CALTECH

High Resolution Spectrometers

(Heterodyne Receiver Development)

JPL

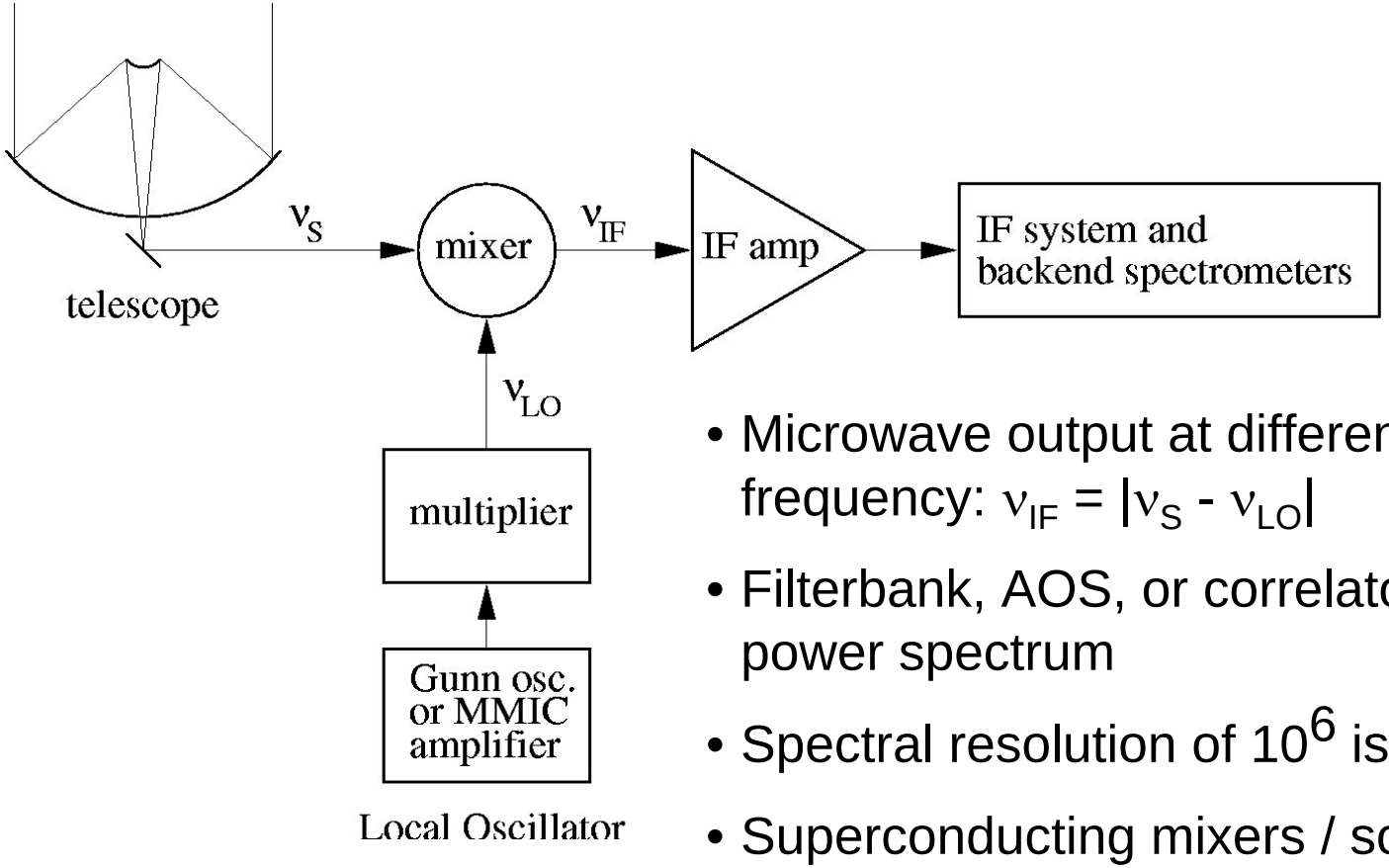
- Very strong effort at JPL/CIT
- SIS mixers up to 1.2 THz (limit ~ 1.6 THz)
- Solid-state LO's beyond 1.5 THz (JPL)
- Herschel / HIFI – 1.2 THz SIS
- SOFIA / CASIMIR
- CSO facility receivers (200 – 900 GHz)
- New developments

CALTECH

High Resolution Spectrometers

JPL

Heterodyne Spectroscopy



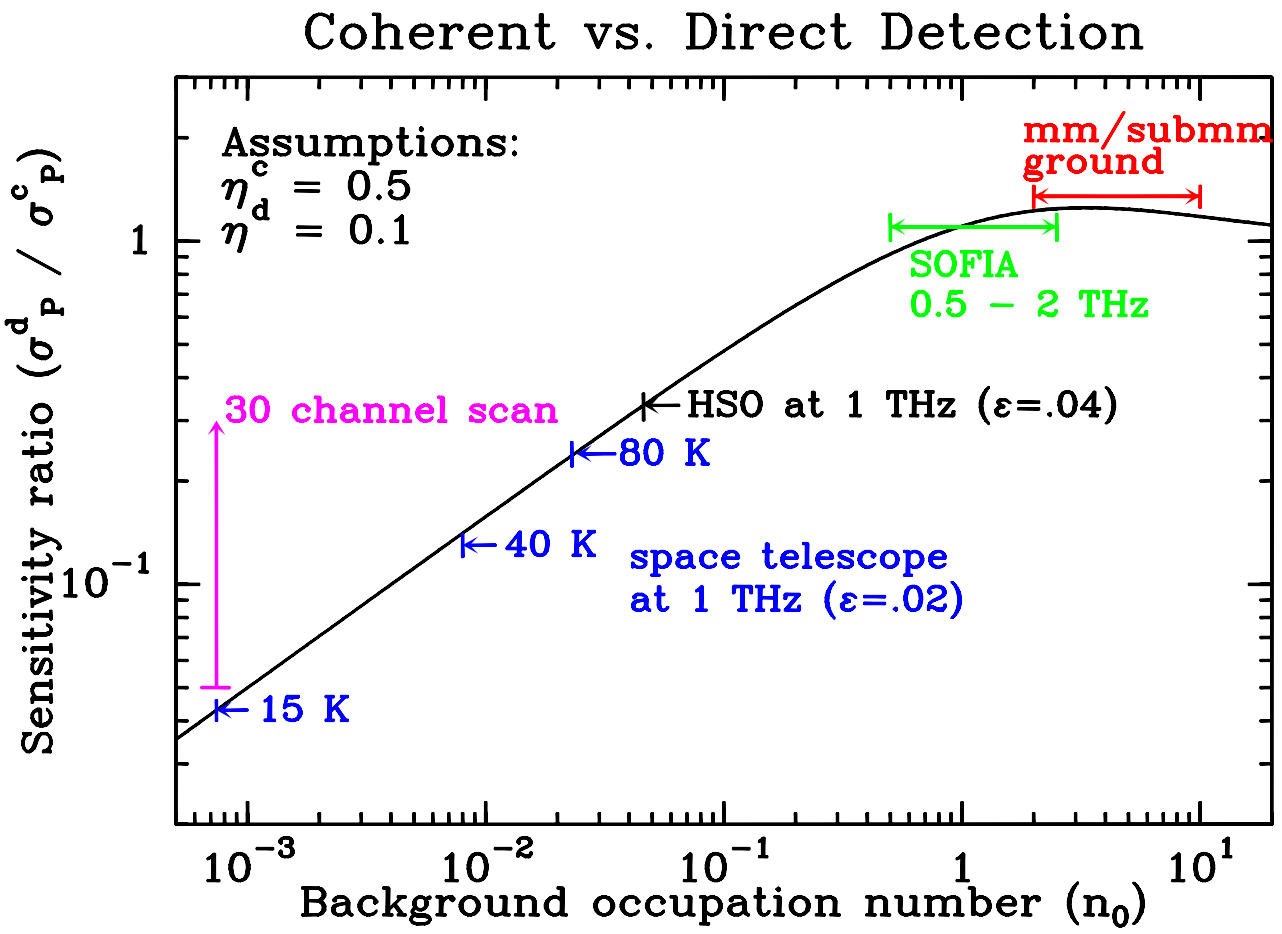
- Microwave output at difference (IF) frequency: $\nu_{IF} = |\nu_S - \nu_{LO}|$
- Filterbank, AOS, or correlator measures IF power spectrum
- Spectral resolution of 10^6 is *easy*
- Superconducting mixers / solid-state LO's
- "Quantum Limit" to sensitivity: Tn > hf/k

