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Finger Lakes Instrumentation Information Guide

Finger Lakes Instrumentation is a company based in Lima, NY and Binghamton, NY. We specialize in scientific imagers and the accessories that are paired with scientific image capture. We offer four families of cameras: MicroLine, ProLine, Hyperion, and Kepler. Kepler, being the newest addition, is the focus of many sections of this digital guide. Please regard the MicroLine User's Guide, ProLine User's Guide, and Hyperion User's Guide for specifications, installation, and operation specific to those imagers.

This information guide has a wide span of information including, but not limited to the following: Focuser, Filter Wheels, FLI Pilot, Lens and Sensors, and information regarding sCMOS and CCD operation and readout structures. The contents of this website are subject to be changed, added to, and removed with no notification. Many aspects of this website will grow, and many aspects may change completely.

If you have just bought a Kepler camera please check out our Getting Started with your Kepler Guide for a step by step instructions enabling you to go from unboxing your camera to producing high quality, corrected images.

Welcome

Thank you for purchasing an FLI camera. We know that your new camera will bring you years of enjoyment and excellent imaging results.

This User Guide is intended as a reference tool for you to use with the Kepler Imaging System. Please read it and follow the procedures to ensure trouble-free installation of your hardware and software.

If you have any questions about your purchase, please contact us.

Conventions

The following standard conventions are used in this Guide. Review all cautions and dangers prior to operating the system.

Note: To emphasize or clarify information or instructions.

WARNING: To prevent damage to or from the System.

Additional Information

For additional information about the Kepler Imaging System, refer to the following information:

- FLI Software/FLI Pilot User Guide
- www.flicamera.com

Accessories and Ordering Options

FLI provides a variety of accessories including color filter wheels, high-speed filter wheels, research grade filters, digital focusers, adapters and other products to meet your needs. Refer to www.flicamera.com for the most recent products and information.

For information regarding accessories and options for the Kepler Imaging System, refer to the FLI website (flicamera.com).

Warranty and Return Procedure Information

The FLI web site (flicamera.com) contains current information regarding the product warranty and if required, return of the product to FLI. The website's Support tab contains links for Warranty, Returns and the RMA (Return Materials Authorization) form with instructions.

Contact Information

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FLI Yahoo Group

FLI Yahoo Group is an active forum for members wishing to discuss FLI imaging systems, share imaging experiences, techniques, results, and discuss imaging solutions and problem solving. The forum is accessible online at http://groups.yahoo.com/neo/groups/FLI_Imaging_Systems/info.

Corporate Information

This product is designed and manufactured in Lima, NY (USA) by Finger Lakes Instrumentation LLC

Information in this document is subject to change without notice and does not represent a commitment on the part of Finger Lakes Instrumentation LLC (FLI). Although every effort has been made to ensure the accuracy of this documentation, FLI cannot be held liable for any errors. No part of this manual may be reproduced or transmitted in any form or by any means, electronic, or mechanical, including photocopying and recording, for any purpose other than the purchaser's personal use without written permission from FLI.

Kepler

Kepler is FLI’s new series of cooled cameras, providing higher throughput, more channels, and a variety of new sensors, including scientific CMOS.

The official Kepler documentation, including specifications for each camera and sensor available in the Kepler family is available at flicamera.com/kepler/kepler.html.

An overview of the Kepler family is available at flicamera.com/pdf/KeplerOV.pdf.

A setup guide for the Kepler family cameras can be accessed on the Set Up Page.

An overview of the auxiliary connector on the Kepler cameras and the modes of indication of exposure processes can be accessed on the Connectors Page.

KL400

The KL400’s back-illuminated sensor has a peak quantum efficient of 95%, making it one of the most sensitive sensors on the market. The camera can reach video rates at full resolution with as little as 1.6 electrons RMS noise.

For KL 400 operational features click here

For a KL400 spec. sheet, click here

Table 1. KL 400 Specifications
These specifications are subject to change without notice.

Shutter	Rolling
Sensor Type	Front and Back Illuminated
Resolution	2048x2048
Pixel size	11 x 11 microns
Imaging area	22.5mm x 22.5mm
Linear full well capacity (e-)	120000 (FI) / 90000 (BI)
Read noise (RMS)	1.5 e- (FI) / 1.6 e- (BI)
Maximum Frame Rate	48fps (24 fps HDR)
Interface	USB 3, optional QSFP fiber
Peak QE	58% (FI) / 95% (BI)
Dynamic Range (HDR)	96 dB (FI) / 93 dB (BI)
Dark Current @ -20C	0.2 eps (FI) / 0.6 eps (BI)
Sensor Diagonal	31.9 mm
Software / OS Requirements	FLIPilot
Cooling	45ºC Below Ambient
Operating Humidity	<80% Non-condensing
Physical Dimensions	See Mechanical Darwing
Weight	2.65 lbs (1.2 kg)
Electrical Requirements	110-240V AC, 50-60 Hz, 2 Amp max draw
Regulatory Certifications and Standards	EN 61326-1, IEC 61010-1
Operating Temperature	5 to 30*C
System Power	55 Watts
Altitude	2000m Max

KL4040

The KL4040 scientific CMOS camera has the same pixel size and imaging area as the popular KAF-16803 CCD, but with 1/3 the noise and 40% higher quantum efficiency. Kepler cooled sCMOS cameras provide ultra-high sensitivity, ultra-low noise, and high frame rates, all at game-changing price to performance ratio.

For KL 4040 operational features click here

For a KL4040 spec. sheet, click here

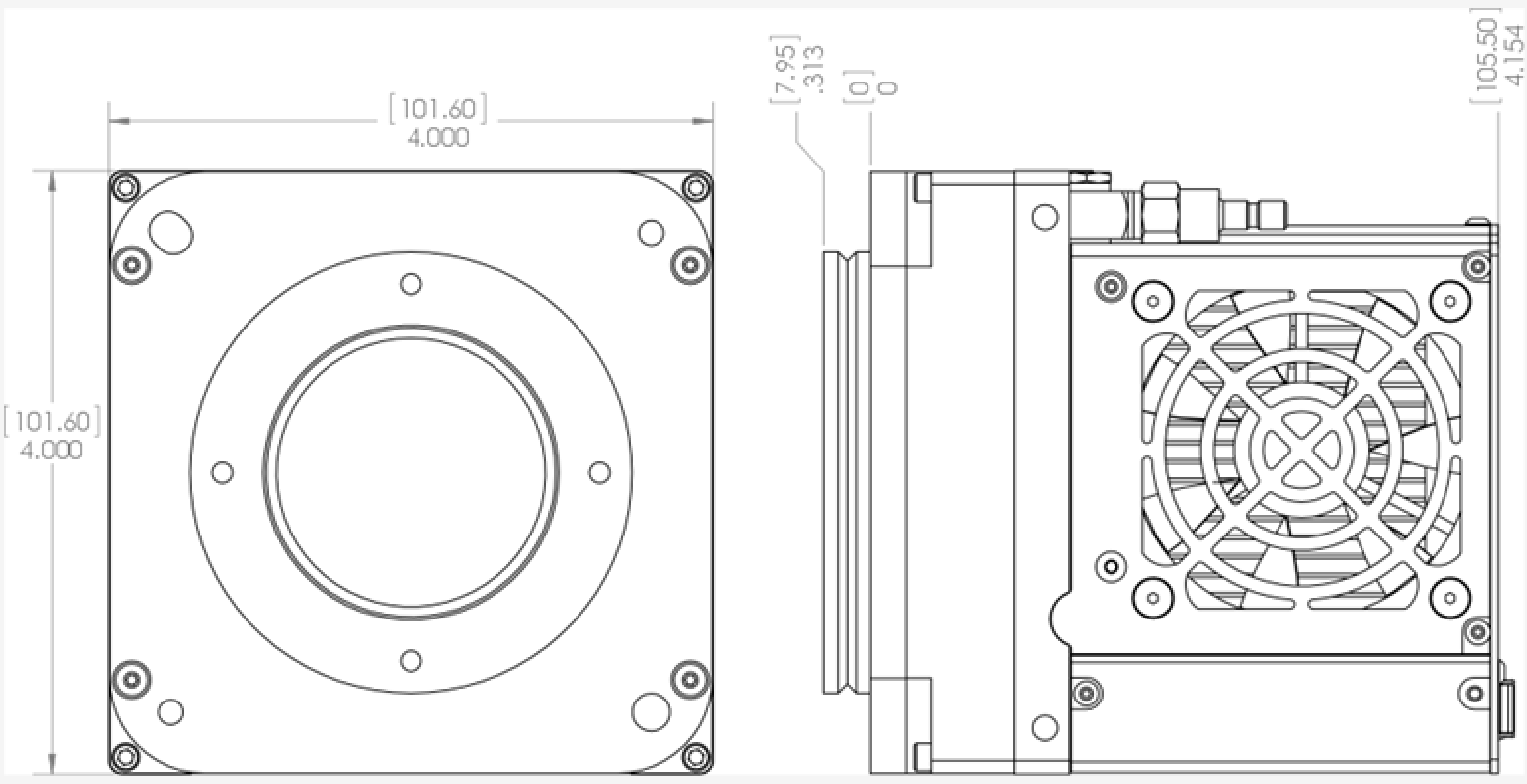
Table 1. KL 4040 Specifications
These specifications are subject to change without notice.

Shutter	Rolling; Rolling with Global Reset
Sensor Type	Front Illuminated
Resolution	4096 x 4096
Pixel size	9 x 9 microns
Imaging area	36.9mm x 36.9mm
Linear full well capacity (e-)	70000 electrons
Sensor Diagonal	52.1 mm
Maximum Frame Rate	23 FPS w/ QSFP V2; 7.3FPS w/ USB 3
Interface	USB 3, optional QSFP fiber
Peak QE	74%
Dynamic Range (HDR)	86dB
Dark Current @ -20C	0.15 eps
Read Noise	3.7e-
Software / OS Requirements	FLIPilot
Cooling	40ºC Below Ambient
Operating Humidity	Non-condensing
Physical Dimensions	See Mechanical Darwing

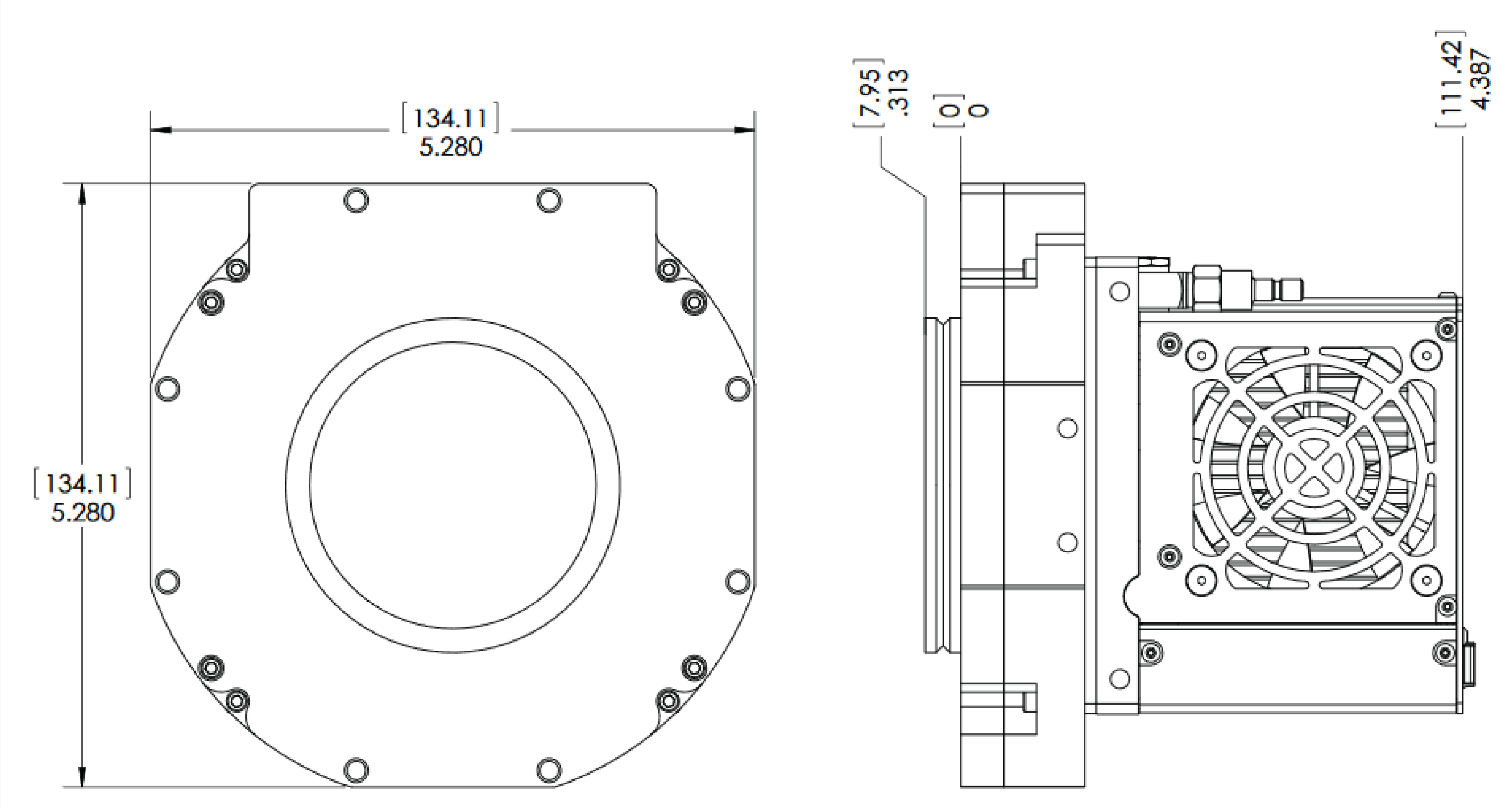
Weight	2.9lbs (1.3kg)
Electrical Requirements	110-240V AC, 50-60 Hz, 2 Amp max draw
Regulatory Certifications and Standards	EN 61326-1, IEC 61010-1
Operating Temperature	-10C to +30C
System Power	65 Watts
Altitude	2000m Max

Mechanical Drawings

Model: KL 400



Model: KL 4040



Getting Started with your Kepler

Thank you for purchasing a New Kepler Camera!

The following are basic steps that will allow you to go from unboxing your camera to capturing and viewing images.

For more information on any of the following instructions please see the links for more specific information on step.

I. Computer Requirements

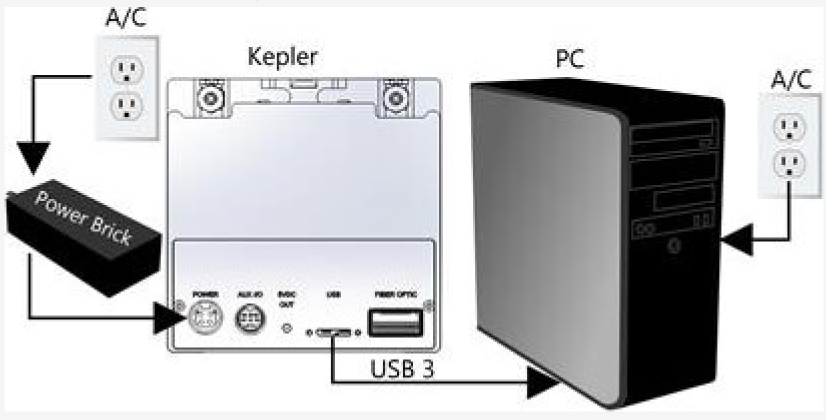
1. OS: Windows 10 - 64bit
2. Processor: i7 core preferred for best performance. i5 core is acceptable
3. Memory: 16 GB Ram, 32 or more preferred
4. An available USB 3 port (Labeled SS for SuperSpeed)

II. Installing Software

1. Download the latest FLI Pilot zip file from our website located here.
2. Click the Download button next to FLI Pilot Software v1.2.xx for Kepler Cameras: Windows 7/8/10 64-bit:
3. Unzip the file and run the FliPilotsSetup.msi
4. Copy the MergeCalculateRegionFile.csv located in the .zip file to a location on your computer for future use.
5. After installation, open FLI Pilot to ensure it is installed correctly.
a. For more information about Installing Pilot please go here.

III. Set Up

1. After receiving your Kepler, unbox all components.
2. Place the camera where it will be operated.
3. Plug in USB 3-Micro B cord to the camera and screw in the holding pins. Connect the USB 3 end into your computer.
a. You should use a 3.0 USB port on your computer, commonly labeled with a small SS next to it.
4. Connect 12-Volt power supply to camera.
a. After the power supply is connected to camera, then connect the power supply to a wall socket or AC power Strip. Ensure power supply is plugged into camera before being plugged into AC power.
b. If you plugged into a power supply you can turn the power supply on now.
c. When the camera has power the fan should start.
5. Start FLI Pilot, in a few moments the camera should connect and be recognized.
a. If the top middle menu says Kepler SCMOS Camera(4040 or 400) – Individual Serial Number – Connected (Super Speed), then you are ready to proceed.
6. For more Set up information please go here.



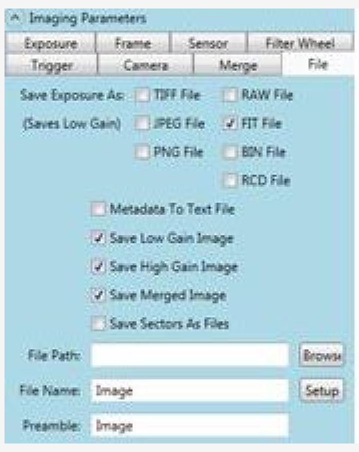
IV. Taking an Image

1. Open FLI Pilot
2. Expand the Grab Control menu.

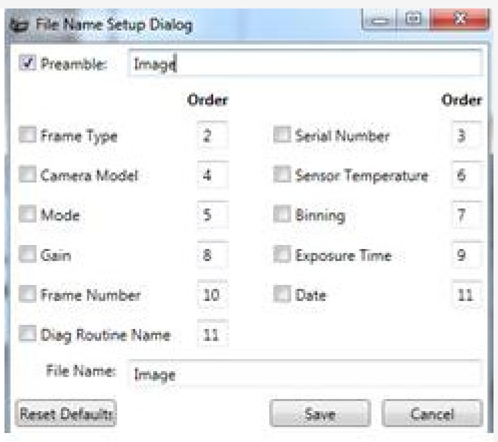
3. The default Grab modes should be Frame Counts: Single and Frame Type: Normal.

Frame Counts: Single
Frame Type: Normal

a. For details of the different grab modes please go here.
4. To automatically save image:
a. Click Save to File on the Grab Control menu.
b. Select file type (ex. FIT).
c. Select the 3 image types (Save Low Gain Image, Save High Gain Image, Save Merged Image)
d. Specify file path (where the image will be saved to).
e. Select the Preamble box and add Image.



Save Exposure As: (Saves Low Gain) ☐ TIFF File ☐ RAW File ☐ JPEG File ☑ FIT File ☐ PNG File ☐ BIN File ☐ RCD File
☐ Metadata To Text File
☑ Save Low Gain Image
☑ Save High Gain Image
☑ Save Merged Image
☐ Save Sectors As Files
File Path:
File Name: Image
Preamble: Image

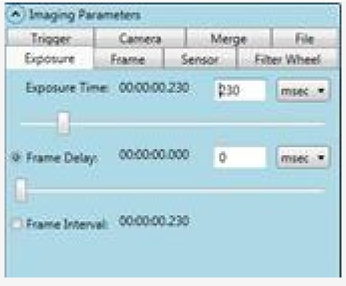


☑ Preamble: Image

	Order		Order
☐ Frame Type	2	☐ Serial Number	3
☐ Camera Model	4	☐ Sensor Temperature	6
☐ Mode	5	☐ Binning	7
☐ Gain	8	☐ Exposure Time	9
☐ Frame Number	10	☐ Date	11
☐ Diag Routine Name	11		

File Name: Image

f. For more information, visit: http://flicamera.com/kepler/keplermanual/File.html
5. To set exposure time:
a. Click Exposure on the Grab Control Menu.
b. Enter your desired exposure time within the Imaging Parameters menu.



Exposure Time: 00:00:00.230 230 msec

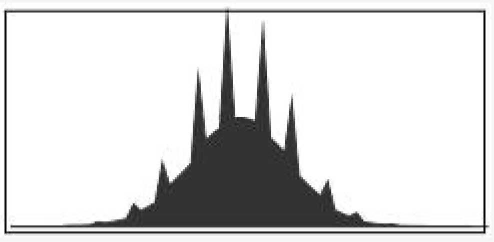
○ Frame Delay: 00:00:00.000 0 msec

○ Frame Interval: 00:00:00.230

I. If you encounter a white image with a mean of 4095, decrease your exposure time.
c. For more information, visit: http://flicamera.com/kepler/keplermanual/Exposure.html
6. Set cooler temperature:
a. Click Cooler Temp in the Grab Control menu to show the Camera menu.
b. Turn on Cooler Temp and enter your desired temperature value.
c. For decreased Dark Current Growth, operate the camera at a lower temperate, ideally -10c. This ensures for a cleaner image.
d. It takes 5 degrees per c to cool, therefore it will take a few minutes to reach -10c.
e. Wait for the camera to reach your operating temperature before continuing.
f. For more information, visit: (http://flicamera.com/kepler/keplermanual/Camera.html)
7. Capture an image:
a. Click Grab Normal Frame, under the Grab Control menu, to take an image.
I. If the previous steps were followed, the image was saved to your desired location.
II. You may revisit any of the previous steps to adjust your image.

V. Reviewing Image

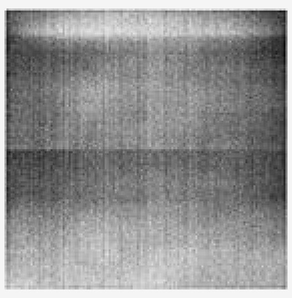
1. Image characteristics are shown in the histogram at the bottom left of FLI Pilot.
   a. This displays image mean, standard deviation, mode, etc.
   b. If you are viewing the Merged image histogram it may have a comb look, like the image below. This is a normal outcome and is due to the truncation and rounding of the individual pixels values.



Once you have captured an image please proceed to the next step.

VI. Stacking Images (Master Dark) for Fixed Pattern Noise (FPN/PRNU) Correction

1. The next step takes a number of Dark images and stack them together to produce an average image. Please see below for normal dark images.



Low Gain Image (Single) High Gain Image (Single)

2. If your camera does not have a shutter please block light from your camera.
3. If your camera does have a shutter go to the Imaging Parameters menu and click on the Camera Tab.
   a. Activate the Manual Shutter Control Enabled box.
   b. Ensure the Close box is checked, this should close your shutter.
4. Similar to the step above, please update the Preamble line, under the Imaging Parameters menu and the Camera tab, to “Stacked”.
5. Once you are able to take a dark image, navigate to the Tester Routines menu
   a. Select Stack Frames from the Routine: list.
   b. Change the Frame Count to 25
   c. Ensure the exposure time and units are the same as your previously captured image.
6. Press the Start button next to Stacked Frames.
   a. When finished the new Stacked Low/High/Merged images are saved then displayed.
7. It is recommended that stack frames be taken at a range of times (100msec, 500msec, 1 sec, 5 sec 10sec). These can be used for image correction of exposure which have similar times. For the best results, FLI recommends using correction frames which exactly equal the exposure time. These can be acquired at any time.
8. This process may also be used to gather Stacked Flats which may be used in 3rd party imaging software for further image correction.

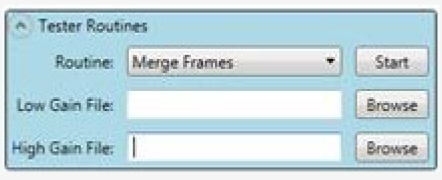
VII. Correcting the Image for FPN

1. Under the Tester Routines menu, select the Frames Difference routine.
2. Select the Browse button next to the Reference Files:
   a. Select the Stacked High gain image file that was created and saved earlier.
3. Select the Browse button next to the Source File:
   a. Select the Image High gain image file that was created and saved earlier.
4. Once both High gain image files have been selected, press the Start button.
   a. This will create a corrected High Gain image file without the fixed pattern noise of the sensor.
5. Manually save this image. Please select File, Save As.
   a. Ensure that the Save As Type is .Fit
   b. Select the path and file name as appropriate. A file name of “Corrected Image” will work.
6. Select the Browse button next to the Reference Files:
   a. Select the Stacked Low gain image file that was created and saved earlier.
7. Select the Browse button next to the Source File:
   a. Select the Image Low gain image file that was created and saved earlier.
8. Once both Low gain image files have been selected, press the Start button.
   a. This will create a corrected Low Gain image file without the fixed pattern noise of the sensor.
9. Manually save this image. Please select File, Save As.
   a. Ensure that the Save As Type is .Fit
   b. Select the path and file name as appropriate. A file name of “Corrected Image” will work.
10. Once the Low and High gain Corrected Images have been saved, proceed to the next step, producing the HDR image.

For further information on Pilot's routines please see Tester Routines

VIII. Producing a 16-bit High Dynamic Range (HDR) Image

1. Under the Tester Routines menu please select the Merge Frames routine.



Routine: Merge Frames

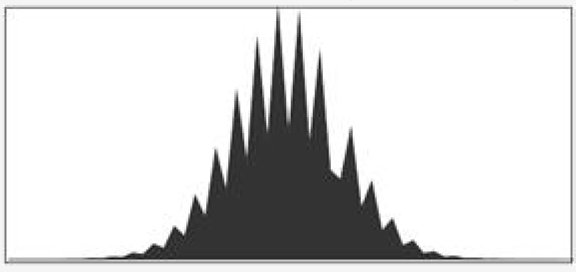
2. Press the Browse button next to the Low Gain File:
   a. Select the Corrected Image_Low image.
3. Press the Browse button next to the High Gain File:
   a. Select the Corrected Image_High image.
4. Press the Start Button.
   a. This will produce a new Merged Image – Manually Merged Image.
5. Manually save this image. Select File, Save As.
   a. Ensure the Save As Type is .Fit
   b. Select the path and file name as appropriate. A file name of “Corrected Image” will work.
6. This completes your tutorial on taking your camera from the box to production of corrected images.

Optional Settings

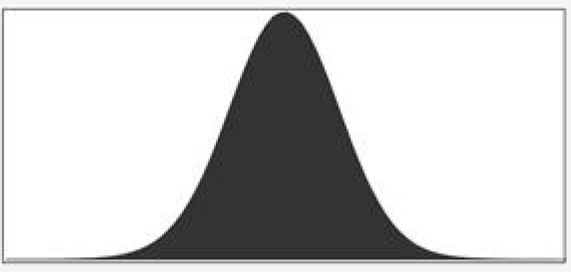
Automatically Correcting Images for FPN (Steps VII & VIII Automatic)

1. After you have created and saved the Stacked Dark Image in step VI you may continue, this section replaces steps VII and VIII.
2. Go to the Imaging Parameters menu and click on the Merge tab.
3. Click on the box next to Subtract Reference Files to enable automatic correction.
4. Click the Browse button next to the High Ref File: and select the Stacked High Gain image obtained from Section VI.
5. Click the Browse button next to the Low Ref File: and select the Stacked Low Gain image obtained from Section VI.
6. Once steps 3-6 are complete each image will automatically have the Fixed Pattern Noise removed prior to display in Pilot.
7. If automatic file saving is enabled the corrected images will be saved.

Correction of Merge Histogram



Normal Histogram



Corrected Histogram

1. Depending on which gain pairs are selected the Merged image histogram may show a comb effect, as demonstrated below. This is due to rounding and truncation of pixel values as you move from the High/Low gain images 12bit 0-4095 pixel count up to the Merged images 16bit 0-65535 pixel count.
2. If you wish to have a histogram without the comb effect please follow the steps below.
   a. Go to the Imaging Parameters menu and click on the Merge tab.
   b. Enable the box next to Correct Histogram.
   c. Click the Apply button below that.

Running Other Gains? Use Merge Calculate

1. If you are using Gains other than the defaults or if your merged image needs further calibration please run the Merge Calculate routine, following the instructions below.
2. Go to the Tester Routines menu and select the Merge Calculate routine.
3. Select the button next to 1, above the Temperature of -10.
4. Select the Gain Pair (Low and High) that you wish to run.
5. Press Browse next to Output Path:
   a. Select a location to save the output file to (this file is only for reference).
6. Press Browse next to Region File:
   a. Select the MergeCalculateRegionFile.csv that was saved earlier during the installation steps.
7. Press the start button.
8. Once the results box says “Straight Line Found” the process has completed.
9. Click the box that says Save As Defaults
10. Your merged calibration has been completed and you may resume image acquisition.

Assumptions

This User Guide is written with the assumption that you are familiar with cameras, computers (PCs), and image enhancement software. This Guide provides information on the use of the Kepler Imaging System.

This Guide describes the standard System components. If you have received custom or optional items, they are not described in the main sections of this Guide. Information for special items may be provided in an Appendix or as separate documentation.

Check your Shipment

Ensure that all the components have arrived safely and that all the items you ordered were properly delivered to you. In the unlikely event of a missing or damaged component, immediately notify your FLI dealer or FLI.

Note: Save the shipping materials that minimize shock and vibration in the event that you need to return the camera.

A camera order should include the following items:

- Camera with shutter cover installed (save this cover)
- Camera Test Report / FLI Quality Assurance Test Summary
- USB cable
- 12 volt power supply
- Packing list
- FLI Software Installation and Documentation (one page)

User Guide available at http://www.flicamera.com/software/index.html

Camera Care and Safety

⚠ **WARNING: Kepler Imaging System is shipped with a 12-volt grounded power supply. Do not use any other power supply with this System or use the power supply in a way other than described in this Guide as it may cause damage to the camera that will not be covered under the warranty.**

⚠ **WARNING: If any liquid spills into the camera, immediately remove the power cord from the wall outlet and remove the power supply cable from the camera. Use a dry cloth to absorb the liquid. DO NOT USE the camera as it may cause personal HARM or damage the camera. Contact FLI for further information and instructions.**

Review the information below. Failure to heed these suggestions may damage to the camera or may adversely affect its operation.

- The camera contains no user serviceable components.
- As a general safety precaution, remove liquids and all unnecessary items from the area in which the camera will be used.
- Provide adequate clearance (2.5 inches (6 cm)) on the camera's intake and exhaust sides for air flow.
- For USB 3 Systems, directly connect the computer and camera power supply to standard grounded electrical power outlets (the same service).
- **Plug the power cord into the camera first, then plug the power cord into the power outlet.**
- When not in use eliminate damage to the camera from electrical surges (for example, lightning strikes) by unplugging both the camera power supply from power and the camera USB cable from the computer.
- Before connecting and disconnecting any cables, shut down the computer. Failure to do so may result in damage to the camera.
- The site should not have excessive dust. Use a dust cover to protect the camera when not in use.
- If the fins of the camera's fan contain debris, use a cotton swab to remove debris.
- The room temperature and humidity should provide adequate operator comfort. High or low temperatures and humidity may adversely affect the camera.
- Dispose of the camera according to national guidelines.

Installing FLI Software

Note: If your system contains an earlier version of the FLI Software, uninstall / remove it by following the onscreen prompts. Then install the most current version. Overwriting an old file is not recommended.

Your computer must run Windows XP/Vista/7/8/8.1/10 32-bit or 64-bit. (If you do not know your system type, it is typically available from the Control Panel / System and Security / System menu.)

As noted in the camera shipping box, go to the "Support" tab of the FLI website. Select the FLI Software Installation Kit corresponding to your computer type. The Installation Kit installs FLI's applications and USB device drivers. Also, download the ASCOM driver for the focuser products if appropriate. Follow the onscreen prompts for the installation instructions.

After installing FLIPilot, click on the FLIPilot icon to launch it and ensure it has been installed.

Note: If your system runs with two GPU's (an internal GPU and a dedicated GPU), you should follow the instructions here to assure that the dedicated GPU is configured as the primary GPU for all Pilot calculations and processes.

Confirming Driver Installation

You can determine if the camera drivers have been properly installed after connecting and powering the camera. The procedure below is typical of most operating systems; however, it may be slightly different on your computer.

1. Choose the Control Panel from the start menu.
2. Choose System Properties.
3. Select the Hardware tab and select Device Manager.
4. Click the (+) next to Universal Serial Bus Controllers.
5. If the FLI Camera is displayed, the drivers are correctly installed.
6. Right Click on FLI Camera, choose Properties to view the driver status, driver date, etc. If the driver does not show up, uninstall FLIPilot then re-install it.

Third Party Software

Kepler cameras are supported by a robust SDK (Windows, LINUX) free of charge. Also included is FLI Pilot software. MATLAB®, LabVIEW®, ASCOM and µManager are fully supported.

Input-output TTL signals via an eight pin AUX port are provided making it easy to synchronize the camera’s operation with external events or light sources.

Before acquiring software to control your camera we strongly advise you to check with the software vendor and contact FLI. New releases of software may differ in functionality from previous versions of the same software and not operate as expected.

Image capture and analysis software includes:

- SkyX from Software Bisque (www.bisque.com)
- MaximDL from Diffraction Ltd (www.cyanogen.com)
- Astroart from MSB software that has a multi-lingual interface (www.msb-astroart.com)

Firmware Updates

The firmware of each camera can be updated if problems arise with its behavior. The process is well documented on the Firmware Updates page.

It is important to make backups prior to preforming updates to avoid losing data or functionality.

Setting up and Powering Your System

Assemble all system components in one area before beginning this set up procedure.

> **Note:** Run the FLI Software Installation Kit before you set up and power your system to ensure the system recognizes and correctly initializes the camera.

Figure 1 shows the camera with the appropriate connections made.

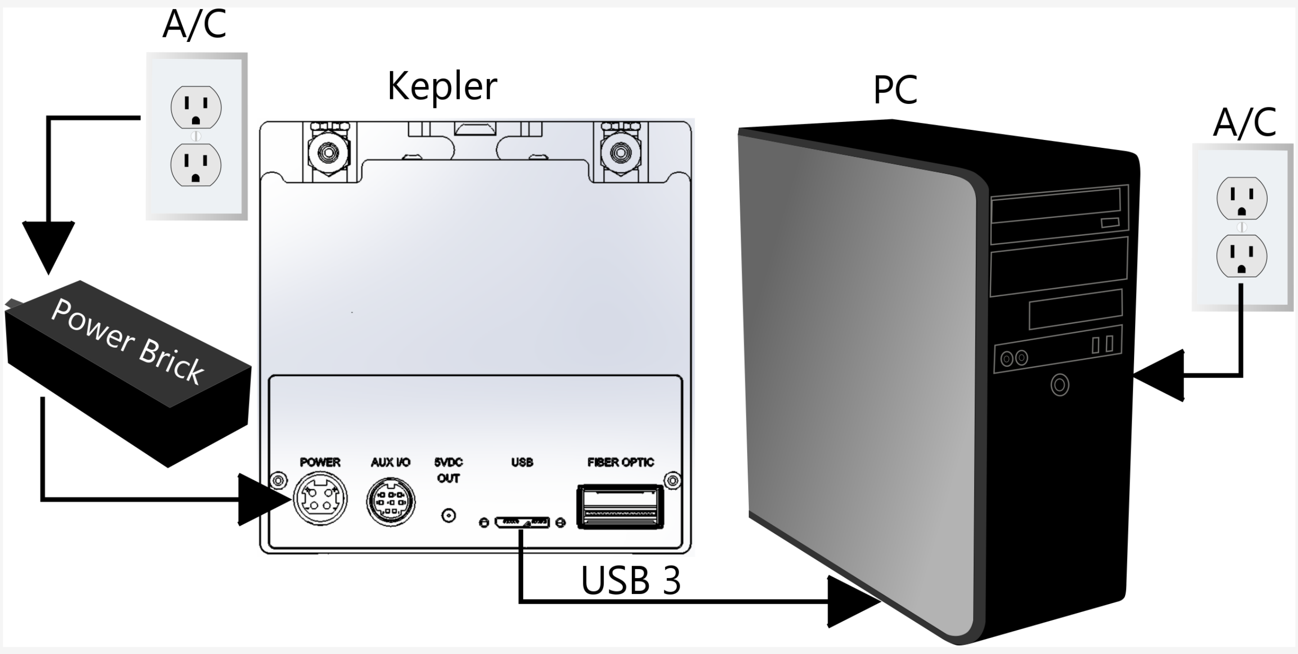


Figure 1. Kepler Camera with System Connections

Set up the system as described in the steps below.

1. Run the FLI Installation Kit to install the software as described previously.
2. Attach the USB cable between the camera and your computer.
3. Connect the 12-volt power supply between the camera’s 4-pin “DC Power Jack” connector and a wall socket or switched AC power strip. The camera’s fans will start running. Your computer should display a screen indicating that the system has found new hardware. If it has not, refer to “Confirming Driver Configuration” earlier in this Guide.

Specifications regarding the power supply and power cable of the Kepler cameras is in the page PT1.

The option to electrically isolate your Kepler is available. See System Isolation

Sensor Temperature / Cooling Information

The standard Kepler camera configuration provides for sensor air cooling (un-cooled). Depending on your application, you camera sensor may require cooling with air or with liquid coolant.

The Kepler family of cameras, like all FLI cameras, have a built-in TEC (Peltier) and a fan that enables the camera to cool the sensor. Removing excess heat from the camera’s electronics and keeping the sensor cool keeps the dark current to an acceptable minimum and reduces drift when capturing multiple frames. Provide clearance on the air intake/output faces of the camera.

The fan power is set at the factory. Refer to the FLIPilot documentation for information on controlling the fan.

Two heater strips on the outside of the camera window keep the window just above ambient temperature to reduce condensation on the window. Refer to the FLIPilot documentation for information on controlling the heater.

If your application requires liquid cooling, refer to Table 1 for connectors for the ports on the camera. The actual cooling for any given camera will depend on the sensor size and ambient temperatures. The Liquid Cooler can accept a flow rate up to 0.5 gallon/minute (1.91 liter/ min).

> **Note:** The Maximum Liquid Cooler inlet pressure is 50 psig. Ensure the tubing has the proper pressure rating. To avoid undesired pressure build up in Liquid Cooler shut off flow on the inlet side before detaching or closing outlet connections.

Connector	Standard User Interface	Additional Information
1/8” ID Hose Barb	1/8” ID Tubing	FLI recommends use of hose clamps. User supplies tubing and clamps with appropriate pressure rating for their application.
Quick Connect Double Shutoff	#10-32 UNC male coupling	FLI supplies both female and male connectors. User supplies the interface.
Quick Connect Dry Break	#10-32 UNC male coupling	FLI supplies both female and male connectors. User supplies the interface.
Custom	Per Customer Requirements	FLI is able to plumb to interfaces not listed. Please contact FLI with your connection requests.

> **WARNING: Using liquid cooling flow rates above the recommended flow rates may cause the liquid cooling system to leak and will void the warranty.**

Table 1. Connectors

External Triggering and/or Exposure Control

Externally trigger the camera using FLI Pilot as described in the steps below.

