NeutronOptics APS-C Compact CMOS Cameras

Our new CMOS cameras have higher efficiency and resolution, with faster readout, than our CCD cameras. All our FS60/VS60 cameras based on the old 1" Sony ICX694 12.5x10mm chip, with an f/1.4 lens, can be replaced by our 24x16mm APS-C IMX571 detector with a faster f/0.95 lens. The area of the APS-C chip is x3 larger, and the aperture of the f/0.95 lens is x2 greater, so **the gain in efficiency is x6** - for the same price ! Some of the following may not apply to your particular camera.

The photo shows our compact APS-C camera, which can be used either for neutrons or x-rays, and especially for our new 1-CMOS Laue camera, which is the same size and price as our old 1-CCD Laue camera.

Detector	†FS60 CCD	APS-C CMOS
Type	Interline ICX694	Pregius IMX571
No. Pixels	2759x2200	6248x4176
Diag. mm	16 (1")	28 (APS-C)
Image mm	12.53x9.99	23.5x15.7
Pixel size	4.54 µm	3.76 µm
Q. effic	~70%	~90%
Fullwell	~20,000 e-	~50,000 e-
Read noise	5 e-	1.0-3.3 e-
Dark e-/p/s	0.0004@-10°C	0.003@0°C
Cooling	Δ-27°C	Δ-35°C
Frame Rate	0.2 fps	3.5 fps
A/D Readout	16-bits	16-bits
Binning	hardware	software
Lens Type	16mm f/1.4	35mm f/0.95
Mount	C-	M43-F-
Usual Dist	200mm	500mm
Usual FOV	125x100mm	250x200mm
Pixel @FOV	45 µm	50 µm
Trigger	Software	Software
Interface	USB2/GigE	USB3
Cost Detect+Lens	4	5

NeutronOptics 125x100mm CMOS Laue Camera

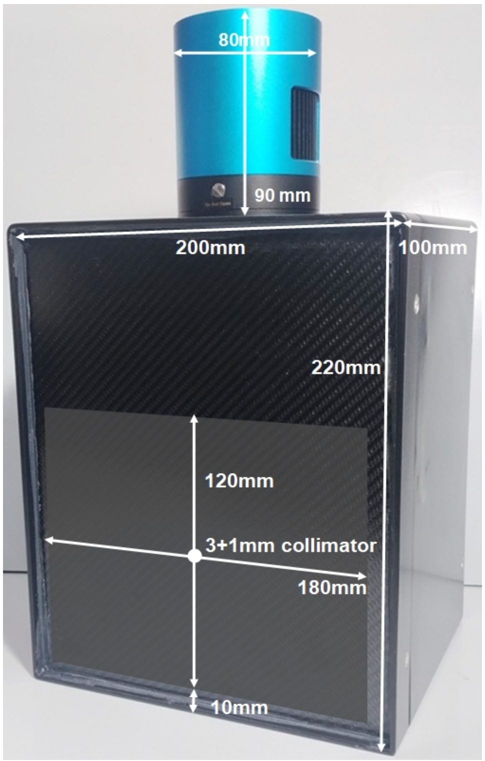
We have developed various Laue crystal alignment cameras for x-rays, and similar cameras can be used with a neutron beam. They allow rapid crystal alignment, and can also be used for hands-on teaching of crystallography. A finely collimated white beam produces a number of "Bragg spots" from a single crystal, and by measuring the positions of these spots the crystal orientation can be determined.

Greater precision is obtained with backscattering, but the intensities are weaker, especially for x-rays because of the scattering "form-factor". A classic bench-top x-ray generator with a spot size of ~1mm and power of 30-50 kV and 30-50 mA is required. The photo opposite shows our new 125x100mm CMOS camera, which is the same size, but x5 more efficient than our old 1-CCD Laue camera for the same price.

NeutronOptics 180x120mm CMOS Laue Camera

This large 1-CMOS Laue camera is designed to **replace our old 2-CCD Laue camera**. By using a larger APS-C 24x16mm CMOS detector instead of two 12.5x10mm CCDs, we increase the total detector area (efficiency) by over 50% allowing a slightly larger Field-Of-View (FOV) for similar exposure times (3-5 minutes). The efficiency is further improved by using a modern f/0.95 lens instead of a pair of f/1.4 lenses. The incident beam collimator (1mm/2mm) passes through a mirror and a scintillator, and the backscattered Laue pattern is collected in real time for crystal orientation.

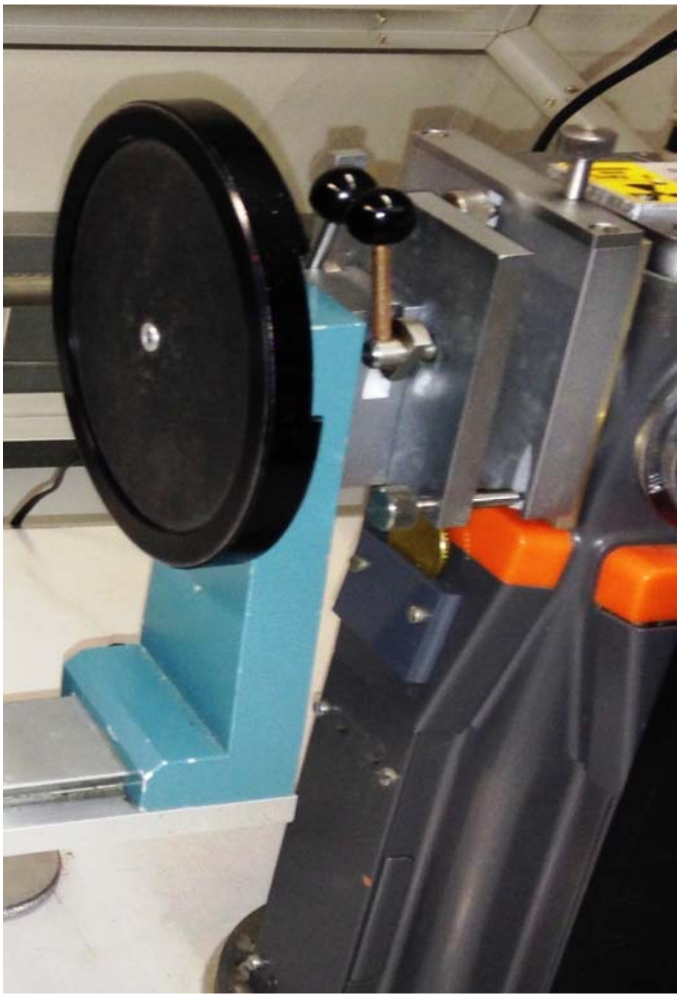
This new camera with higher efficiency and simpler operation is also less expensive !

