DIFFRACTION
ASTRONOMY + SCIENTIFIC IMAGING

SBIG® Aluma AC 4040 / AC2020

Imaging Cameras

User's Manual

Version 1.10 – September 4, 2026

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.

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SBIG Aluma AC 4040 / 2020 User's Manual

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IMPORTANT!

Please read this guide thoroughly before installing and operating your new SBIG Aluma AC Series 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 AC 4040 / 2020 Imaging Cameras

The SBIG Aluma AC Series represents the state-of-the-art in advanced scientific CMOS cameras for astronomical imaging systems. The SBIG Aluma AC4040 and AC4040BSI utilize the Gpixel GSENSE4040 and GSENSE4040BSI scientific CMOS sensors with 16.8 million 9 micron pixels, arranged in a 4,096 x 4,096 array almost 37 mm square. The SBIG Aluma AC2020BSI uses the Gpixel GSENSE2020BSI scientific CMOS sensor featuring smaller 6 um pixels, for a total of 4.2 million pixels in a 2,048 x 2,048 array. The BSI versions are Back-Side Illuminated, for the highest available quantum efficiency.

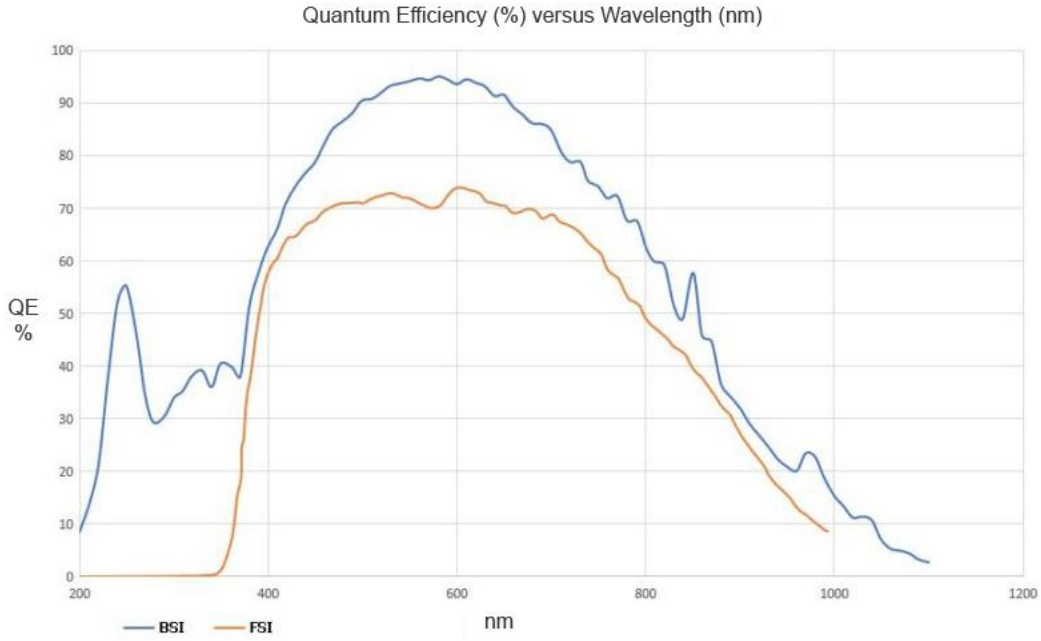
Primary design features include:

- **High Quantum Efficiency**

  Our previous flagship CCD camera, the STX-16803, had very good peak quantum efficiency at 60%. The Aluma AC4040 improves on this significantly. The standard Front-Side Illuminated (FSI) model has a peak Quantum Efficiency (QE) of 74%, and features a much broader peak that is almost flat through the visible spectrum – from 450 nm through to over 900 nm. In practice, the overall sensitivity of the Aluma AC4040 is therefore much higher than its CCD

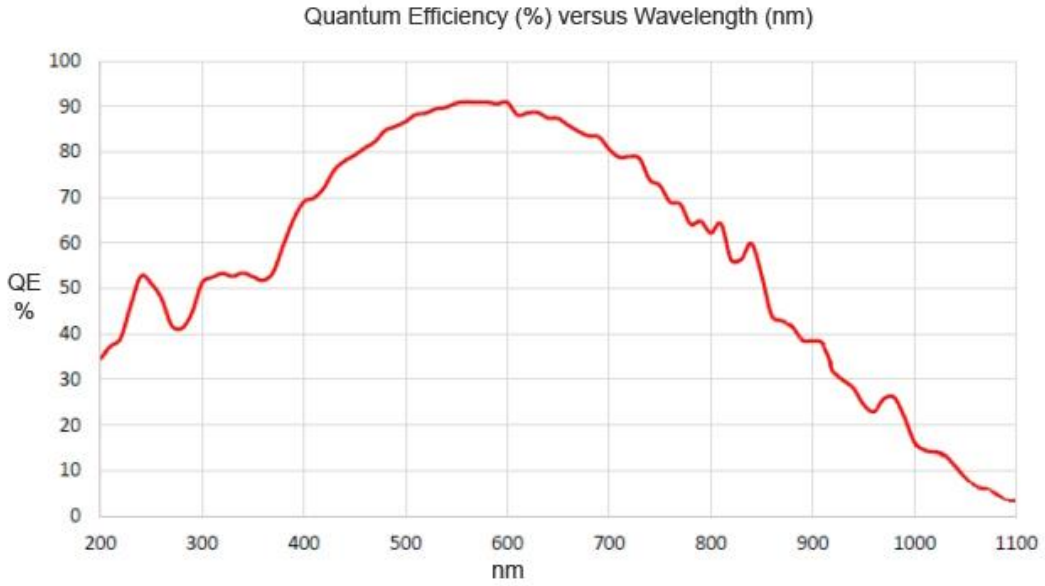
predecessor. The FSI camera is available with a Grade 2 sensor or a premium Grade 1 sensor with fewer pixel defects.

