



ProAcquire

PSP-CCD-C/M Cameras

Operation Manual (version 3.9)



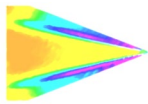


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For questions or comments, please contact ISSI

Innovative Scientific Solutions, Incorporated
7610 McEwen Road
Dayton, OH 45459

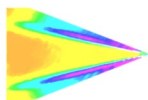
Ph.: (937) 630-3012

Fax: (937) 630-3015

Email: issi-sales@innssi.com

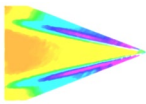
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Revision Date: 5/31/2022

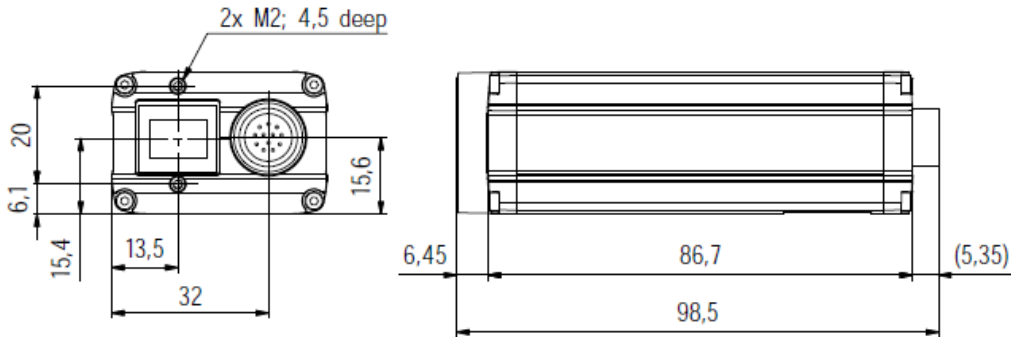


Camera Specifications

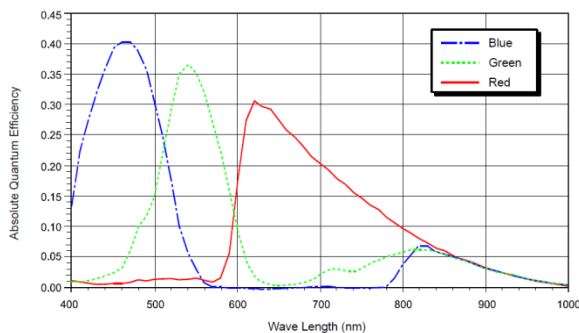
| Sensor | |
|-----------------------------|--|
| Resolution | 1600 x 1200 (2 megapixel) |
| Type | KAI-2020 CCD |
| Format | 11.89 mm (H) x 8.94 mm (V), 14.8 mm diagonal (1" optical format) |
| Pixel Size | 7.4 μm |
| Frame Rate | 35 fps (40 MHz) Standard clock 44 fps (50 MHz) Overclocked |
| Electron Full Well Capacity | 20,000 e^- |
| Readout Noise | 20 electrons |
| Dynamic Range | 60dB |
| Output Format(s) | 8-, 12-bit |
| Binning H/L | 1x, 2x, 3x, 4x, 8x |
| Maximum Exposure | 10 seconds |
| Minimum Exposure | 50 μs |
| Shutter | Global |
| Trigger | |
| Inputs | External (TTL via IN1/IN2), software, computer |
| Options | Level, edge, pulse width, internal exposure |
| Modes | Free-run, standard, double, frame accumulation |
| Strobe Output | Programmable position and duration |
| Communication | |
| Interface | GigE |
| On Board Memory | None |
| Software Interface | ProAcquire |
| Lens Control | Available in ProAcquire (LC-2 integration) |
| Environmental | |
| Vibration/Shock | DIN EN 60068-2-64 |
| Operating Temperature Range | 0°C to 50°C |
| Humidity | 20% to 80% non-condensing |
| Size & Weight | |
| Size | 98.5 mm (L) x 29 mm (H), 44 mm (L) |
| Weight | 220 grams |
| Lens Mount | c-mount |
| Power Requirements | |
| External Power Input | 12-24 VDC |
| Power Consumption | 4.9 W @ 12 VDC |
| Export | |
| ECCN | EAR99 |



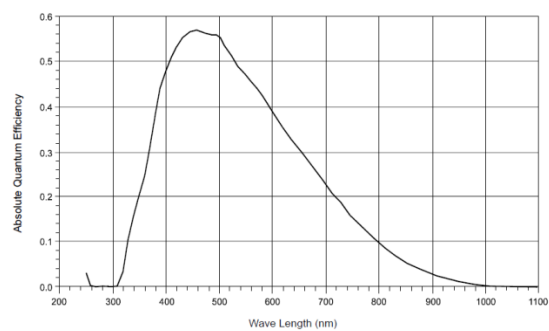
ProAcquire is a software package written for pressure and temperature sensitive paint data acquisition. It can be used with a variety of cameras. The standard camera, the PSP-CCD is a 2-megapixel CCD camera. The camera comes in two styles, one with a color sensor and one with a monochrome sensor. The color camera is used in applications where spectral separation of incoming light is needed such as Binary PSP and particle shadow velocimetry applications. The monochrome version is used in applications where spectral separation of the incoming light is not needed, for example; single luminophore PSP or S3F applications.



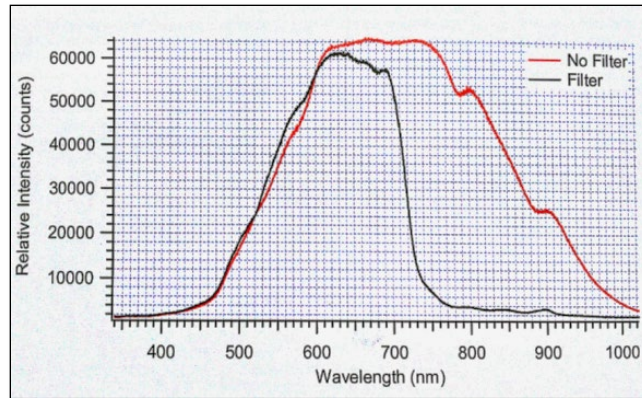
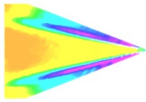
Use of the PSP-CCD-C allows binary pressure sensitive paint data (two separate spectral peaks) to be acquired using a single camera. Rather than use optical filters in front of the camera lens, the filtering is applied on the chip using a standard Bayer filter. In the case of Binary FIB, the signal channel is acquired on the red pixels and the reference channel is acquired on the green pixels. All images are acquired through a single camera and lens and this process minimizes image alignment errors. This single sensor system also accomplishes a second goal, all data is acquired simultaneously, and thus the stability of the illumination source is a less significant issue. The major drawback of this approach is the loss of spatial resolution. In a color chip, only $\frac{1}{4}$ of the pixels are sensitive to the signal channel (red pixels) on the standard Bayer filter. Despite the loss of spatial resolution, the color camera approach produces excellent results at low speeds.



Quantum Efficiency of Color Sensor



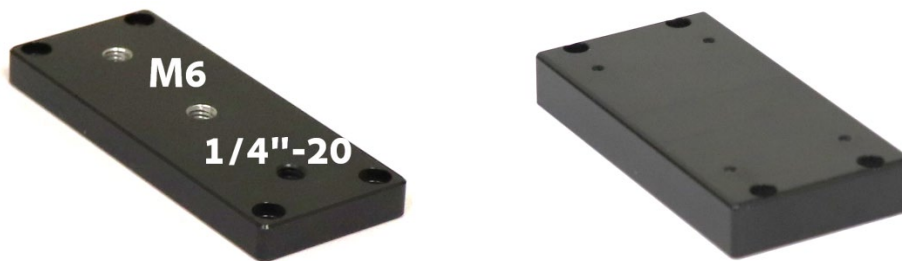
Quantum Efficiency of Monochrome Sensor



Spectral plot of IR Blocking filter in the camera

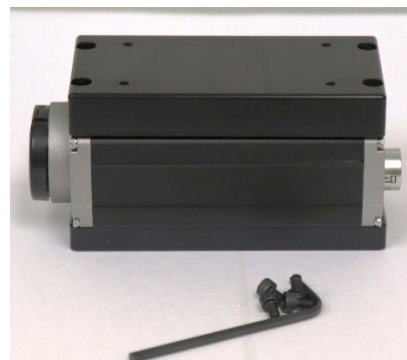
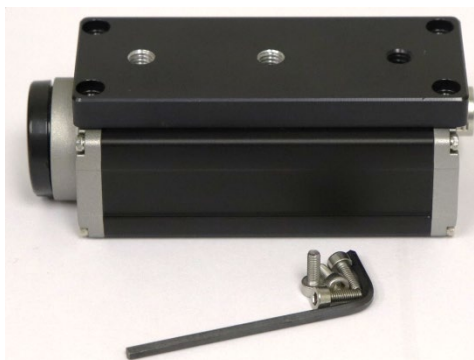
Camera Setup

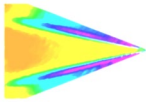
The PSP-CCD camera comes with mounts for camera and accessory mounting.



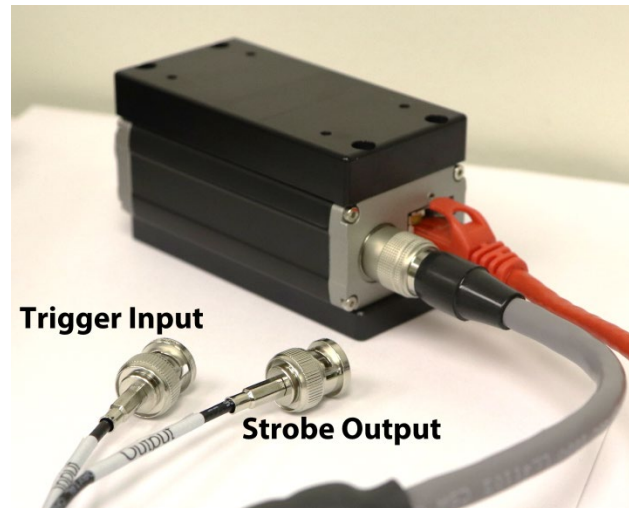
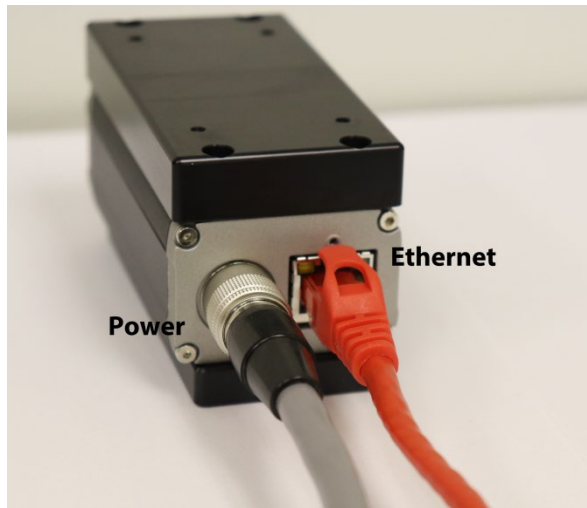
The camera mount (left) has two M6 threaded holes and one 1/4\"-20 hole. The accessory mount (right) is used to mount accessories such as the LC-2 lens controller to the camera assembly.

Locate the mounts in the box. The 4 longer silver M3 bolts are used to mount the camera mount to the camera body. Attach to the side of the camera opposite the label. Secure with supplied hex key. Flip the camera over and attach the accessory mount using the 4 shorter black M3 bolts. Secure with hex key.

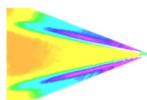




Once the camera is mounted in the desired position, the Ethernet and power connections can be made. Use the supplied Cat6 gigabit Ethernet cable for communication between the camera and computer. This will allow maximum acquisition rate and download speed without dropping frames.

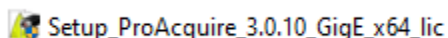


The two connectors labeled **Trigger Input** and **Strobe Output** are used to externally trigger the camera and provide an output pulse mirroring the exposure window respectively. The trigger input can be connected to an external trigger source like the PSG-3. The strobe output can be connected to an LED or other device to synchronize with the camera frame.



Software Installation

The PSP-CCD operates with ProAcquire GigE. The software is compiled for 32- and 64-bit Windows operating systems. It is compatible with Windows XP, Vista, 7, 8 and 10. Locate the appropriate installation file to begin installation.



Note: ProAcquire version 3 is written for cameras purchased November 2018 and later. ProAcquire version 2 is for cameras purchased previously to November 2018.



