LightField®

64-bit Data Acquisition Software

User's Manual

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Princeton Instruments

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Princeton Instruments
3660 Quakerbridge Rd
Trenton, NJ 08619
TEL: 800-874-9789; 609-587-9797
FAX: 609-587-1970

Table of Contents

List of Figures

List of Tables

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Chapter 1: Introduction to LightField®

Introduction

LightField is Princeton Instruments' 64-bit Windows® data acquisition platform for spectroscopy and imaging. LightField combines complete control over Princeton Instruments' cameras and spectrometers with easy-to-use tools for experimental setup, data acquisition and post-processing. LightField makes data integrity priority #1 via automatic saving to disk, time stamping and retention of both raw and corrected data with full experimental details saved in each file. LightField works seamlessly in multi-user facilities, remembering each user's hardware and software configurations and tailoring options and features accordingly. The optional, patent-pending IntelliCal™ package is the highest-performance wavelength calibration software available, providing up to 10X greater accuracy across the entire focal plane than competing routines.

Whether the application is absorbance, transmission, fluorescence, Raman, or lifetime spectroscopy, LightField provides many easy-to-use tools for data acquisition and post-processing. Peak Find, Spectrometer Alignment, and Standard Calibration are among the standard LightField tools included for spectroscopists. LightField also offers spectroscopists a host of additional features, including:

- Control of all Princeton Instruments PI-MAX®3, PI-MAX®4, NIRvana/PIoNIR, PIXIS family, Pro-EM®, ProEM®+, PyLoN®, PyLoN®-IR, and Quad-RO cameras
- Support of PI's high speed kinetics mode
- File export to many common formats
- Control of experimental parameters
- Powerful imaging mode and support for multi-strip mode

LightField Optimal Control

The Princeton Instruments LightField software is designed to enable users of Princeton Instruments digital imaging and spectroscopy systems to derive greater benefits from their high-performance hardware. LightField provides reliable control over all Princeton Instruments detectors with internal controllers. Full access to sensor readout and timing is offered through custom options. Features include multi-camera control, enhanced file types and file information and spectrograph support. LightField gives the user control of every part of the system, including the detector/controller, spectrometer, and experimental synchronization. In addition to data acquisition, LightField offers calibration, processing, printing, and archiving of collected spectra and images. Live data can be displayed simultaneously with yesterday's results to make sure the spectra or images look the same.

Spectrometer Support and Calibration

LightField provides complete control over Acton SP series, IsoPlane® SCT-320, and LS 785 spectrographs. This software control extends to all instrument options, such as multiple gratings, multiple entrance and exit ports, and motorized slits. Spectrometer control and detector operation are independent functions under LightField so users are able to collect data while simultaneously communicating with the spectrometer. LightField software even makes spectrometer calibration easy. Users can employ a simple three-step method to generate a geometric correction that will update the spectral calibration with every move of the grating. LightField automatically converts among nanometers, electron volts, wavenumbers, and relative wavenumbers. LightField makes reliable calibration simpler and quicker than ever before.

Live Processing

While it is always possible to process data after-the-fact, it is important for some data corrections to be available during acquisition. These data processing operations allow the user to better evaluate incoming data while interactively optimizing experimental parameters. For example, it is difficult to monitor a change in spectrum that has many features that are not affected by the parameter being adjusted. Flatfielding can de-emphasize a background shape of the spectrum, accentuating instead in near real-time the effects on the spectrum due to the user's changes. LightField offers several processing operations during data acquisition. These include background subtraction, flatfielding, accumulation of multiple spectra, and blemish correction.

Post-Processing

LightField's post-acquisition display has been developed specifically for single and multiple image or spectra applications. Each image or spectrum can be displayed in its own window, allowing individual auto scaling and zooming. Scaling and zooming can also be linked so that each window displays the identical image area or spectral region. Alternatively, multiple images or

spectra can be displayed in the same window, for direct comparison. All display windows fully support calibration of the wavelength axis, allowing display in any of the units available in wavelength calibration. Additional displays are available to help visualize multiple data. Full support is also included for true grayscale displays of images collected with the detector. This feature is not only useful when the detector is also used in an imaging capacity, but is implemented in many functions of LightField that take advantage of the ability of using a CCD detector as a camera to "photograph" the actual focal plane of the spectrometer. These functions include setting the location of strips on the CCD and checking for focus and rotational alignment of the sensor relative to a spectrometer.

System Requirements

Before running LightField, confirm that your system meets both the hardware and the operating system requirements for this version of the software.

- **Camera:** A Princeton Instruments camera with internal controller and the appropriate interface card [USB 2.0, 1394a (FireWire), or GigE] installed in the host computer.
- **Operating System:** Windows® 7 (64-bit) and Windows Vista™ (64-bit)
- **Computer:**
  - 2 GHz dual core processor
  - 4 GB RAM (minimum)
  - 1 GB storage (Minimum memory required for installation. Additional memory required for image and data storage.)

Specifications are subject to change. Please contact Princeton Instruments for the most current information.

Product Registration

Introduction

The entire LightField package (Experiment Workspace, Data Workspace, and IntelliCal™) is available for a 45-day trial period. If you have installed a trial version, a status icon in the lower left corner of the LightField window will report the trial time remaining. This information is also reported in the License **Status** field on the **Enter Product Key** dialog. When that period expires, you must either plug in the LightField hardware key (a USB memory stick shipped with the software) or enter and activate a software product key to continue using the purchased LightField components.

Registering LightField Components with a Hardware Key

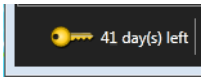


Figure 1. Trial Status Icon

The easiest way to register your purchased LightField component(s) is through a hardware key that has been shipped with the software. The component license or licenses are already stored in the key.

- If you have already installed LightField and your computer is turned on, simply plug the hardware key into an available USB port, wait until the key is installed, and then start LightField. Because the component license or licenses are stored in the key, nothing else is required. **The hardware key must be plugged in for you to use the registered (licensed) components.**
- If you have opened LightField but have not plugged in the hardware key, the **Enter Product Key** dialog may appear. This is a reminder that you need to plug the key into an available USB port. Plug the key in and wait for it to be installed. When the **Enter Product Key** dialog reports "XXXXX" Provided by Hardware Key" (where XXXXX is the component name) for each licensed component, click on the **Close** button to close the dialog. **The hardware key must be plugged in for you to use the registered (licensed) components.**

Figure 2. Hardware Key Status

Registering LightField Components with a Software Key and the Internet

If you have received a 19-digit product key with your purchased LightField component(s), you can register the component(s) via Internet access from the computer on which LightField has been installed. During the activation process, the product key is confirmed and the product is activated by a Princeton Instruments server.

1. If the **Enter Product Key** dialog is already open, go to Step 3. Otherwise, click on the **Application Menu** button  (to the left of the **Experiment** button) to open the **Application menu**.
2. Click on **Enter Product Key** to open the **Enter Product Key** dialog.

Figure 3. Enter Product Key dialog

3. In the **Product Key** field, enter the 19-digit product key (for example, 1234-5678-9123-4567-890) supplied when you purchased the software.

Figure 4. Lightfield Product Key: Activate Product Key

4. After you have entered the key, click on the **Activate** button 
5. Upon activation, the **Enter Product Key** dialog reports the active product key and product license information for each purchased component of LightField will be listed in the **License Status** field. For example, the text will say "XXXXX" Provided by Software Key" (where XXXXX is the component name) for each licensed component.
6. Click on the **Close** button to close the dialog.

Figure 5. LightField Product Key: License Status

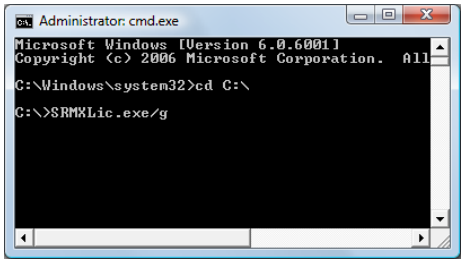
Registering LightField Components without Internet Access

Administrative rights are required to run the program mentioned in this section.

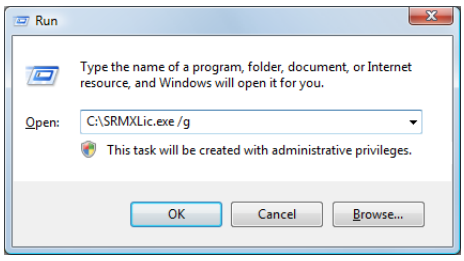
If you do not have Internet access for the computer on which LightField is installed, you will need Administrative rights for that computer, your LightField purchase order number, and you will need to download a program from the Princeton Instruments FTP site and be able to email Princeton Instruments' Technical Support for assistance in registering your product. The download and email can be performed from a computer that does have access.

1. Close all instances of LightField.
2. Download the external licensing tool SRMXLic.exe from the Princeton Instruments FTP site ftp://ftp.princetoninstruments.com/Public/Software/Official/LightField/ and copy it to the computer hard drive that has LightField installed on it. Note the file location.
3. Run the SRMXLic.exe from a command window with the /g option. The example below assumes the file was copied to C:\.

   C:\>SRMXLic.exe/g

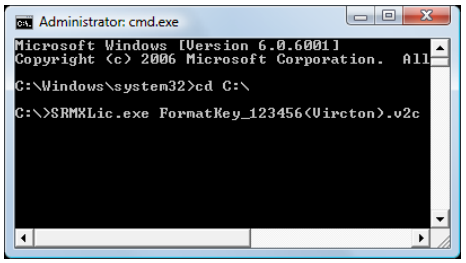
   

   You can also run the tool from the **Windows® Run** dialog (accessed from the **Start** menu).

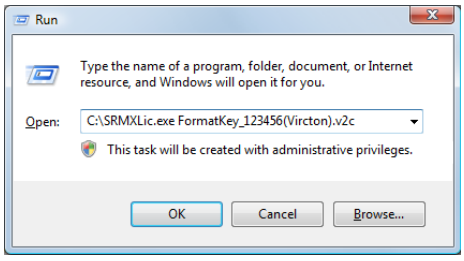
   

4. The generated SRMLic.c2v file will be written to the folder containing the SRMXLic.exe program. Email SRMLic.c2v to Princeton Instruments Technical Support at techsupport@princetoninstruments.com with your purchase order number.
5. In response, Princeton Instruments Technical Support will send you a file named FormatKey_xxxxx(CustomerName)v2c. The xxxxx represents an id number associated with your computer: the number of digits will vary; CustomerName is the name associated with your purchase order.
6. Place this file in the folder containing the SRMXLic.exe tool.
7. Run SRMXLic.exe with the option of the filename you received. The example below assumes that both files were copied to C:\.

   C:\>SRMXLic.exe FormatKey_123456(Vircton).v2c

   You can also run the tool from the **Windows Run** dialog (accessed from the **Start** menu).

8. Restart LightField, open the **Application menu**, select **Enter Product Key** and verify that Licensed Components appears in the **License Status field**.

Product Updates

Introduction

From time to time, updates will be available for LightField. These updates may include enhancements and/or bug fixes. After an update is performed, the version will be added to the update history.

Update History

A listing of all updates to your LightField software is provided on the **LightField Update History** dialog. To access the listing:

1. Open the **Application Menu**. and click on **About LightField... t**o open the **About LightField** dialog.

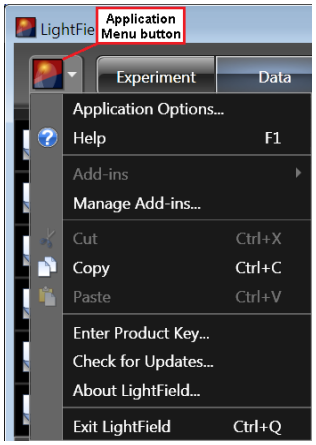


Figure 6. Application menu

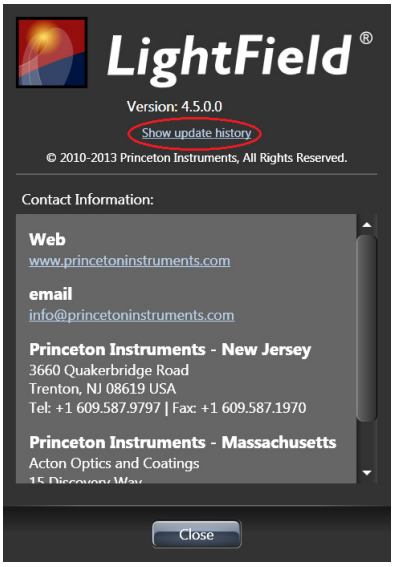


Figure 7. About LightField dialog

2. On the **About LightField** dialog, click on the **Show update history** link to open the **LightField Update History** dialog.

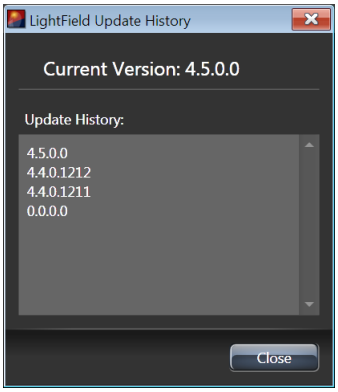


Figure 8. LightField Update History dialog

Automatic Update Check

Each time you start up LightField, it will verify Internet access and then attempt to access the Princeton Instruments' FTP site to check for product updates. It will compare your version of the software with the most recent version. If the two versions differ, you will be given the choice of downloading, ignoring, or waiting until later to update. If Internet access is not available for your computer, LightField will not look for updates.

- **Download:** Goes to the Princeton Instruments' FTP site and sets up the download.
- **Ignore This Update:** If you make this selection, you will not be prompted again about updating to the displayed version.
- **Ask Again Later:** Will ask you again in 30 days about updating to the displayed version. If a subsequent update is released before the 30 days are up, you'll be prompted at that time.

Figure 9. LightField Updates dialog

Manually Checking for Updates

You may want to initiate a check for updates if you leave LightField on for long periods of time or have obtained Internet access after LightField was started. To manually check for updates:

1. Open the **Application Menu** and click on **Check for Updates...** to start the check
2. Upon completion of the check, a dialog with one of the following messages will be displayed.
   - **Could not contact Princeton Instruments:** Close the dialog and connect your computer to the Internet or contact Princeton Instruments' Customer Support to see if there are updates available. Have the LightField version information available. This

information is on the **About LightField** dialog accessed from the Application Menu.

Figure 10. LightField Updates: Could not contact Princeton Instruments

- **LightField is up-to-date:** No action is required. Simply close the dialog.

Figure 11. LightField Updates: LightField is up-to-date

- **New Version Available:** Review the Release Notes and select **Download**, **Ignore This Update**, or **Ask Again Later**.

Figure 12. LightField Updates: New Version Available

- **Download:** Goes to the Princeton Instruments' FTP site and sets up the download.
- **Ignore This Update:** If you make this selection, you will not be prompted again about updating to the displayed version.
- **Ask Again Later:** Will ask you again in 30 days about updating to the displayed version. If a subsequent update is released before the 30 days are up, you'll be prompted at that time.

Updating LightField Components without Internet Access

If you do not have Internet access, contact Princeton Instruments' Customer Support for assistance in updating your product. Have the LightField version and previous update information available. This information is on the **About LightField** dialog accessed from the **Application Menu**.

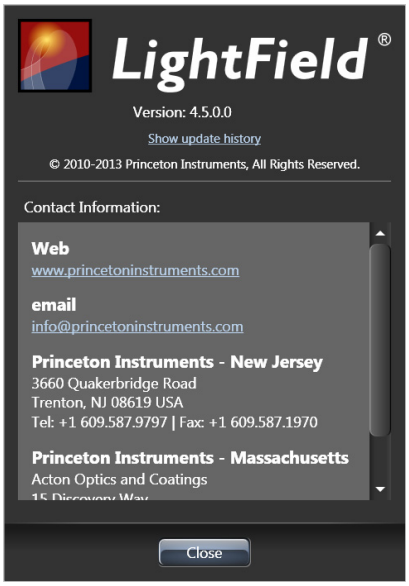


Figure 13. About LightField dialog

Contact Information

Address:	**Princeton Instruments - New Jersey** 3660 Quakerbridge Road Trenton, NJ 08619 (USA) Tel: +1 800.874.9789 / +1 609.587.9797 FAX: +1 609.587.1970
Address:	**Princeton Instruments - Massachusetts** Acton Optics and Coatings 15 Discovery Way Acton, MA 01720 (USA) Tel: +1 800.874.9789 / +1 978.263.3584 Fax: +1 978.263.5086
Customer Support E-mail:	techsupport@princetoninstruments.com
Internet:*	www.princetoninstruments.com

Table 1. Contact Information

*An up-to-date list of addresses, telephone numbers, and e-mail addresses of Princeton Instruments' overseas offices and representatives is maintained on the web page.

Customer Support

For immediate support in your area, please call the following locations directly:

North America	1 877 4 PIACTON (877 474 2286)
Benelux	+31 (347) 324989
France	+33 (1) 60 86 03 65
Germany	+49 (0) 89 660 7793
Japan	+81 (3) 5639 2741
UK & Ireland	+44 (0) 28 3831 0171
Singapore	+65 6293 3130
China	+86 10 6262 5862

Table 2. Customer Support

Otherwise, please contact Customer Support by using the Support Request form (http://www.princetoninstruments.com/support/contact.aspx) or by sending an e-mail request to techsupport@princetoninstruments.com.

Links to Princeton Instruments' Websites

Link to the Princeton Instruments Web site: www.princetoninstruments.com

Link to the Princeton Instruments FTP site: Princeton Instruments Software directory

Link to the Princeton Instruments FTP site: Princeton Instruments Manuals directory

Link to the Princeton Instruments FTP site: Acton Manuals directory

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Chapter 2: LightField Environment

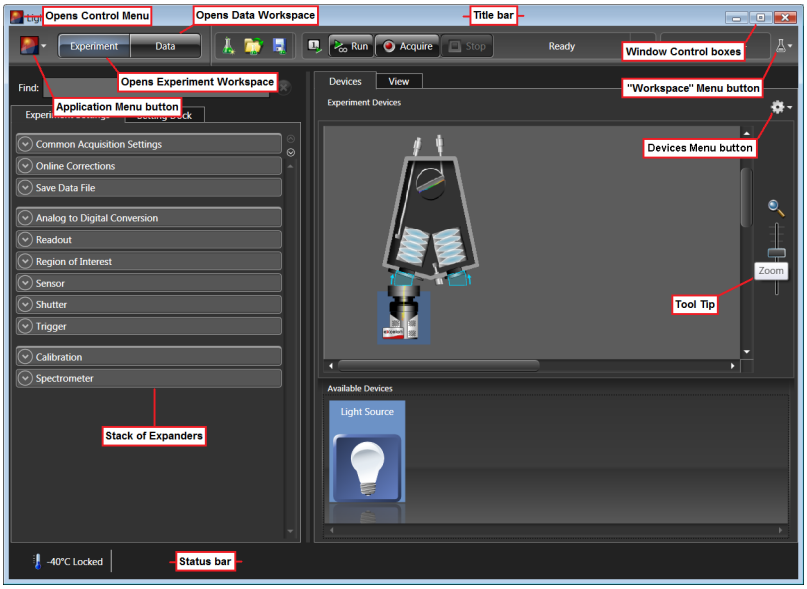


Figure 14. Experiment Workspace with Callouts

Desktop

Introduction

LightField desktop contains two workspaces: **Experiment** and **Data**. The Experiment workspace is the window in which you define the parameters of your experiment, run it, and view the data as it is being acquired. The Data workspace, which has two windows, is used primarily for reviewing previously acquired data, exporting data to other file formats, post-processing, comparing data sets, viewing statistics, and examining file information (i.e., metadata that is contained in a data file).

The LightField Desktop provides access to all of the program's functions.

Application Menu

Introduction

Accessed by clicking on the **Application Menu** button , the **Application Menu** allows you to examine, change, or select settings that affect LightField as a whole. You can change the working and temporary directories, choose to power down monitors during data acquisition, and change a variety of spectrometer and camera units of measure. You can access the online help, activate/deactivate Add-ins, register your LightField software, check for LightField updates, access information about the version and update history of the software, use Windows cut, copy, and paste functions, and exit LightField.

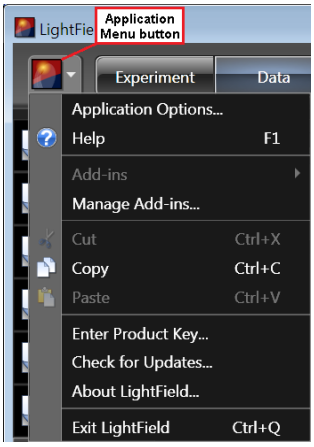


Figure 15. Application menu

Application Options..

Opens the **Application Options** dialog which has the following tabs:

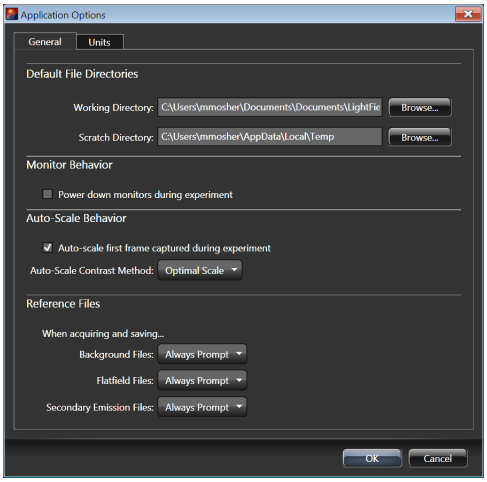


Figure 16. Application Options dialog: General tab

- **General:** After you click on this tab to bring it forward, you can change the Working and Scratch (temporary) directories used by LightField. The default locations of these directories are C:\Users\Username\Documents\LightField and C:\Users\Username\AppData\Local\Temp, respectively. The working directory is the default storage location for data files (another location can be chosen on the **Save Data File** expander). The working directory is also where the Correction Files and Experiment Files subdirectories are located. The scratch directory is used as temporary storage by LightField.

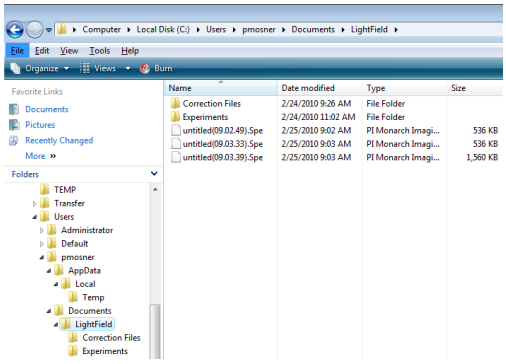


Figure 17. LightField Working Directory

In addition to changing the default LightField directories, you can choose **Power down monitors during experiment** which will have the computer monitor power down while an experiment is underway. This feature is useful when the experiment is acquiring low light level signals and light from the monitor might interfere. Note that monitors will not power down for **Take One Look** (single frame preview).

The default **Auto-Scale** and **Auto-Scale Contrast** settings can be set on this tab. Historically, LightField automatically autoscaled the first frame of a new acquisition. The **Auto-scale...** check box allows you to turn off that autoscaling. The **Auto-Scale Contrast** choice (**Full Scale** or **Optimal Scale**) determines whether LightField will default to showing a histogram based on the **Full Scale** (all pixel intensities are used in the histogram and the drag bars are positioned at outer edges) or the **Optimal Scale** (drag bars are positioned to EXCLUDE the lowest and highest 1% of intensity values).

You can also choose the default action when acquiring and saving reference files (such as background and flatfield files). The choices are always prompt (open **Save As** dialog), always overwrite (overwrites current background), and always new (uses current filename but appends data and time information).

- **Units:** After you click on this tab to bring it forward, you can then choose a device/function and change the related default timing units to be used in LightField.

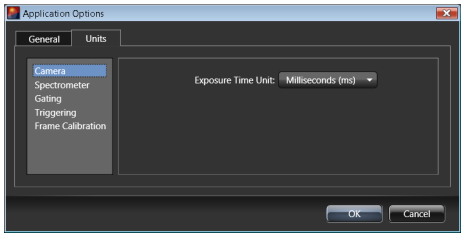


Figure 18. Application Options menu: Units tab

Note: Hyperlinks on the **Common Acquisition Settings** and **Spectrometer** expanders open the **Application Options** dialog to the appropriate tab. When the horizontal axis in a view is in calibrated units, clicking on the label (for example, Nanometers) will open the **Units** tab.

Help (F1)

Opens LightField's online help where you can use the table of contents, index, and search functions to locate general topics about LightField features and procedures to aid you in using LightField.

Add-Ins

One of the locations where Add-in support may be present is the **Add-ins** menu item on the **Application** menu. Add-ins can provide two types of menu elements: a single button or a toggle type of check box. Each add-in can include support for only one menu element in this zone.

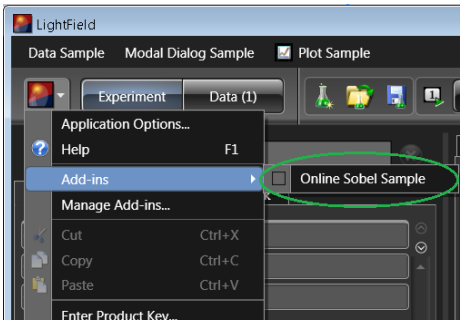


Figure 19. Add-ins

Manage Add-ins...

Opens the **Manage Add-ins** dialog where you can activate or deactivate Add-ins. When starting, LightField checks for available add-ins (sample add-ins provided by Princeton Instruments and any user created add-ins) and populates the lists alphabetically with those that it detects and loads their current status (checked or unchecked) on the appropriate tabs (**Samples** and **Your Add-ins**). The **Manage Add-ins** dialog can also be used to activate and deactivate add-ins from within a current session of LightField. To change which add-ins are activated, select or de-select check boxes and click on the **OK** button.

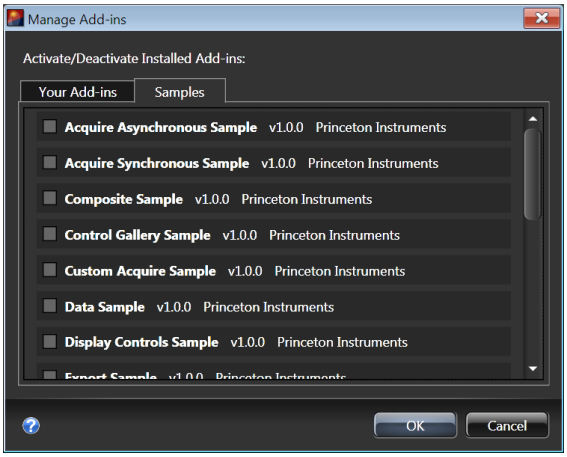


Figure 20. Manage Add-ins dialog

Cut (Ctrl+X)/Copy (Ctrl+C)/Paste (Ctrl+V)

Standard Windows editing functions.

Enter Product Key

Opens the **Enter Product Key** dialog where you can check the status of a trial version of the entire LightField package (Experiment Workspace, Data Workspace, and IntelliCal™) or register and activate your purchased LightField component(s). For more information on product registration and activation, see ***"Product Registration" on page 2***.

Figure 21. Enter Product Key dialog

Check for Updates...

Before selecting this option, make sure your computer is connected to the Internet. When you select this option, LightField will go the Princeton Instruments FTP site and check to see if there are updates available. For more information on updating LightField, ***see "Product Updates" on page 4***.

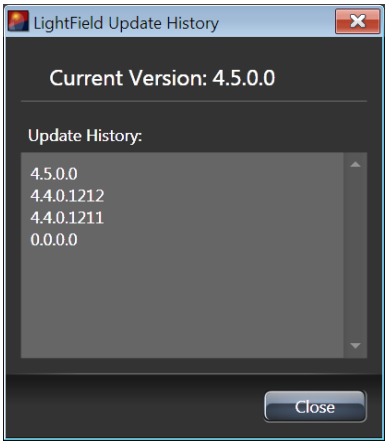


Figure 22. LightField Updates dialog

About LightField...

Opens a dialog that reports the current LightField version, copyright information, and contact information. This dialog also includes a Show update history link which pops up a listing of the versions that have been installed.

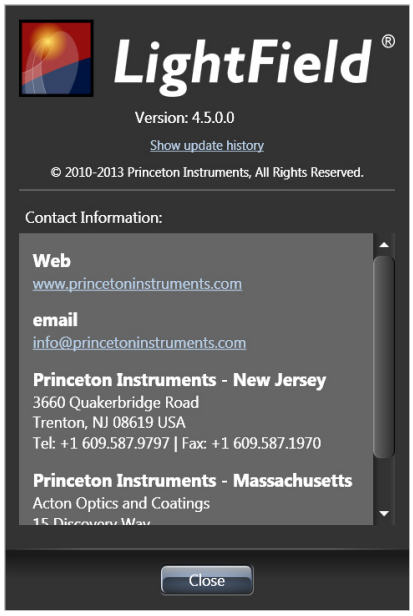


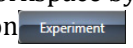
Figure 23. About LightField dialog

Exit LightField (Ctrl+Q)

Closes the current instance of LightField.

Workspaces

Experiment Workspace

The Experiment workspace is initially displayed when you first open LightField. If the Data workspace is being displayed, you can accessed the Experiment workspace by clicking on the **Experiment** button 

The Experiment workspace is used to:

- Add devices to or delete them from your experiment
- Review or change experiment parameters
- Run the experiment
- View data as they are being acquired.
- Run the spectrometer alignment helper
- Activate the step and glue function
- Change data display attributes
- View multiple data sets
- Display previously stored data
- Identify peaks
- View statistical data

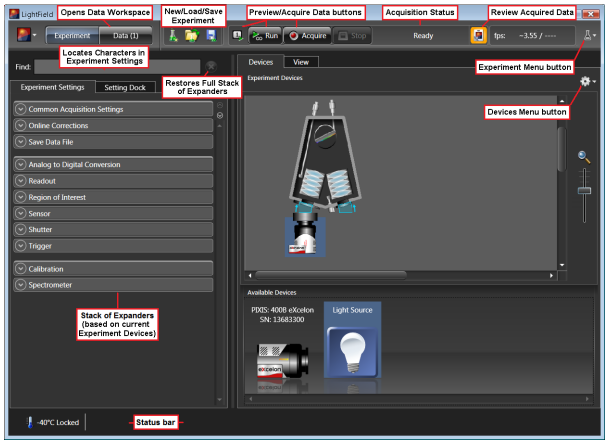


Figure 24. Experiment Workspace with Callouts (Experiment Settings and Devices tab)

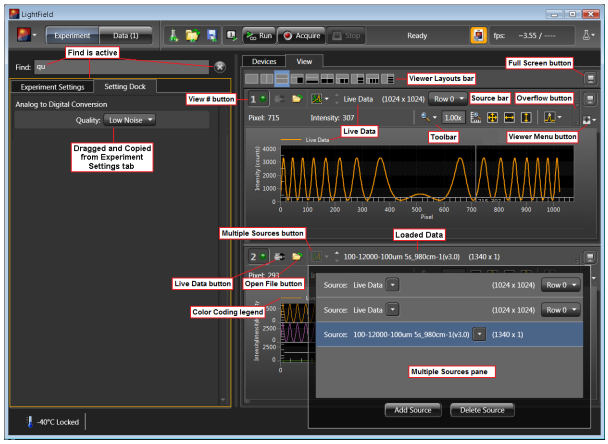
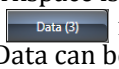


Figure 25. Experiment Workspace with Callouts (Setting Dock and View tab)

For detailed information about the Experiment workspace, see ***see "Chapter 3: Experiment Workspace" on page 17***.

Data Workspace

The Data workspace is accessed by clicking on the **Data** button 

in the Experiment workspace. Data can be viewed in either the Data View or in the Comparison View. The Data workspace is used to:

- Display recently acquired and stored data
- Change data display attributes
- Examine and compare multiple data sets
- Identify peaks
- View statistical data
- Perform post-processing operations on selected data
- Save modified data to.SPE files
- Export data to other file formats (.AVI, .CSV, .FTS, .SPC, and .TIF)

For detailed information about the Data workspace, ***see "Chapter 8: Data Workspace" on page 115***.

