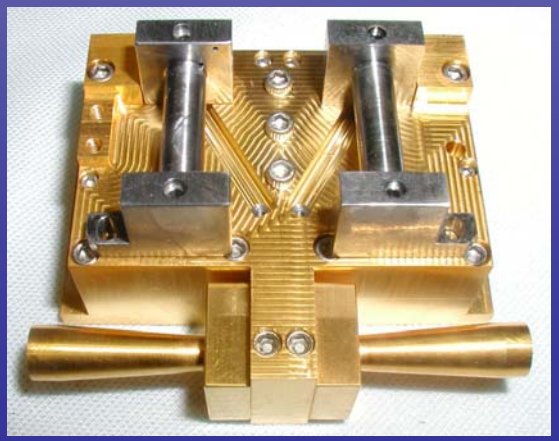


345 GHz Balanced Correlation Rx Optics









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✓Complete Computer Control of Bias Electronics

✓ Performance

✓ = Complete
✓= Under Development

Meet The Family…

The new fix-tuned mixer designs for the CSO.

580 – 730 GHz
400 – 540 GHz
280 – 420 GHz
180 – 280 GHz

-Designed with Supermix (Kovacs et. al).

-Optimized for: Minimum Noise

IF Flatness

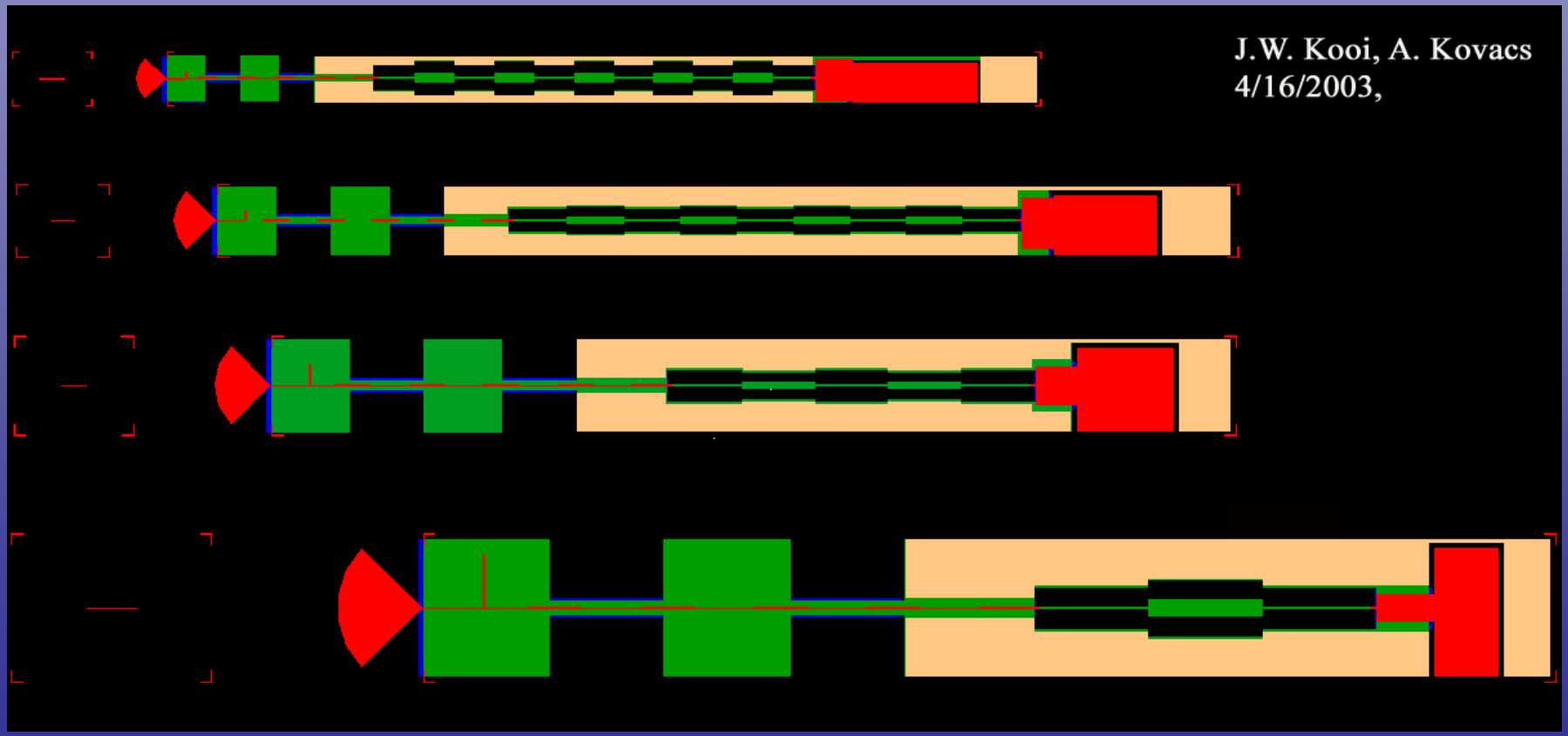
Conversion Gain

RF/IF Stability

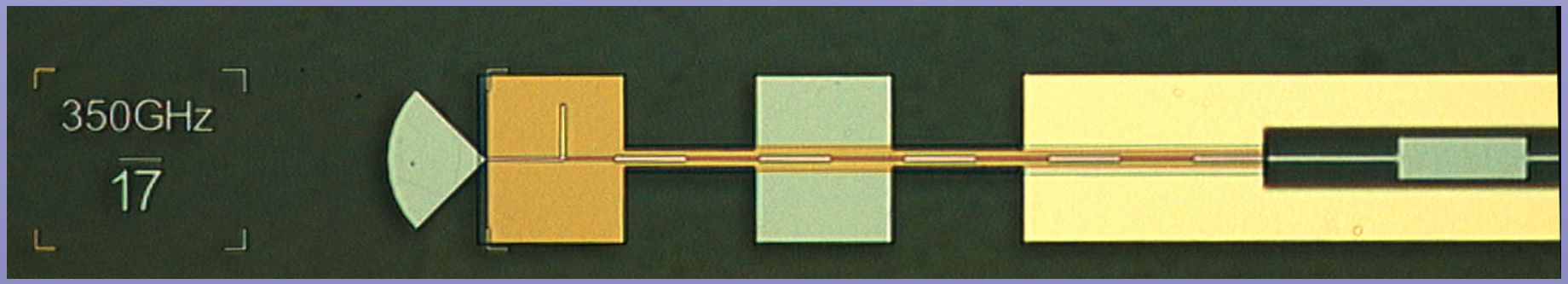
Saturation

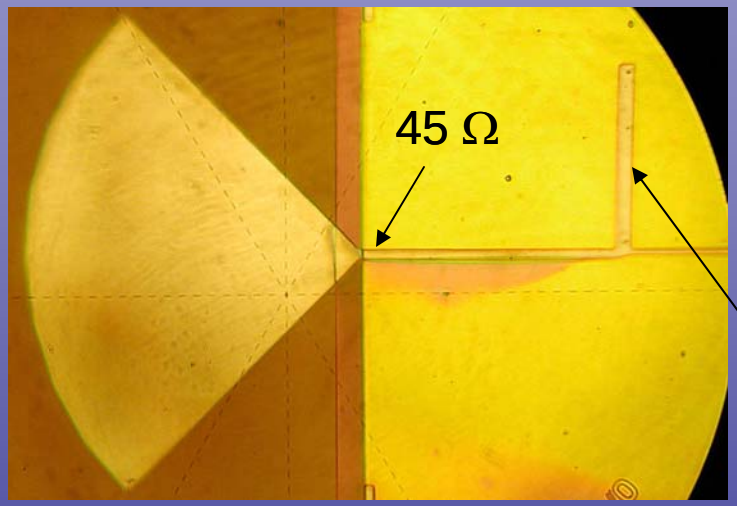
-Jc=25 kA/cm^{2,} RnA=7.6, AlN tunnel barrier.

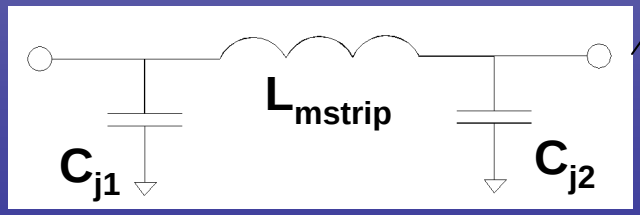
-IF Impedance: 20 Ohm (0.5 – 13 GHz)

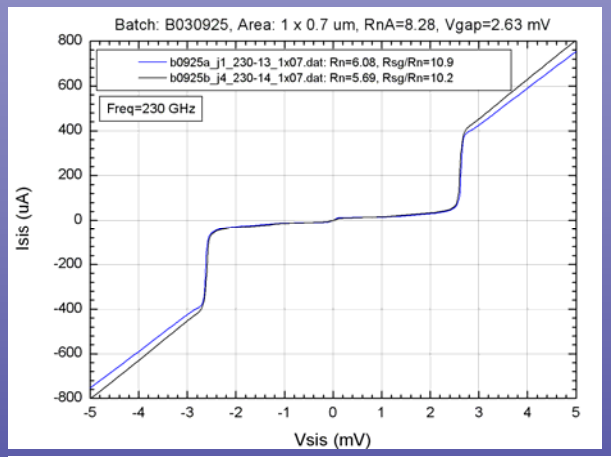


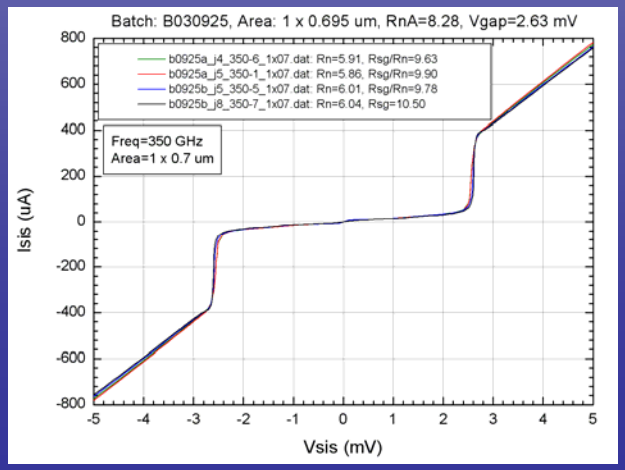
230 and 345 GHz AlN SIS Junctions







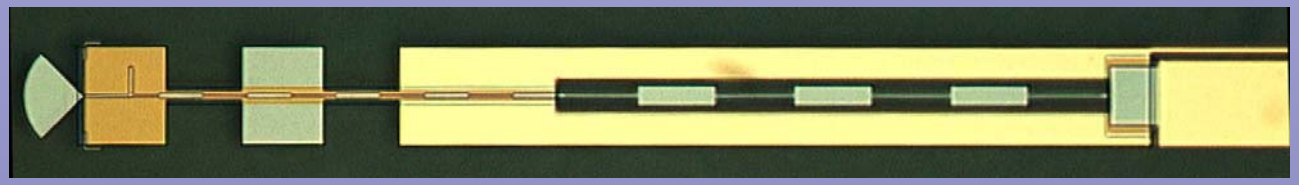


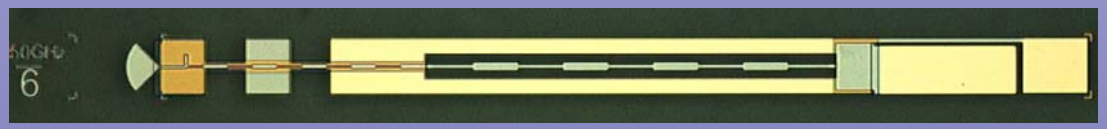


Jc=25 kA/cm^2, RnA=7.6, AlN tunnel barrier.

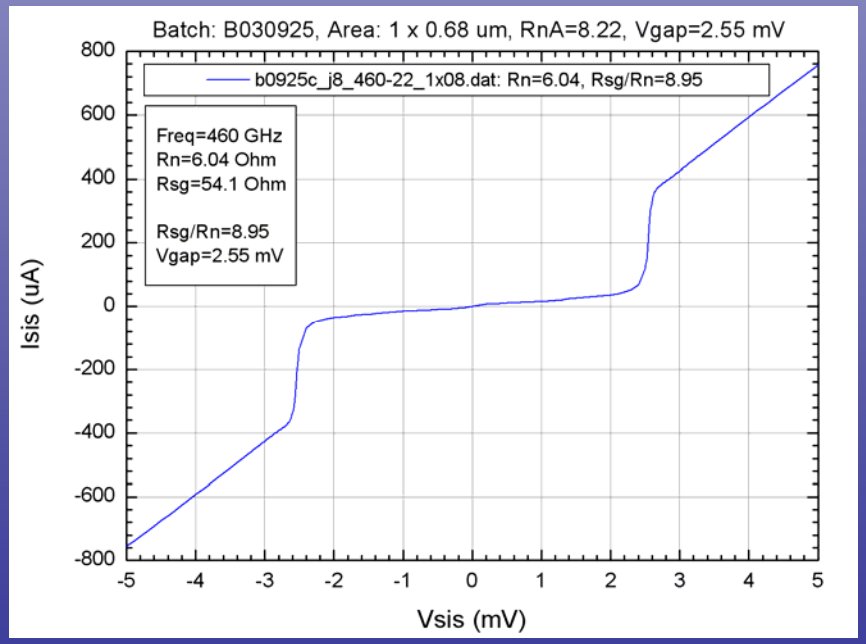
Junction Area: 0.7 x 1 um, Rn=5.1 Ω

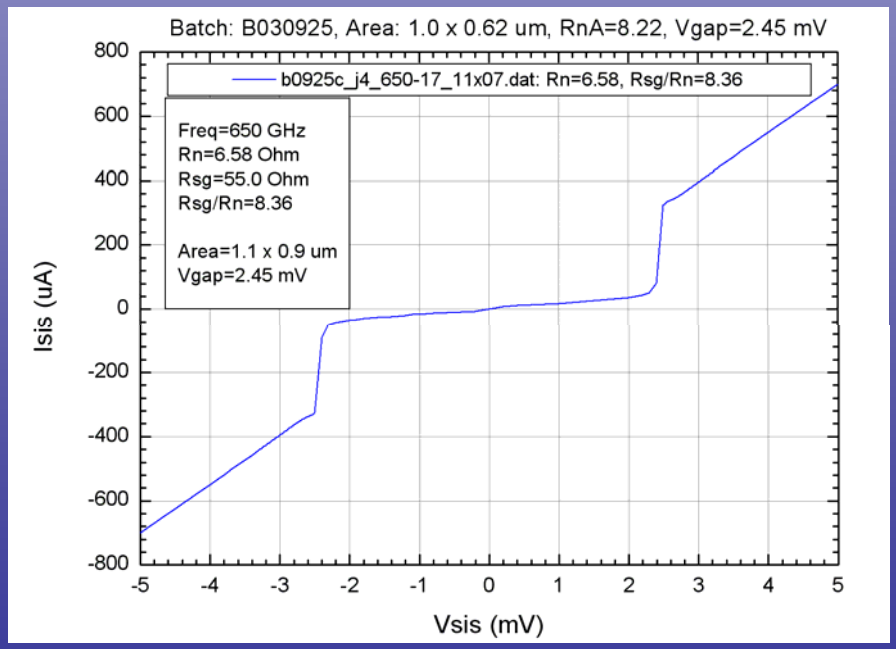
460 & 650 GHz AlN SIS Junctions



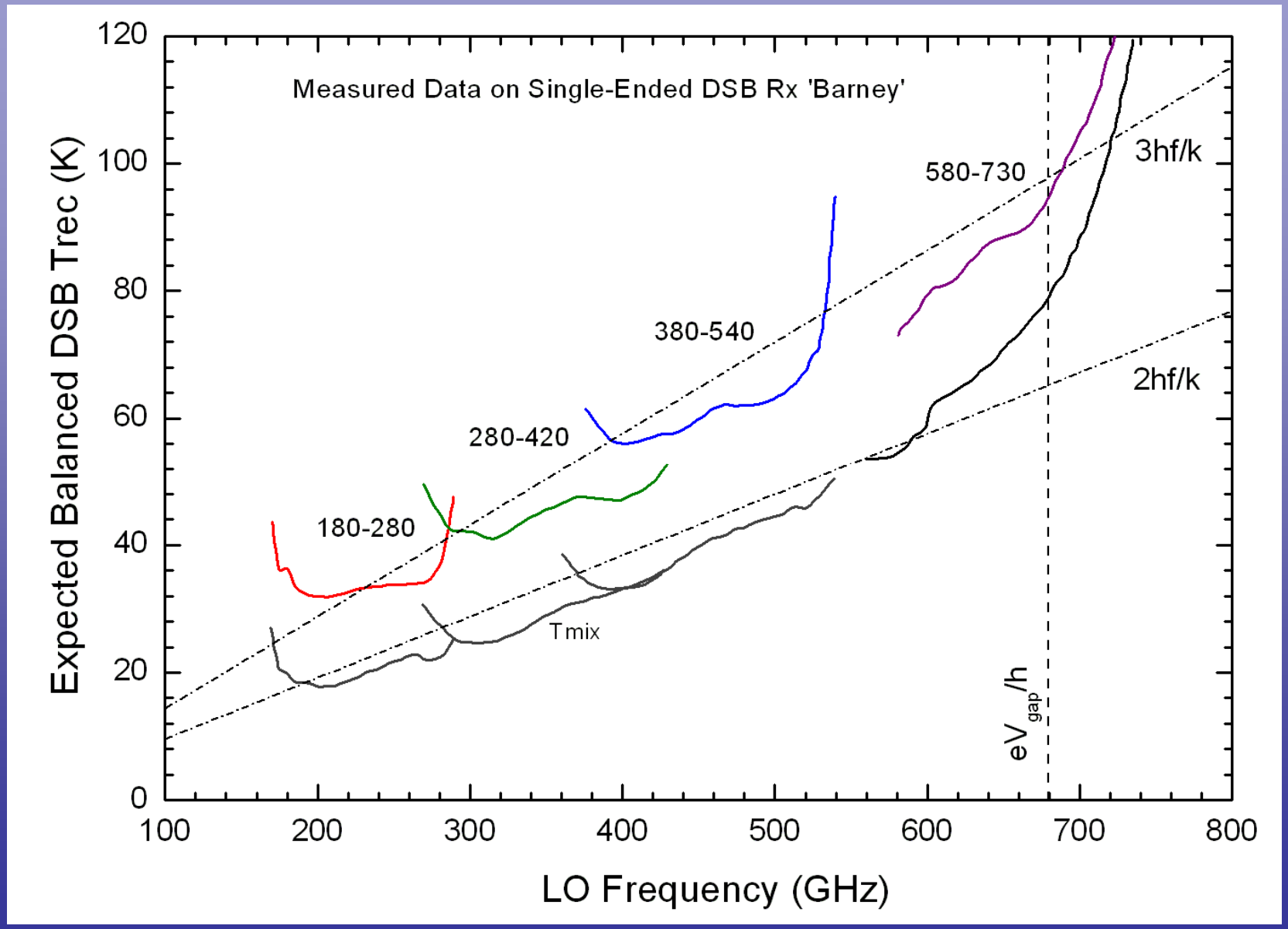


Jc=25 kA/cm^2, RnA=7.6, AlN tunnel barrier.

