



DIFFRACTION
ASTRONOMY + SCIENTIFIC IMAGING

SBIG[®] STC-428-OEM
Imaging Camera



User's Manual

Version 1.06 - July 7, 2021

This equipment has been tested and found to comply with the limits for a Class B digital device pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy, and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the receiver and the equipment.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.
- Use shielded I/O cables when operating this equipment.
- You are also warned that any changes to this certified device will void your legal right to operate it.

Industry Canada Compliance Statement

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

European Union - Compliance to the Electromagnetic Compatibility Directive

This product is in conformity with the protection requirements of EU Council Directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility. This product has been tested and found to comply with the limits for Class B Information Technology Equipment according to European Standard EN 55022. The limits for Class B equipment were derived for typical residential environments to provide reasonable protection against interference with licensed communication devices.

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SBIG STC-428-OEM User's Manual

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IMPORTANT!

Please read this guide thoroughly before installing and operating your new SBIG STC 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!

SBIG STC-428-OEM Imaging Camera

The SBIG STC-428-OEM is high performance imaging camera for demanding applications. It provides extremely high sensitivity, low noise 7 megapixel imaging in a compact, easily integrated package.



The STC-428-OEM scientific CMOS camera represents a major improvement over CCD technology. Compared with previous CCD models, the STC-428-OEM features higher sensitivity (78% QE versus 56%), significantly lower read noise (2.5 e- versus 9.3 e-), and 20X faster readout. While a single exposure can equal CCD dynamic range, the combination of fast readout and very low read noise allows for in-camera stacking using SBIG's StackPro™ to produce a greater dynamic range than previously possible.

In addition, SBIG's SmartCooling™ active regulation maintains the sensor temperature to within 0.1°C, and minimizes fan speed based on heat sink temperature for longer life and quieter operation.

The STC-428-OEM is our most popular scientific CMOS camera for OEM applications such as ELISA microplate readers, colorimetry, fluorescence, and similar low-light level imaging applications.

Camera Features

The STC-428-OEM imaging camera features:

- The high sensitivity, low noise 7 megapixel IMX428 imaging sensor
- Two-stage thermoelectric cooling for minimal noise on long exposures
- SmartCooling™ active temperature regulation to 0.1 degrees C for high calibration stability
- High-speed USB 3.0 interface (USB 2.0 compatible)
- I²C and Trigger I/O interface
- Centered optical axis for optimum instrument balance
- Multiplatform software API and sample code availability

The STC-428-EVAL evaluation kit also include the Windows-based MaxIm LT application for image acquisition and processing.

Refer to [Appendix A-2 STC-428-OEM Specifications](#) for detailed camera specifications.

1 - Installation

1.1 Supplied Components

Camera

The SBIG STC-428 camera is provided in one of two packages, as described below. 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.

Evaluation Kit:

Your STC-428-EVAL Camera Evaluation Kit is provided in a foam-lined hard shell protective case. The kit includes the parts and accessories needed for convenient evaluation of the camera performance.

- STC-428 monochrome imaging camera body, with desiccant plug installed
- T-Thread lens mount (M42 x 0.75)
- 4-40 front panel screw mounts
- 1/4-20 tripod mount
- Camera dust cap
- Power supply:
 - Universal +12V DC supply (60014A)
 - Power cable with USA, European, or Australian plug (specified on ordering), or
- +12 VDC Battery power cable (CA-ALUMABATTERY). Note that this cable is an option in lieu of the AC power supply
- USB flash drive
- Ferrite snap-on chokes to reduce radio frequency interference (qty 2)
- USB 3.0 cable, 15 feet (4.6 meters)

Production Model:

The Production model includes the STC-428-OEM standard monochrome imaging camera body, with installed desiccant plug.

If you require any customization or kit parts, your volume production model is given a designation, in the form STC-428-xxx.

Customization can include modified mounting points or housing, customized firmware, internal mechanical shutter, integrated filter wheel, and so forth.

Kit parts can include any of the parts from the Evaluation Kit, such as adapters, cables, and others. Any standard SBIG adapters and cables that are compatible with the camera can also be included. Custom adapters may also be available.

Please contact Diffraction Limited with your requirements for quotation.

