DIFFRACTION
ASTRONOMY + SCIENTIFIC IMAGING

SBIG®
Aluma AC455 / AC461

Imaging Cameras

User's Manual

Version 2.0 – October 2, 2025

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Industry Canada Compliance Statement

This Class A digital apparatus complies with Canadian ICES-003.

European Union

This product has been tested and found to comply with the limits for Class A Information Technology Equipment according to CISPR 22/European Standard EN 55022. Warning: This equipment is compliant with Class A of CISPR 32. In a residential environment this equipment may cause radio interference.

Visit us at: http://diffractionlimited.com

Tech Support: **http://forum.diffractionlimited.com/**

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SBIG Aluma AC455 / AC461 User's Manual

Contents

IMPORTANT!

Please read this guide thoroughly before installing and operating your new SBIG Aluma AC camera. It is important to fully understand and follow all installation, operation, and maintenance procedures as stated to ensure proper functionality. Failure to do so may affect your warranty!

WARNING

Over time cooled cameras will eventually get some moisture contamination in the sensor chamber. The desiccant module is designed to remove that moisture. We *strongly* recommend recharging the desiccant periodically. **Waiting until frost appears risks damage.**

For windowless sensors we recommend recharging every 6 months. For all other sensors we recommend recharging annually. Recharge should be done more frequently in humid locations.

As soon as any frost appears on the sensor, you must *immediately* cease operation and recharge the desiccant.

Failure to immediately recharge the desiccant will result in permanent damage due to sensor corrosion, which is not covered under our warranty.

SBIG Aluma AC455 /AC461 Imaging Cameras

The SBIG Aluma AC455 and SBIG Aluma AC461 cameras are state-of-the-art advanced scientific CMOS cameras for astronomical imaging systems. The SBIG Aluma AC455M and AC455C utilize the Sony Semiconductor IMX455 monochrome and color CMOS Active Pixel Sensors respectively. The SBIG Aluma AC461 utilizes the Sony Semiconductor IMX461M monochrome sensor. Both cameras have 61.1 million square pixels, 3.76 micron in size, arranged in a 9,568 x 6,380 array. The active array is about 36 mm x 24mm in size (43.3mm diagonal). Both Monochrome and Bayer Color (RGGB) versions are Back-Side Illuminated, for the highest available quantum efficiency.

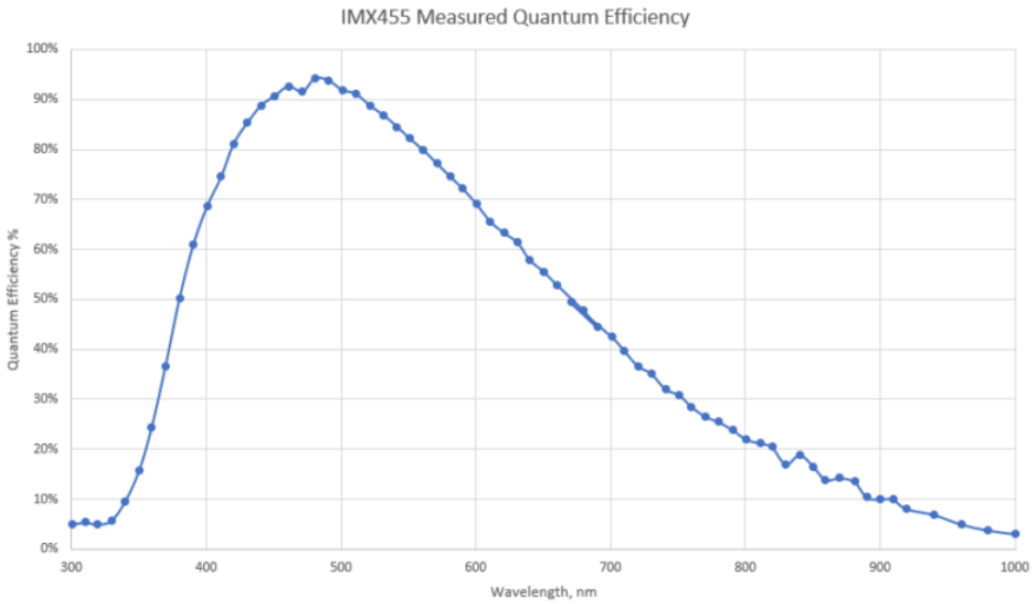
Primary design features include:

- **High Quantum Efficiency**

  The monochrome sensor features a peak Quantum Efficiency (QE) of 94% at 480nm, with good performance across the visual spectrum, exceeding 68% at 400nm through 600nm, and a gradual decrease to 50% at 680nm, near the SII wavelength.

The color sensor adds Bayer-matrix RGGB microfilters which results in decreased sensitivity.

We use only best quality Industrial Grade sensors, rated for operation from -40C to +40C, unlike competing less-expensive cameras.



- **Superior Cooling**

Dual independent heatsinks are used in the camera, to provide active cooling for the image sensor and the primary FPGA. For the image sensor, our **SmartCooling™** function provides intelligent two-stage thermoelectric temperature regulation to 0.1 degrees C for high calibration stability, enabling ~35° C below ambient temperature delta.

- **User-rechargeable Desiccant**

SBIG pioneered the incorporation of a high-tech user-replaceable cartridge with ceramic filter and molecular sieve desiccant. Unlike competing cameras using low-quality silica gel that can contaminate the chamber or complicated models that require factory service when their chamber desiccant eventually saturates out, the user can easily recharge the desiccant. This eliminates the need for costly service – not to mention the associated down-time and shipping costs. This feature is especially important in high-humidity locations.

- **Standard Electronic Shutter and Filter-as-Shutter Options**

  SBIG AC455 and AC461 cameras use the Sony STARVIS electronic rolling shutter to clear pixel voltage. Customers requiring a mechanical dark shutter can configure the included MaxIm LT software to rotate a mechanical "dark" filter into position in front of the camera. AFW filter wheels are supplied with the necessary filter blank for taking dark frames.

  This feature enables convenient dark-frame subtraction for optimal performance and sensitivity. This is essential for remote/robotic operation.

- **High Speed Fiber Optic Interface**

  Aluma AC455 and AC461 cameras utilize a 10 gigabit per second Ethernet SFP+ (Small Form-factor Plugabble Enhanced) fiber link from the camera to the host computer. This allows much greater distance and higher speeds than USB 3.0 interfaces. Several options for computer interfacing are available. Effectively the camera is a network device on a dedicated sub network.

- **AUX Port**

  Aluma AC cameras have a convenient auxiliary control port (also known as an I^2C AUX port), which controls the filter wheel and provides optional external trigger interfaces.

- **MaxIm LT Software**

  All SBIG cameras come with our MaxIm LT software. MaxIm LT is a special version of our venerable MaxIm DL software that provides complete control of your camera, filter wheel, and autoguider, plus advanced image processing capabilities. If you wish you can upgrade to MaxIm DL Pro to get complete observatory integration, scripting, and even more processing and analysis capabilities.

1 - Installation

1.1 Supplied Components

Camera

Your Aluma AC series camera is provided in a deluxe foam-lined hard shell protective case. Observe proper handling procedures for sensitive electronic equipment and unpack the contents carefully in a clean, dry, static-free area. Inspect the contents to ensure all components are present and in good order. The kit includes:

- Aluma AC455M monochrome, AC455C color, or AC461M monochrome imaging camera.
- Installed desiccant plug.
- Camera Optical Adapter Plate, either:
  - STX Style Adapter Plate - 3.5" OD Dovetail and 3x24 TPI threaded interface, or
  - 3” barrel-style adapter (ACC09).
- 6-32 adapter plate mounting screws (installed).
- Camera dust cap.
- Power supply:
  - +12V DC 8A power adapter (60005A)
  - DC extension cable (60008)
  - Power cable with USA, European, or Australian plug (specified on ordering)
- USB flash drive with installation instructions and software
- MaxIm LT software
- 7/64” (0.109") Allen key

Host Interface

Your Aluma AC camera requires a 10-gigabit fiber optic network interface in the host computer.

You can purchase the camera with optional networking hardware. Options include OM3 fiber optic cable, SFP+ transceivers, and 10 GBPS computer adapters and converters.

Please see Appendix F SFP+ Fiber Ethernet Primer for an explanation of the various fiber optic components, and suggested sources if you did not purchase them with the camera.

1.2 Minimum System Requirements

The Aluma AC455 is designed to transfer 61 megapixels or 122 megabytes of data in about ¼ second. The Aluma AC461 is designed to transfer 102 megapixels or 244 megabytes of data in about ½ second. The computer used must be powerful enough to support this.

The recommended computer specifications are as follows:

- 13th Generation i7 or higher
- 32 GB Memory or higher

The minimum computer specifications are as follows:

- 13th Generation i5
- 16 GB Memory

Due to the high speeds involved, lower specification computers may not be able to reliably download image data.

The camera does have Ethernet flow control and buffering capabilities, and the driver software is able to re-request missing packets in the event of data overrun. Even so, if the computer is not fast enough it will not be able to keep up and image corruption may result.

1.3 Installing the Software

NOTE:
If you already have MaxIm DL Pro, **please update to the latest version**.

The MaxIm LT imaging application allows you to operate your Aluma AC camera using a Windows computer and is included with your purchase. Device drivers are available for Windows 10/11. MacOS and Linux operating system drivers are available upon request.

System requirements

The following hardware and software is required for MaxIm LT:

- MS Windows 10 22H2 on 64-bit Intel or AMD processors
- MS Windows 11 22H2 on 64-bit Intel or AMD processors
- Recommended minimum memory size: 8 GB or larger. Processing large arrays or opening multiple images simultaneously may require correspondingly more memory.
- Disk space: 200 MB for program installation
- Mouse

Windows installation

1. Go to the Registration page on the Diffraction Limited website at:
   https://diffractionlimited.com/maxim-lt-registration

2. Enter the requested information and serial number to register for the MaxIm LT application. Use your camera's serial number for this. If your camera is authorized for a free licence you will be automatically emailed a license key.

3. Insert the supplied flash drive into an available USB port.

4. Open Windows Explorer and navigate to the flash drive's root folder.

5. Double-click **Launcher.exe**, then click *DL Config* to install the application. When the installation is completed, launch *DL Config*.

6. Return to the Launcher and click the *Install MaxIm DL/MaxIm LT* button. Follow the onscreen instructions to install the Maxim LT application and then enter the license key you received when prompted.

   NOTE:
   To enter your license key properly, you must select all the text from the email you receive and copy it to the clipboard. You then start MaxIm LT and open the Enter License dialog. The license key will be entered automatically – there is no need to paste it since MaxIm LT finds it on the clipboard and pastes it for you.

7. Click **OK** to finish. You can then proceed to the next section to install your hardware.

1.4 Installing the Network Hardware

For an introduction to SFP+ Fiber Interfaces, please see Appendix F. In short, you will use OM3 or OM4 fiber with LC connectors on each end. The cable plugs into LC transceiver modules at both ends, which in turn plug into the camera at one end and the computer at the other. Some computers may be directly compatible; others will require an adapter.

There are several possible ways to connect SFP+ Fiber Ethernet to your computer:

- Built-in SFP+ compatible 10 GB Fiber Ethernet Interface
  - The easiest option… just plug in the transceiver.
- PCIe SFP+ compatible 10 GB Fiber Interface card
  - If your computer has a spare PCIe x8 slot, this is the best option.
- SFP+ to Thunderbolt Adapter
  - If your computer has a Thunderbolt 3 or 4 connector, simply plug the adapter into the port.
- Built-in RJ-45 10 GB copper Ethernet port
  - Most modern computers have these; if you have a port available that is not being used for network connections, then this is the simplest way to connect.
  - Use an SFP+ to RJ-45 Format Converter. Fiber will run from the camera to the converter, and a CAT6e or CAT7 cable from the converter to the computer.

In all cases, follow the manufacturer's instructions for installing the networking hardware.

Diffraction Limited has adapters and format converters available on our website. It may be less expensive to purchase them directly from suppliers. Please note that we strongly recommend using Industrial temperature range transceivers and adapters, as they are higher quality, run cooler, take less power, and operate over a wider temperature range. These are mandatory if you are operating in cold temperatures, as commercial temperature range devices may fail under winter conditions.

A list of suggested cables, transceivers, and adapters is available in Appendix F.

1.4.1 Computer Ethernet Interface Setup - Windows

Before proceeding, be sure to install your 10GB Ethernet adapter, if you have not already done so.

There are three major items that need to be set up:

- Adjust adapter settings to allow Jumbo Packets and increase the number of Receive Buffers available,
- Disable unnecessary protocols and set the computer IP address on the camera link, and
- Enable Port 6363 on your firewall (we use UDP port 6363 for camera communications.

Since there is a huge amount of data downloaded with every image, the camera uses Jumbo Packets. This makes the data transfer much faster and more efficient. Increasing Receive Buffers helps the computer keep up with the extremely fast data transfer from the camera. We also recommend disabling power management in the adapter so it will never power down while operating.

The computer and camera both need to have an address on their private communications network. Currently the camera is set to 192.168.42.1 and the computer is set to 192.168.42.2. (This may be user-settable in a future firmware/driver update.) We recommend disabling unused protocol options so the computer doesn't send irrelevant messages to the camera, which will just occupy transmission bandwidth.

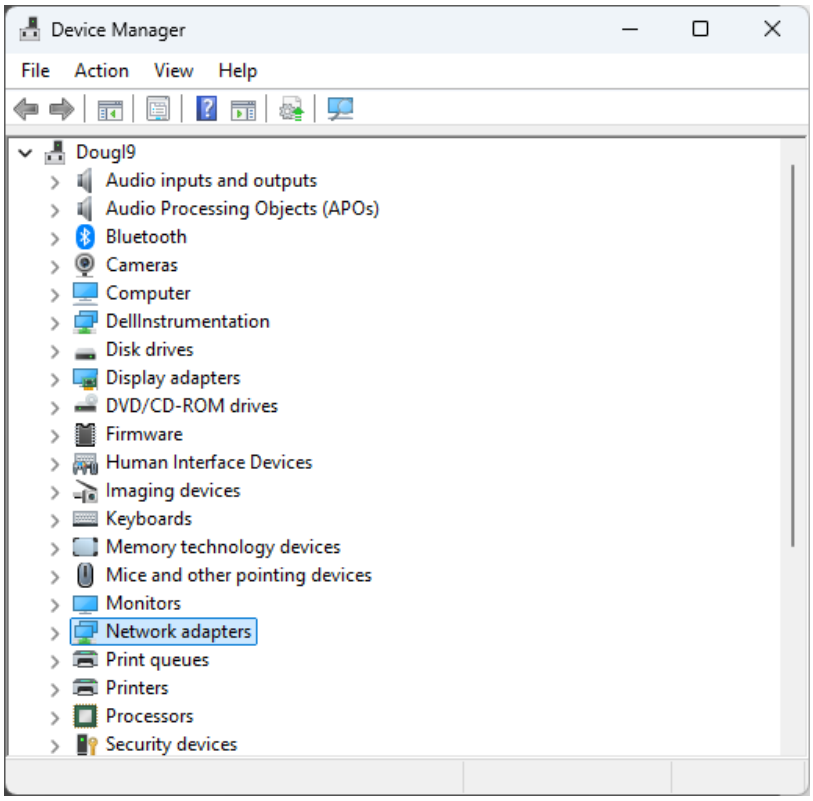
Finally, we will add a firewall rule to allow data packets from the camera to come into your computer. We use UDP protocol on port 6363.

This is a fairly length list of settings to be made, but they will only be necessary to set up once.

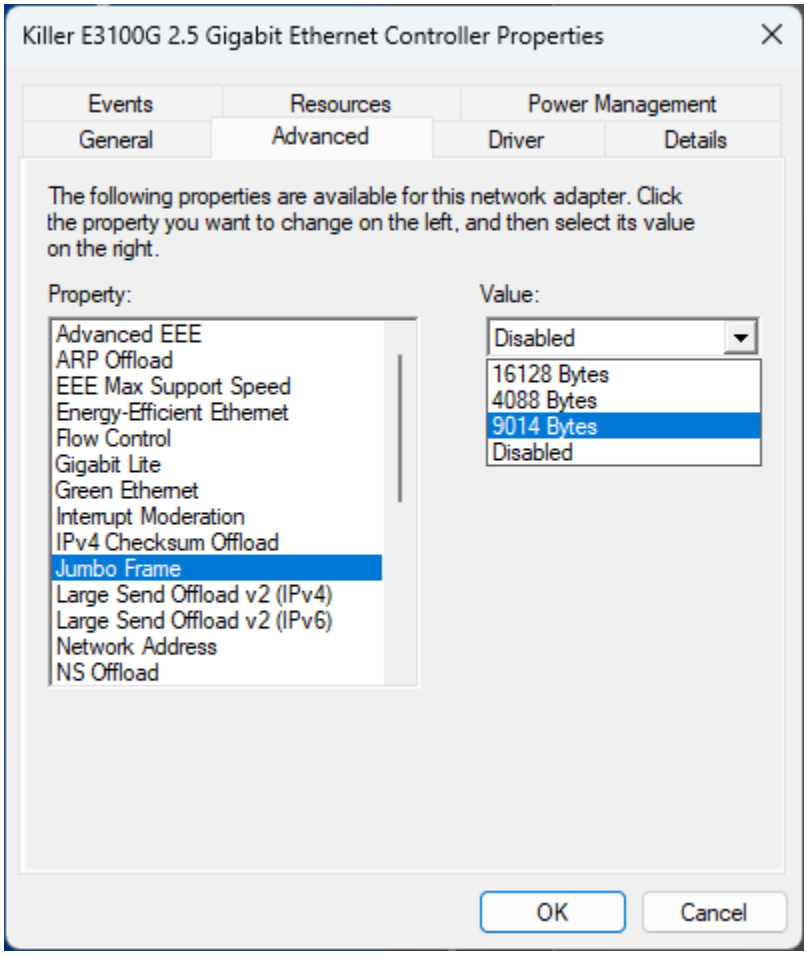
The detailed procedure for Windows 11 is as follows:

1. Make sure your 10GB Ethernet adapter is installed.

2. Open the **Windows Device Manager**. The quickest way to do this is click the Start button and type “Device Manager” and hit Enter.



3. Click the arrow beside **Network Adapters** to see the list of adapters. Find your 10GB Ethernet adapter (n.b. not the adapter used for your main Internet connection), right-click and select **Properties**. Click the **Advanced** tab.



4. In the list find **Jumbo Frame**; by default it is usually disabled. Increase this to **at least 9014 Bytes**.

   Note: If you do not enable Jumbo Frames, you will not be able to download images.

