Chirp readout for kinetic inductance detectors

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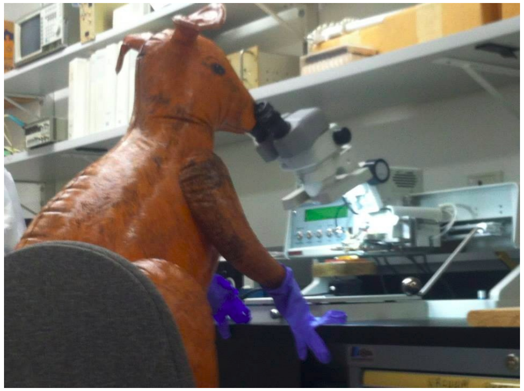
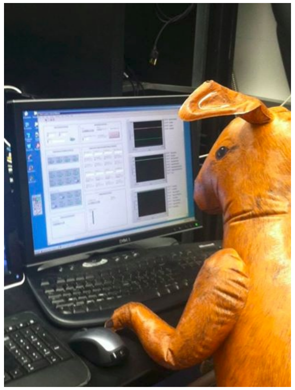


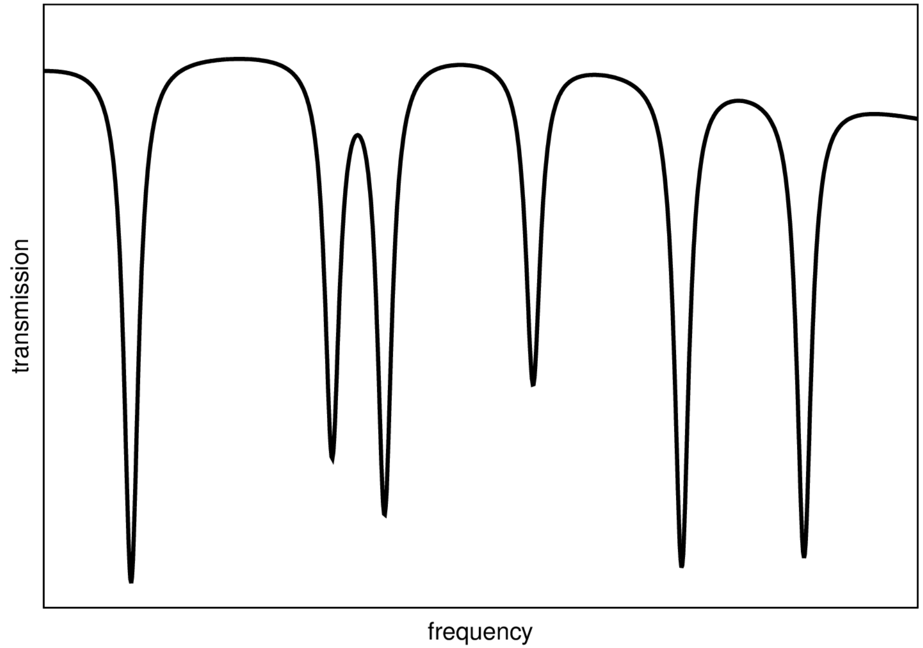


SPIE. ASTRONOMICAL TELESCOPES + INSTRUMENTATION

CCAT

Monreal, 2014 June 26

KIDs and their typical readout

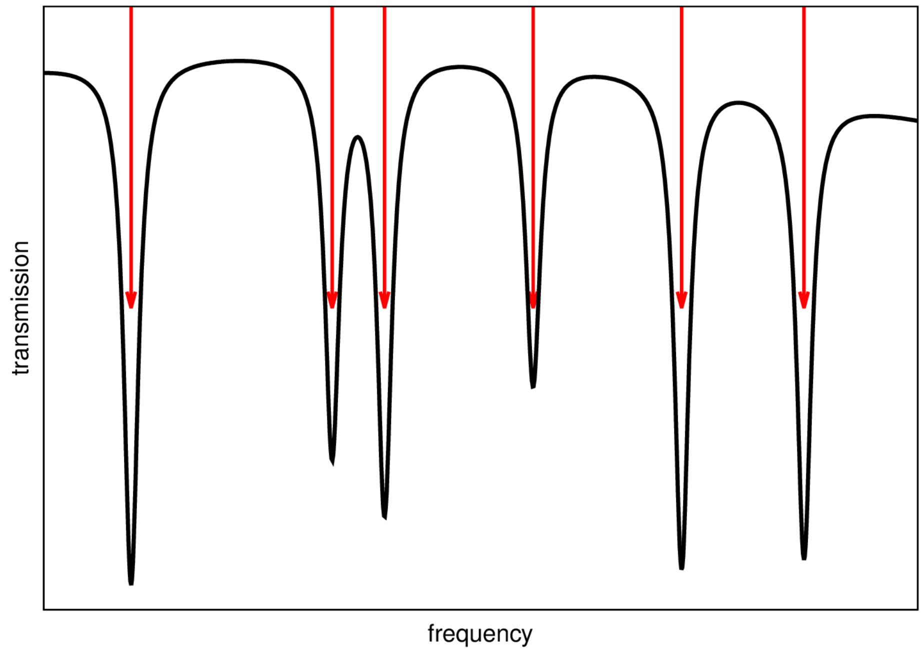