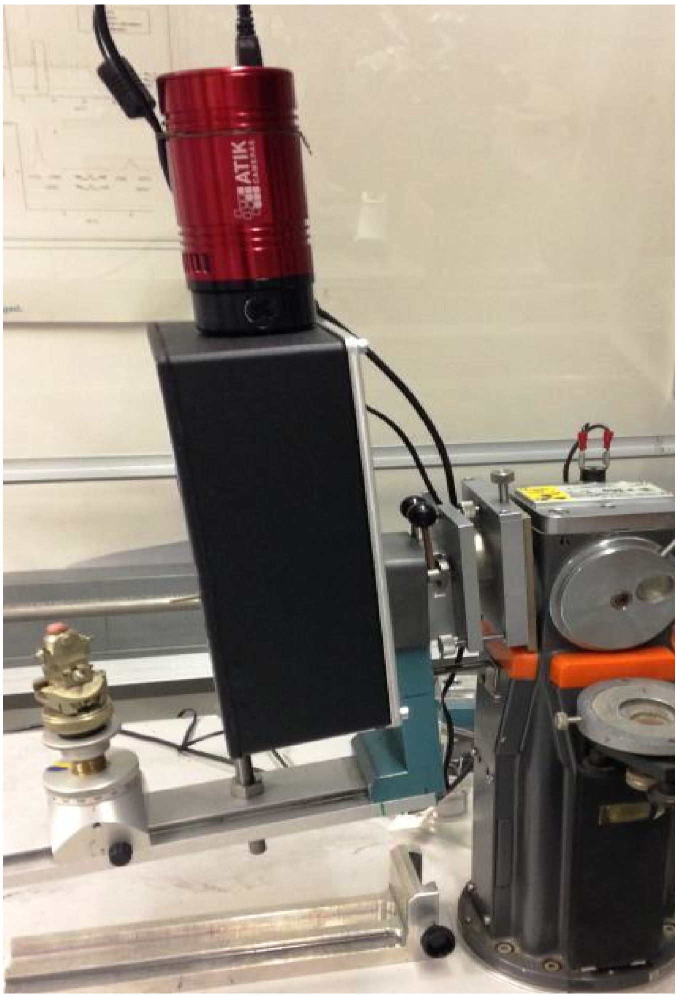


- **Camera dimensions:** 220x200x100mm
- **Field-Of-View:** 180x120 mm
- **Optical Aperture:** f/0.95
- **Sensor:** Sony CMOS IMX571
- **Chip size:** 23.5x15.7mm (APS-C)
- **Resolution:** 6248x4176
- **Pixel Size:** 3.75 x 3.75 μM
- **Binning:** from 2x2 to 8x8
- **High sensitivity:** (QE~90%)
- **Low dark current:** 0.003@-10 °C
- **Full well capacity:** 50,000 electrons
- **ADC:** 16 bit grey scale image
- **Readout Noise:** 3 e- typical
- **Readout Time:** <1s
- **Interface:** USB 3.0 with 10-20m cables
- **Power:** 12v DC to local standards
- **Cooling:** Thermoelectric: ΔT=-35°C
- **Typical Laue Exposure Time:** ~3 min

Installing the NeutronOptics Laue Camera on the x-ray beam

The photos below show how **Prof. W. Donner and Dr L. Diop at the T.U. Darmstadt** converted a Huber Image Plate Laue camera (left) to use the NeutronOptics 1-CCD Laue camera (right). The 1-CMOS camera can be installed in the same way, since the detector box is the same size.





Left photo: The Huber IP camera is the circular disk mounted on a blue support on a guide rail. The collimator is locked and the beam shutter opened with the two black knobbed levers on the double-metal plates that form the Huber-800 alignment mechanism, which is mounted on a 1960's Philips X-ray generator. The screw at the top, and two at the bottom, adjust the height and tilt of the collimator.

Right photo: The Huber-800 unit is retained, together with the blue camera support, when the Huber IP camera is replaced by the 1-CCD camera. An additional support bolt on the rail under the bottom left supports the heavier camera. The new collimator is aligned in the Huber-800 mechanism for maximum intensity, and the camera is then bolted on using an aluminium plate and four M4 bolts.

Mount the camera as close to the source as possible using the 4mm bolt holes at the back; minor adjustments to position and orientation are necessary. Before inserting the 1mm collimator tube into the camera, check that it fits the source exit and allows no x-ray leakage. **You will need to make a small adapter** to take the 2mm collimator tube, depending on your source. The 1mm collimator slides into the 2mm tube, with the nose extending toward the crystal ~30mm from the window.

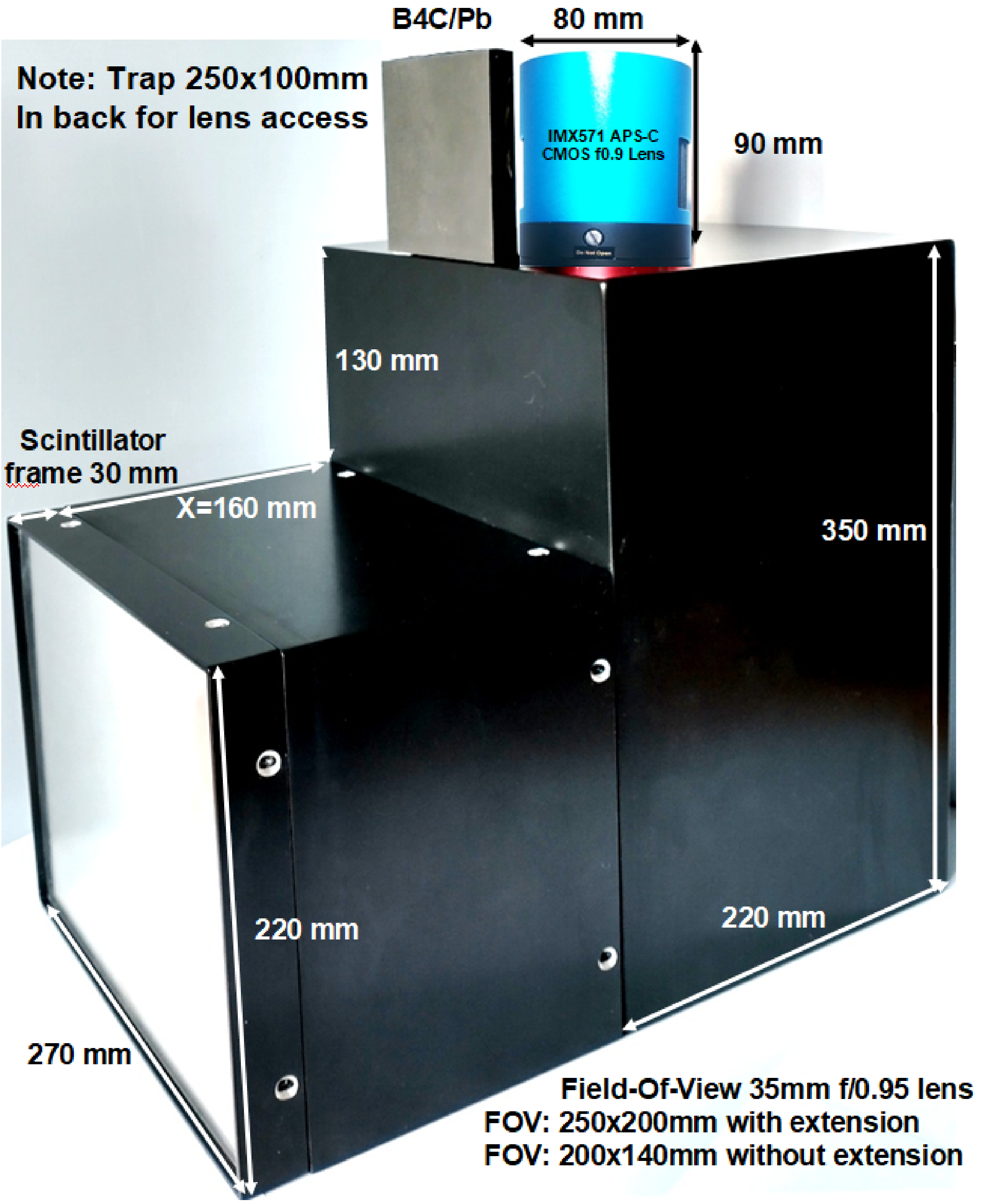
1mm Collimator nose

The collimator must be precisely aligned, and the source voltage and current set for maximum intensity through the collimator. The carbon fibre window & scintillator are not fragile. To remove collimator tubes, **pull them out from the back of the camera**, and insert them from the back. **The O-ring can be sealed** with a very small amount of black mastic or eventually black paint.