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 STC-428-OEM camera using a Windows computer. If you have purchased the STC-428-EVAL kit, the MaxIm LT software for Windows is included. 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

This section details the steps required to connect an STC-428-OEM camera.

1. Install the ferrite snap-on chokes at convenient positions along both the USB cable and the DC power cable, preferably close to the camera ends of these cables. Open a choke and lay the cable into the channel, then snap the choke halves together.



2. 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.

- Attach the power supply cable between the POWER connector and the power supply. The connector clicks into place in the camera body. Pull on the shell to release the connector if required.

Do not turn the power supply on yet.

The camera is now ready to be powered up and tested. Refer to [Section 1.4 Testing the Camera](#).

1.4 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 STC-428-EVAL camera comes with a power supply capable of operating from 90 to 264 VAC. Actual power requirements are +12 VDC at 4A maximum.

The camera may also be powered directly from a capable +12 VDC source using an appropriate cable. The optional CA-ALUMABATTERY cable is available for this purpose. Refer to [Appendix A-1 Connector pinouts](#) for details on creating a custom power cable.

3. Open MaxIm LT and connect to the camera by following the procedure in [Section 2.1 Connecting the STC 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. The front port of the camera mates with a T-thread adapter. Please note that the camera mounting can be customized for your application. Contact Diffraction Limited for more information.


2 - Operating the SBIG STC camera with MaxIm LT

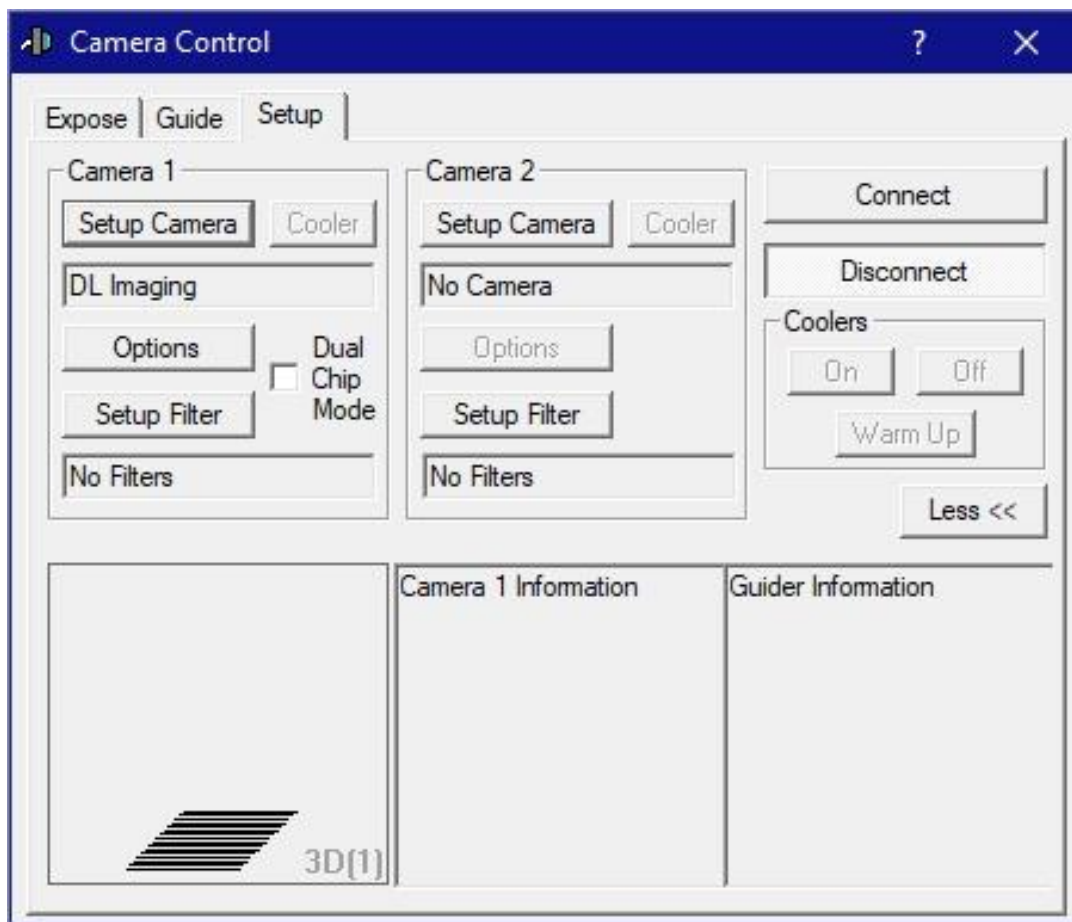
The MaxIm LT application allows full configuration and control of the SBIG STC-428 camera. Calibrating files, automating imaging sequences, logging, and various image processing tasks can all be performed. Please note however that since MaxIm LT and MaxIm DL both share the same Help file, not all features 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 STC hardware. Consult the Help file for further information on specific parameters, detailed procedures, and various tutorials.

