The NeutronOptics 1:1, 2:1, & 3:1 Macro Cameras

The 1:1 NeutronOptics Macro camera (left) uses a high resolution 100 mm Tokina macro lens with close focus to obtain an image equal to the size of the detector chip, with optical resolution equal to the size of its typically ~5 micron pixels. The real resolution depends on beam collimation and **scintillator thickness**.

Any Nikon F-mount or any C-mount camera (not shown) can be used e.g. the Pregius IMX533 square CMOS or larger. This lens uses a unique focus clutch. Pulling the focus ring towards the detector engages manual focus; pushing it away locks focus.

Tokina Macro lens specifications:
- **Focal length:** 100mm
- **Aperture:** f/2.8 - f/32
- **Mount:** Nikon-F
- **Format:** Full-frame
- **Min Focus:** 30 cm
- **Filter Size:** 55 mm
- **Size:** 74x95 mm
- **Weight:** 540 g

The x-ray or neutron scintillator can be changed simply by unscrewing the 41mm diameter window holder. Plastic (powder) X-ray or neutron scintillator disks are supplied as standard. Special thin scintillators (e.g. 20 microns) are needed for high resolution

See: http://neutronoptics.com/advantages.html#scintillators

Higher 2:1 and 3:1 magnifications can be obtained by focussing the 100 mm lens at infinity, and adding a second imaging lens facing the mirror in place of the scintillator holder, which is attached to the back of this second lens (above right). See: http://neutronoptics.com/cameras.html#resolve

Please also see the test results or release notes for your particular camera.
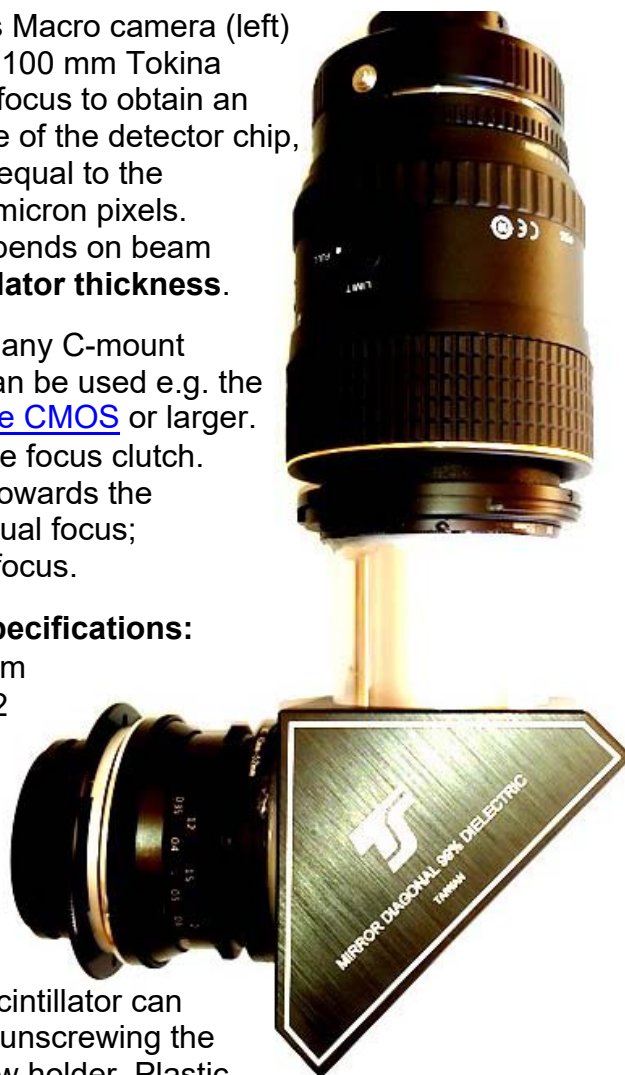
Construction of the NeutronOptics Macro Camera

