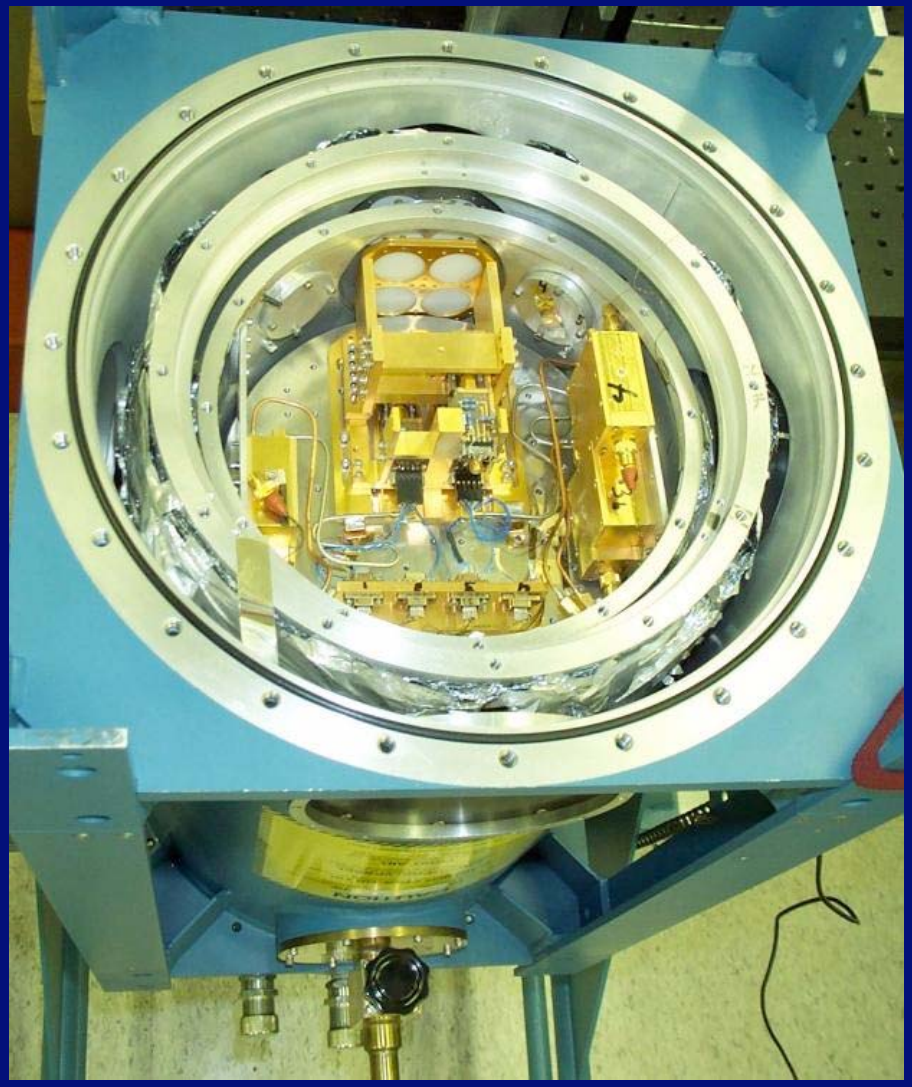
Prospects for Large Format Submillimeter Heterodyne Arrays

Why Now?

A Confluence of Technologies:

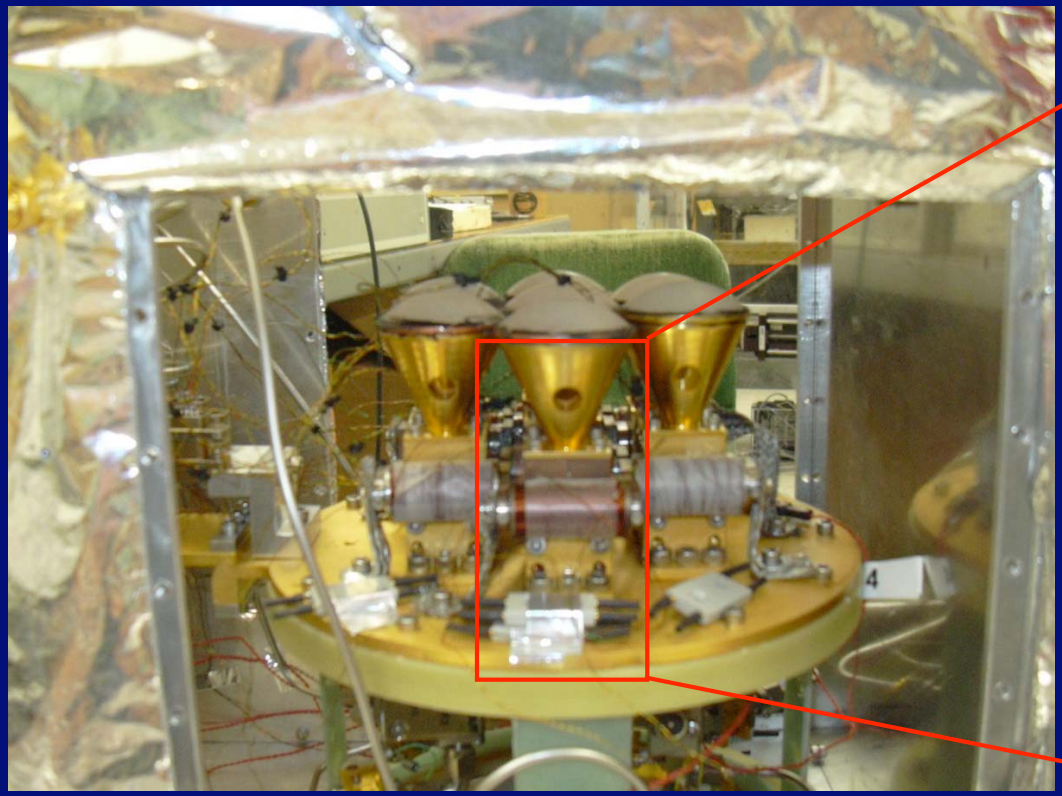
1) Mixer technology
2) LO technology
3) Micromachining
4) IF amplifiers
5) Digital signal processing
6) Experience with Array Packaging

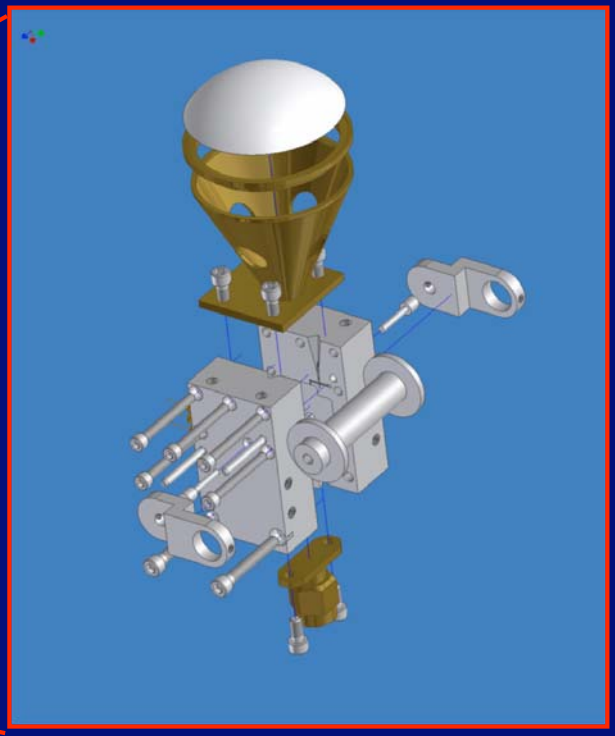
AST/RO PoleSTAR 810 GHz Array



- 810 GHz
- 4 Pixel
- ΔIF~1 GHz
- JPL LO Chain
- Trec~550-650 K
- 4 channel array AOS

DesertStar 7 pixel 345 GHz array



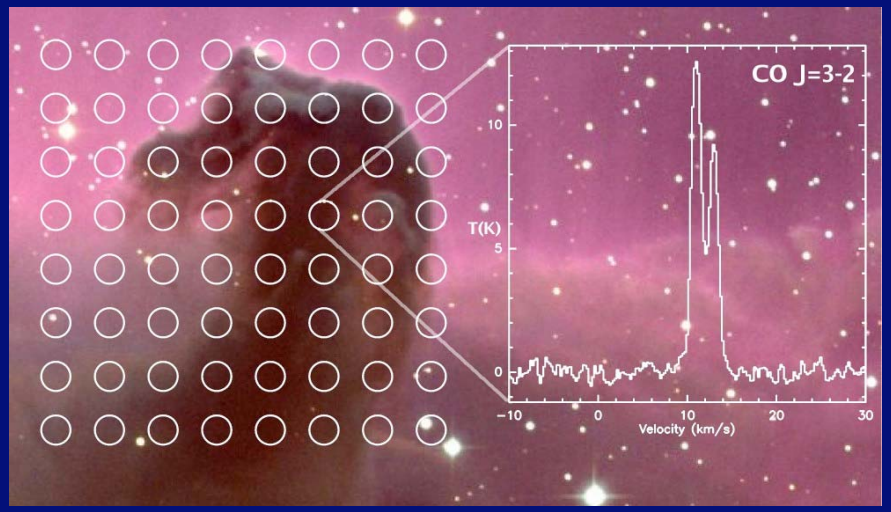


SuperCam 64 beam Heterodyne Array

•SuperCam is a 8x8 pixel heterodyne array receiver (imaging spectrometer), designed to operate in the 870 μm atmospheric window at the 10m Heinrich Hertz Telescope.

