MMIC Receiver Systems Developed at the University of Massachusetts, Amherst

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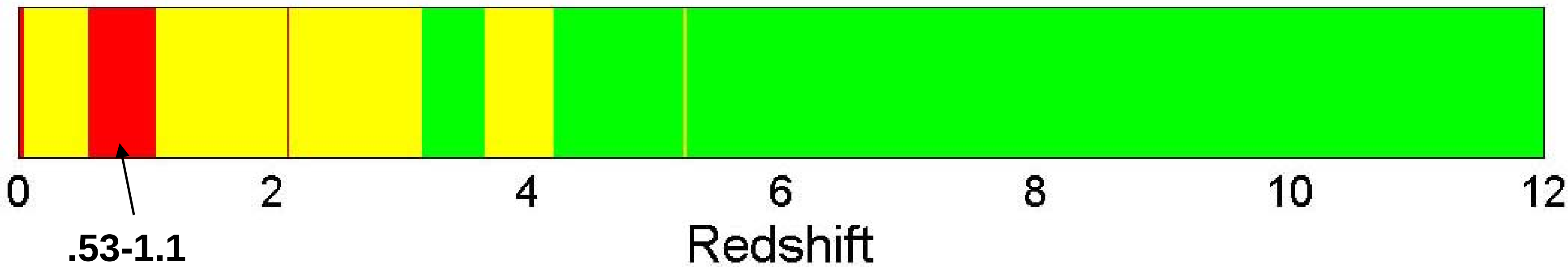
Redshift Search Receiver for LMT

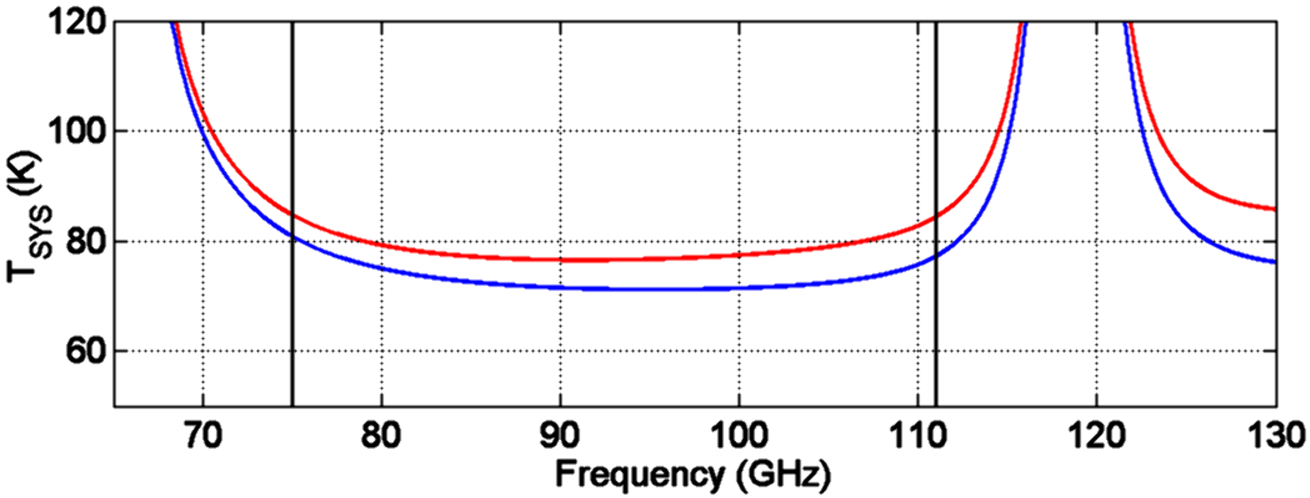
- 74-110.5 GHz covered instantaneously with a receiver/spectrometer having 31 MHz resolution.
- Uses very wideband amplifiers operated at 20 K.
- Two dual polarization beams (4 receivers).
- High-speed electrical beam switch for very flat baselines.
- Backend spectrometer is analog autocorrelator with 36.5 GHz bandwidth per receiver,146 GHz total!

Frequency Range

- Strongest spectral lines from CO and C (492, 810 GHz).
- 3 mm window is well-suited to measure CO up to z ~ 6,
  C(I) z = 4-10.



Redshift coverage in 74-110.5 GHz band, red no CO line, yellow; one line, green; two lines.



System noise temp with Trcvr = 60 K and 2 and 5 mm PWV.

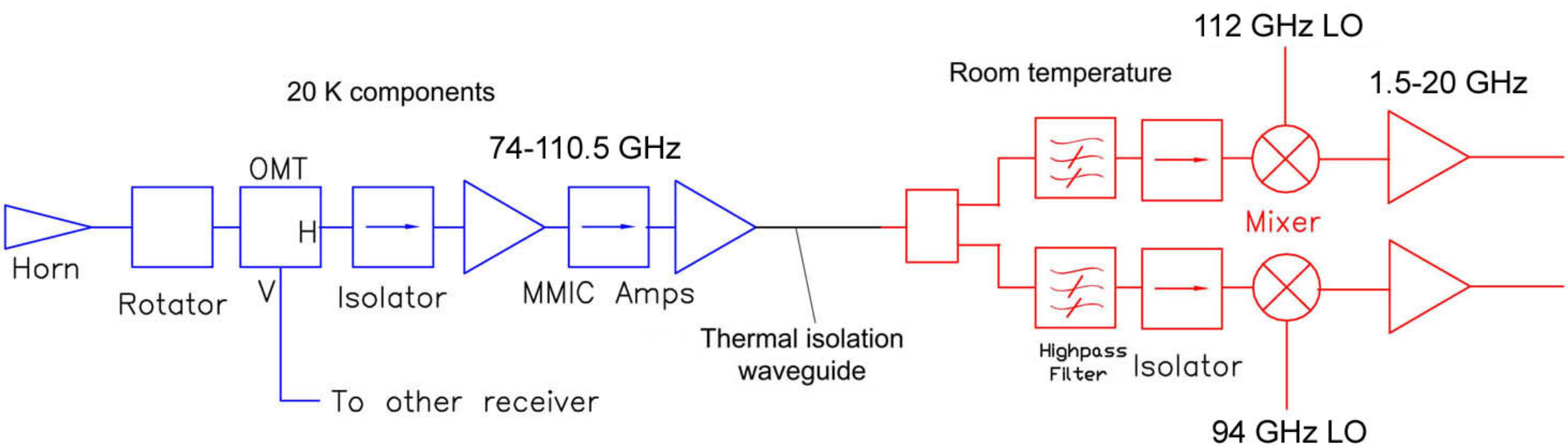
Front end design

•Front end like SEQUOIA, using InP MMIC amps, except that both signal polarizations combined into a single horn.

•Entire signal band down-converted at once to two 18.5 GHz wide IF bands.

•Four receivers with 8 IF outputs in total.

•Each spectrometer is 6.5 GHz wide, 24 in total.