CALTECH

High Resolution Spectrometers

JPL

But QL is not an issue from the ground:

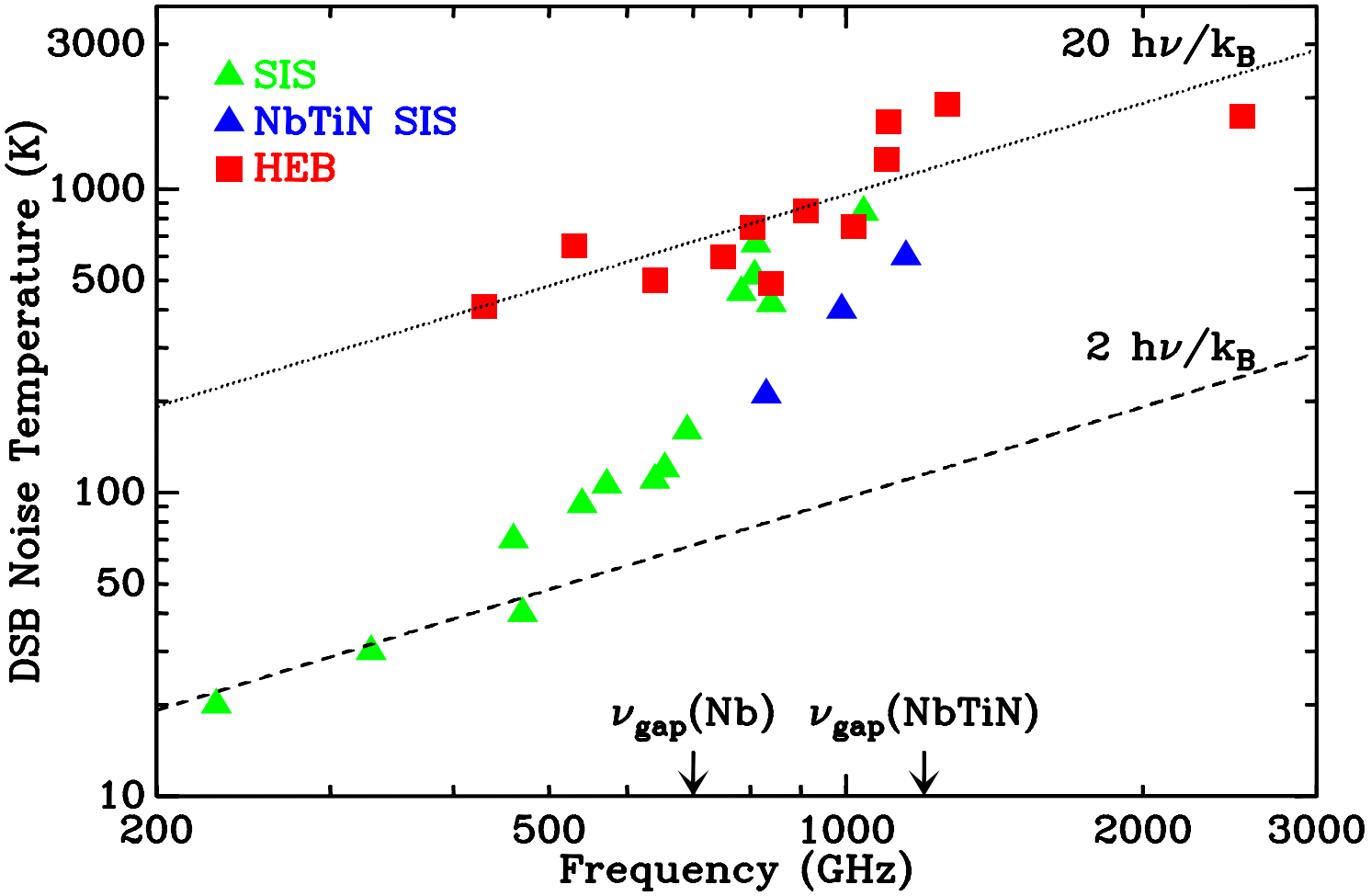


CALTECH

High Resolution Spectrometers

JPL

SIS receivers are near quantum limit



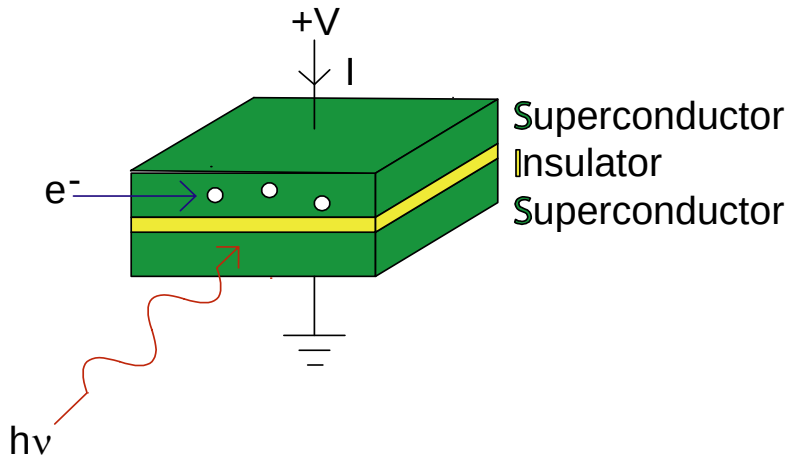
CALTECH

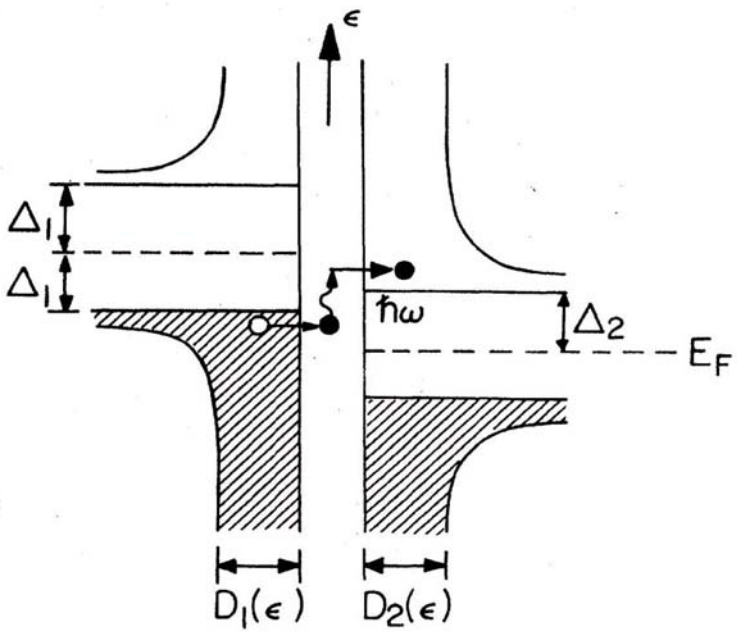
High Resolution Spectrometers

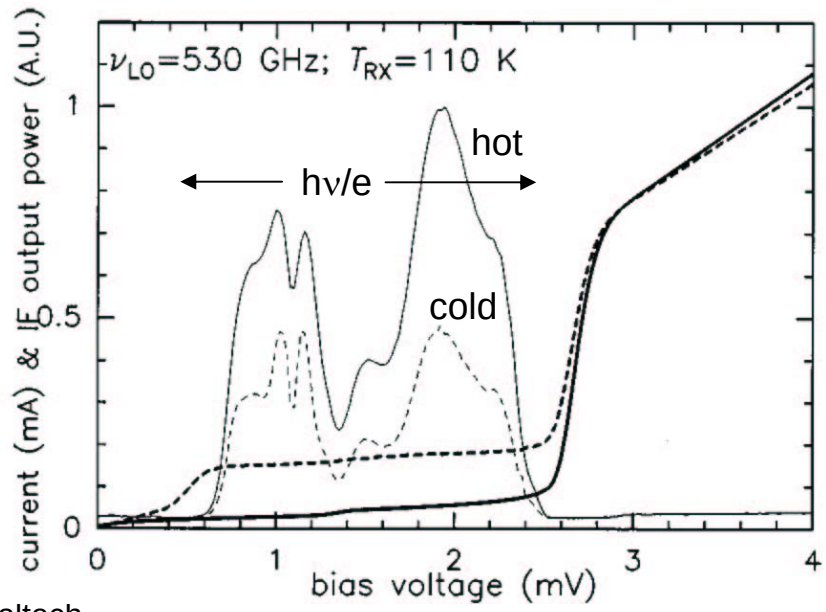
JPL

Basic Principles of SIS mixers

- SIS: superconducting tunnel junction
- SIS is a “submillimeter photodiode”
  - One electron per photon absorbed
  - “photon-assisted tunneling”