For the most demanding applications, the Aluma AC4040BSI features a windowless Back-Side Illuminated (BSI) sensor, which has an incredible peak QE of 95%. In addition the premium BSI sensor features significant UV sensitivity beyond 250 nm, and excellent near IR sensitivity.



Aluma AC4040

The Aluma AC2020BSI is only available with the Back-Side Illuminated (BSI) sensor and also boasts a peak QE of 95%.



Aluma AC2020BSI

- **StackPro™**

  The Aluma AC Series scientific CMOS cameras features **StackPro™**, a revolutionary feature that performs image stacking inside the camera.

  CMOS sensors often have more limited well depth and bit depth than their CCD predecessors. At the same time, the modern CMOS sensors have much lower read noise than the equivalent CCD. This low read noise can be used to advantage, by stacking many shorter exposures to achieve the same final result. This does however result in a lot of extra disk usage and post-processing.

  StackPro™ performs the stacking automatically, inside the camera. It automatically subdivides your exposure into up to 16 individual subexposures, and stacks them inside the camera prior to download. Stacking can also be used as an alternative to HDR mode.

- **HDR Mode**

  The Aluma AC Series sensors are capable of operating in High Dynamic Range (HDR) mode, where high-gain and low-gain images are read out simultaneously. A plug-in is available for MaxIm DL Pro, which can be used to perform HDR merge. Dark frame calibration should be done prior to merge, and flat-fielding should be done after merge.

- **Superior Cooling**

  Proven pin heatsink design shared with our industry leading STX series cameras gets the heat out while producing very little vibration. Our **SmartCooling™** function provides intelligent two-stage thermoelectric temperature regulation to 0.1 degrees C for high calibration stability, enabling a 40° C below ambient temperature delta.

  For high ambient temperature environments, the liquid cooling option enables even higher thermal reduction performance to minimize dark current further.

- **User-rechargeable Desiccant**

  SBIG pioneered the incorporation of a high-tech user-replaceable cartridge with ceramic filter and molecular sieve desiccant. Unlike competing cameras, which 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.

- **Electronic and Mechanical Shutters**

  The GSENSE CMOS sensor has an electronic rolling shutter. In addition the Aluma AC Series cameras include a mechanical shutter to enable convenient dark-frame subtraction for optimal performance and sensitivity. This is essential for remote/robotic operation.

- **USB 3.0 Interface**

  The Aluma AC Series cameras utilize a USB 3.0 interface port for high-speed image downloads. For installations where longer cable lengths are required, the port is also fully compatible with USB 2.0.

- **AUX Port**

  The Aluma AC Series 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. Unlike older SBIG models, the AUX port is not used for adaptive optics AO-X control, as this function is now handled by the optional SBIG StarChaser SC-3 off-axis guiding camera.

- **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 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 AC Series monochrome imaging camera
- Installed desiccant plug
- STX Style Adapter Plate - 3.5" OD Dovetail and 3x24 TPI threaded interface (an optional 3" diameter adapter is also available - Part number: ACC09)
- 2” Nosepiece adapter
- 6-32 front panel screw mounts
- Camera dust cap
- Power supply:
  - +12V DC 8A power adapter (60005B)
  - Power cable with USA, European, or Australian plug (specified on ordering), or
- USB flash drive
- USB 3.0 cable, 12 feet (3.7 meters)
- MaxIm LT software
- 7/64” (0.109") Allen key

1.2 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 Series camera using a Windows computer and is included with your purchase. Device drivers are provided for the Windows, MacOS, and Linux operating systems.

System requirements

The following hardware and software is required for MaxIm LT:

- MS Windows (applicable versions: 7, 8, 8.1, 10)
- Recommended minimum memory size: 2 GB or larger.
  Processing large arrays or opening multiple images simultaneously may require correspondingly more memory.
- Disk space: 100 MB for program installation
- Video display: 1024x768, 16-bit color or higher
- 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 license 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.

1.3 Installing the Hardware

Perform the following procedure to prepare your Aluma AC Series camera for use.

1. Attach the cabling:

   CAUTION:

   Never "hot plug" the cables into or from the units. Always disconnect power before connecting or disconnecting any cables.

   - Attach the USB cable between the USB connector and your computer.
   - The AUX connector is used for various accessories, such as a filter wheel. If you have such an accessory do not connect it at this time for initial testing of the camera.
   - 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.

   Do not turn the power supply on yet.

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

1.4 Connecting the Water Hoses

The Aluma AC Series cameras are equipped with a heat exchanger that allows water circulation if your environmental conditions require additional cooling of the sensor. The camera may be operated with or without water circulation. No special steps are necessary to use water cooling other than connection to a water supply. The camera comes with two water hose fittings that accept hoses with an inside diameter of ¼-inch. The hoses should be clamped to the fittings to prevent leaking. Very little water pressure is needed for the additional cooling. Only enough pressure to maintain a constant flow is required to get the maximum benefit from the water circulation.

It is usually not necessary to cool the water below ambient temperature with ice or refrigeration, but this can be done provided that you monitor the dew point. Water at ambient temperature is an effective heat conductor and a constant flow of water will carry away enough heat from the heat exchanger that further cooling of the water supply will result in very little gain. Cooling the water supply too much may also cool the camera well below the dew point which can allow moisture to form on the inside surface of the case or the outside surface of the sensor chamber window.

Water can be supplied to the camera from a faucet, or if that is unavailable, a small 12-volt pond pump and water bucket can also be used. These types of pumps and the required tubing can be purchased at most hardware stores for this purpose. The water inlet and outlet connections on the camera body are reversible – the water can flow in either direction.

1.5 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 Series 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. Assuming you are connected to the internet, and your system is up-to-date, the USB drivers should install automatically. If this does not happen, please see 1.6 Manual Driver Installation.
4. Open MaxIm LT and connect to the camera by following the procedure in Section 2.1 Connecting the Aluma AC Series camera to MaxIm LT.
5. 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.
6. If your testing is successful, you are now ready to mount the camera to your optical device.