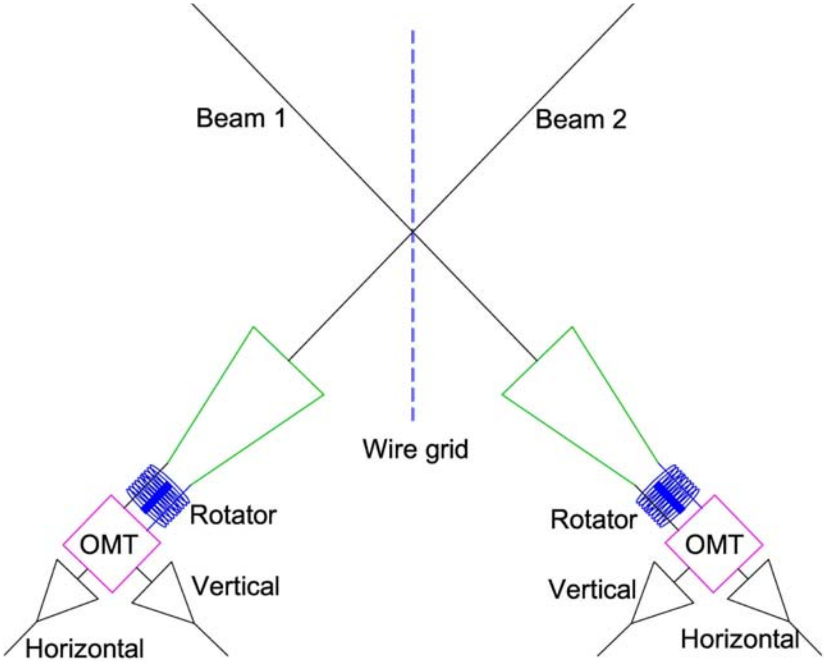


Beamswitch

•Heterodyne receivers require a fast (~1 KHz) beam switch to produce flat spectral baselines over wide bandwidth.

•This receiver uses a polarization switch to change polarization 0 ⇔ 90° at 1 KHz rate.

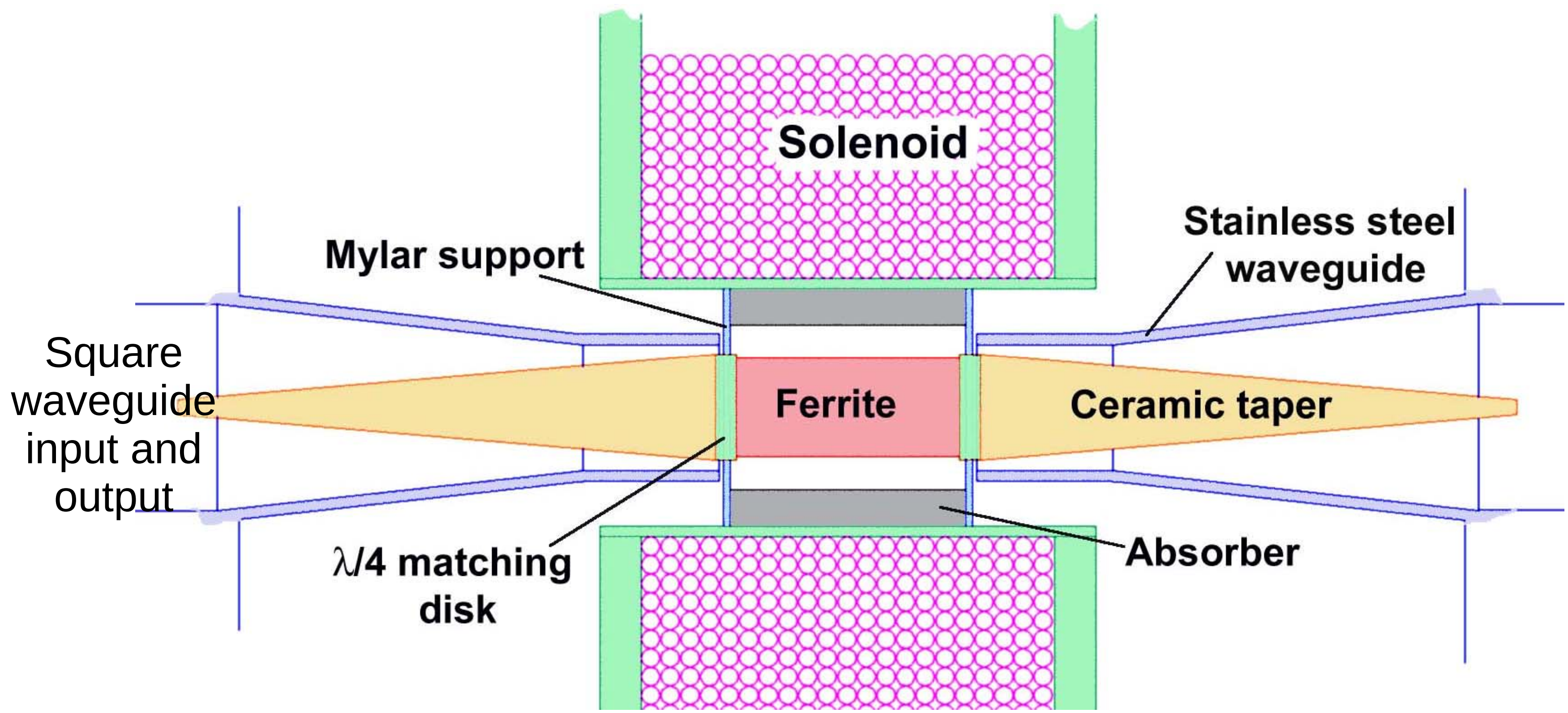
•Wire grid in front of rotator either passes or reflects beam depending on polarization state.