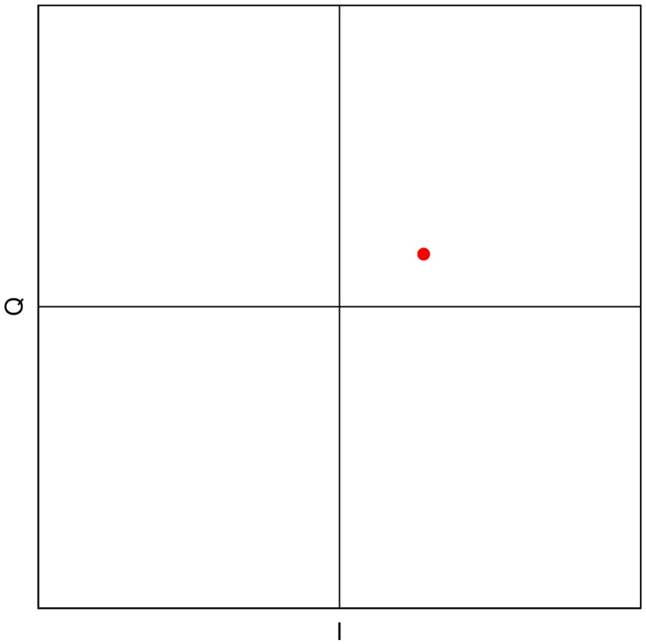
Q ~ 100,000

max. ~4000 channels / octave

f < 250 MHz to process octave

KIDs and their typical readout





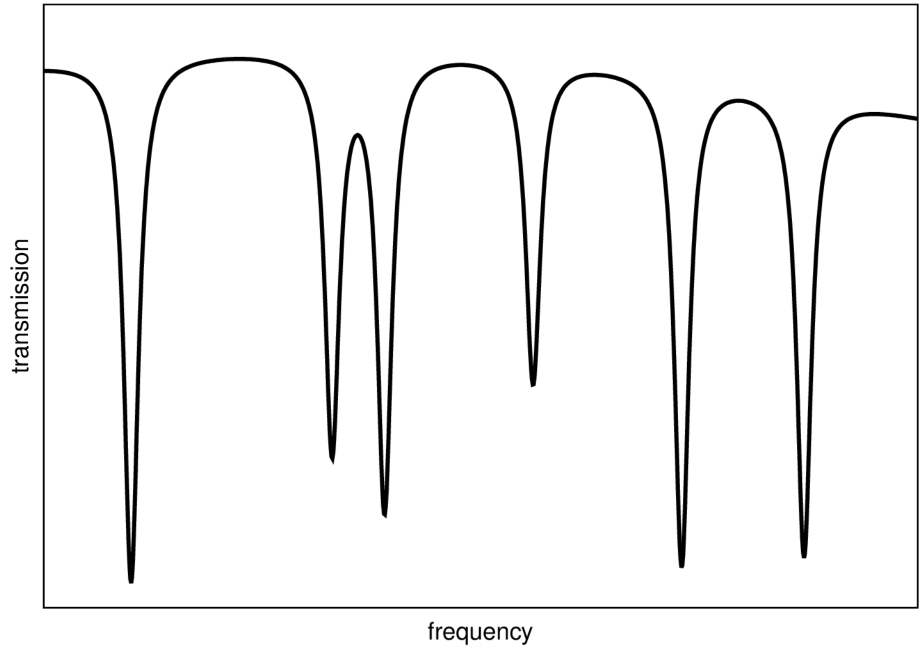
Q ~ 100,000

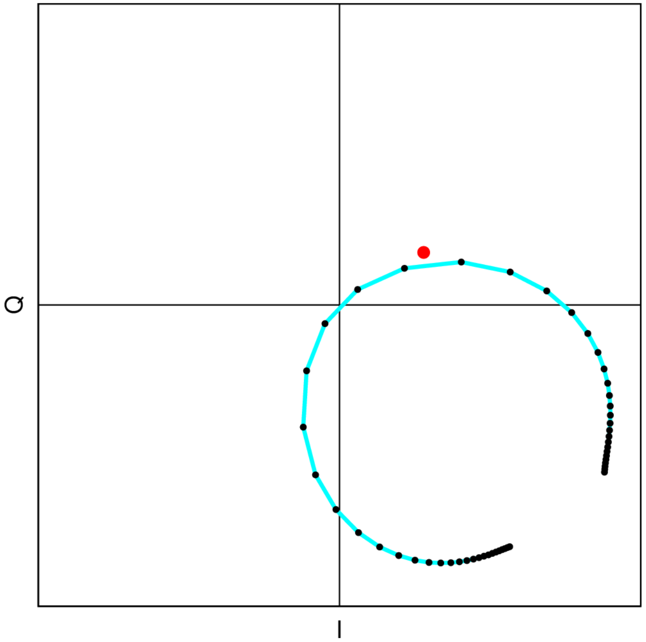
max. ~4000 channels / octave

f < 250 MHz to process octave

1. sweep

KIDs and their typical readout