5. Now find **Receive Buffers**. Increase the value to the maximum available, which is typically **4096**.

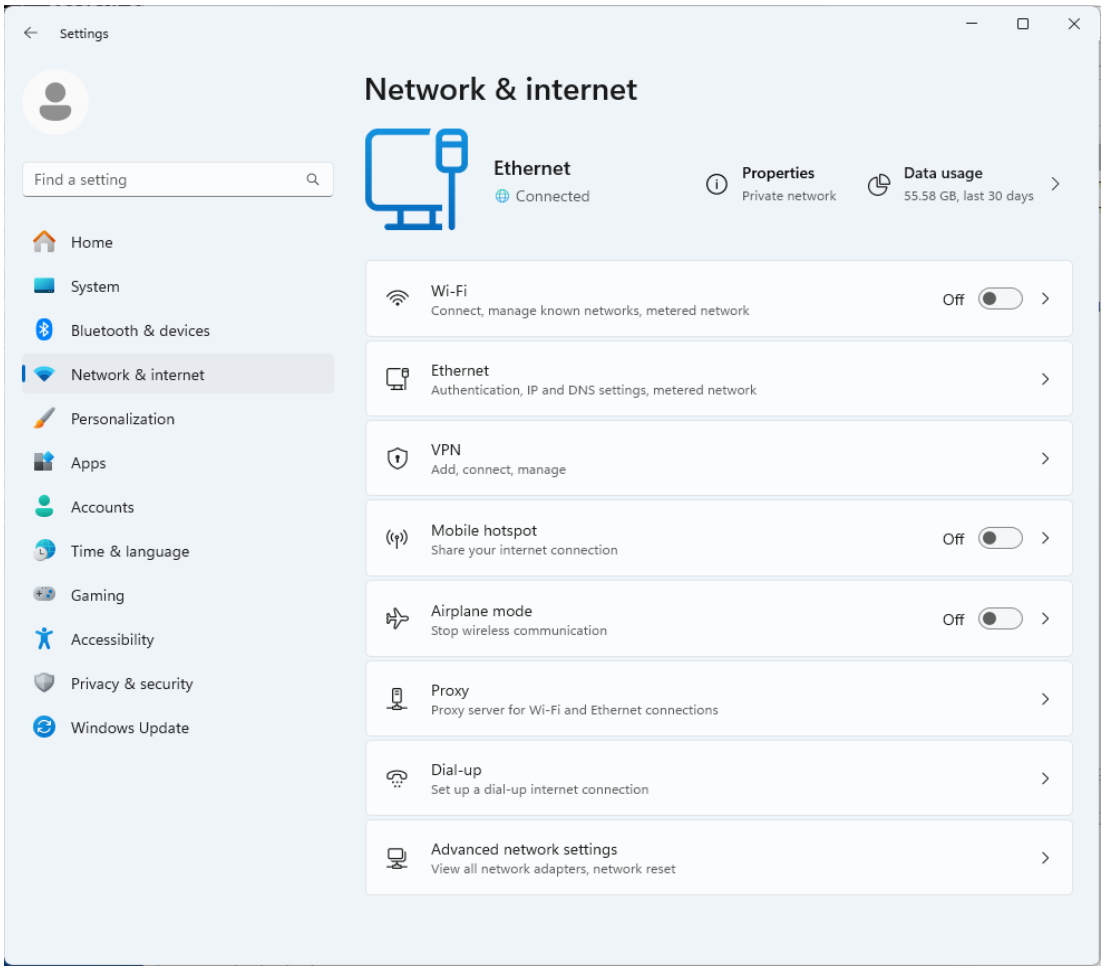
6. Now switch to the **Power Management** tab, and turn **off** "Allow the computer to turn off this device to save power"

7. Click **OK**.

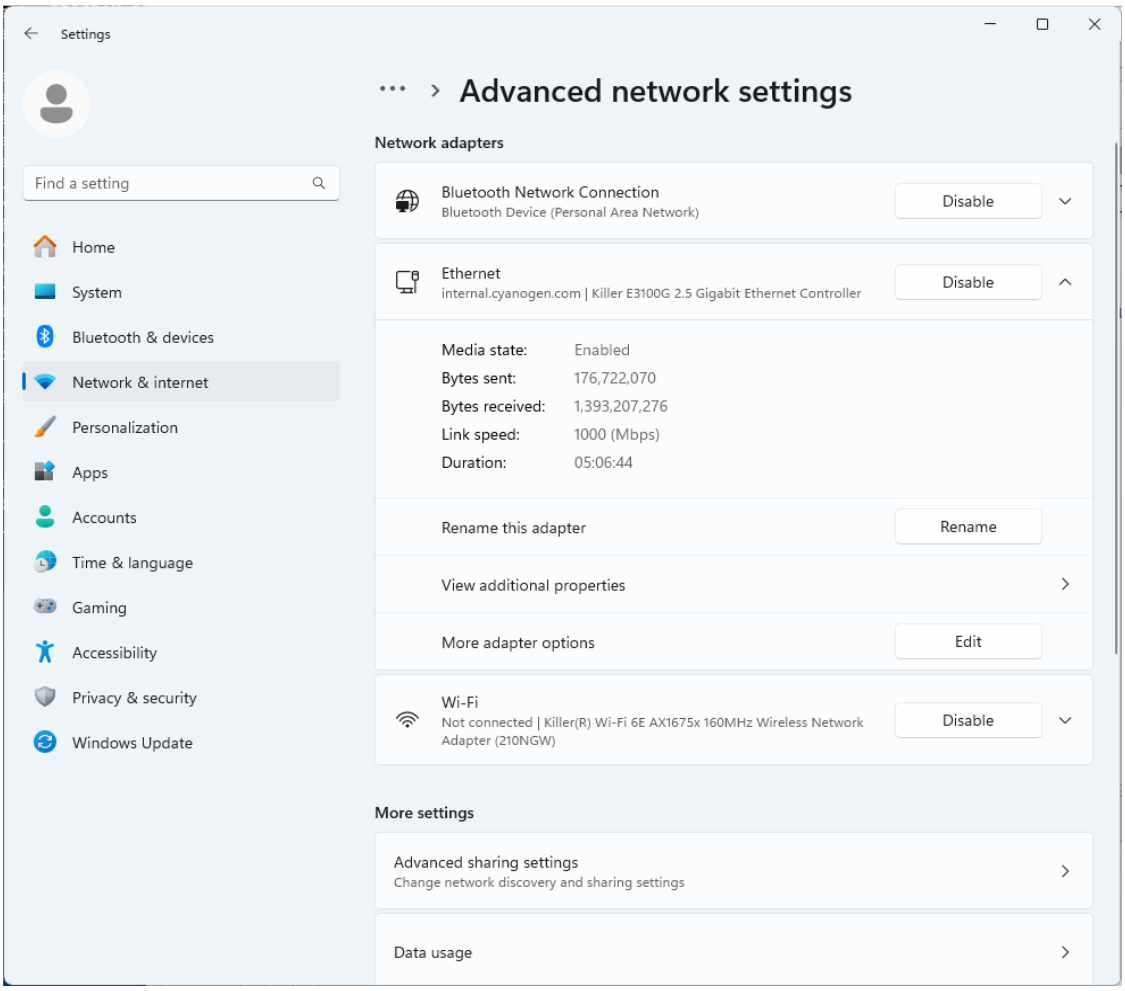
8. Now bring up your **Windows Settings**. The fastest method is to click Start, type Settings, and click **Enter**.

9. On the left side select **Network & Internet**.

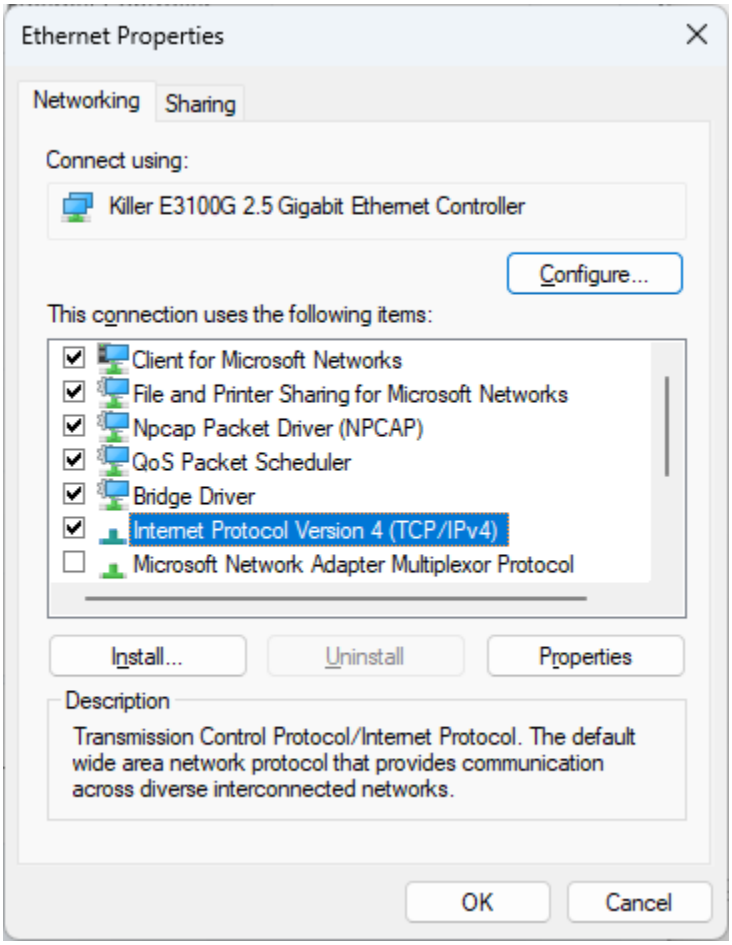
10. At the bottom select **Advanced Network Settings**.



11. Under Ethernet click the Expand button at right. (You may have more than one adapter – be sure to select the correct one).

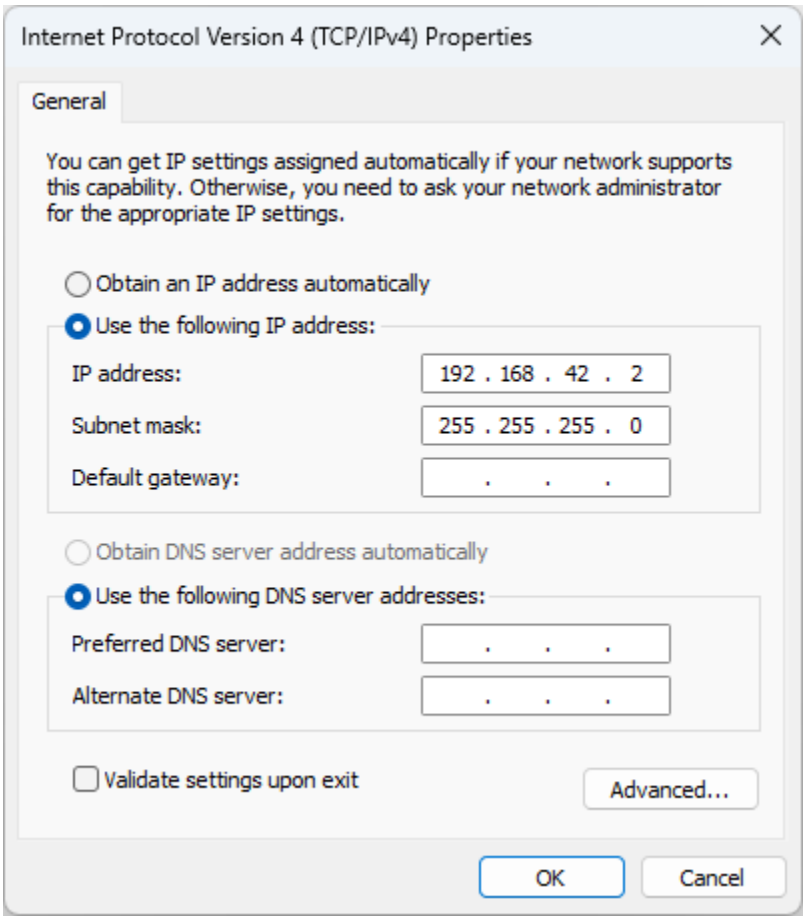


12. Click the Edit button beside **More adapter options**.



13. We recommend that you turn **off** (uncheck) all protocols ***except* Internet Protocol Version 4 (TCP/IPv4)**. This will eliminate unnecessary traffic between the computer and the camera.

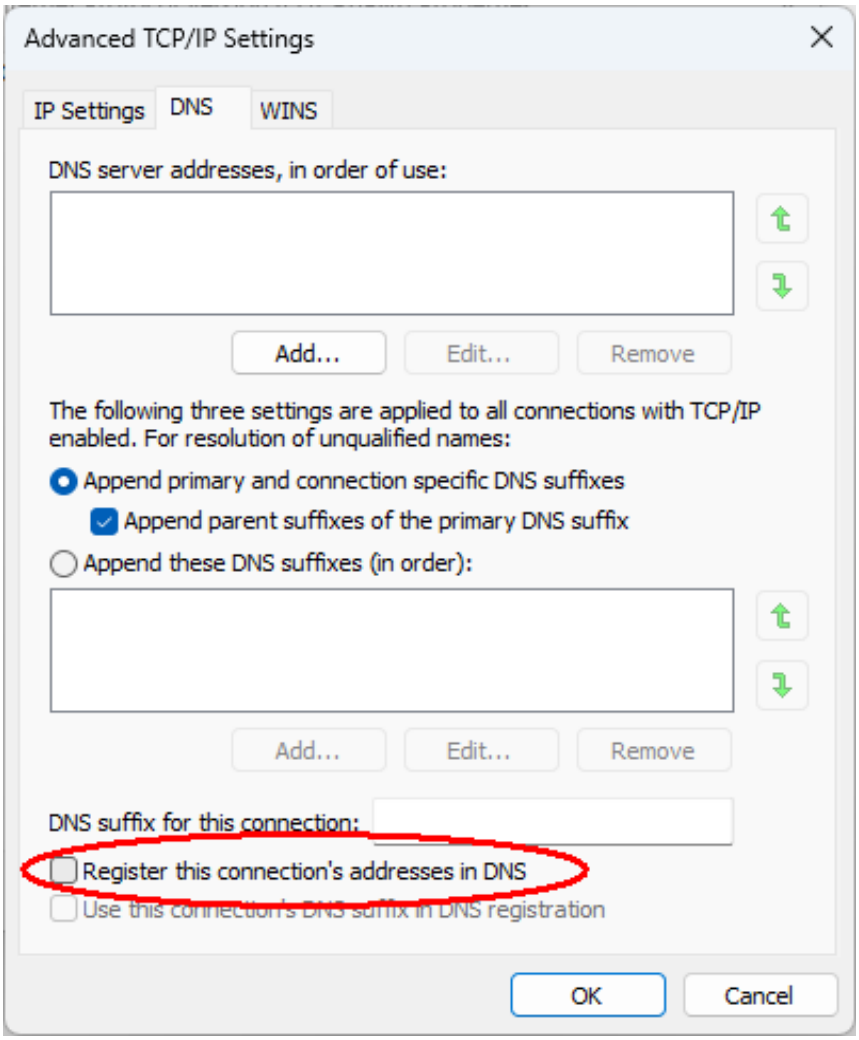
14. Now select **Internet Protocol Version 4 (TCP/IPv4)** and click **Properties**.



15. Select **Use the following IP address** and enter the IP address **192.168.42.2**. The Subnet mask will automatically fill in as 255.255.255.0 – leave that in place.

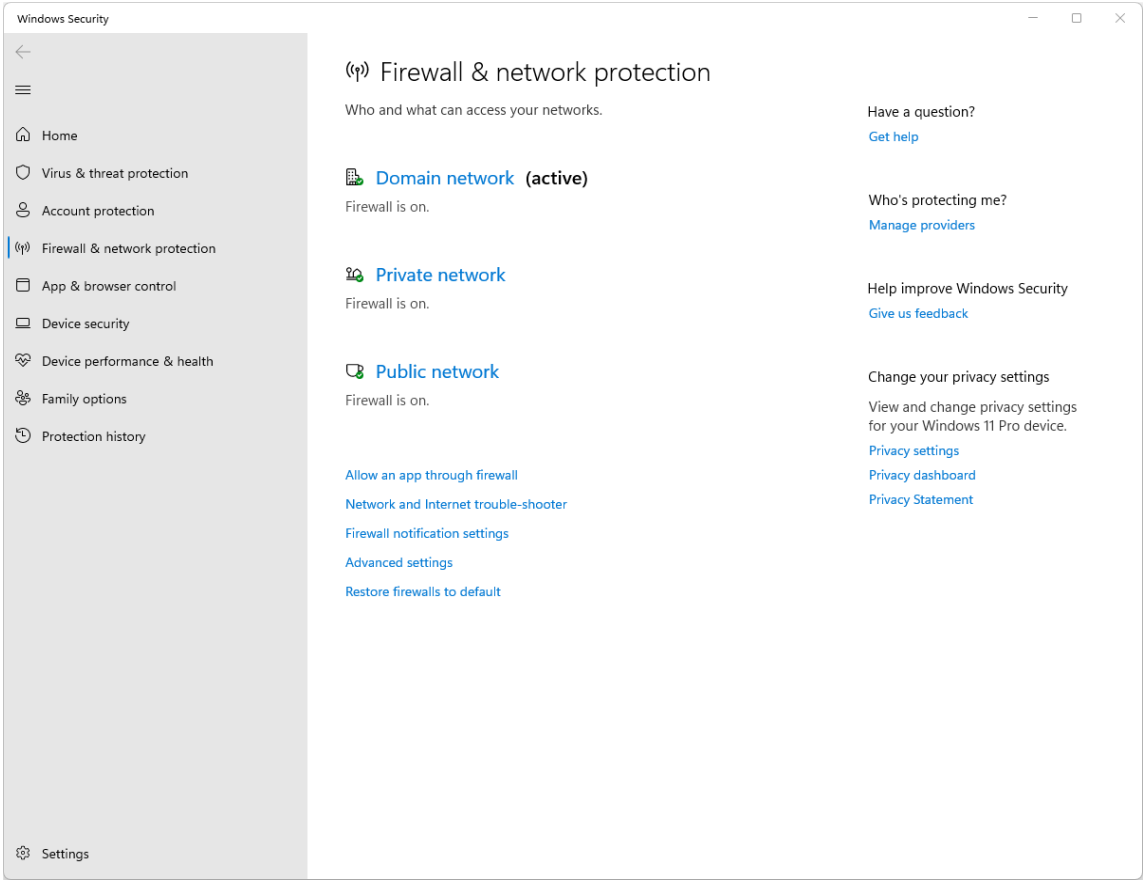
(Your camera will be at address 192.168.42.1)

16. Click the **Advanced…** button and select the DNS tab. **Disable** the option **Register this connection's address in DNS**. This will reduce unnecessary Ethernet traffic on the camera link.

