Eagle XV

Models: EA4240XV-BN-CL, EA4240XV-BNDD-CL, EA4710XV-BN-CL,
EA4710XV-BNDD-CL

USER MANUAL

CONTENTS

1. INTRODUCTION

This document provides detailed instructions for the operation of the Eagle XV, liquid cooled, Scientific X-ray CCD camera. Raptor Photonics Ltd. reserves the right to change this document at any time without notice and disclaims liability for editorial, pictorial, or typographical errors.

1.1 Scope

Detailed information is provided on each of the cameras control parameters, as well as stating important precautions to take when operating the camera. Each camera control is discussed and explained with the use of the XCAP Imaging software from EPIX, which is the core plug and play software option that is offered with Raptor cameras.

Photographs of the Camera module, Power Supply and Camera Power Cable are shown in Figure 1.

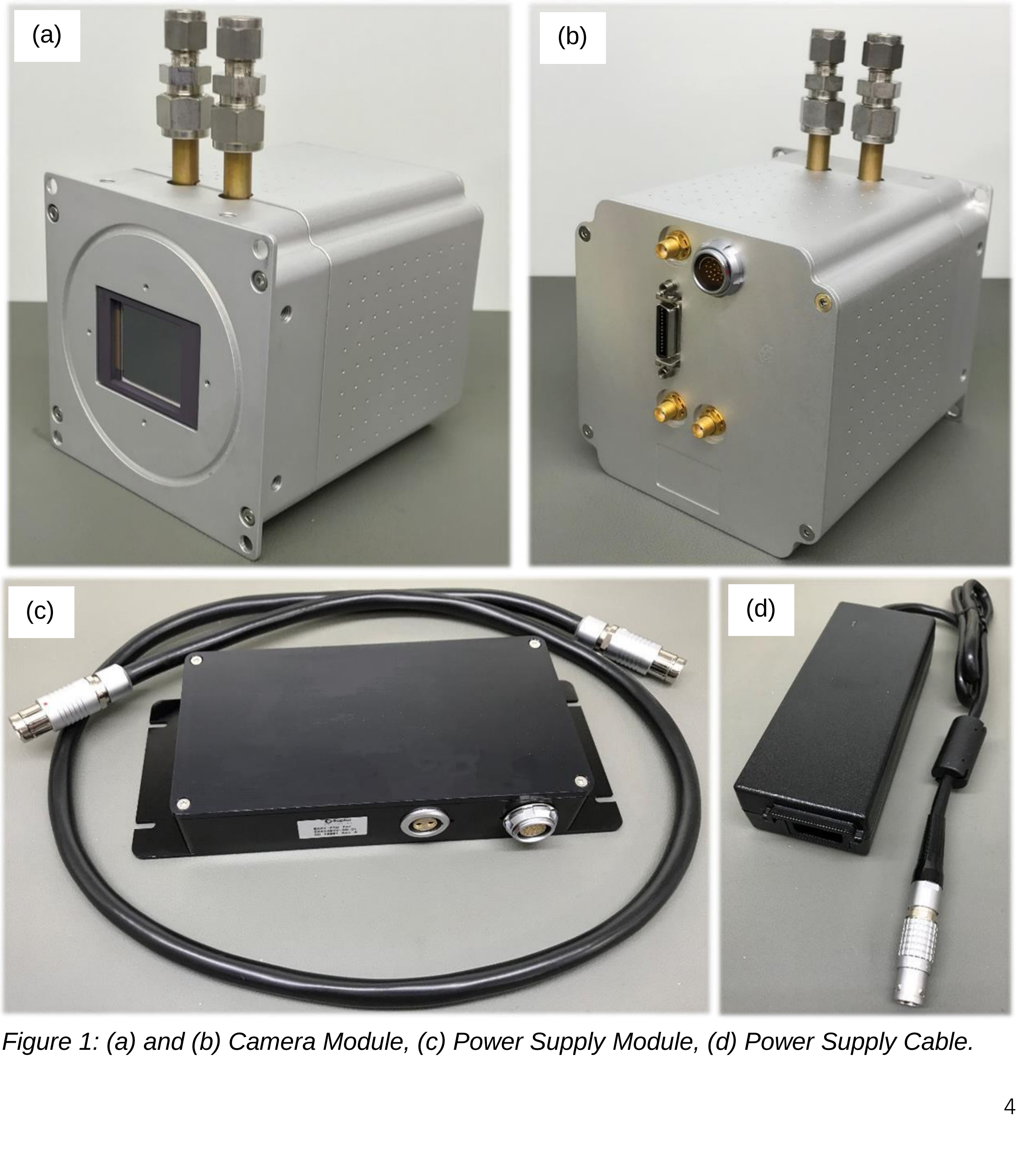


Figure 1: (a) and (b) Camera Module, (c) Power Supply Module, (d) Power Supply Cable.

2. SPECIFICATION

2.1 Camera Specification

The Eagle XV is designed for in vacuum direct X-ray imaging. The camera uses a choice of back-illuminated CCD sensors with a resolution of 2048x2048 or 1024x1024 available, all with 16 bit digital output formats. Low-noise electronics provide a linear response and sensitivity. Cooling to -80˚C is achievable using a TEC and liquid cooling in a vacuum environment. This level of cooling gives an ultra-low dark current reading of 0.0005e-/p/s in the standard sensor format, allowing for longer integration times.

The Camera Link digital interface provides the most stable platform for data transfer and the camera will work with any Camera Link standard frame grabber.

2.2 Specification Table

For the full specification of the Eagle XV, the datasheet for the camera can be downloaded from the Raptor Photonics website using the link below:

https://www.raptorphotonics.com/products/eagle-xv/

3. DESIGN OVERVIEW

3.1 Mechanical Model

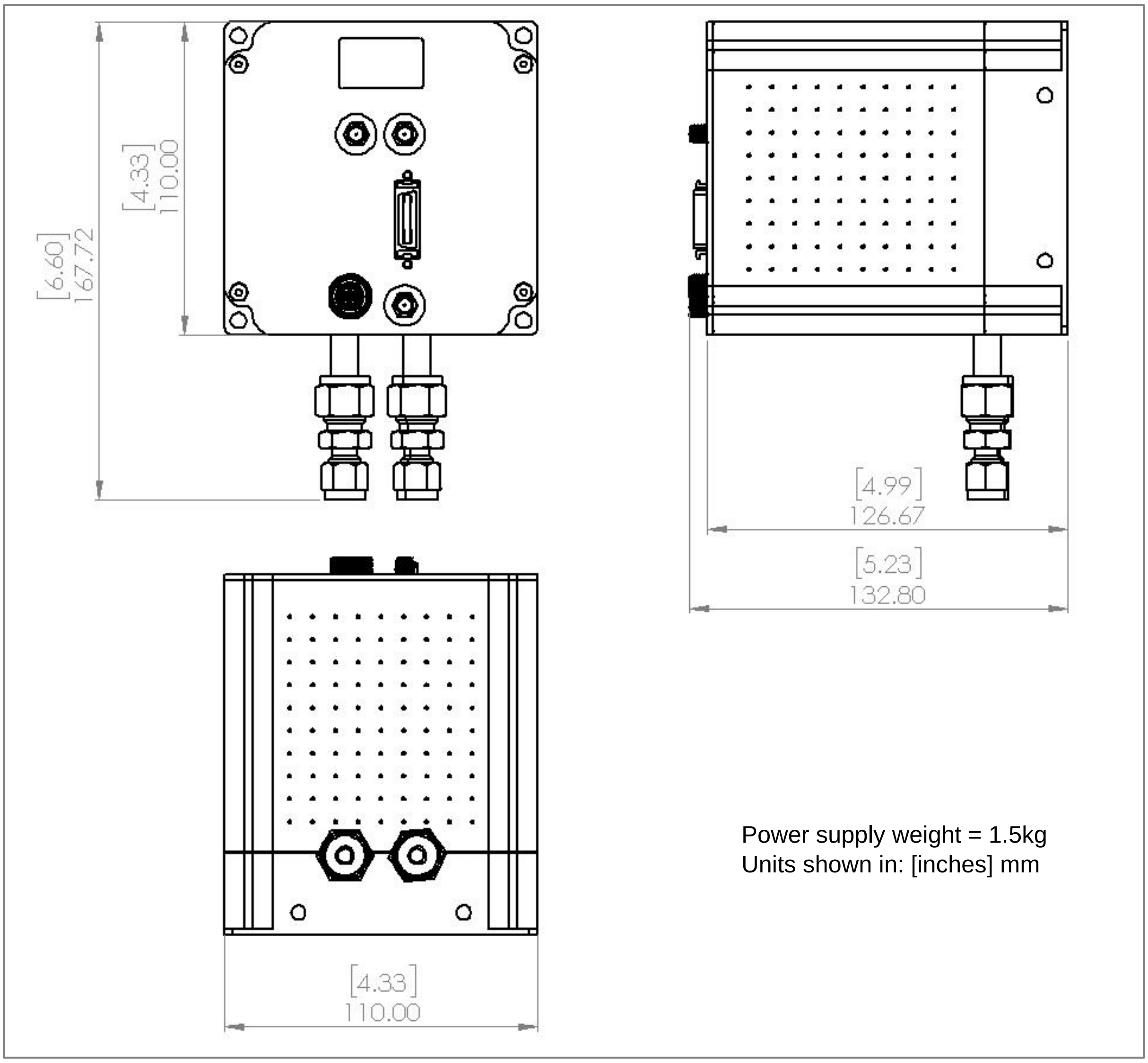


Figure 2: Solid Works Model – Basic 2D mechanical dimensions of the camera.