ProAcquire Version 2

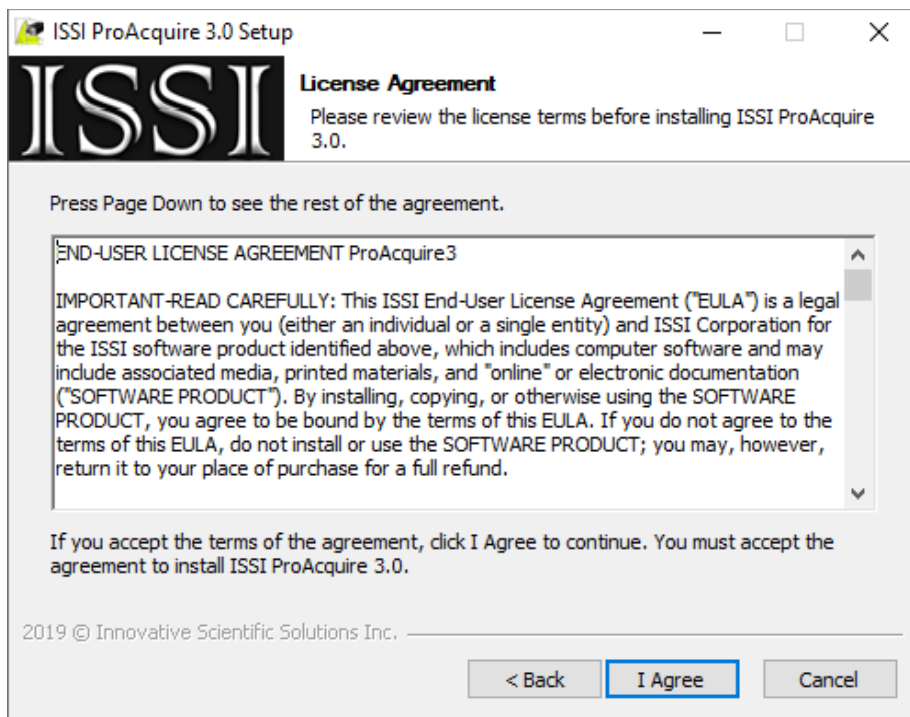
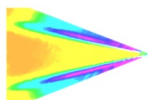


ProAcquire Version 3

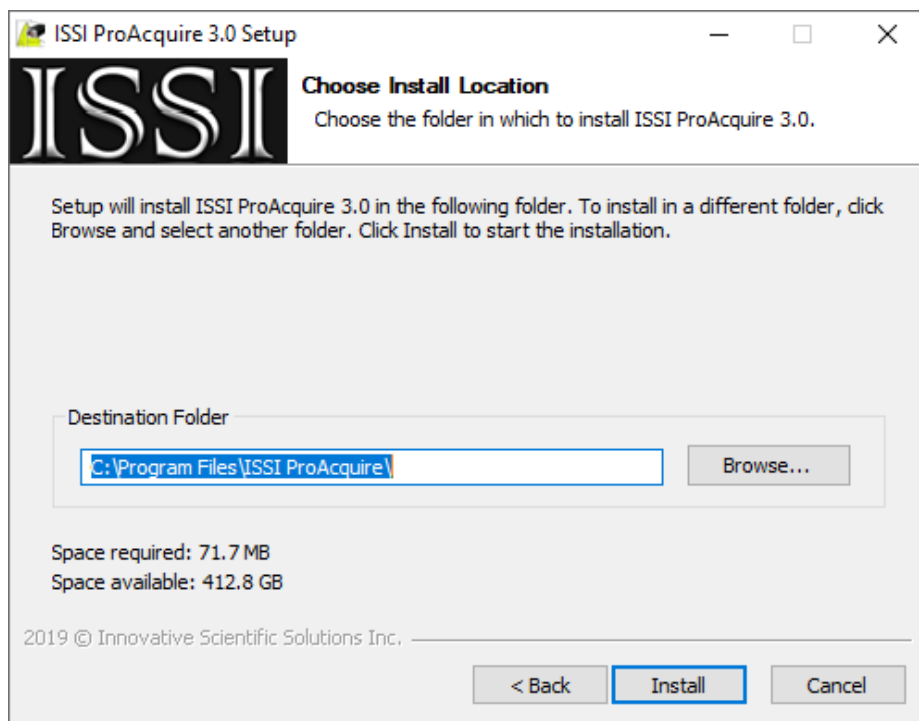
The setup page will open and prompt the user to continue with the installation.

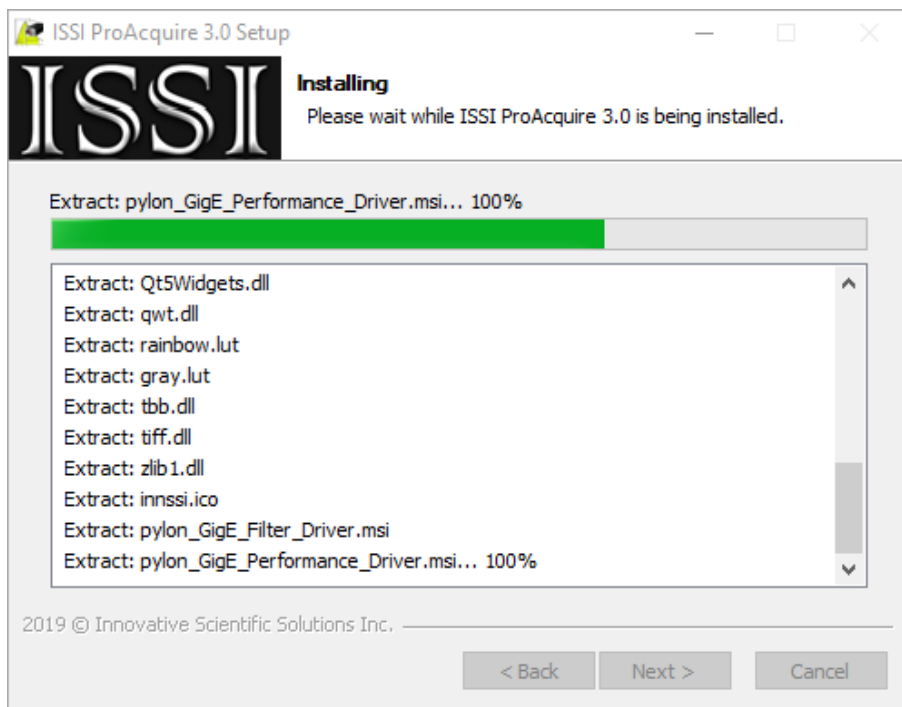
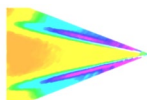


The setup will next open and display the license agreement for the software.



Navigate to the destination where the software will be stored on the computer and proceed with the installation.

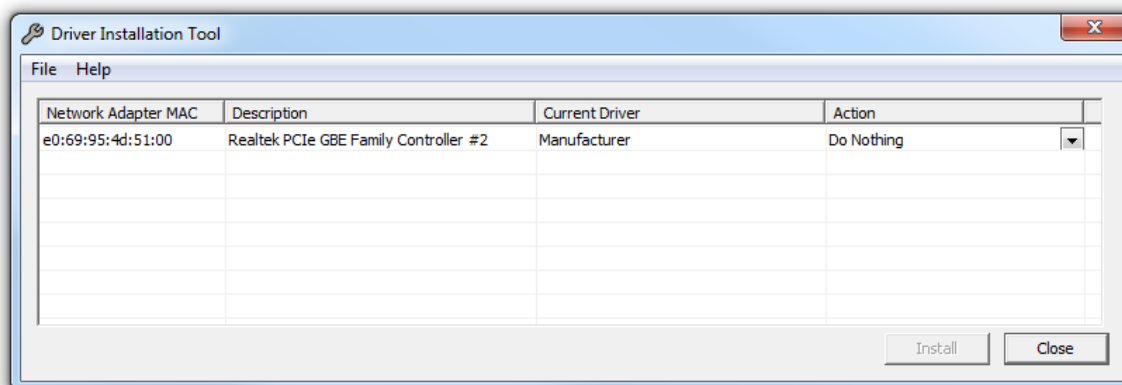


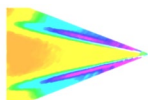


If this is the first time to install ProAcquire, then the drivers will need to be installed to the NIC. If this is an upgrade to an existing version of ProAcquire, the drivers will not need updating, only the software. The installer will ask which option for installation.

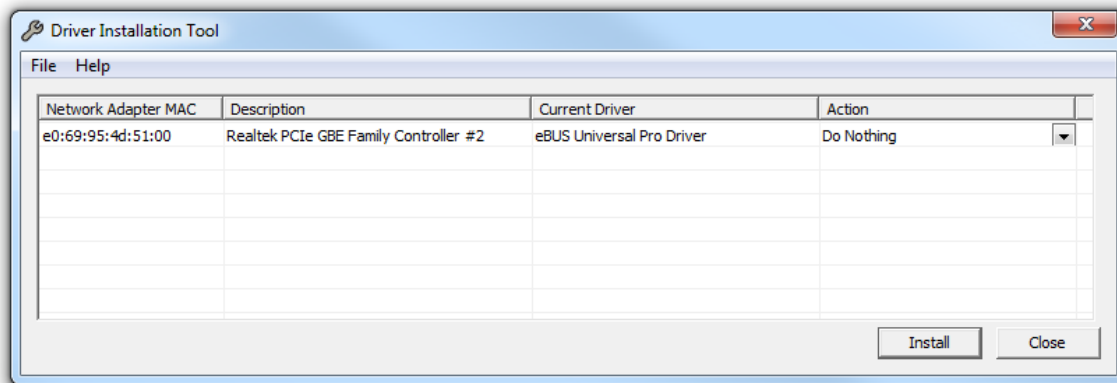
ProAcquire Version 2 Full Install

If a full install is selected, the program will proceed to install the drivers. The eBUS driver installation tool will open and give the option to install the eBUS driver. The driver will be installed on the network interface card on the computer. If the eBUS driver is already installed (as pictured below) select the action 'Do Nothing' and close the window. If it is not yet installed, the 'Current Driver' will be the 'Manufacturer Driver' and the 'Install eBUS Driver' should be chosen for action.



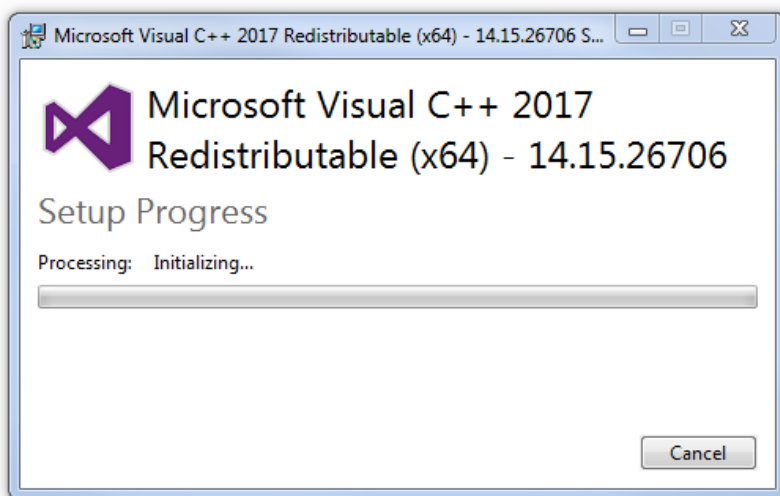
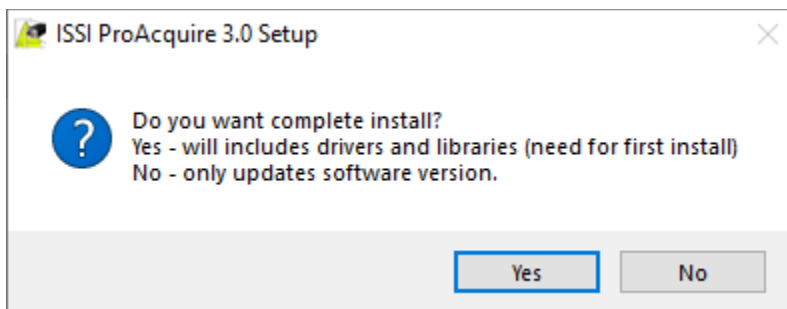


Driver not installed above. Installed below.

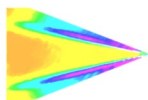


ProAcquire Version 3 Full Install

If a full install is selected, the program will proceed to install the drivers after prompting.



Once installation is complete, reboot the computer.

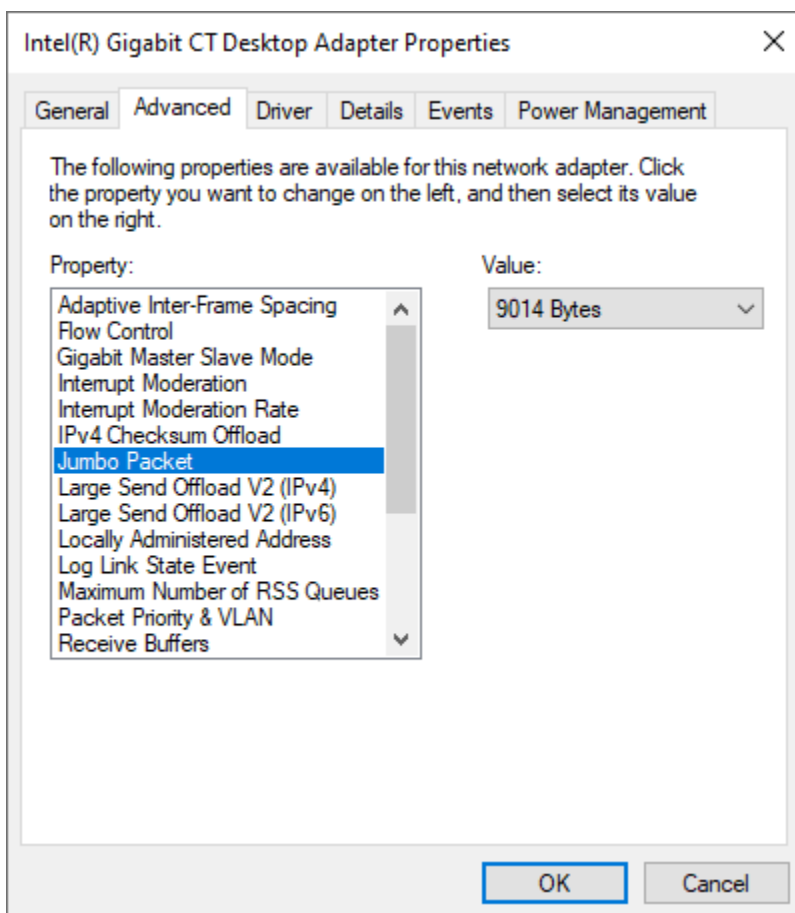


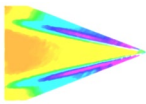
Maximizing Performance

To get the fastest performance from the camera, use a Cat6 Ethernet cable (supplied) and a computer with a Gigabit Ethernet Network Interface Card (NIC). Gigabit Ethernet has a maximum data transfer rate of 1 gigabit per second while fast Ethernet (FE) is limited to 100 megabits per second. Using a computer with a GigE NIC will enable the camera to collect data at its maximum frame rate of 35/44 (normal/overclocked) frames per second. All other Gigabit Ethernet devices should be disconnected from the computer and disabled from the network while using the PSP-CCD. To increase the

frame rate capability on the computer and use the full bandwidth of the NIC, Jumbo frames should be enabled and the value should be set to the maximum for the computer. The maximum values are either 7KB or 9KB MTU. Once the computer has been properly configured for the camera, open the software from the desktop icon to display the GUI. To enable the maximum for jumbo frames, navigate from the Control Panel.