- The NeutronOptics macro camera may be shipped disassembled to its component parts for safe transport
- The camera unit can be suspended from the detector, or from a special clamping ring for small detectors
- The lens has two adjustments - aperture (normally f/2.8), and focus (close focus i.e. maximum extension)
- The manual focus ring is simply **pulled down to lock focus**. Motorised focus may be provided as an option
- The 90-degree mirror unit, with its sliver 1:1 tube, screws into the front of the lens. Don't touch the glass
- The scintillator holder also screws onto the mirror. A thin carbon or alu. window can be screwed over it.
- But first focus on the wire grid in place of the scintillator using room light, then pull down to lock focus
- Replace the wire grid with a scintillator and cover the scintillator with the carbon fibre window (below)

1) Measure the distance to the wire grid for closest (macro) focus of the camera.

2) Replace the wire grid with the scintillator at the same distance

3) Fine adjustments to lens focus must be done with the camera in the beam.

4) If impossible to focus, adjust spacers to move scintillator away (1:1) or closer (3:1)

5) A 200mm scintillator extension tube may be used for a large FOV with a small detector.

These instructions also apply to the 2:1 and 3:1 cameras where the scintillator holder screws onto the back of the second lens, rather than directly onto the mirror, with both lenses focussed near infinity.

Mount on ¼" bolts — C-mount adapter — Mount on ¼" bolts

Set aperture to max f/2.8

Rotate to near max extension i.e. focus 0.3m — Pull down to lock focus

75mm

340mm

1:1 tube

Mirror

40mm

C-window

The operation of the imaging software is described separately, and depends on the type of detector. SharpCap is used for small CMOS detectors, and Artemis Capture for larger cooled CCD cameras.

Latest version: http://neutronoptics.com/downloads/Manual-NeutronOptics-Macro-Camera.pdf

NeutronOptics Fast Imaging Camera Operation

The VS60 fast high resolution thermo-electrically cooled Sony 2750x2200 pixel CCD unit

- **X-ray Scintillator:** Interchangeable fast, fine x-ray scintillator
- **Neutron Scintillator:** Interchangeable high resolution neutron scintillator
- **Optics:** Interchangeable high resolution 25mm f/1.4 low-light lens
- **CCD Sensor:** 1 inch Sony ICX694ALG *EXview HAD CCD II*
- **Chip size:** 12.40x9.99 mm, diagonal 16 mm (Type 1")
- **Resolution:** 2750x2200 pixels (**90 µm resolution over 250x200mm**)
- **Pixel Size:** 4.54x4.54 µM (larger pixels & micro-lenses collect more light)
- **Binning:** from 2x2 to 8x8 (for boosted frame-rate and efficiency)
- **Region-of-Interest:** fully variable (for full resolution at higher frame-rate)
- **High sensitivity** (QE~75% at 500-600nm), low smear
- **Low dark current:** 0.002 electron/pixel/sec @ -10 °C
- **Full well capacity:** 20,000 electrons (large dynamic range)
- **A/D Conversion: 16-bit 65536 levels** in Flexible Image Transport System
- **LiveView Mode:** 8 bit readout mode for faster readout
- **Digitisation Speed:** 6-12 MPixels/s
- **Readout Noise:** 6 e- at -10°C
- **Interface:** USB 2.0 High Speed with 10-20m amplified USB cables
- **Power:** Regulated 12v DC 2.5A, to EU, UK, US/Japan, AU/CN standards
- **Minimum Exposure Length:** 0.001 seconds
- **Maximum Exposure Length:** Unlimited
- **Cooling:** Regulated dual fan thermo-electric Peltier with max ΔT = -35°C
- **External Trigger:** For synchronisation with sample environment
- **CCD Unit:** 120x120mm dimensions, 50mm height, 800g weight
- **SDK:** C++, VB Wrapper, .net Wrapper, ImageJ, LabView drivers

1 – Vcc 3.3V
2 – GND
3 – GPIO Line 0
4 – GPIO Line 1
5 – Trigger Input
6 – Exposure Output

The FS60 cooled CCD unit uses the same Sony ICX694ALG chip as the VS60, with slower readout (~3s)

