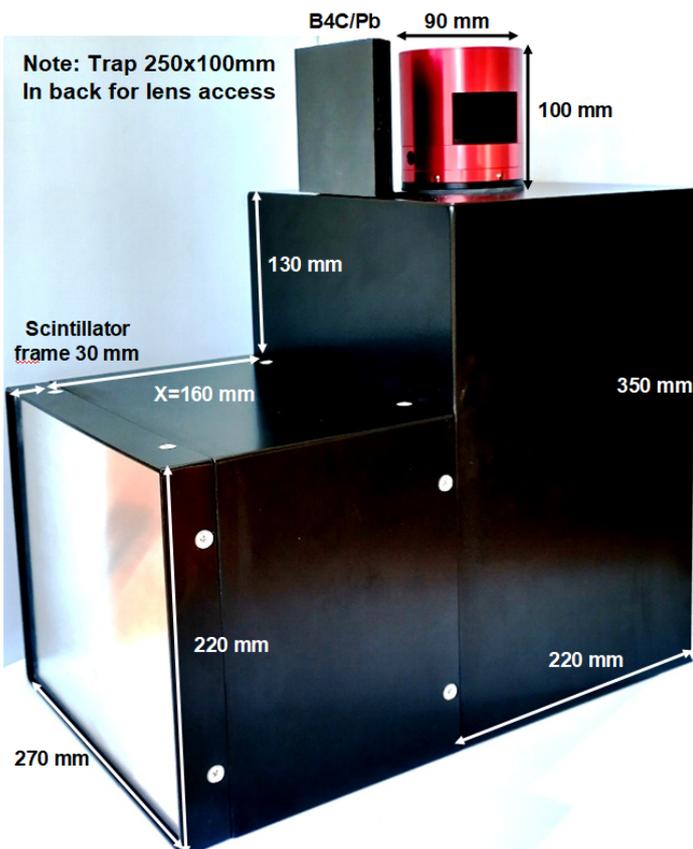




NeutronOptics High-Res CMOS Imaging Camera

The photo below show our 250x200mm L-shaped camera complete with the detector and its B₄C/Pb protection on top, 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.

Various [CMOS detectors](#) can be used, from micro-4/3, APS-C to Full-Frame. All are designed to image the full 250x200mm Field-of-View (FOV), and even the smallest, cheapest 4/3" CMOS detector has a FOV pixel size better than the resolution you can expect from the usual neutron scintillators. 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 is a good compromise, using a modern f/0.95 lens that can focus to 350mm, providing a smaller FOV option with higher efficiency. The full-frame camera uses the old Nikon f/1.2 lens that can now only be provided re-furbished. These bigger sensors have more pixels, which doesn't improve resolution, but these small pixels can be hardware binned to improve efficiency, signal/noise and frame-rate.