1. In FLI Pilot select the Shutter Control.

2. Select how the triggering is setup on the pull down menu:
   “External trigger on LOW” for low edge triggering (transition from +3.3V to 0V or equivalent LVTTL signal) on AUX pin 5.
   “External trigger on HIGH” for high edge triggering (transition from 0V to +3.3V or equivalent LVTTL signal) on AUX pin 5
3. Select “Done”.
4. Open the Grab Control.
5. Select desired frame and exposure settings.
6. Click the Grab button. The camera will now wait for an external trigger.

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1250 Rochester St.
Lima, New York 14485

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Web: www.flicamera.com

8-Pin Connector

The Kepler Imaging Systems have an eight pin AUX connector as shown in **Figure 1** and **Figure 2** with each pin described below. **Figure 1** is from the viewpoint looking at the cable. **Figure 2** is from the viewpoint looking at the camera.

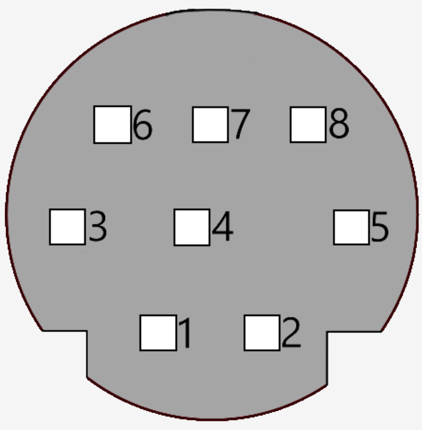


Figure 1. Male AUX Connector (Looking at Cable)

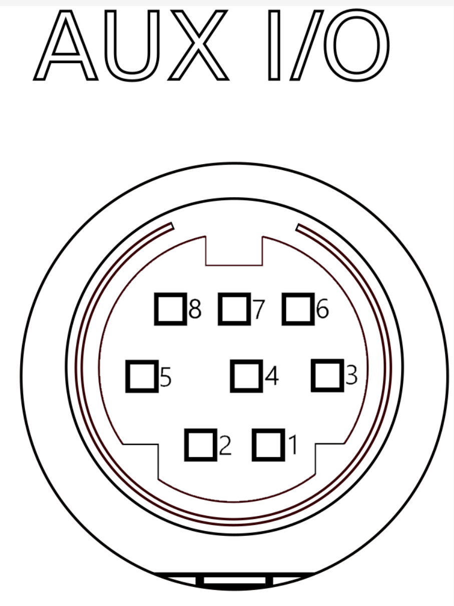


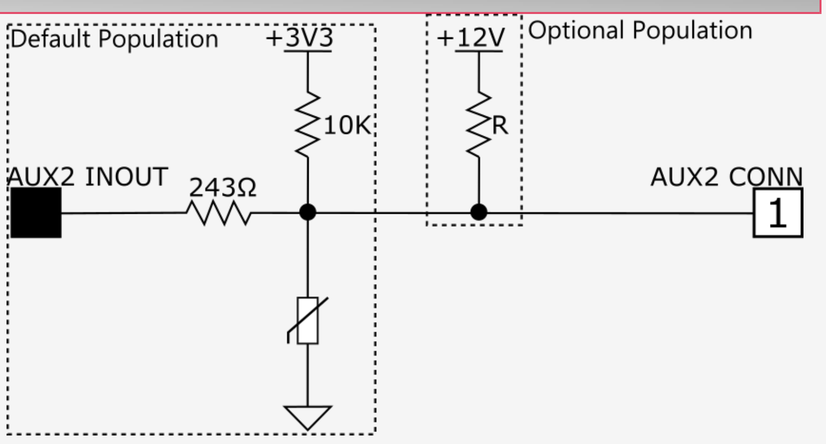
Figure 2. Female AUX Connector (Looking at Camera)

The tables below summarizes the pins on the 8-pin connector by pin number and by description in alphabetical order.

Pin	Description
1	Aux2_InOut
2	Aux1_InOut
3	External Trigger
4	Aux3_InOut
5	Shutter Open
6	Ground Reference
7	Aux4_InOut
8	Exposure Active

Description	Pin
Aux1_InOut	2
Aux2_InOut	1
Aux3_InOut	4
Aux4_InOut	7
Exposure Active	8
External Trigger	3
Ground Reference	6
Shutter Open	5

Pin 1 - Aux2_InOut



Pin 1 of the 8 Pin connector is a 12V supply.

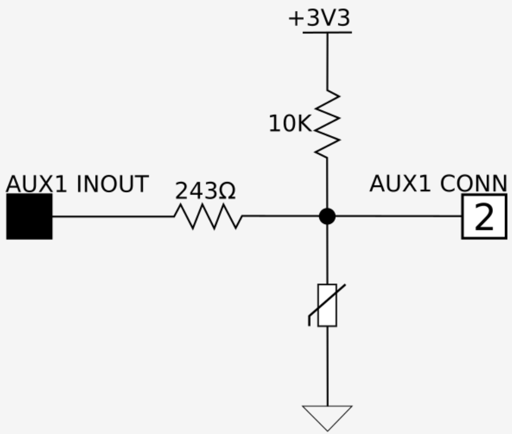
By default, there is a 243 Ohm series pullup resistor to 12V. This configuration allows use of the Kepler Image Time Stamp (KITS) module which requires 12V for operation.

An optional configuration is available to use pin 1 as an auxiliary IO connection. With the optional configuration, there is a 243 Ohm series resistor between the connector pin and the input/output driver. There is also a pullup of 10K to 3.3V.

Note: Installation of this configuration adds an additional aux IO, but removes the ability to use the KITS module.

The optional configuration can be assembled by FLI upon ordering. Contact FLI for information.

Pin 2 - Aux1_InOut



Pin 2 of the 8 Pin connector is auxiliary Input/Output 1.

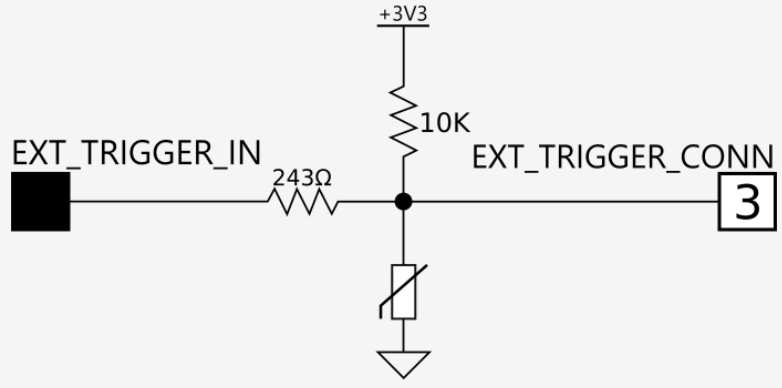
There is a 243 Ohm series resistor between the connector pin and the input/output driver. There is also a pullup of 10K to 3.3V.

This input/output driver is 3.3V LVCMOS compatible. The direction is controlled via the API. The state is controlled by the user or the API, depending on the direction.

Pin 3 - External Trigger

Pin 3 of the 8 Pin connector is the external trigger input signal.

There is a 243 Ohm series resistor between the connector pin and the input driver. There is a 10K Ohm pullup resistor to 3.3V. The state is controlled by the user.



See External Triggering.

Pin 4 - Aux3_InOut

Pin 4 of the 8 Pin connector is auxiliary Input/Output 3.

There is a 243 Ohm series resistor between the connector pin and the input/output driver. This input/output driver is 3.3V LVCMOS compatible. The direction is controlled via the API. The state is controlled by the user or the API, depending on the direction.

This pin can be programmed as a general purpose I/O or as UART in which case this pin becomes the RX for the UART.

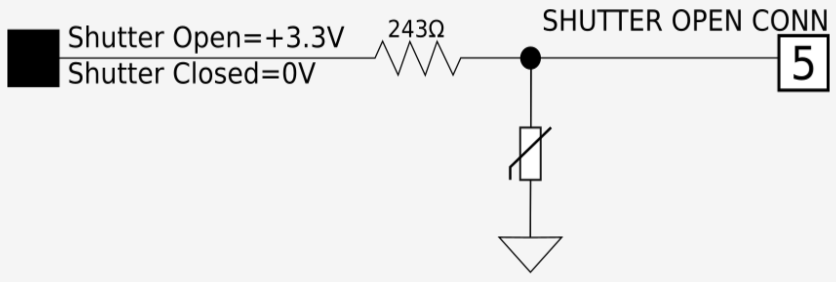
Default configuration operates as a UART, however, can be configured to operate as an IO upon request.

Pin 5 - Shutter Open

Pin 5 of the 8 Pin connector is the shutter_open output signal.

There is a 243 Ohm series resistor between the connector pin and the output driver. The output driver is 3.3V LVCMOS compatible.

Default state is shutter closed, 0V.



Pin 6 - Ground Reference

Pin 6 of the 8 Pin connector is camera ground. All other pins on this connector are referenced to this pin.

Pin 7 - Aux4_InOut

Pin 7 of the 8 Pin connector is auxiliary Input/Output 4.

There is a 243 Ohm series resistor between the connector pin and the input/output driver. This input/output driver is 3.3V LVCMOS compatible. Direction is controlled via the API. The state is controlled by the user or the API, depending on the direction.

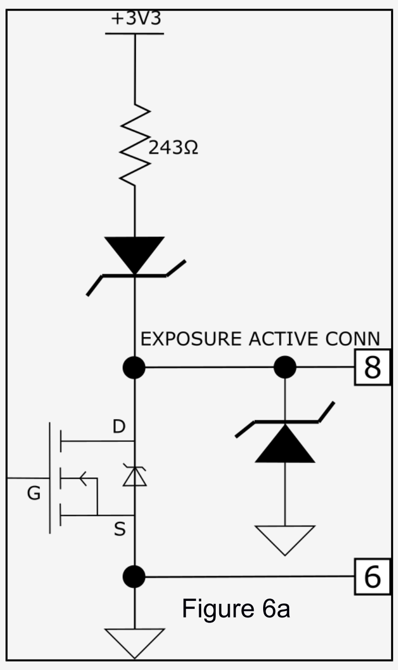
This pin can be programmed as a general purpose I/O or as UART, in which case the pin becomes the TX for the UART.

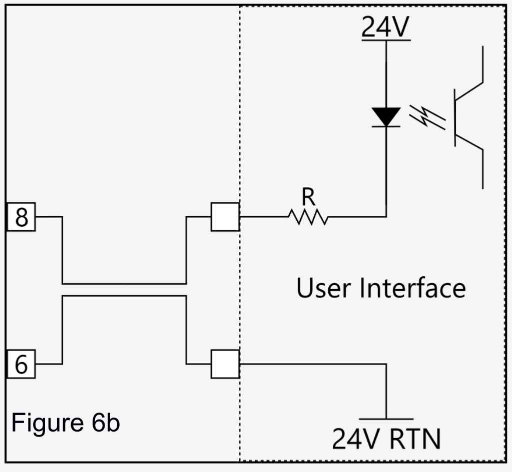
Pin 8 - Exposure Active

Pin 8 of the 8 Pin connector is the exposure active output signal.

There is a 243 Ohm pullup resistor to 3.3V. There is a FET switch to ground. The state is controlled by the camera controller. The default state is low.

This pin is configured to be either a logic output or a driver for optocouplers. Possible optocoupler setups are shown in the figures to the right.





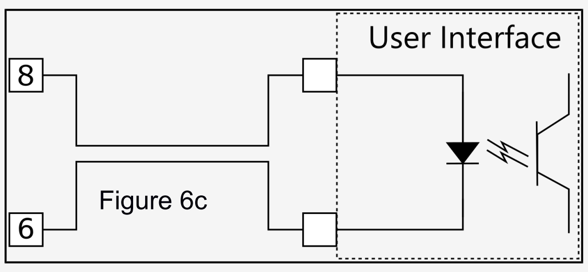
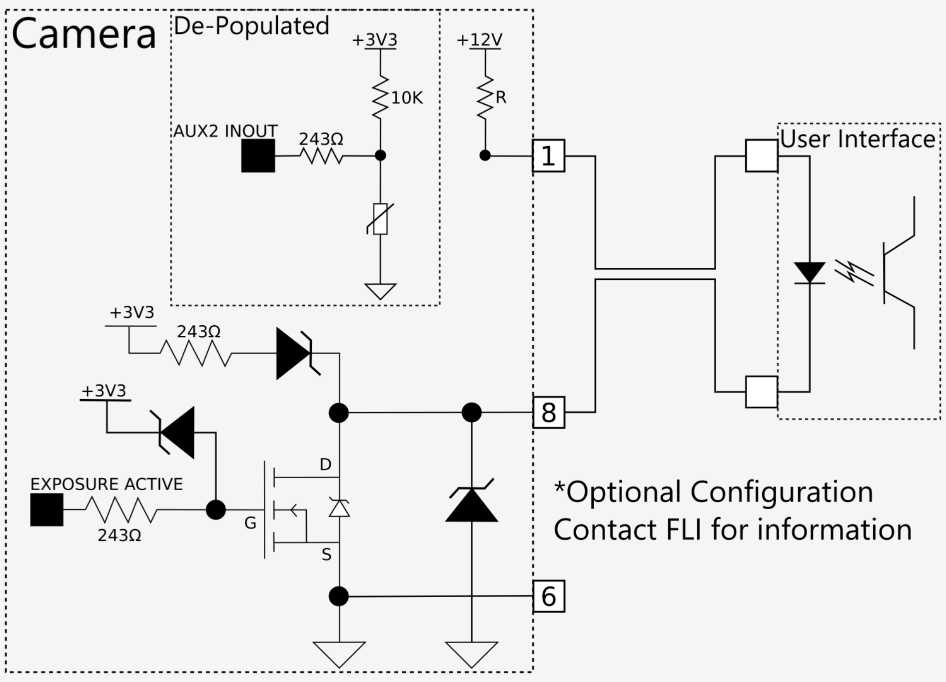


Figure 6a. The internal configuration of pin 8.
Figure 6b. A possible configuration that uses a 24V supplied by the user to drive an optocoupler.
Figure 6c. Another possible usage for pin 8 to use an optocoupler driven by the 3.3V supplied by the camera.

Pin 1 and 8 - Optional Optocoupler Configuration

This configuration uses a 12V source provided by pin 1 to drive an optocoupler.

For more information see Pin 1 and Pin 8. Contact FLI for more details.



*Optional Configuration
Contact FLI for information

Exposure Indicator

Pin 8 will output a signal indicating the state of exposure the camera is in. This external signal can be used to control external devices directly from the exposure state of the camera. This indicator can be used for timing instruments properly, and can be configured in the following modes to vary the output based on specific moments in the sensors process.

First Row Active (Default):
In First Row Active mode, the output signal is high during the first rows' exposure in a single frame. **(Figure 7)**
The length of the signal is dependent on the first rows exposure time. The exposure time can be set in the software by the user.
This mode maximizes frame rates, but results in overlap of frames due to the rolling shutter effect.

Exposure Active:
In Exposure Active mode, the output signal is high when any row in a single frame is exposing. **(Figure 7)**
The length of the signal is dependent on the time between the start of the first rows' exposure and the end of

the last rows' exposure.
It is not possible to achieve maximum frame rates in this mode, but frame overlap is avoided.

Global Exposure Active:
In Global Exposure Active mode, the output signal is high when all rows are simultaneously exposing.
The length of the signal is dependent on the time between the start of the last rows' exposure and the end of the first rows' exposure.
This mode takes advantage of the speed and low noise capabilities of the rolling shutter but eliminates motion artifacts. **(Figure 7)**

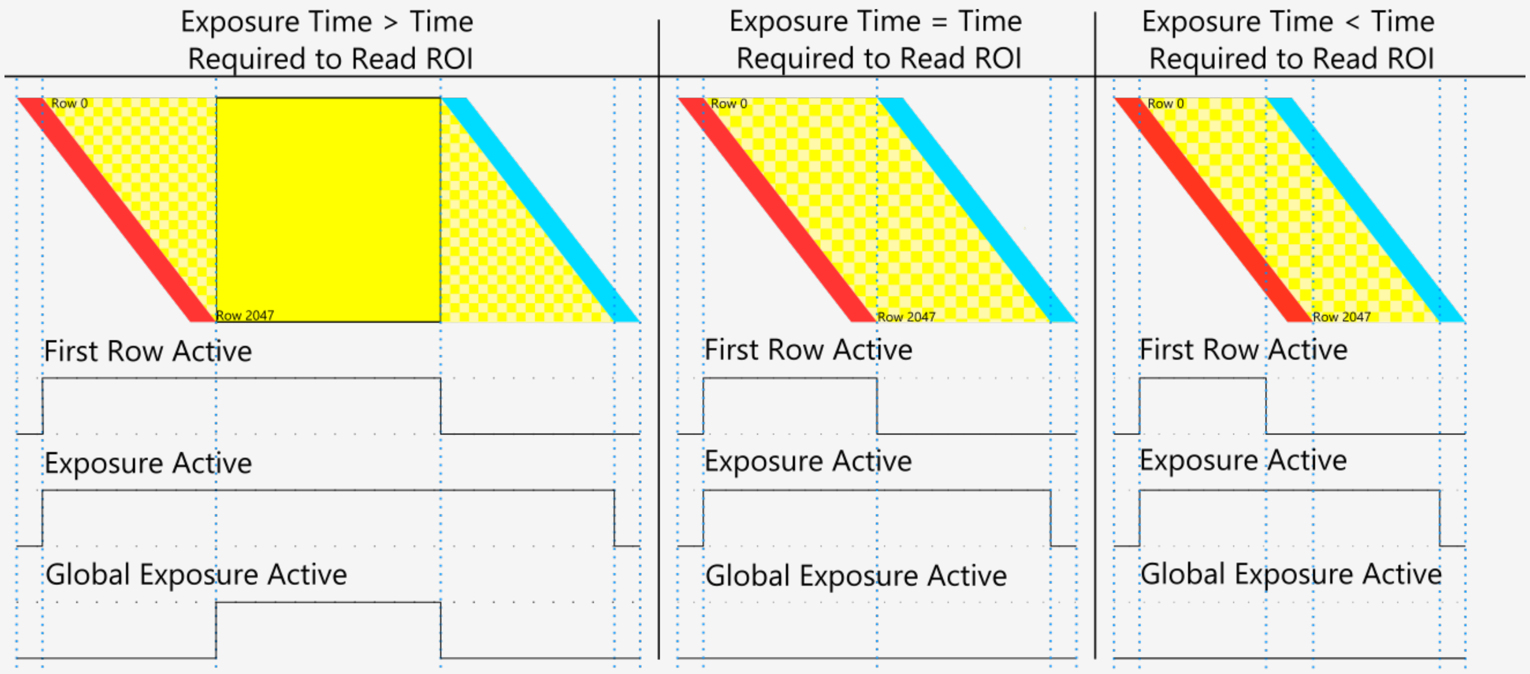


Figure 7. Exposure Control

Exposure Active is the default configuration for pin 8's output. To change this option, one may use LibFLIPro, the SDK behind FLI Pilot, to program the exposure active signal type. The function *FPROAuxIO_SetExposureActiveType(iHandle, eType)* is used for this operation and discussed in greater detail in the SDK documentation. The SDK and SDK documentation is available at flicamera.com. The most up-to-date information can be requested through FLI.

Kepler Rolling Shutter Overview

Kepler cameras use a sensor that is a rolling shutter imager. The pixels in the array are always exposed to light.

A single row within the sensor consists of a three step sequence.

The sequence starts with discarding built up charge, known as a reset or flush, to bring each pixels charge back to the reference level. When a reset is finished, the pixels in that row begin absorbing light (exposing) which accumulates charge. Finally, after the row is done exposing, the built up charge is read, known as readout. **(Figure 1)**

RNI	Read non-imaging row
Rn	Reset
Rdn	Read

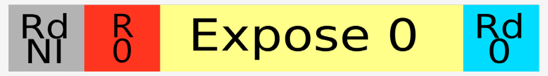


Figure 1. Single Row Sequence

More information regarding rolling shutter imaging can be viewed here.

Kepler Triggering

Kepler cameras support internal and external ways of triggering (commencing exposure) an image. When an image frame is required, the user interface can command a trigger. All trigger commands are executed after the Exposure Delay time has expired This approach makes computer control of when an image is captured easy.

The triggering options can be modified in FLI Pilot under Trigger.

Trigger Options:

Internal: This method uses the software application to issue a trigger request immediately when a capture is requested. This internal trigger is communicated over the USB 3.0 connection or Optical Fiber connection (See System Isolation). These connections introduce a small amount of variable delay. There is also a fixed delay in the camera for the internal trigger to be communicated to the sensor controller.

External Low to High and External High to Low: This method configures the sensor to respond to an external trigger. This input is found on the 8-pin connector, Pin 3. When an external trigger is selected and image capture is requested, the camera waits for the transition of the external trigger pin to start the exposure. With Low to High selected, the camera waits from the signal on Pin 3 to transition from Low to High. With High to Low, the camera waits for a High to Low transition.

External Control High to Low and External Control Low to High: In these modes of operation, the level of the externally supplied trigger signal (provided through Pin 3) controls the start of the image exposure and the end of the exposure. For control high to low, the image exposure starts when the external trigger input transitions from high state to low state and ends when the external trigger input transitions from low state to high state. For control low to high the external trigger states are the reverse. The exposure value entered in the software acts as a maximum exposure. If the external trigger state is still active when the entered maximum exposure is reached the exposure is halted and readout begins. Therefore, ensure the entered exposure setting value is larger than the maximum expected externally controlled exposure time.

External Triggering

Figure 6 indicates a commonly misunderstood feature of external triggering. When a trigger is received during active exposure, the trigger will be ignored by the system, as indicated by the red trigger signal in **Figure 6**. Only until a trigger is received outside of an image capture will the next image begin exposing.

Figure 6 also shows the effect of having a shutter open delay of 0ms. As shown, the exposure begins immediately when the trigger is received. This indicates an **External Low to High**. An **External High to Low** would operate similarly, however the exposure would begin on the falling edge of the trigger pulse. This can be a useful configuration if the goal is to maximize framerate or emulate a mode similar to multiple of continuous capture, while maintaining external control of the system.

To maximize the frame rate with external triggering, there are a few settings that must be checked. First, assure that the shutter is permanently open to assure a shutter delay of 0ms (Controlled via **Imaging Parameters / Camera**). Additionally, assure that the trigger mode is set to **External High to Low** (Controlled via **Imaging Parameters / Trigger**). When these settings are confirmed to be set correctly, all that is necessary is to send a signal to pin 3 whenever pin 8 outputs a signal. With respect to **Figure 6**, this setup shifts the trigger signal to directly after **EA** ends such that the following exposure begins almost immediately after the prior.

This setup essentially emulates continuous frame grabs with the additional responsibility of controlling pin 3 with pin 8.

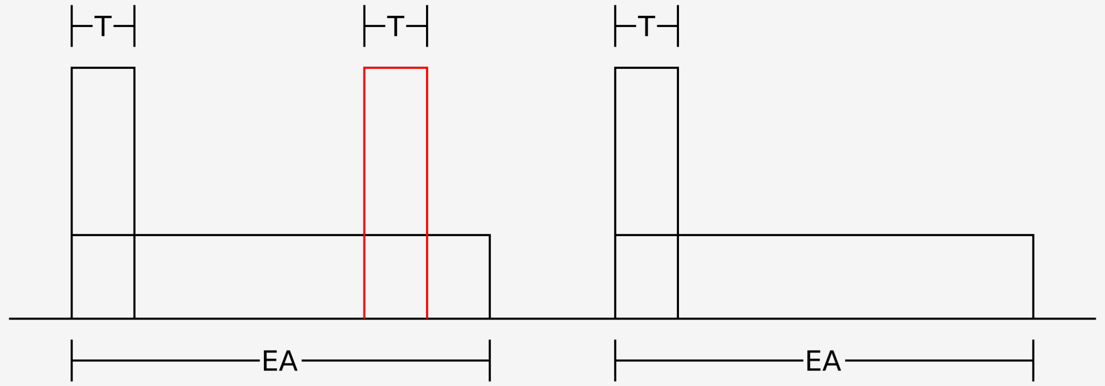


Figure 6. External Triggering

Kepler Exposure Start Options

The Exposure start options are controlled in FLI Pilot under Trigger.

First Row Exposure (Default Exposure Setting)
In first row exposure mode, the trigger may be received at any time during the sensor's idling, however, the sensor will always finish its active cycle of flushing before beginning exposure. Where in this process the trigger was received is unknown, thus, there is a variable delay of between 0 and 21msec.

When an exposure starts, the camera resets the start row and commences exposure as soon as the trigger is received. In this case, no charge that was accumulated in the exposure prior to the trigger is kept since all image rows are reset after the trigger. This results in a start of exposure time difference for each image row. For most imaging applications this is acceptable.

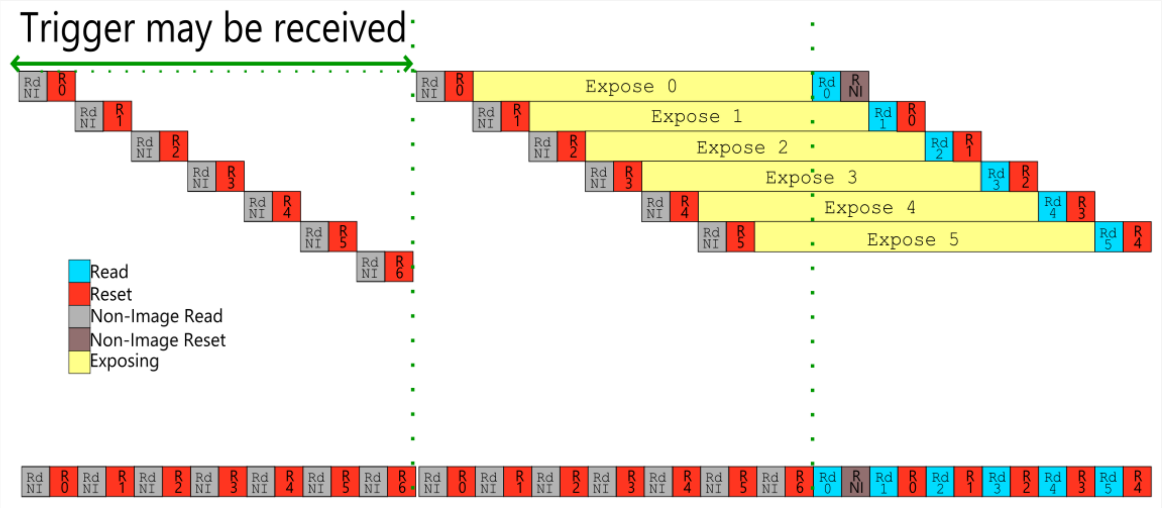


Figure 2: First Row Exposure. Six row example.

Immediate Global Exposure
In immediate global exposure mode, the trigger is received and all row resets cease immediately and all rows are exposing. Therefore, all rows are exposing at the same time without read and reset interruptions.

This prevents a 21/42ms variability that the first row exposure has. However, there still exists a small delay of at most 21usec due to the previously mention time required to complete an active read/reset function. Additionally, there will exist rows with up to 21 msec of exposure which has already occurred due to rows that had not been reset since the previous flush procedure. This is only an issue if the sensor has been exposed to light during the time immediately prior to the trigger. A well functioning shutter or a dark scene with a flash allow this mode to function best.

When the start row has reached the desired exposure duration, image row readout commences and continues for 21/42 usec. In **Figure 3,** for example, row 6 is read first due to the timing of the received trigger. When it reaches row 11, readout loops back to row 0 and continues until row 5, which is the last row to be read. This results in all rows having slightly different exposures, but this is not deemed a problem due to the nature of the image being captured.

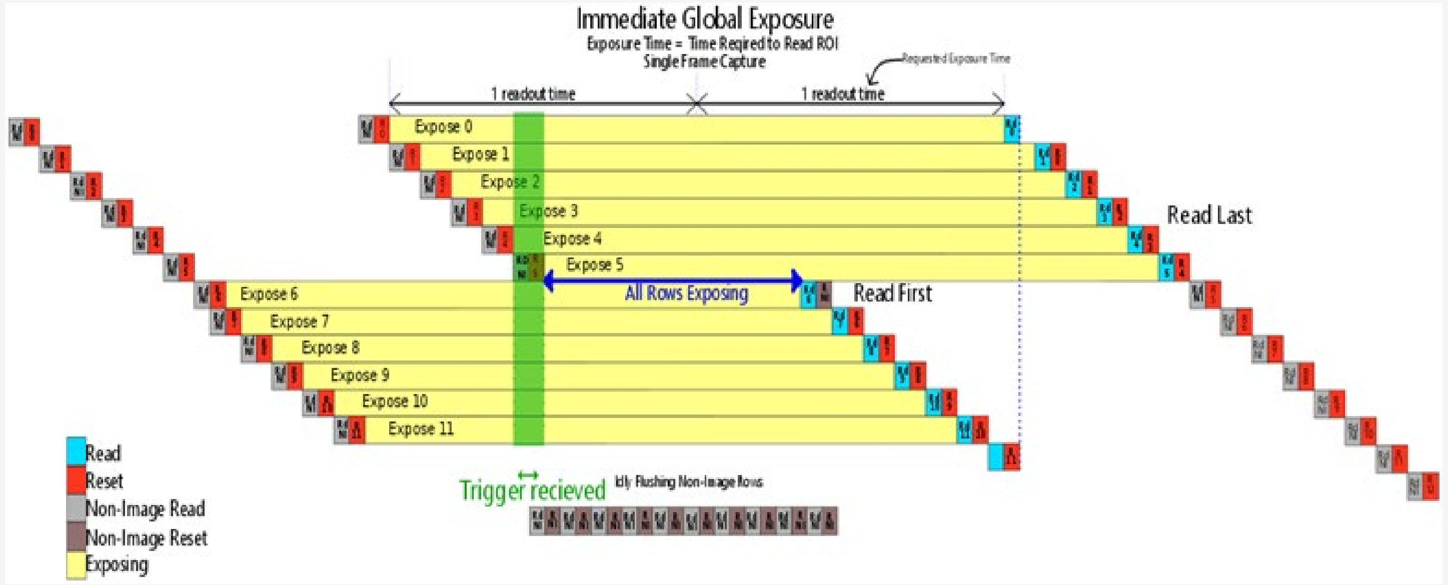


Figure 3. Immediate Global Exposure

Kepler Image to Image Timing

Kepler camera Image to Image timing can be controlled when you are running multiple images or continuous images. Image to Image time consists of exposure time and delay between end of exposure and start of next exposure. Kepler cameras lets you set exposure time and image to image time.

The FLI Pilot interface allows you to define any two parameters and automatically calculates the third parameter of the equation:

Image to Image Time = Exposure Time + Delay Time

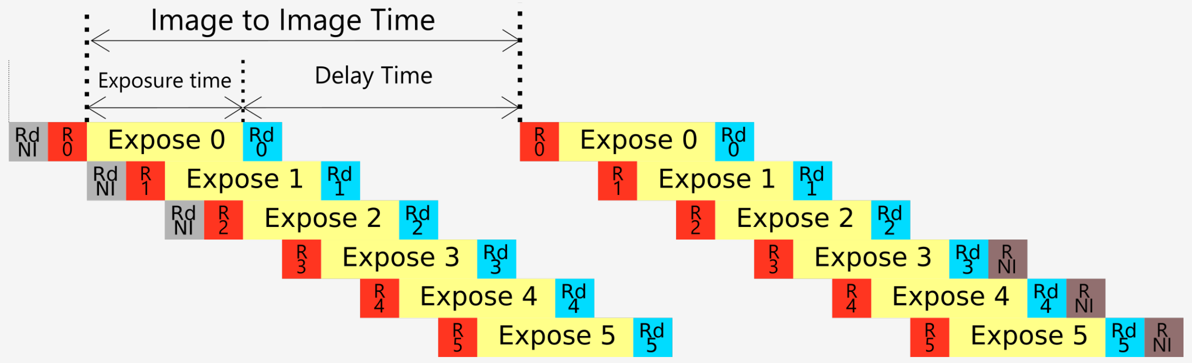


Figure 4. Image to Image Timing

Kepler Camera Modes

The KL400 has four camera modes:

- Rolling LDR
- Rolling LDR-LDC
- Rolling HDR
- Rolling HDR-LDC

The KL4040 has one camera modes:

- Rolling HDR-LDC

Rolling LDR:

LDR (Low Dynamic Range) mode captures a single 12 bit image. This mode consists of 0 to 4,095 counts, but offers high frame rates compared to HDR.
LDR mode is useful for short and bright exposures.

Rolling LDR-LDC:

LDR-LDC (Low Dynamic Range-Low Dark Current) mode is similar to LDR mode. The difference is that LDC leads to less electrons accumulating in pixels when not exposed to light. This results to a smaller full well capacity, but allows for less dark current growth in long exposure images.

Rolling HDR:

HDR (High Dynamic Range) mode captures two images, a high gain and low gain image. In this mode you can view either gain image, or a merged image of the two, which creates a 16 bit image. HDR has slower frame rates than LDR, but is more sensitive and detailed with 0 to 65,535 counts.

Rolling HDR-LDC:

HDR-LDC (High Dynamic Range-Low Dark Current) mode is similar to HDR mode. The difference is that LDC leads to less electrons accumulating in pixels when not exposed to light. This results to a smaller full well capacity, but allows for less dark current growth in long exposure images.

Shutter Delay

When a physical shutter is in use with a Kepler camera, there is an automatic **Shutter Open Delay** (SD) that delays the beginning of an exposure by a certain amount each time an external trigger is received. Additionally, a **Shutter Close Delay** can be implemented to close the shutter prior to the end of exposure or to postpone the following capture. If these features are needed, contact FLI to configure the options for your system.

Figure 5 shows the process clearly. Upon receiving a trigger pulse (**T**), the shutter open delay begins and the shutter opens. Upon the end of the shutter open delay, exposure of the frame begins. As mentioned, a shutter close delay (SCD) is also possible to implement. Figure 6 shows the difference between a positive and negative shutter close delay. A negative SCD will command the shutter to close the entered duration prior to exposure ending. A positive SCD will command the shutter to close when exposure ends and prevent the next image to begin capture until after the set duration.

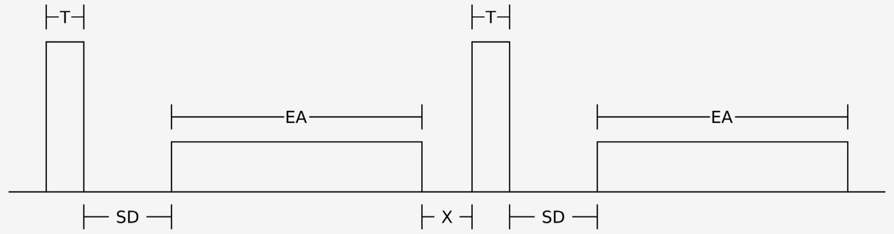


Figure 5. Shutter Open Delay

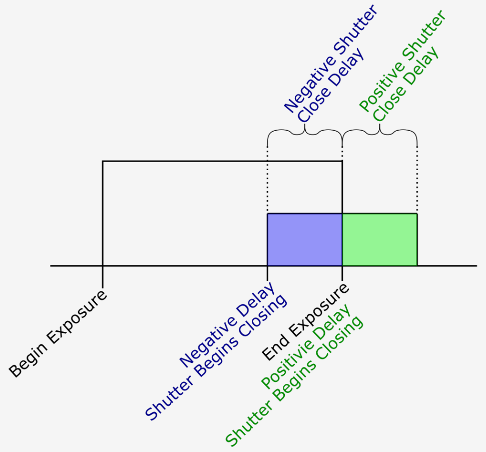


Figure 6. Shutter Close Delay

KL400 Shutter Assembly

If you need to service your shutter assembly or replace the shutter assembly please see the following schematic (Figure 1) to assist you. Please note that the shutter assemblies are very fragile.

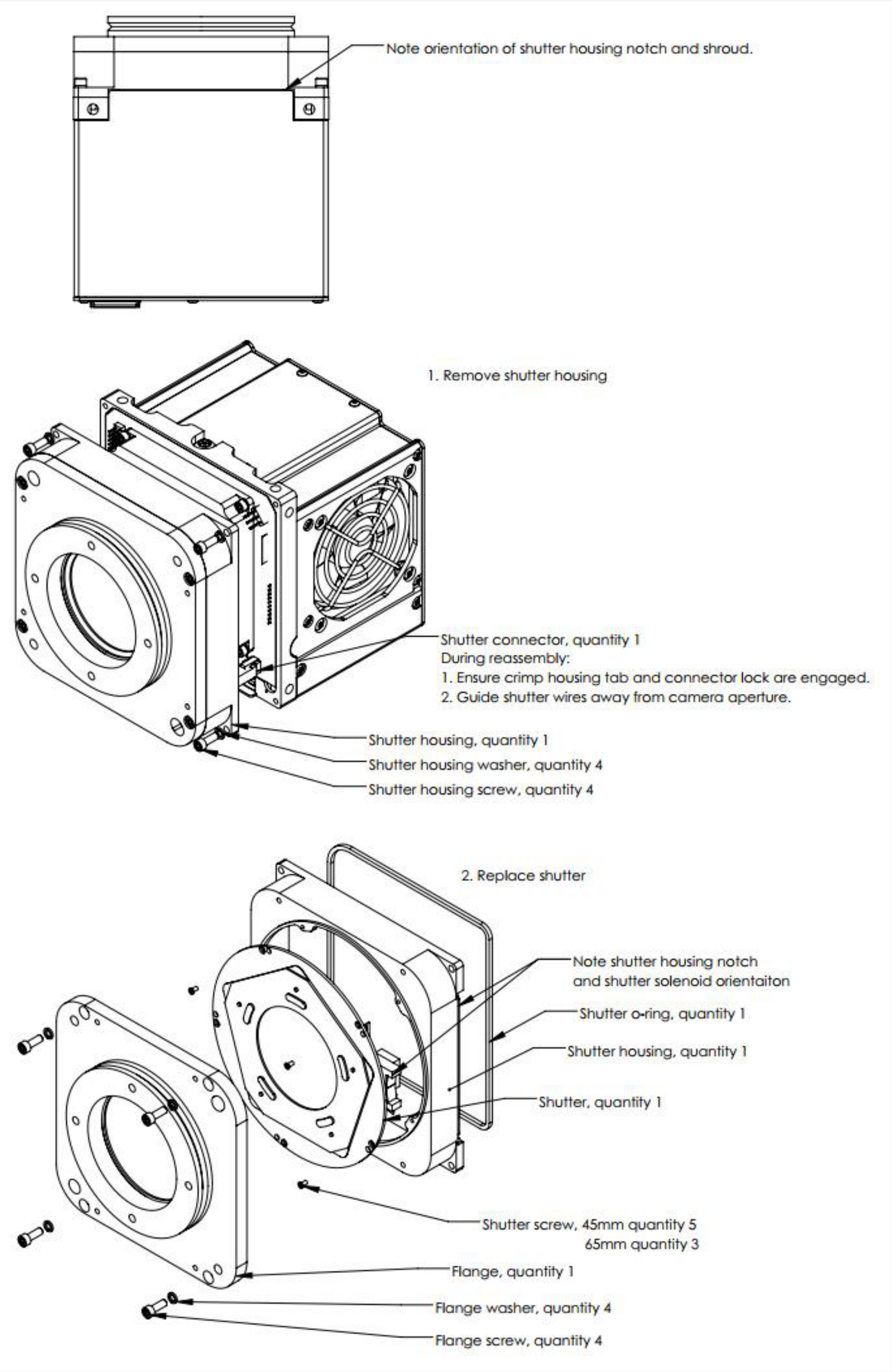


Figure 1. Shutter Assembly

Firmware Updates

Updating the firmware of a Kepler camera is a process that will likely be done multiple times in a cameras lifetime. Firmware updates may contain stability or functional improvements. The process of updated a cameras firmware is not difficult, however, there are important steps which must not be left out.