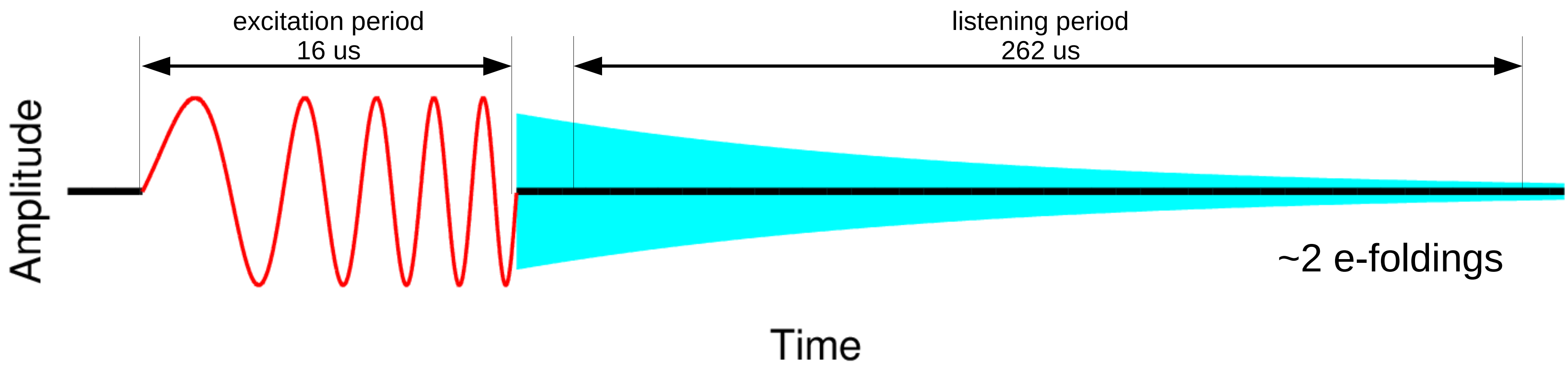
Q ~ 100,000

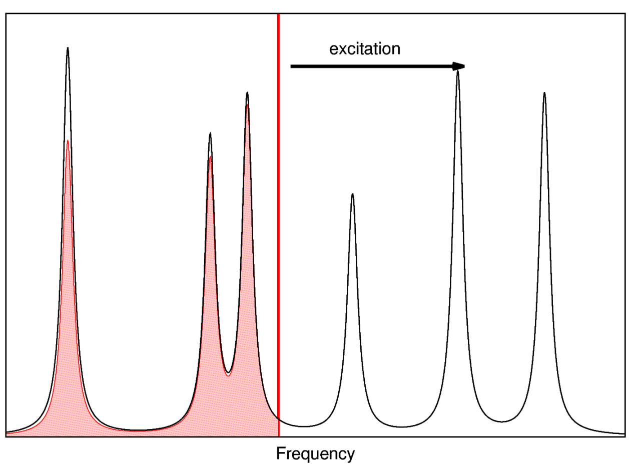
max. ~4000 channels / octave

f < 250 MHz to process octave

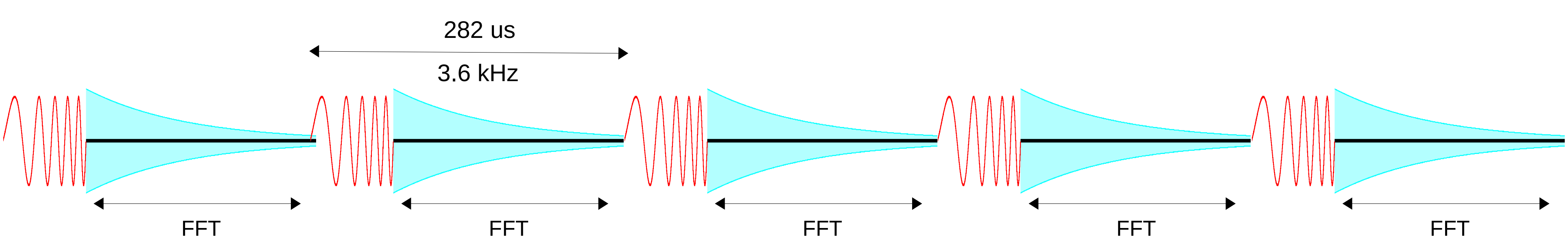
1. sweep
2. calibrate
3. I,Q ⟶ frequency

Chirp 101





Requires FFTs at 200 – 250 MSPS (in ~2Q chunks)

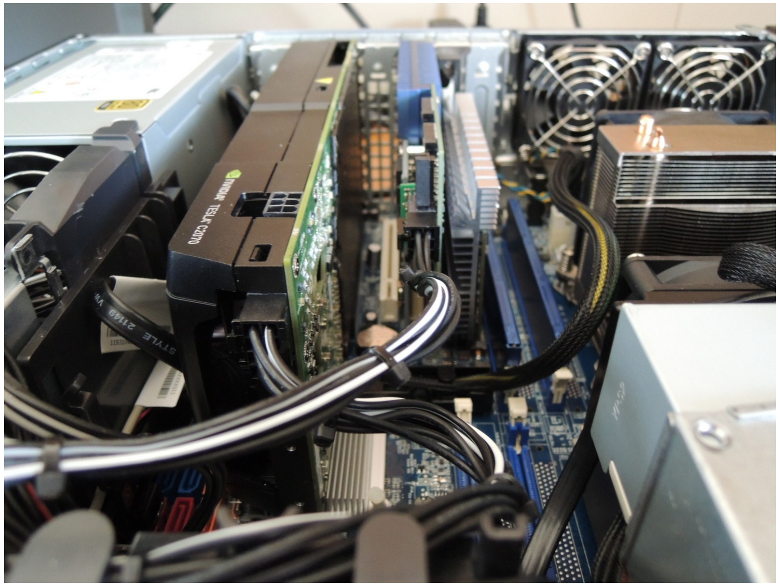


Components

GPU
$ **2K**
(80 W)