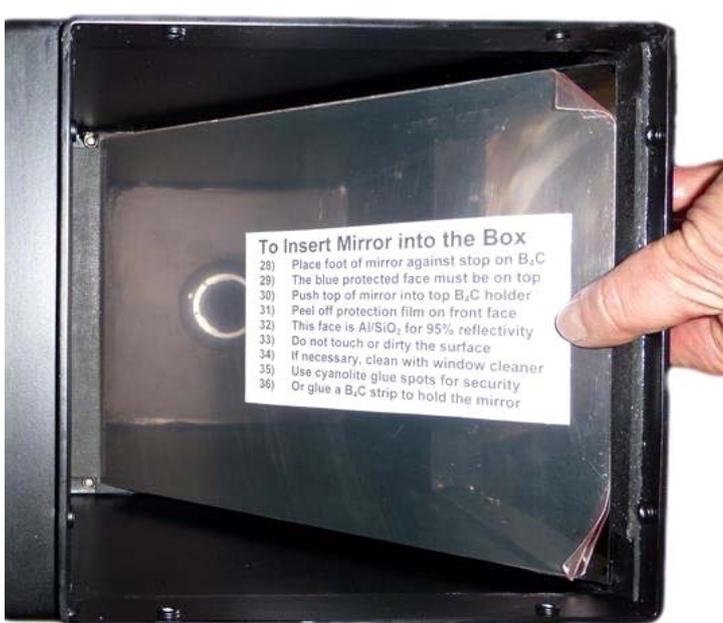


Detector	4/3" CMOS	APS-C CMOS	FullFrame
Type	Pregius IMX294	Pregius IMX571	Pregius IMX455
Lens Type & aperture	MFT 35mm f/0.95	MFT 35mm f/0.95	Nikon 50mm f/1.2
Typ Optical Path length	350-500mm	350-500mm	500mm
Typ FOV mm scintillator	200x250	200x250	200x250
Pixel size at FOV	50-70µm	40-50µm	30µm
Resolution pixel	4144x2822	6248x4176	9576x6388
Image diag. mm	23 (4/3")	28 (APS-C)	43 (35mm)
Image area mm	19.1x13	23.5x15.7	36 x 24
Pixel size µm	4.6 x 4.6	3.76x3.76	3.75x3.75
Quantum effc	~90%	~90%	90%
Fullwell e-	~66,000	~50,000	~50,000
Read noise e-	1.2-7.3	1.0-3.3	1.5-3.5
Dark c. e-/pix/s	0.002@-20 °C	0.003@0 °C	0.003@0 °C
Peltier Cooling	Δ -35 °C	Δ -35 °C	Δ -35 °C
Read time (s)	16 fps	3.5 fps	0.5
A/D Readout	14-bits	16-bits	16-bits
Binning h,v	x1 x2	x1 x2 x4	x1 x2 x4