CALTECH

High Resolution Spectrometers

JPL

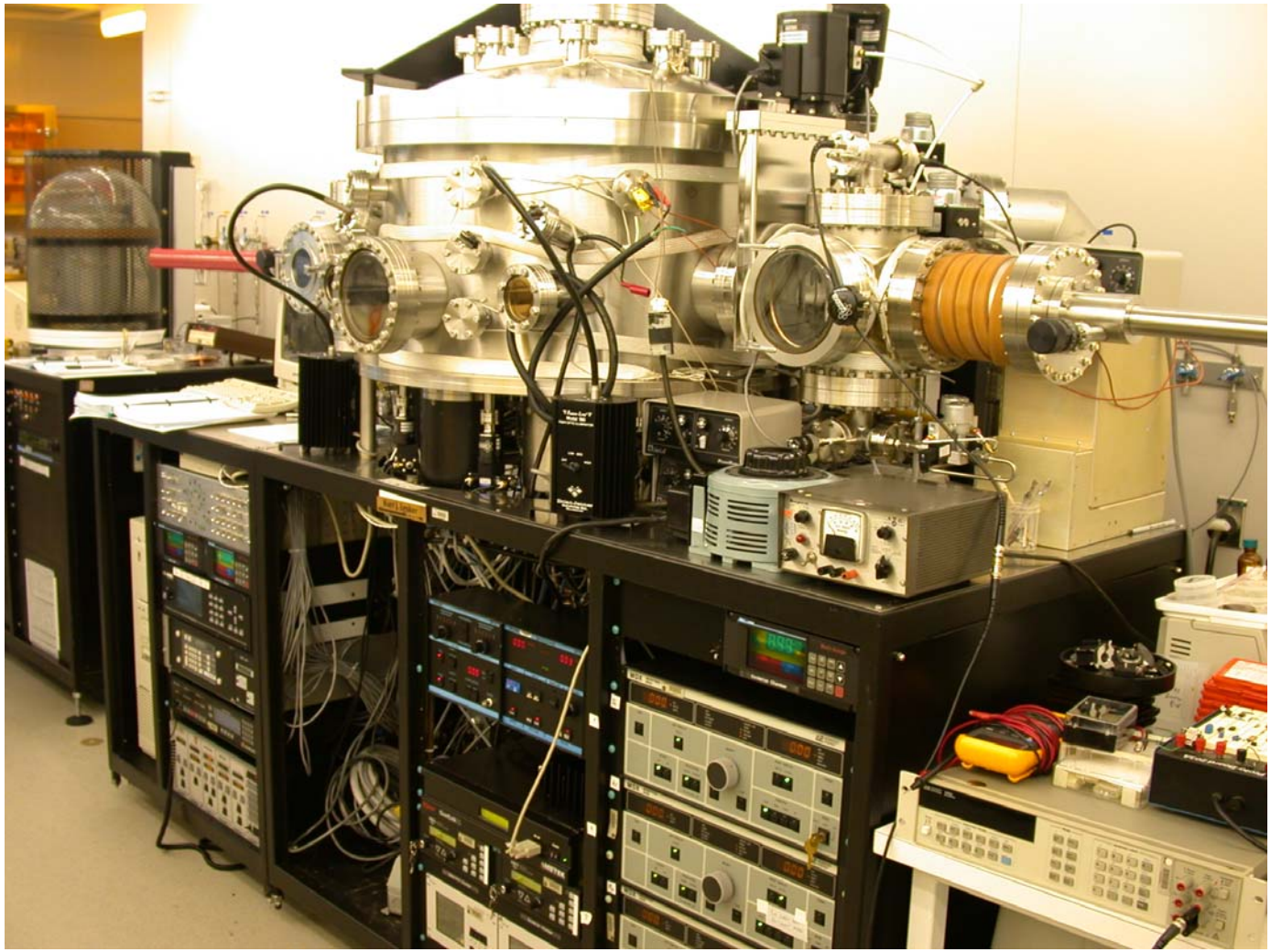
SIS device fabrication at JPL's MDL

CALTECH

High Resolution Spectrometers

JPL

Nb sputtering system for SIS trilayer deposition

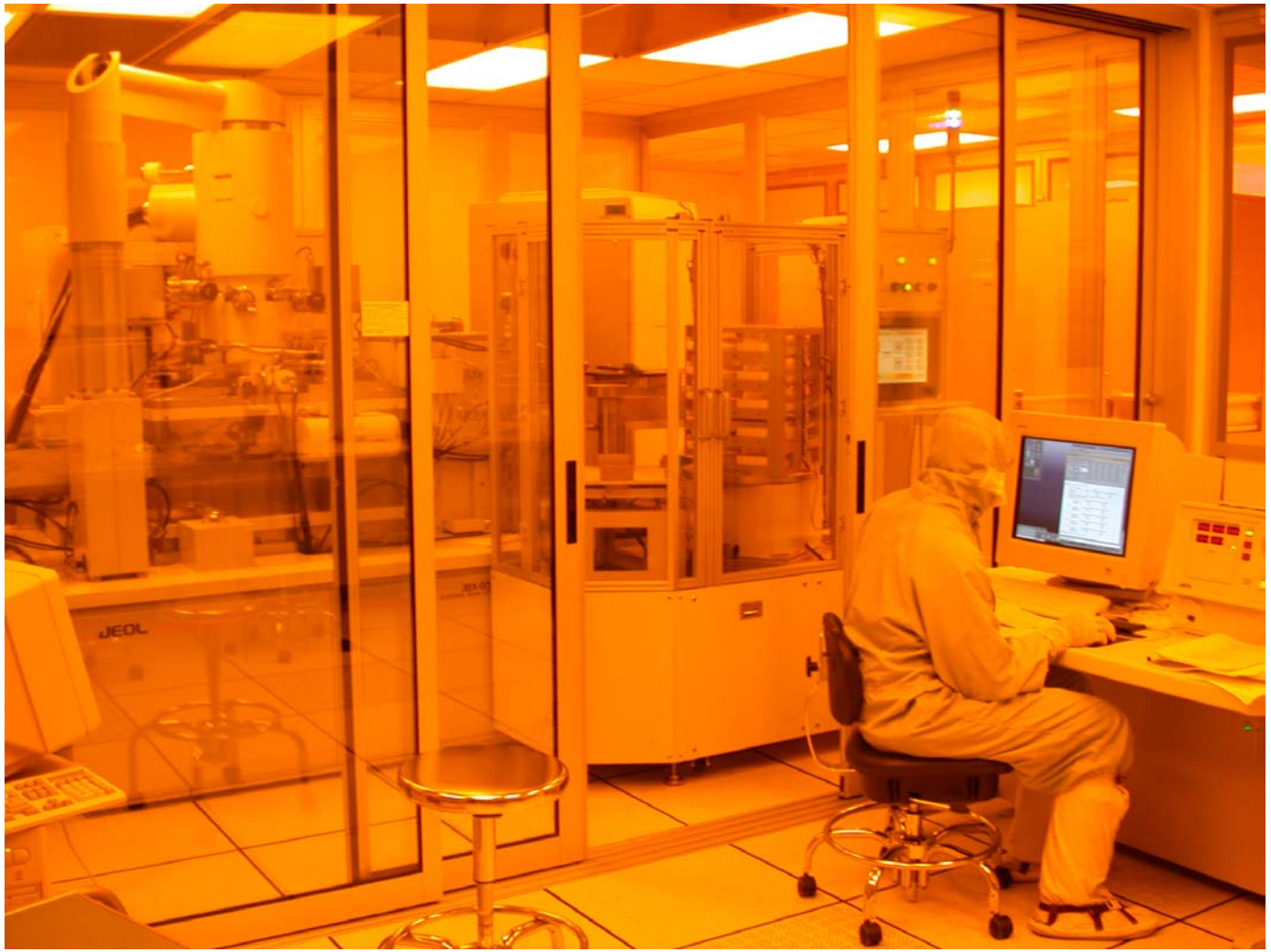


CALTECH

High Resolution Spectrometers

JPL

Electron-beam lithography for sub-micron features

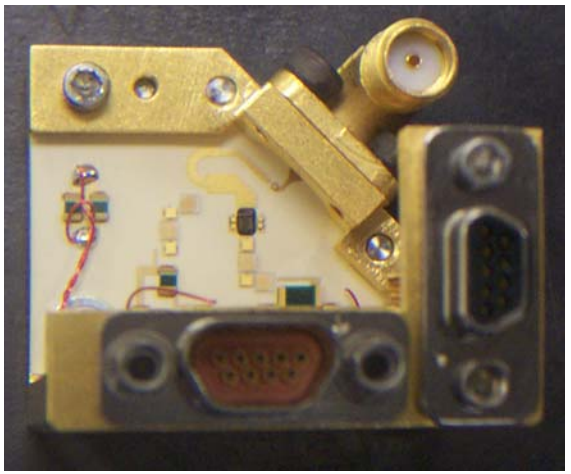


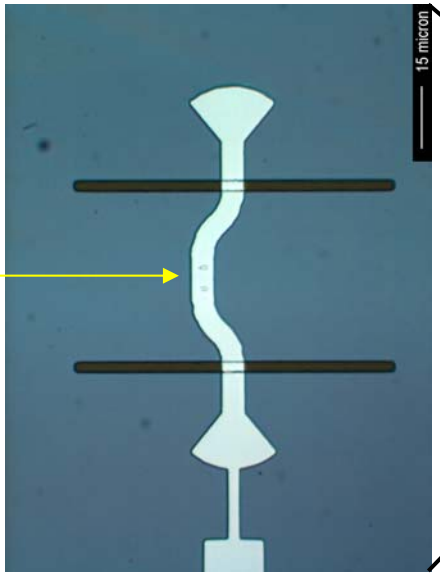
CALTECH

High Resolution Spectrometers

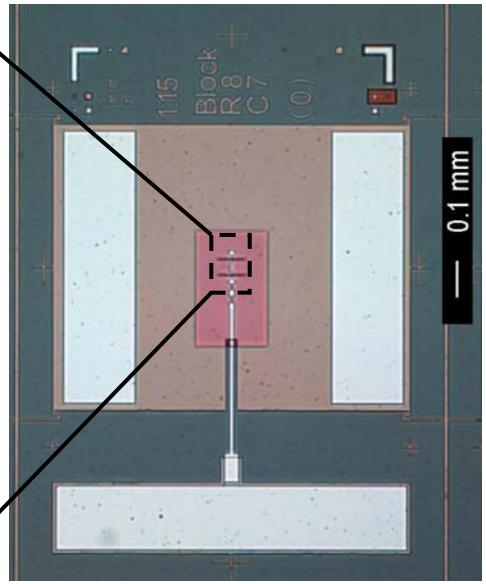
JPL