PDF of the 2D mechanical model available from our website: www.raptorphotonics.com

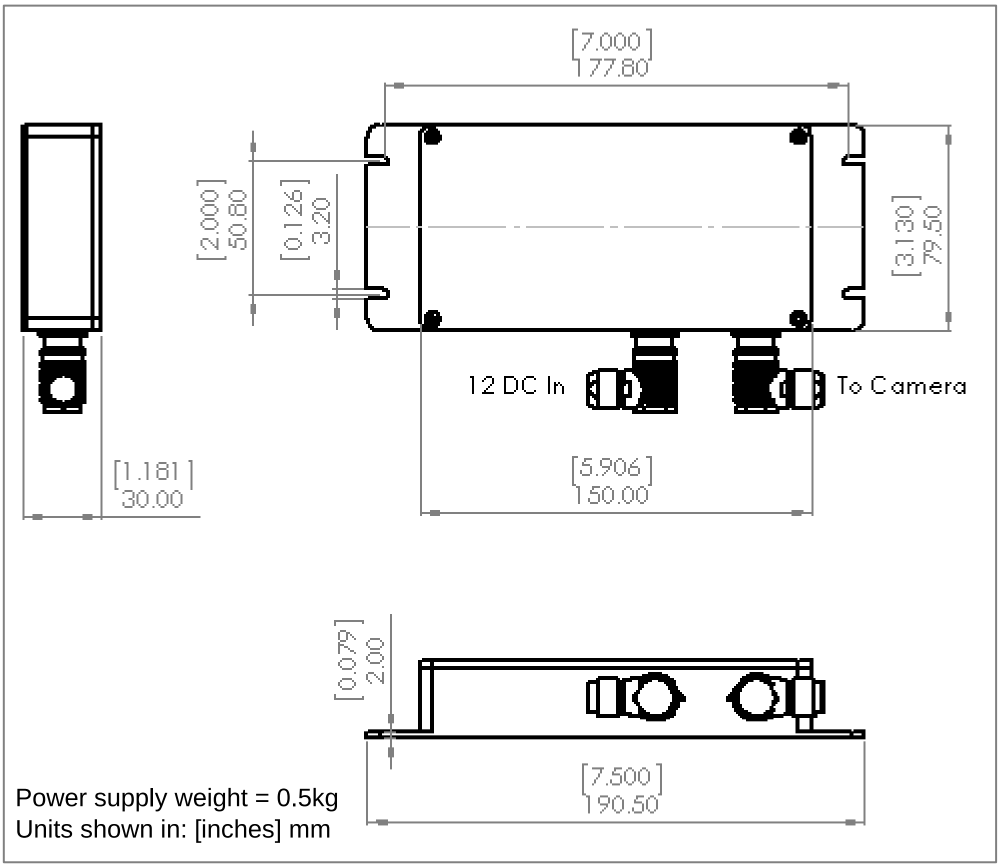
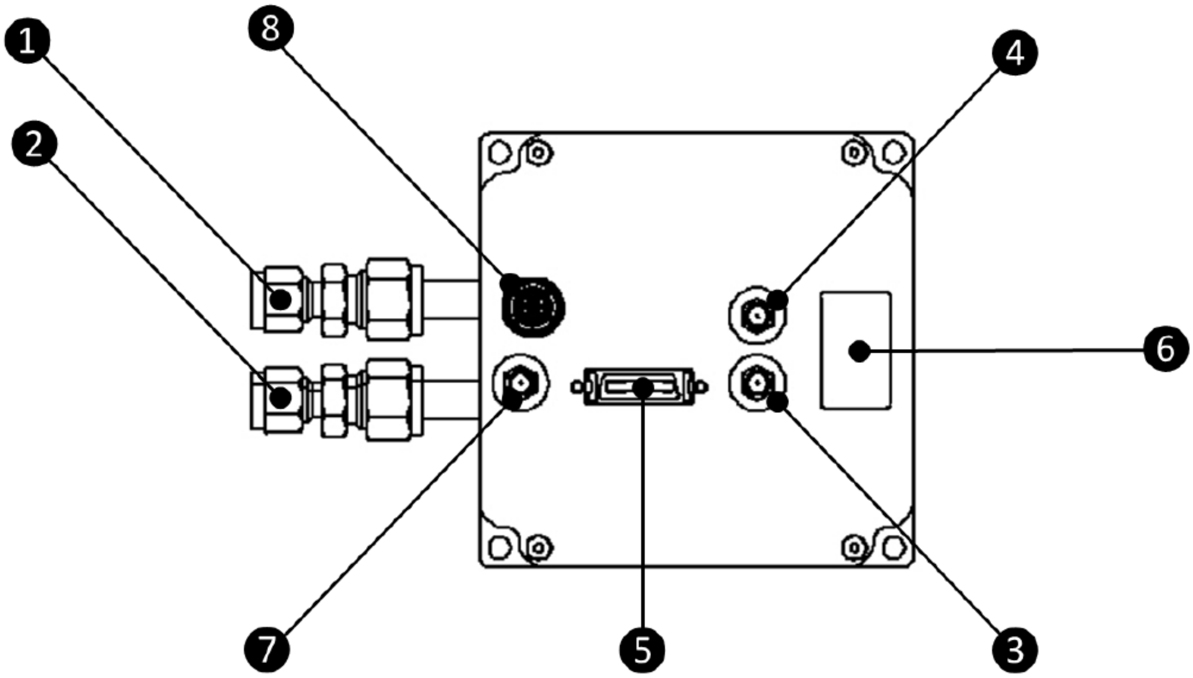


Figure 3: Solid Works Model – basic dimensions of the power supply module.

3.2 Physical Interface



Feature	Description
1, 2	Coolant inlet/outlet (non-valved) Swagelok compression fitting for ¼" O.D. pipe
3	TTL Trigger output, 50ohm SMA (Exposure)
4	TTL Trigger output, 50ohm SMA (Readout)
5	Camera link connector (Base) MDR, 3M P/N 10226-6212PC
6	Label recess, (Model Number. Serial Number)
7	TTL Trigger input, 50ohm SMA (Trigger In)
8	Camera power connector, Fischer P/N DPB 104 Z092-139 (mating cable supplied)

3.3 Input Power to Power Supply Module

12VDC power is delivered to the power supply module via a 2 way LEMO socket, P/N EGG.2B.302.CLL. The corresponding plug connector is P/N FGG.2B.302.CLAD92 (for normal entry version) or P/N FHG.2B.302.CLAD62 (for right angled version). The pin out of the connector is detailed in the table below.

Pin Number	Connection
1	+12VDC
2	GND

3.4 Power Consumption

Unit input power specification is +12VDC ± 10%, power dissipation ≤8W with the TEC switched off. Additional inrush current (peak power) is required when the cooler power is switched from low to high. Peak power ≤85W with total, steady state power consumption ≤65W. The power supply module requires a means of removing the heat dissipated by it, e.g. by screwing the module to a metal surface.

3.5 Trigger IN

External synchronisation with the start of integration signal may be achieved using the Trigger IN connector. Input impedance = 510Ω, 200pF input capacitance. Input logic levels are:

- Logic HIGH > 2.31V
- Logic Low < 0.99V

Min. pulse width = 100ns

3.6 Trigger OUT (Exposure)

For all modes of the camera the Trigger output, Exposure SMA, will represent the integration period of the sensor. The trigger output signal will be a TTL output pulse. The signal will remain low (0V) and then be driven high during the integration period. The source impedance will be equal to 50Ω.

3.7 Trigger OUT (Readout)

For all modes of the camera the Trigger output, Readout SMA, will represent the duration of the CCD readout. The trigger output signal will be a TTL output pulse. The signal will remain low (0V) and then be driven high during the readout period of the CCD. The source impedance will be equal to 50Ω.

5. VACUUM ENVIRONMENT AND PRECAUTIONS

This section outlines information regarding using the camera in a vacuum environment and highlights important precautions to be aware of.

5.1 CCD Sensor Precautions and Camera Storage

The camera is supplied with a temporary plate attached in front of the sensor for protection during transit. An O-ring seal prevents dust ingress during shipping and handling.

Take care when removing this temporary plate as the CCD sensor surface will be exposed and could suffer inadvertent mechanical damage (e.g. from the O-ring) or contamination from the local environment, see Figure 4. It is recommended to keep the temporary plate and O-ring for storage of the camera when not in use or for transportation. Regarding storage temperature, this can be seen from the specification table (-40˚C to +70˚C).