Mount	M43-mount	M43-mount	F-mount
Trigger signals	Software	Software	Software
Interface	USB 3.0	USB 3.0	USB 3.0
Relative cost Detect+Lens	3	5	9

If in doubt, choose the cheaper APS-C camera.

Installing the Front-Surfaced Mirror

1. Place the foot of the mirror against the labelled B₄C 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 B₄C 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 B₄C 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 three 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 Nikon full-frame lens; the MFT lens is different.

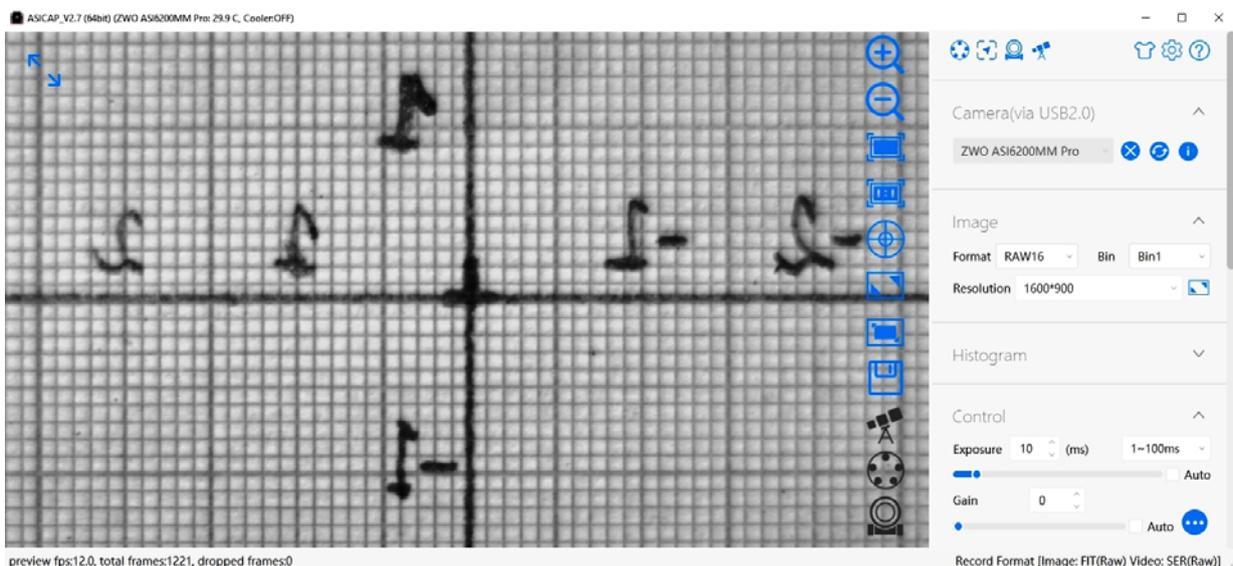
Do not touch the exposed surfaces of the detector cover glass or lens, the front of which is covered by a clear filter that can be replaced if damaged. **Remember to remove the lens cover !**