- **Sensor Type:** Sony ICX825ALA or ICX694ALG
- **Image size:** Diagonal 11mm (Type 2/3") or 16mm (type 1")
- **Resolution:** 1392x1040 or 2759 x 2200
- **Pixel Size:** 6.45x6.45 µM or 4.54 x 4.54 µM
- **Binning:** from 2x2 to 8x8 (improved intensity and read-out)
- **High sensitivity** (QE>75% at 500-600nm), low smear
- **Low dark current** 0.003@-10 °C, excellent anti-blooming
- **Full well capacity:** 20,000 or 40,000 electrons
- **ADC:** 16 bit grey scale image, optional filtering and distortion
- **Readout Noise:** 4 e- typical (slower readout = less noise)
- **Readout Time:** 1-3s
- **Interface:** USB 2.0 High Speed with 10-20m USB cables
- **Power:** 12v DC 0.8A, to EU, UK, US/Japan, AU/CN standards
- **Maximum Exposure Length:** Unlimited
- **Minimum Exposure Length:** 0.001 seconds
- **Cooling:** Thermoelectric set point with max ΔT=-27°C
- **CCD Unit:** 60mm diameter, 122mm length, 400g weight
- **Lens Coupling:** T2-mount, C-mount, F-mount
- **SDK:** C++, VB Wrapper, .net Wrapper, ImageJ, LabView drivers

IMPORTANT

It will be **more difficult to focus** cameras with slow readout, such as the FS60 or Atik 460EX. For faster readout, restrict the readout area (Region-of-Interest) and eventually use binning to reduce the number of pixels transferred. You only need a small readout area, and a small number of pixels, for focussing.

Installing the Driver and Artemis Capture software

- Browse the CD & launch "SetupArtemisUniversal.exe" or "artemisinstaller.exe"
- This installs the driver & "ArtemisCapture" to control the camera
- You can also download and pre-install the [Artemis core software & drivers](#)
- Plug the 12V supply into the camera; the fan should start up
- Connect the 10m USB extension to the computer, and wait for its driver to be installed
- Then connect the camera to this cable, or directly to a USB port on your computer
- The computer should automatically search for and install the driver. Be patient !
- The Windows Device Manager should now show an ArtemisCCD USB controller
- Launch ArtemisCapture to control the camera (see next section)
- If the driver is not found automatically, try manual installation:
    - Click the Windows "Start" button and open "Devices and Printers"
    - Double-click the "Unknown Device", select "Hardware" then "Properties"
    - Click "Change Settings" under the "General" tab
    - Click "Update Driver" under the new "General" tab
    - Choose "Browse for Drivers" on the Product Software CD
    - Select the 32-bit or 64-bit driver from the drivers folder
    - Click "OK" then "Next" then accept and install the camera driver

