New EPICS Support for Low-Cost High-Performance Devices:

Measurement Computing USB-CTR08 Counter/Timer and Point Grey Grasshopper3 Camera

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Measurement Computing Devices

- I gave a TWG talk in 2011 on EPICS devices for the small laboratory, that included 2 USB devices from Measurement Computing
- Original motivation was need for an non-VME scaler for the x-ray lab at University of Chicago
  - Only other solution I knew of was the Ortec 974, NIM module, only 2 channels, expensive. USB-4303 seemed like a possible solution.
- Also talked about EPICS support for USB-1608GX-2A0, which provides high-speed 16-bit analog input and output.

USB-1608GX-2A0 ($799)

- 16-bit analog inputs
  - 16 single-ended channels or 8 differential channels, 500 kHz total maximum input rate
- 16-bit analog outputs
  - 2 channels, fixed +-10V range , 500 kHz total maximum output rate
- Digital inputs/outputs
  - 8 signals, individually programmable as inputs or outputs
- Pulse generator
  - 1 output, 64MHz clock, programmable period, width, number of pulses, polarity
- Counters
  - 2 inputs, 20 MHz maximum rate, 32-bit registers
- Less expensive model (no analog outputs) is being used at APS for the vibration monitoring and logging system

USB-4303 ($349)

- Architecture
  - 2 C9513 counter/timer chips, 5 16-bit counter timers
  - Programmable on-chip interconnects between them
  - 8 digital input
  - 8 digital output
  - I wrote support for EPICS scaler record
- No longer available, 9513 chips obsolete
- USB-CTR08, new model just recently released provides significantly enhanced capabilities

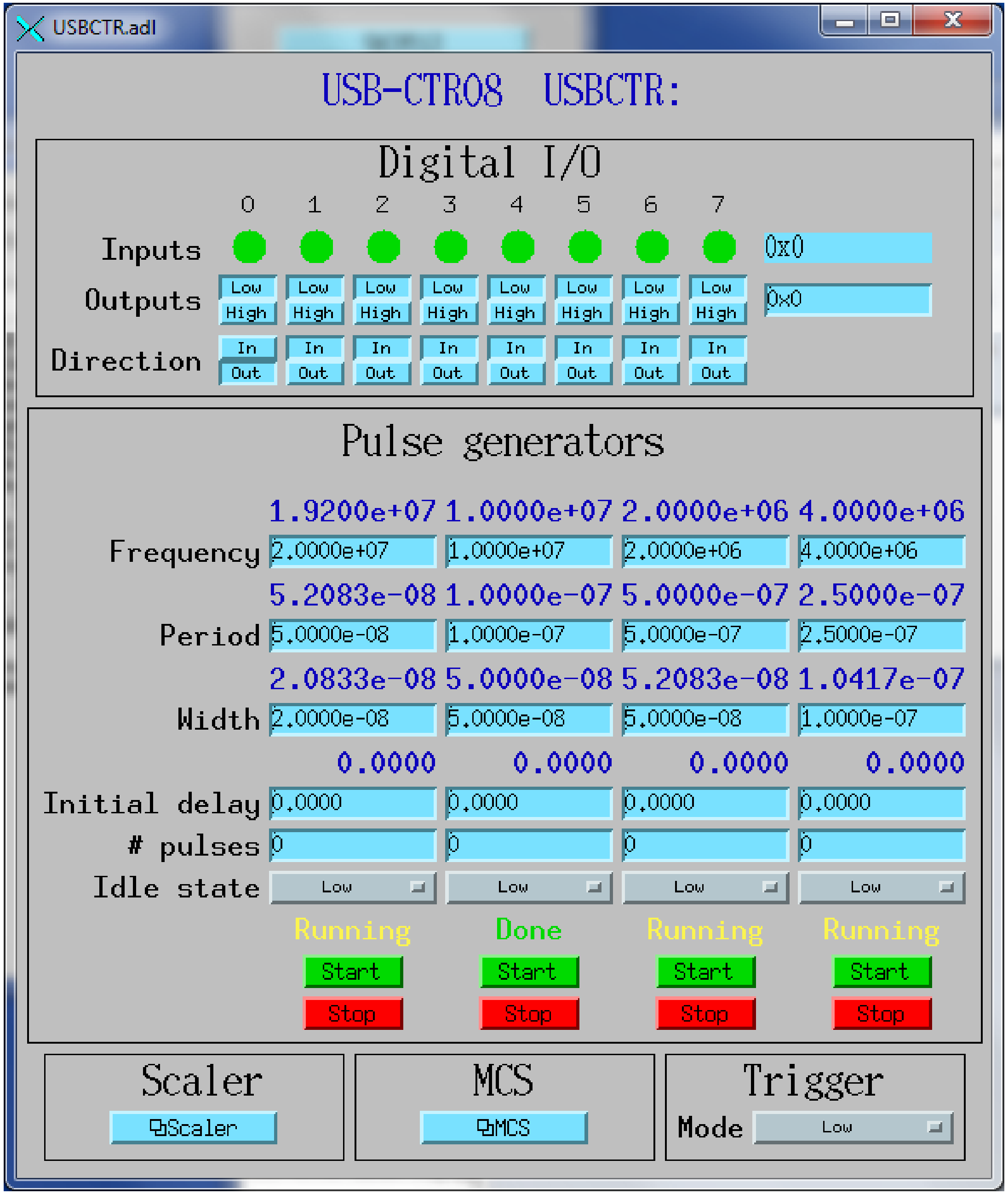
USB-CTR04/08 ($429)

- 8 counters (USB-CTR08) or 4 counters (USB-CTR04)
  - 48 MHz maximum count rate
  - Up to 64-bit counter depth
  - Counters can be read synchronously on-the-fly
  - 4 modes:
    - Totalize (count number of pulses)
    - Period (measure time between rising or falling edge of successive pulses)
    - Pulse width (measure time between rising and falling edge of a single pulse)
    - Timing mode (measure time between edges of two different input signals)
- 4 pulse generators
  - 48 MHz clock
  - Programmable period, width, number of pulses, polarity
- Digital inputs/outputs
  - 8 signals, individually programmable as inputs or outputs