NeutronOptics CMOS Imaging Camera Operation

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

- Launch the Windows camera driver [ZWO ASI Cameras driver Setup V3.23.exe](#) from the DVD Or download it from <https://www.zwoastro.com/software/> or use MacOS or Linux versions. The Linux software will even run on a [Live Persistent Linux MINT USB stick](#).
- You can use ASICap from [ASISudio](#) to control the camera, but we recommend [SharpCap4](#)
- If you want to develop your own software, download the [SDK](#) Software Development Kit
- Do not update the camera firmware if you don't have problems with that already installed
- [LabView demo software](#) is available for Windows
- You can also read the ZWO detector manuals, but these describe astronomical applications

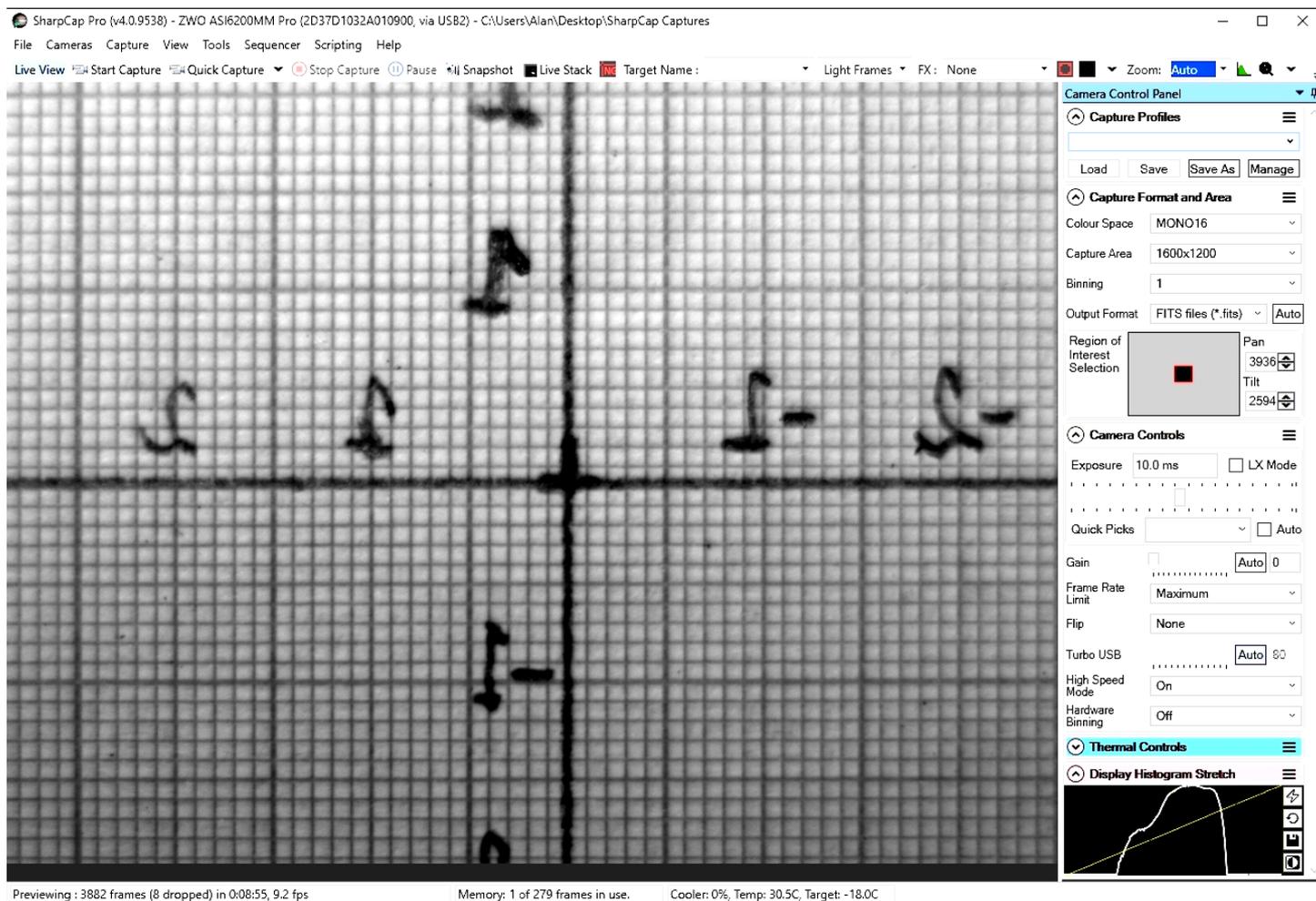


This screen capture of **ASICap** has been limited to 1600x900 pixels to speed up the frame rate for focussing. Note that Raw 16-bit un-binned images have been selected and the exposure set to 10ms. The image shows a small area of the total FOV of millimetric graph paper taped over the scintillator, illuminated by light shining through the open lens trap. Hover the mouse over the blue icons on the right of the image display to understand their function.

ASICap may be sufficient for simple beam monitoring, and is available for both Windows, MacOS and Linux computers, but Windows **SharpCap4** offers more features. You can otherwise download the [ASCOM driver](#) and use many other astronomical imaging applications, including our simple PHD display application and our [ImageJ-for-ASCOM](#) interface which allows you to program complex acquisitions within ImageJ. Windows [MicroManager](#) and a [MicroManager Plugin](#) is also available, as well as a Windows [Direct Show driver](#).

Installing the Recommended SharpCap4 Viewer

Use [SharpCap4](https://www.sharpcap.co.uk/sharpcap/downloads) 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. You must **first install the ZWO driver**. 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 **SharCap4** 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). 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).