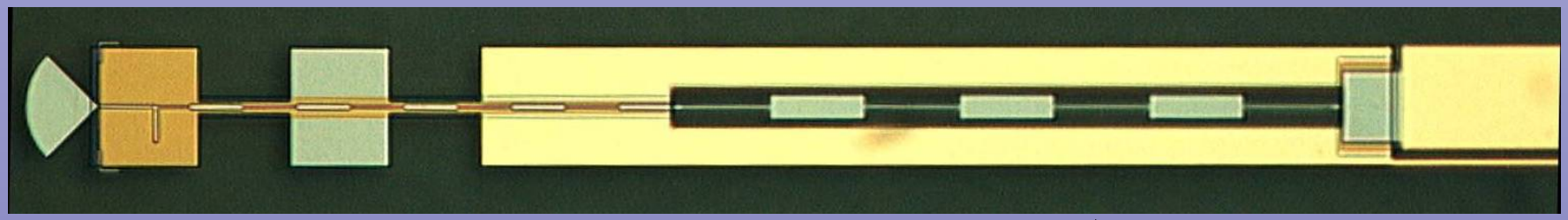


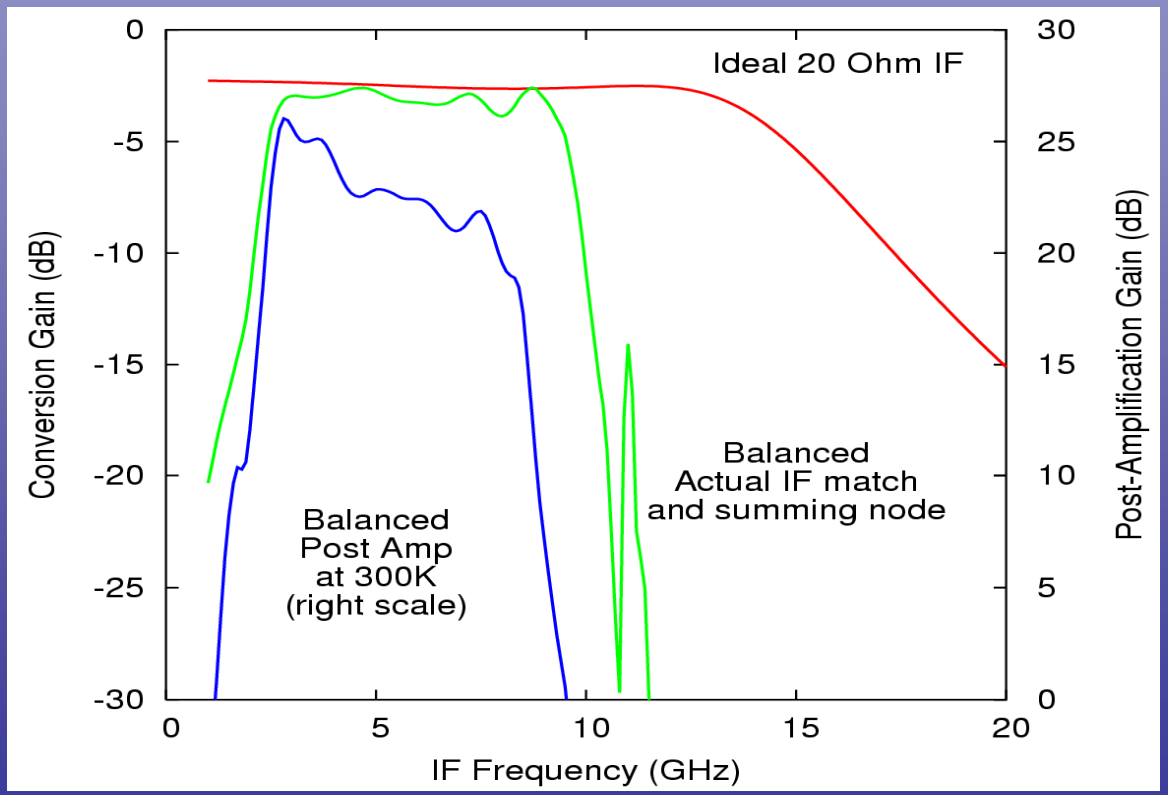


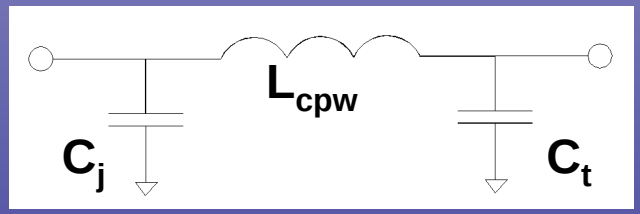
Twin SIS Junction (Balanced) Mixer Performance



IF Performance







IF Tuning Circuit

Needed Technology

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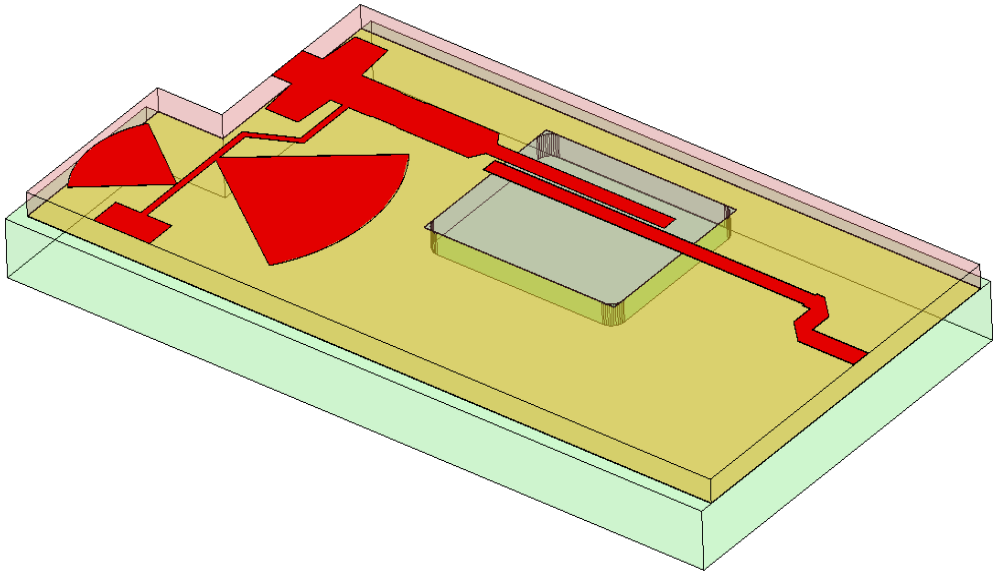
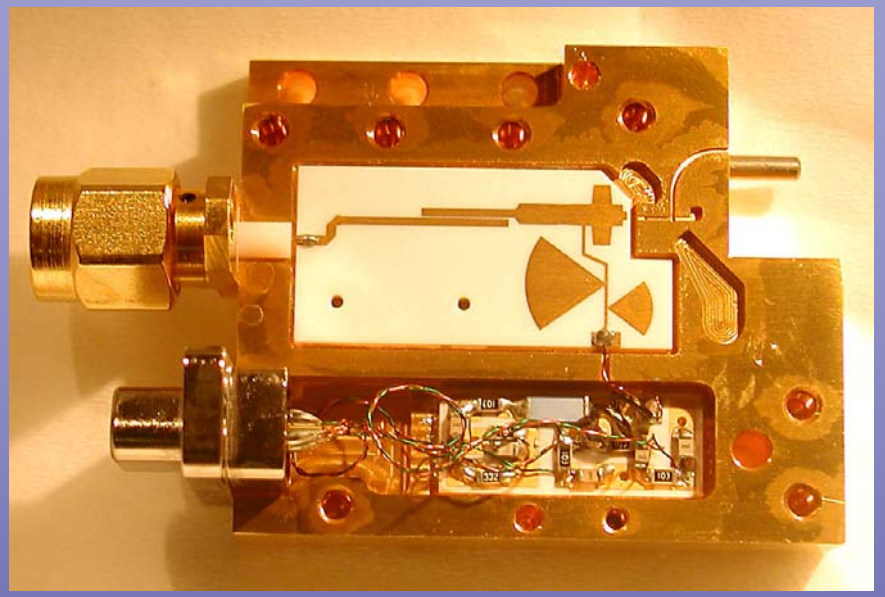
✓Complete Computer Control of Bias Electronics