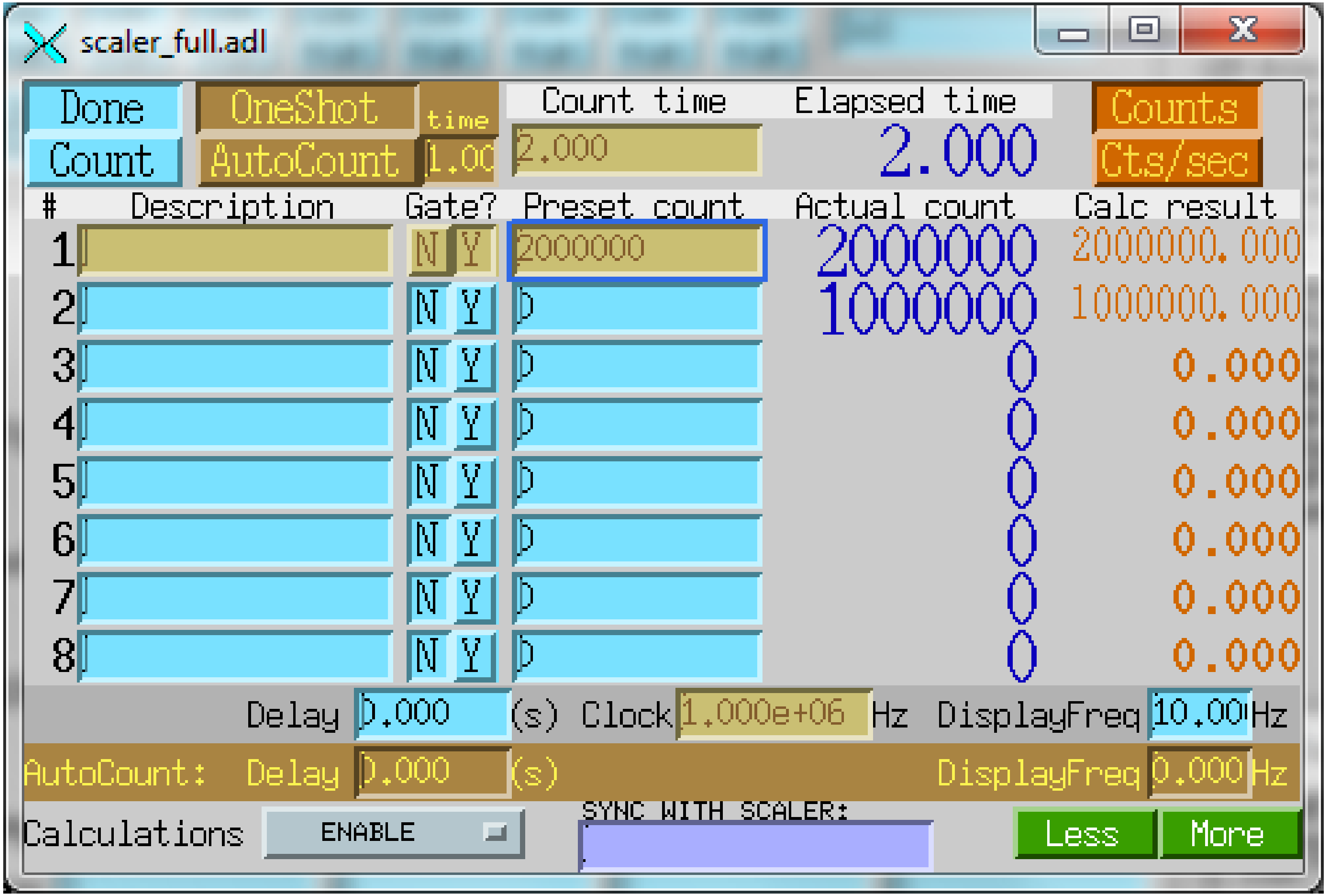
USB-CTR08 vs SIS3820

	USB-CTR08	SIS3280
# Counters	8	32
Interface	USB 2.0	VME
Maximum count rate	48 MHz (TTL)	100 MHz (TTL) 250 MHz (ECL, NIM)
Minimum dwell time	250 ns per active counter	220 ns for 8 active counters
Pulse generators	4	0
Digital I/O bits	8	1
Price	$429	$4,350

