THORLABS

ThorCam

User Guide

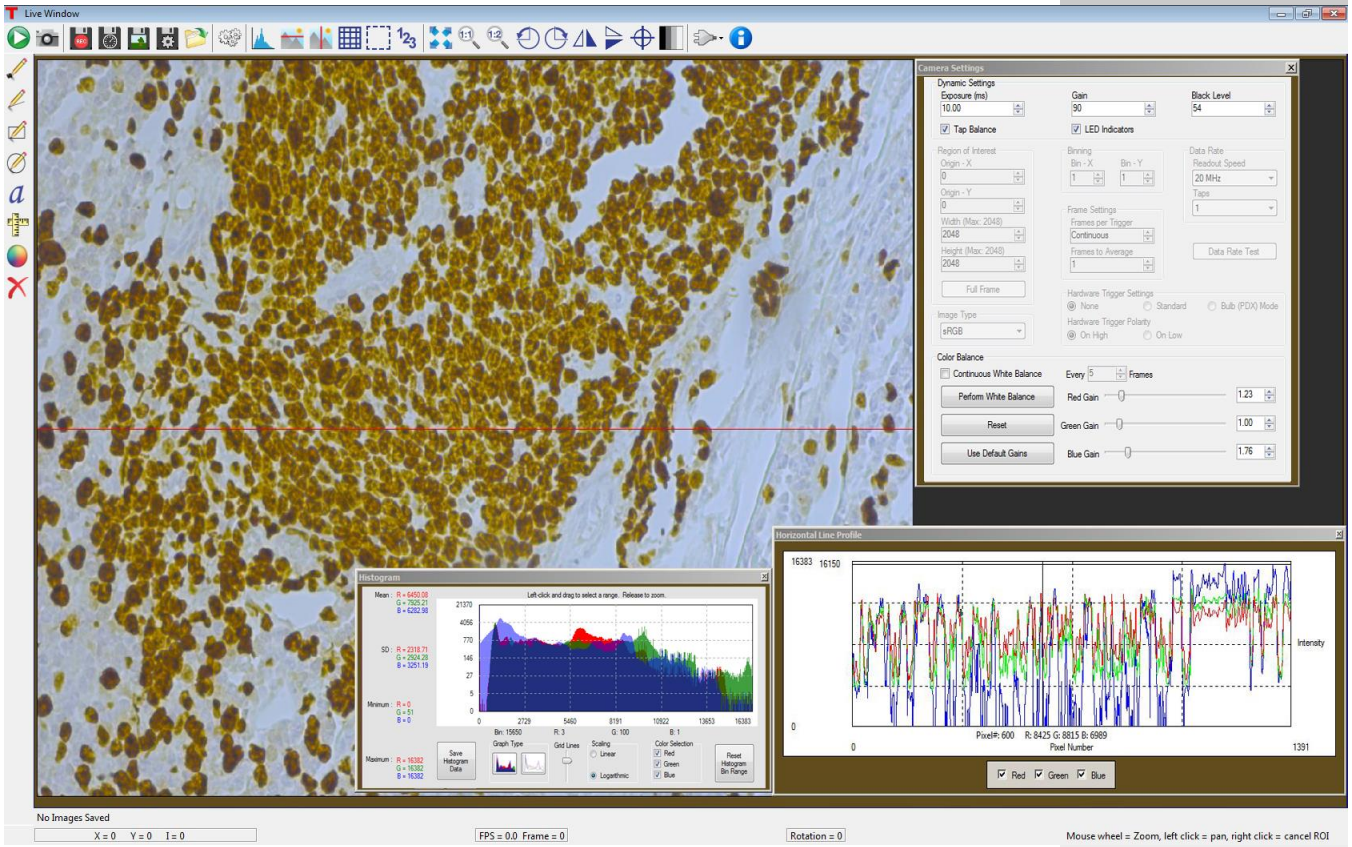


Table of Contents

Chapter 1 Safety

1.1. Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual

Caution: Risk of Electric Shock

Caution: Risk of data loss and damage to operating system

1.2. Precautions

Please read the instruction manual for your ThorCam-compatible instrument carefully before using with ThorCam. All statements regarding safety and technical specifications will only apply when the unit is operated correctly.

1.3. Accessories and Customization

Although the system is easily adapted for custom interfaces, to achieve the listed specifications this system should only be used with accessories provided by Thorlabs. Any modification or servicing by unqualified personnel renders the warranty null and void, leaving Thorlabs free of liability. Please contact Thorlabs for questions on customization.

Chapter 2 Description

2.1. Introduction

This manual is a functional overview of the ThorCam software application, and is meant to be a companion to your camera's User Manual.

ThorCam works with both the compact DCU-series and the high-performance scientific-grade cameras.

ThorCam is installed as part of your camera software installation process. Please follow the instructions in the User Manual or Quick Start Guide that accompanied your camera.

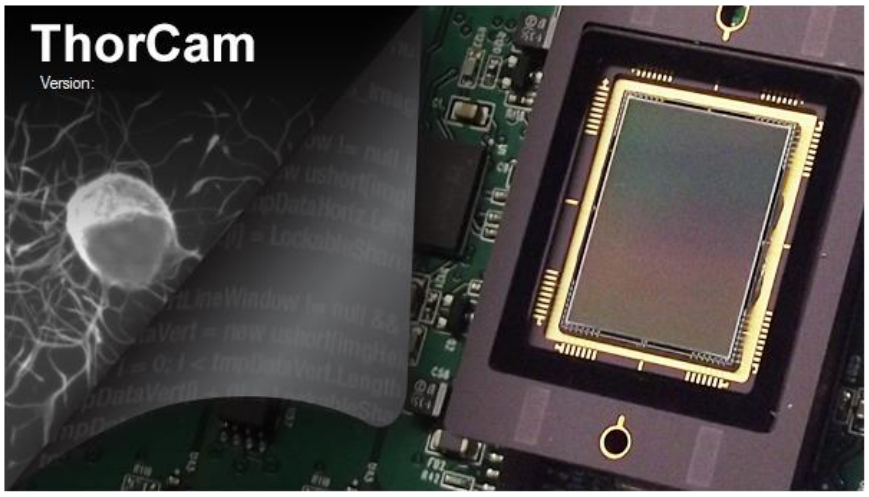
2.1.1. Optional Items

- Auxiliary I/O Patch cable – The auxiliary connector on the camera allows the user to access optional camera control and internal status signals. Please consult your camera's manual for details.

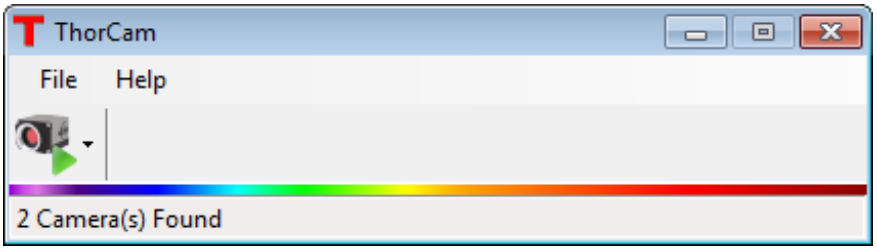
Chapter 3 Using ThorCam

3.1. Launching the application

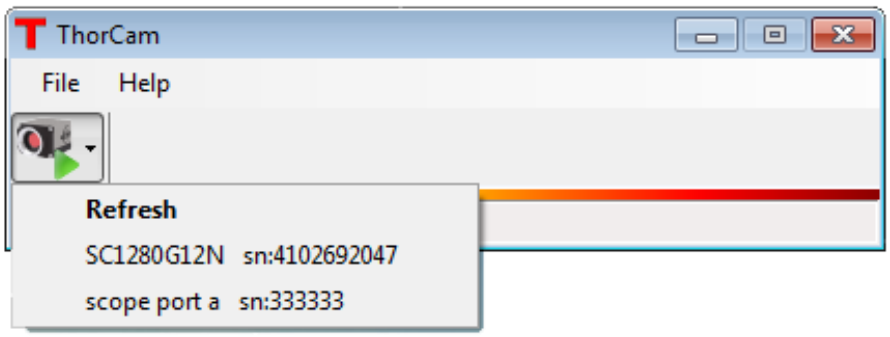
To start the camera, launch the ThorCam application. The following splash screen will momentarily appear:



Followed immediately by this window:



When the camera is recognized, it will appear in the pull-down menu as shown below:



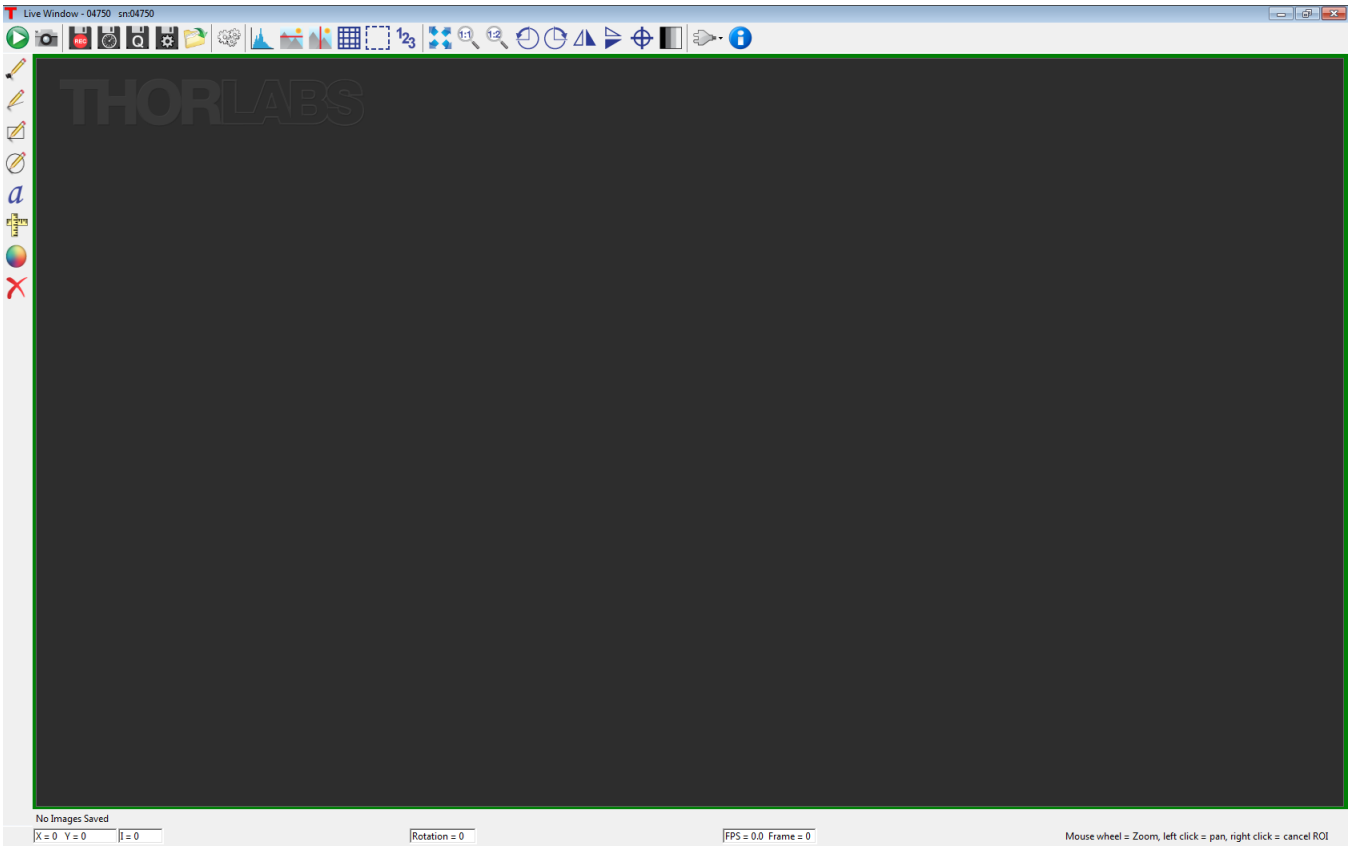
If the camera does not appear, check that the power supply is turned on and the camera is properly connected to the computer. Gigabit Ethernet cameras can take 20-30 seconds to register on the network after power is applied. Select ***Refresh*** to check for the presence of the camera.

Next, select the camera from the pull-down menu. Any or all cameras can be operated simultaneously after selection from this menu. Each time a camera is selected, the ***Live*** window for the chosen camera will appear. The window border is color-coded with a random border color to facilitate association of multiple camera Live windows with their settings and analysis windows.

3.2. The Live Window

The Live window is the main window for the camera and the one in which images are displayed.

There are a few differences between Live window tool icons and functions for the scientific-grade and DCU-series cameras. This was done to maintain a familiar interface for current DCU-series camera owners while tailoring scientific-grade camera functionality to those customers. The scientific-grade Live window is shown below.



3.3. Scientific Camera Controls

The following controls are specific to the scientific-grade Live window. The DCU specific controls will be covered separately, followed by the controls that are common to both GUIs.

3.3.1.  Start/Stop Capture

Commences capture according to the camera settings. When clicked, the start capture button changes to the stop capture button.

