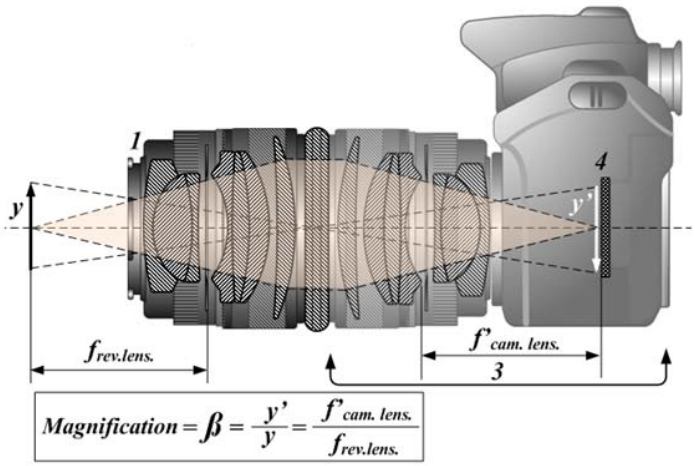
The NeutronOptics 1:1 Tandem Macro Camera

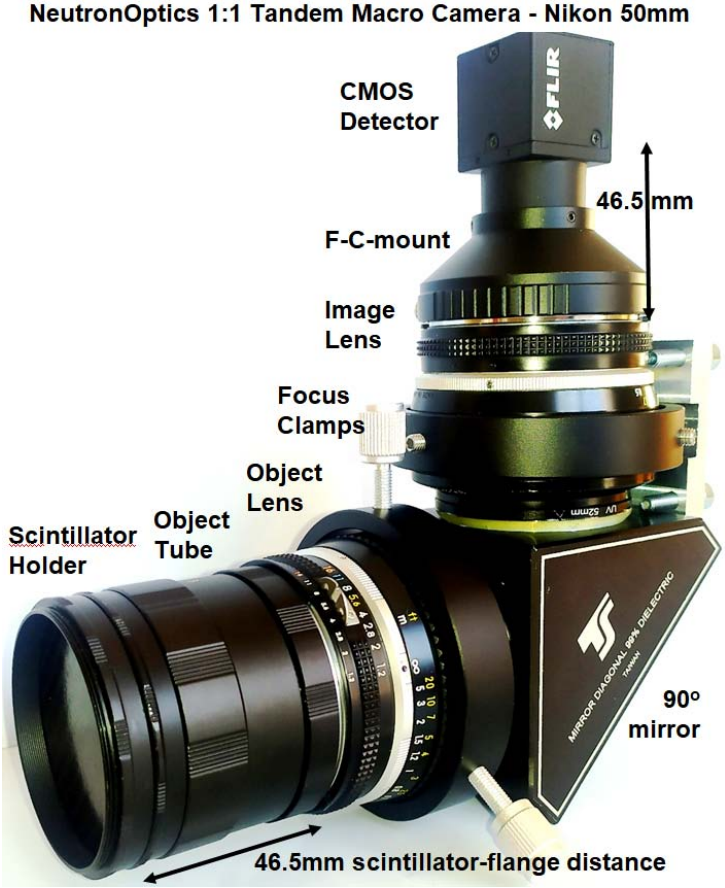


A Tandem Macro camera consists of two lenses face to face, with the object at the focal point of the first lens and the image at the focal point of the second with both lenses focussed near infinity. This allows very close focussing of the object and 1:1 or greater magnification with very high resolution and efficiency. A normal macro camera can also obtain 1:1 magnification, but with the object further away. This is less efficient optically. In fact, the Tandem Macro camera is almost as efficient as direct coupling between the scintillator and the sensor, using an optic fibre bundle .

The 1:1 NeutronOptics Tandem Macro camera uses a pair of very efficient Nikon Nikkor 50mm f/1.2 lenses coupled via a 90-degree mirror to remove the detector from the incident beam. The optical resolution is equal to the size of the detector pixels. The Field-of-View (FOV) is however less than the normal 36x24mm image of these full-frame lenses, due to the distance between them and their limited aperture, and is in practice limited to a circle of diameter ~10mm.