Using ArtemisCapture with the High Resolution Camera

Launch ArtemisCapture to display the image and controls. The "File" menu is used to save the last image, the "Camera" menu connects the camera if it is not done automatically, and the "Colour" menu should be set to "Raw". The icons under the menus launch a single exposure or continuous loop exposures. The three remaining icons open the Exposure, Display and Cooler tabs.
IMPORTANT: Zoom out to see the green outline of the full CCD.
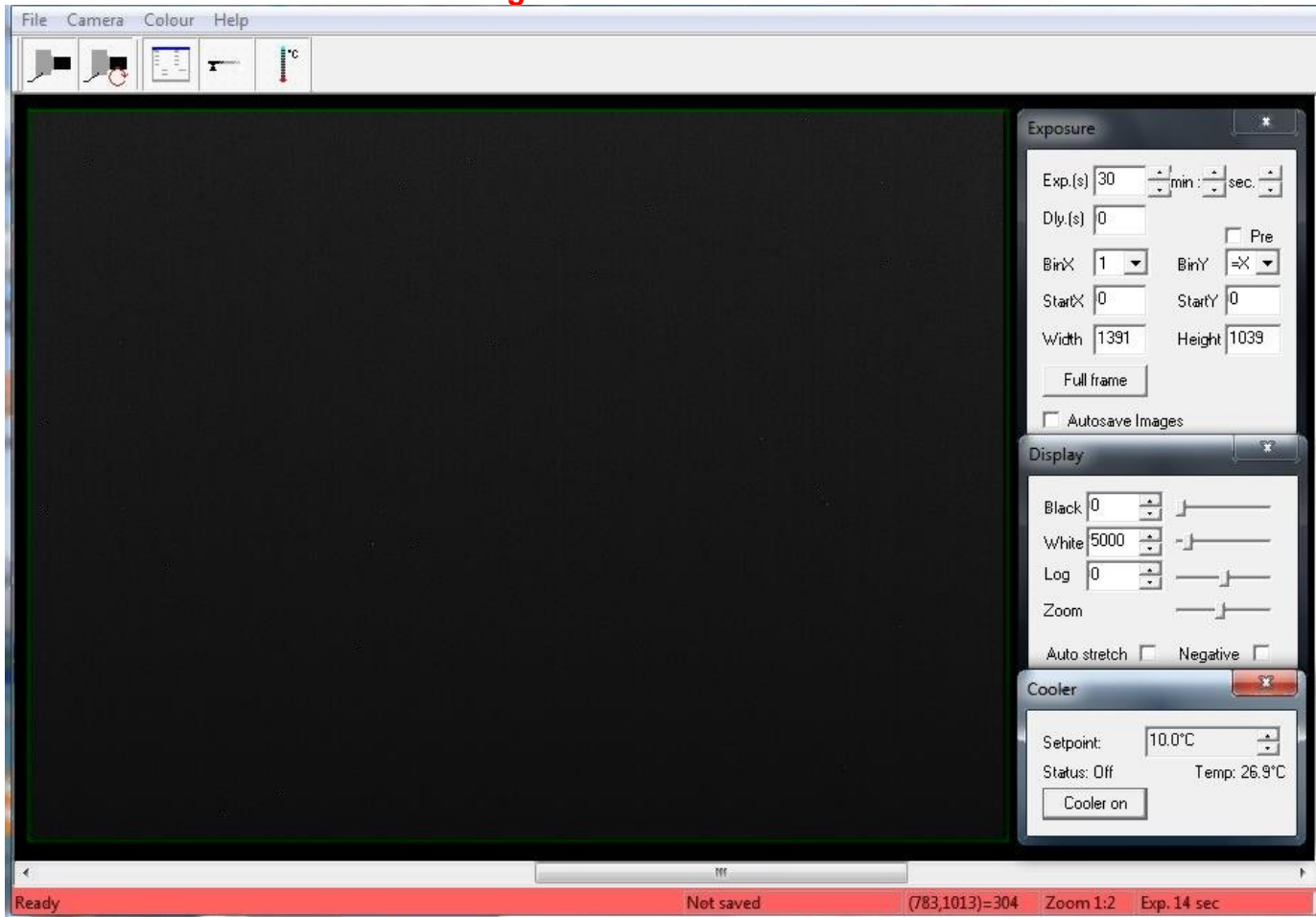
On the "Exposure" tab: (to speed up downloads e.g. when focussing with light)
- Set the exposure time (s) with **BinX=4 and BinY=X** for 4x4 binning
- Select a **subframe** "Width", "Height", "StartX" & "StartY" to reduce readout time
- Use **"loop"** exposures of ~0.1s, which are sufficient for light (but not for neutrons)

On the "Display" tab:
- Check the **"Auto stretch"** option to select the best 8-bits out of the 16-bits. Note that **scintillator afterglow may be seen for some minutes after exposure to light.**
- **"Zoom"** (or the wheel mouse button) zooms the display window

On the "Cooler" tab:
- Set the temperature to -20°C to reduce noise when collecting neutron images
- If the CCD is cold, click **"Warm up"** and wait a few minutes before disconnecting power