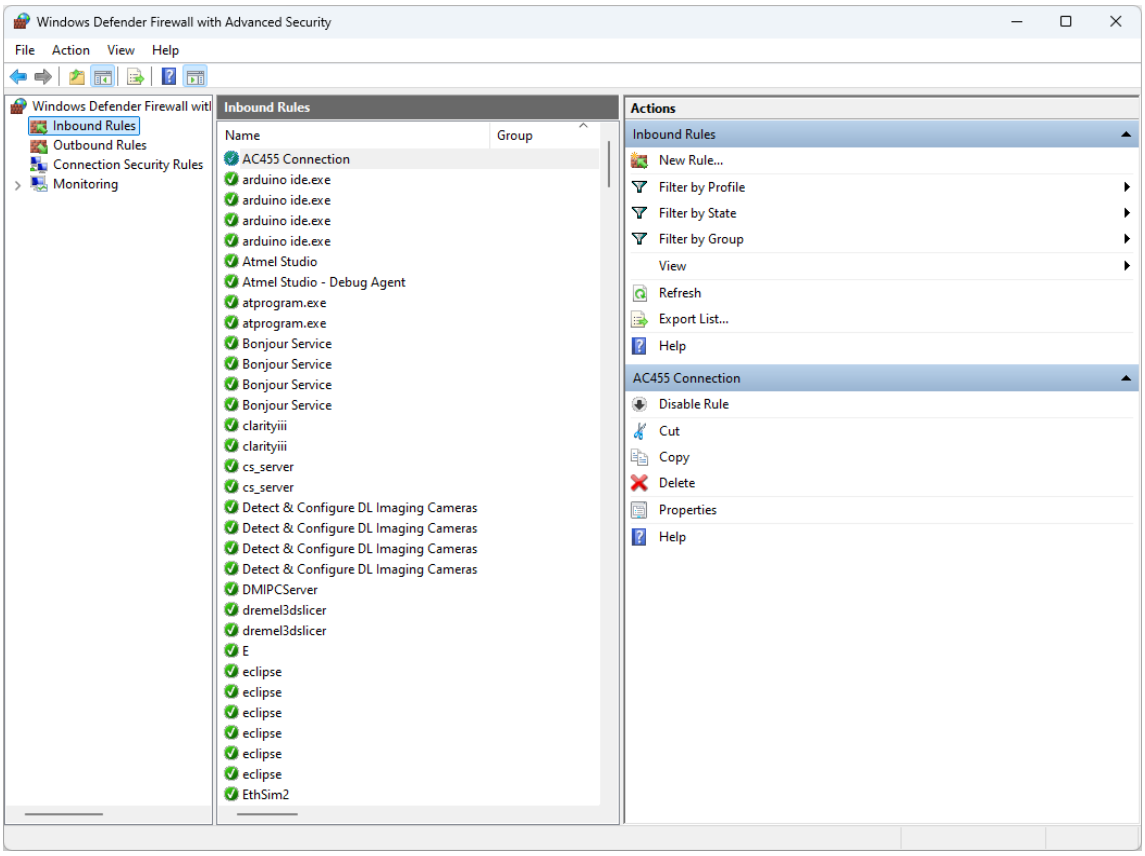


17. Click **OK** twice to save these settings.

18. The last thing is to make a firewall rule so your packets can get through. Open your Firewall settings – the easiest way to do this is to click the **Start** button and type **Firewall**.

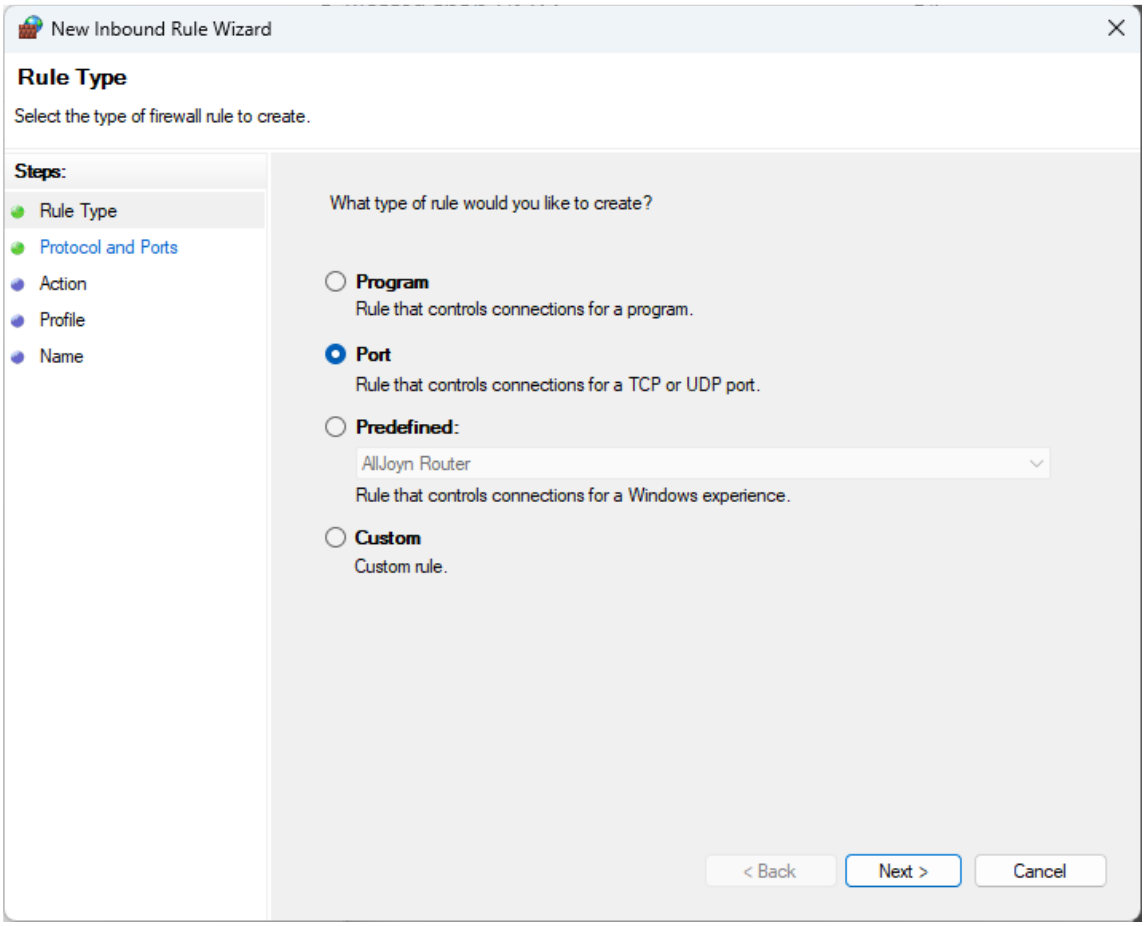


19. Click **Advanced Settings**. Click on **Inbound Rules** in the left column.

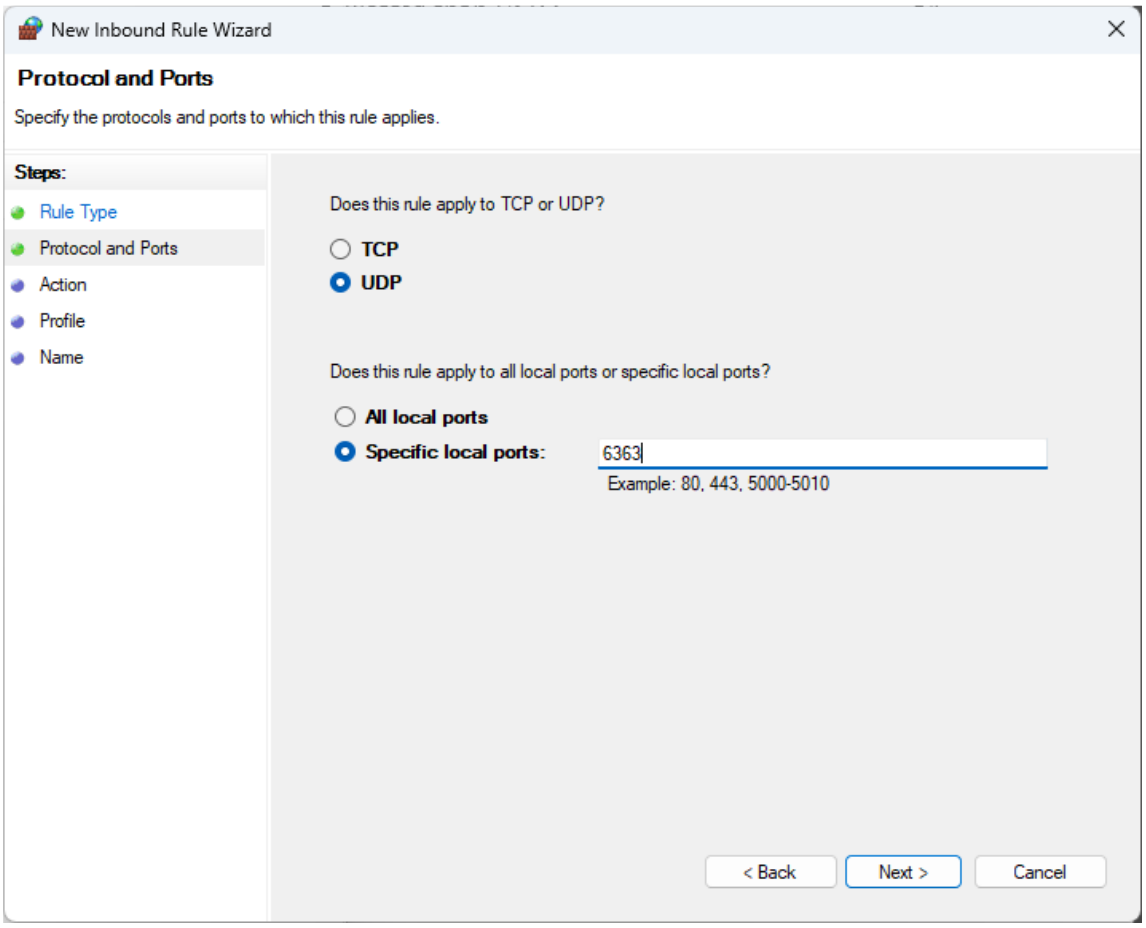


20. On the right side select **New Rule...** The **New Inbound Rule Wizard** will appear.

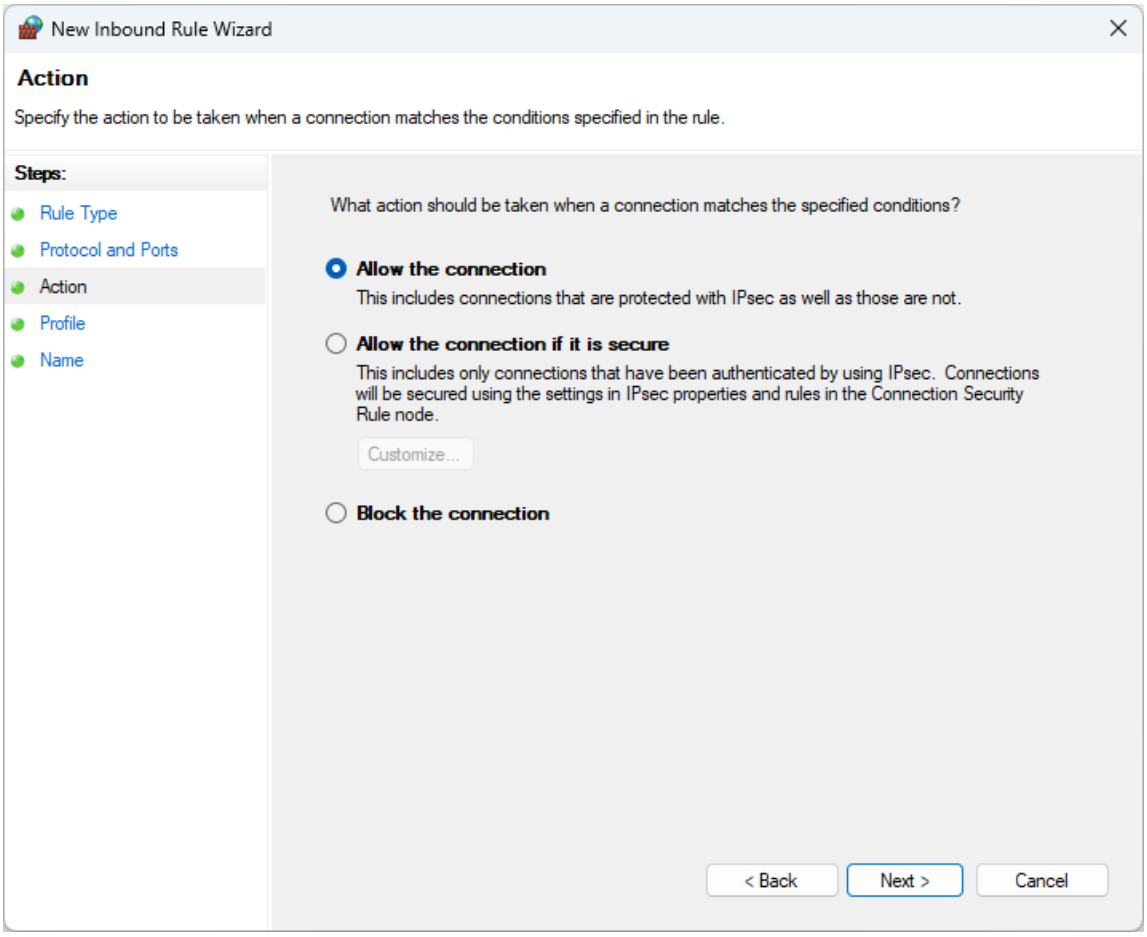
Click **Port** and then click **Next**.



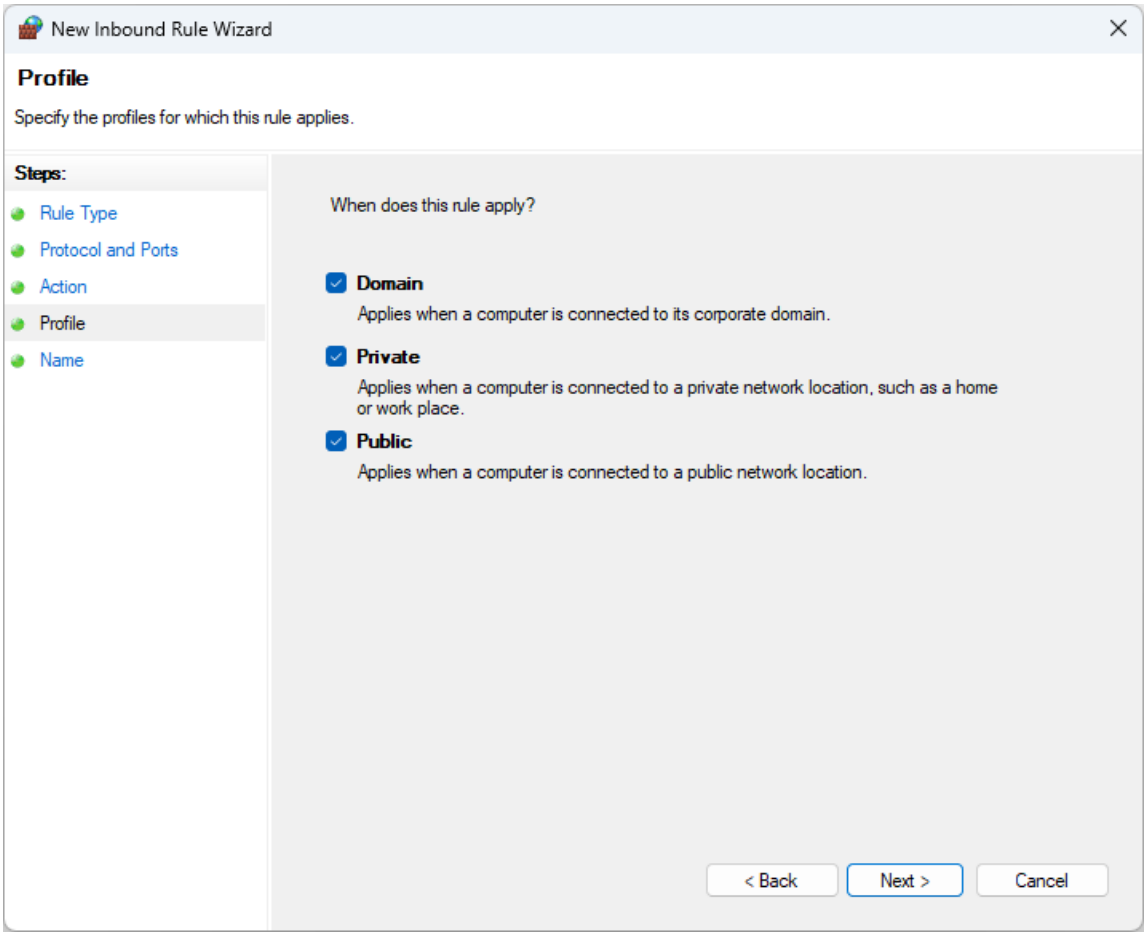
21. Click **UDP**, then click **Specific local ports:** and enter **6363**. Click **Next**.



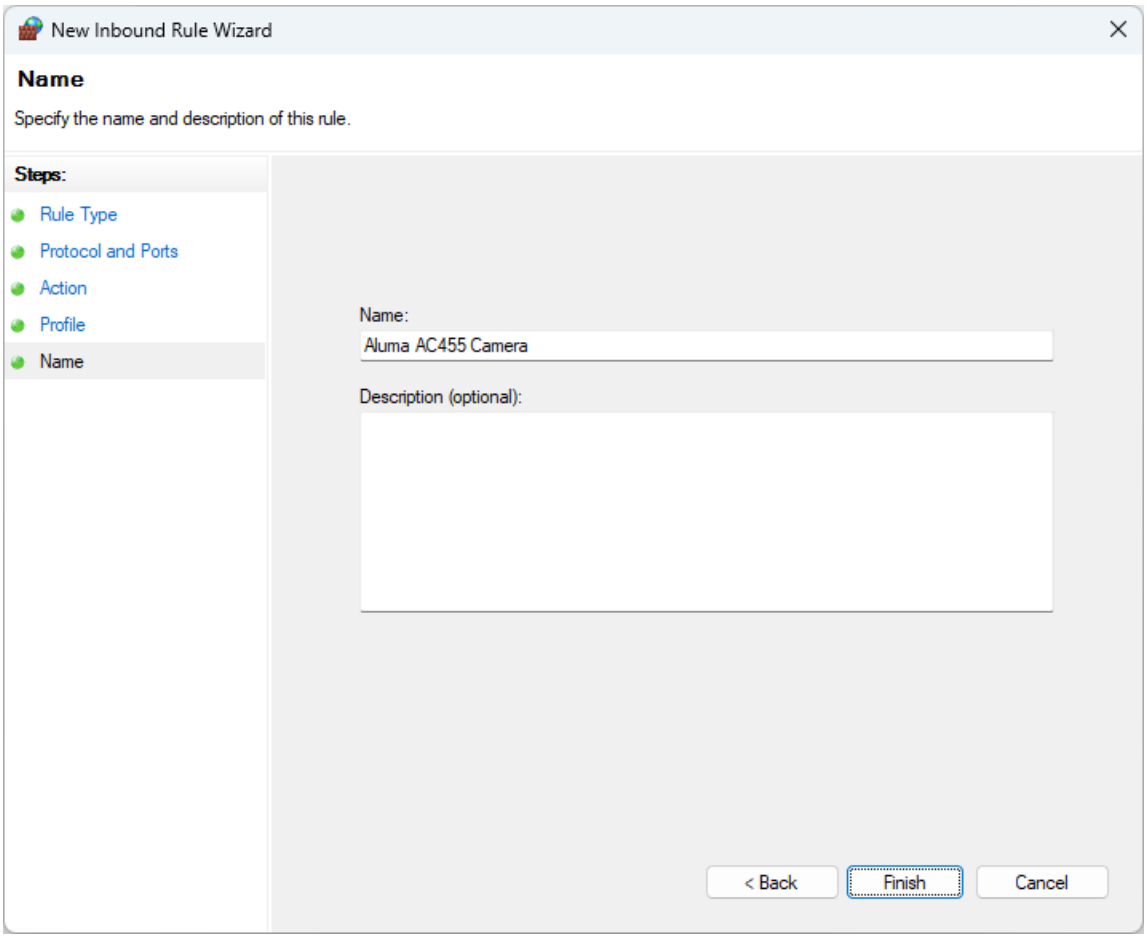
22. Select **Allow the connection** and click **Next**.