1.6 Manual Driver Installation

Automatic installation requires:

- Your Windows system to have the latest updates installed
- An active Internet connection

Simply plug in the camera's USB cable and power it up – the drivers should install automatically.

Should this not happen, these are the steps to install the drivers manually:

1. Plug the included **USB Flash Drive** into your computer, and access it via Windows Explorer
2. Copy this folder to a convenient location on your hard drive:

   `\DL Imaging Driver (Aluma, STC, StarChaser)\System Drivers`

3. Open the **Windows Device Manager**
4. Right-click on **SBIG Driver**, select **Update Drivers**.
5. Click **Browse my computer for drivers**
6. Click **Browse** to open a directory picker
7. Select the folder on your hard drive where you copied the system driver files (Step 2)
8. Click **Next** and continue through until the device drivers are detected and installed
9. If successful go to the section 1.4 Testing the Camera and test out the connection.

Note:

On some systems it may be necessary to also update the FTDI D3XX USB drivers. Our USB drivers are based on FTDI's, and some systems may require these to be updated.

The FTD3XX driver update is available on the USB Flash Drive under:

`\DL Imaging Driver (Aluma, STC, StarChaser)\`

Alternatively, you can download the latest version from:

https://ftdichip.com/drivers/d3xx-drivers/

2 - Operating the Aluma camera with MaxIm LT

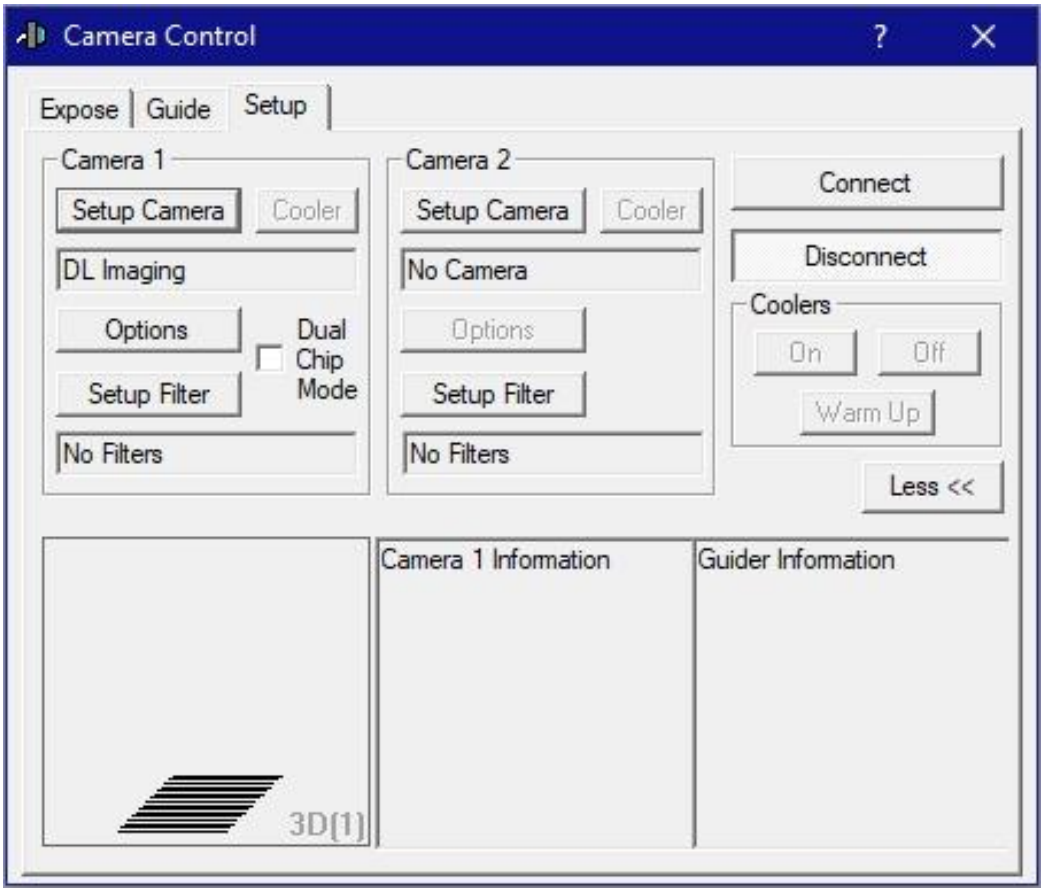
The MaxIm LT application allows full configuration and control of the SBIG Aluma AC Series cameras. Calibrating files, automating imaging sequences, logging, and various image processing tasks can all be performed. Please note however that since MaxIm LT and MaxIm DL both share the same Help file, not 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.

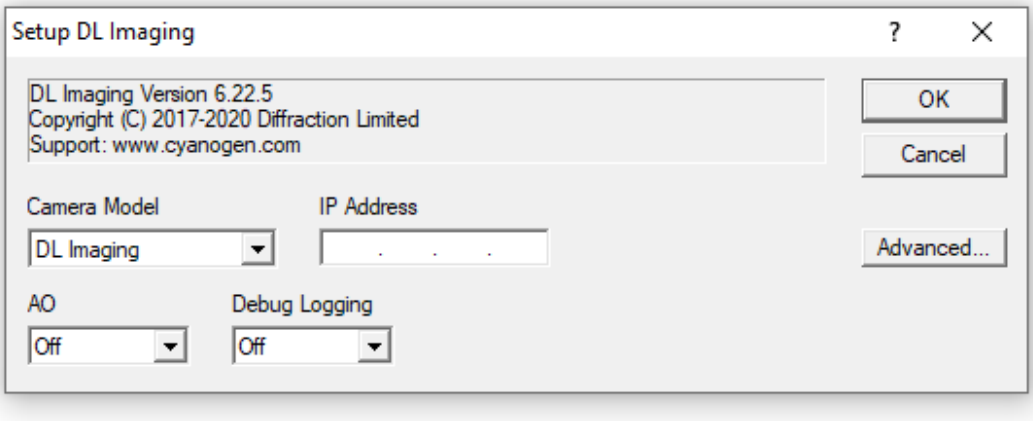
2.1 Connecting the Aluma AC Series camera to MaxIm LT