1.2 THz SIS mixers for HIFI/Herschel





SIS



A. Karpov, J. Stern, D. Miller, J. Zmuidzinas, F. Rice, H. G. LeDuc, W. Hatch, J. Pearson

October 11, 2003

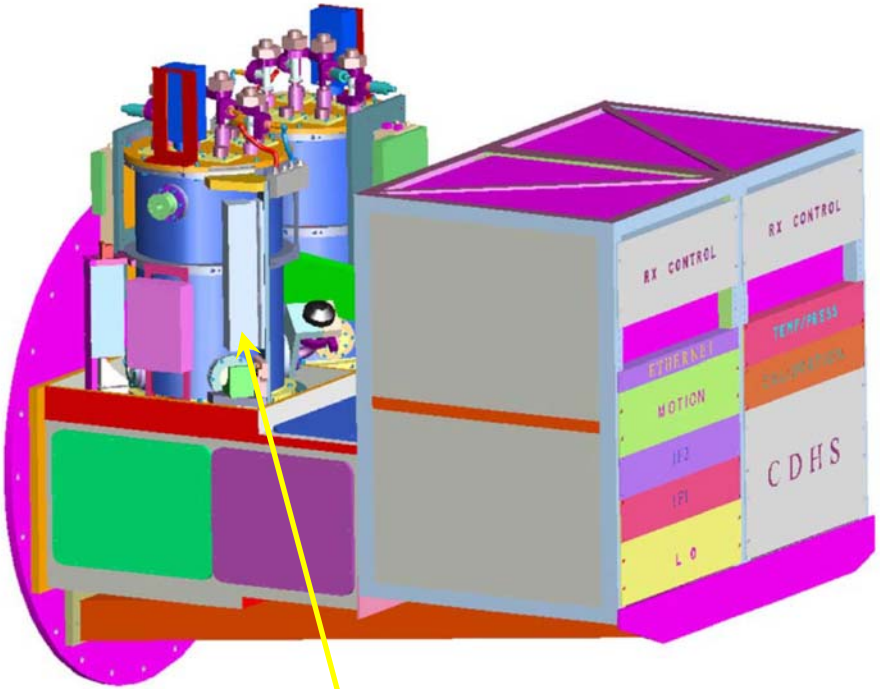
Cornell/Caltech
Large Submillimeter Telescope Workshop

CALTECH

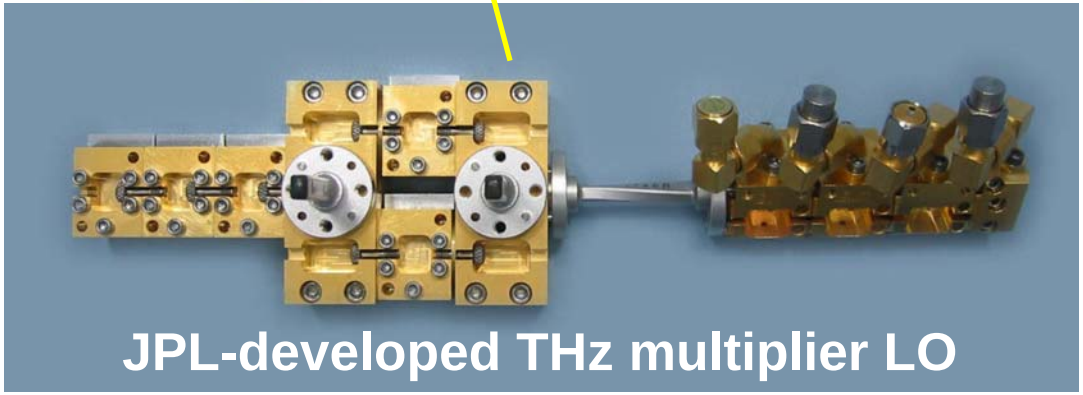
High Resolution Spectrometers

JPL

CASIMIR – a 500-1200 GHz SIS Receiver for SOFIA



- 4 Bands: 500-600, 700-800, 900-1050, and 1050-1200 GHz
- First flights in summer 2005



CALTECH

High Resolution Spectrometers

JPL

CSO Facility Receivers (Kooi et al.)