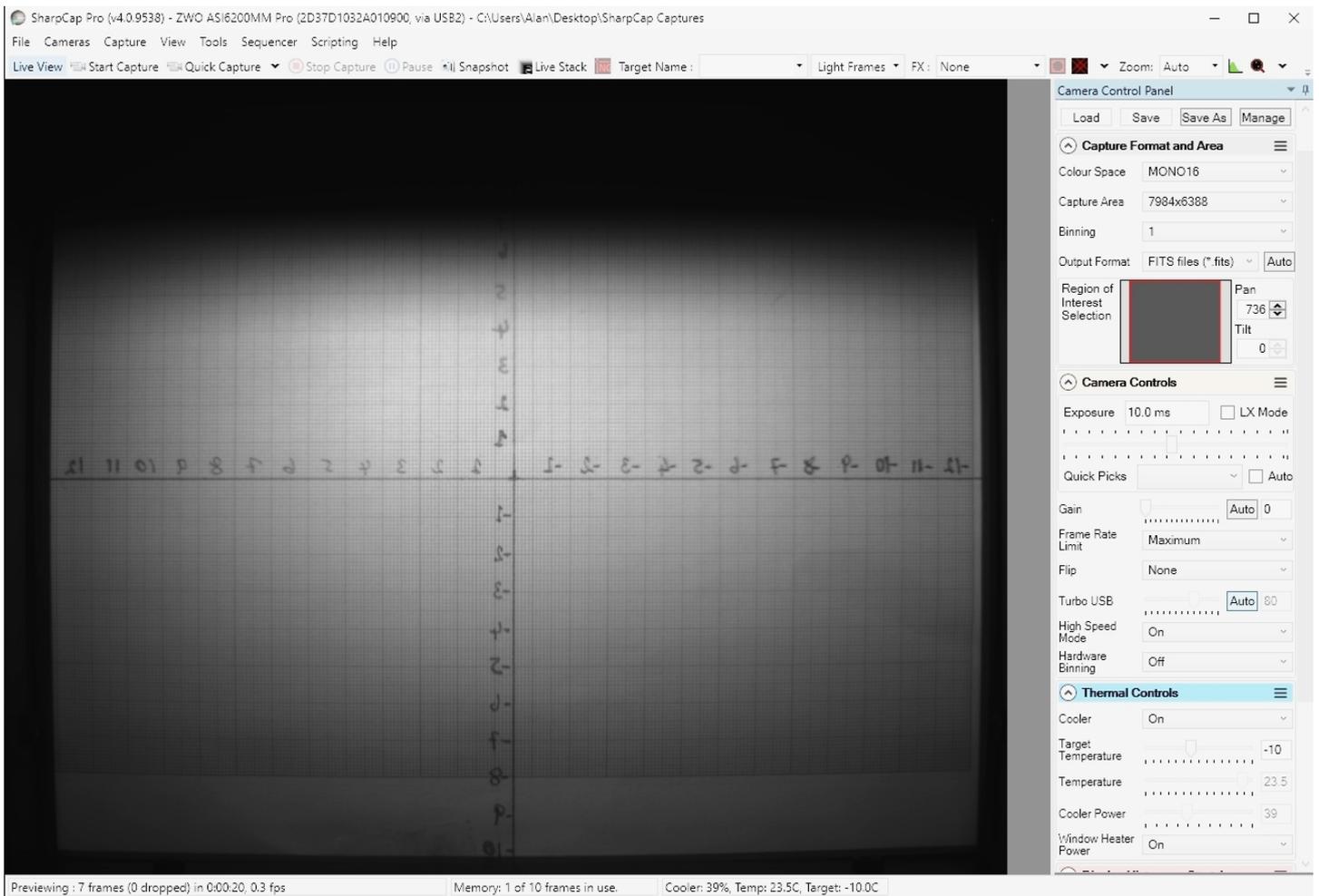
In menu "**File/Settings**" check auto connect and restore, with format AVI and FITS. Choose where and how files are saved. **Tip:** set a "**Default Profile**" to open with those settings on start-up.

The camera settings are in a hidden file called **_autosave (camera name).ini** which can be found in:

C:\Users\\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 with temperature cooling to -10C. **The image is shaded on top** because the screen illumination through the lens trap is not uniform.

Binning and Selected Regions of Interest (ROI) Capture Area

Binning sums intensity in adjacent pixels 2x2, 3x3 etc., effectively increasing the pixel size (higher signal, signal/noise, fullwell capacity etc). If the binning is done in-camera (hardware), the data transfer speed (**frame-rate**) is also increased by a factor of 2x2, 3x3 etc. Software or Hardware Binning is useful when resolution is limited in any case 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. If **hardware binning** is required, the ROI must obey certain rules; The X dimension must be divisible by 16 (for 2x2 binning) or by 24 (for 3x3 binning), and the Y dimension must be divisible by 4 or 6. The largest ROIs that can be hardware binned both x2 and x3, are for the full-frame IMX455 camera:

9552x6384 (3:2 ratio); **8544x6384** (4:3 ratio or 400x300mm); **7968x6384** (3:2 ratio or 250x200mm)
The last two can be x4 hardware binned, but then the framerate is less than for x3 hardware binning.

Image Treatment with ImageJ

[ImageJ](#) is recommended for image analysis. ImageJ will open the 16-bit raw [FITS](#) files, filter noise, modify contrast and other properties, and save them in various formats. More importantly, it will allow you to measure intensity profiles and display your data in ways that will make it more meaningful.

A complete ImageJ installation is included on the NeutronOptics software CD under "Extras". Just copy the ImageJ folder to your C: disk and launch ImageJ to set defaults and update ImageJ.

