

areaDetector: A module for EPICS area detector support

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areaDetector Talk Outline

- Motivation & goals for areaDetector module
- Overview of architecture
- Drivers for detectors & cameras
- Plugins for real-time processing
- Viewers and other clients
- Demo with simDetector

areaDetector - Goals

- Drivers for many detectors popular at synchrotron beamlines
 - Handle detectors ranging from >500 frames/second to <1 frame/second
- Basic parameters for all detectors
 - E.g. exposure time, start acquisition, etc.
 - Allows generic clients to be used for many applications
- Easy to implement new detector
 - Single device-driver C++ file to write. EPICS independent.
- Easy to implement detector-specific features
 - Driver understands additional parameters beyond those in the basic set
- EPICS-independent at lower layers.
- Middle-level plug-ins to add capability like regions-of-interest calculation, file saving, etc.
 - Device independent, work with all drivers
 - Below the EPICS layer for highest performance

areaDetector – Data structures

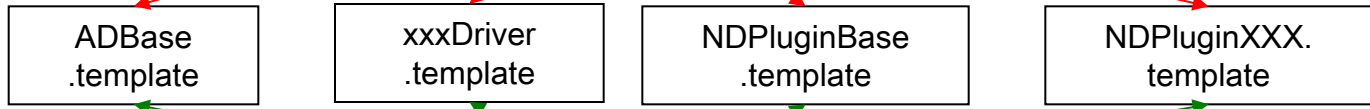
- **NDArray**
 - N-Dimensional array.
 - Everything is done in N-dimensions (up to 10), rather than 2. This is needed even for 2-D detectors to support color.
 - This is what plug-ins callbacks receive from device drivers.
- **NDArrtribute**
 - Each NDArray has a list of associated attributes (metadata) that travel with the array through the processing pipeline. Attributes can come from driver parameters, any EPICS PV, or any user-written function.
 - e.g. can store motor positions, temperature, ring current, etc. with each frame.
- **NDArrayPool**
 - Allocates NDArray objects from a freelist
 - Plugins access in readonly mode, increment reference count
 - Eliminates need to copy data when sending it to callbacks.

EPICS areaDetector Architecture

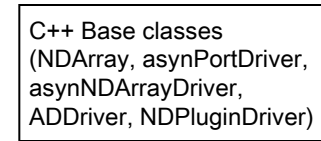
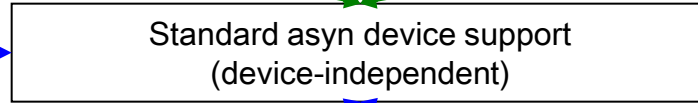
Layer 6
EPICS CA clients



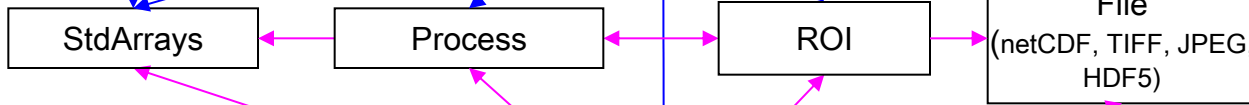
Layer 5
Standard
EPICS records



Layer 4
EPICS device
support



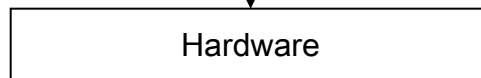
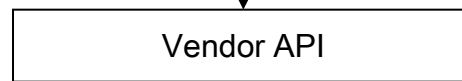
Layer 3
Plug-ins



Layer 2
Device drivers



Layer 1
Hardware API



areaDetector – Data structures

Look at NDArrary.h

Look at NDAttribute.h

Look at an XML attribute file

areaDetector Organization

areaDetector

Top-level module
RELEASE and CONFIG_SITE files, documentation,
Makefile

ADCore

Core module
Base classes, plugins,
documentation

ADSupport

Support libraries for
HDF5, xml2, NeXus,
JPEG, TIFF, etc.

ADSimDetector

Simulation detector
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

Source Code Organization on github

- <https://github.com/areaDetector> is top-level project
- Contains configure/ directory where paths and versions of supporting software are defined
- Contain .gitmodules to define submodules that will be cloned with `git clone --recursive`
- Contains documentation directory that builds and installs documentation
- Contains a top-level Makefile to build all or selected submodules

Detector drivers (32 in Github project)

- ADDriver (in ADCore)
 - Base C++ class from which detector drivers derive. Handles details of EPICS interfaces, and other common functions.
- Simulation driver
- AVT (Prosilica) GigE cameras
- aravisGigE: any GigE camera using the Genicam interface
- Pilatus, Eiger pixel-arrays detectors
- Pixirad CdTe pixel array detectors
- marCCD, mar345 detectors
- Princeton Instruments cameras (3 drivers)
- Andor CCD and sCMOS cameras
- Perkin Elmer flat panel detectors
- Point Grey GigE, USB-3 and Firewire cameras
- Many more ...

Detector drivers

- ADDriver (in ADCore)
 - Base C++ class from which detector drivers derive. Handles details of EPICS interfaces, and other common functions.
- Simulation driver (in ADSimDetector)
 - Produces calculated images up to very high rates. Implements nearly all basic parameters, including color. Useful as a model for real detector drivers, and to test plugins and clients.
- Prosilica driver (ADProsilica)
 - Gigabit Ethernet cameras, mono and color
 - High resolution, high speed, e.g. 1360x1024 at 30 frames/second = 40MB/second.
- Firewire (IEEE-1396 DCAM) (ADFireWireWin, firewireDCAM)
 - Vendor-independent Firewire camera drivers for Linux and Windows
- Roper driver (ADRoper)
 - Princeton Instruments and Photometrics cameras controlled via WinView

Detector drivers (continued)

- Bruker driver (ADBruker)
 - Bruker detectors controlled via their Bruker Instrument Server (BIS)
- LightField driver (ADLightField)
 - Princeton Instruments detectors controlled via their LightField application using the Microsoft Common Language Runtime to automate it
- PSL driver (ADPSL)
 - Photonic Sciences Limited detectors
- URL driver (ADURL)
 - Driver to display images from any URL. Works with Web cameras, Axis video servers, static images, etc.
- Andor driver (ADAndor)
 - Driver for Andor CCD cameras
- Andor3 driver (ADAndor3)
 - Driver for Andor sCMOS cameras with V3 of their SDK

Detector drivers (continued)

- Point Grey driver (ADPointGrey)
 - Driver for GigE, USB-3.0, USB-2.0, and Firewire cameras from Point Grey Research
- Pixirad driver (ADPixirad)
 - Driver for CdTe pixel-array detectors from Pixirad
- Generic GigE driver (aravisGigE)
 - Should work with any GigEVision compliant camera. From Tom Cobb at Diamond. Uses Aravis reverse-engineered GigEVision library
- PVAccess (EPICS V4) driver
 - Receives NTNDArrays over PVAccess
 - Allows plugins to run on other processes or machines from the areaDetector driver

ADBase.adl – Generic control screen

- Works with any detector
- Normally write custom control for each detector type to hide unimplemented features and expose driver-specific features

ADBase.adl

Area Detector Control - 13SIM1:cam1:

Setup

asyn port SIM1
EPICS name 13SIM1:cam1:
Manufacturer Simulated detector
Model Basic simulator
Connected
Connection
More

Shutter

Shutter mode
Status: Det. EPICS
Open/Close
Delay: Open Close
EPICS shutter setup

Collect

Exposure time 0.010
Acquire period 0.000
Images 10
Images complete 703
Exp./image 1
Image mode Continuous
Trigger mode Internal
Acquire
Detector state
Time remaining 0.000
Image counter 703
Image rate 67.0
Array callbacks Enable

Readout

	X	Y
Sensor size	640	480
Binning	<input type="text" value="1"/>	<input type="text" value="1"/>
Region start	<input type="text" value="0"/>	<input type="text" value="0"/>
Region size	<input type="text" value="640"/>	<input type="text" value="480"/>
Reverse	<input type="button" value="No"/>	<input type="button" value="No"/>
Image size	640	480
Image size (bytes)		307200
Gain	<input type="text" value="1.000"/>	1.000
Data type	<input type="button" value="UInt8"/>	UInt8
Color mode	<input type="button" value="Mono"/>	Mono

File

Driver file I/O

Pilatus specific control screen

pilatusDetector.adl Pilatus Detector Control - 13PIL1:cam1:

Setup

asyn port **PIL**
EPICS name **13PIL1:cam1:**
Manufacturer **Dectris**
Model **Pilatus**
Connection **Connected**
Debugging

Shutter

Shutter mode **None**
Status: Det. **Closed** EPICS **Closed**
Open/Close **Open** **Close**
Delay: Open **0.000** Close **0.000**
EPICS shutter setup

Status

Status: **Waiting for acquire command**
To camserver: **Exposure /corvette/home/epics/temp/pilatus_test_A_081.tif**
From camserver: **7 OK /corvette/home/epics/temp/pilatus_test_A_081.tif**

Data corrections

Bad pixel file:
Bad pixels: **0**
Flat field file:
Flat field valid: **No** Min. flat field: **100**

Collect

Exposure time **1.000** **1.000**
Acquire period **0.150** **0.150**
Images **1** **1**
Delay time **0.000000** **0.000000**
Exp./image **1** **1**
Trigger mode **Internal** **Internal**
Acquire **Start** **Stop**
Armed **Unarmed**
Image counter **0** **1**
Image rate **0.0**
Array callbacks **Enable** **Enable**

File

File path **/corvette/home/epics/temp/** Exists: **Yes**
File name **pilatus_test_A**
Next file # **82** **82**
Auto increment **Yes** **Yes** Ancillary information
Filename format **%%s_%.3d.tif** File format **TIFF** **TIFF**
Last filename **/corvette/home/epics/temp/pilatus_test_A_081.tif**

Plugins

All **File** **ROI**
Stats **Other**

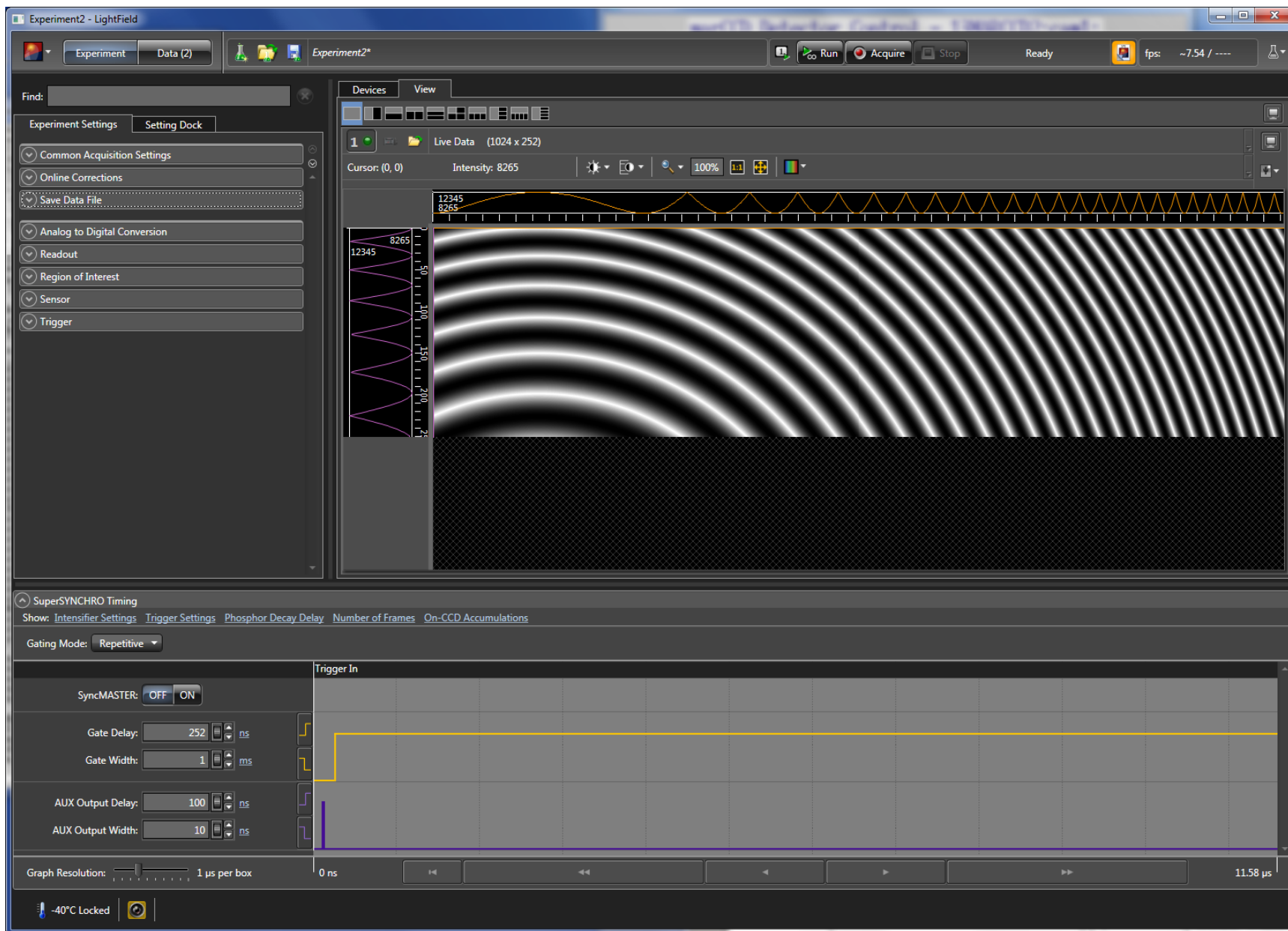
Detector

Detector Size **487** **195**
Threshold (keV) **10.000** **10.000**
Threshold apply **Yes** **Apply**
Shaping time/Gain **5-18KeV/Med/MedG**
Pixel cutoff **1071635**
Read file timeout **20.000**
Gap fill **N.A.**
Temperature **0.0** **-99.0** **0.0**
Humidity **0.0** **-99.0** **0.0**
TVX version **Unknown**