23. Leave all options enabled and click **Next**.



24. Give the rule a name such as **Aluma AC455 Camera**, and click **Finish**.



Your network configuration is now complete.

1.5 Installing the Camera Hardware

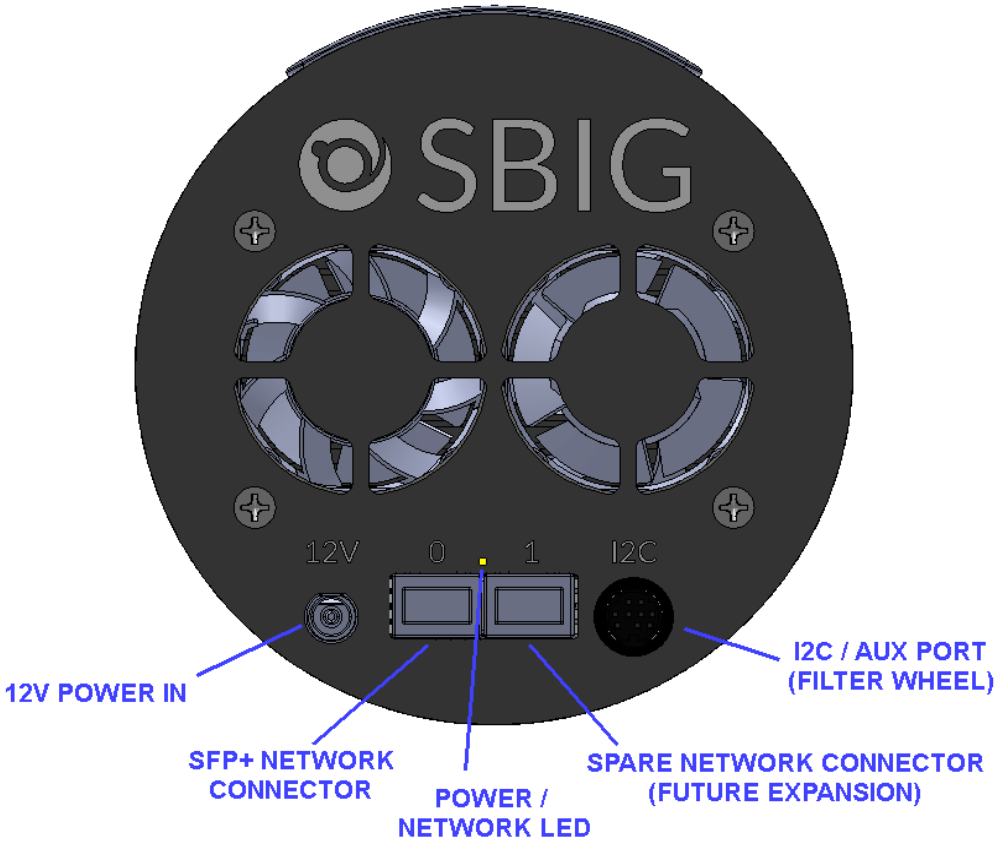
Perform the following procedure to set up the Aluma AC455 or AC461 camera.

CAUTION:

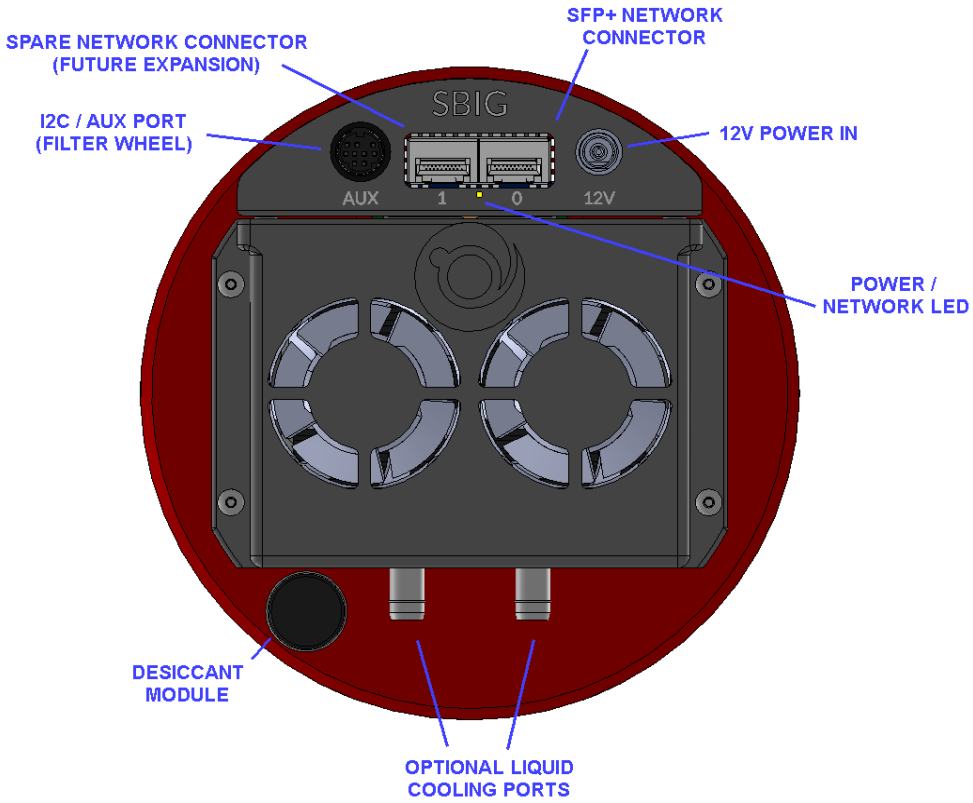
A power up and power down sequence is needed for the correct operation of the camera and long life of the CMOS APS detector. Always disconnect the camera from the control software at least 10 seconds before powering it off. The indicator LED will rapidly flash yellow when it is safe to power down.

CAUTION:

Do not plug/unplug the I2C port while power is connected; otherwise, the filter wheel and/or camera may be damaged.



Aluma AC455 Rear Panel



Aluma AC461 Rear Panel

1. Start with the power supply disconnected from AC power.
2. If you are using an SBIG filter wheel with the camera, connect it via the I2C port.
3. Slide the fiber optic transceiver(s) into the Slot 0 receptacle. Press firmly until it is properly seated. (Slot 1 is reserved for future use.)
4. Remove the protective covers from the fiber optic connector and insert it into the transceiver. Push firmly until it is properly seated. Usually it will make a “click” sound once latched properly.
5. Plug the second transceiver into your 10Gb Ethernet adapter on the computer. (Installation may be required – please refer to the instructions included with the adapter.)
6. Attach the power supply cable between the POWER connector and the power supply. Thread the connector backshell onto the camera to lock it in place.

The camera is now ready to be powered up and tested. Refer to: Section 1.5 Testing the Camera.

1.6 Testing the Camera

Once MaxIm LT is installed and the camera hardware is connected, Diffraction Limited recommends that you perform a simple bench test of the system. Do this before mounting your camera on your optics.

You should read Chapter 2 to familiarize yourself with the basic software connection and operating instructions prior to performing this test.

Proceed with the bench test as follows:

1. Verify that all cabling is properly connected.
2. Apply power to the camera.

   NOTE:
   The Aluma AC camera comes with a power supply capable of operating from 90 to 264 VAC. Actual power requirements are +12 VDC at 8A maximum.

   Refer to Appendix A-1 Connector pinouts for connector details if you need to create a custom power cable.

3. Open MaxIm LT and connect to the camera by following the procedure in Section 2.1 Connecting the Aluma AC 455/461 camera to MaxIm LT.
4. Take a set of exposures. Set your exposure length to a very short duration to avoid saturation if you are conducting this bench test under bright lighting conditions. Alternatively, you can limit the amount of light entering the camera by covering the sensor opening using a piece of cardboard with only a small hole in it.
5. If your testing is successful, you are now ready to mount the camera to your optical device.

1.7 Power-Down Procedure

CAUTION:

A power up and power down sequence is needed for the correct operation of the camera and long life of the CMOS APS detector. Always disconnect the camera from the control software at least 10 seconds before powering it off. The indicator LED will rapidly flash yellow when it is safe to power down.

Although there is an “emergency power loss” feature, which attempts to power the sensor down gracefully when the input voltage drops, this is only effective for brownout conditions (e.g. battery power running out).

Simply cutting power to the camera while operating is unsafe and is not recommended; doing this repeatedly may damage the sensor.

If the camera goes for 10 seconds without any communications with the control PC, then it will automatically power down the sensor. It indicates this by rapidly flashing the LED in yellow (this may look like red and green together).

The CMOS sensor will automatically power back up again when PC communications resume. Note that the cooler does *not* power down with the sensor. If you disconnect from the camera and then reconnect it will seamlessly resume operation, even if the sensor is shut down in the meantime.

At the relatively modest cooler delta-T used by CMOS cameras, thermal shock is not considered a risk; however, best practice is to warm up the cooler prior to shutting down. Therefore, the recommended shutdown procedure is as follows:

1. In the control software, command the cooler to warm up.
2. Wait until the cooler temperature is above freezing (at least 0°C).
3. Disconnect the control software from the camera.
4. Wait at least 10 seconds for the CMOS sensor to power down.
5. Verify the LED is flashing yellow indicating that the sensor is safely shut down.
6. Turn off power to the camera.

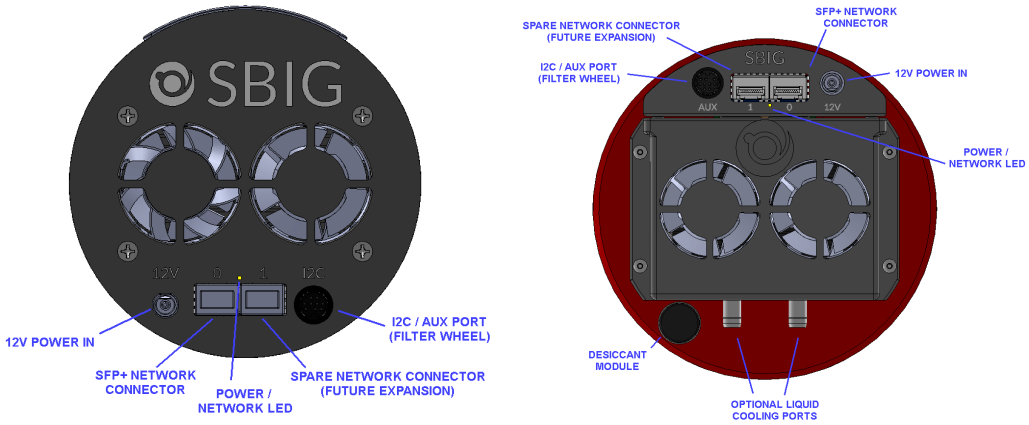
Please note that if the input voltage drops below 9V, the camera will go into emergency shutdown. The following will occur:

- LED will go red continuously.
- Thermoelectric cooler will turn off.
- Sensor will go into power-down mode.
- Firmware processor will shut down.

In this situation, you must cycle power off/on to restore camera operation. Please ensure that sufficient voltage is available. Please note that some through-the-mount wiring has insufficient gauge to handle the camera's power requirements especially when operating at full cooler power.

1.8 Indicator LED

The indicator LED is located on the back panel of the camera, directly above the network port. The primary purpose of the LED is to show power and network status; however, it also has an important function for safely powering down the camera.



The indicator LED functions as follows:

Green	Input Voltage Good (greater than 11.6V)
Yellow (mix of red/green)	Input Voltage Low (less than 11.4V)
Red	Input Voltage Very Low (less than 10V)
Blinking (any color)	Blinks briefly whenever network traffic occurs
Yellow rapidly flashing	Sensor is powered down; safe to turn off camera
Dark	LED turns off during image integration

When the camera is initially powered up, the sensor will be in power-down mode (flashing yellow). The sensor will be powered up when communications with the PC are established. If communications stop then the sensor will be powered off after 10 seconds. Do not power down the camera while the sensor is powered up.

It is possible to force the LED off via the DL Imaging driver setup page; however, the flashing yellow sensor power-down indication cannot be disabled.

1.9 Gain Setting

The IMX455 and IMX461 sensors have adjustable gain settings, which determine the performance parameters of the sensor. The gain is adjustable from 1X to 16X.

MaxIm LT software provides “High Gain” and “Low Gain” readout modes, which by default are 3X gain and 1X gain. The actual gain setting used for each can be adjusted via DL Config software.

The baseline gain of 1X provides a full well capacity (saturation level) of ~51,000 electrons, and a read noise of approximately 2.1 electrons.

The default high gain of 3X provides a full well capacity of ~ 17,000 electrons, and a read noise of approximately 2.6 electrons.

Going to higher gains will result in lower read noise; however, the saturation level will become correspondingly lower. We recommend 3X gain as the best compromise between dynamic range and read noise. It is worth noting that the sky background produces photon shot noise, which will usually become dominant over the read noise on long exposures.

2 - Operating the Aluma camera with MaxIm LT

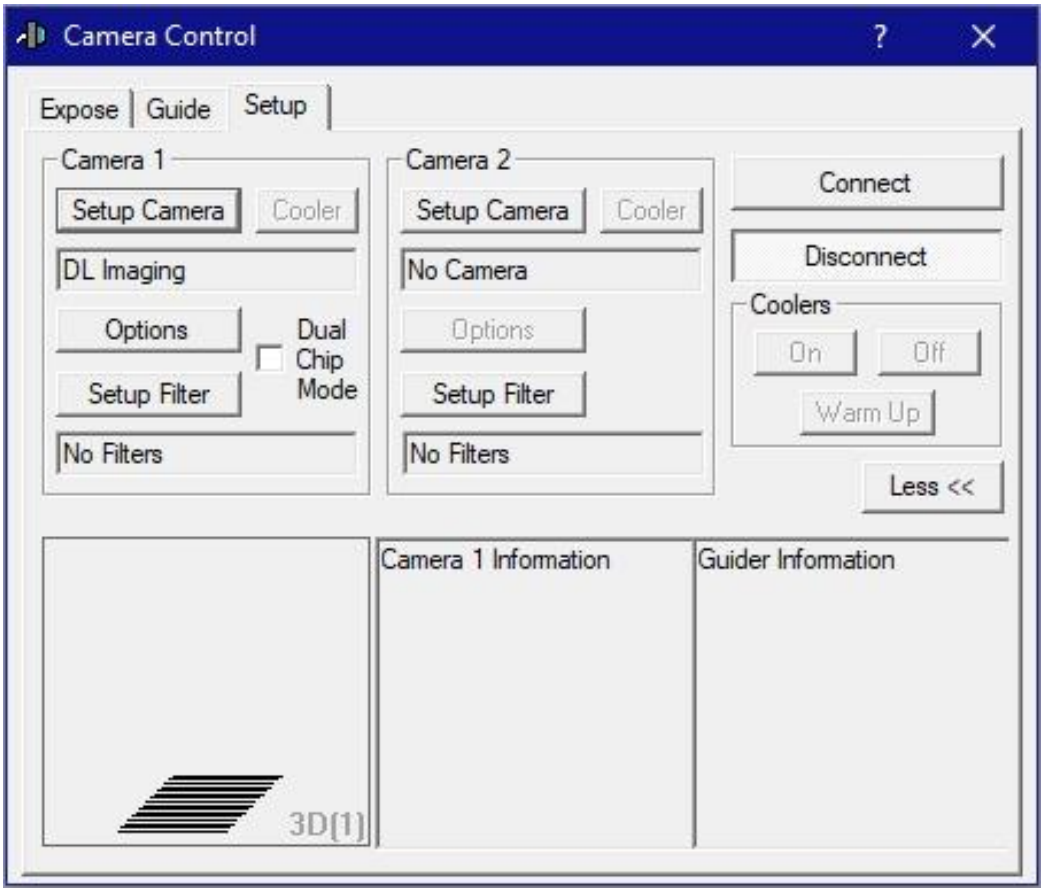
The MaxIm LT application allows full configuration and control of the SBIG Aluma AC cameras. Calibrating files, automating imaging sequences, logging, and various image processing tasks can all be performed. Please note however that since MaxIm LT and MaxIm DL both share the same Help file, not all features detailed in that file will be enabled in MaxIm LT. Full feature access requires MaxIm DL Pro.

The procedures in this chapter are intended as a basic introduction to connecting and operating the Aluma hardware. Consult the Help file for further information on specific parameters, detailed procedures, and various tutorials.

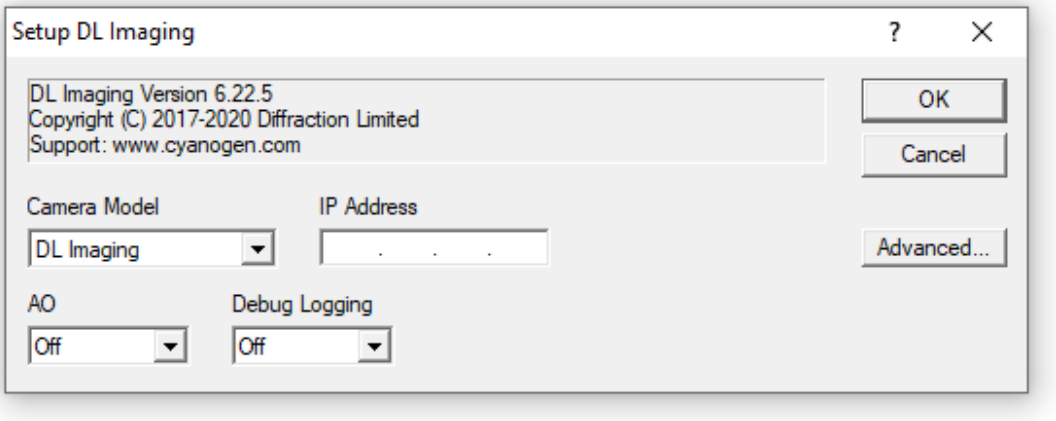
2.1 Connecting the Aluma AC 455/461 camera to MaxIm LT

The following is the basic MaxIm LT procedure used to configure and connect to the Aluma camera. Launch the MaxIm LT application.