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

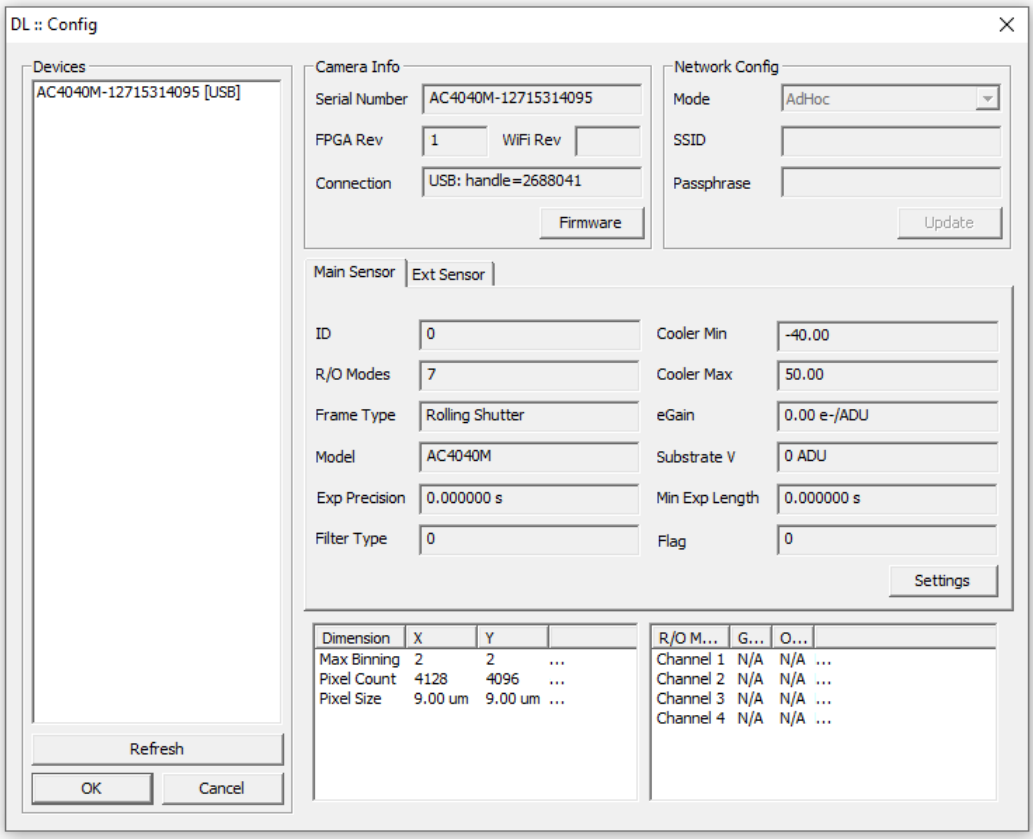
1. Click the Camera Control icon or press Ctrl-W to open the *Camera Control* form and click the *Setup* tab.



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



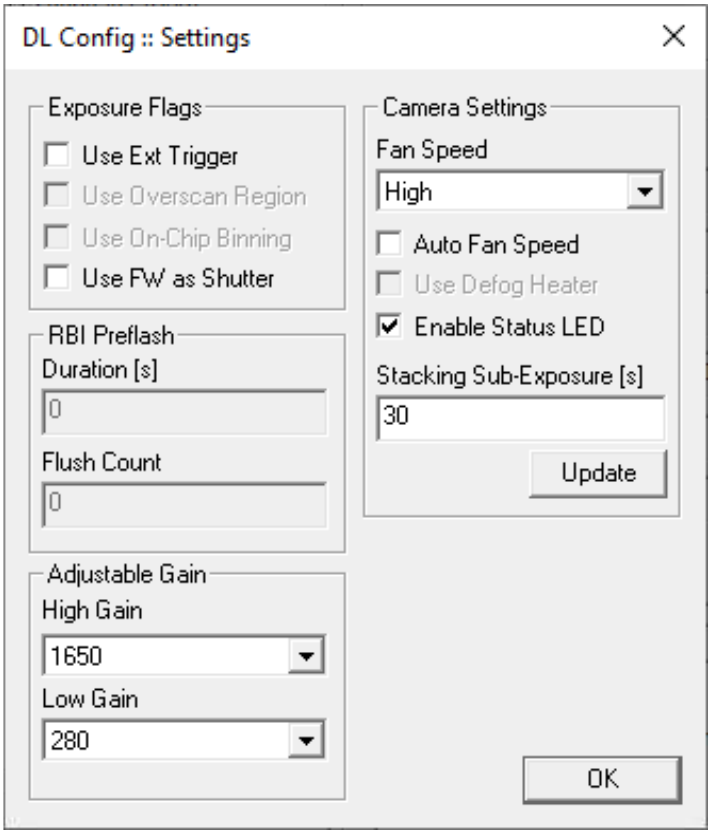
3. Click the *Camera Model* drop-down. Select *DL Imaging*.
4. Ensure that the *AO* selector parameter is set to *Off*.
5. Click the *Advanced* button. The *DL :: Config* form opens.



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.

6. If needed, you can adjust various camera settings by clicking the Settings button. Click OK when you have made your changes.