2.1 Connecting the STC Camera to MaxIm LT

The following is the basic MaxIm LT procedure used to configure and connect to the STC 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.

Setup DL Imaging

DL Imaging Version 6.22.5
Copyright (C) 2017-2020 Diffraction Limited
Support: www.cyanogen.com

Camera Model: DL Imaging (dropdown)
IP Address: . . .

AO: Off (dropdown)
Debug Logging: Off (dropdown)

Buttons: OK, Cancel, Advanced...

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.

DL :: Config

Devices: STC428M-20060201 [USB] *

Camera Info:
Serial Number: STC428M-20060201
FPGA Rev: 2 | WiFi Rev: |
Connection: USB: handle=2754
Firmware

Network Config:
Mode: AdHoc (dropdown)
SSID: |
Passphrase: |
Update

Main Sensor | Ext Sensor |

ID: 0 | Cooler Min: -40.00
Max Channels: 0 / 6 | Cooler Max: 50.00
Frame Type: Progressive | eGain: 0.00 e-/ADU
Model: IMX428 | Substrate V: 0 ADU
Exp Precision: 0.000 s | Min Exp Length: 0.000 s
Filter Type: 0 | Flag: 0
Settings

Dimension	X	Y	Channel	G...	O...
Max Binning	2	2	Channel 1	N/A	N/A
Pixel Count	3216	2208	Channel 2	N/A	N/A
Pixel Size	4.50 um	4.50 um	Channel 3	N/A	N/A
			Channel 4	N/A	N/A

Buttons: Refresh, OK, Cancel

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

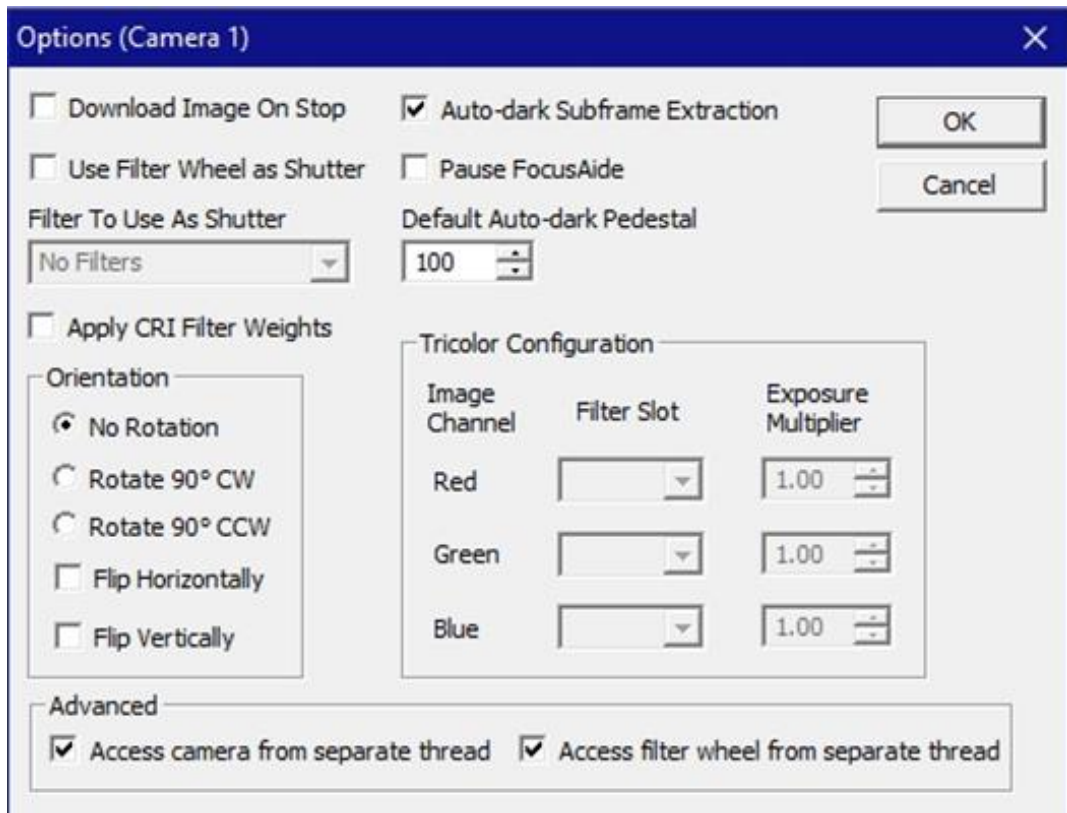
Select your camera from the *Devices* list. The small asterisk (*) indicates the currently selected camera. If there is more than one camera in your system, select the one you want and click *OK*.