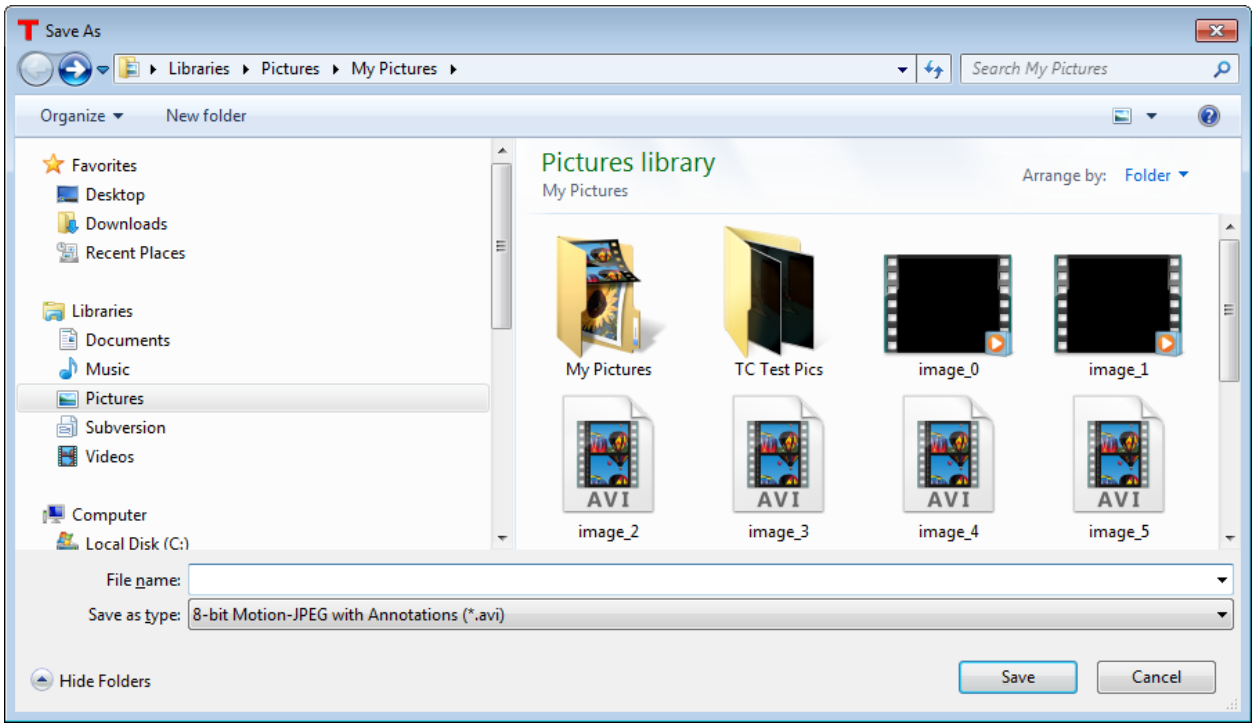
3.3.2.  Snapshot

Takes a single snapshot from camera with the current camera settings.

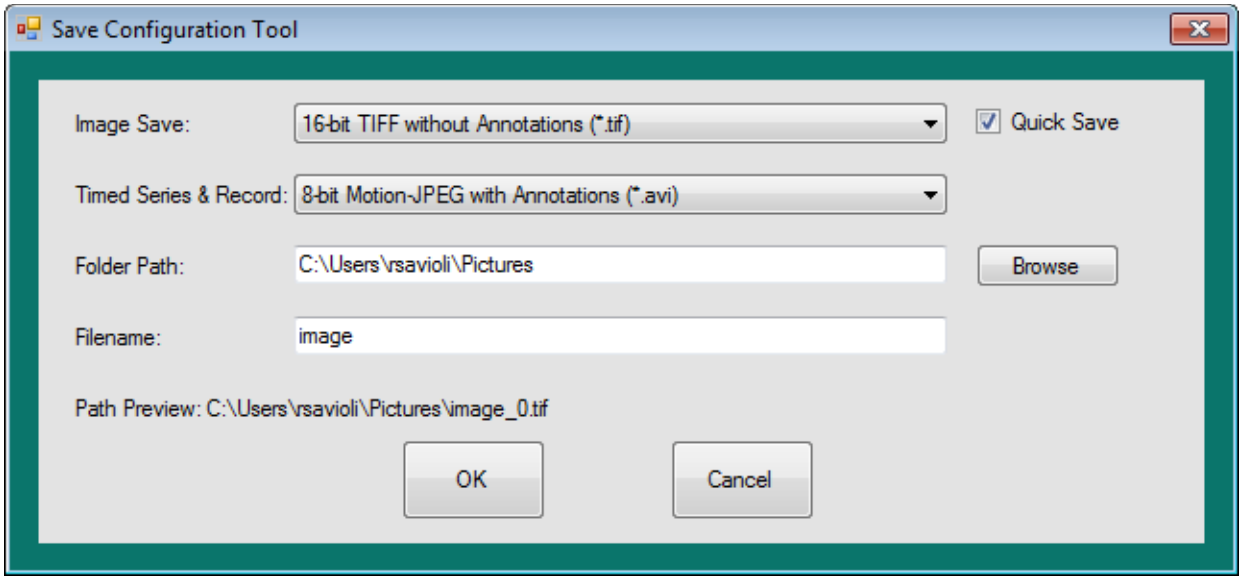
3.3.3.  Start/Stop Record

Commences recording of capture to a Motion JPEG AVI or multipage TIFF file. The AVI file is saved as a scaled 24-bit image, while the TIFF is saved a variety of formats (bit depth and grayscale/color depends on camera model). When clicked, the start record button changes to stop record. While recording, **REC** is visible in the upper left corner of the image.

If the "Quick Save" feature has NOT been selected (see below) you will be prompted for a file name and location using the native Windows Save As dialog window, otherwise the recording will immediately start - saving to the parameters set-up in the ***Save Configuration Tool***.

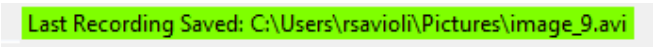


The file type, format, location, and name of the stored image can be viewed or changed in the ***Save Configuration*** dialog accessed from this icon:  . The Quick Save feature is enabled only when the "**Quick Save**" box is checked. The default path is the Window's Users\Pictures folder with a default image prefix of "image". Using the Configuration set-up you can change the image name (Image Prefix), and browse to any folder you wish to save to, provided you have write-access privileges.



The first recording captured will have a file name consisting of the Image Prefix appended with "_0". As additional recordings are captured and saved they will be automatically appended with a numerical suffix _1, _2, _3 …).

The  icon provides a short-cut to the folder in which you have saved your images. Additionally, each time you press the Record icon, the path information will be displayed along the bottom status bar, momentarily highlighted in green to indicate a successful acquisition and save.



Unattended recording can result in excessive use of file storage space and ultimately result in operating system malfunction and/or loss of data.

3.3.4.  Rotate 90 Degrees

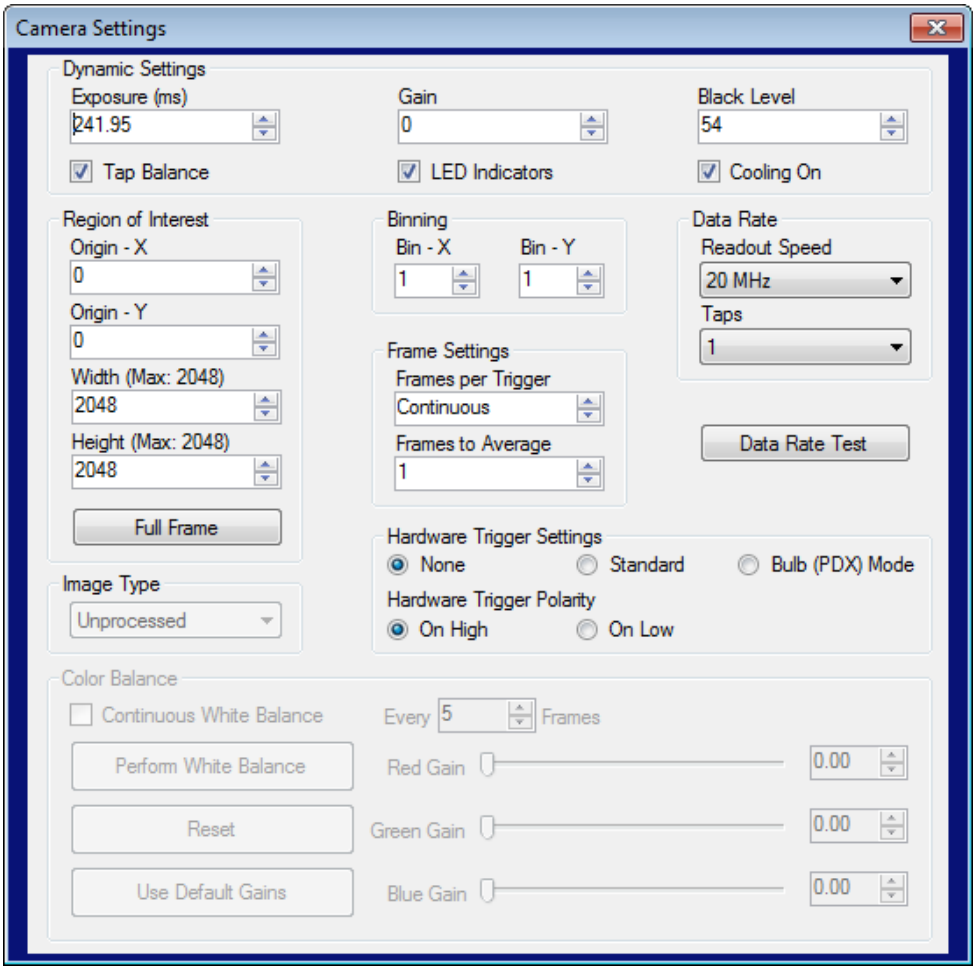
Rotates the image in the viewing window clockwise and counter-clockwise in 90 degree steps. This feature will apply when saving images and video captures. The current rotation angle is displayed along the bottom of the Live window.

3.3.5.  Mirror Flip Horizontal or Vertical

These two icons will mirror the current image from left to right (Horizontal Flip) or from top-to-bottom (Vertical Flip). This feature will apply when saving images and video captures.

3.3.6. Camera Settings (Scientific-Grade Cameras)

The Camera Settings window provides access to camera and display controls. Controls are grouped into dynamic and static settings. Dynamic settings can be adjusted while ThorCam is capturing data and remain active during image acquisition. Static settings require acquisition is stopped before allowing changes to the settings.



Dynamic Settings:

Dynamic settings are active at all times.

Exposure

Sets the exposure time for all frames to be acquired. Units are in milliseconds.

The camera exposure time is very stable, but the exact exposure accuracy and increment depends on a number of settings including Binning, Region of Interest (ROI), and Readout Speed. Therefore, the actual exposure time of the camera will be the closest possible to the value entered.

Gain

The relative gain applied to the analog signal from the image sensor. Units: 0.036 dB/step.

Black Level

The average image signal from the camera in the absence of light. Increments of 0.25 ADU (analog-to-digital unit).

Tap Balance

For multi-tap cameras operating with two or more taps only. Applies a factory-calibrated equalization to each tap to remove the visible “seam” due to natural differences in the signal level for each CCD tap. Tap balance is meant to provide a visually pleasing image and is not absolute. Under extreme contrast stretching and/or camera settings residual tap-to-tap differences can be observed. This is not a malfunction. The 1501x Series cameras will not display the Tap Balance function since they are single tap cameras.

NIR Boost

The 1501x Series cameras provide a special function called NIR Boost that allows for a slight increase of the spectral response of the camera into the near IR wavelengths. This feature is only visible on the monochrome cameras, and color cameras operating in the Unprocessed Image Type. Refer to the Scientific Camera User’s Guide for more information. The check box for NIR Boost is located under the Exposure setting box when available - replacing the Tap Balance option.

LED Indicators

The USB3.0 Series cameras provide a special function to allow the user to control the two LED indicators on the rear panel of the camera. If the box is checked, the LEDs will be turned on. Cycling power to the camera will result in the LEDs, by default, being turned on.

Cooling Mode

For cameras with the thermoelectric cooler option only. Turns on or off the camera thermoelectric cooler.

Static Settings:

Static settings can only be altered when the camera is not actively acquiring images.

ROI/Bin Settings

Origin-X and **Origin-Y** set the origin, or upper left corner of the Region of Interest (ROI). **Width** and **Height** determine the width and height of the region of interest. The ***Full Frame*** button resets the Region of Interest to the maximum CCD sensing area indicated next to the Width and Height labels.

Width and **Height** not only sets the size of the data stored in memory and to disk, but it also determines the region that is read from the CCD sensor in the camera. Specifically, only the Height changes the readout area on the CCD. The Width is truncated in software. As a result, Height entries that reduce the vertical size of the region also increase the readout of the chip and vice versa. This increase in readout speed is not directly proportional to ROI vertical size due to overhead in the readout process. ROI does not impact the noise floor.

Bin X

Horizontal binning factor. Horizontal binning is accomplished in software and has no impact on readout rate. Horizontal binning will increase the offset level and noise floor commensurate with the binning factor selected. The offset level increases as the sum of the offset of individual pixels binned. The noise floor standard deviation increases as the square root of the sum of the standard deviation of the pixels binned. The Bin X control is disabled when the camera is acquiring frames.

Bin Y

Vertical binning factor. Vertical binning is done on the CCD chip in the camera and will produce increased frame rates as the binning factor is increased. In general, vertical binning has little effect on offset level or noise floor. The Bin Y control is disabled when the camera is acquiring frames.

Color capable cameras can only operate at 1 x 1 binning when the Image Type is anything except “Unprocessed”. Unprocessed Type can bin at the specified maximum bin values of the camera. If the Image Type is changed from Unprocessed to one of the RGB Types, the binning settings are automatically reset to 1 x 1.

Readout Speed

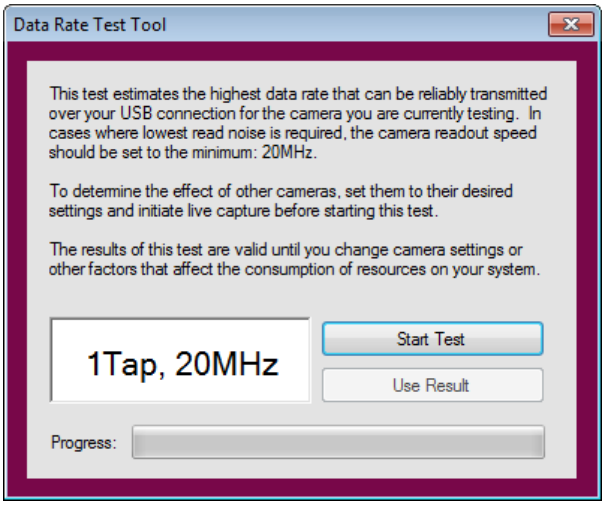
Selectable 20 MHz or 40 MHz. Faster readout speed results in higher achievable frame rates at the cost of slightly higher readout noise in general.

Taps

For cameras with multi-tap readout capabilities only. This control sets the number of taps used to read out the CCD, using more taps will provide faster frame rates.

Data Rate Test

The ***Data Rate Test*** button is only active on USB 3.0 Scientific cameras. Running this test will help determine the maximum Clock and Taps settings that your host computer is capable of operating at. Pressing the button will stop any current acquisitions and open the following window:



Pressing the ***Start Test*** button will commence the test. The ***Progress*** bar will indicate the status of the test. Once it has completed, the Speed Gauge window will show the maximum capabilities of your USB 3.0 system. You may choose to use the maximum settings by pressing the ***Use Result*** button, or you can simply close the window by clicking on the **X**.

Frames per Trigger

The number of frames captured per trigger. Refer to timing diagrams in the camera User’s Manual for more detail.