•SuperCam will be two orders of magnitude faster than current generation single pixel receivers..

•Key project: fully sampled ^{12}CO(3-2) and ^{13}CO(3-2) survey of over 500 square degrees of the Galactic plane.



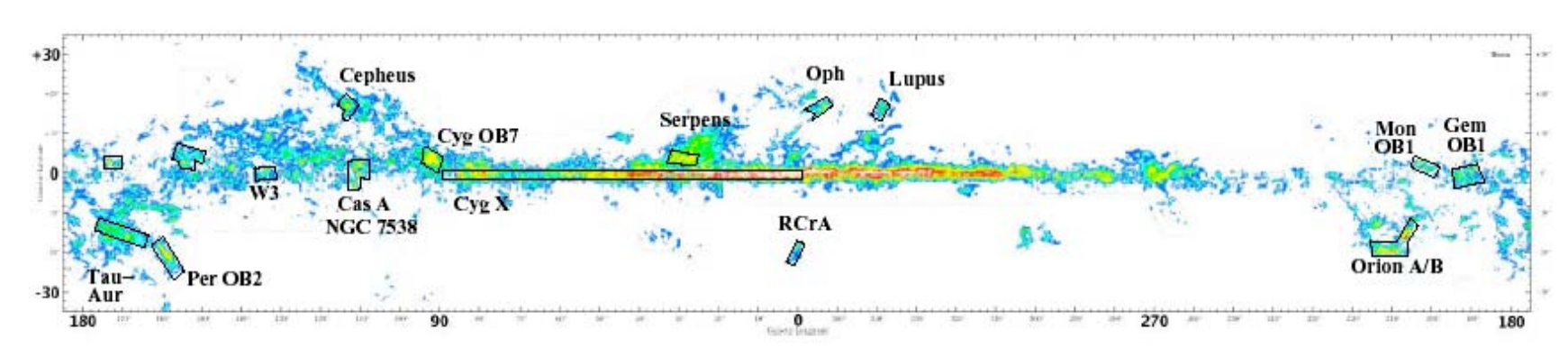
SuperCam Survey

•Proposed Survey: 500 sq. degrees including l=0-90°, and targeted star forming clouds, 22” resolution. 0.3 km/s velocity resolution

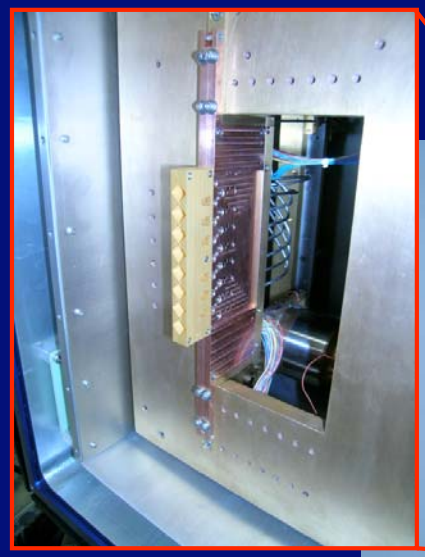
•^{12}CO(3-2) and ^{13}CO(3-2)

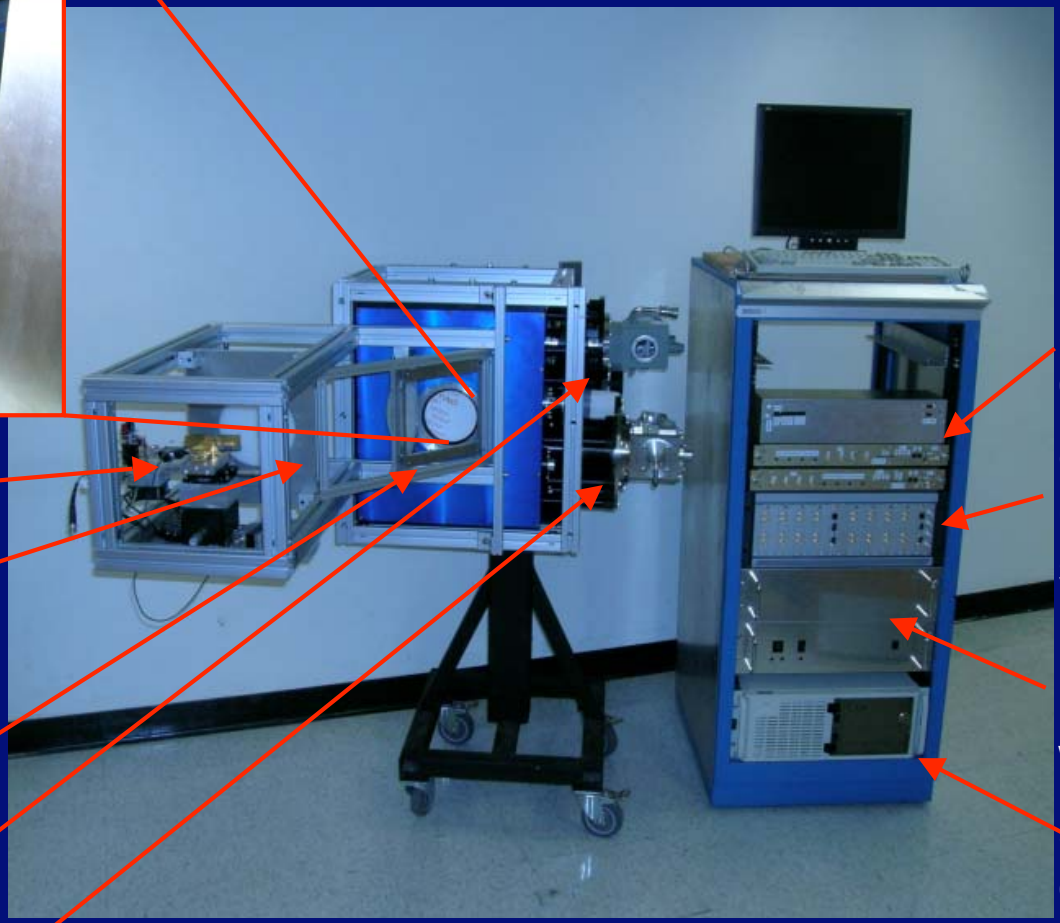
•33 days of observing time per line, including overhead (1.6 hours/sq. degree to σ ~0.35K) with 64 beam SuperCam (T_{rec}~65K)

•A single beam, dual polarization receiver (T_{rec}~65K) would take 6 years of observing time per line.