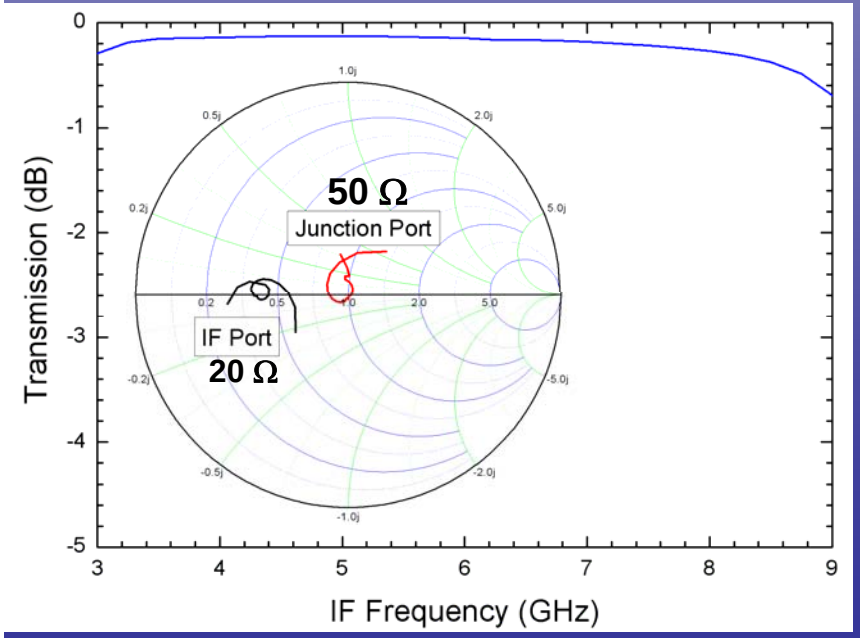
✓ Performance

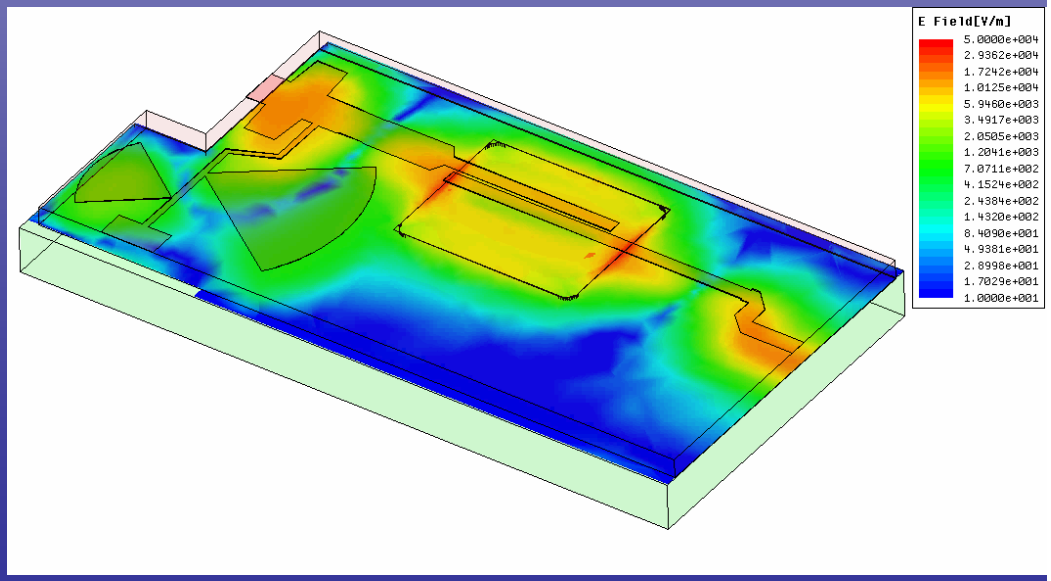
✓ = Complete
✓= Under Development

3-9 GHz Planar IF Design

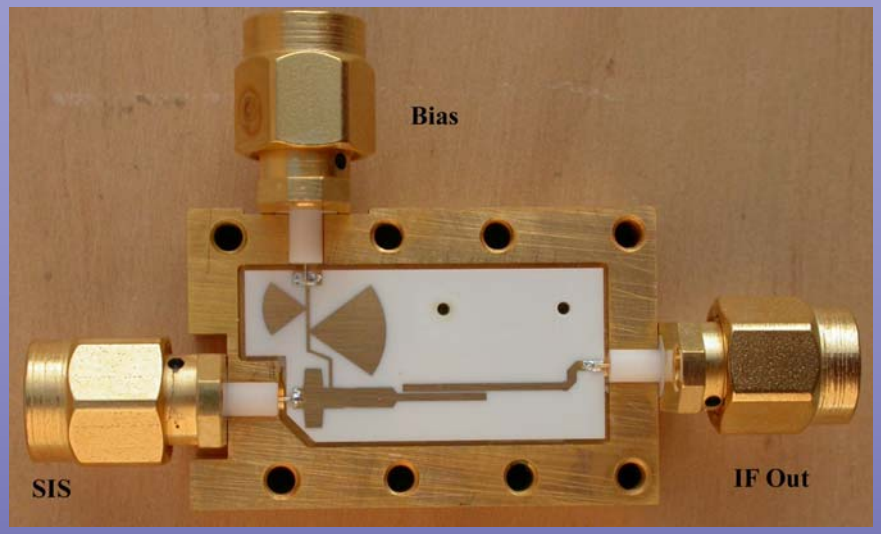


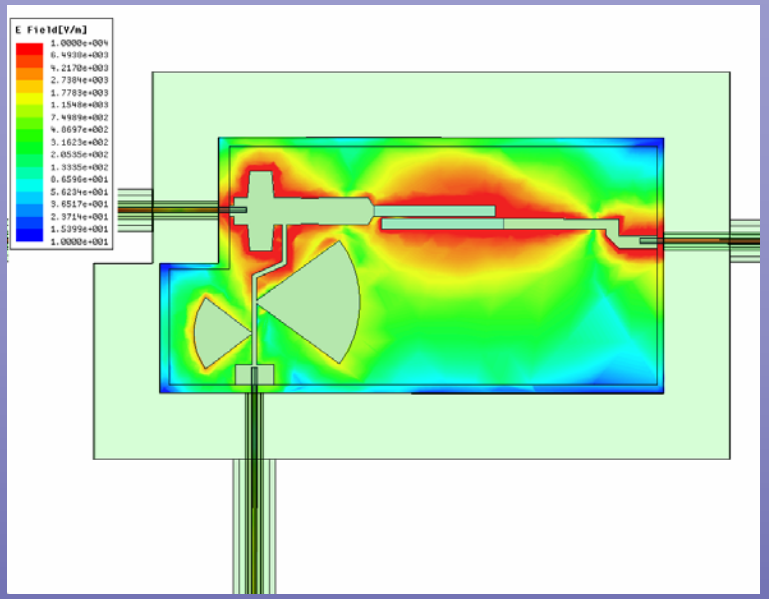


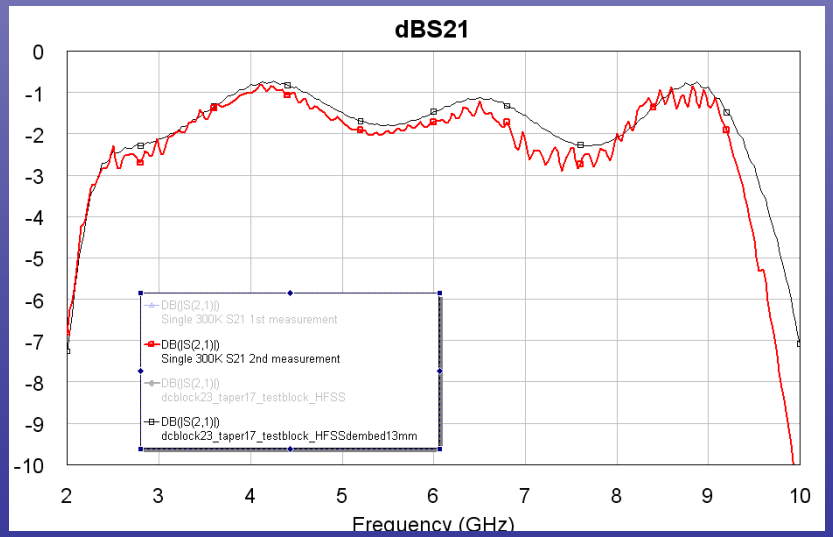


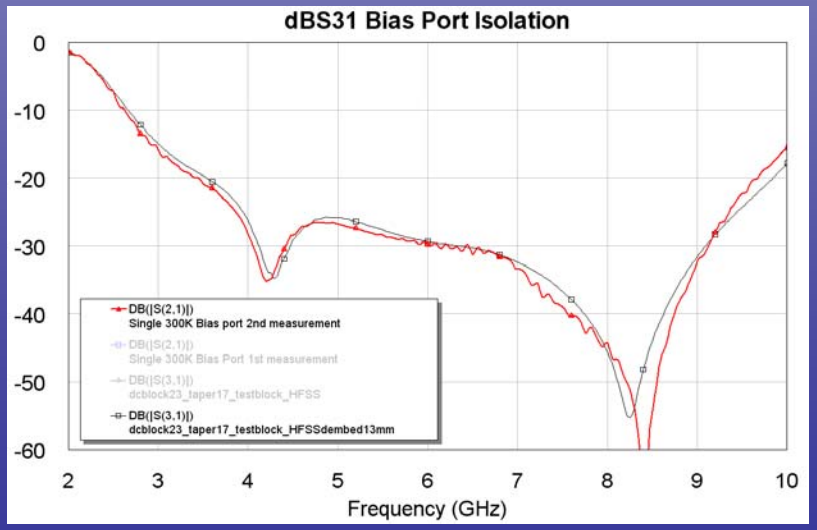


4-8 GHz IF Verification

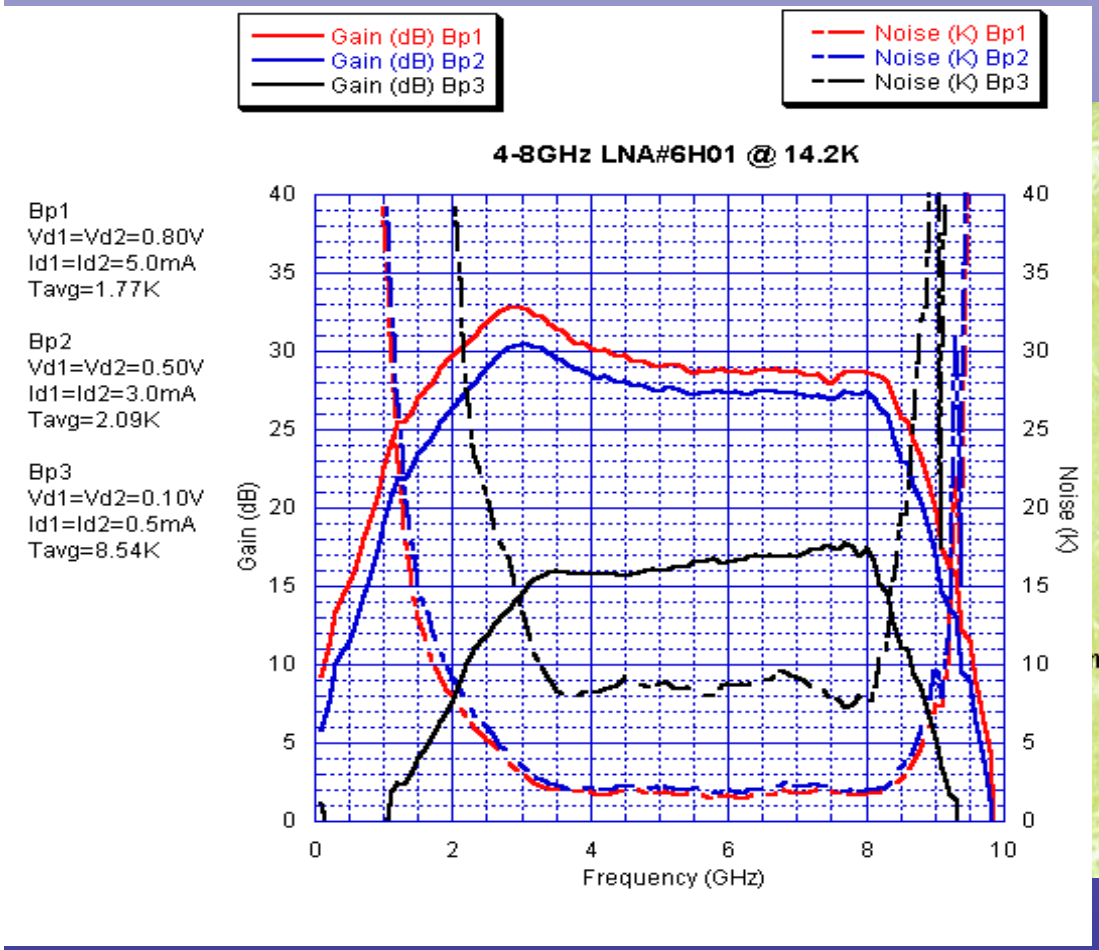


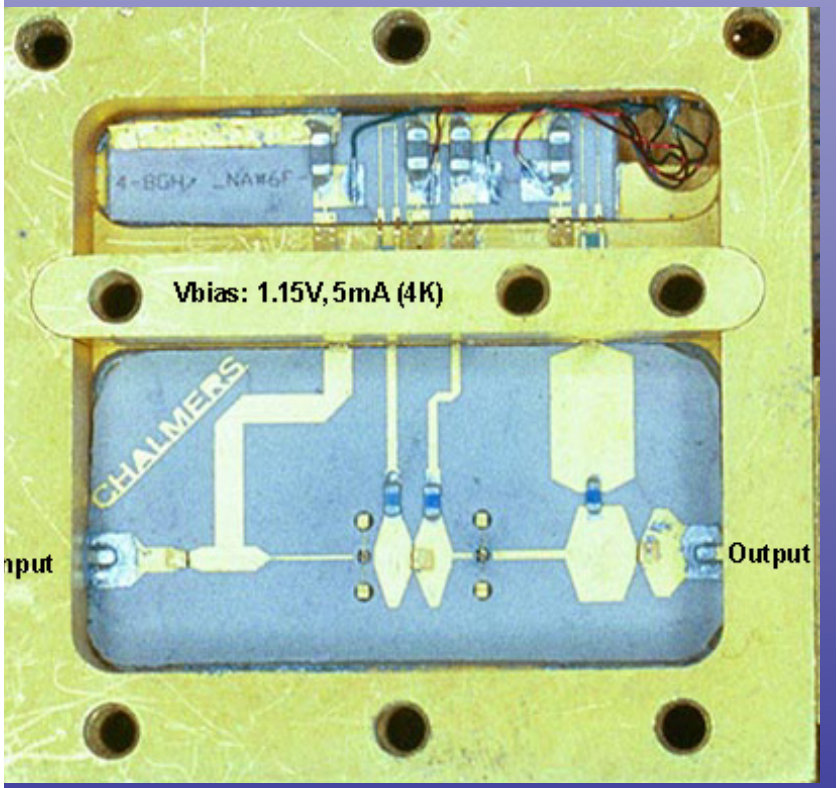




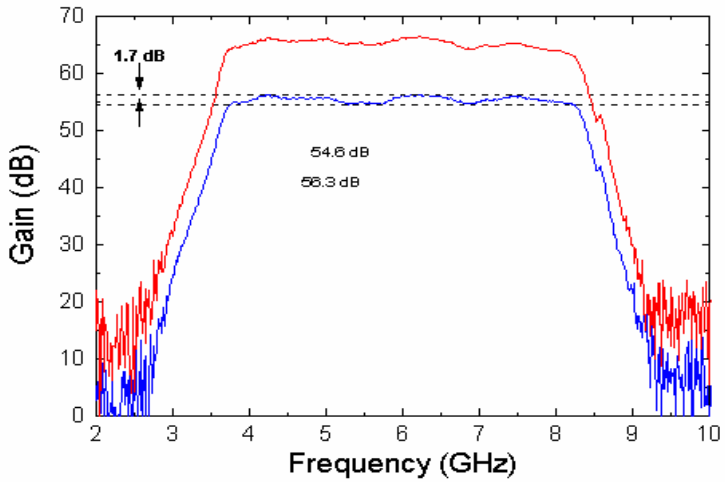


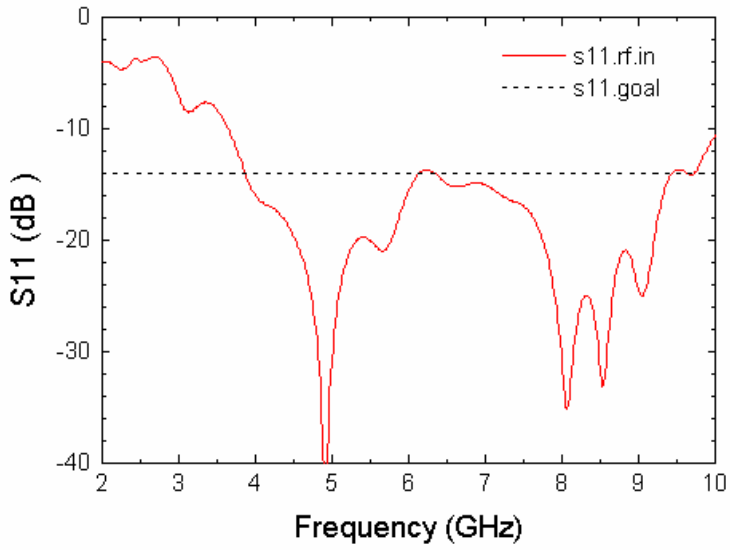
4-8 GHz InP based Low Noise Amplifier

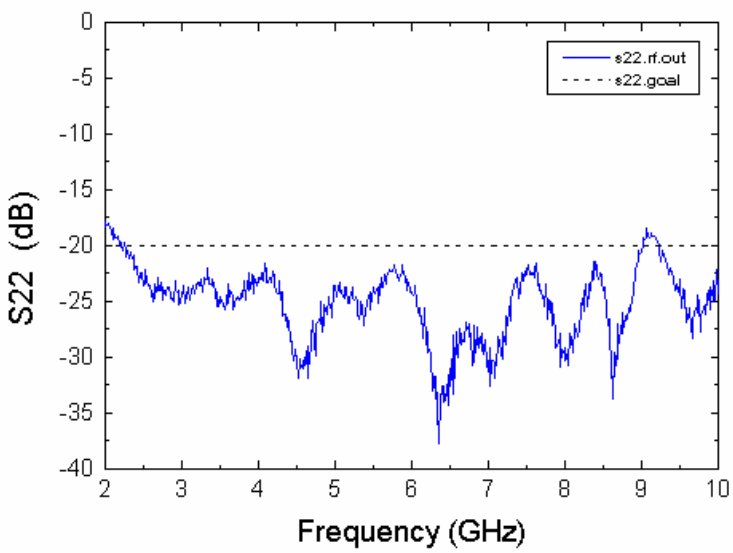




4-8 GHz CTT Inc. Warm IF







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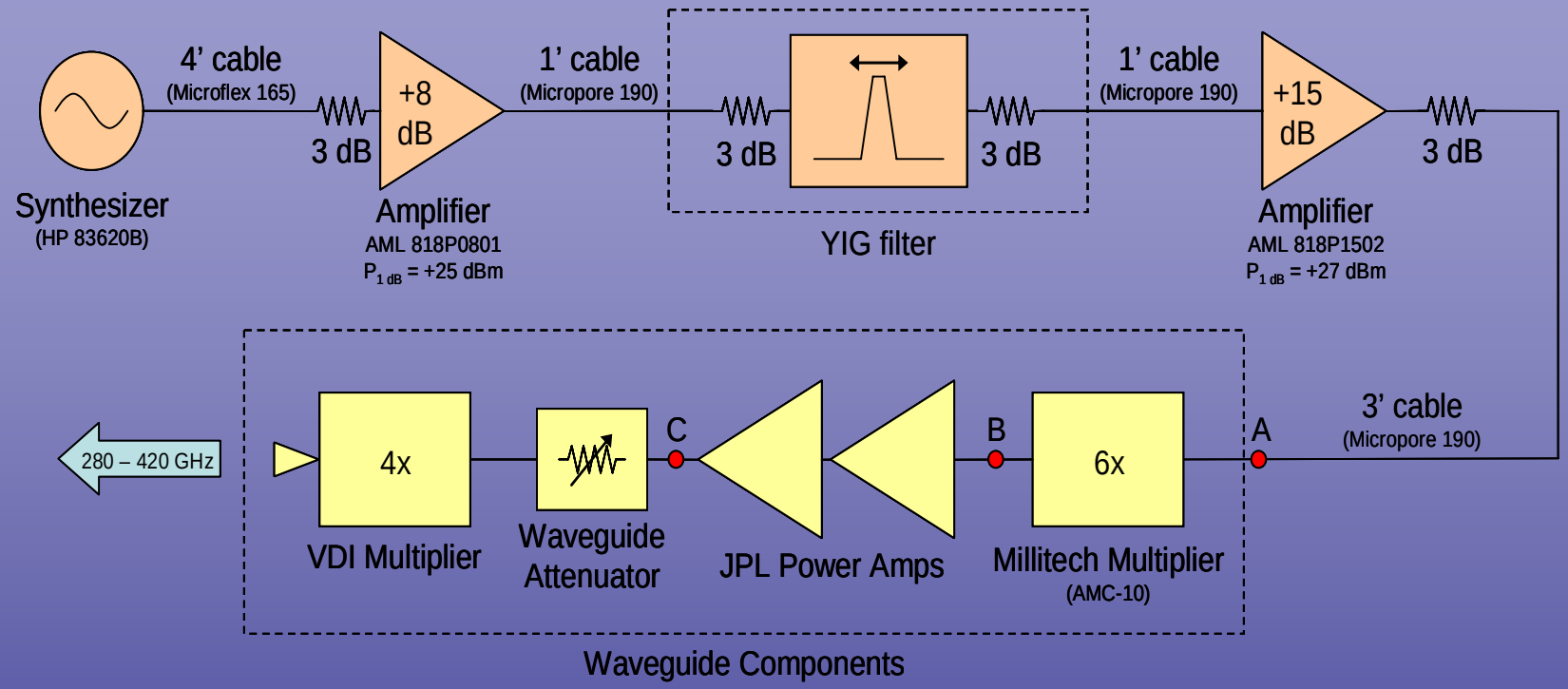
✓ = Complete
✓= Under Development

Synthesized LO (M. C. Sumner)

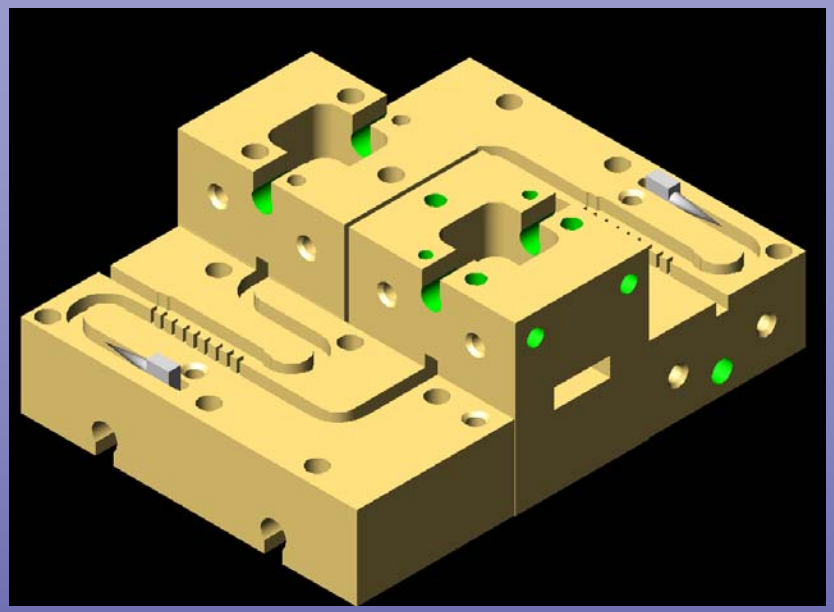


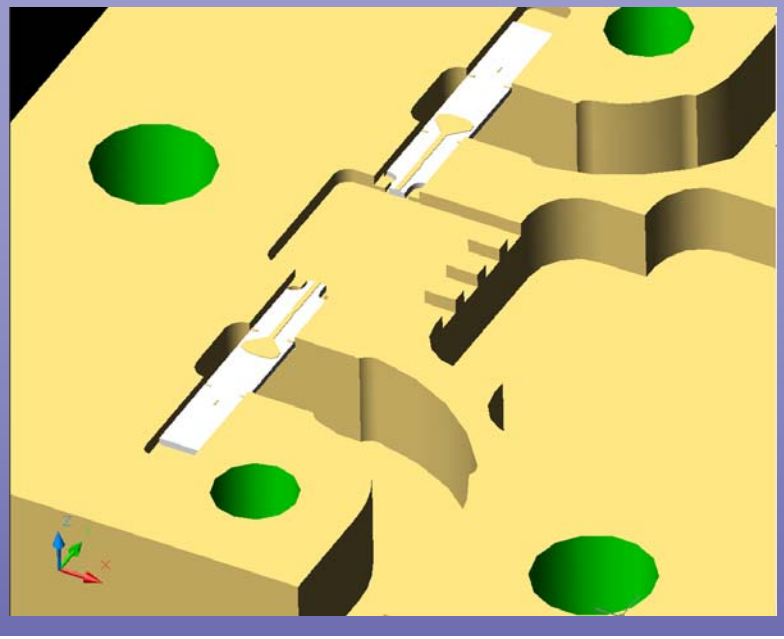
Prototype synthesized LO system tested on telescope

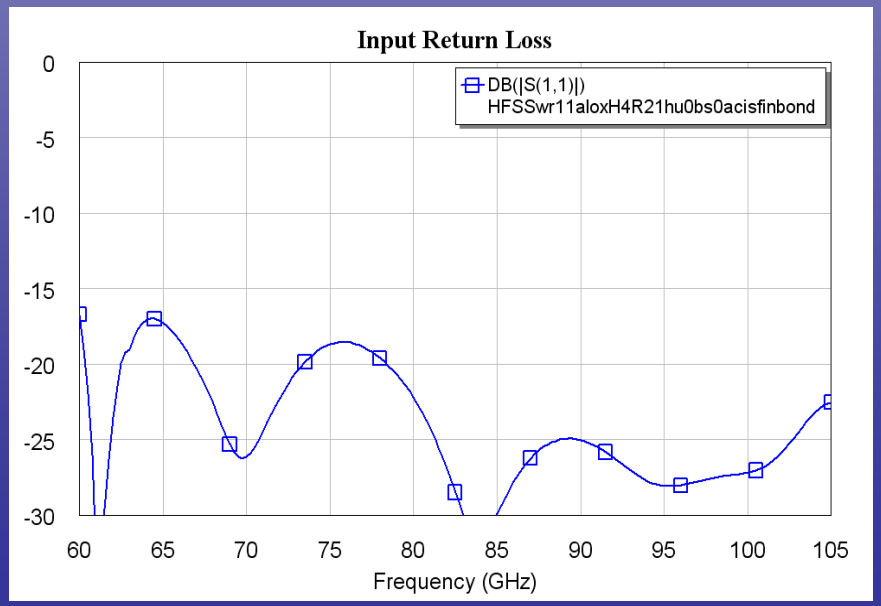
- •T_{sys} comparable to Gunn
- •No spurs
- •Need software control of power amps for final installation

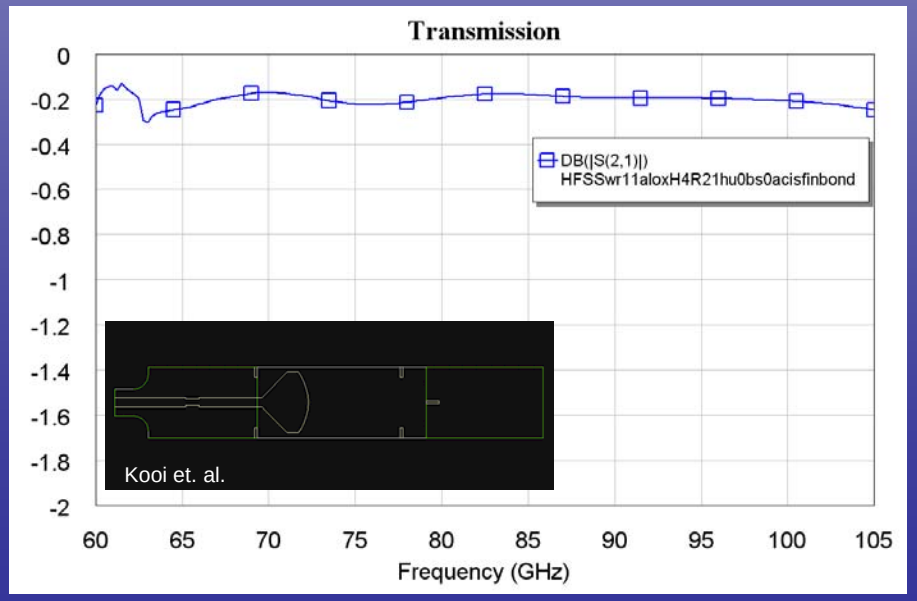
60-105 GHz Balanced Power Amplifier (JPL)