Frames to Average

The number of frames to average from a sequence, from a minimum of 1 (no averaging) to 32.

Hardware Trigger Settings

Selects the method of triggering the camera. Please see your camera manual for detailed timing diagrams of the exposure modes.

None

Trigger is generated by ThorCam (e.g. pressing the capture button will capture the number of frames in Frames per Trigger setting above.

Standard

Trigger is provided through the camera hardware auxiliary connector. Capture is triggered by the rising or falling edge of the trigger signal according to the HW Trigger Polarity setting, with the exposure value according to the Exposure setting.

Bulb (PDX) mode

Trigger is provided through the camera hardware auxiliary connector. Capture is triggered by the rising or falling edge of the trigger signal according to the HW Trigger Polarity setting, with an exposure dependent on the trigger pulse width.

Hardware Trigger Polarity

This setting controls whether the camera will respond to the Low-to-High transition of the external trigger (On High) or to the High-to-Low transition of the trigger (On Low).

Image Type
All monochrome cameras default to an Image Type of ***Unprocessed***, while color capable cameras can operate at any of the three selections; ***sRGB***, ***Linear sRGB***, or ***Unprocessed***. Selecting Unprocessed Image Type with a color camera will result in a monochrome image.

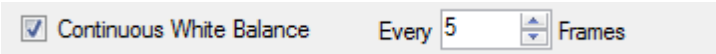
Binning is only allowed when the Unprocessed Image Type is selected.

Image Type is a static setting requiring the camera to be stopped prior to making a change to it.

Color White Balance

The Color White Balance settings group is only active on color cameras and consists of a number of dynamic settings - meaning they can be adjusted while the camera is capturing frames.

The check box for ***Continuous White Balance*** causes the software to automatically make corrections to the white balance parameters. When the box is checked it will enable a settings field allowing you to set how often the balance is adjusted, the range is from 1 frame to 9999 frames:



While operating in the Continuous White Balance mode the manual RGB Gain controls are adjusted automatically, and are still active for the user to manually adjust, however, at the automatic adjustment frame the value will be reset by the Continuous White Balance function.

Alternatively you can press the ***Perform White Balance*** button and the software will perform a one-time calibration of the white balance gains. The RGB Gain controls will be automatically adjusted, and the Gain controls remain active and can be adjusted dynamically.

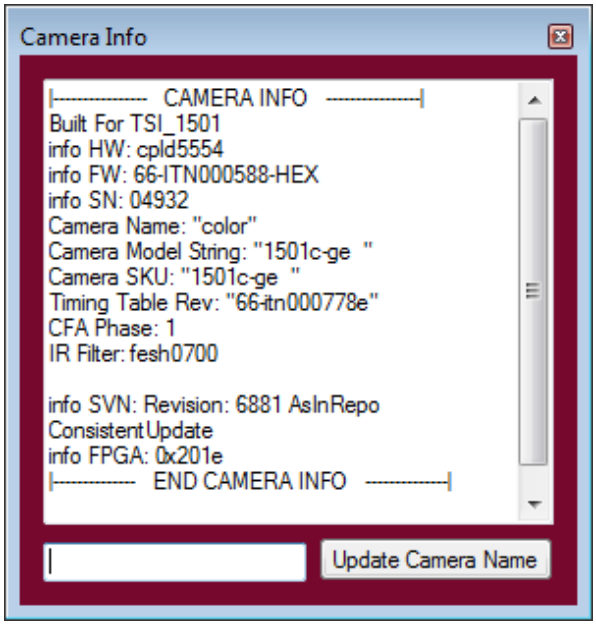
Finally, the color balance can be manually adjusted using the three individual ***Red***, ***Green***, and ***Blue*** slide controls or numeric input boxes, which can be incremented or decremented using the up/down arrow buttons or by typing in a value directly. The usable range of gain values is 0 to 10.00.

Pressing the ***Reset*** button will change all three gain settings to "1.0". Pressing the ***Use Default Gains*** button will change all three gain settings to the default values specific to each camera model.

The Color Balance controls apply to all frames captured AFTER applying the change (including Continuous, Perform White Balance adjustments, Reset, and Defaults). That is, if the camera is stopped and an image is displayed, making adjustments to the White Balance gains will have no effect on that image. Once the camera is started again, or a snapshot is taken, all of the new gains settings will apply.

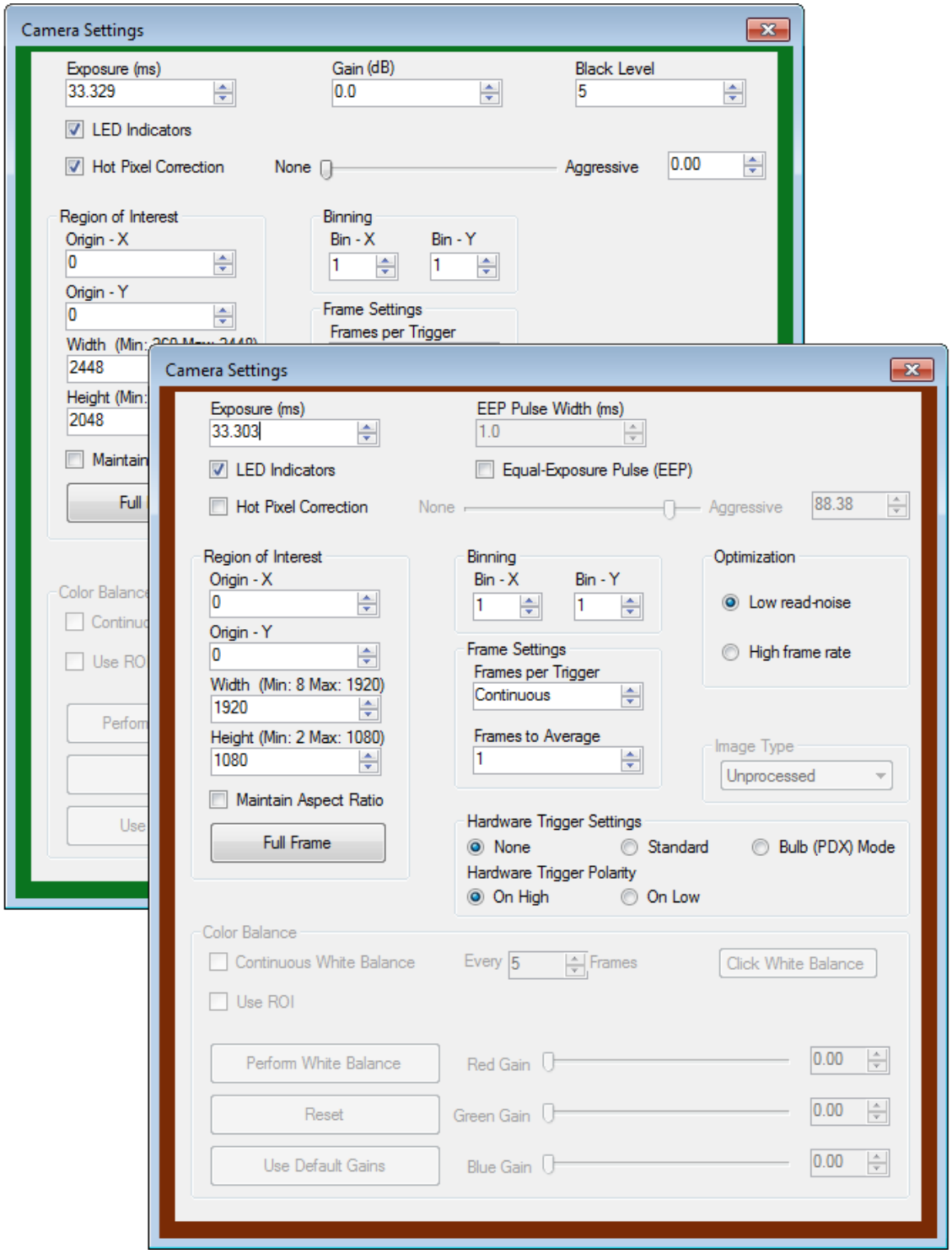
3.3.7. Info

Provides information pertaining to the camera, such as the camera name, serial number, model, and various embedded firmware version numbers. All TSI cameras are shipped with the Camera Name the same as the Serial Number (info SN :). The Info window allows the user to change the camera name to any alpha-numeric format of 31 characters or less, including spaces and special characters. NOTE: Once the camera name has been changed you must close the Live window and cycle power to the camera before the change will take effect in ThorCam.

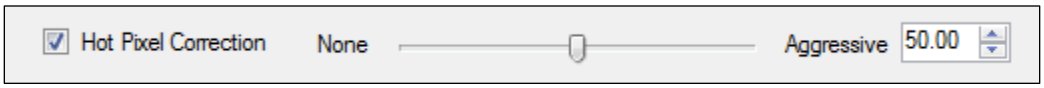


3.3.8. Camera Settings (Compact Scientific Cameras)

The Camera Settings window for the Compact Scientific family of cameras provides access to camera and display controls. While being quite similar to the Scientific Camera settings, there are a few differences that are discussed here, otherwise please refer to the Scientific Camera settings descriptions above.



Hot Pixel Correction



Hot Pixel Correction is a function that identifies and corrects pixels that are much brighter than their surrounding pixels. Typically visible as very bright pixels regardless of the scene being imaged, these are unavoidable by-products of the sensor manufacturing process.

By checking this box, Hot Pixel Correction will be activated and the threshold can then be adjusted using the adjacent slider or the numeric input box. The Hot Pixel Correction box can only be checked and unchecked when the camera is stopped. Once it is checked however, the threshold adjustment can be made on a live image.

The threshold adjustment is made by simply adjusting the slider from the far left position (None) to the right (Aggressive). Care must be taken to not correct too aggressively, as this could affect valid pixels, particularly in bright scenes with high pixel values.

A hot pixel is identified by comparing with the mean value of the surrounding 8 pixels out of a 3x3 neighborhood. If the difference between the pixel value and the mean is larger than a specified threshold value, then this pixel is considered a hot pixel and will be replaced with the median value of those pixels in the neighborhood. As the slider is moved towards “Aggressive,” the threshold is reduced in a linear fashion. The minimum threshold value, corresponding to the upper limit, has been selected to provide users with the ability to correct hot pixels having a deviation of only a few hundred counts. At this most aggressive value, it is quite likely that image content near the maximum pixel values (full scale) will be altered by the Hot Pixel Correction algorithm.

Optimization

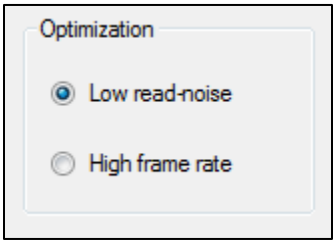
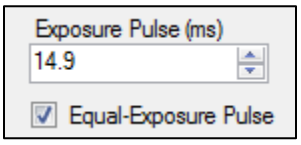


Image optimization can be achieved using the Optimization selections. A choice of “Low read-noise” sets the cameras master clock to a lower frequency, thereby reducing the read-noise. A choice of “High frame rate” increases the master clock, resulting in a higher frame rate. This function is only available on CS2100M-USB Quantalux sCMOS models.

Equal Exposure Pulse



The Equal-Exposure Pulse is an output signal available on the CS2100M-USB Compact Scientific camera’s I/O connector (refer to the Camera User Manual for details on this connector). When the Equal-Exposure Pulse (EEP) box is checked, the Strobe_Out signal on the I/O connector is reconfigured to be active only after the sensor’s “rolling reset” function has completed. The signal will remain active until the sensor’s “rolling readout” function begins. This means that the signal is active only during the time when all of the sensor’s pixels are actively integrating.

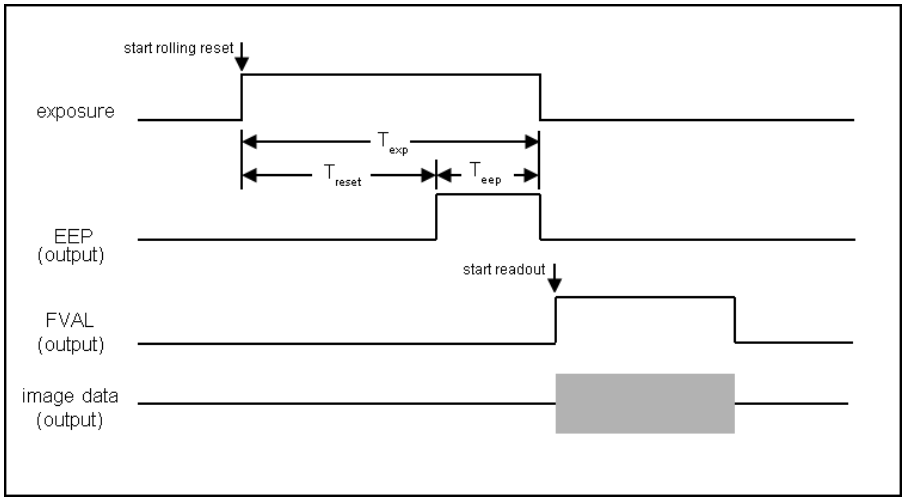
The Equal-Exposure Pulse can only be produced when the exposure time is greater than the frame period - defined as 1/fps. Exposure time, Optimization rate, and ROI all determine the final fps, so varying combinations of all will determine when the signal can be produced.

When a user checks the Equal-Exposure Pulse (EEP) selection box, all camera settings parameters are greyed out and held in their current state. Based on these parameters AND the value in the EEP Pulse Width (ms) input box, ThorCam calculates the exposure setting required to produce an Equal Exposure pulse of the duration entered into the EEP Pulse Width (ms) input box. This new *total* exposure value will be shown in the greyed out Exposure (ms) box.

The EEP Pulse Width (ms) value is the only parameter that can be changed when the Equal-Exposure Pulse box is checked. In order to make adjustments to other parameters you must first uncheck the Equal-Exposure Pulse box.

The Equal-Exposure Pulse is primarily meant to be used to control a light source that will expose a scene for a precise duration only when all pixels are integrating charge. The result is a more consistent exposure across the entire sensor. The user must keep in mind that the Exposure (ms) setting in the Camera Settings dialog will not be the effective exposure produced from the external light source. The effective exposure will be the value in the EEP Pulse Width (ms) setting.

For example, a CS2100M-USB at full frame ROI, with an Optimization setting of Low read-noise, and the EEP Pulse Width (ms) time in the Setting window set to 10.0mS, will have an effective exposure of 10mS, even though your adjusted Exposure (ms) setting will be 43.3mS.