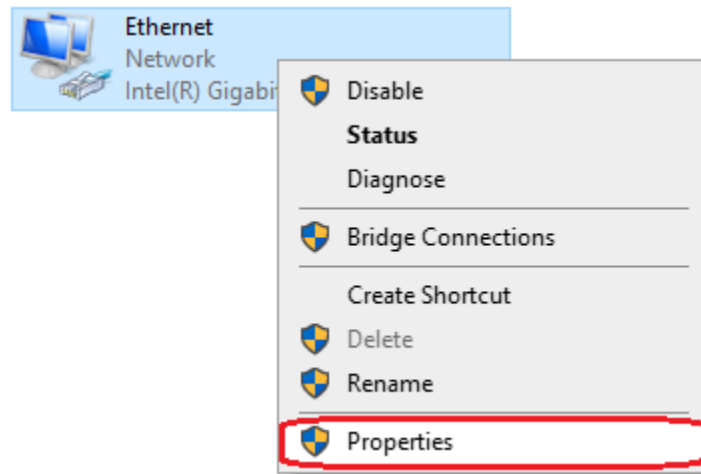
Control Panel > Network and Internet > Network and Sharing Center > Change Adapter Settings > LAN (Right-Click) > Properties > Configure > Advanced > Under 'Properties', select 'Jumbo Frame' and set value to maximum.





NIC Network Setup

The network settings on the PC NIC (network interface card) need to be properly configured for communication over the network. To do this, navigate to the *'Network Connections'* page on the control panel where the local networks of the computer is displayed. Right-click on the network where the PSP-CCD is connected and select *'Properties.'*



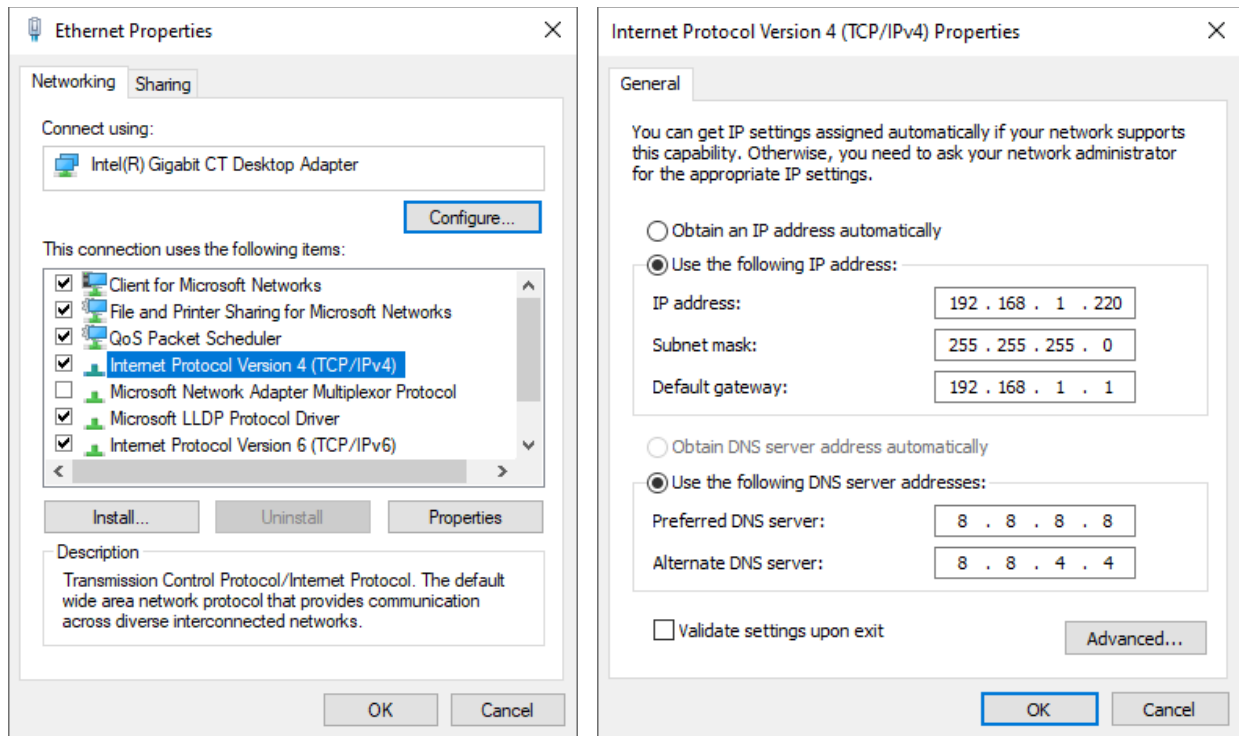
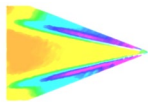
From the *'Local Area Connection X Properties'* window, click on *'Internet Protocol Version 4 (TCP/IPv4)'* and then press the *'Properties'* button, now useable. This will open the *'Internet Protocol Version 4 (TCP/IPv4) Properties'* window. This is where the IP addresses are entered so that PSP-CCD can be reached over the local network. The settings needed for communication are **IP Address** and **Subnet mask**.

The IP address of the NIC should use the following conventions:

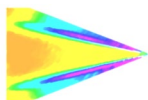
IP Format: **Network.Network.Subnet.Host**

For example:

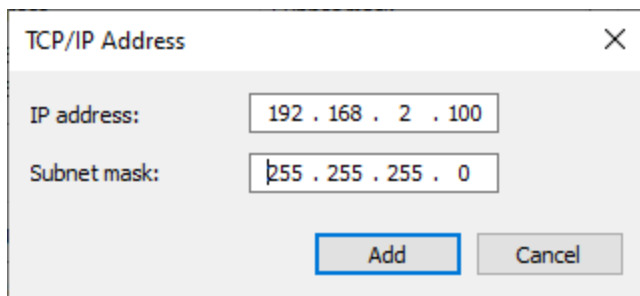
- PSP-CCD IP: 192.168.2.YYY
- NIC IP: 192.168.2.XXX



The NIC IP address should have the same network and subnet addresses but a unique host, the last line of the IP address. The host can be any value 1-254 but different from the host address of the PSP-CCD. The subnet mask should be set to match that of the PSP-CCD which, by default is 255.255.255.0. The **Default Gateway** and all other fields can be left blank.

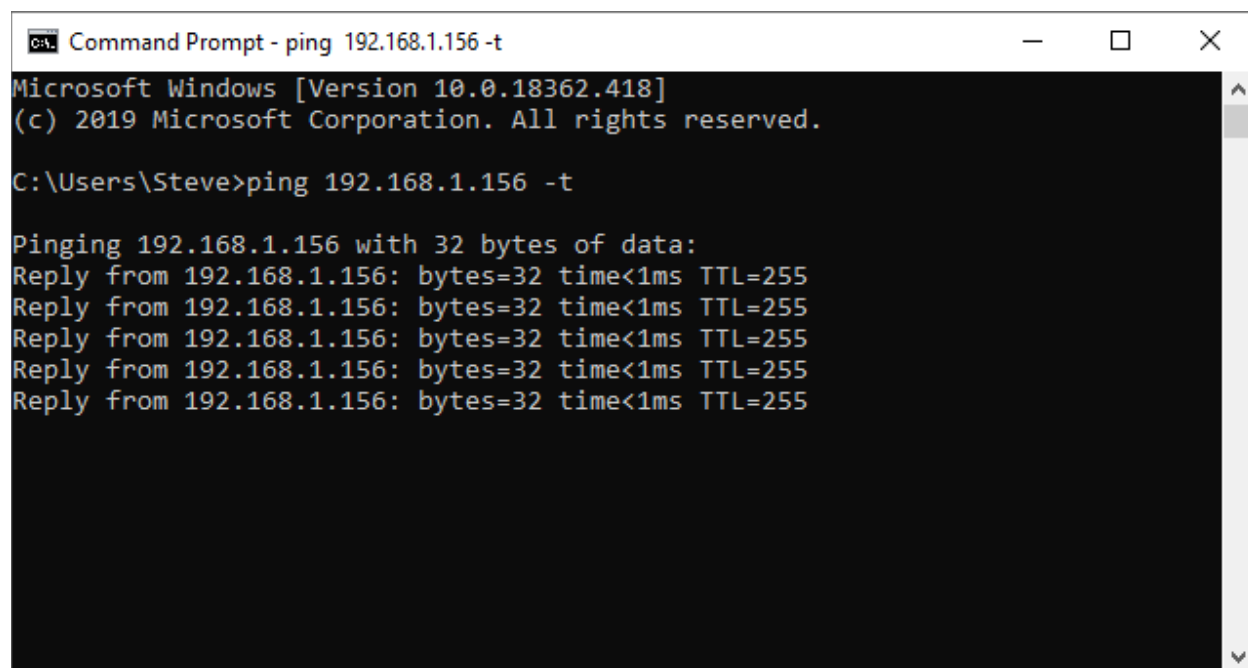


Additional subnetworks can be configured for the same NIC. In the '*Internet Protocol Version 4 (TCP/IPv4)*' window, the **Advanced** button will open the '*Advanced TCP/IP Settings*' window. IP addresses of any subnetwork can be added for that NIC here. If multiple devices are being used on the same network and they have differing subnetworks, this option provides communication for all devices without the need to change IP addresses for each device.



If connection problems persist, check the connection of the Ethernet cable between the computer NIC and the camera. To check that there is a physical connection, ping the IP address of the camera from the Command Prompt. To do this, open the command prompt window and enter:

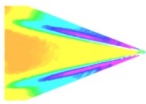
Ping XXX.XXX.XXX.XXX -t



```
C:\> Command Prompt - ping 192.168.1.156 -t
Microsoft Windows [Version 10.0.18362.418]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Users\Steve>ping 192.168.1.156 -t

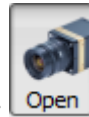
Pinging 192.168.1.156 with 32 bytes of data:
Reply from 192.168.1.156: bytes=32 time<1ms TTL=255
Reply from 192.168.1.156: bytes=32 time<1ms TTL=255
Reply from 192.168.1.156: bytes=32 time<1ms TTL=255
Reply from 192.168.1.156: bytes=32 time<1ms TTL=255
Reply from 192.168.1.156: bytes=32 time<1ms TTL=255
```



Software Interface

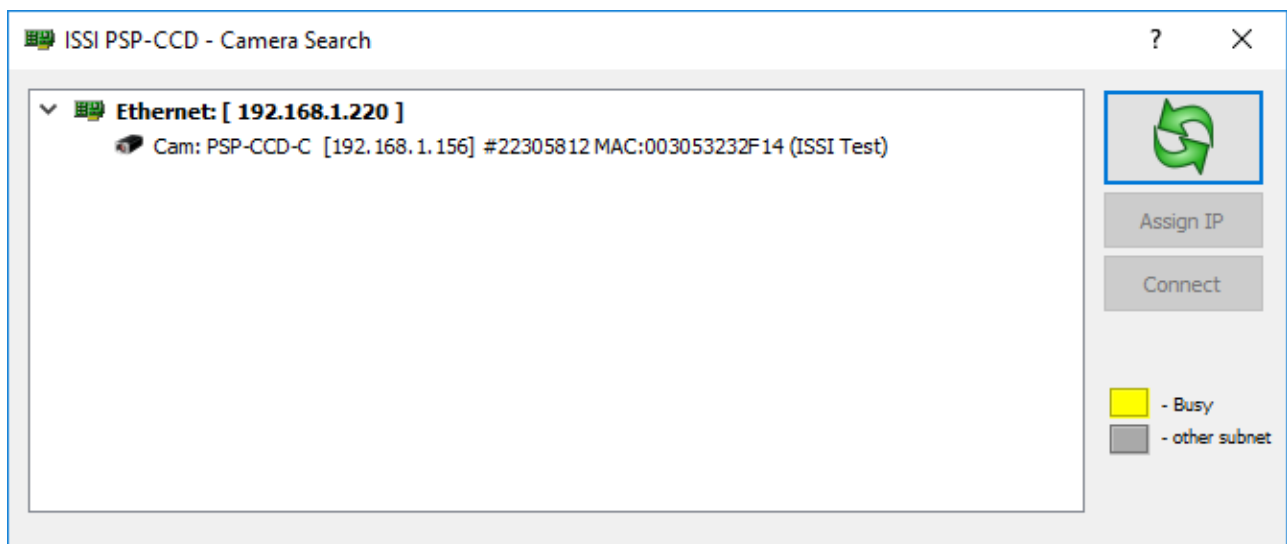
ProAcquire is the software package used with the PSP-CCD. There are three acquisition capabilities of the camera and each has its own control interface within ProAcquire. ProAcquire is made to be a simple and effective interface for the user that is directly compatible in output file format with ISSI post processing software.

Opening the software will open the main page of the software. At this point, the software will be inactive since no camera has been selected.