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).

9. Click *OK* to accept the settings. The *Options* form closes and you are returned to the *Camera Control* form.
10. Leave *Camera 2* set to *No Camera*.

11. Click the *Connect* button to establish camera communications.
 12. Enable the camera cooler by clicking the *On* button.
 13. Click the *Cooler* button under Camera 1. The *Set Camera Cooler* form opens.
 14. Set the desired cooler temperature (in degrees Celsius) and click *OK*. The *Set Camera Cooler* form closes.
 15. The STC-428-OEM 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.

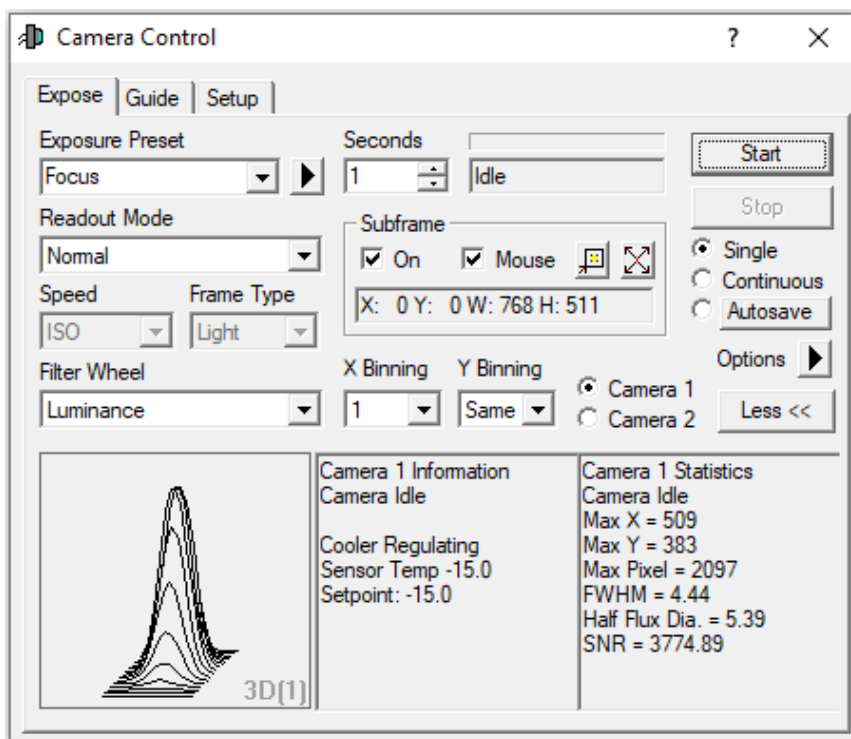
2.2 Basic Imaging Procedure

After setting up the STC-428-OEM camera as stated in [Section 2.1 Connecting the STC 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 STC-428-OEM camera.

NOTE:

You can change the file format used to save your images from the default FITS format to the 16-bit TIFF format. From the main menu click *File* then *Settings*. Click on the *Files* tab and enable the TIFF checkbox. All header information is maintained as TIFF flags, so nothing else changes.