NeutronOptics APS-C CMOS Imaging Camera

The photo below show our 250x200mm L-shaped camera complete with the APS-C detector and its B_4C/Pb protection, with the imaging box containing the interchangeable scintillator in front of the large mirror at the bottom. Other FOV dimensions can be provided from 125x100mm to 500x400mm.

Other CMOS detectors can be used, from micro-4/3 to Full-Frame. All are designed to image the full 250x200mm Field-of-View (FOV). The advantage of the more expensive APS-C and Full Frame detectors is their larger size, since efficiency is proportional to the ratio of the area of the detector to the FOV. The APS-C detector with a modern APS-C f/0.95 lens is again a good compromise, providing a x6 increase in efficiency over our old VS60 imaging camera. The full-frame camera uses the old Nikon f/1.2 lens, with a further small increase in efficiency, and is recommended for larger FOV. The bigger sensors have more pixels, which doesn't improve resolution, but small pixels can be binned to improve efficiency, signal/noise & frame-rate. If in doubt, choose a cheaper APS-C camera.



Installing the Front-Surfaced Mirror into the imaging camera

Large imaging cameras are shipped with the mirrors packed separately for safety.

1. Place the foot of the mirror against the labelled B_4C ledge on the camera back
2. The plastic protected face with its instruction label must be on top
3. Push the top of the mirror into the top labelled B_4C holder
4. When the camera assembly is complete, peel off the protective film
5. The front aluminised face is protected by a transparent SiO layer for 95% reflectivity
6. Do not touch or dirty the surface. If necessary, clean gently with window cleaner
8. If necessary, use cyanolite glue spots for security, or glue a B_4C strip to hold the mirror

Adjusting the Lens Focus (First read the Software Installation & Operation)

- Manual focussing must be done with light, not in the neutron or x-ray beam
- Place a millimetric paper grid over the scintillator plate being careful not to otherwise touch it
- Slide the scintillator front-end box onto the main camera box
- Open the lens trap at the back of the camera to allow light to fall on the paper grid
- Launch the software, and loop expose ~10ms with a restricted ~1600x1200 pixel FOV
- Adjust focus to obtain the sharpest image with light, then **gently** tighten the focus clamp
- When finished, fully open the lens aperture, remove the focusing grid & close the box
- Check that the camera is light-tight with a 10 minute exposure. The camera is very sensitive and **scintillator afterglow may be seen for some minutes after exposure to light**
- **With fast neutron scintillators, wait several hours for the afterglow to completely disappear**

Eventual Replacement of the Detector and/or Lens

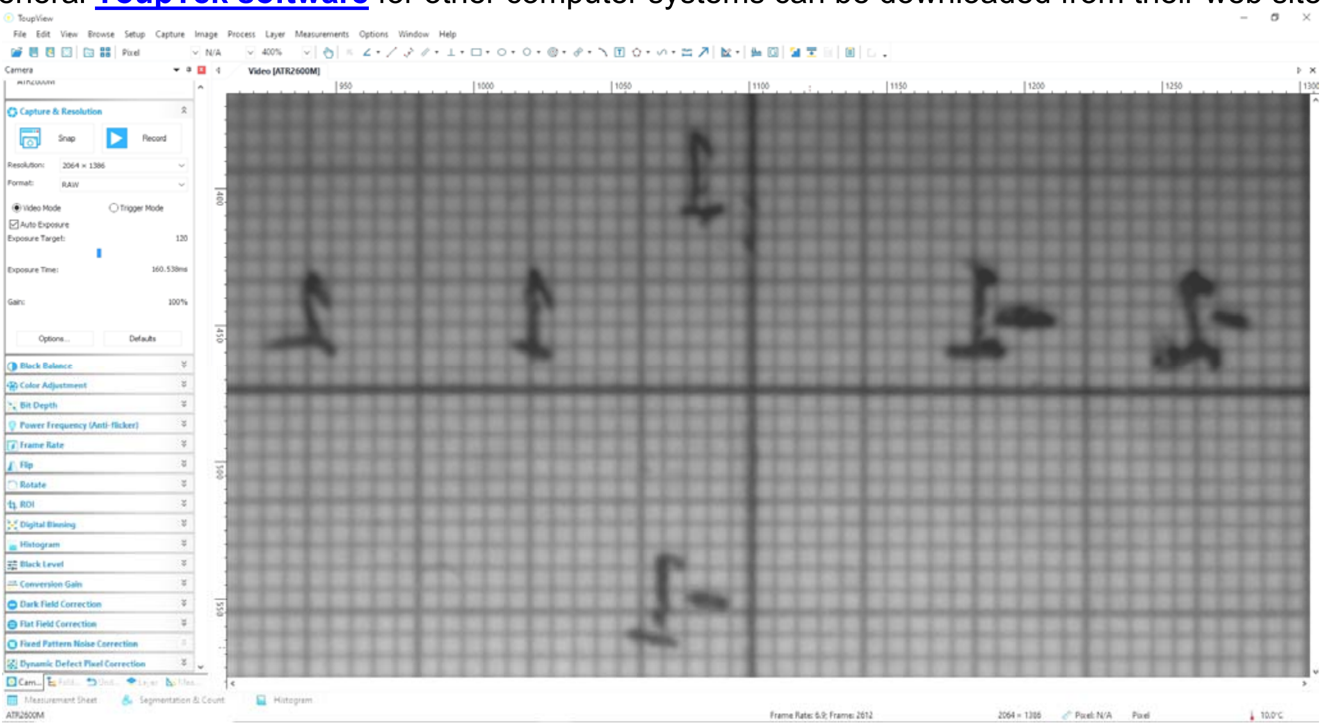
The detector unit can be removed after first unscrewing the lens (left) to reveal four bolts clamping the detector. Unscrew them. There may be a rubber seal between the detector unit and the box, but there are no adjustments, so the detector unit can be replaced easily. The photo shows the MFT-mount lens; the Full frame F-mount lens is a little different.

Do not touch the exposed surfaces of the detector cover glass or lens, the front of which is covered by a clear filter that can be replaced if damaged. **Remember to remove the lens cover !**

NeutronOptics APS-C CMOS Camera Operation

Install the ASI Camera Driver & Software for Windows, Linux or Macintosh

- Install the Windows camera driver toupcam.dll (x64)l from the DVD, or download it from **https://www.touptek-astro.com/downloads?atfWidgetNav=box_win**
- You can use **ToupView** to control the camera, but we recommend **SharpCap4**
- **ToupTekDshowAstro** provides alternative Dshow support
- If you want to develop your own software, download the **SDK** **zip** Software Development Kit
- You may want to install the **ASCOM Platform Driver** if you want to use **ImageJ-for-ASCOM**
- Do not update the camera firmware if you don't have problems with that already installed
- You can also read the **ToupTek** manuals, but these describe mainly astronomy and microscopy
- General **ToupTek software** for other computer systems can be downloaded from their web site