Hints on getting Optimal Performance

- **If the image is black, reduce the exposure to avoid saturation.**
- The exposure time depends of course on the intensity of your beam
- 2x2 binning will give x4 the intensity and faster readout, but halve resolution
- You can also limit readout to a "sub-frame" region of the full image
- The "Display" panel controls what you see, but has no effect on what you collect
- "Zoom" (and the wheel mouse button) zooms the size of the image display
- "Auto Stretch" compresses the 16-bit range of intensities to 8-bits for display
- But usually you will want to select the black and white display limits manually
- Image display is for guidance. Open the image with ImageJ for measurement
- The CCD can be cooled to reduce noisy pixels. You can also use ImageJ filters
- Fogging may occur if you cool below 0°C (the CCD chamber contains a desiccant)
- The desiccant can be replaced by removing the large screw on the camera shaft
- The center of the image doesn't correspond to the centre of the window

Cooling becomes particularly important for very long exposures to greatly reduce the number isolated hot pixels. Those remaining can easily be removed with the [ImageJ Despeckle](#) filter.

Occasional Problems with camera operation

- Be patient when you first launch ArtemisCapture. Wait for it to load and detect the camera.
- If ArtemisCapture complains that it cannot connect to the camera, and the cables are in place, a background copy of the application may already be connected. Unplug the power to the camera - this will close any open connections - then try again.
- Check that an ArtemisCCD device is connected in the USB controller list in the Windows Device Manager, which is accessed by right-clicking MyComputer.
- Try deleting the ArtemisCapture.ini file from the C:\Windows folder to reset Artemis Capture.
- Try a different USB port, waiting for the driver to be found and re-installed.
- USB ports can sometimes become un-responsive. Shut down the computer and remove the computer's power cable for a few seconds. Then re-connect everything and reboot.
- If all else fails, try using a different computer.
- **A black image may simply mean the CCD is over-exposed. Reduce the exposure time.**

Image Treatment with ImageJ

[ImageJ](#) is recommended for image analysis. ImageJ will open the 16-bit raw [FITS](#) files produced by Artemis Capture, remove 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.

Native ZWO ASICap Viewer from ASIStudio for CMOS cameras

You can use **ASICap.exe** from **ASIStudio** to control the camera, but we recommend **SharpCap4**. **ASICap.exe** becomes available after installing ASIStudio, and automatically recognises the camera. There is a help file available under the top right interrogation icon, but ignore all the astronomy help.