The software required to update the camera firmware is located on the FLICamera website under Support. Download **Kepler Camera Firmware Updater** and extract the files. Assure that no other FLI programs are running (such as FLI Pilot), then, run the application titled **FLIP_Installer** and complete the installation procedure.

Prior to updating, a backup of the cameras current configurations should be created. This process is well documented in **Kepler - Saving and Reloading Camera Factory Settings.pdf**, a document which is included in the zip that contained the FLIP Installer.

When you have completed backing up the configurations and settings of the camera, follow the directions included in **Kepler - Firmware Update Instruction.pdf**. If a problem occurs, **Kepler - Saving and Reloading Camera Factory Settings.pdf** documents the procedure to properly reload settings onto a camera.

Installation

The basic installation procedure and requirements for FLI Pilot are found here.

Quick Start

This page contains the basics you need to know for capturing an image and performing post-image analysis.

Display Customization

FLI Pilot provides a very modular and customizable interface. This page discusses the various ways one can alter the interface.

Pilot Overview

This page goes through each part of the FLI Pilot program to familiarize the user with the various components of the interface.

Control Panel

This page reviews every element of the rightmost control panel, from Grab Control to Tester Routines.

FPN Correction

The problem of Fixed Pattern Noise is discussed here, as well as the technique required to remove FPN from an image.

FLI Pilot Installation

The installation files for FLI Pilot can be found on our main website under the Support Tab. The FLI Pilot software download files are labeled FLI Pilot Software for Kepler Cameras: Windows 7/8/10 (32-bit/64-bit).

1) Download the correct version (32-bit or 64-bit) for your computer. It is our recommendation that this software be run on a Windows 10, 64-bit computer.
2) Unzip the FLIPilot folder that was downloaded.
3) Find and open the FliPilotSetup
4) Follow the program prompts to finish the install.
5) Pilot should now be loaded onto your computer. It can be started by clicking on the desktop icon or navigating to Start FLIPilot.

FLI Accessory Drivers Installation

If you have purchased any accessories like our Filter Wheel then you will need additional drivers to connect these devices to your computer. These files can be found in the FLI Software Installation Kit under the Support Tab. The download files are labeled Windows XP/Vista/7/8/8.1/10 (32-bit/64-bit)

1) Download the correct version (32-bit or 64-bit) for your computer. It is our recommendation that this software be run on a Windows 10, 64-bit computer.
2) Unzip the FLISetup folder that was downloaded.
3) Ensure that all FLI programs like FLIPilot are not running, if they are close the program.
4) Find the and open the FLISetup windows installer file.
5) Follow the program prompts to finish the install.
6) Your drivers should now be installed and your filter wheel should automatically be detected by Pilot now.

FLI Pilot Updates

As Pilot is updated, the newest released version will be added to the website. Updating your current version of Pilot is as simple as downloading the new install file and completing the steps above. Once the installer has completed, please restart your computer. Once your computer has rebooted, your existing shortcuts for Pilot will function with the new version.

Beta Versions of Software

As we are updating and modifying our software we may post beta versions on our website, under the software page. These versions of the software programs may have new features however they may also have bugs in the code. While we encourage you to try them, we ask that if you do find an error in the program that you email us with the details. We ask that if you have any problems that you follow our troubleshooting guide.

Quick Start Guide

This Quick Start Procedure provides information to grab the first image. Once you have an image, you can experiment with the settings to optimize the image quality.

You should have already downloaded FLIPilot. See the Set Up page.

With your computer running, insert the camera's interface cable into your computer and insert the camera's power cable into AC. The camera fan will run.

Launch FLI Pilot

Set Image Capture Controls

1. Expand the Grab Control pane.
2. Click the Grab Modes drop-down list to display the type of grab you want to obtain.
3. Click “Exposure”. On the displayed Exposure pane enter the Exposure time and if appropriate, either the Frame Delay or the Frame Interval.
4. Click “Cooler Temp”. On the displayed Camera pane turn on Cooler Temp and enter a temperature value.
5. Click “Camera Mode”. On the displayed Sensor pane select the camera mode you want to use. If you selected an HDR mode, enter different LDR and HDR gain values on this same pane.
6. Click the term “Binning” if binning is available on your camera. (The KL400 does not allow binning.) On the displayed Sensor pane, select horizontal and vertical binning values. (Omit this step when using the KL400).
7. To save the grabbed image as a file, navigate to File under Imaging Parameters. On the displayed File pane, select the file type(s) and enter or browse to identify a file path. If you are capturing an HDR image, choose to save the High Gain and/or Merged Images. (The Low Gain image is automatically saved).
8. To use a trigger, click the Imaging Parameters “Trigger” tab and select the type of triggering.
9. To Initiate the Exposure Sequence, click "Grab".

Review the Image

Consider the following when reviewing the image:

- Magnification of image (slider to left of image)
- Rotation of image (under Display Control)
- Change display scaling by moving the red squares under the histogram to the left of the image
- Perform image analysis on column/row, region, single line (under Image Analysis)
- Check the values on the Merge tab under Imaging Parameters
- Display metadata (under Display on the menu bar)

Optimizing Acquisition

After capturing and reviewing the first image, consider modifying the following features/settings:

- Recapture only the region of interest (ROI) rather than the full image (under Imaging Parameters / Frame)
- Vary exposure time, frame delay/interval (under Imaging Parameters / Exposure)
- Consider immediate start option (under Imaging Parameters / Trigger)
- Capture reference and post-reference data (under Imaging Parameters / Frame)
- Use High Frame Rate settings (under Imaging Parameters / Sensor)
- Black level sun/black adjust values (under Imaging Parameters / Sensor)
- Save to an alternate file format (under Imaging Parameters / File)

Display Customization

Customize the Display

Ways to alter the display:

- Switch control panel display layout
- Switch control panel side
- Change width of display areas
- Swap the image in the image areas
- Rotate or flip the displayed image
- View reference data with image
- Display one window rather than three windows

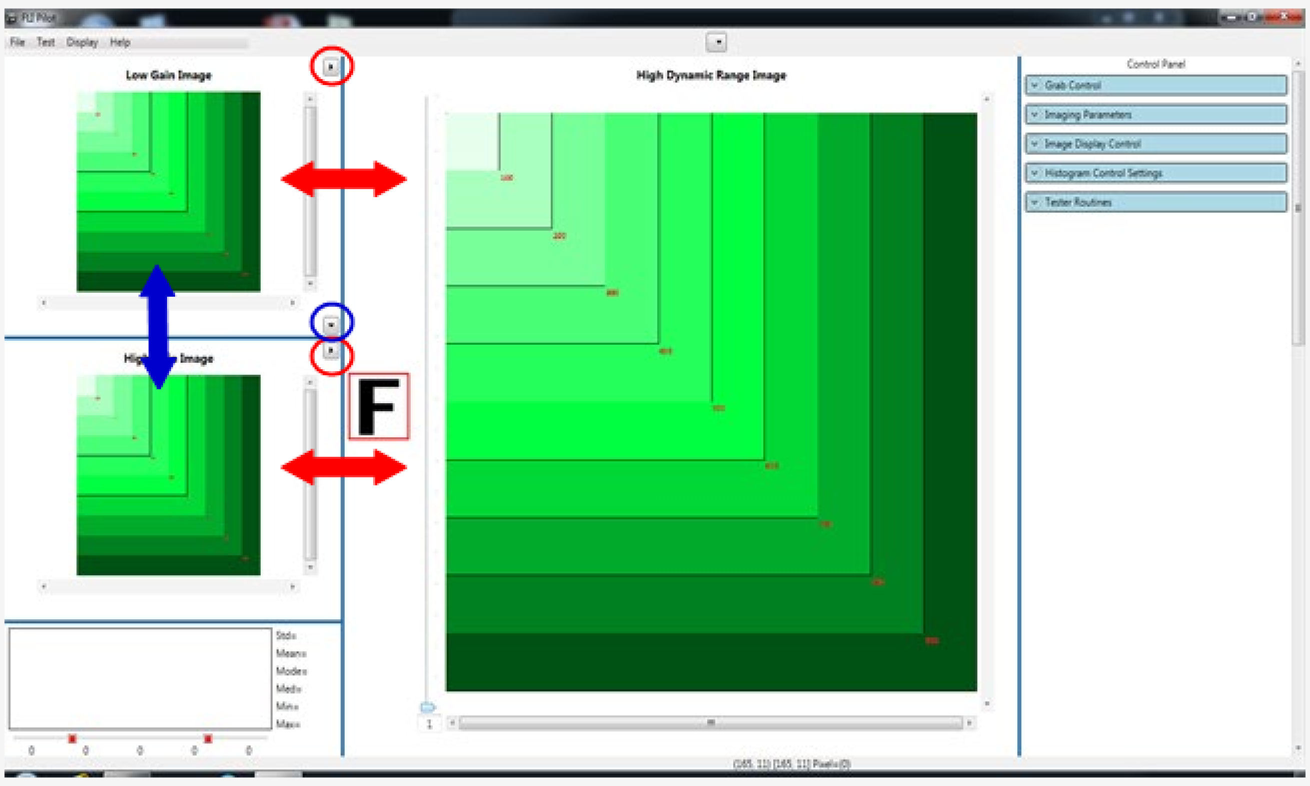
Control Panel Customization

The control panel can be customized by changing its layout, swapping which side the panel resides, and toggling buttons vs. drop down menus. More information is provided under Control Panel Customization.

Switch Image Positions

You can change which images are displayed in the three image panels.
By default the Kepler High Dynamic Range Image is displayed in the Main Image Panel, however, any of the three images can become the larger sized image.

- Use the Top Image Panel's right-facing arrowhead to swap the Top Image Panel's small image with the large image in the Main Image Panel.
- Use the Bottom Image Panel's right facing arrowhead to swap images in the same way.
- Use the Top Image Panel's down-facing arrowhead to swap the vertical position of the two small images (Top Image Panel and Bottom Image Panel).



Change Panel Widths

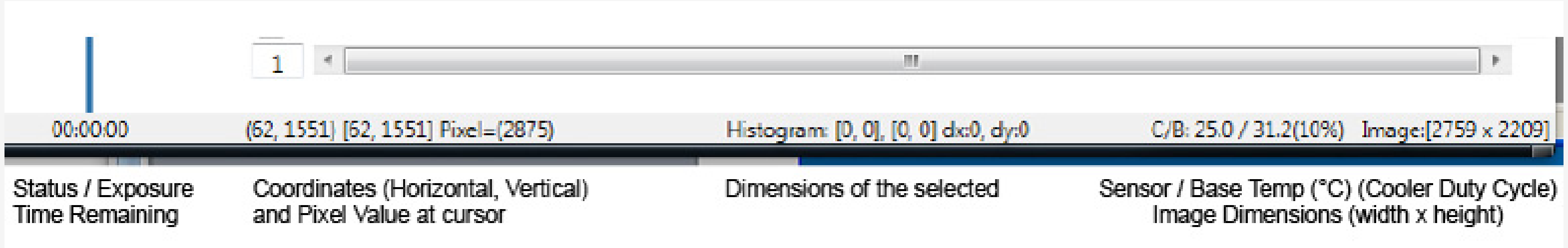
You can change the width of the panels relative to one another. Drag either of the two vertical blue lines that separate the panels or either of the horizontal lines that separate the Top and Bottom Image Panels and the Histogram Panel. The display below identifies the blue lines to use to modify the panel widths. To reset the panels to the default widths, use the Display menu and select Reset.
Additionally, you can remove a panel from the display by dragging the vertical or horizontal line to the edge of the display. If a panel was removed, simply use the blue line to pull the area back into view or use Display/Reset.
You can also opt to display only a single image and the histogram rather than three images. Refer to "Display Single/Three Windows Only."

Review Status Bar Data

The FLIPilot Status Bar is located at the bottom of the screen is continuously updated. If connected, the status bar displays camera information. When an image is opened or captured image and histogram information is displayed.

The Status bar shows:

- Status/ Exposure Duration
- Coordinates (horizontal, vertical) and Value of pixel at mouse cursor
- Dimensions of the selected histogram
- MOS Base: Ambient / Base Temp. (°C) (Cooler duty cycle in %)
- Image Dimensions (width x height)



Use Image Zoom/Magnify Slider

An image with no magnification/zoom is identified as such by a "1" located in the numeric field just outside the bottom left corner of the image. When zoomed, the orientation device is surrounded by a large red box to represent the whole captured image is displayed.
Zoom in on the information in an image in three ways:

> Place the mouse cursor in the image at the area you want to zoom, and scroll the mouse wheel. The image zooms around the cursor.

Move the slide bar located on the left of the image. The image zooms around the center of the original image.

Enter a numeric zoom value in the field on the lower left of the image. The image zooms around the center of the original image. The zoom values are integers from 1 (default normal display) to 100.

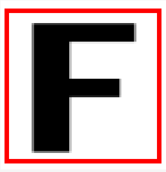
You can unzoom the image using any one or a combination of the three ways used to zoom the image.

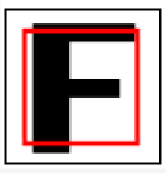
Once zoomed, you can reposition the zoomed image in one of two ways:

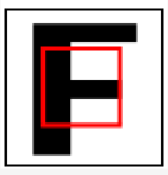
Use the vertical scroll bar on the right of the image and the horizontal scroll bar below the image to translate the image up/down or right/left, respectively.

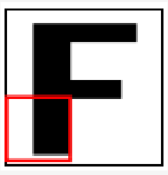
Press the left mouse button on the zoomed image to grab it then move the mouse in any direction.

The location of your zoomed view can quickly be determined by looking to the left of your main image at the F indicator. The F represents your image while the red outline represents your field of view. Please see the images below for representations of different zoom states.

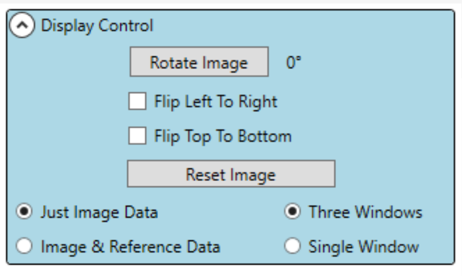








Display Control Functions



Display Control

Rotate Image 0°

☐ Flip Left To Right

☐ Flip Top To Bottom

Reset Image

● Just Image Data ● Three Windows

○ Image & Reference Data ○ Single Window

The Display Control panel gives the user further access to customization of the FLIPilot display.

There is an option to rotate, flip, or reset the captured image, as well as utilize reference data, and change the display type to single window instead of three window.

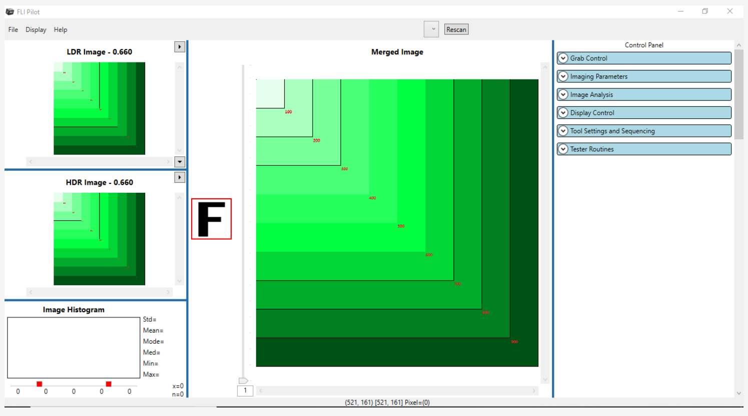
To the left of the main image, a box with an F is displayed. This F shows the orientation of the image, as well as the position of the image in relation to the field of view displayed.

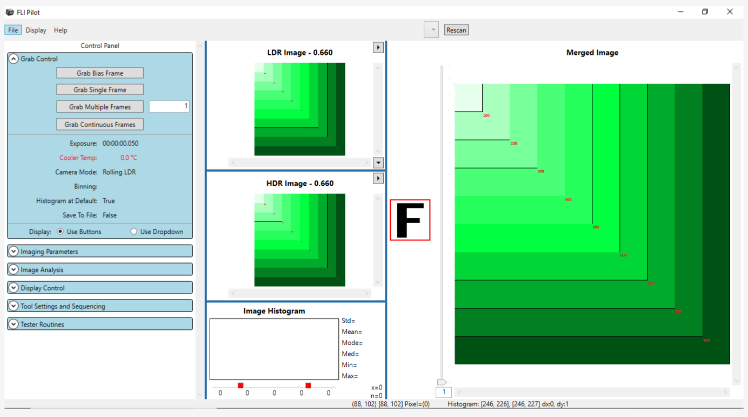
A proper explanation of the display control panel is under Control Panel Overview.

Control Panel Customization

Switch Control Panel Side

The Control Panel can reside on the right or the left side of the images. To switch The Control Panel's position use the display menu to select Switch Control Panel.



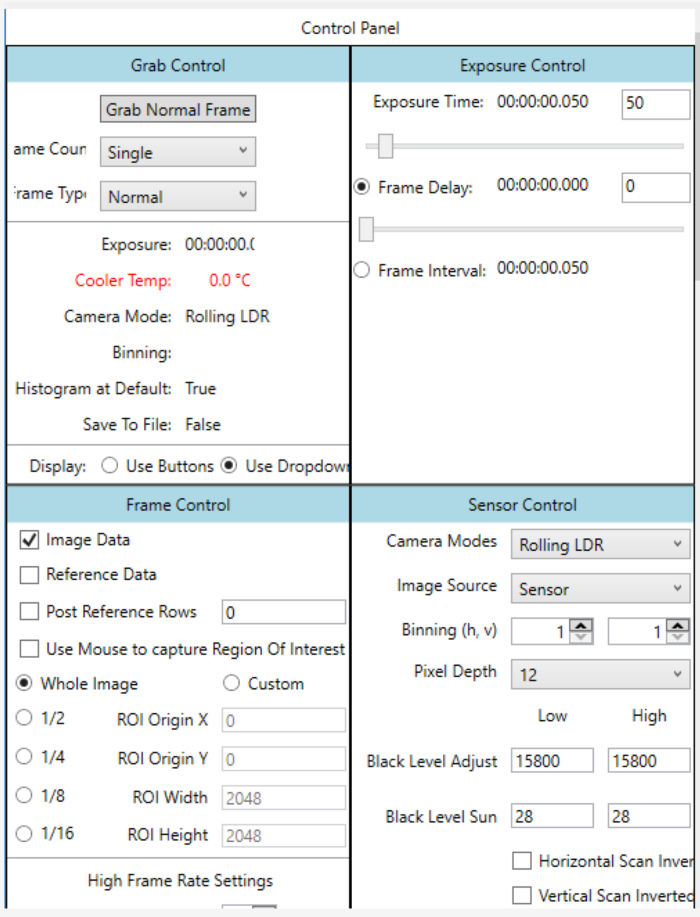


Switch Control Panel Types

You can display the content of the Control Panel in two different ways, although the settings and their location on the images is the same. These options can be toggled under *Display* in the Menu Bar.

Flat control panes: There are 10 different panes all open at once. Use the right-side gray slider to scroll through the other open panes. Use the vertical blue line between Panels to increase or decrease the width of the Control Panel.

Collapsible control panes: There are five panes, two of which (Imaging Parameters and Image Analysis) have multiple tabs. Use the down arrowheads to the left of the control pane title to expand or collapse the pane. If not all the open panes are visible, use the right side gray slider to scroll down the expanded control panes.

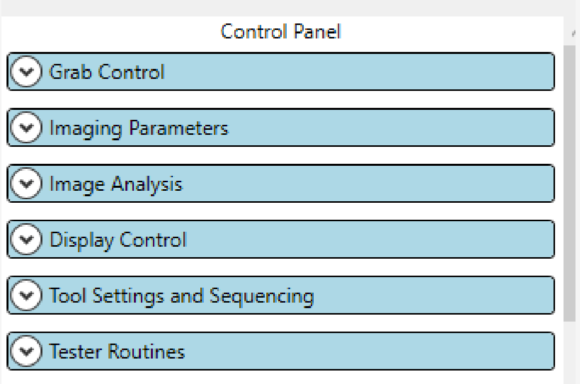


ame Coun: Single
rame Typ: Normal
Exposure: 00:00:00.(
Cooler Temp: 0.0 °C
Camera Mode: Rolling LDR
Binning:
Histogram at Default: True
Save To File: False
Display: ○ Use Buttons ● Use Dropdown

Exposure Time: 00:00:00.050 50
● Frame Delay: 00:00:00.000 0
○ Frame Interval: 00:00:00.050

☑ Image Data
☐ Reference Data
☐ Post Reference Rows 0
☐ Use Mouse to capture Region Of Interest
● Whole Image ○ Custom
○ 1/2 ROI Origin X 0
○ 1/4 ROI Origin Y 0
○ 1/8 ROI Width 2048
○ 1/16 ROI Height 2048

Camera Modes: Rolling LDR
Image Source: Sensor
Binning (h, v): 1 1
Pixel Depth: 12
Black Level Adjust: Low 15800, High 15800
Black Level Sun: 28 28
☐ Horizontal Scan Inver
☐ Vertical Scan Inverted

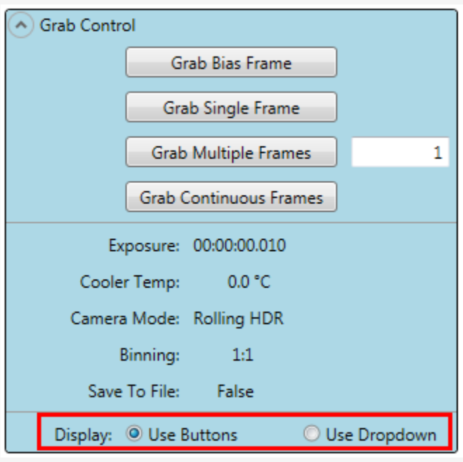


Change Grab Control Panel Display

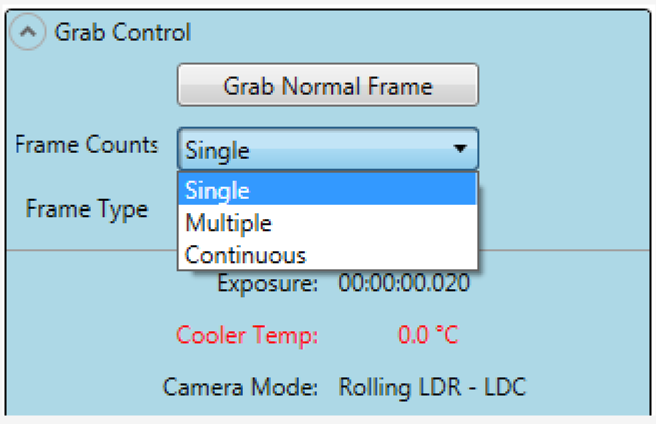
There are two ways to display the selections on the Grab Control Panel:

Use Buttons shows the four most frequently used (but not all) Grab Control options as buttons for quick access.

Use Dropdown identifies the currently selected Grab mode in the button name and provides a complete dropdown list with all available Grab modes.



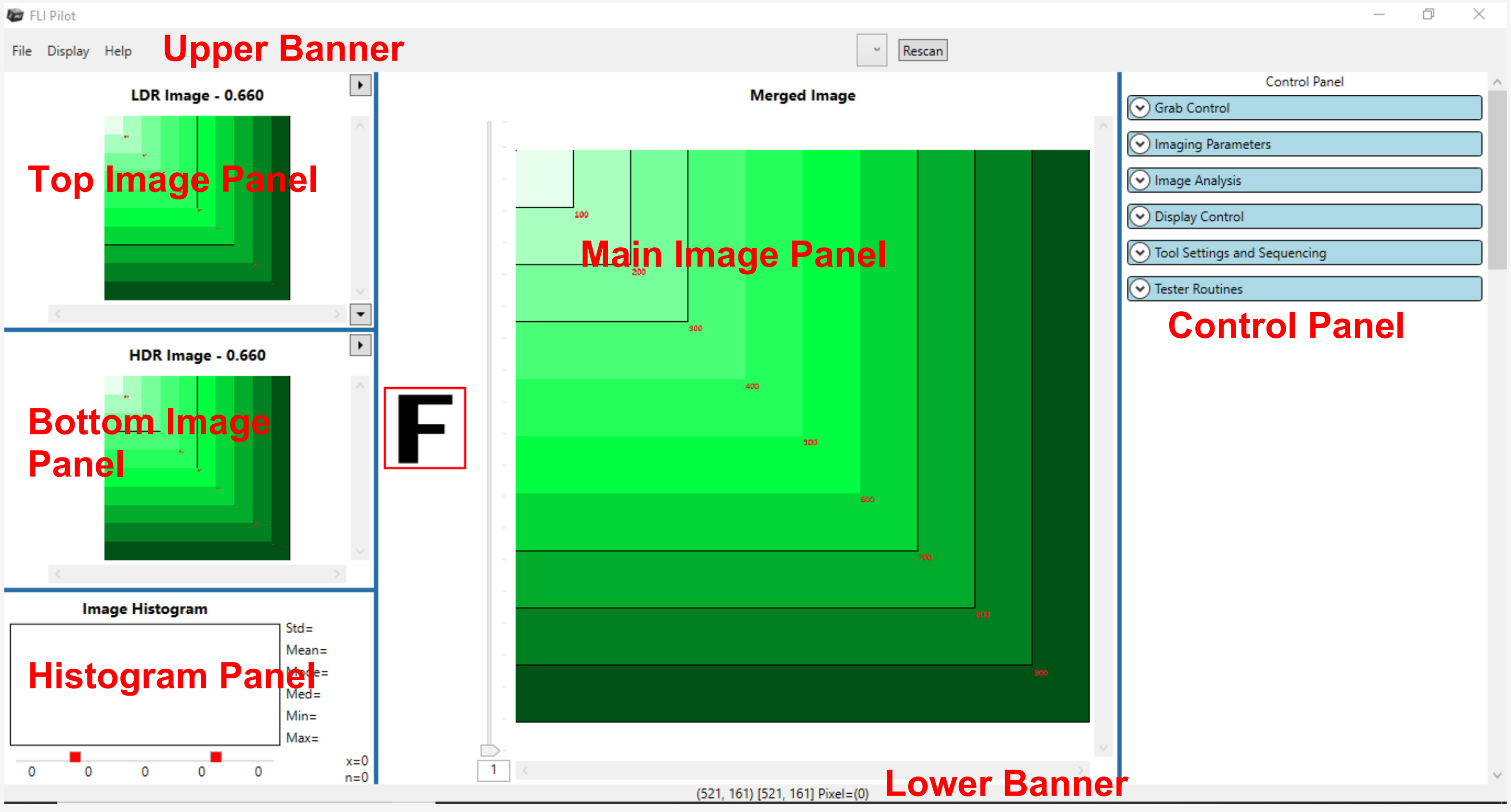
Exposure: 00:00:00.010
Cooler Temp: 0.0 °C
Camera Mode: Rolling HDR
Binning: 1:1
Save To File: False
Display: ● Use Buttons ○ Use Dropdown



Frame Counts: Single
Frame Type
Exposure: 00:00:00.020
Cooler Temp: 0.0 °C
Camera Mode: Rolling LDR - LDC

FLI Pilot Display

FLIPilot allows you yo customize the location of the panels in the display as well as the relative sizes of the panels to make your imaging more efficient and convenient.



Upper Banner

Upper banner contains the Menu Bar with drop down controls. These controls are also provided in the Control Panel. The center of the upper banner also identifies the name of the current camera along with open image files. See Menu Bar for more information.

Top Image Panel

Top Image Panel with a Kepler camera is typically the Low Gain Image.

Bottom Image Panel

Bottom Image Panel with a Kepler camera is typically the High Gain Image.

Histogram Panel

Histogram Panel contains the image histogram. The two red blocks at the bottom set the main image's minimum and maximum pixel brightness. Pixels above the limit will be fully white, pixels below will be fully black.

Main Image Panel

Main Image Panel contains a large image and the Orientation device (F). With a Kepler camera, this panel typically displays the High Dynamic Range Image. You can display a High Gain or Low Gain image in this panel. If a High Dynamic Range Image is not captured, the Low Gain image is displayed in the Main Image Panel. This panel also contains the horizontal slider control to adjust the image position and a vertical Zoom/Magnify slider. See “Switch Image Position” and “Use Image Zoom/Magnify Slider” for additional information.

Lower Banner

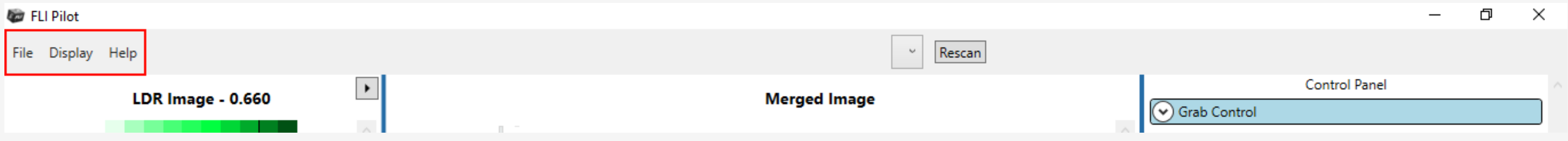
Lower banner contains the Status Bar with data about the image. See Review Status Bar Data for more information.

Control Panel

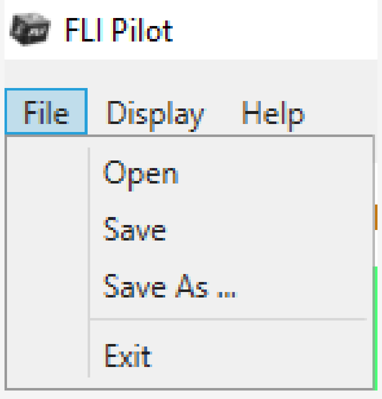
Control Panel contains multiple panes with controls to make selections that affect image capture and image review. See “Switch Control Panel Types” and “Control Panel” for more information on customizing the display.

Menu Bar

The menu bar is located in the upper banner of FLIPilot.



File Menu



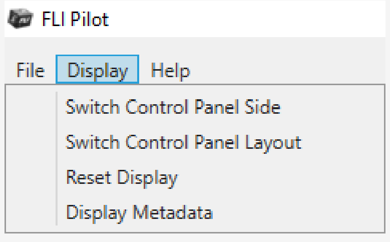
Open - Displays an Open window for you to select files by moving through the directory structure. Once selected, FLIPilot loads the file and displays it.

Save - Saves the currently opened image to disk. The same file name that was used to open the file will be used with the Save command.

Save As - Displays a Save As dialog for you to save the currently opened image in a different file format or with a different name.

Exit - Closes FLIPilot.

Display Menu



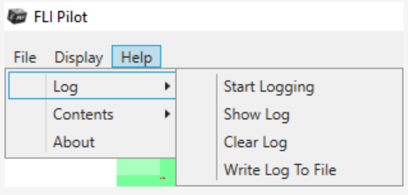
Switch Control Side – Changes the location of the Control Panel from the left side to the right side or the right side to left side of the display.

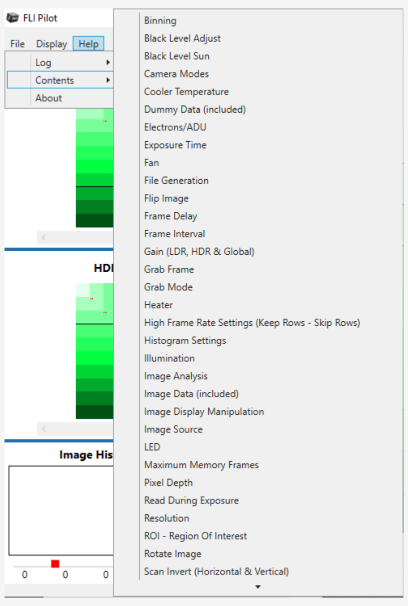
Switch Control Panel – Changes the appearance of the Control Panel from one with control panes all open at the same time to one that allows for expanding and collapsing of various control panes. See Control Panel Customization.

Reset – Returns the display to the default orientation with the control panel on the right, and adjusts the three panes to their default proportions on the display.

Display Metadata – Displays a Meta Data window with values for each of the settings used to obtain the currently displayed image. You can save a metadata file by enabling the “Save Metadata to file” feature (displayed on the File pane).

Help Menu





Log - If enabled, saves a file that logs communication between the camera and the computer. If you have a PC crash or camera issues, FLI may request you send the log file for investigation. The submenus allow you to start logging, show the log, clear the log and write the log to a file.

Contents - Displays a drop down list of key terms in FLIPilot. Selecting a term displays the pane contain that term.

About - Provides version information.

Control Panel

Grab Control

The Grab Control Panel is your direct connection to the camera. Important information regarding the device is displayed, and commands for image capture are initiated here.

Imaging Parameters

The Imaging Parameters Panel contains almost every setting you would set before image capture is located here. From the camera, to the sensor, to the filter wheel, any pre-photo setting is found within the tabs placed in this panel.

Image Analysis

The Image Analysis Panel contains settings for post-capture procedures. Primarily: viewing images, and viewing histograms and profiles of images.

Display Control

The Display Control Panel provides options for customizing the display of FLI Pilot, including orientations and panel options. For small tweaks in FLI Pilot, head here.

Tool Settings and Sequencing

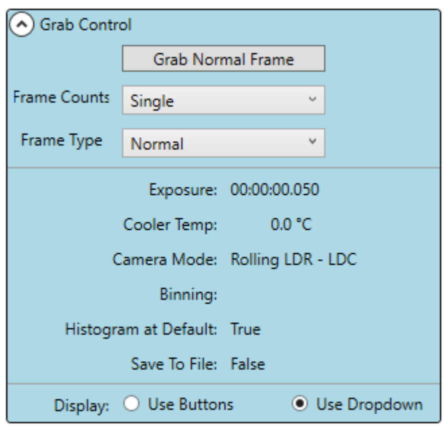
Tool Settings and Sequencing essentially allows you to setup and run a batch file. You are able to setup various settings like different gains etc. to take successive images while you change the settings between images. Execute uses the settings, then does a grab. Then it uses the next set of settings and does another grab.

Tester Routines

The Tester Routines tab includes a number of useful subroutines for the camera. These include the ability to stack frames, run frame subtractions, and more.

Grab Control

The two ways to display the Grab Modes on this panel are selectable at the bottom of the panel. The "Use Buttons" option displays the most frequently used modes for easy access. The "Use Dropdown" option displays a single mode with the option to switch between that mode and others. "Use Dropdown" also gives access to more grab modes that "Use Buttons" provides.

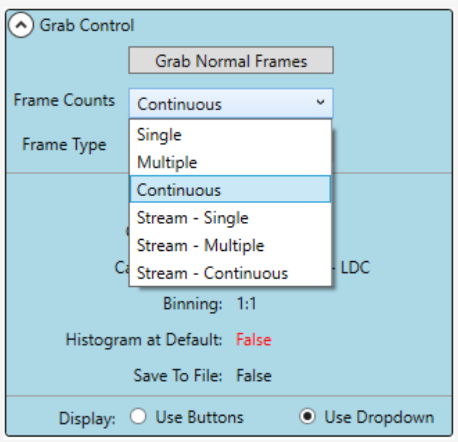

Grab Control
Grab Normal Frame
Frame Counts: Single
Frame Type: Normal
Exposure: 00:00:00.050
Cooler Temp: 0.0 °C
Camera Mode: Rolling LDR - LDC
Binning:
Histogram at Default: True
Save To File: False
Display: ○ Use Buttons ● Use Dropdown

Grab Menu in Standard Operation

Grab Modes

Single Frame
Takes a single inage with the defined exposure length (entered in the Exposure Control panel). When selected, the button changes to **Stop Grab** to abort the capture.
This is a standard frame that exposes light to the sensor by opening and closing the shutter.

Multiple Frames
Captures the number of images entered in the field to the right of this button. Each capture will have the defined exposure length (entered in the Exposure Control panel). When selected, the button changes to **Stop Grab** to abort the capture.


Grab Control
Grab Normal Frames
Frame Counts: Continuous
Single
Multiple
Continuous
Stream - Single
Stream - Multiple
Stream - Continuous
Binning: 1:1
Histogram at Default: False
Save To File: False
Display: ○ Use Buttons ● Use Dropdown

Grab Menu with a QSFP Connection

Continuous Frames
Captures continuous images, each with the displayed exposure length (entered in the Exposure Control panel). When selected, the button changes to **Stop Grab** to abort the capture.

Stream Frames
An additional three modes regarding frame count are available when a QSFP connection is in use. These modes are titles **Stream - Single**, **Stream - Multiple**, and **Stream - Continuous**. These options mirror their non-stream modes and operate in the same way with some slight differences. These modes instruct FLI Pilot to direct all images from the camera directly into the computer's memory. This significantly increases the frame rate of capture, however it removes the ability to change the file type prior to saving. All frames of a stream will be saved as a .RCD file.

Additionally, no image will be displayed in FLI Pilot while the frames are being grabbed. The desired save path for a stream must be set in the Stream tab of Imaging Parameters. Note: This means the save path set in the File tab will not be used.

Dark Frame
If your camera has a mechanical shutter, this mode may help calibrate the pixels by obtaining an image (data) with the shutter closed (essentially no light (dark)) that is same length as your desired image. However, even when the camera is completely blocked by a closed shutter, the array collects a dark charge pattern dependent on exposure time and camera temp. By collecting a dark frame, this information can then be subtracted from the intended image to reduce dark charge artifacts. The longer the exposure and warmer the camera, the larger the dark current growth and noise accumulation may be.

Flood Frame
This mode is applicable for full frame sensors but not sCMOS sensors. It is useful to fill sensor traps that cause ghosting. Enable the LED to flood the image with light. This is sometimes called "Flash."

RBI_Flush
This mode fires the pre-flash with the shutter closed, then reads out the sensor (essentially pre-flash plus bias). the length of the pre-flash is therefore defined by the same bar as the exposure. If you do a long pre-flash, you may want to add one or more additional bias or dark frames (for clearing purposes) to see their effect. Longer dark frames will allow more trapped charge to migrate. The highest uniformity is achieved with a pre-flash that fills all the wells to capacity, but that also adds more noise to the image.

This mode is applicable for full frame sensors, but not sCMOS sensors. It is useful to fill sensor traps that cause ghosting.

During long exposures, images being read do not extract full charge, thus artifacts of the previous image may emerge on the next image (as a ghost). This is a defect in the pixels ability to completely reset. Ghosting is more prevalent at lower operating temperatures.