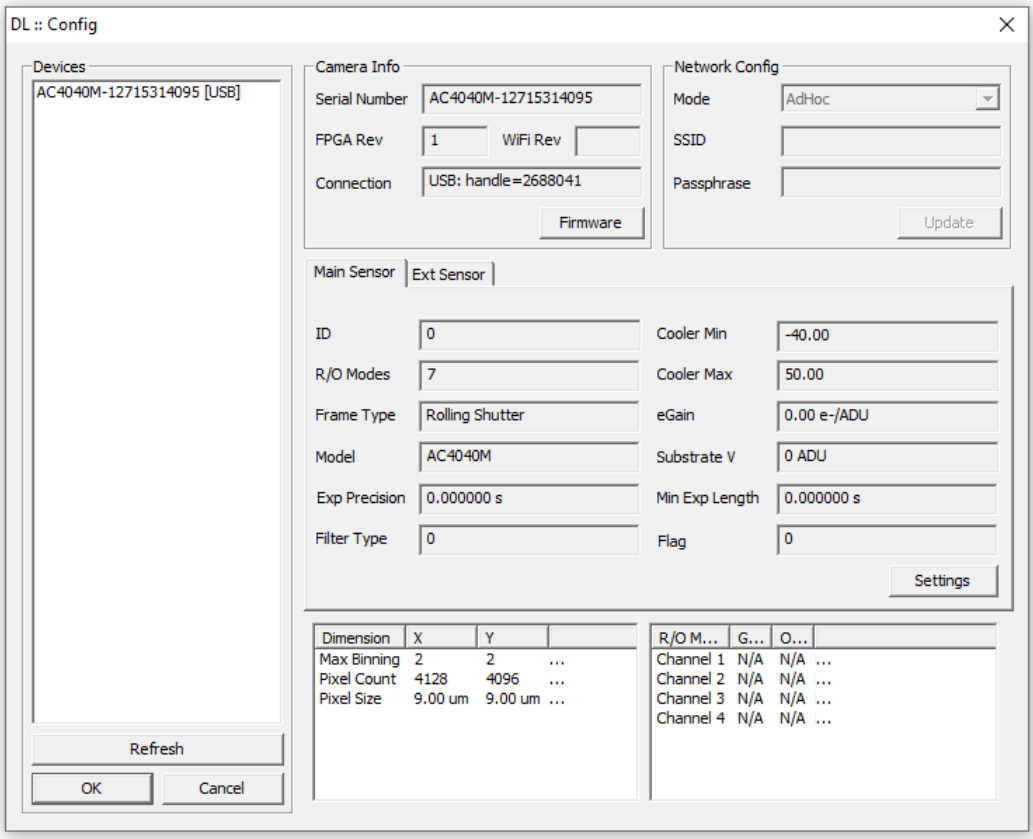
1. Click the Camera Control icon  or press Ctrl-W to open the *Camera Control* form and click the *Setup* tab.



2. Click the *Setup Camera* button under Camera 1. The *Setup DL Imaging* form opens.



3. Click the *Camera Model* drop-down. Select *DL Imaging*.
4. Ensure that the *AO* selector parameter is set to *Off*.
5. Click the *Advanced* button. The *DL :: Config* form opens.



This form allows you to check camera parameters and also to perform firmware updates and additional camera configuration.

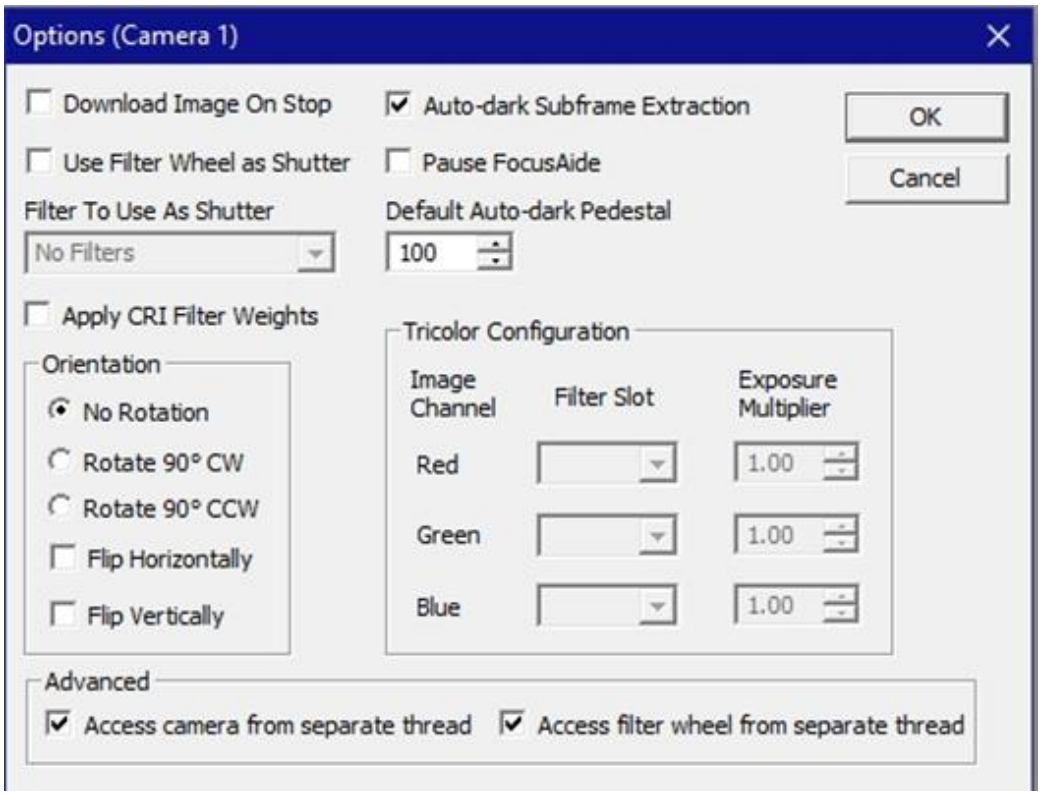
Your camera should appear under *Devices*. The camera serial number is displayed so you can recognize it if there are multiple cameras in your system. Click on the camera you wish to use and its information will appear under *Camera Info*. Click OK.

Various camera parameters will auto-populate the display fields in the form. The default settings should be fine for your initial connection - reconfigure them if required. Full details on these parameters are available in the MaxIm DL Help file and at:

https://diffractionlimited.com/help/maximdl/SBIG_Gen_3.htm

Click *OK* to confirm your camera selection and close the *DL :: Config* form.

6. Click *OK* to accept the settings and close the *Setup DL Imaging* form.
7. Click the *Options* button under Camera 1. The *Options* form opens.
8. Configure any of the optional camera parameters if required or use the default values as a starting point.

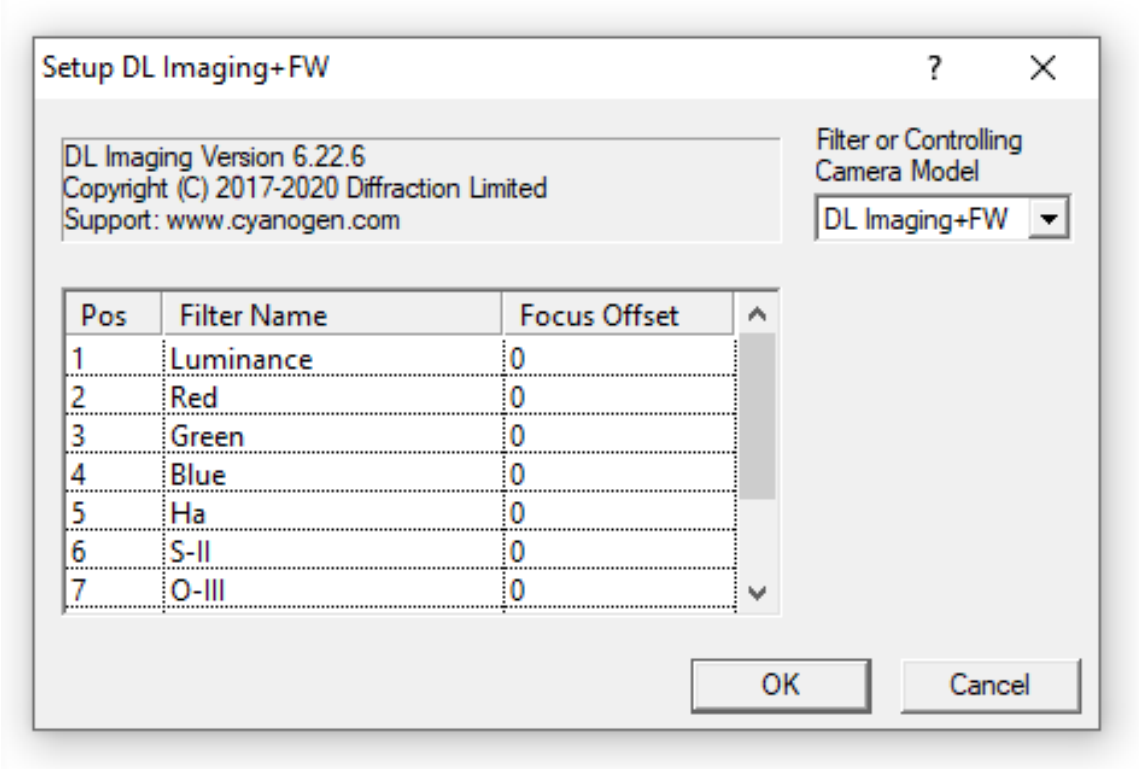


NOTE:
Access camera from separate thread and *Access filter wheel from separate thread* must both be selected for both Camera 1 and Camera 2 (if used).

TIP:
SBIG AFW filter wheels are supplied with a dark frame blank. Install it in the filter wheel, and enable **Use Filter Wheel as Shutter**. **Set Filter To Use As Shutter** to the dark frame slot. This will allow for automated capture of calibration frames.

9. Click *OK* to accept the settings. The *Options* form closes and you are returned to the *Camera Control* form.

10. If you have installed a filter wheel, perform steps 11 through 13. Otherwise go to step 14.
11. Click the *Setup Filter* button under Camera 1. The *Setup DL Imaging+FW* form opens.



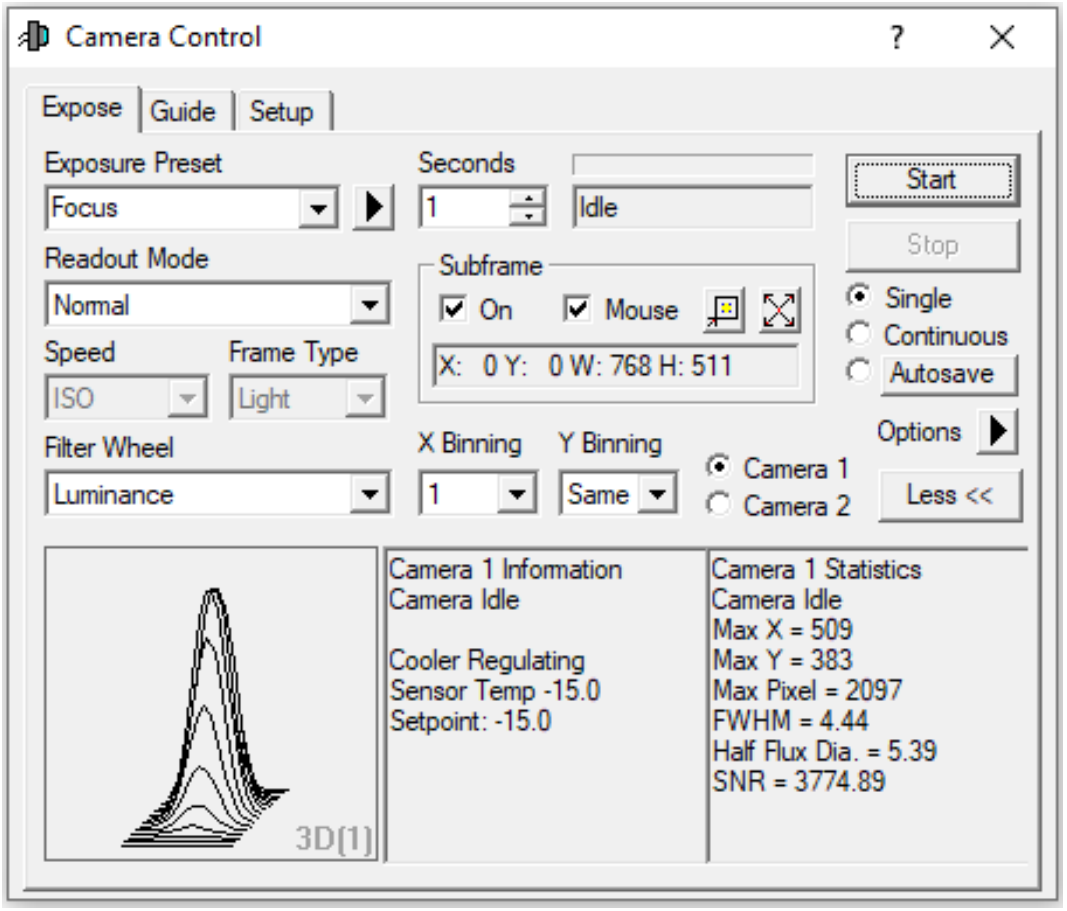
12. Click the Filter or Controlling Camera Model drop-down and select *DL Imaging+FW*. The default filter positions and names are displayed.
13. Click *OK* to accept the settings. The *Setup DL Imaging+FW* form closes and you are returned to the *Camera Control* form.
14. Leave *Camera 2* set to *No Camera*.
15. Click the *Connect* button to establish camera communications.
16. Enable the camera cooler by clicking the *On* button.
17. Click the *Cooler* button under Camera 1. The *Set Camera Cooler* form opens.
18. Set the desired cooler temperature (in degrees Celsius) and click *OK*. The *Set Camera Cooler* form closes.
19. The Aluma AC camera is now connected and ready to begin imaging.

Note that the next time you open MaxIm LT, your option selections will automatically appear in the *Setup DL Imaging* form.

2.2 Basic Imaging Procedure

After setting up your camera as stated in Section 2.1 Connecting the Aluma AC 455/461 camera to MaxIm LT, the *Expose* tab in the *Camera Control* window allows you to set the exposure parameters and initiate imaging. This procedure details the basic approach to imaging with an Aluma AC camera.

1. Click the *Expose* tab. The form displays the following:



2. Click the *Options* menu and select *Camera Settings*. Applicable settings for the Aluma AC 455/461 camera include:
   - *Use Ext. Trigger* (This is not selected by default. Refer to Appendix A-1 Connector pinouts for information on using the *Trigger In/Trigger Out* function.)
   - *Fan Speed* drop-down list
   - *Auto Fan Speed*
   - *Enable Status LED* (Normally enabled. Turn this off to disable the LED on the side of the camera for darkness.)
   - *Subexposure Duration* (refer to 2.3 StackPro™ Subexposure Function for details)

   Configure the parameters as required and click *OK* to accept.

3. Configure the parameters as follows:
   - Click on the *Camera 1* radio button.
   - *Exposure Preset*: The presets allow you to quickly configure the exposure parameters for different types of imaging. Use the Standard exposures option for this introductory imaging procedure.
   - *Readout Mode*: There are five available readout modes: High Gain, Low Gain, StackPro High Gain, StackPro Low Gain, and HDR.
   - *Frame Type*: Light
   - *Filter Wheel:* If a filter wheel is installed, select the desired filter.
   - *X Binning*: 1
     When binning greater than 1 is selected, the electronic charge from groups of adjacent 2x2 pixels is electronically summed in the camera before readout. This process effectively increases sensitivity, but at the cost of lower spatial resolution. Binning of the X and Y axis of the sensor can be configured individually.
   - *Y Binning*: Same or 1
   - *Subframe*: Deselect the On checkbox. This will ensure that you capture the entire frame, rather than just a part of it.
   - *Seconds*: Set the desired exposure time in seconds. You can use the scroll arrows or type in a value into the field. Exposures of less than a second must be entered as decimal values.
4. Click the *Options* arrow. A list of choices is displayed. This menu is used to access and configure a number of imaging parameters to customize your imaging requirements.

   For this introductory imaging procedure, set the following:
   - Click on *No Calibration*.
   - Click on *Set Image Save Path*. The *Select Folder* form opens. Use this to specify where to save your images.
   - Click on *Exposure Delay*. This sets a delay time (in seconds) prior to the start of an exposure. If you are taking a continuous sequence, this delay will be applied between each image.
   - Click on *Show Tool Tips* if you want to display pop-up tips on form options.
5. To begin an individual exposure, click the *Single* radio button and then the **Start** button. You can end the exposure manually at any time by pressing **Stop**. You must save this image manually if you want to keep it.
6. To begin a continuous sequence of identical exposures, click the *Continuous* radio button and then the **Start** button. The sequence only ends when you press **Stop**. This mode is generally used for focusing and framing purposes, and the acquired images are not saved.
7. To configure a custom sequence of exposures, click the *Autosave* button. The *Autosave Setup* form opens.

For this introductory imaging procedure, set the following:

- *Autosave Filename*: Enter the base filename (e.g. “Area A”) you want to use for the sequence of images. Each image file taken will use this name, appended with an individual frame number, for example, "Area A-001.fit".
- *Dither*: Off
- *Delay First*: Specify a delay time (in seconds) prior to taking the first exposure, if desired.
- *Delay Between*: Specify a delay time (in seconds) between exposures, if desired.
- Click the *Slot 1* button and configure each of the parameters on the line as you require. The *Repeat* parameter allows you specify how many of these particular exposures will be taken. An optional *Suffix* can also be automatically applied to the end of the filename to aid you in identifying subgroups of images later on. For example, if you add a suffix of "a", this will produce a filename such as "Area A-001a.fit". If you use only one imaging slot for your custom sequence then you don’t really need a suffix. However, if you set up multiple slots then you **must** add a suffix, and each suffix must be unique. You can configure up to 32 slots when setting up an Autosave sequence.
- Click **OK** when you are finished configuring the sequence.

8. To begin the custom sequence, ensure that the *Autosave* radio button is selected and click **Start**. You can end the Autosave sequence at any time prior to its completion by pressing **Stop**.

3 - Image Calibration

Image calibration, also known as image reduction or pre-processing, applies corrections for tiny defects and variations in the camera sensor and optical system. Proper image calibration is of the utmost importance in producing the highest-quality images possible.

No electronic imaging device is perfect. Each sensor has a unique response in the following three areas:

- Bias level
- Dark current
- Raw sensitivity to light levels

These effects vary from sensor to sensor, and they also vary from pixel to pixel within the same sensor. Each response affects the intensity represented in every pixel of the image in a specific way. The combined effect of these pixel variations may be relatively small on brightly-lit images, but under low-light conditions, they can become extremely important.

The majority of the problems caused by these variations can be readily removed by calibrating the raw image. Performing basic image calibrations can provide a huge improvement in the signal-to-noise ratio, resulting in much greater sensitivity. Normalizing these variations also provides a truer representation of the subject in the working image. This provides the best possible basis for any subsequent image processing.

The basic calibration steps are termed Bias, Dark, and Flat-Field calibration. These are detailed below. A general workflow is then provided for image calibration and the subsequent combining of multiple light frames, if required.

Bias is inherently included in all flat-field and dark-field images. For CCD sensors, there is sometimes a benefit to performing bias frame calibration separately. CMOS imaging sensors work quite differently, and cameras that include features such as StackPro™ affect the bias level. For that reason, we do not recommend using separate Bias frame calibration for CMOS sensors such as those in the Aluma AC cameras.

Please note that calibration images must be taken using the same *Readout Mode* as the images you intend to calibrate. Otherwise the calibration will not be performed correctly.

Refer to the online Help file for further information and more detailed procedures, as required.

3.1 Dark Frame Calibration

Every camera sensor produces a certain amount of dark current, which accumulates in the pixels during an exposure. The dark current is produced by heat. High-performance cameras cool their sensors to minimize this effect.

The main problem with dark current is that it accumulates at a different rate in every pixel. Some pixels are "hot" and others are "cold". Unfortunately there is usually a spattering of pixels that are especially hot, which degrade the image a great deal. Fortunately, the effect of hot and cold pixels can be easily removed by subtracting a dark frame.

A dark frame is an exposure taken under the same conditions as the light exposure, but with no light striking the sensor array. Since each pixel is consistent in its dark current at any one temperature, the dark frame can be subtracted from the light frame to remove the fixed pattern from the image. For most sensors this produces a striking improvement in the image.