L. Samoska, T. Gaier, J. Ward, D. Pukala, and J. Pearson



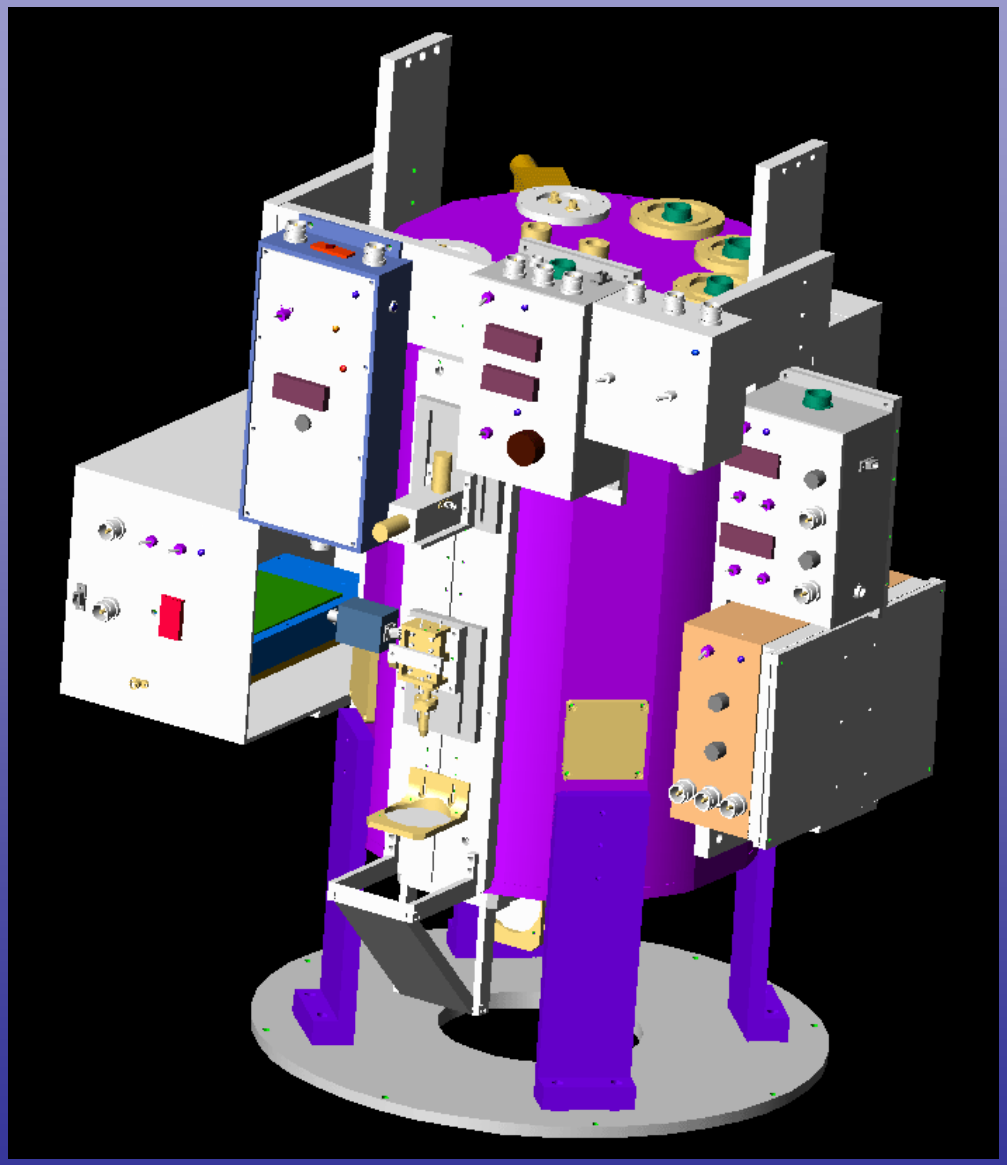


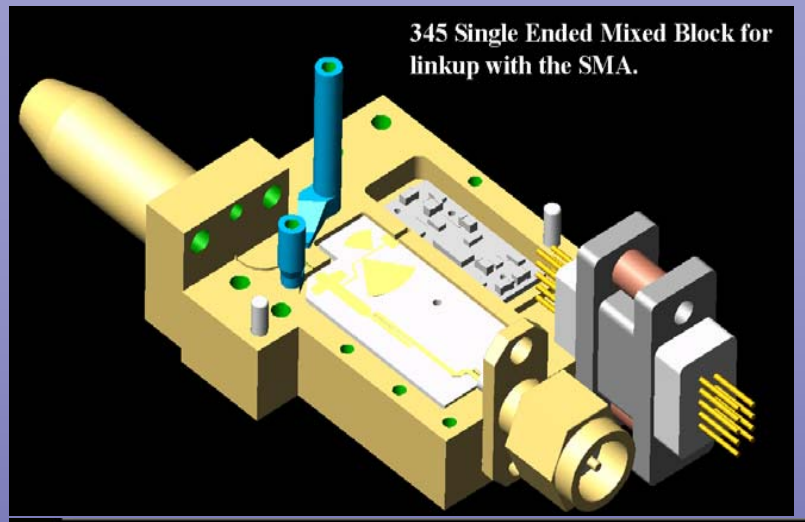


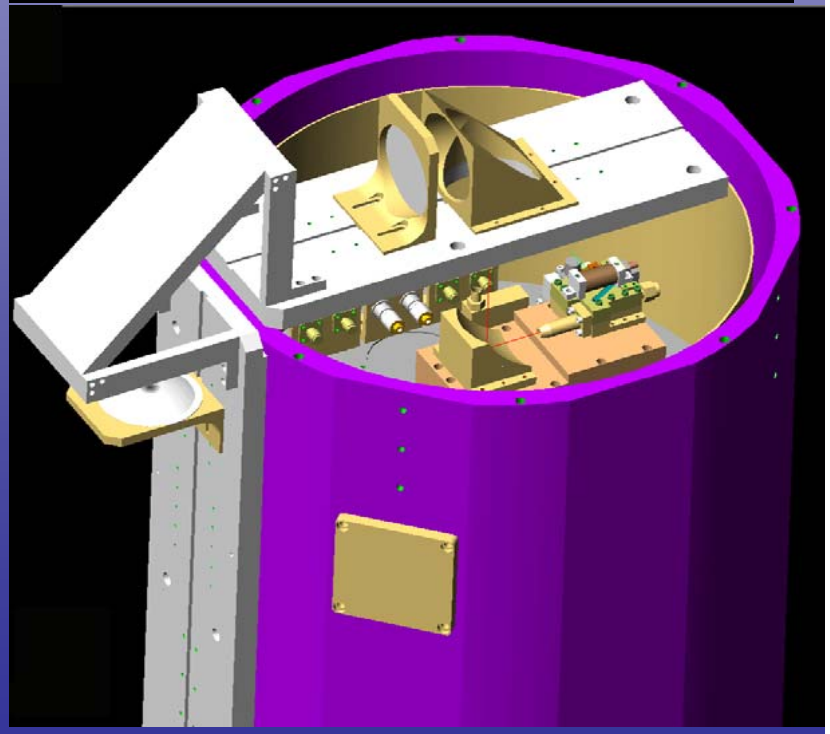


Performance Verification: Meet Virtual Trex…

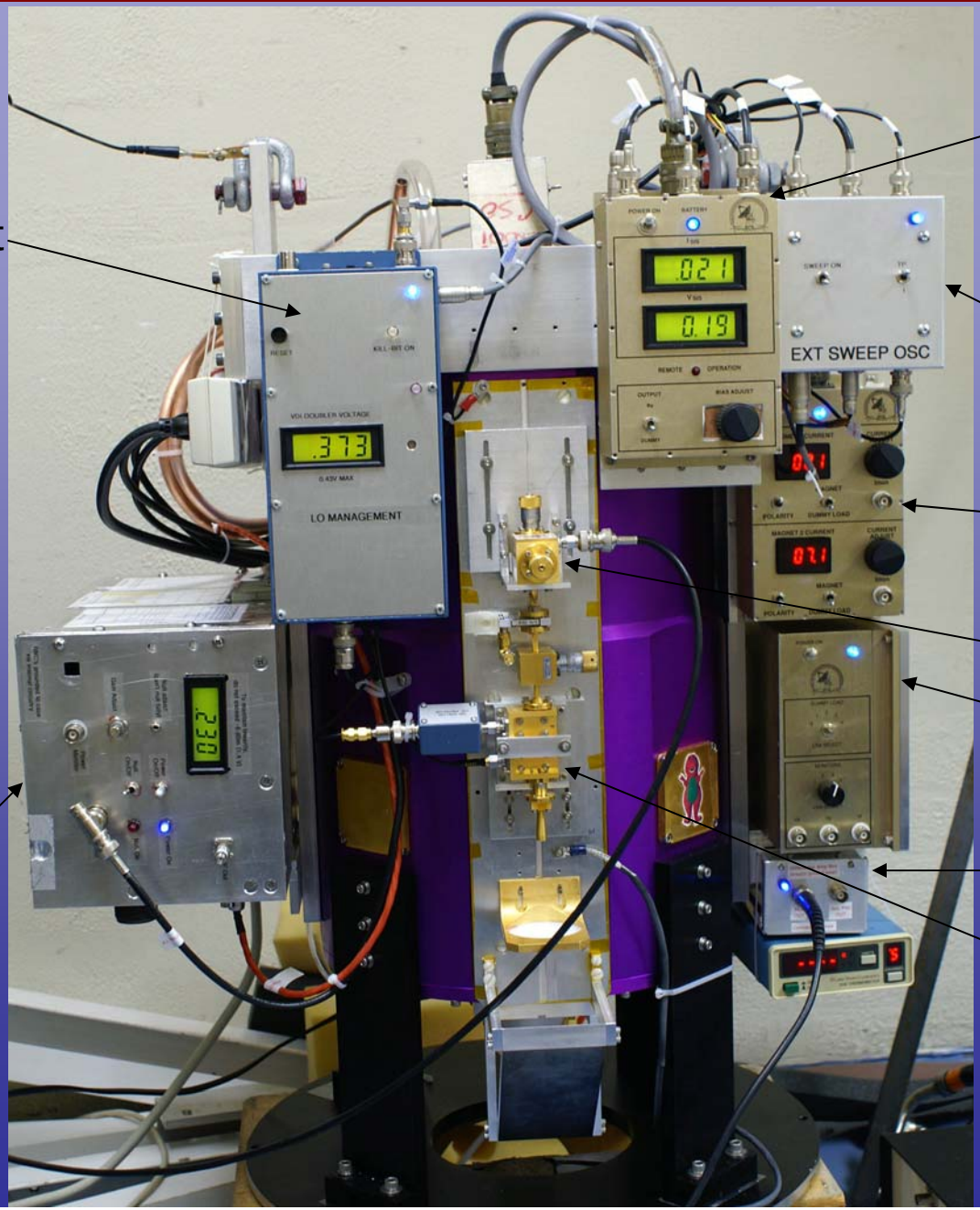
A 280-420 GHz Single-ended (DSB) Receiver







Now meet the Real Trex…



LO Power management

SIS Bias

Ext Oscilator/ Osciloscope Switch

Magnet Supply

70-105 GHz Gunn (Calrstrom)

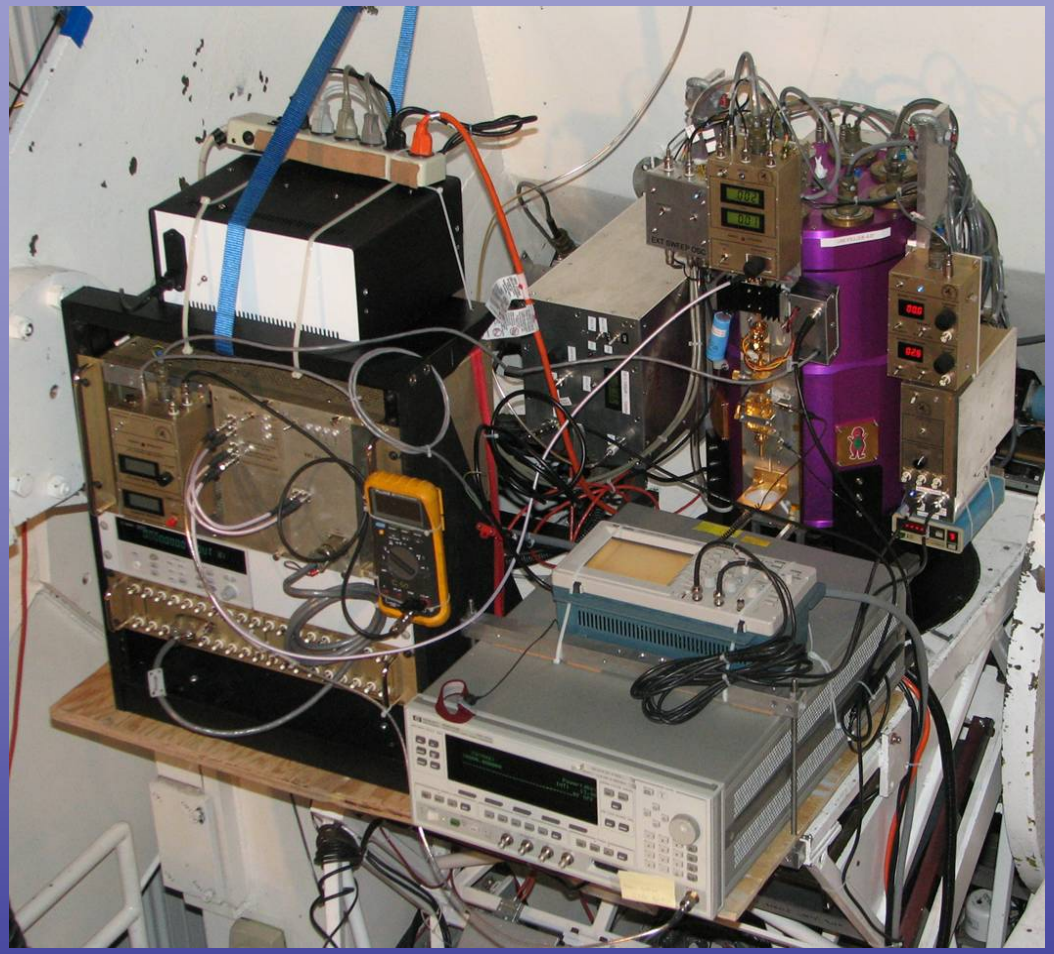
LNA

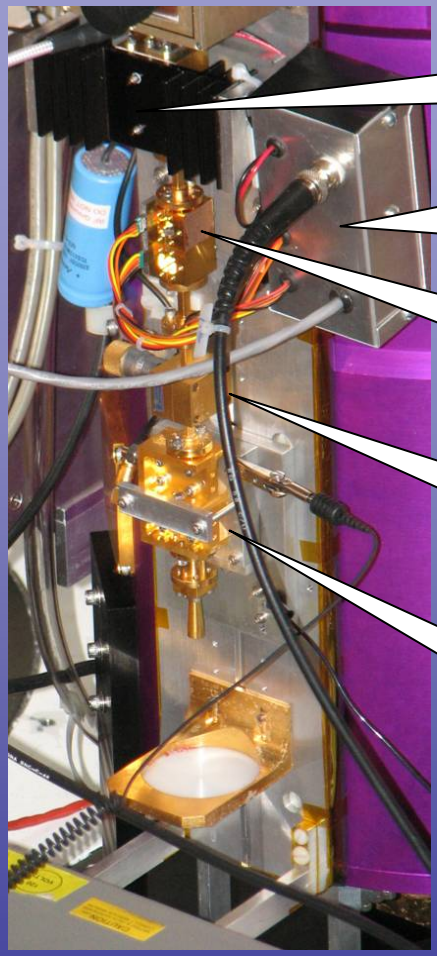
Differential Driver O-scope

280-420 GHz Multiplier (VDI)

Warm IF

Synthesized LO (M. C. Sumner)





Millitech 6x multiplier

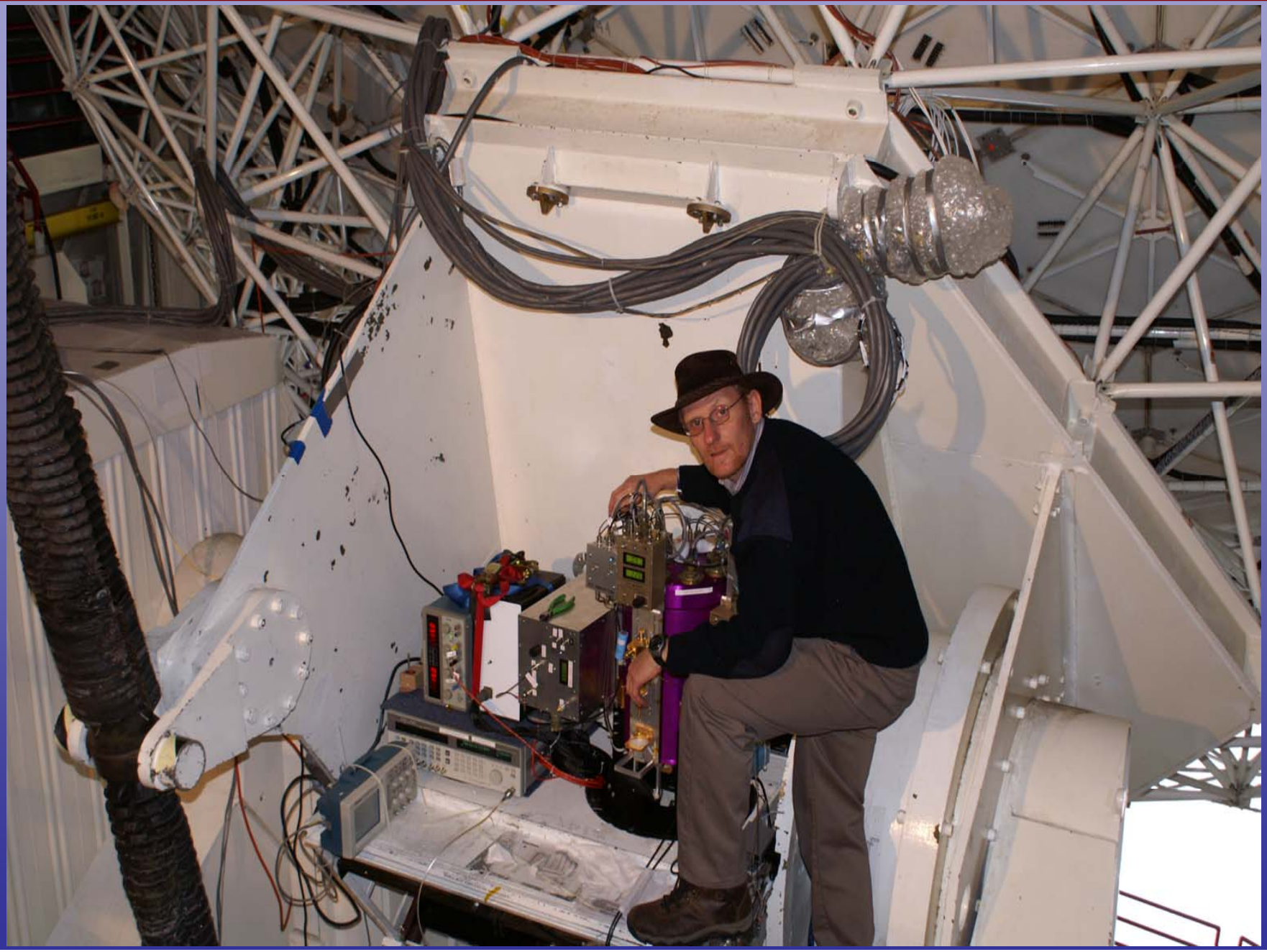
Shielded DC breakout box

JPL power amps (2)