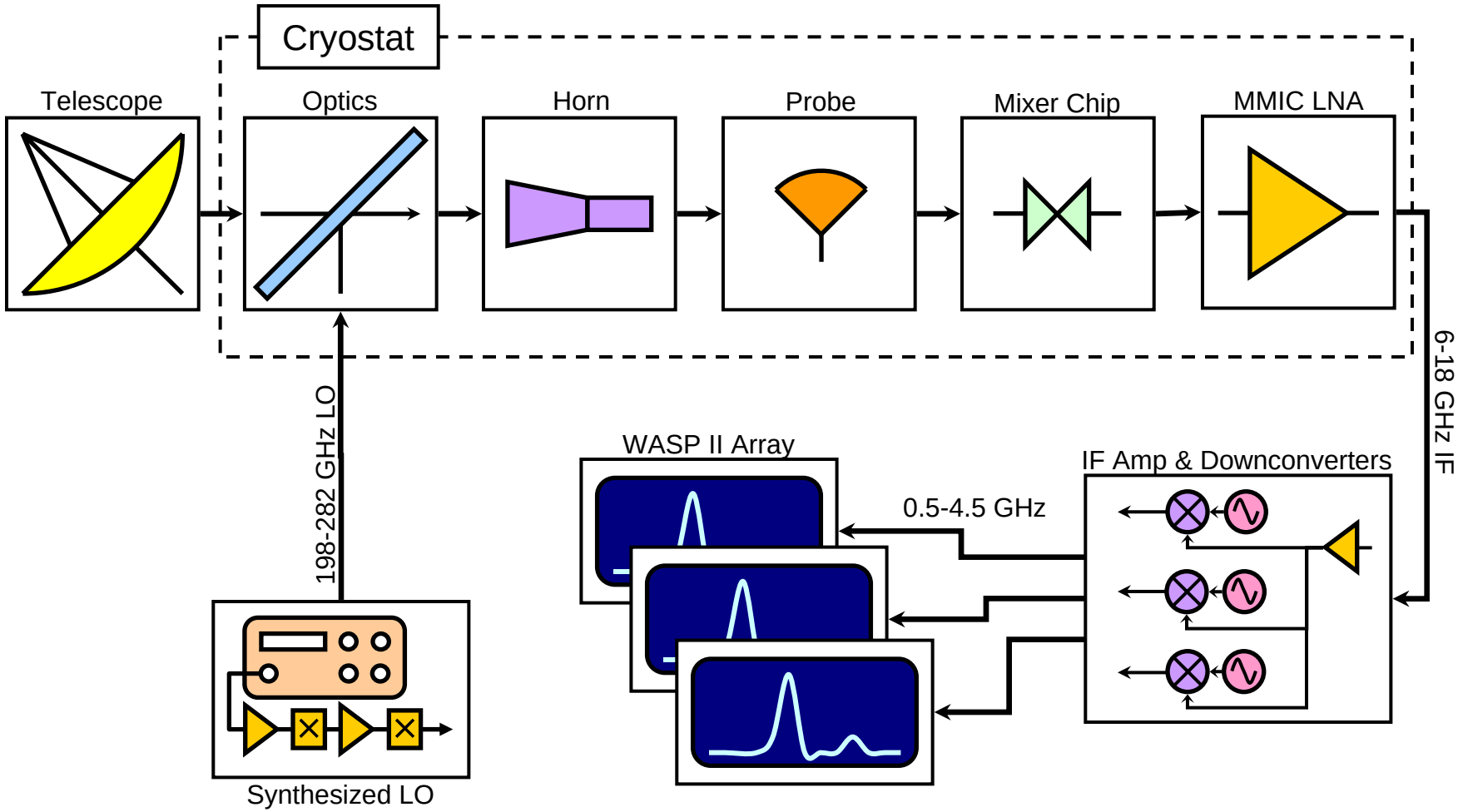
- Cover 200-900 GHz
- State of the art sensitivity
  - 200 K DSB @ 810 GHz (quasioptical NbTiN)
- 4-8 GHz IF upgrades in progress
- New tunerless mixers in progress
  - Wideband radial waveguide probe design
  - Balanced mixers
- Dual-beam, dual pol 350 GHz system