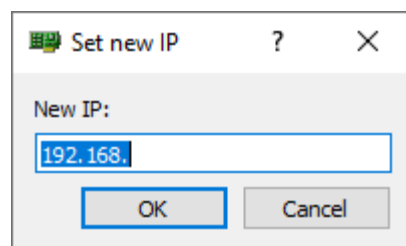


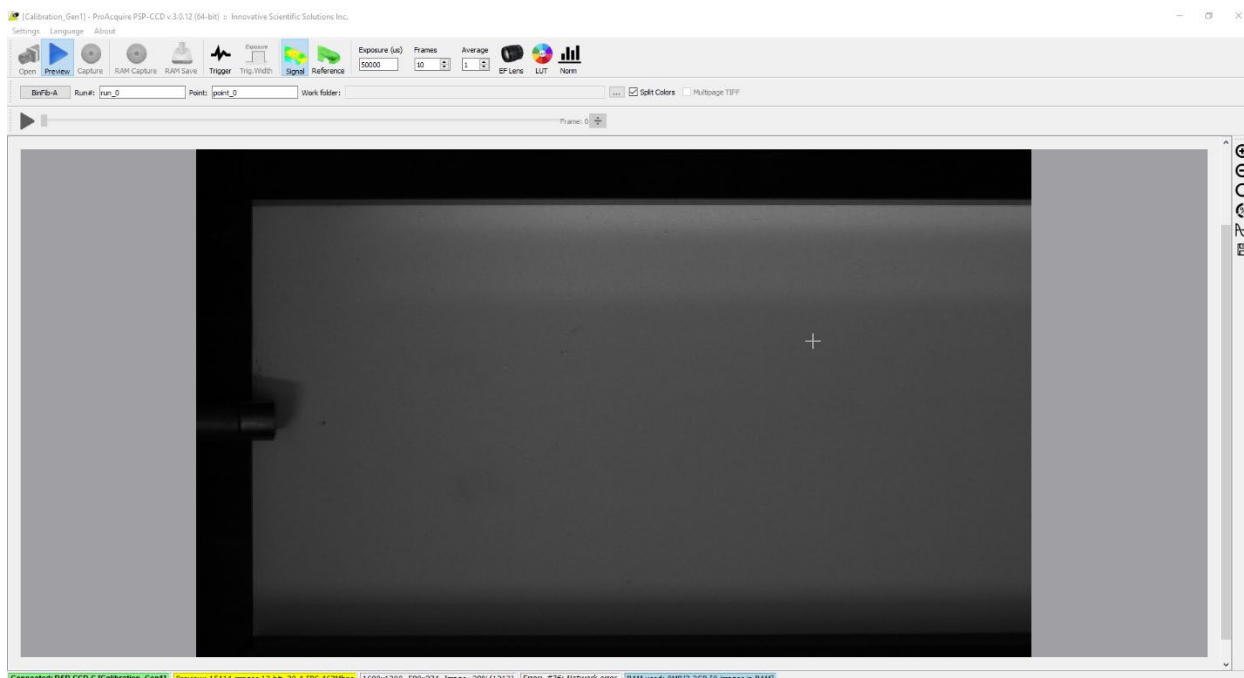
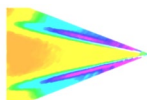
To connect to a camera, press the 'Open' button:

This will show all connected cameras with their IP addresses and serial numbers.



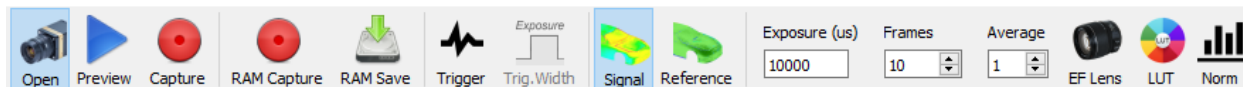
A camera highlighted in yellow is busy and connected to another computer running ProAcquire. If a camera is displayed in grey, its IP address does not match the local network and should be changed to match the local network. To do this, click on the camera in grey and press **Change IP**. Once the IP address matches the local network, the text will change to black. Double-click on the camera to open.





Once the features have been activated, the buttons will show color meaning the camera is connected.

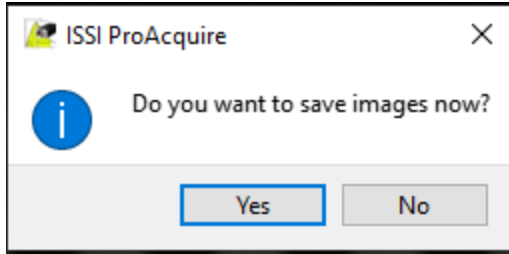
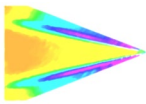
Image Acquisition



Preview will display a preview of the camera view. This can be externally triggered and will operate at the maximum repetition rate possible based on the sensor and exposure settings.

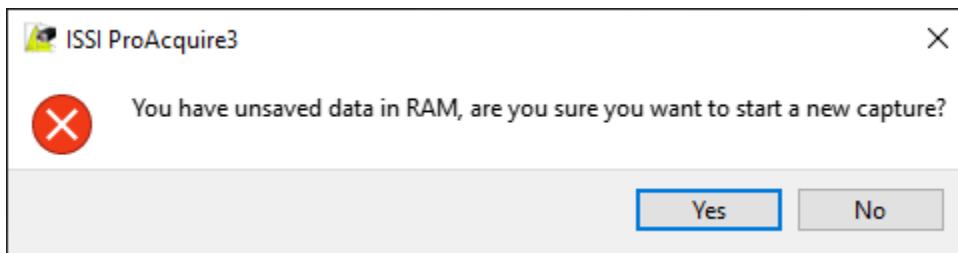
Capture will capture the prescribed number of **Frames** given by the user and then stop.

RAM Capture allows the user to save data with RAM without streaming the data to the hard drive for real-time viewing. Once data is captured in RAM, ProAcquire will ask if data will be downloaded from RAM.

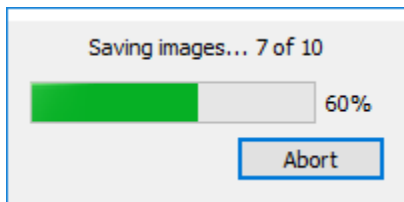


will scroll through data currently saved in RAM.

If data from RAM has not yet been downloaded, a warning will appear if a new RAM capture is started.



RAM Save will save all data from **RAM Capture** to the designated **Work Folder**.



Show Probe Ratio S/R () displays the Red/Green channel ratio from images currently stored in RAM.

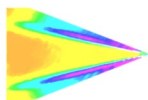


Trigger will start acquisition (**Preview** or **Capture**) once initiated by external trigger.

Trig. Width will take the pulse width of an external trigger to use for the exposure time of the camera. If selected, **Exposure** will be disabled.

For the color camera (PSP-CCD-C), the **Pressure** and **Reference** buttons will be enabled. This enables the user to switch the display on the screen between red (pressure) and green (reference) channels on the array.

Exposure is the exposure time of the camera (in microseconds).



Frames is the number of images the camera will capture in **Capture** mode.

Average is the number of individual frames which will be averaged per **Frame**. For example, to acquire 2 frames, each an average of 50 frames, the number of frames would need to be set to 2 and the number of averages would need to be set to 50. This will save 2 total frames, each an average of 50 frames in the work folder. This is different than the averaging operation used in ProAcquire v2 so note this difference in averaging convention.

Frame and average settings:

| Exposure (us) | Frames | Average |
|---------------|--------|---------|
| 50000 | 2 | 50 |

Images saved:

Name ^

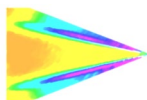
- run_0_point_0.settings
- run_0_point_0_000001_p.tif
- run_0_point_0_000001_r.tif
- run_0_point_0_000002_p.tif
- run_0_point_0_000002_r.tif
- run_0_point_0_p.lst
- run_0_point_0_r.lst

The image list above shows split images using a color camera.

Note: Average frames are always saved for the sum of the images taken whether averaging is being used or not. Each time a set of images is saved; there will also be a .LST file with the same prefix as the images acquired. This is list file containing all images from that acquisition. Opening the list file in Prolmage and then converting to a TIFF file will give the average for all images acquired in the sequence.

List file listing single images saved:

```
run_0_point_0_000001_p.tif
run_0_point_0_000002_p.tif
run_0_point_0_000003_p.tif
run_0_point_0_000004_p.tif
run_0_point_0_000005_p.tif
run_0_point_0_000006_p.tif
run_0_point_0_000007_p.tif
run_0_point_0_000008_p.tif
run_0_point_0_000009_p.tif
run_0_point_0_000010_p.tif
```

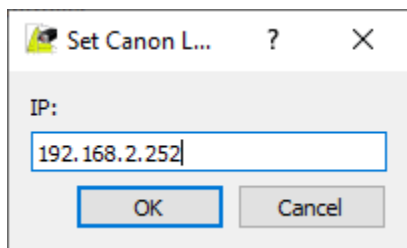


Overclock will put the camera into overclocked mode, giving it a maximum frame rate of 44 fps versus the standard 35 fps. Overclocked mode is not recommended unless necessary as it creates more shot noise in the acquired images leading to lower data quality (Only available with ProAcquire version 2).

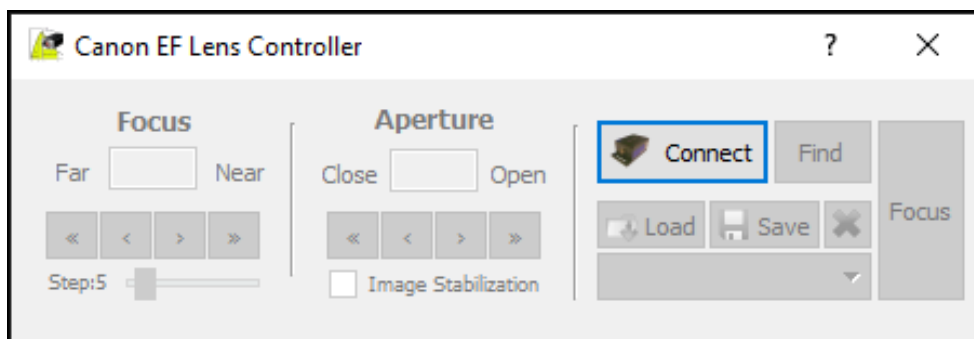


EF Lens controls the LC-2 Canon® lens controller if it is connected on the local network. Click the icon to open.

Press “Connect Lens” and enter the IP address of the lens controller to open communication.



The control interface will then be active so the parameters can be adjusted.

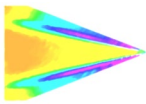


The lens control user interface displays the current positions of the Focus and Aperture. There are two sets of arrows below this which are used to move the position of the motor. The single-arrow moves the focus one step increment and the double-arrow moves the focus 2x one step size for coarse adjustments. Step size can be set from 1 to 50.

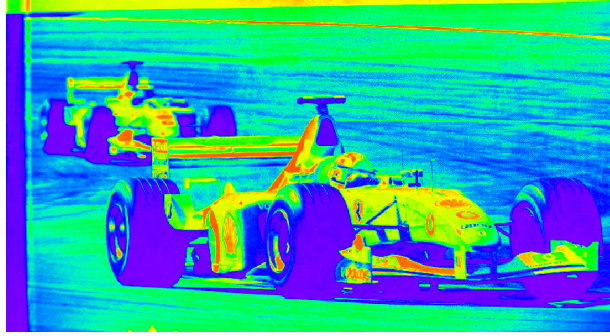
Display Options



LUT is the lookup table. This applies a false color map to the image in the preview window. The image will be saved as grayscale, this is only a visual aid to show features in better contrast. The **LUT** will also auto-adjust the scale so that images in very low-light can also be seen.



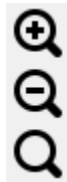
No Look-Up-Table



Look-Up-Table Applied



Norm will display a normalized preview of the image by shrinking the range of pixel intensity values so the image is easier to see. Useful for focusing or in low-light applications where the signal levels are very low.



Zooming tools are incorporated on the side panel. The mouse wheel also zooms the image.



Shows image intensity as percent of dynamic range of image sensor. Enabled by default.



Shows image intensity in counts (bits). Click to enable.

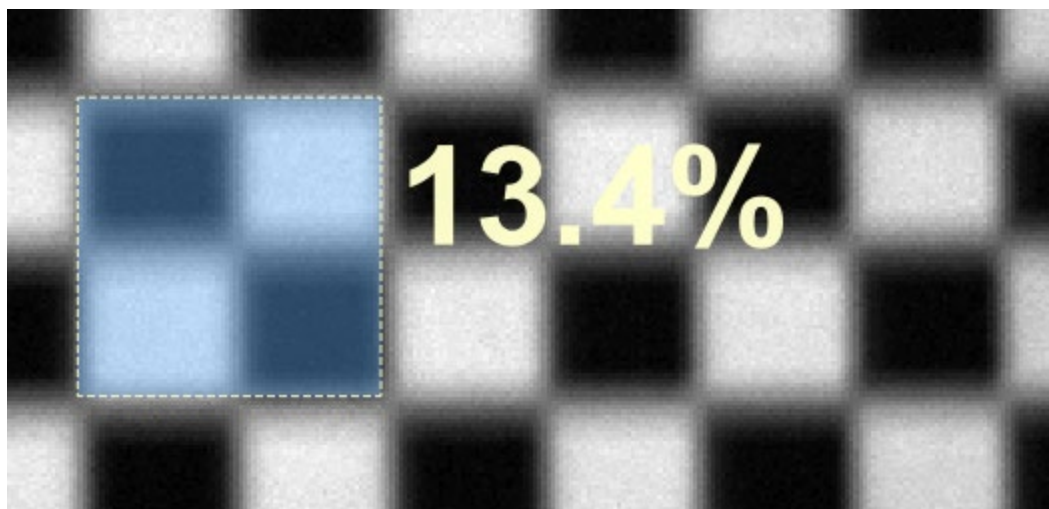
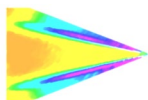


Plotting tool to show the intensity or percentage across the image.

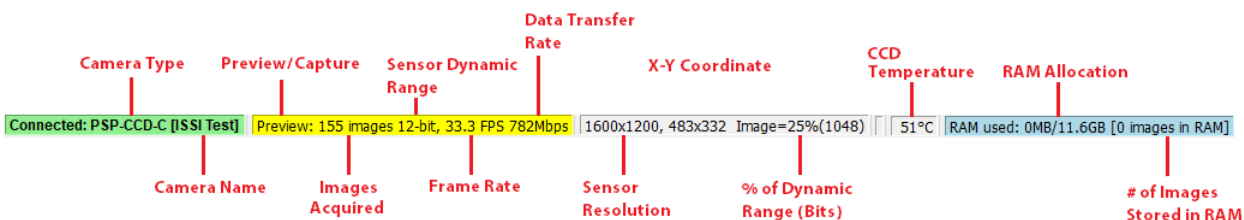
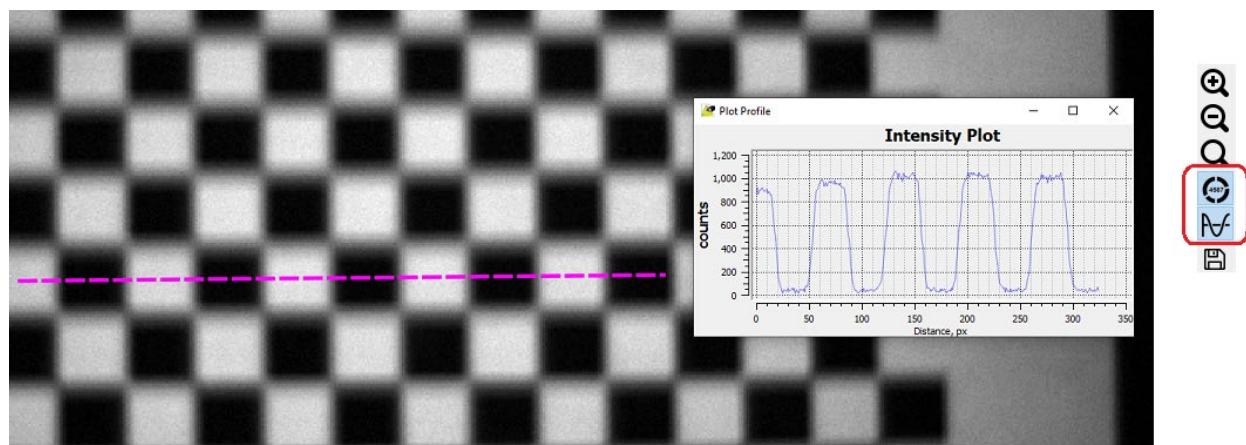


Save current view to PNG, JPEG or BMP file. Used for preview only, not a representation of processed data.