Bias Frame
A bias frame is a frame captured with the shortest exposure time possible. The outcome of such is that any flaws or discontinuities in the image caused by minute differences between pixels can be subtracted out to produce an image with very little influence from internal imperfections.

Exposure

Displays the exposure time that will be used for image capture. The exposure time here may differ from the exposure time inputted in the **Exposure** tab of **Imaging Parameters** if the time entered is not physically possible in the camera connected. This will only ever be a problem for very short exposures (<50us). If the Control Panel layout is collapsible, click "Exposure" to open Exposure under Imaging Parameters to change the time.

Cooler Temp

Displays the current temperature of the sensor. If the Control Panel is collapsible, click "Cooler Temp" to open Camera under Imaging Parameters to change the desired operating temperature. If the current temperature does not match the desired operating temperature, the sensor will cool at a rate of approximately 5°C per minute. This is to ensure the sensor does not receive a thermal shock.

Camera Mode

Displays the current camera mode. If the Control Panel is collapsible, click "Camera Mode" to open Sensor under Imaging Parameters to change the mode.

Binning

Displays the current binning value. If the Control Panel is collapsible, click "Binning" to open Sensor under Imaging Parameters to change the value.

Save to File

Save to File will display True if the captured data will be saved automatically. If it displays False, the file will not be saved automatically. Save to File will only display true if, within **File**, a file type is selected, a image to be saved is selected, and a file path is selected. If the Control Panel is collapsible, click "Save To File" to open File under Imaging Parameters to change the settings.

Display

Imaging Parameters

Exposure

Exposure controls the exposure and frame time for image capture.

Frame

Frame controls what information is included in a frame capture.

Sensor

Sensor controls the options associated with the imaging sensor's operation.

Filter Wheel

Filter Wheel controls the options regarding an optional filter wheel assembly.

Trigger

Trigger controls when an exposure is to start depending on an input via the auxiliary connector.

Camera

Camera controls the operation of the camera during the image capture, as well as the shutter.

Merge

Merge controls the merge of the high gain and low gain images into one HDR image.

File

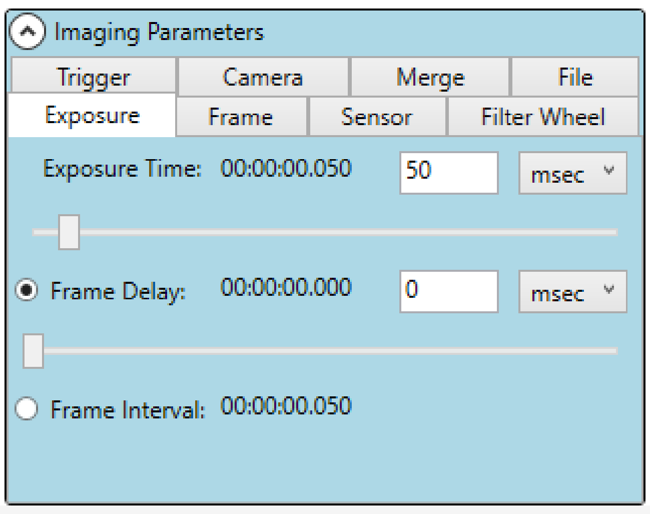
File defines where and with what title the images captured will be saved on the PC running the software.

Stream

Stream defines where frames of a stream will be saved.

Exposure Settings

The **Exposure** tab allows the user to define desired parameters for exposure. For each setting, there is an input and an actual duration. The actual duration may be slightly different than the input duration because of physical limitations of the camera. There will only ever be a difference in the case of very short exposures (<50us).



Exposure Time: 00:00:00.050 50 msec

● Frame Delay: 00:00:00.000 0 msec

○ Frame Interval: 00:00:00.050

Exposure Time

Exposure time is the duration that each row will collect light. Enter a numeric value or use the slider to adjust the exposure time and select the units.

Frame Delay Time

Frame Delay is applicable for multiple and continuous grabs. It is the duration of time between the end of an exposure and the start of the subsequent exposure. This delay may be useful to allow for controlling external items such as illumination.

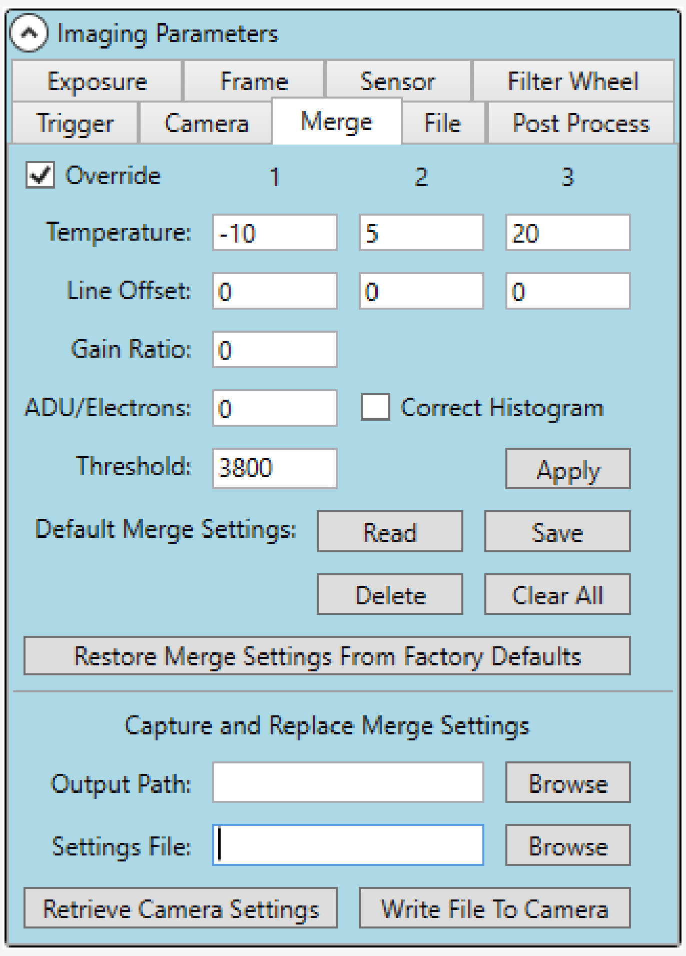
Enter a numeric value or use the slider to adjust the delay time and select the units. Enter 0 to disable.

Frame Interval

Frame interval is applicable for multiple and continuous grabs. It is the duration of time between the start of consecutive exposures.

Enter a numeric value or use the slider to adjust the frame interval and select the units. Enter 0 to disable.

Merge Settings



☑ Override

	1	2	3
Temperature:	-10	5	20
Line Offset:	0	0	0
Gain Ratio:	0		
ADU/Electrons:	0	☐ Correct Histogram	
Threshold:	3800		

Default Merge Settings:

Capture and Replace Merge Settings

Output Path:

Settings File:

The high dynamic range (HDR) image is created by combining the low gain and high gain images. Both images are the same, but read out of the sensor at two different gain settings.

FLI Pilot creates the HDR image by combining these two Low and High gain images into one. The high gain images allow for improved resolution in the darker regions of the image, while the low gain provides better resolution in your bright areas. The resulting HDR image is 16 bits/pixel instead of the 12 bits/pixel that the low and high gain images contain. The user interface provides the ability to input a variety of Merge Variables to modify how the image is merged. Please see below for more information on the Merge Variables. The user interface may also display the default values calculated by the program if the user does not wish to provide custom data.

Generally, the best merged image results when the exposure is adjusted such that the low gain image has pixel values spanning the range of values from 0 to 4095. Under these conditions, the high gain image will be saturated in most image areas.

Automatic vs Fixed Merge Calculation (Override)

Automatic: To use automatic merge calculations uncheck the Override box.
The automatic merge calculates new variables for each image that is captured. This means that each merge image may have different parameters on how it was created. If the camera is not able to determine new variables for an image due to a lack of useable pixel values it will use the last calculated merge variables. It is recommended that you use the fixed merge calculation. If you are operating the camera in an unusual manner please see Merge Calculate to automatically have the camera determine the optimum merge variables for your settings.

Fixed: To use fixed merge calculations check the Override box.
The fixed merge uses the Merge Variables set in the variable boxes to merge each image. This standardizes each merge image if you are capturing multiple images. Many cameras will already have Factory Default Merge Variables for the default Gain Pair and Black Level settings. These were calculated for each camera to deliver the best merged images for the default settings. If you are operating outside of the default parameters you can run Merge Calculate, in the Tester Routines tab, to have the camera determine the optimum Merge Variables for your settings.

Merge Variables

Temperature

By providing sensor temperature values at three points, as well as Line Offset values at the corresponding temperatures, FLI Pilot can calculate an effective Line Offset value for each image at various temperatures, using linear interpolation. If you operate the camera at a different temperature and would like more direct control, that temperature can be used instead of the defaults (KL4040 -10, 5, 20 or KL400 -20, 0, 20). Please see Merge Calculate for determining the best settings at your unique settings.

Line Offset

The Line Offset value is used to ensure there is a smooth transition for pixels around the threshold value. This ensures that the last pixel used from the high gain image and the first pixel from the low gain image will have the same pixel value, ensuring that there is not gap in pixel values in your image.

Gain Ratio

The Gain Ratio is used to ensure that the low gain and high gain pixels mapped to the merged image have an equivalent photon response, which unless otherwise changed is 1 ADU/electron. A higher Gain Ratio will increase the Low Gain photon response compared to that of the High Gain, conversely a lower Gain Ration will decrease the Low Gain photon response compared to that of the High Gain.

ADU/Electrons

On some Low/High gain pair choices it is possible that the combined image calculation may result in pixel values greater than can be expressed in 16bits. These pixels will result in saturated pixels (value of 65535). Exposure time could be reduced to correct for this, however a new image capture would be required. An alternative is to modify this parameter and apply it to update the merged image, using the Merge Frames Tester Routine. This parameter adjusts the photon response slope of the merged image. This can be used to avoid saturation of pixels in the merged image, or to express all images at a certain photon response (1:1, 2:1 etc.).

Threshold

The threshold value is used to determine whether a pixel in the merged HDR image is taken from the high gain image or the low gain image. When a pixel has a high gain value less than or equal to the threshold value, then the high gain pixel value is used in the HDR merged image. Otherwise, the modified low gain image pixel is used. The threshold value is set based on the sensors characteristics from the sensor manufacturer and thus should not need to be modified from its factory default.

Custom Merge Variables

Custom Merge Variables may be used by overwriting the individual boxes and clicking the Apply Button.

User/Factory Saved Settings

Merge Variables may be saved and recalled by the user at any time. For the default Gain Pair, the factory default Merge Variables may be recalled by pressing the Restore Merge Settings from Factory Defaults button. If custom settings are preferred, the user may save one set of Merge Variables for each Gain Pair by pressing the Save button. Similarly, to recall the user saved Merge Variables for the selected Gain Pair press the Read button, this will recall the User saved Merge Variables. It is possible to store around 40 Merge Variable sets. After you have reached maximum capacity the Pilot will not allow you to save any more sets without first deleting existing sets. If you would like to delete one set of Merge Variables pick the Gain pair you no longer use and press the Delete button. If you would like to delete ALL user saved Merge Variable sets press the Clear All button.

Note: Changing Black Level Adjust settings, under the Sensor tab, will impact the merged image. It is recommended that if you modify the Black Level Adjust that you then rerun the Merge Calculate to get new Merge Variables.

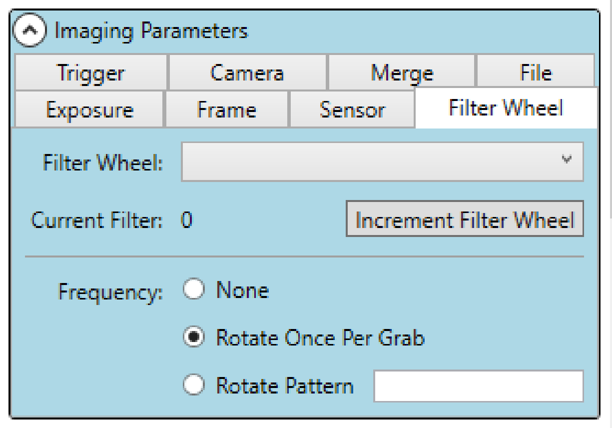
Capture and Replace Merge Settings

The Capture and Replace Merge Settings enables you to save and retrieve Merge Settings from a .csv format file that can be saved on the users computer.

To save the current Merge Settings please click the browse button next to the Output Path: and enter the location that you would like to save the file. Once the Output Path has been specified you may click the Retreive Camera Settings button to save the .csv.

To retireve Merge Settings, click the browse button next to the Settings File: and select the appropriate .csv file containing the Merge Settings you would like to load. Once the Settings File has been selected click on the Write File to Camera button.

Filter Wheel Settings



Filter Wheel:
Current Filter: 0
Frequency: ○ None
● Rotate Once Per Grab
○ Rotate Pattern

Filter Wheel
The dropdown menu will display any connected filter wheels available for use. Select the desired wheel to configure its options.

Current Filter
Displays the current position of the filter wheel.

Increment Filter Wheel
This button will increment the filter position by one.

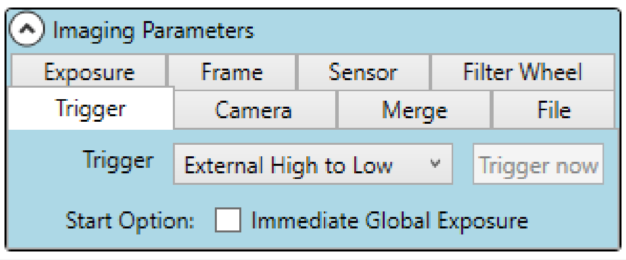
Frequency
Controls the rotation schedule of the filter. The following options allow configuration of the automatic rotation.

•None
The filter wheel will not rotate automatically.

•Rotate Once Per Grab
The filter wheel will rotate one position after an image grab.

•Rotate Pattern
The wheel will increment the given number of positions after each grab. A pattern can be written here, in which case the filter wheel will be incremented based on a comma delimited pattern. Ex) 0,1,3, will not increment the filter after the first grab, then increment once after the second grab, then three times after the third, and the pattern will repeat as such.

Trigger Settings



Trigger: External High to Low

Start Option: ☐ Immediate Global Exposure

Several types of trigger control commands are available. All trigger commands are executed after the Exposure Delay Time has expired, if a non-zero value was entered.

Internal

This method uses the software application to issue a trigger request immediately when a capture is requested. This internal trigger is communicated over the USB 3.0 connection or Adnaco Optical Fiber connection. These connections introduce a small amount of delay. There is also a fixed delay in the camera for the internal trigger to be communicated to the sensor controller.

External High to Low and External Low to High

This method configures the sensor to respond to an external trigger. This input is delivered via the 8-pin connector, on pin 3. When an external trigger is selected and image capture is requested, the camera waits for the transition of the external pin to start the exposure. If "External High to Low" is selected, the exposure will begin when the voltage on pin 3 transitions from high to low. If "External Low to High" is selected, the exposure will begin when pin 3 transitions from low to high.

External Control H to L and External Control L to H

In these modes of operation, the level of the externally supplied trigger signal controls the start of the image exposure and the end of the exposure. For Control H (high) to L (low), the image exposure starts when the external trigger input transitions from a high state to a low state and ends when the external trigger input transitions from a low state to a high state. For Control L (low) to H (high), the image exposure starts when the external trigger transitions from low to high, and the exposure ends when the input transitions from high to low.

The exposure value set in Exposure is the maximum allowed exposure, so, even if the external trigger signal is still active, the exposure will end when the set exposure time is reached. Therefore, ensure that the exposure time set in Exposure is greater than the exposure duration you intend to conduct.

Start Option

When a trigger is commanded (internally or externally) the sensor may be at any point in its continuous loop of resetting rows in the image row space. The image row space is defined as a row in the whole image (row 0-2047) or a row in a defined region of interest (ROI).

The default start option begins exposure at the same spot in the image, that is, the lowest row in the image row space. The trigger is held until the first row (lowest row) in the image space is reset, at which point the image exposure begins. Exposure ends at the highest row in the row space.

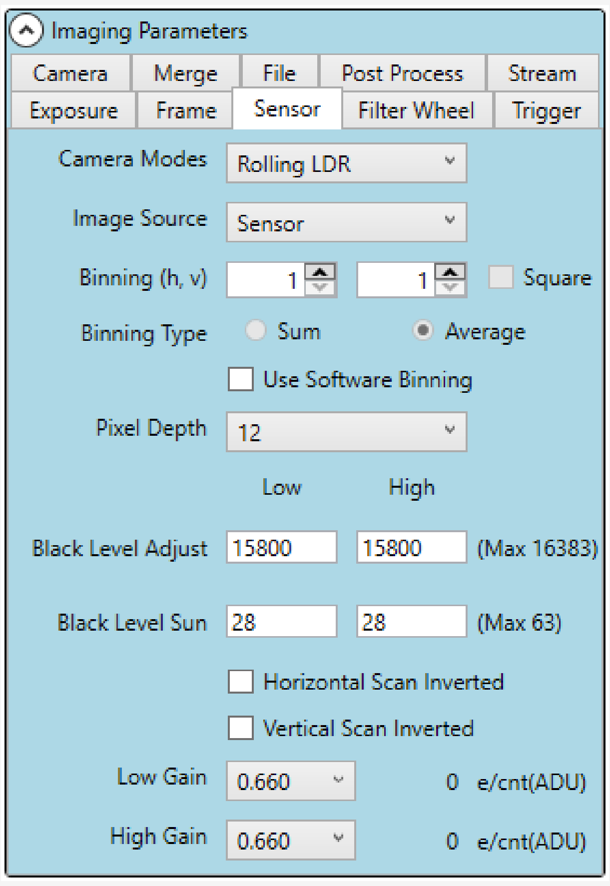
With the Immediate Global Exposure start option, the row reset ends immediately and the requested exposure readout begins with the row following the last row reset. The first row of imagery exposed by the sensor can be any row in the image row space. The last row of imagery similarly can be any row.

Total Integration Time			
Standard Start (Row 0)		Immediate Global Exposure Start (Anywhere in row space)	
LDR	HDR	LDR	HDR
(0 - 21msec) + Exposure Time	(0 - 42msec) + Exposure Time	(0 - 10.26 usec) + Exposure Time + [21msec*(#rows/2048)]	(0 - 20.52 usec) + Exposure Time + [42msec*(#rows/2048)]

The drawback to the standard start, at row 0, is the variable amount of time between the trigger command and exposure start. If you are taking short exposure images, this variable amount of time from trigger to exposure start can, relatively speaking, have a large impact on the image.

The advantage of the Immediate Global Exposure start option is the reduction of variability in the time between trigger and exposure compared to the default trigger option. The drawback to an immediate trigger is that the imaging starts at any row, and due to the characteristics of a rolling shutter imager, any motion during exposure will produce a discontinuity in the image. This flaw is produced by a large gap in time between the initial rows exposure beginning and the final rows exposure beginning. As the beginning and end meet somewhere in the middle of the image, the time differential between the first and last row read will produce an unpleasing image. This mode is best used when the scene is dark, allowing as little incident light in prior to the event as possible. The goal of this is to make the exposure before and after the event insignificant to the final image.

Sensor Settings



Camera Modes: Rolling LDR
Image Source: Sensor
Binning (h, v): 1 1 ☐ Square
Binning Type: ○ Sum ● Average
☐ Use Software Binning
Pixel Depth: 12

	Low	High	
Black Level Adjust	15800	15800	(Max 16383)
Black Level Sun	28	28	(Max 63)

☐ Horizontal Scan Inverted
☐ Vertical Scan Inverted
Low Gain: 0.660 0 e/cnt(ADU)
High Gain: 0.660 0 e/cnt(ADU)

Camera Modes

CMOS cameras allow four camera modes for selection: Rolling LDR, Rolling HDR, Rolling LDR - LDC, and Rolling HDR - LDC.

These modes operate the camera with rolling shutter operation.

LDR and HDR define the dynamic range of the mode of operation.

LDC denotes Low Dark Current mode which decreases the full well capacity of the photosensors, decreasing the number of electrons that accumulate when the pixels are not exposed to light. As a result, the dark current accumulated is decreased, allowing better long exposure images.

Image Source

Typically, the sensor is the image source. "Row Test Pattern" and "Col Test Pattern" are useful for camera diagnostics and are not typically used for any purpose other than such.

Binning

Binning is the process of combining adjacent pixels into a large pixel. The combining occurs either as a feature of a sensor or via Pilot post image readout.

Hardware Binning

The only Kepler camera to support hardware binning is the KL4040. While most Kepler sCMOS sensors do not allow binning, some CMOS sensors do, but the binning must be the same in each direction. For CMOS sensors that allow binning, enable the **Square** checkbox to bin horizontally and vertically equally. CCD sensors permit unequal binning, so the Square checkbox is not required for such cameras.

The two primary benefits of hardware binning are a decrease in transmitted data which leads to a potential increase in FPS and the ability to have a larger well size.

Software Binning

It is also possible to run Binning after the image is captured using software in Pilot. By using the software to accomplish the binning you are not limited to a square bin and can instead accomplish a rectangular binning. Any image can thus go through the binning process.

The primary benefit of software binning is an increase in the Signal to Noise Ratio however this comes at the cost of Sampling Density and therefore Resolution.

To set binning options, first, check Square if required or desired. Then, type or use the up/down buttons to adjust the values. On the left is horizontal (h) and on the right is vertical (v). These options are displayed on the Grab Control Pane.

Binning Type

Words regarding sum and average binning.

Pixel Depth

Pixel depth describes the number of bits used to represent the sensor. It is used to represent a sensor pixel and is determined by the sensor. Typical output is 16 bit. Using a lower number truncates the data in the camera for faster transmission.

The KL400 sensor does not allow for changing the bits per pixel.

For cameras with sensors that offer pixel depth modifications (Interline and Full Frame), the available selections are displayed.

Black Level Adjust

Black level is a measure of a reference voltage. This number is normally defined by non-imaging pixel areas of the sensor, however, the black level adjust option allows a secondary influence on this reference voltage. Black level adjust can be increased to increase the pixel values within your image. If you take a 10msec dark and look at the minimum pixel value, you can adjust it up or down by increasing or decreasing the black level adjust. This can be useful to ensure that you are not clipping your darkest pixels.

Black Level Sun

Very bright areas in an image can cause saturation of the pixel well and "overflow" resulting in that area looking dark. This option allows for mitigation of that effect. Enabling this feature increases noise. Increasing black level sun reduces the black sun effect, while increasing noise.

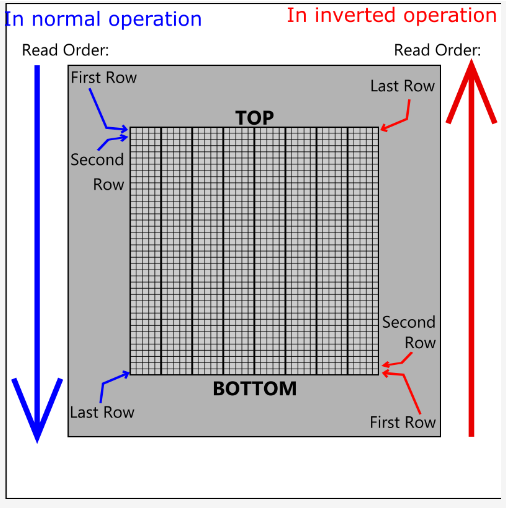
A maximum value of 63 can be selected which will produce quite a lot of noise while correcting the black sun as best it can. If a level this high is required to correct your image, it is recommended to correct the capture rather than this value specifically. adjusting the cameras aperture and exposure, and removing the intense bright light from the sensors FOV will all improve the black sun effect without significantly impacting image quality.

Horizontal Scan Inverted

The scan direction reflects the movement of the rolling shutter. The default horizontal direction is left to right. When "Horizontal Scan Inverted" is enabled, the read direction is right to left. This changes the pixel order in the data file.

Vertical Scan Inverted

The scan direcrion reflects the movement of the rolling shutter. The default vertical direction is from top to bottom. When "Vertical Scan Inverted" is enabled, the read direction is from bottom to top. This changes the pixel order in the data file.



LDR and HDR Gain

Dynamic range can be assigned for both the high and low gain images. LDR images are often captured with a low gain of 1.85 (KL400). HDR images are often captured with a low gain and high gain of 1.29 and 7.25 (KL400) or 2.8 and 16.5 (KL4040).

Global Gain

the global gain option allows the user to define the gain setting for both low and high gain images.

Dynamic Range

Dynamic range is a ratio of the largest signal a system can process, above the noise floor of that system. As the noise floor is essentially constant, the gain values are directly related to the maximum signal strength that can be reported. This has the effect of reporting brighter images with high gain, at a lower quality.

Low gain images are high quality with average lighting.
High gain images are lower quality with brighter lighting.

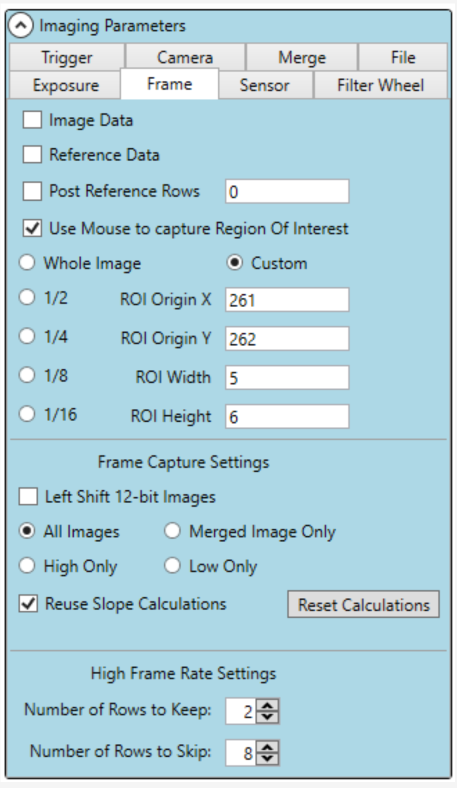
The goal of taking both a low and high gain image is to combine them post-process to give better detail to images with a wide range of lighting. High Dynamic Range describes the intention of achieving a wide range of varying luminance.

LDR and HDR Imaging Modes
In LDR mode, the low gain and high gain settings are the same value corresponding to even and odd rows. Each “line” time of the sensor contains two row reads and two row resets that results in a single image.
In HDR mode, the low and high gain settings are different values. Every pixel has both the low gain and high gain applied to it. Each “line” time of the sensor contains one row read and one row reset. The sensor reads out both the low gain image and the high gain image. In addition, the software displays the calculated (merged or combined) high dynamic range image to increase the accuracy at the low light level without sacrificing resolution of higher light levels.

The time between reset commands (and likewise between read commands) depends if the array is using the Low Dynamic Range (LDR) mode or the High Dynamic Range (HDR). The time between the start of exposure of the first row and the last row are mode dependent as shown below.

Mode	Gain Setting	Minimum Time Between Reset Commands or Read Commands	Time Between Start Exposure of Row 0 to Start Exposure of Row 2047
LDR	Low == High	10.26us	21ms
HDR	Low != High	20.52us	42ms

Frame Settings



Imaging Parameters
Trigger | Camera | Merge | File
Exposure | Frame | Sensor | Filter Wheel
☐ Image Data
☐ Reference Data
☐ Post Reference Rows 0
☑ Use Mouse to capture Region Of Interest
○ Whole Image ● Custom
○ 1/2 ROI Origin X 261
○ 1/4 ROI Origin Y 262
○ 1/8 ROI Width 5
○ 1/16 ROI Height 6

Frame Capture Settings
☐ Left Shift 12-bit Images
● All Images ○ Merged Image Only
○ High Only ○ Low Only
☑ Reuse Slope Calculations

High Frame Rate Settings
Number of Rows to Keep: 2
Number of Rows to Skip: 8

Image Data

The image data describes the full size or region of interest. This checkbox must be selected to obtain image data.

Reference Data and Post Reference Rows

The imaging sensor can capture sensor non-illuminated pixel data that may be useful to review changes that might have occurred between the beginning and the end of a long exposure (drift) or through the image (full image). This information can then be used to improve image quality. You can display the captured images with or without the reference or post reference data overlaid on the image.

The sensor can output reference pixels at the end of every imaging data row. One pixel is generated for each colomn (of 256 pixels) on the sensor, so the reference data is eight pixels wide. The reference data appears as a black band on the right side of the image.

You can also enable the readout of an entered number of rows of data after the exposure. This post-reference data is shown at the bottom of the image.

Use Mouse to Capture Region of Interest and Whole Image

You can capture or view a subregion of the full image. Capturing a region of interest (ROI) has the benefits of reducing trigger variability, increasing frame rate, and reducing image file size. This feature is very useful for small objects such as plants and small galaxies that do not require the full field of view. Decreasing the number of rows in the ROI increases the frame rate, however, decreasing the number of columns does not affect the frame rate. It does, however, reduce the amount of data, thus reducing processing time.

A captured image has no magnification/zoom and is identified as such by a "1" located in the numeric field just outside the bottom left corner of the image. In addition, the large red box around the letter "F" represents the whole captured image that is displayed in the window.

Define a region of interest in one of two ways using the controls on the Imaging Parameters' Frame tab:

- When the “Use Mouse to capture Region Of Interest” checkbox is enabled (on Frame Control panel), place the mouse cursor in the image, press the right mouse button and drag and draw a rectangle. The thin red box on the image identifies the ROI and the Frame tab displays the coordinates and dimensions of the ROI.
- Enter integers into the Origin X and Y fields and into the Width and Height fields. The system displays a thin red box on the image that correlates with the entered values.

After selecting or modifying an ROI, the software automatically recalculates the histogram to reflect the change.

To remove the ROI display and redisplay the whole image, select **Whole Image** on the Frame tab.

For precise region setting, one can either use the text boxes corresponding with origin x and y and width and height.

For those looking for precision scaling or simply looking to reduce unused sensor area, select one of the fractions. This option generates a ROI with that fraction of the whole imaging sensors pixels and centers the region about the center point of the image.

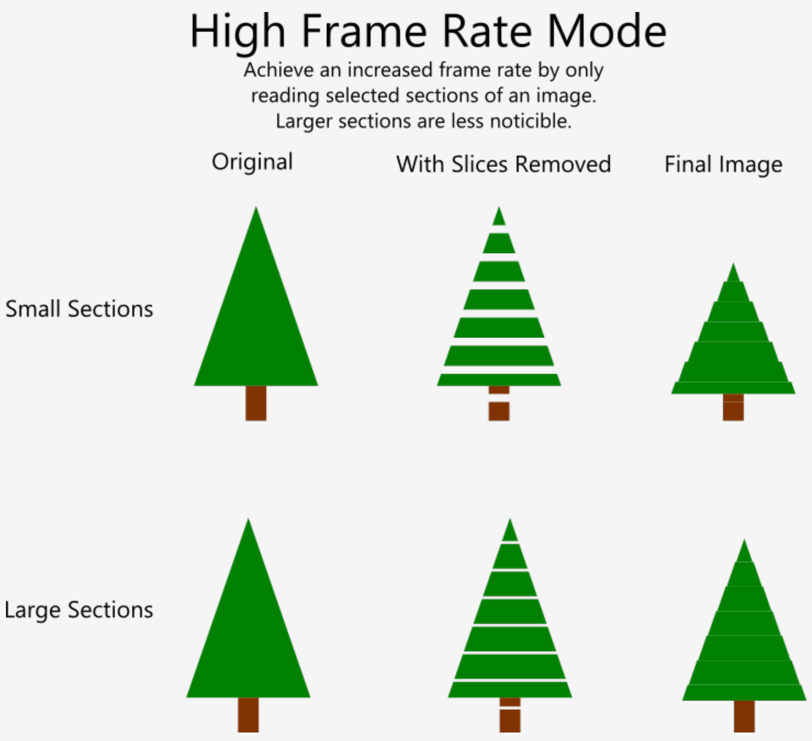
High Frame Rate Settings

Frame rate is in part determined by the amount of data that is read. By reducing the number of rows read, the overall frame rate is increased. High frame rate mode gives users the option to "skip" rows. Small skips are often insignificant in a final image and can reduce the data captured significantly.

Due to the behavior of sCMOS sensors, rows must be selected in pairs, or powers of two (2, 4, 6, 8, etc...). As examples, the system could be set to read every other pair of lines (keep two lines, skip two lines) or read 20 lines, skip 4 lines.

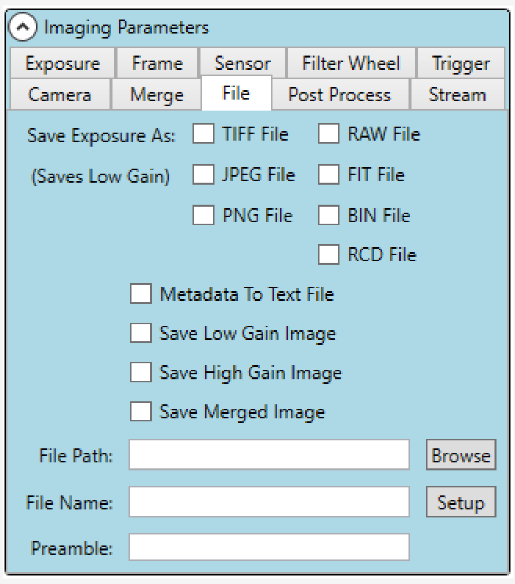
To use this feature, enter the number of rows to capture per block and the number of rows to skip between capture blocks in Frame Settings.

The figure to the right displays an example of high frame rate mode. The top image has larger skipped areas and smaller captured areas, resulting in the final image having minor issues. The bottom image has smaller skips and larger captured areas, resulting in the final image looking proper, while still reducing image size and increasing frame rate.



The default values of 0 will disable this mode.

File Settings



The Grab Control pane displays the "Save to File" status as True or False. If False is displayed, captured and displayed images are not automatically saved. If True is displayed, the captured images are saved automatically according to the user preferences selected such as file type and which of the high, low, and merged images you would like saved. For the program to automatically save, show True, you must select at least one file type, one image or metadata, and the file path. Other options that can be selected are a Preamble and an automatically generated file name. If you would like to have an automatically generated filename for each image, select setup.

Each image may be saved manually as well. The Menu bar at the top of FLIPilot contains a File menu with the Save and Save as controls to allow you to save the currently displayed image.

Save Exposure As

Make a selection to specify the type(s) of data file to save. The file types in alphabetical order are:

BIN File is a binary file format that contains the image data as it was received from the board. The file contains the metadata then the image data with the low and high gain images together (interlaced).
FIT (Flexible Images Transport System) is a 16-bit image defined by NASA/Science Office of Standards and Technology (NOST).
JPEG (Joint Photographic Experts Group) uses lossy compression for images and allows for a selectable degree of compression, storage size and image quality.
Metadata to Text File saves the values for each of the settings used to obtain the displayed image in a text file that may be useful for review. You can display metadata for the currently displayed image using File/Display Metadata.
PNG (Portable Network Graphics) is a raster graphics file that supports lossless data compression.
RAW files will store the entire output of a camera with no compression, however metadata is not stored in this filetype. RAW files cannot be opened in Pilot after they are saved.
RCD is Finger Lakes Instruments’ proprietary format that contains all of the information output by the camera with no compression or loss. Please see the RCD page for a more in depth explanation on the RCD file data structure.
TIFF (Tag Image File Format). Version 6.0 is a 16-bit monochrome and color image format.

Metadata to Text File

When enabled, the system saves the metadata information as an independent .txt file.

Save Low Gain Image

When enabled, the system saves the Low Gain image.

Save High Gain Image

When enabled, the system saves the High Gain image.

Save Merged Image

When enabled, the system saves the High Dynamic Range information (merged image).

Save Sectors As Files

When enabled, the system saves the 8 channels that make up the image as 8 separate files.

File Path and Browse

The File Path identifies the location and directory into which files will be saved. Click Browse to display a window to locate and select a different file path and directory for file saving.

Preamble

The Preamble will be added to the front of each file name. This is useful if you are using the automatically generated file names and want to tag the sequence with a unique identifier to keep them grouped together.

File Name and Setup

The File Name identifies the files saved. Click Setup to customize the file name to be saved. Select the options you wish to include in the file name. Under **Order**, the option to rearrange the texts in the file name with 1 representing the first, and 11 representing the final. The file name is composed next to "File Name:" with the selected options. Press "Reset Defaults" to reset selected texts and order to default values.

The following are the available texts:

Preamble: A prefix to the file name, custom text can be placed here to identify files.
Frame Type: Displays the Frame Type selected in Grab Control.
Camera Model: Displays the model of the camera connected to FLIPilot.
Mode: Displays the camera mode set in Sensor under Imaging Parameters.
Gain: Displays the LDR and HDR Gain set in Sensor under Imaging Parameters.
Frame Number: Displays the number the images frame is in that set of images.
Diag Routine Name: Displays the Routine name selected in Tester Routines.
Serial Number: Displays the serial number of the connected camera.
Sensor Temperature: Displays the temperature of the sensor at the time of capture.

Binning: Displays the binning setting set in Sensor under Imaging Parameters.
Exposure Time: Displays the exposure time set in Exposure under Imaging Parameters.
Date: Displays the date of image capture

Raw Camera Data (RCD) File Format

RCD Files

RCD is a file format created by FLI in order to save the raw and uncompressed data array that is produced by our cameras. The following is a breakdown of the data structure of the RCD files

Metadata
Image Data

The Metadata is broken down into the following
Bytes 0-3: The Magic #. This is the sequence that all of our image files start with. (0x4D657461)
Bytes 4-5: Tell how large the metadata file size is.
Bytes 6-n: The metadata of the image, defined by Bytes 4-5. Our current metadata 0-n is currently 246 bytes long. Older image files may have 156 bytes of information.
Bytes n(245)-m: Include the Image Data

The image data is dependent on the sensor and mode the camera is operating in. For a complete understanding of how the sensor outputs data for the image, please see the sensors manufacturer. Our cameras output the pixel data in a 12bits. Therefore every 2 bytes of data yield 3 pixels worth of data. Below is a brief synopsis of some of the sensors/modes.