CALTECH

High Resolution Spectrometers

JPL

230 GHz Wideband Receiver System

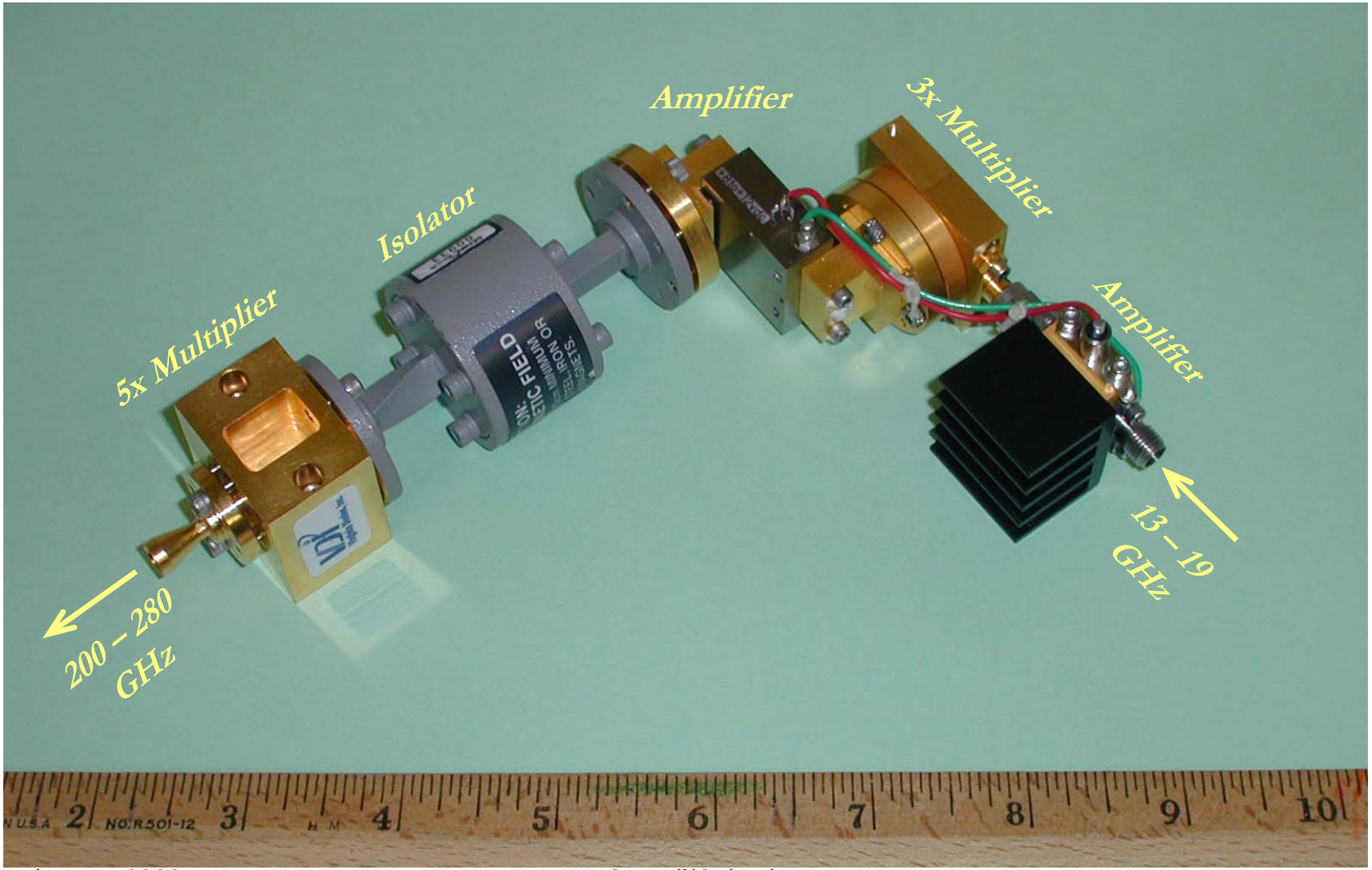


CALTECH

High Resolution Spectrometers

JPL

15x Frequency Multiplier LO



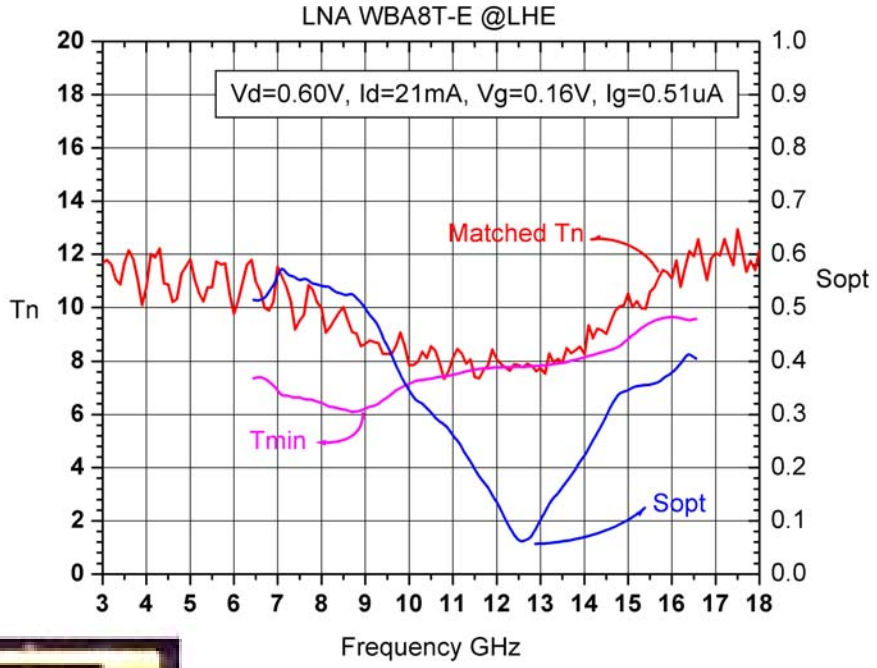
CALTECH

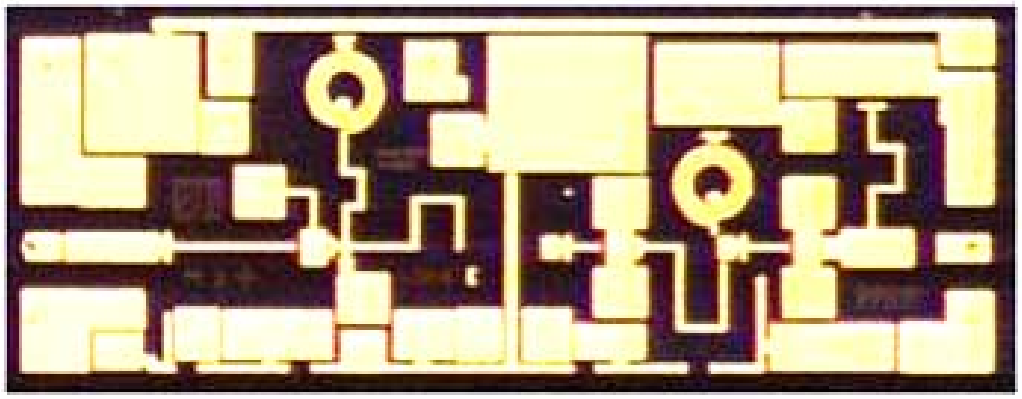
High Resolution Spectrometers

JPL

Wideband MMIC IF LNA

- 3-stage InP HEMT
- 200 um gate width
- Inductive feedback
- JPL/Caltech design
- Fabricated at TRW





R. Hu (U. of Michigan/Caltech),

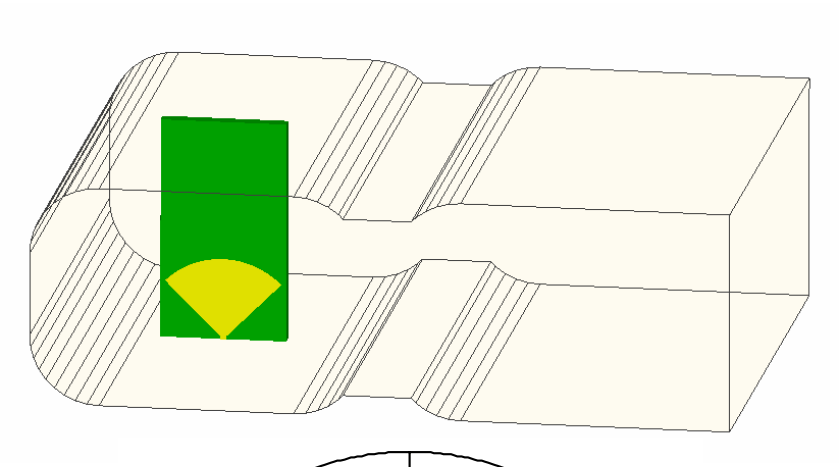
S. Weinreb (JPL)

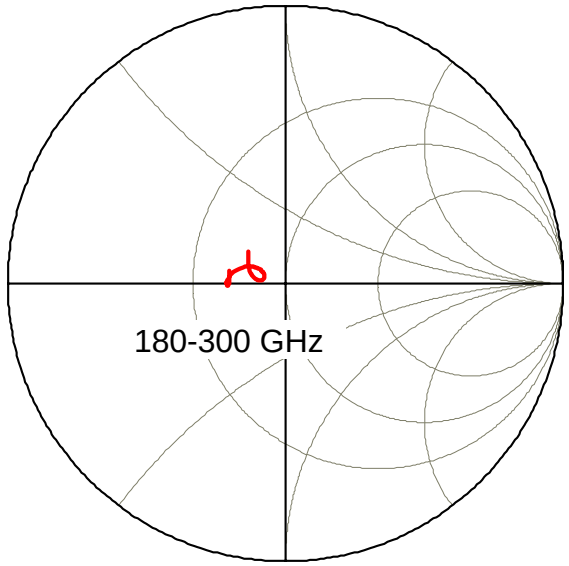
CALTECH

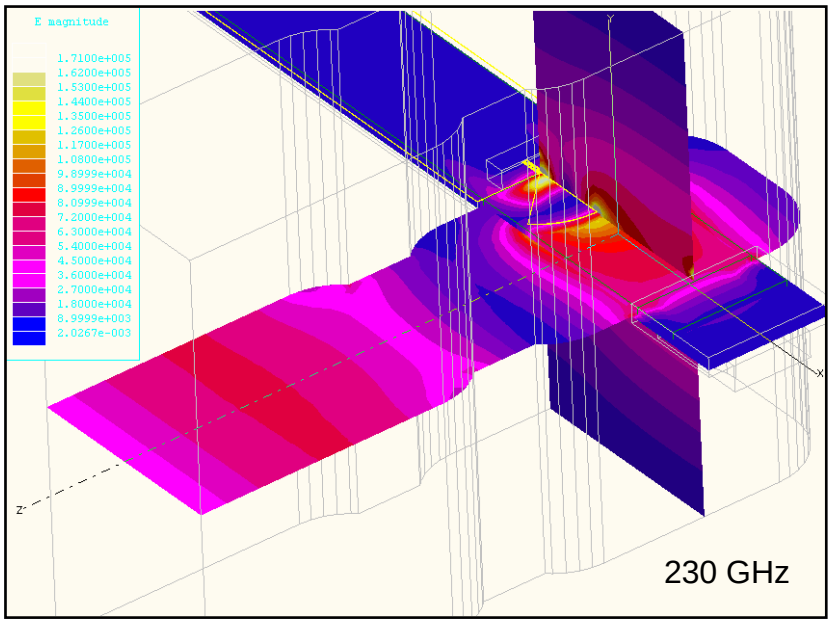
High Resolution Spectrometers

JPL

Probe Design: 3D EM Modeling







- **Ansoft HFSS**
- **Probe design: 109,000 tetrahedra; 637,000 matrix elements**
- **24 mins/solution using 1.3 GHz Athlon**