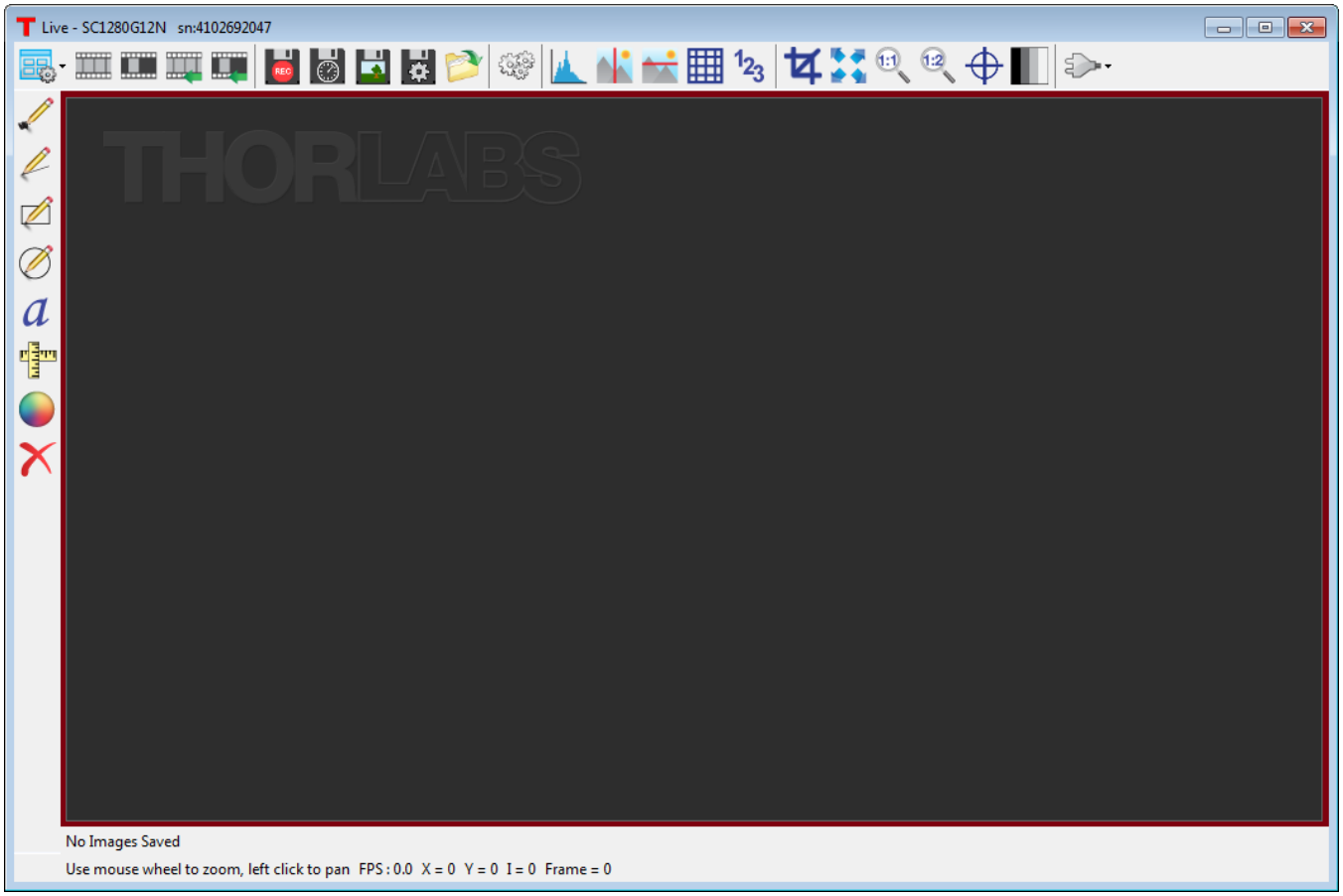


Be aware that the Equal-Exposure Pulse has no bearing on continuously illuminated scenes, and the resulting exposure will be whatever the actual Exposure (ms) time is set to. Please refer to the Compact Camera User Manual for additional timing diagrams and related information.

The minimum EEP Pulse Width is 1 ms, with increments of 0.1 ms thereafter. This function is only available on CS2100 Quantalux sCMOS models.

Gain and Black Level Controls

The Gain control for Compact Scientific cameras accepts values from 0 to 48.0 dB. The Black Level offset control accepts values from 0 to 4095. These functions are only available on CS505 series CMOS cameras.



3.4. DCx-Series Camera Controls

3.4.1. Load/Save Camera Settings

Specific camera settings can be saved in, and retrieved from a Thorlabs Camera Profile (.tcp) file. This icon allows you to name the file and save it to a suitable folder on the host computer. The file will contain information from the camera settings dialog only.

3.4.2. Start Capture

Commences capture according to capture settings. Clicking again stops capture.

3.4.3. Snapshot

Takes a single-frame capture.

3.4.4. Start Continuous Trigger

Arms the camera for capture using external hardware trigger. See camera user manual for further information.

3.4.5.  Snapshot Trigger

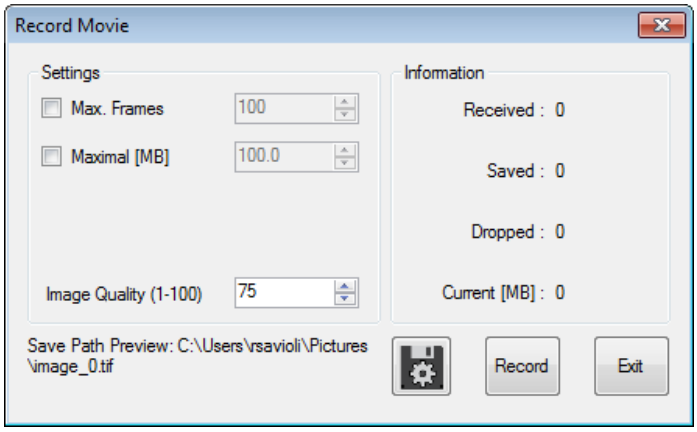
Arms the camera for single capture using external hardware trigger. See camera user manual for further information.

3.4.6.  Start/Stop Record

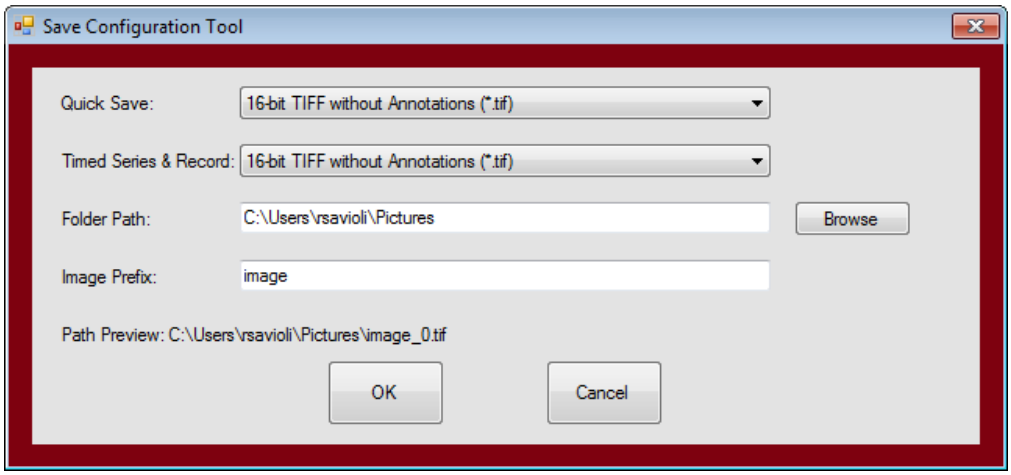
Commences recording of capture to a Motion JPEG AVI (in 24-bit RGB mode) or multipage TIFF file (in 10-bit Monochrome mode). The recording dialog box (for both AVI and TIFF) gives you the option of limiting the recording size by setting the maximum number of frames or the maximum file size in MB.

The actual record is commenced in the Record Movie dialog box by pressing the “Record” button. The Record button then changes to a “Stop” button. Press this button to stop the recording.

The Save Path Preview is informational only and shows where the recording will be saved. To change this location press the  icon and you will be redirected to the Save Configuration dialog.

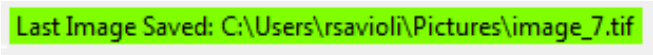


The file type, format, location, and name of the stored image can be viewed or changed in the ***Save Configuration*** dialog accessed from this icon:  . The default path is the Window’s Users\Pictures folder with a default image prefix of “image”. Using the Configuration set-up you can change the image name (Image Prefix), and browse to any folder you wish to save to, provided you have write-access privileges.



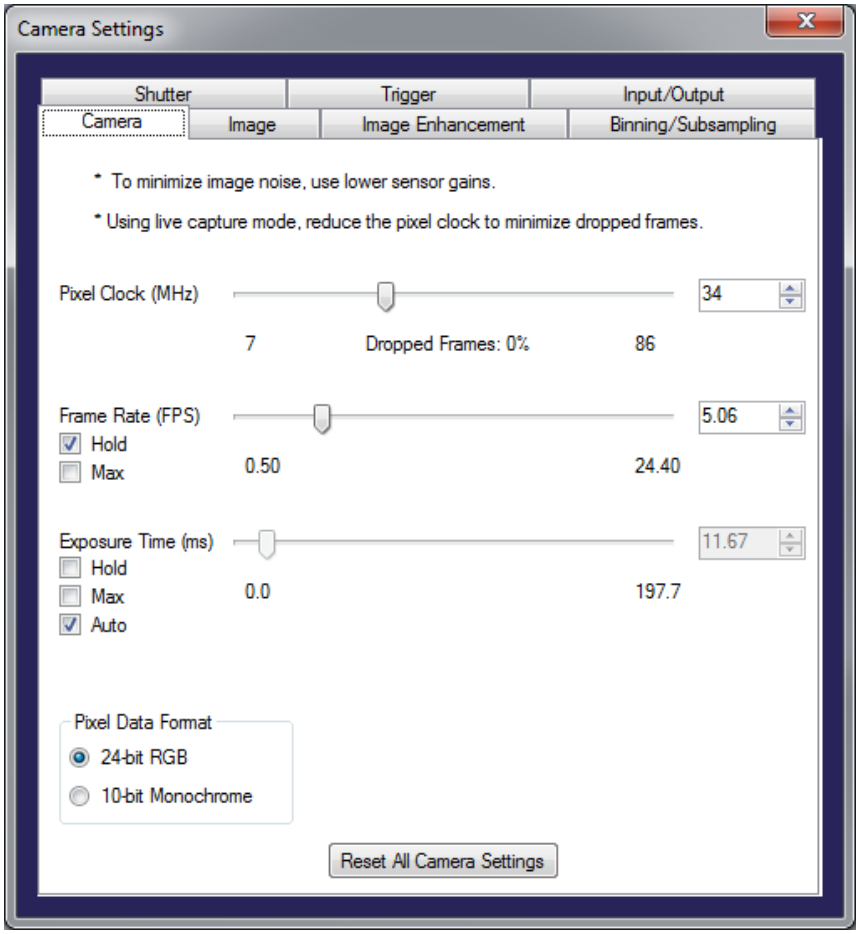
The first recording captured will have a file name consisting of the Image Prefix appended with "_0". As additional recordings are captured and saved they will be automatically appended with a numerical suffix _1, _2, _3 …).

The  icon provides a short-cut to the folder in which you have saved your images. Additionally, each time you press the Record icon, the path information will be displayed along the bottom status bar, momentarily highlighted in green to indicate a successful acquisition and save.



3.4.7.  Camera Settings (DCx-Series Cameras)

Launches the Camera Settings window to allow control of camera parameters.



The Camera Tab:

Pixel Clock

The basic parameter for camera timing is the pixel clock. It determines the speed at which the sensor pixels are read out.

We recommend not setting the pixel clock any higher than necessary to achieve the desired frame rate. To find a pixel clock that meets your imaging needs, start capturing images by pressing the  Start Capture button. Then, adjust the pixel clock while observing the percentage of dropped frames shown beneath the Pixel Clock slider.

Frame Rate

The possible range of settings for the frame rate depends on the currently selected pixel clock. You can select a lower frame rate without changing the pixel clock. To set a higher frame rate, however, the pixel clock might need to be increased.

Exposure Time

The exposure time depends on the currently selected frame rate and is preset to its reciprocal value. A shorter exposure time can be set without changing the frame rate. A longer exposure time will reduce frame rate.

Note: The increments for setting the exposure time depend on the sensor's current timing settings (pixel clock, frame rate). The exposure time values are rounded down to the nearest valid value, if required. For this reason, the actual exposure time can deviate slightly from the exposure time you have selected.

Pixel Data Format

Some DCx cameras provide a user-selectable choice in image pixel format between 24-bit RGB, 24-bit Monochrome, and 10-bit Monochrome. The choice of pixel data format affects how the images will be saved, the scale of the raw data seen in the analysis windows, etc.

The Image Tab:

Gain

To increase image brightness, the signal can be amplified by an analog gain before the digitizing process. The results of analog signal processing are usually better than the results of digital post-processing.

Depending on the sensor type, a global gain value for all pixels (master gain) or a separate gain value for each color (RGB gain) can be set.

Note: Signal gain will also result in a noise gain. High gain settings are therefore not recommended.

Offset

This sets the black level for the camera. The black level is the signal level acquired when there is no light falling on the sensor.

Auto White Balance

Different light sources can have different spectra, characterized as “color temperature” which can result in color casts in the captured images. Sources with low color temperatures (e.g. incandescent lamps), the white point is offset towards a red hue. Sources with high color temperatures (e.g. cool-white fluorescent lamps), the white content is offset towards a blue hue.

The white balance control feature uses the RGB gain settings of the camera to correct the white level. This is achieved by adjusting the gain controls within the 0-100 % range until the red or blue channel matches the average brightness of the green channel. In order to manually influence the color rendering, you can adjust the setpoint values for the red and blue channels relative to the green channel by using an offset value.

Gamma

Applies a digital gamma correction in software which applies a gamma characteristic to the image. Sensor gamma applies additional gamma correction in hardware if the camera model supports it.

The Image Enhancement Tab:

Edge Enhancement

This function enables/disables a software edge-enhancement filter. This function results in a higher computer CPU load.

Color Saturation

Adjusts the color saturation in software. In the U channel, this information results from the difference between the blue level and Y (luminance), in the V channel from the difference between the red level and Y.