Waveguide attenuator

VDI 4x multiplier

Results/Installation CSO



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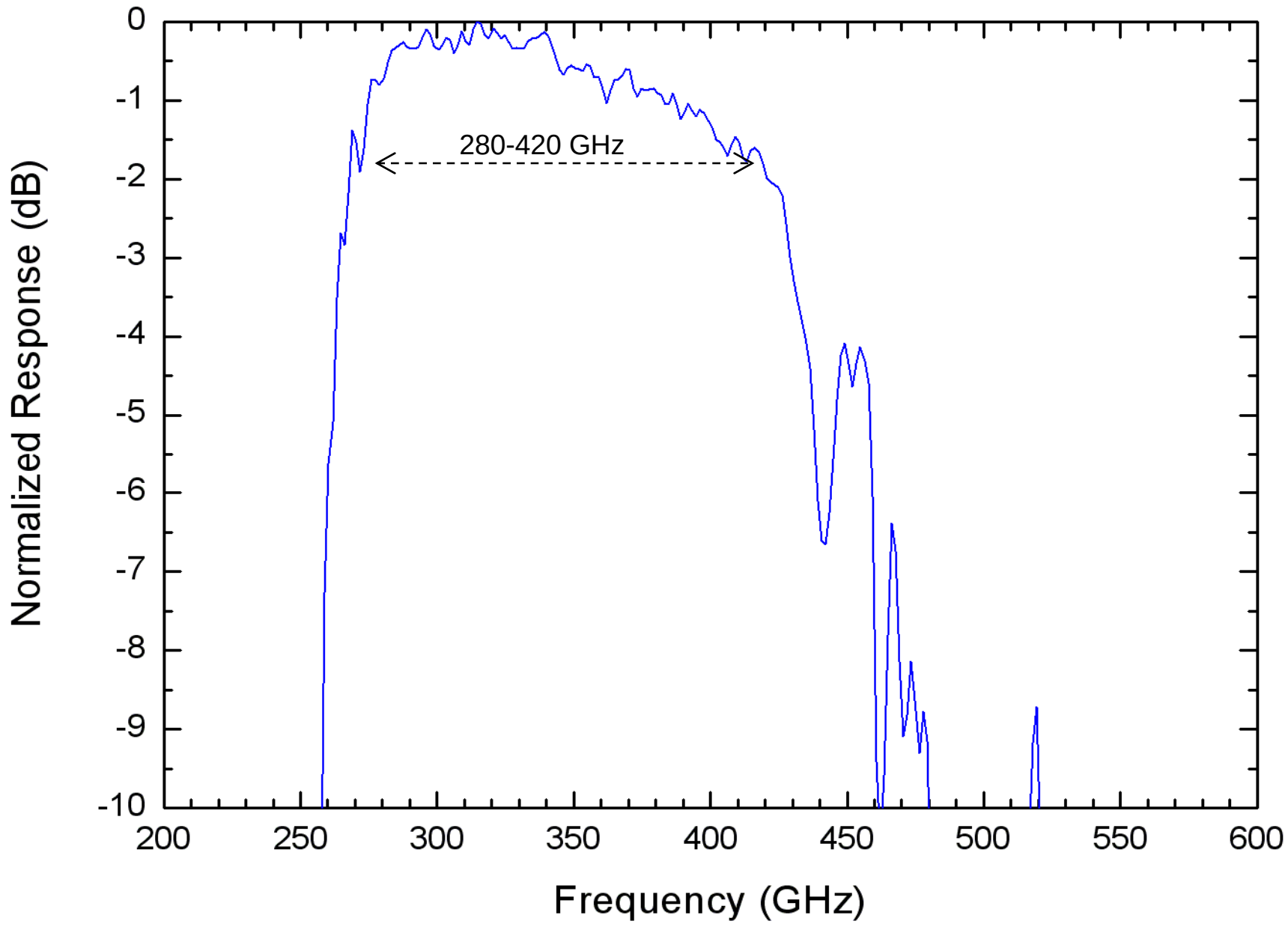
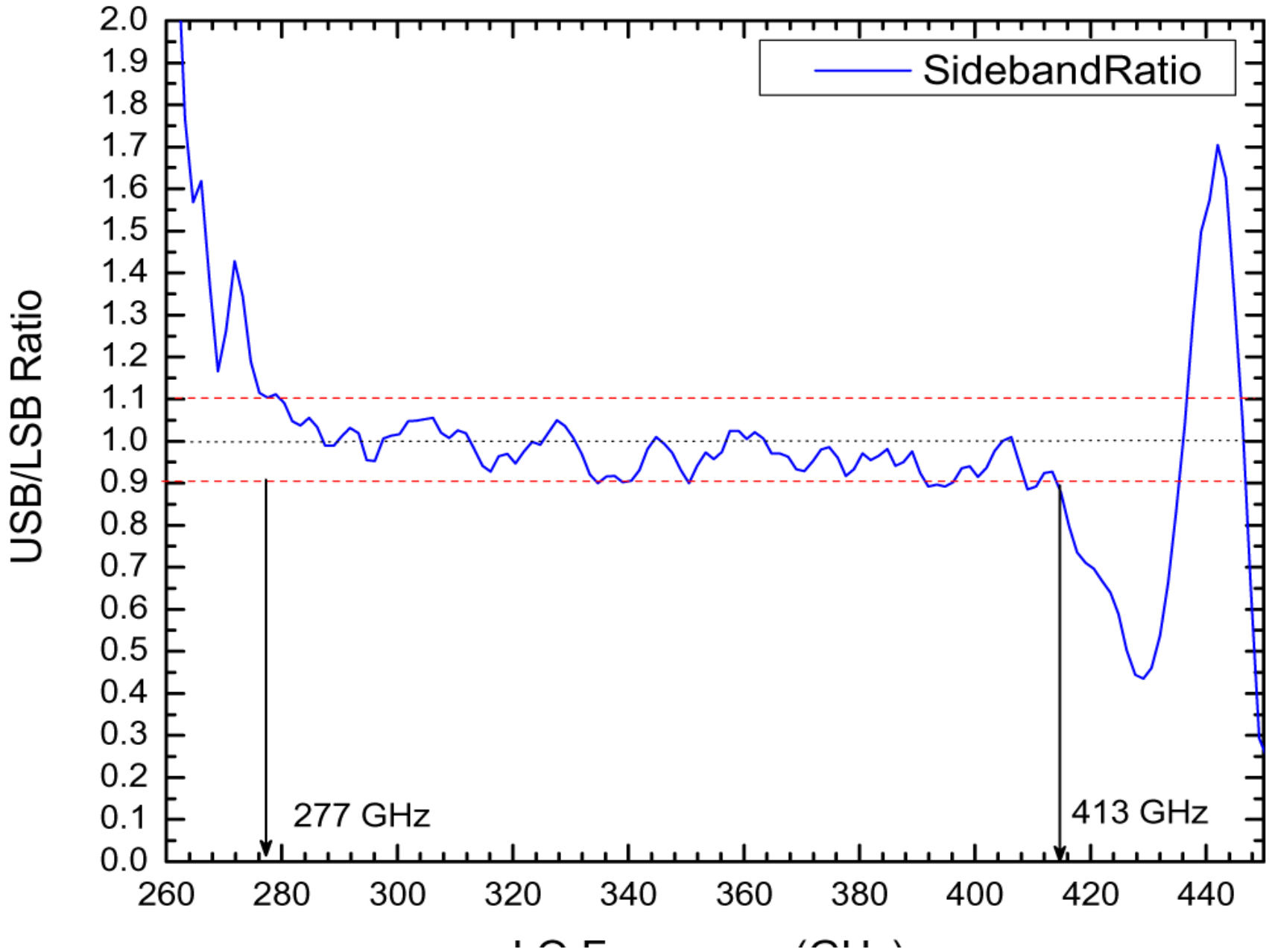
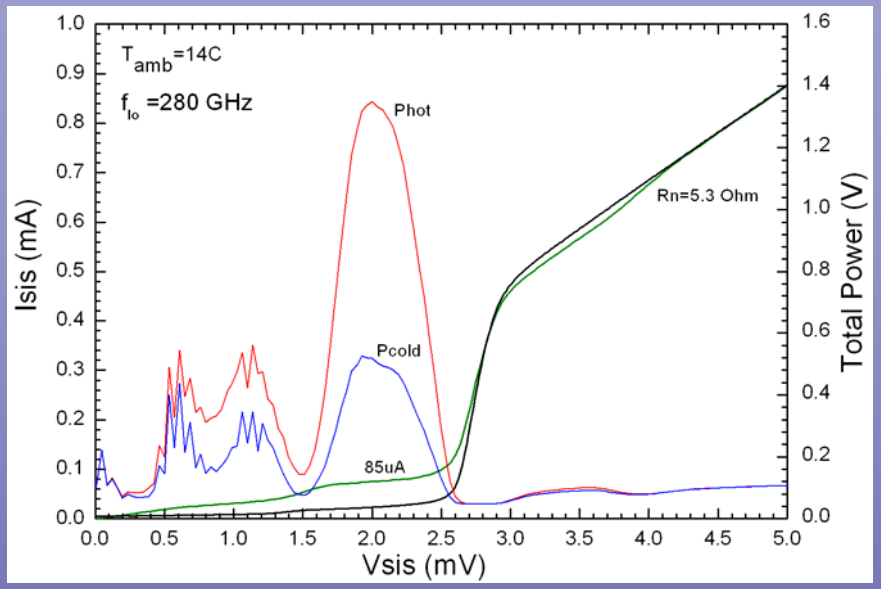
Direct Detection (FTS) Response

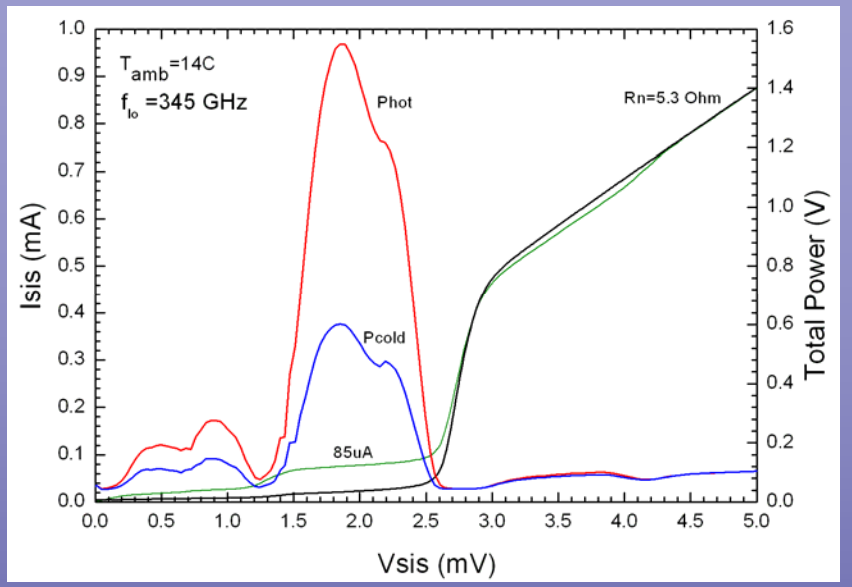


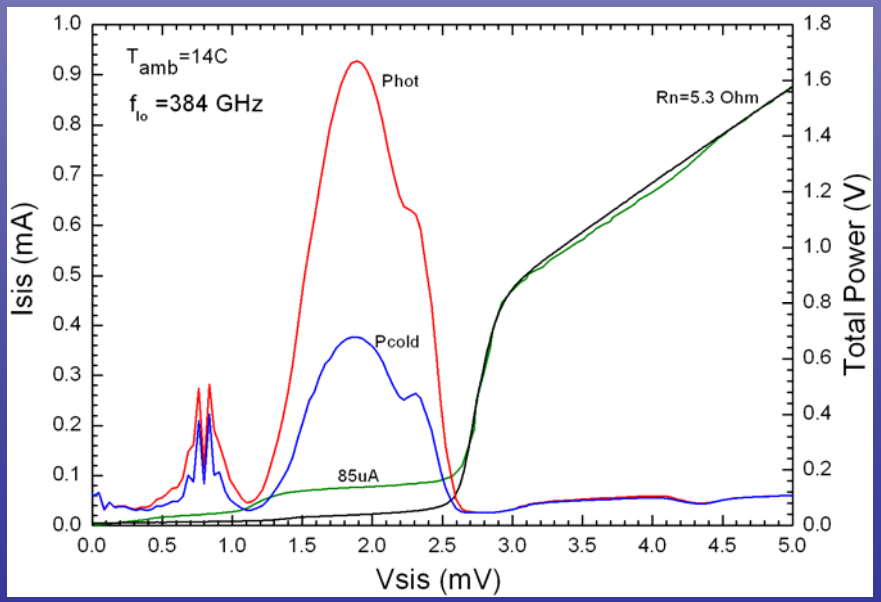
Derived Sideband Ratio from FTS Response