Data View Window

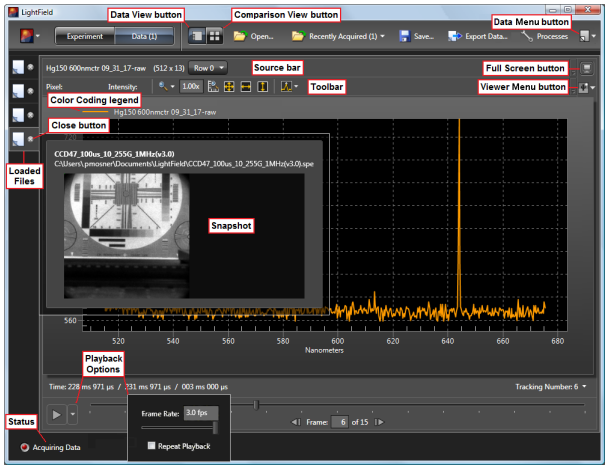


Figure 26. Data View with Callouts

The **Data View** (used primarily for examining and post-processing acquired data and exporting the data to other file formats) is accessed on the **Data** workspace by clicking on the **Data View** button . When a data set is opened in the Data View, an icon is placed in the lefthand panel. Positioning the mouse cursor above this icon opens a snapshot containing the file name and location of the data as well as a small image of the data set. Clicking on the icon will display the data in the view area. If the data contains multiple frames, you can manually cycle through the frames or set up playback (frames per second), with or without looping. If the data is shown as a graph or set of graphs, you can display the data one row at a time by selection from the Row drop-down list or by pressing the arrow keys on the keyboard. If there are multiple ROIs, you can select the ROI for display from the ROI drop-down list. The **Data Menu** allows you to access metadata and to view up to nine statistics for the currently displayed data file. Clicking on the **Comparison View** button opens the Comparison View window.

Note: If you are reviewing data in the Data View while LightField is running in Preview mode or Acquiring data, the message Running Experiment or Acquiring Data will be shown in the lower left corner of the viewer.

For detailed information about using Data View, ***see "Using Data View" on page 125***.

Comparison View Window

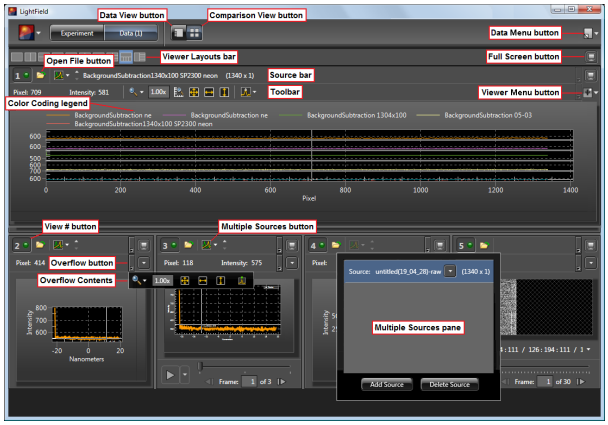


Figure 27. Comparison View with Callouts

The **Comparison View** (used for comparing previously acquired data) is accessed on the **Data** workspace by clicking on the **Comparison View** button . Comparison View allows you to open up to five views and to have either one image or up to five spectra per view. If there are multiple spectra in a view you have the additional capability of either stacking or overlaying the spectra. Another feature of this view is the **Comparison Statistics** dialog accessed via the **Data Menu**. Statistics for the contents of Viewers 1-5 (limited to the current source in the view if more than one graph is displayed). Clicking on the **Data View** button opens the Data View window.

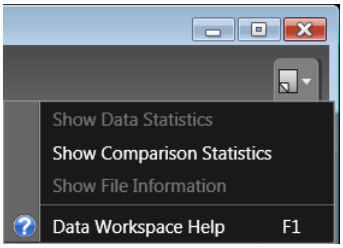


Figure 28. Comparison View menu

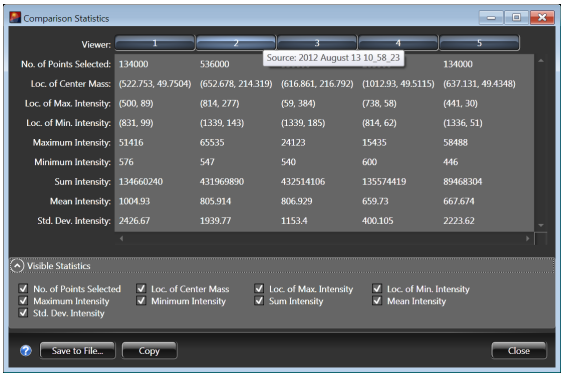


Figure 29. Comparison Statistics dialog

Note: Comparing Live Data and previously acquired data are done in the **Experiment** workspace view area.

For detailed information about using Comparison View, ***see "Using Comparison View" on page 131***.

Supported File Formats

LightField supports several file formats for acquired data. Not all experiments can utilize all file formats. Also, each format can limit the data presentation or processing features because the required experiment information may not be supported by the format and thus lost after storing. Note also each format has different efficiencies, which has an impact on performance and therefore limits the success of an experiment with high data rates. Formats that can only be imported allow LightField to replace old versions of a particular format with a newer version. Formats that can only be exported allow LightField to provide data for use with other software. Supported file formats are:

- **PI Data File (SPE):** (Import or Save) This is Princeton Instruments' native file format. It supports uncompressed, multi-frame, luminance, image data with some metadata describing experiment information. While both WinX/32 and LightField create SPE files, LightField version 3.0 SPE files are more complex than WinX/32 version 2.x SPE files and you may not be able to directly open a WinX/32 file in LightField. LightField includes a converter that will allow you to convert a WinX/32 version 2.x SPE so you can view the data in LightField. Metadata, however, will be limited and ROIs may not translate since WinX/32 and LightField store ROI data differently.
- **Tagged Image File Format (TIF):** (Export) This format is typically used for imaging and supported by a variety of software packages. A subset of version 6.0 can be exported; i.e., uncompressed, multi-frame, luminance, image data with some metadata describing experiment information only.
- **ASCII CSV File Format (CSV):** (Blemish File and Exported File) The Comma Separated Values format is used when you create a blemish correction (defect) file or export a .SPE file to a .CSV file. A blemish file can either be created in an ASCII text editor or in a spreadsheet and must have a CSV extension. Data exported to a .CSV file can be exported as a table or a matrix.
- **Audio Video Interleave (AVI):** (Export) This format is used to export a file containing multiple frames to a video clip. AVI files can be played by various video players, but the player must support the codec used to encode the video data. Data compression provides the greatest compatibility. If the AVI is uncompressed and your player does not play the file, try a different player. If pseudo coloring is applied to an open file and the file is exported to AVI, the pseudo coloring will be applied to the AVI as well.
- **Flexible Image Transport System (FITS):** (Export) This format is typically used for astronomical imaging and supported by a variety of software packages used by astronomers. A subset of version 2.1b can be exported; i.e., uncompressed, multi-frame, luminance, image data with some metadata describing experiment information only.
- **Thermo Scientific File Format (SPC):** (Export) This format is typically used for spectroscopy and supported by a variety of spectroscopic data analysis packages. A subset of version 0x4B can be exported; i.e., uncompressed, multi-frame, spectral data with some metadata describing experiment information only.

Note: FITS, TIF, and SPC formats support only one ROI at a time, so LightField will always write a separate file for each ROI, with all chosen frames inside that file. For example, if there are two ROIs, four frames of data in the source file, and all ROIs and frames are selected for export, two files will be created. The filenames will be the same as the source file name with appended ROI and frame information: such as untitled 09_40_05-Roi-1-Frames-1_4 and untitled 09_40_05-Roi-2-Frames-1_4 with the appropriate extension.

Online Help

LightField help topics are accessed by:

- positioning the cursor on an area in the LightField window and pressing F1,
- clicking on a Help hyperlink in a LightField dialog,

- clicking on a button,
- choosing Help from the Application Menu, and
- opening the LightField.chm file located in the Program Files\Princeton Instruments\LightField directory (this allows you to open the help without having to run LightField).

After you have opened a Help topic, you can access other topics by using the **Contents**, **Index**, and **Search** features in the Navigation pane displayed left of the topic. **Contents** works like a table of contents. Organized into books and topics, it displays a conveniently organized list of the topics in the Help system. **Index** provides a list of alphabetically arranged keywords, allowing topics of interest to be rapidly accessed. **Search** is a search function that allows you to quickly zero in on information relating to the subject of interest. The current help topic is displayed in the window to the right of the tabs. Buttons at the top of the Help window allow you to hide or reveal the Navigation pane, step through topics you have accessed while the Help has been open, print a topic if the computer is attached to a printer, and turn search highlighting on or off.

Note: Some dialogs used in LightField (such those for opening or saving data files) have help that is provided by the relevant Windows® operating system. To access this help, position the cursor on the item for which you would like additional information and press the F1 key. Alternatively, you can click on the button if there is one present.

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Chapter 3: Experiment Workspace

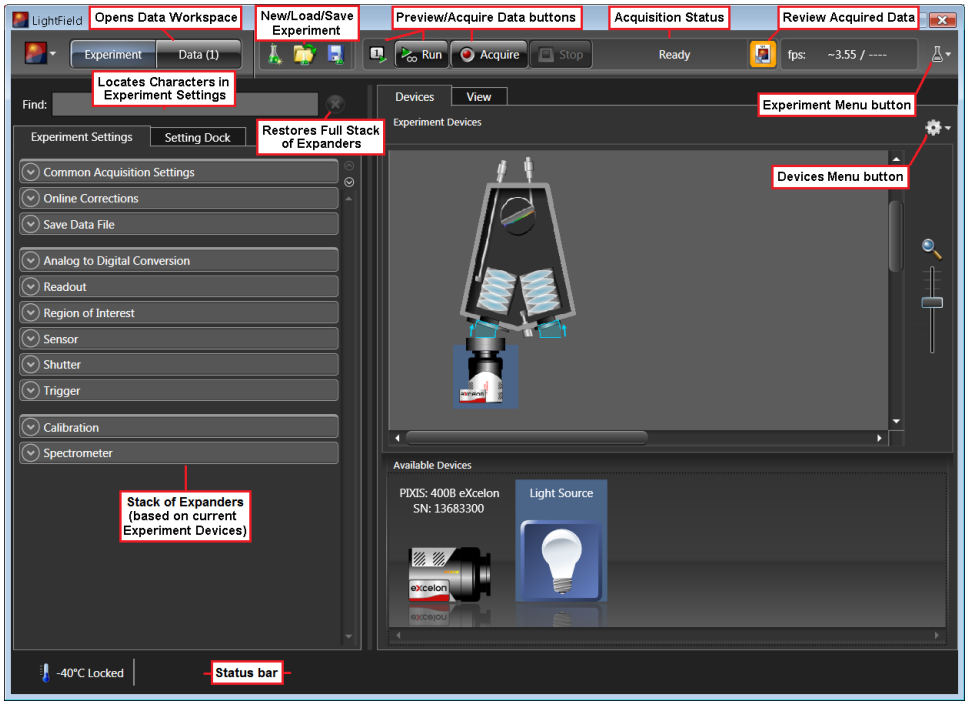


Figure 30. Experiment Workspace with Experiment Settings and Devices tab

Introduction

LightField contains two workspaces: **Experiment** and **Data**. The Experiment workspace is the window in which you define the parameters of your experiment, run it, and view the data as it is being acquired. The Data workspace, which has two windows, is used primarily for reviewing previously acquired data, exporting data to other file formats, post-processing, comparing data sets, viewing statistics, and examining file information (i.e., metadata that is contained in a data file).

Devices tab

The **Devices** tab is where you choose from available devices (devices detected by LightField) to indicate which camera, spectrometer, and/or spectrometer accessories you will be using in your experiment. Experiment devices that are computer-controlled must be powered on and cabled to the appropriate communication ports before LightField is started. When it starts, it interrogates the ports and when it finds a device, places an icon for that device in the **Available Devices** area. To include a device in your experiment, you must drag its icon into the Experiment Devices area. After the devices are all in the **Experiment Devices** area, you can link them if there are link points. For example, you could link a camera to a spectrometer exit port. It is not necessary to link devices but in some instances (for example, you are trying to link a camera to an exit port that is not in the light path) LightField will not allow you to make a link that is inappropriate.

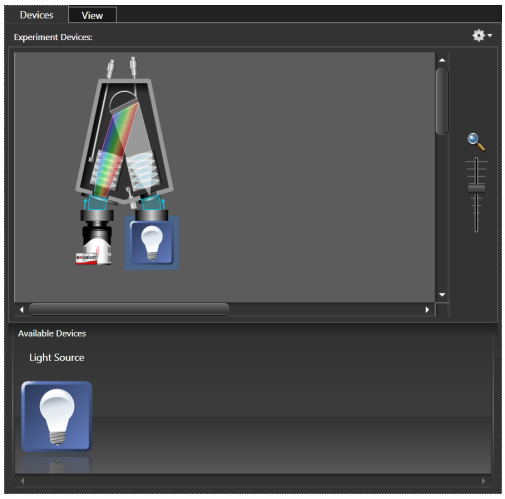


Figure 31. Devices tab

Note: Only one camera and/or one spectrometer is allowed in the Experiment Devices area at any time.

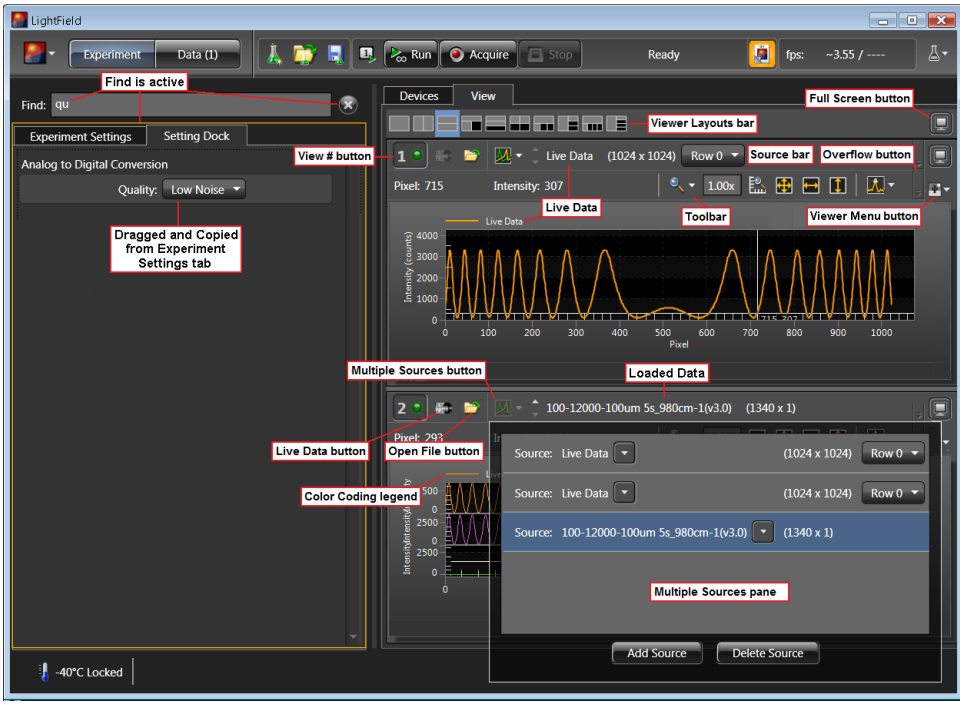


Figure 32. Experiment Experiment Desktop-View with Callouts

The primary reason for dragging device icons into the **Experiment Devices** area is to populate the **Experiment Settings** stack. Whenever a device icon is dragged into or out of the **Experiment Devices** area, the contents of the **Experiment Settings** stack is updated with the appropriate expanders (these contain device-specific settings and features).

Experiment Settings stack

As stated earlier, the **Experiment Settings stack** is populated with expanders when a device icon is dragged from the **Available Devices** area into the **Experiment Devices** area. When a spectrometer is added a single **Spectrometer** expander is added that allows you to specify the light path through the spectrometer, move gratings, change filters, focus and align a camera to the spectrometer optics, and calibrate the spectrometer. When a camera is added to the experiment, eight or more expanders are added that allow you to edit or select a wide range of parameters that affect the way data are acquired, what data are acquired, how data are read out and digitized, if online corrections will be made, and where data are stored. Each expander can be opened to view and edit a group of settings and then collapsed when you have finished.

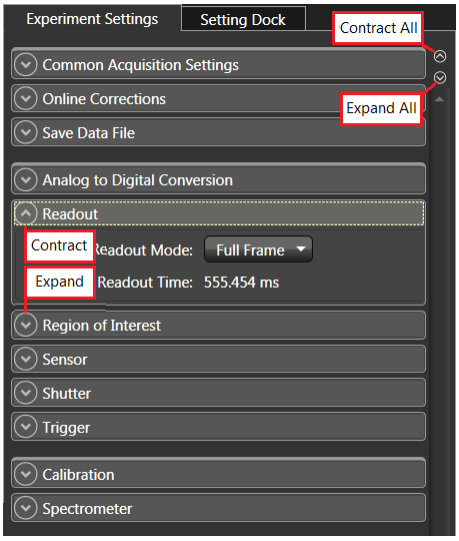


Figure 33. Experiment Settings stack with Callouts

After you have designed the experiment (or while you are designing it), you can save the current settings and devices to an experiment file. This file can be loaded at a later time if you need to edit or rerun an experiment or if you want modify it to create a different experiment. When you load an experiment, LightField will look for the experiment devices and will let you know if there are any devices it cannot find. You have the choice of connecting and powering on the device or canceling the experiment load.

Setting Dock stack

The **Setting Dock stack** is an area into which you can drag frequently used or modified settings. The copy in the **Setting Dock** is linked to the original in the **Experiment Settings** stack. Any changes you make to settings in one of these stacks will also be made in the other.

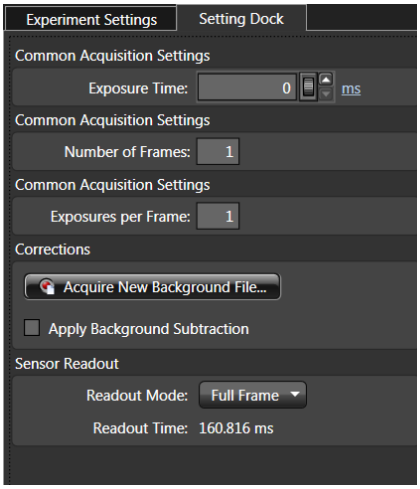


Figure 34. Setting Dock

View tab

The **View** tab is where data will be displayed during and at the end of a data acquisition. The data will be shown as either an Image or a Graph. Up to five views can be selected by clicking on one of the Viewer Layout icons. Only one image can be displayed in a view. However, multiple graphs can be stacked or overlaid in a view. A view or the entire viewer can be maximized to fill the screen or it can be dragged to another monitor if the computer system is configured with two monitors. Each view has its own **Viewer** menu and its own context menu.

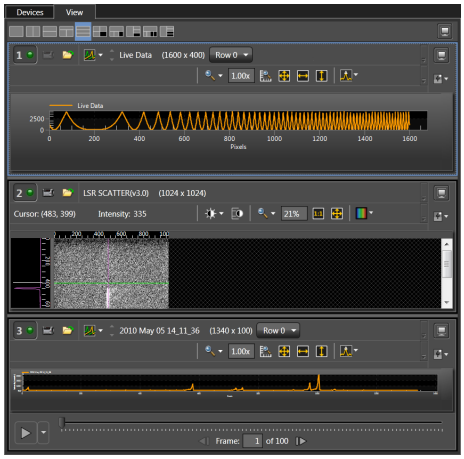
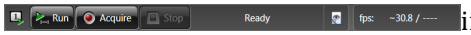


Figure 35. View tab

Acquisition Group

After you have finished setting up and saving your experiment, you can either run the experiment in preview mode or you can acquire data. The **Acquisition group of buttons**



includes **Take One Look**, **Run (Infinite or Single Sequence of Frames)**, **Acquire**, **Stop**, and **Review Acquired Data** buttons. In addition, there is a **Status** panel that reports the current acquisition status (such as Ready, # of # Frames, or Experiment Conflict) and text that reports the approximate rate at which frames of data are being acquired.

Note: If you began by previewing and want to switch to acquiring data, click on the Acquire button. To switch back to previewing, click on the Acquire button again. If you skipped preview and began in Acquire mode, just click on the Acquire button to switch to Preview mode. Click on the Acquire button again to return to acquiring data.

- **Take One Look** previews one experiment frame for you according to your experiment parameters. (If you have Exposures per Frame set to 7, then you will see 7 frames because those 7 frames are needed to give you one resultant frame according to your experiment parameters.)

  Note: When **Take One Look** is selected, the **Power down monitors...** option (if active) will be ignored.

- **Run (Infinite)** Run begins acquisition in preview mode. Data are displayed until preview mode is stopped or acquisition mode is activated; no data are stored in preview mode. When this mode is stopped, the last frame is displayed in the viewer. The **Review Acquired Data** button will not be displayed unless acquisition mode was active. **Run Duration** (auto, infinite or single sequence) is selected via the **Experiment** menu.

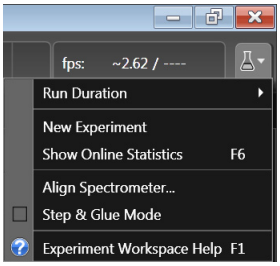


Figure 36. Experiment menu

Note: When Auto is selected from the run duration choices, the preview will be in Run Infinite mode unless Sequential Gating Mode is active (PI-MAX3 or PI-MAX4 only). When Sequential Gating Mode is active, the preview will be run in Single Sequence of Frames mode.

- **Run (Single Sequence of Frames)** 

begins acquisition in preview mode. LightField will only ever give you from the camera the number of resultant experiment frames indicated by the Number of Frames setting. This means that if Number of Frames is 50 (Exposures per Frame = 1), and you start in acquisition mode, you acquire and store 10 frames, and then switch into Preview (sequence) mode, LightField will stop showing frames after it has shown a total of 50 frames (10 were stored, and 40 were previewed). If you start the experiment in Preview (sequence) mode and do not switch to acquisition mode, it will display 50 frames and stop, without storing anything. When this mode is stopped, the last frame is displayed in the viewer. The **Review Acquired Data** button will not be displayed unless acquisition mode was activated. **Run Duration** (auto, infinite or single sequence) is selected via the **Experiment** menu. **Run** (Single Sequence of Frames) will be used for a PI-MAX™3 setup for Sequential Gating.

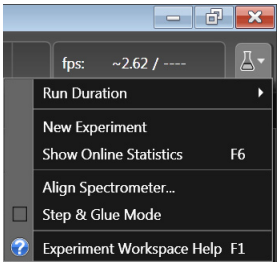


Figure 37. Experiment menu

- **Acquire** 

begins acquisition. One or more frames of data (depending on the experiment design) are acquired, displayed, and stored to the directory named in the **Save Data File** expander. When the acquisition ends or is stopped, the last frame is displayed in the viewer. If there are multiple frames in the acquired data set, you can playback or manually step through the frames after clicking on the **Review Acquired Data** button. See the description of that button below for more information.

- **Stop** 

stops acquisition.

- **Review Acquired Data**  allows you to immediately view the acquired data in the Data View window in the Data workspace. This is particularly useful if you are acquiring more than one frame of data during the acquisition. When you review data in the Data View, you can playback or manually step through the acquired frames in a data set. The Data View window is also where you can export data files to other formats, perform post-processing, review data statistics, examine file information (metadata), load previously acquired data, and save data. The Data View window also includes a link to the Comparison View window where you can visually and statistically compare the data in up to five views.

Other Workspace Features

- The **Application Menu** button  allows you to view application information and to change application options (default working and scratch directories, calibration units, exposure time units, and monitor power down during an experiment).

- The **Experiment** and **Data** buttons 

open the Experiment or the Data workspace. If you are in the Experiment workspace, that button is highlighted.

- The **Experiment File buttons** 

allow you to start a New experiment (it clears the Experiment Settings stack, Setting Dock stack, and the Device tab), Save an experiment, or Load a previously defined experiment.

- The **Find entry field**, above the Experiment Settings and Setting Dock stacks, is used to search for a set of characters in either of these stacks. As you key characters into that field, LightField will examine the expanders for terms that contain those characters. If there are any matches, only the expanders and the settings containing those characters will be shown in the Experiment Settings stack or Setting Dock stack. The stack will have an orange outline to indicate that you have used the Find function. You can restore all of the expanders and/or settings to the stack by clicking on the **Clear** button to the right of the field.

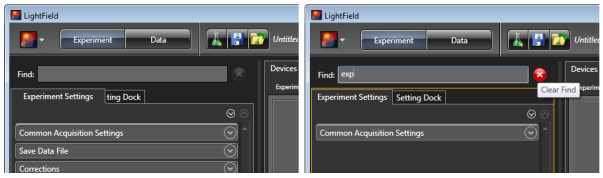


Figure 38. Find entry field

- The **Experiment Menu** button opens a menu of options for the workspace. The choices change depending on the workspace and the workspace window. For example, you can select Show File Information in the Data Viewer window of the Data workspace, but this choice is not available in the Comparison Viewer window.
- The **Full Screen** button associated with each viewer or view will display the viewer or view across the entire monitor screen.
- Context menus are available for views and expanders. Positioning the mouse pointer in an area and right-mouse clicking will open the context menu if there is one associated with that location.
- LightField's online help can be opened at any time by pressing the F1 key on your keyboard. Each expander has its own help topic that can be accessed by clicking on the expander title bar and pressing the F1 key. Many of the menus contain links to help topics related to the feature you are using.

Experiment Menu

Experiment choices related to run duration, opening a new experiment, viewing online statistics, aligning a spectrometer, and activating step and glue mode are listed on the **Experiment** menu (accessed by clicking on the **Experiment Menu** button). Choices available depend on the active experiment devices.

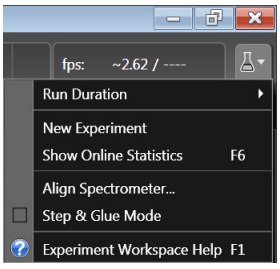


Figure 39. Experiment menu

Devices Menu

Choices on the Devices menu (available when the **Devices** tab is active) allow you to create a Demo camera or clear all experiment devices from the Experiment Devices area. A Demo camera can be used while you familiarize yourself with the LightField software. This allows you to view all of the expanders and settings associated with the camera without requiring connection to a physical camera. After you select a Demo camera from the Create Demo Device dialog, the icon for the camera will be added to the Available Devices area and can then be dragged from there into the Experiment Devices area. At that time the appropriate expanders and default settings will be displayed.

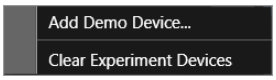


Figure 40. Devices menu

Viewer Menu

Choices on the Viewer menu (available when the **View** tab or viewers are active) determine whether data will be displayed as an image or a graph; with autoscaling; with pseudo color for images; or with stacked graphs, marked data points, grid lines, calibrated data with horizontal axis in pixels, and/or line or point-only plotting for graphs. Each view in a selected view layout has its own **Viewer Menu** button for access to choices that control how data in a view will be displayed. There will be some variation on the choices available depending on the workspace and window.

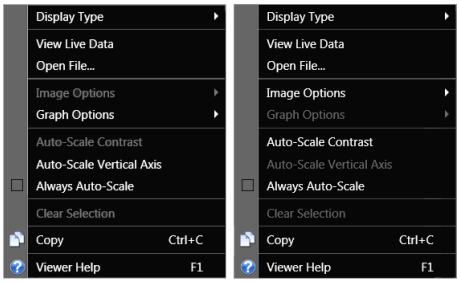


Figure 41. Experiment Workspace

Find function

You can use the Find function to quickly locate a string of characters, word, or phrase in the active panel (Experiment Settings or Setting Dock).

The function begins the search as soon as you begin typing in the **Find** field. If the string of characters, word, or phrase is found, all expanders will be hidden except for those containing text using those characters, word, or phrase. An orange line will be drawn around the stack to indicate that the **Clear Find** button (to the right of the Find field) must be clicked to restore the full stack.

TIP: Use Ctrl+F to jump to the **Find** field. Then begin typing.

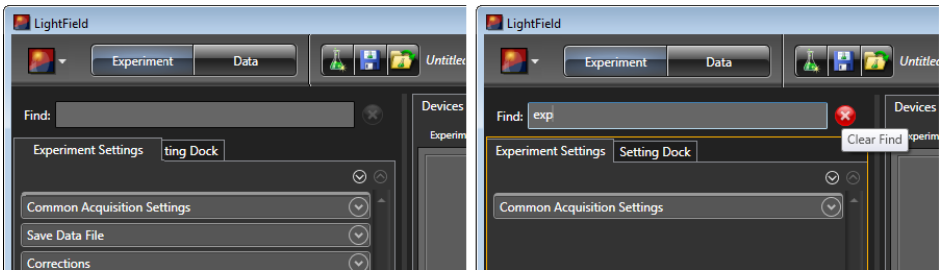


Figure 42. Find function

Specifying the Default Data Directory

The default working and scratch directories can be specified after selecting **Application Options...** from the **Application Menu** and selecting the **General** tab on the **Applications Options** dialog. The working directory will used automatically when LightField stores data unless you change the directory on the **Save Data File** expander. The scratch directory is used for temporary files.

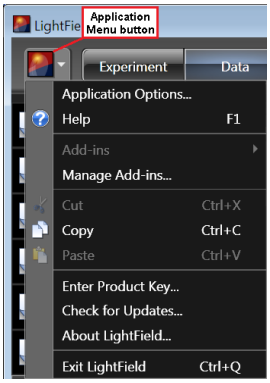


Figure 43. Application menu

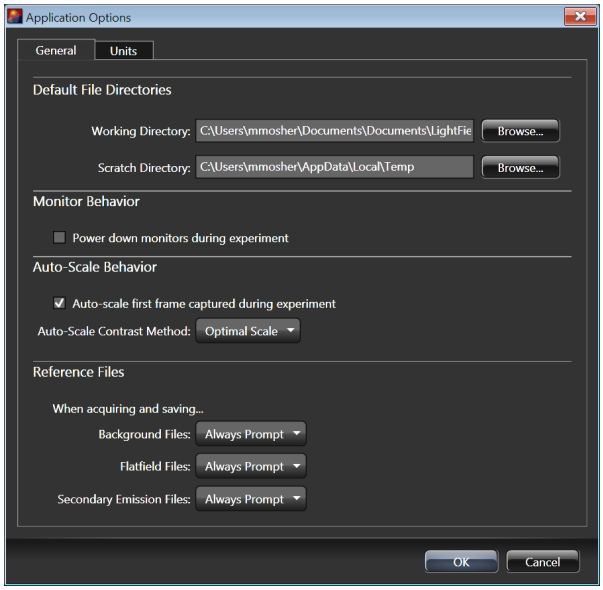


Figure 44. Application Options dialog: General tab

Chapter 4: Device Setup

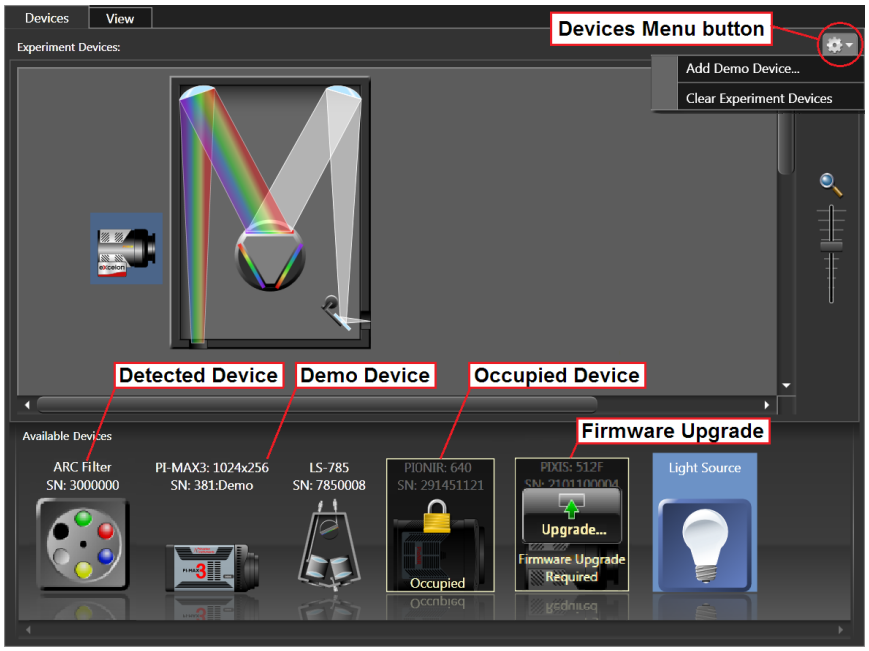


Figure 45. Available and Experiment Devices areas

Device Selection

Introduction

When a device is connected to the host computer and the device is powered on, the device will be detected by LightField when it boots. All detected devices appear as icons in the **Available Devices** area below the **Experiment Devices** area. Devices that will be detected include Acton SP series spectrometers; PI-MAX®3, PI-MAX®4, NIRvana/PIoNIR, PIXIS family, Pro-EM®, ProEM®+, PyLoN®, PyLoN®-IR, and Quad-RO cameras; and the Acton FA-448-2 motorized 6-position filter wheel. The Light Source device is always available and does not represent any specific type of light source.

The LS 785 spectrometer (which is not computer-controlled) will only appear in the **Available Devices** area if the appropriate NoComDevices.xml file is found by LightField.