If the sensor becomes contaminated due to an accident or misuse, please contact Raptor immediately.

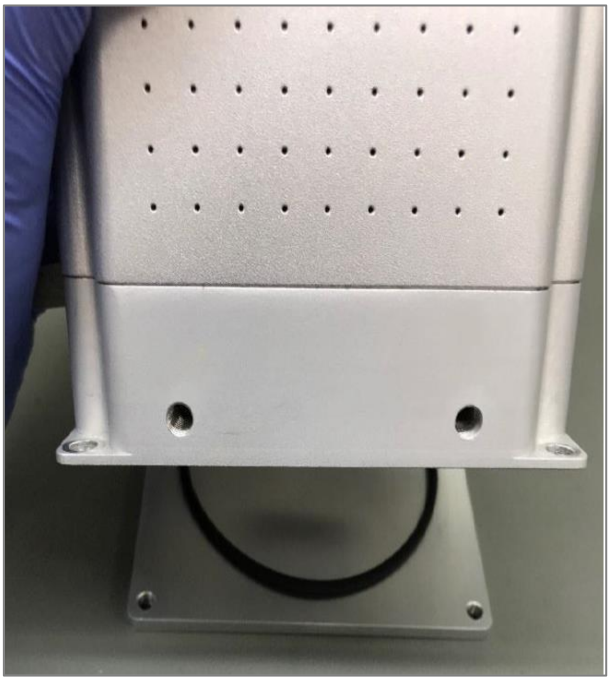


Figure 4: Removing Front Plate and Temporary O-ring.

5.2 Chamber Pumping and Venting

Take care when pumping (or venting) the vacuum chamber, ensuring that any gas flow experienced by the sensor will not cause damage to the bond wires.
Make sure that particulate material does not strike the sensor during the venting process.
Always warm the sensor up to room temperature before venting the vacuum chamber.

5.3 Vacuum Pressure

It is recommended that the local pressure around the sensor is <$5x10^{-5}$ mbar (<$3.75x10^{-5}$ torr) to achieve maximum cooling. Many pressure gauges emit radiation which can be detected by the CCD sensor, if this background signal is affecting your data acquisition it may be necessary to switch off the pressure gauge, once you are satisfied that steady state conditions have been achieved.

Never cool the sensor below the dew point of the environment that it is in, otherwise permanent damage due to condensation may occur. Switch the cooling off immediately if you suspect condensation is forming on the sensor.

5. CAMERA & CHILLER SETUP

This section discusses setting up the camera for operation, including connecting the coolant pipes, along with a description of all feedthrough parts. The use of liquid cooling is also discussed, as well as stating important precautions when using the camera.

5.1 Liquid Cooling

This section discusses setting up the liquid cooling, as well as using the Thermotek chiller, if purchased from Raptor.

Liquid cooling must be used when using the TEC. This is needed to dissipate heat away from the hot side of the TEC. Do not enable the TEC if liquid cooling is not being used, otherwise damage to the camera will occur.

5.1.1 Liquid Cooling Connection to the Camera Head

The camera electronics drive a ThermoElectric Cooler (TEC) to cool the CCD. The hotside of the TEC MUST be cooled via circulating coolant. Connection to the coolant channel is made via two Swagelok compression fittings, suitable for connection to ¼” O.D. coolant pipes, as shown in Figure 5.

Hold central nut of Swagelok fitting secure before attaching (or detaching) pipes.	Ensure ferrule set is in place and pipe is seated correctly in fitting before tightening.

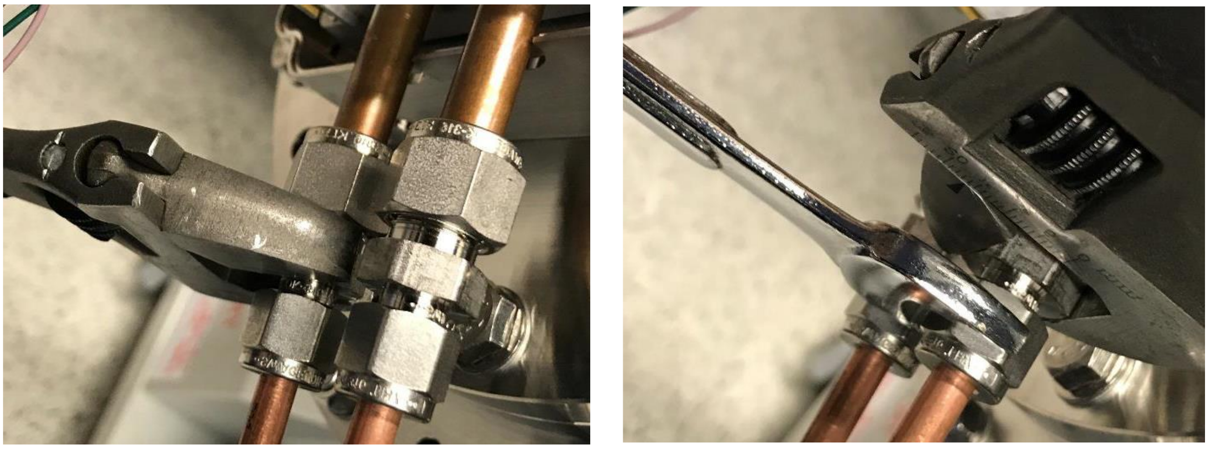


Figure 5: Connecting the Coolant Pipes.

Please ensure compatibility with these connectors on the camera module before attempting to connect the coolant supply. Also ensure the coolant connections are completely leak tight before pumping the vacuum system down and circulating coolant. The TEC within the camera must not be switched on without coolant circulating through the camera otherwise permanent damage may occur.

5.2.2 Connecting the Camera and Chiller

Raptor uses a Chiller from Thermotek, the T257P Precision Chiller. For the datasheet and full user manual from Thermotek, please contact Raptor and we can provide this. The manual should be included with the chiller, however. The instructions to set up the chiller are as follows:

1. Connect the T257P chiller to the Eagle XO using the tubing provided. Connection to the coolant channel on the camera is made via two quick release valve coupling bodies. The polarity of the tubing connections does not matter.
2. Keep the chiller horizontal and on a level surface.
3. Make sure there is a minimum 12" clearance and free path for flow of air entry and exit at the left side and right side of the T257P chiller prior to operation.
4. Remove the reservoir cap and add coolant to the reservoir until the fluid reaches the bottom of the neck. Please refer to section 6.3 for recommended coolants.
5. Close the cap securely to the reservoir. Make sure not to overfill the reservoir.
6. Install the appropriate end of the power cord into the unit and connect to the mains electricity.

If using another chiller model, please refer to its manual for start-up instructions.

5.1.3 Recommended Coolants for the Chiller

The recommended coolants are:

Option 1: Distilled Water
Option 2: 95% distilled water and 5% isopropyl alcohol mixture prevents bio growth.
Option 3: 80% distilled water and 20% inhibited Glycol mixture for set temperatures below 5˚C.

Raptor recommends using option 3. If purchasing the Thermotek model from Raptor or using a demo kit provided by Raptor, there will be inhibited Glycol mixture provided to mix with water.

5.1.4 Setting the Coolant Temperature for Re-circulation

When powering up the chiller, the screen will immediately give the option to set the temperature of the coolant. It is recommended to set a 20˚C set point. After the set point has been configured, selecting start will initiate the coolant re-circulation. For more detailed information on all the operating modes of the T257P Precision Chiller, please refer to the Thermotek user manual.

Never cool the sensor below the dew point of the environment that it is in, otherwise permanent damage due to condensation may occur. Switch the cooling off immediately if you suspect condensation is forming on the sensor.

5.2 Connecting the Camera and Frame Grabber

The camera has the normal MDR port on the interface. The main frame grabber that Raptor offer with this camera has the normal MDR port (EPIX EB1). Therefore, one MDR – MDR Camera Link cable is required to connect the camera to this frame grabber.

6. FEEDTHROUGHS

This section will give information on the feedthroughs used for the camera interface connections.

6.1 Power Feedthrough

The power feedthrough, shown in Figure 6, connects the power supply module (at atmospheric pressure) to the camera head (in vacuum). The power feedthrough, shown in Figure 6, requires a Ø15.1mm through hole with a maximum wall thickness of 21mm. The female side of the feedthrough must protrude into the vacuum chamber. The power cable with grey insulation is intended for in-vacuum connection. Always ensure the cable polarity is correct before attempting to plug in the cable, never force the connection as this may result in damage to camera system components.

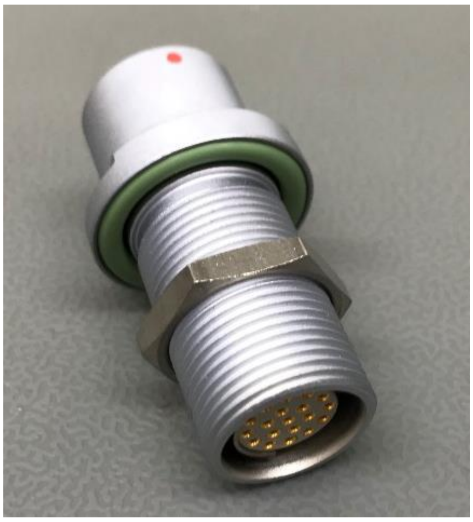


Figure 6: Power Feedthrough.