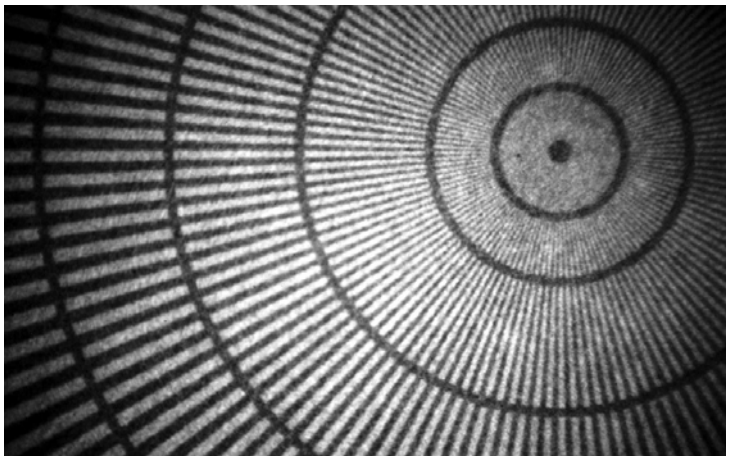
Sensor Type:	FLIR Sony CMOS IMX249
Image size:	11.25x7.03 mm (Type 1/1.2")
Resolution:	1920 x 1200
Pixel Size:	5.86 x 5.86 µm
High sensitivity:	(QE~80% at 500-600nm)
Dark current:	(~1 e/s @ 45C)
Full well capacity:	>30,000 e-
ADC:	12 bit stretched to 16-bit
Gain:	0 dB to 29.9 dB
Readout Noise:	~7 e- (low readout noise)
Readout Time:	~0.025s (41 fps full frame)
Interface:	USB 3.1 (or PoE GigE)
Power:	Power over USB (or Ethernet)
Max. Exposure:	4s USB3, 32s GigE
Image Software:	FlyCap2 or better SharpCap4
SDK:	FLIR FlyCapture C++ SDK

NeutronOptics 1:1 Tandem Macro Camera - Nikon 50mm



The camera is shown with a small uncooled fast CMOS detector, with optical resolution 5.86 microns, but the real resolution depends on beam collimation and most importantly, **scintillator thickness**.

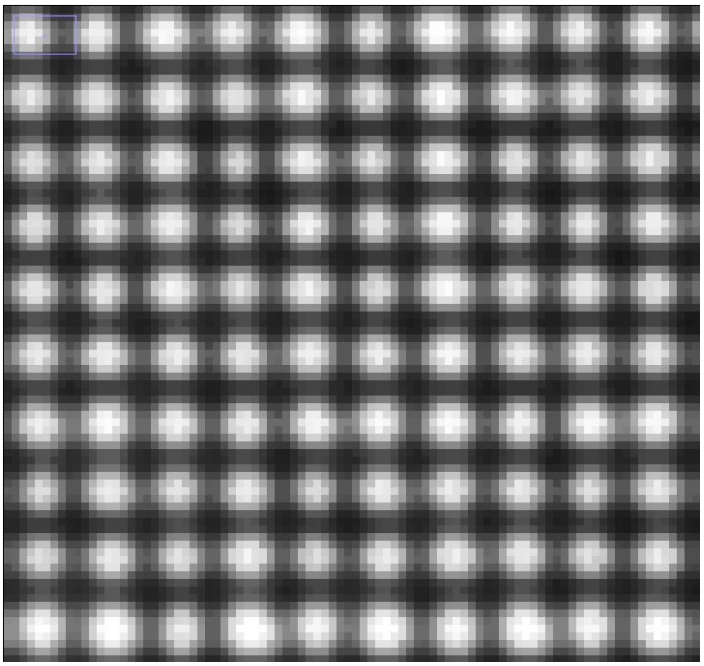
1:1 Tandem Macro Camera Measured Resolution



The image on the left was obtained on the ILL NeXT D50 beam line with our Nikkor 50mm 1:1 Tandem Macro camera using a 10µ thick Gd2O2S:Tb/6LiF PSI/RC-TriTec scintillator with 6% of the light output of their 200µ scintillator. The inner circle shows that at least 25µ resolution was obtained for an exposure of only 3s with a neutron flux estimated to be ~5x10**7 n/cm2/s. This is probably the world's best cold neutron beam line, so images with other sources will take longer. Gd2O2S:Tb is also a good x-ray scintillator. (credit: A.Tengattini & L.Helfen, ILL).