USB-CTR08 Main medm screen

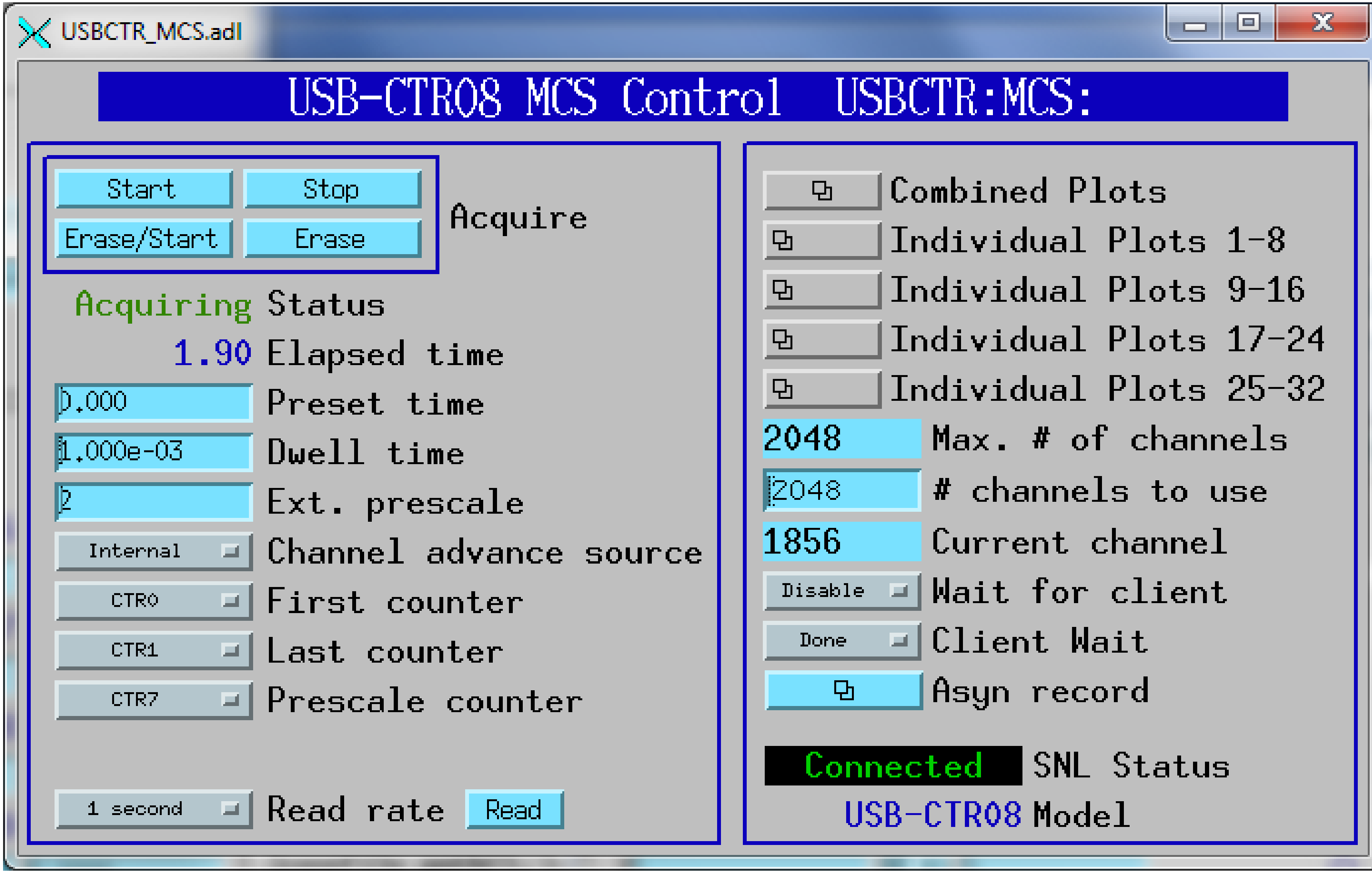


USB-CTR08 EPICS Control

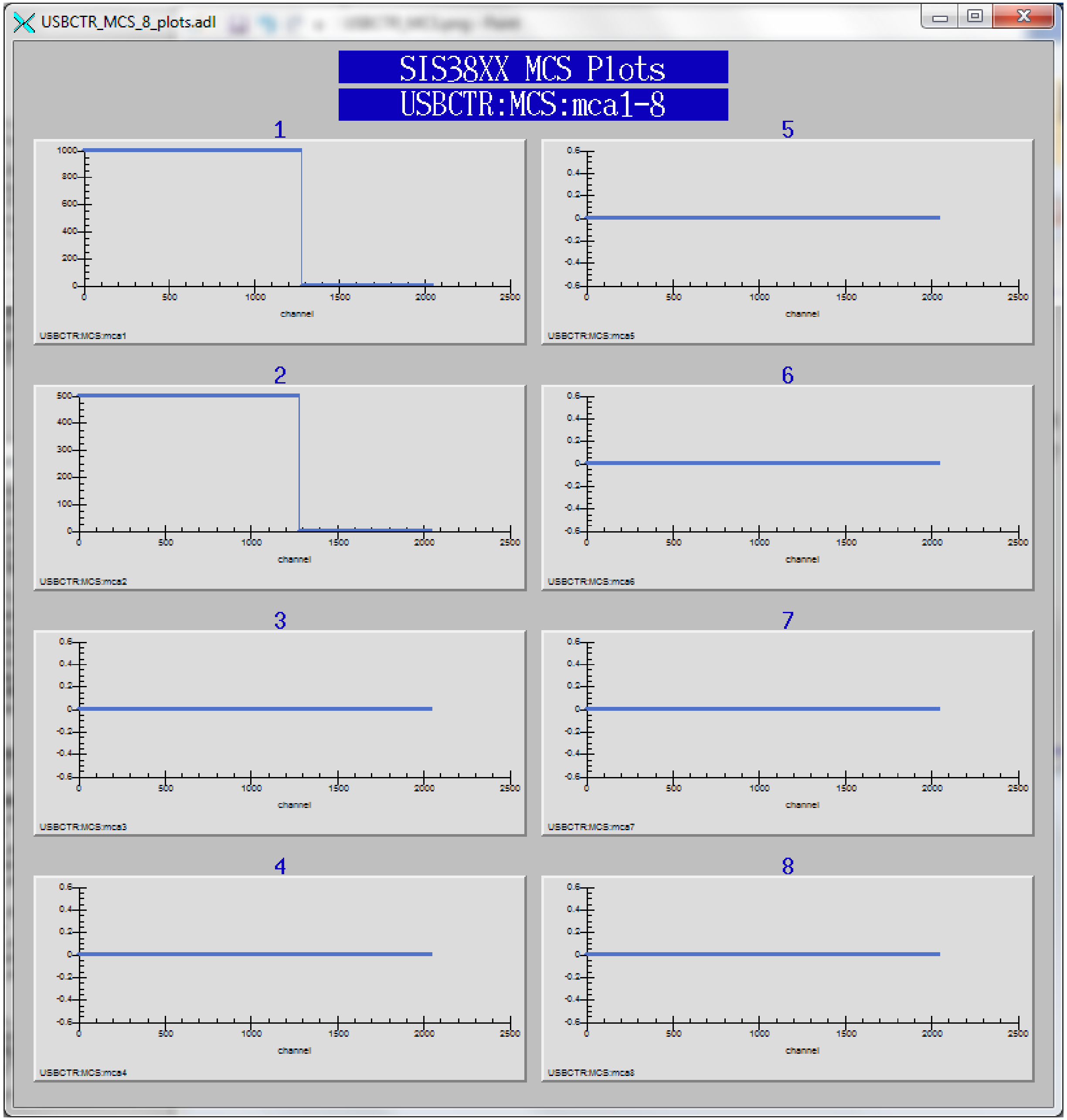


Scaler record

USB-CTR08 Multi-channel scaler (MCS) mode control

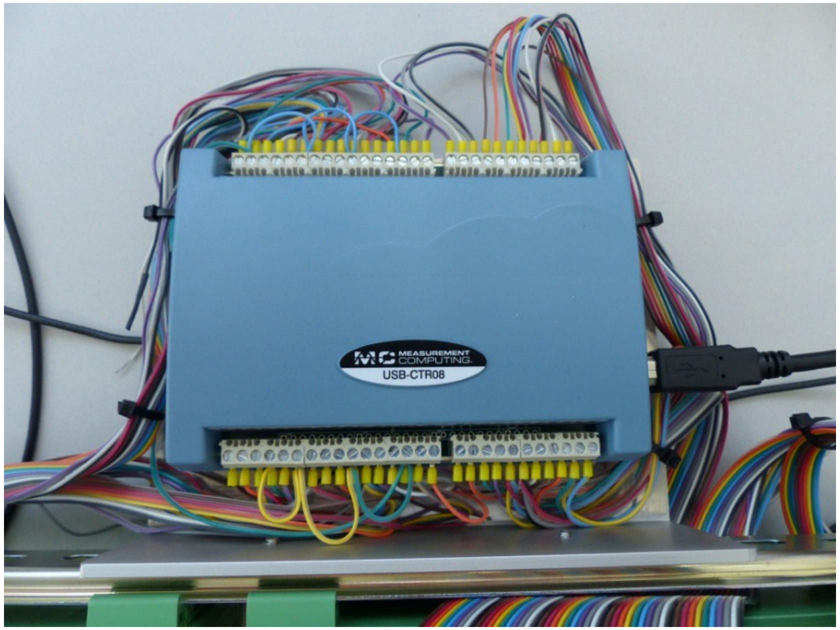


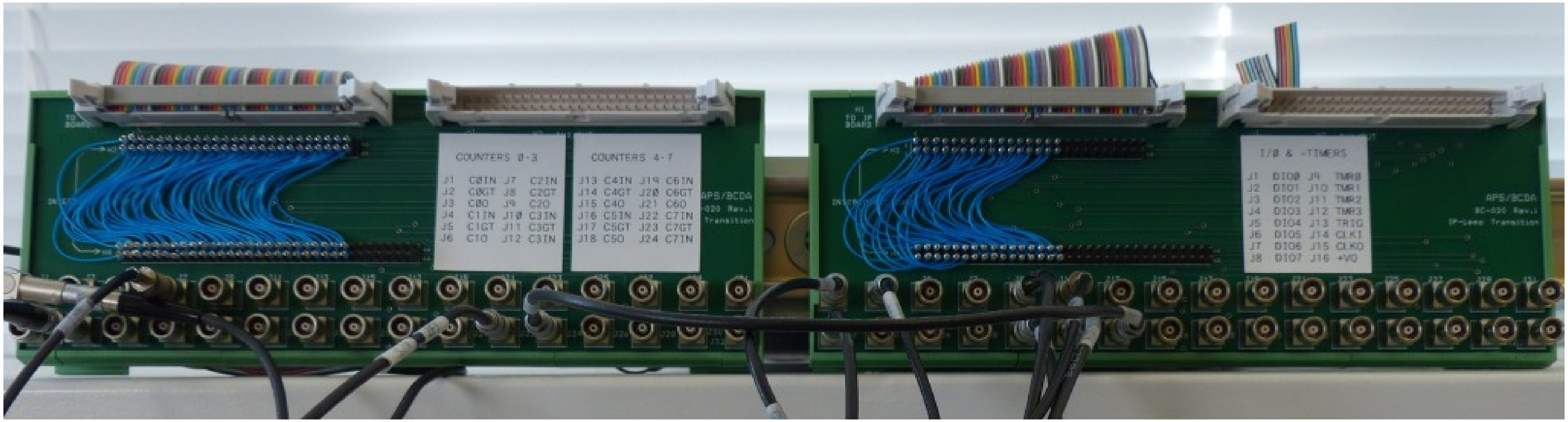
USB-CTR08 Multi-channel scaler (MCS) mode plots



USB-CTR08 Cabling

- Using standard BCDA BC-020 LEMO breakout
- 50-pin ribbon cable with ground on all even pins
- Currently using wire-wrap.
- Kurt Goetze is designing new daughter card to replace wire-wrap.
  - 25 LEMOs plus grounds on even lines





USB-CTR08 Restrictions

- The EPICS driver only works on Windows, because it requires the Measurement Computing Univeral Library which is only available for Windows.
- The EPICS scaler record support has true preset on Counter 0. It will stop all of the other counters instantly. The other counters can also have presets, but they stop the counter in software, with 0.01 second worst-case latency.
- The EPICS driver only uses the Totalize mode of the counters. With the scaler record it does a one-shot totalize, while in the MCS mode it totalizes into time-bins. The USB-CTR08 is also capable of running in 3 other modes.
  - In Period mode it measures the time between the rising or falling edges of successive input pulses.
  - In Pulse Width measurement mode it measures the time between the rising and falling edges of a each pulse.
  - In Timing Mode it measures the time between an event on the counter input and another event on the counter gate.
- None of these modes are currently supported by the EPICS driver, but they could be added in a future release.