SuperCam System





LO System with 8 way power divider

LO Optics

LO Beamsplitter & dewar window

CTI 350 cooler

Sumitomo 4K cooler

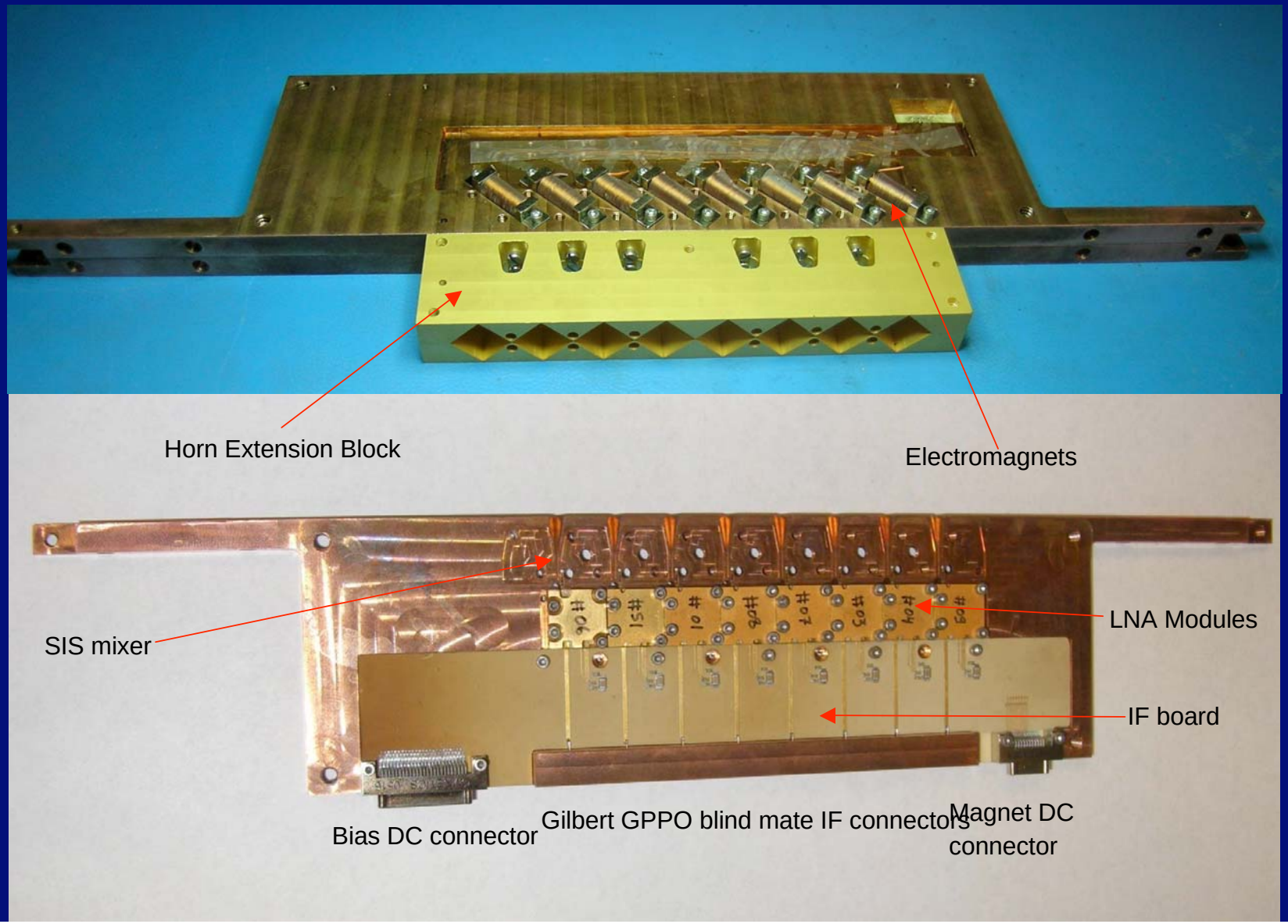
2- 8 channel downconverter modules

Omnisys Spectrometer 64x250 MHz complete system

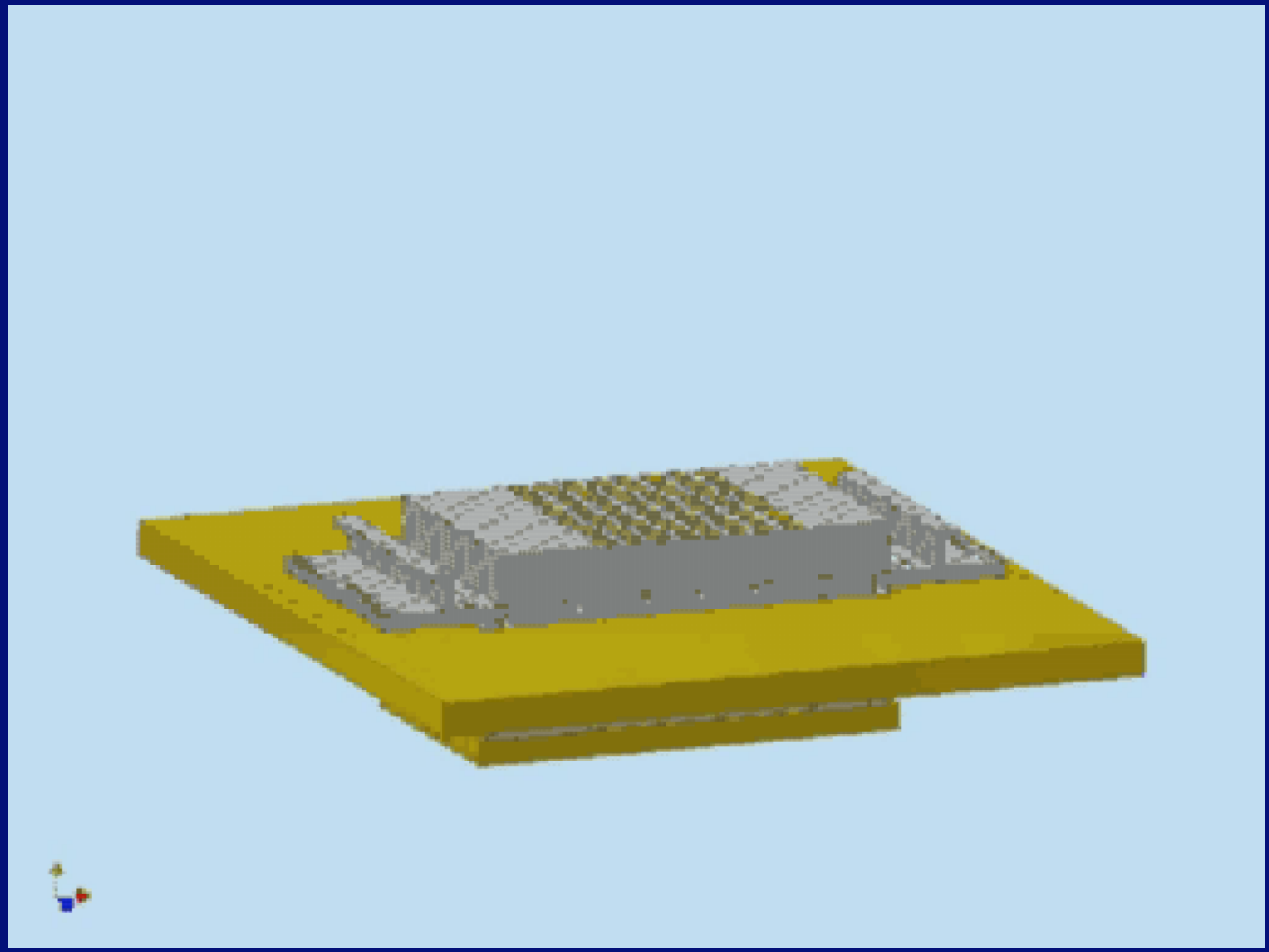
Prototype 8 channel bias system (1 6U card with power supplies)