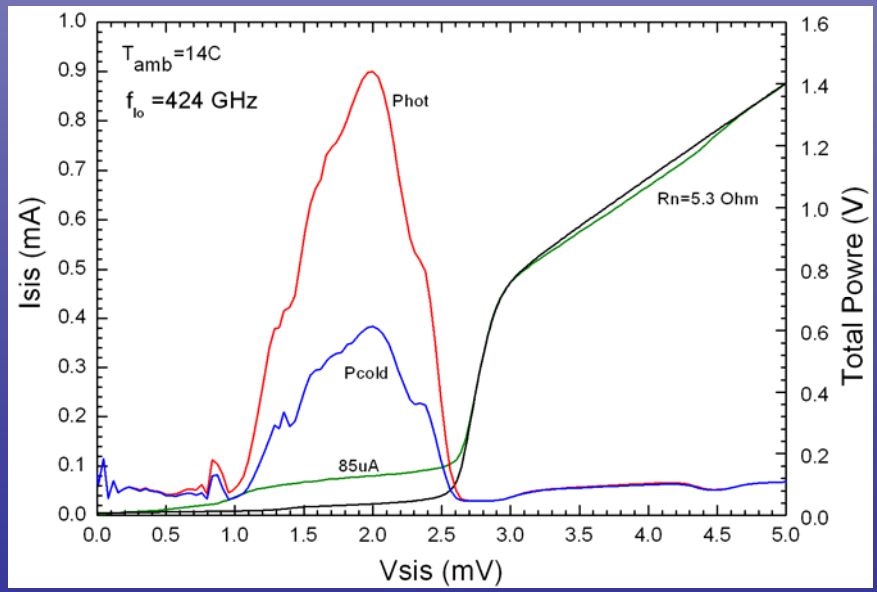


Response at 280, 345, 384, and 424 GHz

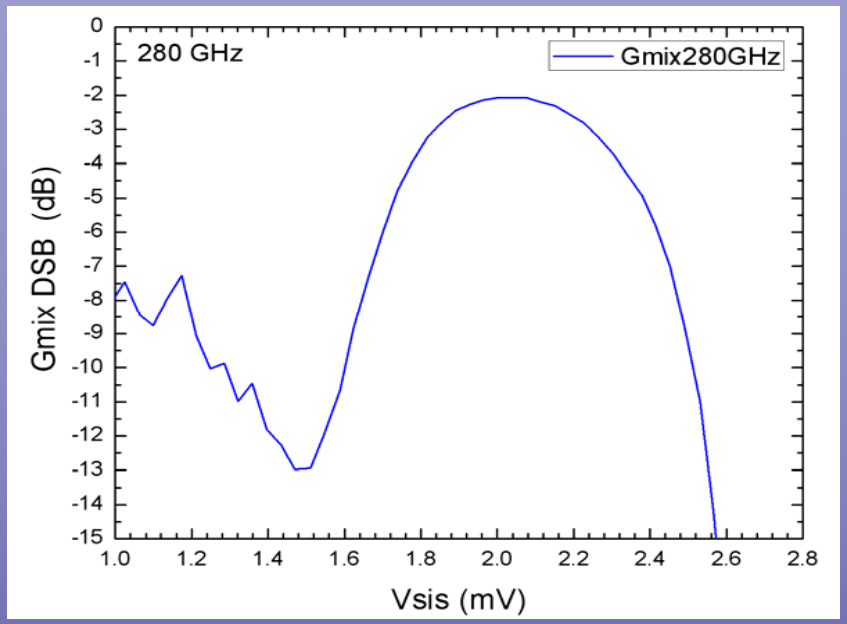


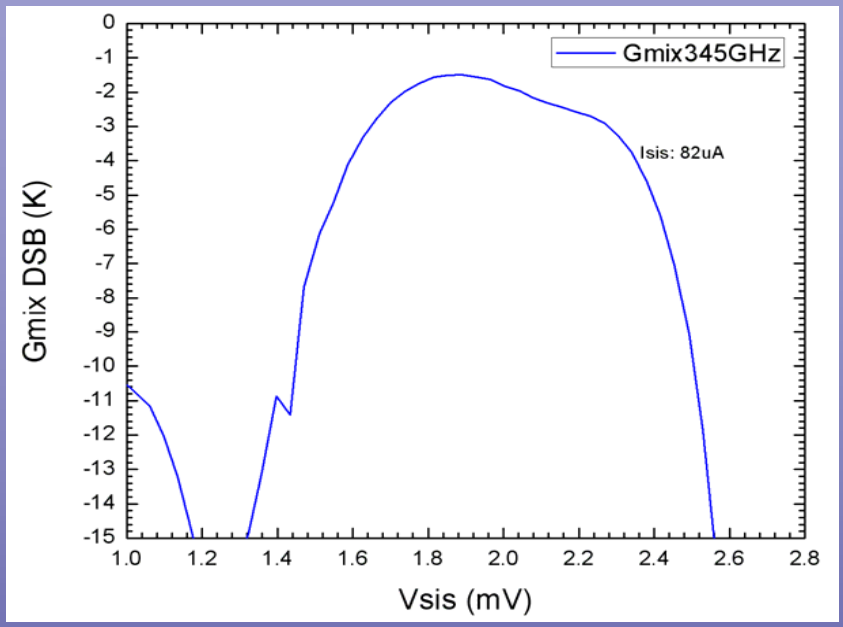


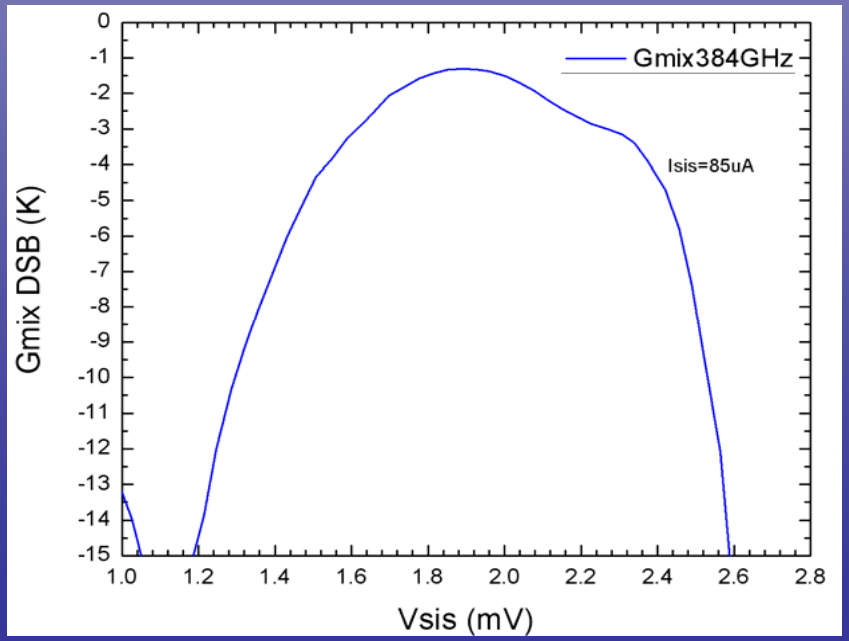


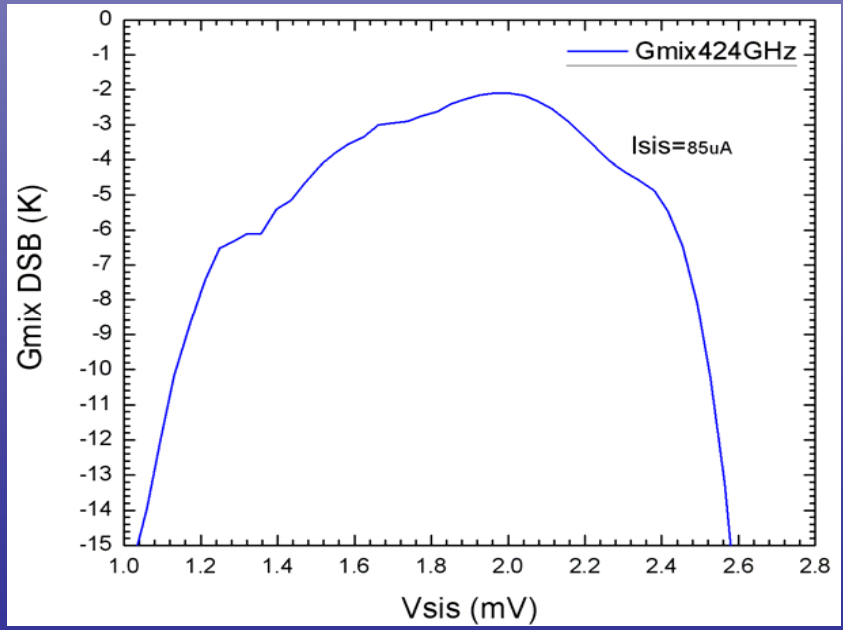


Gmix at 280, 345, 384, and 424 GHz

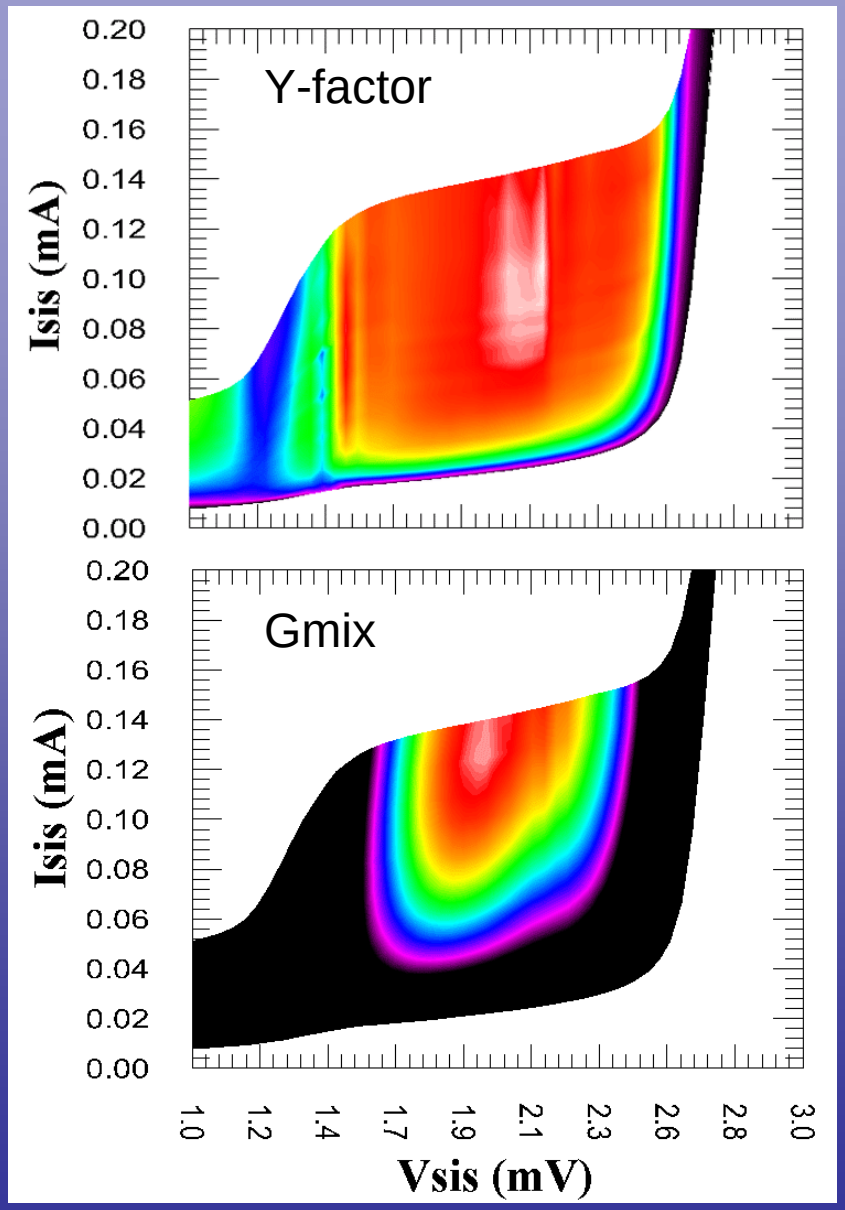


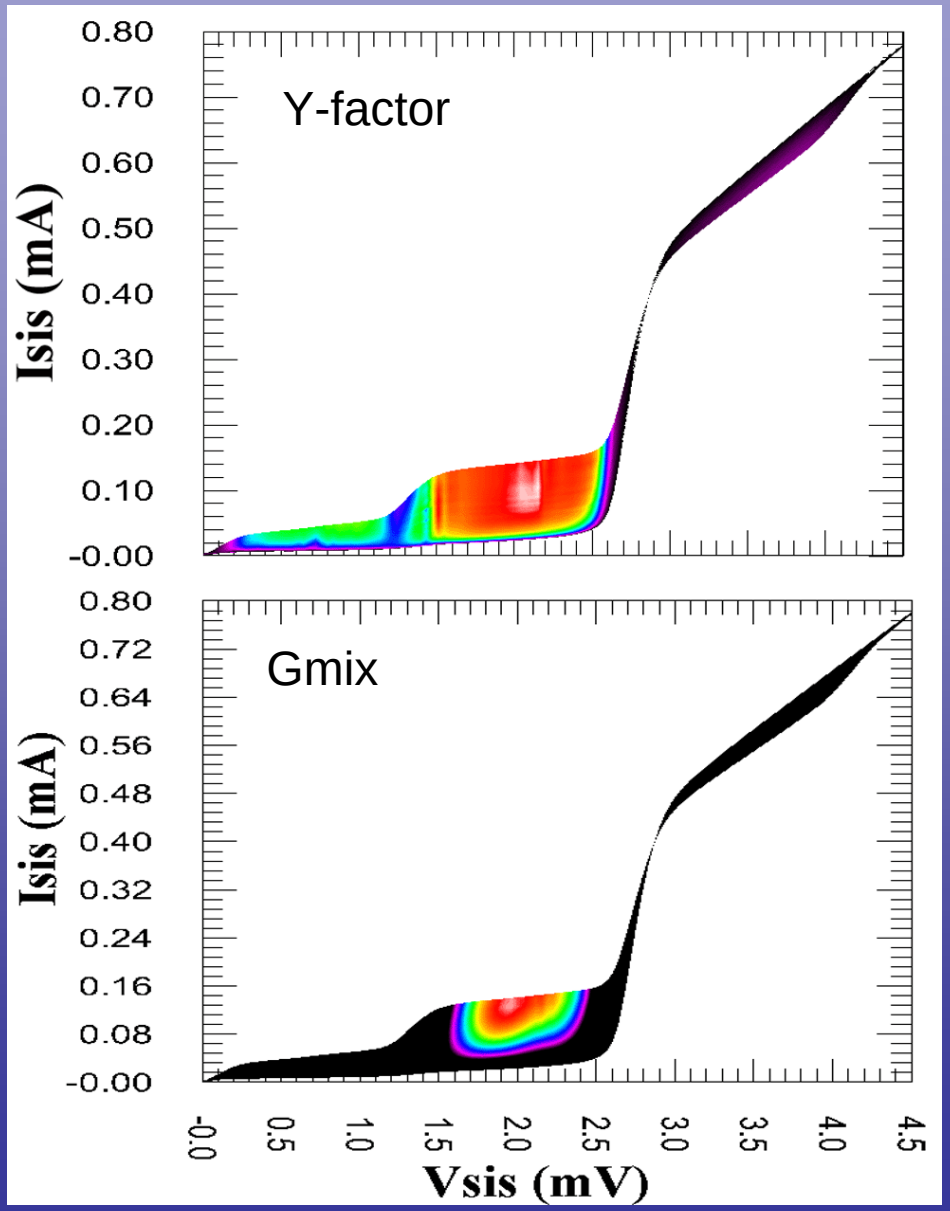






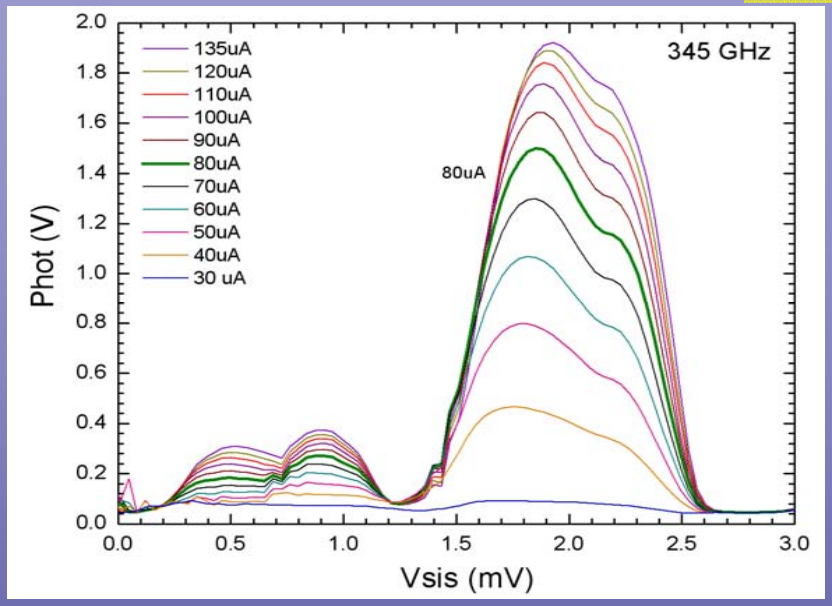
345 GHz Optimal Y-factor and Mixer gain

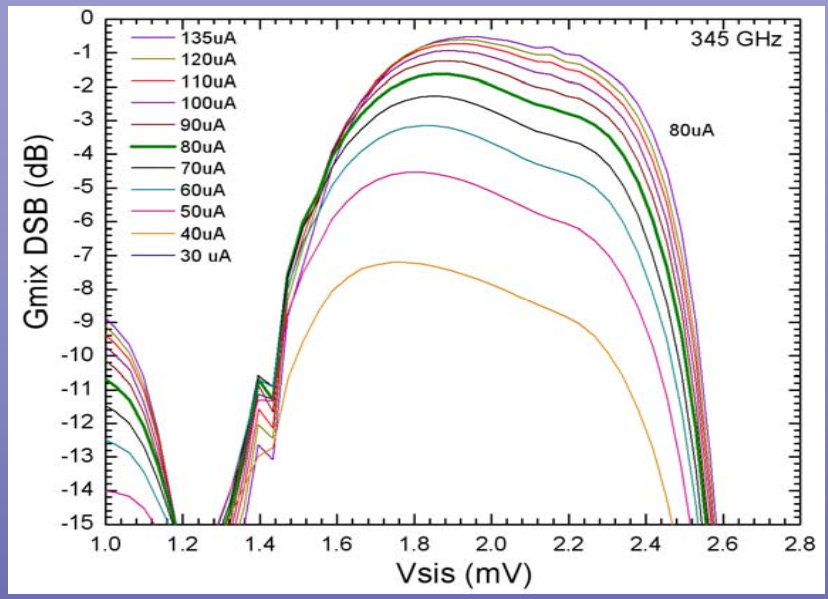


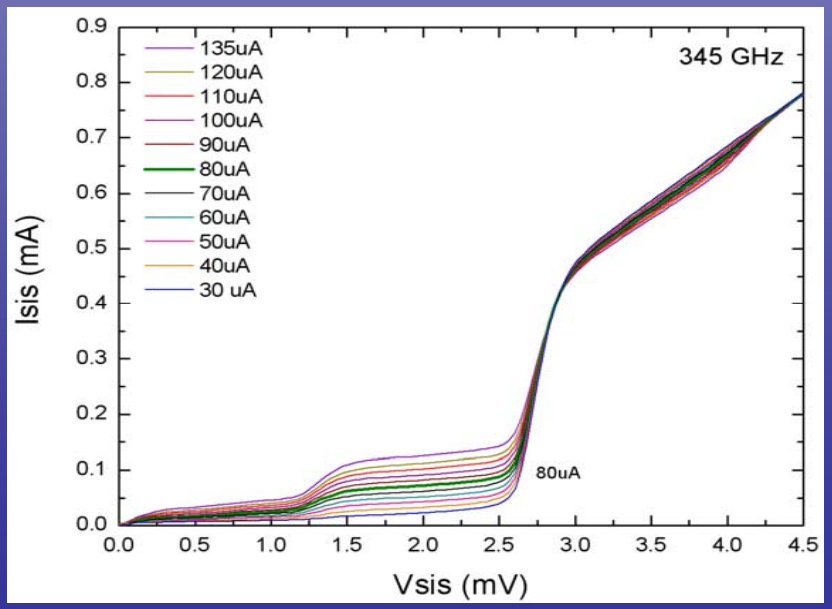


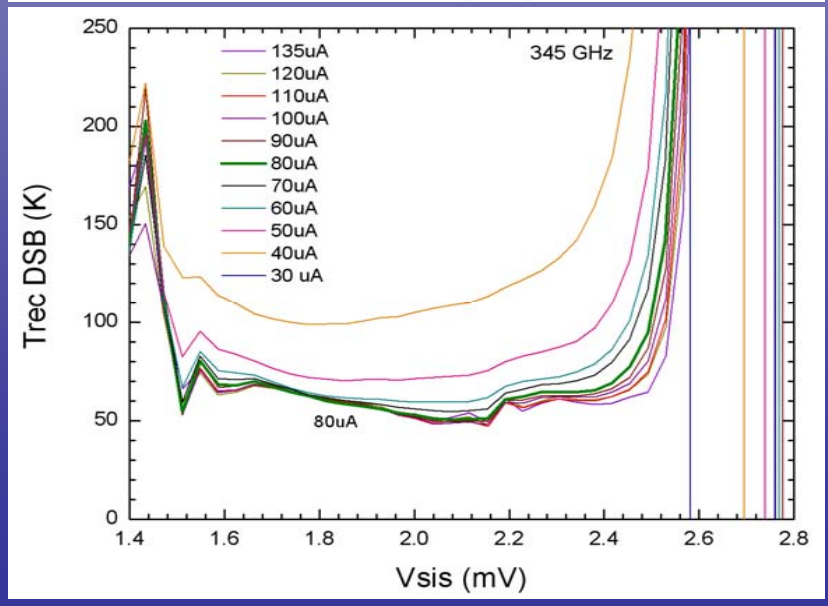
Measured Results at 345 GHz

Varying Isis



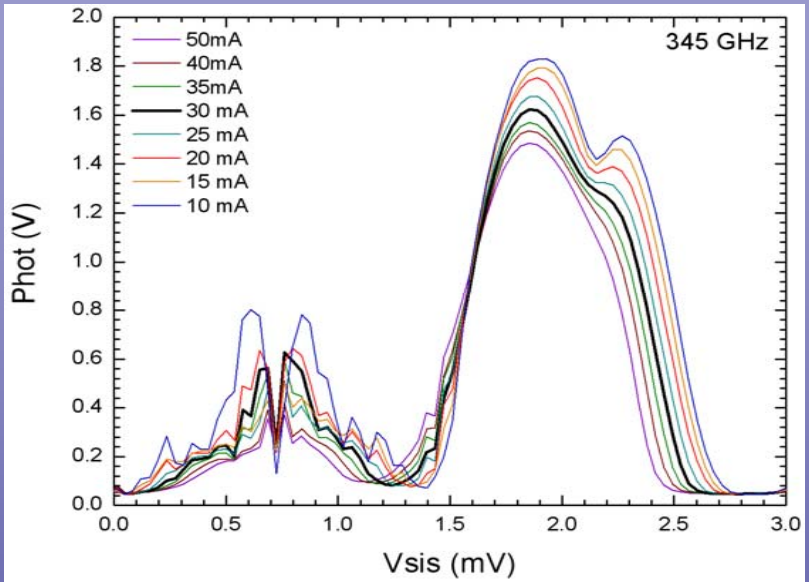


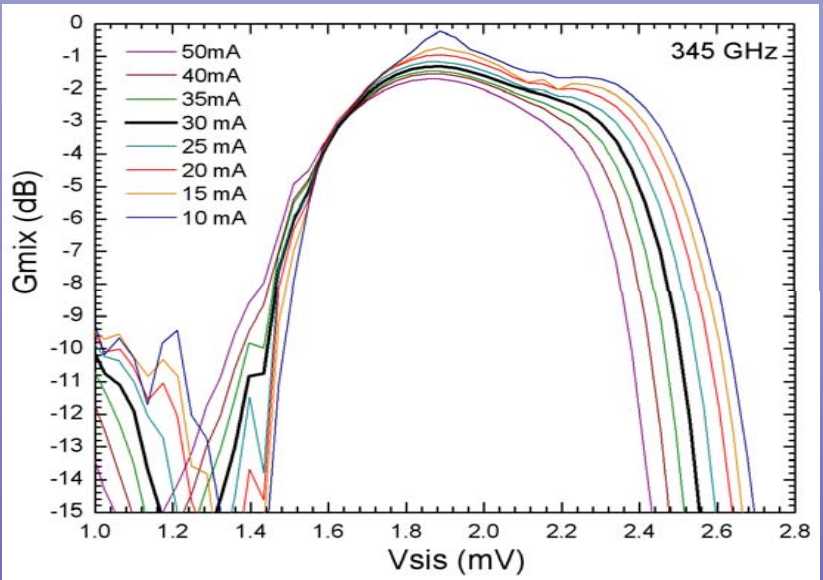


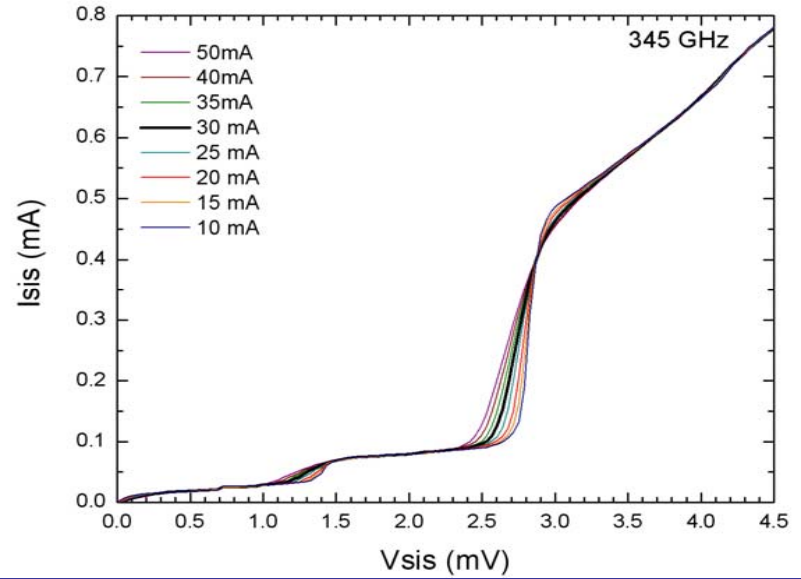


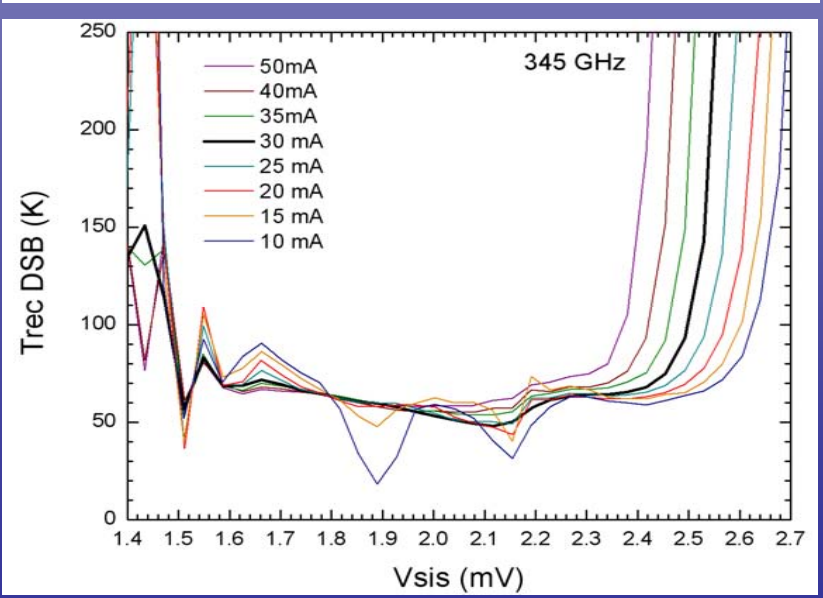