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



2. Click the *Options* menu and select *Camera Settings*. Applicable settings for the STC-428 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* (used to disable the LED on the camera)
 - *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 six available readout modes, divided into two groups – either *StackPro* or *Normal*. Within these groups you can choose *Low-Gain* for the best well depth, *High-Gain* for the best read noise performance, or *Medium-Gain* for a compromise between well depth and noise performance.
 - *Frame Type*: Light
 - *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 STC-428-OEM has very low read noise, this greatly increases the camera's dynamic range while only modestly increases the total read noise in your image. Due to the very fast readout speed of the CMOS sensor, the extra time required is negligible.

As an example, when using the *Medium Gain* mode the camera can record about 10,000 photoelectrons before saturating, corresponding to a readout value of 4095 (12 bits). The read noise is approximately 2.5 electrons.

If you mathematically stack 16 individual *Medium 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 10 electrons, and the stacked exposure can record 160,000 electrons, corresponding to a readout value of 65,535 (16 bits).

In comparison, our previous generation STF-8300-OEM CCD camera has a typical read noise figure of 9.3 electrons, and can record a maximum of 25,000 electrons in a single exposure. The noise performance is about the same, but the total dynamic range achieved is over six times greater.

The STC-428-OEM 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.

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 STC-428-OEM.

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.
 - *Exposure 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.

NOTE:

Since the STC-428-OEM camera does not have a mechanical shutter, the camera must be otherwise covered to prevent light from entering it. You will be prompted to cover the camera before the dark sequence can begin.

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 wantClick **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 a 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 a 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 and Customization

A variety of standard accessories are available:

- Canon and Nikon lens adapters
- Nosepiece adapters
- C-mount adapter (NOTE: Vignetting may occur)
- Desiccant plugs
- Cables
- Power supplies

In addition STC-428 cameras can be customized in a variety of ways. This may incur extra Non-Recurring Engineering (NRE) and/or production costs. Please contact Diffraction Limited for a discussion of your specific requirements.

- Custom firmware - note that firmware is field-upgradable
- Custom mechanical mounting methods
- Housing changes
- Add built-in mechanical shutter for dark frames
- Add filter wheel (see SBIG STC-7 User Manual for one available option)

The STC-428 has a variety of internal connectors that can be used to add functionality, with appropriate firmware support:

- Hall Effect sensor input
- 12V DC power output
- Switchable 12V DC heater control
- Internal I²C connector (in parallel with external connector)
- Bipolar stepper motor driver (12VDC)

Please contact Diffraction Limited for engineering support if you wish to use any of these features.

Appendix A: SBIG STC-428-OEM Camera Details

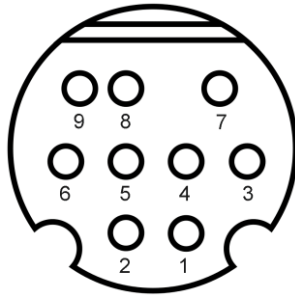
A-1 Connector pinouts



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

AUX connector (9-pin mini-DIN)

The diagram 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	

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.

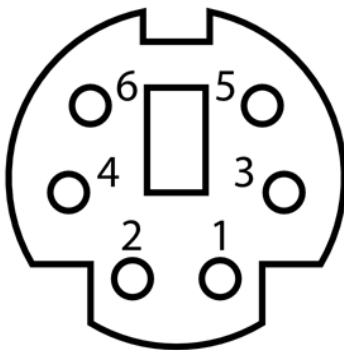
Trigger In is used to initiate exposures via an external control signal. The *Trigger In* signal must be floating (not connected) or connected to the camera's digital GND (or TTL Low Level) before starting the Trigger Mode. When you click Start in the software to begin an exposure, the camera will prepare 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 connector (6-pin mini-DIN)

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



Pins 1, 3, 5: +12V

Pins 2, 4, 6: GND

NOTES:

- Maximum recommended input voltage is 14V DC
- The shell of the connector is connected to ground via 1 Megaohm in parallel with 100 pF, and should be connected to the cable shield.
- Power ground is connected to the chassis of the camera through a low impedance.
- For a positive retention power connection we recommend using locking connector Kycon 806-KMDLAX-6P.