Spectrometer and bias control computer

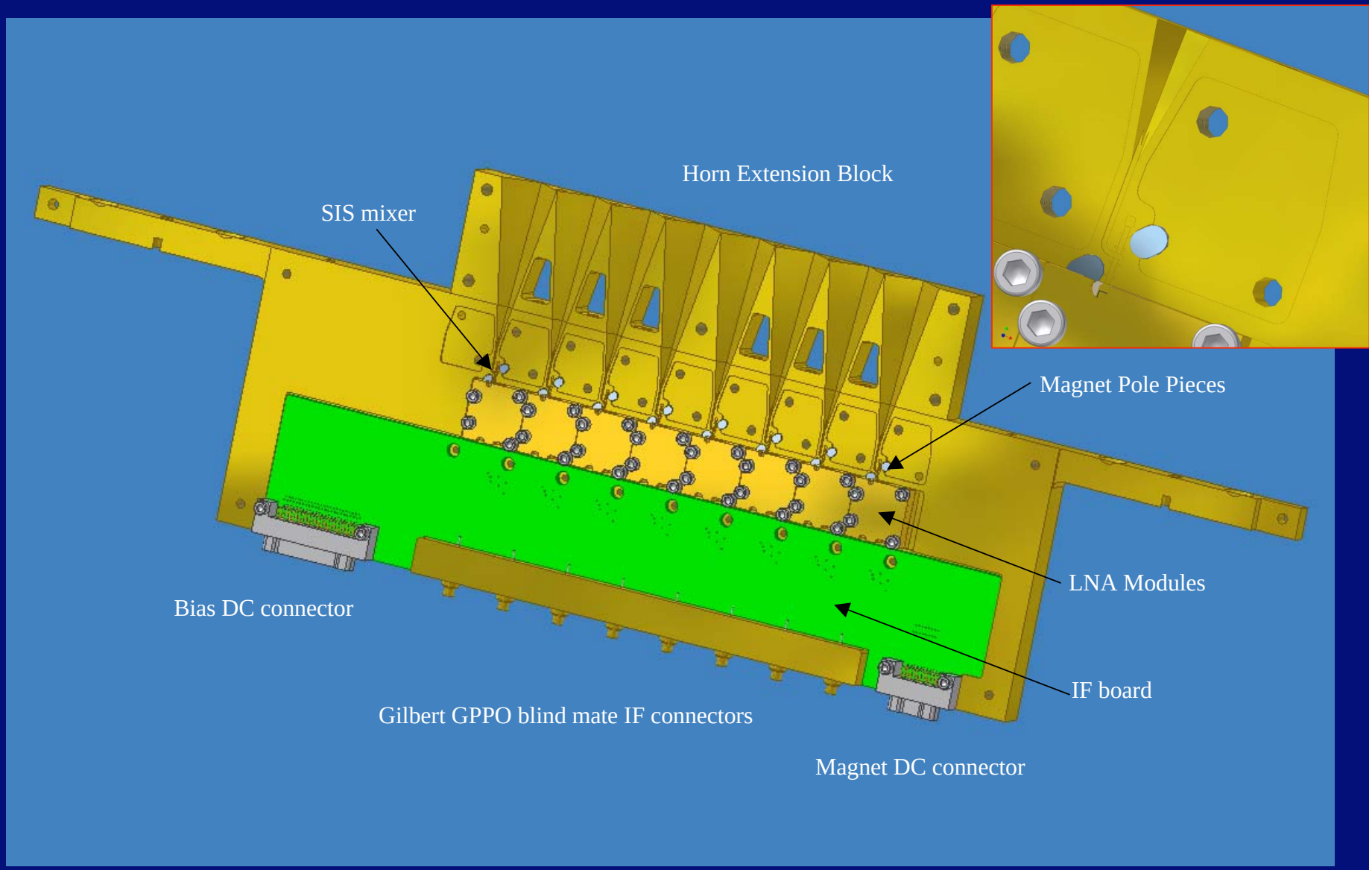
SuperCam 1x8 Subarray Assembly



SuperCam Integrated FPU

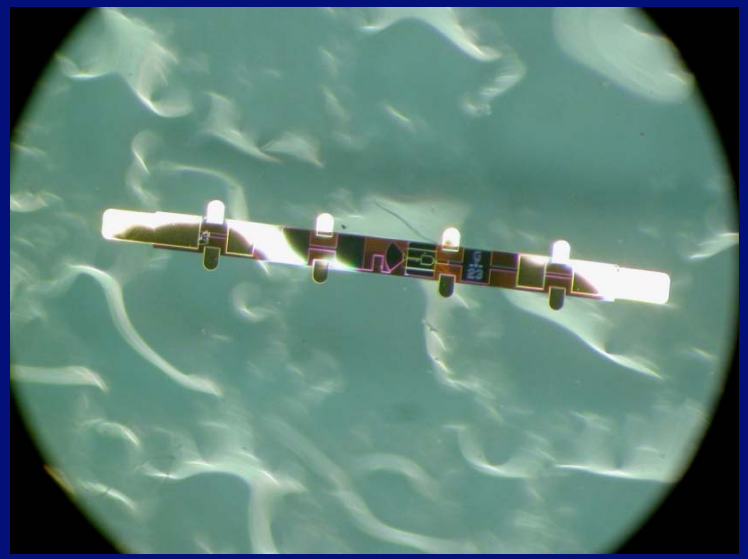


SuperCam 1x8 Mixer Module

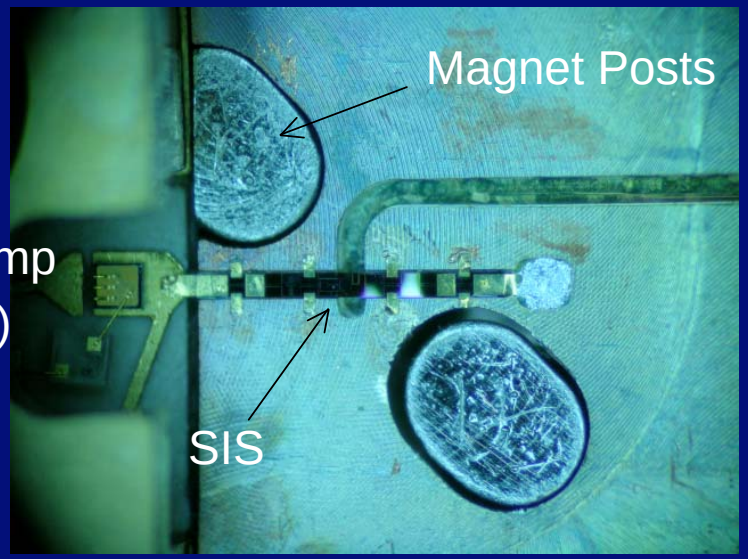


SuperCam beam-lead on SOI SIS devices

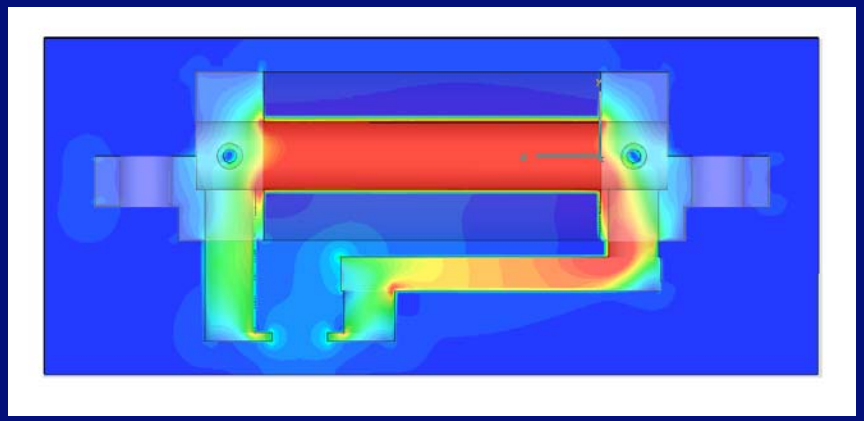
J.



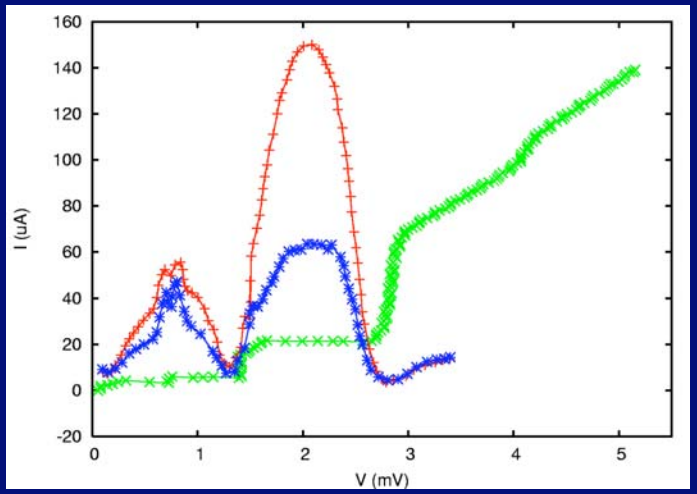
3 micron SOI (Kooi, UVa)



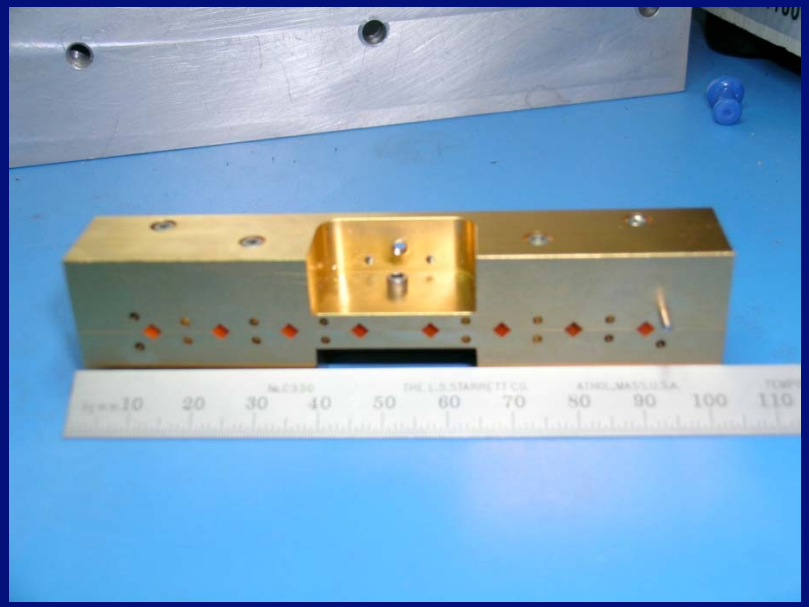
IF Amp
(CIT)



High Efficiency Magnet (Groppi)



Local Oscillator

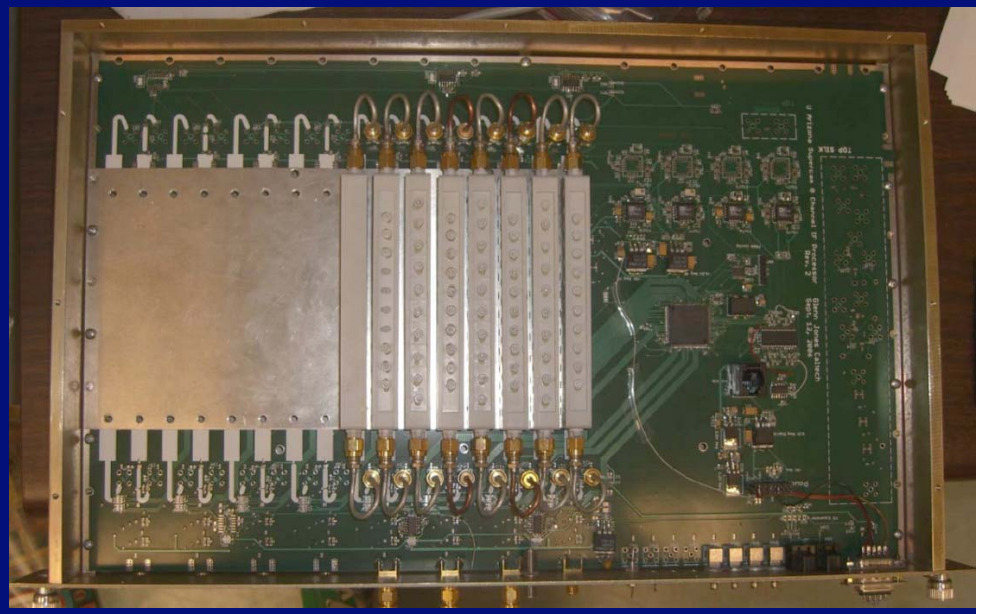


- Virginia Diodes synthesizer driven planar diode LO source
- 2mW power output, tunable from 320-370 GHz
- Waveguide LO power divider

Power Divider Y-Splitter

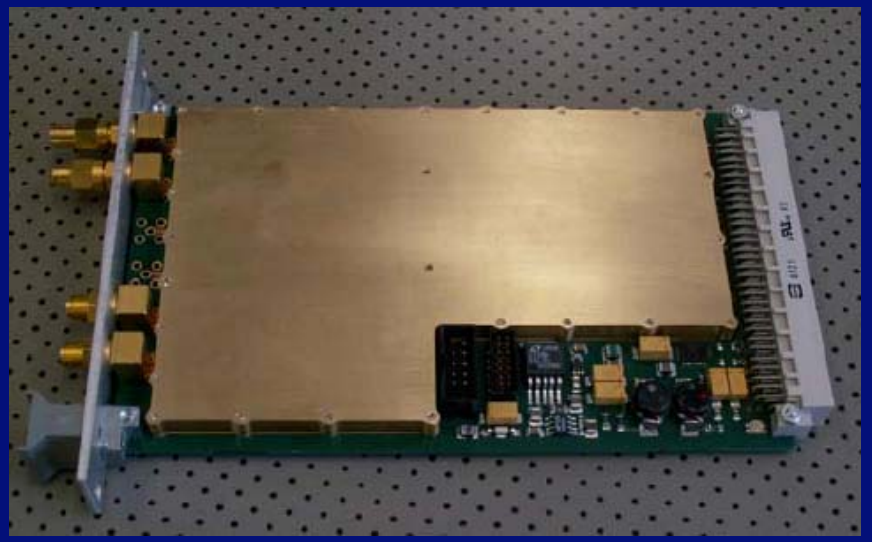
IF Processor

- 8 channel IF downconverter with total power metering, selectable 512 MHz/256MHz BW per channel, ~50 dB gain
- Designed and built by G. Jones and J. Bardin
- Prototype 8 channel IF processor complete and tested, end to end with SIS receiver, and Omnisys backend
- 2nd generation processor finished and undergoing lab testing