Unfortunately, while the rate of dark current is constant, the actual accumulation of dark current is random. Anything that is random in imaging is noise, which is the enemy of sensitivity. Doubling the dark current increases the random noise produced by the square root of 2 (approximately 1.414). This means the hot pixels produce significantly more noise. Since the noise is random and therefore unpredictable, it cannot be removed; in some calibrated images they will be brighter than normal, and in others they will be darker than normal. You can improve hot pixels, but you cannot completely fix them.

So subtracting a dark frame eliminates noise because it gets rid of the gross pixel-to-pixel variations in dark current. Unfortunately, and perhaps counterintuitively, subtracting a dark frame also adds noise to the image. Every pixel has random read noise, plus the residual dark current noise. This noise does not subtract, but rather adds in a root-sum-square fashion. Therefore simply subtracting one dark frame increases the noise level 41%.

The way to get rid of this noise is to remove it by averaging multiple dark frames. Every time you quadruple the number of averaged dark frames, you drop the noise contribution in half.

Taking Dark frames

1. Connect to the camera (as per section 2.1) and click the *Expose* tab.
2. Configure the tab's parameters as follows:
   - Click on the *Camera 1* radio button.
   - E*xposure Preset*: irrelevant
   - *Subframe*: Set to *Off*. MaxIm LT will automatically extract a subframe from the full frame if required.
3. Click the *Options* arrow and set the following:
   - Click on *No Calibration*.
   - Click on *Set Image Save Path* and specify the desired file location.

4. Click the *Autosave* radio button to configure a sequence of 10 to 20 identical exposures. You only need to configure one slot with the required parameters:
   - *Type*: Dark
   - *Exposure*: Set to the same length as your Light frames
   - *Binning*: Set to same as your Light frames
   - *Readout Mode*: The stack mode and gain settings must be set to the same as your Light frames
   - *Repeat*: Set to the number of exposures you want

   Click **OK** when done.

   Note: Since this camera does not have an internal mechanical shutter, light must be blocked through other means. If you have an attached filter wheel, a filter blank can be used to block light. Usually, the highest slot number is used. This can be configured in the MaxIm LT software; please see the software manual for more information.

5. Click the **Start** button to begin the sequence.

When the sequence completes, you will have a set of dark frames that can subsequently be used to create a calibration group and apply a dark calibration to your light frames.

3.2 Flat-Field Frame Calibration

Each pixel in the camera has a slightly different sensitivity to light. These sensitivity differences add another noise component to the image (known as flat-fielding error) unless steps are taken to compensate. While flat-fielding correction is important for achieving high quality images, it is absolutely essential for accurate photometric measurements.

Pixel-to-pixel variations in light sensitivity are imprinted into an image, with the more sensitive pixels showing up as brighter dots. When long exposures are used to image extremely faint subjects, such as in biological or astronomical applications, the ultimate sensitivity limit is determined by how precisely the flat-fielding error can be removed.

There are several common sources of flat-fielding variations. Typical sensors have pixel-to-pixel variations on the order of 1%. Vignetting in the optical system can reduce the light flux at the corners of the sensor. Dust on optical surfaces near the sensor can cast shadows (often called “dust donuts” due to their appearance in centrally-obstructed optical systems). Compressed air can help reduce dust donuts, but it is often difficult to completely eliminate them.

To create a flat-field frame, the optical system must be illuminated by a uniform light source and an exposure is taken. To avoid non-linearity at the top and noise at the bottom of the camera's range, the exposure is usually chosen to get an average value of 30% to 50% of the saturation level. The flat-field is then renormalized by dividing each pixel into the average value in the array. Any pixel that is more sensitive is assigned a number slightly below 1 and any pixel that is less sensitive is assigned a number slightly above 1. When this frame is multiplied by a raw image, it removes the sensitivity variations.

Methods for acquiring Flat-Fields

Flat-fielding is by far the most troublesome calibration method. The entire aperture of the optical system must be evenly illuminated with light – if this is not done very carefully, then the flat-field will be wrong. Light leaks will ruin the calibration by adding unfocussed light that did not pass through the optical system. In addition, once calibrated, the camera cannot be moved or even refocused. Finally, some sensors have significant flat-field variation as a function of wavelength (color), and it can be difficult to create a reasonable facsimile of the normal illumination spectrum.

Given these problems, a good flat-field can be very difficult to achieve for certain types of optical equipment, and so this calibration step is sometimes skipped.

The flat-field frames themselves must be calibrated. To do this you must use flat-darks, which are dark frames having the same exposure duration and settings as the flat-field frames.

NOTE:
We recommend not performing bias frame calibration separately for CMOS cameras. Dark frame calibration also subtracts the bias level. We strongly recommend the use of separate light-dark and flat-dark exposures if the exposure time of the light and flat-field images is not the same, which is almost always the case.

Taking Flat-Field Frames

1. Configure your optical system to acquire flat-fields, as suggested above.
2. Connect to the camera (as per section 2.1) and click the *Expose* tab.
3. Configure the tab's parameters as follows:
   - Click on the *Camera 1* radio button.
   - *Exposure Preset*: irrelevant
   - *Subframe*: Set to *Off*. MaxIm LT will automatically extract a subframe from the full frame if required.
4. Click the *Options* arrow and set the following:
   - Click on *No Calibration*. Calibration must be off when collecting calibration frames.
   - Click on *Set Image Save Path* and specify the desired file location.
5. Click the *Autosave* radio button to configure a sequence of 10 to 20 identical exposures for each filter you used in your light exposures. Configure one slot per filter with the required parameters and number of repeat exposures you want. Click **OK** when done.
   - *Type*: Flat
   - *Exposure*: Set this to produce an image with 30% to 50% of the saturation level
   - *Binning*: Set to same as your Light frames
   - *Readout Mode*: Set to same as your Light frames. If your Light frames are taken using one of the *Stacked* modes, then your Dark frames must also be taken in that mode.
   - *Repeat*: Set to the number of exposures you want

   Click **OK** when done.
6. Click the **Start** button to begin the sequence.

When the sequence completes, you will have a set of flat-field frames that can subsequently be used to create a calibration group and apply a flat-field calibration to your light frames.

NOTE:
When you configure your calibration schema, you will need dark frames matching the exposure duration your flat-field frames, in addition to the dark frames matching the exposure duration of your light frames. In other words, you will usually need a set of "darks" and a set of "flat-darks".

3.4 Understanding Calibration Groups

MaxIm LT allows you to set up the calibration frames into multiple groups of files to provide a high level of calibration automation and flexibility, including:

- Automatic creation of master calibration frame libraries
- Fully-automatic calibration of images sequences involving different exposures and binning
- Automatic selection of flat-darks

As previously discussed, calibration requires bias, dark, and flat files. In practice, users can often take exposures with different settings in a single imaging session. Individual exposures may vary by exposure time, sensor temperature, binning, subframing, and different cameras may even be in use.

Differences in binning, exposure times, and of course cameras cannot be accommodated except by using multiple calibration frames. Switching back and forth manually can be time consuming, particularly if complex exposure sequences are taken with different levels of binning.

A Calibration Group is simply a set of one or more calibration frames that are taken under the same conditions. For instance, a set of 10 dark frames taken at -20C with a specific camera would be one group. A set of flat frames taken at -10C with binning set to 2x2 would be another.

These groups can be automatically generated by scanning a folder or folder tree. All image files with matching characteristics are grouped together, based on the information in their image headers. Alternatively, the user can choose to manually create calibration groups.

All the files in a group are combined using an average, median, sigma combine, or SD Mask algorithm to make an internal "master frame" that is used to calibrate images. This master frame is not visible to the user.

Some users prefer to generate and save the master calibration frames so they can be quickly reloaded and used at a later date. The *Set Calibration* command allows you to do this. This step is completely optional and is not required for the calibration process to work properly.

When master calibration frames are generated and saved to disk, the list of groups in the *Set Calibration* window is automatically replaced by these master frame files. If bias subtraction is enabled and suitable groups are available, the darks and flat masters will automatically be bias-subtracted. Similarly, the flat masters will be dark-subtracted if dark subtraction is enabled and suitable groups are available.

When the masters are saved to disk, they are tagged with image header keywords to indicate whether these subtractions have been done. In that way when they are loaded again later, MaxIm LT will know whether they need to have these subtractions performed or not.

3.5 Calibrating and Combining Images

While calibration reduces or removes the majority of the problems caused by bias, dark current, and light sensitivity variations in a camera sensor, there is still random noise remaining in the actual scene that the sensor records. If a pixel receives 100 photons of light from a target, there will be 10 photons of quantum photon noise due to the statistical nature of light. Some additional noise will be present due to camera read noise and dark current noise.

The key thing to note here is that this noise is random in nature and varies from frame to frame, whereas the object of interest generally does not. By combining numerous individual frames of the same subject, the subject's signal steadily increases in a linear fashion. However, since the noise in a single image is random, its increase in a combined image follows a Poisson statistical distribution and so it increases more slowly. Combining images therefore increases the overall signal-to-noise ratio in the final result, yielding both smoother subject and background appearances.

Combining files (also known as "stacking") is not limited to your light frames, but is also applicable to your calibration frames, since all imaging frames include noise.

When you add or subtract images, the noise is always additive. Subtracting a single dark frame from a light frame will remove large pixel-to-pixel variations in the average accumulation of dark current, but it will also increase the random noise in the light frame by 41%. If instead you averaged sixteen dark frames together prior to subtraction, the noise will only be increased by 10%.

The standard combine method is to Average the frames. This produces the best results for purely random Gaussian noise. Unfortunately if there is an "outlier" pixel on one frame (e.g., a cosmic ray hit) then it will be included in the average.

Median combine is much more effective at suppressing outlier pixels. Unfortunately, median combining increases the noise level 25% compared to averaging. When median combining flat-field frames, renormalization is also required. This ensures that each frame is at the same average brightness. MaxIm LT does this automatically.

An alternative to Median combine is to use Sigma Clipping or Standard Deviation Masking. These techniques throw out outlier pixels and then average the remaining. They are in effect a compromise between median and average, combining the noise reduction advantages of Average with the outlier pixel rejection of Median combine. You can also select renormalization options for these methods.

General workflow for calibrating and combining images

The following is a general summary of the basic workflow used in MaxIm LT to calibrate and combine images. As such, consider it an overview. Numerous parameters not cited here are available to tailor the process to specific imaging types and requirements. Refer to the MaxIm DL Help file for full tutorials, further information, and more detailed procedures, as required.

Under *Automatically Generate Groups* click the *Folder* button to browse to a folder containing your calibration images.

1. Use the *Set Calibration* command to set up calibration groups that will be used to calibrate your individual raw light frames. Proceed as follows:
   a) Click *Process* > *Set Calibration*. The *Set Calibration* form opens.
   b) Click the *Folder* button in the *Automatically Generate Groups* section to browse to the folder containing your calibration images.
   c) Select *Auto-Generate (Clear Old)* using the *Auto-Generate* dropdown button. A set of Calibration Groups will appear in the list, with images pre-sorted by calibration type, exposure, sensor temperature, etc.
   d) To adjust the settings for an individual group, click on the group to highlight it. You can then set the parameters such as *Combine Type* in the Group Properties section as desired. You can also change the *Name* of a group by double-clicking it in the list.
   e) If you want to create a master calibration file for this group of files, click the *Replace w/ Masters* button. MaxIm LT will combine the files and display the master file name in the *Group Membership* field. The master file will automatically be saved in the same folder that contains the individual calibration files. If you choose not to create such master calibration files, MaxIm LT will stack the calibration automatically when you calibrate your light frames.
   f) Click **OK** when you are done.

2. Use the *Stack* command to calibrate and combine your raw light frames. Proceed as follows:
   a) Click *Process* > *Stack*. The *Stack* form opens.
   b) If you are using the camera's integrated filter wheel controlled by MaxIm LT then on the *Select* tab, turn on *Classify by FILTER*. Click the *FILTER* button to set up the filter mapping. This will determine which filters are mapped into the LRGB color channels. To change a row, click once on the row, then click once on the *Filter Color(s*) item, and enter a new value. This will ensure that your filters are automatically assigned to the correct group.
   c) Enable the *Mark added images as Auto Calibrate* checkbox. Each image will automatically be calibrated as it is needed, using the settings from the *Set Calibration* command.
   d) Click the *Add Files* button to select the desired files. You can also use the drop list adjacent to the *Add Files* button to select entire folders of files to add. Browse to the folder where your images are located. When you add individual files or folders, they will appear in the *Groups* tree at left. You can also deselect individual files from the tree so that they will not be included in the stacking process.

e) Configure the parameters in the *Stack* form's remaining tabs as required:

- Select the *Quality* tab to configure parameters that limit which files will be stacked, based on various quality criteria.
- Select the *Align* tab to enable precise alignment of images. This is useful if a certain amount of shift from image to image is present for one reason or another.
- If you are using the camera's integrated filter wheel then select the *Color* tab to customize the color balance settings, if desired. Otherwise click the *Defaults* button, which assumes 1:1:1 color balance.

The parameters contained in these tabs are explained in detail in the Help file. Refer to the *Image Processing – Stacking* tutorial.

f) Select the *Combine* tab and set the *Combine Method*. For large numbers of images, try using *Sigma Clip* - a *Sigma Factor* of 3 is a good starting point. If you have a modest number of images, the *SD Mask* mode will produce a better result but will take more time - a good starting point is a *Sigma Factor* of 0.5 and *Number of Passes* set to 3.

The remaining Combine parameters and options are detailed in the Help file. Set these as required.

g) Click **Go** to start the stacking process. This may take some time, so you can interrupt and restart the process if needed. If you have multiple image groups, they will be stacked separately. Color sets will automatically be color combined.

When the combining process completes, the final product is a calibrated master light frame that can be used as a basis for any further image processing.

You can save this image in a number of different formats. The FITS (Flexible Image Transport System) file is the standard file format used in astronomical applications. It includes extensive support for header information to describe the image, along with the equipment and procedures used to produce it. The FITS file can also save your images in floating point format, which will better preserve the full data range after stacking.

For other applications, we recommend using 16-bit TIFF images. The choice of TIFF or FITS can be set under: *File* menu > *Settings* > *Files* tab > *Default File Extensions Setting*. This determines the default file type created when MaxIm LT takes images.

4 - Accessories

A variety of accessories are available for the Aluma AC cameras:

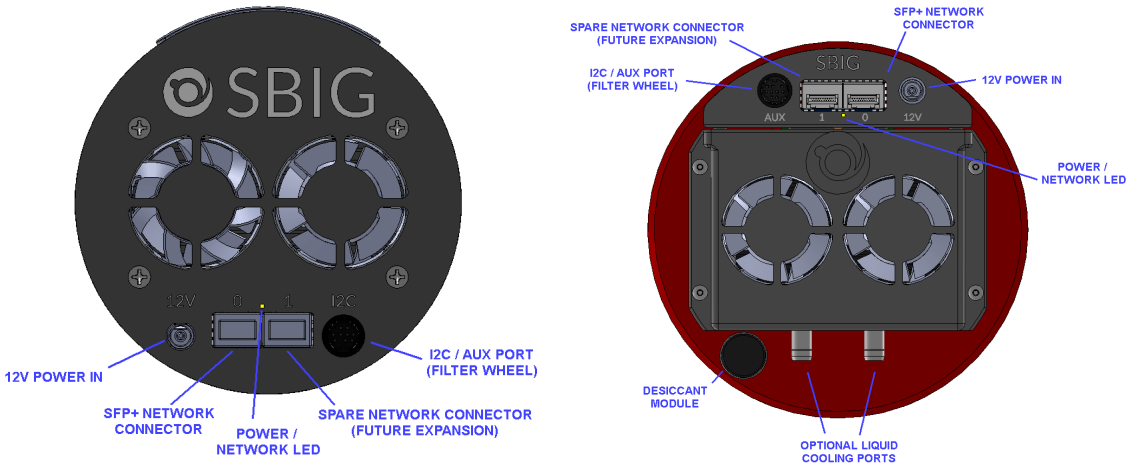
- AFW-10-50SQ ten-position, 50 mm square filter wheel – recommended for AC455.
- AFW-12-50R twelve-position, 50 mm round filter wheel will also work with AC455 but may vignette on faster f/ratio optical systems. It is recommended for f/6 and slower.
- AFW-12-65SQ dual six-position, 65 mm square filter wheel - recommended for AC461.
- StarChaser SC-4 Guide Camera for AC455.
- AO-X Adaptive Optics for use with StarChaser.
- Nosepiece adapters
- Desiccant plugs
- Cables, transceivers, and adapters
- Power supplies

Accessories are available from your authorized SBIG dealer and at:

https://www.diffractionlimited.com

Appendix A: SBIG Aluma AC455 / AC461 Camera Details

A-1 Connector pinouts



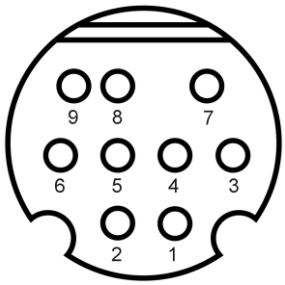
POWER: The POWER barrel connector is center-positive and requires an input of +12.0 VDC (range: 10.0 to 14.5 VDC) at 8 amps maximum.

For a suitable mating connector, we recommend the Switchcraft S10KS17 connector.

NETWORK: The Network connection is a standard slot for an SFP+ transceiver. Use Slot 0 only. Slot 1 is reserved for future expansion, and is currently disabled.

LED: The indicator LED lights up to indicate that power is applied. It also changes color and blinks to indicate power level and network activity. It also rapidly flashes yellow when it is safe to shut off power to the camera. The LED automatically turns off during image acquisition. It can also be turned off via a software setting.

AUX: The AUX connector is a 9-pin mini-DIN. The diagram below shows the pin number identification when looking into the camera connector.



Pin 1: GND	Pin 6: 3.3V Out
Pin 2: I2C SDA	Pin 7: 12V Out
Pin 3: I2C SCL	Pin 8: Trigger Out 0
Pin 4: Trigger Out 1	Pin 9: Trigger In
Pin 5: N/C	

NOTES:

- I2C interface is nominally 3.3V, and will accept up to 5V input.
- The diagram shows the pin number identification when looking into the camera's connector.

NOTE: The *Trigger In* and *Trigger Out* functions are accessed via this connector. The functions must be configured in the MaxIm LT application software when you set up the camera.

CAUTION:

The *Trigger In* input voltage must not exceed 5.5V maximum.

Trigger In is used to initiate exposures via an external control signal. The *Trigger In* signal must be floating (not connected) or connected to the camera's digital GND (or TTL Low Level) before starting the Trigger Mode. When you click Start in the software to begin an exposure, the camera will prepare to start the exposure, and then will wait for the signal. When it sees a rising edge to TTL High Level on the *Trigger In* pin, it will start the exposure. Note that if the *Trigger In* signal is already high when the software command is issued, the exposure will start immediately. The *Trigger In* signal does not need to be held high once the exposure starts; it can be returned to low in preparation for the next exposure.

The *Trigger Out* function can be used to control an external shutter, for activities such as precision timing measurements, or similar. For such purposes, the same signal appears on *Trigger Out 0* and *Trigger Out 1*, and the trigger output signal remains active during the exposure.

Note that *Trigger Out* is an open collector output, which means that it requires an external pull-up resistor to between 3.3V to 12V maximum. When the camera is idle the output is high impedance. While the exposure is in progress the output is pulled low (GND).