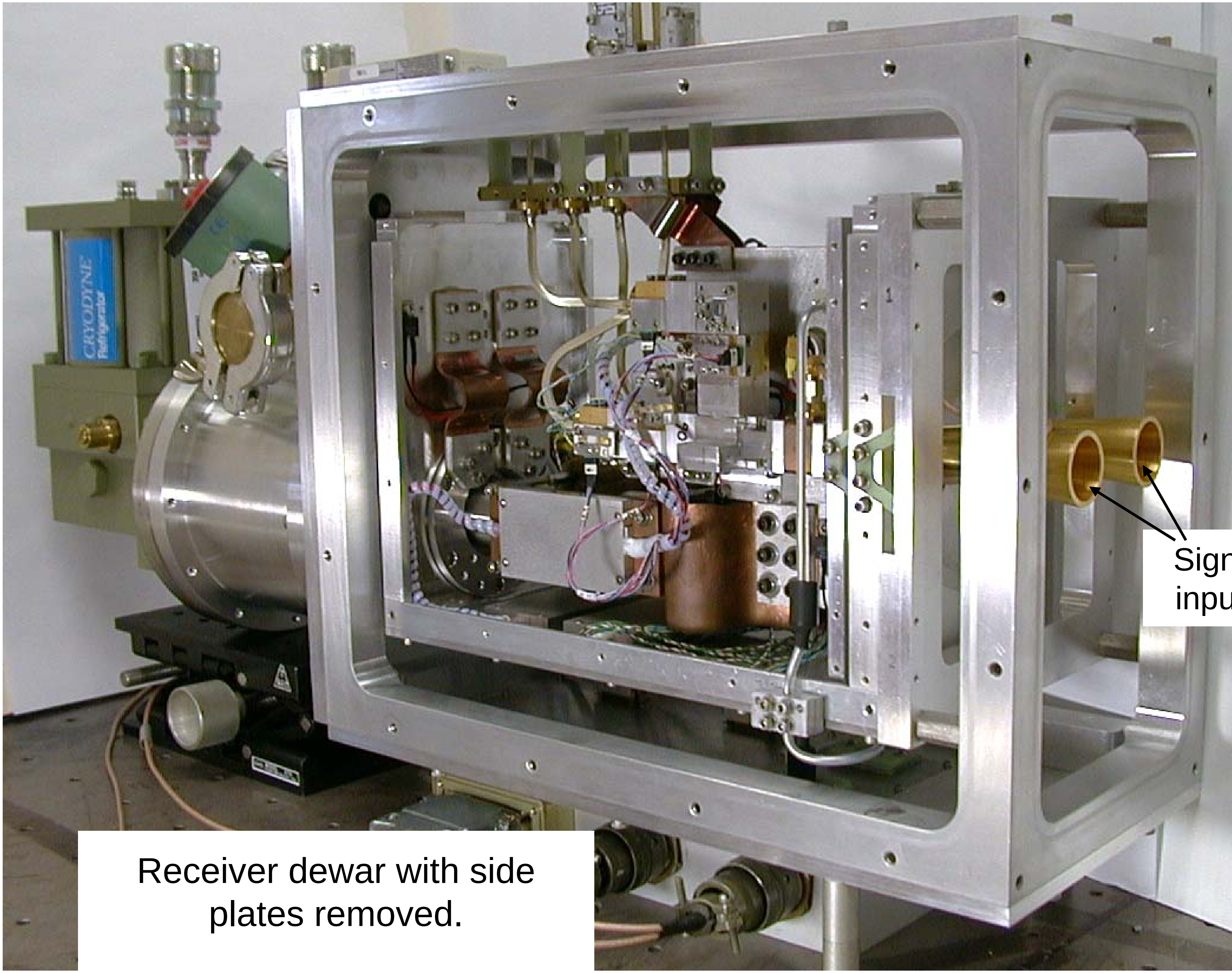


Two dual polarized beams. One beam always on source. Separation 5 arcmin at FCRAO, 1.4 arcmin at LMT.

Polarization Switch

- First wide band low loss electrical switch at 3mm.
- Beam couples into a ferrite (magnetic material with low loss) which has very large Faraday rotation coefficient.
- Within ferrite, polarization is rotated by ±45° using a switched magnetic field, switching time <10 μsec.

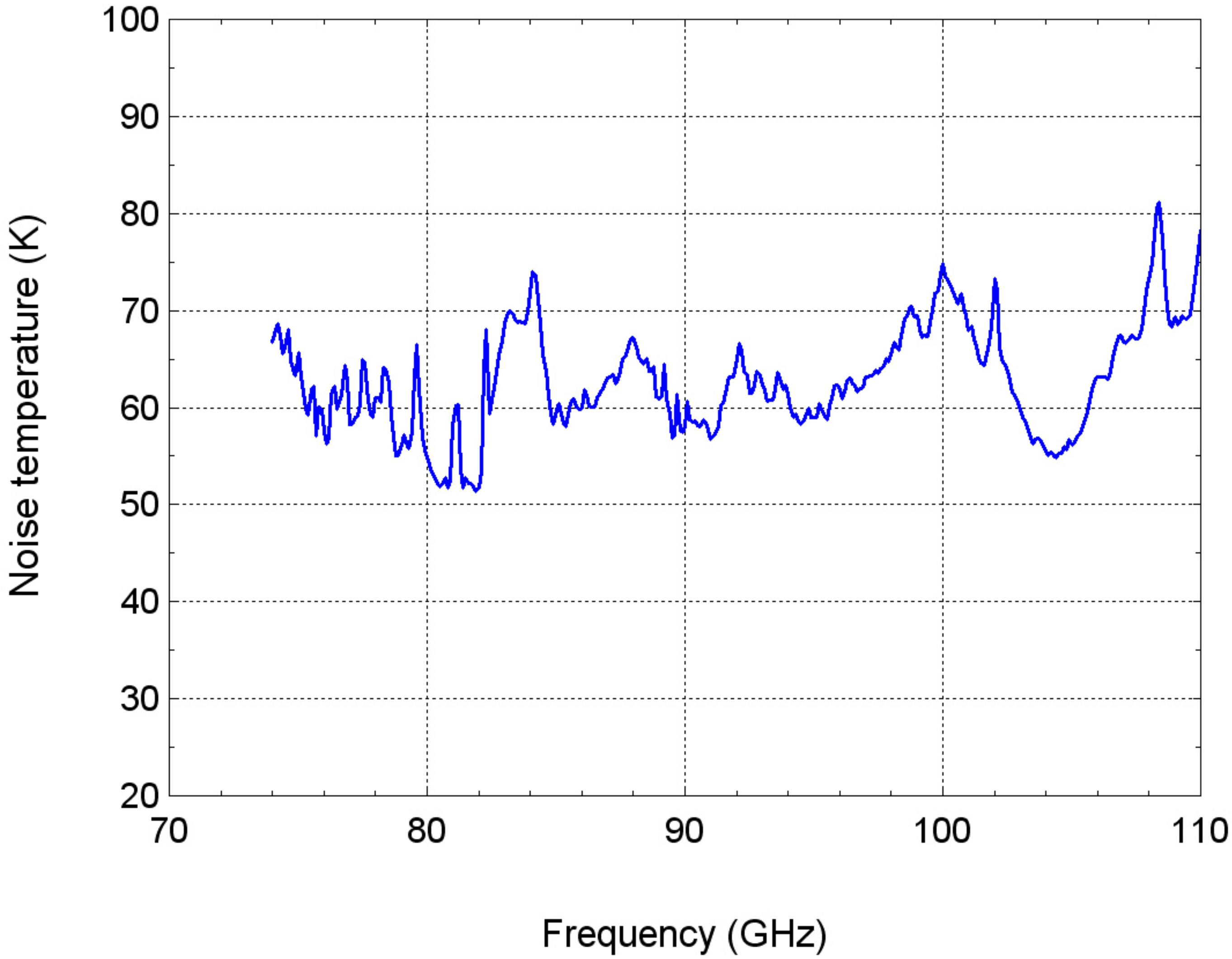




Receiver dewar with side plates removed.

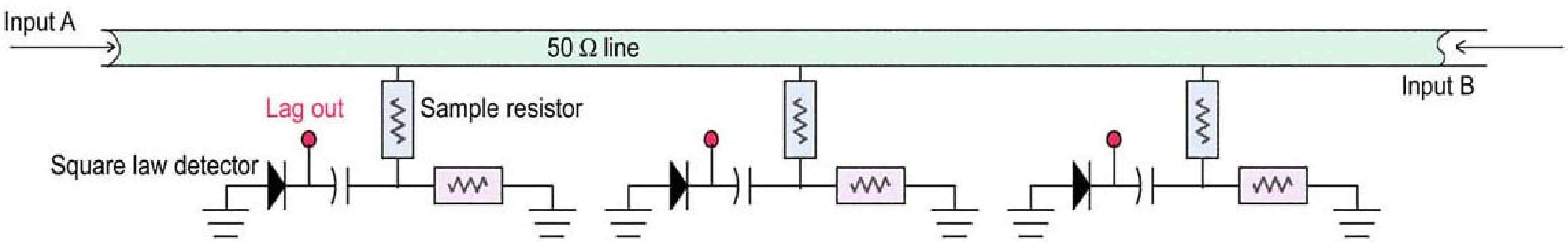
Noise temperature of one complete pixel outside dewar window.

Other three pixels within 10K of this noise.



Analog Autocorrelator

- **Delay lines Nyquist sampled (λ/4) for 8 GHz bandwidth with weak coupling using a resistive tap.**
- **Many taps are practical, we use 64 on each line.**
- **Tap signals are detected with silicon diodes which are very accurate square law detectors. R**esponse is $A^2 + B^2 + 2A*B$**.**
  - To first order A^2 and B^2 (total power) are the same for all taps, and only desired A*B term varies.
  - Switch the phase of A by 0 and 180º relative to B, then A*B term becomes AC, other terms are DC.