Prefer **RAW16** as the image format, with either 1x or 2x binning. This binning is performed by the camera driver after readout, and you can obtain much the same result by post-acquisition binning in ImageJ. Binning increases intensity at the expense of resolution. You can manually set the exposure and gain, or simply use automatically adjusted values. You can capture either a single image by clicking the camera icon, or a short video limited to n frames, by clicking the video icon. Otherwise the camera runs continuously without saving the frames. Hover the mouse over the icons on the right of the image display to understand their function - zoom in and out, zoom 100%, zoom to fill the available display area, draw crosshairs, display the full frame, move the ROI, and save the image. The last three icons are only used in astronomy.
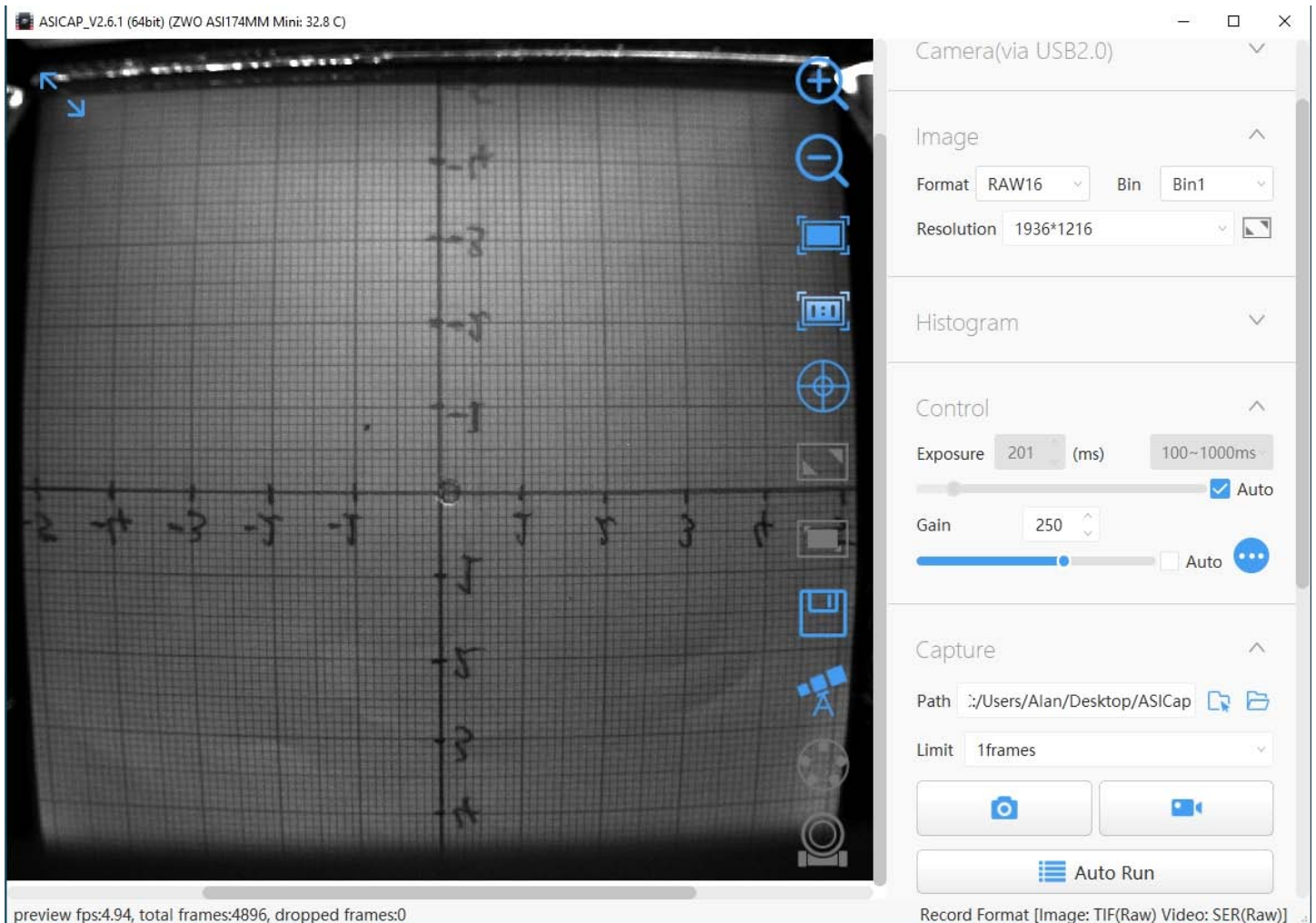

It is useful to choose a **Region-Of-Interest (ROI)** by setting a custom "Resolution" e.g. ~1000x1000 pixels centred on the 100x100mm window of the camera, and then zoom the ROI image to fill the screen. This corresponds to a real-space resolution of ~100 µM, the limit for standard scintillators.

ASICap may be sufficient for simple beam monitoring, and is available for both Windows and Apple computers, but **SharpCap4** on Windows (below) 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 I**mageJ-for-ASCOM** interface http://neutronoptics.com/ascom.html which allows you to program complex acquisitions within ImageJ.

Experiment with different settings on your desktop before placing the camera in the beam.