USB-CTR08 Restrictions

- In Totalize mode each counter has many options in how it works: count up/down, gate clears counter, gate controls counter direction, preset counts where the output signal goes high/low, polarity of the output, etc. These options are not currently exposed in the EPICS driver.
- The EPICS driver only works in 32-bit counter depth mode. The USB-CTR08 can count with a 64-bit counter depth.
  - EPICS does not currently have support for 64-bit integer data types, so this cannot be supported.
- To work with the scaler record the Counter 0 Output must be wired to the Gate Inputs of Counters 1-7. This allows Counter 0 to be the preset counter and stop all of the other counters. This is most easily done on the screw terminals, not on the LEMO breakout.

areaDetector R2-0 Release

- areaDetector was getting too big.
  - New releases being held up waiting for testing on one detector types, etc.
- Hard to collaborate with other sites using APS Subversion repository
  - git and github provide much better tools for multi-site collaborations

R2-0 Organization

areaDetector
Top-level module
RELEASE files, documentation, Makefile

ADCore
Core module
Base classes, plugins, simDetector, documentation

ADBinaries
Binary libraries for Windows (HDF5, GraphicsMagick)

ADProsilica
Prosilica driver

ADPilatus
Pilatus driver

…

- Each box above is a separate git repository
- Can be released independently
- Hosted at http://github.com/areaDetector project
- Each repository is a submodule under areaDetector/areaDetector

R2-0: Point Grey driver

- New driver for all cameras from Point Grey using their FlyCap2 SDK.
- Firewire, GigE and USB 3.0
- High performance, low cost

R2-0: Point Grey driver

Point Grey GigE Camera
BlackFly PGE-20E4C

- e2v EV76C570 CMOS sensor
- Global shutter
- 29 x 29 x 30 mm
- Power Over Ethernet
- 4.5 micron pixels
- 1600 x 1200 pixels, color (mono)
- 47 frames/s
- $595
  - 5X cheaper than comparable Prosilica cameras we bought in the past

Point Grey USB-3.0 Camera Grasshopper3 GS3-U3-23S6M

- 1920 x 1200 global shutter CMOS
- Sony IMX174 1/1.2
- No smear • Distortion-free
- Dynamic range of 73 dB
- Peak QE of 76%
- Read noise of 7e-
- Max frame rate of 162 fps
  - ~356 MB/S, >3X faster than GigE
- USB 3.0 interface
- $1,295

Comparison to Other Cameras

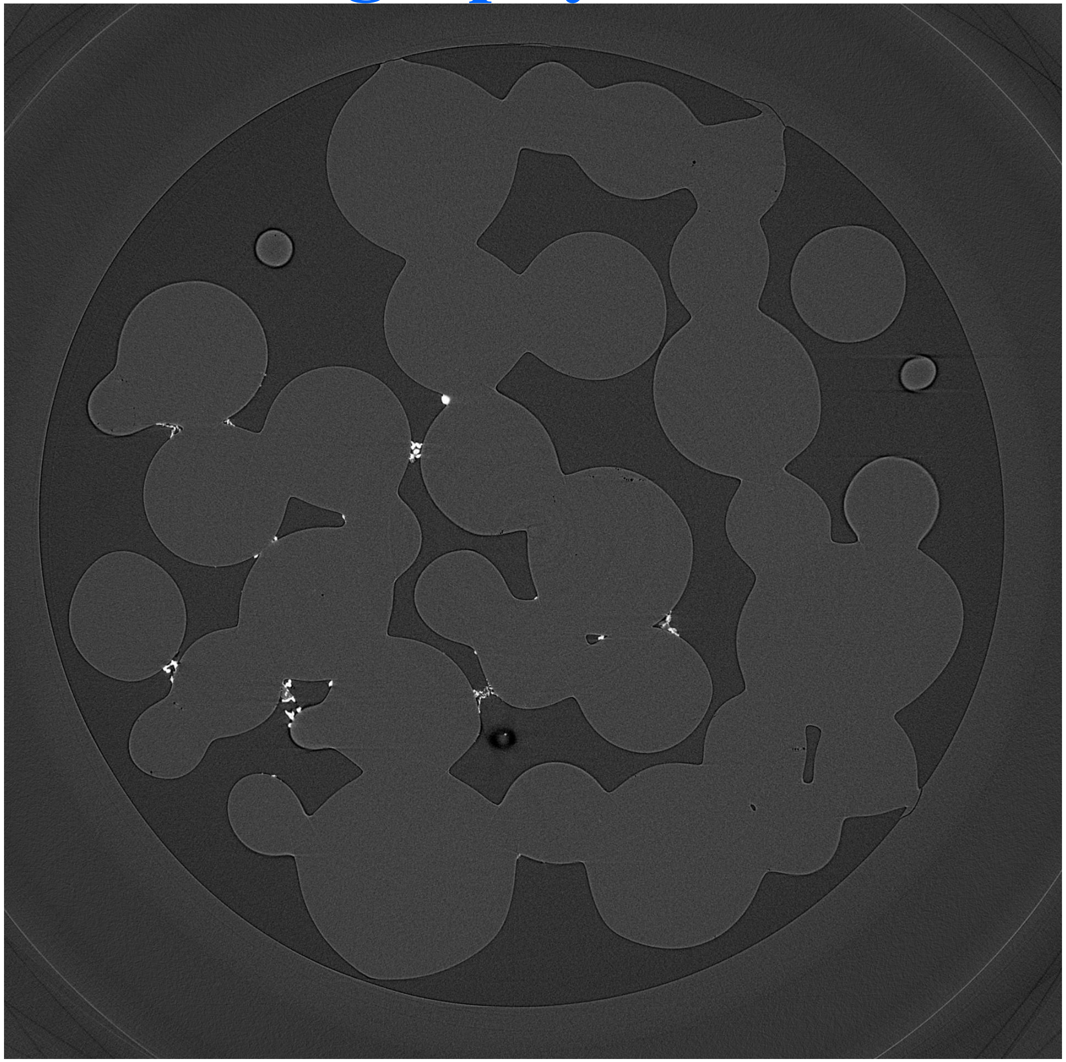
	Grasshopper3	Photometrics CoolSnap HQ²	Andor Zyla	Andor Neo
Format	1920 x 1200	1392 x 1040	2560 x 2160	2560 x 2160
Interface	USB 3.0	PCI Proprietary	CameraLink 10-tap	CameraLink 3-tap
Maximum frame/s	162 (8-bits) 80 (12-bits)	10 (12-bits)	100 (Rolling, 12-bit) 75 (Rolling, 16-bit) 50 (Global 12/16-bit)	30 (Rolling or Global) 79 (1920x1080)
Cooled	No	-30°C	0°C	-30°C
Full-well e^-	32,513	16,000	30,000	30,000
Read noise e^-	7	5.5	1.2 (Rolling) 2.5 (Global)	1.0 (Rolling) 2.3 (Global)
Price	$1,295	~$15,000	$19,500	~$15,000