Attributes

File **pilatusAttributes.xml**

LightField driver



LightField driver

LightField.adl

Area Detector Control - 13LF1:cam1:

Setup

asyn port **LF1**
EPICS name **13LF1:cam1:**
Manufacturer **Princeton Instrument**
Model **PIXIS: 100BR**
Connected
Connection
Debugging

Shutter

Shutter Type
LF Shutter Mode
Status: Det. **Closed** EPICS **Closed**
Open/Close
Delay: Open Close
EPICS shutter setup

Spectrometer

[860nm, 300] [1] [0]
Grating
Center wavelength **750.000**
Entrance width **100**
Exit port **Front**

Plugins

Collect

Exposure time **5.000**
Acquire Period **0.000**
Accumulations **0**
Exposures **1**
Frames **1**
Exposures Complete **0**
Frames Complete **1535**
Acquisitions **0**
Acquisitions Complete **0**
Image Mode **Normal**
Trigger Mode
Acquire **Done**
Detector State **Idle**
Ready to Run **Ready**
Image counter **1535**
Image Rate **0.0**
Array Callbacks **Disable**

Readout

	X	Y
Sensor Size	<input type="text" value="1340"/> 1340	<input type="text" value="100"/> 100
Binning	<input type="text" value="1"/> 1	<input type="text" value="1"/> 1
Region Start	<input type="text" value="0"/> 0	<input type="text" value="78"/> 78
Region Size	<input type="text" value="1340"/> 1340	<input type="text" value="10"/> 10
Reverse	<input type="button" value="No"/> No	<input type="button" value="No"/> No
Image Size	<input type="text" value="1340"/> 1340	<input type="text" value="10"/> 10
Image Size (bytes)		<input type="text" value="26800"/> 26800
Gain	<input type="button" value="Low"/> Low	<input type="button" value="Medium"/> Medium
Data type		<input type="text" value="UInt16"/> UInt16
Temperature	<input type="text" value="-75.000"/> -75.000	<input type="text" value="-75.000"/> -75.000
Actual temperature		<input type="text" value="-75.000"/> -75.000

Intensifier

Int. Enable **Disable**
Intensifier Gain **0**
Gating Mode **Repetitive**
Trigger Frequency **1e+001**
SyncMaster **Enable**
SyncMaster2 Delay **1.00e-004**
Rep. Gate Width **5.00e-002**
Rep. Gate Delay **0.00e+000**
Seq. Start Width **0.00e+000**
Seq. Start Delay **0.00e+000**
Seq. End Width **0.00e+000**
Seq. End Delay **0.00e+000**
Aux I/O Width **2.00e-006**
Aux I/O Delay **0.00e+000**

Experiment

PIXIS 5_29_2013.lfe
Experiment

Attributes

File

URL Driver

- Driver that can read images from any URL.
- Can be used with Web cameras and Axis video servers.
- Uses GraphicsMagick to read the images, and can thus handle a large number of image formats (JPEG, TIFF, PNG, etc.).

URLDriver.adl

Area Detector Control - 13URL1:cam1:

Setup

asyn port URL1
EPICS name 13URL1:cam1
Manufacturer URL Driver
Model GraphicsMagick
Connected
Connection
Debugging

Shutter

Shutter mode
Status: Det. EPICS
Open/Close
Delay: Open Close
EPICS shutter setup

Collect

Acquire period
Images
Images complete
Image mode
Acquire
Detector state
Image counter
Image rate
Array callbacks

Readout

	X	Y
Image size	704	480
Image size (bytes)	1013760	
Data type	UInt8	
Color mode	RGB1	

Attributes

File

URL

URLDriverSetup.adl

URL Setup - 13URL1:cam1:

Description	URL
1 BMC Hutch (Axis)	http://164.54.160.141/jpg/1/hugesize.jpg
2 BMC Sample (Axis)	http://164.54.160.141/jpg/2/hugesize.jpg
3 The Sun!	images/sun.jpg
4 marCCD	images/marCCD.tif
5 MultiTIFF	images/MultiTIFF.tiff
6 URL6	
7 URL7	
8 URL8	
9 URL9	
10 URL10	

Perkin Elmer Flat Panel Driver

PerkinElmer.adl

Perkin Elmer Control - 13PE1:cam1:

Setup

asyn port PEDET1
EPICS name 13PE1:cam1:
Manufacturer Perkin Elmer
Model XRD0820
Connected
Connection
Debugging

Corrections

Corrections Directory

C:\Perkin_Elmer\
 Done
Correction **Available**

Offset

Offset Frames 10 10
 Done
Correction **Available**

Gain

Gain Frames 20 0
 Done
Correction **Not Available**

Bad Pixel File

16#5149_1pF_PxlMask.his
Correction **Available**

Shutter

Shutter mode None
Status: Det. **Closed** EPICS **Closed**
Open/Close
Delay: Open 0.000 Close 0.000
EPICS shutter setup

Collect

Exposure time 0.200 0.200
Gain 0.25pF 0.25pF
Images 20 20
Images complete 31
Skip frames Disable
Frames to skip 1 1
Image mode Continuous
Trigger mode Internal

Collecting
Acquire
Detector state **Acquire**
Image counter 0 151
Image rate 5.0
Array callbacks Enable

Plugins

All
Stats

Readout

	X	Y
Sensor size	2048	2048
Binning	1	1
Image size	2048	2048
Image size (bytes)	8388608	

Setup

Frame Buffers 10 10
Frame buffer index 7
Image Number 31

Attributes

File PerkinElmerAttributes.xml

Point Grey driver

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



Mono
Sensor



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
- Dynamic range of 73 dB
- Peak QE of 76%
- Read noise of $7e^-$
- 12-bit or 8-bit data
- Max frame rate of 162 fps
 - ~356 MB/S, >3X faster than GigE
- USB 3.0 interface
- Now used for tomography at 3 APS beamlines, replaced Andor Neo and PCO Edge
- \$995



Point Grey Driver

pointGrey.adl

Point Grey Area Detector Control - 13PG1:cam1:

Setup

asyn port PG1
 EPICS name 13PG1:cam1:
 Manufacturer Point Grey Research
 Model Blackfly BFLY-PGE-20
 Serial Number 13481965
 Firmware Vers. 1.27.3.0
 Software Vers. 2.6.3
 Debugging

Shutter

Shutter mode
 Status: Det. Closed EPICS
 Open/Close
 Delay: Open Close
 EPICS shutter setup

Status

Status rate
 Dropped frames 0
 Corrupt frames 0
 Driver dropped 0
 Transmit failed 0
 Temperature 42.8

Attributes

File

Plugins

All File ROI
 Stats Other

Readout

	X	Y
Sensor size	1600	1200
Region start	<input type="text" value="0"/>	<input type="text" value="0"/>
Region size	<input type="text" value="1600"/>	<input type="text" value="1200"/>
GigE binning	<input type="text" value="1x1"/>	<input type="text" value="1x1"/>
Image size	1600	1200
Image size (bytes)	1920000	
Gain	<input type="text" value="0.000"/>	<input type="text" value="0.000"/>
Data type	UInt8	
Color mode	Mono	
Video mode	<input type="text" value="Format7"/> Format7	
Format7 mode	<input type="text" value="0 (1600x1200)"/>	
Properties	<input type="button" value="⊞"/>	
Frame rate	<input type="button" value="⊞More"/>	Undefined1
Pixel format	<input type="button" value="⊞More"/>	Raw8
Convert raw	<input type="text" value="None"/> None	
Timestamp	<input type="text" value="Camera"/> Camera	

Trigger

Internal
 Trigger mode
 Trigger source GPIO_0
 Trigger polarity High
 Trigger delay 0.000
 Skip frames 0
 Software trigger

Strobe

Strobe source GPIO_1
 Strobe enable Enable
 Strobe polarity Low
 Strobe delay 0.001
 Strobe duration 0.020

Collect

Exposure time 0.033
 Acquire period 0.033
 Frame rate 30.000
 # Images 1000
 # Images complete 189
 # Exp./image 1
 Image mode Multiple
 Acquire
 Detector state Waiting
 Status
 Image counter 189
 Image rate
 Array callbacks Enable

Collecting

Bandwidth Control

Max packet size 9000
 Packet size 1440
 Packet size 1440
 GigE packet delay 400
 Bandwidth (MB/s) 54.9

Buffers

Buffers max/used	0	1
Buffers alloc/free	2	1
Memory max/used (MB)	0.0	3.7
Buffer & memory polling	<input type="text" value="1 second"/>	

Point Grey Driver (Grasshopper3 camera)