Analog Autocorrelator vs Digital Sig. Processing

Advantages

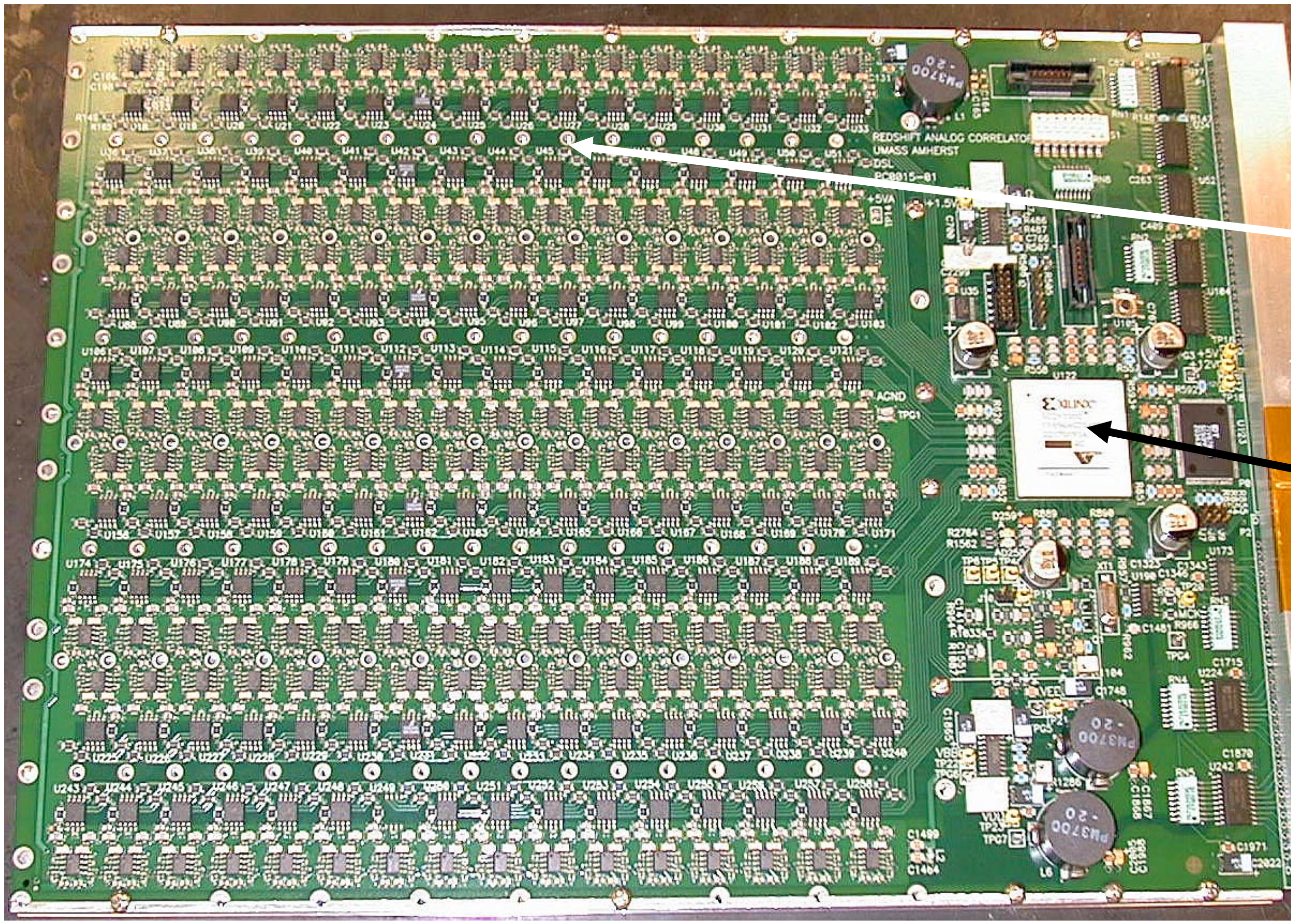
- Analog bandwidth is much larger.
- Analog requires no high speed signal sampler.
- Wide dynamic range -- no sampling noise.
- Very wide bandwidth with low cost, if resolution is low.

Drawbacks

- Many ways to corrupt the autocorrelation function.
- Simple FFT will not recover the spectrum, calibration required.
- Moore’s Law not helping out

4 delay lines with 256 taps, detectors, AC amplifiers, A/D converters, FPGA signal processor, all on one board. ~4000 parts. Bandwidth 1.3 - 7.9 GHz

Overall size 34 x 23 cm

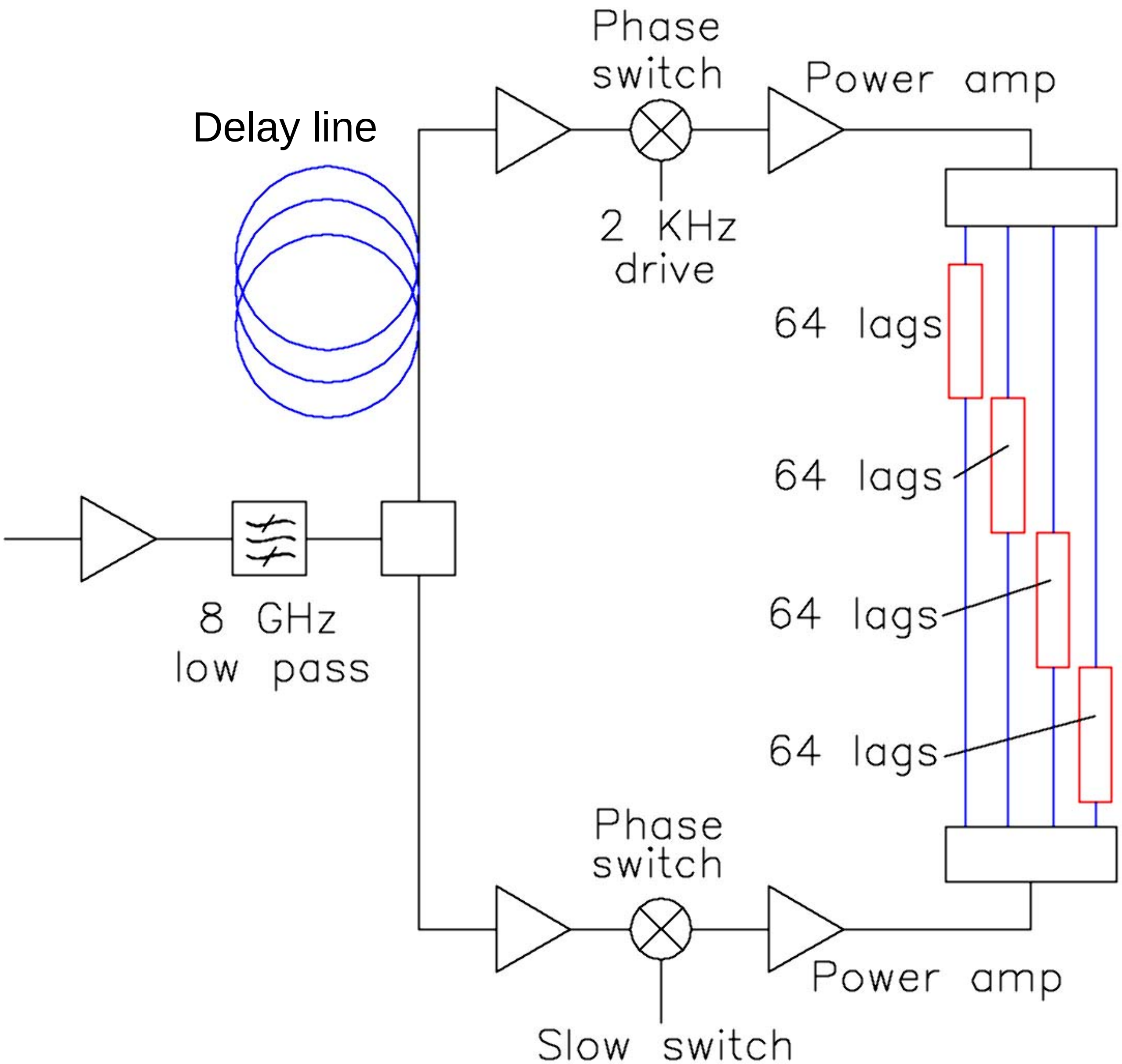


View of digital side of the board.