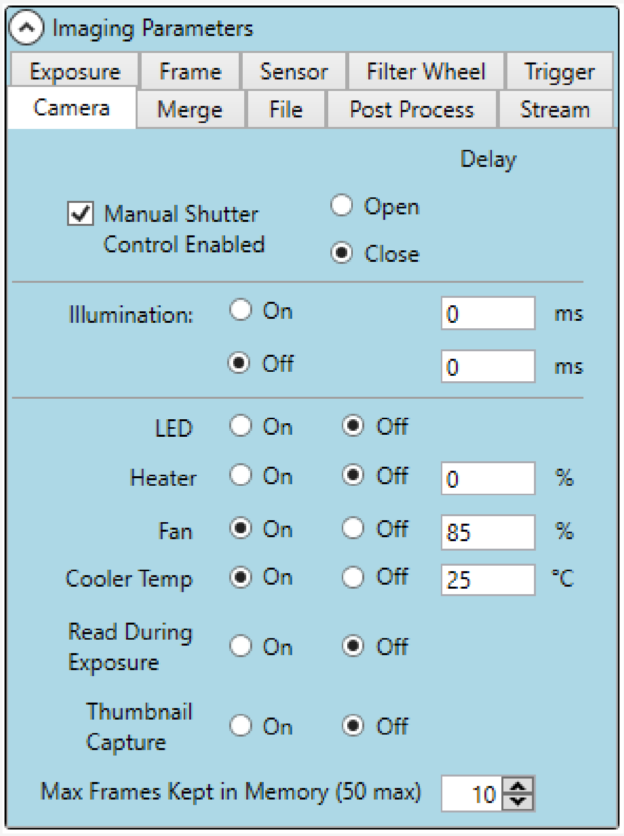
```
// In HDR mode, the capture contains both images interlaced so the pixels are:
// (LDR, row0, pixel0), (LDR, row0, pixel1) ... (LDR, row0, pixelN),
// (HDR, row0, pixel0), (HDR, row0, pixel1) ... (HDR, row0, pixelN),
// (LDR, row1, pixel0), (LDR, row1, pixel1) ... (LDR, row1, pixelN),
// (HDR, row1, pixel0), (HDR, row1, pixel1) ... (HDR, row1, pixelN),
// (LDR, rowN, pixel0), (LDR, rowN, pixel1) ... (LDR, rowN, pixelN),
// (HDR, rowN, pixel0), (HDR, rowN, pixel1) ... (HDR, rowN, pixelN),
//
// If there is dummy data at the end of the rows on the KL400 the pixels are:
// (LDR, row0, pixel0), (LDR, row0, pixel1) ... (LDR, row0, pixelN),
// (HDR, row0, pixel0), (HDR, row0, pixel1) ... (HDR, row0, pixelN), (HDR, row0, pixelD0), (HDR, row0, pixelD1), ... (HDR, row0, pixelDN),
// (LDR, row1, pixel0), (LDR, row1, pixel1) ... (LDR, row1, pixelN),
// (HDR, row1, pixel0), (HDR, row1, pixel1) ... (HDR, row1, pixelN), (HDR, row1, pixelD0), (HDR, row1, pixelD1), ... (HDR, row1, pixelDN),
// (HDR, rowN, pixel0), (HDR, rowN, pixel1) ... (HDR, rowN, pixelN), (HDR, rowN, pixelD0), (HDR, rowN, pixelD1), ... (HDR, rowN, pixelDN),
//
// If there is dummy data at the end of the rows on all other cameras the pixels are:
// (LDR, row0, pixel0), (LDR, row0, pixel1) ... (LDR, row0, pixelN), (LDR, row0, pixelD0), (LDR, row0, pixelD1), ... (LDR, row0, pixelDN),
// (HDR, row0, pixel0), (HDR, row0, pixel1) ... (HDR, row0, pixelN), (HDR, row0, pixelD0), (HDR, row0, pixelD1), ... (HDR, row0, pixelDN),
// (LDR, row1, pixel0), (LDR, row1, pixel1) ... (LDR, row1, pixelN), (LDR, row1, pixelD0), (LDR, row1, pixelD1), ... (LDR, row1, pixelDN),
// (HDR, row1, pixel0), (HDR, row1, pixel1) ... (HDR, row1, pixelN), (HDR, row1, pixelD0), (HDR, row1, pixelD1), ... (HDR, row1, pixelDN),
// (LDR, rowN, pixel0), (LDR, rowN, pixel1) ... (LDR, rowN, pixelN), (LDR, rowN, pixelD0), (LDR, rowN, pixelD1), ... (LDR, rowN, pixelDN),
// (HDR, rowN, pixel0), (HDR, rowN, pixel1) ... (HDR, rowN, pixelN), (HDR, rowN, pixelD0), (HDR, rowN, pixelD1), ... (HDR, rowN, pixelDN),


// In LDR mode, the capture contains straight pixel data so the pixels are:
// (LDR, row0, pixel0), (LDR, row0, pixel1) ... (LDR, row0, pixelN),
// (LDR, row1, pixel0), (LDR, row1, pixel1) ... (LDR, row1, pixelN),
// (LDR, rowN, pixel0), (LDR, rowN, pixel1) ... (LDR, rowN, pixelN),
//
// If there is dummy data at the end of the rows the pixels are:
// (LDR, row0, pixel0), (LDR, row0, pixel1) ... (LDR, row0, pixelN),
// (LDR, row1, pixel0), (LDR, row1, pixel1) ... (LDR, row1, pixelN), (LDR, row1, pixelD0), (LDR, row1, pixelD1), ... (LDR, row1, pixelDN),
// (LDR, row2, pixel0), (LDR, row2, pixel1) ... (LDR, row2, pixelN),
// (LDR, row3, pixel0), (LDR, row3, pixel1) ... (LDR, row3, pixelN), (LDR, row3, pixelD0), (LDR, row3, pixelD1), ... (LDR, row3, pixelDN),
// (LDR, rowN, pixel0), (LDR, rowN, pixel1) ... (LDR, rowN, pixelN), (LDR, rowN, pixelD0), (LDR, rowN, pixelD1), ... (LDR, rowN, pixelDN)
```

For Cobalt Cameras, the data is slightly different.

```
// Process the image data. We are processing 2 rows per loop
// The capture contains images with the following pixel configuration:
// (row0, pixel0), (row0, pixel1) ... (row0, pixelN/2), (row0, pixelN), (row0, pixelN-1), ... (row0, pixelN/2+2), (row0, pixelN/2+1)
// (rowN, pixel0), (rowN, pixel1) ... (rowN, pixelN/2), (rowN, pixelN), (rowN, pixelN-1), ... (rowN, pixelN/2+2), (rowN, pixelN/2+1)
// (row1, pixel0), (row1, pixel1) ... (row1, pixelN/2), (row1, pixelN), (row1, pixelN-1), ... (row1, pixelN/2+2), (row1, pixelN/2+1)
// (rowN-1, pixel0), (rowN-1, pixel1) ... (rowN-1, pixelN/2), (rowN-1, pixelN), (rowN-1, pixelN-1), ... (rowN-1, pixelN/2+2), (rowN-1, pixelN/2+1)
// ...,
// (rowN/2, pixel0), (rowN/2, pixel1) ... (rowN/2, pixelN/2), (rowN/2, pixelN), (rowN/2, pixelN-1), ... (rowN/2, pixelN/2+2), (rowN/2, pixelN/2+1)
// (rowN/2+1, pixel0), (rowN/2+1, pixel1) ... (rowN/2+1, pixelN/2), (rowN/2+1, pixelN), (rowN/2+1, pixelN-1), ... (rowN/2+1, pixelN/2+2), (rowN/2+1, pixelN/2+1)
```

Camera Control Settings



Delay

☑ Manual Shutter Control Enabled ○ Open ● Close

Illumination: ○ On 0 ms
● Off 0 ms

LED ○ On ● Off

Heater ○ On ● Off 0 %

Fan ● On ○ Off 85 %

Cooler Temp ● On ○ Off 25 °C

Read During Exposure ○ On ● Off

Thumbnail Capture ○ On ● Off

Max Frames Kept in Memory (50 max) 10

Figure 1: Camera Control Panel

Manual Shutter Control Enabled

CMOS cameras do not require an electromechanical shutter for exposure gating. The optional shutter is used for acquiring calibration bias and dark images. For light exposures, enable manual control of the shutter and leave it open until you want to acquire the calibration images.

> **Note**: If the mechanical shutter is an "iris type" opening, it may expose the center of the sensor slightly longer than its edges.

There are three shutter modes that can be used. These modes are detailed below.

Automatic Mode Enabled
Camera will automatically open the shutter when an image capture is requested, and close the shutter when the exposure time has concluded. Notice that the Open / Close buttons are not selectable when manual mode is active.

Manual Mode Enabled, Shutter Closed
Camera will keep shutter closed regardless of image capture request.

Manual Mode Enabled, Shutter Open
Camera will keep shutter open regardless of image capture request.

Illumination

This feature provides control for an external illumination source connected to the 8-pin auxiliary I/O port. Enable this operation and enter a delay time. The On delay is the time the system waits before turning on the output/illumination. the Off delay is the time the system waits before turning off the output/illumination.

LED

Control the operation of the internal LED. Enable the operation.

Heater

Some cameras have optional heaters. If the camera has heaters they are two heater strips on the outside of the camera window. These strips keep the window just above ambient temperature the reduce condensation on the window. FLIPilot allows you to turn the heater strips on and off and enter a value that represents the duty cycle. FLI recommends you keep the heater on as a means of preventing condensation/frosting.

Fan

The fan power is set at the factory. You can enable or disable the fan operation.

Cooler Temp

Removing excess heat from the camera's electronics and keeping the sensor cool keeps the dark current to a minimum and reduces drift when capturing multiple frames. To accomplish this, the camera housing includes a Thermoelectric Cool (TEC) System, cold finger, and a fan. Provide adequate clearance (2.5 inches(6cm)) on the camera's intake and exhaust sides for airflow.

When Cooler Temp is enabled on the Camera Control panel the software will attempt to maintain the entered temperature setpoint. The current temperature is displayed on the Grab Control panel. If the temperature is displayed in a red color, the actual temperature and the set point temperature are different. If the temperatures are different the camera will attempt to rectify the difference.

Read During Exposure

The software displays the current temperature of the Cold Finger base in the status bar at the bottom of the screen. The temperature is sampled every three to five seconds. During an exposure, the temperature is sampled, but it is typically not updated in the status bar.

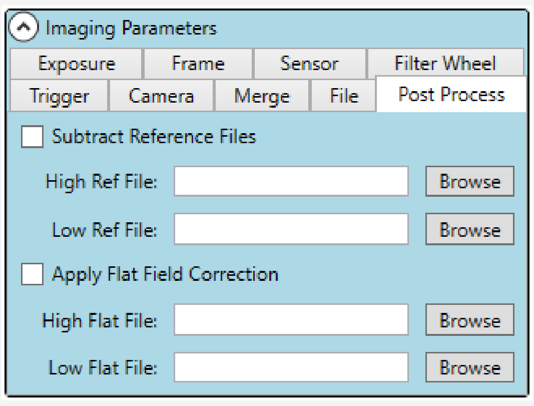
Thumbnail Capture

Thumbnails can be generated to provide small format images to accompany the full images for use in icons.

Max Frames Kept in Memory

FLIPilot will store the last images taken within its memory. This allows the user to go back to a previous image if they forgot to save it or if they would like to see a number of images in a row. Depending on the computers capabilities you may change the number of stored images. Fifty is the maximum number of frames FLIPilot will store in memory. When the entered value is reached, FLIPilot will automatically discard the oldest frames. This value defines the number of frames available in Frame Slide Show.

Post Process Settings



The post process panel is used to control automatic fixed pattern noise correction and flat field correction.

Fixed pattern noise (FPN) is a type of noise generated during the imaging of long exposure images. A detailed account of fixed pattern noise can be found at Fixed Pattern Noise Correction. The ability to apply fixed pattern noise correction to previously captured images is detailed at Manual Fixed Pattern Noise Correction.

Flat field correction (FFC) is a correction for non-uniform lighting across the sensor. This occurs most often when lenses are used that focus more light towards the center of the sensor than the outer edges and corners. More information on flat field correction is available at Flat Field Correction. The option to apply flat field correction to images already taken and saved is available at Manual Flat Field Correction.

Fixed Pattern Noise Correction

To apply FPN correction to an image being taken, select **Subtract Reference Files**, then use **Browse** to select the high and low gain master darks best for the images that will be taken. A master dark needs to have been taken with the same gain, exposure time, and sensor temperature to produce high quality results. More information on master dark frames is available at Fixed Pattern Noise Correction.

The FPN corrected image will be displayed when **Subtract Reference Files** is checked.

Note:
These aspects of imaging must remain constant between a master dark frame and final image:
- Gain
- Exposure Time
- Sensor
- Temperature

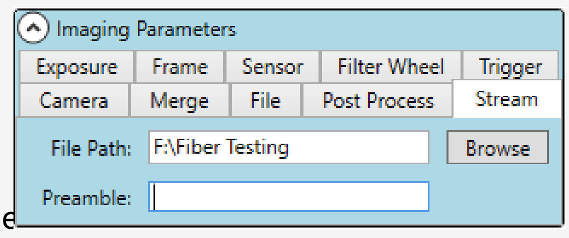
Flat Field Correction

To apply FFC to an image being taken, select **Apply Flat Frame Correction**. Use **Browse** to select the high and low gain master flat frames that are best for the image being taken. A master flat frame needs to be taken with the same hardware configuration, as well as the same gain settings and mean pixel value as the image being taken. More information on master flat frames is available at Flat Field Correction. Note that steps 1-6 must be completed to generate a master flat frame, and thus must be done prior to using this feature to apply flat field correction automatically.

The flat field corrected image will be displayed when **Apply Flat Frame Correction** is checked.

Note:
These aspects of imaging must remain constant between master flat and final image:
- Gain
- Lens
- Mean Pixel Value

Stream Settings



File Path: F:\Fiber Testing
Preamble:

The stream settings tab allows the user to declare where a Stream is saved. When a stream is taken, the **Stream** tab is responsible for where the files are saved, not the **Files** tab as with image capture in any other mode.

Capturing images as a stream will allow for a much higher rate of frame capture by circumventing the process of converting each frame to a specified file type and rendering the frame on the screen. Instead, every frame is saved as a .RCD file type and no frames are displayed in the process.

File Path

The file path of the images to be saved. each group of images (if taken in multiple or continuous grab mode) will be saved in a folder whose name is the date and time of capture. File path must be filled out for a Stream to be captured.

Preamble

The preamble is a prefix for images being taken. Every frame of a stream will be saved with this prefix at the beginning of its file name.

Image Analysis

Data Analysis

Data Analysis controls how the image data is displayed. High and Low gain images can be replaced by either a profile analysis tool or a histogram analysis tool.

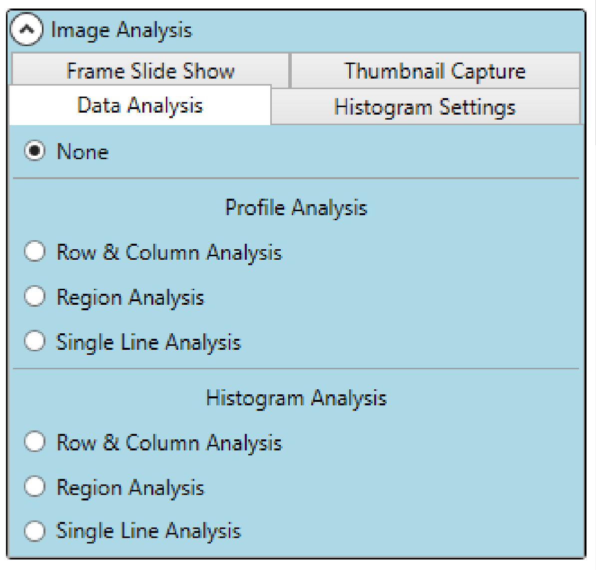
Histogram Settings

Histogram Settings controls how the histogram and a captured image are displayed. This allows you to change the default settings for the histogram.

Frame Slideshow

The Frame Slide Show feature allows you to review captured frames in order as if they were in a slide show.

Data Analysis



This menu controls how data regarding the image is displayed. Depending on your selection, the High and Low gain images will be replaced by either a profile analysis tool or a histogram analysis tool.

There are multiple options for data analysis using this menu. There are two formats and three area selection tools for each. One can also decide to not use any of those and only display the full image histogram.

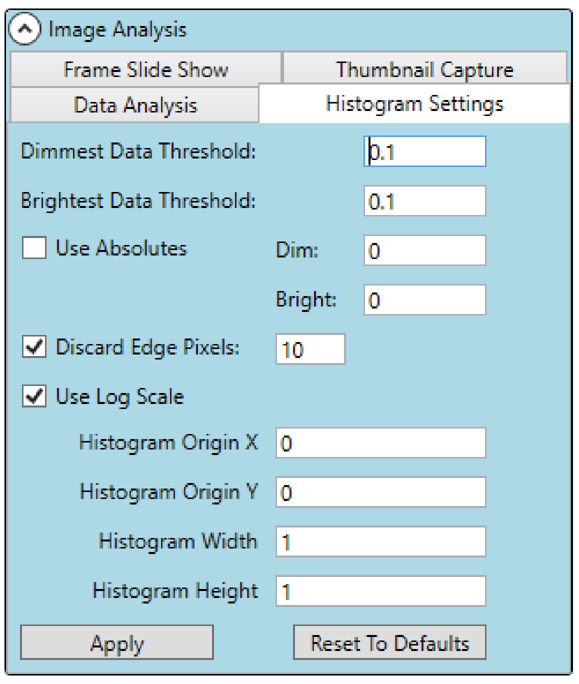
Selecting **None** will do just that, all other analysis panels will be removed and only the histogram representing the full image will be displayed on the left side of the screen. To retrieve high and low gain images on the left panel, see "Three Windows" under Display Control.

Under **Profile Analysis** are the options for displaying data in a profile view.
"Row & Column Analysis" allows selection of a row and a column of the image and their profiles are displayed on the right.
"Region Analysis" allows selection of a rectangular region for analysis.
"Single Line Analysis" allows the user to draw a single line from any two points and view the profile of that selection.

Under **Histogram Analysis** are similar options.
"Row & Column Analysis" produces histograms for a selected row and column.
"Region Analysis" produces a histogram for a selected area of the image.
"Single Line Analysis" provides a histogram for a line connecting any two selected points in an image.

To select the rows, columns, areas or lines for any of the previously mentioned operations, right click on the image and move the cursor. The selection will appear as a red line.
For "Row & Column," two perpendicular red lines intersecting at the cursor represent the row and column that will be analyzed.
For "Region," a red rectangle will be displayed and the section of the image inside the rectangle is that which will be analyzed.
For "Single Line," a red line will be drawn from the point where you first right click, to the location where you release. This line will be the section analyzed.

Histogram Settings



Dimmest Data Threshold: 0.1
Brightest Data Threshold: 0.1
☐ Use Absolutes Dim: 0
Bright: 0
☑ Discard Edge Pixels: 10
☑ Use Log Scale
Histogram Origin X 0
Histogram Origin Y 0
Histogram Width 1
Histogram Height 1

When you capture an image, the system will automatically display a histogram that measures and graphs the brightness and contrast characteristics of the image. The histogram is displayed in the Histogram Panel. You can view and analyze the histogram and manipulate it to enhance the image. To change the size of the histogram, you can change the size of the panel in which it resides. See Display Customization.

You can move the red histogram pointers to adjust the image's screen display settings. The red points represent minimum and maximum brightness for the displayed image.

This panel displays parameters that influence the histogram display and the calculations it provides (std, mean, mode, median). After making changes to Histogram Settings, click **Apply** to update the histogram.

Dimmest Data Threshold

This parameter accepts a percentage as input. The X% of the dimmest pixels will be discarded from the histogram display and calculations.

Brightest Data Threshold

This parameter accepts a percentage as input. The X% of the brightest pixels will be discarded from the histogram display and calculations.

The process of converting the sensor pixel values to monitor pixel values maps a potentially very high number of values to a constant 256 values. The center 80% of image data is mapped to pixel values between 0 and 255 by default. This can be changed with the **Dimmest / Brightest Data Threshold**. As exposure increases, the range of values to be mapped increases. The result of this is fewer pixels being displayed as bright, and the image being displayed darker.

Use Absolutes

Use the given absolute Bright and Dim values as fixed thresholds to draw the histogram. When not active, values will be calculated based on the percentages given above.

Dim

The absolute dimmest pixel value used to draw the histogram.

Bright

The absolute brightest pixel value used to draw the histogram.

Discard Edge Pixels

When enabled, the histogram discards the entered number of pixels on the left and right edges of the image from the histogram display and calculations.

Use Log Scale

The histogram's x-axis can be displayed in two different scales. A linear histogram is a representation of how the camera sees the data. A logarithmic histogram is a representation of how our eyes see the data. If the checkbox is enabled, the logarithmic scale is used.

Histogram Origin X, Y, Width, Height

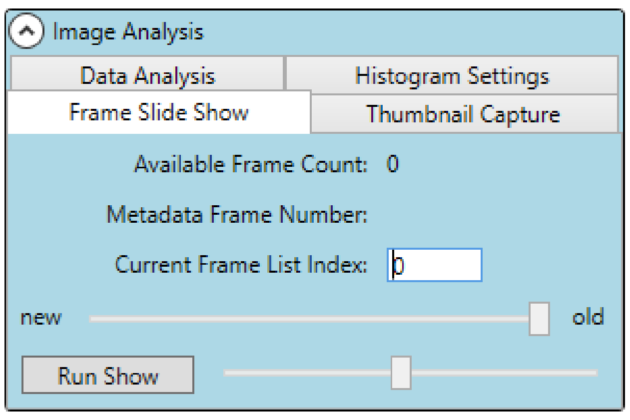
These parameters allow manual selection for the region displayed in the histogram. One can enter an x and y coordinate and a width and height, or one can use the right mouse button to click and drag over an area to select the intended region. Remember to click apply after either input to update the histogram.

Apply

set

by the system.

Frame Slide Show



Available Frame Count: 0
Metadata Frame Number:
Current Frame List Index: 0

The Frame Slide Show feature allows you to review captured frames in order as if they were in a slide show. You can view the frames in either newest-to-oldest or oldest-to-newest order using the keyboard arrow keys or clicking the cursor on the new-old scroll bar. The currently displayed frame is identified by the numeric in the list index field, which also allows you to enter a value to display a specific frame.

The maximum Available Frame Count is defined by the “Max Frames Kept in Memory (50 Max) value on the Camera Control panel. Hence, capturing 10 frames with a value of 5 in the “Max Frames Kept in Memory” field will result in only five available frames in the slide show.

Available Frame Count
The number of frames currently held in memory as set in Max Frames Kept.

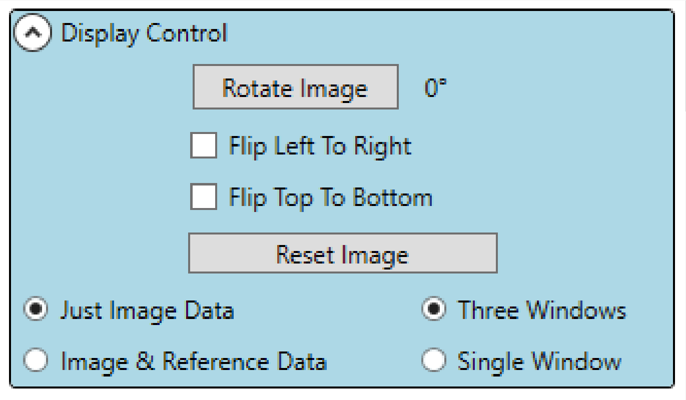
Metadata Frame Number
The frame number stored in the metadata of the current frame.

Current Frame List Index
The index in the list of frames.

New - Old
From newest to oldest, the list of frames held in memory.

Run Show and Slider
Run Show controls which frame will be displayed from the list of frames in memory. The slider determines the rate at which the frames are present. Left is quicker, right is slower.

Display Control Panel



0°
☐ Flip Left To Right
☐ Flip Top To Bottom
● Just Image Data ● Three Windows
○ Image & Reference Data ○ Single Window

Figure 1. Display Control

Rotate Images

You can rotate all three images (High Gain, Low Gain and High Dynamic Range) in 90° increments together. Rotate the images using the Display Control Panel's **Rotate Image** button. The current rotation is displayed to the right of the Rotate Image button and represented by the orientation device. Click **Reset Image** to return the image to its original orientation.

Flip Image Left To Right, Flip Top To Bottom

You can flip all the images (High Gain, Low Gain and High Dynamic Range) together horizontally and vertically. Use the checkboxes on the Image Display Control to rotate the images. The current rotation is represented by the orientation device (F). Examples of this can be seen in Figure 2 & 3. Deselect the selected checkbox or click **Reset Image** button to return the image to the original orientation.

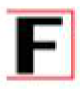
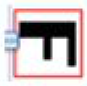
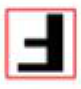
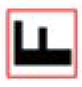
Orientation Device	Rotate Position
	0° / Default
	90°
	180°
	270°

Figure 2. Image Orientation (Rotated)

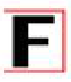
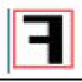
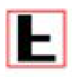
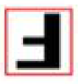
Orientation Device	Flip Position (with 0° Rotation)
	Standard Orientation
	Flip Left To Right
	Flip Top To Bottom
	Flip Left To Right & Top to Bottom

Figure 3. Image Orientation (Flipped)

Reset Image

Returns the image to the original orientation (top/bottom (rotation) and left/right (flip)).

Display Just Image Data / Image & Dummy Data

Use these two radio buttons to select which set of data to display on the screen. Refer to "Frame Control Settings" for more information on capturing reference data.

Three Windows / Single Window

If you captured only a low gain image (entered a value for the LDR Gain), it is displayed in the Main Image panel and its corresponding histogram is displayed in the Histogram panel.

If you set two different gains, you will obtain and can view the Low Gain, High Gain and the merged High Dynamic Range (HDR) images. The default image in the Main Image panel is the High Dynamic Range image with the Low Gain image in the Top Image panel and the High Gain image in the Bottom Image panel. This default with three images in the three Image panels and the histogram in the Histogram Panel is referred to as the Three Windows layout. You can change which image is displayed in which Panel using the arrowheads in the panel borders as described earlier. The displayed histogram corresponds to the image in the Main Image Panel.

You can change the display so only a single image (Low Gain, High Gain or the merged High Dynamic Range (HDR) Image) appears in the Main Image panel and its corresponding histogram is displayed. This layout is referred to as the Single Window layout. Change the layout using the **Single Window** (Figure 4) or **Three Windows** (Figure 5) radio buttons located on the Image Display Control panel.

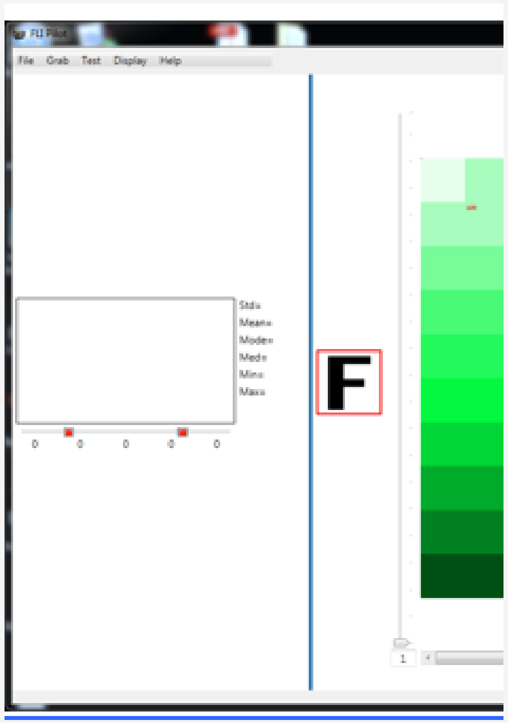


Figure 4. Single Window Mode

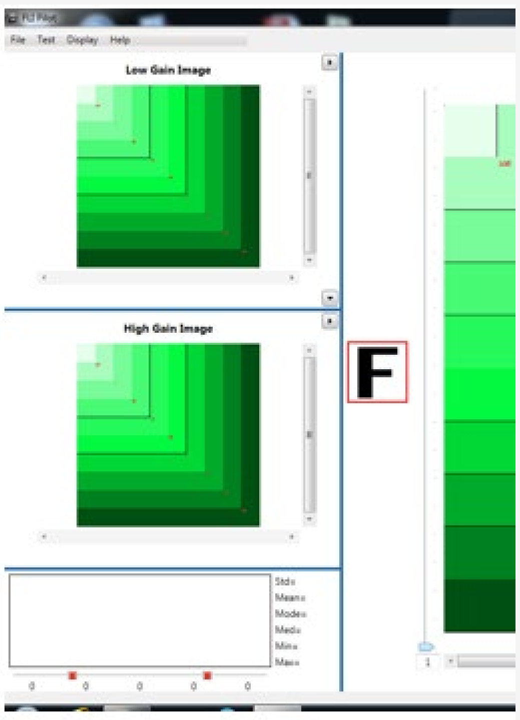
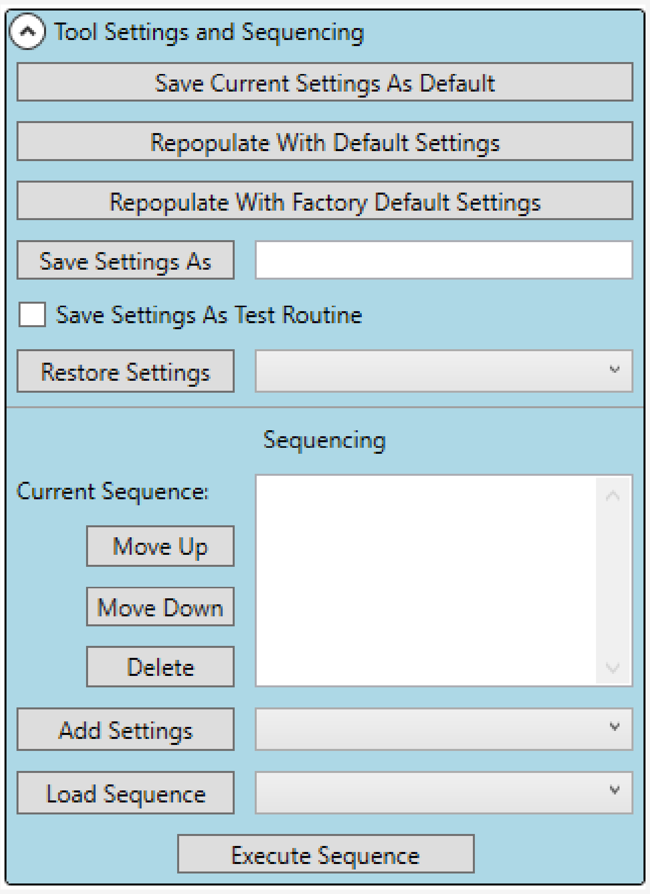


Figure 5. Three Window Mode

Tool Settings and Sequencing Panel



The **Tool Settings and Sequencing** panel provides a simple way to create, save and load setting presets in FLI Pilot. The upper panel of the page allows for the creation of setting profiles, and the lower portion provides the ability to form a series of setting profiles to be executed in a particular order.

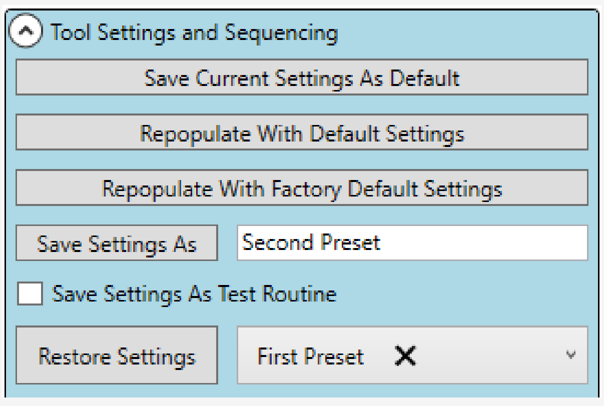
Tool Settings and Sequencing also allows the user to define the default profile for FLI Pilot that will be automatically set on startup.

The functions of this panel are provided in the following pages:

- **Tool Settings**
- **Setting Sequencing**

Tool Settings and Sequencing

The upper portion of the **Tool Settings and Sequencing** panel provides the options necessary to create, save, and restore setting profiles. The profiles defined by this portion of the panel are used in the lower portion of the panel, where Setting Sequences are managed.



Save Settings As: Second Preset
Restore Settings: First Preset ✕

Save Current Settings As Default
This button saves the current imaging parameters settings as the “default” set, after which, those settings will be set on each startup of FLI Pilot.

Repopulate with Default Settings
This button loads the saved default set to make it the current set. Note: This function will load the default settings as defined by **Save Current Settings As Default**, and will not restore the factory default settings.

Repopulate with Factory Default Settings
This button will load the factory default settings profile.

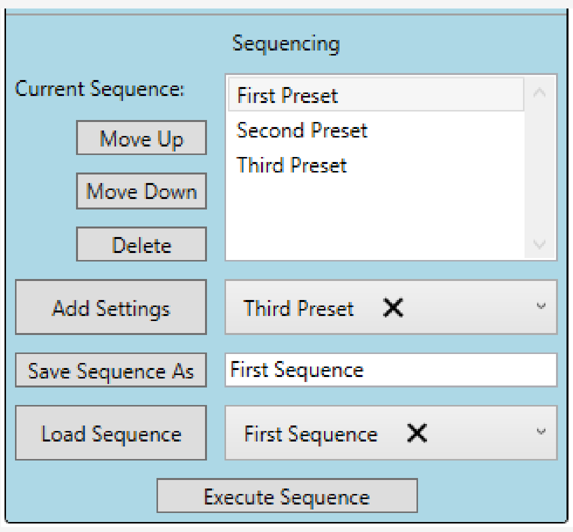
Save Settings As

Enter a name for the current setting profile in the adjacent text box, and press this button to add that profile to the list of saved profiles. After being saved, the profile will be seen in the drop down menus adjacent to **Restore Settings** and **Add Settings**.

Restore Settings

Use the drop-down list to select the name of the profile you want to restore then click this button to update the FLI Pilot settings to that of the selected profile. Clicking the X in the drop down list will delete the profile from memory.

Tool Settings and Sequencing



Current Sequence:
First Preset
Second Preset
Third Preset

Add Settings: Third Preset ✕
Save Sequence As: First Sequence
Load Sequence: First Sequence ✕

Setting Sequencing allows you to define a sequence of setting profiles to be executed in a particular order. This can be useful in instances where a set of images in needed, all with one or many setting differences between them. This menu gives the user the ability to create, save, and manage their sequences.

Current Sequence

The list displays the profiles in the order in which they would be executed. If you add a continuous capture to the sequence, the sequence will continue until you manually stop the continuous capture.

Move Up, Move Down

These buttons move the selected profile up or down, respectively, in the **Current Sequence** list.

Delete

Button removes the selected profile(s) from the **Current Sequence** list.

Add Settings

The adjacent drop-down list displays the saved sets that can be added to a sequence. Select the set to add to the bottom of the **Current Sequence** list, then click this button. Clicking the X in the drop down list will delete the profile from memory.

Save Sequence As

Enter a name for the active sequence defined in the **Current Sequence** list (a unique name for a new sequence or an existing sequence name to overwrite) then click this button to save the sequence with the entered name.

Load Sequence

Use the drop-down list to select the name of the sequence you want to make active then click this button. The profiles in the loaded sequence appear in the **Current Sequence** list.

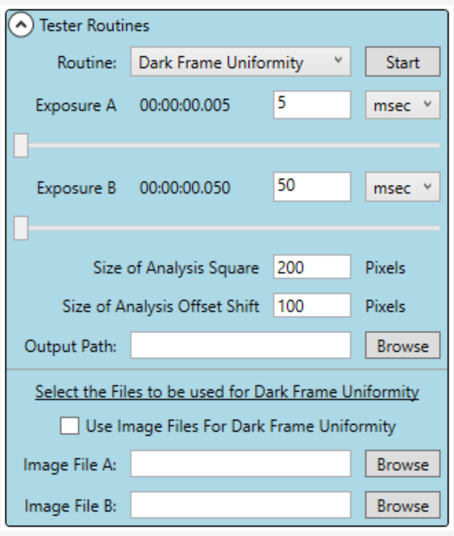
Execute Sequence

Executes the capture command beginning with the topmost setting profile shown in the **Current Sequence** list.

Tester Routines

Dark Frame Uniformity (Figure 1)

The Dark Frame Uniformity function is designed to quantify Dark Current Growth across the sensor by taking two dark exposures of differing times and determining the difference in the pixel values in user controlled regions.



Tester Routines
Routine: Dark Frame Uniformity | Start
Exposure A 00:00:00.005 5 msec
Exposure B 00:00:00.050 50 msec
Size of Analysis Square 200 Pixels
Size of Analysis Offset Shift 100 Pixels
Output Path: | Browse
Select the Files to be used for Dark Frame Uniformity
☐ Use Image Files For Dark Frame Uniformity
Image File A: | Browse
Image File B: | Browse

Figure 1.

Exposure
Set the two exposure times for Exposure A and Exposure B either numerically or using the slider bar.

Size of Analysis Square
Size of Analysis Square determines the size of the square region that will be used to calculate the Mode values throughout the image.

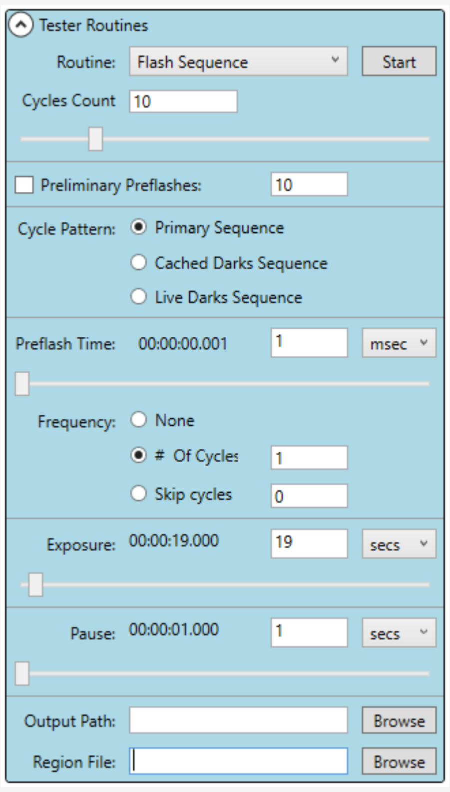
Size of Analysis Offset Shift
Size of Analysis Offset Shift is the distance that each region will be shifted when calculating subsequent Mode values throughout the image.

Output Path
The output path, selected by clicking on Browse, is the location the .csv file will be saved to once the images statistical data has been processed.

Manual or Automatic Image Processing
While the default of this function is to capture images at the time of clicking start, it is also possible to manually tell this function what images to use. If you would like to analyze two images that have already been captured and saved, enter their locations into Image File A and Image File B using the browse buttons. If both File locations are populated, Pilot will analyze those images using the above settings. If the File locations are not populated, Pilot will proceed to automatically capture two images and analyze them with the above settings.

Flash Sequence (Figure 2)

This function is designed to run through an exposure sequence containing preflash, dark exposure, and normal exposures. The function is designed to control ghosting due to a bright flash from your illumination equipment.



Tester Routines
Routine: Flash Sequence | Start
Cycles Count 10
☐ Preliminary Preflashes: 10
Cycle Pattern: ● Primary Sequence ○ Cached Darks Sequence ○ Live Darks Sequence
Preflash Time: 00:00:00.001 1 msec
Frequency: ○ None ● # Of Cycles 1 ○ Skip cycles 0
Exposure: 00:00:19.000 19 secs
Pause: 00:00:01.000 1 secs
Output Path: | Browse
Region File: | Browse

Figure 2.

Cycles Count
The Cycles Count controls how many time the function loops through the Flash Sequence. This can be changed by using the slider or numeric control.