A-2 Aluma AC Camera Specifications

AC455M Monochrome

Imaging sensor	Sony Semiconductor IMX455ALK-K
Peak QE	94% (Monochrome)
Sensor size	40.961 mm (H) × 31.108 mm (V)
Imaging pixel array	61 million active pixels
Pixel size	3.76 µm (square)
Full well capacity	51,000e- (depends on gain mode)
Read noise	Depends on gain. Typical 3.6 e- at 1X gain, < 2.1 e- at 3X or higher gain.
A/D converter	16-bit
Exposure duration	0.00016 – 16,000 seconds
Pixel digitization rate	72 MHz
Full frame download	Approximately 0.25 seconds
Binning modes	1x1 and 2x2 software binning
Power	12 VDC at 8A maximum
Power cable	USA, European, Australian
Shutter	Electronic rolling shutter
Temperature regulation	Yes
Cooling delta below ambient	~35° C typical
Dimensions	4.5 inch diameter x 5.6 inch long (11.4 x 14.2 cm)
Weight	3.2 lbs (1.45 kg)
Computer interface	SFP+ 10 gigabit fiber optic Ethernet
OS compatibility	Windows 10 x64, Windows 11 x64

AC455C Color

Imaging sensor	Sony Semiconductor IMX455AQK-K
Sensor size	40.961 mm (H) × 31.108 mm (V)
Imaging pixel array	61 million active pixels
Pixel size	3.76 µm (square)
Full well capacity	51,000e- (depends on gain mode)
Read noise	Depends on gain. Typical 3.6 e- at 1X gain, < 2.1 e- at 3X or higher gain.
A/D converter	16-bit
Exposure duration	0.00016 – 16,000 seconds
Pixel digitization rate	72 MHz
Full frame download	Approximately 0.25 seconds
Binning modes	1x1 and 2x2 software binning
Power	12 VDC at 8A maximum
Power cable	USA, European, Australian
Shutter	Electronic rolling shutter
Temperature regulation	Yes
Cooling delta below ambient	~35° C typical
Dimensions	4.5 inch diameter x 5.6 inch long (11.4 x 14.2 cm)
Weight	3.2 lbs (1.45 kg)
Computer interface	SFP+ 10 gigabit fiber optic Ethernet
OS compatibility	Windows 10 x64, Windows 11 x64

AC451M Monochrome

Imaging sensor	Sony Semiconductor IMX451ALR-C
Peak QE	94% (Monochrome)
Sensor size	43.86 mm (H) × 32.9 mm (V)
Imaging pixel array	102 million active pixels
Pixel size	3.76 µm (square)
Full well capacity	51,000e- (depends on gain mode)
Read noise	Depends on gain. Typical 3.6 e- at 1X gain, < 2.1 e- at 3X or higher gain.
A/D converter	16-bit
Exposure duration	0.00016 – 23,779 seconds
Full frame download	Approximately 0.5 seconds
Binning modes	1x1 and 2x2 software binning
Power	12 VDC at 8A maximum
Power cable	USA, European, Australian
Shutter	Electronic rolling shutter
Temperature regulation	Yes
Cooling delta below ambient	~35° C typical
Dimensions	4.5 inch diameter x 5.6 inch long (11.4 x 14.2 cm)
Weight	4.6 lbs (2.1 kg)
Computer interface	SFP+ 10 gigabit fiber optic Ethernet
OS compatibility	Windows 10 x64, Windows 11 x64

Appendix B: Maintenance

B-1 Cleaning the filters and sensor window

The design of the Aluma AC cameras allows for easy cleaning of the window covering the sensor chamber. There is no need to open the camera body. If internal chamber maintenance is required, please return the camera to Diffraction Limited for service. Opening the sensor chamber will void your warranty.

Remove any accessories that you have attached to your camera, such as a filter wheel and/or off-axis guider.

Dust on the outward-facing sensor chamber window should be blown off if possible. Use a cotton-tipped swab and isopropyl alcohol only if necessary. Use one end of the swab with alcohol and the other end for drying. Never re-use a swab and do not scrub with it – use only gentle pressure.

Filters can be cleaned in the same way.

If you have a few small dust specs remaining, don't worry. Sometimes it is almost impossible to remove them all. Performing a flat field calibration can remove them effectively.

NOTE:
Cans of compressed air may be used to remove dust, but be cautious. Some types may leave a residue if used with too much vigor or improper proximity. Keep the can vertical to avoid expelling the propellant. Follow the manufacturer's instructions, but also test it on another surface prior to using it on the camera.

B-2 Regenerating the desiccant

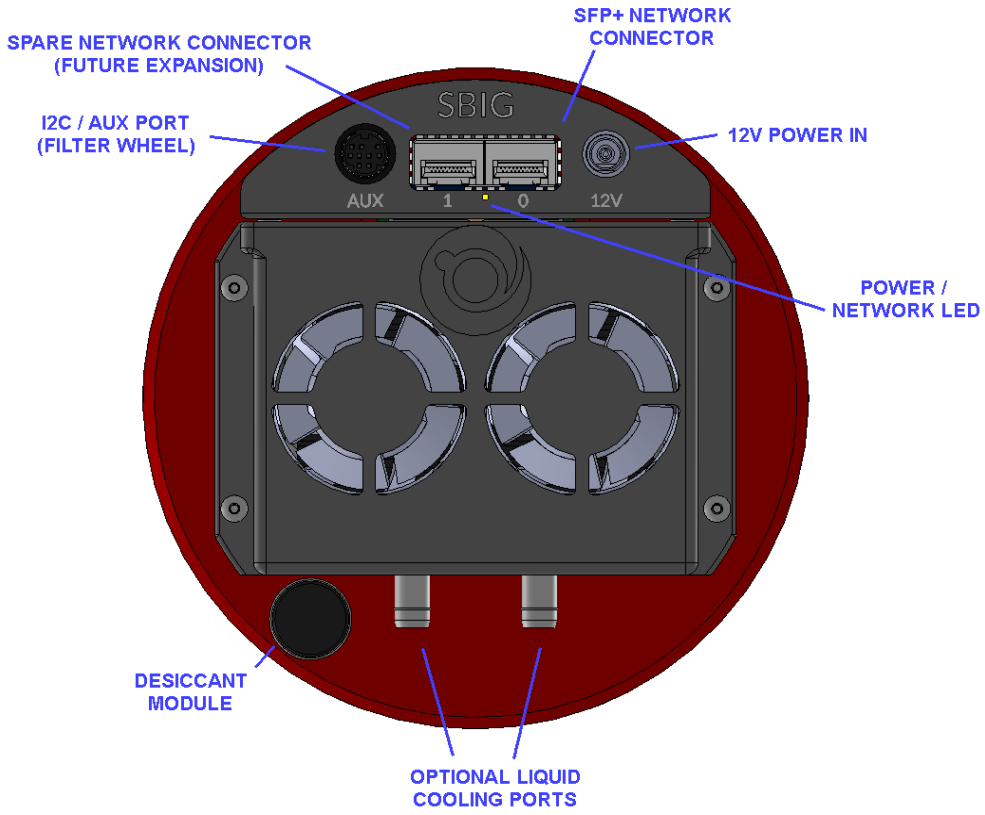
This section describes the regeneration procedure for the desiccant used in the Aluma AC455 and AC461 cameras. The desiccant absorbs moisture inside the camera body, lowering the dew point below the operating temperature of the cooled imaging sensor and thereby preventing the formation of frost.

The desiccant is contained in a small cylindrical container that screws into the back of the camera chamber. In normal operation, the useful life of the desiccant is over a year. However, if the camera is used in high humidity conditions you are advised to regenerate the desiccant every six months, or even sooner if frosting is noticed.

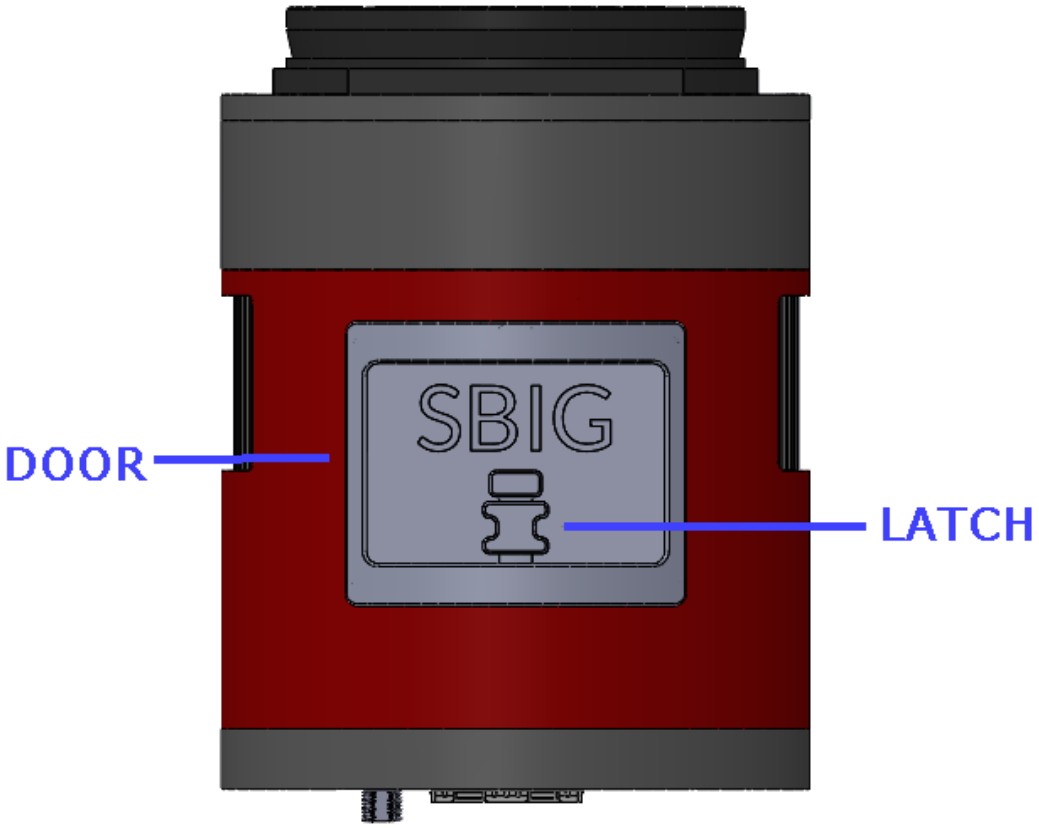
Note: When using a domestic oven with self-cleaning capability, please run a self-cleaning cycle before attempting to recharge the desiccant. Otherwise, the desiccant could become contaminated.

CAUTION:

Failure to regenerate the desiccant regularly can lead to expensive corrosion damage inside the camera body and will void your warranty. Do not ignore this procedure!



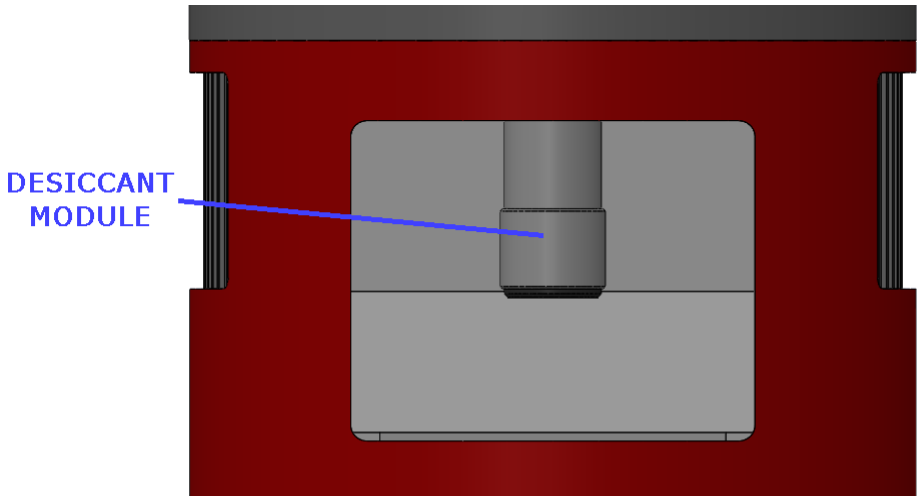
Aluma AC461 Desiccant Module Location



Aluma AC455 Desiccant Module Access Door

To regenerate the desiccant:

1. Place the camera on a clean dry surface with the nosepiece facing upwards.
2. AC455 only: Locate the desiccant access door. Gently slide the latch up towards the front of the camera.
3. AC455 only: Pivot the door outwards from the bottom, remove and place aside. The desiccant module is visible inside.



4. Unscrew the desiccant module and remove from the camera.
5. Set the camera aside with the opening facing down. This will prevent dust from falling into the chamber.
6. Remove the O-ring from the desiccant module and place it aside.
7. Heat the desiccant container in an oven at **350° F (175° C) for 4 hours**. Preheating the oven to avoid hot spots is advised.

   Warning: The temperature must be at least 350° F (175° C) but should not exceed 400° F (205° C). Lower temperatures will not recharge the molecular sieve desiccant, but higher temperatures may melt the adhesive used to seal the module. For this reason, we recommend using a thermometer to check the oven temperature.
8. Remove the desiccant module from the oven when done and as soon as it has cooled enough to handle. Reinstall the O-ring and insert the module into the camera. Ensure that the O-ring does not get pinched.
9. Turn the module clockwise by hand to tighten it. Do not use tools.
10. AC455 only: Replace the door, tilting it in from the top. Ensure it is fully flush with the camera body, before gently sliding the latch download to lock the door.
11. The camera may take up to 24 hours to reach a stable frost-free state after inserting the container. If you need to capture images prior to this time and it frosts again, adjust your cooling so the temperature is above 0° C. This will prevent frosting and the dark current will still be quite low.

    Additional desiccant modules are available from Diffraction Limited.

B-3 Updating the camera drivers and firmware

You should periodically check for updates to your camera's drivers and firmware to ensure the best possible performance. Diffraction Limited supplies a software utility program named *DL Config* that will update the firmware elements in the camera via USB. This is a standalone version of the *DL Config* form mentioned in Section 2.1 Connecting the Aluma AC455/461 camera to MaxIm LT. The program requires a PC with an internet connection and it can be freely downloaded from the Diffraction Limited website at:

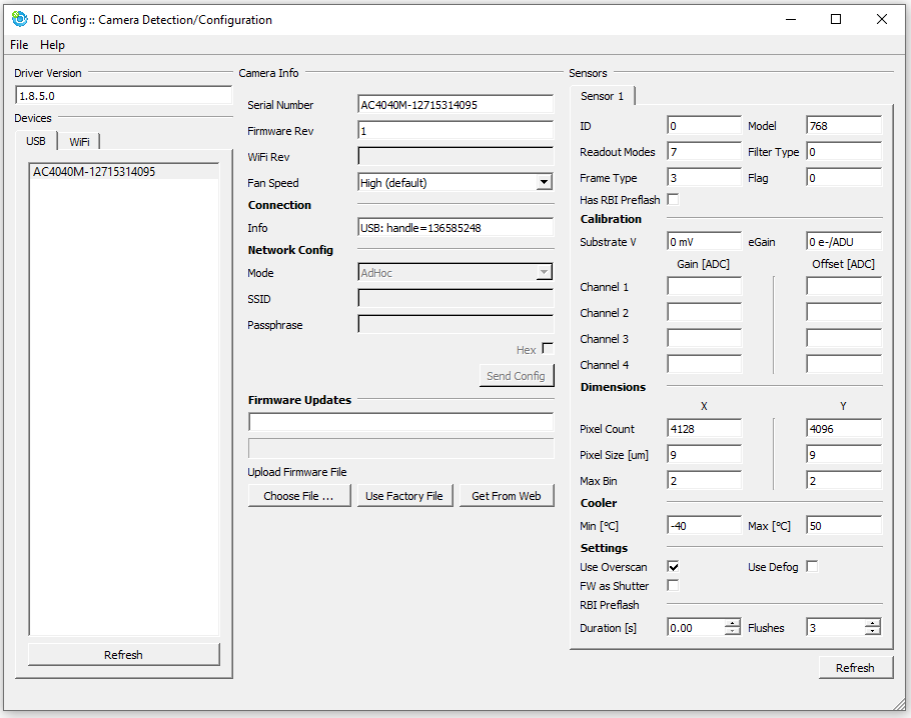
https://diffractionlimited.com/product/aluma-ac455/

https://diffractionlimited.com/product/aluma-ac461/

Click the *DOWNLOADS* button for your specific camera. There you will find a link to the latest version of the utility program. Download and run the program. New drivers are automatically installed together with the *DL Config* utility. A firmware update is also automatically downloaded when you download the utility, but this is not automatically installed. You can choose whether or not to install this. All further instructions are accessible from the application itself.

To update the camera firmware, proceed as follows:

1. Install the latest version of DL Config. This will also update your camera drivers.
2. Power up your camera and connect to the computer, but make sure it is not connected to MaxIm LT or other control software.
3. Go to *Start* menu > *DL Config Utility* and run the DL Config Utility.



4. Make sure that your camera is selected.

5. Under *Upload Firmware File,* click the *Get From Web* button, or navigate to https://diffractionlimited.com/aluma-fpga-firmware/ and download the latest FPGA firmware for your camera.

6. Under *Upload Firmware File* click the *Choose File …* button.

7. Browse to the firmware file you downloaded, and click *OK*.

8. Confirm the upload process in any pop-up dialogs.

9. Wait until the process is completed. Do not interrupt the process or it will revert to old firmware.

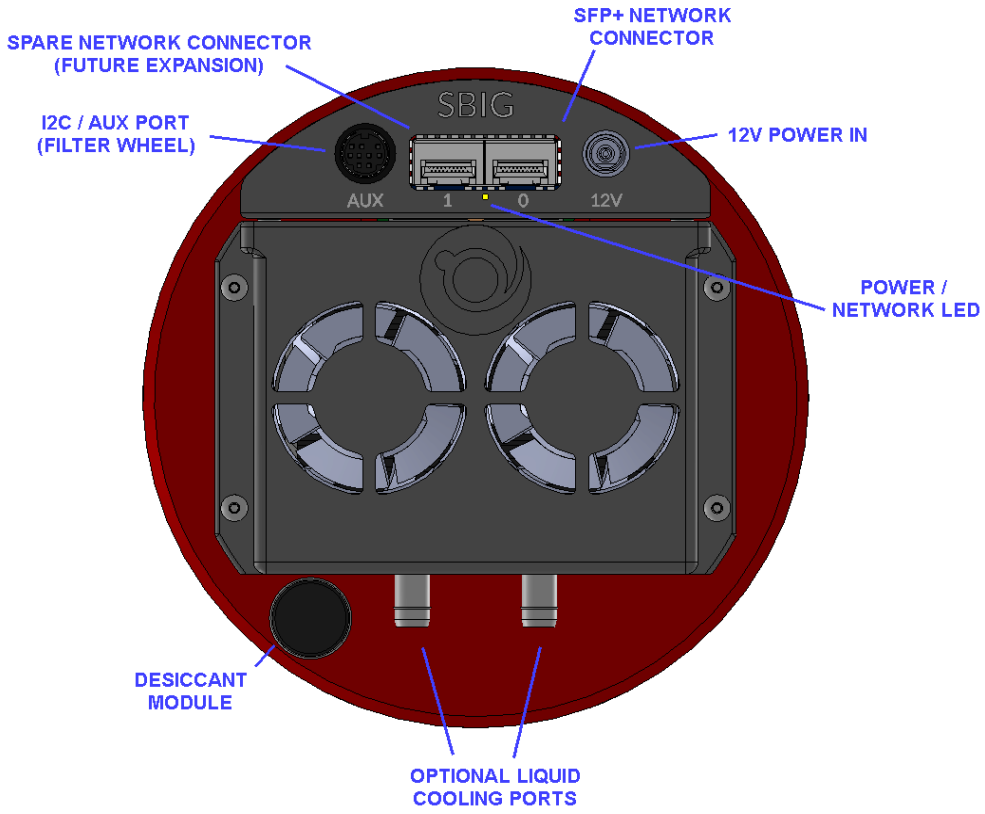
10. When complete, power down the camera and power it up again.