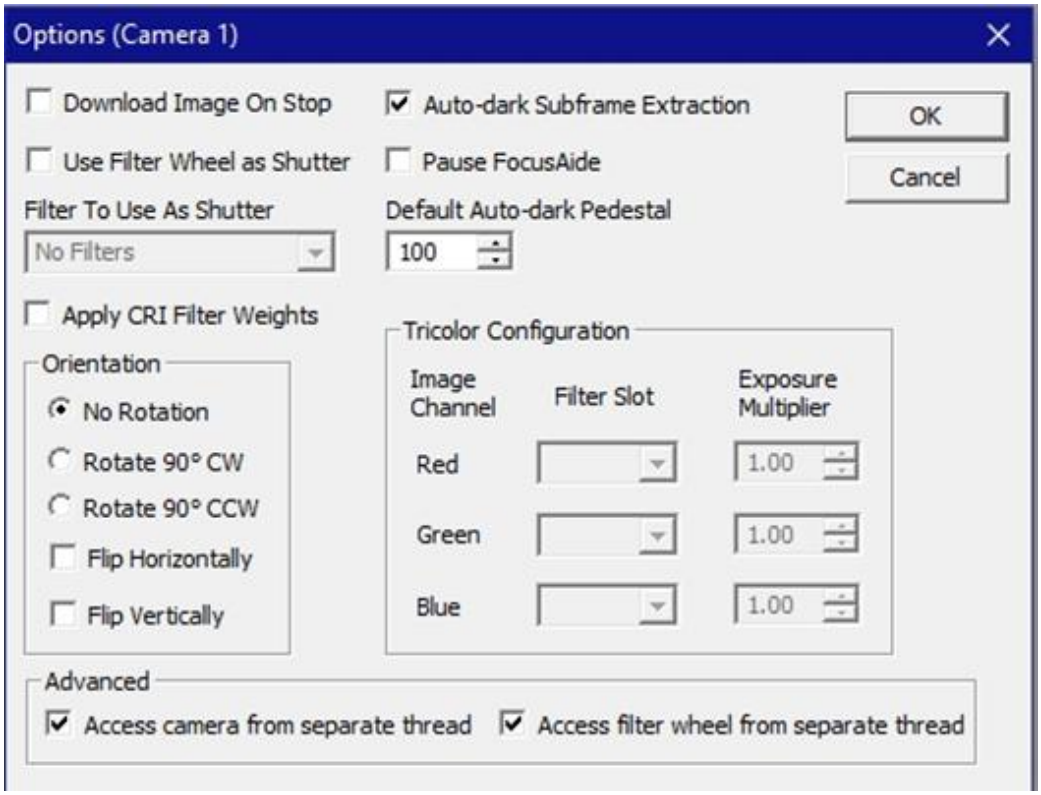


Important parameters include:

- Use Ext Trigger – camera will not start its exposure until it sees a signal on the AUX port. See Appendix A-1 for more information.
- Use FW as Shutter. Most Aluma AC models include a built-in mechanical shutter for taking dark frames. If your camera does not have a shutter, then turn on this check box. The camera will automatically select the highest filter slot to use as a shutter position.
- High Gain determines the camera gain when in High Gain or High Gain StackPro readout mode. The number divided by 100 is the gain setting. Default settings are as follows:
    - Aluma AC4040 – 1650 (16.5X = 0.82 e-/ADU)
    - Aluma AC4040BSI – 1200 (12.0X = 0.35 e-/ADU)
    - Aluma AC2020BSI – 1050 (10.5X = 0.46 e-/ADU)

- Low Gain determines the camera gain when in Low Gain or Low Gain StackPro readout mode. The number divided by 100 is the gain setting. Default settings are as follows:
    - Aluma AC4040 – 280 (2.8X = 18.7 e-/ADU)
    - Aluma AC4040BSI – 300 (3.0X = 10.4 e-/ADU)
    - Aluma AC2020BSI – 150 (1.5X = 13.9 e-/ADU)
- Fan Speed – normally this is set to Auto, but you can override the setting. Note that the camera's SmartCooling feature will override this setting if the camera is getting too hot.
- Enable Status LED turns on/off the indicator LED on the camera. Note that the LED automatically extinguishes when an exposure is in progress.
- Stacking Sub-Exposures – enter the time in seconds to be used for the StackPro sub-exposures. Click the Update button to send the command to the camera. This setting is retained when the camera is powered off. Please see 2.3 StackProTM Subexposure Function for more information on setting the sub-exposure time.

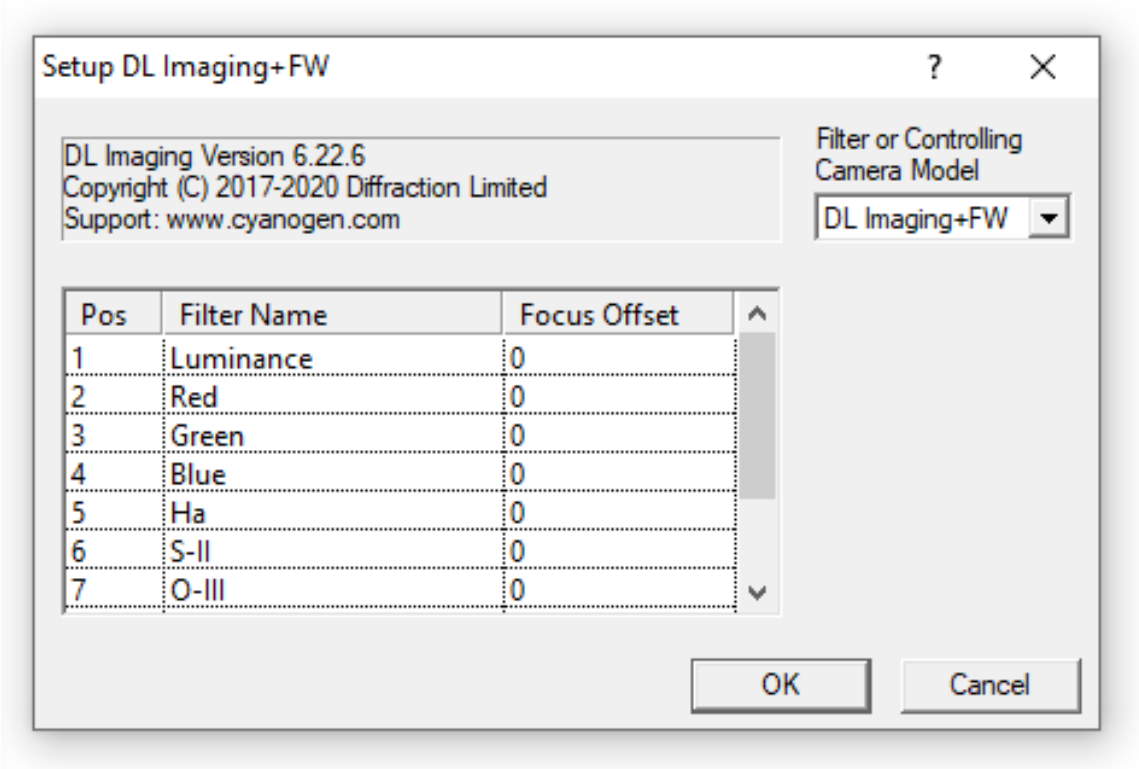
7. Click *OK* to confirm your camera selection and close the *DL :: Config* form
8. Click *OK* to accept the settings and close the *Setup DL Imaging* form.
9. Click the *Options* button under Camera 1. The *Options* form opens.
10. Configure any of the optional camera parameters if required or use the 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).