The x-ray or neutron scintillator can be changed simply by unscrewing the 56mm diameter window holder. Normal resolution OG2 X-ray or 400µ neutron scintillator disks are supplied as standard, but thin scintillators are needed for high resolution

The scintillator surface must be located within the 46.5mm flange-focal distance of the Nikon F-mount lens. The camera image lens focus is clamped at infinity by the support plate, but if the scintillator is slightly closer than 46.5mm the scintillator object lens must be focussed at shorter distances. Depending on the thickness of the scintillator, 1mm spacer rings can be added or subtracted, and fine distance adjustments can be made by placing 0.5mm focus spacers between these rings. Focus and resolution can be tested with light using the supplied 50µ wire grid (right). **Clamp the lens focus firmly but not too tightly.**



The 50µ wire focus grid

B4C around scintillator

The 0.5mm focus spacers

For focussing and imaging, see the FLIR FlyCap2 or preferably the SharpCap4 user manual.

SharpCap and FLIR (Point Grey) Camera Operation

NeutronOptics x-ray or neutron cameras can be supplied with an optional FLIR (Point Grey) IMX249 CMOS or similar detector when high frame rates are required (up to 41 fps). The normal maximum exposure of the IMX249 detector with USB3 is 4 seconds (32 seconds for the GigE version); CMOS dark current noise is higher requiring shorter exposures, but SharpCap can reducesthese limitations.

The IMX249 is a slower frame-rate version of the IMX174, and currently the best Sony CMOS detector for low-light imaging. It is a relatively large sensor, with big pixels favouring light capture, with high Quantum Efficiency (QE) The USB3 camera is powered by a USB cable up to 25m long, and the GigE version by a PoE GigE cable. Note the optional cooling fins on the FLIR camera to limit temperature (and dark current) by air cooling, and the carbon fibre window for the x-ray version..

- **Sensor Type:** Pregius CMOS IMX249
- **Resolution:** 1920 x 1200
- **Image size:** 11.25x7.03 mm (Type 1/1.2")
- **Pixel Size:** 5.86 x 5.86 µm
- **Quantum Efficiency:** ~80%
- **Full well capacity:** >30,000 electrons
- **A/D Readout:** 12 bit scaled to 16-bit
- **Readout Noise:** ~7 e-
- **Dark current** (~1 e-/pixel/sec @ 45°C)
- **Peltier Cooling:** uncooled
- **Frame Rate:** 41 fps with <5m USB3
- **Binning:** Software binning post capture
- **Mount:** C-mount
- **Trigger Signals:** Software trigger
- **Interface:** USB 3.1 or PoE GigE
- **Power:** power over USB or ethernet
- **Maximum Exposure Length:** 4s or 32s
- **SDK:** FLIR FlyCapture C++ SDK