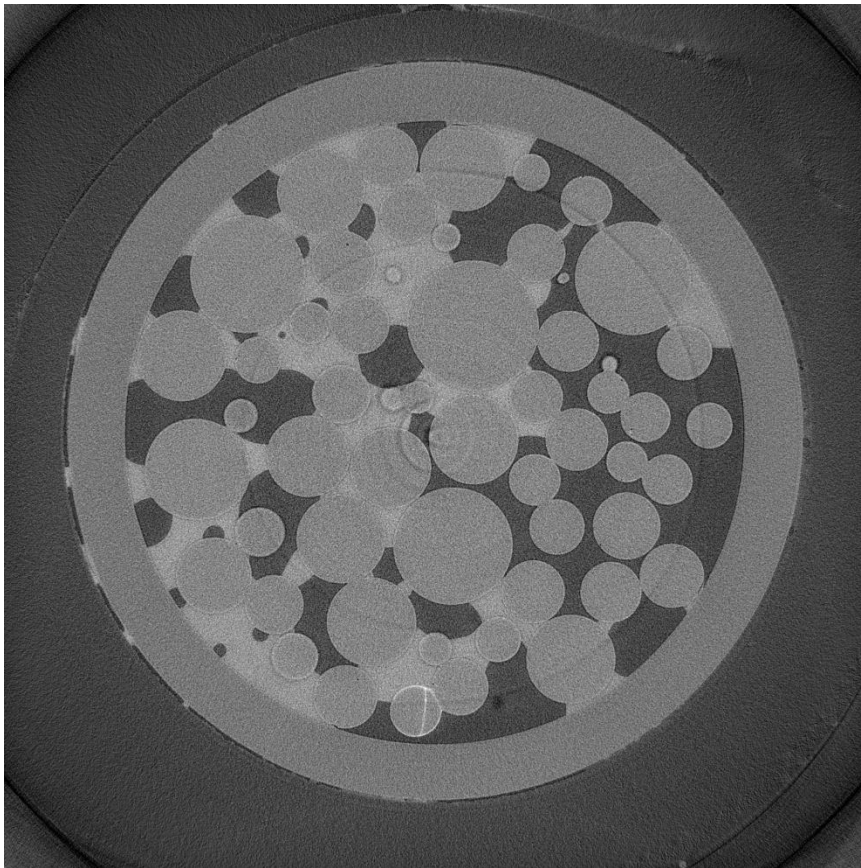
pointGreyProperties.adl

13PG1:cam1: Point Grey Properties

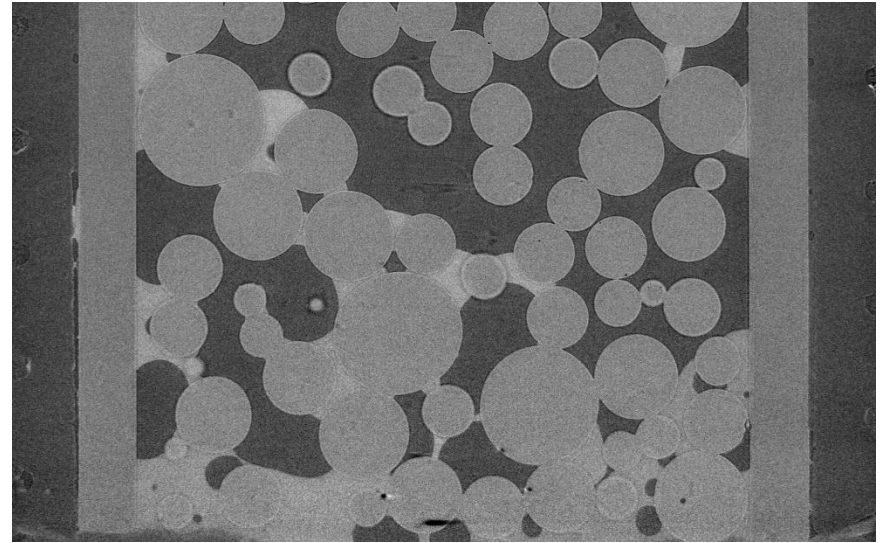
Property	Device Unit Control			Absolute Control			
	On/Off	One push	Auto/Manual	Set	Readback	Min	Max
Brightness	On			0	0	0	511
Auto exposure	On	Push	Manual	468	468	1	1023
Sharpness	Off		Manual	0	0	0	4095
White bal. red	Off						
White bal. blue							
Hue	Off						
Saturation	Off						
Gamma	On			512	512	512	4095
Shutter	On	Push	Manual	1181	1242	1	1242
Gain	On	Push	Manual	8	240	0	240
Iris	Off						
Focus	Off						
Temperature	Off						
Trigger mode	On		Manual	5	0	2844	1
Trigger delay	On			0	0	0	4095
Frame rate	Off		Manual	752	407	407	1629
Zoom	Off						
Pan	Off						
Tilt	Off						
				0.000	0.000	0.000	12.476
				-3.679	1.285	-7.585	2.414
				0.937	0.500	0.500	3.999
				23.779	76.311	0.061	76.311
				2.772	23.997	0.000	23.997
				20.000	3.133	0.000	inf
				0.000	0.000	0.000	0.077
				15.000	12.984	3.974	12.984

Pink Beam Tomography

- Mirror angle=2.0 mrad (Beads_Pink_H)
- 2 mm Al absorber
- 8-bit data
- 1 ms exposure time, 124 frames/s, 900 projections, 7.3 seconds total
- Rotation axis orientation corrected for mirror angle



Horizontal slice



Vertical slice

Plugins

- Perform real-time processing of data, running in the EPICS IOC (not over EPICS Channel Access)
- Receive NDAarray data over callbacks from drivers or other plugins
- Plug-ins can execute in their own threads (non-blocking) or in callback thread (blocking)
 - If non-blocking then NDAarray data is queued
 - Can drop images if queue is full
 - If executing in callback thread, no queuing, but slows device driver
- Allows
 - Enabling/disabling
 - Throttling rate (no more than 0.5 seconds, etc)
 - Changing data source for NDAarray callbacks to another driver or plugin
- Plugins are also sources of NDAarray callbacks, as well as consumers.
 - Allows creating a data processing pipeline running at very high speed, each in a different thread, and hence in multiple cores on modern CPUs.
 - ADCore R3-0 allows each plugin itself to run in multiple threads. More later.

Plugins (continued)

- NDPlugInStdArrays
 - Receives arrays (images) from device drivers, converts to standard arrays, e.g. waveform records.
 - This plugin is what EPICS channel access viewers normally talk to.
- NDPluginROI
 - Performs region-of-interest calculations
 - Select a subregion. Optionally bin, reverse in either direction, convert data type.
 - Divide the array by a scale factor, which is useful for avoiding overflow when binning.
- NDPluginColorConvert
 - Convert from one color model to another (Mono, RGB1 (pixel), RGB2 (row) or RGB3 (planar) interleave)
 - Bayer conversion removed from this plugin, now part of Prosilica and Point Grey drivers.
- NDPluginTransform
 - Performs geometric operations (rotate, mirror in X or Y, etc.)

Plugins (continued)

- NDPluginStats
 - Calculates basic statistics on an array (min, max, sigma)
 - Optionally computes centroid position, width and tilt.
 - Optionally Computes X and Y profiles, including average profiles, profiles at the centroid position, and profiles at a user-defined cursor position.
 - Optionally computes the image histogram and entropy
- NDPluginROIStat
 - Multiple ROIs with simple statistics in a single plugin
 - More efficient when many ROIs are needed, e.g. for peaks in a 1-D energy spectrum
 - Min, max, total, net, mean
 - Time-series of each of these statistics

Plugins (continued)

- NDPluginProcess
 - Does arithmetic processing on arrays
 - Background subtraction.
 - Flat field normalization.
 - Offset and scale.
 - Low and high clipping.
 - Recursive filtering in the time domain.
 - Conversion to a different output data type.
- NDPluginOverlay
 - Adds graphic overlays to an image.
 - Can be used to display ROIs, multiple cursors, user-defined boxes, text, etc.
- ffmpegServer
 - MJPEG server that allows viewing images in a Web browser. From DLS.

Plugins (continued)

- **NDPluginAttribute**
 - Extracts NDAttributes from NDArrays and publishes their values as ai records
 - Can collect time-series arrays of the attribute values
- **NDPluginCircularBuff**
 - Buffers NDArrays in a circular buffer
 - Computes a trigger expression using up to 2 NDAttribute values
 - When trigger condition is met then outputs NDArrays
 - User-specified number of pre-trigger and post-trigger arrays to output
- **NDPluginTimeSeries**
 - Accepts 1-D NDArrays[NumSignals] or 2-D [NumSignals,NewTimePoints] and appends to time-series buffer
 - Operates in fixed length (stop when full) or circular buffer modes
 - Optional time-averaging of input data

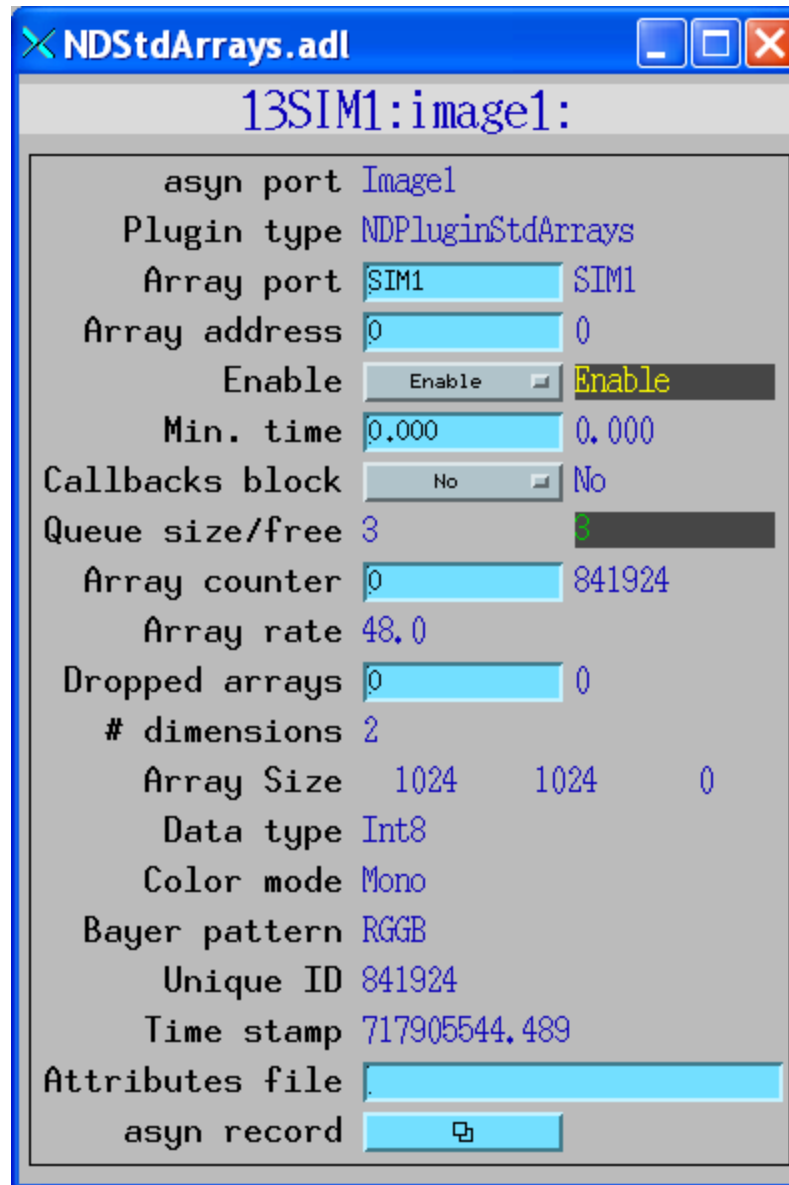
Plugins (continued)

- NDPluginFFT
 - Computes FFT of 1-D or 2-D NDArrays
 - Exports NDArrays containing the absolute value (power spectrum) of the FFT
 - Exports 1-D arrays of the FFT real, imaginary, absolute values, and time and frequency data.
- NDPluginPVA
 - Converts NDArrays to EPICS V4 NTNDArrays
 - Exports the NtNDArrays over PVAccess with internal V4 server
 - Can be used to send structured data to EPICS V4 clients
 - When used with the PVAccess driver then areaDetector plugins can be run on different machine from the detector driver

commonPlugins.adl All plugins at a glance

Plugin name	Plugin type	Port	Enable	Blocking	Dropped	Free	Rate		
Image1	NDPluginStdArrays	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	3	89.0	More
PROC1	NDPluginProcess	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	20	89.0	More
TRANS1	NDPluginTransform	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
CC1	NDPluginColorConvert	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
CC2	NDPluginColorConvert	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
OVER1	NDPluginOverlay	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
ROI1	NDPluginROI	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	19	89.0	More
ROI2	NDPluginROI	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
ROI3	NDPluginROI	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
ROI4	NDPluginROI	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
STATS1	NDPluginStats	ROI1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
STATS2	NDPluginStats	ROI2	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
STATS3	NDPluginStats	ROI3	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
STATS4	NDPluginStats	ROI4	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
STATS5	NDPluginStats	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	885	0	21.0	More
FileNetCDF1	NDFileNetCDF	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	20	0.0	More
FileTIFF1	NDFileTIFF	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
FileJPEG1	NDFileJPEG	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
FileNexus1	NDPluginFile	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	20	0.0	More
FileMagick1	NDFileMagick	SIM1	Disable <input type="checkbox"/>	Disable	No <input type="checkbox"/>	0	20	0.0	More
FileHDF1	NDFileHDF5 ver1.8.7	SIM1	Enable <input type="checkbox"/>	Enable	No <input type="checkbox"/>	0	20	0.0	More

NDStdArrays plugin



ROI plugin

NDROI.adl

13SIM1:ROI1:

asyn port	ROI1		
Plugin type	NDPluginROI		
Array port	SIM1	SIM1	
Array address	0	0	
Enable	Enable	Enable	
Min. time	0.000	0.000	
Callbacks block	No	No	
Queue size/free	20	20	
Array counter	0	834794	
Array rate	48.0		
Dropped arrays	0	0	
# dimensions	2		
Array Size	1024	1024	0
Data type	Int8		
Color mode	Mono		
Bayer pattern	RGGB		
Unique ID	834794		
Time stamp	717905394.895		
Attributes file	i		
asyn record			

Definition

Name: Upper left

Data type: Automatic

Enable scaling: Enable

Scale divisor: 2

	X	Y	Z
Input Size	1024	1024	0
Enable	Enable	Enable	Disable
Binning	1	1	1
ROI start	0	0	0
ROI size	512	512	1
Reverse	No	No	No
ROI Size	512	512	0