Drawing a box around a region of interest on the image will show the image percentage or intensity value over that area. This feature is enabled by default.

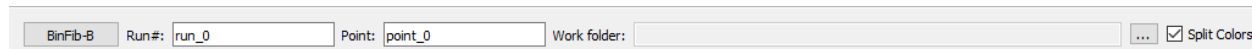


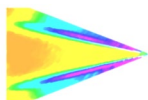
When enabled, the plotting tool allows the user to probe the camera view and spatially plot the intensity values. This is useful for real-time preview of the data during acquisition.



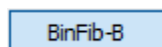
The bottom toolbar displays information about the camera settings and image acquisition parameters as shown above. Some of this information can be changed in the settings while other parts are just displayed to monitor or for reference.

Image Saving

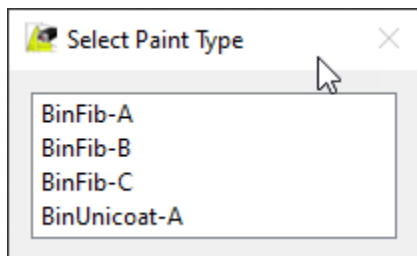




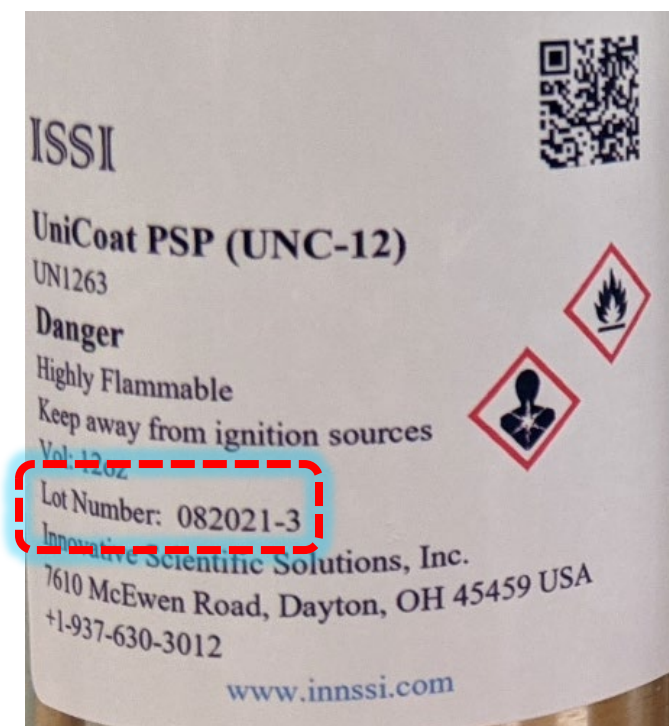
The first box on the left displays the paint type. This is only needed when using color cameras and Binary PSP. The most recent batch of BinaryFIB® for example, is **BinFIB-B**, the default selection.

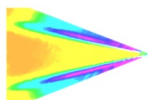


This paint selection should be done prior to acquisition and is saved with the raw data. Paint bottles of Binary PSP will display the paint type which should be selected. If you are unsure, please contact ISSI with the Lot Number at support@innssi.com.



Lot number displayed on the PSP/TSP container:





Run# is the file name of the image. This is also the name of a subfolder that will be created within the designated file path. All images stored in the folder created will have the same Run# prefix. These images will be enumerated for sequential images with the same name taken in the same stream. If images are acquired and saved and then the file name or directory is unchanged, the new acquisitions will overwrite the previous. A settings file will be saved with each image capture, saving the camera settings from that acquisition.

Test > CAM_CAMERA.1

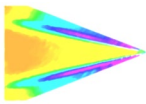
| Name | Date modified | Type | Size |
|-------|--------------------|-------------|------|
| Run_1 | 11/5/2019 11:37 AM | File folder | |

Point is the description of the image in the run. Images with different Point names but with a common Run# will be stored in the same subfolder. For example:

Run#: Run_1

Point: OFF, ON (2 separate image sequences captured)

| | | | |
|--------------------|-------------------|---------------|--------|
| Run_1_OFF.settings | 11/6/2019 1:51 PM | SETTINGS File | 1 KB |
| Run_1_OFF_000001_p | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_OFF_000001_r | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_OFF_000002_p | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_OFF_000002_r | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_OFF_p.lst | 11/6/2019 1:51 PM | LST File | 1 KB |
| Run_1_OFF_r.lst | 11/6/2019 1:51 PM | LST File | 1 KB |
| Run_1_ON.settings | 11/6/2019 1:51 PM | SETTINGS File | 1 KB |
| Run_1_ON_000001_p | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_ON_000001_r | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_ON_000002_p | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_ON_000002_r | 11/6/2019 1:51 PM | TIF File | 938 KB |
| Run_1_ON_p.lst | 11/6/2019 1:51 PM | LST File | 1 KB |
| Run_1_ON_r.lst | 11/6/2019 1:51 PM | LST File | 1 KB |



Work Folder is the directory where the images will be saved to. The camera has no on-board memory so all images will be streamed directly to this folder.

Split Colors should be checked when using a color camera. By default, this option is enabled when connected to a color camera. For monochrome cameras, this option will not be available. This feature will split the image into the 4 color channels on the camera. The software will only save the two needed for data processing, the red (pressure) and green (reference). Below is an example of split color and monochrome saved data.

Run_1_000002_p
Run_1_000002_r

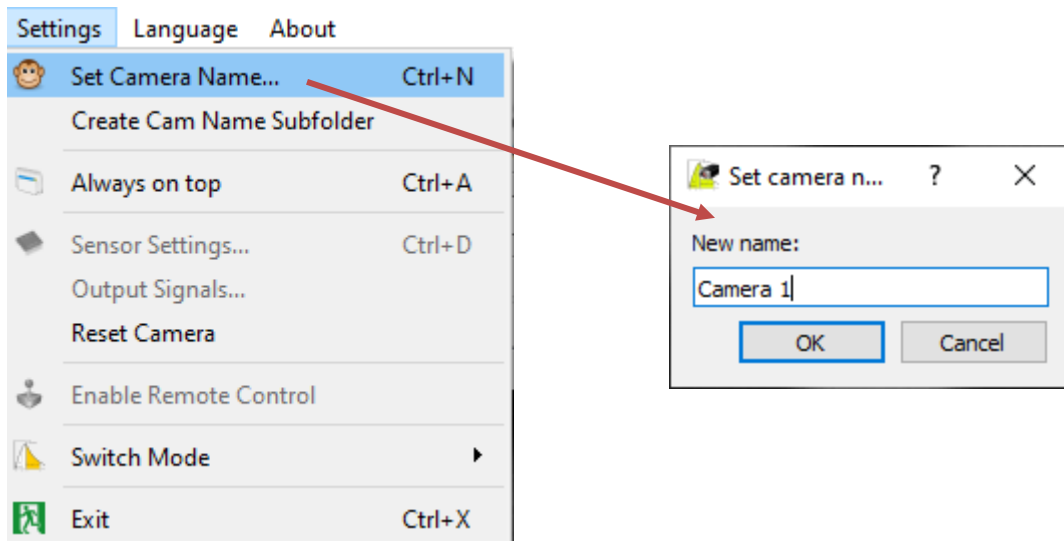
Pressure sensitive (red) images will have the extension **_p**, while reference (green) images have the extension **_r**. Monochrome camera images will have no such extension.

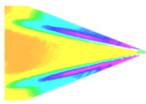
Note that the resolution of the color camera split images is one fourth of the total resolution of the camera due to this splitting.

Settings

The **Settings** tab contains additional options for camera customization and control.

A unique name can be assigned to the camera. This is especially useful if an array of cameras is connected and unique identifiers are needed to differentiate them.





Create Cam Name Subfolder will create a subfolder within the **Work Folder** with the name of the camera that was set by the user. This is typically used in multi-camera configurations. To enable this option, simply click the text.

Subfolder created in Work Folder:

Test

| Name | Date modified | Type |
|--------------|--------------------|-------------|
| CAM_CAMERA.1 | 11/5/2019 11:37 AM | File folder |

Run# folder inside camera name subfolder:

Test > CAM_CAMERA.1

| Name | Date modified | Type | Size |
|-------|--------------------|-------------|------|
| Run_1 | 11/5/2019 11:37 AM | File folder | |

Always on Top will lock the ProAcquire window at the front of your screen so that no other program is displayed over top of it.

Sensor Settings allow the user to change the settings on the sensor array and display. To change any sensor settings, the camera must be taken out of **Preview** mode first.

Sensor Settings

limit FPS: 1000.00 Hz → Sets the maximum frame rate of the camera

Speed: Normal

*Depth: 12-bit → Sets the bit depth of the sensor. Options for 8- or 12-bit

Binning: x1

* Stop Preview/Capture first

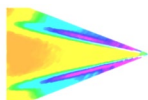
Data Correction

Black Lev.: Off

Flat Field: Off

V.Smea: Off

Speed options are normal (35 fps) and overclocked (44 fps). Overclocked data will be noisier than normal mode. The max frame rates are for full frame, no binning.



Depth is the bit depth (dynamic range) of the sensor. This is the ratio between the smallest and largest values of intensity. This is the scale used to display the intensity scale on the bottom toolbar. Choices are 8- and 12-bit.

Binning is a way of low pass filtering the camera array. It takes an X by Y pixel block (user sets the size of that block here) and makes those pixels all the average value. This should **ONLY** be done with a monochrome camera. This function is disabled for color cameras.

Data Correction is sensor array feature corrections. User cannot edit these functions.

Note: The maximum speed the PSP-CCD camera can run at is 188.4 fps, binning by 8, using 8-bit mode and two tap mode overclocked.

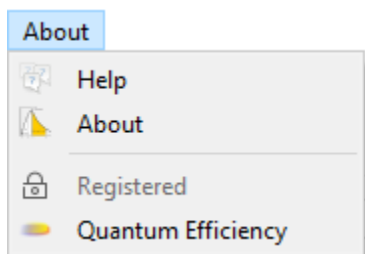
Output Signals controls the function of the “Strobe” output on the power supply. Disabled for most cameras.

ExposureWindow is the default and puts out a pulse with the same width and frequency as the camera frame.

Output Signals is disabled for ProAcquire v3.0.0 and later.

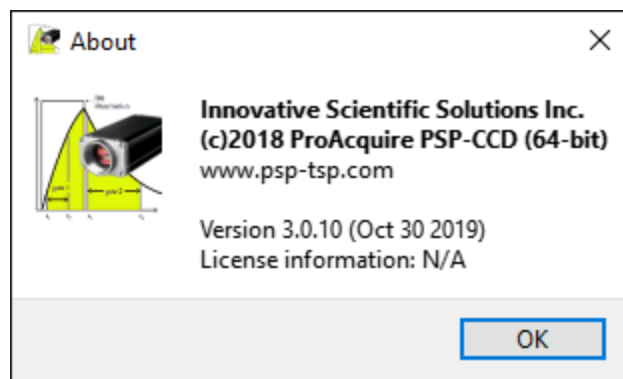
There are three acquisition modes in the software. The default mode is radiometric mode. Each mode will be covered in the next sections.

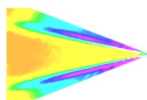
The **About** menu contains the help file and registration information for the camera and software.



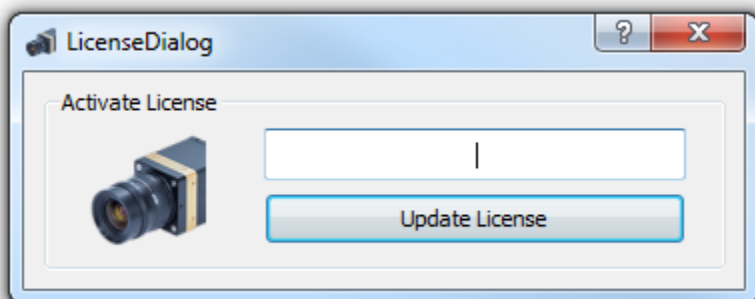
Help contains this user manual.

About contains the software version and the license owner information for the license. It also displays the cameras which are connected to the license and the product key for the license.






Registration will open the license activation box. If a product key has not been entered to activate a license, it can be entered here. If a new license is acquired for additional cameras to use on the same license, that can also be updated here.

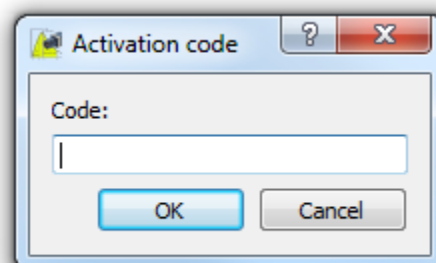


ProAcquire can also be activated offline by use of a .REG file provided on the USB drive with the camera. If multiple cameras are purchased together, there will be one license that is shared by all cameras so any camera can be used on any computer, not tied to a specific system.