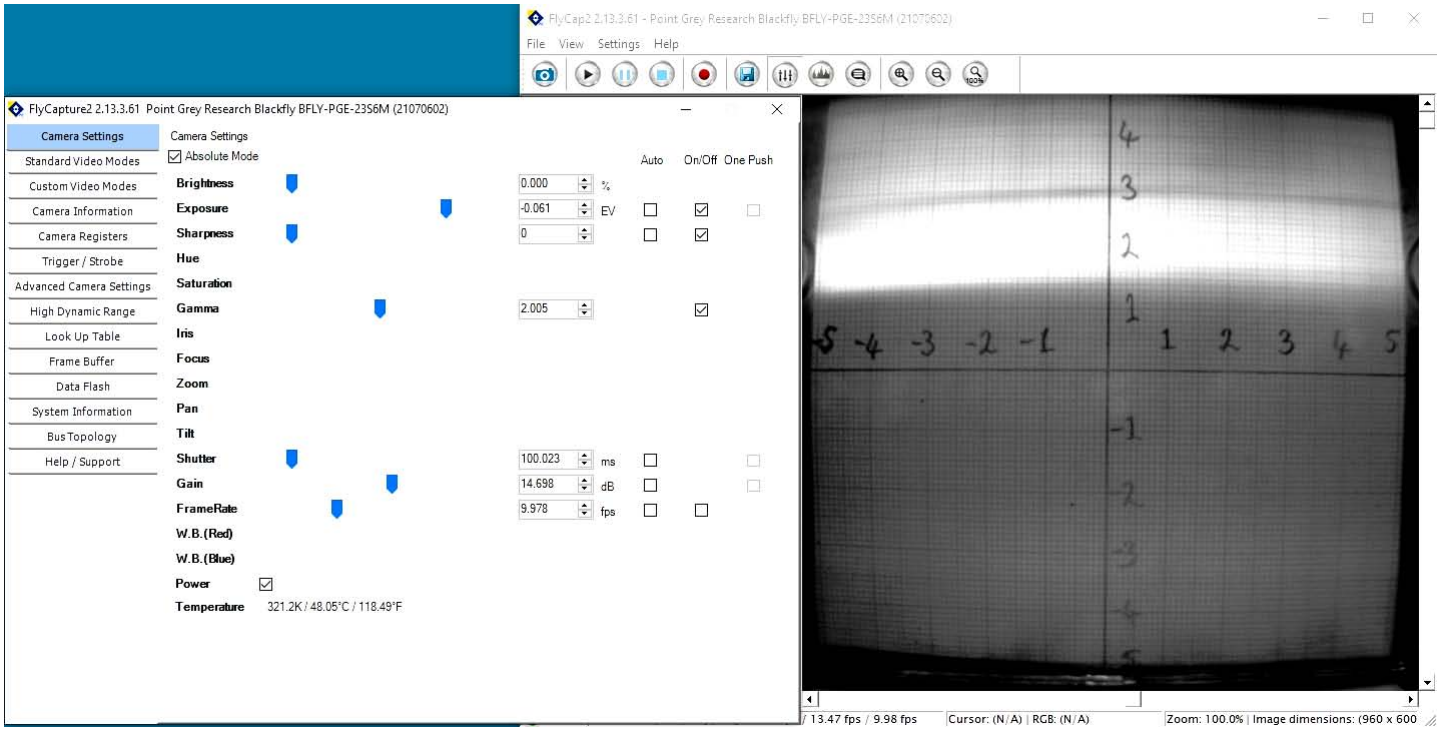
* **Very high frame rates (41 fps) are only possible with short USB3 cables (5.0m)**.
But rates of 9 fps (IMX249) can be obtained even with 10+ metre amplified USB2 extension cables.