Sensor Hot Pixel Correction

During the manufacture of our cameras, all sensors that will be used in DCx Cameras are checked for hot pixels. In the process, images are taken with a darkened sensor and long exposure times. Pixels with a brightness higher than a specific value are classified as hot pixels. Hot Pixel Correction suppresses these pixel values.

Area of Interest (AOI)

Using this function, you can set the size and position of an area of interest (AOI) within an image. In this case, only data included in this AOI will be read out and transferred to the computer. The smaller partial image enables the camera to use a higher frame rate. Note: Area of interest is sometimes called region of interest (ROI).

The Binning/Subsampling Tab:

Binning

Binning is a function that averages or adds multiple sensor pixels to obtain a single value. This reduces the amount of data to be transferred and enables higher camera frame rates. The captured image has a lower resolution but still the same field of view compared to the full-resolution image. This mode can be used as a fast preview mode for high-resolution cameras.

Subsampling

Subsampling is a technique that skips multiple sensor pixels when reading out image data. This reduces the amount of data to be transferred and enables higher camera frame rates. The captured image has a lower resolution but still the same field of view compared to the full-resolution image. This mode can be used as a fast preview mode for high-resolution cameras.

The Shutter Tab:

Global Shutter

On a global shutter sensor, all pixel rows are reset and then exposed simultaneously. At the end of the exposure, all rows are simultaneously moved to a darkened area of the sensor. The pixels are then read out row by row.

Exposing all pixels simultaneously has the advantage that fast-moving objects can be captured without geometric distortions. Sensors that use the global shutter system are more complex in design than rolling shutter sensors.

All CCD sensors as well as some CMOS sensors use the global shutter method.

Rolling Shutter

With the rolling shutter method, the pixel rows are reset and exposed one row after another. At the end of the exposure, the lines are read out sequentially. As this results in a time delay between the exposure of the first and the last sensor rows, captured images of moving objects are distorted.

To counteract this effect, the DCx Camera software provides a global flash window where you set the time by which flash activation is delayed. You can also specify the flash duration. This allows implementing a global flash functionality which exposes all rows of a rolling shutter sensor simultaneously.

Rolling Shutter with Global Start

Some rolling shutter sensors also provide a global start mode, which starts exposure of all rows simultaneously. For best results, use a flash for this mode. No light is allowed to fall on the sensor outside the flash period because otherwise the image brightness will be distributed unevenly.

Log Mode

Log mode is a special mode in some camera models that defines a threshold at which the linear response of the camera switches over to a logarithmic response.

The Trigger Tab:

Trigger

In trigger mode, the camera is on standby until it receives an electrical input signal telling it to start acquisition. The Trigger settings tab allows you to set the delay time between the trigger and start of acquisition, whether the trigger is a rising or falling edge, and how long the camera should wait for a trigger signal before timing out.

The Input/Output Tab:

The input/output tab allows you to setup hardware input/output signals with camera. Not all cameras support all features.

3.5. Common Control and Analysis Tools

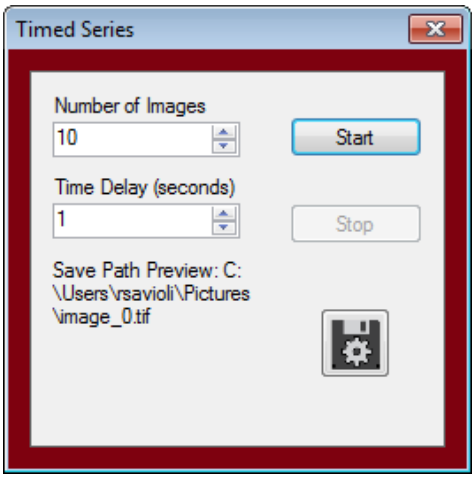
3.5.1. Pan/Zoom

To pan the image, left click and hold the left mouse button. Drag to pan around the image.

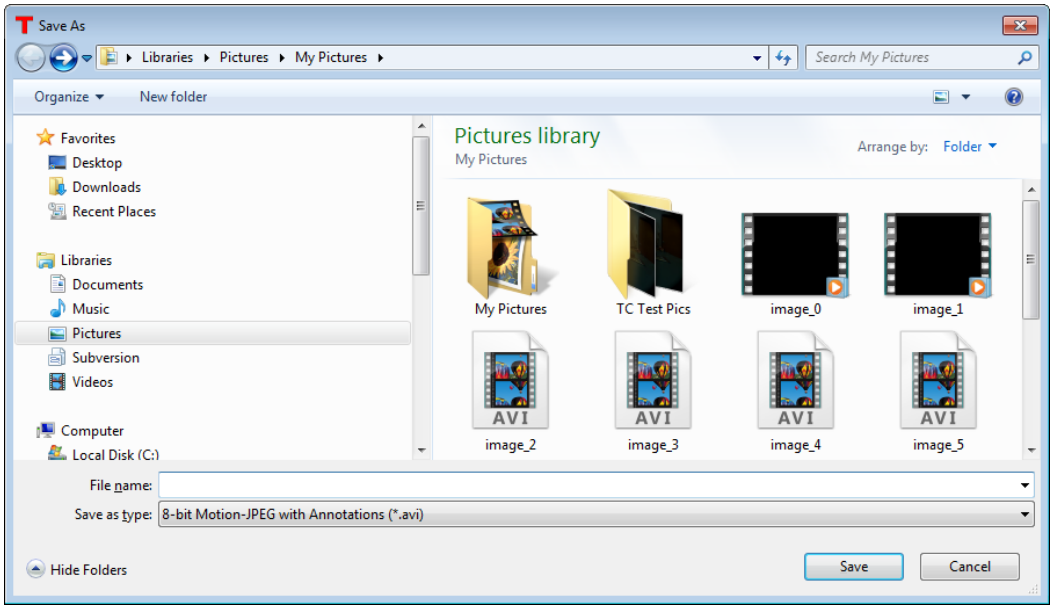
To zoom, use the mouse wheel to zoom in and out. This applies to both the DCU-series and scientific-grade Live windows.

3.5.2.  Timed Series

Launches Timed Series control window to set up recording of a time lapse.

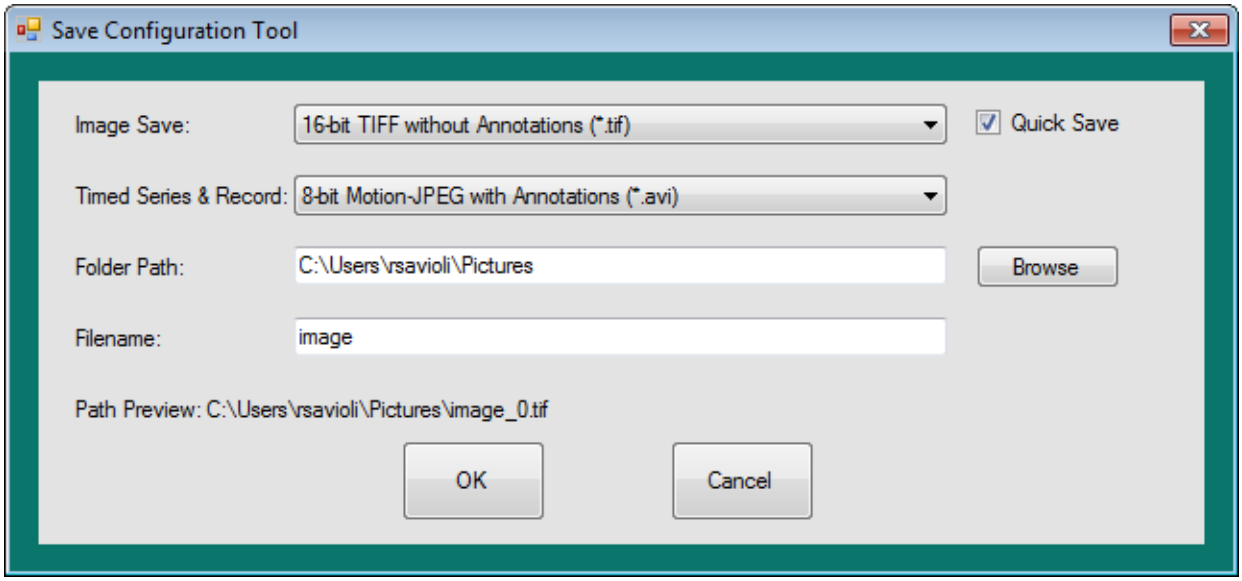


Set the Number of Images and the Time Delay, then press the **Start** button. If the "Quick Save" feature has NOT been selected (see below) you will be prompted for a file name and location using the native Windows Explorer window, otherwise the timed series will immediately start - saving to the parameters set-up in the ***Save Configuration Tool***.



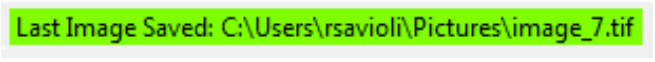
The Save Path Preview is informational only and shows where the recording will be saved. To change this location press the  icon and you will be redirected to the Save Configuration dialog.

The file type, format, location, and name of the stored image can be viewed or changed in the ***Save Configuration*** dialog accessed from this icon:  . The Quick Save feature is enabled only when the "**Quick Save**" box is checked. The default path is the Window's Users\Pictures folder with a default image prefix of "image". Using the Configuration set-up you can change the image name (Image Prefix), and browse to any folder you wish to save to, provided you have write-access privileges.



The first recording captured will have a file name consisting of the Image Prefix appended with "_0". As additional recordings are captured and saved they will be automatically appended with a numerical suffix _1, _2, _3 …).

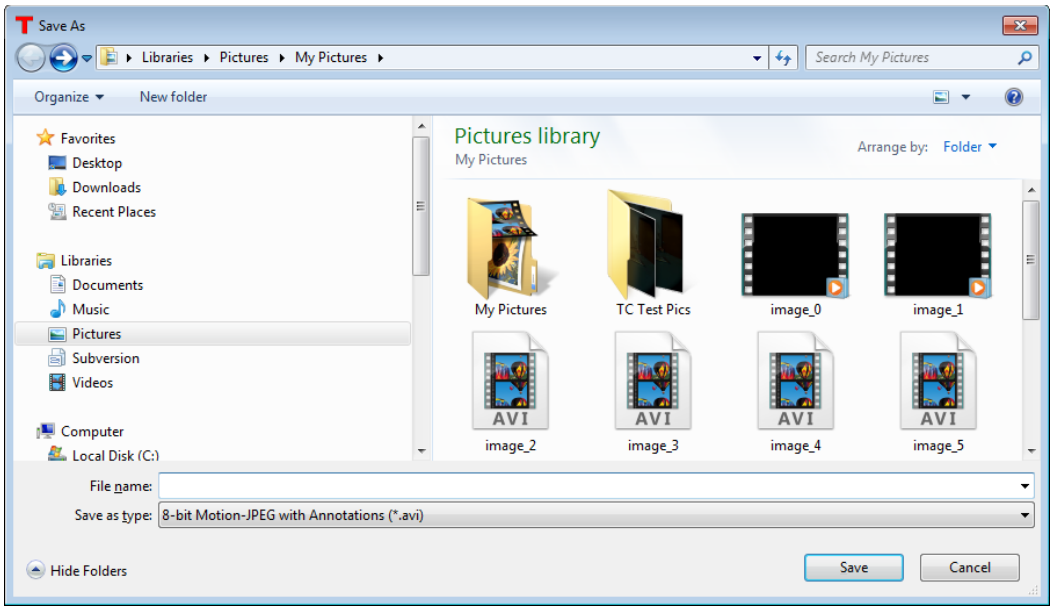
The  icon provides a short-cut to the folder in which you have saved your images. Additionally, each time you press the Quick Save icon, the path information will be displayed along the bottom status bar, momentarily highlighted in green to indicate a successful acquisition and save.



3.5.3.  Save Image

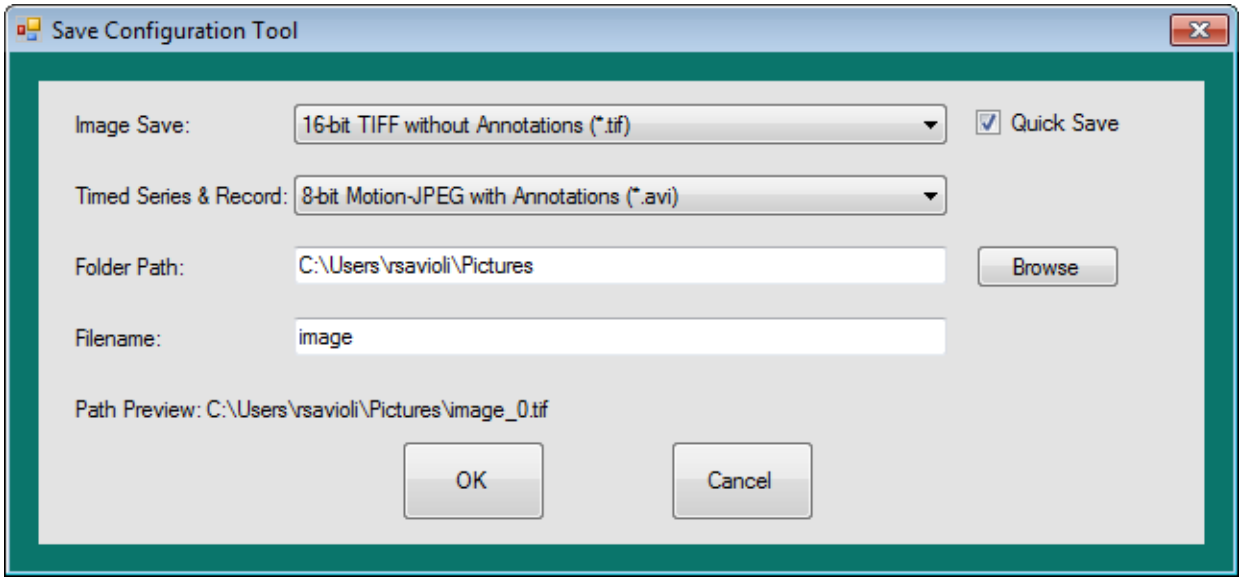
Pressing this floppy disk icon  saves the current image to file. Users can select a variety of file formats. This feature can be selected to capture a static image (camera is stopped) or capture a snapshot of a live video image without pausing the acquisition.

If the "Quick Save" feature has NOT been selected (see below) you will be prompted for a file name and location using the native Windows Explorer window…



… Otherwise a single frame acquisition will start - saving to the parameters set-up in the ***Save Configuration Tool***.