128 dual op amps and dual A/D converters.

FPGA and associated memory.

Delay lines and detectors on back side.



Red blocks are single boards with 4 units of 64 lags each.

Black parts are microstrip drivers.

Blue lines are delays in coaxial cable.

256 lag correlator with 6.5 GHz bandwidth

Spectrometer Performance

(without receiver)

•Alan variance timescale >>100 sec in 1 kHz beam switched mode.

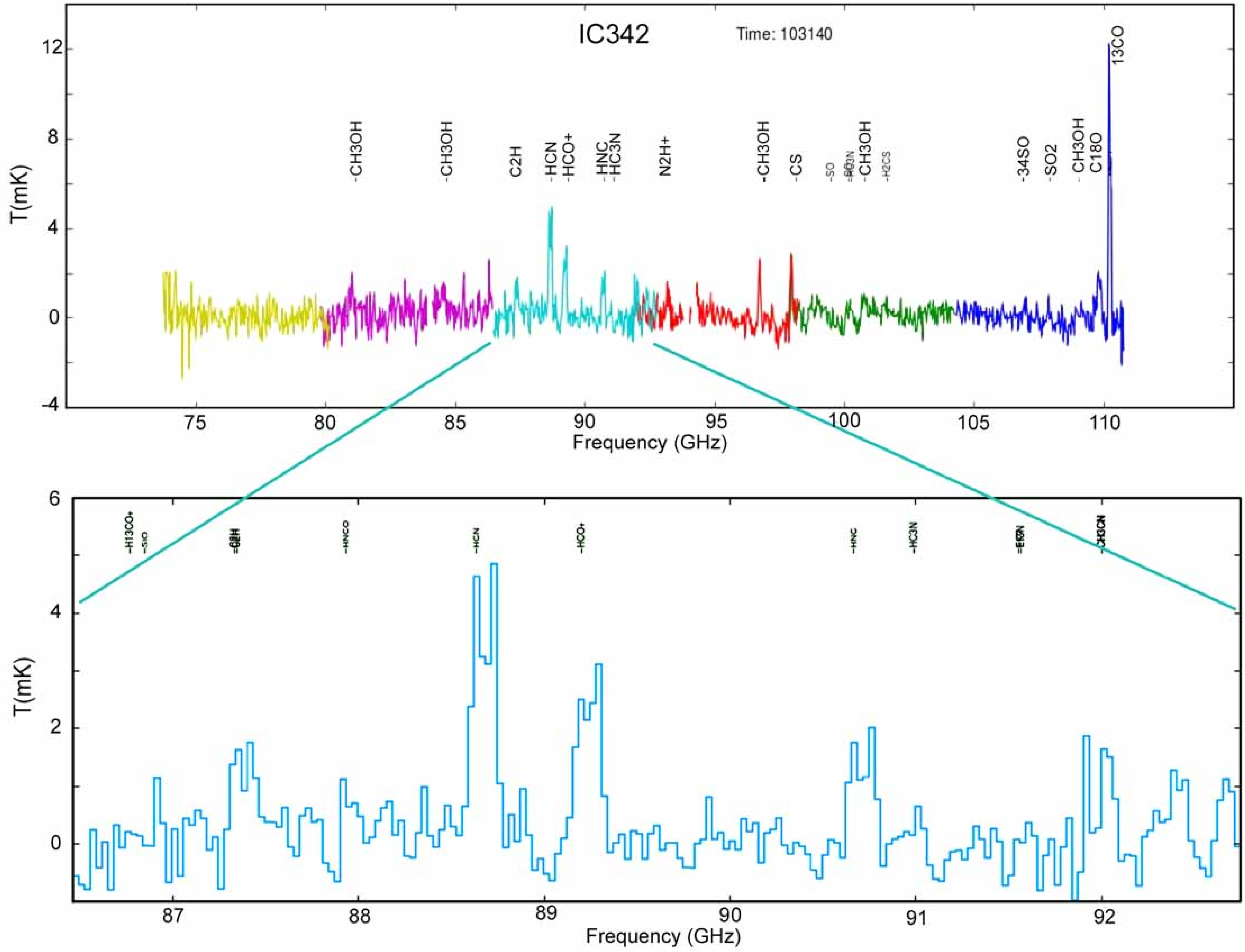
•Noise is 5% higher than theory.

•Dynamic range: If power level drops a factor of 4 below optimum, noise rises 10%.

•Receiver at present has a lot of power variation -- noise rises at the band edges.   This will be fixed.

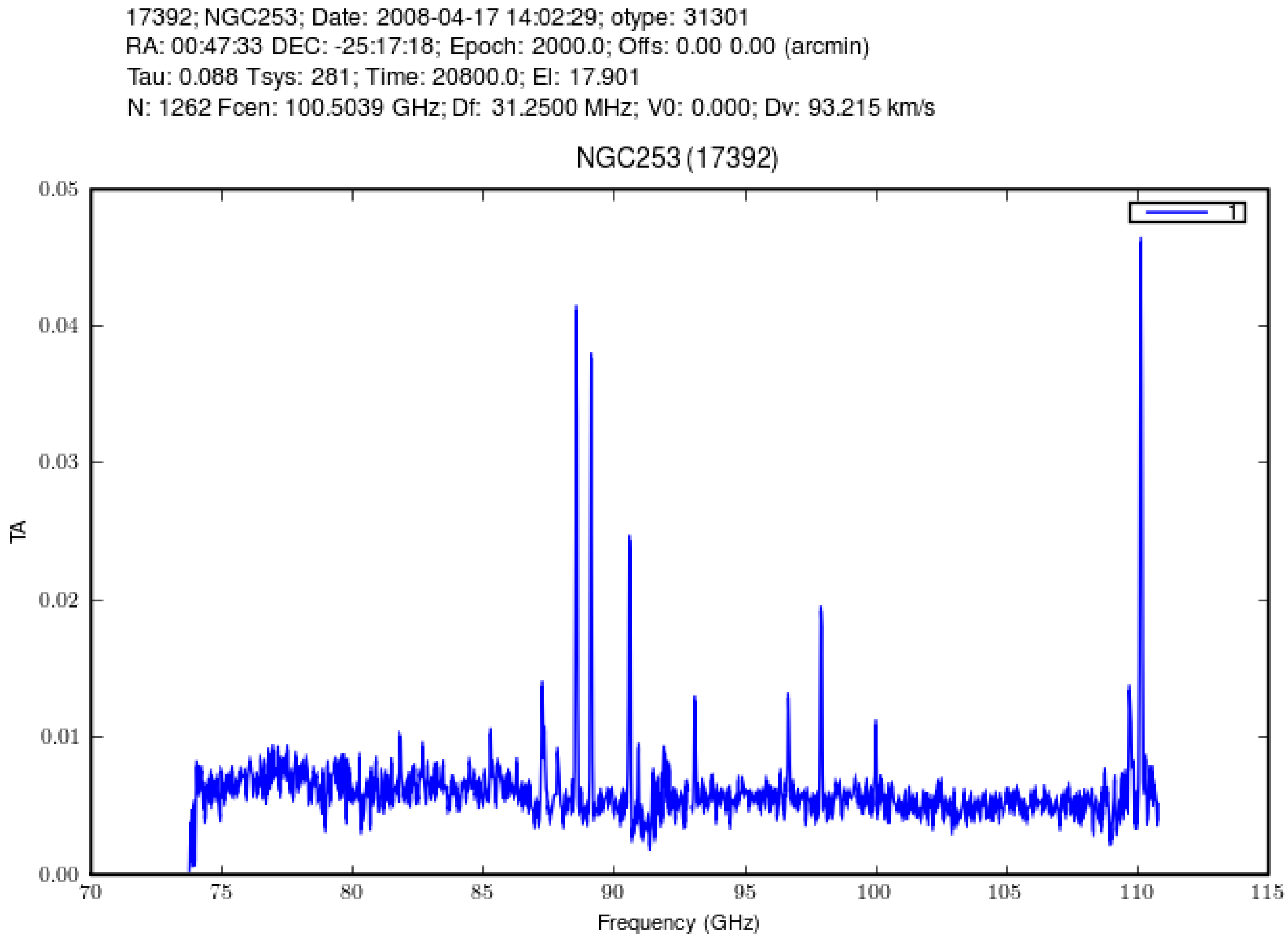
•No spurious line problems.