If settings for a spectrometer accessory cannot be read by LightField, its settings will be set to default values.

Note: If your camera is not connected and turned on, you can create a "Demo" device. A Demo device allows you to see what settings are available for a camera without actually having one connected or turned on. For more information, ***see "Demo Devices" on page 24***.

Available Devices

Devices supported by LightField currently include Princeton Instruments cameras (PI-MAX3, PI-MAX4, NIRvana/PIoNIR, PIXIS, PIXIS-XB, PIXIS-XF, PIXIS-XO, ProEM, ProEM+, PyLoN, PyLoN-IR, and Quad-RO) and Acton spectrometers. Also supported are Acton accessories such as the Acton motorized filter wheel. An **Available Device** is one that appears in the **Available Devices** area if it:

- is supported and detected by LightField,
- is a LightField "Demo Device",
- is an LS 785 spectrometer, or
- is a Light Source (the Light Source icon is a generic light source that always appears in Available Devices).

A device can only be used when setting up an experiment if it falls into one of the categories listed above and is therefore shown in the **Available Devices** area. If the icon for the device you are using does not show up in the Available Devices area and it meets the criteria, see ***"Unavailable Devices" on page 27***.

Detected Devices

In order for a supported Princeton Instruments camera, an Acton SP series spectrometer,

IsoPlane® SCT-320 spectrometer, or a motorized Acton accessory to be detected by LightField, it must be powered on and in communication with LightField through a computer interface.

Demo Devices

Any one of the supported Princeton Instruments cameras can be created as a Demo Device by selection from the **Create Demo Device** dialog. Having the capability of creating a device gives you the flexibility of familiarizing yourself with LightField without having to have actual devices in place. For more information about creating Demo Devices, ***see "Demo Devices" on page 24***.

LS 785

An Acton LS 785 spectrograph has no motorized parts and is not computer-controlled. However, its icon will be placed in the **Available Devices** area if LightField finds the **NoComDevices.xml** file on your computer. Because its settings cannot be read by LightField, LightField uses the default settings contained in the XML file.

Dragging LS 785 icon into the **Experiment Devices** area with an available Princeton Instruments camera allows you to align the camera to the spectrograph optics and to calibrate the data acquired by the camera. If you have an LS 785 but no icon appears in the Available Devices area, see ***"Live Data is Not Appearing in the Experiment Viewer" on page 163***.

Demo Devices

Introduction

A Demo device allows you to see what settings are available for a camera without actually having the camera connected and turned on. When you drag a Demo device into the **Experiment Devices** area, LightField will load the **Experiment Settings** tab panel with the settings appropriate to that camera. Then you can try out various values, practice creating ROIs, and preview and acquire data. The data acquired, displayed, and stored are demo data.

Creating a Demo Device

If your camera is not connected and turned on, you can create a Demo device by clicking on the **Devices Menu** button  to the right and above the **Experiment Devices** area. Click on **Add Demo Device**. After the **Create Demo Device** dialog appears, select the appropriate camera, enter a serial number or identifying text, and click on the **Create Demo Device** button. An icon for the demo device is added to the **Available Devices** area. Its label will include the Camera Model, Serial Number, and the word Demo (for example, PIXIS:1024B; SN:123456; Demo). The **Experiment Settings** tab panel will be loaded with expanders when you drag the icon into the **Experiment Devices** area.

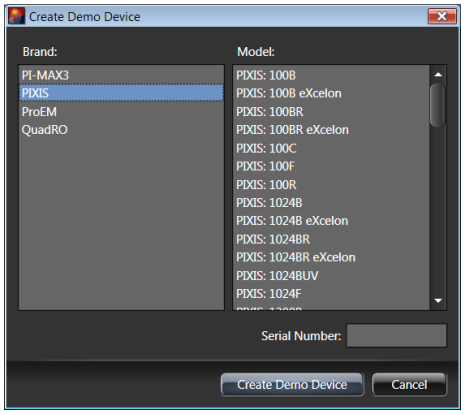


Figure 46. Create Demo Device dialog

Deleting a Demo Device

If you want to delete a demo device that is in the **Experiment Devices** area, either right-mouse click on the icon and select **Remove** from the menu or drag the icon into the **Available Devices** area. When the demo device icon is in the **Available Devices** area, right-mouse click on it and select **Delete this Demo Device**.

Experiment Devices

Introduction

Experiment Devices are devices whose icons have been dragged from the **Available Devices** area into the **Experiment Devices** area of the **Devices** tab. An experiment device is a LightField-supported Princeton Instruments camera (PI-MAX3, PI-MAX4, NIRvana/PIoNIR, PIXIS, PIXIS-XB, PIXIS-XF, PIXIS-XO, ProEM, ProEM+, PyLoN, PyLoN-IR and Quad-RO), an Acton spectrometer, or an Acton accessory such as the Acton motorized filter wheel. When a device is dragged into the **Experiment Devices** area, the **Experiment Settings** tab is populated with the expanders appropriate to the device.

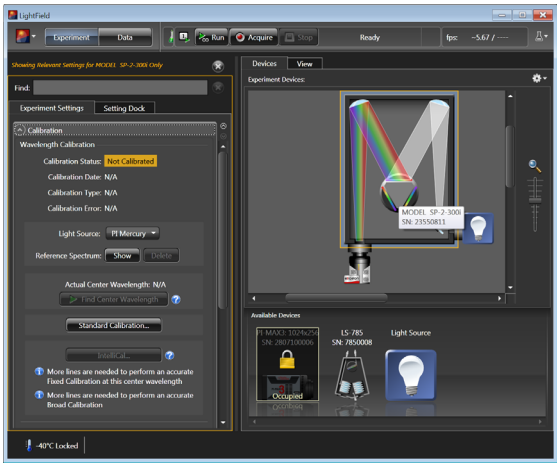


Figure 47. Experiment Devices area

The rules for the **Experiment Devices** area are:

1. Only one camera may be present. If you need to change to a different camera, first drag the current camera back into the Available Devices area or right-mouse click on the camera and select **Remove** from the context menu. Then, drag the new camera from the Available Devices area.
2. Only one spectrometer may be present. If you need to change to a different spectrometer, first drag the current spectrometer back into the Available Devices area or right-mouse click on the spectrometer and select **Remove** from the context menu. Then, drag the new spectrometer from the Available Devices area.
3. If a device is being used in one instance of LightField, it cannot be used by a different instance until it has been removed from the Experiment Devices area or that instance of LightField has been closed. A device used by a different instance will be shown in the Available Devices area as "Occupied."
4. If a device requires a firmware upgrade, it cannot be used until the upgrade occurs. A device needing an upgrade will be shown in the Available Devices area as "Firmware Upgrade Required."

To look at a device name and serial number, position the cursor over the device and this information will be displayed for about 5 seconds.

Relevant Experiment Settings

To see the relevant experiment settings for a camera, spectrometer, or filter wheel in the **Experiment Devices** area, right-mouse click on the device and select **Show Relevant Settings Only** from the context menu. The appropriate expander or expanders will be shown in the **Experiment Settings** tab and an orange border will be drawn around the device icon. Click on the **Show All Settings** button to re-display all of the settings.

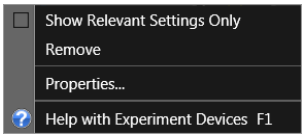


Figure 48. Experiment Devices context menu

Device Properties

To see information about a device, right-mouse click on the device and select **Properties** from the context menu. If the device is a camera, the **Device Properties dialog** may have up to three tabs:

- **Sensor Attributes:** Includes information about the sensor such as name type, characteristics, active and inactive areas, and pixel size.
- **Intensifier Attributes:** Includes information about the intensifier in a PI-MAX3 or PI-MAX4 camera such as intensifier options, photocathode sensitivity, gating speed, phosphor type, and intensifier diameter.
- **Firmware:** Includes information about the firmware logic and interface.

If the device is a spectrometer, the **Device Properties** dialog will provide information about turrets, gratings, entrance and exit ports, detector angle, and focal length.

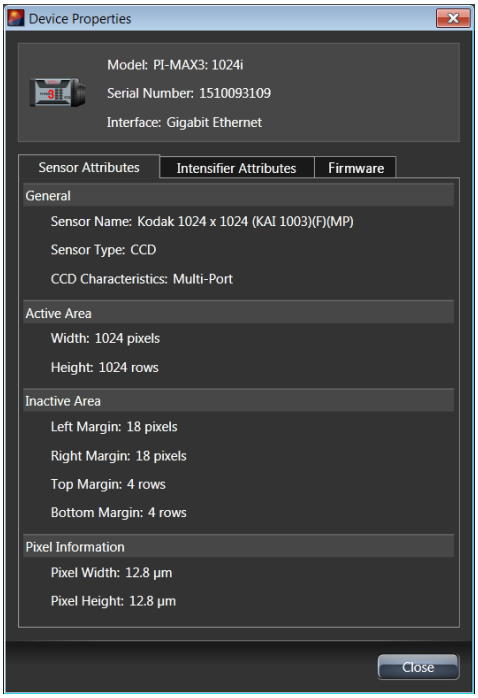


Figure 49. Device Properties dialog - PI-MAX

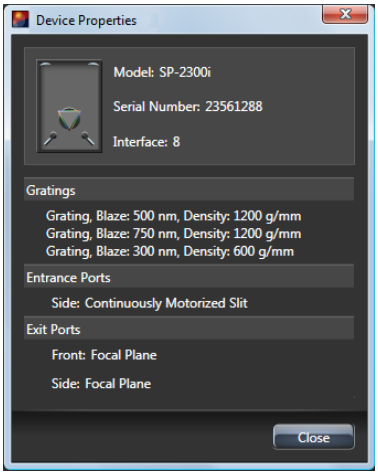


Figure 50. Device Properties dialog - SP-2300i

If there are multiple devices in the Experiment Devices area (for example, the setup shown in Figure 47.), devices can be dragged into the **Experiment Devices** area (Figure 51.) or they can be dragged into the area and "linked" together (Figure 52.). As you drag a device already in the **Experiment Devices** area toward a linking position, a green highlight will appear at that position and when you release the mouse button, the device will snap into place.

Note: LightField will not allow you to link a camera to a spectrometer entrance port.

Selecting a Device

To select a device for an experiment, drag-and-drop its icon from the **Available Devices** area into the **Experiment Devices** area by holding down the left mouse button on the device, dragging the icon into the **Experiment Devices** area, and releasing the mouse button. After the device is released in the **Experiment Devices** area, expanders related to that device will appear in the **Experiment Settings** tab panel to the left of the **Experiment Devices** area.

Linking Devices

Introduction

The reasons for the linking devices to each other are to allow you to set up a visual representation of the experiment devices and their relationships and to assist you in making setting choices based on some of the links. A camera can be linked to a spectrometer exit port. A light source can be linked to a camera or to the entrance port of a spectrometer.

Devices can only be linked after they have been dropped into the **Experiment Devices** area. Once you have dropped a device into the **Experiment Devices** area, LightField loads device settings and it knows enough about the device to indicate where potential dock points are. You can then drag it around in the area and, when it is close enough to a docking point, a green highlight will appear at that point. The device will snap into place when you release the mouse button.

You do not have to link any devices together in order to successfully perform the experiment. If you DO link devices together, then LightField has a little more information with which to help you make setup decisions.

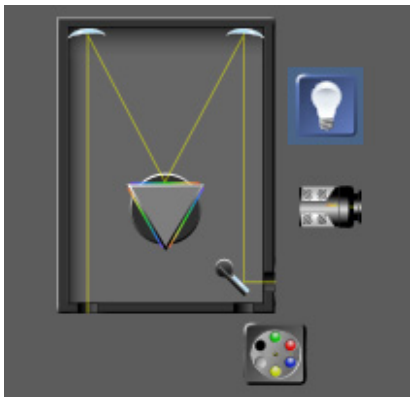


Figure 51. Examples of Devices in the Experiment Devices area

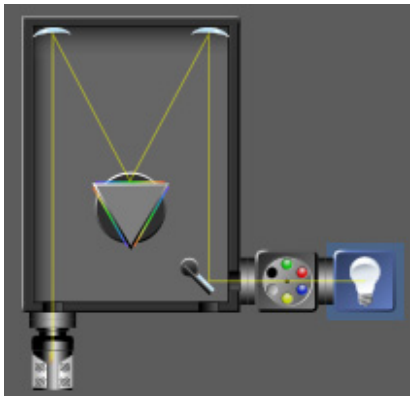


Figure 52. Examples of Linked Devices

Valid Device Linking

The following are all valid combinations of devices at an entrance port:

- Light --> Spectrometer Entrance Port
- Light --> Filter wheel --> Spectrometer Entrance Port
- Light --> Filter wheel --> Shutter --> Spectrometer Entrance Port

The following are all valid combinations of devices at an exit port:

- Spectrometer Exit Port --> Camera
- Spectrometer Exit Port --> Filter wheel --> Camera
- Spectrometer Exit Port --> Filter wheel --> Shutter --> Camera

Unavailable Devices

Missing Devices

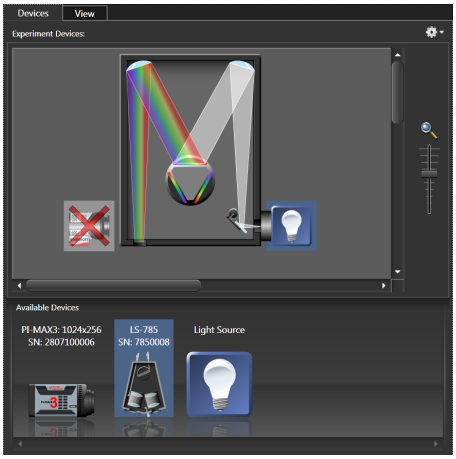


Figure 53. Missing Camera

A missing device is shown with a Large red X superimposed on it. For example, the spectrometer is missing (i.e., LightField cannot find it). This can occur under a couple of conditions:

- The interface cable is disconnected and/or the device is no longer powered on.
- The device was turned off and then back on while LightField was open.

Actions to Take

1. Make sure that the interface cable is connected to both the device and your computer.
2. Make sure the device is connected to a power source and that the device is turned on.
3. If the device is still shown as missing or you cannot move the icon to the Experiment Devices area, close LightField, cycle power for the device, and then restart LightField. LightField will scan for available devices and should now find the device.

Undetected Devices

Supported Camera, Acton SP series Spectrograph, IsoPlane SCT-320 Spectrograph, or Motorized Acton Accessory

If you connect a new device (such as an Acton SP series spectrograph or a different Princeton Instruments camera that is supported by LightField) to the computer and power up the device; but it does not appear in the **Available Devices** area, you may need to close LightField. Verify that the interface cable is connected between the device and the computer and that the device is powered on. When you restart LightField, the program will scan for the device and load the icon if the device is found.

LS 785 Spectrograph

If you have an LS 785 and its icon is not appearing in the **Available Devices** area, you will need to check to see if the required **NoComDevices.xml** file is on your computer and in the correct location. LightField expects to find the file in a hidden directory on the your computer: **C:\ProgramData\Princeton Instruments\Spectral Devices.** If this directory is not visible in Windows Explorer, you will need to unhide the directory before your search.

To Unhide Hidden Directories:

1. Open the Windows **Control Panel**.
2. Enter the word **hidden** in the search field at the top right of the panel.
3. Click on **Show hidden files and folders**.
4. Click on the **Show hidden files and folders** radio button.
5. Click on **Apply** and then click on **OK**.
6. You should now be able to see the **ProgramData** directory and its subdirectories on your C drive.

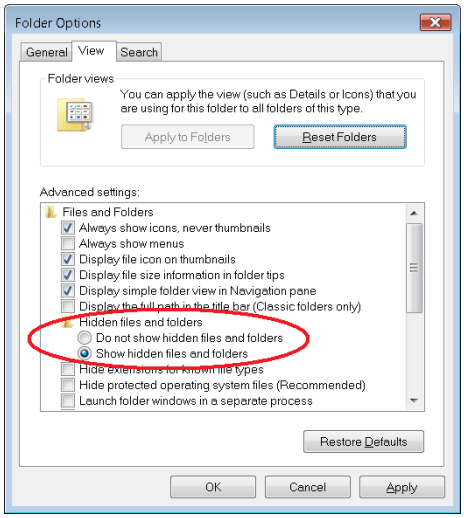


Figure 54. Folder Options dialog

To Locate the File:

1. Check to see if the **NoComDevices.xml** file is in the **ProgramData\Princeton Instruments\Spectral Devices** subdirectory.
2. If the file is not there, search on the filename.
   - If it is in a different location, copy or move it to the correct subdirectory.
   - If it is not on your computer, contact Princeton Instruments Customer Support for assistance.
3. If the file is in the correct location, but the LS 785 icon still does not appear when you

start LightField, contact Princeton Instruments Customer Support.

Occupied Devices

Icons for Occupied Devices are displayed in the **Available Devices** area with an overprinted padlock and the word "Occupied". An occupied device is one which has been detected by the current instance of LightField but is being used (i.e., the icon is in the **Experiment Devices** area) by a different instance of LightField. Before you can use an occupied device, its icon must be cleared from the **Experiment Devices** area of the other instance.

Figure 55. Occupied Device icon

Firmware Upgrade Required

Introduction

Princeton Instruments cameras contain firmware to enable each device's basic operation as well as implementing higher-level functions. When a device is connected to the computer interface and is turned, LightField examines the firmware as part of the device recognition process. If LightField determines that the device requires a firmware upgrade in order to be compatible with LightField, the device icon for the device will be loaded into the **Available Devices** area but you will not be allowed to use the device until the firmware upgrade has been completed.

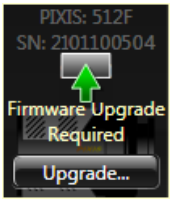


Figure 56. Firmware Upgrade Required

Before Upgrading

1. Because all instances of LightField will be shut down for the upgrade, save your experiment and data in the current instance of LightField and the experiments and data in any other instances of LightField.
2. Turn off all OTHER devices that have been detected by LightField. This includes devices that are being used by other instances of LightField.
3. Close any OTHER software that is in communication with the devices.

Upgrading

1. Click on the **Upgrade** button on the device icon.
2. Make sure you have saved your experiment(s) and any data that you may have processed but not yet saved.
3. Do not turn off or disconnect the device being upgraded.
4. When you click on Upgrade, all instances of LightField will close and a **DOS command window** will pop up and begin running the PI_Update.exe program.

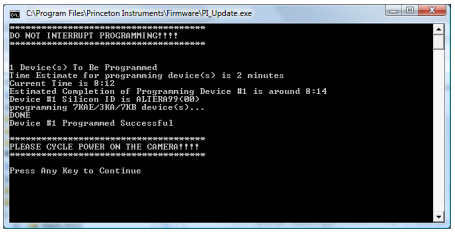


Figure 57. DOS command window

5. When you are notified that the device has been successfully programmed, turn the upgraded device off and then back on.
6. Press any key to continue: the window will close and a single instance of LightField will be started.
7. The upgraded device will now be available.

Device Cannot Be Upgraded

If the update program reports that the device cannot be upgraded, follow the instructions in the window to exit the update program.

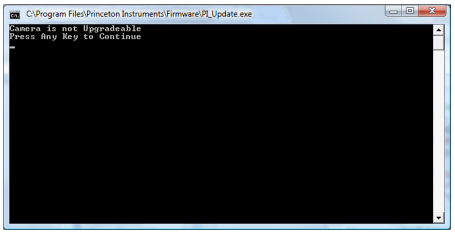


Figure 58. Device Cannot Be Upgraded message

Then, contact Princeton Instruments Customer Support for assistance. For immediate support in your area, please call the following locations directly:

North America	1 877 4 PIACTON (877 474 2286)
Benelux	+31 (347) 324989
France	+33 (1) 60 86 03 65
Germany	+49 (0) 89 660 7793
Japan	+81 (3) 5639 2741
UK & Ireland	+44 (0) 28 3831 0171
Singapore	+65 6293 3130
China	+86 10 6262 5862

Otherwise, please contact Customer Support by using the Support Request form (http://www.princetoninstruments.com/support/contact.aspx) or sending an e-mail request at techsupport@princetoninstruments.com.

Removing Devices

Clearing the Experiment Devices Area

Clearing devices from the **Experiment Devices** area also clears changes you have made to the **Experiment Settings** parameters associated with the devices, especially for cameras. If you do not want to lose the changes, save your experiment before using either the **Remove** or **Clear Experiment Devices** function.

To clear a single device from the **Experiment Devices** area, right-mouse click on the device and click on **Remove**. The device icon will be returned to the **Available Devices** area.

To clear all devices from the **Experiment Devices** area, click on the **Devices Menu** button and click on **Clear Experiment Devices**. All devices in the **Experiment Devices** area will be returned to the **Available Devices** area.

Note: Clicking on the **New Experiment** button (or selecting **New Experiment** from the **Experiment** menu) also clears the **Experiment Settings** and **Experiment Devices** area. However, LightField asks if you want to save your current experiment before it completes the clearing operation.

Clearing the Available Devices Area

To clear a demo device from the **Available Devices** area, right-mouse click on the icon and select **Delete this Demo Device**.

The icon for a supported camera, Acton SP series spectrograph, IsoPlane SCT-320 spectrograph, or Acton motorized accessory will be cleared when the device is turned off or disconnected from the computer.

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Chapter 5: Experiment Setup

Introduction

Experiment setup requires both hardware and software setup. Once you have made the physical connections between the actual components of your system (including connecting the communication interface cables) and powered the devices on, you can begin establishing the LightField parameters to be used when you initiate data acquisition.

The previous chapter covered topics associated with device setup for LightField. The main purpose of device setup is to confirm that the LightField-compatible devices you will be using in your experiment are available for use (i.e., turned on and communicating with LightField). Once the icons for your devices are shown in the **Available Devices** area, dragging them into the **Experiment Devices** area allows you to start opening expanders on the **Experiment Settings** tab and selecting and/or editing the settings for your devices.

Initially, this chapter discusses how to create, save, load, and delete LightField experiments; how to restore default values; and how multiple instances of LightField affect saving experiments upon closure and experiment loading upon opening. The remainder (and bulk of the chapter) describes features of the **Experiment Settings** and **Setting Dock** stacks and reviews the settings that may be available on each of the **Experiment Settings** expanders. The topics are organized according to each expander's position on the **Experiment Settings** tab. Depending on the devices in your experiment, you may not see all of the expanders or parameters that are discussed.

Creating, Saving, Loading, and Deleting Experiments

Figure 59. Create/Load/Save Experiment panel

Creating an Experiment

Click on the **New Experiment** button (or select **New Experiment** from the Experiment menu) to clear the **Experiment Settings** and **Experiment Devices** area; the default experiment title will be "Untitled Experiment." Drag the appropriate devices for the new experiment into the **Experiment Devices** area and begin changing default settings to meet the requirements of your experiment setup. When you have finished, you can save the experiment to a custom experiment name.

Note: Some experiment settings can be reset to their default values without creating a new experiment or remembering the defaults. For more information, see ***"Restoring a Setting to Its Default Value" on page 32***.

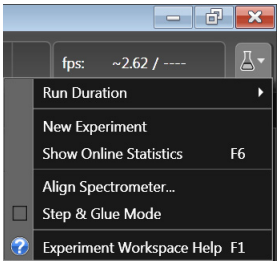


Figure 60. Experiment menu

Saving an Experiment

Experiment settings can be saved at any time an experiment is not in progress by clicking on the **Save Experiment** button (or by pressing **F4)** above the **Experiment Settings** panel in the **Experiment** workspace. When the **Save Experiment Settings** dialog appears, the default Experiment name will be "**Experiment#**" (as in Experiment1) but you can enter a more descriptive name. when you are satisfied with the name, click on **Save**. An experiment is saved to an "lfe" experiment file in the Experiments subdirectory of the current **Working Directory** (specified on the **Applications Options** dialog). For example, if the current working directory is **C:\Users\Username\Documents\LightField**, the experiment file is saved to **C:\Users\Username\Documents\LightField\Experiments**. The saved experiment settings include all settings in the **Experiment Settings** tab and the **Experiment Devices** information. Invalid settings are savable but may not be restorable.

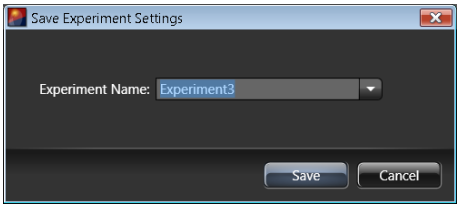


Figure 61. Save Experiment Settings dialog

When exiting LightField, you are given the choice of saving or not saving the current experiment

settings for the experiment devices. If you have made changes to the settings in a previously saved experiment, the earlier version will be overwritten if you save the experiment. To preserve the original experiment file, either change the experiment name or do not save the experiment.

When you exit LightField, the experiment active at that time will be loaded when you restart LightField.

Loading an Experiment

Experiment settings previously saved to an experiment file can be loaded after clicking on the **Load Experiment** button (or by pressing **F3**). When the **Load Saved Experiment** dialog appears, review the list of experiments and double-click on the name of the previously saved experiment. If the experiment name is not enough for identifying the correct experiment, you can preview the saved settings for each experiment. To do so, click on an experiment name, click in the **Settings to be Loaded** pane and use the up and down keyboard arrows to move through the settings. Repeat this operation until you find the correct experiment. Then double-click on that experiment name.

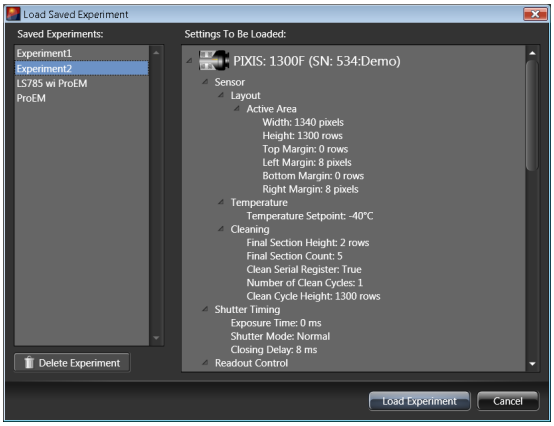


Figure 62. Load Saved Experiment dialog

Note: If changes have been made to the current setup, the **Load Experiment query** dialog will open before the **Load Saved Experiment** dialog. You will be asked if you want to save the current settings before loading a different experiment.

Responding to Failed Experiment Load

Saved settings are tied to the specific hardware devices belonging to the experiment at the time of saving. Loading an experiment effectively redefines the system to be those devices and therefore requires these same devices be detected. If any of these hardware devices are not detected, the **Devices Missing** dialog will be displayed until the missing device is detected. If you no longer have the device, click on **Cancel Load** and define a new experiment that includes the device(s) you do have. If you fix the problem (power the device on or cable it to it a communications port) and the device is or devices are detected, the saved experiment settings are loaded for all devices.

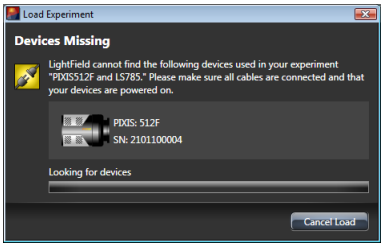


Figure 63. Devices Missing dialog

Note: LightField expects the exact same devices and serial numbers when restoring a saved experiment. If the last used experiment file is missing, LightField will default to the settings for a new experiment ("Untitled Experiment).

Deleting a Saved Experiment

Click on the **Load Experiment** button (or press F3) to open the **Load Saved Experiment** dialog. Click on the desired **Saved Experiment** and click on the **Delete Experiment** button Delete Experiment This will delete the selected experiment. If you will not be loading an experiment, click on the **Cancel** button Cancel to exit the dialog.

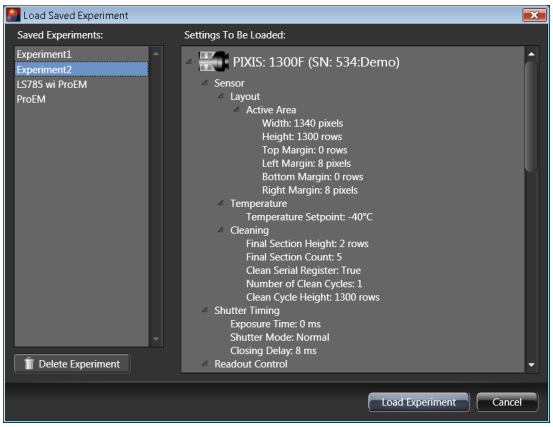


Figure 64. Load Saved Experiment dialog

Restoring a Setting to Its Default Value

Settings associated with **Temperature Setpoint**, **Closing Delay** and **Opening Delay** (shutter), **Vertical Shift Rate**, **Storage Shift Rate**, **Phosphor Decay Delay** and **Resolution**, **Custom Sensor**, and **Sensor Cleaning** have default values that are based on the camera or sensor being used. When these values are changed, a **Restore to Default** button will appear to the right of the

setting. In some cases, there is also a **Restore Settings to Default Values** button 

which restores all changed settings on a pane to their defaults.

Note: If you use the **Find** function to apply a filter, ONLY the currently visible settings will be reset when you click on the **Restore Settings to Default Values** button.

Multiple LightField Environments

In a multiple LightField environment, experiment settings are saved each time an instance of LightField is closed. The last instance closed will have its experiment settings loaded the next time LightField is launched. In a multiple LightField environment, only the first instance of LightField automatically restores the auto-saved Experiment Settings. Subsequent launches restore no settings.

Experiment Settings stacks

Introduction

The **Experiment Settings stack** (at the left side in the **Experiment** workspace) contains expanders consisting of one or more control groups of settings that govern data acquisition and storage. The number and content of the expanders are based on the devices that have been dragged into the **Experiment Devices** area from the **Available Devices** area. Depending on the current state of an expander, the control in the upper right of each expander will expand to show the contents or contract to hide them. Two smaller controls in the upper right of the **Experiment Settings** stack expand or contract all of the expanders.

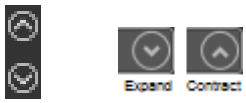


Figure 65. Contract/Expand controls

Finding a Setting

The **Find** function is used to locate a string of characters, word, or phrase used in one or more of the expanders on the **Experiment Settings** or **Setting Dock** stack. The function begins the search as soon as you begin typing in the **Find** field. If the string of characters, word, or phrase is found, all expanders will be hidden except for those containing text using those characters, word, or phrase. The stack will have an orange outline to indicate that you have used the find function. To restore the full stack of expanders, click on the round **Clear Find** button  to the right of the **Find** field.

Copying a Setting to the Setting Dock

The **Copy to Setting Dock** function is used to copy frequently modified settings and settings groups to the **Setting Dock** so they can be quickly found and changed. Settings and groups of settings have a light frame around them. Copied settings remain linked to those on **Experiment Settings** stack and changes made in one stack will be duplicated in the other. Once settings have been moved to the **Setting Dock**, you can drag and drop them within the **Setting Dock** to rearrange their order.

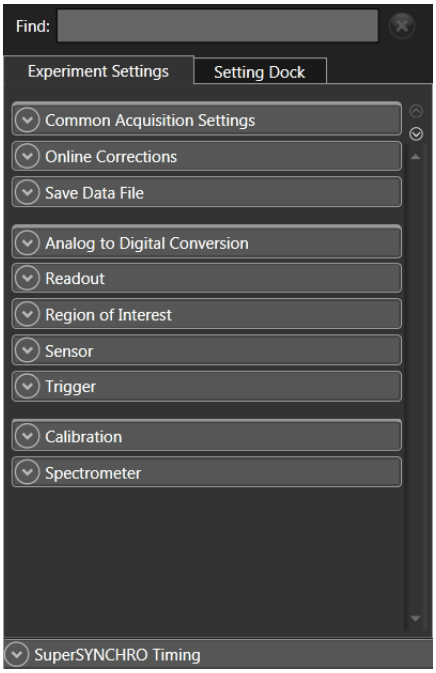


Figure 66. Experiment Settings stack

To copy a setting from its original expander location to the **Setting Dock**, open the expander that contains the setting(s) to be copied. Using the left mouse button, click and drag the setting to the **Setting Dock** tab panel and then release the mouse button.

Changing the Width of the Experiment Settings stack

You can change the width of the **Experiment Settings** stack. The **Experiment Settings** tab can be up to four columns wide or it can be hidden.

To change the width of the **Experiment Settings** stack, position the cursor between the Experiment Settings/Setting Dock stacks and the Devices/ View tabs in the **Experiment** workspace. When the cursor becomes a double-headed arrow, click and drag the **Experiment Settings** stack to the desired width. Dragging the cursor to the left boundary of the **Experiment** workspace hides the

Experiment Settings and **Setting Dock** stacks. Dragging the cursor to the right will spread out the **Experiment Settings** stack to take up multiple columns (up to four).