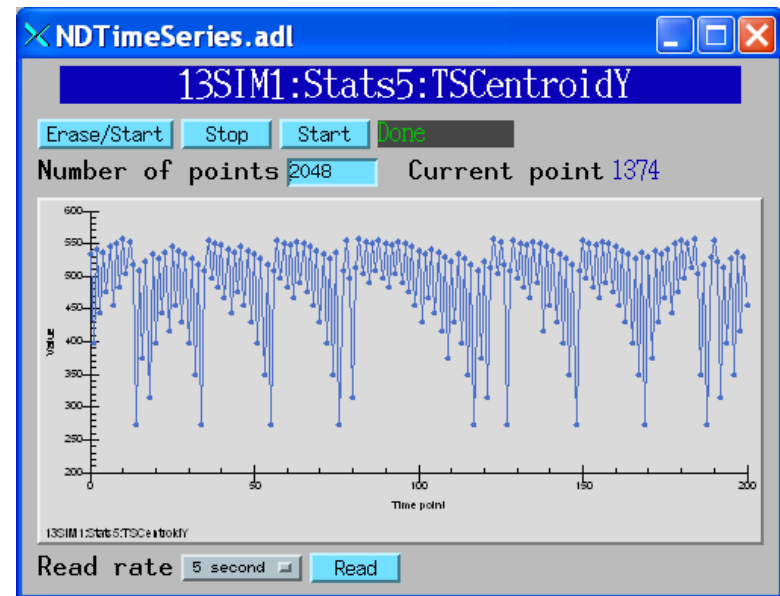
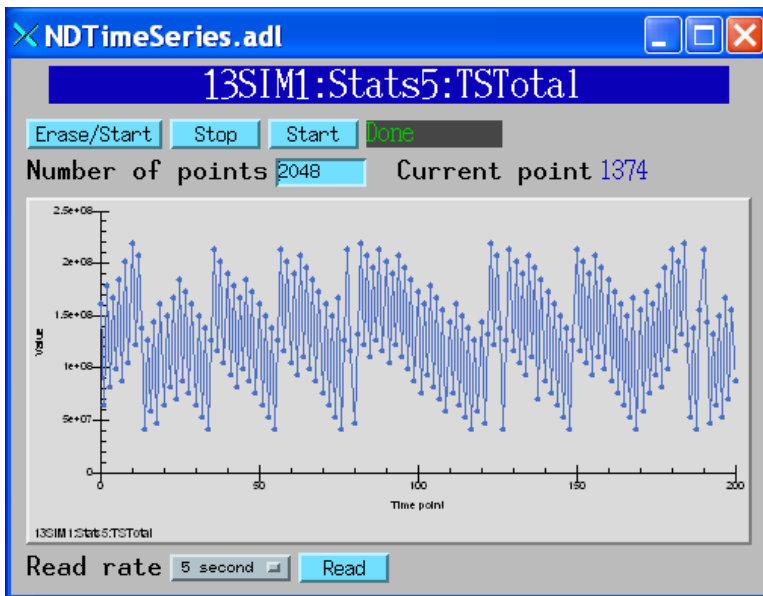
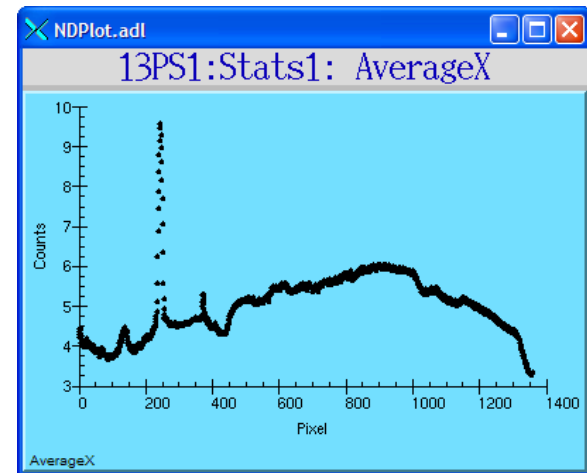
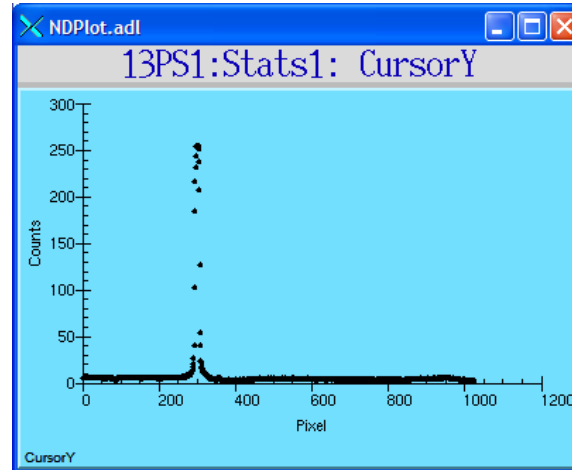
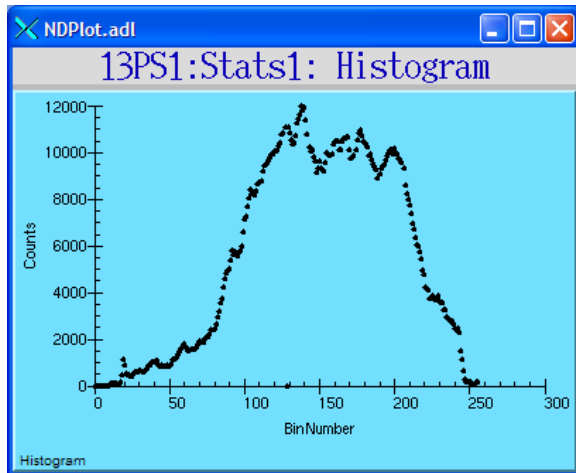
Statistics plugin

NDStats.adl

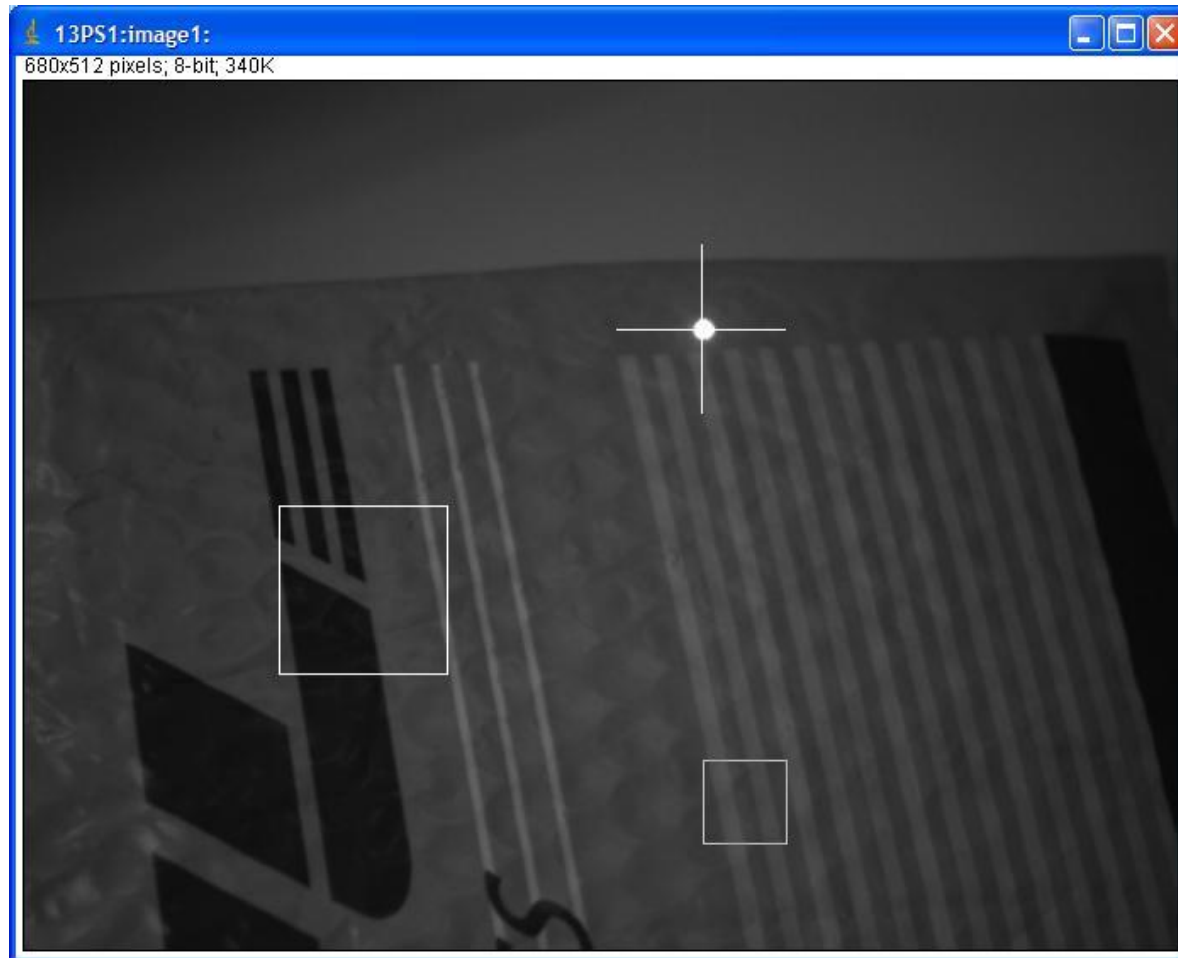
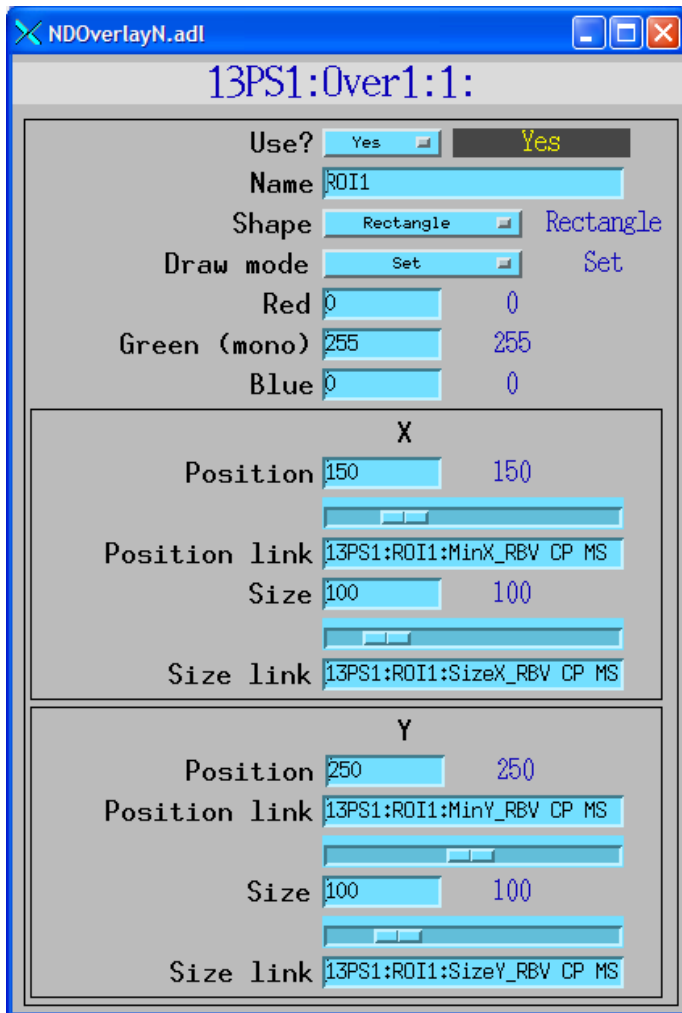
13SIM1:Stats5:

<p>asyn port STATS5</p> <p>Plugin type NDPluginStats</p> <p>Array port SIM1 SIM1</p> <p>Array address 0 0</p> <p>Enable <input type="checkbox"/> Enable Enable</p> <p>Min. time 0.000 0.000</p> <p>Callbacks block <input type="checkbox"/> No No</p> <p>Queue size/free 20 12</p> <p>Array counter 0 4056</p> <p>Array rate 25.0</p> <p>Dropped arrays 0 395</p> <p># dimensions 2</p> <p>Array Size 1024 1024 0</p> <p>Data type Int8</p> <p>Color mode Mono</p> <p>Bayer pattern RGGB</p> <p>Unique ID 4451</p> <p>Time stamp 717886862.801</p> <p>Attributes file .</p> <p>asyn record <input type="checkbox"/></p>	<p>Statistics</p> <p>Compute statistics <input type="checkbox"/> Yes Yes</p> <p>Background width 1 1</p> <p>Minimum 0 Maximum 6</p> <p>Min. X 0 Max. X 200</p> <p>Min. Y 0 Max. Y 148</p> <p>Total 622 Net 622</p> <p>Mean 0 Sigma 0.0</p> <p>Time series plots <input type="checkbox"/></p>	<p>Profiles</p> <p>Compute profiles <input type="checkbox"/> Yes Yes</p> <p>Size X 1024 Y 1024</p> <p>256 256</p> <p>Cursor X <input type="checkbox"/></p> <p>256 256</p> <p>Cursor Y <input type="checkbox"/></p> <p>Plot <input type="checkbox"/></p>
	<p>Centroid</p> <p>Compute centroid <input type="checkbox"/> Yes Yes</p> <p>Centroid threshold 1 1</p> <p>Centroid X 200.0 Y 150.1</p> <p>Sigma X 3.9 Y 3.9</p> <p>Sigma XY -0.024</p> <p>Time series plots <input type="checkbox"/></p>	<p>Histogram</p> <p>Compute histogram? <input type="checkbox"/> Yes Yes</p> <p>Size 256 256</p> <p>Minimum 0 0</p> <p>Maximum 255 255</p> <p>Entropy -13.860</p> <p>Plot <input type="checkbox"/></p>
	<p>Time Series</p> <p>Erase/Start <input type="checkbox"/> Stop <input type="checkbox"/> Start <input type="checkbox"/> Acquiring</p> <p>Number of points 2048</p> <p>Current point 82</p> <p>Read rate <input type="checkbox"/> 5 second <input type="checkbox"/> Read</p>	

Statistics plugin (continued)



Overlay plugin



Centroid of laser pointer calculated by statistics plugin
Cursor overlay X, Y position linked to centroid

Processing plugin

NDProcess.adl

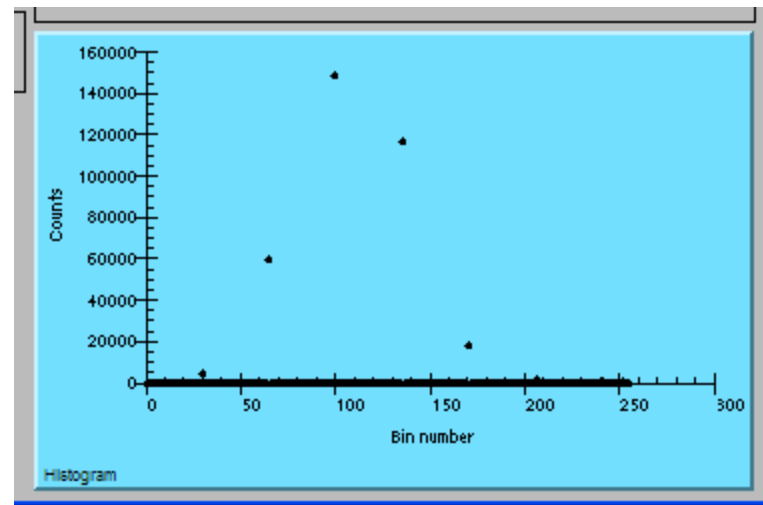
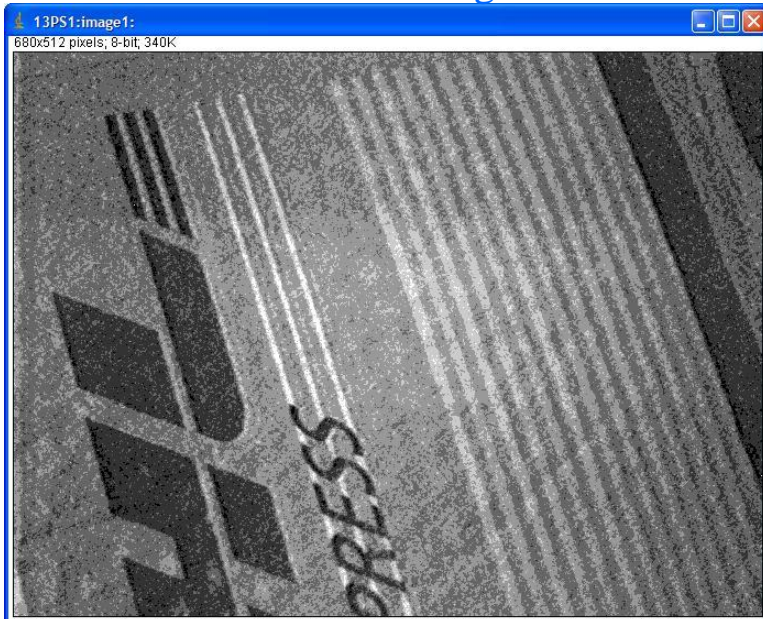
13SIM1:Proc1:

asyn port PROC1 Plugin type NDPluginProcess Array port SIM1 SIM1 Array address 0 0 Enable Enable Enable Min. time 0.000 0.000 Callbacks block No No Queue size/free 20 20 Array counter 0 11572 Array rate 47.0 Dropped arrays 0 0 # dimensions 2 Array Size 1024 1024 0 Data type Int8 Color mode Mono Bayer pattern RGGB Unique ID 12032 Time stamp 717887092.888 Attributes file asyn record	<h3>Background subtraction</h3> Save background Save Invalid Enable background Disable Disable <h3>Flat field normalization</h3> Save flat field Save Invalid Enable flat field Disable Disable Scale flat field 255 255 <h3>Scale and Offset</h3> Enable scale/off. Disable Enable Auto scale/off. Auto calc Scale value 0.10 42.50 Offset value 0.00 0.00 <h3>Low/High Clipping</h3> Enable low clip Disable Enable Low clip value 100 0 Enable high clip Disable Enable High clip value 150 255 <h3>Output data type</h3> Data type Automatic Automatic	<h3>Recursive filter</h3> Enable filter Disable Disable N filter 100 100 N filtered 0 Filter type RecursiveAve Reset filter Reset Auto reset filter Yes Filter callbacks Every array OOffset 0.00 0.00 OScale 1.00 1.00 OC1 1.00 1.00 OC2 -1.00 -1.00 OC3 0.00 0.00 OC4 1.00 1.00 FOffset 0.00 0.00 FScale 1.00 1.00 FC1 1.00 1.00 FC2 -1.00 -1.00 FC3 0.00 0.00 FC4 1.00 1.00 ROffset 0.00 0.00 RC1 0.00 0.00 RC2 1.00 1.00 $O[n] = Ooffset + OScale * ((OC1+OC2/N) * F[n-1] + (OC3+OC4/N) * I[n])$ $F[n] = FOffset + FScale * ((FC1+FC2/N) * F[n-1] + (FC3+FC4/N) * I[n])$ <p>On filter reset: $F[0] = Roffset + RC1 * F[n] + RC2 * I[0]$ I = Input array in callback F = Stored filter (double precision) N = value of NumFiltered O = Output array passed to clients</p>
--	---	---

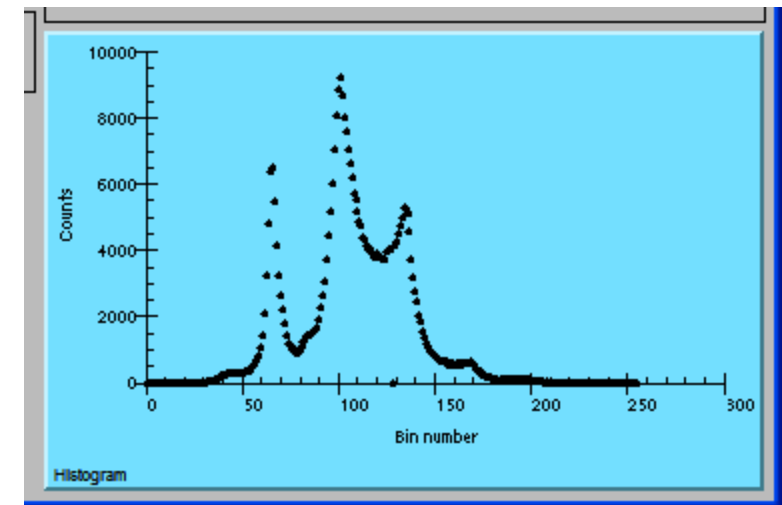
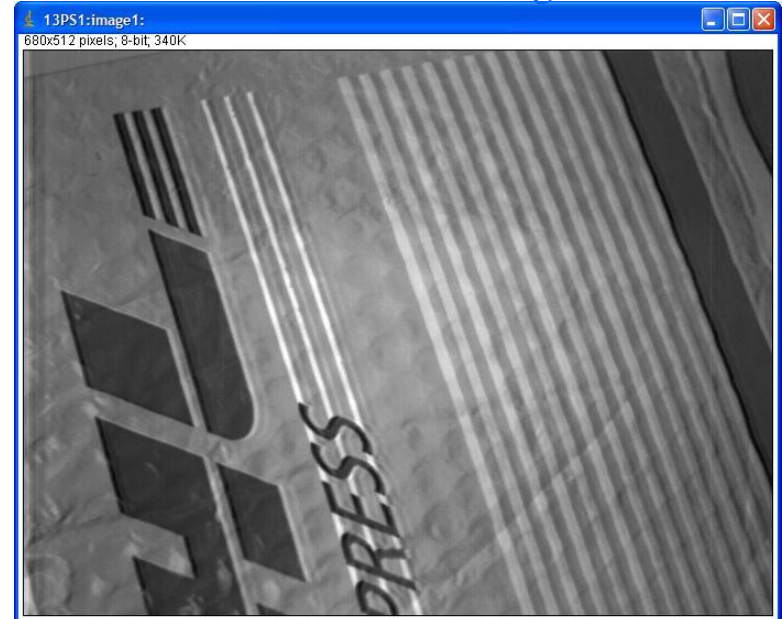
Processing plugin