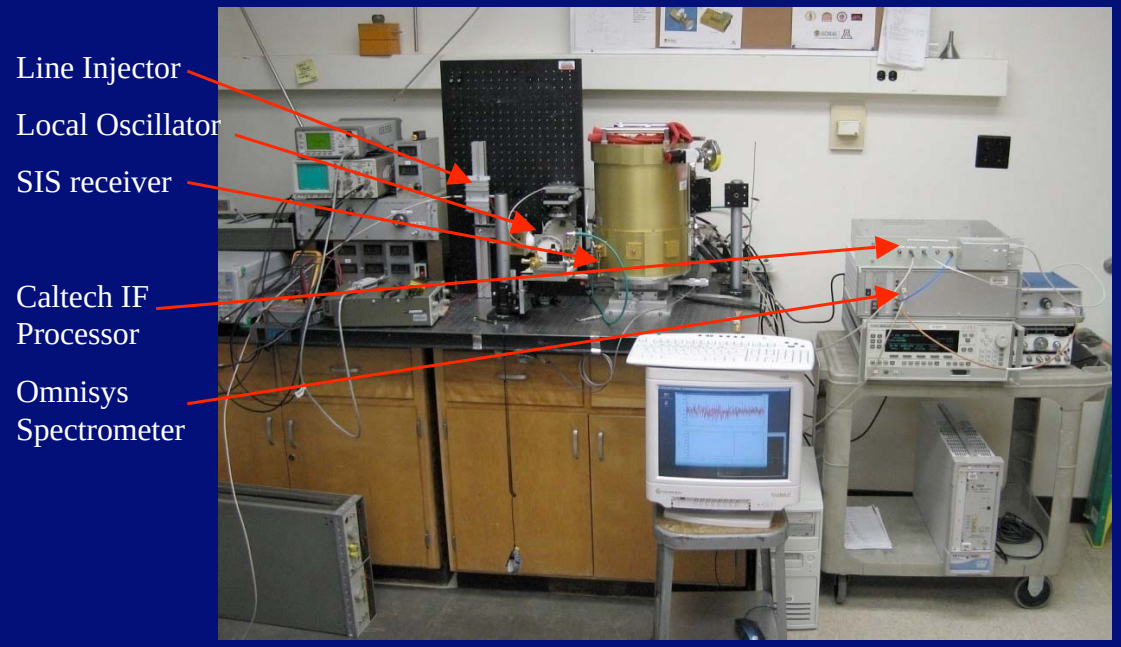
SuperCam Spectrometer System

- Built by Omnisys AB
- Real-Time FFT system
- Virtex 4 SX55 FPGA
- 4x 500 MHz or 2x 1 GHz per board
- 1024 channels
- power consumption 25W per board
- Ethernet interface
- SuperCam spectrometer initially uses 8 identical boards for 64 x 250 MHz or 16 x 1 GHz operation

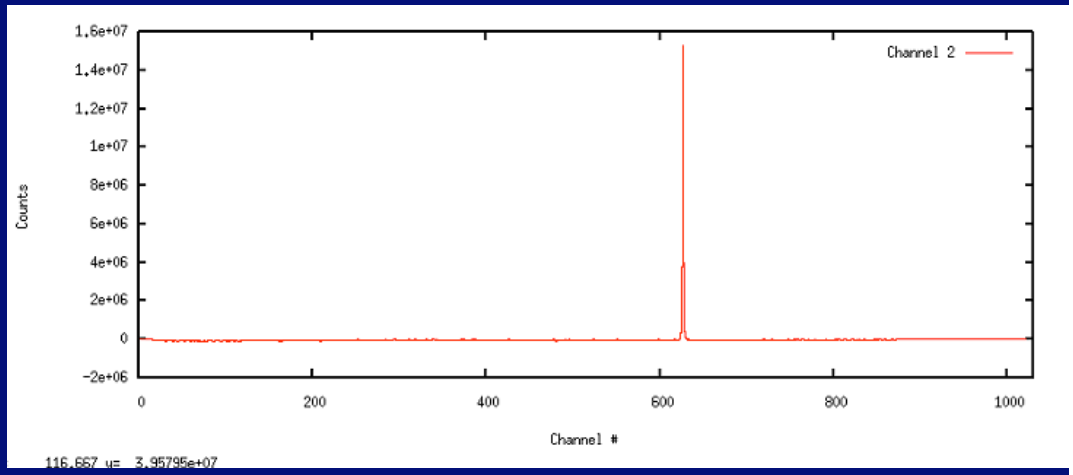


End to End Test

- End-to-end tests were done using the full SuperCam IF and spectrometer system, with a SIS receiver and line injector.
- The SIS mixer with integrated LNA
- The line injector fed the receiver a 345 GHz line
- The setup was used for long term stability testing of the system as well:
  - Noise temperature less than +/- 10% variation across the band
  - Allan time (spectroscopic): 650 seconds