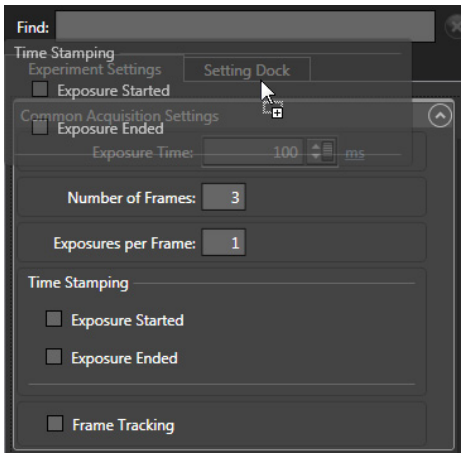


Figure 67. Example of Timing Stamping being copied to Setting Dock

Settings Dock stack

Introduction

Many of the settings/controls on the **Experiment Settings** expanders can be copied to the **Setting Dock stack** by using drag-and-drop. Rather than having the full complement of controls, you can copy those you use most frequently to the **Setting Dock** and have them at your fingertips. When changes are made to settings in the **Setting Dock**, these changes are copied to the settings in the **Experiment Settings** expanders. Since Exposure Time, Shutter Timing Mode, and Gain settings/controls can be changed DURING acquisition, you might want to have them handy while fine-tuning an experiment. The **Setting Dock** can be up to four columns wide. Settings or settings groups can be repositioned vertically and, when viewing in multiple columns, horizontally.

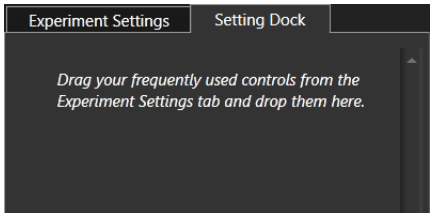


Figure 68. Setting Dock

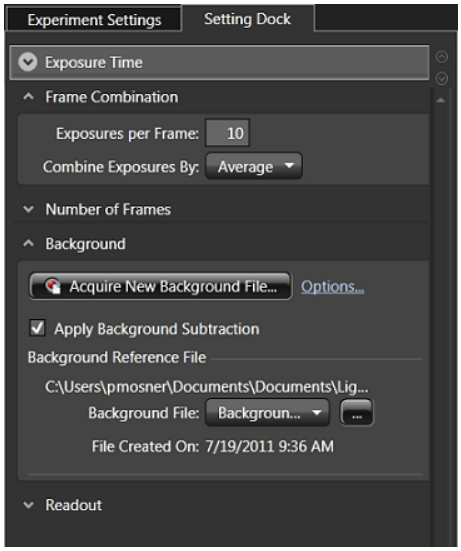


Figure 69. Open and Closed Expanders on the Setting Dock

Deleting a Setting from the Setting Dock

A setting that has been dragged from the Experiment Settings stack can be easily removed from the Setting Dock. Right-click on the setting, click on **Remove from Setting Dock**, and the setting will be removed.

Clearing the Setting Dock

All of the settings can be removed at the same time from the **Setting Dock**. Right-click on the tab and click on **Clear Setting Dock**.

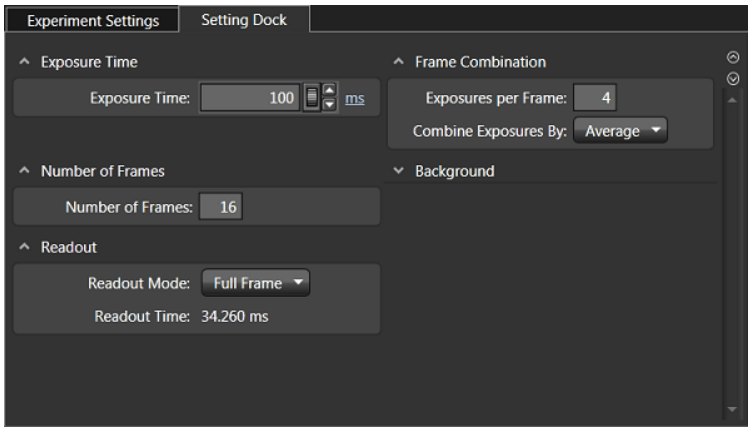


Figure 70. Example of Two Columns

Arranging Settings on the Setting Dock

You can change the width of the **Setting Dock** and you can reposition settings or settings groups (multiple settings contained in a panel) within the **Setting Dock**.

The **Setting Dock** can be up to four columns wide or it can be hidden. To change the width of the **Setting Dock**, position the cursor between the two sets of tabs in the **Experiment** workspace. When the cursor becomes a double-headed arrow, click and drag the **Setting Dock** to the desired width. Dragging the cursor to the left boundary of the **Experiment** workspace hides the **Experiment Settings** and **Setting Dock** stacks. Dragging the cursor to the right will spread out the **Setting Dock** to take up multiple columns (up to four).

You can reposition the groups of settings in the **Setting Dock** vertically at any time AND horizontally when viewing more than one column.

To Move a Setting/Setting Group:

1. Make sure the expander for the setting/setting group is open. An expander must be open before you can drag the setting/s to a different location in the **Setting Dock**.
2. Click in an empty area of the setting panel and drag the setting/s until the white line indicates where you want the setting/s to be positioned. Then release the mouse button. This allows for maximum flexibility so you can chose the configuration that works best for you while still allowing you to see all the settings you need to see, simultaneously, without having to scroll.

Note: If you click on the expander title (for example, Background), you will not be able to drag the setting/s to another location. You must click in the panel and then you can drag the setting/s (for example, in the panel area to the right of Apply Background Subtraction).

Common Acquisition Settings

Introduction

The settings on the **Common Acquisition Settings** expander are settings related to exposure timing and frames. The exposure time determines how long the sensor will be exposed to incoming signal. A frame contains the data read out after the exposure and may contain the averaged or summed data from 2 or more exposures if Exposures per Frame are greater than 1. Time stamping and frame tracking are additional functions related to exposure timing and frame accumulation.

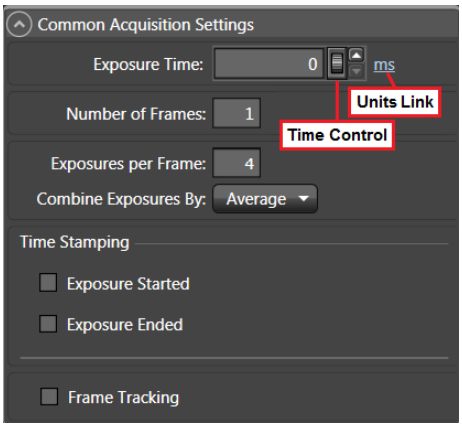


Figure 71. Common Acquisition Settings expander

Exposure Time

Exposure time is the time between the start acquisition and stop acquisition commands sent by LightField to the camera. In combination with triggers, these commands control when continuous cleaning of the sensor stops, how long the sensor is exposed, and when the accumulated signal is read out. The value in the Exposure Time field can be changed by keying in a new value or by positioning the cursor over the time control to the right of the field and dragging the cursor. Dragging up or to the right increases the exposure time; dragging down or to the left decreases it.

By default, the **Exposure Time** is entered in milliseconds (ms) on the **Common Acquisition Settings** expander. However, you can change the units (ns, µs, ms, s, m, or h units are selectable). To change the units, click on the units shown for Exposure Time. This hyperlink will pop up the **Application Options** dialog **Units** tab where you select the new units and click on **OK** to implement the change.

For cameras without an internal shutter, signal can accumulate on the sensor during readout and result in smearing. For exposures that are significantly longer than the readout time, smearing should be negligible. If smearing is an issue, the **Not Reading Out** (or **Exposing** depending on the camera) or **Shutter Open** signal at the LOGIC OUT connector (on the back of the

camera) can be used to synchronize an external shutter with exposure and permit readout in darkness. The signal at the LOGIC OUT connector is selected from the **Output Signal** drop-down list on the **Trigger** expander**.**

Notes:

1. Exposure time for NIRvana\PIoNIR cameras must be greater than 0 seconds.
2. Exposure time is not a settable parameter when a PI-MAX3 or PI-MAX4 is one of the experiment devices. The time that the sensor is exposed is determined by the Trigger Source setting on the **Trigger** expander and the **SuperSYNCHRO Timing** expander settings.

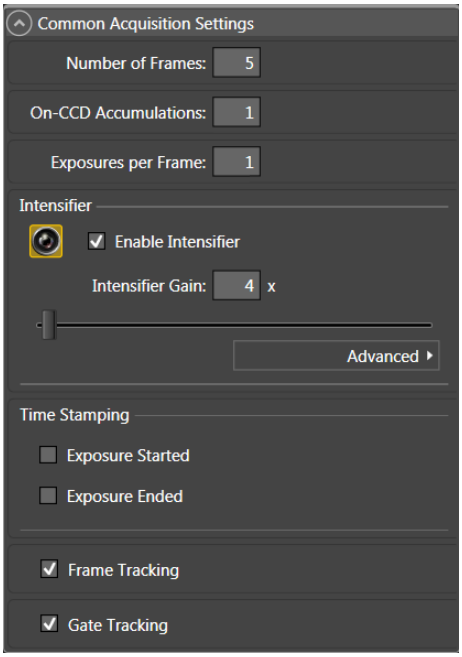


Figure 72. Common Acquisition Settings expander for PI-MAX

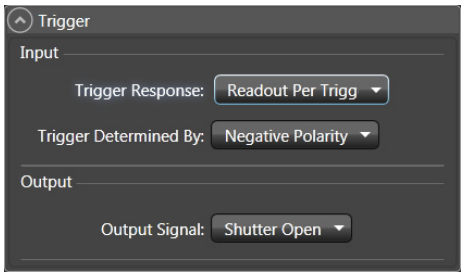


Figure 73. Trigger expander

If exposures are initiated by an external trigger and **Open Before Trigger** is selected, the shutter opens (if previously closed) just after the camera begins an acquisition and closes just after the **Closing Delay** ends.

Number of Frames

A frame contains the data read out after the exposure time has ended. One frame equals one image. **Number of Frames** determines how many images will be acquired and stored during the experiment. When **Exposures per Frame** = 1, the number of exposures and number of frames are the same. However, if the **Exposures per Frame** = 3 for example, the total number of exposures taken would be 3 times the final number of frames in the stored data set.

Note: This setting is not available when **Step & Glue** is active.

Exposures per Frame

Usually a frame contains only the data from a single exposure (i.e., **Exposures per Frame** = 1). However, you can change the number of exposures per frame to be greater than 1. By increasing the number of exposures per frame and summing, you can enhance low light level signals. When the **Exposures per Frame** is greater than 1, the sensor will be exposed and read out the entered number of times and each stored frame will contain either summed or averaged data (depending on your choice) from two or more exposures. The resulting frame will be about the same size as that for a single exposure. The trade off is that increasing the number of exposures per frame increases the time required for an acquisition.

The two choices for frame combination are:

- **Sum:** The data from multiple exposures are summed together pixel by pixel. The resulting data are stored in a single frame.

- **Average:** The data from multiple exposures are summed together pixel by pixel and the result for each pixel is divided by the number of exposures. The resulting data are stored in a single frame.

Notes:

1. When there are multiple exposures per frame, the **View** area will display the exposures as follows:
   - Assuming there are 3 exposures per frame and the exposures are summed, 3 successively brighter images will be displayed and the last data set will be stored as the frame data.
   - Assuming there are 3 exposures per frame and the exposures are averaged, 2 successively brighter images will be displayed and the third image will be the averaged result that will be stored as the frame data.
2. Since the summing/averaging processes modify the actual data acquired, both the corrected and uncorrected data can be saved if the **Back Up Raw Data** check box is selected on the **Save Data File** expander. Thus, two data files are acquired and saved for a data acquisition. These files are saved to the same location and have the same file name with the exception that the raw data file name also includes **-raw**. For example, if your regular acquisition file was named "**untitled.spe**", the raw data file would be named "**untitled-raw.spe**". When there are X number of exposures per frame, the raw data file will be X times larger than the corrected data file.

On-CCD Accumulations

This function appears when a PI-MAX3 or PI-MAX4 is being used in the experiment. You can specify the number of times the photocathode will be gated on during the exposure. Charge will accumulate on the sensor as those gates occur during the exposure and the accumulated charge will be readout at the end of the exposure. The acquired data will contain signal from multiple exposures and read noise from a single readout. Signal is limited by pixel well capacity and the A/D converter (for a 16-bit A/D, this is 65536 counts).

Photon Detection

This function appears when a PI-MAX4:512B/EM or PI-MAX4:512EM is being used in the experiment. The Photon Detection setting can be Disabled (no Photon Detection), Thresholding, or Clipping. When Photon Detection is active, the value in the Threshold field sets the threshold level (0 to 65535, increments of 1 count). If Thresholding has been selected, any pixel with an intensity value equal to or less than the Threshold value will be set to zero. All other pixels will be set to a value of 1. If Clipping is active, pixels with an intensity value equal to or less than the Threshold value will be set to zero and all other pixel values are left as-is.

Photon detection is best used in low light experiments and in conjunction with software accumulations.

Intensifier

This function appears when a PI-MAX3 or PI-MAX4 is being used in the experiment.

- **Enable Intensifier:** By default, this check box is unselected and the PI-MAX's intensifier is disabled. To turn on the intensifier, check the box. After you turn on the intensifier, you can change the intensifier gain.

  Note: This setting will have no effect unless the I.I.T. PWR switch on the rear of the PI-MAX is in the ON position.

- **Intensifier Gain:** This function is enabled after you turn on the intensifier. You can use either the Intensifier Gain field or the slidebar below it to set the intensifier gain of a PI-MAX camera from software, even when acquiring data. The gain setting range extends from 1 to 100 (values are purely arbitrary). It is usually best to begin with a low setting and then try higher settings. A midrange setting will turn out to provide good performance in many experiments.
- **Advanced:** The flyout pane opened by this button allows you to enter a **Phosphor Decay Delay** time, select the **Phosphor Decay Resolution** (100 ns, 100 µs, or 1 ms) and, if the camera is a PI-MAX4-EM, select the **emICCD Gain Mode** (Optimal or Manual).

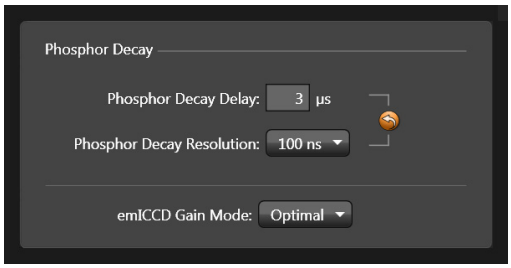


Figure 74. Common Acquisition Settings: Advanced flyout pane

Phosphor Decay time is used to delay the shift of pixels behind the mask on an interline sensor; this has no effect on the physical decay time of the phosphor. Typically, phosphor decay time is the time it takes the phosphor to decay to 1% emission and varies depending on the phosphor type. For example, the phosphor decay time for a P43 phosphor is 3 ms and for a P46 phosphor 2 µs. The default setting is based on the phosphor in your camera. If you change the value of the delay and/or the resolution you can always reset to the defaults by clicking on the **Restore to Default Value** button .

emICCD Gain Mode determines how the intensifier and the EM gains are controlled. When **Optimal** is selected, a mixture of Intensifier and EM gains is used to provide the best signal-to-noise. When **Manual** is selected, Intensifier and EM gains can be controlled separately via the **Common Acquisition Settings** and **Analog to Digital Conversion** expanders.

Time Stamping

This function attaches timing data to each frame when Exposure Started, Exposure Ended, or both are selected. This information will be displayed in the Timing panel below the data in the **Experiment** workspace **View** area and below the data in the **Data** workspace **View** and **Comparison View** areas. If only one time is displayed, position the cursor over that time to find out whether it is the start or end time. To change the Time Stamp scale (Absolute or Relative), click in the Timing panel to pop up the **Time Stamp/Tracking** dialog. This dialog also allows you to show or hide exposure time information if time stamping was active at the time of data acquisition.

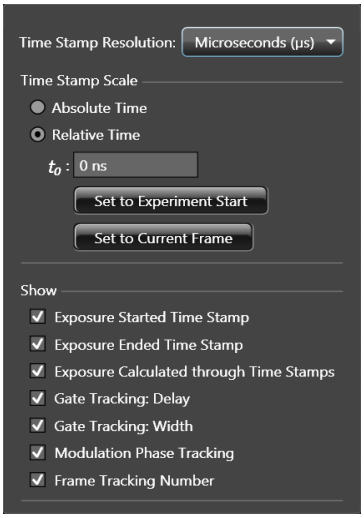


Figure 75. Time Stamp and Tracking dialog

- **Exposure Started:** This is the time that the exposure began.
- **Exposure Ended:** This is the time that the exposure stopped.

Time Stamping combined with Frame Tracking is a powerful tool for time-resolved or time-lapse experiments.

Note: Time Stamping is not available when **Step & Glue** is active.

Frame Tracking

During data acquisition, LightField maintains a running record of the number of frames when **Frame Tracking** is active. If frame tracking is turned on, each frame (acquired or discarded) will be tagged with the number that corresponds to its place in the record. This information will be displayed in the **Timing** panel below the data in the **Experiment** workspace **View** area and below the data in the **Data** workspace **View** and **Tiled View** areas. If frame tracking was active at the time of data acquisition, you can hide or show the frame tracking information after clicking in the Timing panel to pop up the **Time Stamp/ Tracking** dialog.

Example of Usage: You have set up an experiment with 40 frames and click on **Acquire** to start acquisition. After 10 frames you realize that nothing of interest is occurring, so you click on **Acquire** again to go into Preview mode. The tracking numbers continue to increment while Preview mode is going on (acquiring, displaying, and discarding data) and will continue to increment when you click on **Acquire** to resume the uncompleted data acquisition. Frames 1-10 will have Tracking numbers 1-10. If you realized that change was occurring in the data you were seeing and you restarted the interrupted acquisition after 20 Preview frames, these frames will have been associated with Tracking numbers 11-30. The remainder of the frames in the data set will have Tracking numbers 31-60. The break in the Tracking number sequence in the data set lets you know that there was an interruption and can be used to approximate the timing of the event.

Frame Tracking combined with Time Stamping information is a powerful tool for time-resolved or time-lapse experiments.

Gate Tracking

This check box appears when the camera is a PI-MAX3 or PI-MAX4 and Sequential Gating is active on the **SuperSYNCHRO Timing** expander. When **Gate Tracking** is selected, the gate width and delay information will be attached to each frame. If the information is not displayed, open the **Time Stamp/Tracking** dialog and verify that the **Gate Tracking** boxes are also selected on this dialog.

Modulation Tracking

This check box appears when the camera is a PI-MAX4-RF, **Use RF Modulation** is selected on the Common Acquisition Settings expander and Sequential Gating is active on the **SuperSYNCHRO Timing** expander. When **Modulation Tracking** is selected, the phase information will be attached to

each frame. If the information is not displayed, open the **Time Stamp/Tracking** dialog and verify that the **Modulation Phase Tracking** box is selected on this dialog.

Frame Combination

Usually a frame contains only the data from a single exposure (i.e., **Exposures per Frame** = 1). However, on the **Common Acquisition Settings** expander you can change the number of exposures per frame to be greater than 1. By increasing the number of exposures per frame and summing, you can enhance low light level signals. When the **Exposures per Frame** is greater than 1, the sensor will be exposed and read out the entered number of times and each stored frame will contain either summed or averaged data (depending on your choice) from two or more exposures. The resulting frame will be about the same size as that for a single exposure. The trade off is that increasing the number of exposures per frame increases the time required for an acquisition.

The two choices for frame combination are:

- **Sum:** The data from multiple exposures are summed together pixel by pixel. The resulting data are stored in a single frame.
- **Average:** The data from multiple exposures are summed together pixel by pixel and the result for each pixel is divided by the number of exposures. The resulting data are stored in a single frame.

Notes:

1. When there are multiple exposures per frame, the **View** area will display the exposures as follows:
   - Assuming there are 3 exposures per frame and the exposures are summed, 3 successively brighter images will be displayed and the last data set will be stored as the frame data.
   - Assuming there are 3 exposures per frame and the exposures are averaged, 2 successively brighter images will be displayed and the third image will be the averaged result that will be stored as the frame data.
2. Since the summing/averaging processes modify the actual data acquired, both the corrected and uncorrected data can be saved if the **Back Up Raw Data** check box is selected on the **Save Data File** expander. Thus, two data files are acquired and saved for a data acquisition. These files are saved to the same location and have the same file name with the exception that the raw data file name also includes **-raw**. For example, if your regular acquisition file was named "**untitled.spe**", the raw data file would be named "**untitled-raw.spe**". When there are X number of exposures per frame, the raw data file will be X times larger than the corrected data file.

Time Stamp/Tracking dialog

The **Time Stamp/Tracking** dialog, opened by clicking in the **Timing** panel below the displayed data that were acquired with **Time Stamping**, **Frame Tracking**, **Modulation Tracking**, and/or **Gate Tracking** active, allows you to turn off/on the display of this information and to adjust the scale for time stamping.

Figure 76. Timing panel

Time Stamp Scale: Time stamping can be displayed in either Absolute or Relative time.

- **Absolute Time:** This time is the time stamping performed by the computer. Time is expressed in hours, minutes, and seconds and shows the offset from Greenwich Mean Time (GMT). In the image below there is a 5 hour difference (the data was acquired in New Jersey). The exposure calculated based on the Exposure Start and End times is a little over 12 ms.
- **Relative Time:** This time can be referenced to a user-entered time, the experiment start time, or to exposure start time for the current frame.

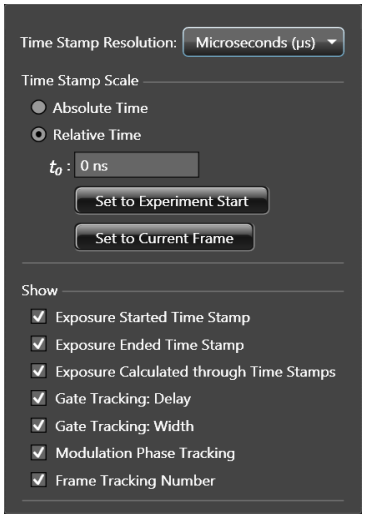


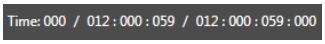
Figure 77. Time Stamp and Tracking dialog

- **t_0:** The time in this field (expressed in nanoseconds) is the offset from t_0 (the time that the experiment started). When Set to Experiment Start is selected, the entry in this field is 0 ns. When Set to Current Frame is selected, the entry in this field will be the time offset from t_0 to the exposure start in the current frame. If the exposure start time for the current frame is 148:692:571 and Set to Current Frame is selected, the value in the field will be 148692571 ns. You can enter your own offset in nanoseconds, microseconds, milliseconds, seconds, minutes or hours. Simply click in the field and key in the value

followed by ns, us, ms, s, m, or h and LightField will make the conversion to nanoseconds.

- **Set to Experiment Start:** This time is based on t_0 of 0 ns, the time that the experiment started. Note that in the image below about 149 ms elapsed before the exposure time started.

- **Set to Current Frame:** This time sets the exposure start time for the current frame to 0. The times for all preceding and following frames are adjusted accordingly.



- **Show:** These check boxes control the display of time stamps, exposure calculated from exposure start and end times, modulation phase tracking, frame tracking, and gate tracking numbers if any of these time stamp/ tracking functions were active when the data were acquired.

Note: Exposure Calculated through Time Stamps will only display if both **Exposure Started** and **Exposure Ended** were selected on the **Common Acquisition Settings** expander.

Online Corrections

Data Correction Overview

Data can either be corrected (modified) while it is being acquired or it can be modified afterwards.

Online processes (occur while data are being acquired) are selectable on the Experiment Workspace and include: Background Subtraction, Flatfield Correction, Exposures per Frame, Sensor Blemish Correction, Orientation, and Binning (software or hardware).

Post-Processes (applied after data has been acquired) are selectable on the Data Workspace and include: Background Subtraction, Blemish Correction, Flatfield Correction, Frame Combination, Orientation, and Software Binning.

Four types of online corrections are selectable on the **Online Corrections** expander**.** Additional online processing of data occurs when multiple exposures per frame are set up on the Common Acquisition Settings expander and when hardware binning and/or ROIs are activated on the Region of Interest expander.

The data corrections include two arithmetic choices: Background Subtraction and Flatfield Correction. Sensor Blemish Correction (requires user-generated TXT file) and Orientation are also available. Currently selected data corrections are reported in the Status bar.

Raw Data

Since all of these online corrections (except for Orientation) modify the data, the **Back Up Raw Data** check box on the **Save Data File** expander is selected by default. When this check box is selected, LightField automatically saves both the raw data file and the corrected data file. When acquisition occurs, a raw data file (the data from the camera before any corrections) will be created in addition to the regular acquisition data file. Each frame of raw data will be captured and saved before corrections are performed on it. The raw data file will be saved to the same directory as the regular acquisition file. The raw data file will be given the same name as the regular acquisition file, but with "**-raw**" appended. For example, if your regular acquisition file was "**untitled.spe**", the raw data file would be "**untitled-raw.spe**".

Note: Irreversible online data manipulations/ corrections that will be backed up with raw data include software binning, background subtraction, flatfield correction, sensor blemish correction, and accumulations (exposures per frame). Because orientation processes can be reversed, an orientation change by itself will not be enough to cause raw data to be saved.

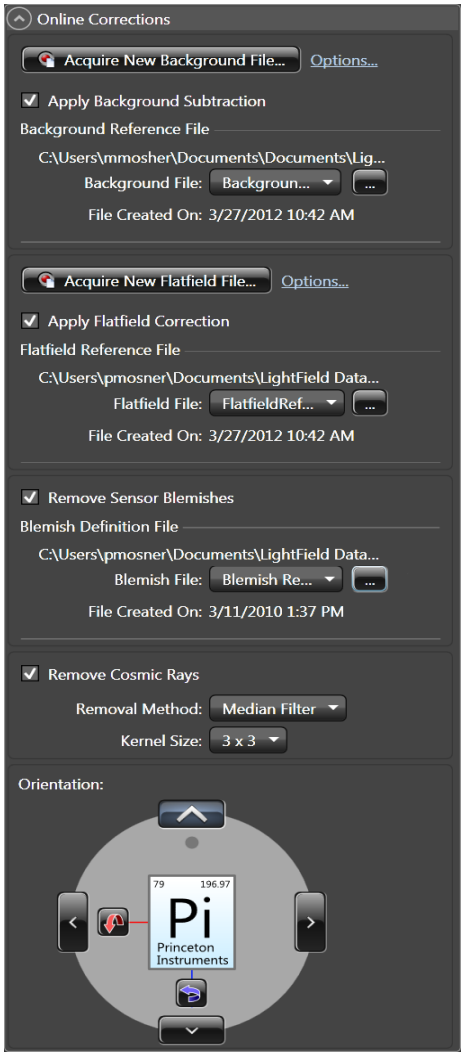


Figure 78. Online Corrections expander

Background Subtraction

Introduction

When the **Apply Background Subtraction** box is checked, the currently active background subtraction file will be subtracted point-by-point from the data as it is collected. If an appropriate background file is not active and one was previously acquired, you can load it (use the **Browse** ... and **Background File** buttons to find and select the file). After the file is selected, its file name and date of creation will be displayed. If an appropriate background is not available, you will need to acquire a background.

Initially, the default for filenaming and saving a background reference file is **Always Prompt** (open the **Save As** dialog before acquiring and saving the file). You can change this by clicking on the **Options...** link and choosing a different option (**Always Overwrite** or **Always New**) on the **Application Options** dialog's **General** tab. When you click on the **Acquire New Background File** button Acquire New Background File... to acquire and save a suitable background file, the current option will be used.

When active (i.e., a suitable background file has been selected and background subtraction is turned on) background subtraction applies an automatic subtraction of any constant background in the signal. This includes both constant offsets caused by the amplifier system in the controller as well as the time-dependent (but constant for a fixed integration time) buildup of dark charge. It also includes the small offset applied by Princeton Instruments systems to insure that small signals are not missed. Background subtraction data files are sometimes acquired with the shutter open to include any ambient light background. The background subtraction equation is

raw – background = corrected.

If the background and flatfield corrections are both performed, the background subtraction is always performed first. The equation that implements both corrections is

(raw – background)/flatfield = corrected.

Note that the data type may be changed to insure that any negative values generated by background subtraction are stored without loss of sign.

Background subtraction data files must be SPE files. A background subtraction file can be created from within Experiment Setup or an existing SPE file can be specified for the correction.

- If the background file is to be acquired using the **Acquire New Background File...** function, a set of five frames will be acquired, averaged into a single frame and saved into a background subtraction file that can then be applied to subsequent acquisitions using the same experiment settings. Even though an experiment setup specifies multiple frames (for example, **Number of Frames**= 3), a background subtraction file will only contain the single frame generated as stated in the preceding sentence.

- If an existing .SPE file containing multiple frames is selected via the **Background Reference File** function, only the first frame of that file will be used when background subtraction is active.

Notes:

1. If the background subtraction data does not match the dimensions of the experiment setup (including any ROIs selected), an error message is displayed and the experiment cannot be started. If background subtraction data has been captured, and then a ROI is added to the experiment setup, the background subtraction data becomes invalid and an error message is displayed.
2. A warning is displayed when any change to an experiment that affects orientation is made and a background subtraction is to be done. This is because adjusting the background data file to match the new orientation does not take into account any irregularities that might arise from light hitting a particular part of the sensor. New background data should be captured.

Acquiring a Background File

1. Set the sensor temperature to precisely the same temperature to be used in data collection. Wait at least 30 minutes after the sensor has reaching operating temperature to ensure stability.
2. Set the same binning parameters and ROIs as will be used for data collection.
3. In most cases, you will want to prevent light from falling on the sensor. If there is no shutter, block light from falling on the sensor. If there is a shutter, LightField will close it during background acquisition.
4. On the **Online Corrections** expander, click on the **Acquire New Background File...** button 

5. When the **Save Background File As... dialog** appears, you can change the file name from the default name "BackgroundSubtraction.spe" so it will not overwrite a previously acquired background. You can also specify a directory other than the default "Username"\Documents\LightField\Correction Files. When creating the file name, it is a good idea to include some indicator in the name that this is a background file and perhaps a short description of the experiment. This is especially a good idea if you decide to store file outside of the default Correction Files directory. Click on **Save** when you finished. If this file will overwrite an existing file, you will be given a second chance to change the name or destination.

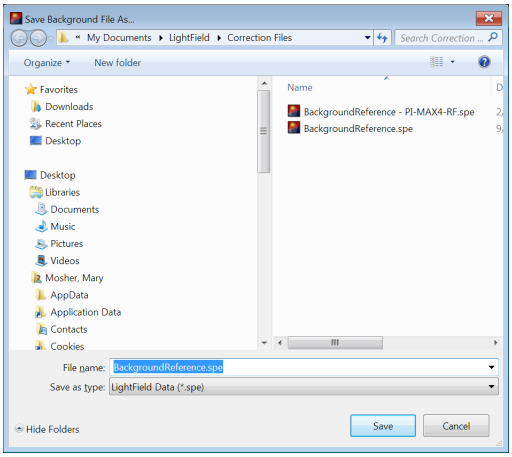


Figure 79. Save Background File As... dialog

6. Once the background name is saved, the background file is acquired using the current experimental parameters. If there is a shutter, LightField will close the shutter while data are acquired. The file will be stored and background subtraction will be turned on and applied to subsequently acquired data until it is turned off, a new background is acquired, a different background is selected, a new experiment is opened, or a previously saved experiment is loaded.

Selecting a Background File

The most recently acquired background will be the default until you acquire a new background, select a different background file, open a new experiment, or load a previously saved experiment. A previously acquired background file can be used whenever identical experiment settings are in effect and background subtraction is selected. If the settings within a background file do not match the current experiment devices or settings, an experiment conflict warning will appear and you will be prevented from acquiring data until you select a compatible file or turn background subtraction off.

1. To locate a background file, click on the **Browse** button  (next to the Background File button) and examine the names of the background files in "Username"\Documents\LightField\Correction Files.
2. Select a suitable background file for the experiment setup and click on **Open**.
   - If the file you want is not in the Correction Files directory, browse to the appropriate directory and make your selection.
   - If there are multiple background files to choose from, the choice may not be obvious. In that case, you can click on **Cancel** to close the **Select Background Reference File**

dialog. Then click on the **Data** button to open the Data workspace. Click the **Open...** button 

, browse to the location and load one or more of the files (multiple files can be selected and opened at the same time). Select one of the files and when the data are displayed in the View area, open the **Data Menu**. Click on **Show File Information** to open the **File Information** dialog and then click on the **General** tab if it is not in front. Review the information to determine whether or not the file is suitable. Repeat for each file until you find the correct one. Note the file name, return to the **Online Corrections** expander, and select that file.