30 microsec exposure time

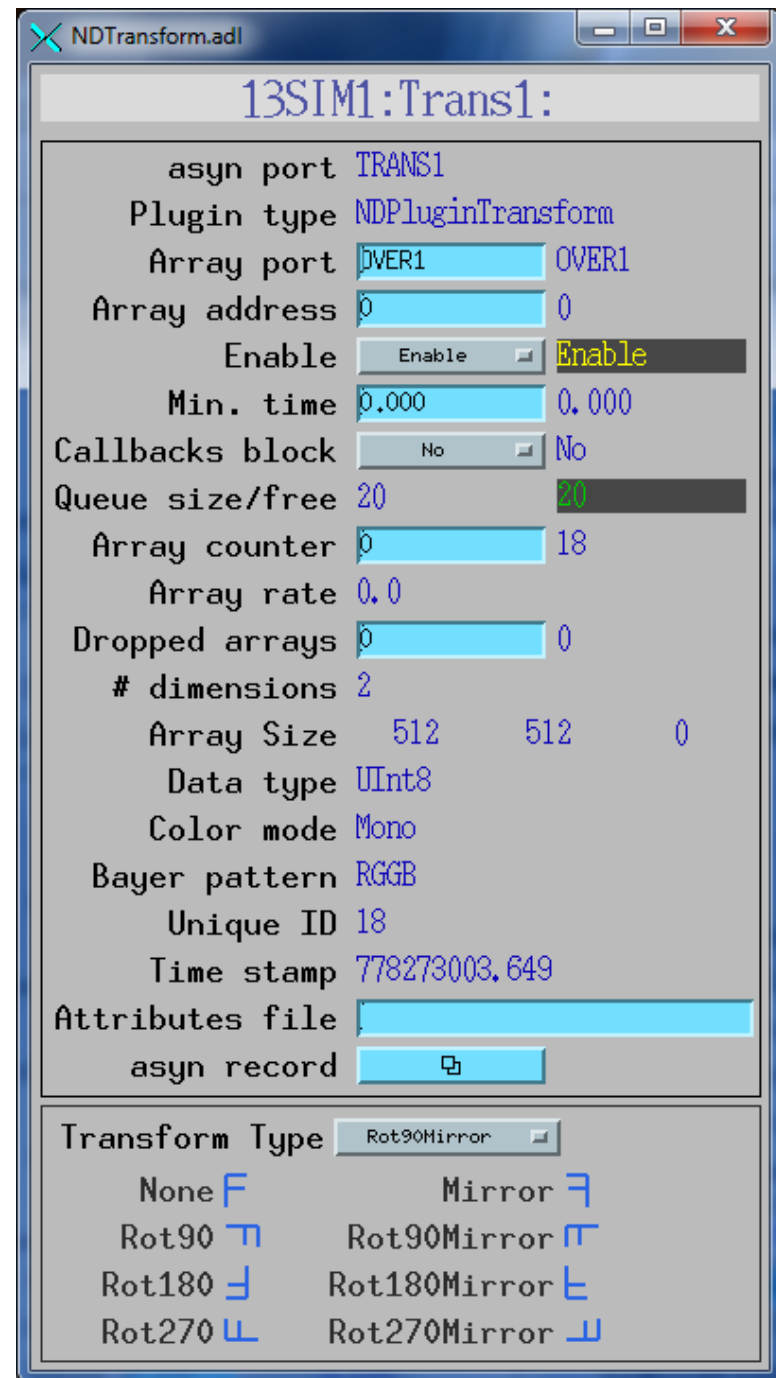
No filtering



N=100 recursive average filter

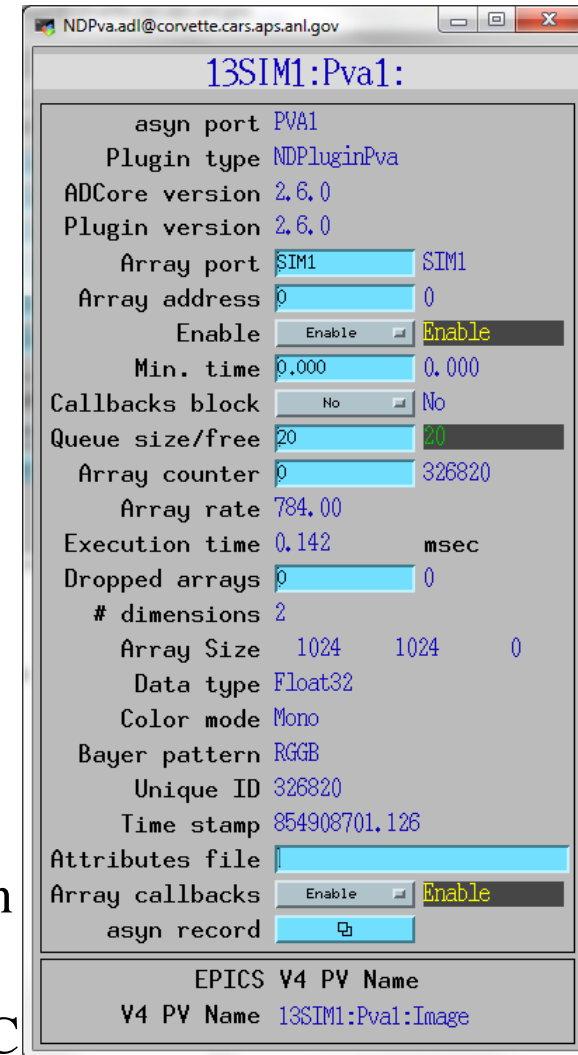


Transform plugin



NDPluginPva

- New plugin that converts NDArrays into the EPICSv4 normative type NTNDArray
- An embedded EPICSv4 server serves the new NTNDArray structure as an EPICSv4 PV
- High performance, ~3.2GB/s shown here
- Can be received by any EPICSv4 client
 - Java, Python, C++ versions of pvAccess
 - CSS has a widget that can display NTNDArrays
 - caQtDM has a new camera widget to display NTNDArrays
 - New version of the Java areaDetector ImageJ plugin based on pvAccess; talks to this plugin
 - Can include an NTNDArray receiver in another IOC



Plugins: NDPluginFile

- Saves NDArrays to disk
- 3 modes:
 - Single array per disk file
 - Capture N arrays in memory, write to disk either multiple files or as a single large file (for file formats that support this.)
 - Stream arrays to a single large disk file
- For file formats that support it, stores not just NDArray data but also NDAttributes

Plugins: NDPluginFile

- File formats currently supported
 - NDFileTIFF
 - Supports any NDArray data type
 - Stores NDAttributes as ASCII user tags
 - NDFileJPEG
 - With compression control
 - NDFileNetCDF
 - Popular self-describing binary format, supported by Unidata at UCAR
 - NDFileHDF5
 - Writes HDF5 files with the native HDF5 API, unlike the NeXus plugin which uses the NeXus API. Supports 3 types of compression.
 - Supports using an XML file to define the layout and placement of NDArrays and NDAttributes in the HDF5 file
 - Support Single Writer Multiple Reader (SWMR). Only supported on local file systems, GPFS, and Lustre (not NFS or SMB)

Plugins: NDPluginFile

- File formats currently supported
 - NDFileNeXus
 - Standard file format for neutron and x-ray communities, based on HDF5, which is another popular self-describing binary format; richer than netCDF
 - May be deprecated in a future release since NeXus files can now be produced with the NDFileHDF5 plugin using an appropriate XML layout file
 - NDFileMagick
 - Uses GraphicsMagick to write files, and can write in dozens of file formats, including JPEG, TIFF, PNG, PDF, etc.
 - NDFileNull
 - Used only to delete original driver files when no other file plugin is running

File saving with driver

- In addition to file saving plugins, many vendor libraries also support saving files (e.g. marCCD, mar345, Pilatus, etc.) and this is supported at the driver level.
- File saving plugin can be used instead of or in addition to vendor file saving
 - Can add additional metadata vendor does not support
 - Could write JPEGs for Web display every minute, etc.

NDPluginFile display: TIFF

The screenshot shows the NDPluginFile display window for the TIFF format. The window title is "NDFileTIFF.adl" and the main title is "13SIM1:TIFF1:". The interface is divided into two main sections: configuration on the left and file management on the right.

Configuration Section (Left):

- asyn port: FileTIFF1
- Plugin type: NDFileTIFF
- Array port: SIM1 (selected)
- Array address: 0
- Enable: Enable
- Min. time: 0.000
- Callbacks block: No
- Queue size/free: 20 / 30
- Array counter: 0 / 357
- Array rate: 82.0
- Dropped arrays: 0 / 83
- # dimensions: 2
- Array Size: 1024 x 1024 x 0
- Data type: Int8
- Color mode: Mono
- Bayer pattern: RGGB
- Unique ID: 438270
- Time stamp: 717964044.637
- Attributes file: [empty text box]
- asyn record: [empty text box]

File Management Section (Right):

- File path: /corvette/home/epics/scratch/ADFileTest/ Exists: Yes
- File name: test_tiff
- Next file #: 358 / 358
- Auto increment: Yes
- Filename format: %s%s_%d.tiff Example: %s%s_%3.3d.tif
- Last filename: /corvette/home/epics/scratch/ADFileTest/test_tiff_357.tiff
- Save file: Save Read file: Read Auto save: No
- Write mode: Stream Stream # Capture: 1000 / 1000 / 157
- Capture: Start Stop Delete driver file: No
- Write status: Write OK
- Write message: [empty text box]

Example: saving 82 frames/second of 1024x1024 video to TIFF files, a few dropped frames.

NDFFileHDF5

NDFileHDF5.adl

13SIM1:HDF1:

asyn port	FileHDF1
Plugin type	NDFFileHDF5 ver1.8.7
Array port	SIM1 SIM1
Array address	0 0
Enable	<input type="checkbox"/> Enable <input checked="" type="checkbox"/> Enable
Min. time	0.000 0.000
Callbacks block	<input type="checkbox"/> No <input checked="" type="checkbox"/> No
Queue size/free	20 0
Array counter	0 611
Array rate	10.0
Dropped arrays	0 0
# dimensions	2
Array Size	1024 1024 0
Data type	UInt8
Color mode	Mono
Bayer pattern	RGGB
Unique ID	3461
Time stamp	779563295.068
Attributes file	
asyn record	<input type="checkbox"/>

File path	/home/epics/scratch/	Exists: Yes
File name	test_mono	
Next file #	220 220	
Auto increment	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> Yes	
Filename format	%s%s_%3.3d.h5	Example: %s%s_%3.3d.h5
Last filename	/home/epics/scratch/test_mono_219.h5	
Lazy open	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> Yes	
Save file	<input type="button" value="Save"/> <input type="button" value="Read file"/> <input type="button" value="Read"/> <input type="button" value="Auto save"/> <input type="checkbox"/> No <input checked="" type="checkbox"/> No	
Write mode	<input type="checkbox"/> Stream <input checked="" type="checkbox"/> Stream	# Capture 100 100 28
Capture	<input type="button" value="Start"/> <input type="button" value="Stop"/> <input type="button" value="Delete driver file"/> <input type="checkbox"/> No <input checked="" type="checkbox"/> No	
Write status	Write OK	
Write message		

Compression	<input type="checkbox"/> None <input checked="" type="checkbox"/> None	Extra dimensions
# data bits	8	# (0-2) 0 0
Data bits offset	0	Size N 1 1
SZip # pixels	16 16	Name N frame number n
Zlib level	6	Size X 1 1
Store performance	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	Name X scan dimension X
Store attributes	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	Size Y 1 1
Run time	9.913	Name Y scan dimension Y
I/O speed	80.7	

Exists: Yes

hdf5_layout_demo.xml

XML File name hdf5_layout_demo.xml

NDFFileHDF5

XML file to define file layout

```
<xml>
  <group name="entry">
    <attribute name="NX_class" source="constant" value="NXentry" type="string"></attribute>
    <group name="instrument">
      <attribute name="NX_class" source="constant" value="NXinstrument" type="string"></attribute>
      <group name="detector">
        <attribute name="NX_class" source="constant" value="NXdetector" type="string"></attribute>
        <dataset name="data" source="detector" det_default="true">
          <attribute name="NX_class" source="constant" value="SDS" type="string"></attribute>
          <attribute name="signal" source="constant" value="1" type="int"></attribute>
          <attribute name="target" source="constant" value="/entry/instrument/detector/data"
            type="string"></attribute>
        </dataset>
        <group name="NDAttributes">
          <attribute name="NX_class" source="constant" value="NXcollection" type="string"></attribute>
          <dataset name="ColorMode" source="ndattribute" ndattribute="ColorMode">
            </dataset>
          </group>
          <!-- end group NDAttribute -->
        </group>
        <!-- end group detector -->
      <group name="NDAttributes" ndattr_default="true">
        <attribute name="NX_class" source="constant" value="NXcollection" type="string"></attribute>
      </group>
      <!-- end group NDAttribute (default) -->
      <group name="performance">
        <dataset name="timestamp" source="ndattribute"></dataset>
      </group>
      <!-- end group performance -->
    </group>
    <!-- end group instrument -->
    <group name="data">
      <attribute name="NX_class" source="constant" value="NXdata" type="string"></attribute>
      <hardlink name="data" target="/entry/instrument/detector/data"></hardlink>
      <!-- The "target" attribute in /entry/instrument/detector/data is used to
        tell Nexus utilities that this is a hardlink -->
    </group>
    <!-- end group data -->
  </group>
  <!-- end group entry -->
</xml>
```

NDPluginDriver (R3-0)

Multiple Threads per Plugin

- Added support for multiple threads running the processCallbacks() function in a single plugin.
- Can improve the performance of the plugin by a large factor. Linear scaling with up to 5 threads (the largest value tested) observed for most of the plugins that now support multiple threads.
- Maximum number of threads that can be used for the plugin is set in constructor and in IOC startup script.
- Actual number of threads to use controlled via an EPICS PV at run time, up to the maximum value passed to the constructor.
- Note that plugins need to be modified to be thread-safe for multiple threads running in a single plugin object.