6.2 Camera Link Feedthrough

The camera head is connected to the frame grabber by means of a Camera Link feedthrough flange, as shown below in Figure 7. The O-ring side of the flange must be the vacuum side when the flange is installed.

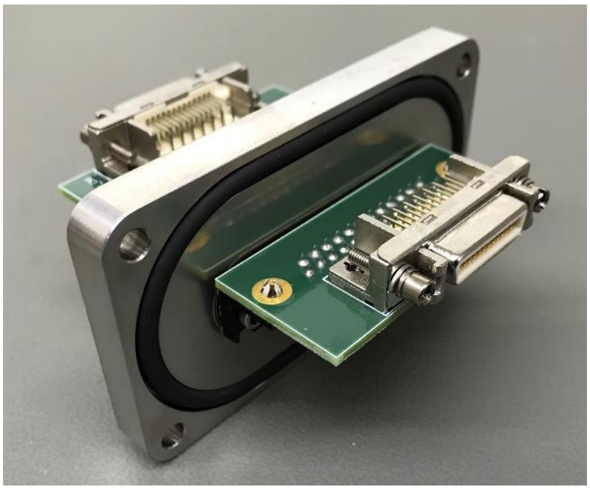


Figure 7: Power Feedthrough.

The recommended cut-out is 65mm x 26mm as shown in Figure 8. The bulkhead flange must be secured using 4-off screws at the corners, also indicated in Figure 8.

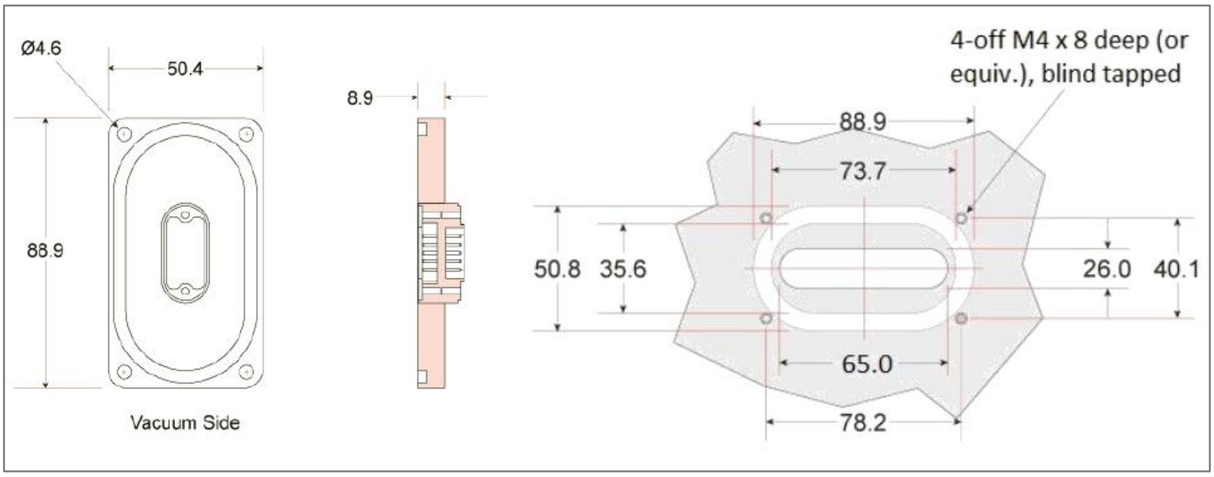


Figure 8: Dimensions and cut-out for Camera Link Feedthrough Flange.

6.3 Trigger Feedthrough (Optional Item)

Connection(s) to the SMA trigger input / outputs on the camera head can be made using co-axial cable and a SMA feedthrough flange, such as that shown in Figure 9. Contact Raptor Photonics Ltd to discuss flange size and format options.

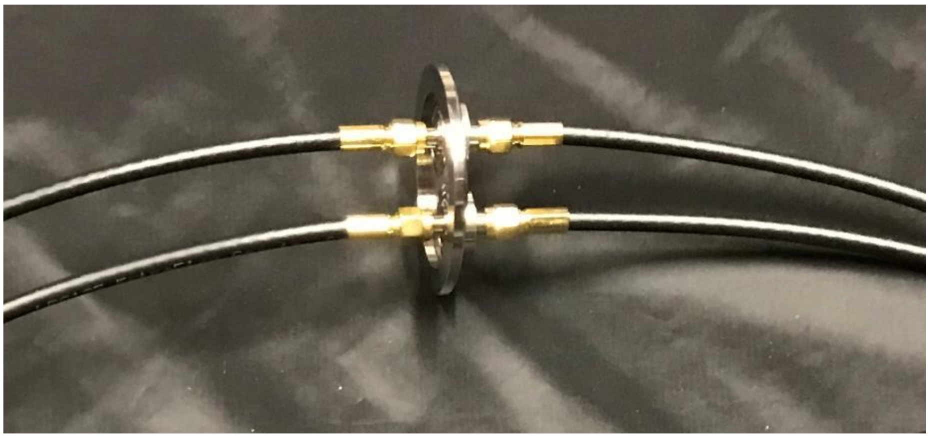


Figure 9: Trigger Feedthrough.

6.4 Liquid Feedthrough (Optional Item)

Coolant connections to the Swagelok fittings on the camera head can be made using ¼" OD pipe and a feedthrough flange, such as that shown in Figure 10. Contact Raptor Photonics Ltd. to discuss flange size and format options. Ensure that no torque is transferred to the mounting flange to pipe joints when tightening the Swagelok connections.

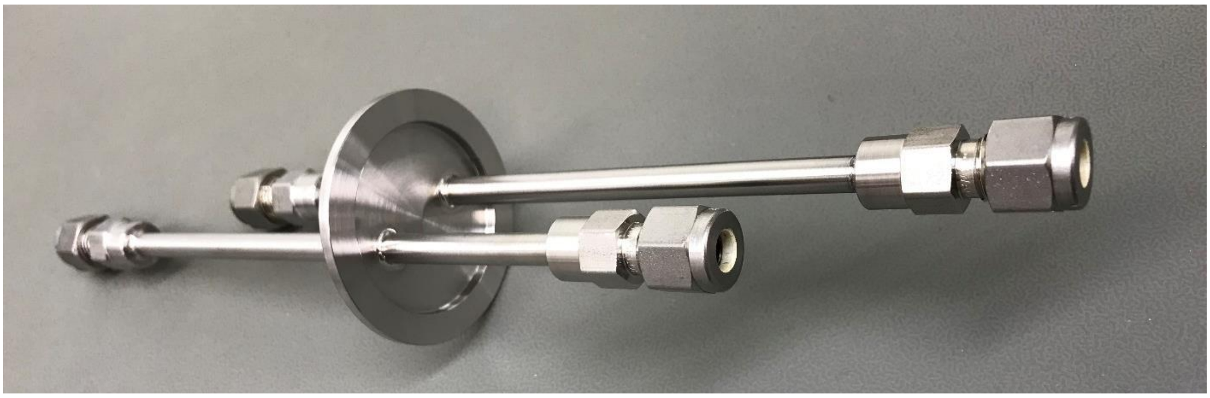


Figure 10: Liquid Feedthrough.

7. SOFTWARE COMPATIBILITY

This section outlines the options relating to software that are available for the Eagle XV.

7.1 XCAP Compatibility

Raptor works closely with EPIX who integrate all of the Raptor camera models into their XCAP Imaging Software package. XCAP is the core plug and play software package that is offered with Raptor cameras.

7.2 Micromanager Compatibility

The Eagle XV can be controlled and imaged using the free open source imaging software Micro-manager.

7.3 LabView Compatibility

Raptor can supply a LabView .icd file which can be used to control the camera on National Instruments imaging tools such as NI MAX. The file may also be useful if attempting to create your own LabView VI.

7.4 Custom Software Interfacing

Raptor works closely with EPIX Inc, who integrates all Raptor cameras into their software package, XCAP. The EPIX frame grabbers are the models that we offer with our cameras. We offer their Software Development Kit (XCLIB) for interfacing with custom software. If using a frame grabber from a different company, then you will have to obtain their SDK. Raptor can provide an ICD which includes a list of all serial commands to control the camera. This would be required along with the SDK from the frame grabber device to integrate the camera.

8. XCAP IMAGING SOFTWARE

This section will discuss downloading and acquiring an image using XCAP, as well as stating system and frame grabber requirements.

8.1 Computer/Laptop System Requirements

The basic requirement is that the PCIe bus of the system must provide sufficient bandwidth to handle video rate transfers. The amount of bandwidth required depends on the camera in-hand. The Eagle XV uses a Base Camera Link interface which can be handled with a x1 PCIe bus and PIXCI EB1, providing about 200MB/sec maximum bandwidth. Contact EPIX Inc. for further information regarding minimum computer/laptop specification requirements to run the XCAP Imaging Software.