A-2 STC-428-OEM Specifications

Imaging sensor	IMX428
Peak QE	78%
Sensor size	14.4 mm x 9.9 mm
Imaging pixel array	3208 x 2200 pixels
Pixel size	4.5 μm (square)
Total pixel count	7.1 million pixels
Full well capacity	20,800 e- Low-gain mode, 9,420 e- High-gain mode
Read noise (typical)	1.9 e- High gain / 2.5 e- Medium gain / 5 e- Low gain
StackPro Capable	Yes
Dark current e-/p/s at -5° C	0.1 e-/p/s typical
A/D converter	12-bit with three gain modes
Exposure duration	0.001 to 3600 seconds
Full frame download	90 msec typical
Binning modes	1x1, 2x2
Power	12 VDC at 4A maximum
Power cable	USA, European
Shutter	Electronic
Temperature regulation	Yes
Cooling delta below ambient	Typical maximum: -30° C
Dimensions	5" x 4" x 3" (12.7 x 10.1 x 7.6 cm)
Weight	2 lbs (0.91 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
<i>Supported options:</i>	
Adaptive optics	No
Filter wheel	Yes. Contact Diffraction Limited for custom options.
Self-guiding filter wheel	No

Appendix B: Maintenance

B-1 Cleaning the sensor window

The design of the STC cameras allows for cleaning of the window covering the sensor chamber. The camera body is not evacuated and is easy to open. When opening or reassembling the camera (see [Section 1.3 Installing the Hardware](#)), you must be careful not to damage any of the structures contained inside. Treat the instrument delicately.

Do not open the sensor chamber itself. If internal chamber maintenance is required, please return the camera for service. **Opening the sensor chamber will void your warranty.**

The sensor chamber window can be cleaned with a cotton-tipped swab and isopropyl alcohol. Do not get alcohol on the other components. Dust on the window should be blown off if possible. Use alcohol only if necessary. Use one end of the swab it with alcohol and the other end to dry it. Never re-use a swab and do not scrub with it – use 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 STC-428-OEM camera. 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.

➔ 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 STC 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/stc-428-oem/>

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 DL or other control software.
3. Go to *Start* menu > *DL Config Utility* and run the DL Config Utility.

The screenshot displays the DL Config utility interface, titled "DL Config :: Camera Detection/Configuration". The interface is divided into several sections:

- Driver Version:** 1.8.1.0
- Camera Info:** Serial Number: STC428M-20060201, Firmware Rev: 2, WiFi Rev: [empty], Fan Speed: High (default), Connection Info: USB: handle=163610656
- Network Config:** Mode: AdHoc, SSID: [empty], Passphrase: [empty]
- Devices:** A list of detected devices including AC4040M-100060600 and STC428M-20060201.
- Sensors:** Sensor 1 settings including ID (0), Model (1280), Readout Modes (6), Filter Type (0), Frame Type (0), and Flag (0).
- Calibration:** Substrate V (0 mV), eGain (0 e-/ADU), Gain [ADC], and Offset [ADC].
- Dimensions:** Pixel Count (3216 X, 2208 Y), Pixel Size [um] (4.5 X, 4.5 Y), and Max Bin (2 X, 2 Y).
- Cooler:** Min [°C] (-40), Max [°C] (50).
- Settings:** Use Overscan (checkbox), Use Defog (checkbox), RBI Preflash (checkbox), Duration [s] (0.00), and Flushes (3).

Buttons for "Send Config", "Choose File ...", "Use Factory File", "Get From Web", and "Refresh" are visible throughout the interface.

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 STC 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 STC-428-OEM camera employs 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

Authorized Repair Center

Bill Lynch – SBIG Service & Repair Center

554 Andromeda Drive

Lompoc, CA 93436

Bill Lynch – email via: **bill at sbig.com**

NOTE: You must contact our authorized service & repair center for an RMA number prior to returning your equipment.

Phone: (805) 308-6979

Diffraction Limited Main Address

For non-repair purposes & enquiries only:

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

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 column, 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.

Pixel Size - The smallest resolution element of an electronic camera sensor is the pixel. Its size is usually specified in microns, such as the STC-428-OEM's 4.5 micron pixels. 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.

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.

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.



DIFFRACTION

ASTRONOMY + SCIENTIFIC IMAGING