Multiple Threads per Plugin

Sorting of Output NDArrays

- When plugin uses multiple threads likely that the NDArray output will be slightly out of order, i.e. NDArray::uniqueId fields will not be monotonically increasing.
 - This is because the threads are running asynchronously and at slightly different speeds.
- A downstream file plugin would write NDArrays to the file in the "wrong" order.
- Plugins have an option to sort the NDArrays by uniqueId to attempt to output them in the correct order. Sorting enabled by setting SortMode=Sorted

NDPluginDriver medm Screens

NDSStdArrays.adl@corvette.cars.aps.anl.gov

13SIM1:image1:

asyn port Image1
Plugin type NDPluginStdArrays
ADCore version 2.6.0
Plugin version 2.6.0
Array port SIM1 SIM1
Array address 0 0
Enable Enable Enable
Min. time 0.000 0.000
Callbacks block No No
Array counter Reset to 0 22044
Array rate 250.00
Execution time 9.922 msec
Dropped arrays Reset to 0 19513
dimensions 2
Array Size 1024 1024 0
Data type Float32
Color mode Mono
Unique ID 520875
Time stamp 858383304.571
Attributes file .
Array callbacks Disable Disable
Process plugin Process
More

NDPluginBaseFull.adl@corvette.cars.aps.anl.gov

13SIM1:image1:

asyn port Image1
Plugin type NDPluginStdArrays
ADCore version 2.6.0
Plugin version 2.6.0
Array port SIM1 SIM1
Array address 0 0
Enable Enable Enable
Min. time 0.000 0.000
Callbacks block No No
threads 1 1
Max # threads 5
Queue size/free 200
Sort mode Unsorted Unsorted
Sort time 0.100 0.100
Sort size/free 0
disordered Reset to 0 0
Array counter Reset to 0 42764
Array rate 250.00
Execution time 2.942 msec
Dropped arrays Reset to 0 38194
Dropped outputs Reset to 0 0
dimensions 2
Array Size 1024 1024 0
Data type Float32
Color mode Mono
Bayer pattern RGGB
Unique ID 560283
Time stamp 858383388.180
Attributes file .
Array callbacks Disable Disable
Process plugin Process
asyn record

Multiple Threads per Plugin 1 Thread

NDPluginBaseFull.adl@corvette.cars.aps.anl.gov

13SIM1:Stats5:

asyn port **STATS5**

Plugin type **NDPluginStats**

ADCore version **2.6.0**

Plugin version **2.6.0**

Array port **SIM1** SIM1

Array address **0** 0

Enable Enable **Enable**

Min. time **0.000** 0.000

Callbacks block No **No**

threads **1** 1

Max # threads **5**

Queue size/free **200**

Sort mode Sorted **Sorted**

Sort time **0.050** 0.050

Sort size/free **50**

disordered Reset to 0 **2501**

Array counter Reset to 0 **2323**

Array rate **120.00**

Execution time **8.151** msec

Dropped arrays Reset to 0 **26491**

Dropped outputs Reset to 0 **0**

dimensions **2**

Array Size **1024** **1024** **0**

Data type **Float32**

Color mode **Mono**

Bayer pattern **RGGB**

Unique ID **319525**

Time stamp **858340043.780**

Attributes file **StatsAttributes.xml**

Array callbacks Enable **Enable**

Process plugin **Process**

asyn record

corvette (epics)

Terminal Sessions View X server Tools Games Settings Macros Help

6. corvette (e) 14. corvette (e) 8. corvette (e) Quick connect...

```
top - 06:48:51 up 56 days, 19:07, 15 users, load average: 1.76, 1.75, 1.18
Threads: 2251 total, 5 running, 2246 sleeping, 0 stopped, 0 zombie
%Cpu(s):  8.9 us,  1.4 sy,  0.0 ni, 89.6 id,  0.0 wa,  0.0 hi,  0.1 si,  0.0 st
KiB Mem : 65693432 total, 1427156 free, 3147908 used, 61118368 buff/cache
KiB Swap: 62500860 total, 61232724 free, 1268136 used, 61595632 avail Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
44219	epics	20	0	6890364	1.260g	5876	R	99.9	2.0	6:53.98	STATS5_plugin_1
93793	epics	20	0	6890364	1.260g	5876	R	57.7	2.0	6:33.77	SimDetTask
93993	epics	20	0	470608	17040	5812	R	8.9	0.0	1:04.03	medm
93995	epics	20	0	6890364	1.260g	5876	S	6.9	2.0	0:55.83	CAS-event
89627	epics	20	0	470608	17040	5812	S	6.6	0.0	189:31.91	medm
93880	epics	20	0	6890364	1.260g	5876	S	5.2	2.0	1:32.56	cbLow
3254	epics	20	0	447296	3520	824	S	2.0	0.0	626:21.20	medm
44315	epics	20	0	66644	4544	1564	R	1.6	0.0	0:00.52	top
111915	epics	20	0	379296	10280	5432	S	1.0	0.0	10:12.91	medm
112333	epics	20	0	378916	2808	704	S	1.0	0.0	526:57.51	medm
147095	epics	20	0	379176	10044	5392	S	1.0	0.0	44:50.84	medm
8046	gpd_user	20	0	123592	5952	1032	S	0.7	0.0	355:03.32	motorPoller
8058	gpd_user	20	0	123592	5952	1032	S	0.7	0.0	305:43.29	164.54.160.56:5
17270	epics	20	0	3444656	4500	1124	S	0.7	0.0	87:32.98	164.54.160.190:

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Multiple Threads per Plugin

3 Threads

NDPluginBaseFull.adl@corvette.cars.aps.anl.gov

13SIM1:Stats5:

asyn port **STATS5**
Plugin type **NDPluginStats**
ADCore version **2.6.0**
Plugin version **2.6.0**
Array port **SIM1** SIM1
Array address **0** 0
Enable **Enable**
Min. time **0.000** 0.000
Callbacks block No
threads **3**
Max # threads **5**
Queue size/free **200**
Sort mode Sorted
Sort time **0.050** 0.050
Sort size/free **50** 15
disordered **Reset to 0** 17814
Array counter **Reset to 0** 22578
Array rate **384.00**
Execution time **8.141** msec
Dropped arrays **Reset to 0** 1139
Dropped outputs **Reset to 0** 0
dimensions **2**
Array Size **1024** 1024 0
Data type **Float32**
Color mode **Mono**
Bayer pattern **RGGB**
Unique ID **383608**
Time stamp **858340176.423**
Attributes file **StatsAttributes.xml**
Array callbacks **Enable**
Process plugin **Process**
asyn record

corvette (epics)

Terminal Sessions View X server Tools Games Settings Macros Help

6. corvette (e) 14. corvette (e) 8. corvette (e) Quick connect...

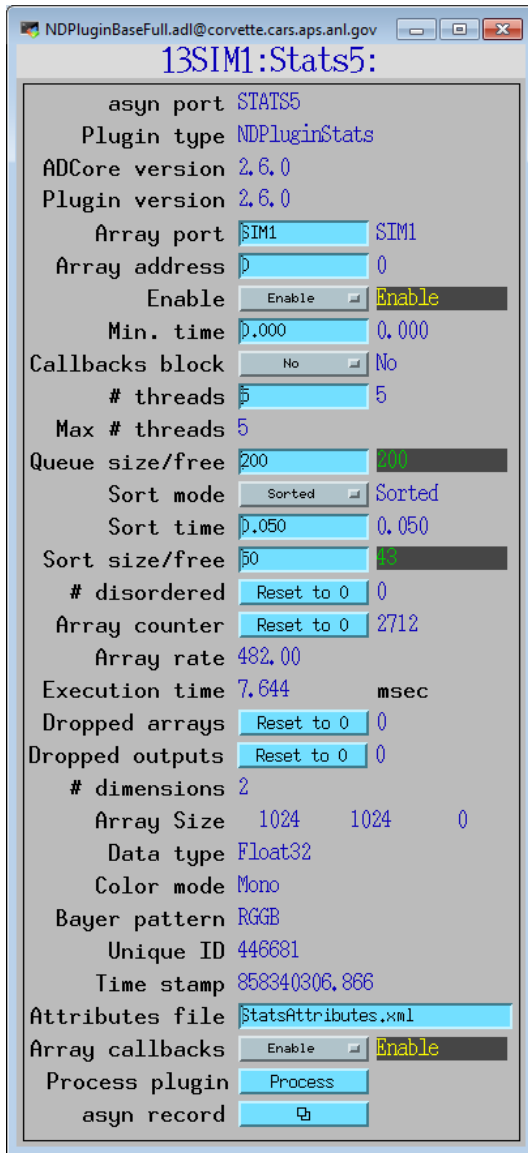
top - 06:50:14 up 56 days, 19:08, 15 users, load average: 3.18, 2.16, 1.37
Threads: 2250 total, 5 running, 2245 sleeping, 0 stopped, 0 zombie
%Cpu(s): 18.4 us, 1.4 sy, 0.0 ni, 80.0 id, 0.0 wa, 0.0 hi, 0.1 si, 0.0 st
KiB Mem : 65693432 total, 1428852 free, 3145276 used, 61119304 buff/cache
KiB Swap: 62500860 total, 61232724 free, 1268136 used. 61598204 avail Mem

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
44353	epics	20	0	6890364	1.261g	5876	R	99.9	2.0	0:53.86	STATS5_plugin_2
44352	epics	20	0	6890364	1.261g	5876	R	99.7	2.0	0:53.81	STATS5_plugin_1
44354	epics	20	0	6890364	1.261g	5876	R	99.7	2.0	0:53.82	STATS5_plugin_3
93793	epics	20	0	6890364	1.261g	5876	R	43.6	2.0	7:16.72	SimDetTask
93993	epics	20	0	470608	17040	5812	S	8.2	0.0	1:10.80	medm
93995	epics	20	0	6890364	1.261g	5876	S	7.5	2.0	1:01.70	CAS-event
93880	epics	20	0	6890364	1.261g	5876	S	6.6	2.0	1:37.71	cbLow
89627	epics	20	0	470608	17040	5812	S	6.2	0.0	189:36.91	medm
44315	epics	20	0	66644	4544	1564	R	1.6	0.0	0:01.66	top
70655	epics	20	0	104600	1964	708	S	1.3	0.0	397:18.04	medm
990	root	20	0	4368	236	212	S	1.0	0.0	438:34.32	rngd
8057	gpd_user	20	0	123592	5952	1032	S	1.0	0.0	478:24.34	XPSAuxPoller
30451	epics	20	0	106224	3928	1332	S	1.0	0.0	465:56.41	XPSAuxPoller
92347	epics	20	0	5285724	6296	1324	S	1.0	0.0	336:21.35	XPSAuxPoller

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Multiple Threads per Plugin

5 Threads



NDPluginBaseFull.adl@corvette.cars.aps.anl.gov

13SIM1:Stats5:

asyn port **STATS5**

Plugin type **NDPluginStats**

ADCore version **2.6.0**

Plugin version **2.6.0**

Array port **SIM1** SIM1

Array address **0** 0

Enable **Enable**

Min. time **0.000** 0.000

Callbacks block **No**

threads **5** 5

Max # threads **5**

Queue size/free **200** 200

Sort mode **Sorted**

Sort time **0.050** 0.050

Sort size/free **50** 50

disordered **Reset to 0** 0

Array counter **Reset to 0** 2712

Array rate **482.00**

Execution time **7.644** msec

Dropped arrays **Reset to 0** 0

Dropped outputs **Reset to 0** 0

dimensions **2**

Array Size **1024** 1024 0

Data type **Float32**

Color mode **Mono**

Bayer pattern **RGGB**

Unique ID **446681**

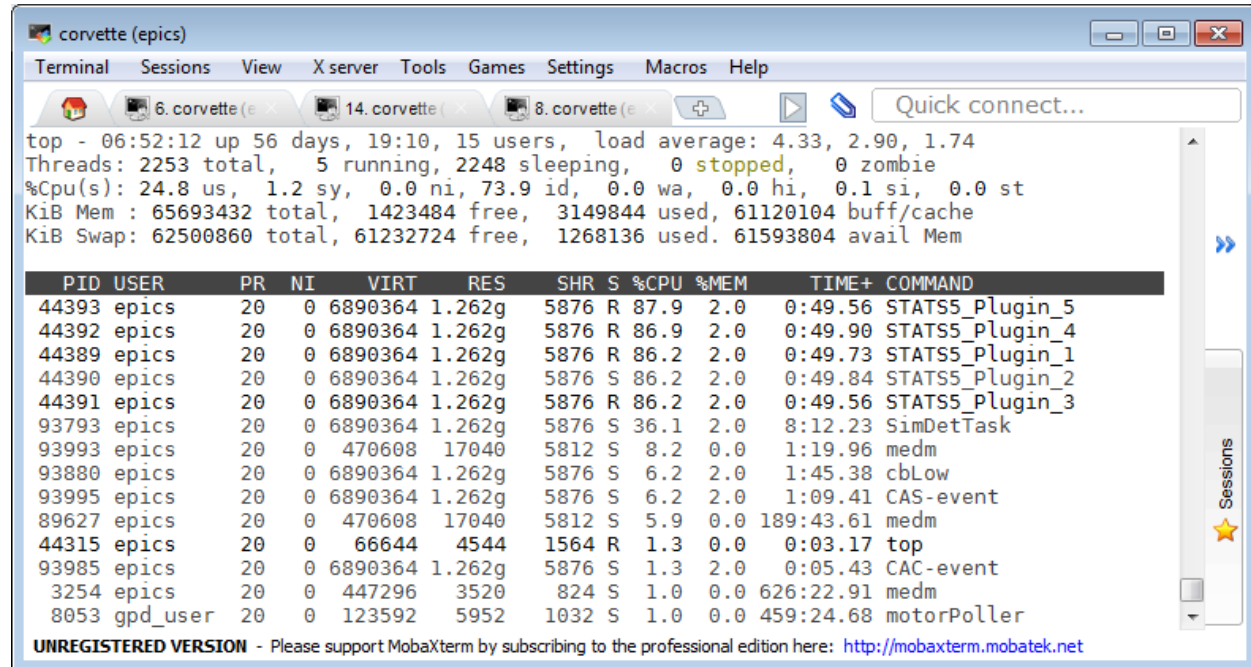
Time stamp **858340306.866**

Attributes file **StatsAttributes.xml**

Array callbacks **Enable**

Process plugin **Process**

asyn record



corvette (epics)

Terminal Sessions View X server Tools Games Settings Macros Help

6. corvette (e) 14. corvette (e) 8. corvette (e) Quick connect...