Install the Driver and FlyCapture software

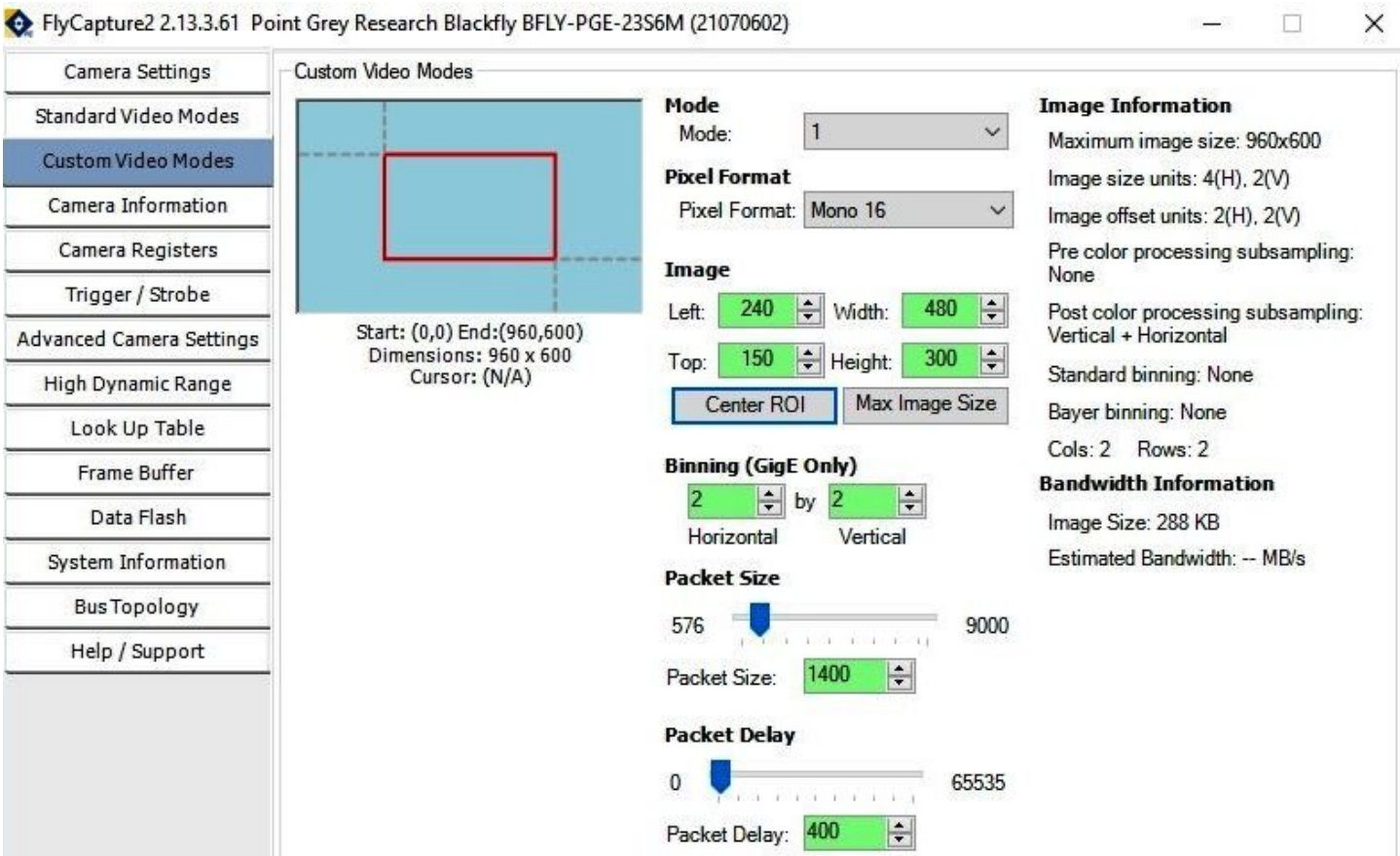
- Click on the FlyCapture SDK download then open the folders and download **FlyCapture2/Windows/FlyCap2Viewer...x86.exe** (The 32-bit version is more compatible)
- FlyCap2Viewer is also on the DVD, and installs camera drivers for USB and/or GigE cameras
- You can optionally assign a FLIR ethernet camera to a static persistent IP number

FLIR Point Grey FlyCap2 for Camera Control and Acquisition

FlyCap2 was designed for high frame rate and video capture in daylight and contains additional features you won't need for slower x-ray or neutron imaging. The camera will be automatically recognised when plugged in. FlyCap2 is designed to control multiple cameras simultaneously. A window will open displaying the image using default exposure, gain etc. as shown to the left below.



To change these, click the "**Settings**" menu and "**Toggle Camera Control Dialogue**" to open the control window (insert above). Uncheck **Shutter, Gain** and **FrameRate**. Also switch the **FrameRate "Off"**. You can now increase the Shutter (Exposure) to a maximum of 4 seconds (USB model). You can increase the **gain** from **"0.0"** but this will also increase noise in the image. Increasing the **Intensity**, **Exposure**, **Sharpness** and **Gamma** only changes the display, not the saved image.