PC Host
$ **4K**
(~200 W)

Pentek board
$ **13K**
(18 W)



... 5000+ lines of code (C / CUDA)

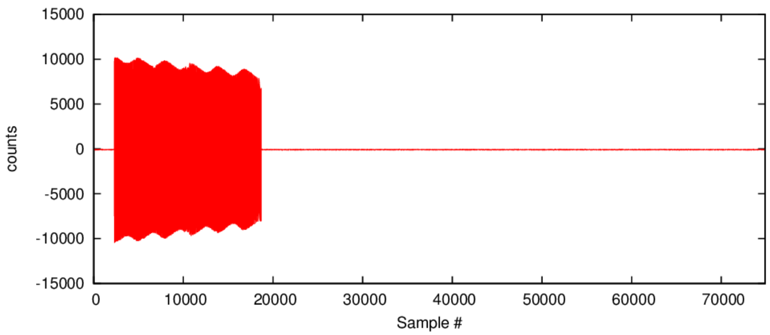
$ 5 / channel **$ 500k** for 10^5 channels

75 mW / channel **7.5 kW** for 10^5 channels

SWCam: Stacey et al. **9153-21**

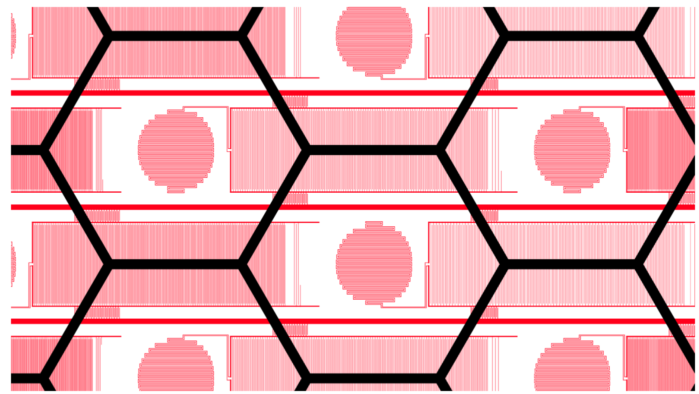
Test Configuration

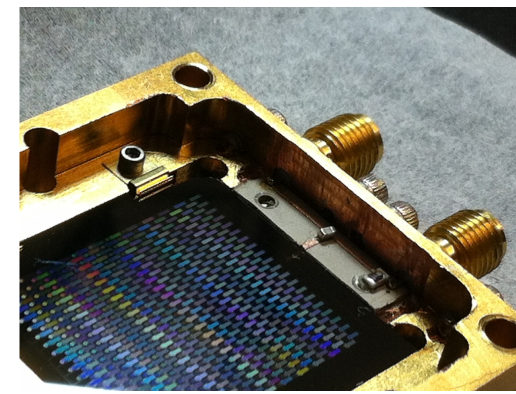
2014 January 28 – 30



actual chirp timestream

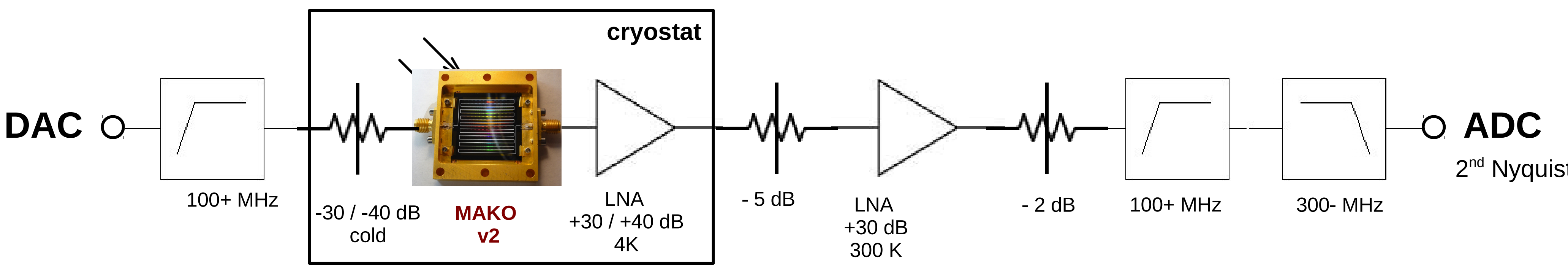
MAKO 2nd Generation Devices (**9153-5**)