Grasshopper3 GS3-U3-23S6M Applications

- I originally purchased the camera for planned fast pink-beam tomography
  - Not a full-time need, did not want to spend $15K
  - Radiation damage worry. $1,295 can be replaced frequently if needed
- Starting yesterday Grasshopper3 has replaced CoolSnap HQ2 as standard camera for regular tomography at 13-BM-D
  - 13 ms readout vs 100 ms in 12-bit mode, 6 ms in 8-bit mode
  - 2.5 more voxels in reconstruction
  - Equivalent quality
- Planning to do first pink-beam tomography this weekend, can do 900 projections in 11.25 seconds at 12-bit, 6.5 seconds in 8-bit

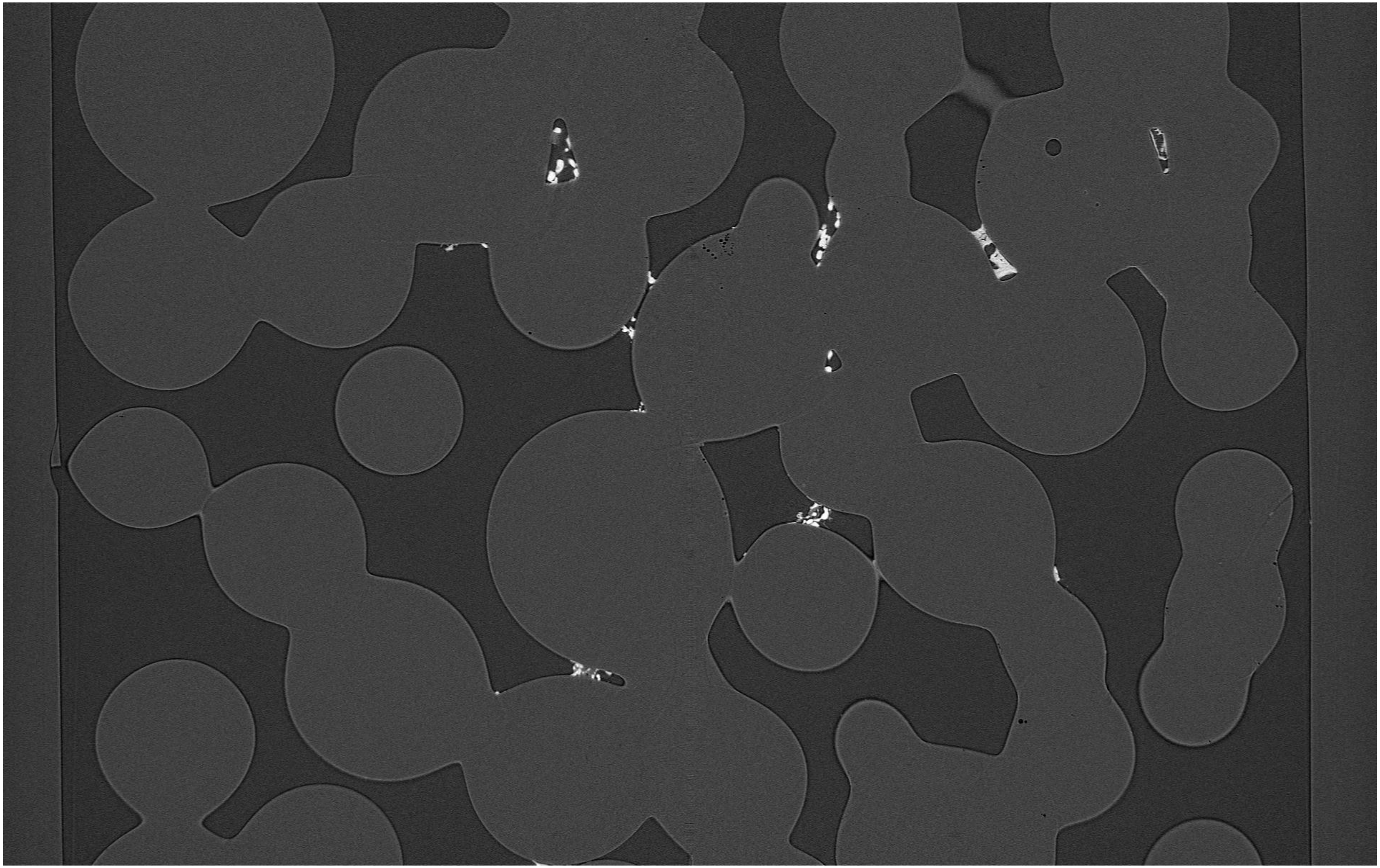
Grasshopper3 GS3-U3-23S6M
First Tomography Data