Measured Results at 345 GHz

Varying B-field

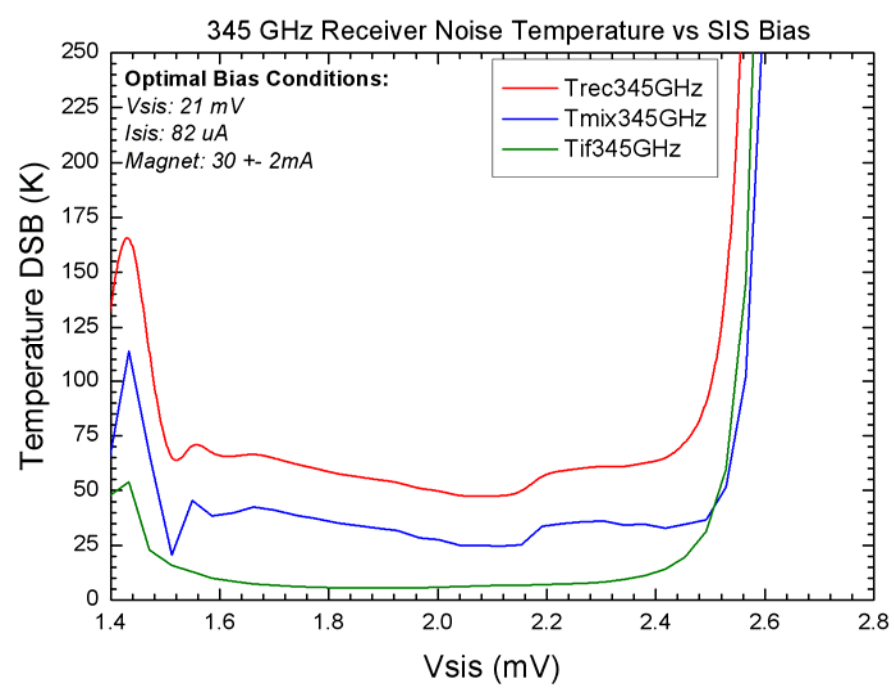








345 GHz Noise temperature Breakdown

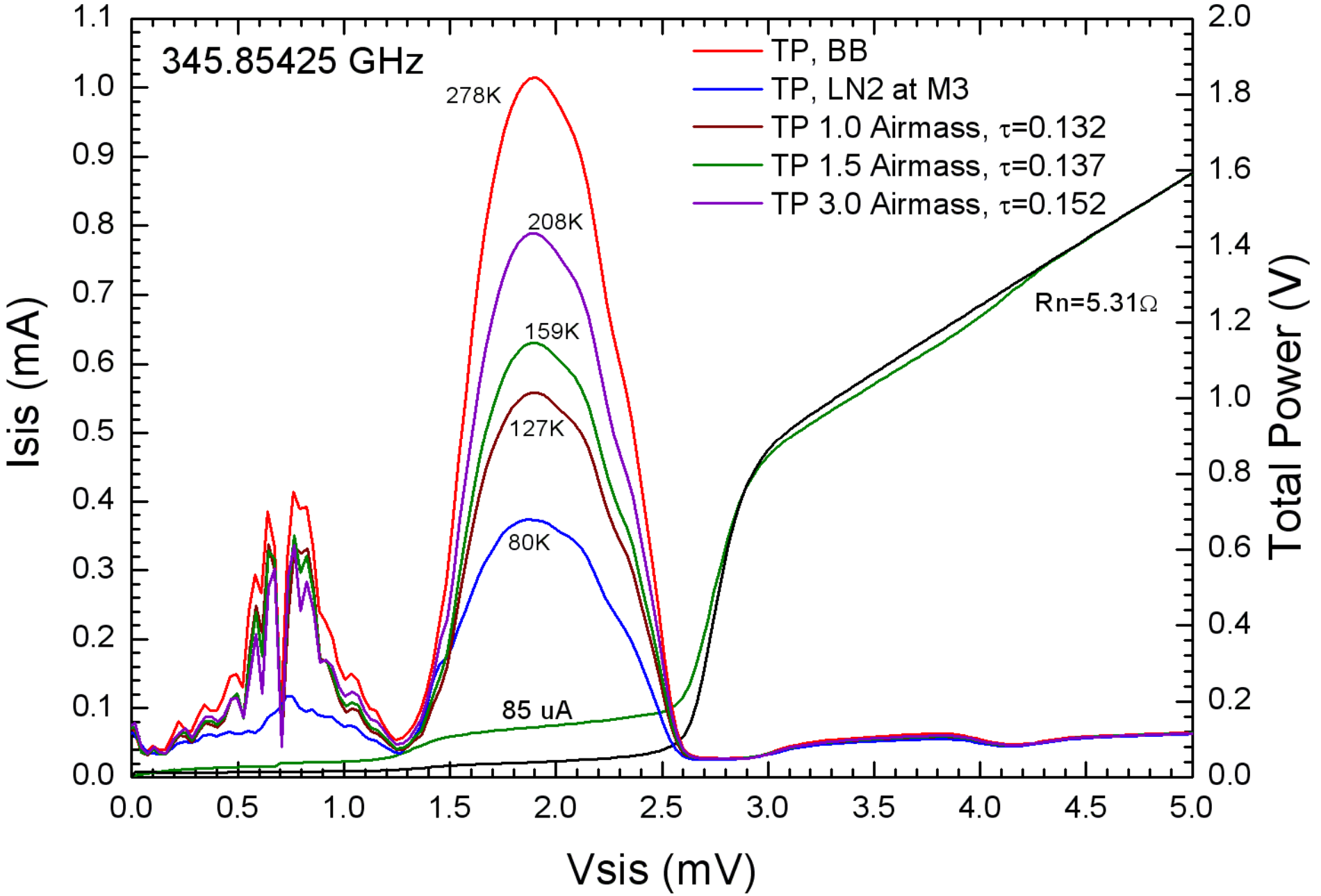


Toptics:	6.7K
Tbeamsplittter	13.9K*
Tif:	7.0K
Tmix:	19.8K
Trec (DSB):	47.4K

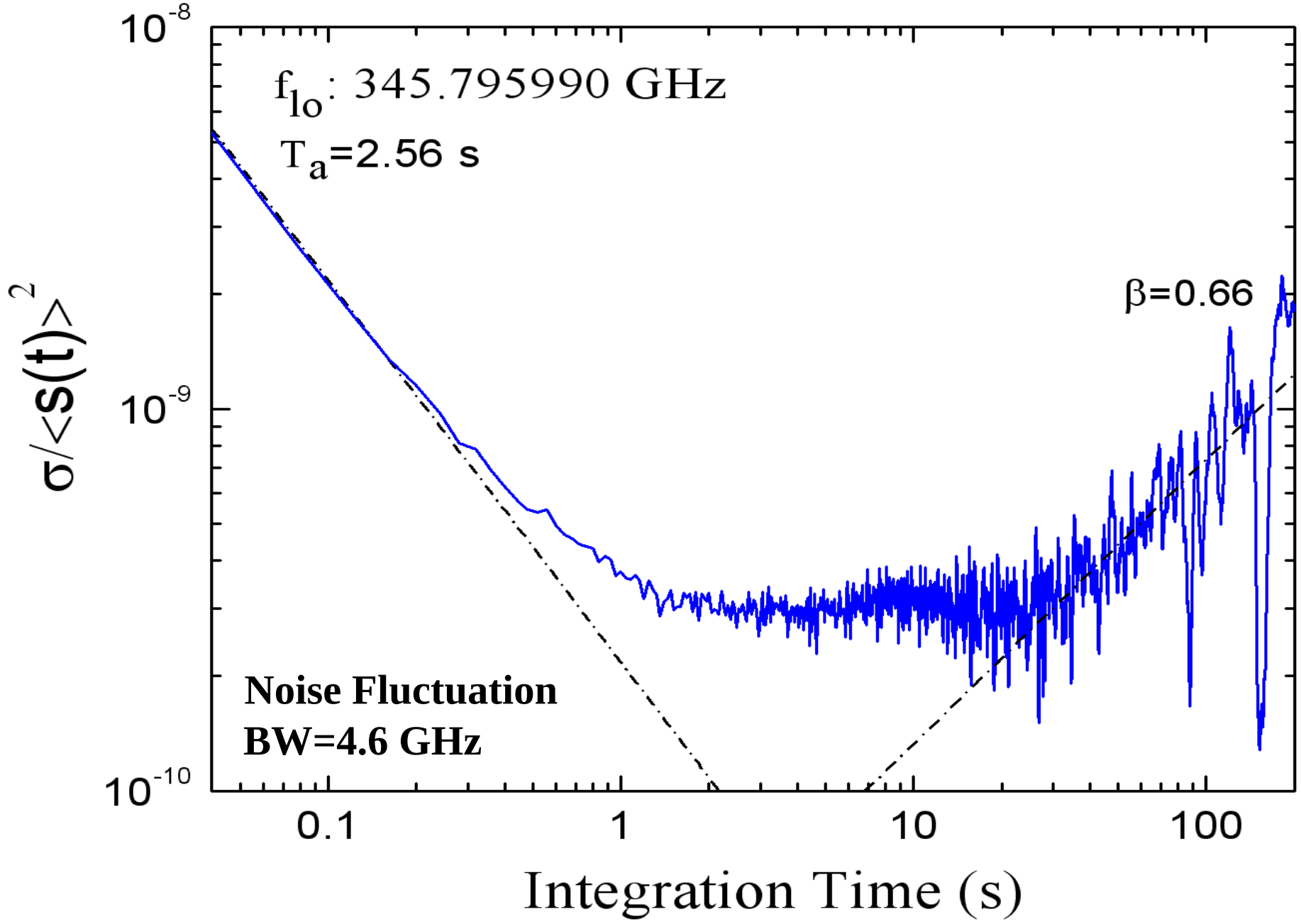
Tmix:	19.8K
Shot +MAR:	9.0K
hv/2k :	8.2 K

*Improvements: Balanced Rx gains ~13K in Optics noise.

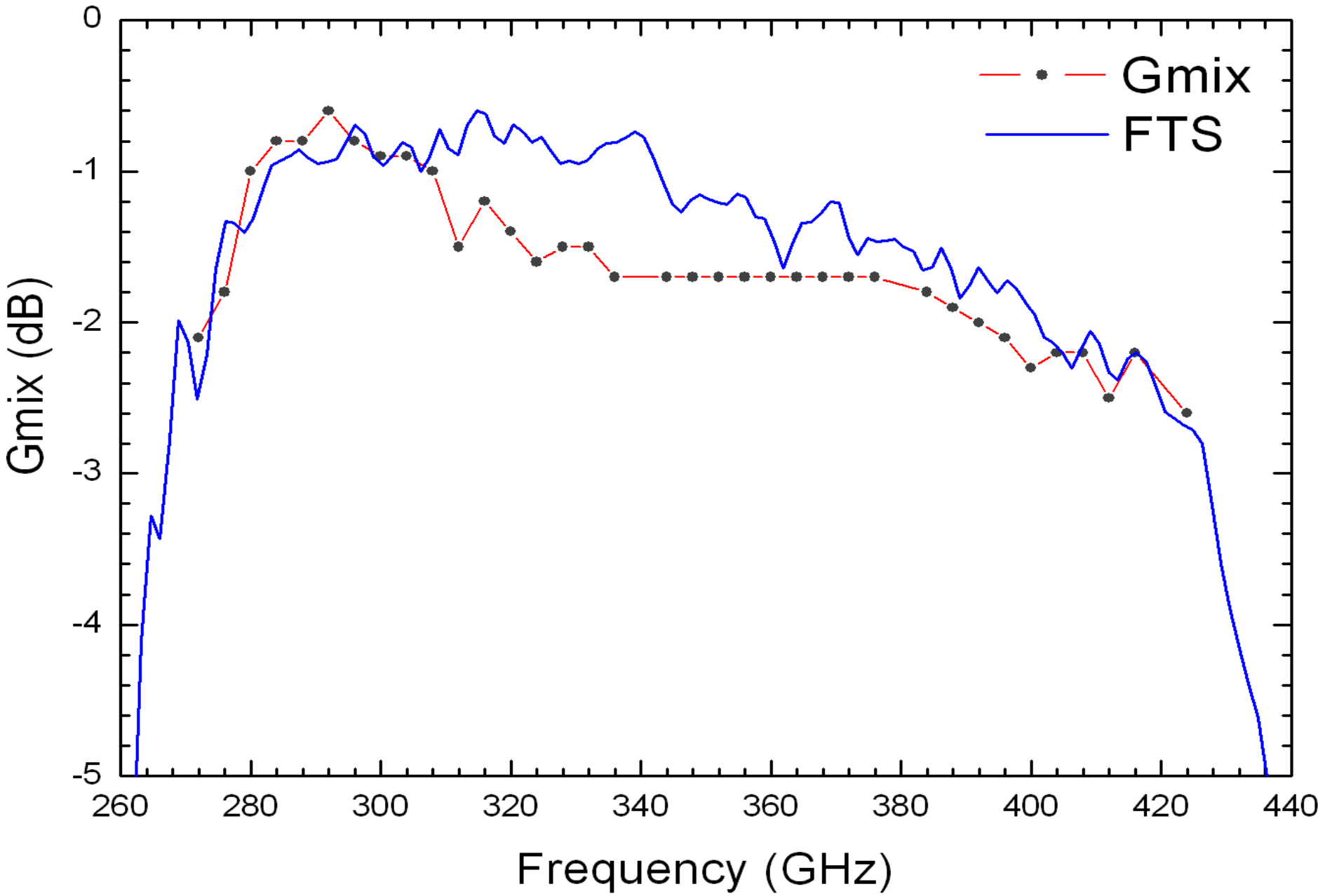
Total Power Response vs Airmass



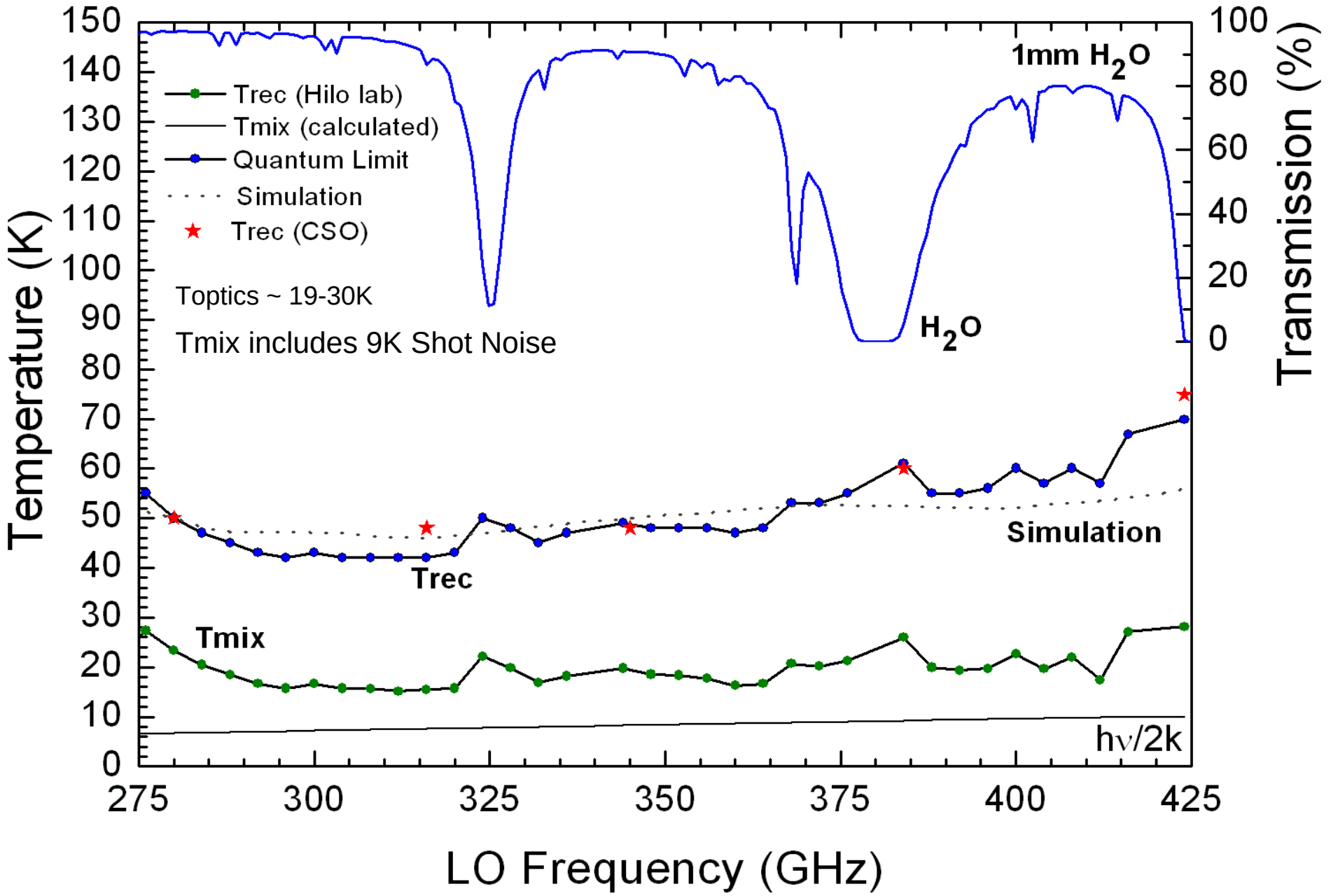
Continuum Stability as measured on the Telescope



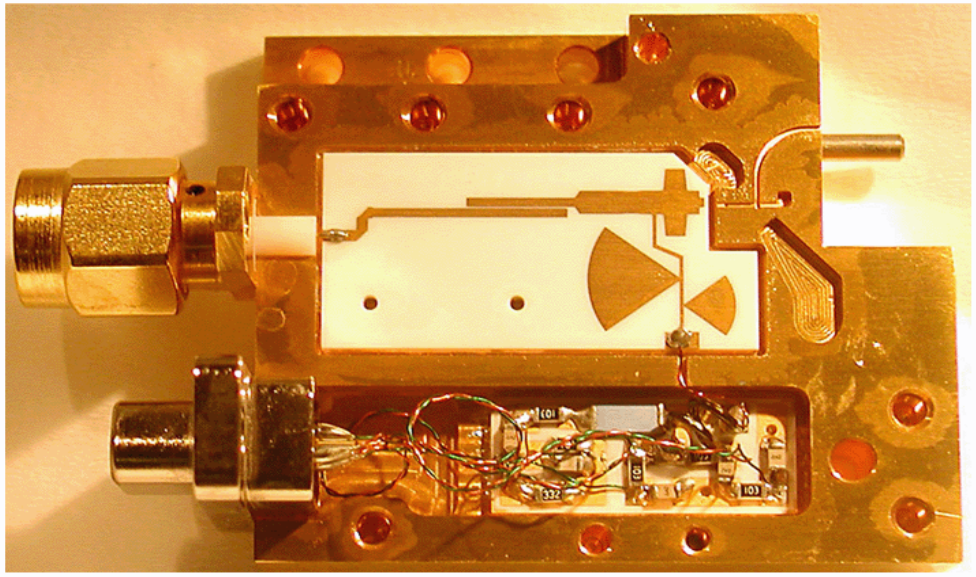
FTS Response overlaid with Mixer Gain



Measured Receiver Noise Temperature



IF Response of Trex



f_{lo}=345 GHz
Vsis=2.2mV
Isis=82 uA
B-field: 29.4 mA

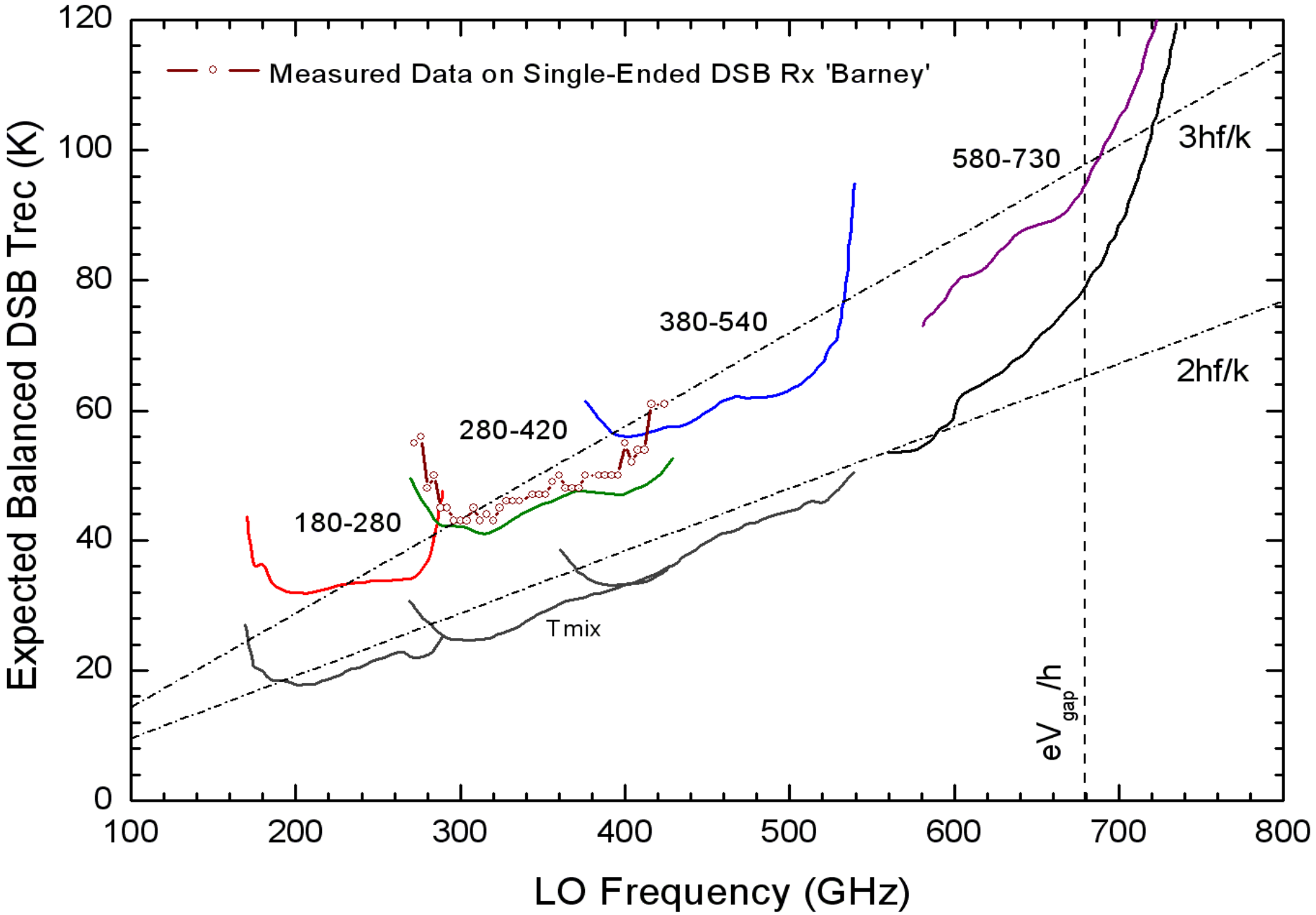
Trec DSB (K)