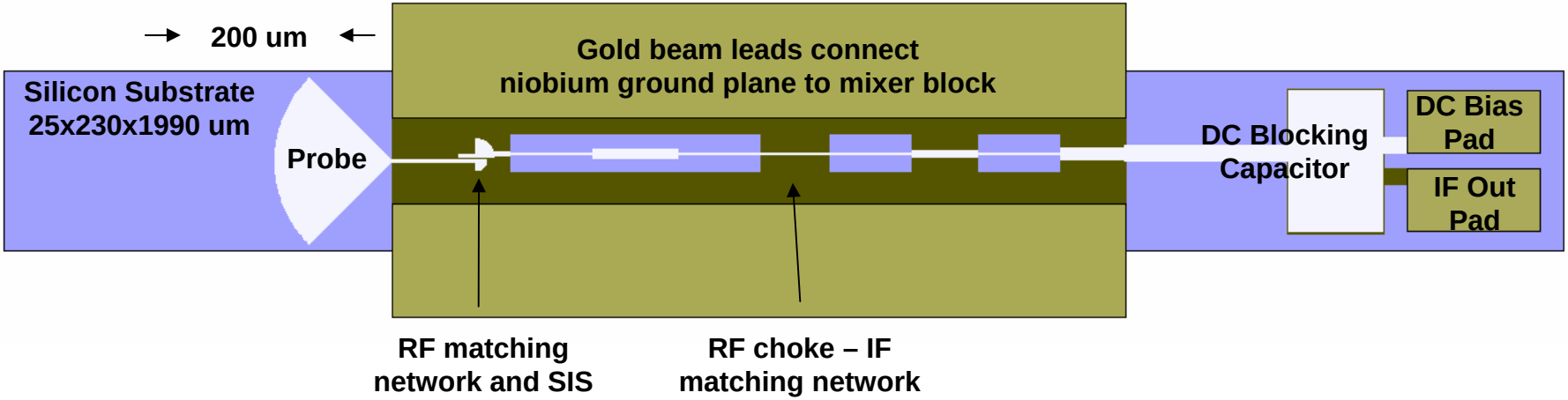
F. Rice, J. Kooi, G. Chattopadhyay , S. Withington

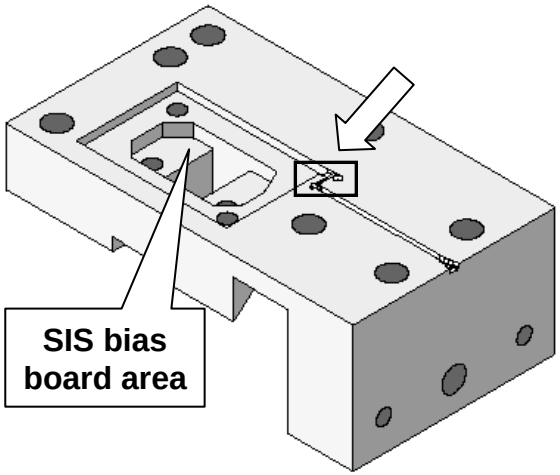
CALTECH

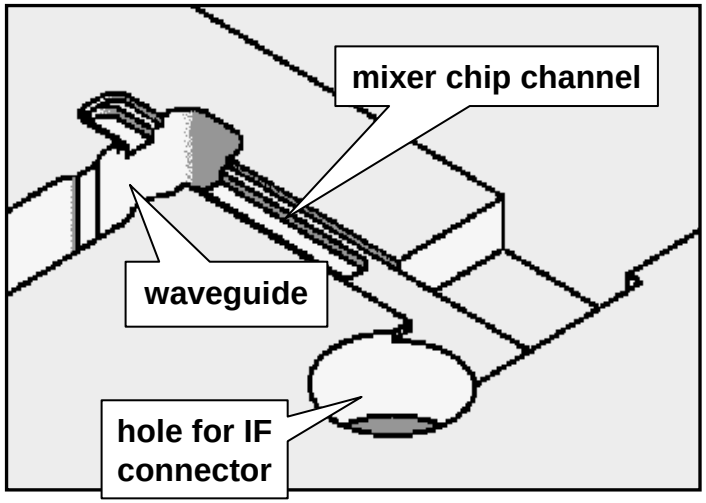
High Resolution Spectrometers

JPL

RF chip and mixer block







CALTECH

High Resolution Spectrometers

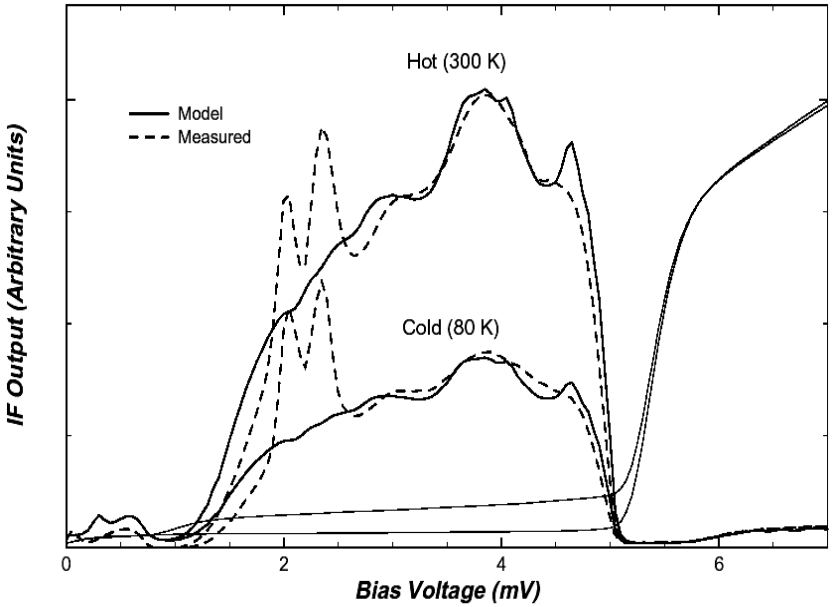
JPL

SuperMix simulation software

Powerful circuit modeling tool:

- C++ class library
- 47,000+ lines of code
- Linear and nonlinear modeling
- Arbitrarily complex designs
- Superconducting transmission lines
- SIS junctions – Tucker theory
- Developed at Caltech, 1997 to present
- Most powerful tool available for SIS development

SuperMix website:
www.submm.caltech.edu/supermix



Plot shows a comparison of measured data and model results for a 530 GHz receiver