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

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



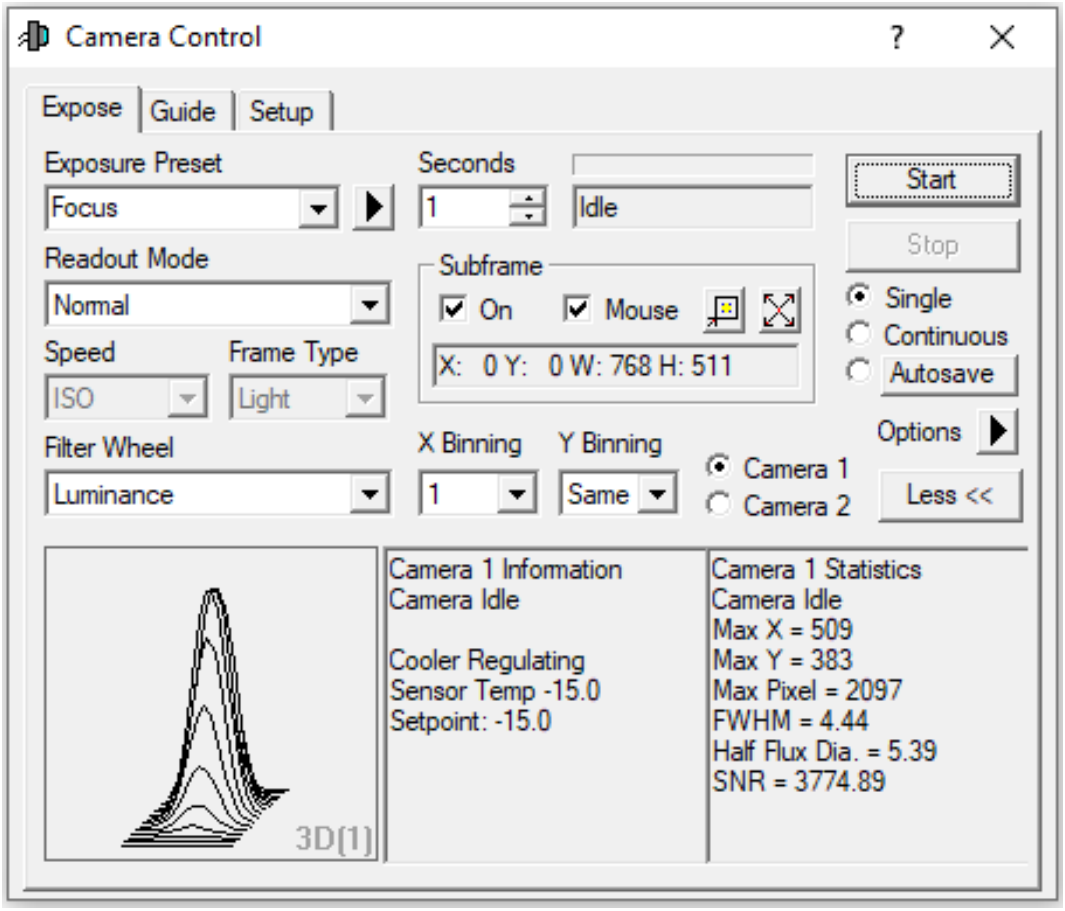
14. Click the Filter or Controlling Camera Model drop-down and select *DL Imaging+FW*. The default filter positions and names are displayed.
15. Click *OK* to accept the settings. The *Setup DL Imaging+FW* form closes and you are returned to the *Camera Control* form.
16. Leave *Camera 2* set to *No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

2.3 StackPro™ Subexposure Function

The subexposure function allows you to increase the effective dynamic range of the camera. It works by taking a series of shorter exposures, and then numerically summing them internally to the camera. Since the Aluma AC Series cameras have very low read noise, this greatly increases the camera's dynamic range while it only modestly increases the total read noise in your image. Due to the fast readout speed of the CMOS sensor, the extra time required is negligible.

As an example, when using the Aluma AC4040 (FSI) in High Gain mode, the camera can record about 3,300 photoelectrons before saturating, corresponding to a readout value of 4,095 (12 bits). The read noise is approximately 3.7 electrons.

If you mathematically stack 16 individual High Gain exposures the total number of photoelectrons that can be recorded increases 16X, but the readout noise only increases 4X. The read noise is now 14.8 electrons, and the stacked exposure can record 52,800 electrons, corresponding to a readout value of 65,535 (16 bits).

The camera automatically performs the subframe exposures internally, so they appear from the outside to be a single exposure. The camera also automatically adjusts the number and duration of the subframes to try to achieve the target *Subframe Duration*. The actual subexposures may be slightly longer if the requested exposure is not an exact multiple, as explained below.

Subexposure Duration must be at least 1 second. This allows ample time for the stacking to occur after each subframe is read out into the camera's internal memory.