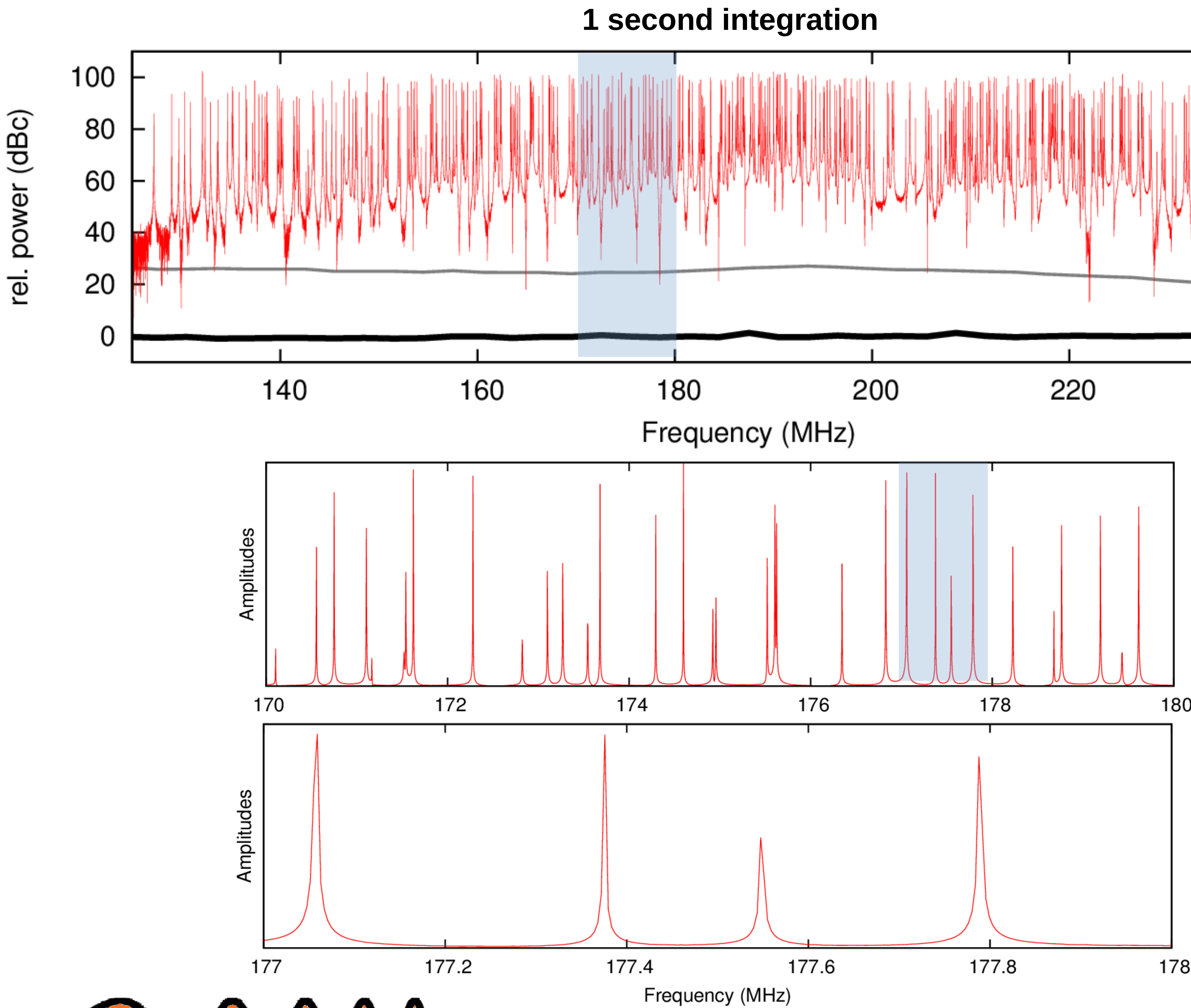
C. McKenney

125 – 250 MHz



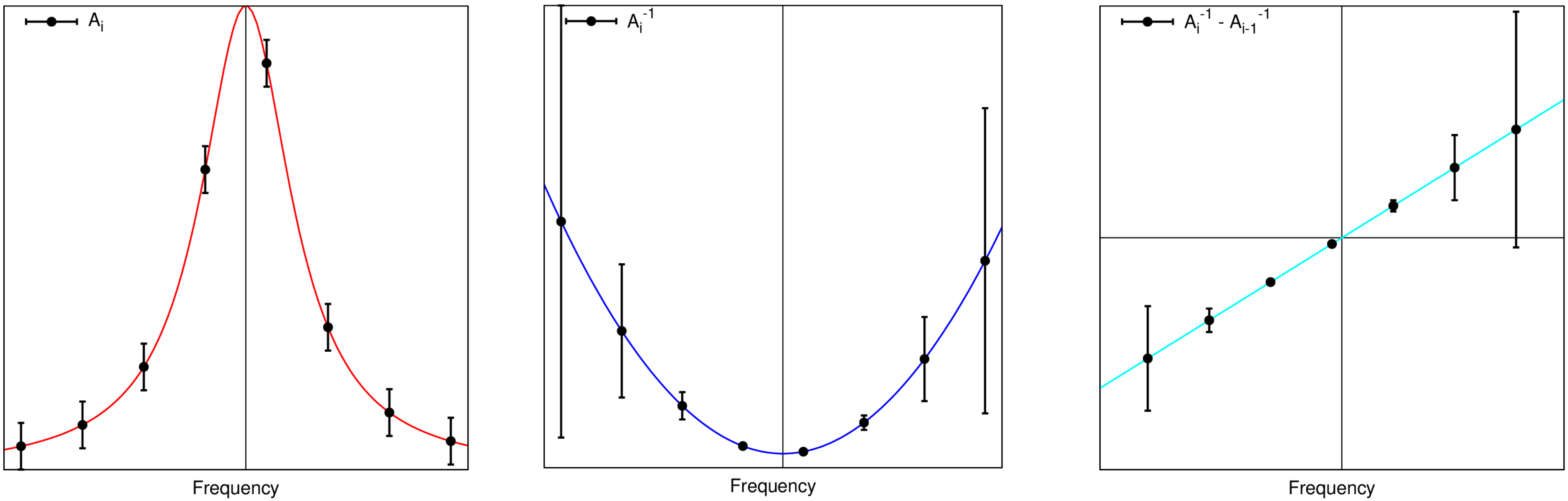
~400 resonators, Q ~ 100k →~ +25 dB

First Results



2014 January 28-30

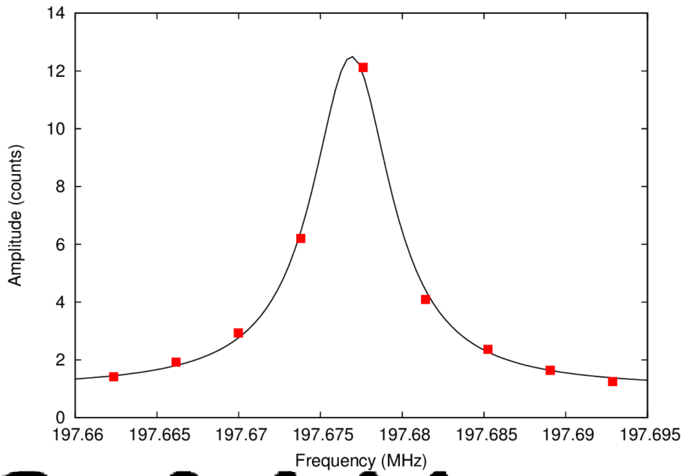
Real-time resonance fitting



observed amplitudes