- 4-slot, 8-junction, balanced mixer
- 45-port, 2-harmonic simulation

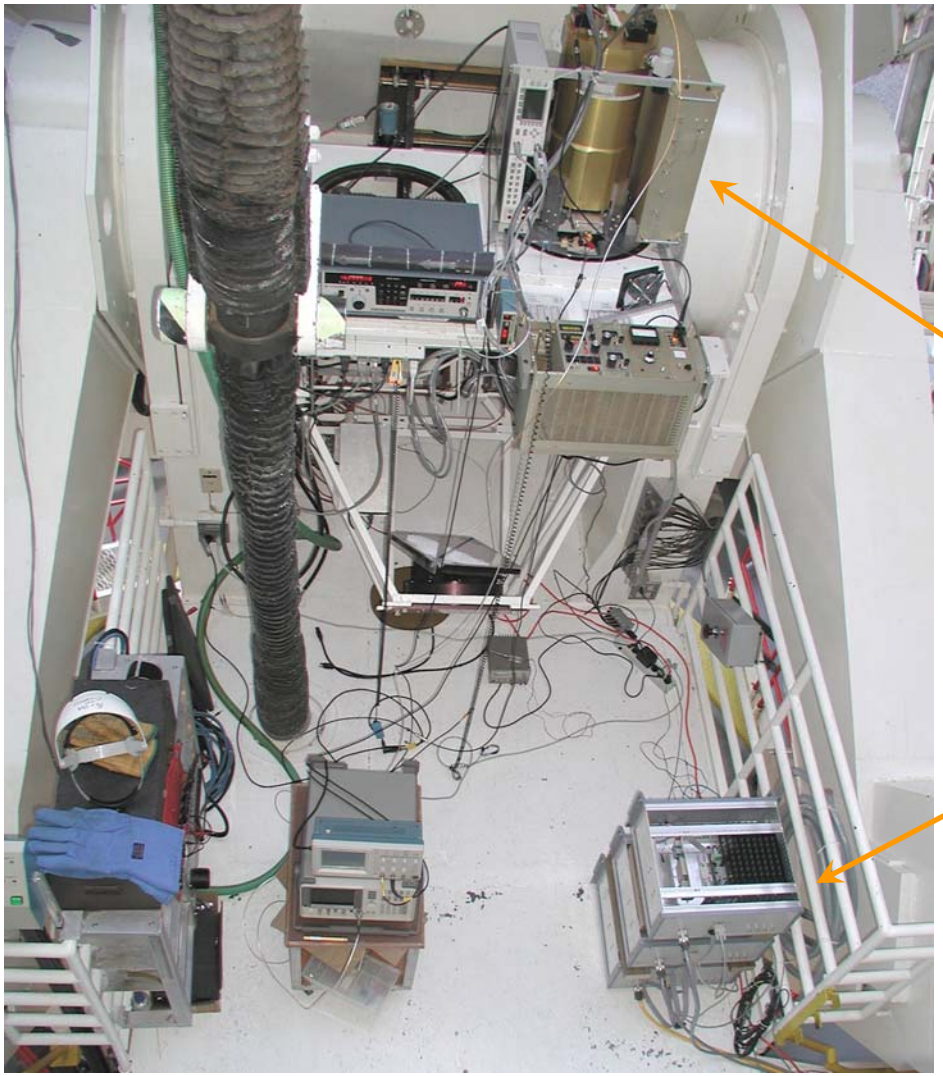
F. Rice, J. Ward, G. Chattopadhyay, J. Zmuidzinas

CALTECH

High Resolution Spectrometers

Z-Rx and WASPs at the CSO

JPL



August 2003

Front-end:
RF: 200-300 GHz
IF: 6-20 GHz
(28 GHz DSB)

Downconverter splits IF into 4 sub-bands

WASPs' nest with 3 3.5 GHz WASPs

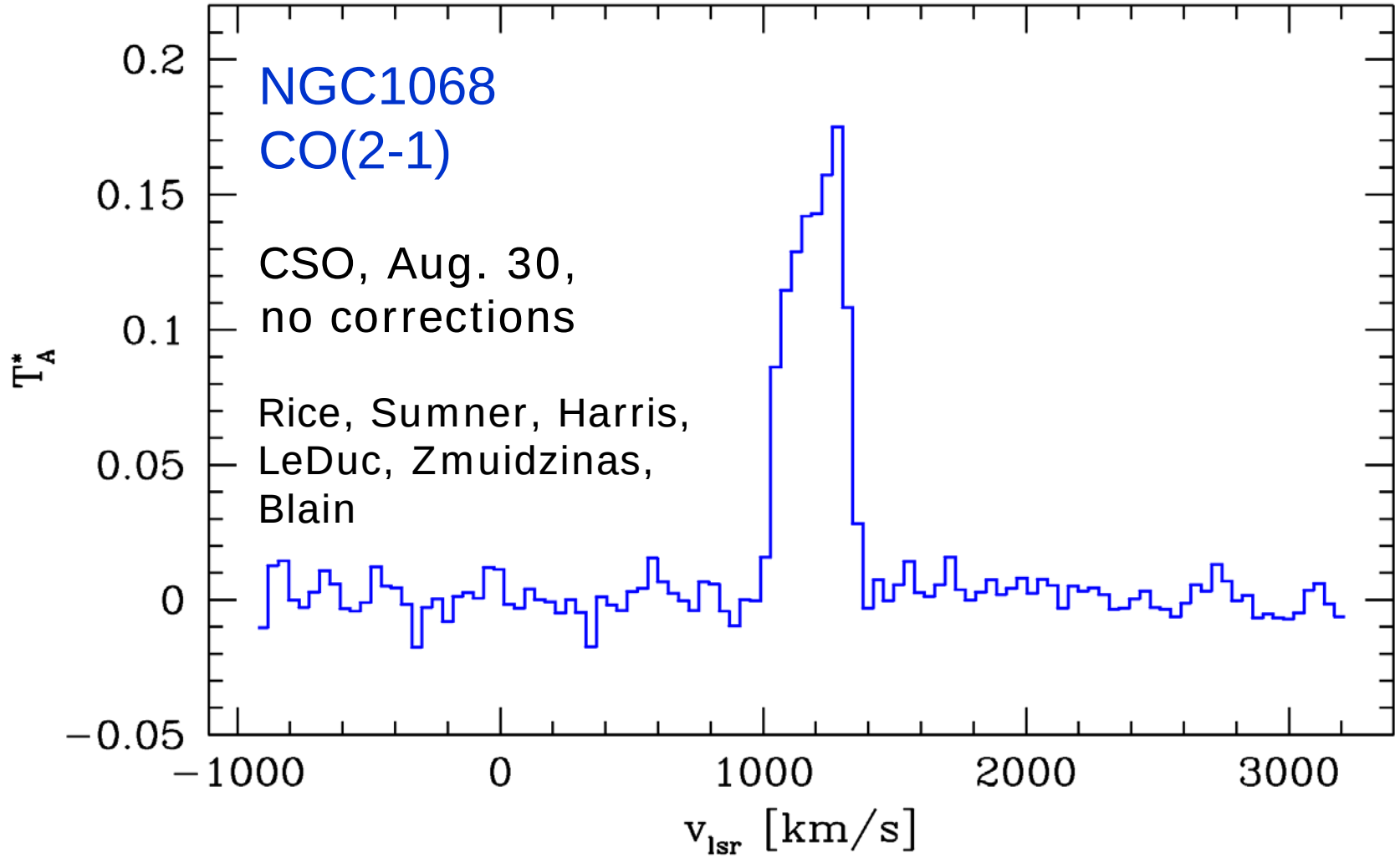
Rice, Sumner, Harris, LeDuc, Zmuidzinas, Blain

CALTECH

High Resolution Spectrometers

JPL

First-night Z-Rx and WASP spectrum



CALTECH

High Resolution Spectrometers

JPL

SIS-related personnel

Mick Edgar	**Engineer**	**SOFIA Instrument Lead**
Robert Hu	**Ph.D. student**	**MMIC IF amplifier**
Alexandre Karpov	**Engineer**	**HIFI/Herschel Lead**
Attila Kovacs	**Ph.D. student**	**CSO Receivers**
Jacob Kooi	**Engineer**	**CSO Receivers Lead**
Rick LeDuc	**JPL**	**Junction fabrication**
Sean Lin	**Engineer**	**SOFIA Instrument**
David Miller	**Engineer**	**HIFI/Herschel & SOFIA**
Tom Phillips	**Professor**	
Frank Rice	**Staff / Ph.D. student (LOA)**	**Wideband 230 Rx**
Jeff Stern	**JPL (CIT/TGP Ph.D.)**	**Junction fabrication**
Chip Sumner	**Ph.D. student**	**CSO & Wideband 230 Rx**
Doug Warden	**Technician**	**HIFI/Herschel**
Sandy Weinreb	**JPL/Caltech**	**MMIC IF amplifier**
Jonas Zmuidzinas	**Professor**	