The file type, format, location, and name of the stored image can be viewed or changed in the ***Save Configuration*** dialog accessed from this icon:  . The Quick Save feature is enabled only when the "**Quick Save**" box is checked. The default path is the Window's Users\Pictures folder with a default image prefix of "image". Using the Configuration set-up you can change the image name (Image Prefix), and browse to any folder you wish to save to, provided you have write-access privileges.



The first image captured will have a file name consisting of the Image Prefix appended with "_0". As additional images are captured and saved they will be automatically appended with a numerical suffix _1, _2, _3 …).

The  icon provides a short-cut to the folder in which you have saved your images. Additionally, each time you press the Quick Save icon, the path information will be displayed along the bottom status bar, momentarily highlighted in green to indicate a successful acquisition and save.

Last Image Saved: C:\Users\rsavioli\Pictures\image_2.jpg

The Quick Save feature does not work in Record mode or Timed-series capture mode.

When a TIFF file is opened by ThorCam the relevant bits per pixel parameter is read from a custom tag in order to properly display the image. Other metadata stored within custom tags in the TIFF file include various camera settings.

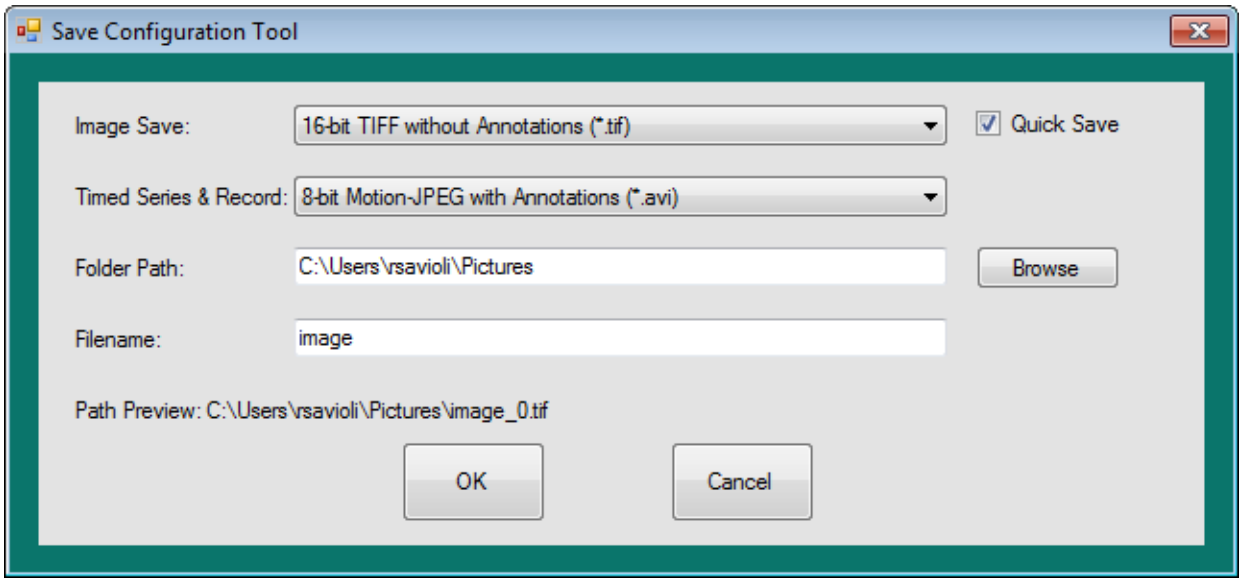
Annotations and display settings are not saved in TIFF images. Use PNG or JPEG formats if annotation is to be saved.

Caution: Not all imaging programs preserve custom TIFF tags. Thorlabs metadata might not be preserved if the ThorCam TIFF file is processed and saved by a third-party program.

PNG and **JPEG** formats are provided in order to save an image as displayed. Both display rendering (contrast) and annotations are preserved. **PNG** or ***Portable Network Graphics*** file format converts the image in 8 bits/pixel/color uncompressed. This results in larger images but with no loss of quality relative to the image as it is displayed in the Live window. **JPEG** format also saves the image in 8 bits/pixel/color, but the image is JPEG-compressed. This will create much smaller files. Use JPEG for casual documentation or email.

3.5.4.  Image Save Configuration Tool

The file type, format, location, and name of a stored image can be viewed or changed in the ***Save Configuration*** dialog. The default path is the Window's Users\Pictures folder with a default image prefix of "image". Using the Configuration set-up you can change the image name (Image Prefix), and browse to any folder you wish to save to, provided you have write-access privileges. The parameter fields are only active when the Quick Save box is checked.



The first image or recording captured will have a file name consisting of the Image Prefix appended with "_0". As additional images or recordings are captured and saved they will be automatically appended with a numerical suffix _1, _2, _3 …).

The save path displayed in the path preview can be the actual location an image or recording is to be saved to, but the file name is not guaranteed. It is possible that another image or recording of the same name has been previously saved to the same path displayed in the path preview. When this happens the existing file will not be overwritten and ThorCam will save the new image or recording using the naming scheme previously outlined. The actual file name will be displayed on the status bar of the Live window.

3.5.5.  Browse Saved Images

The Browse Saved Images icon provides a shortcut to your current location for saving Recordings, Time Series, and Quick Save Images.

3.5.6.  Histogram

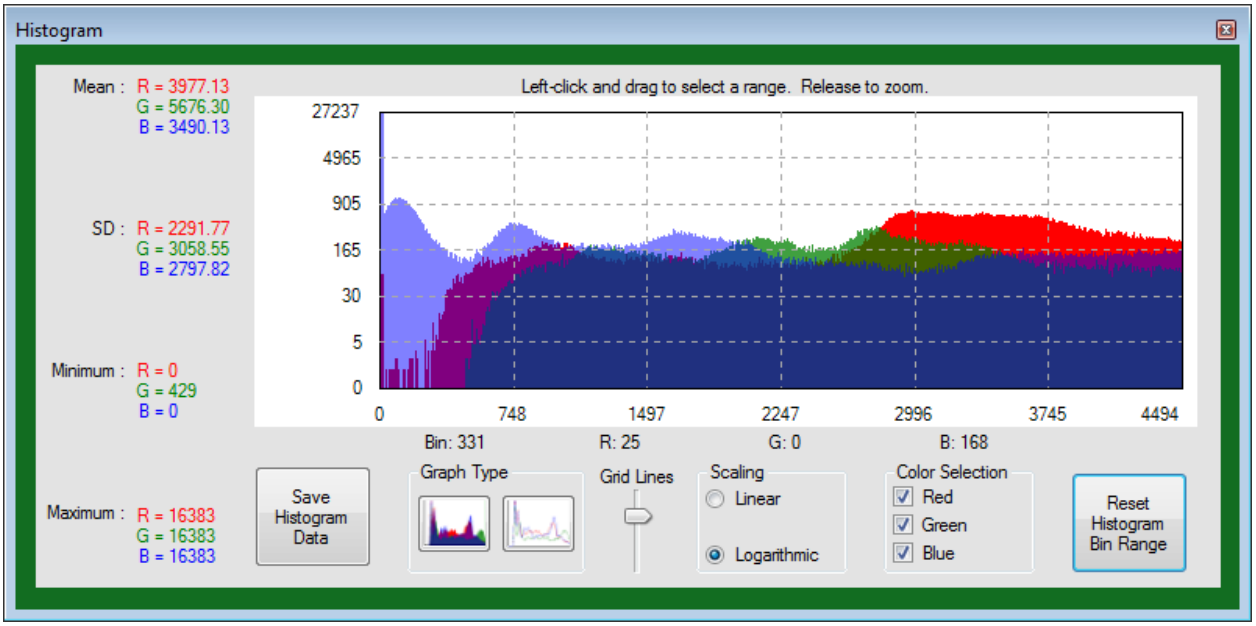
Displays the histogram of the captured image values. If an analysis ROI is defined, the histogram uses that ROI.

TSI Scientific Cameras:

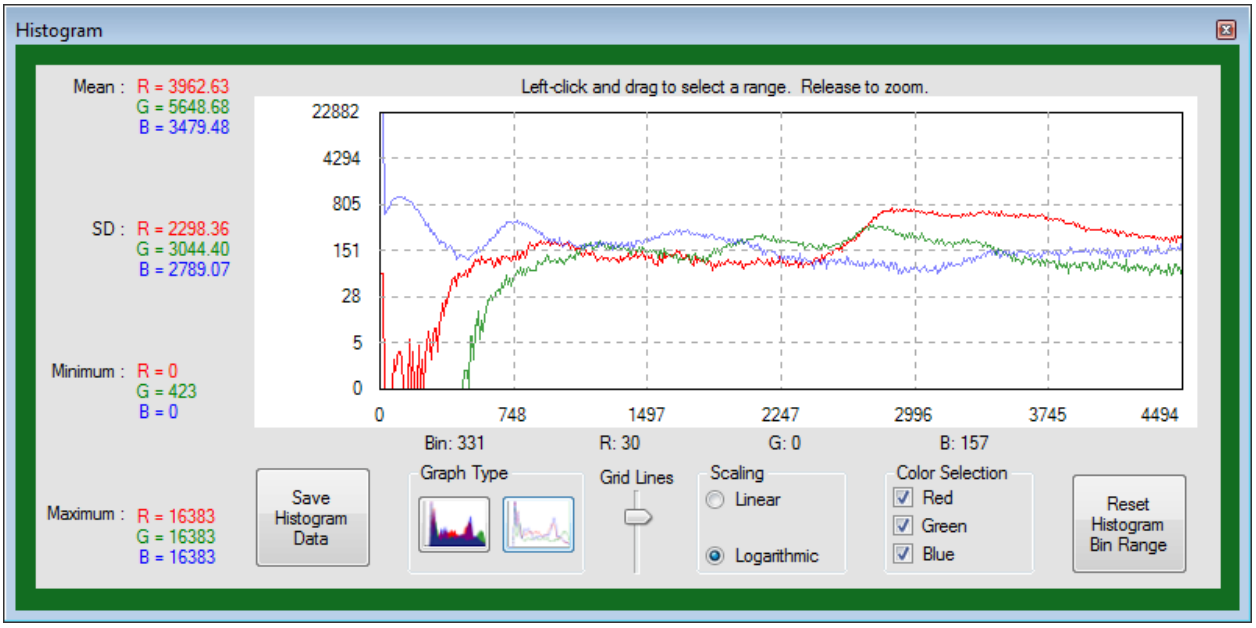
Close inspection of histogram values can be accomplished left-clicking on the graph and swiping left or right while holding the left mouse button down. Pressing ***Reset*** or right-clicking on mouse reverts back to the full histogram range. The histogram can also be viewed in a log-linear fashion by selecting the Logarithmic ccaling button.

The histogram can be displayed as a bar graph by clicking this icon  , or as a line graph by clicking this icon  . Hovering you mouse over the Histogram will allow you to inspect individual bins for their respective R, G, B, or Unprocessed values. Use the ***Linear sRGB Image Type*** for more consistent RGB bin values. For color images each of the R, G, B waveforms can be turned on or off using the corresponding check box.

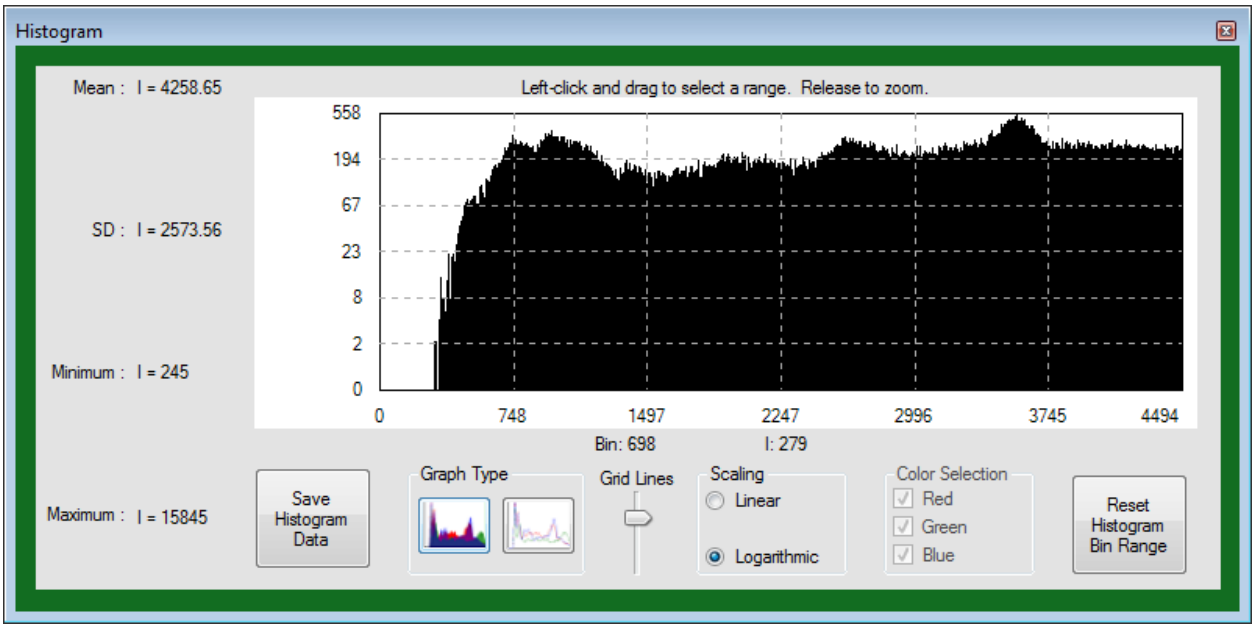
The histogram data can be saved to a text file using the Save Data button, and imported into a spreadsheet as a comma delimited file for further evaluation.