```
top - 06:52:12 up 56 days, 19:10, 15 users, load average: 4.33, 2.90, 1.74
Threads: 2253 total, 5 running, 2248 sleeping, 0 stopped, 0 zombie
%Cpu(s): 24.8 us, 1.2 sy, 0.0 ni, 73.9 id, 0.0 wa, 0.0 hi, 0.1 si, 0.0 st
KiB Mem : 65693432 total, 1423484 free, 3149844 used, 61120104 buff/cache
KiB Swap: 62500860 total, 61232724 free, 1268136 used. 61593804 avail Mem
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
44393	epics	20	0	6890364	1.262g	5876	R	87.9	2.0	0:49.56	STATS5_plugin_5
44392	epics	20	0	6890364	1.262g	5876	R	86.9	2.0	0:49.90	STATS5_plugin_4
44389	epics	20	0	6890364	1.262g	5876	R	86.2	2.0	0:49.73	STATS5_plugin_1
44390	epics	20	0	6890364	1.262g	5876	S	86.2	2.0	0:49.84	STATS5_plugin_2
44391	epics	20	0	6890364	1.262g	5876	R	86.2	2.0	0:49.56	STATS5_plugin_3
93793	epics	20	0	6890364	1.262g	5876	S	36.1	2.0	8:12.23	SimDetTask
93993	epics	20	0	470608	17040	5812	S	8.2	0.0	1:19.96	medm
93880	epics	20	0	6890364	1.262g	5876	S	6.2	2.0	1:45.38	cbLow
93995	epics	20	0	6890364	1.262g	5876	S	6.2	2.0	1:09.41	CAS-event
89627	epics	20	0	470608	17040	5812	S	5.9	0.0	189:43.61	medm
44315	epics	20	0	66644	4544	1564	R	1.3	0.0	0:03.17	top
93985	epics	20	0	6890364	1.262g	5876	S	1.3	2.0	0:05.43	CAC-event
3254	epics	20	0	447296	3520	824	S	1.0	0.0	626:22.91	medm
8053	gpd_user	20	0	123592	5952	1032	S	1.0	0.0	459:24.68	motorPoller

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Multiple Threads per Plugin

Plugin	Supports multiple threads	Comments
NDPluginColorConvert	Yes	Multiple threads supported and tested
NDPluginFFT	Yes	Multiple threads supported and tested
NDPluginOverlay	Yes	Multiple threads supported and tested
NDPluginROI	Yes	Multiple threads supported and tested
NDPluginROIStat	Yes	Multiple threads supported and tested NOTE: time series needs ordering
NDPluginStats	Yes	Multiple threads supported and tested NOTE: time series needs ordering
NDPluginStdArrays	Yes	Multiple threads supported and tested NOTE: waveform callbacks will be out of order
NDPluginTransform	Yes	Multiple threads supported and tested

Multiple Threads per Plugin

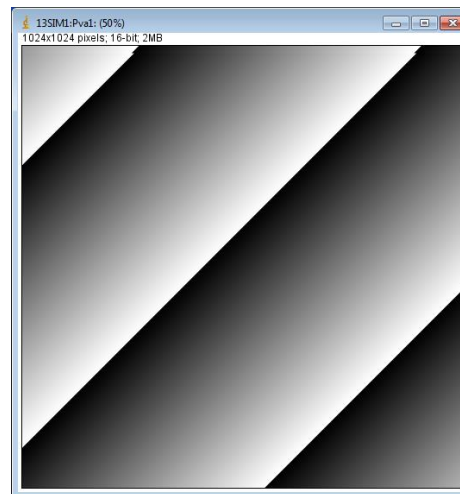
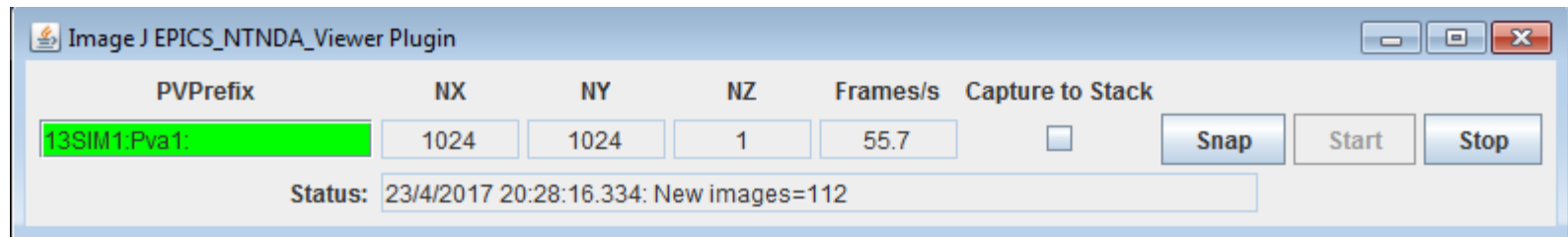
Plugin	Supports multiple threads	Comments
NDPluginFile	No	File plugins are nearly always limited by the file I/O, not CPU
NDPluginTimeSeries	No	Plugin does not do much computation, no gain from multiple threads
NDPluginAttribute	No	Plugin does not do any computation, no gain from multiple threads
NDPluginCircularBuff	No	Same
NDPluginGather	No	Same
NDPluginScatter	No	Same
NDPosPlugin	No	Same
NDPluginProcess	No	Recursive filter stores results in the object itself, hard to make thread safe
NDPluginPva	No	Plugin is very fast, probably not much gain from multiple threads

Viewers

- areaDetector allows generic viewers to be written that receive images as EPICS waveform records over Channel Access
- Current viewers include:
 - ImageJ plugin EPICS_AD_Display. ImageJ is a very popular image analysis program, written in Java, derived from NIH Image.
 - EPICS_NTNDA_Viewer. Same as above but uses pvAccess rather than Channel Access.
 - ffmpegServer allows image display in any Web browser
 - ffmpegViewer high-performance Qt-based viewer for MJPEG stream

EPICS_NTNDA_Viewer ImageJ plugin

- New ImageJ plugin written by Tim Madden and Marty Kraimer
- Essentially identical to EPICS_AD_Viewer.java except that it displays NTNDArrays from the NDPluginPva plugin, i.e. using pvAccess to transport the images rather than NDPluginStdArrays which uses Channel Access.



NDPluginPva Advantages

- NTNDArray data transmitted "atomically" over the network
 - Channel Access requires separate PVs for the image data and the metadata (image dimensions, color mode, etc.)
- With Channel Access data type of waveform record is fixed at `iocInit`, cannot be changed at runtime.
 - If the user wants to view both 8-bit images, 16-bit images, and 64-bit double FFT images then waveform record needs to be 64-bit double, adding a factor of 8 network overhead when viewing 8-bit images.
 - `pvAccess` changes the data type of the NTNDArrays dynamically at run-time, removing this restriction.
- Channel Access requires setting `EPICS_CA_MAX_ARRAY_BYTES`
 - Source of considerable confusion and frustration for users.
 - `pvAccess` does not use `EPICS_CA_MAX_ARRAY_BYTES` and there is no restriction on the size of the NTNDArrays.

Viewers

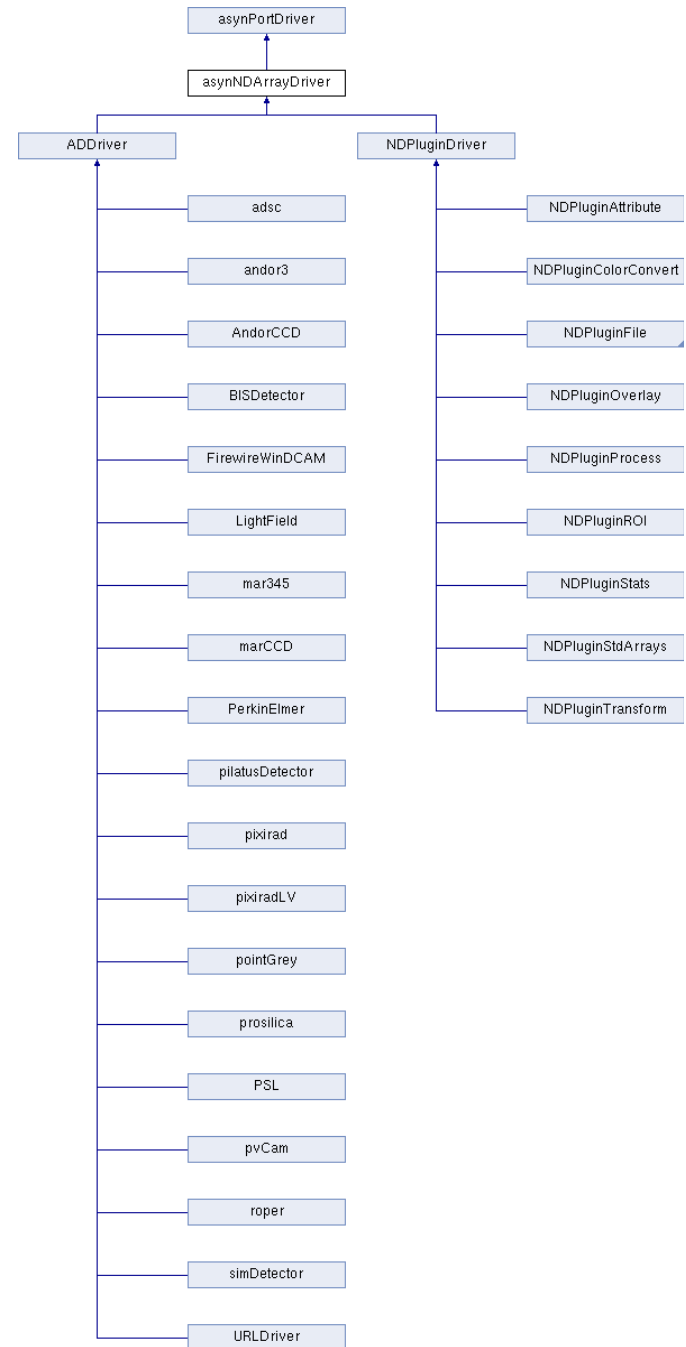
- EPICS_AD_Controller. Allows using the ImageJ ROI tools (rectangle and oval) to graphically define the following:
 - The readout region of the detector/camera
 - The position and size of an ROI (NDPluginROI)
 - The position and size of an overlay (NDPluginOverlay)
 - The plugin chain can include an NDPluginTransform plugin which changes the image orientation and an NDPluginROI plugin that changes the binning, size, and X/Y axes directions. The plugin corrects for these transformations when defining the target object.
 - Chris Roehrig wrote an earlier version of this plugin.

Other Drivers that use ADCore

- NDArrays are not limited to 2-D detectors
 - File, ROI, and statistics plugs are useful for other types of detectors
- Used for spectra arrays [NumMCAChannels, NumDetectors, NumPixels] for:
 - Xspress3 from Quantum Detectors
 - xMAP, Mercury and new FalconX from XIA
- Used for time-series data [NumTimePoints, NumInputs] for the quadEM quad electrometer software
 - AH401, AH501, TetrAMM from CaenEls
 - Two types of electrometers from BNL Instrumentation group (Peter Siddons)

Internals

Class hierarchy



Conclusions

- Architecture works well, easily extended to new detector drivers, new plugins and new clients
- Base classes, asynPortDriver, asynNDArrayDriver, asynPluginDriver actually are generic, nothing “areaDetector” specific about them.
- They can be used to implement any N-dimension detector, e.g. the XIA xMAP (16 detectors x 2048 channels x 512 points in a scan line)
- Can get documentation and pre-built binaries (Linux, Windows) from our Web site:
 - <http://cars.uchicago.edu/software/epics/areaDetector>
- Can get code from github
 - <https://github.com/areaDetector>