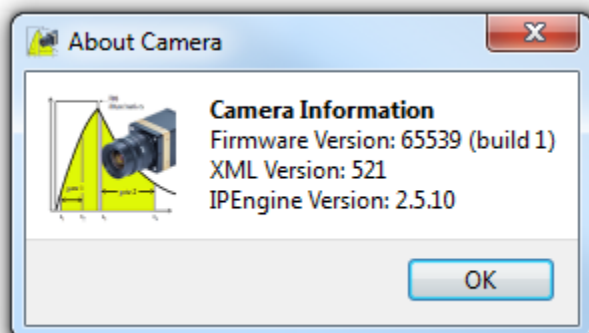
 PAcqGigE-18H640WWYZ61AU5-9825967

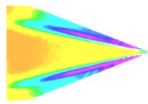
Features Activation is a license activation tool to activate additional features in ProAcquire. This requires an additional product key to activate.

Quantum Efficiency displays the quantum efficiency of the array of the connected camera. It will display either the color or monochrome chart depending on the connected camera.



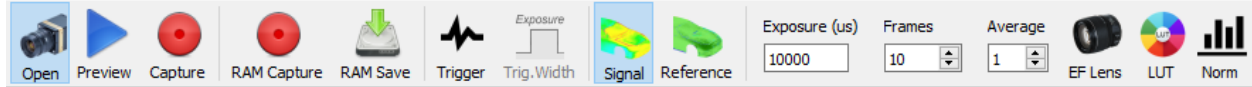
Camera Info (*ProAcquire Version 2 only*) displays the current firmware version installed on the camera. The latest version as of January 1, 2017 is displayed below.





Camera Operating Modes

Radiometric Mode (Available in Version 2 and 3)



Hardware needed:

- PSG-3
- PSP-CCD-M/C
- UniCoat PSP / UniFIB PSP / Binary FIB PSP / Binary UniCoat PSP / TSP
- LM2X-DM LED / LM2XX-DM LED / LM3X / LM4X-DM LED

Radiometric mode refers to the mode of operation where images are acquired in individual frames and stored for post-processing. In this mode, images are taken at a reference condition (wind-off) and then at a loaded condition (wind-on). Then the ratio of those images is done to compute the intensity ratio which is then converted to a useable quantity via a calibration. Background images are taken with the experiment illumination sources off to capture any ambient light the camera may see and then subtract that from the other images.

Images should be acquired first at a background condition with the illumination sources turned off. Next, images at a reference condition are acquired. These images should be taken while the model is unloaded (i.e. without the test section or wind tunnel running). Lastly, images should be taken while the model is under load (i.e. with the test section or wind tunnel running at a steady condition).

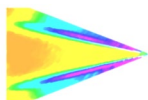
Radiometric mode is the standard mode for ProAcquire as well as the most commonly used. The radiometric approach is used for both single and dual luminophore PSPs.

$$I(P, T) = \frac{F(P_{on}, T_{on}) h n L}{F(P_{off}, T_{off}) h n L} = \frac{F(P_{on}, T_{on})}{F(P_{off}, T_{off})} \frac{R(P_{off}, T_{off}) \frac{n_S}{n_R}}{R(P_{on}, T_{on}) \frac{n_S}{n_R}} = F(P, T)$$

Single-luminophore PSP

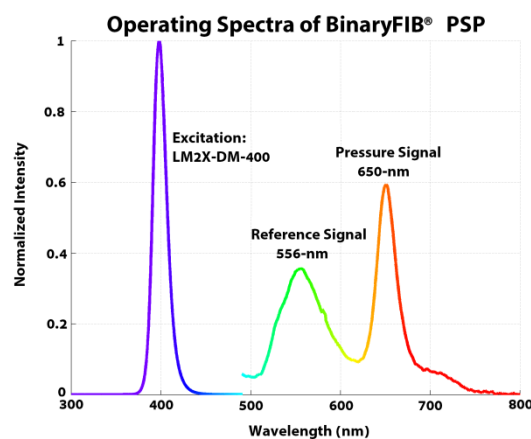
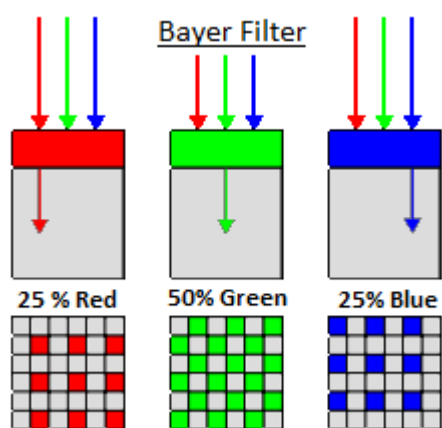
Binary PSP

The binary PSP system acquires signal from two different luminescent molecules to minimize the temperature sensitivity of the system. This involves the use of a color camera (PSP-CCD-C) to spectrally separate the signals from these two sources. One is sensitive to illumination, pressure and temperature while the other is sensitive to illumination and temperature.





Taking the ratio of the two signals drops illumination spatial variation and temperature variation from the equation. This is a requirement for most low-speed PSP applications and wind tunnels or facilities with large temperature changes during a run (i.e. blowdown wind tunnels).

The color camera separates the signals by use of Bayer filter. The Bayer filter spectrally separates the signals from the two sources to different pixels on the camera array.

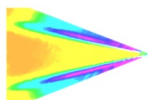


The Bayer filter of the PSP-CCD-C (see quantum efficiency for PSP-CCD-C) matches the spectral emission of BinaryFIB® PSP, making it an ideal match for the paint. The images acquired by the color camera are split into the different color planes of the Bayer mask by use of the **Split Colors** function. This will split the array into red, green and blue signal. The red image is what is called the pressure sensitive image because the pressure sensitive emission is captured here. The green image is referred to as the reference image because it captures the signal of the pressure in-sensitive reference. The blue is unused.

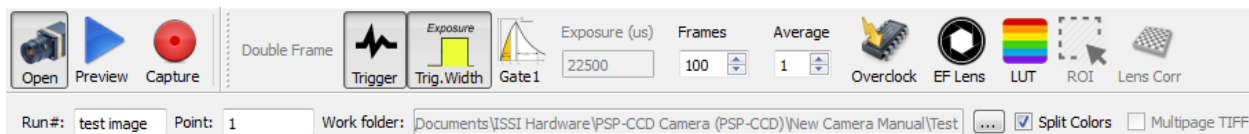
This split gives the final images $\frac{1}{4}$ the resolution of the full array. However, this allows acquisition of the pressure sensitive and reference image on the same camera frame. The camera will only save a red and green image noted with _p (pressure sensitive) and _r (reference).

 Run_1_000002_p
 Run_1_000002_r

The images are then post-processed by means of the Binary PSP equation on the previous page and converted to pressure.



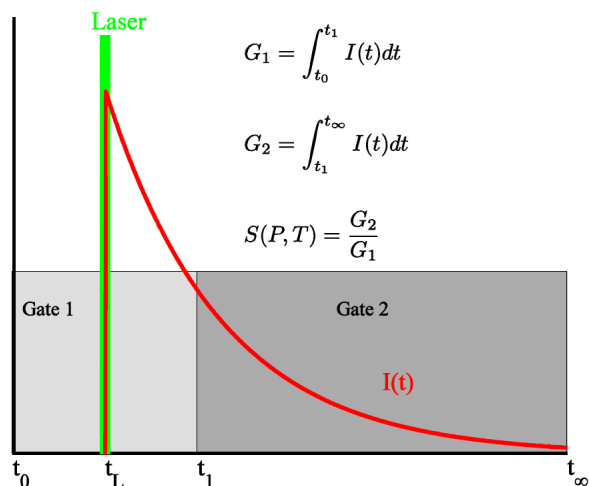
Double Framing Mode (Available in Version 2 Only)



Hardware needed:

- PSG-3
- PSP-CCD-M
- UniFIB PSP / FP-100 PSP / TurboFIB PSP
- PIV Laser (YAG 532-nm)

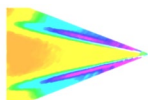
The PSP-CCD is a gated camera. Double framing mode uses the camera as a gated camera, splitting the acquired image into two gates with a very small time division (200-ns) between them. This technique is sometimes referred to as *Single-Shot Lifetime* mode because the wind-on and wind-off images are both acquired in a single camera frame that is gated.



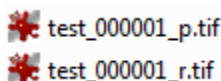
The two-gate approach allows the gates of the image to be acquired at different delay times during and after the excitation pulse from a laser which is used in this technique. Gate 1 is typically a shorter gate during the excitation pulse. Gate 2 is typically longer, taken after the pulse and during the decay of the paint excitation.

Since the excited state of the paint has minimal pressure sensitivity, Gate 1 is used as a reference condition (wind-off). The decay of the paint has pressure sensitivity, making Gate 2 the pressure sensitive gate.

The delay between the gates of the camera is fixed at 200 ns. Gate 1 is entered in the PSG and Gate 2 is fixed. The laser is used due to its highly-energetic yet short (nanoseconds) duration pulse.

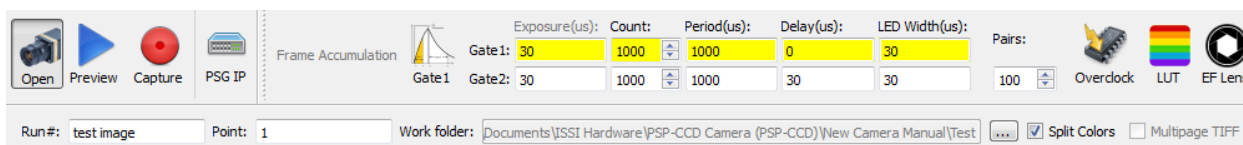


Typical uses for the double framing mode are rotating machinery such as helicopter blades. In those cases, the motion of the blade needs to be frozen so that the camera can acquire its images. A gated camera and a highly energetic light source with very small pulse widths (10s of nanoseconds) like a YAG laser are required. Fast paint (FP-100) is also needed to reduce the motion blur of the passing blade.



Data acquired is saved as: **filename_p.tif** for Gate 2 and **filename_r.tif** for Gate 1.

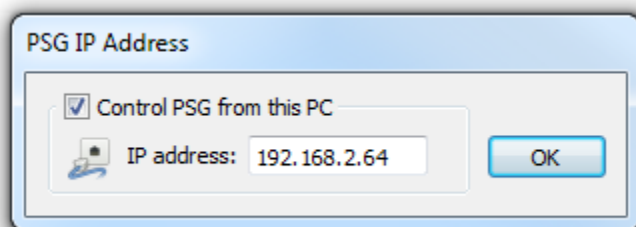
Frame Accumulation Mode (Available in Version 2 Only)



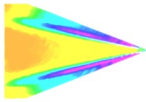
Hardware needed:

- PSG-3
- PSP-CCD-M
- UniFIB PSP
- LM2X-DMHP LED / LM2XX-DMHP LED / LM3X / LM4X-DMHP

Frame accumulation mode is a lifetime acquisition mode without the need for a laser. Lasers are costly and LEDs offer a much cheaper alternative. The frame accumulation mode uses the accumulated pulses of an LED light source to produce its individual camera gates. When using frame accumulation mode, the LED should be connected to channel 1 of the PSG and the camera should be connected to channel 2.

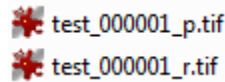


PSG IP is set upon opening frame accumulation mode. It can be changed by pressing this button.



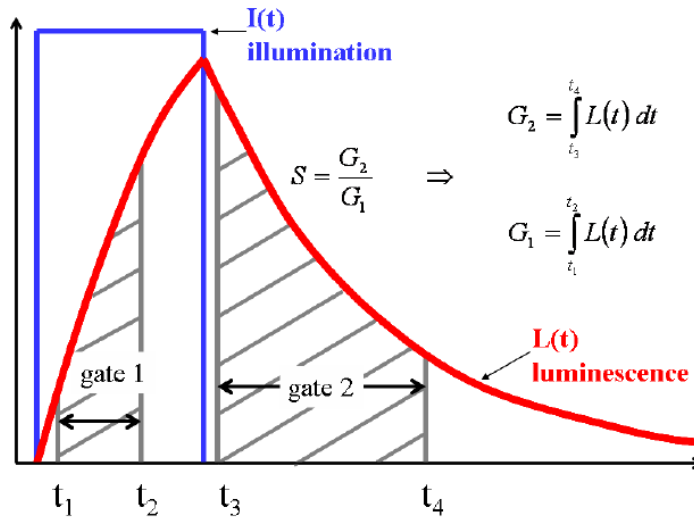
The **Frame Accumulation** toolbar contains the accumulation mode settings that will be used by the PSG to control the acquisition.

The frame accumulation mode creates two gates by shifting the delay relative to the excitation pulse of a pulsed LED. Gate 1 is integrated over the excitation pulse of and LED. Gate 2 is shifted and integrated over the decay of the fluorescence which contains the response of the PSP.



Data acquired is saved as: **filename_p.tif** for Gate 2 and **filename_r.tif** for Gate 1.

Gate 1 is a reference gate, sensitive to the illumination with little to no pressure sensitivity.

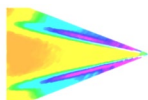


Gate 2 is a sensitive gate, sensitive to the illumination and very sensitive to the reaction of the PSP to local oxygen. By taking the ratio of the signal from the two gates, illumination intensity is removed and the resulting intensity ratio is sensitive to pressure. The gates are positioned to optimize the pressure sensitivity while maintaining a good signal-to-noise ratio. The Gate 1 / Gate 2 ratio is calculated and then, the image is then converted to pressure by use of a

calibration. The advantage to this technique is near real-time data processing. The off-condition is acquired during wind-on and with lower temperature sensitivity than radiometric mode using single-luminophore PSPs.

The settings entered in the timing section of frame accumulation model are described below.

- 1.) **Gate 1** is the pressure insensitive gate
 - a. **Exposure** is the exposure time of the camera ($t_1 - t_2$) for **Gate 1**
 - b. **Count** is the number of accumulations for **Gate 1**
 - c. **Period** is the repetition rate (inverse) of the LED in microseconds for **Gate 1**
 - d. **Delay** is the delay time in microseconds of **Gate 1** relative to t_0
 - e. **Width** is the LED pulse width (same for Gates 1 and 2)
- 2.) **Gate 2** is the pressure sensitive gate
 - a. **Exposure** is the exposure time of the camera ($t_3 - t_4$) for **Gate 2**
 - b. **Count** is the number of accumulations for **Gate 2**



- c. **Period** is the repetition rate (inverse) of the LED in microseconds for **Gate 2**
- d. **Delay** is the delay time in microseconds of **Gate 2** relative to t_0
- e. **Width** is the LED pulse width (same for Gates 1 and 2)

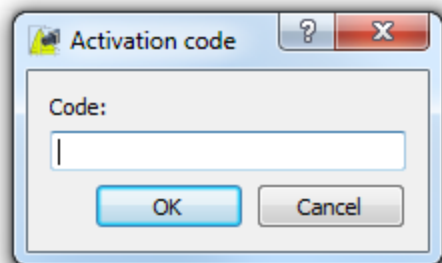
Pairs refers to the number of image pairs (Gate 1, Gate 2) to capture.