IC342 line survey



NGC253 Spectrum From 2 pixels

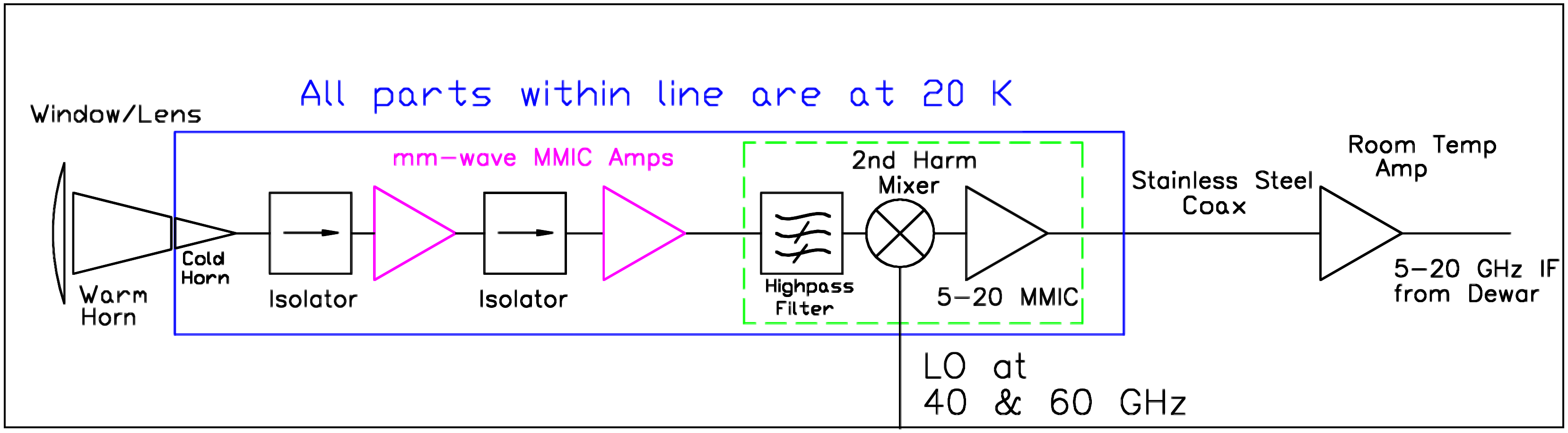
Baseline offset is true measure of continuum, but presence of continuum adds baseline ripple.



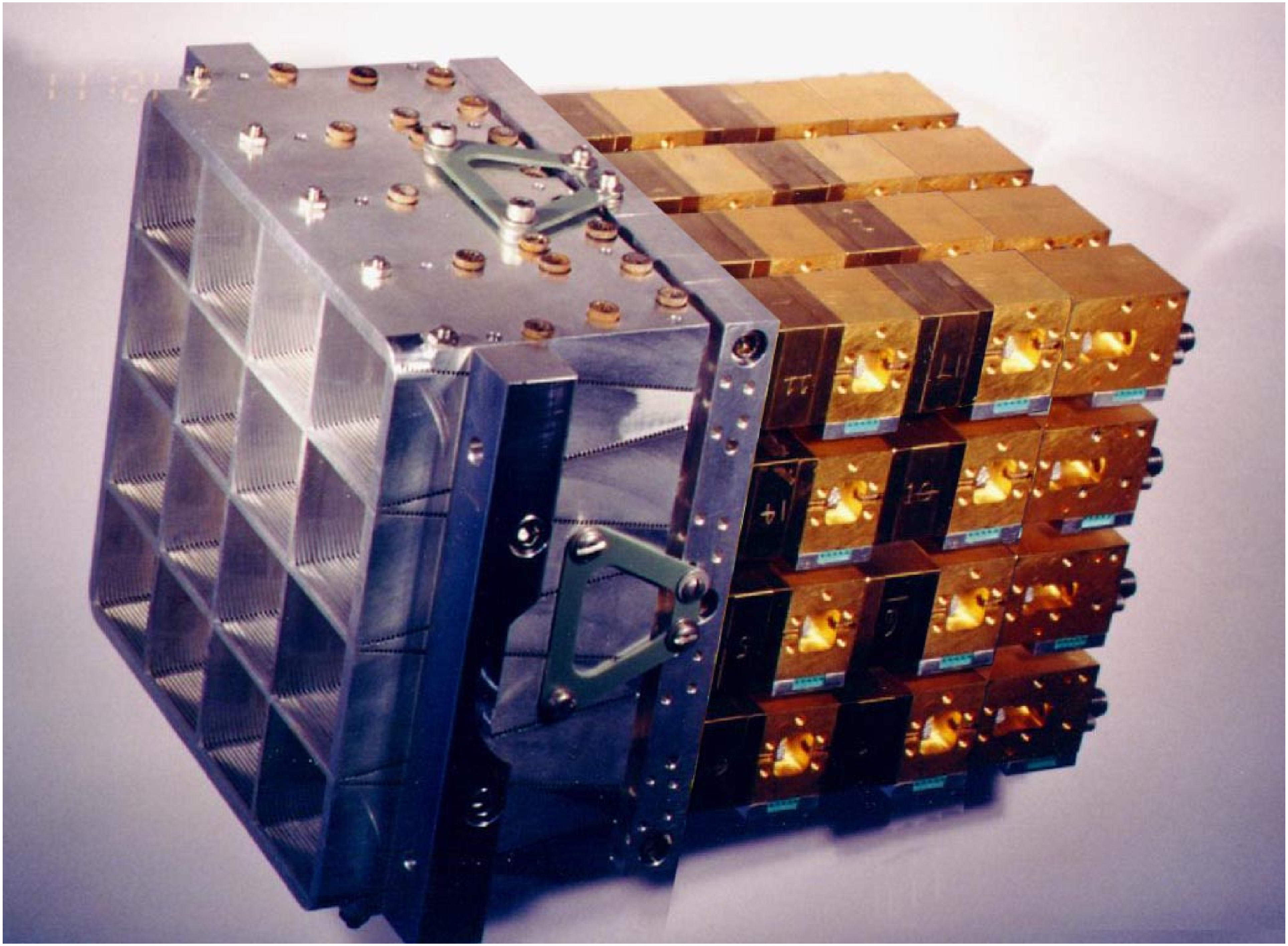
SEQUOIA FOCAL PLANE ARRAY

A cryogenic focal plane array designed for the 85-115.6 GHz range

- **32 pixels arranged in dual polarized 4 x 4 array. Two nearly identical dewars with 16 pixels each. Wire grid combiner.**
- **Uses InP MMIC preamplifiers with 35-40 dB gain.**
- **Preamp followed by subharmonic mixer with IF band 5-20 GHz.**
- **Band covered with SSB response using two LO's (40 and 60 GHz).**
- **Two backend spectrometers available for each pixel, may be tuned anywhere in IF band.**