150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

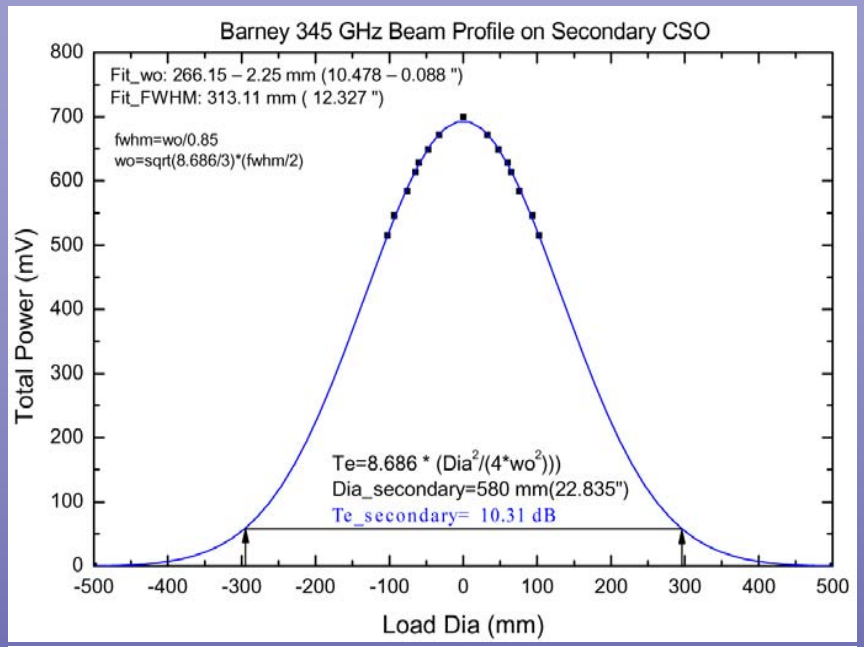
3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0

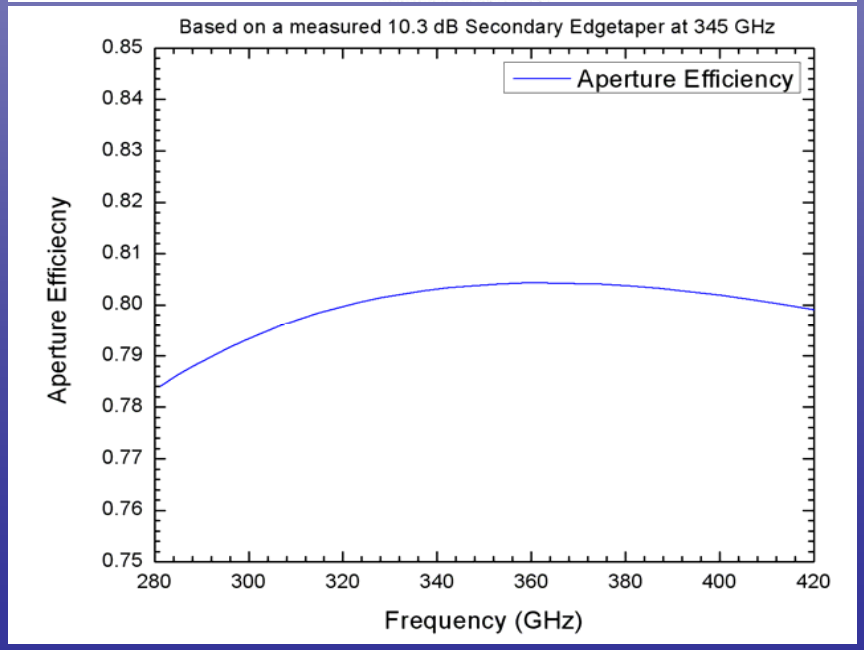
IF Frequency (GHz)

Predicted Balanced Mixer Performance

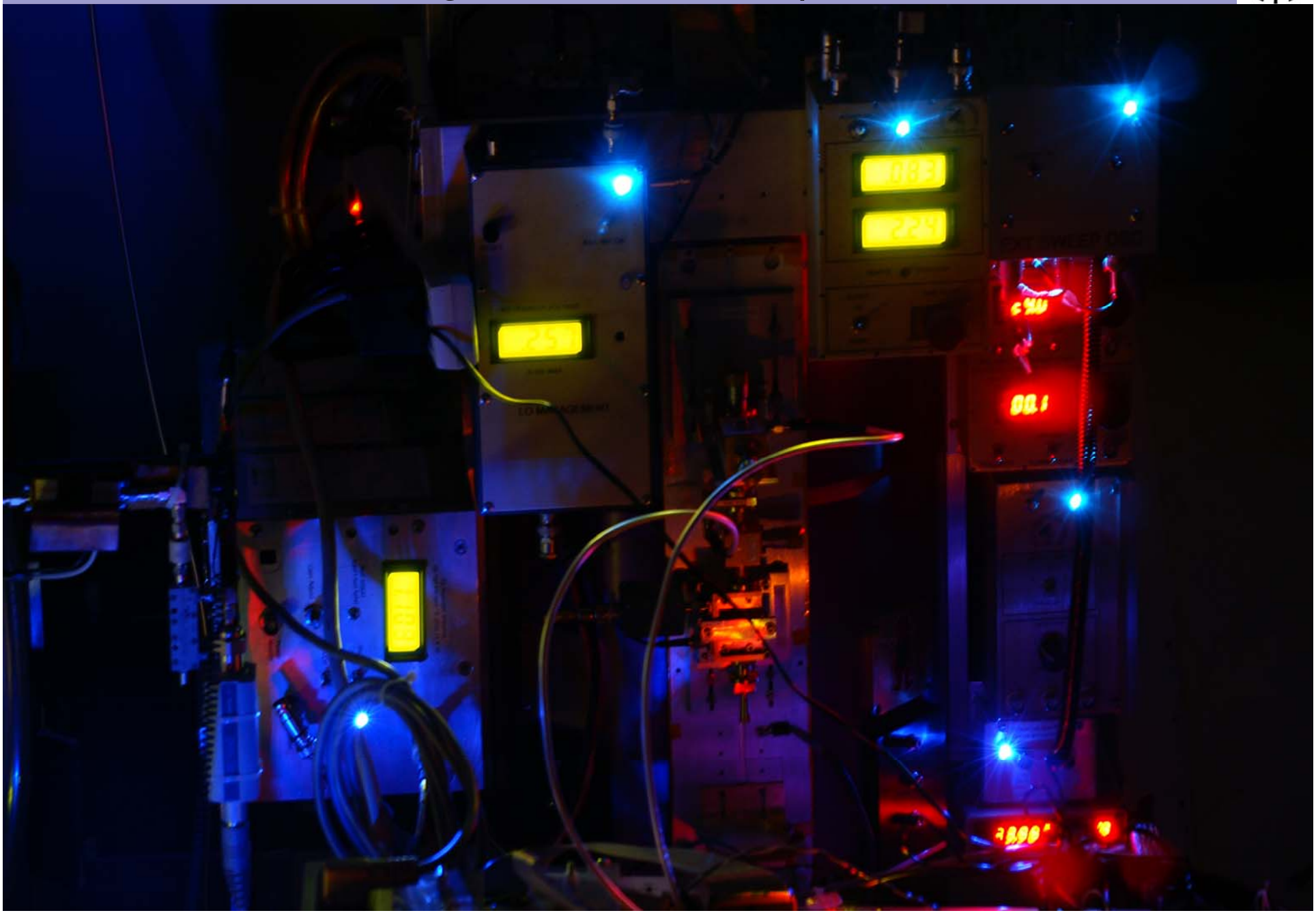


Optics Verification

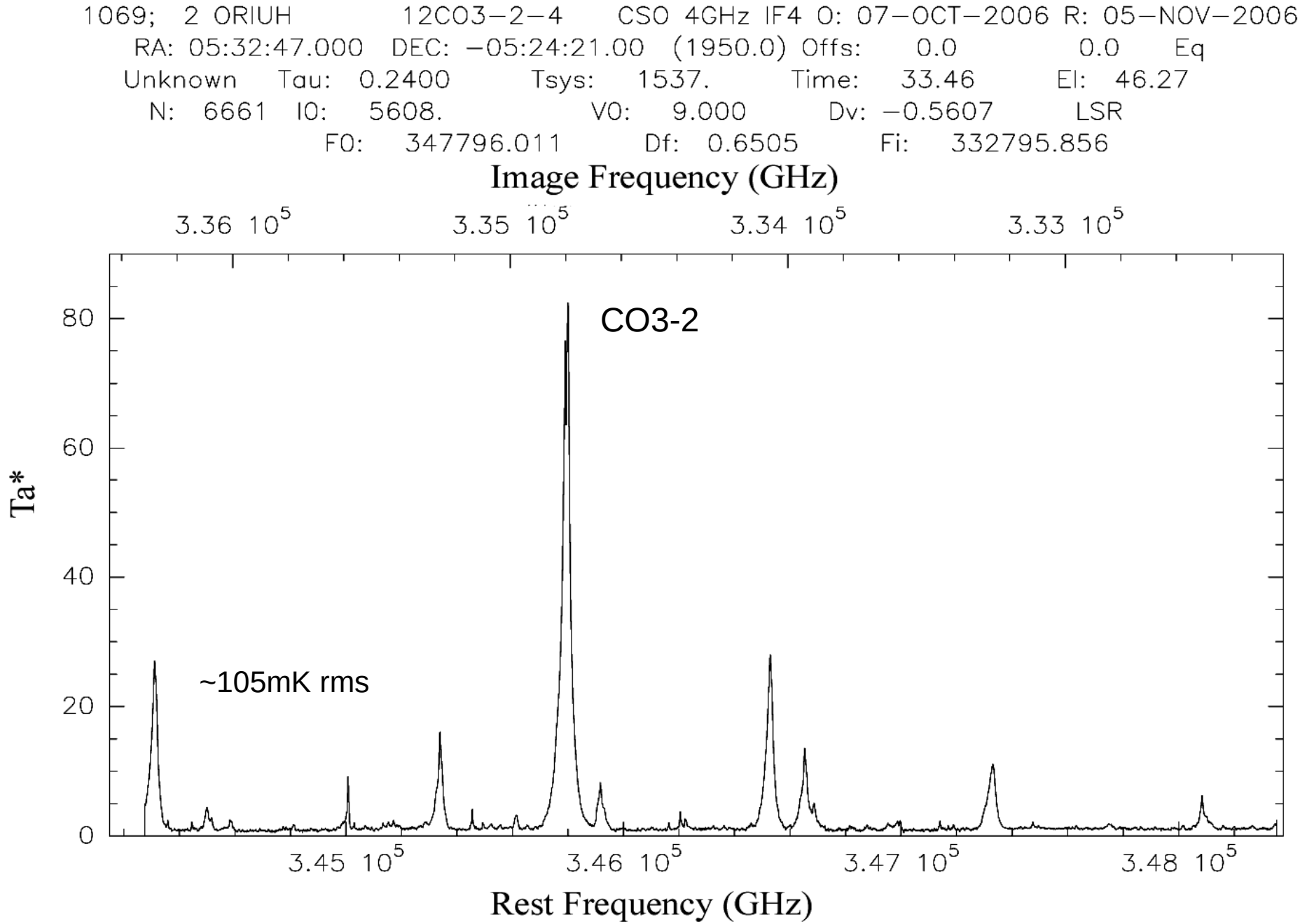




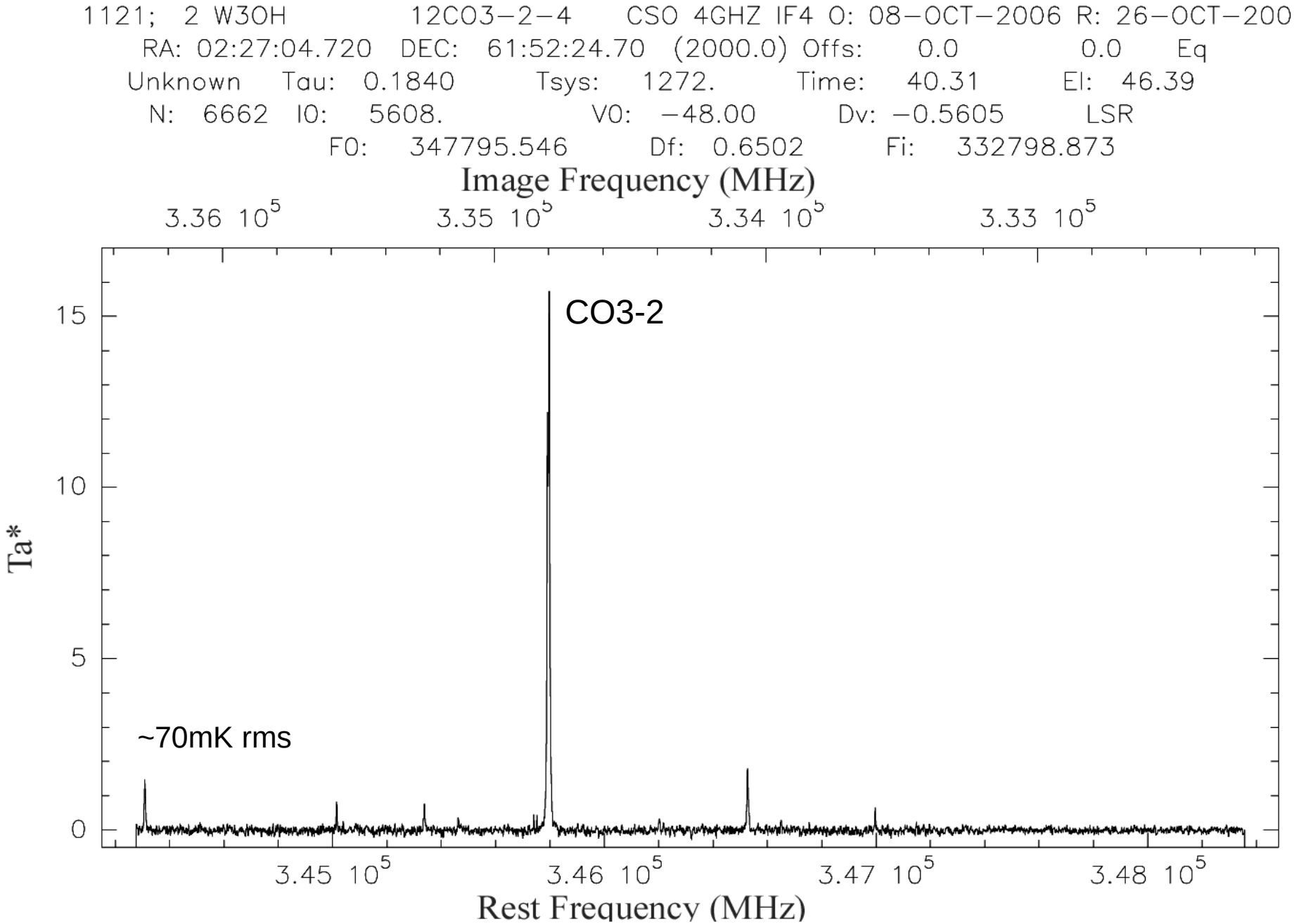
Trex at night on the Telescope

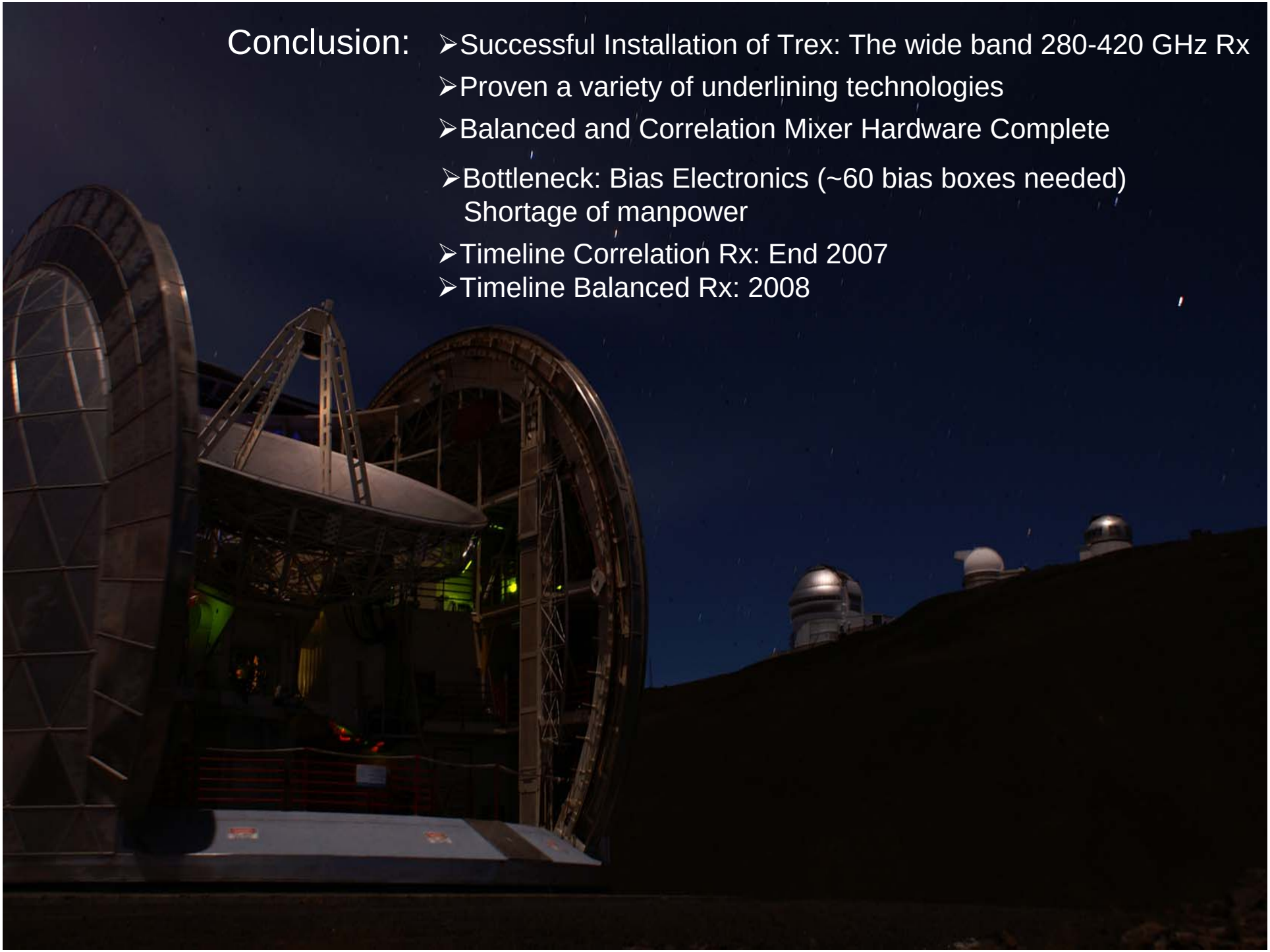


Orion-KL (Oct, 2006)



W3, Young Globular Cluster in NGC 7252 (Oct 2006)





Conclusion:

- Successful Installation of Trex: The wide band 280-420 GHz Rx
- Proven a variety of underlining technologies
- Balanced and Correlation Mixer Hardware Complete
- Bottleneck: Bias Electronics (~60 bias boxes needed)
  Shortage of manpower
- Timeline Correlation Rx: End 2007
- Timeline Balanced Rx: 2008