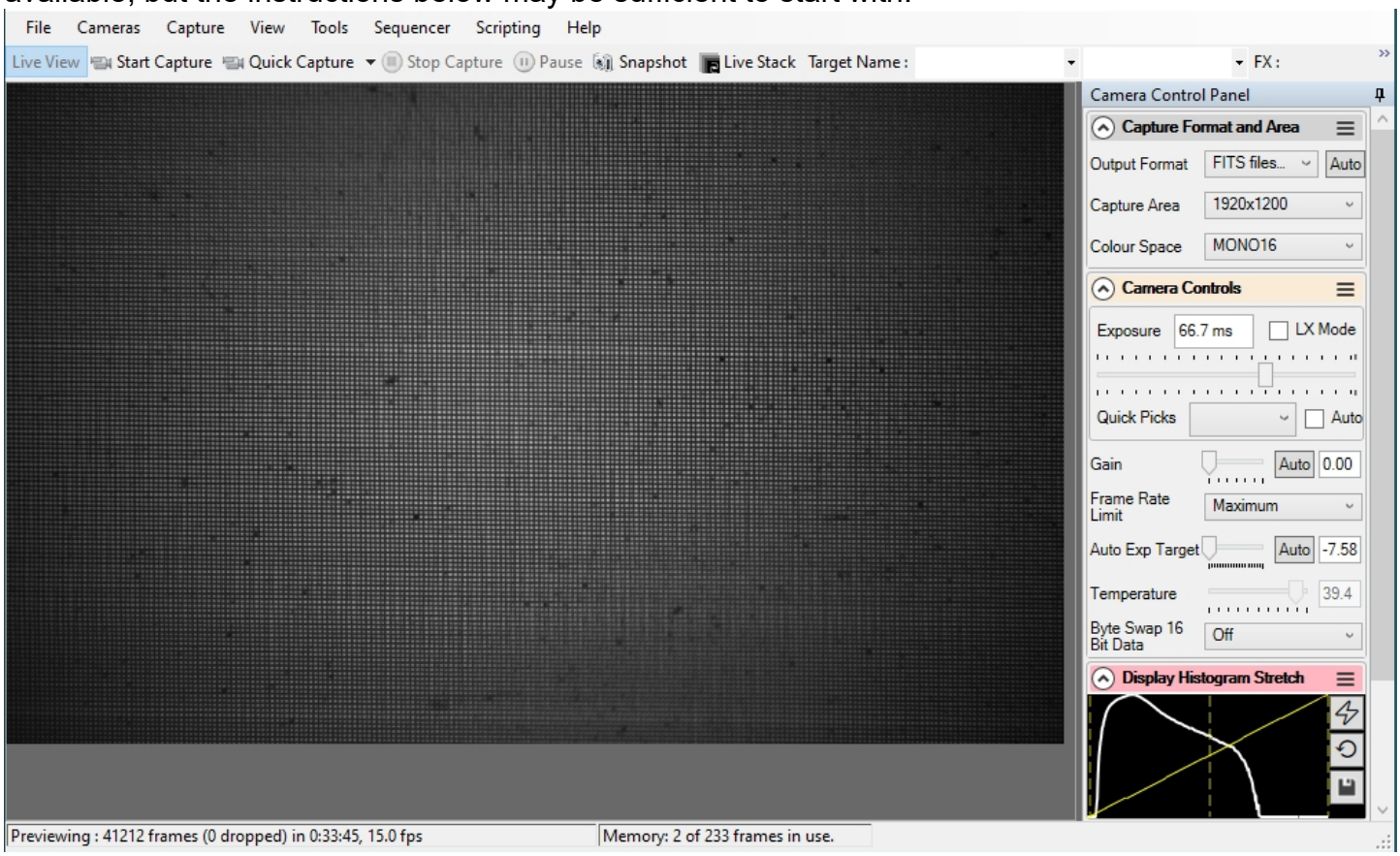


In the Settings window, click on “**Custom Video Modes**” and select “**Mode 1**” and **“Mono16**” rather than **“Mode 0”** with **“Mono8”**. You can restrict the image to a **“region of interest”** to increase frame rate. You can only apply “**binning**” to increase intensity at the expense of resolution if you have a GigE camera, but you can do binning off-line in imageJ. **Binning of 2x2** is recommended with this high resolution detector. Finally, In "**Settings/Advanced Camera Settings**" toggle "**Mirror Image**".

Of the remaining control dialogues, only “**Camera Information**” is of much use, but there is a control for hardware synchronisation via GPIO. Sotware synchronisation may be more convenient.