When you request an exposure, the camera automatically calculates an actual subexposure duration and number of subexposures, based on the target *Subexposure Duration,* according to the following rules:

- If the exposure time is less than twice the *Subexposure Duration*, a single exposure will be taken
- If the exposure time is greater than 16 times the *Subexposure Duration*, then the total exposure time will be divided by 16, and 16 subexposures will be taken and stacked.
- If the exposure time is an exact multiple of 2X to 16X the *Subexposure Duration*, then the appropriate number of subexposures of the target duration will be taken and stacked.
- If the exposure time is not an exact multiple, then the *Subexposure Duration* will be increased by the minimum amount required to make an even number of 2 to 16 exposures. For example, if you have a *Subexposure Duration* of 10 seconds and ask for an exposure of 25 seconds, you will get two subexposures of 12.5 seconds.

This approach makes it easy to adjust the total exposure time as needed, without having to worry about always adjusting the subexposures manually.

If you always want the maximum number of subexposures, then leave the *Subframe Exposure* set to 1 second.

On the other hand, if your shorter exposures are not going to cause sensor saturation, you may wish to avoid the extra read noise for short exposures. You may therefore wish to increase the *Subframe Exposure* target to 10 seconds.

If you are taking very long exposures at very low light levels, then you may wish to set the *Subframe Exposure* target to 30 to 60 seconds or more.

As a general rule, the ideal *Subexposure Duration* target should be modestly below the level where you expect to see sensor saturation occur. That provides the maximum dynamic range with the minimum extra read noise.

2.4 Readout Modes

The Gpixel sensor has two 12-bit readouts which operate simultaneously. One is a high-gain readout and the other is a low-gain readout. The low-gain output provides the full dynamic range of the sensor, but loses the low-end signal. The high-gain output provides the best read noise characteristics, but saturates at a fairly low level. Neither readout makes full use of the dynamic range of the sensor.

You can read out just the high-gain or just the low-gain readout. You can also select StackPro to create a higher dynamic range image with up to 16-bit data. The StackPro High Gain mode is particularly useful for imaging faint targets.

Alternatively, you can acquire the full dynamic range of the sensor using the High Dynamic Range (HDR) mode. In this mode, both the high-gain and low-gain images are acquired simultaneously and saved in the image. This results in an image that is twice as tall as normal, with the high-gain image in the top half, and the low-gain image in the bottom half.

During post-processing the two halves of the image can be combined together to make a single image. This image will have the full sensitivity as recorded by the high-gain readout, plus the full well depth as recorded by the low-gain readout. This processing needs to be performed carefully for best results. To ensure accurate zero points for each image the camera can output "dark pixels" for each array; these appear on the right side of the image. The other factor that is needed is an accurate measurement of the relative gain of the two images.

Tools are available in MaxIm LT for performing the necessary merge function. Please refer to the MaxIm DL online manual for more information.

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 Series 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.
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 Series cameras:

- AFW-10-50SQ ten-position, 50 mm square filter wheel
- AFW-12-50R twelve-position, 50 mm round filter wheel
- FW7-STX seven-position, 50 mm square filter wheel
- Optical filters
- StarChaser SC-3-SHORT off-axis guide camera
- AO-X adaptive optics unit (requires StarChaser SC-3-SHORT)
- Nosepiece adapters
- Desiccant plugs
- Cables
- Power supplies

Accessories are available from your authorized SBIG dealer and at: https://www.diffractionlimited.com

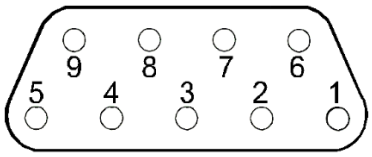
Appendix A: SBIG Aluma AC Series Camera Details

A-1 Connector pinouts

USB connector pinout is to the USB standard. The connector works with both USB 2.0 and USB 3.0 cables.

AUX connector (DB-9 Male)

The diagram shows the pin number identification when looking into the camera's connector.



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

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).

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

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

A-2 Aluma AC Series Specifications

AC4040

Imaging sensor	Gpixel GSENSE4040
Peak QE	74% for FSI (Grade 1 and 2); 95% for BSI
Sensor size	36.8 mm x 36.8 mm
Imaging pixel array	4096 x 4096 pixels
Pixel size	9.0 µm (square)
Total pixel count	16.8 million pixels
Full well capacity	74,000 e- (depends on mode)
Read noise	3.7 e- typical
Dark current e/p/s at 0° C	0.3 e-/p/s typical
A/D converter	Dual 12-bit with HDR capability
Exposure duration	0.001 to 3600 seconds
Pixel digitization rate	100 MHz
Full frame download	200 msec
Binning modes	1x1 and 2x2 binning Selectable hardware/software binning for FSI sensor Software binning only for BSI sensor
Power	12 VDC at 8A maximum
Power cable	USA, European, Australian
Shutter	Rolling electronic plus mechanical dark shutter
Temperature regulation	Yes
Cooling delta below ambient	~40° C typical, water cooling option included
Dimensions	5.5” x 6.1” x 4.7” (14.0 x 15.5 x 11.9 cm)
Weight	3.5 lbs (1.6 kg)
Computer interface	USB 3.0 (USB 2.0 compatible)
OS compatibility	Windows 7, 8, 10 x86/x64, MacOS 10.14 “Mojave” x86 binaries, Ubuntu 18.04 LTS x64, Raspbian Buster armhf, Ubuntu MATE arm64
Supported options:	
Off-axis guiding	Yes, with StarChaser SC-3-SHORT
Self-guiding in front of filters	Yes, with StarChaser SC-3-SHORT
Filter wheel	Yes, with FW7-STX Filter Wheel (uses 50 mm square filters)
Adaptive optics	Yes, with AO-X plus StarChaser SC-3-SHORT