inverse amplitudes

inverse amplitude increments



Cramer-Rao lower bound:

$$\sigma_b \geqslant \frac{2}{SNR}\sqrt{\frac{2m}{\pi}}$$

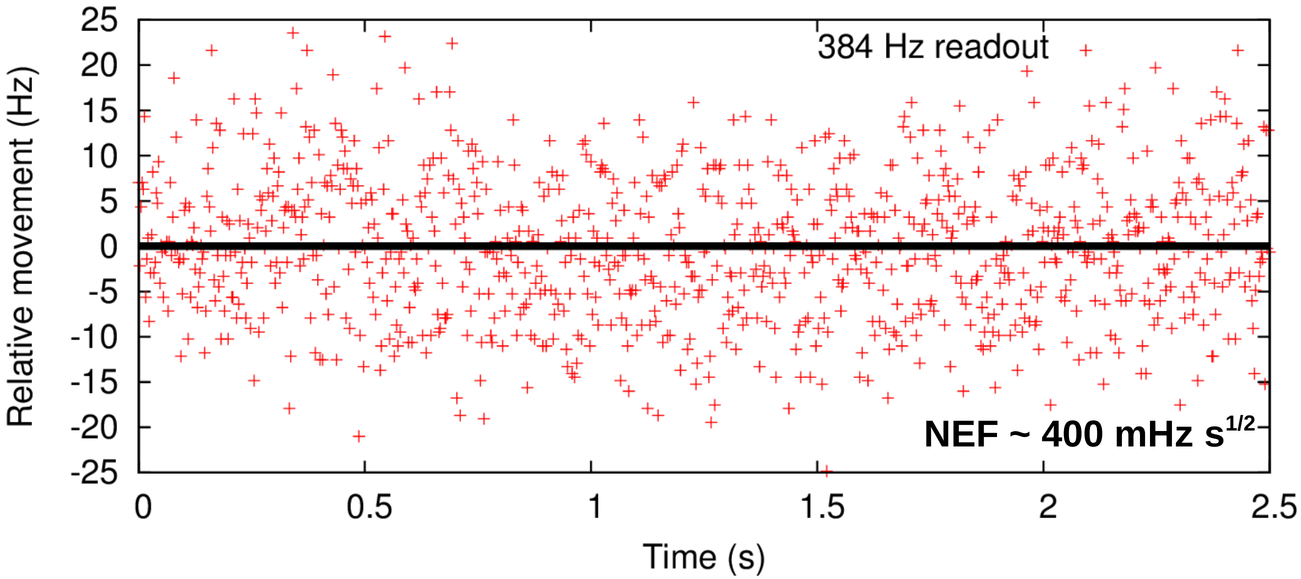
a x + b

$$\mathbf{f_c = -b/a}$$

Noise performance

Within a factor ~2 of tones

(+20 dB DAC noise)