Recommended SharpCap Viewer

Instead of FlyCap, you can use SharpCap4 (also on the DVD), which 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 and run FlyCap2** (above) to install the drivers and **set Mono16** and eventually binning with the GigE camera. 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 to start with.



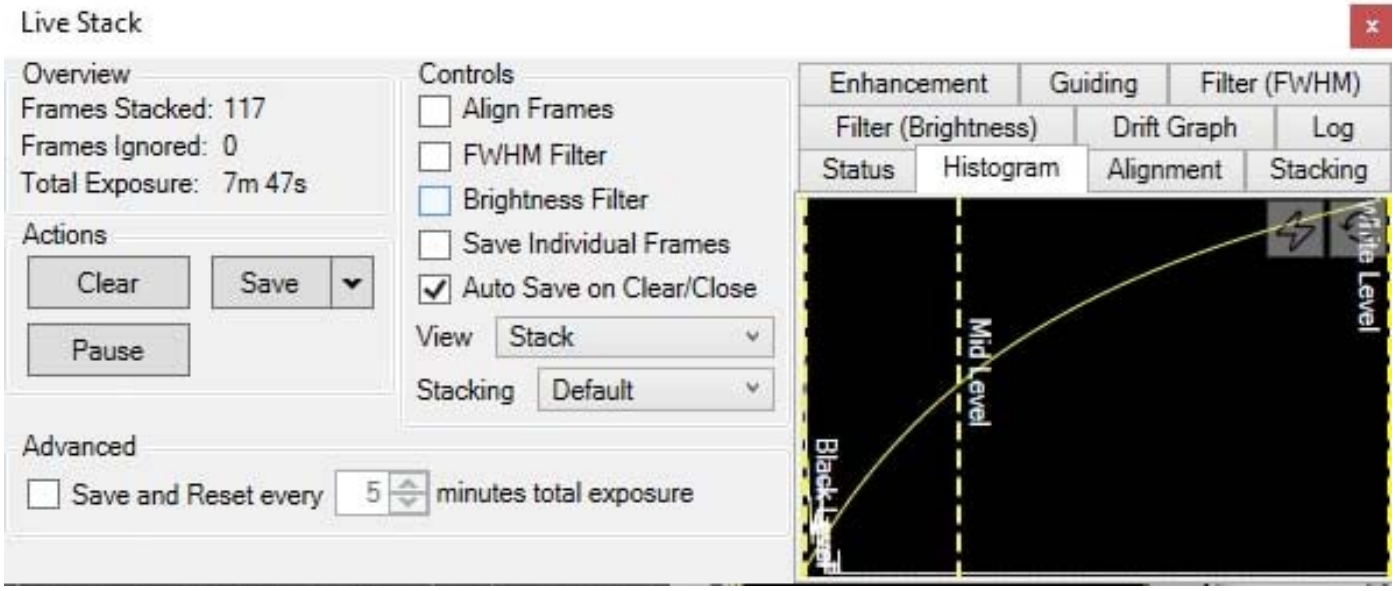
Zoom the image with Ctrl-mouse-scroll or the zoom selection at the top right. Set **"Capture Format"** to TIFF or FITS, Capture Area, and Mono16. In the **"Camera Controls"** set the Exposure (toggle LX mode for long exposures), set the Gain to zero (or increase it, at the expense of noise) and read the sensor temperature. Toggle **Byte Swap OFF** (or ON) to obtain a curve in the Display Histogram. The top rightmost icon allows you to use Edge Detection and other focussing aids. You can drag the vertical line in the **"Display Histogram"** to stretch the intensity display to emphasise lower intensities. Focussing may be best 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"** (insert) 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

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 (and to overcome the maximum exposure limit of the FLIR camera). 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 amature astronomy that you might also use for neutron and x-ray imaging with our FLIR (Point Grey) camera. FLIR has not yet developed an ASCOM driver for their cameras.

Hints on getting Optimal Performance

- The center of the image may not correspond to the centre of the window
- because the CCD chip is not centred to better than 0.5mm in its housing
- The exposure time depends of course on the intensity of your beam
- 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

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