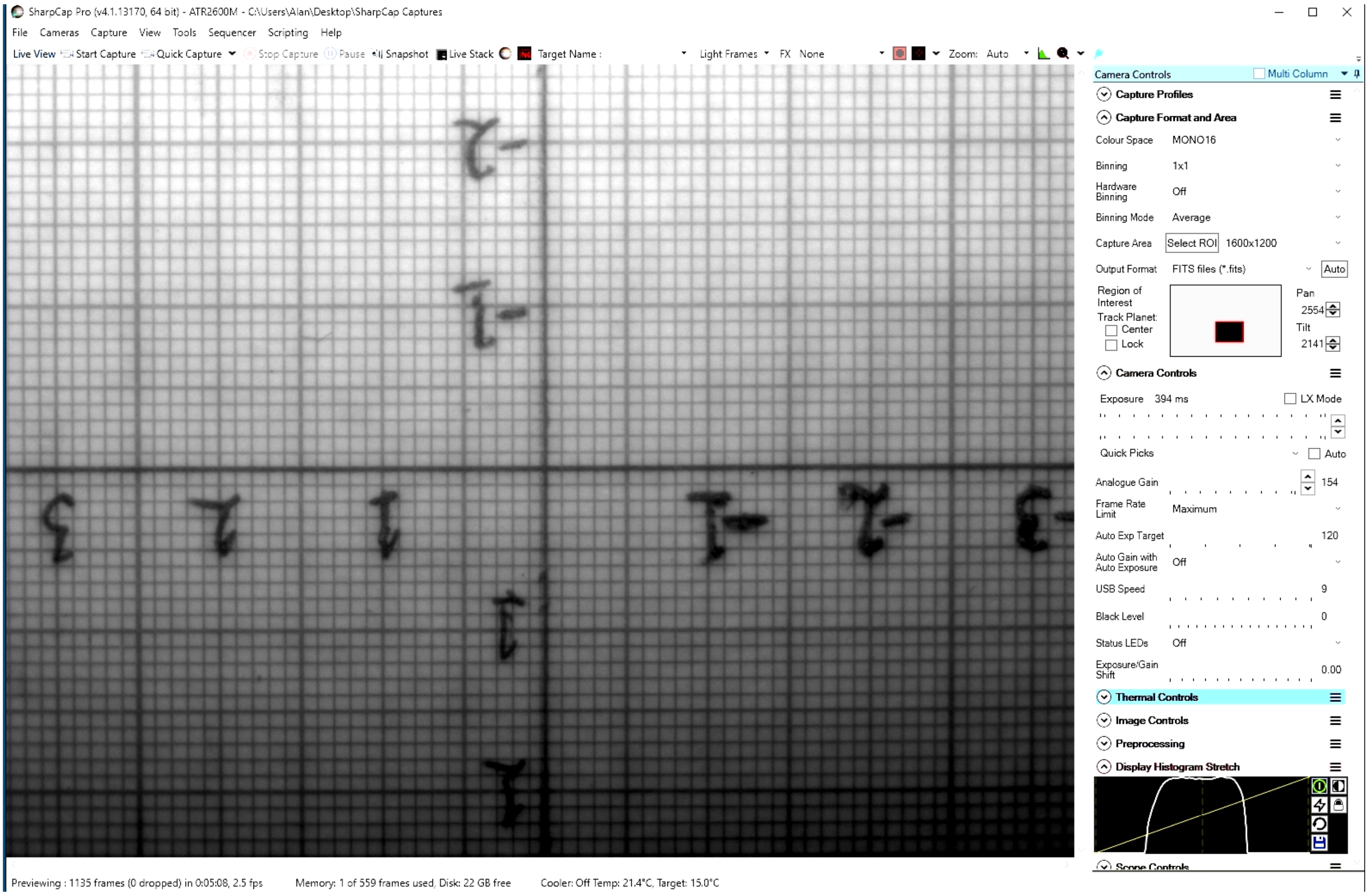


This screen capture of **ToupView** has been limited to 2064x1386 pixels to speed up the frame rate for focussing. Note that Raw 16-bit un-binned images have been selected and the exposure set to auto. The image shows a small area of the total FOV of millimetric graph paper taped over the scintillator, illuminated by light shining through the open lens trap.

ToupView may be sufficient for simple beam monitoring, and is available for both Windows, MacOS and Linux computers, but Windows **SharpCap4** offers more features. Our **ImageJ-for-ASCOM** interface allows you to program complex acquisitions within ImageJ.

Installing the Recommended SharpCap4 Viewer

Use SharpCap4 from the DVD or download it from https://www.sharpcap.co.uk/sharpcap/downloads SharpCap was designed for low-light imaging for amateur astronomers, with more complete controls, including many you will not need for x-ray or neutron imaging. **Prefer the 64-bit version** for memory management. The camera will be automatically recognised if it is plugged in, and you just need to choose it from the "Cameras" menu. A window will open with the image and camera controls on the right. You can arrange the order of controls by dragging the 3-line icon. An exhaustive SharpCap User Manual is available, but the instructions below may be sufficient.



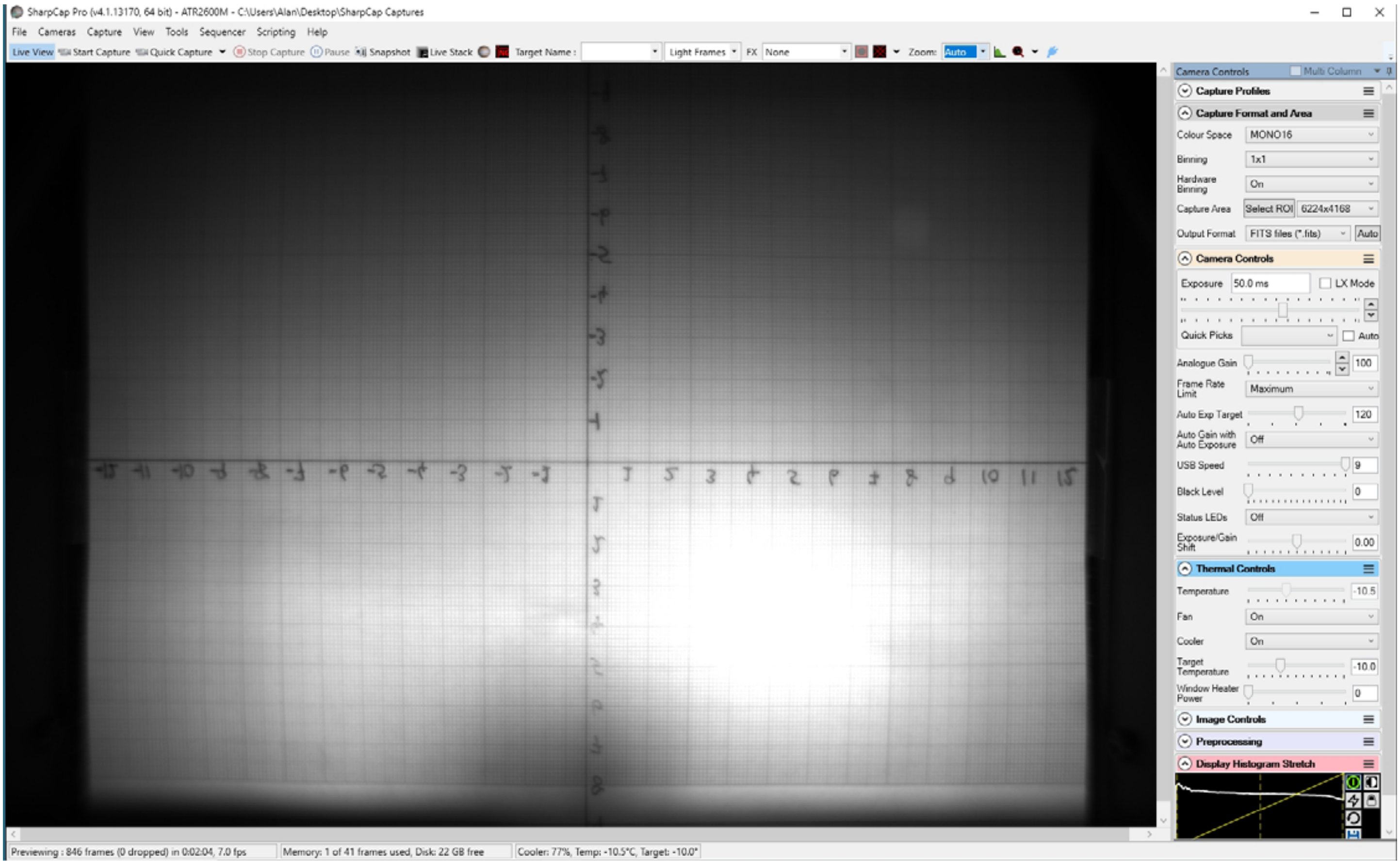
This screen capture of **SharpCap4** has been limited to 1600x1200 pixels to speed up the frame rate. Zoom the image with Ctrl-mouse-scroll or the zoom selection at the top right. Set **"Capture Format"** to TIFF or FITS, Capture Area, and Mono16. In the **"Camera Controls"** set the Exposure (toggle LX mode for long exposures), set the Gain to zero (or increase it, at the expense of noise). **Maximum gain may be needed with hot neutrons**. You can drag the vertical line in the **"Display Histogram"** to stretch the intensity display to emphasise lower intensities. You can zoom in to make focussing easier or examine details. Focussing may be optimal when the Display Histogram curve maximises.