8.2 Frame Grabber Requirements

If using a computer, it is a minimum requirement to use an PIXCI EB1 frame grabber. If using a frame grabber from another company, the specification requirements of this frame grabber must meet those supplied by the PIXCI EB1 model.

If using a laptop, EPIX offers base Camera Link frame grabbers for a laptop system, such as the ECB1/ECB1-34.

8.3 Downloading and Installing XCAP

The latest version of XCAP can be downloaded from the link below:
http://www.epixinc.com/support/files.php

please select the appropriate version of XCAP for your computer. Ensure that you download from the section labelled "***Pre-release version with support for the latest cameras and latest PIXCI® imaging boards***"**.** Open the downloaded file when complete and follow the onscreen instructions in the installation wizard. If a pop-up message appears asking whether to install the PIXCI driver, ensure that you click yes.

8.4 Opening the Camera Configuration

After opening XCAP, select *"PIXCI Open/Close"* from the *"PIXCI"* tab from the top menu bar in the main window. A PIXCI Open/Close pop-up box will open as shown in Figure 11.

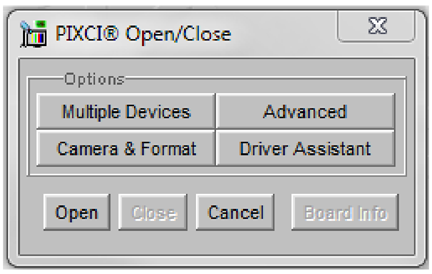


Figure 11: PIXCI Open/Close.

Click on *"Camera & Format"* that is highlighted in Figure 2 and a *"PIXCI Open Camera & Format"* box will appear, as shown in Figure 12.

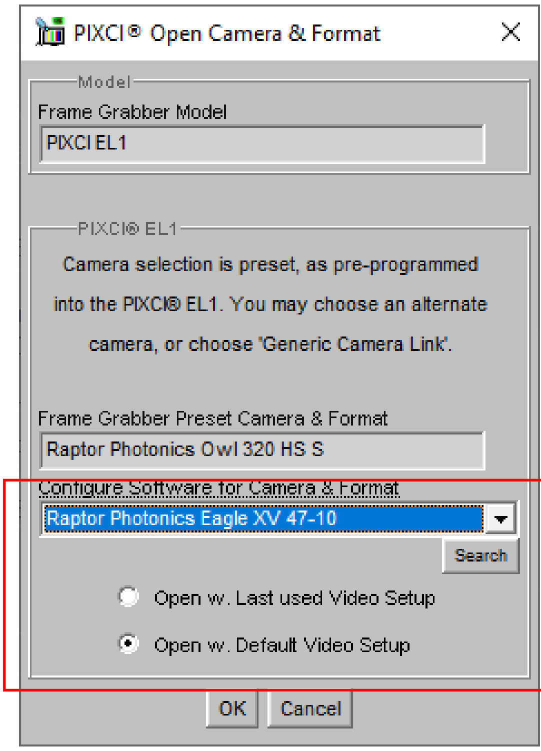


Figure 12: PIXCI Open Camera & Format.

Using the dropdown menu highlighted, search for *"Eagle XV".* You will see the configuration for *"Eagle XO & XV 42-40"* and *"Eagle XO & XV 47-10".* Select the appropriate configuration for the sensor format of the camera being used. Selecting *"Open w. Default Video Setup"* will open the control panel with all control parameters set to the default states. *"Open w. Last used Video Setup"* will open the control panel with all parameters set at the last known state. Once this option between the two has been selected, click *"Ok"*. To open the camera control panel and imaging window, click *"Open"* in the *"PIXCI Open/Close"* window (Figure 2).

Two windows will now open in XCAP, and imaging window and control panel, as shown in Figure 13.

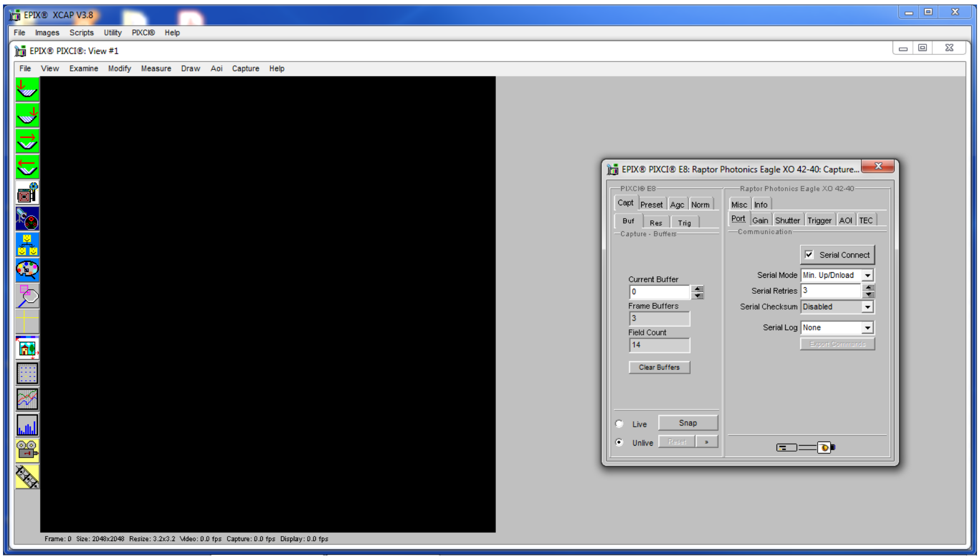


Figure 13: Imaging Window & Control Panel.

8.5 Acquiring a Live Image Sequence

There are two things to observe in the control panel that inform you that the camera is connected and ready to image.

The serial connect checkbox must be ticked in the control panel. This informs you that you have established a serial connection with the camera and can control the camera.

Secondly, the symbol near the bottom right of the control panel will have three moving dots that flash. This indicates that you are obtaining video data from the camera. The imaging statistics displayed directly underneath the imaging window will also inform you if you are receiving a video feed from the camera.

Once you have established a serial connection with the camera and are receiving video data, you can now grab a live image feed. Clicking the *"Live"* button will grab a live image sequence which you will now see in the imaging window.

The symbols in the control app discussed above are displayed in Figure 14.

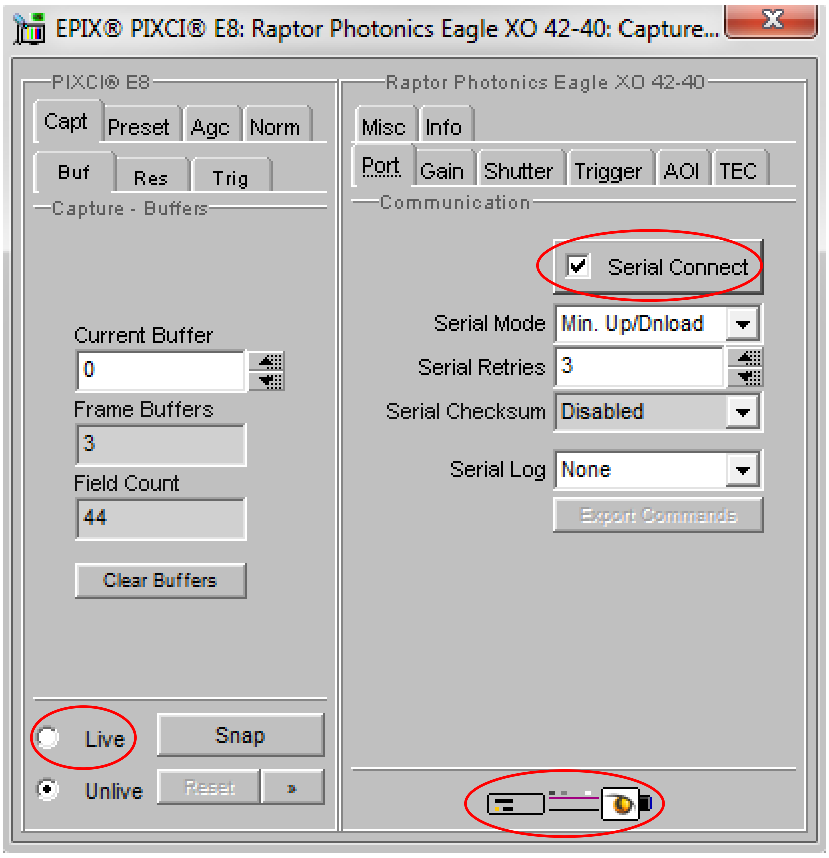


Figure 14: Port Tab – Checking Camera Connection.

9. CONTROLLING THE CAMERA (XCAP)

The sections below will give information on using each control of the Eagle XV, giving a description on how to use each control parameter and their effect on the camera's performance. The software used to illustrate the camera controls is XCAP.

9.1 Gain and Exposure Time

The gain and exposure can be controlled in the *"Gain"* tab. By default, high preamp gain will be enabled, offering the lowest noise. If you are imaging with a higher intensity signal, high preamp gain can be disabled. The exposure time and frame rate controls are shown under every tab in the GUI.