Bar Histogram



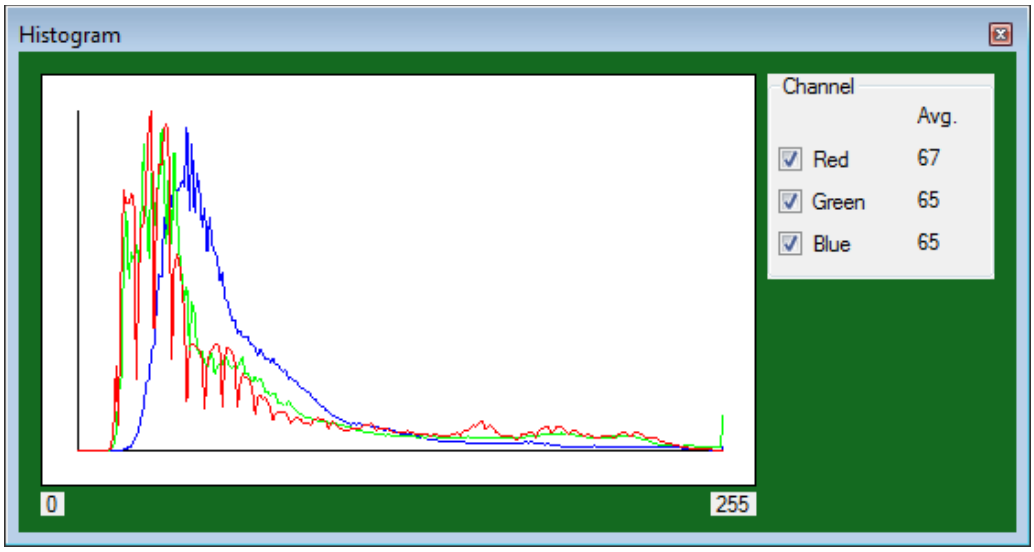
Line Histogram



Monochrome Bar Histogram

DCx-Series Cameras:

The histogram for the DCx-Series cameras is shown below and contains very few of the features provided for our scientific cameras. Color cameras can display all or none of the R, G, B waveforms, along with the average value of each.

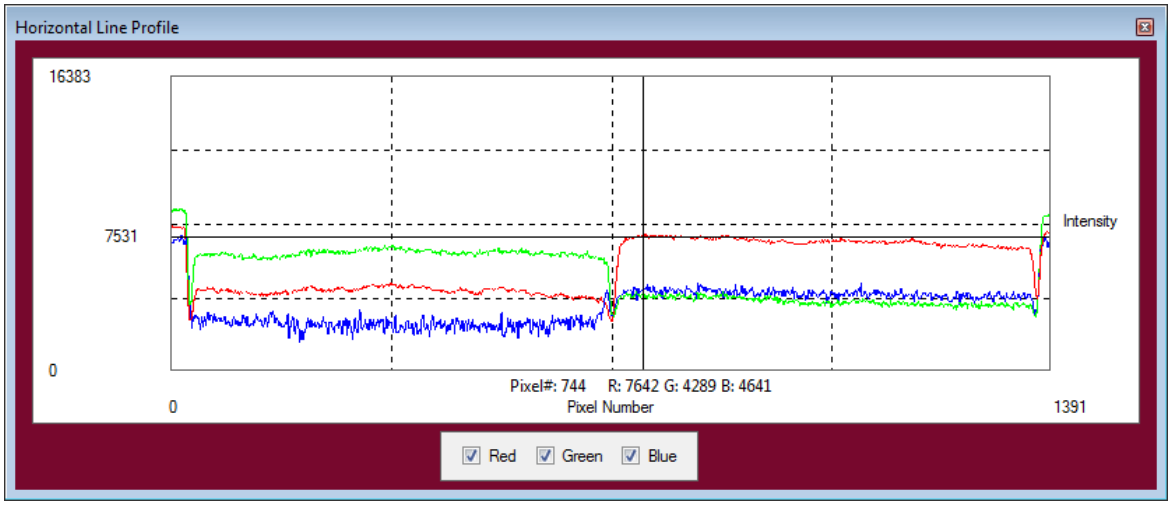


DCx-Series Histogram

A note about histograms: Due to the method that the histogram values are calculated, in conjunction with the various color balancing gains applied to the digital data received from the camera, there may be certain conditions that result in a histogram having the appearance of missing data bits. This is not an indication of poor image processing from the camera and only a side-effect of the complexities of the graphical representation of the data.

3.5.7. Horizontal Line Profile

Draws a horizontal line across the image and displays the values of the pixels along the line in a separate window. The position of the line can be moved by left-clicking anywhere in the image. With your cursor anywhere within the profile graph, a set of cross-hairs appear allowing you to measure the intensity of specific pixels. For color cameras, individual R, G, B plots can be viewed or turned-off by checking the appropriate box. Clicking on the Horizontal Line Profile icon a second time removes the line and window.



3.5.8.  Vertical Line Profile

Draws a vertical line across the image and displays the values of the pixels along the line in a separate window. The position of the line can be moved by left-clicking anywhere in the image. Other functionality is the same as the Horizontal Line Profile. Clicking on the Vertical Line Profile icon a second time removes the line and window.

3.5.9.  Pixel Peeker

Shows the user the value of the pixel that the mouse is currently over (gray box in center), as well as pixel values in the surrounding neighborhood. This window is resizable to allow viewing of a smaller/larger neighborhood.

3.5.10.  Analysis ROI

Allows a rectangular region to be drawn in the image for analysis such as histogram, mean, and standard deviation, and auto-scaling of the image display. Right-click to de-select. Note: The DCU-series cameras crop the visible area when an ROI is selected. Right clicking un-crops.

3.5.11.  Tally Counter

Launches a tally counter window that allows counting and marking objects in the image. Hold the shift key and left-click to count/mark. Releasing shift key pauses counting and resumes normal dragging and zooming to allow interactivity with the image in between counting.

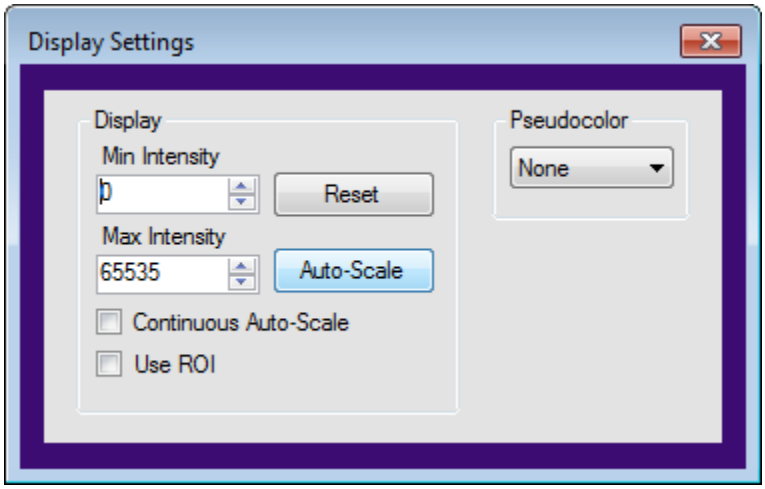
3.5.12.  Image Resize: Fit to Window, Display 1:1, Display 1:2

Fits image to window, maps each display pixel to each camera pixel, maps each display pixel to every 2 camera pixels.

3.5.13.  Reticle

Places a reticle cross-hair target in center of image for visual reference.

3.5.14.  Display Settings



The ***Min Intensity*** and ***Max Intensity*** controls set the contrast of the image. Pixel values equal to or less than the Min intensity level are set to a display value of 0, or black. Pixel values greater than or equal to the Max Intensity level are set to a display value 255 or white. Pixel values in between are mapped to the display linearly from 0 to 255.

The ***Reset*** button resets the Min Intensity and Max Intensity to their default values based on the camera's native bits/pixel.

The ***Auto-Scale*** sets the Min Intensity and Max Intensity according to the image data captured at the time the button is clicked. Auto-Scale ignores extreme outlying values so that the values are not influenced by one or a small number of pixels.

Continuous Auto-scale performs Auto-scale on each frame as they are rendered.

Use ROI works in conjunction with the Analysis ROI tool (See 3.5.10). Draw a box around the specific area of the image that you wish to have the Auto-scale values calculated from.

Pseudo Color provides a means of visualizing subtle intensity differences in a greyscale image. Selecting the ***Rainbow*** option from the drop down menu will colorize a monochrome image by substituting a unique color for each intensity level.

3.5.15.  Plug-ins

Identifies and launches plug-in windows if plug-ins are installed. See 4.1

3.6. Common Annotation functions

Image annotation functions are accessed from the toolbar on the left side of the Live window. The user can select whether or not to save annotations in the Save As or Quick Save dialogs. Not all formats support annotation.

3.6.1.  Draw Freehand, Line, Rectangle, Circle

Clicking on any one enters the annotation mode for that graphical element. Multiple graphical objects can be drawn in succession, and annotation mode persists until either right-click or icon is clicked again to disable. Deletion of each graphical item is done in order using successive clicks of the Undo Last Annotation icon.

3.6.2.  Draw Text

Clicking on the Draw Text icon enters annotation mode for text. Next click on the desired location for the text, which will bring up the text annotation box. Enter text and select font size. Click OK to place text. Multiple text objects can be placed in succession, and text annotation persists until either right-click the Draw Text icon is clicked again to disable.

3.6.3.  Measure

Enters measurement mode. Click on image location to begin measurement. Drag to draw line. Release to end measurement. Result is displayed in units of pixels. Multiple measurements can be made in succession, and measurement mode persists until either right-click or Measurement icon is clicked again. Use Undo Last Annotation to delete.

3.6.4.  Choose Annotation Color

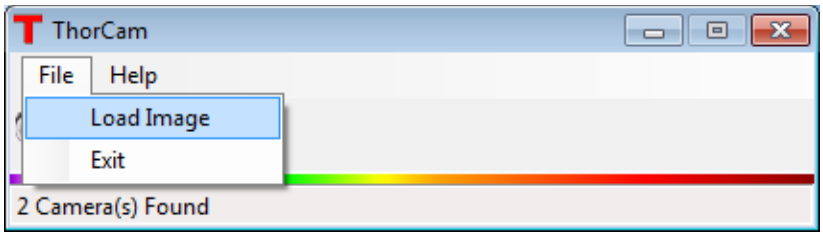
Launches a color-picker window for annotations. Color choice does not affect prior annotation.

3.6.5.  Undo Last Annotation

Deletes the last annotation in the image. Successive clicks will delete multiple annotations in reverse order.

3.7. Reading save images

Saved images can be viewed in Thorcam by loading them using the File->Load Image command in the main Thorcam window:



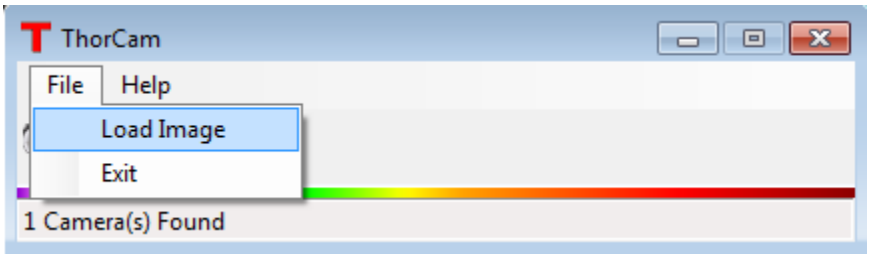
3.7.1.  Multi-Page TIFF sequence Playback Controls

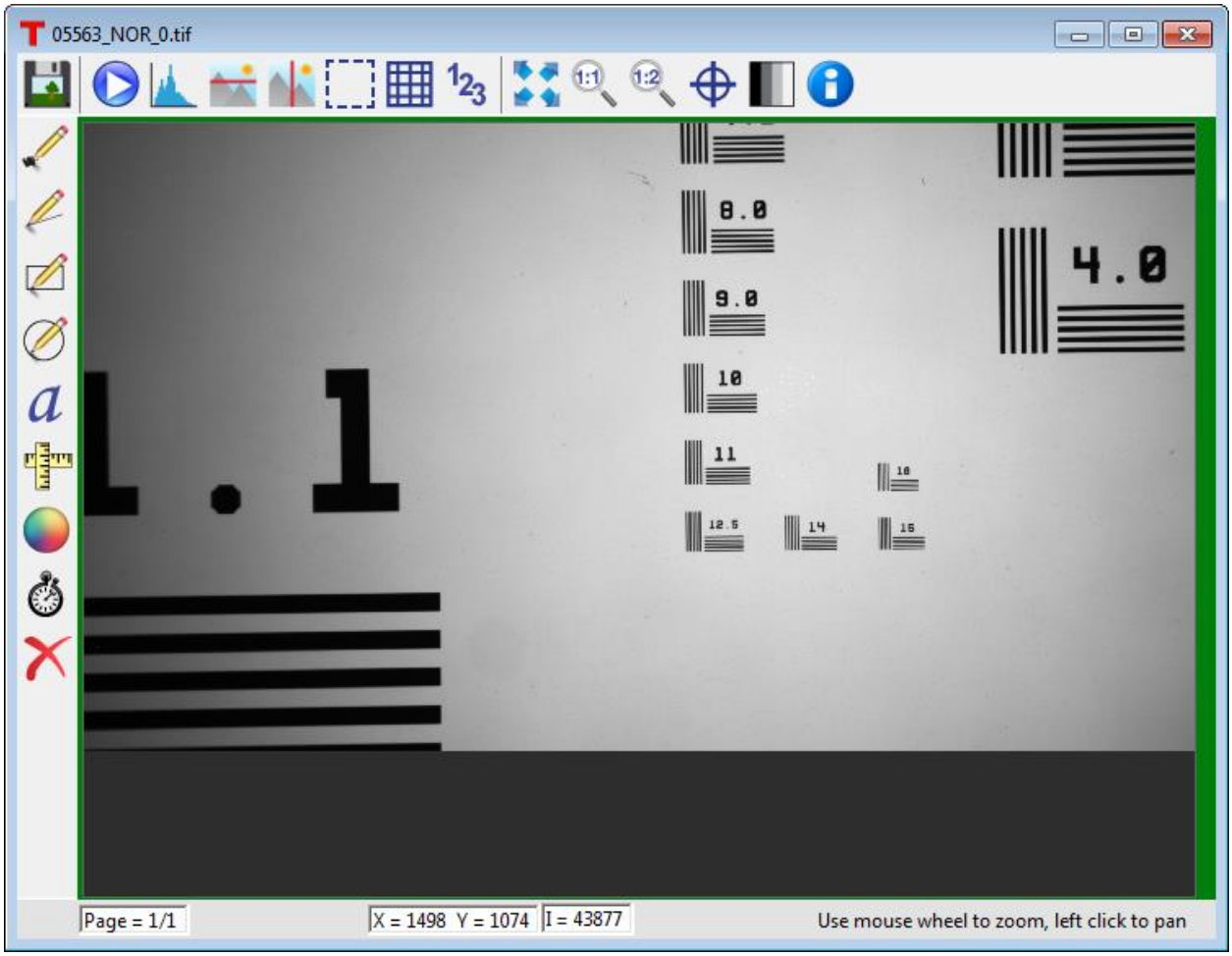
Sequences from scientific-grade cameras are stored in multi-page TIFF format in order to preserve the high-precision, unaltered image data. A multi-page TIFF file is a single file that contains multiple images. ThorCam will read back the multi-page TIFF files it generates during the Record or Timed Series modes and provides a set of

simple controls to play the sequence, step forward or backward one frame at a time, or advance to the beginning or end of the sequence using the control buttons shown above.