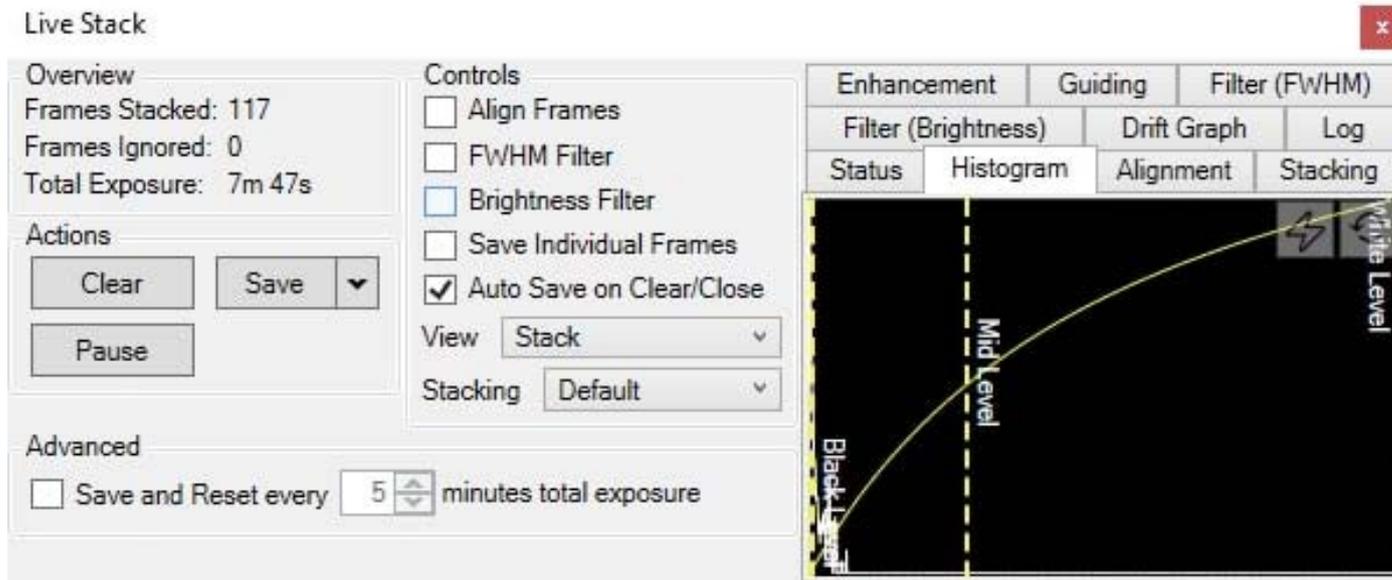
Hints on getting Optimal Performance

- 2x2 binning will give x4 the intensity and faster readout, but halve 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 can be cooled to reduce noisy pixels. You can also use ImageJ filters
- 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 becomes particularly important for very long exposures to greatly reduce the number of isolated hot pixels. Those remaining can easily be removed with the [ImageJ Despeckle](#) filter.

Stacking short exposures in SharpCap (usually not needed)

An interesting feature of SharpCap is real-time stacking of a series of short exposures. This allows you to judge when you have sufficient intensity. Click on the "**Live Stack**" icon above the image display to open this stacking window. You can drag this window so that it does not cover the image. Switch off "**Align Frames**" which refers to alignment based on stars. Most of the controls to the right are also for astronomers; only the live histogram is useful, but normally you might save the summed stack as a 32-bit image and filter noise from it with imageJ.



You can also use imageJ to stack a series of short exposures, which allows filtering of noise from the individual images before averaging. For very short exposures this may be better than averaging first and then filtering. Use the SharpCap menu **Capture/Start_Capture** then enter the number of images to be saved. After capturing those images, use the ImageJ menu **File/Import/Image_Sequence**, open the first image, and then OK to import all images in that directory into a displayed stack. Use **Image/Adjust/Brightness-Contrast** to examine the noise, and apply **Process/Noise/De-speckle** to all images. You may need to **De-speckle** twice. Finally sum or average the stack using **Image/Stacks/Z-Projection**.