Single pixel block diagram

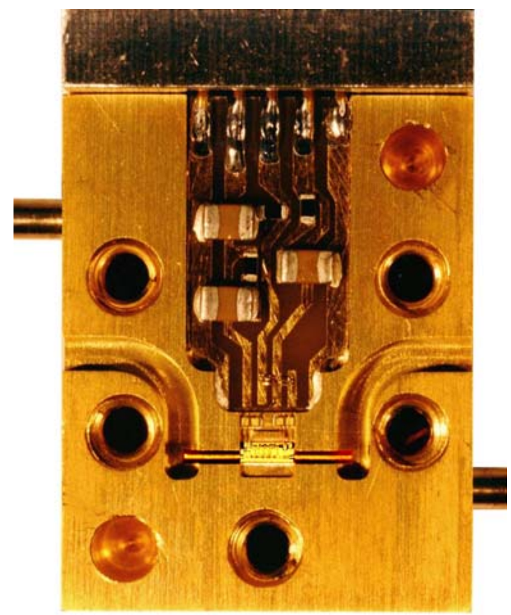


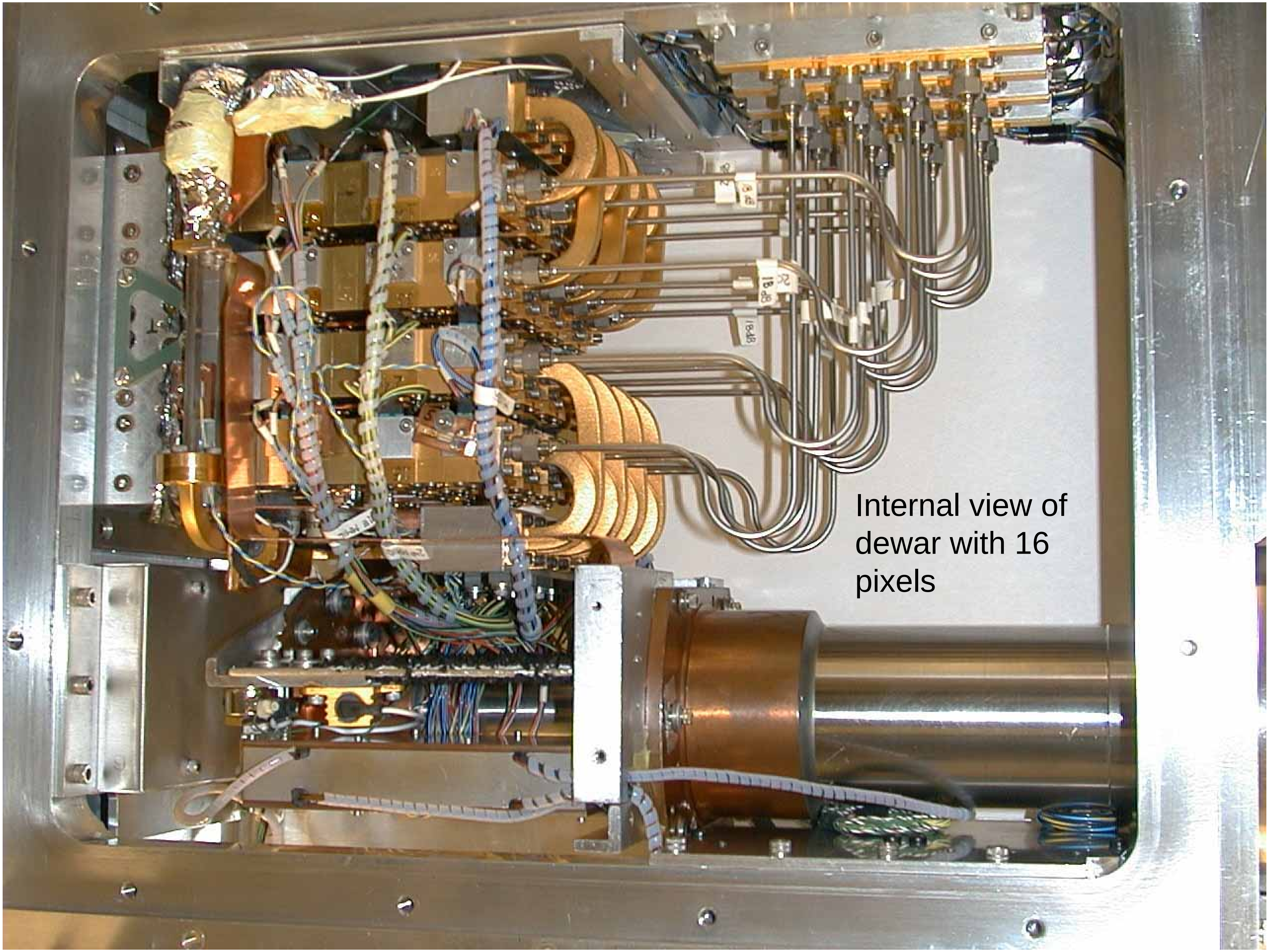
MMIC Preamplifiers

- 3mm amplifiers use InP technology, designed at UMass, fabricated at TRW.   Second stage amps made at HRL.
- Narrow band noise as low as 27 K at 100 GHz