Preliminary Preflashes
If Preliminary Preflashes is enabled, the number of times the light will flash can be manually controlled. If Preliminary Preflash is disabled then the light will flash once.

Cylce Pattern
The following Cycle Patterns are programed with the following image/flash routines.
Primary Sequence: Preflash, Dark Exposure, 2 Normal Exposures
Cahed Darks Sequence: Preflash, 2 Normal Exposures, Pause
Live Darks Sequence: Preflash, Dark Exposure, 2 Normal Exposures, Dark Exposure, Pause

Preflash Time
The length of time of the preflash can be controlled numerically or with the slider bar.
Frequency:
None: Omits any preflash and replaces it with a Dark Exposure with a duration equal to the Preflash Time
Of Cycles: This allows you to only run the Preflash for the set number of cycles entered, then it runs a Dark Exposure for the remaining cycles.
Skip Cycles: This runs the Preflash Exposure then skips (replaces the Preflash with a Dark Exposure) for the set number of cycles before running it again.

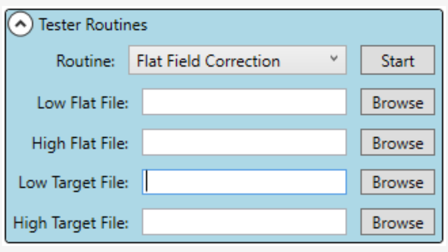
Exposure
Exposure length for the Normal and Dark images may be set here either numerically or with the slider bar.

Pause
Pause controls the pause during every cycle in which it is included. This can be set numerically or with the slider bar.

User Fields
Output Path: The output path can be set using the browse button. This is where the images taken will be stored.
Region File: If you would like to only sample a subframe, a Region File may be selected using the browse button.

Flat Field Correction (Figure 3)

Flat Field Correction is a tool used to apply Flat Field Corrections to images. The use of this tool is documented further at the Manual Flat Field Corrections page.



Tester Routines
Routine: Flat Field Correction | Start
Low Flat File: | Browse
High Flat File: | Browse
Low Target File: | Browse
High Target File: | Browse

Figure 3.

Low/High Flat File: Use **Browse** to select the high/low gain master flat frame file that will be used to flat field correct the target image.

Low/High Target File: Use **Browse** to select a high/low gain image that the flat field correction will be applied to.

Please note the importance of continuity between the flat file and the target file. The images should have the same gain settings, the same average pixel value, and the same camera setup used to take the images with no physical changes between the capture of the master flat frame and the target image.

Force Training (Figure 4)

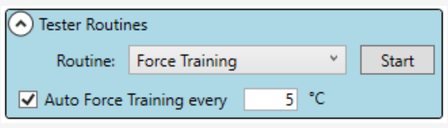

Tester Routines
Routine: Force Training
Start
☑ Auto Force Training every 5 °C

Figure 4.

Force Training ensures that the camera is reading the sensor output during the correct time. If the camera starts reading the output during the transition from one byte of data to another the signal/image will be will show irregularities. If there is an image defect it is always recommended that you run a Force Training first to see if that solves the problem.

Auto Force Training: When enabled automatically force trains as the camera changes temperature by the value entered.

LED Control (Figure 5)

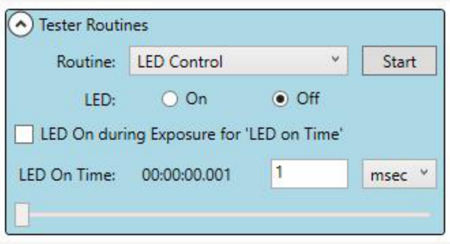

Tester Routines
Routine: LED Control
Start
LED: ○ On ● Off
☐ LED On during Exposure for 'LED on Time'
LED On Time: 00:00:00.001 1 msec

Figure 5.

The LED Control allows you to manually control the onboard camera LED as well as set parameters to control the LED during an exposure.

In order to manually control the LED, use the On/Off buttons.

In order to automatically have the camera flash the LED during exposures select the LED On during Exposure for 'LED on Time' toggle, then set the amount of time you wish the LED to stay on for using the LED On Time by either entering a numeric value or using the slider.

Merge Frames (Figure 6)

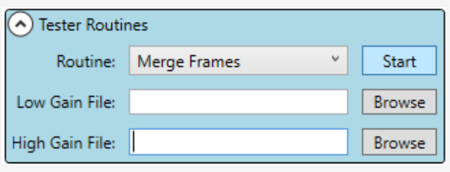

Tester Routines
Routine: Merge Frames
Start
Low Gain File:
Browse
High Gain File:
Browse

Figure 6.

Merge Frames allows you to manually merge two image files together. First select which Low Gain and High Gain image files you wish to merge by selecting the Browse buttons. The program will use the settings in the Imaging Parameters - Merge tab to control the merge function. Please ensure that the settings there are adequate and then press Start. The program will create the merged image which you can then save.

Frames Difference (Figure 7)

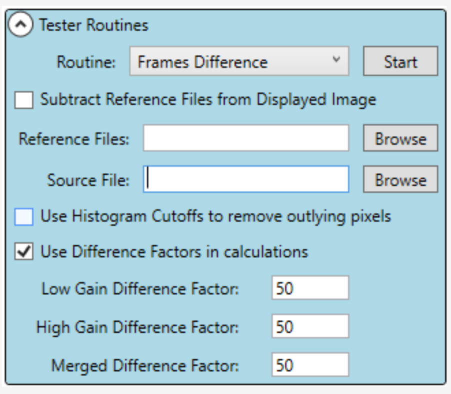

Tester Routines
Routine: Frames Difference
Start
☐ Subtract Reference Files from Displayed Image
Reference Files:
Browse
Source File:
Browse
☐ Use Histogram Cutoffs to remove outlying pixels
☑ Use Difference Factors in calculations
Low Gain Difference Factor: 50
High Gain Difference Factor: 50
Merged Difference Factor: 50

Figure 7.

Frames Difference allows you to subtract one images pixel values from another. This is primarily used to subtract a dark stacked frame from an image to remove the pattern noise.

The image file should be added to the Source File line using the Browse button while the reference image that will be subtracted should be added to the Reference File line using the Browse button.

Subtract Reference Files from Displayed Image: allows you to subtract the reference frame from the currently captured image displayed from the camera that may or may not have been saved to a file yet.

Use Histogram Cutoffs to Remove Outlying Pixels: This uses the settings for the Dimmest Data Threshold and Brightest Data Threshold found in Histogram Settings (LINK) to remove the outlying pixels.

Use Difference Factors in Calculations: This function allows you to shift every pixel in each image by the amount entered. This function is useful if the image pixel values are being clipped at 0.

Stack Frames (Figure 8)

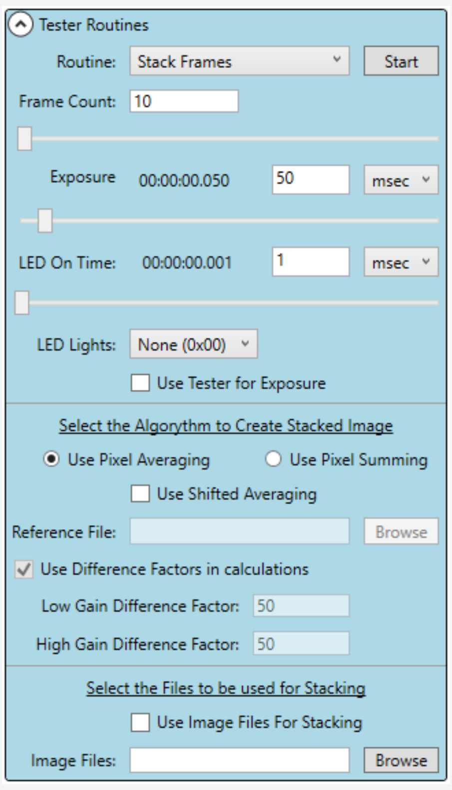

Tester Routines
Routine: Stack Frames
Start
Frame Count: 10
Exposure 00:00:00.050 50 msec
LED On Time: 00:00:00.001 1 msec
LED Lights: None (0x00)
☐ Use Tester for Exposure
Select the Algorythm to Create Stacked Image
● Use Pixel Averaging ○ Use Pixel Summing
☐ Use Shifted Averaging
Reference File:
Browse
☑ Use Difference Factors in calculations
Low Gain Difference Factor: 50
High Gain Difference Factor: 50
Select the Files to be used for Stacking
☐ Use Image Files For Stacking
Image Files:
Browse

Figure 8.

Stack Frames takes a number of images equal to the Frame Count and averages the images pixel values to create a single Stacked Image. This allows you to gain an image showing the pattern noise of the sensor while minimizing the impact of noise.

Frame Count: Is the number of images that will be taken and averaged together.

Exposure: Is the exposure time for the images that will be captured.

LED On Time: Is the amount of time the LED will flash for each image. The LED can be enabled or disabled with the LED Lights dropdown list.

Pixel Averaging: Creates a Stacked image where the Pixels value is an average of the respective pixels in each of the reference images.

Pixel Summing: Creates a Stacked image where the Pixels value is a summation of the respective pixels in each of the reference images minus the bias pixel times the Frame Count. In order to specify the Bias Image you must fill out the Reference File by selecting Browse. If more than one bias image is selected they will be averaged together before proceeding with the correction. (Image1Pixel1 + Image2Pixel1 +...+ ImageNPixel1) - (N*BiasPixel1) = StackedPixel1

Use Shifted Averaging: Shifted Averaging is used to minimize truncation errors by using a 16bit value for each pixel instead of a 12bit value. Essentially this means each pixel is multiplied by 16 before averaging.

Use Difference Factors in Calculations: If there is concern about clipping negative values you can enable Use Difference Factors in Calculations. This raises each pixels value by the amount entered to ensure that no values are clipped.

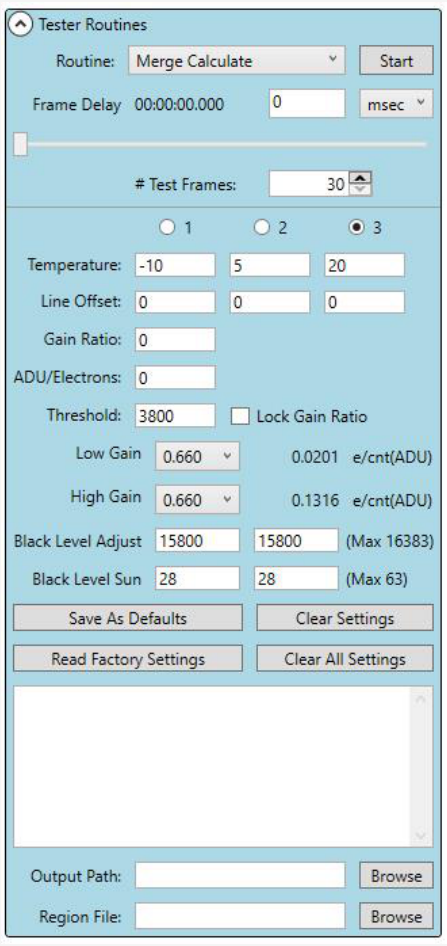
Stack Images Manually: It is possible to stack images that have already been saved. In order to manually stack images, select Use Image Files For Stacking, then select the Image Files using the Browse button and the program will stack the images using the above factors.

Merge Calculate (Figure 9)

In order to create a linear response across the range of a merged image, Pilot requires a number of Merge Variables. Merge Calculate is designed to find the best Merge Variables for the current settings of the camera. In order to better understand the Merge Variables please review the Merge page.

The Merge Variables are based on the Gain Pair you are using. So a low gain of 1 and high gain of 5 will have different Merge Variables then a low gain of 1 and a high gain of 10.

Merge Calculate is designed to automatically find the optimum settings for a given set of image parameters. If you are operating the camera with unique settings, running this routine will provide you with the Merge Variables



Routine: Merge Calculate
Frame Delay 00:00:00.000 0 msec
Test Frames: 30
○ 1 ○ 2 ● 3
Temperature: -10 5 20
Line Offset: 0 0 0
Gain Ratio: 0
ADU/Electrons: 0
Threshold: 3800 ☐ Lock Gain Ratio
Low Gain 0.660 0.0201 e/cnt(ADU)
High Gain 0.660 0.1316 e/cnt(ADU)
Black Level Adjust 15800 15800 (Max 16383)
Black Level Sun 28 28 (Max 63)
Output Path:
Region File:

Figure 9.

needed to produce good merge images for those settings.

To understand the variables that go into creating a merged image please see the Merge page.

Before Initiating the Routine

Select which of the three Temperature/Line Offset settings you would like to change. If you are not running the camera at one of the three predesignated temperatures please select the one closest to the current temperature.

The temperature of the camera should be set under the Camera Tab under Imaging Parameters. Merge Calculate will fill in the Temperature the camera is running at when the program is initiated, therefore the camera temperature should be changed far enough in advance for the temperature of the sensor to stabilize. If you are taking long exposures we recommend allowing the sensor to sit for 10-15 minutes, or longer, for the sensor and thermal mass of the camera to stabilize.

Select the Gain Pair that you wish to use.

Select the MergeCalculateRegionFile.csv that was included in the installation zip folder from the Software page. This can be selected by pressing the Browse button next to Region File: at the bottom of the Merge Calculate tab.

Prevent exterior light from entering the camera. If your camera has a built in shutter, it will automatically close for this routine, you should not need to take any special precautions. If you do not have a shutter, you can place the camera on a flat table in a dark room or on a black mat in a dark room. To test if it is dark, take a 0 sec image and a 20 msec image. If it is dark the mean of these two images should be the same or very close (1 count difference). If the camera does not have a dark environment, Merge Calculate may not produce reasonable values.

If you are concerned about ghosting effects, you can enter a frame delay between images. Adding a frame delay can substantially increase the run time of this routine but if you will have a long delay between image captures it may be worth adding a frame delay to the test. If however you will be running the camera in continuous mode or with little to no delay between image captures it is not recommended that you set a frame delay here.

Initiating the Routine and Expectations

In order to start the routine, once the above has been completed, press the Start Button. The routine should complete in less than 10 minutes, unless a frame delay has been set. As the program runs you should see sdiff and idiff values appear after each step, these values should approach 0. If these after a few minutes these values are still increasing toward larger numbers then you should recheck the above settings and restart the test. You can cancel the test by pressing the Abort button, where the Start button was.

Requirements to run Merge Calculate
FLI Pilot 1.2.10 or later
KL400: Revision 4 of the FPGA Code (6 and 9 do not work)
KL4040: Revision D of the FPGA Code or later
A way of blocking light to the camera (Shutters if installed will close automatically) If you do not have a shutter you will need to manually block light for this process.

Note: This program should calculate the new Merge Variables in less than **10 minutes**. If you find this program does not complete after this time please check that you have blocked all light from entering the camera with its shutter or some form of light block and restart the process.

Advanced Topics

Fixed Pattern Noise (FPN) Correction

Fixed Pattern Noise Correction intends to eliminate fixed pattern noise from an image. The user may correct their images either post capture or automatically during the image acquisition process. For more information on this system please click here.

Flat Field Correction (FFC)

Flat Field Correction intends to eliminate pixel to pixel brightness variation in an image. The user may correct their images either post capture or automatically during image acquisition. For more information on this system please click here.

Master Dark Frame Library

A master dark frame library is a collection of dark frames that can be used to correct for fixed pattern noise generated by the camera. Fixed pattern noise is affected by the temperature of the sensor, the exposure time of images, and the gain settings of images. The master dark frame library is a compilation of dark frames captured at varying gains, exposure times, and temperatures, which can then be used for later images taken at the same or similar conditions.

It is good practice to save any dark frames taken, and label them in the file name. This will accrue a library of usable dark frames which can then be used for images taken under similar conditions.

Master Flat Frame Library

A master flat frame library is a collection of flat frames that can be used to correct pixel to pixel brightness variation in an image. Flat frame correction is dependent on the mean pixel brightness of an image, and thus a master flat frame library contains images that have many mean brightness values. Additionally, an images gain as well as any hardware that influences the light captured by the sensor will change the pixel to pixel brightness values and thus need to be accounted for in the flat frame library. Thus, flat frames correction will need to be used with a flat frame of the same gain, hardware, and mean pixel value.

It is good practice to save any flat frames taken with the gain, mean pixel value, and any hardware that may be subject to variation (Ex: filter wheel position, aperture, lens type). This will allow the user to compile a collection of flat frames that can be used in future instances.

Note: Due to the nature of flat frames, small changes in hardware or settings can influence the effectiveness of the capture. In cases where very precise correcting is required, the flat frame library will need to be remade regularly to account for changes that cannot be predicted (Ex: dust, lens position, focal point, and ware and tear of optical parts between use).

Fixed Pattern Noise Correction

Fixed-pattern Noise (FPN) is a term given to a noise pattern often generated during long exposures. This noise is generated when particular pixels are susceptible to producing brighter signals than the background noise.
FPN is visible when one takes an image with no noise correction, as seen in **Figure 1**, and an example of an image corrected for fixed pattern noise is shown as **Figure 2**.

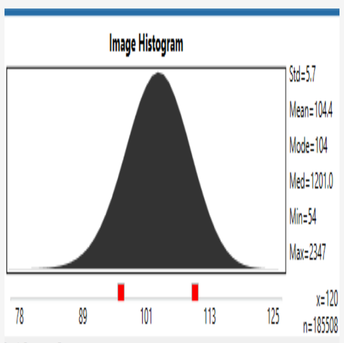


Figure 1: Stacked frame, uncorrected

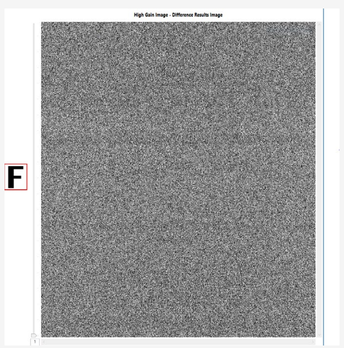


Figure 2: Stacked frame, corrected

Fixed pattern noise correction is removed by subtracting a master dark frame taken with the same gain, sensor temperature, and exposure time as the intended image. This is done by first identifying the gain, sensor temperature, and exposure time intended for the final image, then taking a completely dark image with those settings. The easiest way to do this is to cover the lens completely such that no light leaks and taking an image. The most important aspect of a dark image is that it is completely dark. Save this image, and title it with the exposure time, gain and sensor temperature. It is recommended to save any dark frames taken into a master dark frame library so it can be used again (See Advanced Topics).

With an appropriate master dark frame collected, the user can use the Post Process Panel to subtract the fixed pattern noise from images, or, the user may manually subtract the fixed pattern noise of a previously captured image, found at Manual Fixed Pattern Noise Correction.

Manual Fixed Pattern Noise Correction

The correction of fixed pattern noise is quite easy with the FLI Pilot application. The following sequence of steps will guide you through the process of correcting fixed pattern noise.

Generating a Master Dark Frame

1. Open the **Stack Frames** menu of Tester Routines. (**Figure 1**)

2. Enter the desired quantity of frames you wish to produce. 20 is generally an acceptable number.

3. Select your desired exposure. The generated set of stack frames can only be used to correct images with the same exposure as the stack, so one will likely want to produce multiple stacks in the case of multiple exposure durations being used.

4. The subsequent settings can be left at their default, however, you can reference the Tester Routine page for information regarding possible configuration.

5. Press start to begin capture and production of a stacked frame. (**Figure 2**)

6. Save the stacked frame with **File** ⟶ **Save As …**

Note:
These aspects of imaging must remain constant between a master dark frame and final image:
- Gain
- Exposure Time
- Sensor
- Temperature

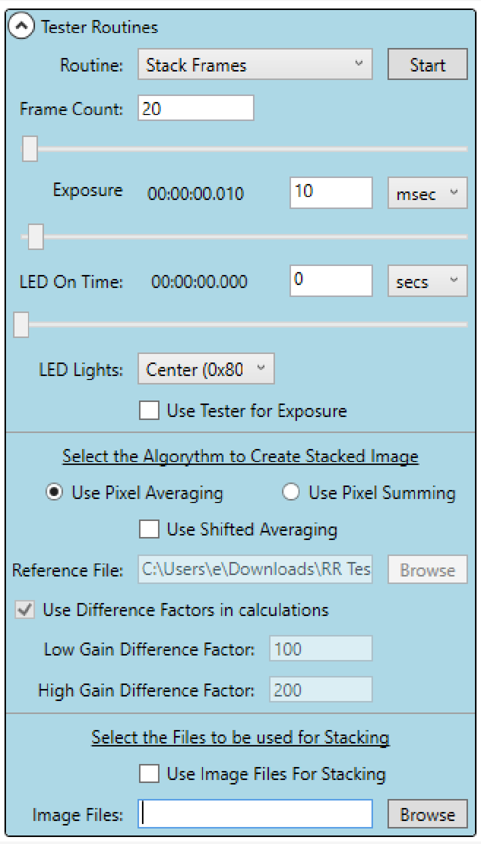

Tester Routines
Routine: Stack Frames
Frame Count: 20
Exposure 00:00:00.010 10 msec
LED On Time: 00:00:00.000 0 secs
LED Lights: Center (0x80
☐ Use Tester for Exposure
Select the Algorythm to Create Stacked Image
● Use Pixel Averaging ○ Use Pixel Summing
☐ Use Shifted Averaging
Reference File: C:\Users\e\Downloads\RR Tes
☑ Use Difference Factors in calculations
Low Gain Difference Factor: 100
High Gain Difference Factor: 200
Select the Files to be used for Stacking
☐ Use Image Files For Stacking
Image Files:

Figure 1: Stack Frames

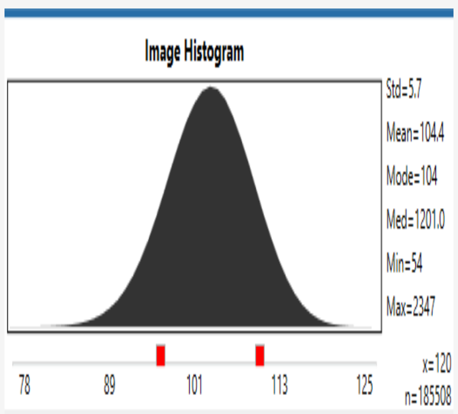


Figure 2: Stacked Frames

Correcting Fixed Pattern Noise

1. Enter the **Frames Difference** menu of Tester Routines. (**Figure 3**)

2. Use **Browse** to select a reference file. This will be the image previously saved as a result of the stacked frame generation.

3. Select a source file, which will be the image you wish to remove FPN from.

4. Confirm that neither the **Use Histogram Cutoffs** nor the **Use Difference Factors** boxes are enabled. In a case where these settings are required, reference the Tester Routine page for information regarding their functions.

5. Select **Start** to generate the final image (**Figure 4**), which can then be saved.

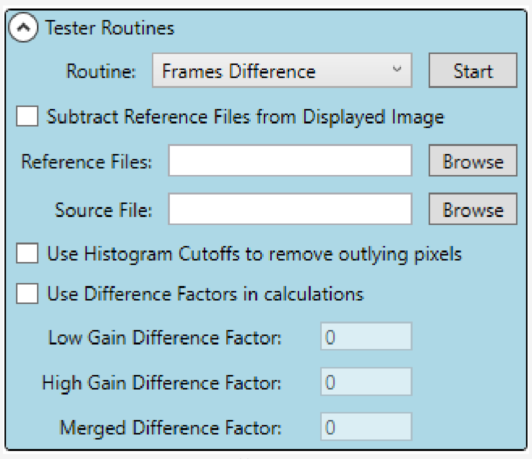

Tester Routines
Routine: Frames Difference
☐ Subtract Reference Files from Displayed Image
Reference Files:
Source File:
☐ Use Histogram Cutoffs to remove outlying pixels
☐ Use Difference Factors in calculations
Low Gain Difference Factor: 0
High Gain Difference Factor: 0
Merged Difference Factor: 0

Figure 3: Frames Difference

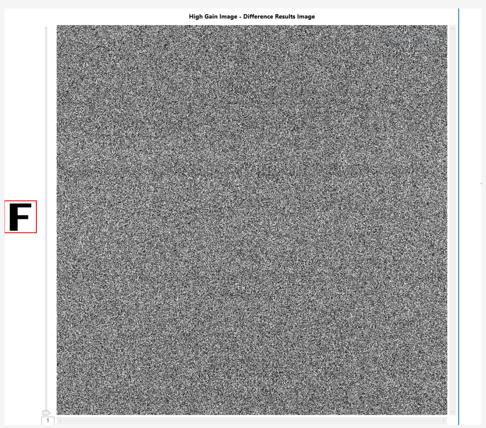


Figure 4: Final Image

Flat Field Correction

A flat field image is an image of uniform brightness, meaning there is no objects, and no brightness difference across the frame. A flat field image can be taken of a well lit wall, or, for a more accurate flat, of the sky with no clouds at a time where there is no gradient across the frame. The goal of a flat field image is to determine how high or low each pixel is compared to the mean pixel value.

Flat field correction (FFC) is a process where irregularities in pixel values are corrected by multiplying each pixel value by a factor that uniformizes the brightness across the image. FFC can correct for very small irregularities caused by dust or damage on a lens, however it is best used to correct vignette caused by a lens.

An image with no flat field correction applied is displayed as **Figure 1**. The final result of the correction is displayed as **Figure 2**. Most notably, one can clearly see how the edges are brighter than the center in **Figure 1**, and in **Figure 2**, the image brightness is uniform.

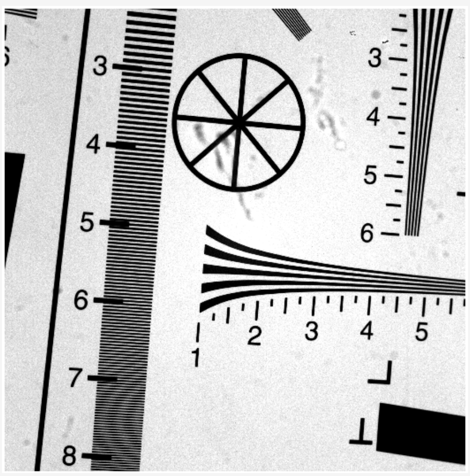


Figure 1: Uncorrected Image

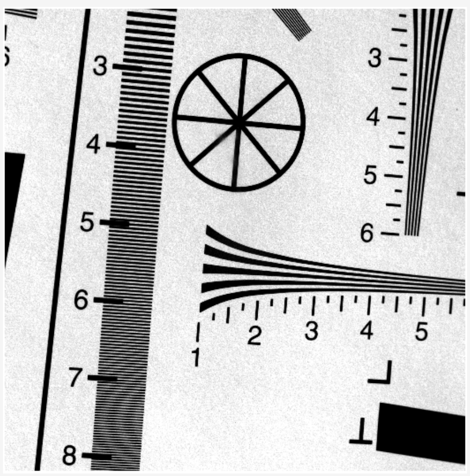


Figure 2: Flat Field Corrected Image

Within FLI Pilot, there are two ways to apply FFC: manually and automatically. One may manually apply flat field correction with the Flat Field Correction menu of Tester Routines. One may have a flat field correction applied automatically after each image taken with the Post Process menu.

The images used to make a flat field correction are called master flat frames. These master flat frames are stacked images of a flat field with Fixed Pattern Noise Correction applied. Flat field correcting requires the settings and configurations used for taking a master flat frame to be the same settings and configurations for the image intended to be corrected. Thus, users will likely have many master flat frames for the various settings they intend to use. FLI recommends the development of a master flat frame library to store many master flat frames in one location.

For precision imaging, it is not recommended to expect a master flat frame library to maintain precision over time or between hardware changes such as lens swapping or focal changes. This is due to the likelihood that small changes, such as dust, imperfections, and scratches will move relative to the sensor, regardless of how careful the user may be. For general imaging, this may not cause problems, however it is still not recommended. Additionally, when using filter wheel devices, a set of master flat frames need to be generated for each filter, as each will alter the incoming light in a different way.

Manual Flat Field Correction

Flat field correction is a type of post process correction that uses a reference flat frame to correct for lighting discontinuity in an image. The process uses a master flat frame to scale up or down the brightness of individual pixels to make the brightness of the final image balanced.

Notice in **Figure 1** and **Figure 2** that **Figure 2** shows noticeably more even brightness, and damage to the lens has been corrected.

The process of applying a flat field correction is not difficult, however it requires an understanding of what it is capable of doing. A master flat frame is similar to the pickiness of a master dark frame, in that the master frame needs to be taken with continuity between its capture and the capture of the image to be corrected.

Note:
These aspects of imaging must remain constant between master flat and final image:
- Gain
- Lens
- Mean Pixel Value

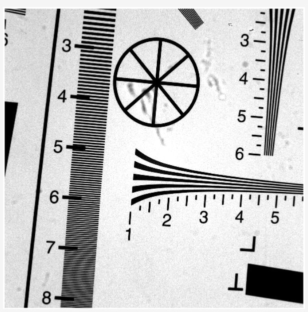


Figure 1: Uncorrected Image

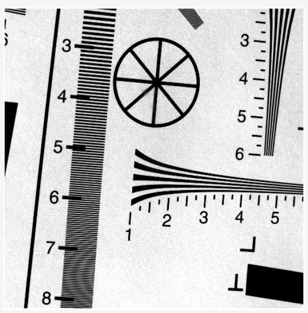


Figure 2: Flat Field Corrected Image

Generating a Master Flat Frame

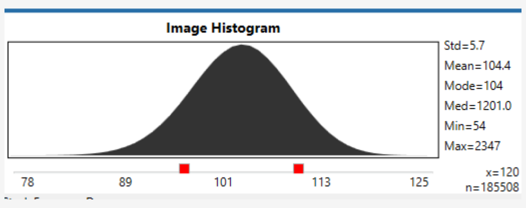
1. Capture an image with the intended settings, exposure, and camera configuration you intend for the final image.

2. Generate a master dark frame for the configuration desired. Reference Fixed Pattern Noise Correction for information on how to do so.

3. Apply the fixed pattern noise correction to the image initially taken and take note of the mean pixel value.

4. Ready your camera for a flat field capture.

5. Capture a flat field image whose mean pixel value is equal to the mean pixel value of the FPN corrected initial image. This is achieved by adjusting the exposure time. The mean pixel value is shown with the Histogram **(Figure x)**



6. Generate a master flat frame with the exposure time discovered in the prior step.

7. Save the master flat frame with **File** ⟶ **Save As …**

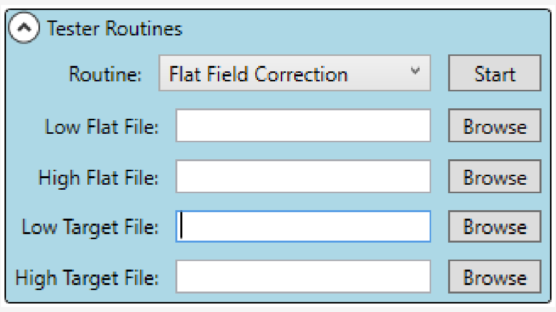
Apply Flat Field Correction

1. Enter the **Flat Field Correction** menu of Tester Routines. (**Figure x**)

2. Use **Browse** to select a **Low Flat File** and **High Flat File**. These will be the images previously saved as a result of the Master Flat Frame Generation.

3. Select a **Low Target File** and a **High Target File**, which will be the low and high gain images of the image you wish to apply flat field correction to.

4. Select **Start** to generate the final image, which can then be saved.


Tester Routines

Routine: Flat Field Correction

Sensor Selection

The selection of the appropriate sensor for your purposes in defined primarily by your intended use. FLI cameras are available with sensors optimized for every corner of the scientific world. Variables such as sensor type, size, and shape, alongside pixel size and density will help define which sensor is appropriate for its intended use.
A list of all available sensors alongside information regarding each sensors qualities is available on this chart:
Sensors Supported in FLI Cameras

Sensor Size

Sensor size influences the field of view of the image. A sensor with a large area can capture a larger area of light, resulting in a larger field of view. A sensor with a small area cannot capture the same area of light, resulting in a narrower field of view. Each sensors area, in mm^2, is displayed in the chart referenced above.

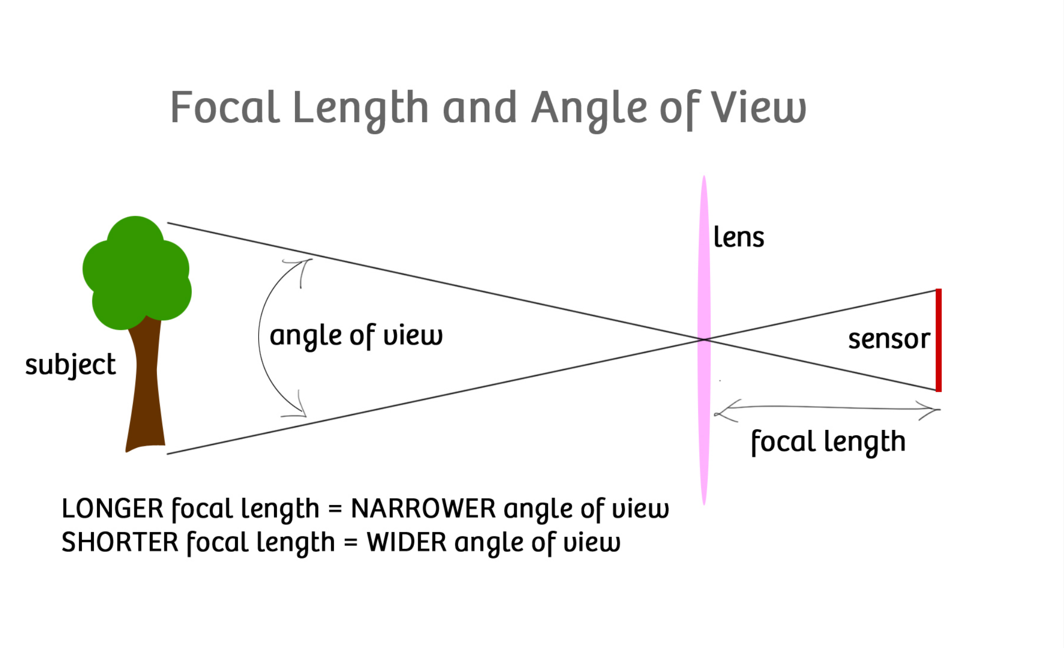


Figure 1: Sensor Size and Field of View
Image Credit: Jack Hollingsworth, snapsnapsnap.photos

If one can imagine the size of the sensor in the **Figure 1** modulating between larger and smaller, with the lines drawn from its edges intersecting at the same location, one may note that the angle of view increases as sensor size increases, thus capturing a larger portion of the scene.

Sensor Shape

The FLI cameras come with two available shapes. While the shapes are not explicitly stated on the chart referenced above, one can deduce from the array size (X and Y) that some sensors are square and nearly square, and others are much wider than they are tall.

The most common is square and rectangular with similar height and width dimensions (**Figure 2**). These sensors are applicable for nearly every use for a camera.

The second available option is the Hamamatsu horizontally stretched sensors, which are significantly wider than they are tall (**Figure 3**). These sensors are well designed for applications such as spectrophotometry, but are not well designed for most applications.

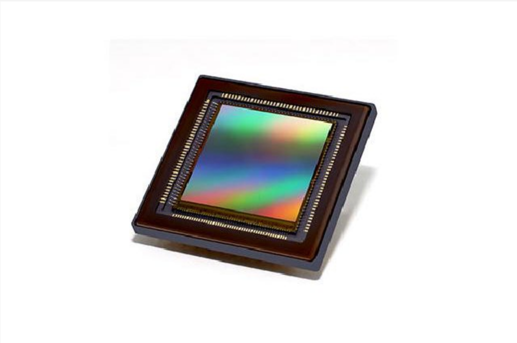


Figure 2: GSense400
Image Credit: GPixel, gpixelinc.com

Figure 3: S9979
Image Credit: Hamamatsu, hamamatsu.com

Pixel Size

Pixel size is very important to quality imaging. A pixel with a large area will collect more light, however it will result in a decreased resolution, as the pixels precision is lost when it collects light over a large area. A pixel with a smaller area will collect less light, but it will hold more precision by better identifying the location of where photons impacted the sensor. On the chart referenced above, pixel size is shown as a measure of microns, another name for which is micrometers.

As displayed in **Figure 4**, the wide pixel bucket has capacity to not only store more light information, but collect light from a greater area.

The decision of what size a sensor's pixels needs to be is often concluded with a balance between resolution and sensitivity. A system intended for low light situations should prefer larger pixels, while a system intended for well lit scenes should prefer smaller pixels.

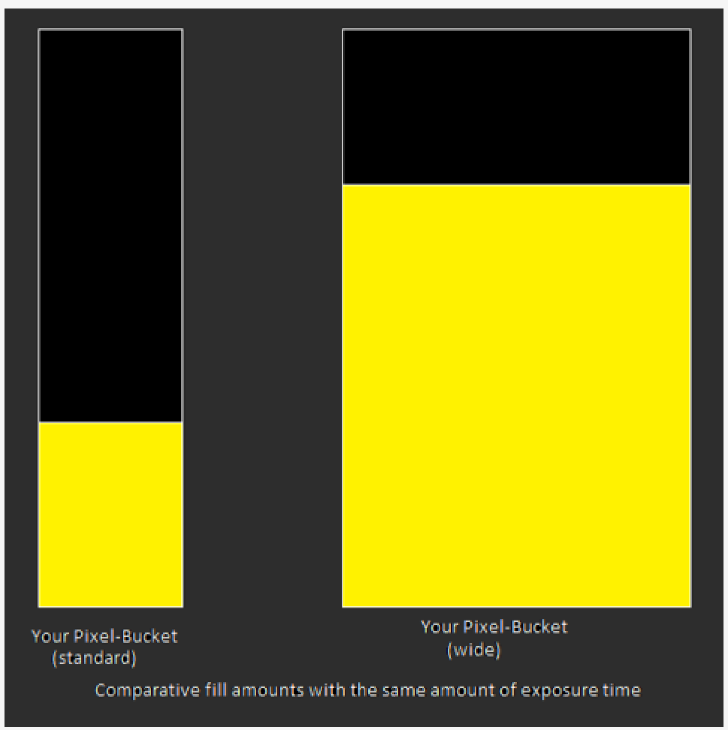


Figure 4: Effect of Pixel Size
Image Credit: Jon Minnick, cloudbreakoptics.com

Pixel Density

High density pixel arrangements collect less light with more precision, while low density pixel arrangements collect more light with less precision. On the chart referenced above, there is no given measure of pixel density; however, you can get a good idea of how each sensor compares by taking the number of pixels and dividing it by the sensor area. For example, the KAF-4301 has a pixel density of approximately 1700pixels/mm^2, while the KAF-50100 has a pixel density of approximately 28,000pixels/mm^2. The KAF-50100 is clearly much more dense than the KAF-4301 because it has almost 16 times more pixels the amount of pixels per mm^2.

Pixel density goes hand in hand with pixel size. As pixel density increases, the size of the pixels must decrease. High density sensors have a greater number of pixels, and thus have greater precision when identifying where light came from, producing higher resolution images. Low density sensors, however, include larger pixels more capable of collecting light when there is not a lot of light in the scene.