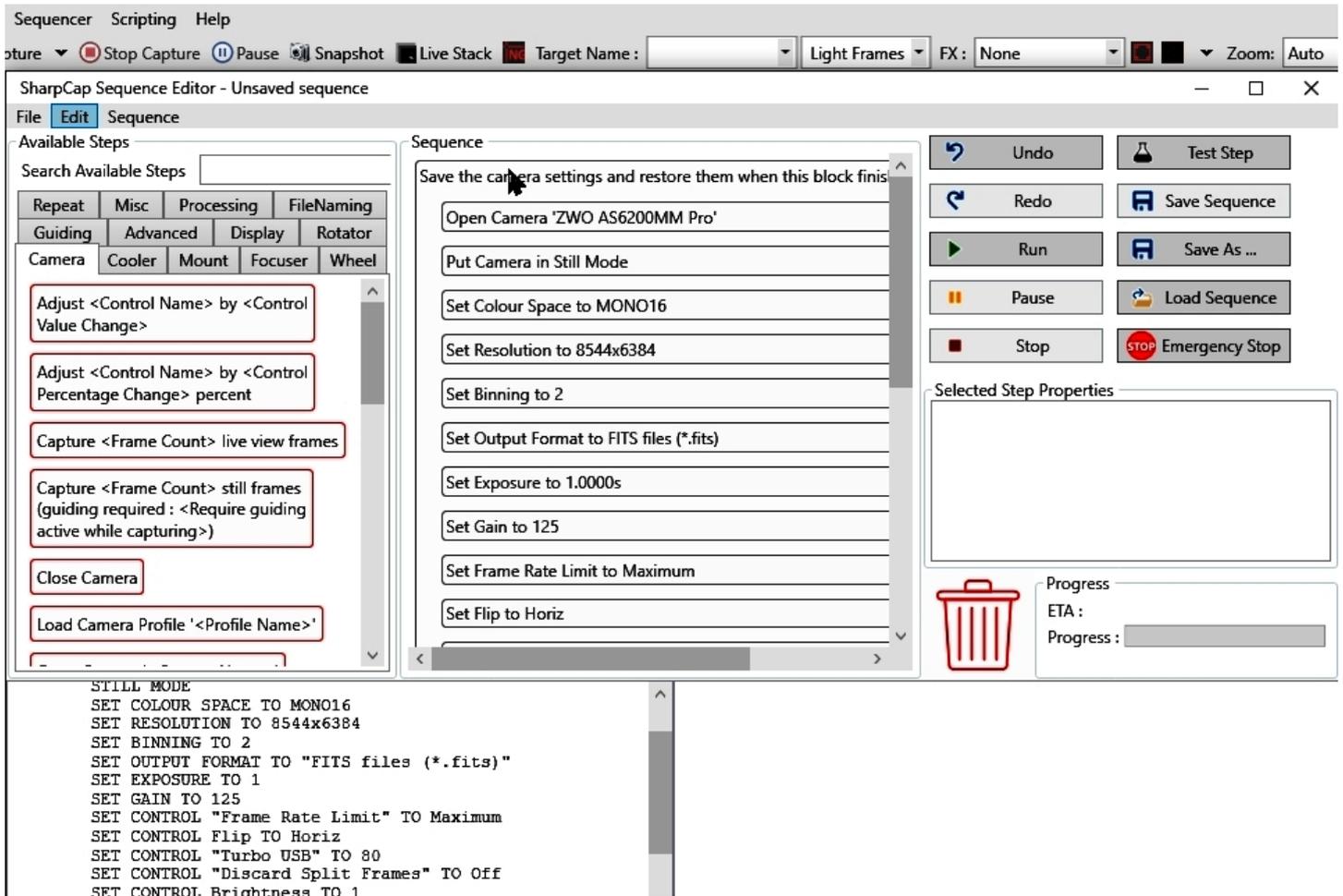
For long stacked exposures you may see a diffuse background patch due to amplifier glow. Depending on the speed of your computer, frames may be dropped for frame rates >8 fps.

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

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 Position Relative 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°.