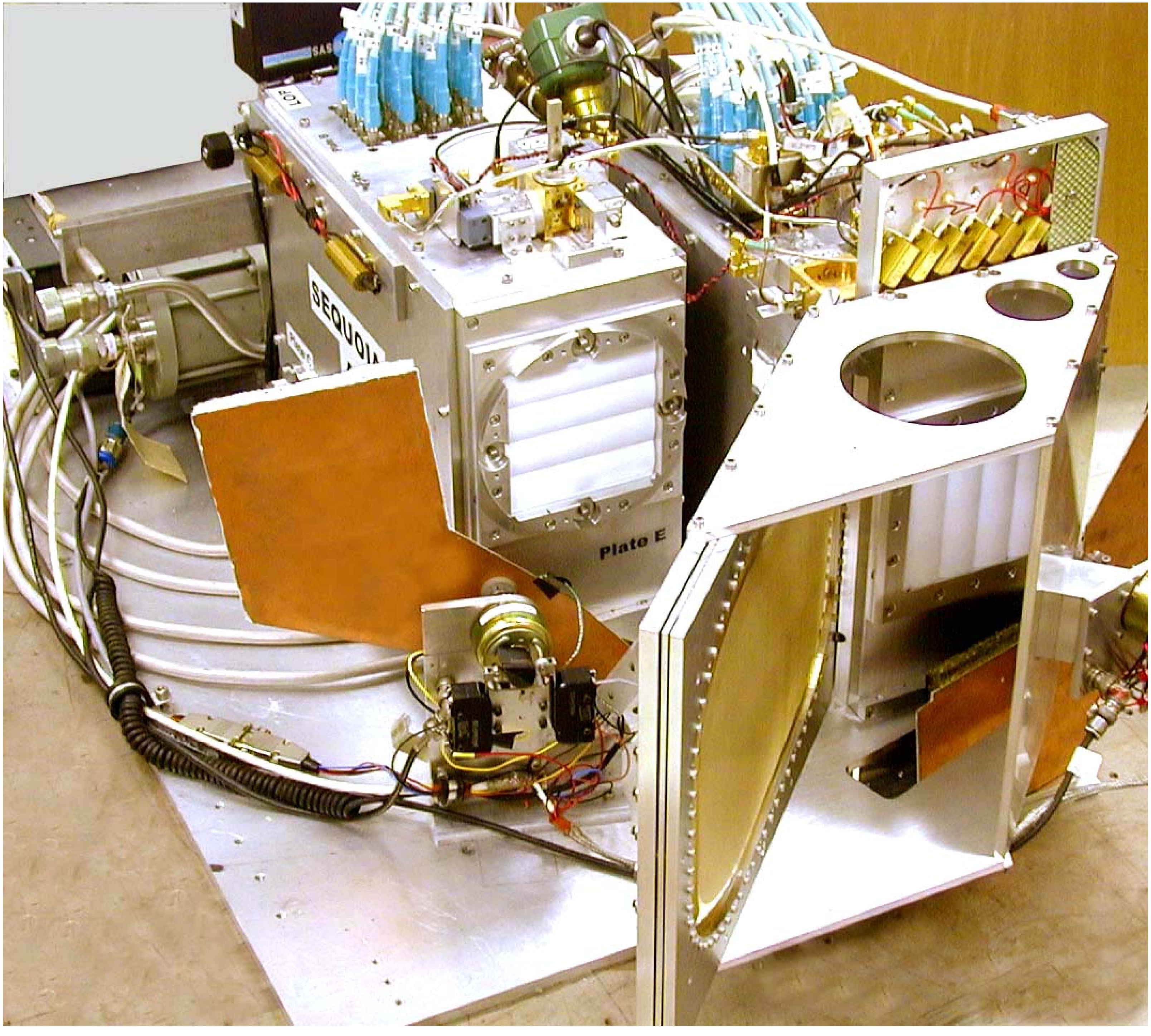
(<40K 85-115 GHz).

- Chips have four gain stages each.
- Block is straight through design, 15 mm long, using WR10 waveguide.





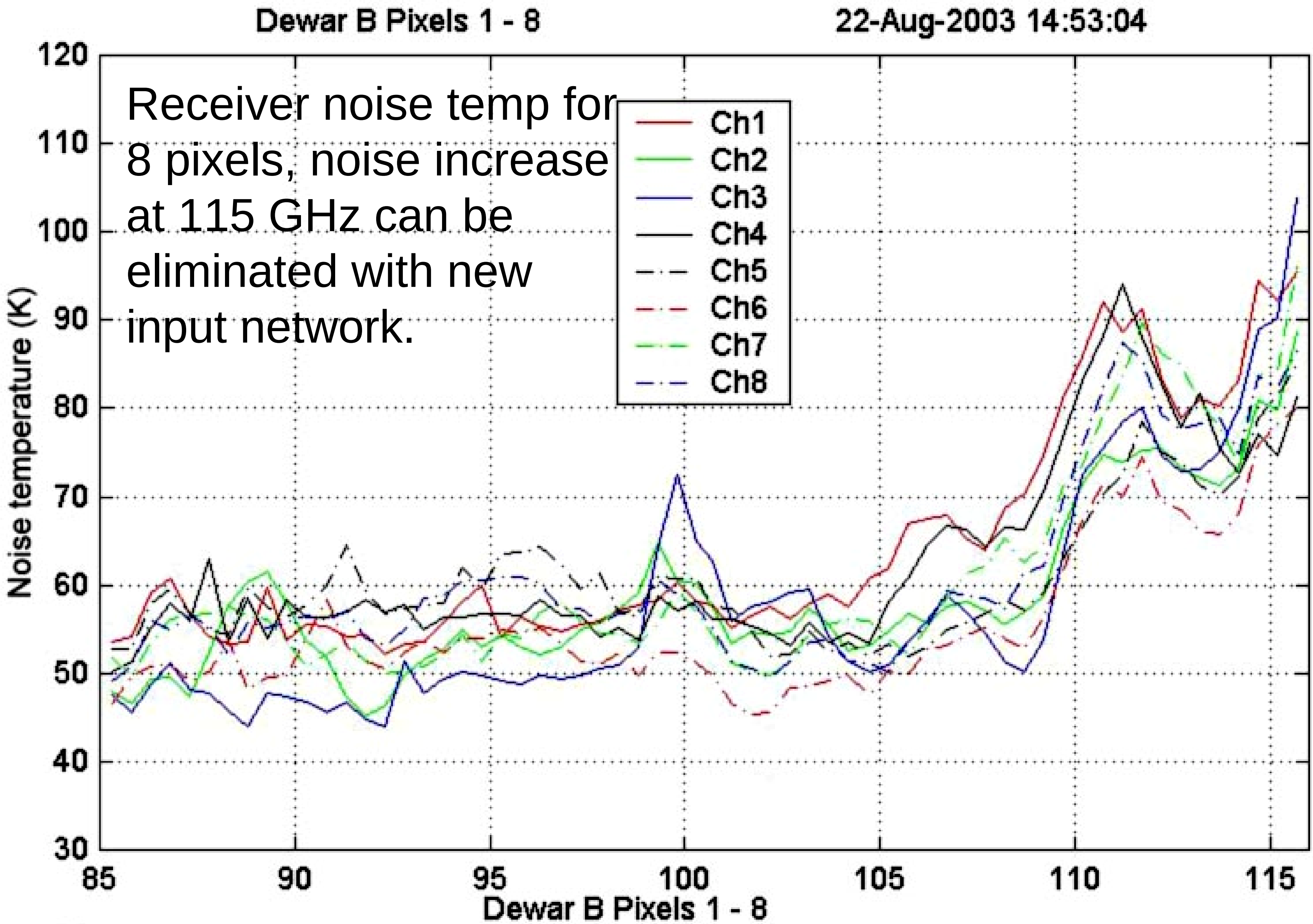
Internal view of dewar with 16 pixels


SEQUOIA
Plate E

System Performance

45 million spectra taken!

- Very low noise, individual pixels competitive with wideband SIS receivers.
- Two line observations simultaneously.
- High observing efficiency, no tuning.
- Excellent baseline stability on spectral lines.
- Reliability excellent, < 1 pixel flaky at any time.
- Pixels all very similar performance.
- On-The-Fly mapping eliminates sensitivity to bad pixels, increases observing efficiency.


Dewar B Pixels 1 - 8
22-Aug-2003 14:53:04
Receiver noise temp for 8 pixels, noise increase at 115 GHz can be eliminated with new input network.
Ch1
Ch2
Ch3
Ch4
Ch5
Ch6
Ch7
Ch8
Noise temperature (K)
120
110
100
90
80
70
60
50
40
30
85
90
95
100
105
110
115
Dewar B Pixels 1 - 8