NOTE:
DL Config ships with a "factory file" that can be used in place of a specified firmware in the event of an emergency. If you need to restore your camera's firmware using that file, click the *Use Factory File* button in DL Config. This file is updated with every release of DL Config, and may not be the latest, depending on which version of DL Config you have installed.

B-4 Optional Water Cooling (AC461 Only)

The SBIG Aluma AC461 includes optional water cooling. Water circulation allows you to maintain a lower operating temperature in warm environments. The water circulation helps lower the temperature of the heat exchanger located in the back of the camera and this, in turn, makes it easier for the TE cooler to reach lower temperatures. The water does not need to be cooled, but it may be for additional efficiency. If you do cool the water, be careful that the camera's outer surface does not drop below the ambient air dew point, as this will cause moisture to condense onto the camera.

The water fittings of the Aluma AC461 cameras accept tubing with 1/4 inch inside diameter.



Appendix C: Troubleshooting

If you experience problems with the camera operations, check the following areas:

Check the power:

- Ensure that your camera's power cabling is undamaged and securely attached.
- If you are using a portable power supply such as a 12V battery, check the voltage to ensure that it is operating at a proper level.
- Ensure that the camera is receiving power. The Aluma AC cameras employ thermoelectric cooling and a fan to remove heat. When your camera is powered up, you should hear the fan operating.

Check the network interface:

Follow these recommendations to ensure good network connectivity:

- Use only good quality SFP+ cables and transceivers.
- Ensure that the cable is undamaged and securely attached.
- Do not use a network switch. The connection should be direct from the camera to a dedicated interface on the computer.
- Check that all settings have been made as recommended in 1.3.1 Computer Ethernet Interface Setup - Windows.

Check the firmware and SBIG drivers:

Use the *DL Config* utility program to ensure the camera's firmware is up to date and that the latest drivers are installed. Refer to Appendix B-3 Updating the camera drivers and firmware.

Appendix D: Technical and Warranty Support

D-1 Software Downloads

Downloads are included on the Diffraction Limited website product pages:

http://diffractionlimited.com/

Navigate to your product and click the *Downloads* tab. Software utilities, drivers, user documentation, and a Software Development Kit are available here.

D-2 Technical Support

Technical Support: http://forum.diffractionlimited.com/

Technical Support Phone: (613) 225-2732

D-3 Diffraction Limited Address

Note: You must request an RMA number before returning equipment for repair.

Diffraction Limited
59 Grenfell Crescent, Unit B
Ottawa, ON K2G 0G3, Canada

Appendix E: Compatible software products

E-1 MaxIm LT

MaxIm LT is a limited version of MaxIm DL, and is specifically for controlling SBIG Aluma, and STC cameras. The program operates on Windows computers only. Refer to the Windows Installation section in this guide for details installation.

E-2 MaxIm DL Pro

MaxIm DL Pro is a full-featured camera control and image processing program available from Diffraction Limited. It can control all SBIG camera models and a wide variety of third-party cameras. For product details, refer to the Software page of the Diffraction Limited web site at:

http://diffractionlimited.com/products/software-products/

E-3 Third-Party Programs

A variety of third-party programs exist. To support these, our DL Imaging drivers support the industry-standard ASCOM interface. For more information on ASCOM, and to download the required ASCOM Platform, please visit:

https://ascom-standards.org

Appendix F: SFP+ Fiber Ethernet Primer

A key feature of the Aluma AC455 and AC461 cameras is a high-speed fiber optic connection between the camera and computer. The cameras use a widely-available, industry-standard SFP+ (small form factor pluggable enhanced) fiber optic interface. The computer may require an optional add-on network card or external dongle. This interface has many advantages over USB 3.0:

- Very high speed of 10 Gigabits per second for fast image transfers.
- Cable length can be up to 100X longer than USB 3.0.
- Cables are very lightweight and flexible.
- Eliminates hubs, unreliable USB ports, driver issues, etc.
- Completely immune to electromagnetic interference.
- No possibility of indirect lightning damage as there is no copper connection.
- Using fiber optics means the huge 61megapixel array downloads in about half a second.

All components are industry standard and often used in commercial network products used in businesses and institutions. This means they are readily available, although they are not typically sold in local retail stores. Diffraction Limited offers a limited selection of components if you wish to purchase it as a package.

F-1 Is This More Complicated than USB?

Not at all! In fact, in many ways it is simpler. Ethernet interfaces are standardized across the industry. You might not be familiar with optical fiber, but it basically works the same as copper Ethernet. It is also simpler from a driver perspective. Included software automatically finds your camera's MAC address, and once that is done it simply works! Your computer will need to have an SFP+ 10Gbps fiber optic interface port which may be an add-on accessory.

F-2 Can I Share over a Network?

This is not recommended. Other network protocols may interfere with camera operations. For the best results a single, direct connection to

the computer is strongly recommended. The network protocol used by the camera is not routable over a wide area network.

F-3 What are the Components of an SFP+ Interface?

Fiber cable assembles consist of a few pieces:

- The fiber optic cable itself, which is a pair of flexible plastic or glass fibers in a protective covering.
- Fiber Connectors, which are attached at each end of the cable.
- Transceiver Modules, which the Fiber Connectors plug into at each end.

You will want to purchase the cable with "LC" style Fiber Connectors already built in – one on each end. (You can buy unterminated cable, but you probably don't want to buy the tool to terminate it!)

The Transceiver Module converts between laser light and electronic data. It is usually purchased separately, though sometimes you can purchase a complete kit of cable and Transceivers. Again, Transceivers are needed for both ends of the cable.

The Fiber Connector simply clicks into the Transceiver Module. Then the Transceiver Module plugs into the camera (slot 0) at one end, and the computer at the other end. Simple!

F-4 Am I Buying the Right Parts?

There are many different fiber formats available, and you must buy the right ones. Fortunately, this is simpler than it sounds:

- The Transceiver Modules must be **SFP+**.
    - Make sure they have **LC** type connectors.
    - Do not purchase the older, slower SFP modules as they are **not** compatible.

- The cable must be the correct type:
    - Make sure the cable has **LC** type connectors at both ends (often labeled LC/LC).
    - We recommend OM3 cable, which is **aqua** in color.
    - You can also use OM4 cable, which is **violet** in color.
    - Other types / colors of cables are not compatible and *will not work*.

The aqua color OM3 cables are less expensive and work extremely well over the distances you will be using. Violet OM4 cable will also work, but it is intended for kilometers-long cable runs and there is no reason to use it.

The LC style connectors are standard. There is another type called SC – don't get those.

F-5 What About the Computer Port?

Of course, if your computer doesn't already have an SFP+ compatible Ethernet port, you will need one more piece. Fortunately, there are many options:

- If your computer has a free PCIe slot, then you'll want to get a PCIe SFP+ Fiber Ethernet card.
- If your computer has a Thunderbolt 3 or 4 port, then you'll want to get an SFP+ to Thunderbolt adapter. (Tip: Several Primaluce Eagle series computers have Thunderbolt built in. This includes Eagle4 Pro, Eagle5 Pro, and Eagle5 S.)
- If your computer has a copper 10GB Ethernet port that you aren't already using, you can use a format converter to convert from fiber to copper. Be sure to use CAT6a or CAT7 cables on the computer side of the converter.

There are also SFP+ copper modules with RJ-45 connectors available. **Do not use these.** Our testing has shown that they do not work properly; they may connect to the camera, but the connection is unstable, and you will not be able to download images.

F-6 Where Can I Buy These Parts?

Diffraction Limited offers a limited selection of components and cables on our webstore. We provide this option for convenience; they will often be available at lower cost elsewhere.

We list below a selection of sources for fiber optic cable, transceivers, and interface cards. Please note that options will likely change over time, and this list may not always be fully up to date. A quick Internet search will quickly identify other sources.

F-6.1 Fiber Optic Cable

Fiber optic cable is inexpensive and readily available. The main thing is to remember that you want OM3 (aqua) or OM4 (violet) with LC connectors on both ends (LC/LC). Many options are available on Amazon, with a variety of suppliers and various lengths. Here is just one example of many – search around because options will probably change frequently:

https://www.amazon.com/Monoprice-106389-10-Meters-Multi-Duplex/dp/B00LTD26RC/

F-6.2 Transceivers

Since the Transceiver is an electronic device, if you intend to operate it in an observatory where freezing temperatures are expected, you will want to get an industrial temperature range unit.

Here is an example of a compatible industrial temperature Transceiver (other options are also available on the same site):

https://www.fs.com/products/111899.html

Amazon also has various options. This product is available in both industrial temperature range, and in lower cost commercial temperature range versions:

https://www.amazon.com/10Gtek-SFP-10G-SR-Transceiver-10GBASE-SR-300-meter/dp/B00U8Q7946/

We **strongly recommend** using an industrial temperature range transceiver. We find that these are more reliable and run cooler. Inexpensive transceivers tend to consume twice as much power and run hot, and they are unlikely to work in winter conditions.

F-6.3 PCIe Interface Card

If your computer has a spare PCIe slot, this is an excellent option:

https://www.fs.com/products/75600.html

F-6.4 Thunderbolt Adapter

This is a great option if your computer has a Thunderbolt port. It will need to be a Thunderbolt 3 or Thunderbolt 4 port. Thunderbolt is becoming quite common on modern computers. Here is one example of a format converter:

https://www.sonnetstore.com/products/solo10g-sfp-tb3

F-6.5 SFP+ to Copper Format Converters

If your computer has an unused RJ-45 10GB Ethenet port, then you can use a Format Converter instead. Note that the Ethernet port should be dedicated to just the camera, and not shared with a network. Here are some examples:

https://www.fs.com/products/101476.html (Temperature rated to -10C.)

https://www.amazon.com/10G-SFP-Fiber-Media-Converter/dp/B09G5YHK41/?th=1

Appendix G: Concepts and Terminology

Astrometry - Astrometry is the study of stellar positions with respect to a given coordinate system.

Autoguider - An autoguider a secondary camera that operates alongside the main imaging camera. Its function is to take a continual stream of short duration exposures of the sky that contains a suitably bright guide star. These images are used to monitor if the selected star moves at all. If it does, then signals are sent to the telescope mount to correct for small drive errors and long-term pointing drift. This ensures that stars in the main image remain stationery and perfectly round.

CCD - A CCD (Charged Coupled Device) sensor is a flat, two dimensional array of very small light detectors referred to as pixels. Each pixel acts like a bucket for electrons. The electrons are created by photons (light) absorbed in the pixel. During an exposure, each pixel fills up with electrons in proportion to the amount of light entering the pixel. After the exposure is complete, the electron charge for each pixel is shifted one at a time to an amplifier in one corner of the chip. The resulting voltage is transferred to an external amplifier, filter, and digital converter. When a pixel is displayed at the computer screen, its displayed brightness is proportional to the number of electrons that had accumulated in the pixel during the exposure.

CMOS - A CMOS (Complementary Metal-Oxide Semiconductor) sensor is a flat, two dimensional array of very small light detectors referred to as pixels. Each pixel acts like a bucket for electrons. The electrons are created by photons (light) absorbed in the pixel. During an exposure, each pixel fills up with electrons in proportion to the amount of light entering the pixel. After the exposure is complete, the electron charge at each pixel is amplified and converted to a voltage by a tiny circuit at the pixel. The voltages from each pixel are read out by built-in digital converters, often with one converter per 8 columns, and the brightness values are read out from the sensor via a high-speed digital interface. When a pixel is displayed at the computer screen, its displayed brightness is proportional to the number of electrons that had accumulated in the pixel during the exposure.

Color imaging with a monochrome camera - One-shot Color (OSC) cameras with a built-in Bayer matrix are handy for shooting quick color pictures However, imaging with a monochrome camera provides the best quality, sensitivity, and resolution.

A filter wheel with appropriate filters is used to create color images using a monochrome camera. The simplest method is to use three filters, one for Red, Green and Blue. Once the three images are captured, calibrated, aligned and stacked, it is very simple to create the color composite image.

That is because images are *normally* stored as three red, green, and blue planes. Your computer monitor simply displays the three colors directly and your brain interprets different combinations of those three colors as a full

gamut of different colors. It works because the retina in the human eye itself is based on red, green, and blue light-sensitive cells.

Dark Frame - A Dark frame is an image taken completely in the dark. The camera shutter must cover the sensor or the optical system must be capped to prevent any light from reaching the sensor. Dark frames are subtracted from normal exposures (light frames) to eliminate fixed pattern and dark current noise from the image. Dark frames must typically be of the same integration time and temperature as the light frame being processed.

Dark Current –Dark Current is the result of thermally-generated electrons building up in the sensor's pixels during an exposure. The number of electrons due to Dark Current is related to two parameters, namely the integration time (exposure length) and the temperature of the sensor. The longer the integration time, the greater the dark current buildup. Conversely, the lower the operating temperature, the lower the dark current. This is why the sensor is cooled for long integration times. Dark Current is a mostly repeatable noise source, therefore it can be subtracted from the image by taking a Dark Frame exposure and subtracting it from the light image.

Dark Noise - Dark Noise is Poisson shot noise from the Dark Current. It results from exactly the same process and statics as photon shot noise, just with thermal electrons instead of photo electrons. Hot pixels are noisier due to higher Dark Noise, and that noise is not subtracted when you subtract a Dark Frame.

Double-Correlated Sampling – Double-Correlated Sampling (DCS) is a technique employed to lower the digitization errors due to residual charge in the readout capacitors of the camera. This results in lower readout noise.

False Color - False Color images are images that have had colors assigned to different intensities instead of gray levels.

FITS Image File Format – The FITS image file format (which stands for Flexible Image Transport System) is a common format supported by astronomical image processing programs. MaxIm LT can save and read image files in this format.

Flat Field - A Flat Field is an image with a uniform distribution of light entering the optical system. An image taken this way is called a flat field image and is used to correct images for vignetting and minor obscurations caused by dust particles on the sensor or camera window. It also corrects pixel-to-pixel variations in light sensitivity within the sensor.

Focal Reducer - A focal reducer reduces the effective focal length of an optical system, and thereby provides a larger field of view to the camera sensor. While this reduces image resolution, it also decreases exposure times since it decreases the system's effective focal ratio. It consists of a lens mounted in a cell and is usually placed in front of an eyepiece or camera. Focal reducers are often used in electronic imaging.

Full Well Capacity - Full Well Capacity refers to the maximum number of electrons that a sensor's pixel can hold. This number is usually directly proportional to the area of the pixel.

Histogram – A histogram is a simple bar graph that shows the range of brightness in an image. Each bar in the graph represents a range of brightness. The leftmost bar represents the dimmest pixels, and the rightmost bar is for the brightest pixels. The height of the bar is the total number of pixels in that particular brightness range of the image. Every image has a different histogram depending on how much of the image is bright or dark.

A typical histogram will have a peak that shows the most common brightness in the image. For astronomical images this is often the sky background.

Light Frame - A Light Frame is the image of an object or scene before a Dark Frame has been subtracted.

Photometry - In astronomical applications, photometry is the measurement of the flux or intensity of an object's radiation. Typically this measurement is performed in defined wavelength bands to facilitate comparison and analysis

Pixel Size - The smallest resolution element of an electronic camera sensor is the pixel. Its size is usually specified in microns. The term is a contraction derived from "picture element".

Quantum Efficiency - Quantum Efficiency (QE) refers to the fractional number of electrons formed in a sensor pixel for a given number of impinging photons. Quantum Efficiency is usually plotted as a function of wavelength.

Readout Noise - Readout noise is a combination of various noise sources within the sensor.

Resolution and binning - The resolution of a camera sensor is determined by its pixel size. Pixel size can be increased by combining or "binning" more than one pixel and displaying the combined light received as a single pixel. Doing so decreases the effective resolution but increases relative sensitivity. It also shortens the image download time. Maximum absolute resolution is determined by the size of an individual unbinned pixel and the characteristics of the optical system you are using.

Saturation - Saturation refers to the full well capacity of a sensor's pixel as well as the maximum counts available in the A/D converter. A pixel is said to be saturated when the number of electrons accumulated in the pixel reaches its full well capacity. The A/D converter is saturated when the input voltage exceeds the maximum permissible.

Sky Background - The sky background illumination or brightness is the number of counts in an image in areas free of stars or nebulosity and is due to primarily to city lights and natural sky glow. High levels of sky background can increase the noise in images just like dark current. For some objects, filters can be used to reduce the sky background level.

Seeing - Seeing in the astronomical sense refers to the steadiness of the atmosphere during an observing or imaging session. Poor seeing is caused by air mass turbulence and atmospheric temperature variations. Seeing quality is often determined by measuring the Full Width Half Maximum (FWHM) diameter of recorded star images. Refer also to "Transparency".

SFP+ - Small Form-factor Plugabble Enhanced. This is a standardized 10 GBPS fiber ethernet interface standard. Typically this is comprised of an OM3

(aqua colored) or OM4 (violet colored) cable with LC connectors on each end. A compatible SFP+ transceiver module with LC connector is attached at each end, and these are plugged into the camera and the computer.

TE Cooler - A TE cooler is a thermoelectric cooling device used to cool the camera sensor down to a low operating temperature. Every camera sensor produces a certain amount of dark current, which accumulates in the pixels during an exposure. This unwanted dark current is produced by heat, and high-performance cameras cool their sensors to minimize this effect.

The sensor is mounted to the TE cooler, which in turn, is mounted to a heat sink, usually the camera head housing. A TE cooler is also often referred to as a Peltier cooler.

TIFF Image File Format - The TIFF image file format (which stands for Tagged Interchange File Format) was developed jointly by Microsoft and Aldus Corporations to allow easy interchange of graphics images between programs in areas such as presentation and desktop publishing. MaxIm LT can save and read image files in this format.

Transparency – Transparency in the astronomical sense refers to the total transparency of the atmosphere from the ground to the edge of space. It is largely dependent on the amount of water vapor in the air, but not entirely analogous to the amount of the cloud cover present in a location. There can be isolated clouds in a finely transparent air mass, and conversely, poor transparency can occur when there is little or no cloud present. Man-made light pollution and aerosols (i.e. industrial pollutants, volcanic ash, pollen, sea salt, and forest fire smoke) also degrade transparency. Refer also to “Seeing”.

Tri-Color - Tri-Color refers to color images created using three different colors mixed into a balanced color image using red, green and blue filters. An object is imaged three times, once with each color filter. The three images are then co-added and color balanced using appropriate software, such as MaxIm LT.

Vignetting - Vignetting is the obstruction of portions of the incoming light path by parts of an optical system. It usually occurs in the off-axis portions of the image and is seen as an uneven illumination of the image plane. When imaging using a vignetted optical system, the corners of the camera sensor will receive less light. This can be compensated for by using flat-fielding calibration, but it is usually preferable to physically avoid vignetting if possible.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