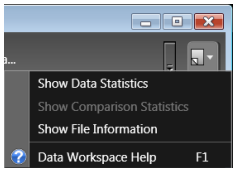


Figure 80. Data menu

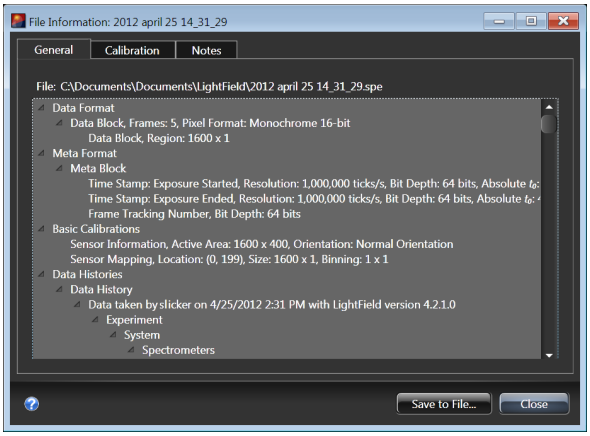


Figure 81. File Information: General tab

Setting Automatic Background Subtraction

Whenever **Apply Background Subtraction** is active and a valid background file is selected, background subtraction will be automatically applied to subsequent acquisitions.

Flatfield Correction

Introduction

Uniform illumination of an ideal sensor would result in all pixels producing identical signals and a uniform (flat) image. However, uniform illumination of a real sensor results in a range of signal values. Variations in signal over an array arise from random noise associated with dark current variations and from gain variations (due to the signal processing electronics, variations in illumination, lens effects, and sensor characteristics). Flatfield normalization adjusts the signal of each pixel to account for these variations and yields a more uniform camera response. The data to be used in the normalization are acquired as a set of five frames that are averaged into a single frame and saved into a flatfield correction file which can then be applied to subsequent acquisitions using the same experiment settings.

Note: Even though an experiment setup specifies multiple frames (for example, Number of Frames= 3), a flatfield correction file will only contain the single frame generated as stated above.

When the **Apply Flatfield Correction** box is checked, the currently active flatfield file will used when acquiring data. Data will be divided point-by-point by the selected flatfield correction file as the data are collected. If an appropriate flatfield file is not active and one previously acquired, you can load it (use the **Browse**  and **Flatfield File**  buttons to find and select the file). After the file is selected, its file name and date of creation will be displayed.

If an appropriate flatfield is not available, you will need to acquire a flatfield. Initially, the default for filenaming and saving a flatfield reference file is **Always Prompt** (open the **Save As** dialog before acquiring and saving the file). You can change this by clicking on the **Options...** link and choosing a different option (**Always Overwrite** or **Always New**) on the **Application Options** dialog's **General** tab. When you click on the **Acquire New Flatfield File** button 

to acquire and save a suitable flatfield file, the current option will be used.

Shutter Mode Setting

Before a Flatfield correction file is acquired, LightField checks the current Shutter Mode setting and, if necessary, will change the setting for the correction file acquisition. After the file is acquired, the original setting will be restored.

- If the current Shutter Mode is **Always Closed**, then it will be set to **Normal** (if available, otherwise **Always Open**) for the correction file acquisition.
- If the current Shutter Mode is **Normal** or **Always Open**, the Shutter Mode will not be changed for the file acquisition.

Acquiring a Flatfield Correction File

This operation is similar to normal data acquisition.

1. Set the sensor temperature to precisely the same temperature to be used in data collection. Wait at least 30 minutes after the sensor has reaching operating temperature to ensure stability.
2. Set the same binning parameters and ROIs as will be used for data collection.

3. Illuminate the sensor uniformly. The uniformity of this illumination determines the accuracy of the flatfield file data.
4. On the Online Corrections expander, click on **Acquire New Flatfield File...** button 

.
5. When the **Save Flatfield File As...** dialog appears, you may want to change the default name "FlatFieldCorrection.spe" or change the default destination from "Username"\Documents\LightField\Correction Files to prevent the new file from overwriting an existing correction file. Click on **Save** when finished. If this file will overwrite an existing file, you will be given a second chance to change the name or destination.

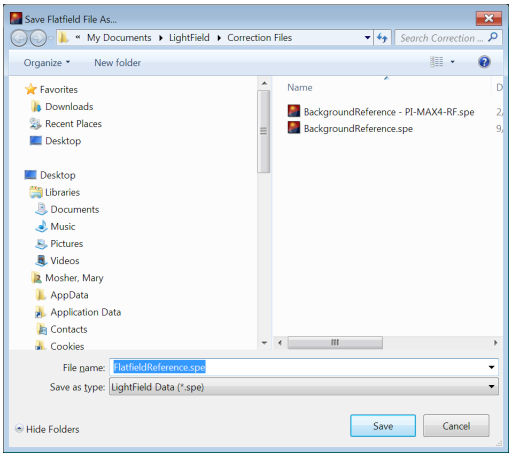


Figure 82. Save Flatfield File As... dialog

6. Once the flatfield name is saved, the flatfield file is acquired using the current experimental parameters. The shutter will either operate normally or will be always open during the acquisition (see ***"Shutter Mode Setting" on page 43***). The file will be stored and flatfield correction will be turned on and applied to subsequently acquired data until it is turned off, a new flatfield is acquired, a different flatfield is selected, a new experiment is opened, or a previously saved experiment is loaded.
7. If the Shutter Mode setting was changed from **Always Closed** to **Normal** or **Always Open** for the acquisition, the original Shutter Mode setting will be restored after the flatfield correction file is acquired.

The flatfield data file can now be used whenever identical experiment settings are in effect and flatfield correction is selected.

If the **Acquire New Flatfield** function is found to be too limiting in some way, a flatfield file can be collected as a normal data file.

Selecting a Flatfield Correction File

The most recently acquired flatfield will be the default until you acquire a new flatfield, select a different flatfield file, open a new experiment, or load a previously saved experiment. A previously acquired flatfield file can be used whenever identical experiment settings are in effect and flatfield correction is selected. If the settings within a flatfield file do not match the current experiment devices or settings, an experiment conflict warning will appear and you will be prevented from acquiring data until you select a compatible file or turn flatfield correction off.

1. On the **Online Corrections** expander, select **Apply Flatfield Correction**.
2. Select the flatfield file to be applied.
   - If you have just acquired the file, that file will automatically be selected.
   - If the file was acquired earlier and is not listed under the **Flatfield File** button 

, click on the Flatfield **Browse** button 
, browse for and select the file to be used, and click on the **Open** button.

Note: If the experiment settings have changed since the flatfield was acquired and the **Experiment Conflict**  icon is present, either locate the correct flatfield or acquire a new flatfield using the current experiment settings.

Setting Automatic Flatfield Correction

Whenever **Apply Flatfield Correction** is active and a valid flatfield file is selected, flatfield correction will be automatically applied to subsequent acquisitions.

Sensor Blemish Correction

Introduction

The purpose of blemish correction is to correct for bad sensor pixels, rows, columns, and/or clusters either at the time of acquisition (Online Correction) or after acquisition (Post-Process Blemish Correction). With the release of LightField 4.4, there are now two versions of blemish files. Version 1.X files correct for pixel, row, and column defects and these files will continue to be valid. Version 2.X files added cluster defect correction to permit the correction of bad pixels that were completely surrounded by bad pixels. This kind of correction could not be done in Version 1.X files because the pixel, row, and column correction methods require good adjacent pixels from which to correct. Version 2.X

files are valid for LightField Version 4.4 and higher.

Note: With the exception of the NIRvana/PIoNIR camera, you will need to create a blemish correction file in order to use this function. Each NIRvana/PIoNIR has its own blemish correction file that is downloaded from the camera to the **Correction Files** directory when the camera icon is dragged into the **Experiment Devices** area. **Remove Sensor Blemishes** is the default selection for a NIRvana/PIoNIR.

When identifying defective rows or columns, the coordinates of the starting point must be defined, as well as the length of the defective row or column. (Column and row numbering start at zero.) Pixel defects are defined by the coordinates of the defective point. When identifying cluster defects, the defective rows, pixels, and columns in cluster must all have the same Cluster ID and must be identified as to Type, Column, Row, and Length (a pixel defect has a length of 1 when defined as part of a cluster). Note that all pixels in a cluster must be touching (even if only at a corner).

Hardware binning is done before blemish correction, and binned pixels are corrected if they contain any pixels identified as defective.

For instructions on how to create either a Version 1,X or a Version 2.X blemish file, ***see "Creating a Defect Map"***, starting on page 46. If you do not have access to either a spreadsheet or a database application, you can also retrieve the data table file into either an ASCII text-editing or a word-processing application.

Defect Map Files (Blemish Files)

A defect map file (blemish file) must be in CSV (Comma Separated Values) format and have a CSV extension. Figure 83 shows a sample file viewed in Microsoft Notepad and the same information after it was opened in Microsoft Excel. Note that Version 2.X files allow cluster defect correction in addition to the column, row, and pixel correction available in Version 1.X files: 2.X files are compatible with LightField Version 4.4 and higher. Version 1.X files created in earlier versions of LightField will still be valid.

For **Online Correction**, a defect map file is invalid and an **Experiment Warning** is displayed if the file contains points outside the active area of the full sensor, no defective pixel data, the version is not compatible with the current LightField version or invalid data such as letters or characters in a number field. When this correction is being performed as a post-process, the **Preview** button will be grayed out.

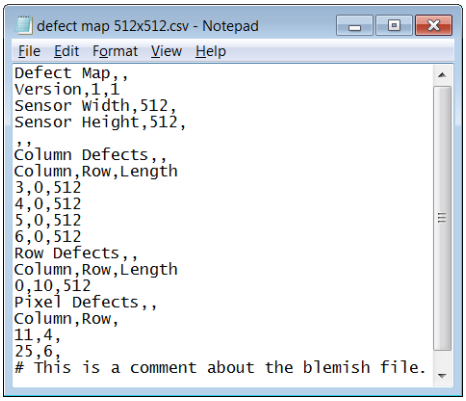


Figure 83. Version 1.X Defect Map in Text Editor

	A	B	C	D
1	Defect Map			
2	Version	1	1	
3	Sensor Width	512		
4	Sensor Height	512		
5				
6	Column Defects			
7	Column	Row	Length	
8	3	0	512	
9	4	0	512	
10	5	0	512	
11	6	0	512	
12	Row Defects			
13	Column	Row	Length	
14	0	10	512	
15	Pixel Defects			
16	Column	Row		
17	11	4		
18	25	6		
19	# This is a comment about the blemish file.			

Figure 84. Version 1.X Defect Map in Spreadsheet

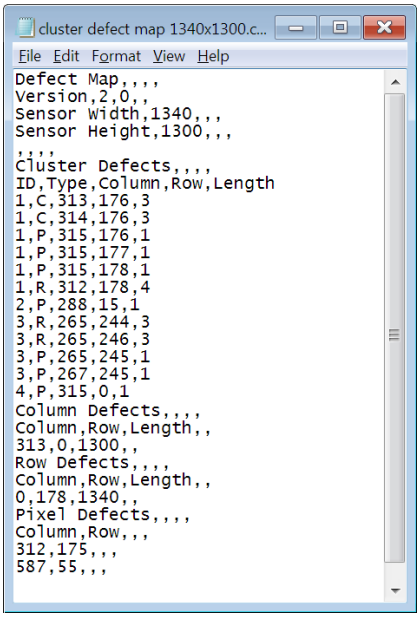


Figure 85. Version 2.X Defect Map in Text Editor

	A	B	C	D	E
1	Defect Map				
2	Version	2	0		
3	Sensor Width	1340			
4	Sensor Height	1300			
5					
6	Cluster Defects				
7	ID	Type	Column	Row	Length
8	1	C	313	176	3
9	1	C	314	176	3
10	1	P	315	176	1
11	1	P	315	177	1
12	1	P	315	178	1
13	1	R	312	178	4
14	2	P	288	15	1
15	3	R	265	244	3
16	3	R	265	246	3
17	3	P	265	245	1
18	3	P	267	245	1
19	4	P	315	0	1
20	Column Defects				
21	Column	Row	Length		
22	313	0	1300		
23	Row Defects				
24	Column	Row	Length		
25	0	178	1340		
26	Pixel Defects				
27	Column	Row			
28	312	175			
29	587	55			

Figure 86. Version 2.X Defect Map in Spreadsheet

Correction Method

For blemish corrections, each pixel is treated as a **Cluster**, **Row**, **Column**, or **Pixel** (depending on the blemish file version), and this classification determines which adjacent cells are used for correction. LightField assigns a group to each pixel based on its listing in the defect map file. If a pixel is listed under multiple groups in the defect map, the first instance of the pixel determines its group. For example, if a pixel were first listed as part of a **Column**, and later as part of a **Row**, the system would treat that pixel as a **Column** pixel.

Defective pixel values for the columns, rows, and/or pixels listed in a defect file are replaced by the average of specific adjacent pixels. **Column** pixel values are replaced by the average of the pixels to the left and right of the **Column** pixel. **Row** pixel values are replaced by the average of the pixels above and below the **Row** pixel. **Pixel** pixel values are replaced by the average of the pixels to the left, right, above, and below the **Pixel**.

With Version 1.X blemish files, only "good" pixels (i.e., pixels that have not been identified as defective in the defect map) are used to calculate a corrected value for a defective pixel. If a defective pixel appears along the outer edges of the active area, only the available adjacent pixels are used to calculate a mean value. If no good pixels are available for calculating a new value for a defective pixel, the value of the defective pixel remains unchanged.

Version 2.X blemish files include the added function of cluster defect correction. Cluster defect correction enables the correction of a bad pixel surrounded by other bad pixels.

Regions of Interest

Defect map files always contain information for the full active area of the sensor. If ROIs are included in the experiment, the blemish information must be applied to each ROI. Each ROI is treated as a small "active sensor area" in that a defective pixel on its outside edge is treated in the same was as defective pixel on the outside edge of the sensor.

Orientation

The defect map file is mapped to the sensor array based on a Normal orientation of the array. Information stored in the camera (NVRAM) indicates whether the **High Capacity** or **Low Noise** value for the ADC **Quality** setting yields an image in Normal orientation. A defect map file must be based upon a Normal orientation (i.e., pixel locations in the file must reflect the image as seen by the naked eye).

Creating a Defect Map

Introduction

Blemish correction requires a camera-generated (NIRvana/PIoNIR cameras only) or a user-generated .CSV defect map file. A user-generated .CSV file can be created in a spreadsheet program such as Microsoft Excel or in an ASCII text editor such as Notepad. This file documents the type of blemish, its location, and the extent of the blemish. The defect map file must be based upon a Normal orientation (i.e., pixel locations in the file must reflect the image as seen by the naked eye). Once the file has been created and stored (usually in the Corrections subdirectory of the working directory), the file can be selected for blemish correction.

Note: The sensor dimensions used in the defect map must match the dimensions of the sensor in the camera.

Creating a Defect Map File (Blemish Correction File) with a Spreadsheet

The defect map file shown above documents one column defect that is 256 pixels long (the height of the sensor), one row defect at row 10 that is 1024 pixels long (the length of the sensor), and two pixel defects (one at column 10, row 3, and the other at column 25, row 6). This file also contains a comment.

	A	B	C	D
1	Defect Map			
2	Version	1	1	
3	Sensor Width	1024		
4	Sensor Height	256		
5				
6	Column Defects			
7	Column	Row	Length	
8	3	0	256	
9	Row Defects			
10	Column	Row	Length	
11	0	10	1024	
12	Pixel Defects			
13	Column	Row		
14	10	3		
15	25	6		
16	# This is a comment about the blemish file.			

Figure 87. Defect Map in spreadsheet

Using a Spreadsheet:

1. Open the spreadsheet. The defect map will contain three columns. The first four lines are the header information about the map and the sensor.
2. On Row 1, key in Defect Map in Column A. Refer to the sample CSV file "defect map.csv - Excel"
3. On Row 2, key in Version in Column A and enter the version numbers in Columns B and C.
4. On Row 3, key in Sensor Width in Column A and key in the width in pixels in Column B.
5. On Row 4, key in Sensor Height in Column A and key in the height in pixels in Column B.
6. Skip Row 5.
7. On Row 6, key in Column Defects.
8. On Row 7, key in Column, Row, and Length in Columns A, B, and C, respectively.
9. On Row 8, key the coordinates of the column defect (the column, the starting row for the defect, and the column length) into Columns A, B, and C, respectively. Repeat this step for any other column defects.
10. After completing the entry of Column Defects, start a new row and key in Row Defects.
11. On the next row, key in Column, Row, and Length in Columns A, B, and C, respectively.
12. On the next row, key the coordinates of the row defect (the starting column, the row, and the row length) into Columns A, B, and C, respectively. Repeat this step for any other row defects.
13. After completing the entry of Row Defects, start a new row and key in Pixel Defects in Column A.
14. On the next row, key in Column and Row in Columns A and B.
15. On the next row, enter the coordinates of the pixel defect (the column and the row) in Columns A and B. Repeat this step for any other pixel defects.
16. If you want to add a comment to the file, start the next line with the "#" character and enter the comment. Anything after the "#" character on THAT line will be ignored when the file is used.
17. Save the file with a .CSV extension. We recommend that you save the file to the Correction Files subdirectory of the LightField working directory.

Creating a Defect Map File (Blemish Correction File) with a Text Editor

The defect map file below documents four column defects that are 512 pixels long (the height of the sensor), one row defect at row 10 that is 512 pixels long (the length of the sensor), and two pixel defects (one at column 11, row 4, and the other at column 25, row 6). This file also contains a comment.

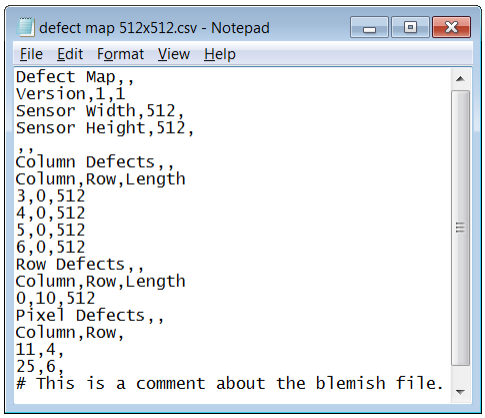


Figure 88. Defect Map in Text Editor

Using a Text Editor:

1. Open an ASCII text editor. The defect map will contain three columns. The first four lines are the header information about the map and the sensor.
2. On the first line, key in Defect Map. Include commas. Refer to the sample CSV file "defect map.csv - Notepad"
3. On the second line, key in Version and enter numbers.
4. On the third line, key in Sensor Width and key in the width in pixels.
5. On the fourth line, key in Sensor Height and key in the height in pixels.
6. On the fifth line, key in 2 commas.
7. On the sixth line key in Column Defects.

8. On the next line key in Column, Row, and Length separated by commas.
9. On the next line enter the coordinates of the column defect: the column, the starting row for the defect, and the column length. Repeat this step for any other column defects.
10. After completing the entry of Column Defects, start a new line and key in Row Defects.
11. On the next line key in Column, Row, and Length separated by commas.
12. On the next line enter the coordinates of the row defect, the starting column, the row, and the row length. Repeat this step for any other row defects.
13. After completing the entry of Row Defects, start a new line and key in Pixel Defects.
14. On the next line key in Column and Row separated by commas.
15. On the next line enter the coordinates of the pixel defect, the column and the row. Repeat this step for any other pixel defects.
16. If you want to add a comment to the file, start the next line with the "#" character and enter the comment. Anything after the "#" character on THAT line will be ignored when the file is used.
17. Save the file with a .CSV extension. We recommend that you save the file to the Correction Files subdirectory of the LightField working directory.

TIP: To keep track of pixel numbers with long sensor arrays, use a spreadsheet application that can save data to TXT files. Then change the extension to CSV.

Specifying a Blemish Correction File

If you have created and stored a .CSV file for the sensor in your camera, you can retrieve this file by clicking in the **Remove Sensor Blemishes** box on the **Online Corrections** expander, and select it from the **Blemish File** button's drop-down list or use the **Browse** button to locate and select the correct file.

Note: The **Remove Sensor Blemishes** box is selected by default for a NIRvana/PIoNIR camera. The .CSV file for a NIRvana/PIoNIR is generated when the camera icon is dragged into the **Experiment Devices** area and is stored in the **Corrections File** directory.

To select an existing defect map file, click on the  button, go to the **Correction Files** directory (a subdirectory of the working directory) and select the .CSV file for the sensor. For step-by-step information on creating a defect map, see ***"Creating a Defect Map"***, starting on page 46.

Specifying Automatic Blemish Correction

Blemish correction will occur automatically whenever an appropriate blemish correction file is selected, the **Remove Sensor Blemishes** box is checked on the **Online Corrections** expander, and data are previewed or acquired.

Note: If the **Back Up Raw Data** check box is selected on the **Save Data File** expander, data acquired when sensor blemish correction is active will be stored in both the corrected and raw data files. Thus, two data files are acquired and saved for a data acquisition. These files have the same file name with "-raw" appended to the raw data file name.

Performing Blemish Correction

For Online Corrections (corrections performed during data acquisition), open the **Online Corrections** expander in the Experiment workspace, check the **Remove Sensor Blemishes** check box, click on the **Blemish File** button and select from the list (or to browse to a different directory folder, click on the  button, go to the appropriate directory, and select the .CSV blemish file for the sensor). After the file is selected, its file name and date of creation will be displayed. When the **Remove Sensor Blemishes** box is checked and data acquisition is in process, the pixels and columns specified as bad in the blemish correction file will be replaced by interpolated data as the data are collected.

For information about post-process blemish correction, see ***"Applying Blemish Correction to Previously Acquired Data" on page 148***.

Note: If blemish correction has been turned on, the correction will be applied to data being acquired. It will also be applied when background and flatfield files are acquired and during calibration.

Cosmic Ray Removal

This function removes highly localized spikes (such as those that could be caused by cosmic rays interacting with the silicon of the sensor) from the data after it is acquired but before it is stored. When activated, one of the two filters (**Despeckle Filter** or **Median Filter**) and its **Kernel Size** (3x3, 5x5, or 7x7) can be selected. When one of these filters is used to correct data, the selected kernel matrix is applied to every pixel in the image. The overall data is smoothed during the correction. Because of this, both the raw data and the corrected version of the data are saved in separate files (the basic file names are identical but the raw data file name has "-raw" appended to it).

- The **Median Filter** adds the values of the pixels within the selected matrix and then divides by the number of pixels in the

matrix. The center pixel value is replaced by the result of the calculation.

- The **Despeckle Filter** compares the original center pixel value with a calculated median value. If the difference between the two is greater than the **sens** constant, the center value will be replaced with the calculated median value. If the difference is less than or equal to the **sens** constant, the center value will not be changed.

For more information about these filters, ***see "Cosmic Ray Removal Filters" on page 181***.

Orientation

Orientation refers to the image as it will be displayed in a viewer. Depending on your experiment setup, you may want to change the graphical or image orientation to provide a more conventional or appropriate view of your data.

To adjust image orientation, open the **Online Corrections** expander on the **Experiment Settings** tab and scroll down to the **Orientation panel**. Three operations are available: flip along the blue line, flip along the red line, and rotate 90°, 180°, or 270°. These may be performed in any combination and in any order.

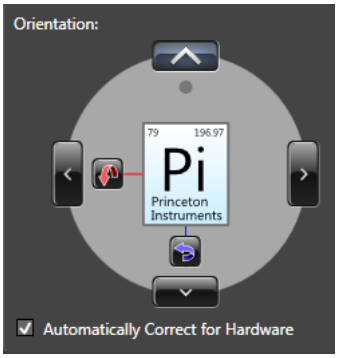


Figure 89. Orientation panel

- To flip the image along the blue line, click on the **Rotisserie** button at the end of the blue line.
- To flip the image along the red line, click on the **Rotisserie** button at the end of the red line.
- To rotate the image without flipping, click on one of the rectangular rotate buttons along the perimeter of the gray circle to rotate the image such that the button at the end of the blue line moves to the location of that rotate button.

The **Automatically Correct for Hardware** option only appears when a readout port selection is changed or a spectrometer entrance or exit port has changed. When present, the **Automatically Correct for Hardware** option is selected by default. When it is selected, LightField automatically adjusts the image to compensate for any orientation changes due to ADC Quality or Spectrometer settings.

Note: As of **January 2012**, the orientation of the PI-MAX3:1024x256 sensor has been corrected for right reading. PI-MAX3 1024x256 cameras built before that date require that you use the orientation function to rotate the image 180°. This correction is not necessary for the PI-MAX4:1024x256.

Save Data File

Introduction

Settings on the **Save Data File** expander determine where the data will be saved (.SPE format) after it is acquired and the file naming conventions applied when the data are saved. Unless you change the file destination, file name, and naming options, the data will be saved to the default working directory (set in the **Application Options** dialog) and will be named "untitled."

Note: When an online correction function (for example, background subtraction or summing/averaging of frames) is active at the time data are acquired, the uncorrected data is also saved if the Back Up Raw Data check box is selected. The uncorrected data file uses the same file name as the corrected data but includes -raw in the file name. For example, the corrected data might be saved to a file named Data 1.Spe and the uncorrected data would be saved to Data 1-raw.Spe.

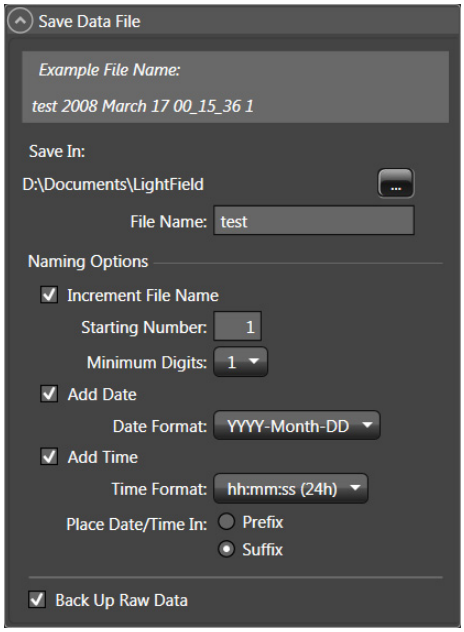


Figure 90. Save Data File expander

File Name

Example File Name: This text is updated whenever a new file name is entered or a naming option is selected or changed.

Save In: The location where data will be saved to is displayed. By default, the data file will be saved the working directory (set in the **Application Options** dialog). However, you can change the destination directory by clicking on the **Browse** button ... to open the **Browse For Folder** dialog, browsing and choosing (or creating) a new location, and clicking on the **OK** button.

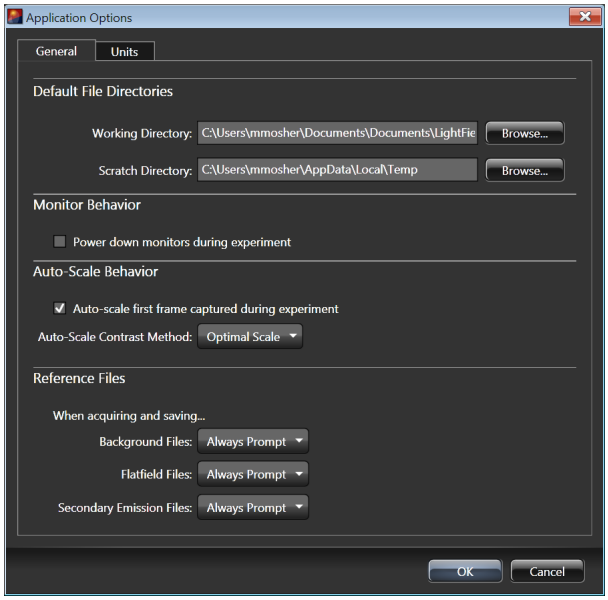


Figure 91. Application Options dialog: General tab

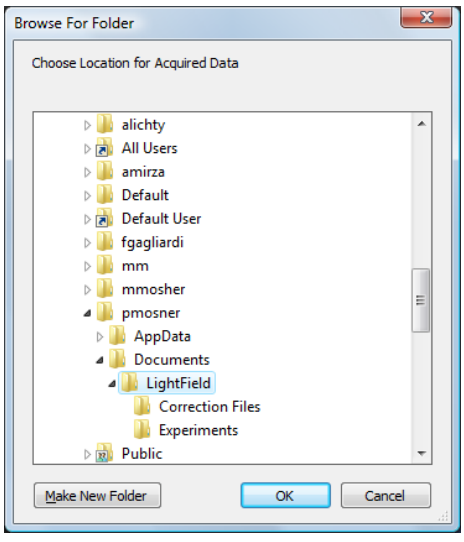


Figure 92. Browse for Folder dialog

File Name: The default file name is **untitled**. For a particular experiment, it would probably be a good idea to enter a more descriptive file name. This name is the basic name for the data file. To prevent overwriting a file, it is also a good idea to add one or more naming options to be added to the basic file name.

Naming Options

The naming options add information (date, time, and or file increment number) to the basic file name. This means that a file name such as **Data** could altered to **Data 2010-02-25 13_50_46 1** by activating all four of the options with **Suffix** selected. Choosing **Prefix** would change the file name to **2010-02-25 13_50_46 Data 1**.

- **Increment File Number:** You can enter a starting number at 1 or any number other than 1 and choose the minimum number of digits for the file number (from 1 up to 6 digits). If multiple digits are selected, leading zeros will be added to the file number if required. For example, if you select 3 digits and the file number is 4, the file number will be added to the file name as 004.
- **Add Date:** The choices are YYYY-MM-DD, YYYY-Month-DD, DD-MM-YYY, DD Month-YYYY, MM-DD-YYYY, and Month-DD-YYYY. Data 2010-02-25 13_50_46 1 above uses the format YYYY-MM-DD. Data February 25, 2010 13_56_34 007 uses the format Month-DD-YYYY.
- **Add Time:** The choices are hh:mm:ss (24 hour) and hh:mm:ss (a.m./p.m.). The time applied is based on the computer clock and is the time that the data are received at the computer. The example in Add Date uses the 24-hour format. Data 2010-02-25 02_01_57_PM 011 uses the 12-hour a.m./p.m. format.
- **Place Date/Time In:** When Prefix is selected, the date and/or time information is positioned before the basic file name. When Suffix is selected, the information is positioned after the basic file name.
- **Back Up Raw Data:** This check box appears when an online correction function is active and is selected by default. If you do not want raw data to be saved, deselect the check box.

  The **Save a Raw Data File icon** will appear in the Status bar when backing up uncorrected data is active.

Naming Data Files

Default Data Directory: The default directory used by LightField is the working directory set up via the **General** tab on the **Application Options** dialog. This dialog is accessed by selecting **Application Options...** from the **Application Menu**, which is accessed by clicking on the **Application Menu** button located to the left of the **Experiment** button.

Typically the working directory is **C:\Users\Username\Documents\LightField**, where "Username" is the user's name. The working directory is the default storage location for data files (another location can be chosen on the Save Data File expander). The working directory is also where the **Correction Files** and **Experiment Files** subdirectories are located.

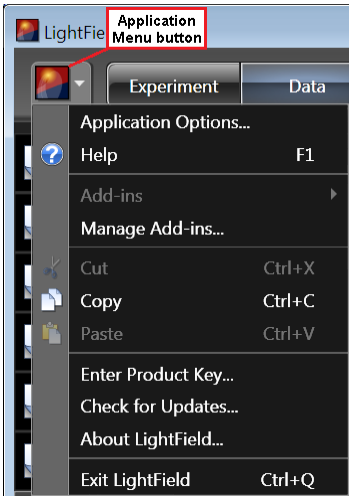


Figure 93. Application menu

Filename Generation: When data are saved by LightField, it is saved to the current working directory unless you specify a different directory on the **Save Data File** expander. The file name is automatically generated by combining the base name with options such as incrementing, dating, and/or timing. Unless you change the base name before each acquisition or select one or more options, LightField will pop up a dialog each time you run an experiment to ask if you want to overwrite or keep existing data. Data are saved using the LightField version 3.0 SPE file format.

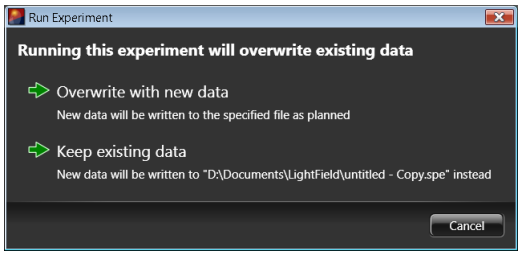


Figure 94. Experiment: Overwrite? dialog

The general format for a file name is **Basename Suffix Increment.SPE** or **Prefix Basename Increment.SPE** where **Basename** is required, **Prefix** or **Suffix** is optional and contains the date and/or time, and **(Increment)** is optional.