Click "**Snapshot**" to save a single image frame, or "**Livestack**" to sum several (see below). **FITS files can be opened with imageJ and the Windows Store QuickLook with the FitsViewer plugin**

In menu **"File/Settings"** check auto connect and restore, with format AVI and FITS. Choose where and how files are saved. **Tip:** set a **"Default Profile"** to open with those settings on start-up.
The camera settings are in a hidden file called **_autosave (camera name).ini** which can be found in:
C:\Users\<your windows user name>\AppData\Roaming\SharpCap\CaptureProfiles
You can delete this file and it will be created again next time you exit SharpCap

If you do use SharpCap, consider paying £12 for a license https://store.astrosharp.co.uk/Store
You need a license if you want to use advanced features like scripting, useful for tomography.

This screen capture of SharpCap4 shows the full 250x200mm FOV, cooling to -10C below ambient. **The image is shaded on top** because the screen illumination through the lens trap is not uniform.



Binning sums or averages intensity in adjacent pixels 2x2, 4x4 etc., increasing the pixel size (higher signal, signal/noise, full well etc). If the binning is done in-camera (hardware), the data transfer speed is also increased. **Resolution is ultimately limited by beam divergence or scintillator thickness.**

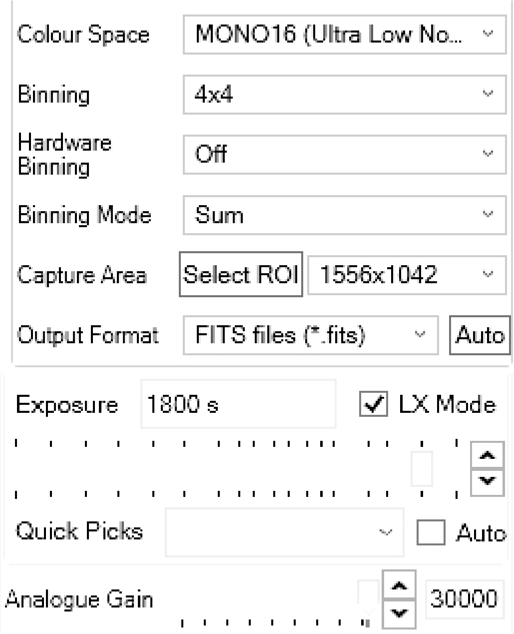
Frame-rate can also be increased by selecting an ROI **Capture Area**. You can select a pre-defined ROI, kept in the Windows Registry, or a custom ROI. This is useful to speed up focussing.

Hints on getting Optimal Performance

- **Experiment thoroughly without radiation until you fully understand the camera controls**
- High Gain will multiply the intensity, but reduce the dynamic range
- Binning will multiply the intensity and speedup readout, but reduce optical resolution
- You can also limit readout to a "sub-frame" ROI region of the full image
- The "Display" panel controls what you see, but has no effect on what you collect
- Drag the vertical dashed line in the display panel to adjust the displayed intensity
- "Zoom" (and the wheel mouse button) zooms the size of the image display
- Image display is for guidance. Open the image with ImageJ for measurement
- The CMOS chip is cooled to reduce noisy pixels. You can also use ImageJ Despeckle filter
- The Window heater prevents fogging below 0°C (the CMOS chamber contains a desiccant)
- The centre of the image doesn't correspond precisely to the centre of the window
- For serious imaging, subtract a "Dark Frame" to remove constant background features
- Also use a "Flat frame" with no sample to calibrate the intensity across the FOV area.

Cooling/Despeckling is important for very long exposures, where you may be **using high Gain with hot neutrons or weak sources**. Under extreme conditions, you may need to tape around the lens trapdoor to ensure light exclusion. **The camera is extremely sensitive to the tiniest light leak.**

Very Low-Light Imaging with SharpCap



Recommended 16-bit high dynamic images. 8-bit gives faster readout

Increase software binning up to 4x4 or 8x8 to increase signal

Alternative hardware binning speeds up transfer

Use "Sum" with software binning for very weak signals

A limited Region-Of-Interest or Binning will speed up transfer

FITS or TIFF files allow 16-bit output (view with imageJ or QuickView)

LX mode is for long exposures (minutes)

Exposure times are not limited to Quick Picks

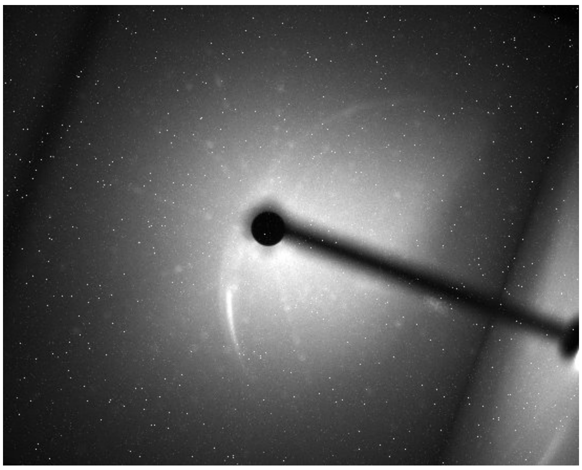
Experiment with high gain at the expense of higher noise

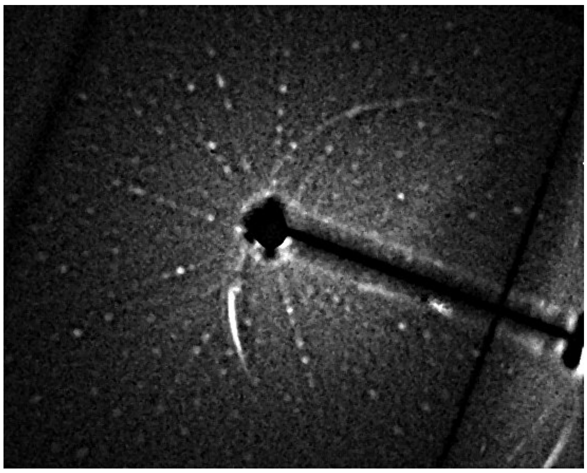
Image Treatment with ImageJ and Laue Pattern Indexing

ImageJ will open the 16-bit raw FITS files, filter noise, modify intensity/contrast, and save them in various formats. An ImageJ installation is included on the NeutronOptics software CD under "Extras". **Copy the ImageJ folder to your C: disk** and launch ImageJ to set defaults and update ImageJ.