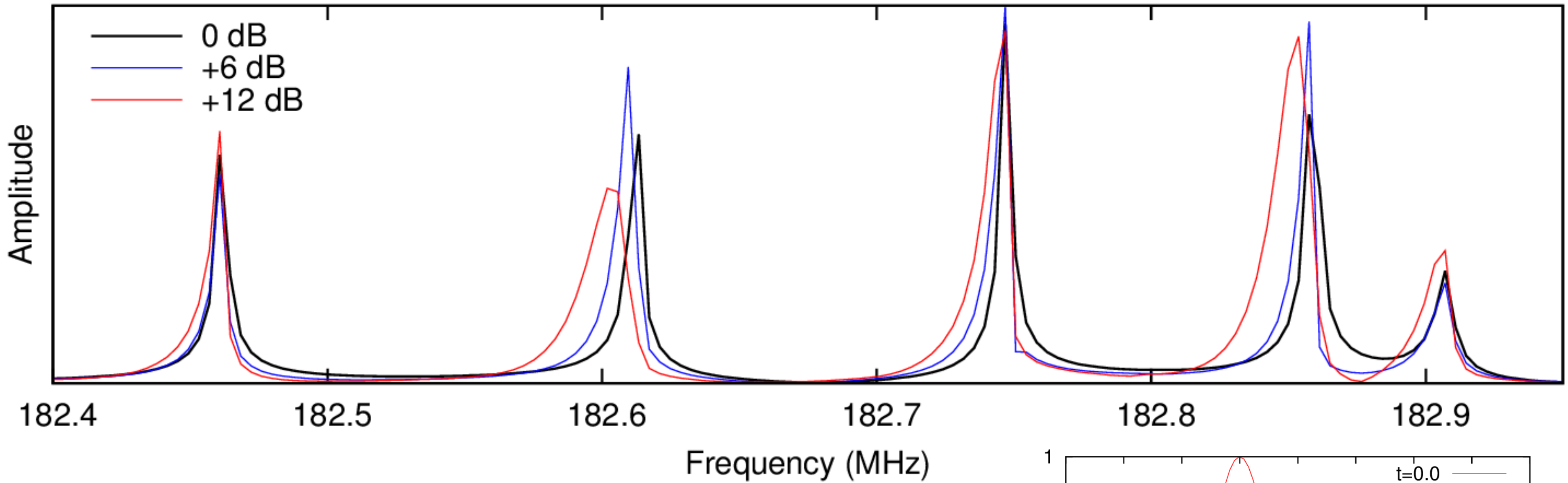


MAKO 2013: 400 mHz $s^{1/2}$
BLIP(CSO): ~80 mHz $s^{1/2}$
BLIP(CCAT): ~5 mHz $s^{1/2}$

SNR (1s)	**NEF**	**PSD** (df/f)
75 dB	400 mHz $s^{1/2}$	1.4 – 5.4 × 10^{-18} / Hz
85 dB	130 mHz $s^{1/2}$	1.4 – 5.4 × 10^{-19} / Hz
105 dB	**13 mHz $s^{1/2}$**	**1.4 – 5.4 × 10^{-21} / Hz**
118 dB	3 mHz $s^{1/2}$	0.8 – 3.3 × 10^{-22} / Hz