- **File Name:** By default the base file name is "untitled". However, you can enter a more specific base name in the File Name field. Spaces within the base name are allowed (e.g., "IMPORTANT EXPERIMENT"), but leading or trailing spaces are trimmed off.
- **Increment: Optional.** The numerical value to be incremented by one at the end of each experiment. When selecting the Starting Number, you can also enter the Minimum Digits for it. If the value of Starting Number takes up fewer digits than Minimum Digits, then the Starting Number is padded with zeros on the left. When incrementing is used, the number (in parentheses) will be added at the end of the file name. For example, if the base name is Experiment, the starting number is 1 with a minimum of three digits, and you have just acquired the first set of data with this file name, the data will be saved to Experiment 001.spe.
- **Date: Optional.** The current date. Several date formats are available: see Date Formats below. The date is taken just before the experiment starts. The date (and time if selected) form either the Prefix or Suffix.
- **Time: Optional.** The current time. Several time formats are available: see Time Formats below. The time is taken just before the experiment starts. The time (and date if selected) form either the Prefix or Suffix.

Date Formats

The following date formats are available:

Date Format	Example
YYYY_MM_DD	2010-04-13
YYYY_Month_DD	2010-April-13
DD_MM_YYYY	13-04-2010
DD_Month_YYYY	13-April-2010
MM_DD_YYYY	04-13-2010
Month_DD_YYYY	April-13-2010

Table 3. Date Formats

Time Formats

The following time formats are available:

Time Format	Example
hh.mm.ss (24h)	14_41_02
hh.mm ss (12h)	02_41_02_PM

Table 4. Time Formats

Examples of Generated File Names

File names must always have a base name and will always be saved as LightField version 3.0 SPE files. The general format for a file name is **Base Suffix Increment.SPE** or **Prefix Base Increment.SPE** where **Base** is required, **Prefix** or **Suffix** is optional and contains the date and/or time, and **(Increment)** is optional. Several examples of file names are listed below:

Experiment.SPE

Experiment 1.SPE

Experiment 01.SPE

Experiment April-13-2010.SPE

Experiment 04-13-2010.SPE

Experiment 13-04-2010.SPE

Experiment April-13-2010 01.SPE

Experiment 04-13-2010 01.SPE

Experiment 14.38.30 01.SPE

14_38_30 Experiment 01.SPE

Experiment 02_38_30_PM 01.SPE

02_38_30_PM Experiment 01.SPE

Experiment April-14-2010 14_38_30 01.SPE

April-13-2010 14_38_30 Experiment 01.SPE

Experiment 14-04-2010 02_38_30_PM 01.SPE

13-04-2010 02_38_30_PM Experiment 01.SPE

Specifying the Default Data Directory

The default working and scratch directories can be specified after selecting **Options** from the **Application Menu** and selecting the **General** tab on the **Applications Options** dialog. The working directory will used automatically when LightField stores data unless you change the directory on the **Save Data File** expander. The scratch directory is used for temporary files.

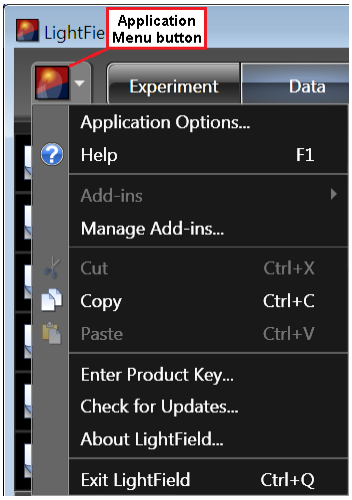


Figure 95. Application menu

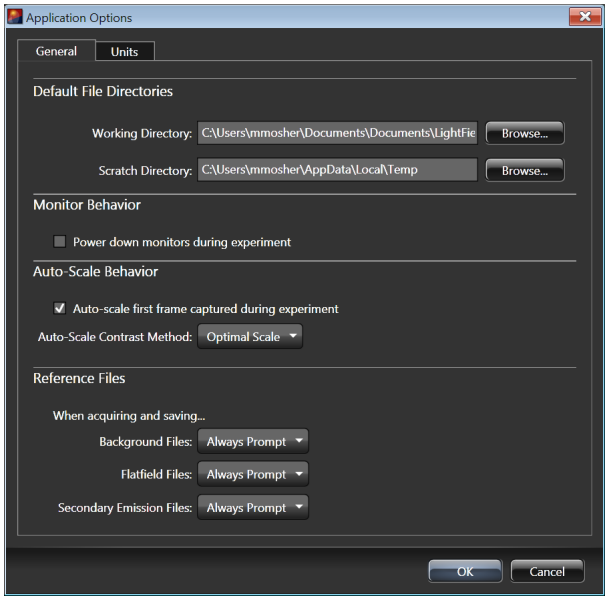


Figure 96. Application Options dialog: General tab

Analog to Digital Conversion

Introduction

Depending on the camera type, several aspects of the analog to digital conversion of data during sensor readout can be configured on the **Analog to Digital Conversion** expander. The potentially configurable aspects include:

- **Quality:** Affects the over-all quality of the data from the sensor.
- **Speed:** The rate (in MegaHertz) at which pixels are digitized.
- **Analog Gain:** Determines the number of electrons required to generate a single Analog-to-Digital Unit (ADU).
- **Bit Depth:** Determines the maximum signal value of a pixel.
- **EM Gain:** Determines the amount of electron multiplication that will be applied to improve the signal for a ProEM/ProEM+ camera or for a PI-MAX4-EM camera with **emICCD Gain Mode** set to **Manual**.
- **Advanced:** Correct Pixel Bias corrects for pixel bias drift for ProEM/ProEM+ and PyLoN cameras. Not available for PyLoN-IR cameras.

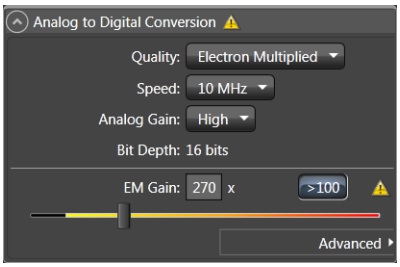


Figure 97. Analog to Digital Conversion expander

It is possible that when the Analog to Digital Conversion settings are modified, the system will send data out of a different sensor port, which could result in reversed data. Any such reversal is taken into account whenever LightField automatically applies data corrections dependent on data orientation. If the **Automatically correct for hardware** option is not selected on the **Online Corrections** expander, you will need to manually adjust the image orientation.

It is possible that when the ADC Control settings are modified, the system will send data out of a different sensor port, which could result in reversed data. Any such reversal is taken into account whenever LightField automatically applies data corrections that are dependent on data orientation.

For information about other factors (in addition to ADC settings) that should also be considered with regard to sensor readout, ***see "Readout Mode" on page 55***.

Quality

Description

Quality refers to the characteristics of analog to digital conversion and affects the overall quality of the data from the sensor as well as the readout speed. The choices vary depending on the number and type of readout ports a camera has. For information about readout ports, ***see "Readout Port Selection" on page 200***. The choices for Quality are:

- **Low Noise:** Minimizes the noise of the data. Provides the highest sensitivity performance and is suitable when you have weak signals.
- **High Capacity:** Maximizes the dynamic range of the data. Provides a spectrometric well capacity that is approximately 3 times the well capacity for the Low Noise amplifier selection. High Capacity is suitable when you have intense light signals or signals with high dynamic range.
- **Electron Multiplied:** (ProEM/ProEM+ and PI-MAX4-EM) Changes the readout port from the Low Noise to the Electron Multiplied readout port. The number of electrons generated in each pixel will be multiplied by the EM Gain which can be varied in precise linear steps from 1 (unity gain) to 1000. This mode is most useful in applications requiring low-light sensitivity at high frame rates. For more information, ***see "Electron Multiplication" on page 182*** and ***"Electron Multiplication Gain Calibration" on page 183***.

Note: The choice of the quality and analog gain settings should be considered together for the best signal capture. For examples of the interaction of output amplifier and analog gain selections, ***see "Examples of Analog Gain Selection" on page 54***.

Selecting the Quality

1. Open the **Analog to Digital Conversion** expander on the Experiment Settings tab panel.
2. Select the desired **Quality** from the drop-down list.
3. If **Electron Multiplied** is selected:
   - Confirm that the Speed is 5 or 10 MHz.
   - For ProEM/ProEM+ cameras and for PI-MAX4-EM cameras with **Manual** emICCD Gain selected: Enter the EM Gain to be used. Gain in the range of 1-100 is recommended for most applications. However, larger gain settings can be entered if the experiment will be run in low-light conditions. Note that when **Optimal** emICCD Gain is selected for a

PI-MAX4-EM, EM gain is not selectable on the **Analog to Digital Conversion** expander.

Speed

Description

Speed is the rate at which the data from the sensor are digitized. The available speeds are camera dependent. Typically, there are two ADC speeds, such as 0.5 and 1 MHz. Because the readout noise of sensors increases with readout speed, it is sometimes necessary to trade off readout speed for dynamic range. The higher conversion speed is used for the fastest possible data collection and the lower conversion speed is used where noise reduction is of paramount concern. Switching between the conversion speeds is completely under software control for total experiment automation.

Selecting the Conversion Speed

1. Open the **Analog to Digital Conversion** expander on the **Experiment Settings** tab panel.
2. Select the desired **Speed** value for the drop-down list.

Warning! If a sudden change in the baseline signal is observed and readout speed has not been changed, excessive humidity may be present in the camera's vacuum enclosure. *TURN OFF THE SYSTEM IMMEDIATELY.* Contact Princeton Instruments Customer Support for information on how to refresh the vacuum. For Contact Information, see ***"Contact Information" on page 6***.

Analog Gain

Description

Analog Gain (a function of the preamplifier) is used to change the relationship between the number of electrons acquired on the sensor and the Analog-to-Digital Units (ADUs or counts) generated. In LightField, the Analog Gain choices vary depending on the sensor and the number of output amplifiers (Quad-RO:4320 and Quad-RO:4096 have a single amplifier per readout port). After analog gain has been applied to the signal, the ADC (Analog-to-Digital Converter) converts that analog information (continuous amplitudes) into a digital data (quantified, discrete steps) that can be read, displayed, and stored by LightField.

- **Low:** Requires the most electrons to generate an ADU count. Strong signals can be acquired without flooding the sensor. If at this setting, images or spectra appear to be weak, you may want to change the gain to Medium or High.
- **Medium:** An intermediate setting. If the sensor appears to be flooded with light, change to Low. If the images or spectra do not appear for take up the full dynamic range of the sensor, you may want to change the setting to High.
- **High:** Requires the fewest electrons to generate an ADU count. Weaker signals can be more readily detected. If at this setting, sensor appears to be flooded with light, you may want to change the gain to Medium or Low.

Examples of Analog Gain Selection

The following descriptions assume that the actual incoming light level is identical in all three instances. The numbers used illustrate the effect of changing an analog gain setting and may not reflect actual performance: gain at the Low, Medium, and High settings depends on the sensor installed and the amplifier selected.

- **Low:** Requires four electrons to generate one Analog-to-Digital Unit (ADU). Strong signals can be acquired without flooding the image. If the gain is set to Low and the images or spectra appear weak, setting the gain Medium or High may be preferable.
- **Medium:** Requires two electrons to generate one ADU. If the gain is set to Medium and the images or spectra do not appear to take up the full dynamic range of the CCD sensor, setting the gain High may be desirable. If the image appears to be flooded with light, setting it to Low may be preferable.
- **High:** Requires one electron to generate one ADU. Because fewer electrons are needed to generate an ADU, weaker signals can be more readily detected. If the image appears to be flooded with light, setting the gain to Medium or Low may be preferable.

	Low	Medium	High
Low Noise Readout Port	4 e^-/count	2 e^-/count	1 e^-/count
High Capacity Readout Port	16 e^-/count	8 e^-/count	4 e^-/count

Table 5. Analog Gain Selection

Selecting Analog Gain

1. Open the **Analog to Digital Conversion** expander on the Experiment Settings tab panel.
2. Select the desired **Analog Gain** value from the drop-down list.

Note: The "Certificate of Performance" supplied with the camera lists the measured gain values at all settings.

Bit Depth

Bit depth is the number of bits per pixel. The choice of bit depth is limited by A/D type selection. A greater number of bits give greater resolution. Most cameras currently supported by LightField have ADC speeds that result in a bit depth of 16 (i.e., 2^{16} or decimal 65,536).

EM Gain

ProEM/ProEM+ cameras and PI-MAX4-EM cameras with Manual emICCD Gain selected. Determines the amount of electron multiplication that will be applied to improve the signal. EM gain in the 1-100 range is recommended for medium to high light level signals and is the least likely to cause damage to the EM sensor. If the experiment is acquiring low light level signals, gain can be set higher. More intense light combined with high gain can accelerate sensor ageing while lowering effective dynamic range.

Note: When the **>100** button 

is depressed, the >100 portion of the slidebar shows a yellow to red gradient as a visual reminder that higher gains may have a negative impact on sensor life.

Correct Pixel Bias

ProEM/ProEM+ and PyLoN cameras (not available for PyLoN-IR cameras). Corrects pixel bias drift for these cameras. This correction can be turned on or off via the **Advanced** button.

Readout

Introduction

After the exposure time has elapsed, the charge accumulated in the sensor pixels needs to be read out of the sensor, converted from electrons to digital format, and transmitted to the application software where it can be displayed and/or stored. Readout begins by moving charge from the sensor image area to the serial register. The charge in the serial register pixels, which typically have twice the capacity of the image pixels, is then shifted into the electrons/count. This result leaves the sensor and goes to the preamplifier where gain is applied.

The settings and the type of reported information on the **Readout** expander vary depending on the sensor installed in the camera and whether the Kinetics or Spectra-Kinetics option has been installed in the camera.

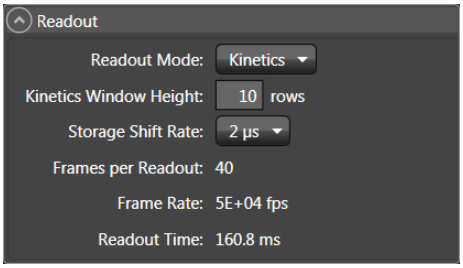


Figure 98. Readout expander

Readout Mode

Readout mode is the selected method of data transfer from the sensor to the application software. Available readout modes vary depending on the camera and its sensor. Selecting a readout mode also affects the **Trigger Responses** available in the **Trigger** expander.

- **Full Frame:** The camera reads out one frame at a time.
- **Frame Transfer:** The camera will expose the next frame while reading out the current frame. The camera must have a frame transfer sensor.
- **Kinetics:** Kinetics operation requires that the Kinetics option has been installed in the camera. In Kinetics mode, the camera will rapidly expose multiple frames on the sensor before reading out. When Kinetic mode is selected, you can specify the height of the "unmasked" area used for kinetics. For detailed information about Kinetics setup and operation, see the Kinetics Mode and Setting up for Kinetics or Spectra-Kinetics Mode topics.
- **Spectra-Kinetics: ProEM or ProEM+ frame-transfer sensor only.** Spectra-Kinetics operation requires that the Spectra-Kinetics option has been installed in the camera (Spectra-Kinetics is standard for the ProEM:512BK and ProEM+:512BK sensor). For detailed information about Spectra-Kinetics setup and operation, see the ***"Spectra-Kinetics Mode" on page 198*** and ***"Setting Up for Kinetics or Spectra-Kinetics Mode Procedure" on page 197*** topics.
- **DIF: PI-MAX3 or PI-MAX4 with interline sensor only.** Dual Image Feature (DIF) allows you to acquire a pair of gated images in rapid succession. The time between frames can be as short as 2 µs (limit imposed by P46 phosphor decay time) with exposure times as short as 5 ns. For detailed information about DIF, ***see "DIF Gating Mode" on page 187***.

Kinetics Window Height

Kinetics Window Height is the height (in rows) of the unmasked area used for Kinetics or Spectra-Kinetics.

- **Kinetics:** The minimum height is 1and the maximum height is 1/2 x sensor height for a full frame sensor, and the maximum for a frame-transfer sensor is the sensor area height. For example, the range for a full frame sensor that has 2048 rows is 1-1024. The range for a frame-transfer sensor that has a sensor area with 512 rows is 1-512.
- **Spectra-Kinetics:** Since Spectra-Kinetics only applies to ProEM/ProEM+ frame-transfer sensors, the minimum height is 1 and the maximum height is the sensor area height. The range for a frame-transfer sensor that has a sensor area with 512 rows is 1-512.

Storage Shift Rate

Storage Shift Rate is associated with **Frame Transfer**, **Kinetics Readout**, and **Spectra-Kinetics** modes. It determines the speed of the image transfer from the exposed area of a sensor to the masked area. Setting a lower value increases the shift speed. A higher value gives a slower shift. If the shift is too fast, not all of the charge will be transferred. If too slow, image smearing will be increased due to the exposure that takes place while the transfer is in progress. The default value gives good results in most measurements.

Frames per Readout

Frames per Readout is associated with the **Kinetics Readout** and **Spectra-Kinetics Readout** modes.

- **Kinetics:** The number of Frames per Readout is determined by dividing the sensor height by the Kinetics Window Height. For example, if the Kinetics Window Height is 10 and the sensor is 100 rows high, the Frames per Readout will be 10. If the Kinetics Window Height is 10 and the sensor is 1024 rows high, the Frames per Readout will be 102.
- **Spectra-Kinetics:** The number of Frames per Readout is based on the number of rows under the frame-transfer mask.

Frame Rate

Frame Rate is associated with the **Kinetics Readout** and **Spectra-Kinetics Readout** modes. This is the rate at which a full set of frames will be captured on the sensor. If for example the sensor is 100 rows high, the window is 10 rows high, the exposure time is 10 ms, and the storage shift rate is 15.2 µs, it will take about 101.5 ms to acquire all 10 frames on the sensor. This frame rate does not include the Readout Time (time spent shifting the data to the serial register, amplifying, digitizing, and transmitting it to the computer).

Readout Time

Readout Time is the time it takes to read data from the sensor once.

Region of Interest

Introduction

The selections on the **Region of Interest** expander allow you to choose how much of the charge acquired on the sensor (full-frame or less than full-frame region of interest) will be saved: how much binning, if any, should be performed (either in hardware or in software): and, in the case of the Quad-RO:4096, which readout port will be used. After the sensor has been exposed for the specified time, the charge in the pixels are read out and processed before data can be displayed or saved to a file. Factors to be consider are incoming signal intensity, the signal-to noise ratio, readout time, and the capacity of serial register pixels and the output node (typically only 2-3 times the capacity of imaging pixels).

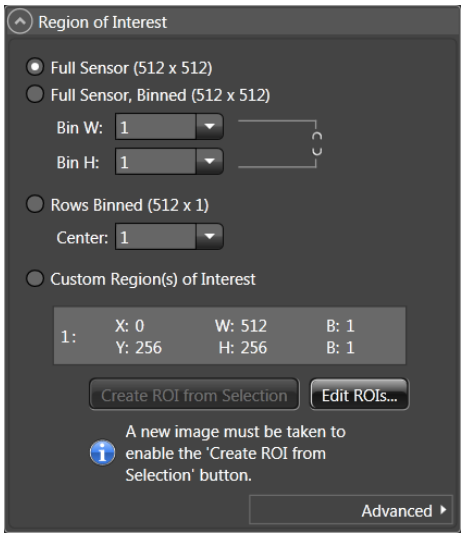


Figure 99. Region of Interest expander

Note: If you are running a ProEM/ProEM+ camera, the number of pixels in the serial (horizontal) direction must be evenly divisible by 4, even after binning.

Caution: If you plan to create a Custom Sensor and you have created ROIs for the current experiment, save the experiment before opening the **Custom Sensor** flyout pane. ANY time you change the **Active Area Width** or **Active Area Height** and there are ROIs, LightField will either delete or modify existing ROIs.

Raw Data

Software binning irreversibly modifies data as it is being acquired. However, if you activate "**Back Up Raw Data**" on the **Save Data File** expander before starting acquisition, a raw data backup file will be generated and saved to the same directory as the regular acquisition file when acquisition occurs. Each frame of raw data will be captured and saved before corrections are performed on it. The raw data file will be saved to the same directory as the regular acquisition file. The raw data file will be given the same name as the regular acquisition file, but with "**-raw**" appended. For example, if your regular acquisition file was "**untitled.spe**", the raw data file would be "**untitled-raw.spe**".

Note: Irreversible online data manipulations/ corrections that are backed up with raw data include software binning, background subtraction, flatfield correction, sensor blemish correction, and accumulations (exposures per frame). Because hardware binning occurs before the data are digitized, raw data files cannot be created when hardware binning is active. Because orientation processes can be reversed, an orientation change by itself will not be enough to cause raw data to be saved.

Hardware Binning or Software Binning

As indicated in the introduction, if a region of interest includes binning, you have the choice of binning in hardware or in software. The following information covers the advantages and disadvantages of your choice. For detailed information about binning, ***see "High Speed Camera Add-in" on page 178***. To select the type of binning (hardware or software), click on the **Advanced** button and make your choice on the flyout pane.

- **Hardware Binning:** Occurs in the serial registers and before signal is readout of the sensor output amplifier. The advantage to hardware binning is that it allows you to increase sensitivity and frame rate. Because this binning is performed before the signal is digitized and processed, the drawback to hardware binning is that a raw data file will not be saved. Because hardware binning is performed while the signal is shifted into the serial register, the readout time and the burden on computer memory are reduced. However, this time and memory savings are at the expense of resolution. Since serial register pixels typically hold only twice as much charge as image pixels, hardware binning of large sections may result in saturation and "blooming," spilling charge into adjacent pixels.
- **Software Binning:** Occurs after the data have been sent to the host computer. Both a raw data and a binned data file are saved. If blooming is an issue, use software binning instead of hardware binning. While software binning will prevent saturation of the sensor's serial register pixels, it is not as fast as hardware binning.

Full Sensor (# x #)

When **Full Sensor** is selected, the entire active area of the sensor will be read out at full resolution. Every pixel will be digitized separately. The (# x #) values are based on the sensor information loaded into LightField when a camera is detected.

Full Sensor, Binned (# x #)

When **Full Sensor, Binned** is selected, the largest possible region, centered on the sensor, will be read out but as groups of pixels (i.e., super pixels). The bin values used can be those selected from the dropdown lists or those that you key into the fields. If you link Bin W and Bin H, the binning values in both directions will be identical. If the sensor is 512x512 and Bin W=2 and Bin H=2, the resulting region would be 256x256. If Bin W=5 and Bin H=2, the resulting region would be 102x256.

The advantages to binning are reduced readout time and an improved signal-to-noise ratio. The disadvantages to binning are the loss of resolution and the potential for data corruption (either by blooming into the image area because serial registers have become saturated or saturation at the output node leading to loss of charge). The (# x #) values are updated whenever the binning factors change.

Rows Binned (# x 1)

This function is primarily used in spectroscopy experiments. When Rows Binned is selected, the resulting data will be the full active width of the sensor and the specified number of active rows (centered about the center line) will binned down to a single row. The number of rows centered on the sensor can be one of the three values in the Center drop-down list or the number of rows you key into the field. If you select 1, only the row above the center will be output. If you enter a number such as 256, only the 128 rows above and the 128 rows below the center line will be binned together to create the single row. If the sensor is only 256 rows high, then all of the sensor's active rows will be binned together to create the single row.

Custom Region(s) of Interest

A Custom Region of Interest (ROI) may cover the entire CCD array or only a rectangular subregion of it. The width and height of each ROI is defined by its top left X and Y coordinates on the sensor and the width and height entries. Additionally, the pixels within the ROI may be binned horizontally

and/or vertically. Depending on the camera, there may be limitations on the number of pixels binned and the location of the ROI(s) on the sensor.

After one or more regions have been created in the **Edit Regions of Interest** window, LightField uses these regions to determine which information is read out and displayed and which is discarded. Note that the first three ROIs are listed in the Region of Interest expander. If there is an Experiment Conflict due to ROI size, position, overlap or binning, the list border will be red.

A full sensor data set can be acquired without the loss of any ROI parameters. Selecting Full Sensor results in full-frame data sets and any ROI parameters are ignored. Subsequently selecting Custom Region(s) of Interest activates the ROI parameters again. When ROIs used for acquisition, the ROI information will be stored with the data. When the data are displayed in the View panel, you can choose to display up to five ROIs at a time.

Create ROI from Selection

This function allows you to acquire data and, from its display in the Experiment Viewer, create a single ROI by drawing a selection box around the area of interest. Any already defined custom ROIs (location and dimensions are shown in the Custom ROIs panel) will be overwritten when you use this function.

1. Set up your experiment.
2. Switch to the **View** tab.
3. On the **Region of Interest** expander, select **Custom Region(s) of Interest**. The **Create ROI from Selection** button may be disabled.
4. Acquire data. You can do so by clicking on the **Run** and then **Stop** buttons or by clicking on the **Acquire** button.
5. When the new data is displayed in the viewer, draw a selection box around the area of interest. This action activates the **Create ROI from Selection** button.
6. Click on the **Create ROI from Selection** button. The Custom ROI panel will be updated with the location and dimension information for the ROI. You can draw a different selection box if you want to overwrite the information in the panel.
7. To add binning to the ROI you have created or to add additional ROIs, click on the **Edit ROIs...** button and make your changes in the Edit Regions of Interest window.

Edit ROIs...

This button opens the **Edit Regions of Interest window**. This viewer is similar to the **Experiment** and **Data** viewers in that it has the Brightness/Contrast, Zoom, and Autoscale functions. However, it does not support graphs or opening files: the viewer will show created ROIs and in the background there will be either no image or a captured reference image.

When you click on the **Capture Reference Image** button, the current experiment settings will be used to capture an image that will be displayed in the **Edit Regions of Interest** viewer. You can then create and easily position ROIs over the areas of interest.

While you are creating or modifying ROIs, Experiment Conflict errors may occur because of positioning, height and width constraints, and special binning requirements. Errors will be indicated by the **Experiment Conflict icon**, red outlining, and brown shading (when ROIs overlap or ROIs share rows but do not have the same Bin H values or have the same Bin H values but the binning is not aligned). For even more information about creating and editing ROIs, ***see "Regions of Interest - Editing" on page 201***.

Note: The coordinate starting point for an ROI is always the top left corner of the ROI as it appears in the current orientation. The X and Y coordinates for that starting point are zero-based: if the ROI starting point was the top left corner of the sensor, the coordinates would be 0,0.

Warning! If you plan to create a **Custom Sensor** and you have created ROIs for the current experiment, save the experiment before opening the **Custom Sensor** flyout pane. ANY time you change the **Active Area Width** or **Active Area Height** and there are ROIs, LightField will either delete or modify existing ROIs. If you use the **Align Spectrometer** function or the **Create ROI from Selection** function, your ROIs will be deleted. Because of this, be sure to save your experiment so you can reload the ROI information after you have finished the alignment or used the **Create ROI from Selection** function..

Using Edit ROI View

1. Open the **Experiment** workspace.
2. Click on the **Region of Interest** expander.
3. Select **Custom Region(s) of Interest**.
4. Click on the **Edit ROIs...** button.
5. **Optional:** Click on the **Capture Reference Image** button. An image will be acquired using the current experiment settings (with the exception of existing ROIs) and will be

displayed in the viewer as a background aid to in creating or modifying ROIs. If **Custom Sensor Active Rows** (**Sensor|Custom Sensor** pane) is set to a value LESS than the default, LightField will acquire multiple times to ensure that the last image is clean, and has usable data. The smaller the number of **Active Rows**, the more acquisitions will be performed.

6. The **Toolbar** displays the cursor location and intensity information, brightness and contrast tools, zoom tools, autoscale contrast tool, pixel ratio tool, fit image tool, and the pseudo color access button. When there is not enough room to display all of a bar's contents, the contents are hidden but can be accessed by clicking on the **Overflow** button at the right side of the bar. 
7. You can now create, center, delete, or modify ROIs.
   - **Create:** If you click on the Create button, LightField will draw and center an ROI in the viewer. If there is an existing ROI, you can select that ROI and click on the Duplicate button to create an exact copy of that ROI (you must then reposition the new ROI to clear the Experiment Conflict). You can use the mouse cursor to draw an ROI on the viewer and then click on the Create button to finalize the creation.
   - **Center:** Select the ROI to be centered by clicking on the ROI in the ROI list or by clicking in the ROI in the viewer. Then click on the Center button to reposition the ROI at the center of the sensor. This function is particularly useful for Quad-RO cameras that are using four-port readout.

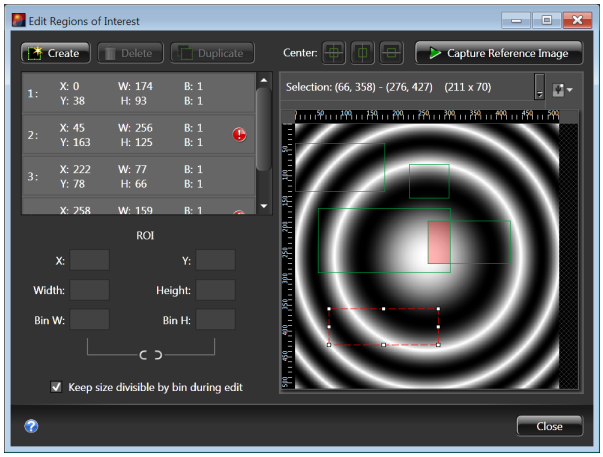


Figure 100. Edit Regions of Interest window

- **Delete:** Select the ROI to be deleted by clicking on the ROI in the ROI list or by clicking in the ROI in the viewer. Then click on the **Delete** button.**Modify:** Select the ROI to be modified by clicking on the ROI in the ROI list or by clicking in the ROI in the viewer. The settings for the selected ROI will be displayed below the ROI list. You can reposition and resize the selected ROI in the viewer by grabbing and dragging the ROI to reposition it and grabbing a handle and dragging it to resize. For finer positioning and sizing, key in the values in the ROI settings fields for the selected ROI(s). Binning is changed via the settings fields. You can use the Link function to synchronize height and width binning changes. You can use the **Keep size divisible by bin during edit** check box to prevent error conditions where the height or width of the ROI is not divisible by its associated bin value.

Note: You can select multiple ROIs for modification. To do this, use Shift+mouse click or Ctrl+mouse click to select two or more ROIs in the ROI list. Depress the Ctrl key and drag the cursor to select all or part of the ROIs in the viewer. Any ROI settings fields that do not have the same values for the selected ROIs will be blank.

Capturing a Reference Image

1. Set up and turn on the equipment for your experiment. Then start LightField.
2. Set up the experiment: make sure the devices are in the **Experiment Devices** area and enter/select the **Experiment Settings**.
3. Open the **Region of Interest** expander.
4. Select **Custom Region(s) of Interest**.
5. Click on the **Edit ROIs...** button.
6. Click on the **Capture Reference Image** button at the top of the Edit Regions of Interest window.

Note: If **Custom Sensor Active Rows** (**Sensor|Custom Sensor** pane) is set to a value LESS than the default, LightField will acquire multiple times to ensure that the last image is clean, and has usable data. The smaller the number of **Active Rows**, the more acquisitions will be performed.

Special Cases

Quad-RO: These cameras do not support multiple ROIs. If a Quad-RO is using four-port readout, the ROI must be centered horizontally and vertically on the sensor and have an even number of pixels in the X and Y dimensions. A binned ROI for four-port readout must have an even number superpixels in the X and Y dimensions. Binning,

centering, and dimensional constraints do not apply if a Quad-RO 4096 is using single-port readout.

PI-MAX3 or PI-MAX3:1024i: If a PI-MAX:1024i camera is using dual-port readout, the ROI must be centered horizontally on the sensor and have an even number of pixels in the X dimension. A binned ROI for dual-port readout must have an even number superpixels in the X dimension. Binning, centering, and dimensional constraints do not apply if this camera is using single-port readout.

NIRvana/PIoNIR: The number of pixels in the serial (horizontal) direction must be evenly divisible by 4 and the X value must be zero or a multiple of 4.

ROI Experiment Conflict

If an **Experiment Conflict** occurs (for example, two overlapping ROIs is an Experiment Conflict) no data can be acquired until the conflict is resolved or **Custom Region(s) of Interest** is de-selected on the **Region of Interest** expander. If conflicts remain when you close the **Edit Regions of Interest** window, the **Custom Region(s) of Interest** list will be framed in red and a conflict icon will be shown in the **Region of Interest** panel and header bar. De-selecting **Custom Region(s) of Interest** removes these conflict indicators. Re-selecting **Custom Region(s) of Interest** restores the indicators.