3.7.2. Analysis of saved images

ThorCam offers the same analysis/annotation functionality for loaded images that it has for live images.





Chapter 4 Appendix

4.1. Appendix A: Plug-ins

Plug-ins are small, application specific programs provided with ThorCam that allow a user to perform specialized tasks that are not provided in the main ThorCam application. They are accessed by clicking on the Plug-in icon along the top row of function icons. There is currently a limited number of Plug-ins that come standard with the ThorCam installation. More may be added as the need arises.

4.1.1. The Two Camera Overlay Plug-in

The Two Camera Overlay plug-in is used in conjunction with the Thorlabs Scientific Imaging Two Camera Adapter 2SCM1-DC. The 2SCM1-DC is a two-way camera microscope mount which can be used in a variety of ways to simultaneously image the output of a microscope split by a dichroic mirror or a plate beam splitter to two cameras. The Two Camera Overlay Plug-in provides a number of controls to aid in visualizing the outputs of both cameras. This plug-in only works with TSI Scientific Cameras.

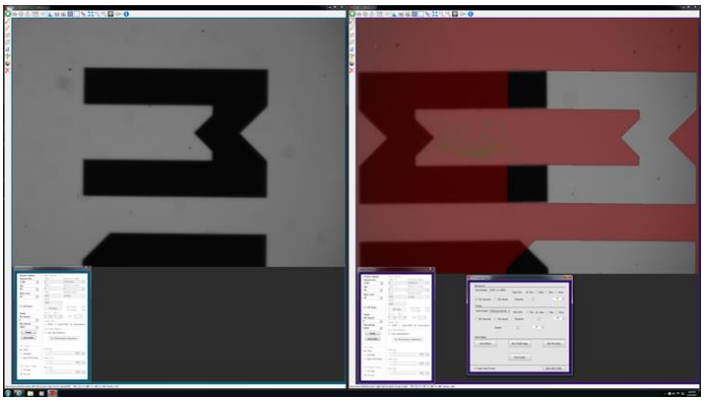
Set-up

Prior to working in the Two Camera Overlay plug-in, you must first focus and align the cameras you intend to use. Refer to the ***2SCM1-DC Two Camera Mount User Guide*** for details on mounting your cameras. Open the ThorCam Software. A small window will pop up telling you how many cameras you have connected. It should register two available cameras; if they are not both showing up, hit the refresh button. Make a note of the serial number associated with each of the two cameras and their respective positions on the 2SCM1-DC (Refer to ***0*** for information on renaming each camera with a more descriptive identifier). The transmitted image is being captured by the camera mounted to the CXY2 while the reflected image is captured by the camera mounted to the LCP02R. Either camera can be used as the Background image, but it is most common to use the transmitted image as the Background Image. From the GUI for the desired background image, open the Two Camera Overlay from the plug-in tab at the top of the window. Click on each of the two available cameras to open their image view windows. Hit the “Play” button in the upper left corner of each window to start live image capture. Depending on the light level used for excitation and the filter/mirror configuration used for your application, the exposure time and contrast levels may need to be adjusted on each camera to capture the desired image. ***Note: setting too long of an exposure time will greatly decrease the frame rate capture of the camera and make the output image choppy in real-time during alignment and adjustment.***

Now you will adjust each camera individually to properly focus the image onto the image sensor. This is accomplished by making slight adjustments to the depth that the ER1 cage rods are inserted into the CXY2 and the LCP02R. Start with the cameras flush against their respective mounts (e.g. with the ER1 cage rods fully inserted). Apply a light amount of pressure to the cage rods with the set screws, just enough that there is a slight resistance to changing the inserted rod depth. By using the embedded line profile tool in the toolbar of the ThorCam Software (see ***3.5.7***) in conjunction with visual inspection of the output image on the screen you can fine tune the focus of each camera’s output image. Bring the image into focus by incrementally sliding the camera away from its mount. When the image is in focus, the peaks of the line profile histogram will be at their tallest and narrowest readings, meaning the greatest amplitude and smallest variance. At this point the output image should appear in its crispest form on the screen. Once this is done for both cameras, tighten the cage rods; you are now ready to align the transmitted and reflected images in overlay.

Alignment

In order to align the transmitted and reflected images you will use the Two Camera Overlay Plug-in. Click on the “Plug-In” button on the toolbar of the transmitted image window and click on “Two Camera Overlay.” When this is done a “TSI Overlay Plug-In” window will open. Choose the second camera from the drop-down list and click on “Start.” Depending on how the reflected image is flipped, you will need to click on either the “Flip Horizontal” or “Flip Vertical” box of the reflected image to orient the two images in the same manner on the screen. Now, using the X & Y plane adjustment knobs on the CXY2 and the rotation adjustment knob on the LCP02R, you can position the two images so that they are perfectly overlaid.



(L) Original Background Image; (R) False colored background image with reflected image overlaid

Operation

The main window of the TSI Overlay Plug-in is used to initiate Overlays, Single Image Saves and Recordings from two TSI cameras.

From the ThorCam main menu window (see section ***3.1***) select the two cameras you will be working with from the drop down selection. You will now have two instances of the imaging GUI open - one for each camera. Determine which camera will be used for the Background image and open the Two Camera Overlay plug-in from that camera's GUI. The name and serial number of the other camera will now be listed in the Overlay section of the plug-in screen.

The main window of the TSI Overlay Plug-in is used to initiate Overlays, Single Image Saves and Recordings from two TSI cameras.

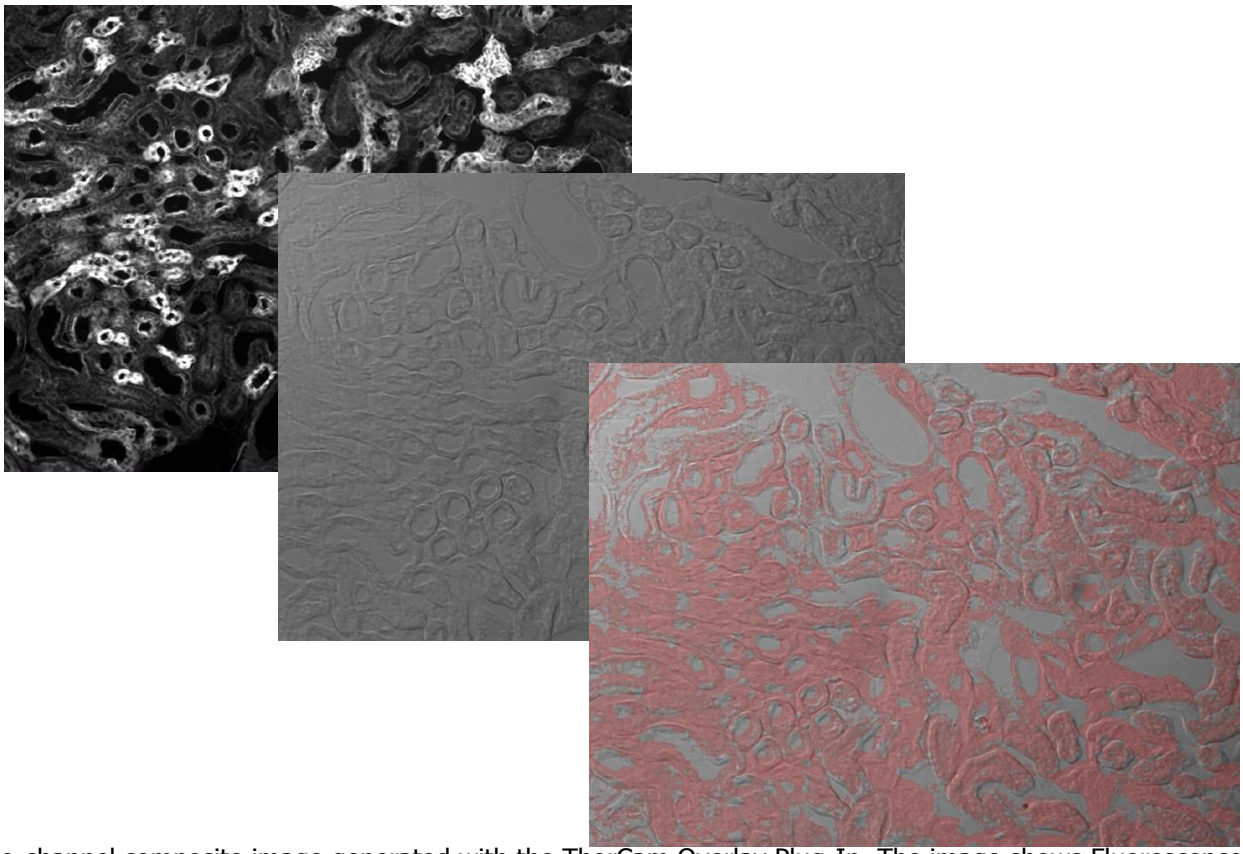
An overlay session is initiated by clicking the Start Overlay button. During an overlay session the image data from a secondary camera will be projected over the image data from the background camera. The image data presented to you during an overlay session can be false colored in order to highlight desired image features. This false coloring will be applied to pixels which have intensity values greater than the threshold set for the selected color channel. For example, if you set the threshold to 127 and select red for

the false color, then any pixel with an intensity value greater than 127 will be false colored to red while all other pixels in the image will be fully transparent. By selecting different false colors and setting the proper thresholds for the images delivered from the background and secondary cameras, different image features can be highlighted for the purpose of differentiation and inspection. This becomes especially useful when using multiple light sources and a dichroic mirror for fluorescence imaging. By selecting the "None" option for false coloring you will simply be overlaying the reflected image on the transmitted image. This is useful when aligning the two images. Two image sources are always required for an overlay session. In addition to setting the intensity threshold for the false colored pixels, the opacity of false colored pixels can be adjusted with the "Opacity" slide bar on the Overlay Plug-in window.

You may also elect the flip the false colored pixels along the X or Y axis to align the information you are seeing to accommodate your needs. The actual image from the background camera is not flipped and only the image from the background camera is displayed in the Live Window hosting your overlay session.

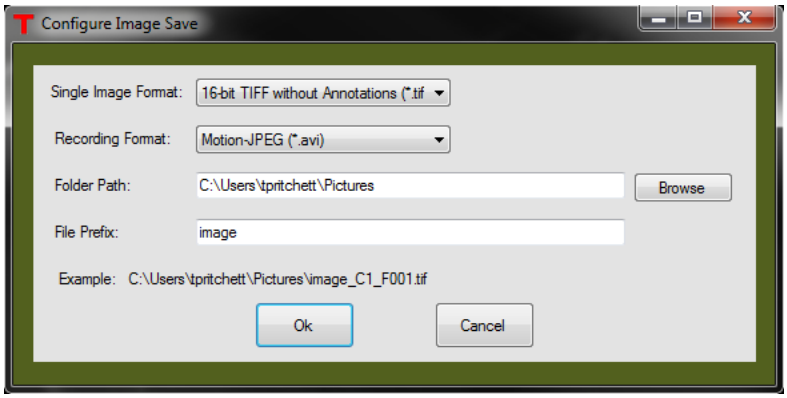
The opacity of false-colored pixels from the background camera and the secondary camera is adjusted with the Opacity slide bar.

At any time you can elect to save individual images or recordings from the background and secondary cameras. An image is saved in its original form from the image source, meaning no false coloring is applied to pixels in saved images. You can configure how images are saved using the TSI Save Configuration Tool for the TSI Overlay Plug-in. To use the TSI Save Configuration Tool click the "Save Options" button on the TSI Overlay Plug-in Main Window.



Live two-channel composite image generated with the ThorCam Overlay Plug-In. The image shows Fluorescence (Pink) and DIC (Grayscale) images of a mouse kidney.

TSI Overlay Plug-in Save Configuration Tool:



The TSI Save Configuration Tool is used to configure how individual images and recordings are saved when using the TSI Overlay Plug-in. You may configure the saving of both individual images and recordings.

To configure how individual images are saved' select an option from the Single Image Format drop-down box. You will notice that annotations are supported when saving images to the PNG or JPG format, however, only 8 bits per color channel is supported when using these image formats. If you require greater fidelity in your images then it is suggested that you use the 16-bit TIFF image format.

To configure how recordings are saved, select an option from the Recording Format drop-down box. Annotations are not supported for recordings. If you require smaller files when recording then it is suggested that you select the Motion-JPEG format and save your recording to an AVI file. If you require greater image fidelity then it is suggested you select the Multipage TIF format and save your recording to a TIFF file. Be aware the Motion-JPEG format uses 8 bits per pixel and are compressed using lossy JPEG compression, while the Multipage TIF format uses 16 bits per pixel and are not compressed, resulting in substantially larger files.

You may select where your images are saved by directly entering a valid path to your desired save folder or by clicking the Browse button and navigating to it. Be aware that you must have write permission at the selected save location.

You may define a file prefix for the artifacts you wish to save. This prefix can be any valid file name. If the filename is already in use at your save location then ThorCam will attempt to generate an unused filename automatically using your requested prefix as a base. ThorCam will append a numeric suffix to your prefix when attempting to generate an unused filename for you. For example if "myFile.tif" already exists at your save location then "myFile_1.tif" will be generated and then "myFIle_2.tif" until an unused filename is discovered or it is determined that it is not possible to generate a unique filename automatically for you.

The TSI Overlay Plug-in will always append a suffix to your filename's prefix using the following convention:

Suffix = _C[Camera number]_F[Frame Number]_Z000.[File Extension]
Ex. _C1_F0001_Z000.tif

Filename = prefix + suffix
Ex.
Prefix = myImage
Suffix = _C1_F0001_Z000.tif
Filename = myImage_C1_F0001_Z000.tif

This convention is used to make it easier for you to identify from which camera a saved image originated and which frame number associates two images from two cameras. Be aware the frame number used is always that from the background camera. The,"_Z000," portion of the suffix is reserved for future use by Thorlabs.

As you select image formats, save locations, and the prefixes for filenames, you will see a preview of the filename generated for you. The actual name of your file is not knowable until the moment your data is stored, because frame numbers are not constant and there is no way to pre-determine whether a filename is already in use at your selected location. The preview is provided to help you understand where your images will be saved and how they will be named, but it cannot tell you absolutely what a saved image will be named at any given moment.

Chapter 5 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at **www.thorlabs.com/contact** for our most up-to-date contact information.

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