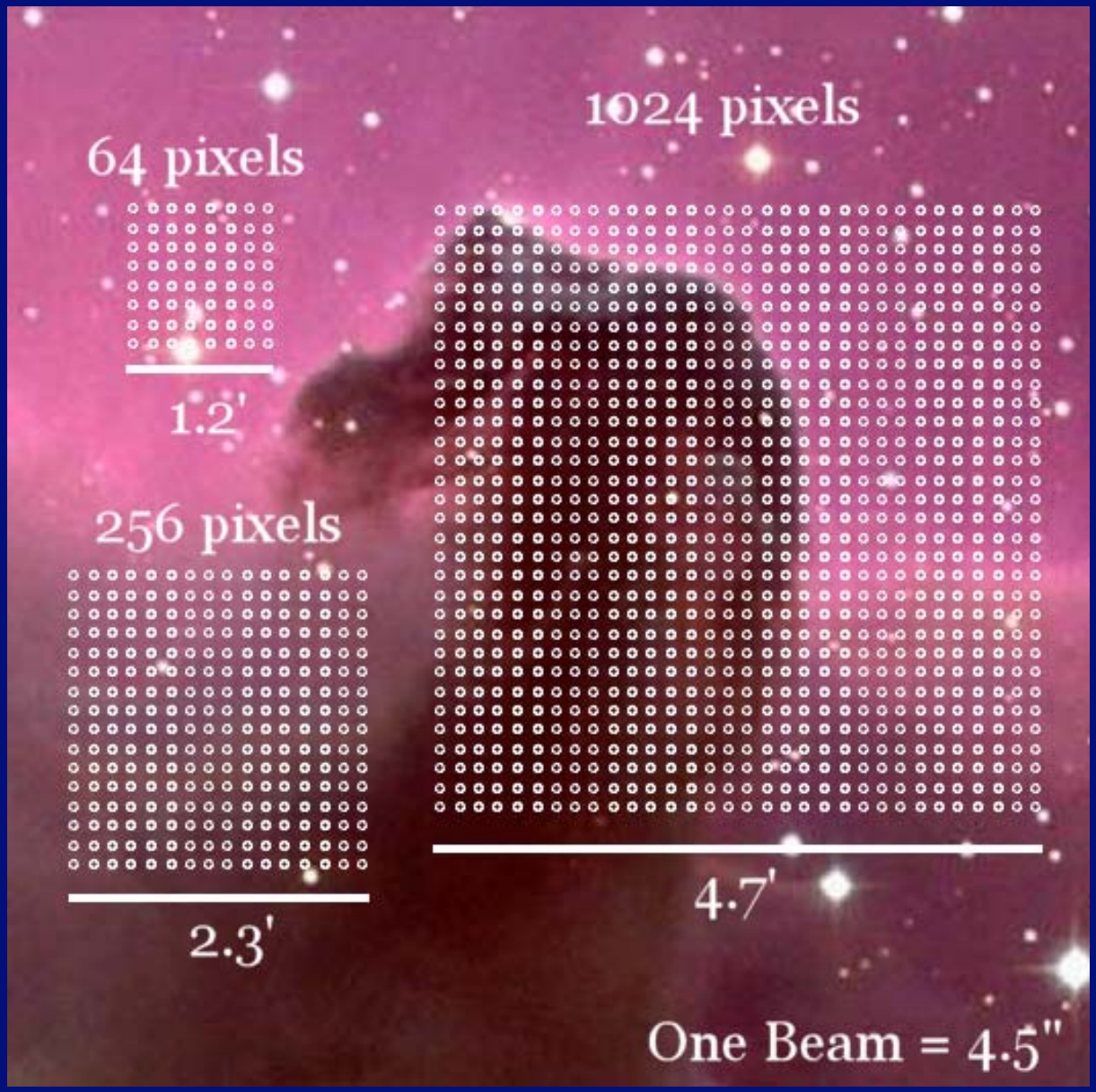


End-to-End test setup

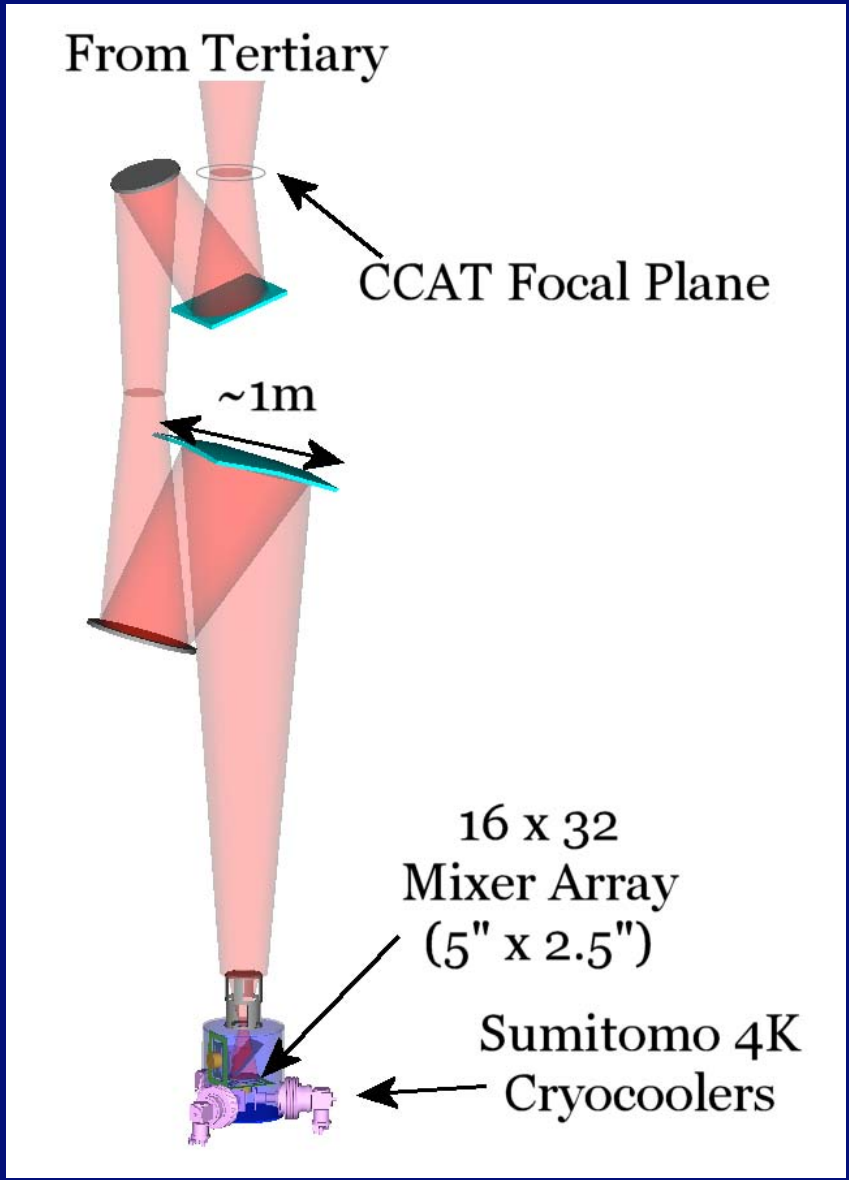


End-to-end Spectrum

Prospects for Large Arrays on CCAT



A Kilo- Pixel Array for CCAT

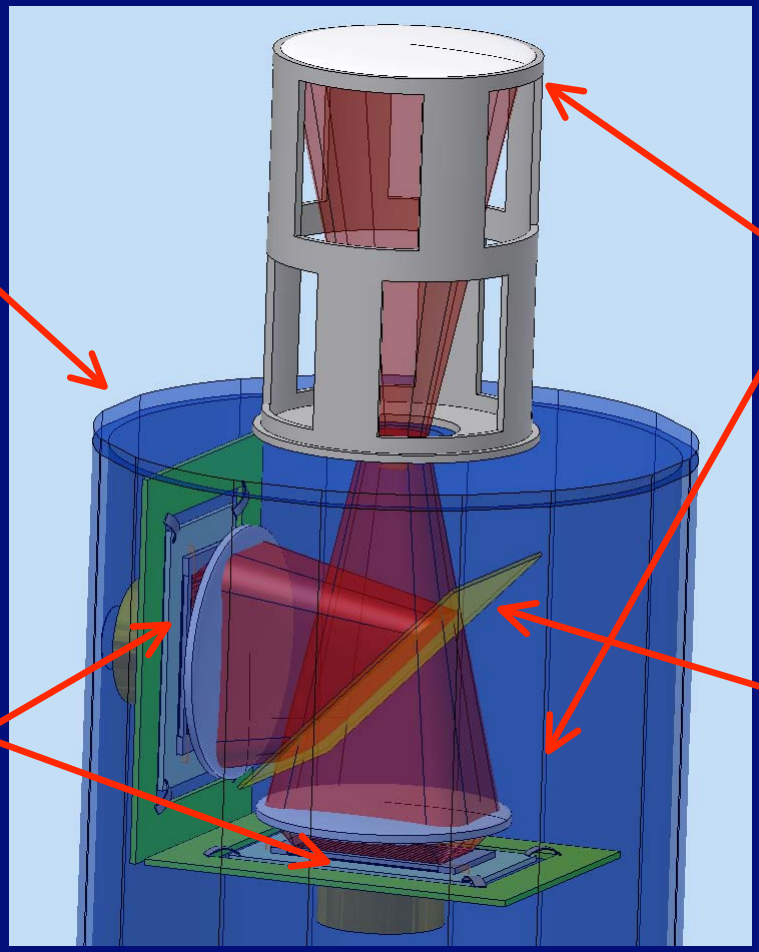


- Stacked,16x8 arrays
- MMIC IF modules
- On-board IF processor
- Solid-State LOs (~5mW)
- >2 GHz/per pixel
- Cryo-Coolers