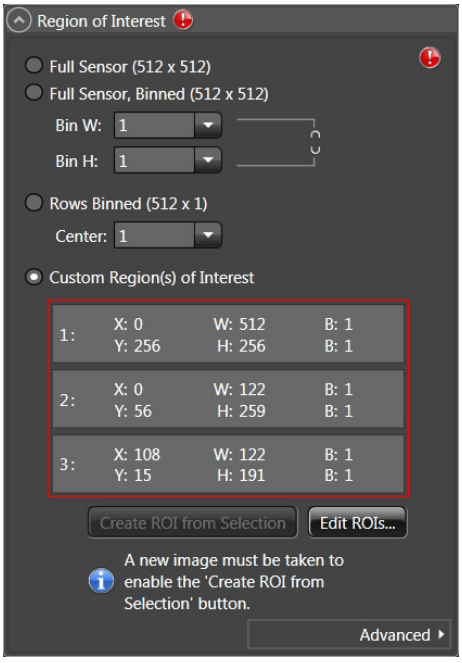


Figure 101. Experiment Conflict Shown on Region of Interest expander

Advanced

Functions on this flyout pane vary depending on the camera. Among the possible functions are selectable **Hardware** or **Software Binning** and selectable **Readout Port** (currently only for the Quad-RO:4096 and PI-MAX3:1024i or PI-MAX4:1024i).

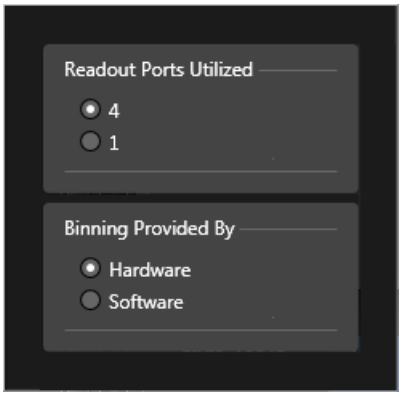


Figure 102. Region of Interest: Advanced flyout pane

Readout Ports Utilized

- **4 Port Readout:** (Quad-RO:4096) Default setting. Four-port readout maximizes the frames per second readout of the sensor. All quadrants are readout at the same time.
- **2 Port Readout:** (PI-MAX3:1024i, PI-MAX4:1024i) Default setting. Dual-port readout maximizes the frames per second readout of the sensor. Data are read out via both ports.
- **1 Port Readout:** Not available for the Quad-RO:4320.
  - **Quad-RO:4096:** Single-port readout means that all quadrants will be read out via the factory-selected port. Readout in single-port mode is significantly slower than for four-port mode. However, you may want to choose this readout if you have created an asymmetrical ROI (i.e., an ROI that does not conform to the symmetry rules required for four-port readout).The factory-selected port was chosen because it had the lowest noise performance of the four ports.
  - **PI-MAX:1024i:** Single port readout means that all the data are read out via the factory-selected port. Readout in single-port mode is slower than for dual-port mode. However, you may want to choose this readout if you have created an asymmetrical ROI (i.e., an ROI that does not conform to the symmetry rules required for dual-port readout).

Binning Provided By

- **Hardware Binning:** Performed as the signal is being read out of the sensor.
- **Software Binning:** Performed after the signal has been digitized and sent to the host computer.

Sensor

Introduction

Settings and functions on the **Sensor** expander deal with sensor cooling, sensor redefinition, and cleaning and discarding unwanted signal.

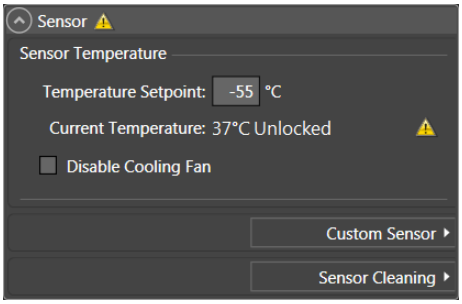


Figure 103. Sensor expander

Sensor Temperature

Each Princeton Instruments camera contains a mechanism (fan, Peltier-effect thermoelectric cooler, circulating coolant, or combination of mechanisms) that is used to control the temperature of the sensor. Lowering the sensor temperature generally enhances signal quality. Once the target sensor temperature (Temperature Setpoint) is entered, LightField controls the camera's cooling circuits until that temperature is reached. The control loop then locks at the Temperature Setpoint for stable and reproducible performance. When temperature lock is attained (the temperature is within 0.05°C of the Temperature Setpoint), LightField reports that the current temperature has stabilized. The **on-screen indicator** (in the **Status** bar) allows easy verification of temperature lock status: temperature is reported as Current Temperature (**Temperature Setpoint)** so you can monitor the progress of the cool down. Unlike other supported cameras, ProEM/ProEM+ cameras feature software control of the fan On/Off status.

Figure 104. Temperature Status

Note: The Experiment Warning icon will be displayed on the **Sensor** expander and next to the **Current Temperature** whenever the sensor temperature is unlocked. You can still acquire data.

Temperature Set Point

This parameter is used to raise or lower the temperature at the sensor. The range of valid settings depends on the sensor and the cooling mechanism(s).

Setting the Temperature:

1. Open the **Sensor** expander.

   TIP: You can open the expander by clicking on the temperature indicator in the Status bar.

2. Key in the desired temperature in the **Temperature Setpoint** field and press the Enter key.

Current Temperature

This reports the current temperature and the locked or unlocked status. The time required to achieve temperature lock can vary considerably and depends on camera type, sensor type, ambient temperature, and other factors. You can acquire data while the temperature status is unlocked (i.e., temperature at the sensor has not yet reached the setpoint), but for the best data, you should wait until the temperature has been locked for about 20 minutes.

Disable Cooling Fan

This check box only appears if the camera is a ProEM/ProEM+. The ProEM/ProEM+ uses circulating coolant and an internal fan to control temperature. If fan vibration may affect results, you can turn off the fan operation by checking the **Disable Cooling Fan** check box. However, you must make sure that the coolant is circulating through the camera to maintain the sensor cooling temperature.

Custom Sensor

Caution: Princeton Instruments does not encourage users to change the sensor size parameters loaded when the camera is dragged into the Experiment Devices area. For most applications, the default settings will give the best results. We *strongly advise* contacting the factory for guidance before customizing the sensor definition.

Introduction

The **Custom Sensor** flyout pane (opened by clicking on **Custom Sensor**) allows you to redefine the sensor. The default values for the custom sensor parameters conform to the physical layout of the sensor and are optimal for most measurements.

Normally, not all of the pixels in a sensor are exposed and read out: a frame of "inactive" pixels bounds the active area. These inactive pixels are usually masked and are not normally read out.

However, they could be read out by changing the sensor definition in software by decreasing the size of inactive areas. Thus, you could measure the dark charge with every readout.

It is also possible to increase image acquisition speed by reducing the size of the active area in the definition. The result will be faster but lower resolution data acquisition. Operating in this mode would ordinarily require that the sensor be masked so that only the reduced active area is exposed. This prevents unwanted charge from spilling into the active area or being transferred to the serial register.

Depending on the sensor, you may be able to select from a list of vertical shift rates to either speed up or slow down the rate at which a row is shifted into the serial register.

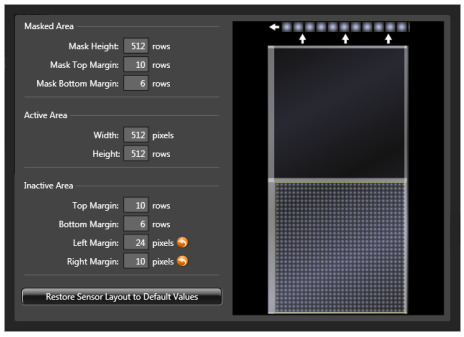


Figure 105. Custom Sensor flyout pane: 512x512 Frame Transfer Sensor

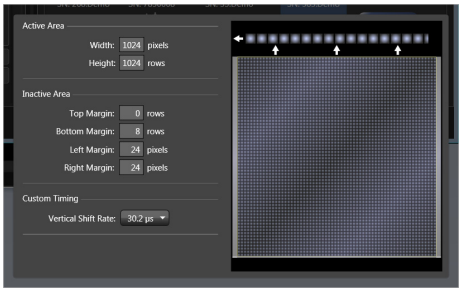


Figure 106. 1024x1024 Full Frame Sensor

Changes made to the sensor definition are indicated by a **Restore to Default Value** button to the right of a changed field. Click on that button to reset the information in that field to the default value or click on the **Restore Sensor Layout to Default Values** button Restore Sensor Layout to Default Values to reset all of the changed values to their default values.

Note: Custom Sensor is not available for Quad-RO cameras.

Caution: If you plan to create a Custom Sensor and you have created ROIs for the current experiment, save the experiment before opening the Custom Sensor flyout pane. ANY time you change the Active Area Width or Active Area Height and there are ROIs, LightField will either delete or modify existing ROIs.

Masked Area

Frame Transfer sensors have a built-in masked area positioned just below the serial register. The Masked Area "inactive" margins are sensor-specific and are inactive rows at the boundary of the masked area and Inactive Area Top margin and the boundary of the masked area and the serial register.

Active Area

The height and width of the active area are the normal limits of the sensor's imaging area. When a camera is dragged into the Experiment Devices area or is otherwise detected by LightField, the default values are read from the camera.

Inactive Area

Normally, a frame of "inactive" or "dark" pixels bounds the active area on a sensor. These inactive pixels are usually masked and the signal in them is usually shifted into the serial register and then discarded. However, the signal in inactive pixels can be read out and retained by changing the sensor definition in LightField. By default, if there is no Top Margin, the serial register is cleaned before rows are shifted (i.e., Clean Serial Register is automatically selected in the **Sensor Cleaning** flyout pane.)

Configuring a Custom Sensor

TIP: Before changing the active and/or inactive values for a sensor, it is a good idea to save your experiment. This is particularly true if you have created ROIs, since these will either be deleted or modified when you make changes to the Active Area Height or Width.

1. Open the **Sensor** expander on the **Experiment Settings** tab panel.
2. Click on the **Custom Sensor** button to open the **Custom Sensor** flyout pane. The default values for the settings in the Active Area control group are loaded when a camera is selected for an experiment and placed in the Experiment Devices area:
   - **Active Area Height:** The number of active rows that run parallel to the serial register.
   - **Active Area Width:** The number of active columns that run perpendicular to the serial register.

3. Enter the desired Height and Width. To restore a value to its default, click on the **Restore to Default Value** button next to its field. Click on the **Restore Sensor Layout to Default Values** button Restore Sensor Layout to Default Values to reset all of the changed values to their default values.

4. Move to the **Inactive Area** settings. Normally, a frame of "inactive" or "dark" pixels bounds the active area on a sensor. These inactive pixels are usually masked and the signal in them is usually shifted into the serial register and then discarded. However, the signal in inactive pixels can be read out and saved with the data from the active area by decreasing the size of the Inactive Area and increasing the size of the Active Area accordingly. Alternatively, you can increase the size of the Inactive Area by increasing the margins and decreasing the size of the Active Area. By default, if there are no inactive rows in the Top Margin, the serial register is cleaned before rows are shifted (i.e., **Clean Serial Register** is automatically selected in the **Sensor Cleaning** flyout pane).

   - **Top Margin:** The number of inactive rows between the Active Area and the serial register. If the camera contains a frame transfer sensor, the top margin is the number of inactive rows between the Active and Masked Areas.
   - **Bottom Margin:** The number of inactive rows below the Active Area.
   - **Left Margin:** The number of inactive columns to the left of the Active Area.
   - **Right Margin:** The number of inactive columns to the right of the Active Area.

   Note: When the camera is a PI-MAX:1024i, all margins can be adjusted if single-port readout is selected. If dual-port readout is selected, only the **Top** and **Bottom Margins** can be changed. **Readout Ports Utilized** is selectable on the **Advanced** pane of the **Region of Interest** expander.

5. Enter the desired **Margin** values. To restore a value to its default, click on the **Restore to Default Value** button next to its field. Click on the **Restore Sensor Layout to Default Values** button Restore Sensor Layout to Default Values to reset all of the changed values to their default values.

6. If the **Vertical Shift Rate** setting is available, change or leave it as it is. The smaller value in the field, the faster a row will be shifted into the serial register. The larger the value, the longer it will take to shift the row. Selecting a shorter time increases the frame rate by speeding up the shift. A longer time increases the quality of data.

7. Click outside of the flyout pane to close it.

Sensor Cleaning

Introduction

An acquisition consists of one or more exposure and readout periods. At all other times, the camera is waiting to be told to acquire spectra or images. While the camera is waiting, charge generated from various sources builds up on the sensor unless there is ongoing cleaning of the array (the software clears the unwanted charge by shifting it to the serial register and then discarding it). Cleaning may also occur during readout if an ROI is smaller than full sensor.

The clean settings on the **Sensor Cleaning** flyout pane allow for optimal configuration of the cleaning feature so that the software cleans the camera as efficiently as possible without impeding the experiment.

Figure 107. Sensor Cleaning flyout pane

Cleaning Cycles

Cleaning Cycles is the basic cleaning function and is regulated through the parameters **Clean Cycle Height** and **Number of Clean Cycles**. These cycles start when the camera (or controller) is turned on and a clean pattern is programmed into the controller, and they continue until **Acquire** is selected. The timing diagram in Figure 108 is for an experiment set up to acquire three (3) spectra in **No Response** timing mode with normal shutter operation selected. In this diagram, clean cycles occur before the first exposure and after the last readout period.

Note: The start of the exposure is signaled by **Not Reading Out** going high but will not occur until the current clean cycle has finished.

When the detector is set up for the first time, default values are automatically inserted for the

parameters **Clean Cycle Height** and **Number of Clean Cycles**. These values will give the best results for most applications.

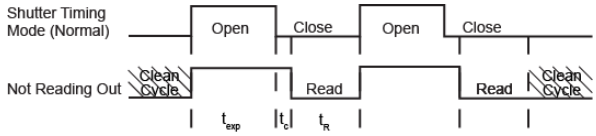


Figure 108. Clean Cycles Timing diagram

Number of Clean Cycles
Usually set to zero, these clean cycles are in addition to the automatically run clean cycles that are occurring in the background while the camera is waiting. By entering a value other than 0 in the **Number of Clean Cycles** field, you are specifying that that number of ADDITIONAL clean cycles are to occur after a start exposure has been received and the current clean cycle has finished.

Clean Cycle Height
This parameter is the number of rows shifted and discarded per clean cycle. While a large number of rows or the entire array may result in the best cleaning, this may produce a significant delay between the receipt of a start exposure signal (**Not Reading Out** signal goes high) and the beginning of the actual exposure. This delay occurs because the current clean cycle must be completed before a start exposure signal received during the cycle is implemented. The default setting is much smaller than the array size and should be 1-2 when data collection speed is critical.

Clean Until Trigger

Clean Until Trigger is provided when the start of exposure is tied to an external trigger (i.e., **Trigger Response** is set to **Readout Per Trigger**, **Shift Per Trigger** or **Start On Single Trigger**) and provides cleaning in addition to that of **Clean Cycles** when you want to remove the charge that accumulates on the array if **Shutter Timing Mode** is set to **Open Before Trigger**.

Figure 109 shows the timing diagram for an experiment in a triggered mode with the trigger active on the falling edge. Note that the timing diagram shows two possible setups for the shutter. In the first setup (**Shutter Timing Mode** is set to **Normal**), the shutter is opened when External Sync (the input to the **EXT SYNC** port) goes low. Because it takes time to open a shutter, data may be missed while the shutter is opening. In the second setup (**Shutter Timing Mode** is set to **Open Before Trigger**), the shutter is opened when the **Not Reading Out** signal goes high. The advantage with this mode is that the shutter is fully opened when the exposure (triggered by External Sync) begins. The disadvantage is that ambient light is no longer being blocked from the array during the period between Not Reading Out going high and the External Sync going low. **Clean Until Trigger** removes the signal that accumulates on the array during that interval.

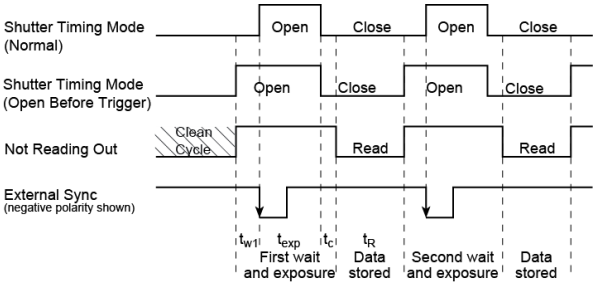


Figure 109. Clean Until Trigger Timing diagram

Figure 110 shows the same timing diagram with selection of **Clean Until Trigger** (indicated by the shaded areas labeled CUT). **Clean Until Trigger** cleans are additional clean cycles and are defined by the same parameter values (**Clean Cycle Height** and **Number of Clean Cycles**) as those for the standard **Clean Cycles**. When the External Sync trigger arrives during **Clean Until Trigger** cleaning, the current clean cycle must be completed before the exposure begins. When fast data acquisition is crucial, **Clean Cycle Height** should be set to 1–2 to minimize the delay. **Clean Until Trigger** also includes horizontal shifts while doing vertical shifts for a faster clean.

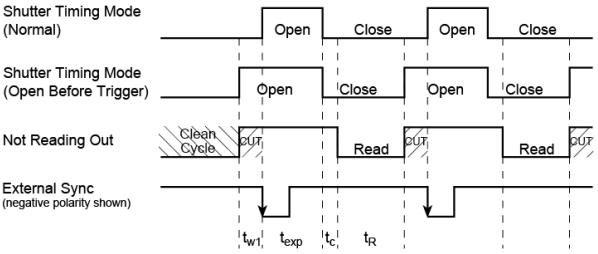


Figure 110. Cleaning with Triggered Exposure

Clean Before Exposure

Clean Before Exposure is only provided for cameras that have a Frame Transfer sensor, and is only available for selection when in **Full Frame** readout mode and the trigger mode is S**tart on Single Trigger**. When these settings are active, cleaning will occur during acquisition: immediately after reading out, the whole sensor will be cleaned once before each exposure.

Clean Serial Register

When the **Clean Serial Register** check box (located on the **Sensor Cleaning** flyout pane) is available, it is checked by default. If you would like to speed up sensor readout, you can uncheck the box. Keep in mind that if the serial register is not cleaned before readout, the initial row(s) read out may be "dirty".

Cleaning and Skipping

The **Final Section Height** and **Final Section Count** parameters are used by the Cleaning and Skipping Algorithm which decomposes a sensor segment to be cleared into sections of unequal size and then bins and reads out each section so that the largest section is read out first and the last sections read out are small enough to avoid blooming, thus leaving no charge on the sensor when the next exposure begins. **Final Section Height** determines the number of rows contained in the final section(s) of cleaning. **Final Section Count** determines how many rows are binned into the smallest of the sections used to read out and discard charge from the sensor during cleaning and while reading out ROIs smaller than full sensor.

The default values vary from camera to camera depending on sensor size and serial register capacity. The defaults will generally give good results. For more information, ***see "Cleaning and Skipping Algorithm" on page 180***.

Shutter

Introduction

Settings on the **Shutter** expander are associated with camera-controlled shutter operation. The settings that actually appear are determined by camera capabilities and the currently active readout mode.

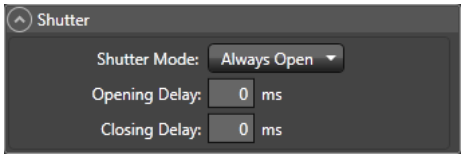


Figure 111. Shutter expander

Shutter Mode

There are four options for how long the camera-controlled shutter is held open and the time it takes for the shutter to close during an acquisition:

- **Normal:** The shutter opens (if previously closed) just before exposure begins and closes just after the Closing Delay ends
- **Always Closed:** The shutter closes (if previously open) just after the camera begins an acquisition and stays closed until commanded otherwise (even after an acquisition ends).
- **Always Open:** The shutter opens (if previously closed) just after the camera begins an acquisition and stays open until commanded otherwise (even after an acquisition ends).
- **Open Before Trigger:** The availability of this option depends on the **Trigger Response** selected on the **Trigger** expander. In this mode, shutter operation is only partially synchronized to the experiment. As soon as the camera is ready to collect data, the shutter opens. Upon arrival of the first External Sync pulse, the shutter remains open for the specified exposure period, closes, and the sensor is read out. As soon as readout is complete, the shutter reopens and waits for the next trigger.

Opening Delay

Delays the exposure until the mechanical shutter has fully opened. The opening delay time will vary depending on the camera and the shutter used.

Closing Delay

Delays the sensor readout until the mechanical shutter has fully closed. If an image is shifted while the shutter is open or not yet fully closed, the charge that collects while the image is moving makes the image look smeared. Smearing can occur in several situations: if the camera is set to read out without closing the shutter, if the shutter is still closing and read out has begun, or in frame transfer sequences where the shutter stays open while the image is shifted to the storage array. The closing delay time will vary depending on the camera and the shutter used.

Trigger

Introduction

Settings on the **Trigger** expander are associated with triggers used to initiate data acquisition and with the logic levels at the Logic Output connector on the camera. The settings that actually appear are determined by camera capabilities and the currently active readout mode. With the exception of PI-MAX3 and PI-MAX4 cameras, external triggering requires that one or more pulses are input at the camera's EXT SYNC connector.

The settings for a PI-MAX3 or a PI-MAX4 differ in that this camera can be triggered either internally or externally. If external trigger is selected, you need to specify the triggering characteristics (threshold, coupling, termination, as well as polarity). For a PI-MAX camera, external triggering requires that one or more pulses be input at the camera's TRIGGER IN connector.

Trigger Response

This selection determines how the camera responds to a trigger detected at the EXT SYNC or TRIGGER IN connector.

- **No Response:** The camera ignores any triggers.
- **Expose During Trigger Pulse:** Bulb Trigger mode. Available for ProEM and ProEM+ cameras. The camera exposure is set by the

input at the EXT SYNC connector. This allows an external timing generator to control the exposure time of the camera. In Full Frame, Frame transfer, or Kinetic modes, the transition from the inactive state to the active state of the External Sync at the EXT SYNC connector starts the exposure; and the transition from the active state to the inactive state ends the exposure. Kinetics mode-Single trigger is not a valid option for Bulb Trigger mode.

- **Readout Per Trigger:** Data are read from the sensor after the appropriate camera shutter timing. A single trigger acquires a sequence of frames. Once the initial trigger is received, the camera ignores any further triggers until the entire exposure/readout sequence is completed. For DIF acquisition (PI-MAX3 or PI-MAX4 with an interline CCD), the acquisition of each image for a dual image acquisition requires a trigger.

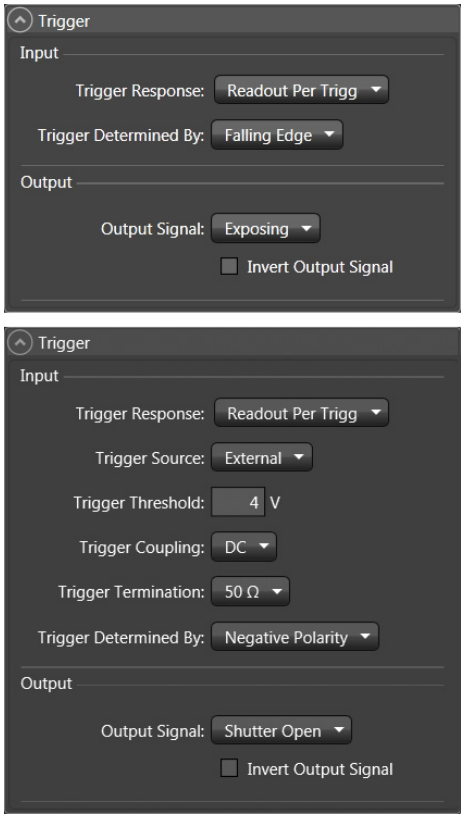


Figure 112. Trigger expander

- **Shift Per Trigger:** Available only in Kinetics mode or DIF acquisition. For Kinetics mode, a trigger initiates either the shift of a new frame into the masked area or the readout of the entire array depending on the Kinetics setup. For DIF acquisition (PI-MAX3 or PI-MAX4 with an interline CCD), a trigger initiates an acquisition and its subsequent shift behind the mask; a second trigger initiates the second acquisition and subsequent readout of the entire sensor.
- **Start On Single Trigger:** (NIRvana/PIoNIR, ProEM, ProEM+, PyLoN, and PyLoN-IR) After you start acquisition, the camera will wait until it receives the first trigger to start sending data to LightField. After that, it continues on performing the experiment without listening to (or waiting for) any further triggers.

When the Trigger Response is **Readout Per Trigger**, **Shift Per Trigger**, or **Start On Single Trigger** and the camera is a NIRvana/PIoNIR, PIXIS, ProEM, ProEM+, PyLon, PyLoN-IR, or Quad-RO, the trigger edge is also selectable. If the camera is a PI-MAX3 or PI-MAX4, trigger characteristics (including polarity) must be entered when External is the trigger source.

Trigger Source

For PI-MAX3 or PI-MAX-4 cameras, this selection specifies the origin of the trigger: internal or external. **Internal** uses the **Internal Trigger Frequency** set via the **SuperSYNCHRO Timing** expander. **External** uses triggers input at the TRIGGER IN connector. The trigger characteristics must be entered so LightField will recognize the triggers and take the appropriate action upon receipt of a trigger.

Trigger Threshold

Trigger Threshold defines the trigger threshold (required height) for the external trigger to be recognized. Possible values range from -10 to +10 V, in 0.005 V increments.

Trigger Coupling

Trigger Coupling defines the coupling between the external trigger and the camera. The choices are AC and DC.

Trigger Termination

An input impedance of **High** or **50Ω** is selectable.

Trigger Determined By

This setting tells LightField which edge or level of a pulse should be recognized as a trigger.

- **Positive Polarity:** Acknowledges the first trigger on a rising edge and additional triggers on a high level.
- **Negative Polarity:** Acknowledges the first trigger on a falling edge and additional triggers on a low level.
- **Rising Edge:** Acknowledges all triggers on a rising edge.

- **Falling Edge:** Acknowledges all triggers on a falling edge.

Output Signal (LOGIC OUT Signals)

The TTL-compatible logic level output (0 to +3.3 V) from the LOGIC OUT connector on the camera's rear panel can be used to monitor camera status and control external devices. The timing of the level changes depends on the output type selected in LightField. The output signals available depend on the camera being used. All of the possible signal types are listed below.

- **Acquiring:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the camera is acquiring or ready to receive the first trigger.
- **Always High:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is always high.
- **Always Low:** PIXIS. The signal is always low.
- **Busy:** PIXIS. The signal is high when the camera is busy.
- **Effectively Exposing:** ProEM, ProEM+. The signal is always high during the entire time the sensor is exposed.
- **Exposing:** NIRvana/PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the sensor is exposed for the entered Exposure Time.
- **Not Reading Out:** PIXIS, Quad-RO. The signal is low when the sensor is reading out.
- **Reading Out:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the sensor is reading out.
- **Ready For Start:** ProEM, ProEM+. The signal is high when the camera is ready to receive the first trigger.
- **Shifting Under Mask:** PI-MAX3:1024i, PI-MAX4:1024i, ProEM, ProEM+, PyLoN. The signal is high when image is shifting under the sensor's mask.
- **Shutter Open:** Logic high when the shutter is open. The output precisely brackets the shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter.
- **Waiting for Trigger:** PI-MAX3, PI-MAX4, NIRvana/PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the camera is waiting for a trigger.

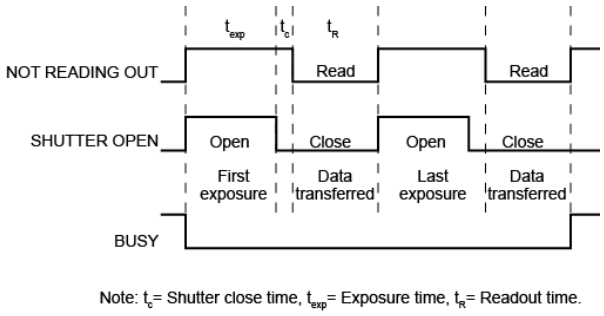


Figure 113. Timing Diagram of Not Reading Out, Shutter Open, and Busy (2 exposures)

Invert Output Signal

Inverts the active state of the output signal. For example, **Shutter Open** signal is normally a logic high when the shutter is open, but if **Invert Output Signal** is checked, the signal will instead be a logic low when the shutter is open.

Calibration

Introduction

Calibration for spectroscopy is the process of preparing LightField to assign appropriate calibration values over the scanned range of an acquired spectrum. Calibration functions present on the **Calibration** expander fall under the major categories of **Wavelength Calibration** and **Intensity Calibration**. LightField can be calibrated by performing either a **Standard Calibration** or a **Fixed** or a **Broad Calibration** via **IntelliCal**™ (a purchased add-on to the LightField software). Additionally, if IntelliCal and the Princeton Instruments Intensity Calibration lamp are available, **Intensity Calibration** can also be performed. Intensity calibration is especially useful for the **Step & Glue** function.

Calibration units can be electron volts, Angstroms, nanometers, microns, absolute wavenumbers, or relative wavenumbers (requires Laser Line entry). The choice of units is made from the drop-down list on the **Application Options** dialog's **Units** tab.

A **Standard Calibration** is a broad calibration that precisely calibrates the movement of a spectrograph grating using the spectrograph stepper motor.

An IntelliCal **Fixed Calibration**, which relies upon the positions of known peaks of a known source such as a mercury or neon lamp, is valid for only one position of the grating. If the grating is moved, either manually or by controlling the stepper motor, a new **Fixed Calibration** must be performed for the new spectrograph position.

An IntelliCal **Broad Calibration** calibrates for all wavelengths on the selected grating: the software will tell you wavelength accuracy for every pixel in an array, or equivalently, at every point on a spectrum.

Notes:

1. If **Remove Sensor Blemishes** has been turned on via the **Online Corrections** expander, blemish correction will be applied during calibration.
2. The **Clear All Calibrations** function will clear **ALL** calibrations (wavelength and intensity) for the current camera and spectrograph combination.
3. Even after the spectrograph setting has been fixed, moving the sample, refocusing, or almost any adjustment of the input optics can affect a **Fixed Calibration**. For the most accurate calibration possible, Princeton Instruments recommends recalibration after any optical adjustment.

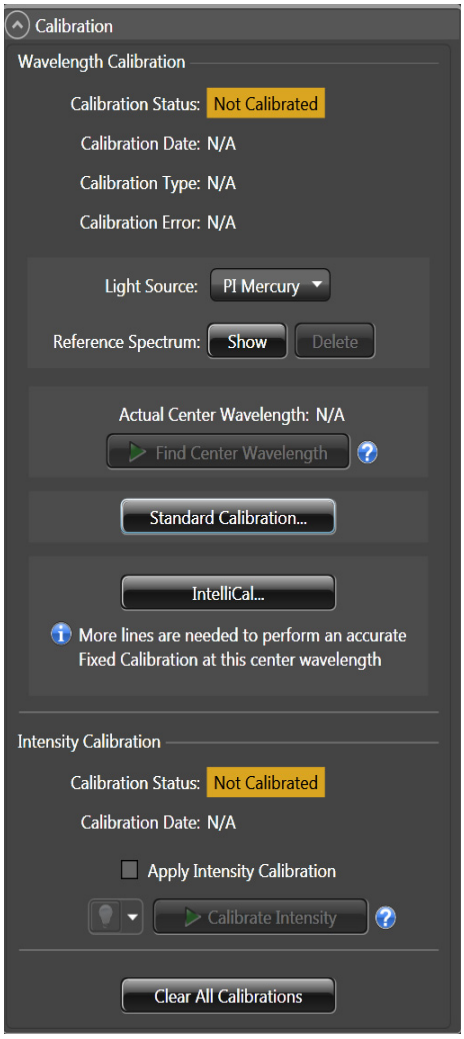


Figure 114. Calibration expander

Wavelength Calibration

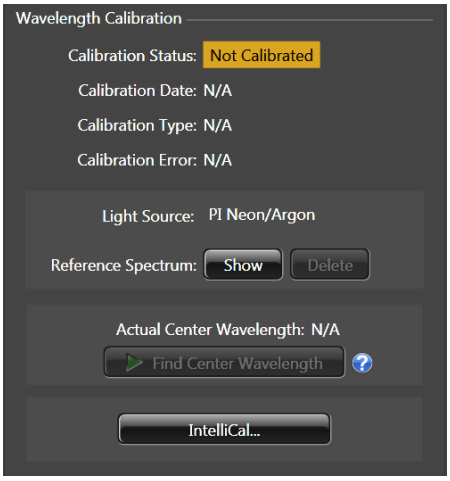


Figure 115. Wavelength Calibration panel

- **Light Source:** Four light sources are listed for selection: PI Neon/Argon, PI Mercury, Mercury, and Neon. Choose the one that matches the light source being used for calibrating the spectrometer. That choice will be used when generating and displaying a reference spectrum.

  Note: The USB-powered PI Neon/Argon light source is required for calibrating an LS 785 and performing an IntelliCal calibration.