AC2020

Imaging sensor	Gpixel GSENSE2020BSI
Peak QE	95%
Sensor size	13.3 mm x 13.3 mm
Imaging pixel array	2048 x 2048 pixels
Pixel size	6.5 µm (square)
Total pixel count	4.2 million pixels
Full well capacity	55,000 e- (depends on mode)
Read noise	1.6 e- typical
Dark current e/p/s at 0° C	0.16 e-/p/s @ -20° C
A/D converter	Dual 12-bit with HDR capability
Exposure duration	0.001 to 3600 seconds
Pixel digitization rate	100 MHz
Full frame download	100 msec
Binning modes	1x1 in hardware, 2x2 in software
Power	12 VDC at 8A maximum
Power cable	USA, European, Australian
Shutter	Rolling electronic plus mechanical dark shutter
Temperature regulation	Yes
Cooling delta below ambient	~40° C typical, water cooling option included
Dimensions	5.5” x 6.1” x 4.7” (14.0 x 15.5 x 11.9 cm)
Weight	3.5 lbs (1.6 kg)
Computer interface	USB 3.0 (USB 2.0 compatible)
OS compatibility	Windows 7, 8, 10 x86/x64, MacOS 10.14 “Mojave” x86 binaries, Ubuntu 18.04 LTS x64, Raspbian Buster armhf, Ubuntu MATE arm64
Supported options:	
Off-axis guiding	Yes, with StarChaser SC-3-SHORT
Self-guiding in front of filters	Yes, with StarChaser SC-3-SHORT
Filter wheel	Yes, with FW7-STX Filter Wheel (uses 50 mm square filters)
Adaptive optics	Yes, with AO-X plus StarChaser SC-3-SHORT

Appendix B: Maintenance

B-1 Cleaning the filters and sensor window

The design of the Aluma AC Series 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 AC Series 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 side of the camera chamber. In normal operation, the useful life of the desiccant is over a year. However, if the camera body is opened often or 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!

To regenerate the desiccant:

1. Place the camera on a clean dry surface with the knurled aluminum desiccant knob facing upwards.
2. The container screws into the side of the camera body. Use your fingers and turn it counter-clockwise to extract it.
3. Remove the O-ring from the container and place it aside.
4. Set the camera aside with the container opening facing down. This will prevent dust from falling into the opening.
5. Heat the desiccant container in an oven at 350° F (175° C) for 4 hours. The adhesive used to seal the can will melt at very high temperatures, so be sure to keep the oven temperature below 400° F (205° C). Preheating the oven to avoid hot spots is advised.
6. Remove the container from the oven when done and as soon as it has cooled enough to handle. Reinstall the O-ring and insert the container into the camera. Insure that the O-ring does not get pinched.
7. Turn the container clockwise by hand to tighten it. Do not use tools.
8. 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, reduce your cooling to the 0° C range - the dark current will still be quite low.

   Additional desiccant plugs are available from Diffraction Limited.

B-3 Updating the camera drivers and firmware

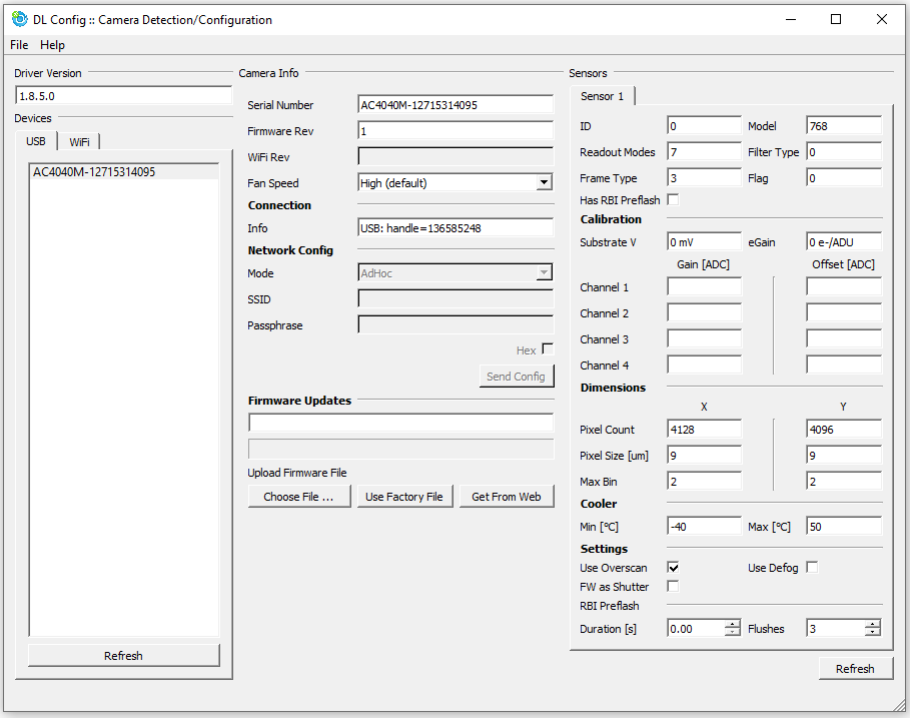
You should periodically check for updates to your camera's drivers and firmware to ensure the best possible performance. Diffraction Limited supplies a software utility program named *DL Config* that will update the firmware elements in the camera via USB. This is a standalone version of the *DL Config* form mentioned in Section 2.1 Connecting the Aluma AC Series 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-ac4040/

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 (USB recommended), 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.

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 Series cameras employ thermoelectric cooling and a fan to remove heat. When your camera is powered up, you should hear the fan operating.

Check the USB interface:

Follow these recommendations to ensure good USB connectivity:

- Use only good quality USB cables.
- Ensure that the USB cable is undamaged and securely attached.
- Avoid using a USB hub if possible. If you do need a hub, try to avoid putting two cameras on the same hub.
- If you are operating in outdoor ambient temperatures, be aware that commercial-quality hubs often do not work well in freezing temperatures. You should use an industrial-quality USB hub in such conditions.
- Avoid using front panel USB ports on desktop computers. They have internal wiring that will degrade USB signal quality.
- Diffraction Limited suggests tie wrapping the USB cable and power cable together near the camera in order to minimize risk of the USB connector coming loose or being pulling out.

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

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.

Technical Support

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

Technical Support Phone: (613) 225-2732

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

MaxIm LT

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

MaxIm DL

MaxIm DL 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 third-party cameras. For product details, refer to the Software page of the Diffraction Limited web site at:

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

Appendix F: 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”.

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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