You can use ImageJ's **"Process/Noise/Despeckle"** to filter out electronic noise and **"Process/ Subtract Background"** with "rolling ball radius 25-50 to remove some of the diffuse backround. You might also try ImageJ's **"Process/FFT/Bandpass filter"** to filter out large structures of 30+ pixels and small structures of 3+ pixels, with "autoscale" and "saturate" to emphasise the peaks.

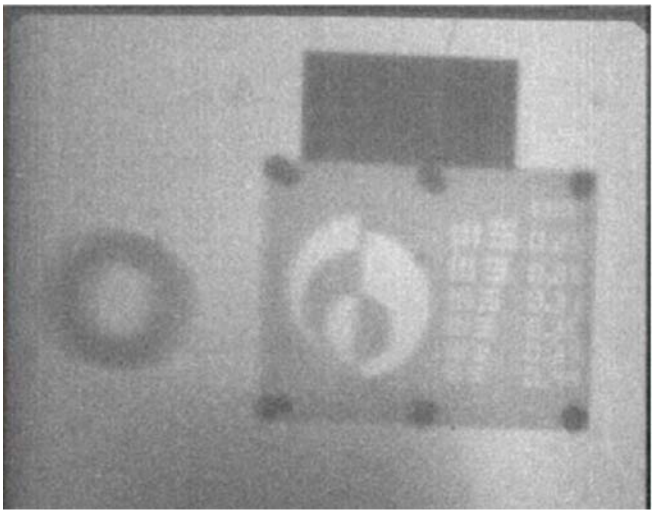
A more powerful macro routine can be downloaded to **ImageJ\macros\toolsets** then loaded by clicking on the **red ">>"** menu item on the far right and selecting "Subtract Diffuse Bkgd". This will install the command **"Plugins/Macros/Subtract Diffuse Bkgd"**. The left image below shows a very poor image with isolated bright pixels and no obvious Laue pattern. The right image shows the astonishing effect of this macro command. This organic material showed strong diffuse scattering. This "median filtering" macro was written by M. Cammer as an alternative to the **Bandpass filter.**





A number of Laue indexing applications are freely available. The **Cologne Laue Indexing Program (CLIP)** is one of the best, along with the **QLaue Indexing Program**. Older applications such as OrientExpress and the ambitious new ESMERALDA Laue suite might also be tried. First try **WinLaue** to simulate Laue patterns and become familiar with what to expect.

Imaging with Fast Neutrons (2.45MeV or 14MeV)

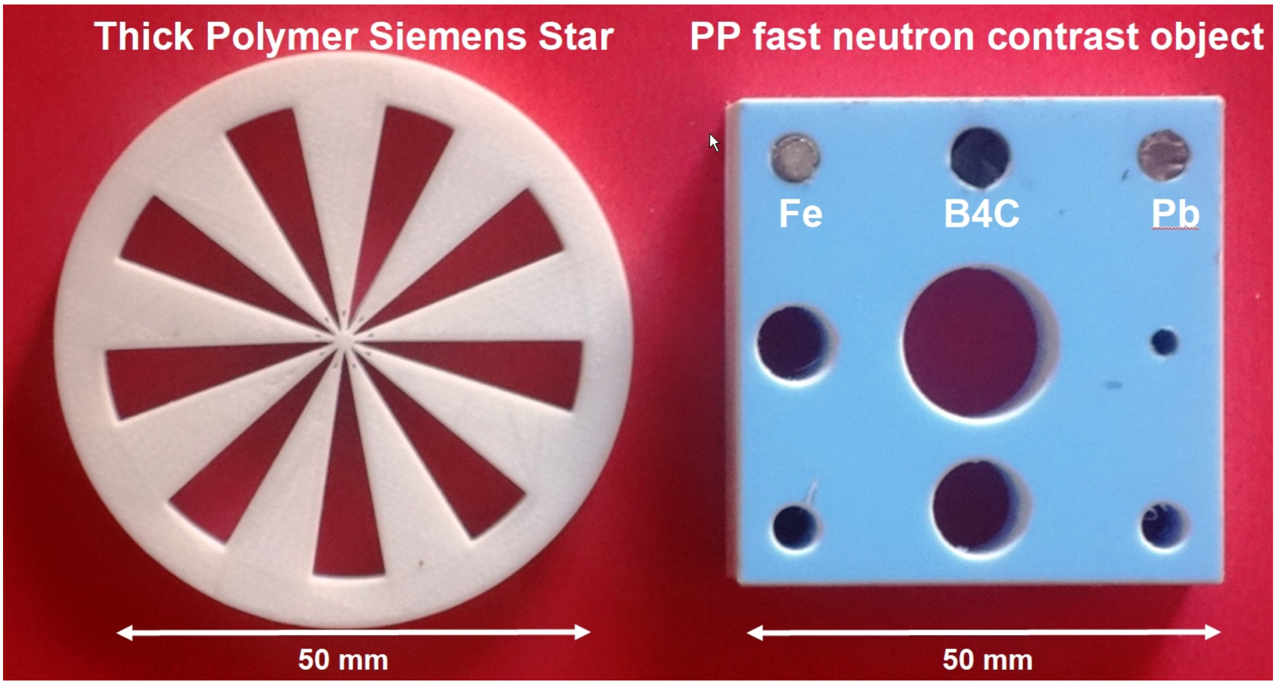


Fast neutrons are very much harder to detect than thermal neutrons because they are not captured by nuclei to provide ionising fission fragments. However, scintillation in ZnS can be achieved with knock-on protons rather than 6Li fission, though long exposures are needed. RCTriTec fast neutron scintillators use high density polypropylene PP/ZnS as a source of knock-on protons. Small D-D and D-T neutron generators are a promising development for low-cost neutron radiography, though the fast neutron flux is low. Even so, one of our 250x200mm cameras has already been used with an AdelphiTech 2.45 MeV D-D neutron generator to obtain radiographs with long exposures (~10 min), though the resolution is low due to the 2.5mm PP/ZnS scintillator thickness (left).

Unless you have a particular need to use fast neutrons (eg for high penetration), you should consider installing a simple hydrogenous moderator on your fast neutron source.

Special Fast Neutron Test Samples

Fast neutrons are strongly attenuated (scattered) by hydrogenous materials, so a thick (1-2 cm) polypropylene "Siemens star" is used to estimate resolution. A contrast object containing polypropylene, Fe) B4C and Pb can be used to distinguish between fast/thermal neutrons & gammas