Recommended SharpCap Viewer for CMOS and CCD cameras

Use [SharpCap4](#) from the DVD or download it from https://www.sharpcap.co.uk/sharpcap/downloads
SharpCap was designed for low-light imaging by amateur astronomers, with more complete controls, including many you will not need for x-ray or neutron imaging. **Prefer the 32-bit version** for compatibility. 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.
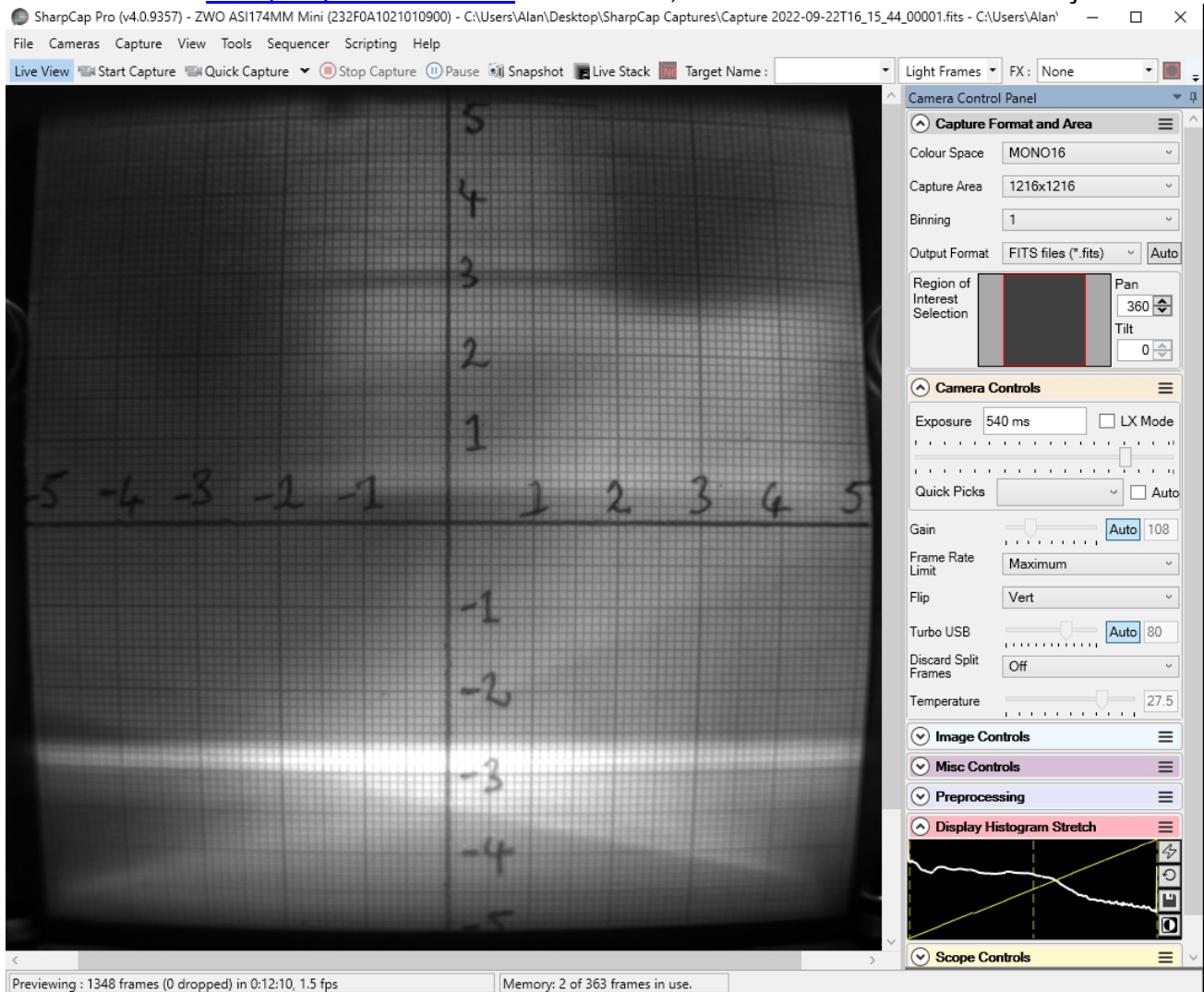
Zoom the image with Ctrl-mouse-scroll or the zoom selection at the top right. Set **"Capture Format"** to TIFF or FITS, Capture Area, and Mono16. In the **"Camera Controls"** set the Exposure (toggle LX mode for long exposures), set the Gain to zero (or increase it, at the expense of noise). You can 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.