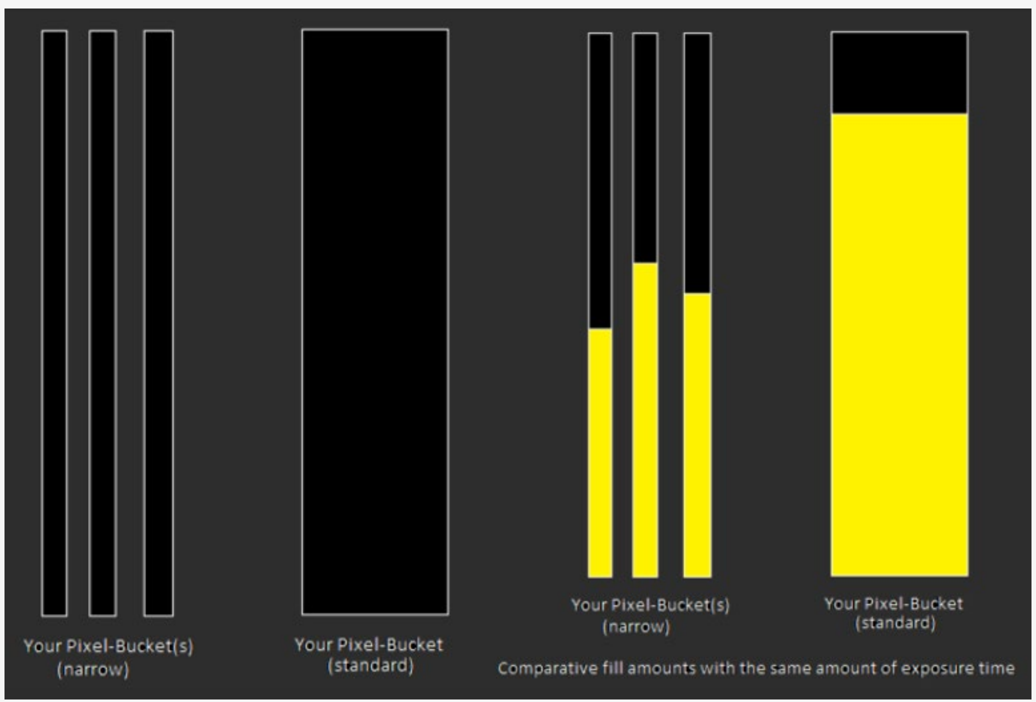


Figure 5: Effect of Pixel Density
Image Credit: Jon Minnick, cloudbreakoptics.com

Sensor Type

There are two primary sensor types to chose from: CCD and sCMOS. On the chart referenced above, any GPixel sensor is a sCMOS sensor, and any of the other sensors are CCD.

CCD sensors provide low dark current images at the cost of higher frame rate availablility. These sensors are ideal for long exposure imaging. CCD sensors are discussed further here.

sCMOS sensors provide images with very low noise, significantly higher frame rates, and a large field of view. sCMOS sensors are ideal for imaging requiring quick image capture and low noise. sCMOS sensors are discussed further here.

Sensor Illumination

Two options exist with sensor illumination, backside and frontside. The root of this option sprouts from a pixels architecture. **Figure 6** shows how front illuminated sensors require light to first pass through a layer of circuitry on the front side of the photodiode. Inversely, back illuminated sensors place the circuitry on the backside of the photodiode. Back illuminated sensors require a significantly more challenging procedure to produce. Thus, black-illuminated sensors are more expensive that front illuminated sensors.

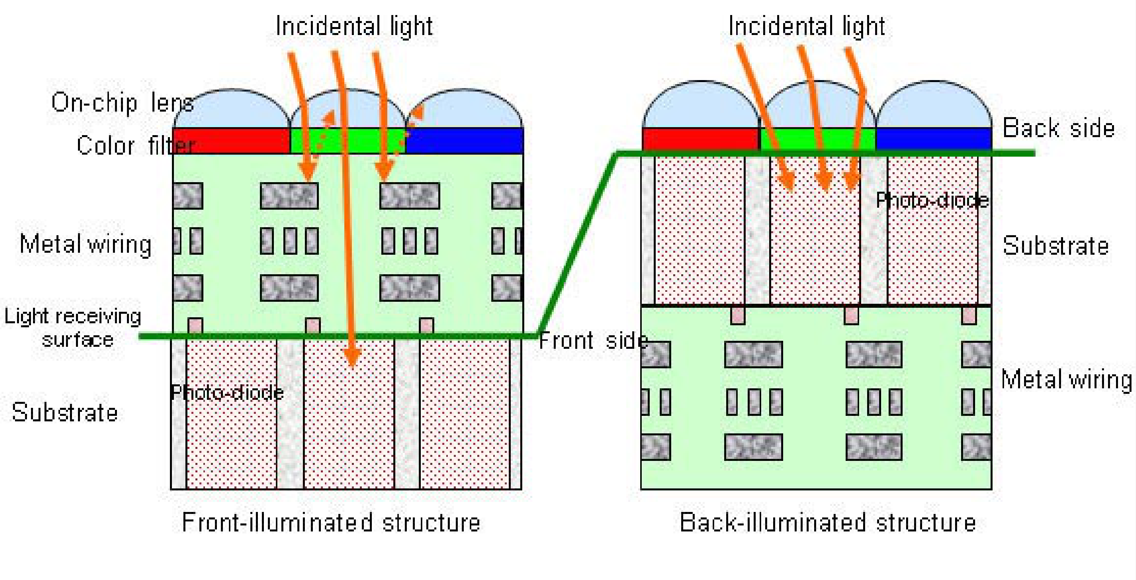


Figure 6: Pixel Illumination
Image Credit: Sony, Sony.net

The chart referenced above shows front illuminated sensors with a red font, and the back illuminated sensors with a blue font. Sensors shown in neither a red nor blue font are interline transfer CCD sensors, which are discussed in further detail on the CCD Sensors page.

interline transfer sensors are a type of CCD sensor that do not provide a choice between front/back illuminated, thus earn their own category. Interline transfer sensors are less sensitive to light due to their architectures, however, they avoid smear and are capable of higher image capturing rates than other CCD architectures.

Back illuminated sensors allow more light into the photodiode, because less light is blocked, reflected, or absorbed by the circuitry in a frontside illuminated sensor. With this increased light, the low-light capabilities of the sensor are enhanced, and digital noise is reduced.

Back illuminated sensors are ideal for low light imaging, due to its ability to capture more light.

Front illuminated sensors are ideal for imaging devices not expected to be used in low light situations.

Interline transfer sensors are ideal for high rates of frame captures, but not very low light situations.

Quantum Efficiency

Quantum efficiency (QE) is provided as a percentage and is a measure of efficiency a sensor can measure incident photons. We know light to be composed of photons, objects which we can then measure with photodiodes. With a sensor capable of 100% QE, the photodiodes of the sensor would translate one incident photon into one measurable electron. As QE decreased towards 90%, 50%, etc, the amount of photons recorded by the sensor decreases, subsequently resulting in decreased sensitivity to light.

High QE sensors capture the most light, and thus are more sensitive imaging devices. Devices with low QE may suffer from dark images, and will not operate optimally in low light situations.

The image to the right shows an example of a pixel with decreased QE (on the right). As light enters the pixel well, some is reflected, some is absorbed, and some gets to the sensing area. The more in the way of the lights path, the lower the QE is due to less light being read.

The pixel to the right would be an example of a front illuminated sensor, with various objects blocking the lights path.

QE is not shown on the chart referenced above, however, a simple internet search of the sensor ID, example: KAF-50100, will return the sensor specifications from the manufacturer and will include the sensors quantum efficiency.

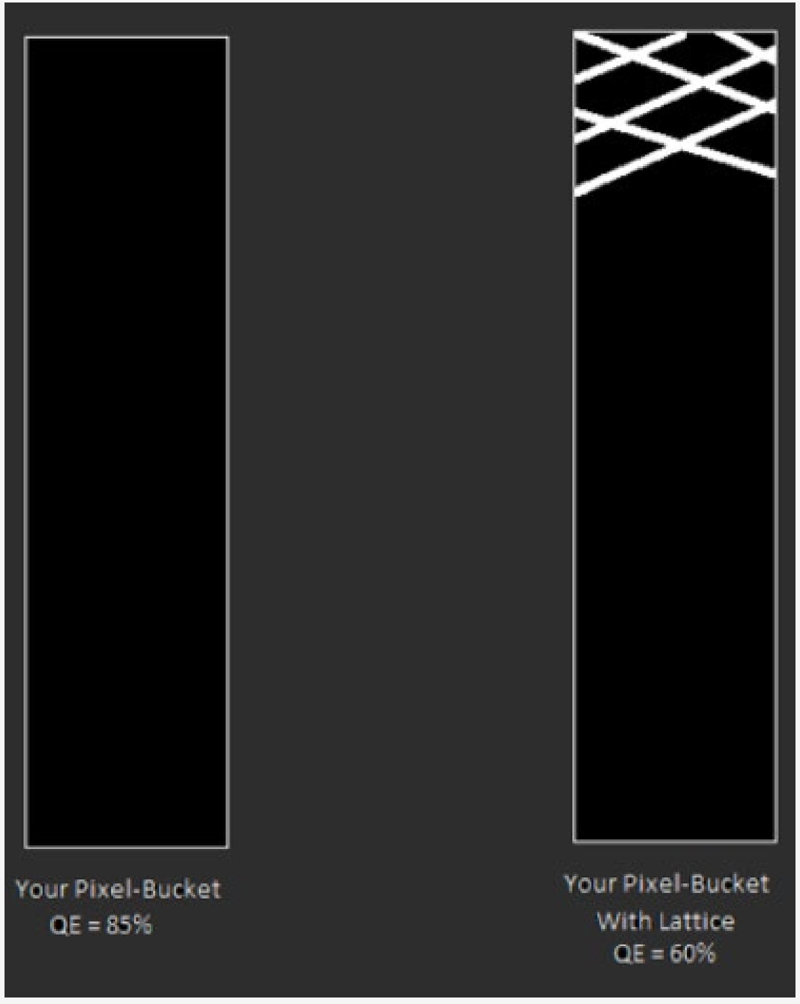


Figure 7: Quantum Efficiency Example
Image Credit: Jon Minnick, cloudbreakoptics.com

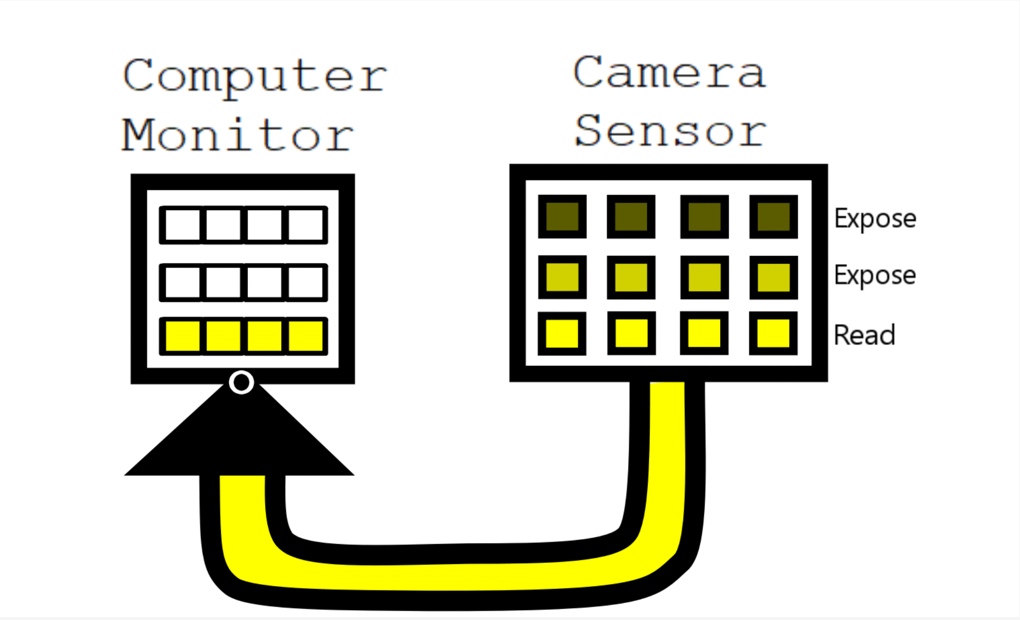
Scientific Complementary Metal Oxide Semiconductor

Scientific Complementary Metal Oxide Semiconductor (sCMOS) Sensors provide high frame rate imaging with a variety of imaging options to create a modular system valuable to a wide array of applications. sCMOS sensors operate with a Rolling Shutter, allowing high frame rate while maintaining low noise operation and high resolution images. More information on rolling shutter imaging can be found here.

Potential applications of a camera with a sCMOS sensor installed may include the following implementations.

- Orbital Debris Detection
- Occultations
- Solar Astronomy
- TEM
- Photometry
- Near Earth Object (NEO)
- Super Resolution Microscopy
- Wavefront Sensing
- Speckle Imaging
- Forensic Imaging
- Photocell Inspection

Animation



As displayed in the animation above, there are three states a row of pixels can be in: read, reset, expose. The exposure time of this example is the minimum. With longer exposure times, there are periods where all rows are exposing, known as Global Exposure.

The arrow and the "Computer Monitor" represent the flow of information during each read row process. during each read process, the entire rows data is sent to the PC for interpretation.

Pertinent Pro's and Con's

One can see that while every row is always actively preforming a function, each row begins exposure at a slightly different time. The severity of the timing variance is dependent on whether the camera is operating in HDR or LDR mode.

This lag between exposure starts only begins to cause problems when a subject is moving at very high speeds. This problem is discussed fully in Rolling Shutter. For this reason, very high speed subjects are often better captured with CCD Sensors.

Despite the problems endured with high speed subjects, sCMOS sensors are very efficient. Due to the constant progress in each row, time is not wasted as it is in CCD sensors. This results in faster readout and thus, a faster frame rate.

Available Products

As of September, 2018, The only sCMOS sensors Finger Lakes Instrumentation offers are the GPixel GSense 400, 2020, 4040, and 6060, all of which are only available in the Kepler family of cameras. The 400, 2020, and 6060 are available as Back Illuminated Sensors, benefits of which are discussed under Sensor Selection.

Rolling Shutter Overview

In a rolling shutter imager, the pixels in the array are always exposed to light unless physically blocked by a shutter mechanism.

A single row within the sensor consists of a three step sequence, as shown in **Figure 1**.

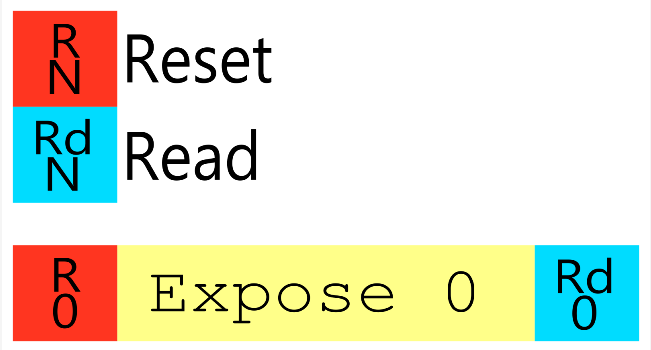


Figure 1. Single Row Sequence

Exposure causes charge to accumulate at each pixel in proportion to the incident light. The pixels' accumulated charge must be removed prior to exposure to assure the user-defined exposure start time and duration are met.

The accumulated charge is removed when a reset occurs (also referred to as a flush or a clear). Pixels are reset and read one row at a time, not individually or globally.

After requesting an image capture, the camera waits, if set for a delay time, then resets the first row of the image. Immediately following each rows reset, exposure begins for that row, for the requested length of time. When the exposure has completed, the camera issues a read command for that row.

Once the first rows exposure begins, the following row begins its process. The result is a staggering of the start of exposure for the rows in the array. This staggered reset and read timing is referred to as a “rolling shutter exposure,” or simply “rolling exposure,” as there is no associated physical shutter. The graphic below depicts this concept. (**Figure 2)**

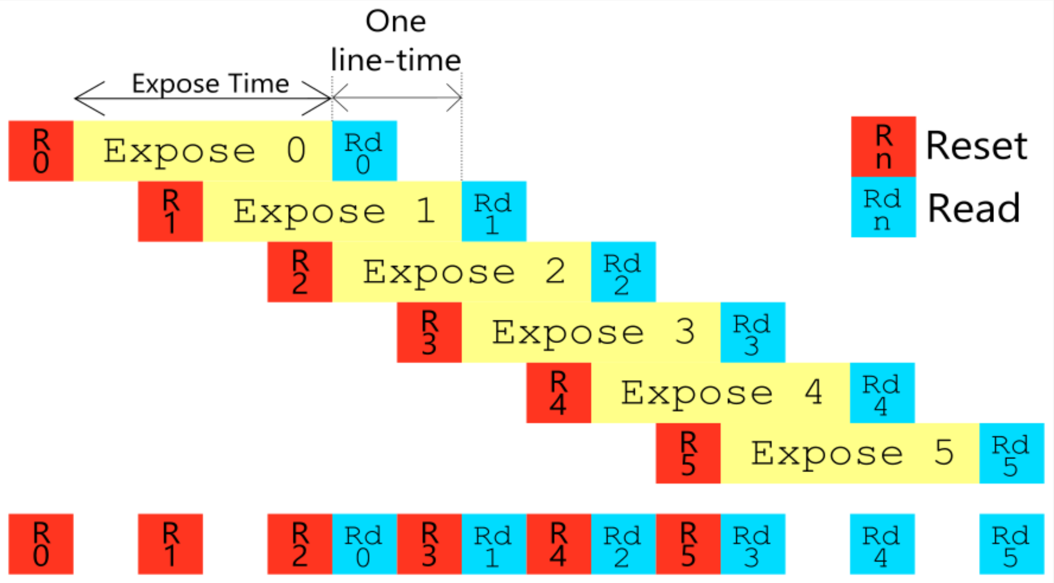


Figure 2. Rolling Shutter Sequence

Since the time between read commands is the same as the time between reset commands one is able to expose all rows of the imager for the same amount of time, however, the time of the exposure is shifted from the first row for each subsequent row. A more comprehensive depiction of the sensor’s activity is shown below with each row resetting, exposing and reading.

One line time consist of a read and reset. In LDR mode it is 10.26 usec and in HDR mode it is 20.52 usec. Thus, there is a time delay every 10.26 usec or 20.52 usec due to the overlap of the row sequences.

When the sensor is not actively collecting information from the rows, such as in an idle mode, the sensor continues its process of reading and resetting. However, it reads a "non-imaging row" for each row it resets. This process keeps the sensor ready to capture an image with minimal delay while not wasting resources collecting unwanted row data. This action is referred to as flushing.

An unfortunate consequence of rolling shutter photography is that is often fails to accurately capture objects moving quickly due to the difference in start time of each rows exposure. An effect may occur where the moving object may look oblong, or, in the case of this spinning colour wheel (**Figure 3**), the object may distort into odd patterns.

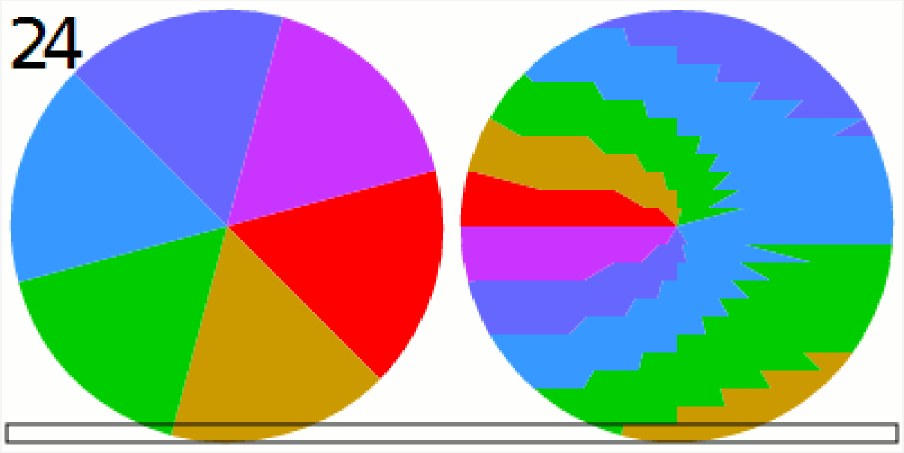


Figure 3: Rolling Shutter Color Wheel
Image Credit: Cmglee, wikimedia.org

This unfortunate sideaffect only appears when the object moves fast enough as to move a significant distance in the time it takes for the sensor to complete a single exposure-read-reset cycle. Results like this disc are uncommon, unless the object moves very quick like a propeller.

Charge Coupled Device Sensor

Charge Couple Device (CCD) sensors provide low-noise, high quality images. CCD sensors are capable of long duration exposures while effectively collecting a large portion of the available light. Alongside its ability to capture low noise images with long exposures, CCD sensors operate with a Global Shutter. A global shutter begins exposure of the whole sensor at the same time, preventing motion blur associated with rolling shutter imaging sensors.

Potential applications of a camera with a CCD sensor installed may include the following implementations.

- X-ray Applications
- Fluorescence
- Bioluminescence
- Chemiluminescence
- Solar Panel Inspection
- Gel Documentation
- Astronomical Imaging
- Digital Radiography
- Forensic Imaging

Animation

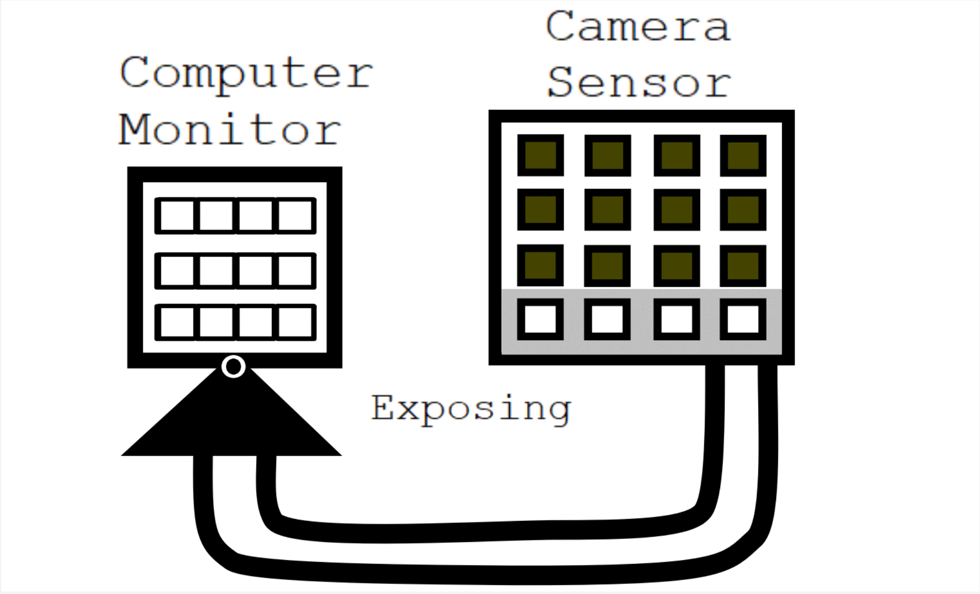


Figure 1: CCD Frame Cycle

Figure 1 shows an animation that displays a frame cycle of a CCD interline sensor. One should note that during readout, rows are read into a bus, then sent to the computer. Also note that each row begins exposure at the same time.

CCD Architecture

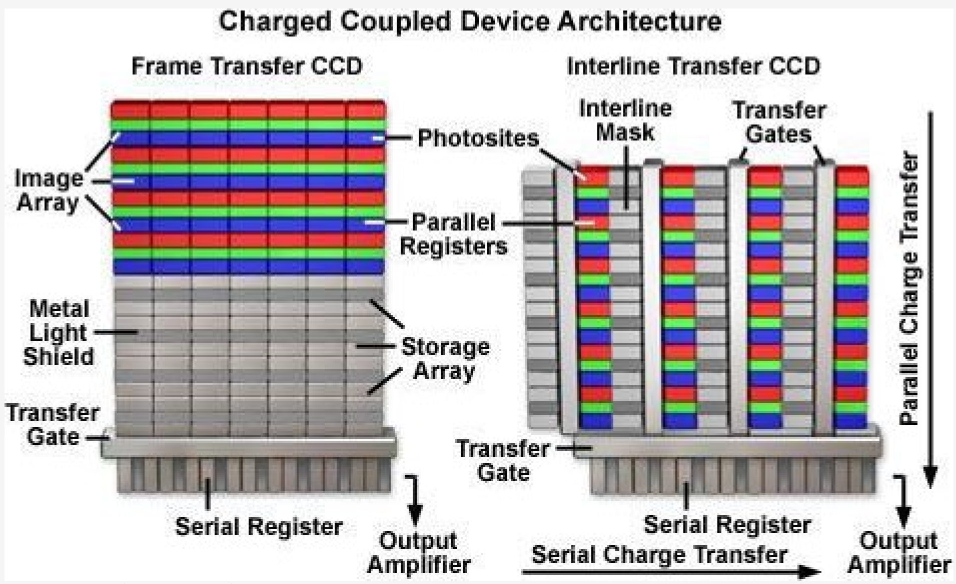


Figure 2: Charged Coupled Device Architecture
Image Credit: Olympus, Olympus-LifeScience.com

Interline CCD
Interline CCDs use part of each pixel to collect light, and part of each pixel to store and move charge. The storage area has a metal mask to prevent corruption of the image during readout. New CCDs have a microlens over each pixel to focus incoming light onto the photodiode portion of the pixel so that light is not lost landing on the metal masks. Because only part of the pixel is used to collect light, the full well capacity of interline CCDs is typically lower than comparably sized full frame pixels.

Interline transfer CCDs shutter the image by moving the charge from the photodiode to the storage diode side of the pixel. As a result, interline frame times can potentially be very short. For FLI cameras, interline frame times can be as low as 30 microseconds (as opposed to about 30 milliseconds for an electromechanical shutter). Usually interline CCDs are used without electromechanical shutters. However, it is complicated to take a dark image without a shutter unless you have some way of keeping the camera in a 100% dark environment.

Full Frame CCD
Full frame CCD's use 100% of each pixel to collect, store, and transfer charge. The readout procedure begins with each row flushed, then each row begins exposure simultaneously with the aid of a physical shutter. After the requested exposure time, the physical shutter closes and readout begins. Individual rows are shifted into the readout area, with each shift adding one row to the readout area and subtracting one row from the photosensitive area. As each row leaves the photosensitive area, its row is reset in preparation for the following image. Once every row is in the readout area, information begins to be transferred to the computer and a new image begins exposing.

Due to the operation of a full frame CCD, they require an electromechanical shutter unless the camera is going to be used in a 100% dark environment. Full frame devices typically have higher full well capacities and higher quantum efficiencies than interline sensors.

Pertinent Pro's and Con's

The primary benefit of CCD sensors is their ability to grab very low noise, long exposure images. The design of the sensor produces very little noise and with an effective use of the sensor area. Additionally, CCD sensors do not suffer from the row offset that CMOS sensors produce.

Unlike CMOS sensors, however, CCD sensors suffer from smear, a side effect of the readout procedure that produces bands of light in columns with extremely bright light. Additionally, full frame CCD sensors are a much larger profile, and interline transfer CCD's do not provide an option concerning back/front illumination.

Available Products

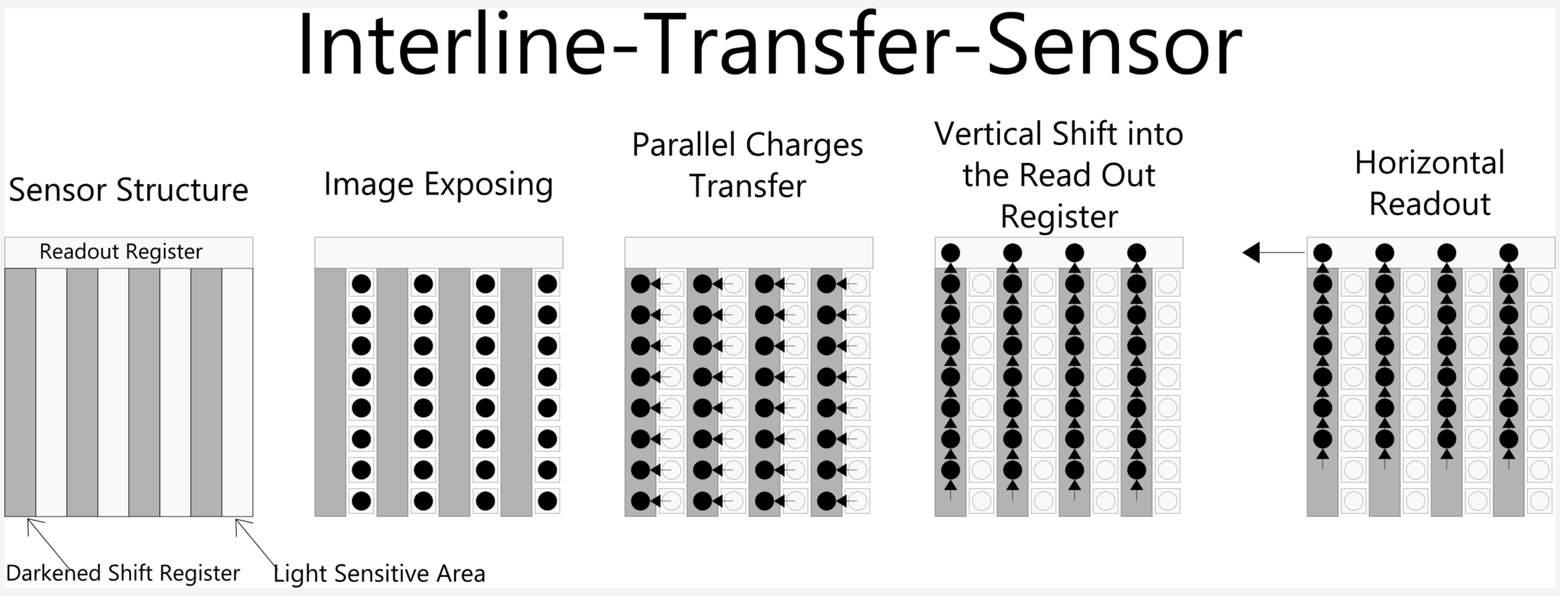
As of October, 2018, CCD sensors are provided by Finger Lakes Instrumentation in every family of cameras except the Kepler Family. The Hyperion, MicroLine, and ProLine families only use CCD sensors. The Kepler family contains no CCD sensor imagers.

There are too many CCD sensors to discuss individually. Refer to Sensor Selection to analyze what aspects are important for you. You can also contact FLI directly for more information of the selection.

Smear

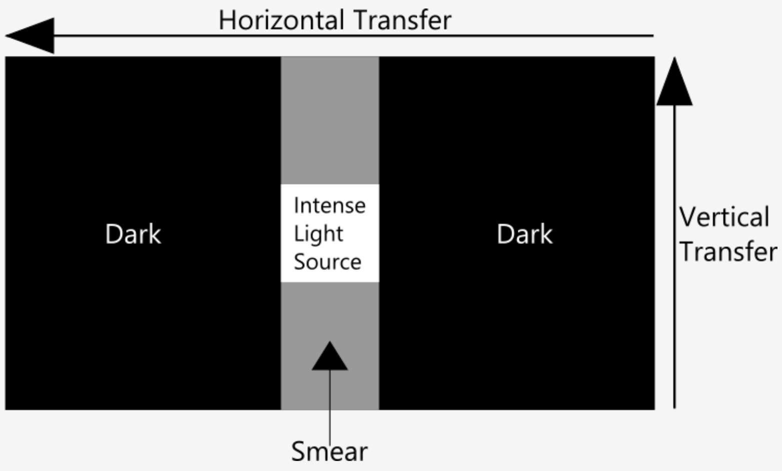
Interline Transfer Sensor

The sensor is divided into alternating vertical columns of light sensitive and light blocking areas. the light sensitive area is the image sensor where light is collected and transformed into charges. the light blocking area is the vertical shift register, where those charges are stored and shifted into the read out register. When the image sensor area recieves the requested duration of exposure, the charges are transfered to the vertical shift register directly beside the image sensor area. Once the charges enter the vertical shift register, the charges begin to shift vertically towards the read out register. The read out register reads the charges row by row until all the stored charges have been moved into the read out register and read.



Smear

Smear is an excess signal that becomes visible when an interline sensor is exposed to an intense light source during its readout period. Smear results from light leaking into the vertical shift registers as charges are being moved towards the readout register to be read out. As the charges move, light from intense sources can penetrate the vertical shift register, brightening the image above and below where the source should expose the image. This causes unattractive bands of brightness in the image.



Filter Wheels

Two families of filter wheels are sold by FLI. The Color Filter Wheel family offers 8 filter wheel options with various quantities of filters. The CenterLine Filter Wheel family offers a unique design, two filter wheels are used together to balance the system and reduce any unnecessary motion and destabilization.

FLI produces filter wheels for any of your imaging needs.

Kepler Image Time Stamp

The Kepler Image Time Stamp (KITS) is a product sold with the Kepler imaging system to provide precise time logs. the KITS can allow the Kepler imaging system to log exposure times extremely accurately because the duration is based of satellite feed rather than a local computer, which may have inaccuracies.

KITS reduces variability in time logging that may occur, and results in logging precision of +-1 microsecond.

Adnaco Fiber Optics

With the use of two Adnaco products, it is possible to completely electrically isolate your imager and your computer. An added benefit of which is the ability to use a fiber optic connection, which is capable of longer distances and higher speeds that USB 3.0.

System isolation is important when the camera is placed in an electrically unsafe place, such as high altitude observatories susceptible to lightning. The fiber optics connection protects computers operating the camera from electrical damage the camera may endure.

Camera Lenses

There are thousands of camera lenses for sale. Each lens has important characteristics such as f/number and focal length. As well as lens mounting and modularity, the choice of which lens is best is often quite complicated.

Fortunately, FLI has compiled the answers to many of the questions one may ask and explained important aspects in the hunt for a lens, here.

USB 3.0 Extension Cables

If you are in the market for a longer USB Cable, we have some third party products that might be right for you.

Liquid Cooling

FLI Cameras have the ability to be liquid cooled. Liquid cooling your camera will allow for lower temperatures to be reached and as a result noise in long exposure images decreases.

Focusers

FLI provides three options for focusers that provide a range of precision.

ASCOM

FLI offers the use of an ASCOM driver which will allow most FLI cameras to be controlled through a preferred interfaces such as Maxim DL in place of FLI Pilot.

PT1

PT1 is the designation for the power cable used with FLI cameras. Information regarding the cable and the power supply is found here.

Available Filter Wheels

CFW4-5 with a ProLine16803

Color Filter Wheel

Description:
The FLI Color Filter Wheel is designed with astrophotography in mind. Our traditional Color Filter Wheel line has six different body styles that hold either round of square filters in various sizes.. The Color Filter Wheel product number identifies the body type and the number of filter cups.

Documentation:
Color Filter Wheel User's Guide

Additional Information:
Color Filter Wheel

CenterLine Dual Color Filter Wheel

CenterLine Filter Wheel

Description:
The CenterLine Filter Wheel is designed with astrophotography in mind. Our filter wheels feature a centrally located aperture that presents a symmetrical mass distribution, eliminating the offset weight problems associated with virtually every other color filter wheel on the market. It is also ideal for prime focus installations where a zero or symmetric shading of the primary mirror is critical. The CenterLine Filter Wheel holds filters in two independently operated wheels. Mechanical attachment of the CenterLine Filter Wheel is realized through the robust Zero-Tilt Adapter™ mechanism, which is incorporated into both the housing and cover side of the filter wheel and operated using easily accessible set screws.

Documentation:
CenterLine Filter Wheel User's Guide

Additional Information:
CenterLine Filter Wheel

Color Filter Wheel

Mechanical Connection to Camera

The default front flange of FLI cameras is the FLI dovetail. This mates to the back of CFWs with a 2.93inch pocket in the Frame Connection column on the following chart:
Color Filter Wheel Specifications

As shown, the CFW9 and CFW10 filter wheels require the camera to have a special front flange with the mating bolt pattern.

Additional parts are sold by FLI, contact an FLI sales representative at IHSKeplerSupport@IdexCorp.com

Mechanical Connection to Telescope

Our adapters page includes several adapters, however, our customers often require a custom length to cooperate with their back focal distance. Custom adapters are available from preciseparts.com. The necessary numbers to calculate the back focal distance is in the following chart:
Color Filter Wheel Specifications

Filter Size

The most important aspect of color filter wheel selection is assuring the filter wheel uses filters that cooperate with your sensor. If the filter is too small, vignette will appear at certain f/ ratios. A chart of all sensor FLI currently handles is available here:
Sensors Supported in FLI Cameras

A sensors diagonal measurement is most important in this situation. We recommend selecting a filter wheel capable of handling filters with diameters greater than the sensor's diagonal, or, if the filter is square, select filters with horizontal and vertical measurements greater than that of the sensor. Filter wheel sizes and shapes are displayed on the following chart:
Color Filter Wheel Specifications

Another important aspect is the quantity of filters the filter wheel can handle. Depending on the model, between 5 and 20 filters can be stored. The number of filters a wheel stores is indicated by the final number in its model identification. Select a filter wheel with appropriate filter dimensions and quantity of filters.

Quick Setup

1. Install FLI Software Installation Kit (Includes FLI Filter).
2. Plug the power supply cable into the Color Filter Wheel.
3. Attach the USB cable between the Color Filter Wheel and your computer.
4. Plug the power supply cable into a wall socket or switched AC power strip.
5. Run FLI Filter to initialize the Color Filter Wheel and make control selections.

Complete Setup Procedure, including filter installation and homing procedure, is available in the online manual found here.

CenterLine Filter Wheel

CenterLine Filter Wheels are chosen because of its center aperature with balanced weight. This prevents destabilization when the filter wheel rotates.

Three general difficulties arise when a filter wheel is introduced to a system. These are discussed below, as well as information valuable to purchasing.

Mechanical Connection to Camera

CenterLine Filter Wheels require either a front flange with a CenterLine ZTA dovetail (so the filter wheel is flush to the camera), or an adapter that threads into the default FLI dovetail. The adapter adds approximately 8mm of offset.

Utilizing the adapter provides easy switching between the FLI dovetail flange and the CenterLine ZTA flange if it is desirable to do so.

Additional parts are sold by FLI, contact an FLI sales representative at IHSKeplerSupport@IdexCorp.com

Mechanical Connection to Telescope

Our adapters page includes several adapters, however, our customers often require a custom length to cooperate with their back focal distance. Custom adapters are available from preciseparts.com. The necessary numbers to calculate the back focal distance is in the following chart:
Color Filter Wheel Specifications

Filter Size

The most important aspect of color filter wheel selection is assuring the filter wheel uses filters that cooperate with your sensor. If the filter is too small, vignette will appear at certain f/ ratios. A chart of all sensor FLI currently handles is available here:
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Color Filter Wheel Specifications

Another important aspect is the quantity of filters the filter wheel can handle. Depending on the model, between 10 and 20 filters can be stored. However, due to the double carousel design of the CenterLine wheels, one position on each wheel is left empty. The number of filters a wheel stores is indicated by the final number in its model identification, minus two. For example, the CL-1-10 has 10 empty positions, 8 of which are usable.