Array FPU

Cryostat
Optics Head

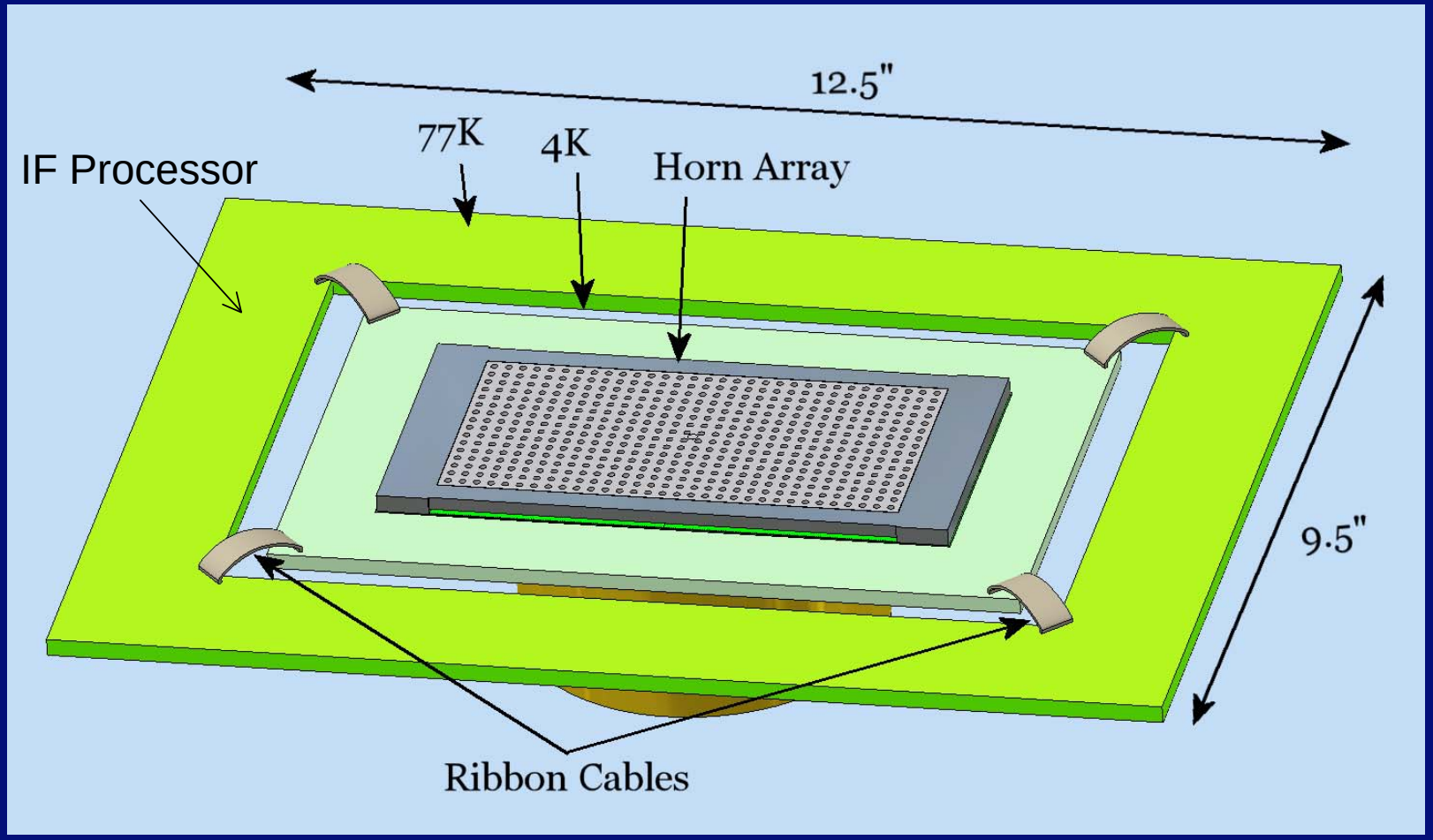
16x32 Arrays



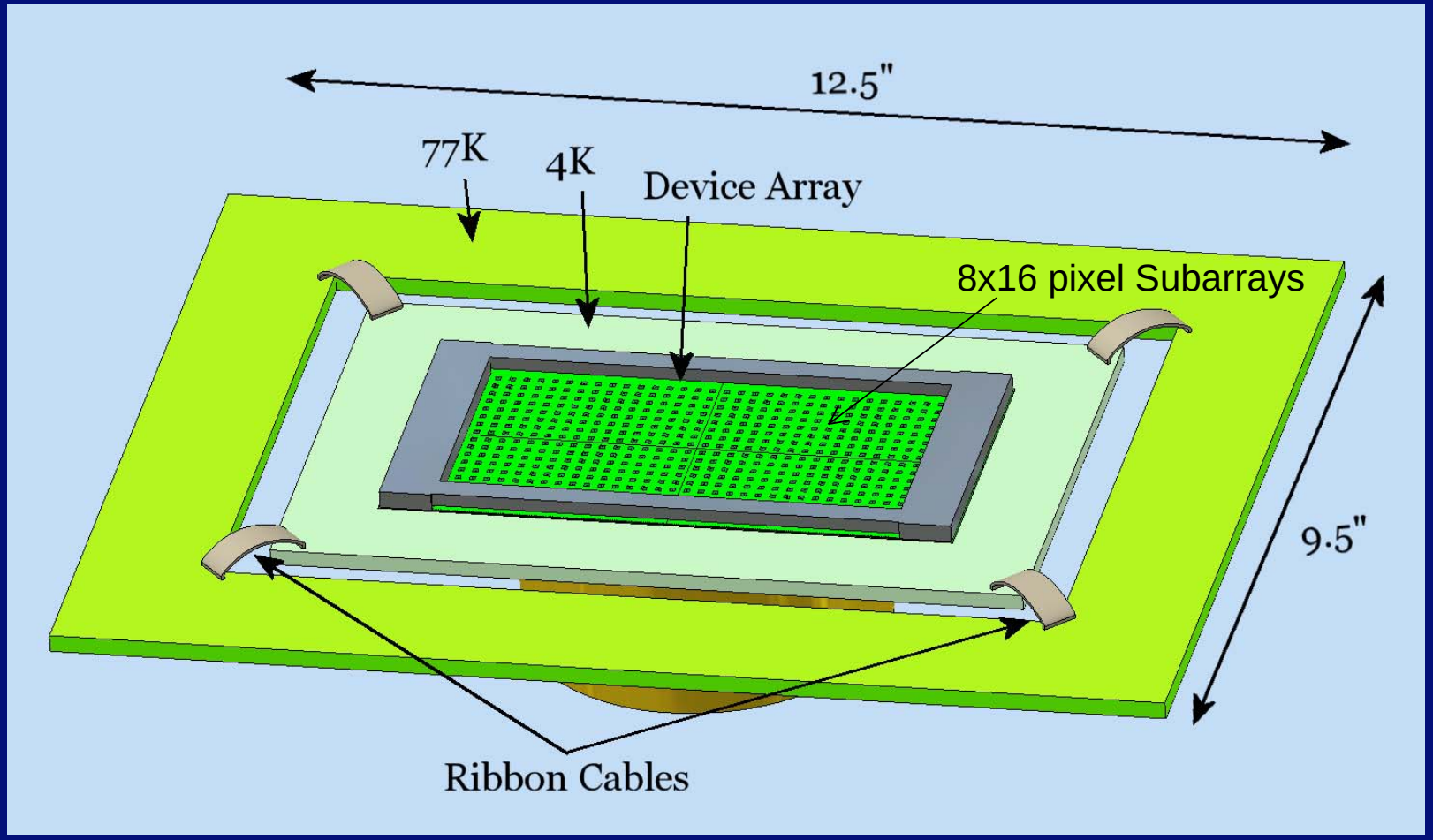
Re-Imaging
Lenses

Polarizing
Grid

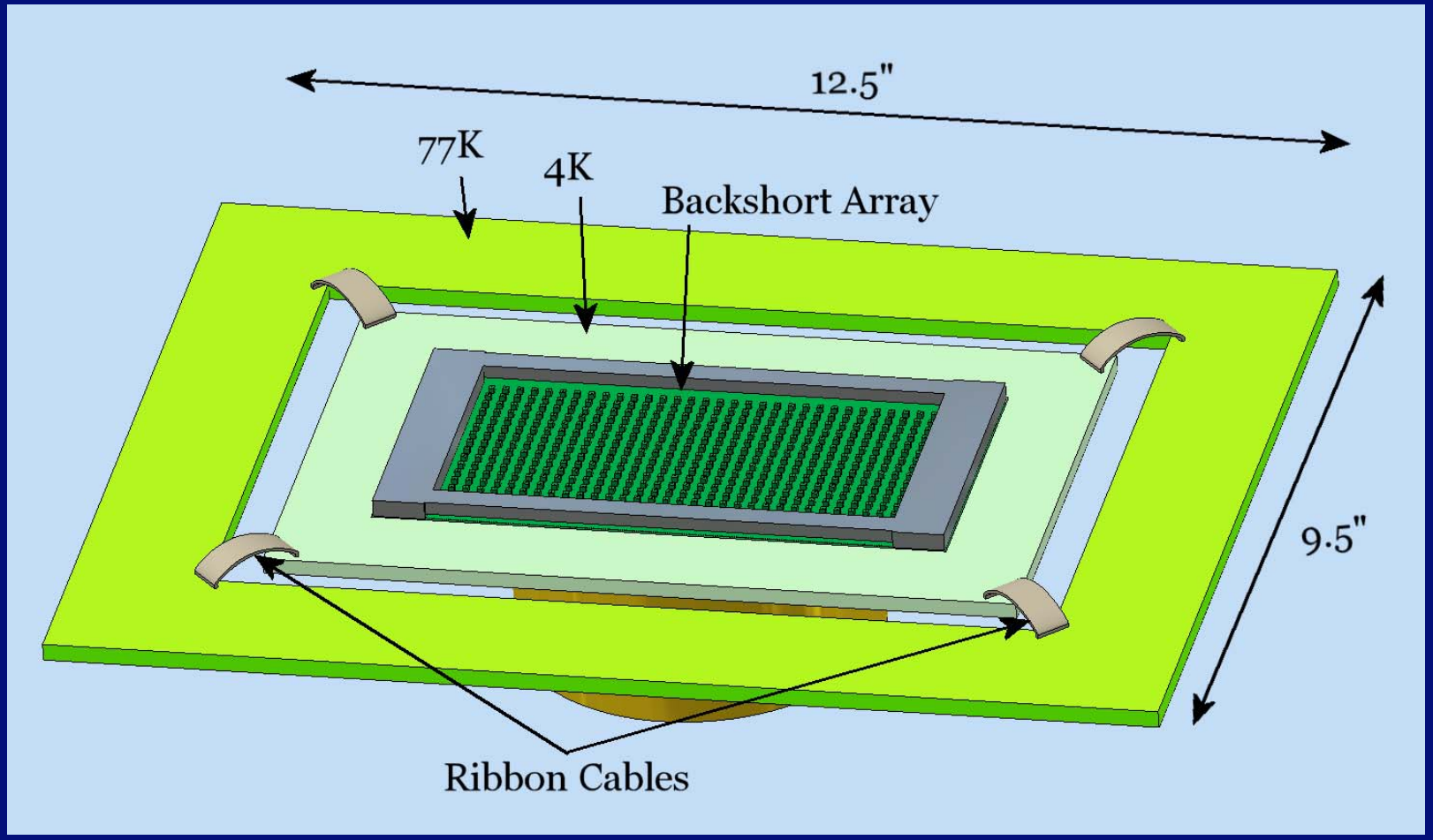
16x32 Array Concept



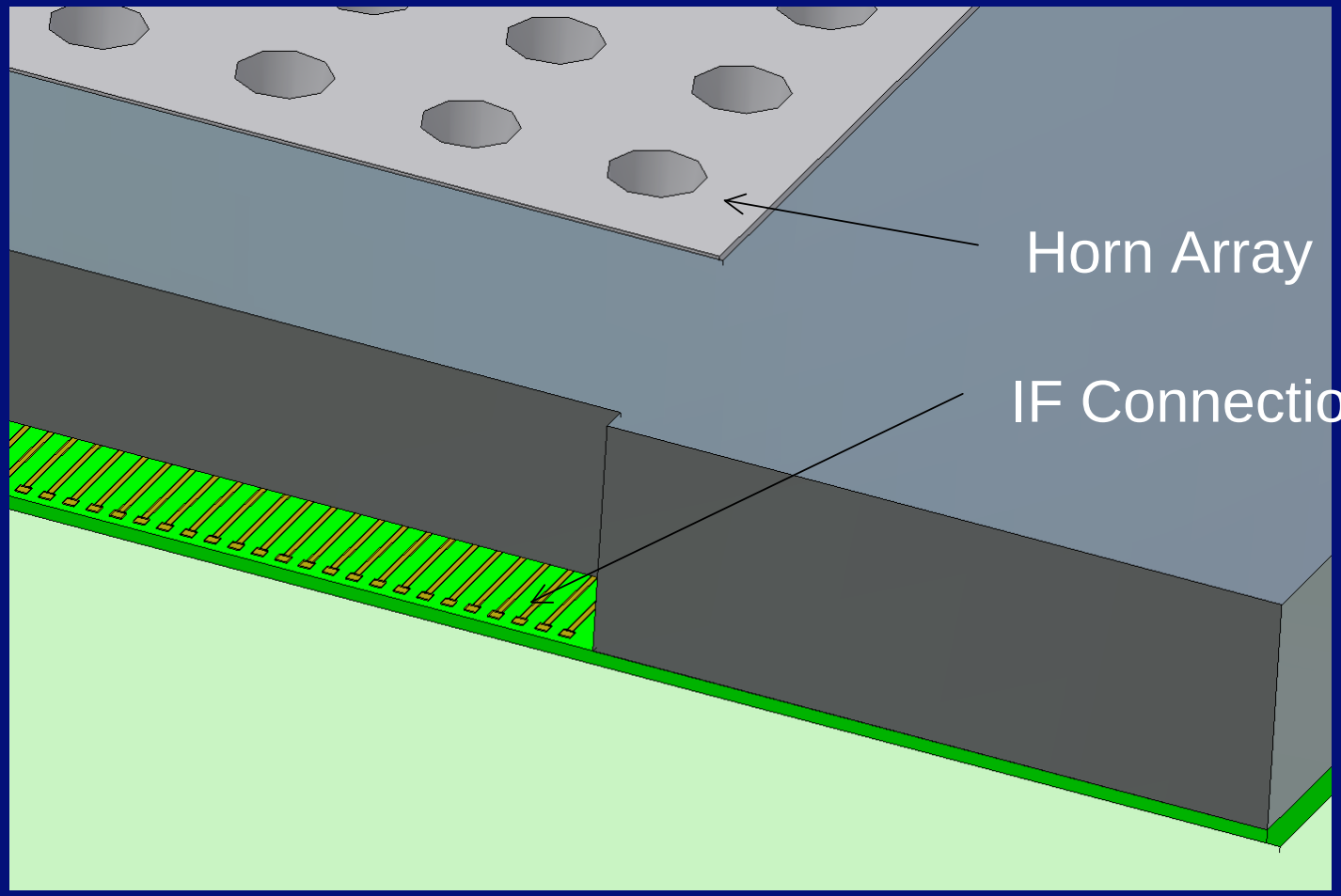
16x32 Array Concept



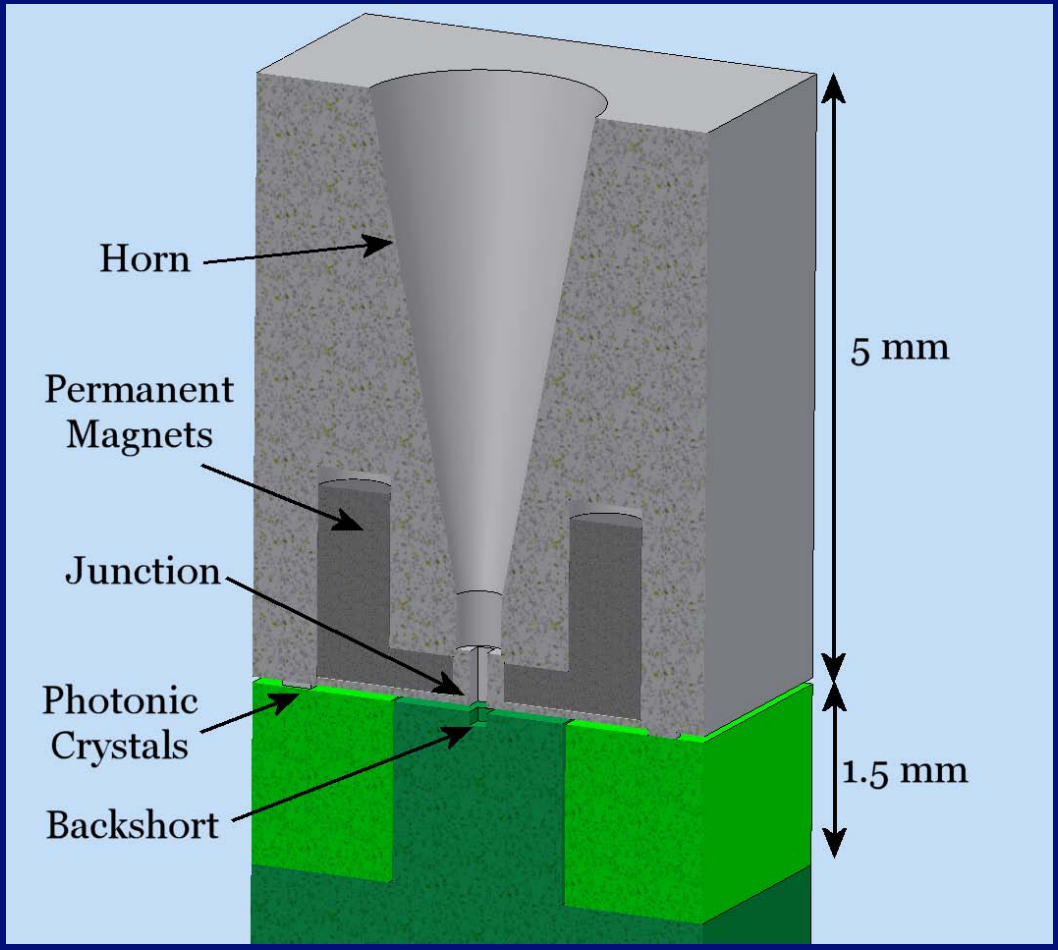
16x32 Array Concept



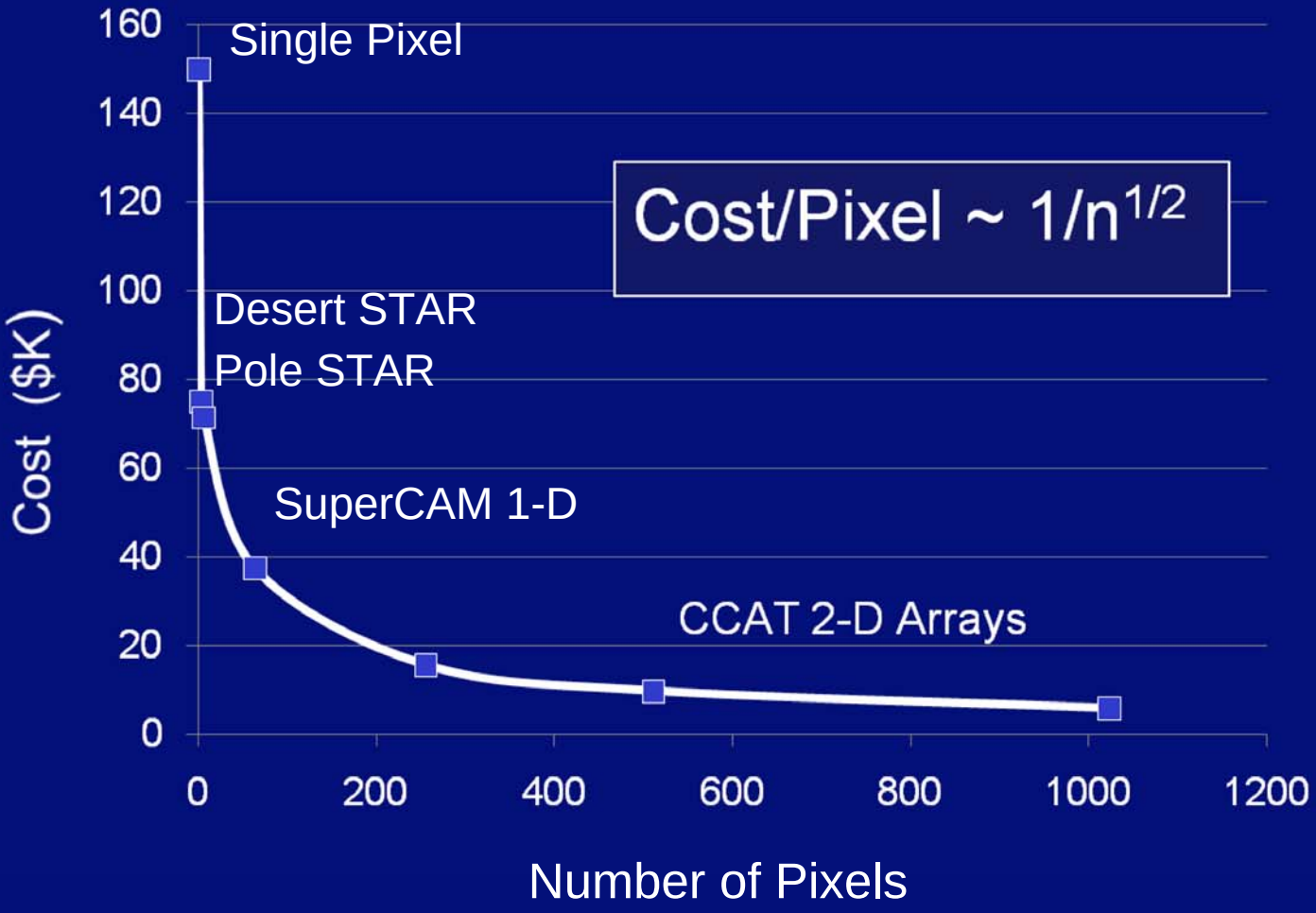
16x32 Array Concept



Stacked Pixel Concept



Cost/Pixel vs. Size



Summary

- A confluence of technologies now permits the realization of large format heterodyne arrays.
- Integration essential to increasing robustness and minimizing cost.
- By swapping mixer arrays and expanding the spectrometer (1 GHz/pixel), 64 pixel SuperCam could be used on CCAT at 650/810 GHz (~$1M).
- Conduct a design study to explore large 2-D integrated arrays for CCAT.