There is an exposure time user input box and slider bar to control the exposure time. The theoretical maximum exposure is 7.6 hours. In practice, the maximum exposure will be limited by the amount of background radiation events and at warmer CCD temperatures the dark current of the device.

These controls are illustrated in Figure 15.

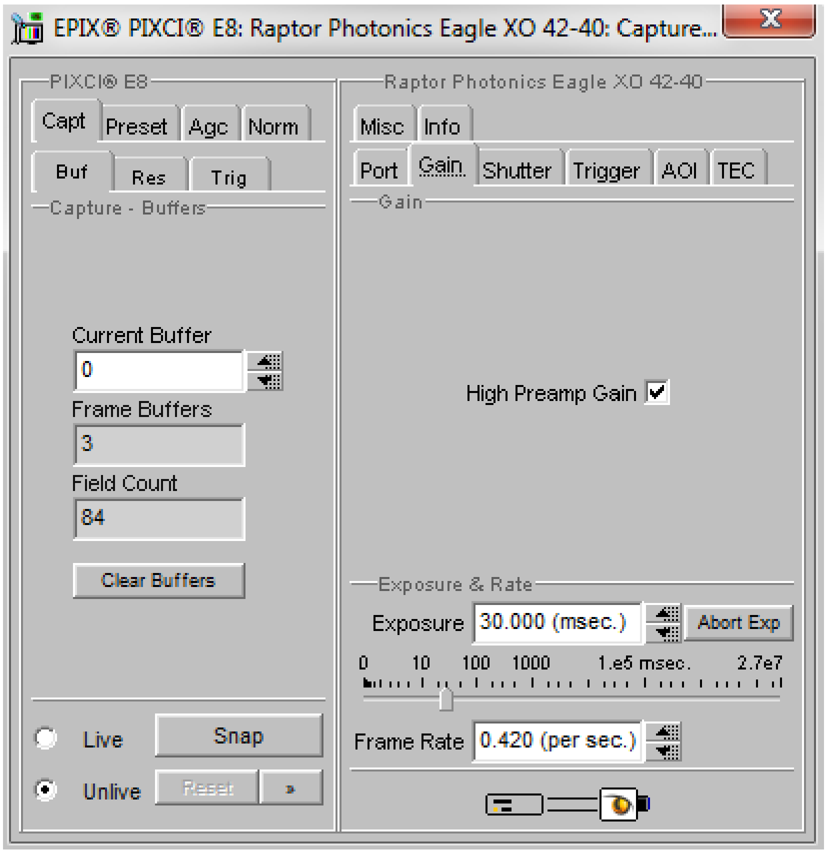


Figure 15: Gain and Exposure Controls.

9.2 Shutter Control

The Eagle XV cameras are not supplied with a shutter. However, provision for shutter control is still present and can be configured. By default, the shutter is in the closed position. It can be programmed to be:

- Permanently closed
- Permanently open
- Open for the duration of a valid exposure time

Additional delay registers may also be programmed to allow a shutter to be fully open before and fully closed after the exposure period, prior to the CCD being readout. This will prevent light falling on the sensor during readout and causing smear. If a shutter is not being used it is recommended to set the open and close delay times both to zero.

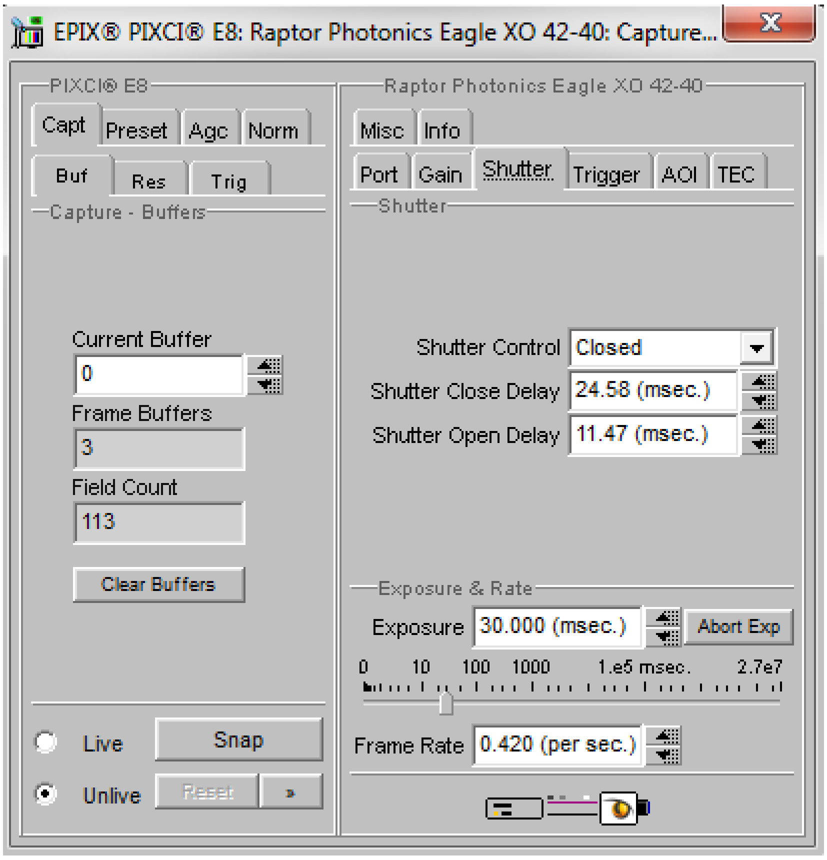


Figure 16: Shutter Tab.

9.3 Trigger Control

The trigger mode can be controlled from the *“trigger”* tab in the GUI. The three trigger mode options are listed and described below. The pixel clock speed and readout mode options are also stated. All these controls can be seen from Figure 17.

9.3.1 Live ITR (Integrate then Read)

In this mode, the camera uses an internal trigger to start the integration and readout of the sensor. The camera will run with continuous integration and readout of the sensor. This mode is used to capture a continuous sequence of images. The camera will immediately trigger the start of a new integration period when the previous image readout has completed.

9.3.2 Live FFR (Fixed Frame Rate)

If the fixed frame rate mode is enabled, then the camera will generate an internal trigger signal at a user programmable frame rate. The Frame rate user input box under “Exposure & Rate” becomes active when this mode is selected, giving the user control to program the frame rate.

9.3.3 Ext. Triggered (External Trigger)

If this mode is enabled, then the camera will use an external trigger to start the integration and subsequent readout of the sensor. Enabling this mode will also make the *“trigger polarity”* control become active. Selecting *“Rising Edge”* means that the rising edge of an incoming trigger pulse is used to trigger the start of integration. Selecting *“Falling Edge”* means that the falling edge is used to trigger the start of integration.

9.3.4 Btn. Triggered (Snapshot Trigger)

Selecting this mode will give the user an option to capture a single exposure. When this mode is enabled, the *“single exposure”* control will become active and the customer can manually trigger an exposure by clicking it.

9.3.5 Pixel Readout Clock Speed

The pixel readout clock speed can also be selected from this tab. By default, the readout speed will be set to the fastest 2MHz. The user can change to a speed of 75kHz, which offers the lowest readout noise.

9.3.6 Readout Mode

The user also has the option to toggle the Readout Mode from the dropdown box. For all readout modes of the camera, a test pattern image may be read from the camera instead of CCD data. The test image will consist of a fixed ramp pattern that will start with a value of 0 on the first pixel read from the camera and increment by one for each subsequent pixel read from the camera. By default, the readout mode will be set to "Normal Data", which reads out the CCD data.

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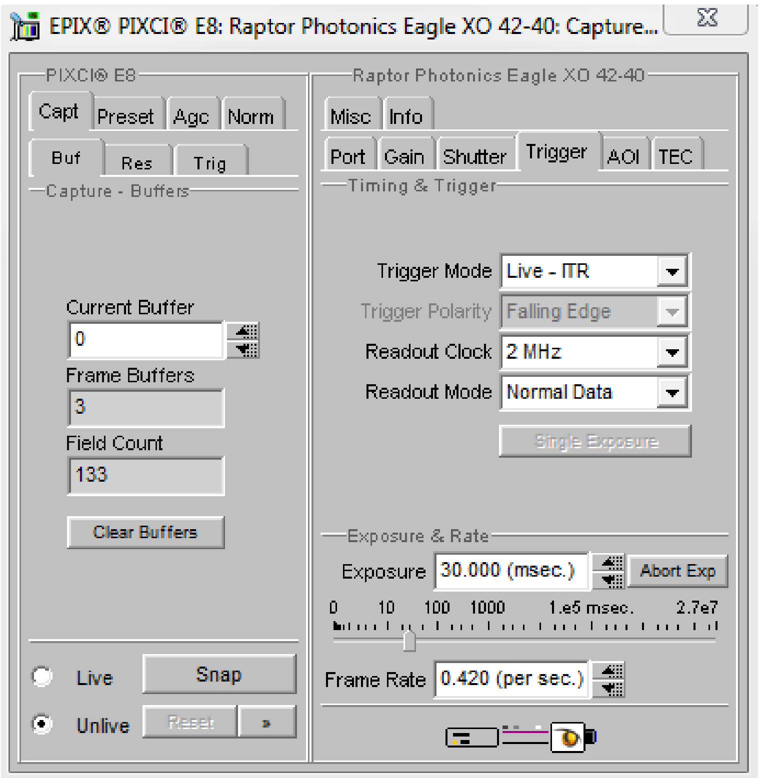

Figure 17: Trigger Tab.