Select a filter wheel with appropriate filter dimensions and quantity of filters.

Quick Setup

1. Install FLI Software Installation Kit (Includes FLI Filter).
2. Plug the power supply cable into the CenterLine Filter Wheel.
3. Attach the USB cable between the CenterLine Filter Wheel and your computer.
4. Plug the power supply cable into a wall socket or switched AC power strip.
5. Run FLI Filter to initialize the CenterLine Filter Wheel and make control selections.

Complete Setup Procedure, including filter installation and homing procedure, is available in the online manual found here.

FLI Fiber Optics

There are two ways to implement an optical connection between the camera and the computer.

FLI offers support for the Adnaco R1USB30B, which converts the USB 3 port on the rear of the FLI Camera to an optical signal which is then read out through a Adnaco PCIe that needs to be installed in the users PC.

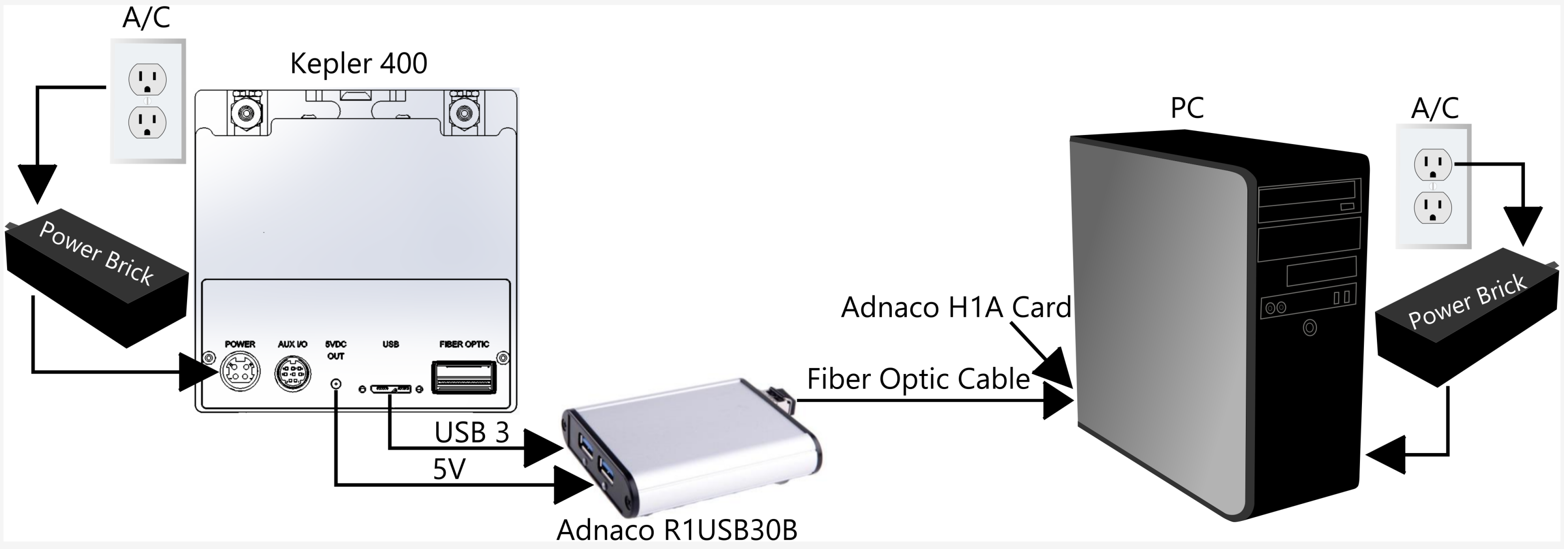
In Kepler cameras, FLI recommends using the fiber optic port on the rear in unison to an FLI PCIe card to connect the device via QSFP optical cable. This process is documented at QSFP Connection.

FLI Fiber Optics with Adnaco

FLI offers options to utilize fiber optics to transmit information from computer to camera and from camera to computer. The primary benefit of fiber optics is the significantly extended range compared to USB 3. USB 3 is limited to 3 meters of cable before the cable will fail to successfully transfer data. Fiber optics, on the other hand, can reach over 100 meters without issue.

A secondary, and equally important benefit of fiber optics is that fiber optics does not conduct electricity. With a fiber optical connection, there is protection from a power surge in one location damaging a second location. This is a very beneficial feature for situations where the camera is located off site from the operating computer. If, for example, a lightning strike occurs and damages the camera, the surge of electricity from the lightning would not have a path to the operating camera. Thus, this type of connection can add a secondary layer of protection to important equipment.

Below is a drawing to represent how the fiber optics protects and extends the connection. The camera and the computer can be on completely separate electrical circuits and the use of non-conductive fiber optics cable provides complete electrical isolation. The system below utilizes the Adnaco fiber optics connection.



There are two necessary products for the setup above to operate: the Adnaco R1USB30B, and the Adnaco H1A Card. The R1 is an external device that accepts USB 3 input and outputs a fiber optic signal. The H1A is a PCIe card that must be installed into ones PC. Instructions on operation and setup for these products are available via Adnaco documentation. Visit Adnaco.com for more information.

Beyond product setup and installation on the computer, the FLI camera will operate with the computer exactly as it had prior to the injection of the Adnaco products.

QSFP Fiber Optic Connection

FLI offers the ability to connect a FLI camera to a desktop computer via a fiber optic connection. The fiber optic connection on the rear of each FLI camera has the ability to connect to the FLI PCIe fiber optic card.


Fiber Optic Port on the Rear of a Kepler Camera

The use of this PCIe card in the users computer replaces the need for a USB 3 connection, allowing for significantly longer connections, and a faster response time. With many cameras, there will be impressive FPS gains when using a fiber optic connection due to the removal of the bottleneck of data through USB 3.

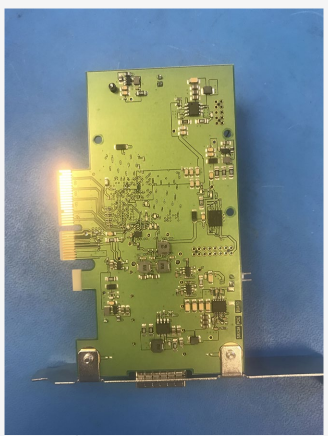
This setup requires M.2 memory because of the significant amount of data being transferred. Typical SSD memory with a SATA connection does not provide the required bandwidth to use the QSFP connection to the full extent of its ability. If a M.2 connection is not included on the motherboard of the computer, a PCIe to M.2 adapter card is required. Additionally, this will use a second PCIe port.

Minimum Requirements

Windows 10 x86 or x64
FLI Pilot v1.2.19 or later
7th gen i7 Core CPU
Motherboard with either {1 M.2 port and 1 PCIe port} or {2 PCIe ports}
1 PCIe to M.2 adapter (only required if the motherboard does not have an M.2 port)
250GB M.2 memory
FLI QSFP PCIe board
QSFP fiber optic cable or copper QSFP cable (for testing)
32GB of DDR3 or DDR4 RAM


Optional PCIe to M.2 Adapter


Optional Copper QSFP Cable


FLI PCIe board

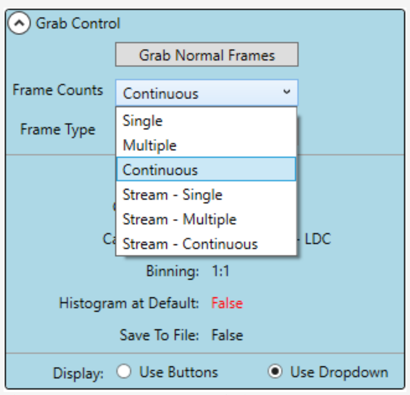
Setup

1. Install the required products to have the FLI PCIe board and M.2 memory installed.
2. Install FLI Pilot onto the computer.
3. Run a QSFP cable from the computer to the Fiber Optic port on the rear of the Kepler camera.
4. Launch FLI Pilot and confirm that a connection is made and everything is operational.

Operation

With the QSFP connection, there will be a noticeable increase in frame rate when taking multiple of continuous grabs. Additionally, three new options under **Frame Count** in the Grab Control Panel will be available: **Stream - Single**, **Stream - Multiple**, and **Stream - Continuous**. These additional modes direct FLI to dump all incoming image data directly to disk, bypassing the traditional path through software where the image type is converted, and the image is displayed in pilot prior to saving. Capturing images as a stream increases the rate of frame capture dramatically, at the disadvantage of not being able to see the images displayed as they are captured in FLI.

A stream will not capture if a file path is not defined under Stream in the Imaging Parameters panel. The file path defined under **File** will not affect where files are saved when a stream mode is being used.


Grab Control
Grab Normal Frames
Frame Counts: Continuous
Single
Multiple
Continuous
Stream - Single
Stream - Multiple
Stream - Continuous
Frame Type
Binning: 1:1
Histogram at Default: False
Save To File: False
Display: ○ Use Buttons ● Use Dropdown

Grab Menu with a QSFP Connection

Troubleshooting

In the case where the computer does not recognize the M.2 SSD, soft reboot the computer by clicking **Restart** under **Power** in the Windows 10 taskbar. If this does not resolve the problem, check the M.2 SSD's included documentation for any specific information regarding its installation and operation.

Lens Selection

An important aspect of lens selection is the intended use. Low light situations require large aperture lenses, while day time or well illuminated scenes do not require large aperture. In these conditions it is more likely to use smaller apertures than the maximum size.

For astrophotography, it is important to get a lens that supports a quite large aperture. This quality can be noted by a reported f-ratio around or below f/2. So, the closer to f/1 a lens can operate, the more light and more information can be recorded.

A lens' ability to magnify is significant to an image as well. Prime lenses lack dynamic magnification, however the image is often better than dynamic zoom lenses due to the internal mechanisms of the dynamic lens reducing the possible light capture.

Some lenses, such as fisheye, will increase the field of view of the lens, at the cost of distortion in the image.

It is also important to locate a lens that works with the sensor you need. If the lens is meant for sensors smaller than the sensor its used with, vignette will appear because the lens can't fill the sensor's area.

The best advice for lenses is to research what other members of your community use for the use you intend. Try lenses, if possible, and understand what qualities are important to you, such as autofocus, fixed-focus, telephoto, fisheye, or macro lenses.

There exists a large range of lenses with many possibilities. Chose a lens that works best for your needs and your sensor needs, then focus on connecting it to your camera. The following sections discusses FLI supported mounts, with which you can connect most modern lenses on the market.

F Mount

F Mount is the mount type on Kepler cameras. F Mount describes the mounting mechanism used to attach the lens to the camera. The lenses come in a wide variety, so the correct lens for any use should be available.

C Mount

Merely to say that a lens is "C-mount" says very little about the lens' intended use. C-mount lenses have been made for many different formats.

C-mount is a system heavily used in the photograph industry, and thus, its applications spread a very wide span. Lens types from macro to telephoto are applicable, with a large range of apertures, focal lengths, and options. The ability to use lenses with mounts beyond what is seen here can come through c-mount connectors, as the range of use C-mount gets has introduced interest in making it even more universal.

50mm

50mm lenses refers to the focal length of the device. The focal length influences the field of view of the images captured inversely. Thus, the 50mm lenses will produce a narrower field of view than the 35mm. With a 50mm focal length, these lenses are capable of producing images with a field of view very similar to the human eye.

50mm lenses are prime lenses, meaning they have a roughly fixed focal length. Most lenses will have a small range for focusing the image properly, but often not more than +-3mm.

35mm

35 mm lens refers to the focal length of the device. The focal length influences the field of view of the images captured inversely. Thus, the 35mm lenses will produce a wider field of view than the 50mm.

The 35mm lens is also a prime lens, meaning the focal length is only adjustable in small increments to correct focus. The benefit of this is that the image quality is significantly higher than in adjustable focus lenses because the design is simple and doesn't block light with unnecessary parts.

4/3

Four Thirds was an initiative by multiple optics companies in the early 2000's to produce universally cooperating products. With this, came a large selection of Four Thirds cameras and lenses. The lenses are similar to c-mount in that Four Thirds doesn't really describe anything specific about the lens. Four Thirds lenses are available in as many different optical configurations as exist, including macro, telephoto, fisheye and prime.

The Four Thirds lens mount is specified to be a bayonet type with a flange focal distance of 38.67 mm.

The important quality of Four Thirds lenses is that they are first and foremost designed for operation with Four Thirds systems. Particularly, this means that the lenses maximum sensor dimensions are 4/3" with a 4:3 aspect ratio. A Four Thirds lens will not work properly on a full frame sensor, or any sensor larger than 4/3".

Micro 4/3

Micro Four Thirds (MFT) refers to the brand name for this family of lens. "Four thirds" also refers to the sensor format the lens is designed for (4/3" with a 4:3 aspect ratio).

MFT shares the original image sensor size and specification with the Four Thirds system, designed for DSLRs. Unlike Four Thirds, the MFT system design specification does not provide space for a mirror box and a pentaprism, which facilitates smaller body designs and a shorter flange focal distance, and hence smaller lenses. The MFT system design specifies a bayonet type lens mount with a flange focal distance of 19.25 mm.

Micro 4/3 cameras can still use older Four Thirds lenses, but an adapter is needed to extend the length from rear element to the sensor.

Like Four Thirds and C-mount, Micro Four Thirds is title for the adapter which is used. No specification of the lens type is defined by its name. Zoom, fixed focal, macro, fisheye, prime, 3D and pinhole lens varieties are produced.

Kepler Image Time Stamp (KITS)

Kepler systems allow the use of the Kepler Image Time Stamp (KITS) device, which is capable of very precise timing information, as well as positional information. KITS is a 32-channel receiver that yields 10 Hz update rates. When enabled, this option provides accurate timing, longitude, and latitude information by using GPS and GLONASS satellite data.

With the addition of KITS, a Kepler camera will report timestamps with an accuracy of 1.5 microseconds*. Comparatively, a Kepler camera with only a connection to a computer may have an accuracy of 1 millisecond.
*Note: The Kepler Imager needs 4.5 minutes upon initial satellite connection to achieve this level of accuracy. See **Timing** below for more information.

The KITS is connected to the Kepler system via pin 1, pin 4, pin 6, and pin 7. Pin 1 operates as a 12V power supply for the KITS module. Pins 4 and 7 operate a UART connection, where pin 4 is the RX, and pin 7 is the TX. Pin 6 is ground, and connects into the cameras ground. The maximum cable length that connects the KITS to the Kepler camera is 30 feet (9.1 meters). Custom cables can be ordered through FLI to adhere to any length requirements less than 30 feet.

The Kepler Image Time Stamp specifications are available here.

Operation

To enable KITS, just plug the KITS connector into the auxiliary port of your Kepler Camera. There is a delayed connection of up to two minutes. Once the KITS is connected and operational, a small green lock symbol will activate in the lower right hand corner of Pilot (**Figure 1**), if it has not yet connected, it will show a small red unlocked symbol (**Figure 1**). Please note that the KITS device must be in visual contact of the sky and the GPS satellites for successful connection.

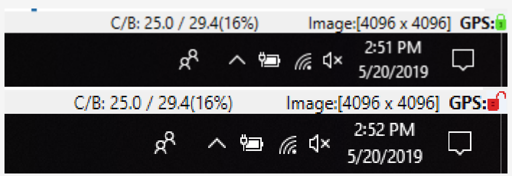


Figure 1: Locked GPS Signal (Top) and Unlocked GPS Signal (Bottom)

The KITS timestamp is updated via a signal from the Garmin head, once every second. Upon loss of this signal, the camera's internal clock will generate timestamps until its accuracy is less than that of a computer's clock. The camera clock will maintain significant accuracy for 50 seconds. Then, the computer will begin generating timestamps. This allows for the metadata accuracy to stay consistent upon brief losses of GPS signal.

FLI Pilot monitors the connection status of the camera using FPROCtrl_GetGPSState, which is documented in Time Stamp Metadata. The result of this function will define whether the GPS unit is disconnected, locked, or unlocked.

FPROCtrl_GetGPSState will return 0 if there is no detected GPS unit.
It will return 1 if a GPS unit is detected but there is no satellite connection.
And it will return 2 if a GPS unit is detected and there is a satellite connection.

Timing

The KITS device is designed to accurately log the beginning of exposure with an accuracy of 1.5 microseconds. Upon connection to a GPS signal, the camera will need 4.5 minutes to fully synchronize and begin reporting time with 1.5 microsecond accuracy. During the initial 4.5 minutes, the timestamps can only be accurate to 26 microseconds.

When a camera does not have a KITS connection, its time information must come from the connected computer. A computer connected to the internet with "Set Time Automatically" enabled can achieve 1 millisecond of accuracy under typical conditions; however, the timestamp can only be as accurate as the computer. Additionally, if the computer's time is set manually, it should not be assumed that it is accurate to any degree.

There are two operational states in which timestamps are associated with an image. When KITS is connected and operational, the metadata timestamp is assigned at the beginning of the image exposure. In any other case, the metadata timestamp is assigned at the end of the image exposure.

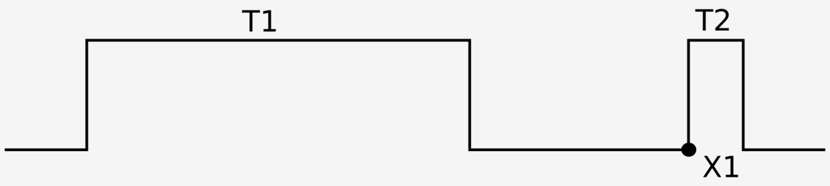


Figure 2: Timing when KITS is not used

Figure 2 displays a timing diagram in the case that KITS is not responsible for the metadata timestamp. **T1** is the time required for an image to expose and **T2** is the time required for the image to be processed and saved by the computer. **X1** is the point at which the timestamp reports, which is the point in time at which the computer first receives image data from the camera.
It is important to note that when KITS is not in use, the time at which an image is timestamped will be the time at which the computer receives image data.

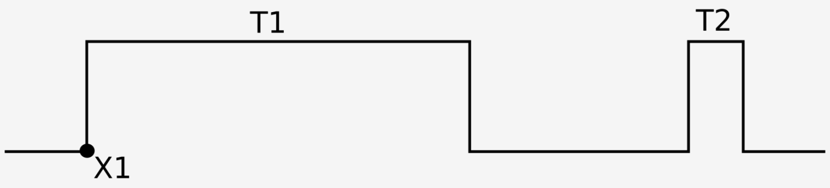


Figure 3: Timing when KITS is used

Figure 3 represents a situation where KITS is enabled and operational. **T1** is the time of exposure and **T2** is the time of image processing on the users computer. **X1** is the beginning of exposure for an image, and is the time at which the timestamp for that image will report.
It is important to note that when KITS is enabled, the time at which an image is timestamped will be the time at which that image began exposing.

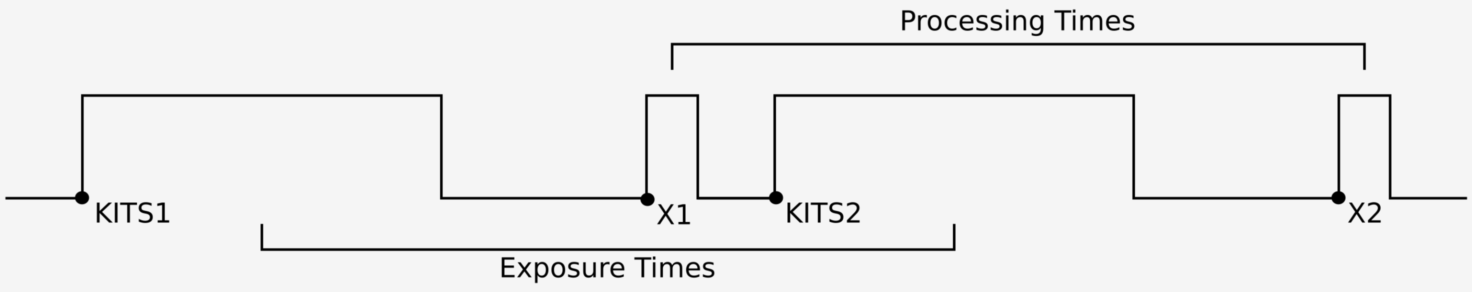


Figure 4: Timing for two image captures

Figure 4 shows the timing diagram of two images being taken back to back. The rises marked **Exposure Times** represent the duration of the defined exposure time for the first and second image. The rises marked **Processing Times** represent the duration required for the computer to process each image.
When KITS is disabled, the points in time marked **X1** and **X2** show the points in time that would be saved as the image timestamp.
When KITS is enabled, the points in time marked **KITS1** and **KITS2** show the points in time that would be saved as the image timestamp.
When the KITS unit fails to connect and the 50 second buffer concludes, the point at which a timestamp is assigned shifts. With respect to **Figure 4**, this shift is from **KITS1** and **KITS2** to **X1** and **X2**. During this transition, a pair of images will have an image to image time of **KITS1** to **X2**. This will cause the time between two frames to appear to double.

Focuser

Finger Lakes Instrumentation offers three focusers for use with our imaging systems. These focusers are designed to operate with FLI cameras to precisely focus an image.

The three focusers we offer are the DF-2, PDF, and Atlas. The DF-2 is a small digital focuser. The PDF is a digital focuser with a large aperture with support for high resolution imaging. The Atlas focuser is designed for a critical focus with heavy loads.

FLI's website pertaining to the focuser systems can be found here.

A well detailed users guide for the Focusers we offer can be found here.

A data sheet for the Atlas focuser can be found here.

Below is a specifications table pertaining to the DF-2, PDF, and Atlas focusers.

Focuser Specification	DF-2	PDF	Atlas
Minimum Travel	0.20"	0.35"	0.35"
Dimensions	5.0" x 6.5"	8.0" diameter	7.0" x 7.0"
Thickness in Closed Position (Factory Set)	1.05"	1.05"	1.26"
Weight	1.6lbs	2.4lbs	3.0lbs
PC Interface	USB	USB	USB
Telescope Side Threads	2.005"-24 UNS-2B	3.750"24 UNS-2B	*
Number of Steps	2,000	7,000	105,000
Resolution per Step	2.5 micron	1.25 micron	0.083 micron
Clear Aperature	50 mm	89 mm	89 mm

*The Atlas is not threaded. use a Zero Tilt Adapter™ to interface with a telescope.

USB Extension Cables

If you are in need of a USB Extension Cable please see the products listed below. There are traditional copper USB cables for shorter runs as well as some fiber optic systems for longer requirements. Please see below for which cables have been tested for compatibility with our camera system.

Copper USB Extension

Manufacturer: StarTech
  Length: 3m (not tested)
  PN: USB3AAEXT3M
  Link: StarTech.com

  Length: 5m (TESTED)
  PN: USB3AAEXT5M
  Link: StarTech.com

  Length: 10m (TESTED)
  PN: USB3AAEXT10M
  Link: StarTech.com

Fiber Optic USB Extension

Manufacturer: Corning
  Length: 10m (not tested)
  PN: AOC-ACS2CVA010M20
  Link: Amazon.com

  Length: 15m (not tested)
  PN: AOC-ACS2CVA015M20
  Link: Amazon.com

  Length: 30m (TESTED)
  PN: AOC-ACS2CVA030M20
  Link: Amazon.com

  Length: 50m (not tested)
  PN: AOC-ACS2CVA050M20
  Link: Amazon.com

Fiber Optic USB 3.0 Hub Extension
Requirements:
Win 10
1 - PCIE slot on Motherboard

Manufacturer: Adnacom
  Length: 1m (not tested)

  Length: 10m (TESTED)

  Length: 25m (not tested)

  Length: 50m (not tested)

  Length: 100m (not tested)

Liquid Cooling

As a standard, all FLI cameras incorporate a TEC (Peltier) that enables the camera to cool the sensor. The actual cooling for any given camera will depend on the sensor size and ambient temperatures. The Kepler Liquid Cooler can accept a flow rates up to 0.5 gallon/minute (1.91 liter/min). Please contact FLI with your custom cooling requirements for either air, liquid, or un-cooled system. For other families of cameras, check their specific manual.

With liquid cooling, a Kepler cameras sensor temperature can drop an additional 10*C. A liquid cooled camera can achieve a maximum change in temperature of 40*C.

The liquid can be cooled to ambient, but not lower, without potentially damaging the camera.

It is advised to use either antibacterial tubing, or antibacterial liquid, however using both in the same system is not recommended.

Note: Maximum Kepler Liquid Cooler inlet pressure is 50 psig. Ensure tubing selected has the proper pressure rating. To avoid undesired pressure build up in Liquid Cooler shut off flow on the inlet side before detaching or closing outlet connections.

Warning: Using flow rates above the recommended flow rates may cause the liquid cooling system to leak and will void the warranty.

The following connection fittings are currently available:

Connector	Standard User Interface	Additional Information
1/8" ID Hose Barb	1/8" ID Tubing	FLI recommends use of hose clamps. User supplies tubing and clamps with appropriate pressure rating for their application.
Quick Connect Double Shutoff	1/8" ID Tubing	FLI supplies both female and male connectors. User supplies the interface.
Quick Connect Dry Break	1/8" ID Tubing	FLI supplies both female and male connectors. User supplies the interface.
Custom	Per Customer Requirements	FLI is able to plumb to interfaces not listed. Please contact FLI with your connection requests.

ASCOM Documentation

For users that have a preferred control interface, like Maxim DL, for their camera operations, FLI offers the ASCOM driver, which will allow many of the common interfacing programs to communicate with FLI cameras. Full documentation regarding the installation and use of ASCOM can be accessed through flicamera.com under support, or through the following link: ASCOM Documentation

The latest stable ASCOM drivers are available through flicamera.com under support.

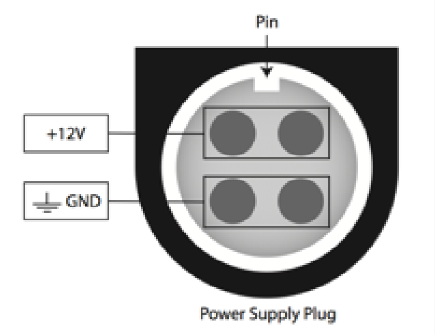
Four Conductor Power Cable (PT1)

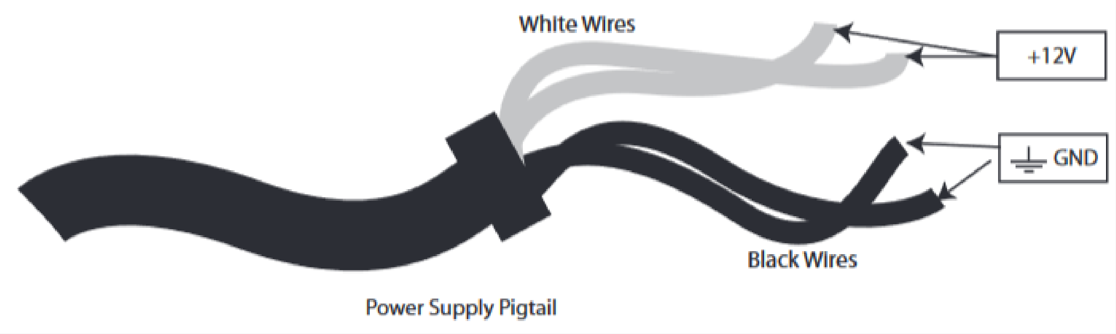
It is strongly discouraged by FLI to modify the power cables, or use third party power supplies. Any damage done to the camera as result of third party power supplies or tampering with the power supply unit will not be covered under warranty. The following information is for informational use only.

FLI cameras' power connector is a four conductor cable which provides 12V power to the system. The shield of the 4-Pin Jack Socket (KPJX-4 at www.mouser.com) is connected to ground. The PT1 cable is shown below.

The FLI power supply outputs 12V at 10A from an input of 100-240V AC at 2.0-1.0A at 50-60Hz.

⚠ **WARNING: If the polarity of the power connection is reversed it can cause damage to the camera. This damage will not be covered by the FLI product warranty. Verify the polarity of the voltage using a meter before attaching a power cable to the camera. Also verify the chosen system has the same current capability.**





Troubleshooting

The following are problems and steps that may fix them. We ask that if you are experiencing a problem listed below that you follow these steps first. If that does not eliminate your error please follow the instructions on the Reporting Issues page.

Issue	Remedy
The fan on the camera does not turn.	Check that the camera is plugged into a suitable power supply and that power is available.
The fan turns but when I use FLIPilot, the camera does not work or works erratically.	Make certain that all cables are well seated and are not stretched.
FLIPilot runs, the camera fan turns but FLIPilot cannot locate the camera.	Turn off your computer and camera and leave them switched off for two to three minutes, this will flash the USB chips. Try again.
I get a Windows “Communication” error.	Turn off your computer and camera and leave them switched off for two to three minutes, this will flash the USB chips. Try again.
Everything is connected and FLIPilot has been installed but the software cannot locate the camera.	Make certain that you have installed the software and drivers as described in this documentation. Letting Windows locate the camera during installation is likely to create problems.
I captured an image but the image appears as a flat black or white frame.	You are over exposing or under exposing. Check the settings in the FLIPilot.
While running stacked, multiple, or continuous frame capture, The GPU utilization rises significantly (visible on the Task Manager in Windows), and FLI Pilot crashes after several frames are captured.	There is likely a compatibility problem with the internal GPU. If your computer has both an internal GPU and a dedicated GPU, instruct the computer to use the dedicated GPU. This procedure is documented here.
As exposure time increases, the image becomes darker.	This is due to the process that maps image data to pixel values. As the image exposure increases, the range of the pixel data increases. Thus, images with wide ranges displaying darker because less of the data gets mapped to bright pixel values. If you wish to view images with the mapping more constant, change **Brightest / Dimmest Data Threshold** in **Histogram Settings** to 0.
While running a Kepler camera in continuous mode, only a very low frame rate (approximately 1fps) can be achieved.	The transfer rate of USB 3.0 is required for the high volume of data being transferred from the camera to the computer. Be sure that a USB 3.0 (or better) cable is in use, and plugged into a SuperSpeed USB port.

Power Cycling

When the camera is turned off, one must be certain it has remained off for at least 10 seconds before turning it back on to avoid errors in operation.

Image Defect

Please note that certain sensors have inherent defects that are a result of the manufacturing process. These row and column defects tend to show up as a single row or column that does not output realistic pixel values, ie a line in the image. Incorrect image defects may be random length horizontal lines scattered about the image, 1/8th or more of the image missing, or a completely random distribution of pixel values where there should be order.

In the event of an image defect please do the following.
1) Run Force Training. Retake image, was the problem solved? If yes, then you have a slight imbalance in the timing sequence of your camera at the current operating condition. If the problem reappears in the future please rerun Force Training.
2) Is the image defect in every image? If the image defect is only in the Merged image but does not exist in the High or Low image, then you may have an issue with your Merge Settings.
3) If the image defect was only in the High or Low image please change the gain setting for that image or change the Mode you are operating in. If the defect goes away switch back to the previous mode/gain. Without changing any other settings take an image, if the image does not reappear then it may be a setting you changed. Changing the mode resets some settings back to their factory defaults.
4) If the defect did not go away in step 3, please note what temperature you are currently operating the camera at. If you are operating it warm, please cool the camera off. If you are operating the camera cold, please warm it up. As the temperature changes, perhaps every 5 deg or so take an image. Does the defect go away at any point?
5) If you were not using Pilot up until this point, please rerun the above tests using Pilot. This will help eliminate a software issue. If Pilot does not show the defect under the same operating conditions/settings please contact us.
6) What is the physical conditions your camera is operating in? While our sensors are designed to operate at below freezing temperatures, our cameras are not. If your camera is in an extreme environment, please run a test of the camera once it comes closer to standard indoor temperatures. If the defect goes away you are trying to operate the camera too far outside of its design window.
7) If at this point you still have your defect or if you need further guidance please see the Reporting Issues page.

Frequently Asked Questions

What are the major differences between using FLIPilot with CCD and CMOS cameras?

- Grab modes. Flood and RBI Flush do not apply to CMOS cameras. Flood and RBI flush are solutions to CCD ghosting issues.

- Hardware binning. Binning for CCD Interline and Full frame sensors can be in odd combinations such as 1x2, 1x3, 3x1, etc. Binning is available in CMOS only as squares such as 2x2. The sensor in the KL400 does not support hardware binning.

- Background Flush. The default status is Background flush = on. For CCDs flush can be turned off. For CMOS sensors, flush cannot be turned off: it is always on.

- Pixel Depth is not available with KL400.

How can I Increase the imaging frame rate?

- Reduce the size of the image. This can be from a single reduced ROI selection, or from selecting multiple vertical image bands that are wanted, allowing unwanted vertical rows to be skipped.

- Use LDR mode as it nearly halves the duration of a line read compared to HDR mode.

- Use High Frame Rate Settings. By increasing the number of rows to skip, the overall time spent reading is decreased, thus increasing frame rate.

- Not for KL400: Reduce the camera's resolution by binning or by changing the pixel depth format. This lower resolution maintains the field of view while speeding up download time; a useful feature when centering objects. Make changes to the binning and pixel depth parameters from the Imaging Parameters/Sensor tab.

How can I increase download time?

- For models that support hardware binning (excludes KL400): Reduce the camera's resolution by binning or by changing the pixel depth format. This lower resolution maintains the field of view while speeding up download time; a useful feature when centering objects. Make changes to the binning and pixel depth parameters from the Imaging Parameters/Sensor tab. Download time can be increased as indicated above for achieving higher frame rates.

- Under some circumstances, the data rate achievable on USB 3 can be a limiting factor. If this is the case, then changing to optical fiber can reduce download time and increase frame rate. Also be sure that both the cable and the port on your computer are SuperSpeed compatible.

Reporting an Issue

Before reporting an issue, please see if our troubleshooting guide may be able to help. If you are still stuck please send us an email at IHSKeplerSupport@IdexCorp.com.

In order to best help you solve your problem please include the following information. As a general rule of thumb the more information you can provide us about the issue you are having the quicker we can determine the root cause and get you back in operation.

What camera model do you have?
What is the serial number of the Camera?
What programs are you running when the issue occurs? Pilot or ASCOM? If you are using ASCOM what third party software are you using as an interface?
What versions of software are you using? In pilot these can be found under Help-About. With the camera connected, there should be 4 software versions listed, please include all 4. In ASCOM please provide the ASCOM drivers version number.
Please provide a description of the issue you are having. If it is a new issue, please provide details about possible changes that may have occurred leading to this error. What mode are you in, what gain settings are you using, etc.
If you are encountering an image issue/defect. Please provide a .raw file of both the high and low gain image (hdr) single image (ldr). If you would like to provide screenshots in addition to (not a replacement of) the .raw file to help explain the issue please do so.
If there is any other information you believe might be relevant to the issue please include that as well.

Finger Lakes Custom Software Guide

We understand that some users may wish to either create a custom program or integrate our camera command structure into an existing program to allow it to operate FLI Cameras. We encourage this and will try and support those questions you may have. If you are interested in custom programming, please email us about access to our Software SDK package. The SDK package provides examples of how to interact with the camera.

In addition to the SDK package we also detail FAQ in the section below. The following contain basic answers to how we accomplish certain tasks in Pilot.

Programming FAQ

Metadata Time Stamp

Metadata Time Stamp

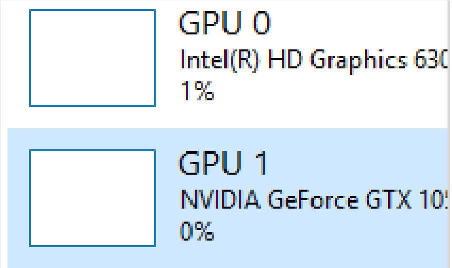
Frequently Asked Questions

Question:
How is the timestamp in the metadata assigned?

Answer:
Every 5 seconds, when we are not exposing, we call FPROCtrl_GetGPSState to see if there is a GPS unit attached and if so, what is its state. This function can return 0 – Not Detected, 1 – Detected but not Locked, 2 – Detected and Locked. When it is not detected (0) or detected and not locked (1), the metadata on every image will have a Capture Date earlier than 2018. When Pilot sees that this is the case we take the computer time and insert it back into the metadata. The Latitude and Longitude will also be 0. However, if the GPS is Detected and Locked (2), then the metadata is populated with the date and time stamp passed from the GPS.

Configuring the Preferred GPU

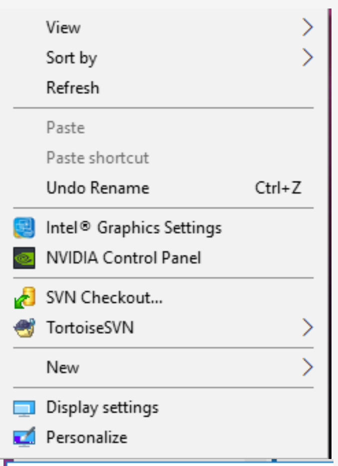
In a computer system that contains multiple GPU's, meaning an integrated GPU in the CPU and a dedicated GPU like NVIDIA, you have the option to select a preferred GPU to be used. In rare instances, FLI Pilot may have issues with some integrated GPU's, where the GPU utilization will jump to 100% then Pilot will crash. One way to tell if your computer has two GPUs is to open the Task Manager (ctrl + alt + del) and navigate to the Performance tab. If you scroll to the bottom of the Performace list you should see your GPUs listed, please see the figure below for an example.



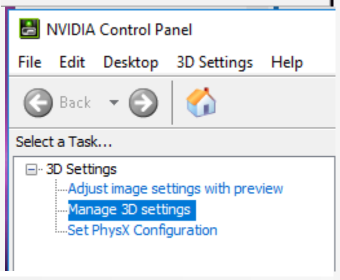
To check if the problem you are having can be corrected with this technique, monitor the GPU utilization with the Windows Control Panel, under the Performance tab. Some versions of Windows will have this information in the Resource Monitor application, accessible through the Control Panel Performance tab. Run a multiple frame capture with at least 50 frames while monitoring the GPU utilization. If Pilot crashes following the GPU utilization jumping to 100%, this fix should correct the issue. Otherwise, review the Troubleshooting Page, then contact FLI if a solution cannot be found.

The following solution is used with NVIDIA GPU's, however a similar process can be done with other GPU manufacturers.

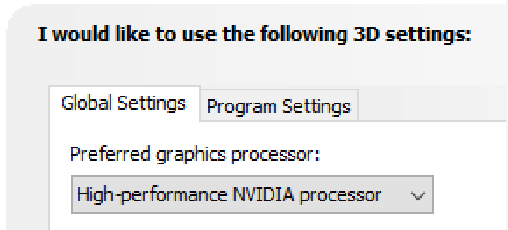
Right click a blank area of the windows desktop, and select **NVIDIA Control Panel**.



Select **Manage 3D Settings** on the left panel.



Use the drop down menu to select the NVIDIA GPU as the preferred graphics processor.


I would like to use the following 3D settings:

Preferred graphics processor:
High-performance NVIDIA processor

Now, try running a multiframe process in Pilot again, and confirm that the capture can complete. If this solution does not repair the issue, contact FLI.