All other functions are the same as previously described.

Multi Camera Mode

ProAcquire Multicam makes one computer (any one can be) the master and all others slaves to it. It controls every camera in a multi camera system from one place. Control of preview, capture, exposure and data save location are all controlled from the master computer. Additional devices like the PSG are also controlled through multi cam and PSGs associated with slave subsystems are controlled via the master PC just as the cameras are. This eliminates mistakes in camera and PSG settings as it all comes from one source and identical settings are applied to each subsystem. For large systems with multiple cameras, multi cam

mode is a necessity.

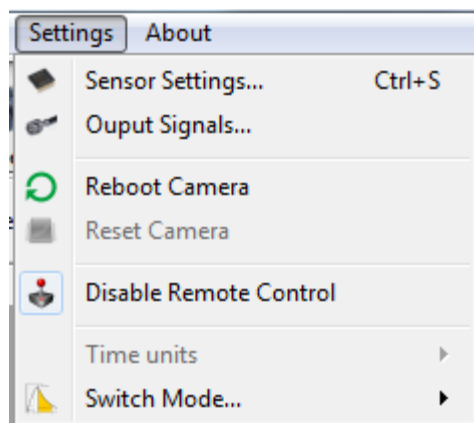
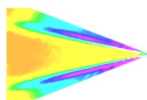


ProAcquire GigE Multicam is activated with an additional license. Multi camera mode allows the slave camera systems to be controlled via a master computer with the add-on activated.

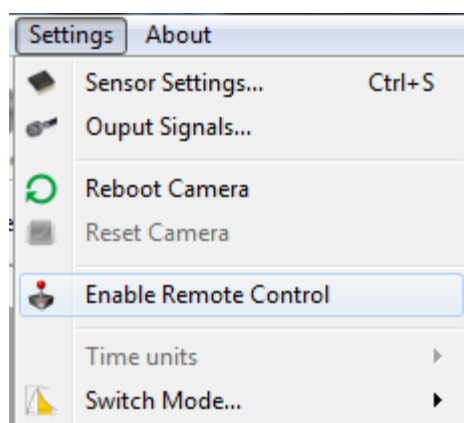
To activate multi camera mode, the license first must be purchased. After receiving the license key, activate the feature on **ALL** computers which will be used with ProAcquire.

Only one license is needed for multiple computers and it should be entered in the **Activation Code** window on all computers used. The ProAcquire licenses will be combined into one product key if multiples are purchased.

ProAcquire GigE Multicam is a separate interface and will be installed when ProAcquire is installed. The program can be found in *C:\Program Files\ProAcquire GigE 64-bit*. Add an icon to the desktop for easier access. To enable the feature in ProAcquire, **Enable Remote Control** should be selected in the settings tab.

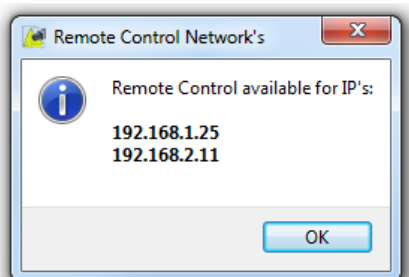


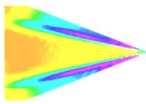
Enabled



Disabled

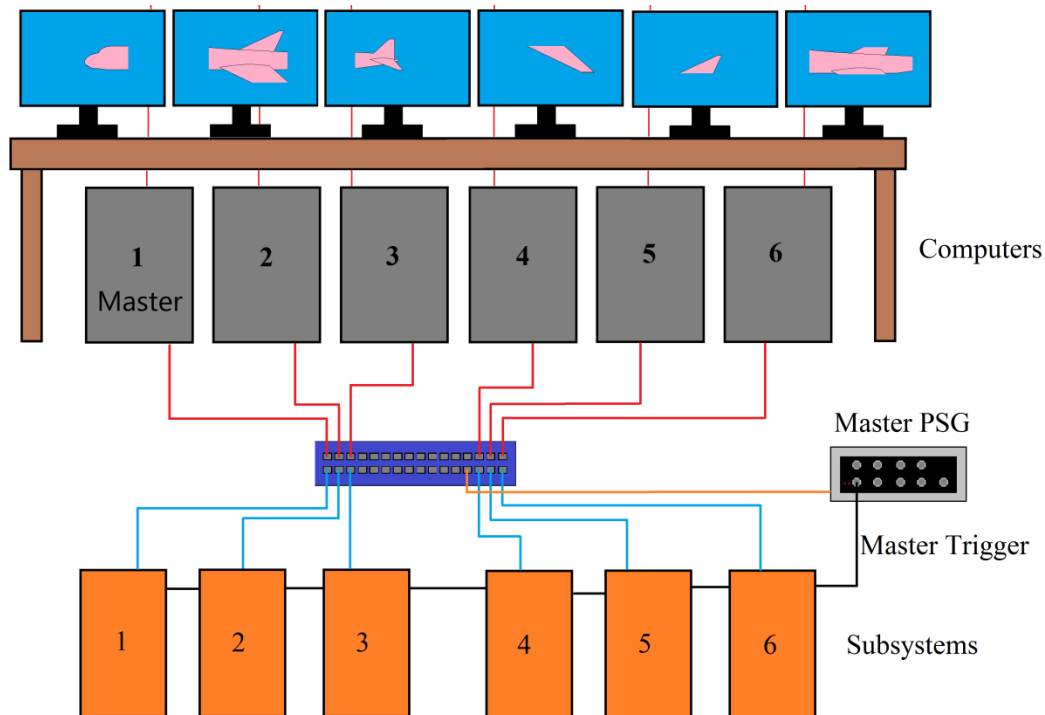
Enable remote control should be selected on each computer being used with multi camera mode. Once enabled, it will display all available IP address detectable on the network (NIC IP address).





Network Configuration For Multi-Camera Mode

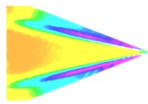
The network configuration for multi camera mode must be set up correctly for the system to function properly. The network consists of computers and subsystems (cameras and other Ethernet devices) all connected via a common network switch. An example of a configuration is shown below.



The multi camera control comes from the computer network interface card (NIC). The NIC of each computer should be on the same subnetwork with a unique host number. The connection to the switch links each computer together so it can communicate with all others via that network.

Remember the IP Format: **Network.Network.Subnet.Host**

Each camera (and any other Ethernet device) should have a unique host number but also be on the same subnetwork as the PC NICs. This will allow each computer to see all devices on the network. An IP address chart should be kept so that it is known which devices each PC is controlling.

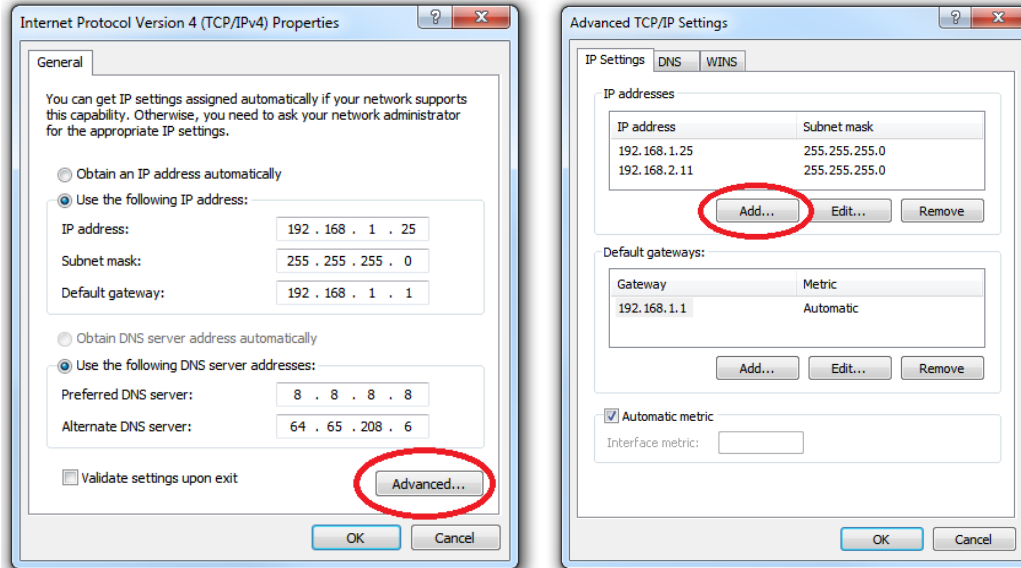


An example configuration is shown below:

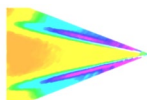
| System 1 | System 2 | System 3 |
|-----------------------------|-----------------------------|-------------------------|
| Computer 1 (Master) | Computer 2 | Computer 3 |
| PC NIC: 192.168.2.10 | PC NIC: 192.168.2.11 | PC NIC: 192.168.2.12 |
| Camera 1 NIC: 192.168.2.116 | Camera 2 NIC: 192.168.2.113 | Lens NIC: 192.168.2.235 |
| Camera 1: 192.168.2.201 | Camera 2: 192.168.2.202 | Camera 3: 192.168.2.203 |
| PSG: 192.168.2.45 | PSG: 192.168.2.44 | PSG: 192.168.2.33 |
| | | |
| System 4 | System 5 | System 6 |
| Computer 4 | Computer 5 | Computer 6 |
| PC NIC: 192.168.2.13 | PC NIC: 192.168.2.14 | PC NIC: 192.168.2.15 |
| Lens NIC: 192.168.2.112 | Lens NIC: 192.168.2.117 | Lens NIC: 192.168.2.114 |
| Camera 4: 192.168.2.204 | Camera 5: 192.168.2.205 | Camera 6: 192.168.2.206 |
| PSG: 192.168.2.41 | PSG: 192.168.2.36 | PSG: 192.168.2.46 |

Ping the IP address (PC NIC) of all slave machines from the master PC to check if they are detectable.

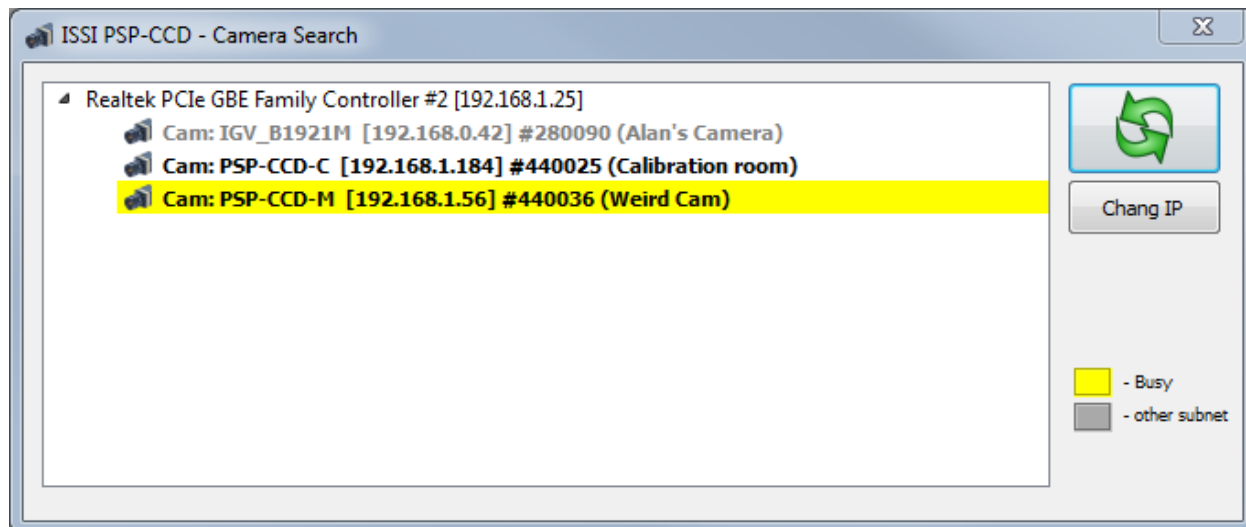
Multiple subnetworks can be added to each NIC if needed. Open the TCP/IPv4 window and click on Advanced. Then add IP addresses to the NIC.



If devices on the system are on different subnetworks, they can be left unchanged and still communicate with each NIC.



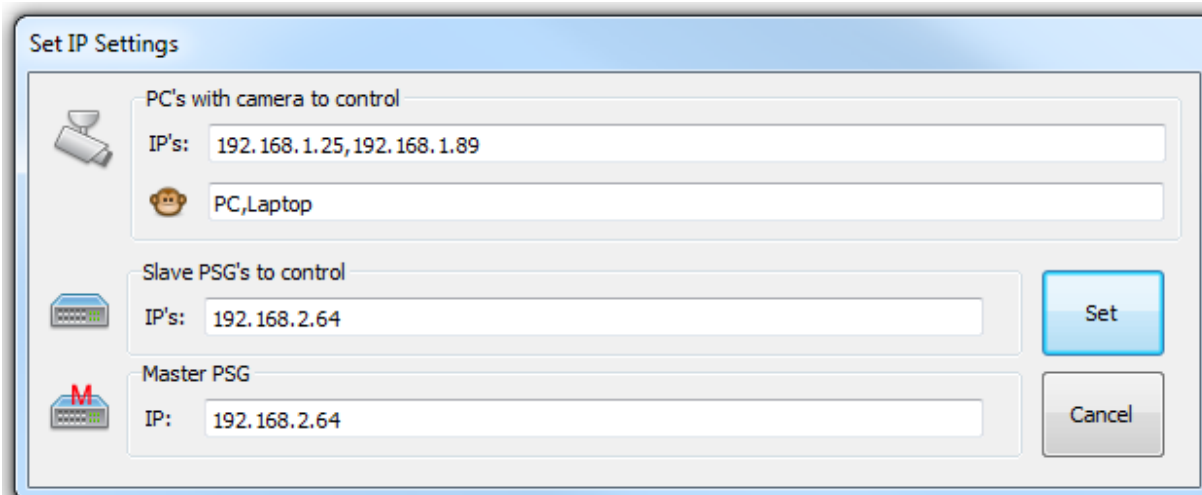
Open ProAcquire on each PC and connect to their respective camera. All cameras will appear on the network here and cameras already connected will be highlighted in yellow as below.