30 minutes total



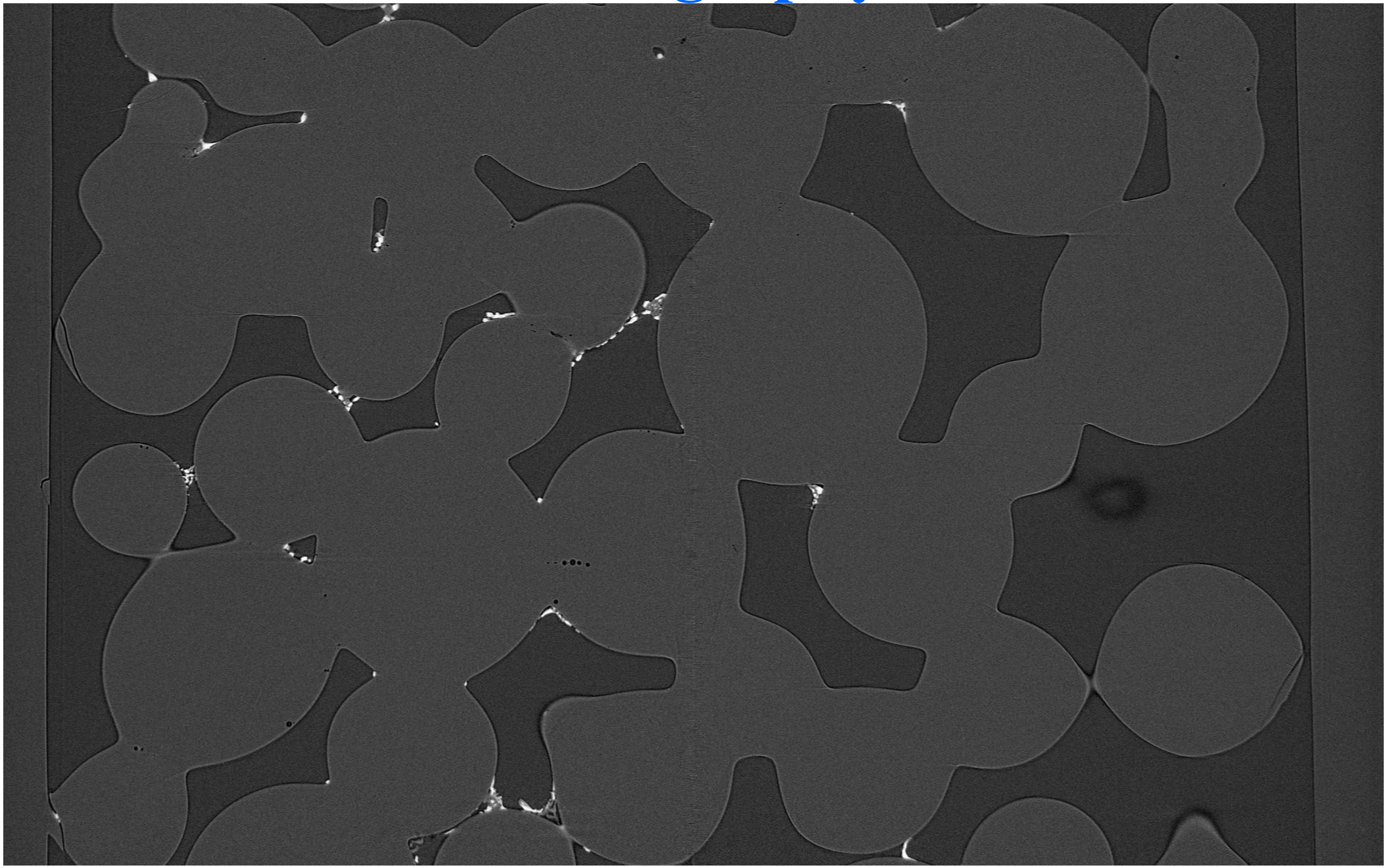
Z slice for normal slow scan, 0.85 s exposure, 1800 projections

Grasshopper3 GS3-U3-23S6M
First Tomography Data



X slice for normal slow scan, 0.85 s exposure, 1800 projections

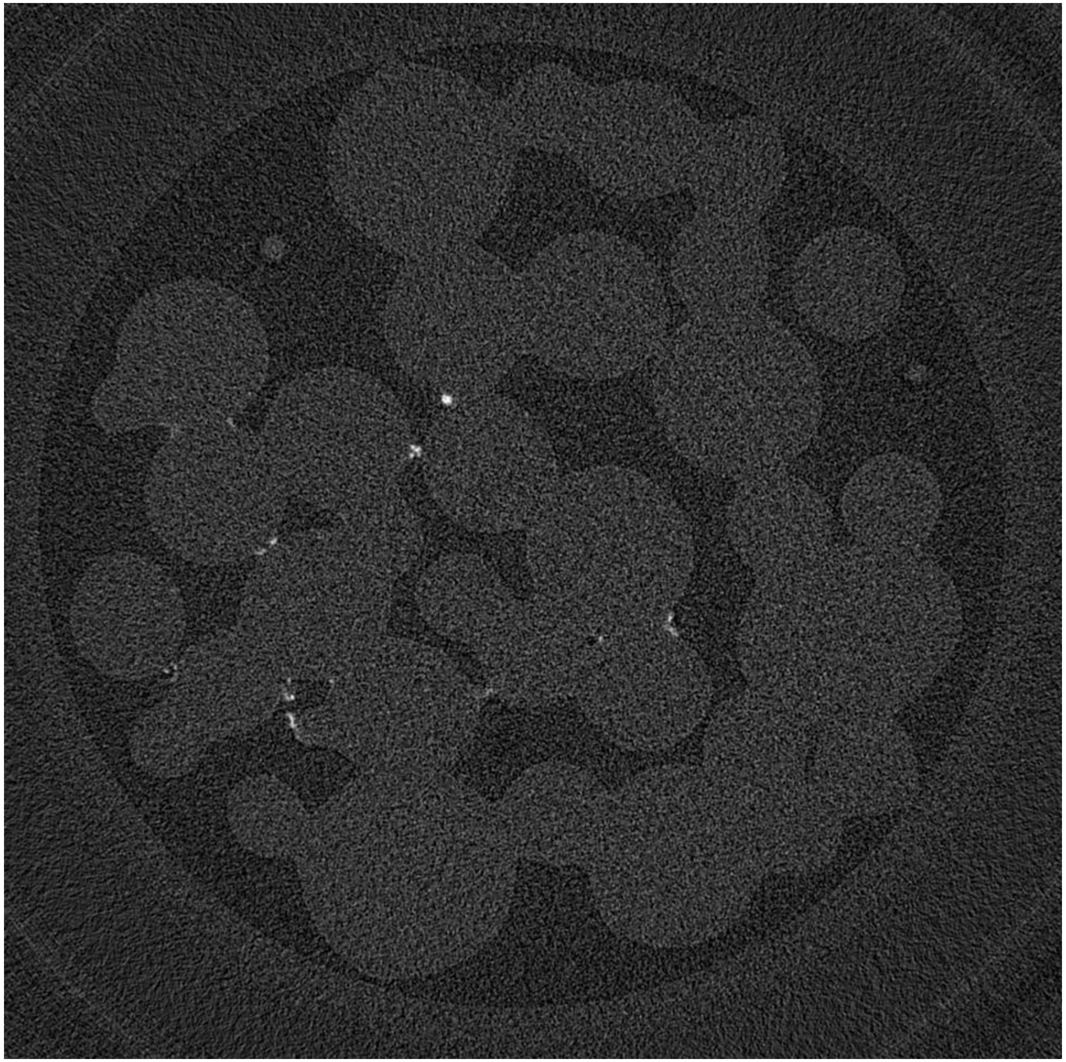
Grasshopper3 GS3-U3-23S6M
First Tomography Data