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>

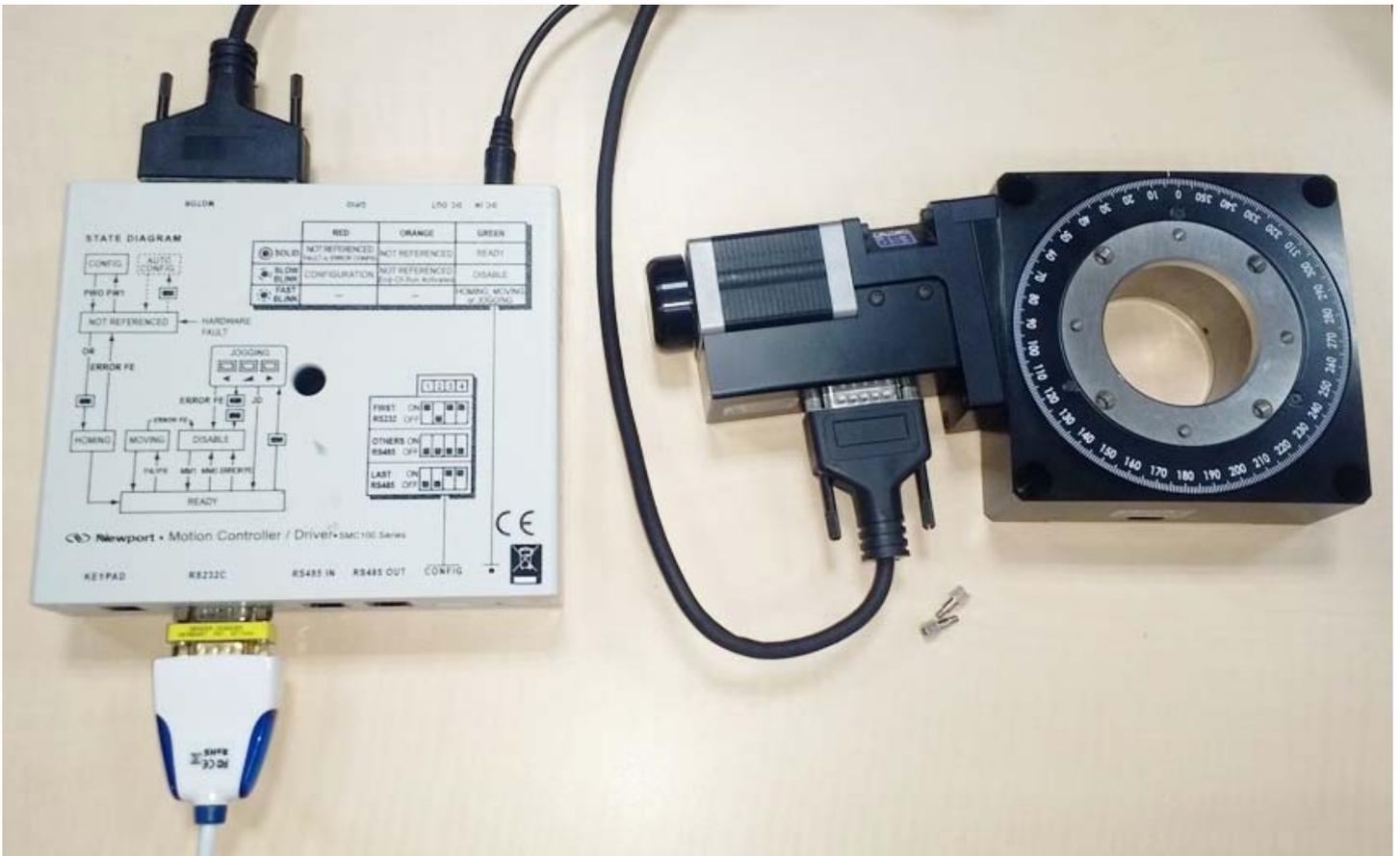
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Newport Micro-Controle Tomography Turntable

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 $\pm 165^\circ$ [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 Position Relative 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