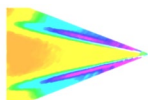
Once all computers have ProAcquire running and remote control enabled, open **ProAcquire GigE Multicam** by the icon:



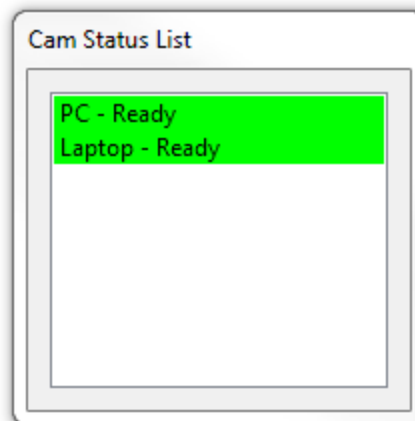
This will open the **Set IP Settings** window.



PC's with camera to control are the PC NICs that are connected to the network. This tells the program which computers are going to be linked via multi camera mode.



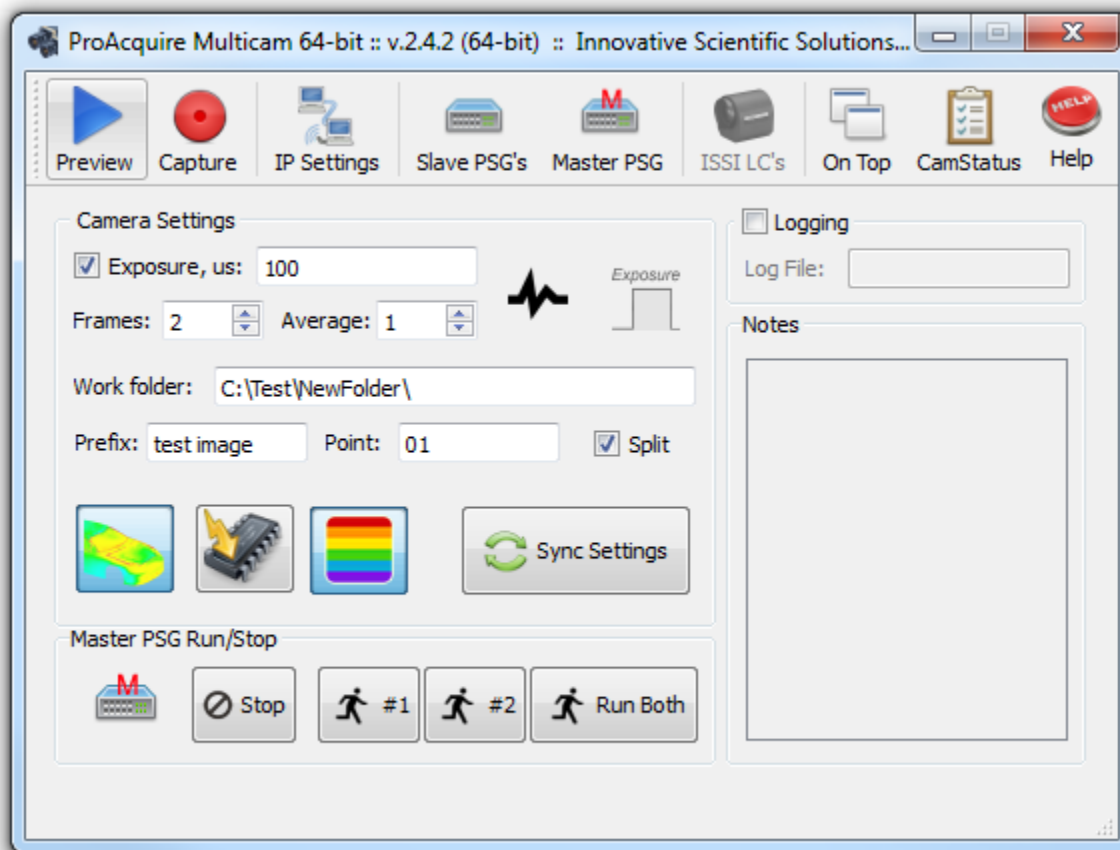
IP's is where the IP address of the NIC should be entered for each PC. Separate them with a comma. They can also be named below (monkey face icon). They should be named in the same order as the IP addresses. They should also be separated with a comma. Once connected, they will be shown in the pop-up **Cam Status List** window. It will show if they are connected or not and what function they are performing.

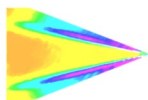


Slave PSGs to Control is where any connected PSG IP addresses for slave subsystems should be entered.

Master PSG is where the IP address of the master PSG should be entered. The master PSG controls the start trigger of the entire system including all subsystems.

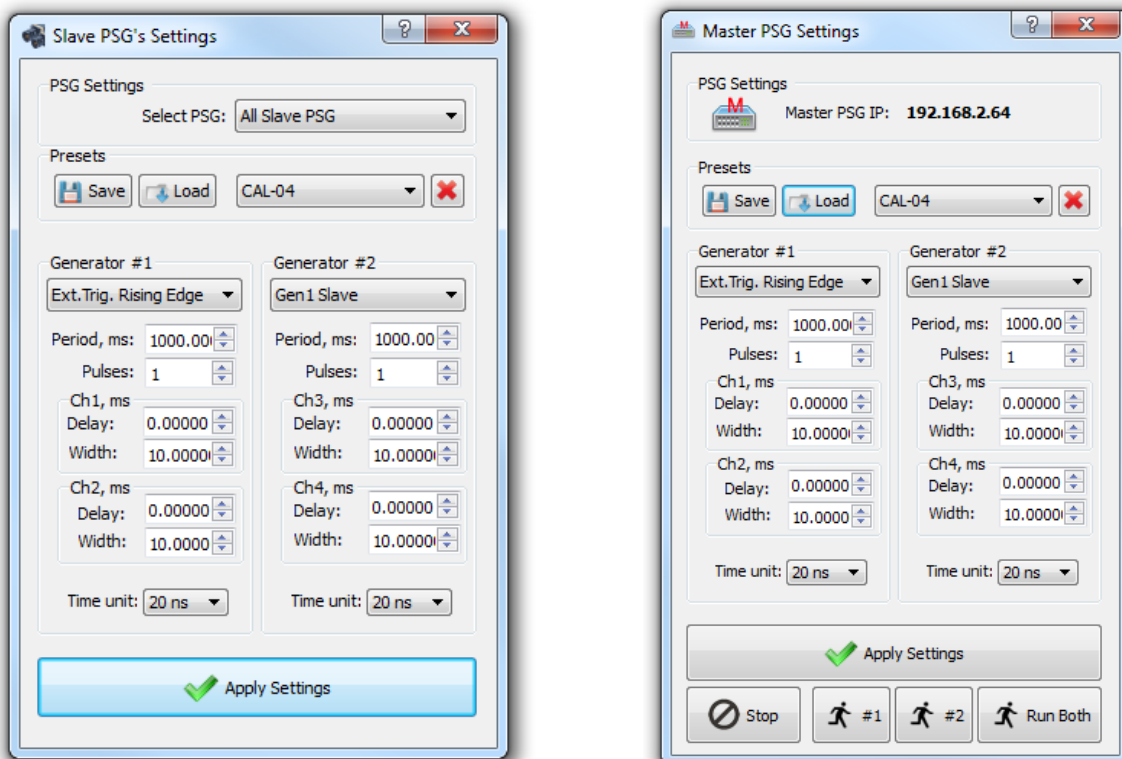
After clicking **Set** to apply the setting, the multi camera main window will open. Here, all functions shown can be controlled for each subsystem simultaneously.



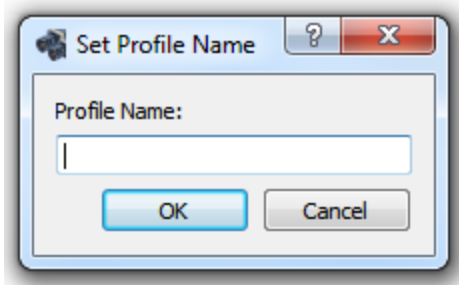


The functions are all the same as described in the single camera control of ProAcquire with some additional controls added for the pulse generator and lens controller (future implementation).

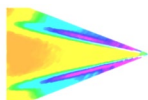
IP Settings will open up the initial IP setting and naming window when multi camera mode is first opened. If any changes need to be made, they can be applied here.



The PSG controls are for the slave PSGs and the master PSG. Slave PSGs form each subsystem need to be added individually in the **Slave PSGs Settings** window. Once added, the settings entered here will be applied to each PSG. Presets can also be saved so each PSG setting can be simultaneously and identically changed all from the master PC. To add a slave PSG it must be connected to the network. Add a slave PSG by use of the **Select PSG** feature. Select the IP address of a connected PSG to add it. Refer to the network chart to select the PSG. Settings can be entered below for the output of the PSGs (see PSG-2/3 manual for description of the settings). Once all settings have been entered, **Apply Settings** to set for all slave PSGs. Presets can be saved and will be stored on the computer they are saved by (in this case the master PC).

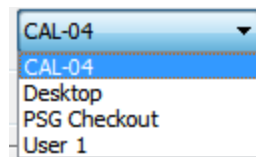


To save a new setting, click **Save** and then enter a profile



name.

To load a setting, select the desired setting from the drop-down list and press.



The  button will delete the selected preset.

In this configuration, the slave PSGs will always be triggered by the master so they are always used in Ext. Trigger mode. The master PSG can be started from the Master PSG Settings window which will then trigger all PSGs for each subsystem simultaneously.

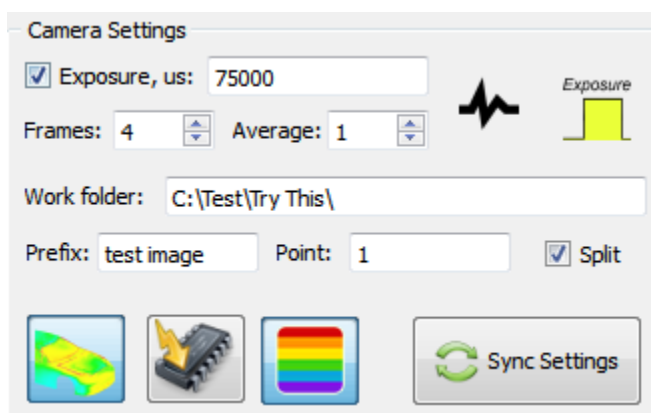
ISSI LC's refers to lens controllers (LC-1 and LC-2) that will be implemented into the multi control software similar to the PSG in future upgrades.

On Top will make the *ProAcquire Multicam* will make the program remain on top of all other programs on the desktop.


CamStatus will open the **Cam Status List** window showing all cameras connected via multicamera and their names and status.


Help will bring up the help file for *ProAcquire Multicam*.

The **Camera Settings** toolbar controls the acquisition of all of the connected cameras.

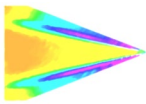


Exposure, us is the exposure time of the cameras in microseconds. Leave this checked to edit

the exposure time. The  button puts the cameras into external trigger mode and they

will wait for their trigger pulse before framing. The  button puts the camera into external pulse width mode. This means that the exposure time of the camera is taken from the pulse width of an external TTL pulse width. This could be from the PSG.

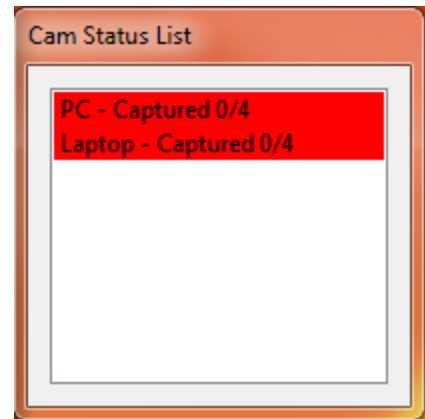
The **Frames** and **Average** function the same way as they are described above for ProAcquire.



The bottom buttons are the signal/reference image display, overclocked mode and LUT respectively. All are described earlier.

Sync Settings will synchronize all camera settings to all slave computers. The screen on the slave computers ProAcquire will update automatically when this button is clicked.

Clicking **Preview** or **Capture** in *ProAcquire Multicam* will put all cameras connected via the software into those modes. While the cameras are capturing data, the progress for all connected cameras will be shown in the **Cam Status List** window.



Another additional feature of *ProAcquire Multicam* is the log file generation. If **Logging** is checked, a log file will be saved with the images on the master PC. There is a section for notes below the file path for the log file (use same file path as image save). These notes will be saved as *comments* in the log file. The log file will display the date and time, list of connecte PCs (by their NIC IP address), list of slave PSGs, the master PSG and the settings entered in the multi camera settings.

```
Fri Jan 22 2016 15:14:41 Start logging
Fri Jan 22 2016 15:21:37
Comments: Test logging feature
Camlist = 192.168.1.25,192.168.1.89
SlavePSGlist = 192.168.2.64
MasterPSG = 192.168.2.30
Exposure=100us
Frames=4
Folder=C:\Test\NewFolder\
File_prefix=test image
Point=1

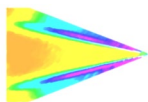
PSG:192.168.2.64
```

This is a useful feature for note taking during a test through a range of test conditions.

To trigger the entire system, the master PSG can be controlled right from the control panel of *ProAcquire Multicam* in the **Master PSG Run/Stop** toolbar.

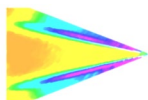


The purpose of the multi camera software is to streamline the system and make it faster and easier to use and minimizing user mistakes. Multi camera software gives the master operator complete control of the system, leading to less time spent in the facility and less confusion while tests are running.



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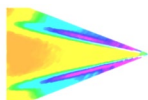
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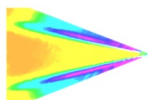
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