9.4 Region of Interest (ROI) and Binning

The ROI and binning controls are found in the *"AOI"* tab (Area of Interest) on the XCAP GUI.

ROI: A region of interest within the main active region of 2048 × 2048 may be defined (or 1024 x 1024 if using the 47-10 model). The ROI is setup using a bank of registers to control the X offset, the ROI width, the Y offset and the ROI height. These parameters are shown pictorially in Figure 9. The user must ensure that X offset + ROI width is ≤ 2048 and similarly the Y offset + ROI height is ≤ 2048 (or 1024 if using the Eagle XV 47-10 model). Also, ROI width and ROI height must be > 0.

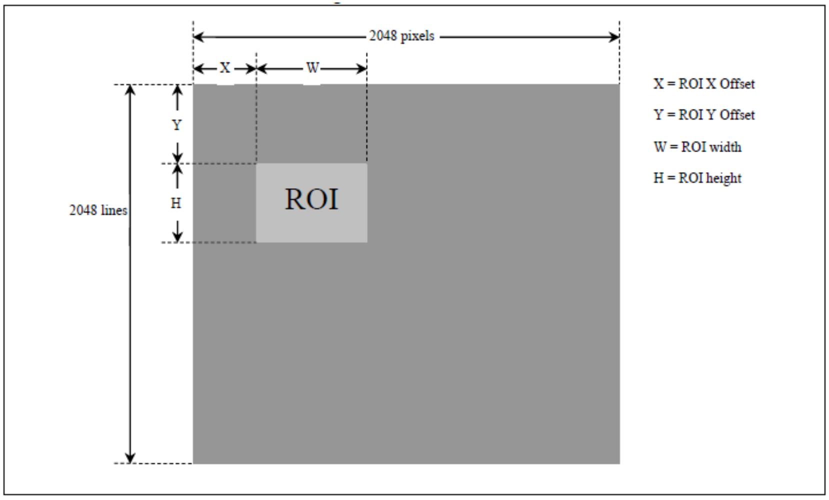

Figure 18: Region of Interest.

Binning: In addition to standard 1×1 output, various levels of pixel binning may be programmed up to 64*64. Pixel binning is performed on the CCD and asymmetric binning combinations may be used e.g. (1 × 2); (2 × 1); (1 × 3); (3 × 1); (4 × 7) etc. XCAP gives the user a lot of different binning options to choose from. If there are binning formats that the user wishes to use that are not an option in XCAP, please contact Raptor for support.

The ROI and Binning may be active simultaneously. The ROI is determined on a single pixel basis after which binning may be applied. The ROI and binning controls in XCAP are shown in Figure 19.

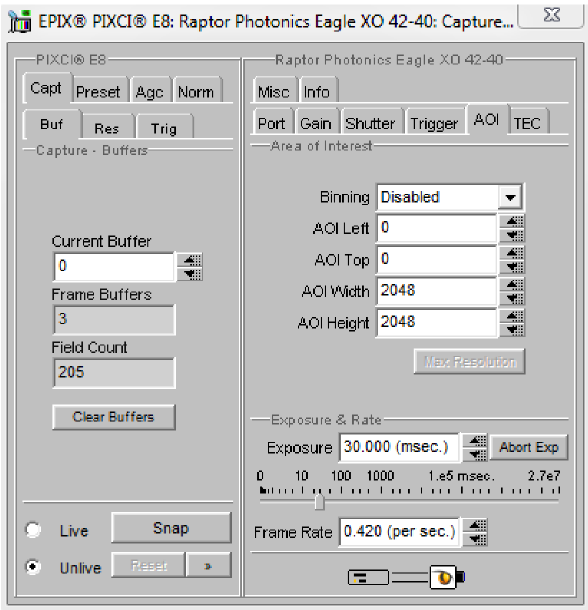

Figure 10: Region of Interest and Binning Controls.

9.5 Thermoelectric Cooling (TEC)

The "TEC" tab gives the user control over the cooling of the camera sensor. By default, the TEC will be disabled. When the TEC is enabled, the Eagle XV can cool to -80˚C with liquid cooling.

Liquid cooling must be used when using the TEC. This is needed to dissipate heat away from the hot side of the TEC. Do not enable the TEC if liquid cooling is not being used, otherwise damage to the camera will occur.

The sensor temperature can also be read back by clicking *"Update Temp".* The current sensor temperature is then displayed in the *"Sensor Temp"* box. The TEC tab is shown in Figure 20.

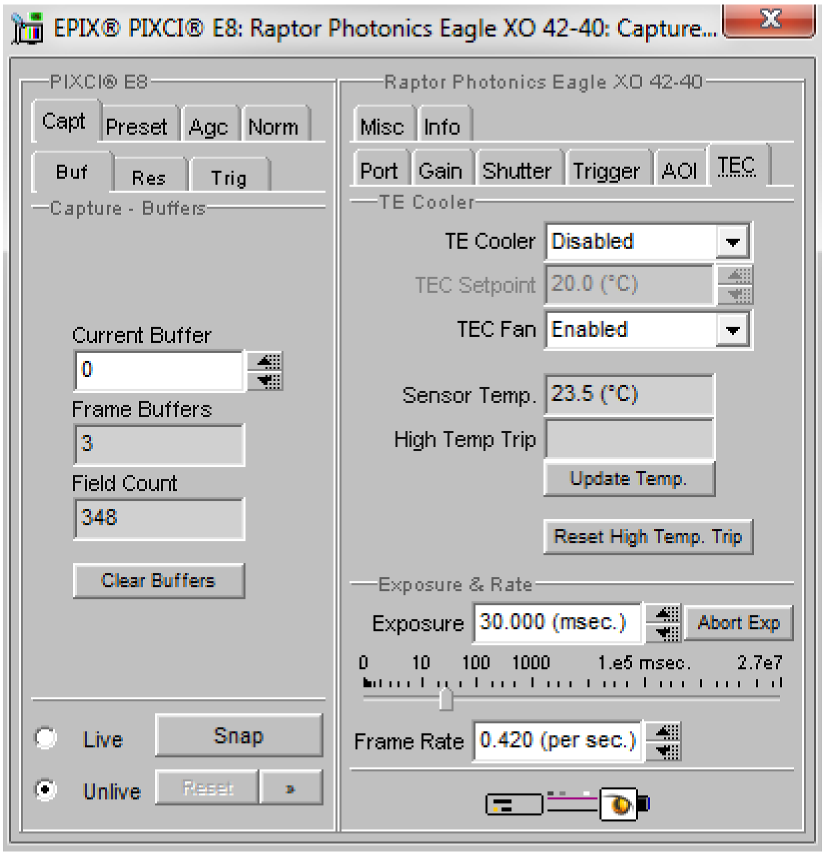

Figure 20: Region of Interest and Binning Controls.

9.6 Information Tab (Manufactures Data)

The “Info” tab displays information about the camera such as the manufactures data:

FPGA & Micro Version: The current firmware version of the camera is displayed.

Serial Number: States the serial number of the camera.

Build Date & Code: Gives the date that the camera was built.

ADC & DAC Calibration Values: These are calibration values that are used to set the TEC set point and read back the sensor and PCB temperatures. They are not needed for the user as the XCAP GUI has simple buttons to set and read back these temperatures, discussed in earlier sections.

CCD & PCB Temperature: The current sensor and PCB temperature of the device can be read by clicking “Update Temp”.

The parameters discussed can be seen in Figure 21.

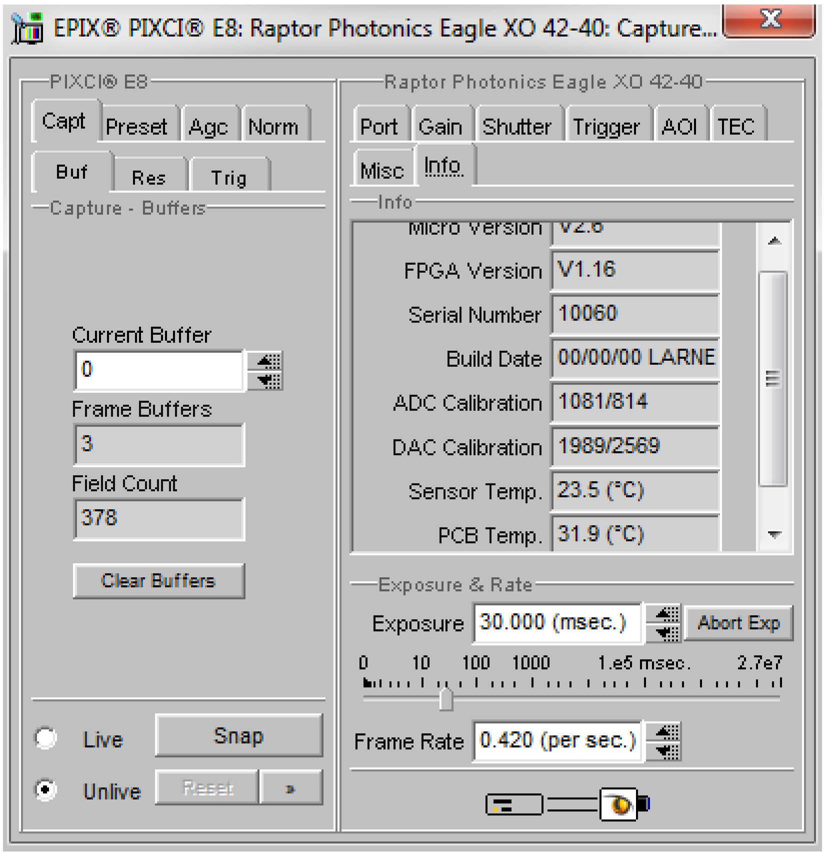

Figure 21: Information Tab.