Y slice for normal slow scan, 0.85 s exposure, 1800 projections

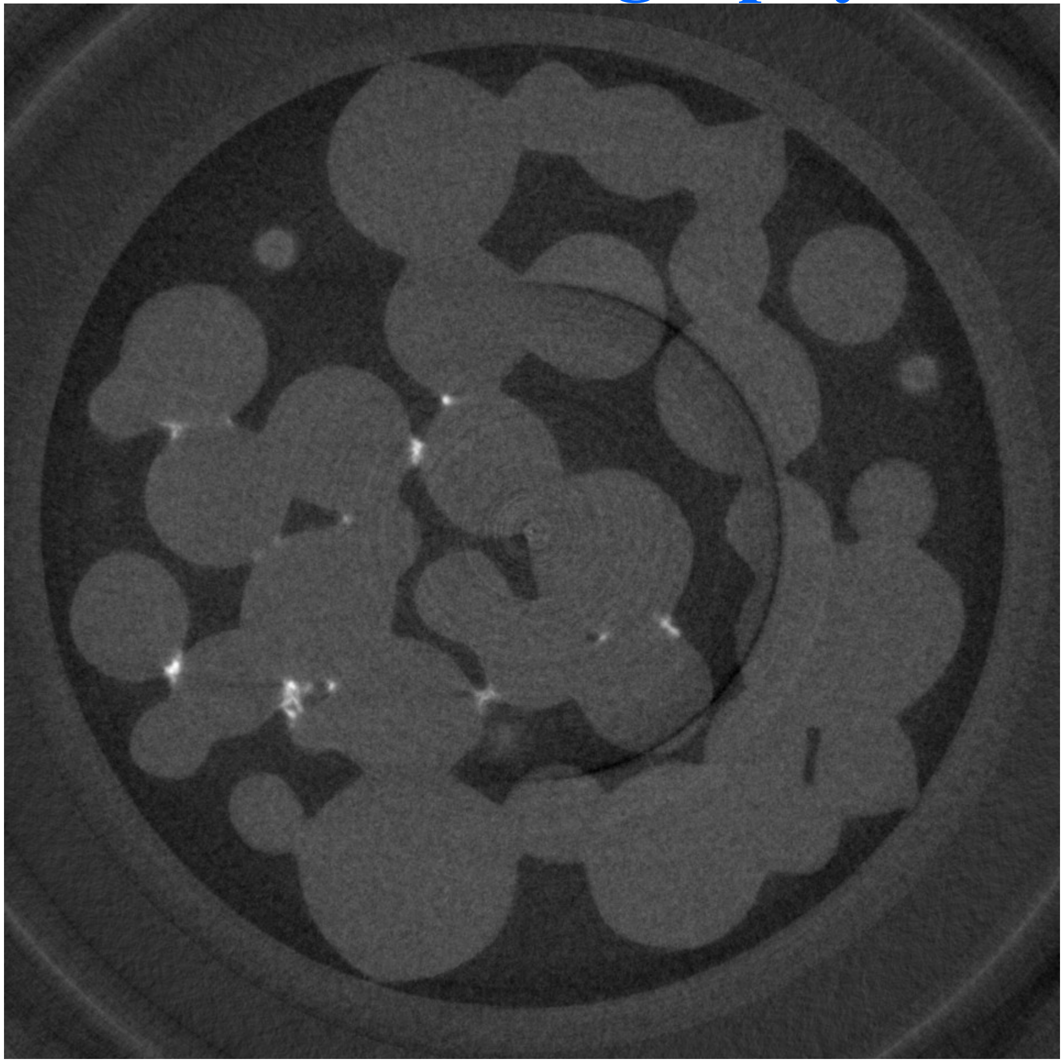
Grasshopper3 GS3-U3-23S6M
First FastTomography Data
Si 111 mono beam

11.25 seconds total



Z slice for fast scan, 2x2 binned, 0.006 s exposure, 900 projections

Grasshopper3 GS3-U3-23S6M
First FastTomography Data



Same fast scan, but reconstructed by Doga with phase retrieval rather than Gridrec

Very promising for doing fast tomography even with monochromatic beam!

How many bits do I really have/need?

Common misconceptions about required number of bits in a camera

- The ADC should be set so 1 LSB is ~read noise.
- The number of bits required is then given by the ratio of the full-well capacity to the read noise. Example of Grasshopper3:
  - Full well = 32,513 e^-
  - Read noise = 7 e^-
  - Ratio = 4644 = 12.18 bits, so 12 bits required
- But this does NOT mean that the full-well is captured with 12 bit precision!
  - Noise in full-well measurement = sqrt(30,000) = 173 e^-
  - Signal to noise in full-well measurement = 30,000/173 = 173. This is less than 8 bits!
  - So a 12-bit camera is not required to digitize the full-well with full precision.

How many bits do I really have/need?

- Example: Tomography where air/flat field use full-well (close to saturation) and maximum absorption is 80%.
- Darkest pixels have 20% transmission = 30000 * 0.2 = 6000 e^-
- Noise in darkest pixels is sqrt(6000) = 77 e^-
- Brightest pixels are 30000 e^-, so dynamic range is 30000/77 = 387. This is 8.6 bits. So a 9 bits is all that is required for this application.
- Collecting 12 or 16 bits is completely overkill for a camera with 30000 e^- full-well UNLESS the range of the pixel intensities in a single image really covers the entire range from the read-noise to the full-well capacity. This applies to Andor and PCO Edge cameras.