Tip: Set a Custom Capture Area to the region of interest (ROI) and magnify it to fill the screen. e.g. set the Capture Area to ~1000x1000 centred on the 100x100mm camera window.

Click "**Snapshot**" to save a single image frame, or "**Livestack**" to sum several (see below).

In menu **"File/Settings"** check auto connect and restore, and 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.**

Stacking short exposures in SharpCap

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.
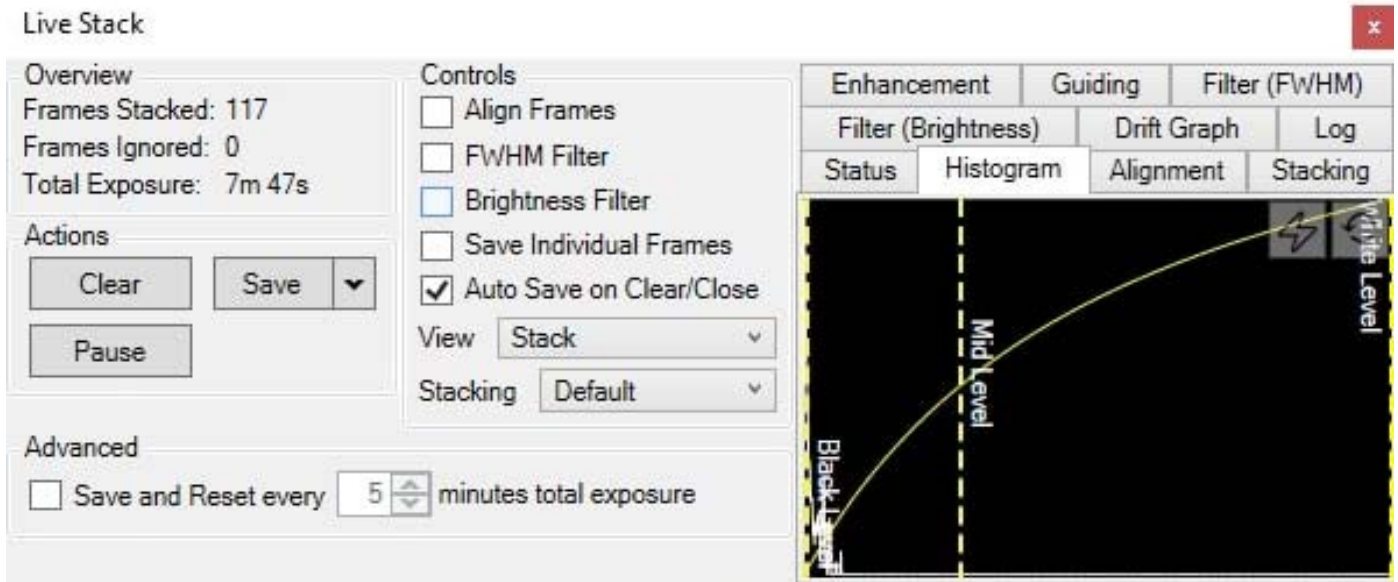
You can also use imageJ to stack a series of short exposures, which allows filtering of noise from the individual images before averaging. For very short exposures this may be better than averaging first and then filtering. Use the SharpCap menu **Capture/Start_Capture** then enter the number of images 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.

FireCapture Imaging Software

FireCapture is another image capture application developed for amateur astronomy that you might also use for neutron and x-ray imaging.

Hints on getting Optimal Performance

- The centre of the image will not correspond to the centre of the window
- Use a Custom Capture area centred on your Region of Interest (ROI)
- The exposure time depends of course on the intensity of your beam
- You can always reduce image intensity by reducing the lens aperture
- Exposure time and frame rate can be controlled separately for short exposures
- Use "Process/Noise/De-speckle" in ImageJ to remove noisy pixels from saved files
- Use "Process/Remove Background" in ImageJ to remove diffuse background patches
- Use automatic scaling in "Image/Adjust/Brightness-Contrast" in ImageJ to emphasise details.
- 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.

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