Imaging with X-rays and Gamma radiation

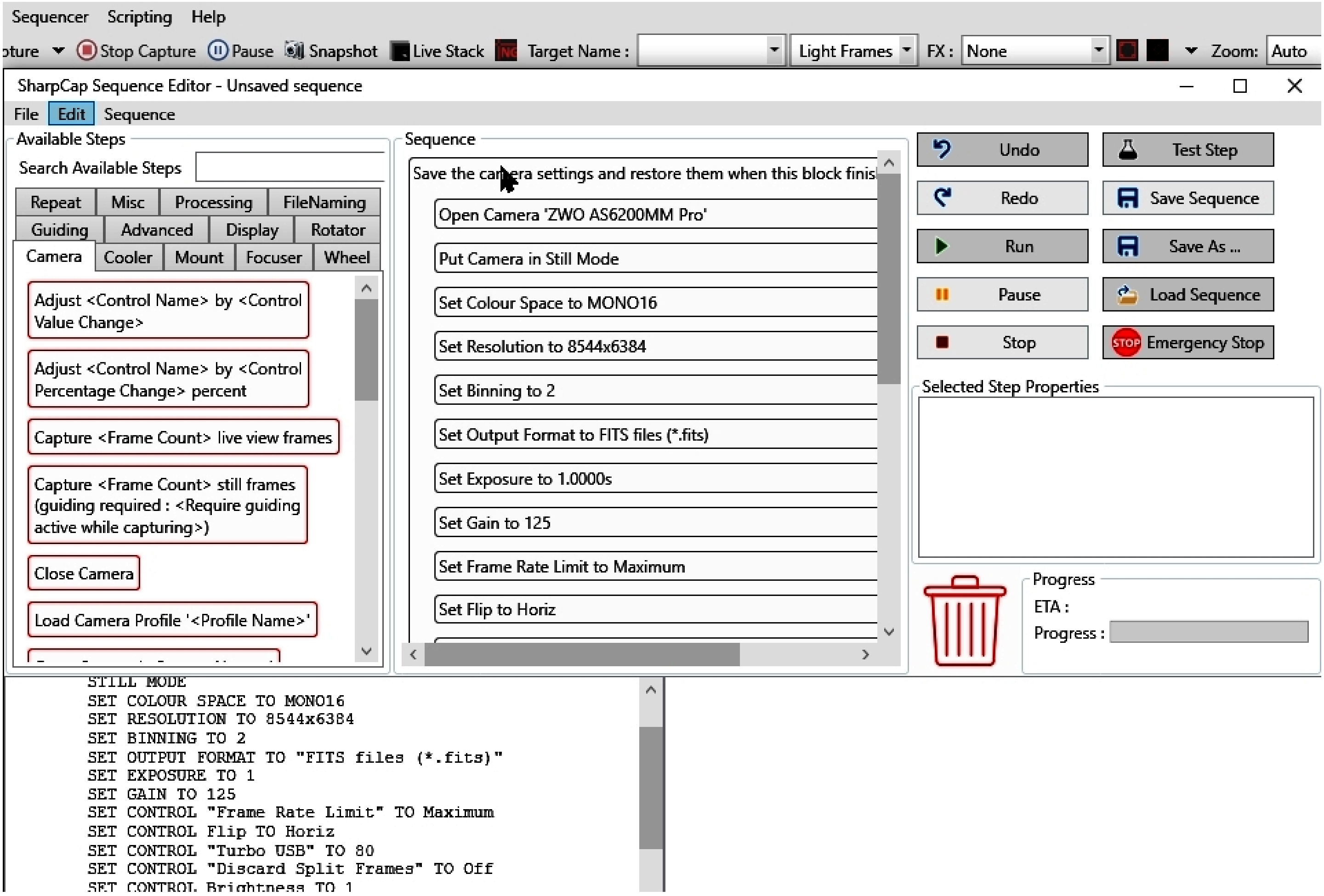
X-rays are converted to visible photons by scintillators containing heavy metal oxides. NeutronOptics uses the most sensitive CAWO (Agfa-Gevaert) OG2 scintillators for our x-ray cameras, with resolution of ~100µ (5 lp/mm). Light channeling in columnar CsI(Tl) allows scintillators to be thicker, and up to 16 lp/mm can be obtained with high efficiency using columnar CsI scintillators. 20µ thick Gd2O2S:Tb powder can do even better (with longer exposures}.

For more information, read our article on the specifications and advantages of our cameras.

Tomography and the SharpCap Sequencer

For tomography you collect a series of images, calling a script to rotate the sample after each image by using the **SharpCap Sequencer**. For example, we take 360 2x2 binned exposures of 1s, writing individual files to "MyFile???.FITS" then executing script "orient.bat" and waiting 2 seconds before starting the next exposure. Substitute any application for "orient.bat" to control the turntable.

To Edit the Sequencer, select Camera, Cooler or Repeat and drag the relevant Command Boxes to the central Sequence box. Click on a command to set its properties in the right box. Once you have saved a Sequence file, you can edit it with a simple text editor rather than this dialogue box. Note that post-processing with dark and flat frames is done with MuhRec Tomographic reconstruction software



For tomography, a precision sample turntable is needed to rotate the sample in increments of eg 0.5 degree between images. For samples of up to 30 Kg, we recommend the Newport Micro-Controle URS turntables which start at ~€2500, together with the SMC100PP motor controller (~€650) and SMC-PS80 power supply (~€93) and SMC-USB USB interface(~€63). For high loads, the RV120BPP, a smaller version of the RV350BPP used at ILL, is recommended. The Newport turntable is controlled by COM port scripts eg using PuTTY's Plink command. A system file **orient.bat** is used to pass a file **commands.bat** to the turntable to **P**osition **R**elative **0.5** degrees.

orient.bat: C:\commands.bat | Plink -v -serial COM4 -sercfg 57600,8,n,1,N

commands.bat: echo 1PR0.5 , timeout /t 1 /nobreak >nul 2>&1 , taskkill /f /IM Plink.exe , exit

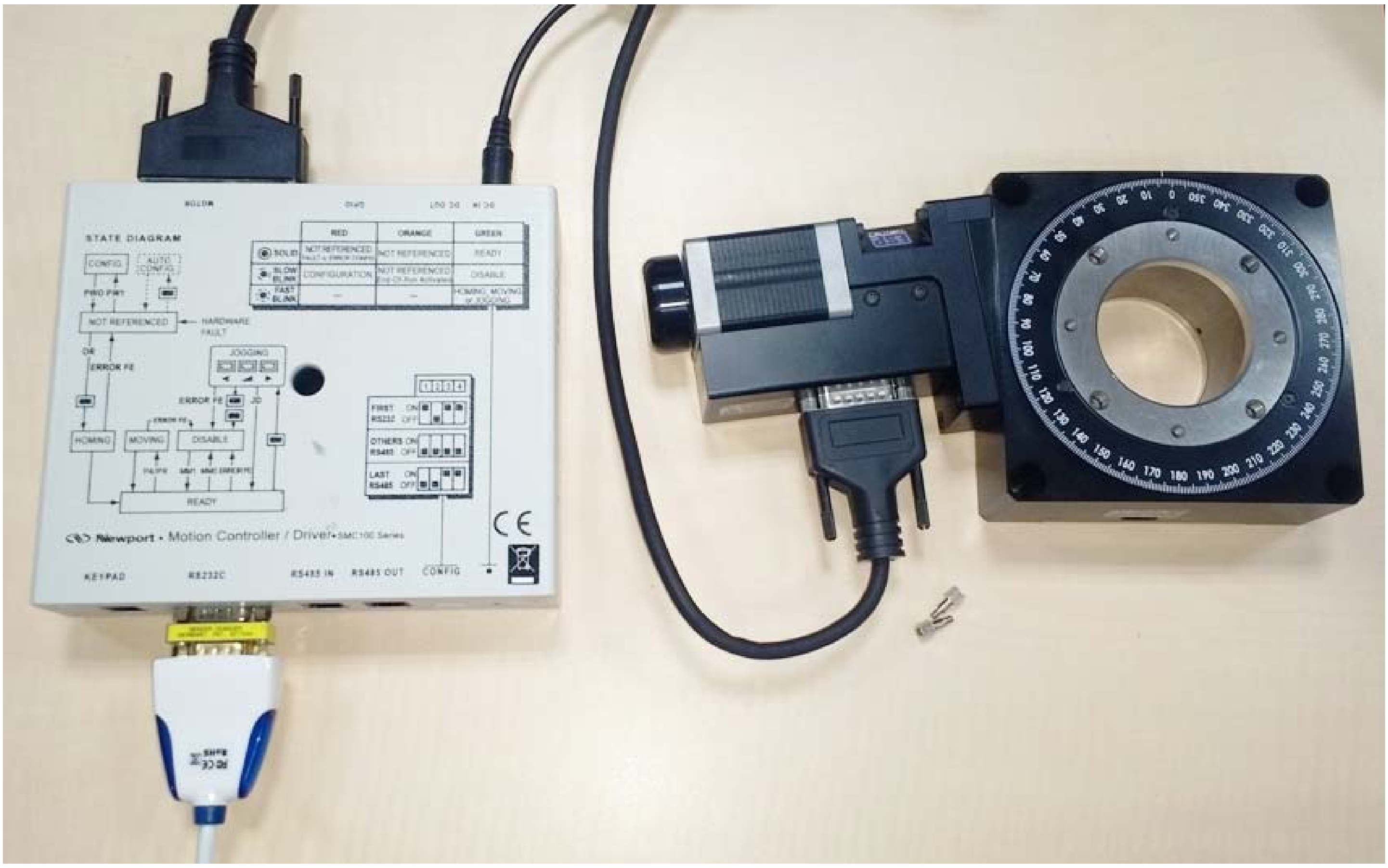
Plink opens port COM4 and pipes commands such as 1PR0.5 to 1 Position Relative 0.5^{o}. waiting 1s before killing Plink, which will be restarted after the next camera acquisition.
But first **open the SMC100 Software, click “Initialize”** so the controller light turns blue (ready state)