increased responsivity – or – better ADCs

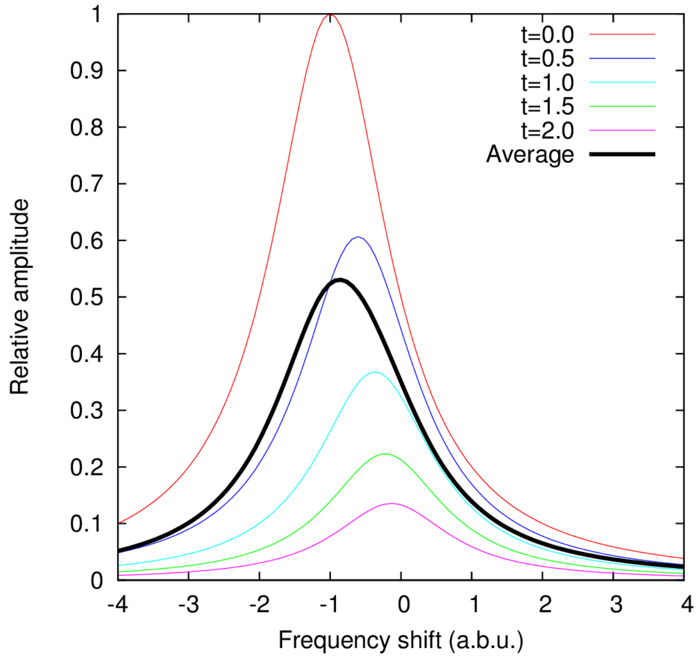
Excitation Power



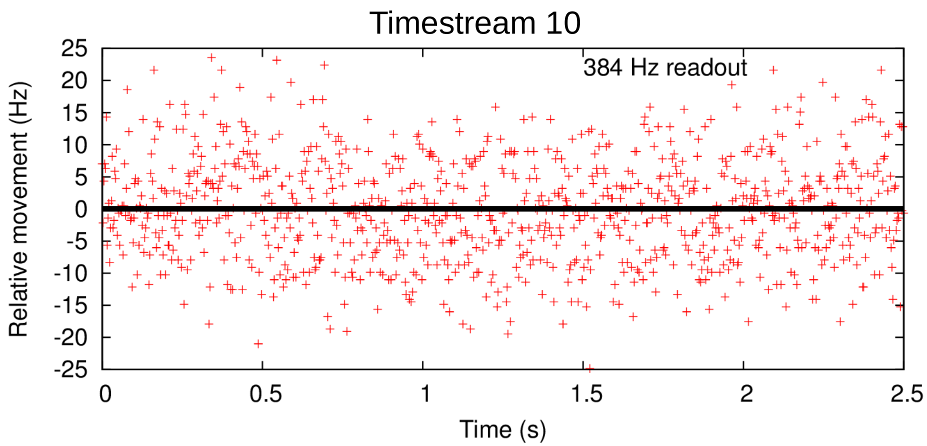
Suppress TLS Noise

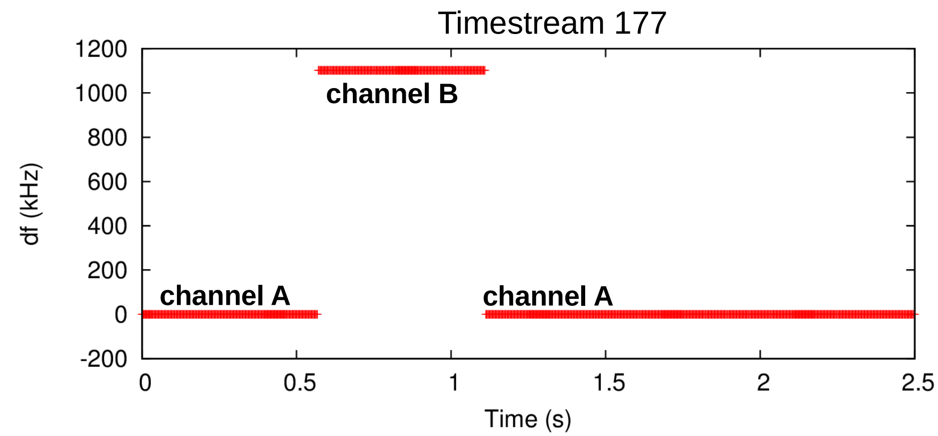
- vs -

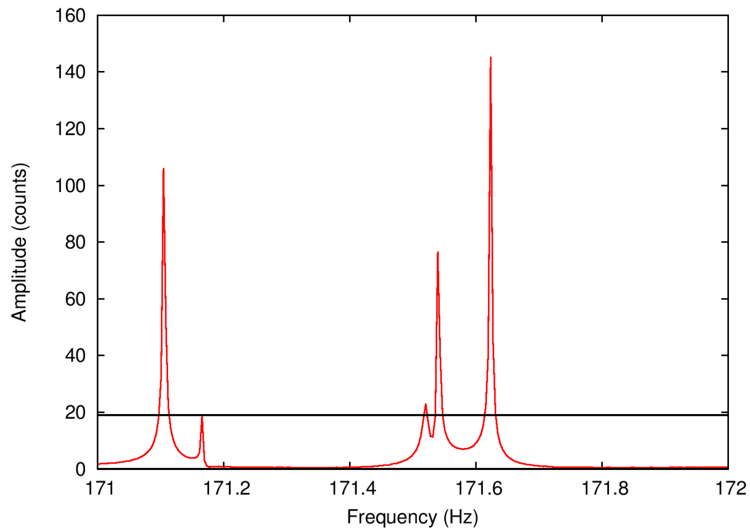
Smearing at high power levels



Real-time Line Matching







near search threshold

collisions

spurious features

image band resonances

Line matching: ordered resonances → steady detector stream

GPU Task List

accumulate

decay correction

FFT

peak search

collision check

line fitting

catalog matching

... @ 1 GB / sec FP ...

Where next?

Make it (a lot) cheaper and less power hungry...

NVIDIA Tegra K1
(ARM Cortex A15 + 192 CUDA cores)
mini PCIe (x1)

$ **192**

(~10 W)

+

?

How to get 250 MSPS
(2nd Nyquist)
streamed to it?

FPGA

ADC interface
- or -
fibre optic interface

$ 0.10 / channel $ 10k for 10^5 channels

5 mW / channel 500 W for 10^5 channels

Advantages

Direct frequency measure (*phase*)

Dynamic range

Uniform sensitivity

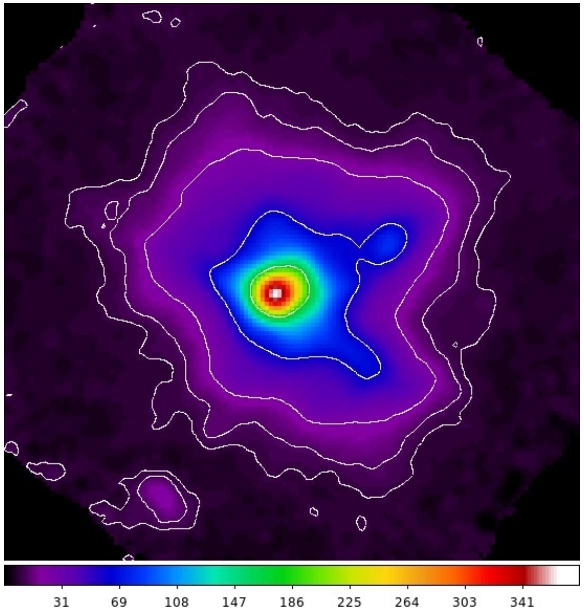
Faster readout rate

Insensitive to voltage noise (1/*f*)

Emission (*no background*)

1 DAC to rule them all...

Line intensities (*dissipation*) and widths (*Q*)



MAKO 2013

Chirp Mapping at the CSO? (August)