10. XCAP CONTROL FEATURES

XCAP has many different control functions and analytical tools that can be used when imaging the camera. For the full XCAP user guide, please refer to the link below:

http://www.epixinc.com/manuals/pixci_eb1/index.htm

This section will discuss in detail a few features on XCAP that Raptor thinks would be of immediate use when using the camera.

10.1 Recording Images on XCAP

Capturing an image sequence is outlined in the full XCAP user manual (link in section 10). Raptor also has a separate user manual which covers recording images on XCAP. Please contact Raptor to obtain this manual.

10.2 Saving Preset Settings

Different camera and frame grabber settings can be saved in the *"Preset"* tab under the PIXCI (relevant frame grabber model number) section of the GUI, as shown in Figure 22.

Up to three different presets can be saved per settings file. If the camera is set to a desired state outside of the default state, clicking *"Save 1"* will save all the current parameter states that have been set. This can be done a further two times. These camera states can be recalled at any time by using the recall buttons. The overall settings file can then be saved and loaded in this tab also. Three preset states is the maximum number that can be saved in a settings file.

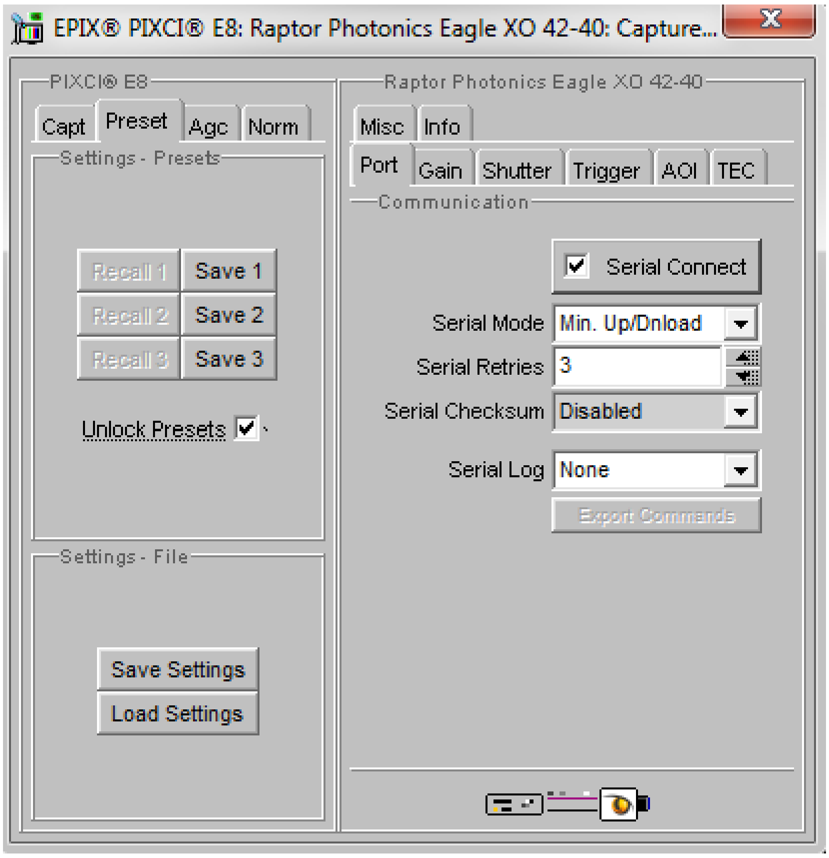

Figure 22: Presets Tab.

10.3 Contrast Modification (XCAP Std. Only)

The image contrast can be modified from the *"Contrast Modification"* section under the *"Modify"* tab in the XCAP imaging window. Figure 23 shows where this setting can be found. Raptor recommends having this enabled at all times when imaging the camera. If applying ROI or binning controls, the contrast modification will have to be re-enabled each time.

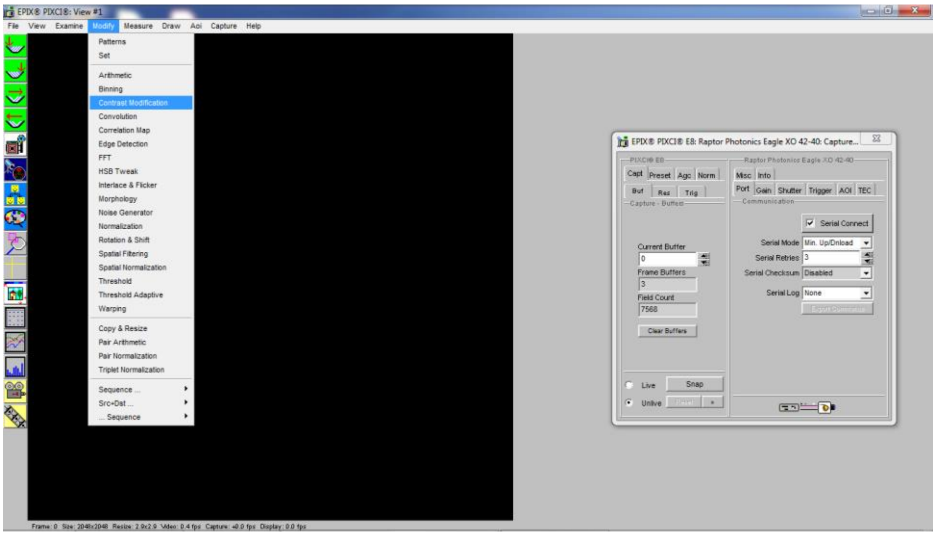

Figure 23: Contrast Modification Location on Toolbar.

In the contrast modification box, that can be seen from Figure 24, select *"Stretch Contrast, Histogram Percentile Endpoints"* and click *"preview".* The contrast modification will now be applied over the live image feed. The contrast can be adjusted using the low and high end percentile point controls. The default settings are usually adequate for most applications.

NOTE: This control feature is only applicable with XCAP Std.

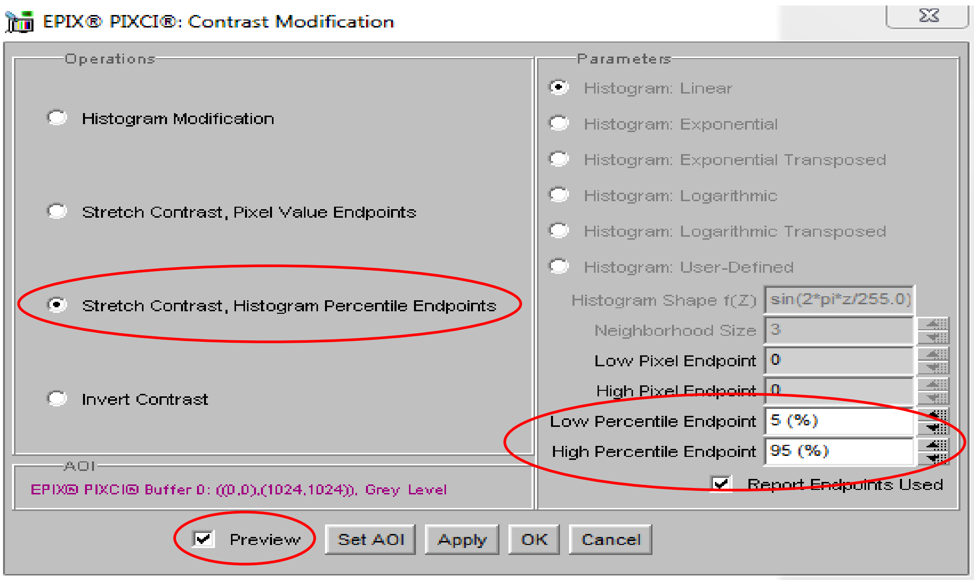

Figure 24: Contrast Modification.

CORPORATE HEADQUARTERS
Raptor Photonics LTD
Willowbank Business Park
Larne, Co Antrim
BT40 2SF
Northern Ireland
PH: +44 2828 270141

www.raptorphotonics.com