SharpCap Scripting is another way of controlling complex imaging sequences using Python scripts.

For the latest information, please check our web site http://neutronoptics.com/software.html

Newport Micro-Controle Tomography Turntable

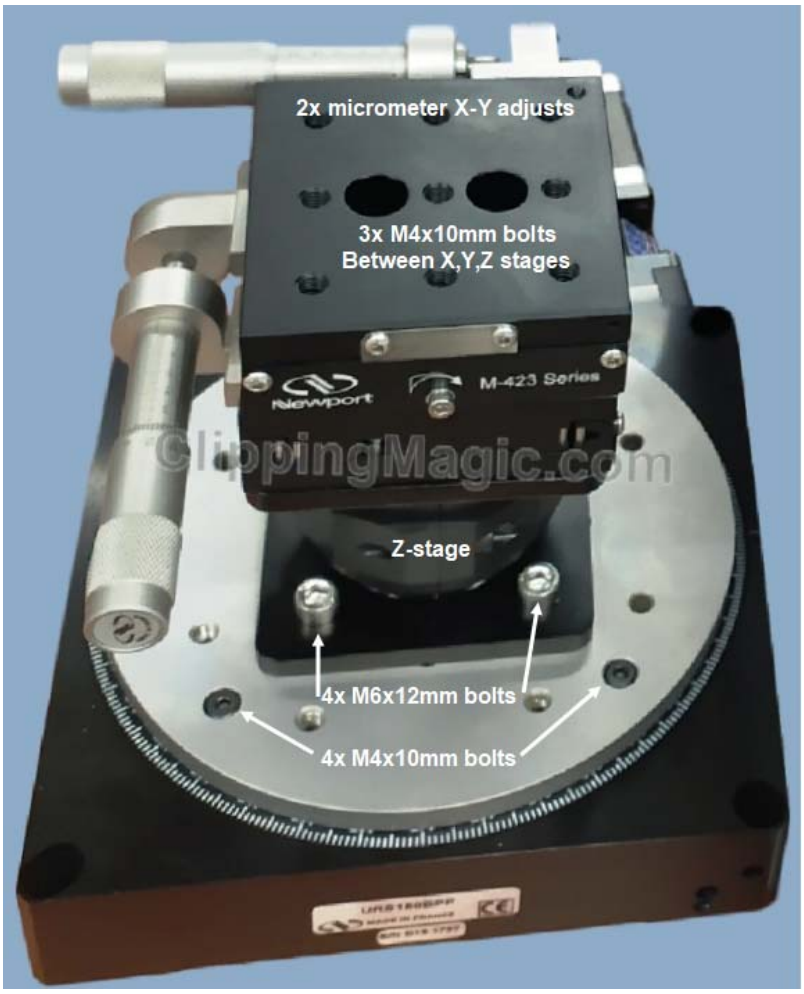
Installing a Newport Micro-Controle Turntable for Tomography



We recommend the Newport Micro-Controle URS turntables which start at ~€2500, together with the SMC100PP motor controller (~€650) with the SMC-PS80 power supply (~€93) and SMC-USB interface(~€63). The URS150BPP is usually sufficient, but for high loads, the RV120BPP can be used. These turntables use stepper motors for precise relative positioning without encoders.

You can use an SMC-RC manual remote control and display to rotate the turntable for alignment, and you may need an M-SK-4MA M4 screw kit to assemble the optional mechanical components such as a manual 9204-M Z-elevator, and X-Y translations M-423 with SM-25 Vernier Micrometers.
you may need an M-SK-4MA M4 screw kit to assemble the optional mechanical components such as a manual 9204-M Z-elevator, and X-Y translations M-423 with SM-25 Vernier Micrometers.

Mounting the sample base plate and Z,X,Y stages onto the turntable



The Newport URS150BPP turntable is shown with its URS150 mounting plate plus a manual 9204-M Z-elevator and M-423 X-Y translations with SM-25 Vernier Micrometers.

The mounting plate is bolted to the turntable using 4x M4x10mm hex bolts. then the Z-stage is bolted on top using 4x M6x12mm bolts. The X-Y stages are bolted on top using M4x10mm bolts with washers. Displace the top of each stage to obtain access to these bolts via the two large holes in the top of the stage.

Instructions for mounting the micrometers are provided with the stages, with video instructions for stacking stages and swapping micrometer orientation.

You will probably want to change the +-165° hardware limits on turntable rotation.

The nominal positioning precision can be obtained if the turntable is bolted to a horizontal surface using the 4x M8 bolt holes at its corners.

Installing the Controller Software and linking to the Camera Software

- Download SMC100-V2.0.0.3.zip right-click & "extract all", then launch **Drivers/ EasySync.exe**
- Connect the **RS232C socket** on the controller to a USB socket on the computer using SMC-USB
- Connect the 25 pin **Motor socket** on the controller to the 15 pin turntable socket
- Connect the **DC-In socket** on the controller to the 48V power supply and plug it in
- Run the **SMC100 Utility Installer** from the V2.0.0.3 folder. Use it to manually monitor the turntable
- **Open the SMC100 Software, click "Initialize"** so the controller light turns blue (ready state)
- Open the **Parameters** tab to change the SL and SR software limits from +-1650 to +-3600
- Download and install PuTTY This will also install the command-line version called **Plink**
- Open a **Windows Command Prompt** (cmd) as Administrator and check that Plink runs
- In the **Windows Device Manager** check under Ports (COM) for a USB serial port
- Note the number of this USB serial port eg COM4: this is used in the **Orient.bat** script
  C:\commands.bat | Plink -v -serial COM4 -sercfg 57600,8,n,1,N
  Plink opens COM4 and configures it as required for the controller
- The **Command.bat** script is then piped to the port to execute the following commands:
  echo 1PR0.5
  timeout /t 1 /nobreak >nul 2>&1
  taskkill /f /IM Plink.exe
  exit
  Command **1PR0.5 steps motor 1** to **P**osition **R**elative **0.5**°, we wait 1s, then kill Plink and exit
- These ***.bat scripts** can be kept on disk **C:** or anywhere else. Double click **Orient.bat** to test it