- **Reference Spectrum:** Click on the **Add** button to generate a reference spectrum based on the selected light source. The reference spectrum will be displayed as Source 1 in View 1 of the Experiment Viewer. Clicking on the **Delete** button removes the spectrum from the view. Alternatively, you can click on the **Multiple Sources** button to open the **Multiple Sources panel** and delete the spectrum there.

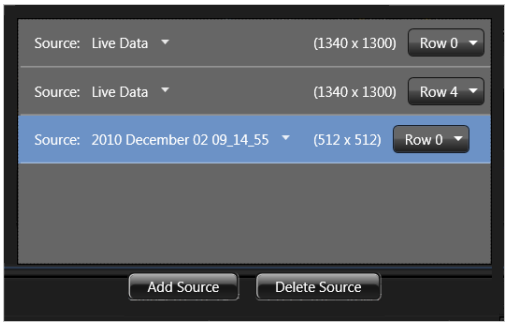


Figure 116. Multiple Sources panel

- **Find Center Wavelength:** Finds the actual Center Wavelength at the grating position. If **Custom Sensor Active Rows** (**Sensor|Custom Sensor** pane) is set to a

value LESS than the default, LightField will acquire multiple times to ensure that the last image is clean, and has usable data. The smaller the number of **Active Rows**, the more acquisitions will be performed.

- **Standard Calibration:** The Standard Calibration tool is provided with every purchase of LightField. Standard calibration routine operates in wavelength space, working with centroids of Hg, Ne, and Ar emission lines. Standard Calibration performs a fixed calibration based on the current grating. Clicking on the **Standard Calibration...** button opens the **Standard Calibration** dialog (Figure 117) where you are prompted to place a light source at the entrance slit, focus and align the camera to the spectrometer optics, and acquire a background correction file. If you have already performed these operations, select the two reference wavelengths to be used in addition to the center wavelength for calibration.

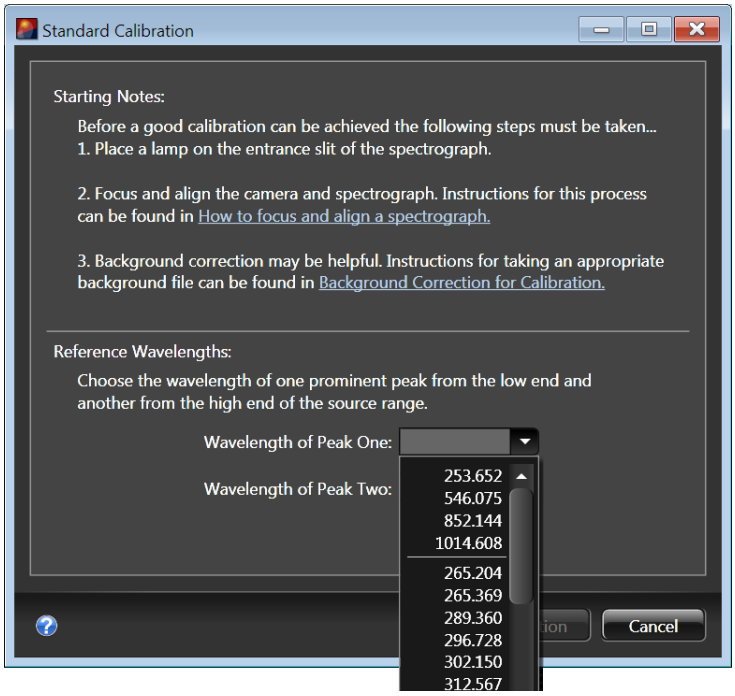


Figure 117. Standard Calibration dialog

The dropdown lists of available wavelengths are based on the selected light source.

> **Note:** The wavelengths recommended by Princeton Instruments are the ones above the line in the dropdown lists.

After you finish selecting the wavelengths from the dropdown lists, click on the **Start Calibration** button to open the **Standard Calibration** window where you will begin the actual calibration. For detailed information on setting up and performing a Standard Calibration, ***see "Rotational Alignment and Focusing for an Acton SP Series Spectrograph" on page 80, "Background Correction for Calibration" on page 85,*** and ***"Performing a Standard Calibration" on page 85***.

- **IntelliCal:** IntelliCal™ is an optional calibration tool that must be purchased in addition to LightField. IntelliCal wavelength calibration operates in intensity space to refine spectrograph parameters across the entire spectrum. IntelliCal uses a patent-pending algorithm that refines spectrograph parameters to match observed and NIST tabulated line spectra in intensity space. It provides point-by-point calibration across entire spectrum: up to 10X improvement in accuracy over the Standard Calibration tool. Based on the Center Wavelength and selected light source, IntelliCal reports whether the current setup is suitable for an IntelliCal fixed or broad calibration. Clicking on the **IntelliCal...** button opens the **IntelliCal** dialog where you are prompted to focus and align the camera to the spectrograph optics and acquire a suitable background correction file if you have not already done so. If you have already performed these operations, select the **Calibration Type** and then click on the **Start**

Calibration button. The IntelliCal window opens and immediately begins the calibration process. At the end of the calibration, if the results of the calibration fall within the Target accuracy and the error is low enough, you will have the choices of Calibrate Again, Use, or Discard. Otherwise, you may need to run the calibration again or discard and change the target accuracy or switch to a different grating and/or center wavelength. For detailed information on setting up and performing a IntelliCal Calibration, see the following topics: ***"Rotational Alignment and Focusing for an Acton SP Series Spectrograph" on page 80***, ***"Background Correction for Calibration" on page 85***, and ***"IntelliCal™ Wavelength Calibration" on page 87***.

- **Current Calibration In Use:** Reports the date, type, and calibration error of the calibration being used. If the spectrometer is not calibrated or the calibration is not appropriate for the current grating, these fields will report N/A.

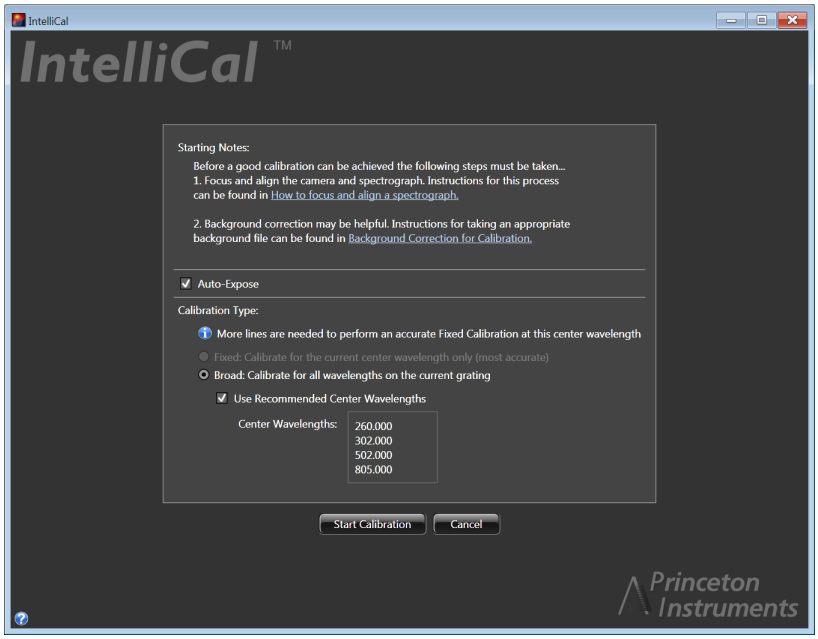


Figure 118. IntelliCal dialog

Intensity Calibration

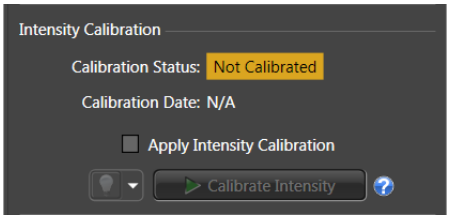


Figure 119. Intensity Calibration panel

Intensity Calibration is available whenever IntelliCal is available. This process uses a Princeton Instruments, USB-powered Intensity Calibration light source to generate an intensity calibration file. This file can then be applied to data subsequently acquired using the same grating and center wavelength or over the same wavelength range if the **Step & Glue** function will be used to acquire data. For information about the **Step & Glue** function, see ***"Step & Glue" on page 95***. For detailed information on performing an intensity calibration, ***see "Intensity Calibration" on page 92***.

Clear All Calibrations

Clicking on this button clears **ALL** of the calibrations (including intensity calibration) for the current camera and spectrometer combination.

Calibration Procedures

For Standard Calibration, see ***"Standard Calibration" on page 85***.

For an IntelliCal **Fixed Calibration**, see ***"Performing an IntelliCal Fixed Calibration" on page 88***.

For an IntelliCal **Broad Calibration**, see ***"Performing an IntelliCal Broad Calibration" on page 90***.

For an IntelliCal **Intensity Calibration**, ***see "Intensity Calibration" on page 92***.

Spectrometer

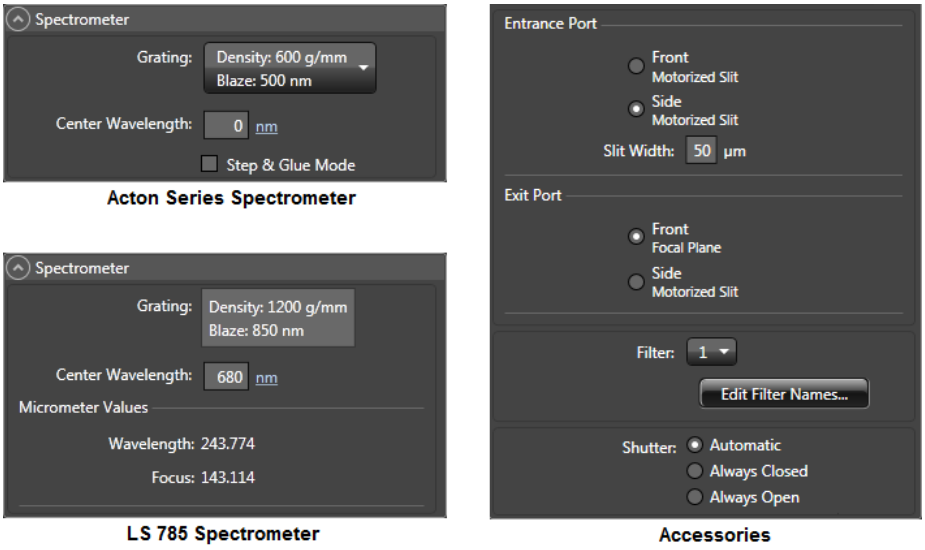


Figure 120. Spectrometer expander

Introduction

The hardware settings and functions associated with the **Spectrometer** expander are used in setting up and controlling Acton SP series, IsoPlane SCT320, and LS 785 spectrographs and related accessories. Wavelength and intensity calibration functions are accessible on the **Calibration** expander.

Spectrographs

Acton SP series spectrographs include the software-controlled SP2150, SP2300, SP2500,and SP2750. The IsoPlane SCT320 is a Schmidt-Czerny-Turner software-controlled spectrometer. The LS 785 is a high throughput, NIR lens spectrograph and has no motorized parts or communication interface.

Spectroscopy Accessories

Accessories include shutters, filter wheels, and light sources. Any combination of software-controllable accessories that are powered on and connected directly to the computer through plug-and-play interfaces will be detected and uniquely identified throughout the lifetime of the LightField installation. LightField also detects when these identified software-controlled accessories are disconnected or powered off. Accessories connected through the serial port behave similarly as above, but usability is severely limited due to the lack of plug-and-play support. These accessories are detected only during LightField startup or by the explicit command of the user, and if they are disconnected or powered off, this is detected only when LightField tries to use them.

Software-controllable accessories that are not connected directly to the computer, but are connected to and controlled through a software-controllable spectrometer, are considered components of the attached spectrograph, and the manner and timing of their detection is joined to that of the spectrograph.

LightField identifies a spectroscopy accessory through the:

- type of accessory (**Accessory Type**),
- brand name of the accessory (**Accessory Model**),
- manufacturing serial number (**Serial Number**), and
- communication interface connecting the spectrometer to the computer (**Computer Interface**).

An accessory that is a component of a spectrometer is identified through the

- type of accessory (**Accessory Type**),
- brand name of the attached spectrometer (**Spectrometer Model**),
- manufacturing serial number of the spectrometer (**Spectrometer Serial Number**), and
- communication interface connecting the spectrometer to the computer (**Spectrometer Computer Interface**).

Grating/Center Wavelength/ Micrometer Values

Grating Selection: If the spectrometer has a turret with multiple gratings, this button allows you to select the grating most suitable for your experiment. After you make the selection, you should hear the grating drive system moving the grating into place.

Center Wavelength: After you enter a center wavelength, you will hear the grating drive system position the grating for that wavelength. Due to minute variations in the drive stepping, the position may not be exactly at the entered wavelength. If the **Find Center Wavelength** button is active, click on it to find out what the actual Center Wavelength is at the current position.

Micrometer Values (LS 785): The values for Wavelength and Focus are the micrometer settings to be used for setting the respective micrometers at the rear of the LS 785. These values are associated with the entered Center Wavelength and should be used to reset the micrometers for that Center Wavelength.

LS 785 Micrometer Values

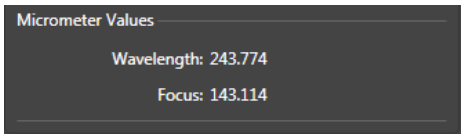


Figure 121. LS 785 Micrometer Values

Step & Glue Mode

The **Step & Glue** function is available for computer-controlled Acton SP Series spectrographs. This function can be activated on the **Spectrometer** expander or from the **Experiment** menu. This function allows you to enter a wavelength range that defines the range across a series of spectra will be acquired and glued together to create a single spectrum. When you start the acquisition, the grating moves to the beginning wavelength, a spectrum is acquired, the grating moves, another spectrum is acquired and "glued" to the previous spectrum, and so on until the wavelength range is covered. When the spectra are glued together intensity variation due to grating position and other factors during acquisition may distort the comparative intensities of peaks within the range. To acquire a step and glue spectrum that more accurately reflects comparative peak intensities within the spectrum, perform an intensity calibration using the same wavelength range.

For information about using the **Step & Glue** function, see ***"Setting Up and Performing a Step & Glue Acquisition" on page 95***.

Note: Number of Frames and **Time Stamping** (on the **Common Acquisition** expander) are unavailable when **Step & Glue** is active.

Entrance Port

This panel of settings will appear if the spectrometer has motorized slits. The entrance port can be selected here or it can be chosen by clicking on the entrance mirror in the spectrometer icon (in the Experiment Devices area) to reposition it for the appropriate entrance port. The slit width of the selected motorized slit is entered here. After the selection and entry have been made, the slit at the selected port will be widened or narrowed to the width entered.

Exit Port

This panel will appear if the spectrometer has two exit ports. The exit port can be selected here or it can be chosen by clicking on the exit mirror in the spectrometer icon (in the Experiment Devices area) to reposition it for the appropriate exit port.

Filter Wheel

Whenever LightField detects an Acton SP series 6-position filter wheel, it will add an **ARC-Filter icon** to the **Available Devices** area. When you drag the icon to the **Experiment Devices** area, the **Filter Wheel** panel will be added to the **Spectrometer** expander. The **Filter** drop-down list allows you to select the filter to be positioned in front of the slit. You can also edit the filter names so you can more easily choose the correct filter for your experiment.

The 6-position filter assembly is designed to mount directly to the slit housings of an Acton SP series spectrograph/monochromator or IsoPlane SCT320 spectrograph or to be mounted between the light source or detector and the slit housing. If you are using a light source that is designed to mount directly on the entrance slit housing and to focus the light on the entrance slit, it is recommended that the filter assembly be mounted on the exit slit housing. If it is necessary to install or change filters, do so before mounting the filter wheel to the Acton SP series spectrograph/monochromator or IsoPlane SCT320 spectrograph. Refer to the manual supplied with the filter wheel for additional information.

Figure 122. Filter Wheel icon

Filter: Click on the **Filter** button to open the

on the filter to be used and this filter will be rotated into place. To make the choice easier to make, you may want to replace the default designations with more descriptive names.

Edit Filter Names: Opens the **Edit Filter Names...** dialog where you can begin keying a descriptive name for each filter position. For example, replace 1 with Open or 2 with 320 nm cut-off. **Cancel** quits the operation without making changes; **OK** implements any changes.

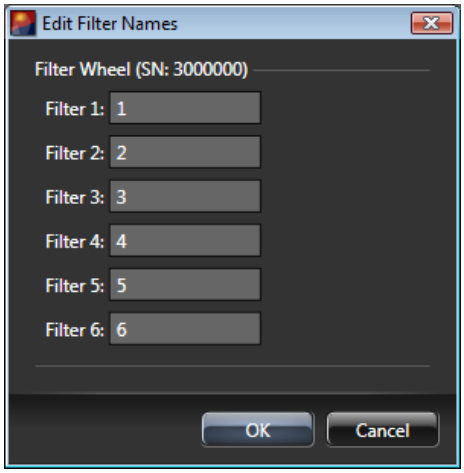


Figure 123. Edit Filter Names dialog

Shutter

This panel appears if the spectrometer has a spectrometer-controlled shutter.

Automatic: The spectrometer shutter open or closed state will be controlled by LightField.

Always Closed: The spectrometer shutter is always closed unless LightField is acquiring a flatfield correction file in which case the shutter will be opened for the acquisition and then closed after the flatfield is acquired.

Always Open: The spectrometer shutter is always open unless LightField is acquiring a background file in which case the shutter will be closed for the acquisition and then opened after the background is acquired.

Grating Selection

Introduction

For spectrographs with interchangeable gratings on a software-controllable turret, the grating can be selected from a pre-defined list and the turret will be adjusted accordingly. If the selected grating is on another software-controllable turret, manually install the appropriate turret before selecting a grating from that turret.

If changing a grating results in an invalid center wavelength for the new grating, the center wavelength is changed to the valid value closest to the original center wavelength and a notification is displayed.

While the grating is being moved into place, some other operations may be started and run, but tasks such as starting an experiment or changing the grating cannot be done at this time.

Installing a Different Turret

In some cases, the spectrometer will be programmed for additional optional interchangeable turrets. If so, this information will be read from the spectrometer, and each turret and its gratings will be listed in the **Grating** drop-down list. If you will be changing turrets, install the new turret in the spectrometer **BEFORE** selecting one of its gratings from the list.

Selecting a Grating

1. Drag the spectrometer icon into the **Experiment Devices** area.
2. On the **Spectrometer** expander, click on the **Grating** button. The blaze and density of the current grating is shown on the button.
3. Select the desired grating from the drop-down list.
4. If the spectrometer is near, you should hear the turret as it moves the selected grating into place.

Slit Width Selection

If a spectrometer has one or more motorized slits, this information will be added to the **Spectrometer** expander and you will be able to change the slit width of the slits in the current light path. If there are two ports, make sure the correct port is selected and then enter the new slit width. After you finish entering the new width, LightField will move the slit blades accordingly. While the slit width change is in process, you cannot start an experiment or change the slit width to a different value.

If a spectrometer has micrometer-adjustable bilateral slits, the **Slit Width** field does not appear on the **Spectrometer** expander.

Turret Interchange

Introduction

Some Acton SP series and IsoPlane SCT320 spectrographs have optional interchangeable turrets that were purchased with the spectrometer. If your spectrometer has optional turrets, the turret number and grating information for each has been programmed into the spectrograph When a spectrograph with optional turrets is dragged into the **Experiment Devices** area, the grating information for each

turret will be loaded into the **Grating** drop-down list on the **Spectrometer** expander.

Installing a Different Turret

If you will be changing turrets, install the new turret in the spectrograph **BEFORE** selecting one of its gratings from the **Gratings** drop-down list. Follow the supplemental turret instructions provided with these turrets when making the changeover from one turret to another.

Laser Line Information

Introduction

If you plan to work with units of relative wavenumbers, you need to input the laser line wavelength on the **Application Options|Units** tab. Prior to Version 4.1, laser line was an application setting only and was applied to all data (SPE) files. No record of the actual laser line used was stored in the SPE file. If an SPE file containing data acquired using a laser line were opened later on, that SPE would show relative wavenumbers using the current APPLICATION laser line value, not the laser line actually used. For example, the actual laser line used might have been 456 but the laser line currently entered on the **Units** tab is 300. 300 would be used in the graph label for that data even though 456 was the actual laser line used.

Entering a Laser Line

1. Open the **Application Options** dialog.

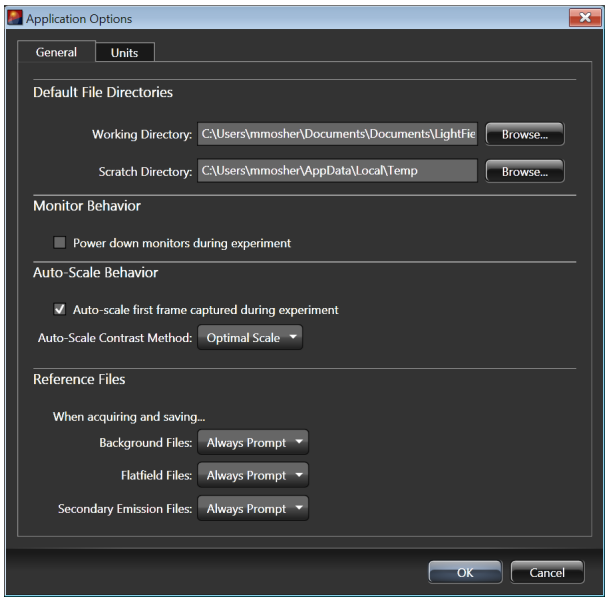


Figure 124. Application Options dialog: General tab

2. Select the **Units** tab.

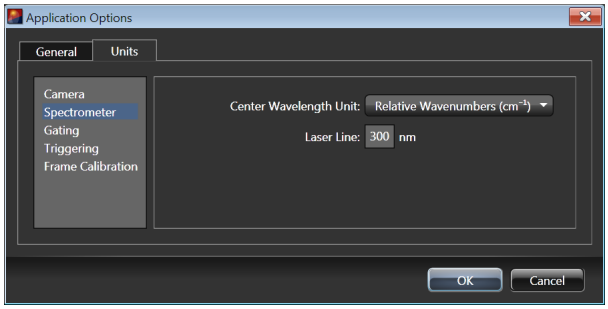


Figure 125. Application Options dialog: Units tab

3. Click on **Spectrometer**.
4. Change the **Center Wavelength Unit** to **Relative Wavenumbers(cm^{-1})**.
5. In the **Laser Line** field, enter its wavelength.

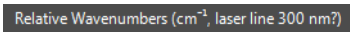
> **Note:** The laser line wavelength must be a positive value greater than 0.

6. Click on **OK** to complete the entry and close the dialog.

Editing the Laser Line Value on the File Information|Calibration tab

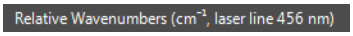
If you acquired data with a pre-4.1 version of LightField and open that SPE file, the graph label will display the current APPLICATION laser line value followed by a ?. The Laser Line field will be empty on the Calibration tab but you can enter the laser line used when acquiring the data. After you have made an entry, that value will be displayed in the graph label.

Application Value: Graph label showing the current Application laser line value followed by **?** (value shown is the one entered on the **Application Options|Units** tab).



File Information|Calibration tab**:** Enter the correct value in the **Laser Line** field (for example, 456).

Edited Value: The value entered now appears in the graph label.



> **Note:** If you have made changes to the file information for a SPE file, the file icon on the left will change from a light blue to a light tan and show a circle and dots. When you save the changed file, the icon color will revert to the light blue. Unless you save the changed file, you will have to re-enter the change the next time you open the file.

SuperSYNCHRO Timing

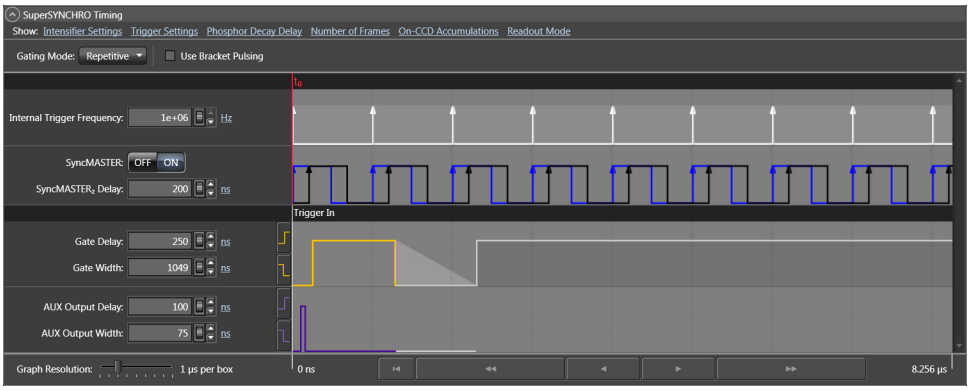


Figure 126. SuperSYNCHRO Timing expander

Introduction

The **SuperSYNCHRO Timing** expander is located above the Status bar at the bottom of the LightField window. This expander is used to set up gating for a PI-MAX3or PI-MAX4 camera and is only active when a PI-MAX camera is connected/ selected.

Gating acts like a shutter in that gating the intensifier on allows the sensor to "see" light and gating the intensifier off prevents the sensor from seeing light. Whether the intensifier's photocathode or microchannel plate (MCP) is being gated depends on the board set in your camera. Standard PI-MAX3 and PI-MAX4 cameras gate the photocathode. Only those with the MCP Gating board will gate the MCP also. For more information about MCP gating, ***see "MCP Gating" on page 185*** and refer to the PI-MAX manual supplied with your camera.

Gating is initiated by a trigger from either an external source (input at the **TRIGGER IN** connector on the rear panel) or an internal source (generated by the PI-MAX3or PI-MAX4). The Gate Width setting is in effect the exposure time. The Gate Delay setting is the delay between the recognition of a trigger and the start Gate Width time.

Gating can be:

- **Repetitive:** Each gate is the same width and has the same delay.
- **Sequential:** The gate width and/or delay changes based on the starting and ending values for the gating parameters.
- **DIF:** Only available for a PI-MAX3 or PI-MAX4 camera with an interline CCD when DIF readout mode is active. The number of frames must be greater than one and a multiple of two. **Number of Frames** is entered on the **Common Acquisition Settings** expander. For detailed information about setting up for DIF readout, see ***"DIF Gating Mode"*** on page 187.
- **RF Modulation:** Only available for PI-MAX4-RF camera. Uses an RF source to vary the intensifier gain of an intensified CCD at a radio frequency (RF) rate. For detailed information about setting up this type of gating, see ***"RF Modulation"*** on page 192.

Elements on the SuperSYNCHRO Timing expander

Hyperlinks

The hyperlinks (Intensifier Settings, Trigger Settings, Phosphor Decay Delay, Number of Frames, On-CCD Accumulations, and Readout Mode) at the top of the SuperSYNCHRO Timing expander, take you directly to parameters that affect experiment timing.

Gating Mode button

The Gating Mode button allows you to select either Repetitive or Sequential gating. This button is not available for selecting the DIF gating mode: that mode is selected on the **Readout** expander by choosing DIF as the readout mode.

Note: DIF is only available for the PI-MAX3:1024i or PI-MAX4:1024i camera.

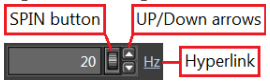
Use Bracket Pulsing check box

The **Use Bracket Pulsing** check box turns bracket pulsing on or off if this feature has been enabled for your camera. Bracket pulsing is available for PI-MAX3 and PI-MAX4 cameras with Gen II intensifiers. This technique enhances the intensifier's on/off ratio in UV measurements by automatically adjusting the on/off switching of the MCP to bracket the photocathode gate pulse. For more information about bracket pulsing, refer to the PI-MAX manual supplied with your system.

Value Entry elements

After you open the SuperSYNCHRO Timing expander, you will be able to enter Internal Trigger Frequency, Gate Width and Delay, and

AUX Output Width and Delay values. You will also be able to turn SyncMASTER ON and enter the delay for the SyncMASTER2 output. There are several ways for you to enter these values. Depending on the numbers and units of measure used, you may find that one or more of these ways are more appropriate for parameter value entry.



- Key the value into the field.
- Grab and drag on the spin button to the right of the field. If you click on the spin buttons, although you may see the increment values change, the actual visible value of the Starting Gate Width setting may NOT appear to change because the incremental change is so small.
- Click on the up or down arrow to the right of the spin button.
- Position the mouse cursor on the graphical representation of the parameter and when the two-headed white arrow appears, drag the right edge of the delay or the width to modify the setting. Or you can adjust delay and width at the same time by positioning the cursor on the left edge of the pulse until 2 two-headed white arrows appear and then dragging. Using the click and drag method of changing the value changes in different (larger) chunks, so you see an immediate effect on the setting value.
- Click on the units hyperlink to change the units via the **Units** tab of the **Application Options** dialog.

Edge Buttons

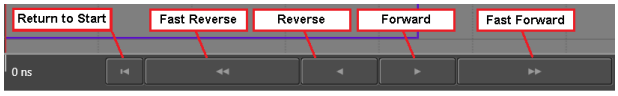
Edge buttons may appear to the left of a timing diagram. If the scale is such that entire width of the first gate cannot be seen in the timing graph you can use the falling edge button to bring that edge into view. If you can see the falling edge of the first gate but cannot see the rising edge, click on the rising edge button.

Note: When DIF mode is active, both gates are shown on a single graph. The buttons to the right of the **Initial Gate** settings are tied to the rising and falling edges of the first gate. The buttons to the right of the **Second Gate** settings are tied to the rising and falling edge of the second gate.

Graph Resolution Slider

The Graph Resolution slider sets the resolution for the timing diagrams shown on the timing graph. These diagrams represent the timing values and their relationships. Because there can be large differences in values you may need to increase or decrease the resolution to see pulse and/or internal frequency representations.

Advance Buttons



The Advance buttons, located below the timing graph, allow you to "scroll" through an entire timing diagram. These can be useful when the scale is so large that the entire timing diagram cannot be displayed in the timing graph.

Gating Setup Parameters

The gating parameters displayed on the parameters panel depend on the selected gating mode, the trigger source (internal or external), and the on/off state of the SyncMASTER.

Internal Trigger Frequency

This field controls the frequency at which internally-generated pulses will be output via the SyncMASTER1 and SyncMASTER2 connectors on the AUX I/O cable. The settable frequency is in the range of 0.002 kHz to 1000 kHz (in increments of 0.001 kHz).

SyncMASTER

The SyncMASTER feature allows you to output 500 ns wide pulses generated internally by the PI-MAX3 and PI-MAX4. The pulses will appear at the SyncMASTER1 and SyncMASTER2 connectors on the AUX I/O cable and are at the frequency set by the value in the Internal Trigger Frequency field. These pulses can be used to synchronize a PI-MAX and other devices (such as a laser). These outputs are activated by clicking on the SyncMASTER ON button and the output of SyncMASTER2 can be offset from that of SyncMASTER1 by entering a delay. Once these signals are turned on, they are ON whether the camera is capturing an image or not and will stay ON until either SyncMASTER or the camera is turned OFF. This is different from the Aux OUTPUT pulse.

User RF Output (RF Modulation Gating)

If you want to drive an RF amplifier via the **User RF Out** connector on the back of the PI-MAX4-RF, click on the User RF Output **ON** button. Then select the appropriate output frequency and output amplitude level (Vp-p). Note that the **User RF Output** must be connected to a 50 Ohm load (standard for RF).

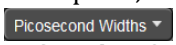
Gate Delay (Repetitive Gating)

Gate Delay is the time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse. This gate delay will be used for each frame to be acquired.

Gate Width (Repetitive Gating)

Gate Delay is the time during which light will be detected by an intensifier, intensified, and applied to the sensor. Basically, the intensifier controls what the chip 'sees'. For signal to be detected, it must fall in a valid gate width. This gate width will be used for each frame to be acquired.

Picosecond Widths

If the PI-MAX3 or PI-MAX4 contains the picosecond option, the **Picosecond Widths** button 

will appear below the **Gate Width** or **Starting Gate Width** field. You can either use non-picosecond widths (enter the width as if the button were not present) or click on the button to access a list of valid gate widths for sub-nanosecond timing. When you choose a width from the list, that value will be entered in the Gate Width (or Starting Gate Width) field. If sequential gating is active, that value will also be entered into the Ending Gate Width field.

Starting Gate Delay (Sequential Gating)

Starting Gate Delay is the time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse for the first frame to be acquired. The goal is to set both gate width and gate delay in such a way that the intensifier is gated ON during the entire event of interest.

Starting Gate Width (Sequential Gating)

Starting Gate Width is the time during which light will be detected by an intensifier, intensified, and applied to the sensor for the first frame to be acquired. Basically, the intensifier controls what the sensor 'sees'. For signal to be detected, it must fall in a valid gate width.

Initial Gate Delay (DIF Gating)

Initial Gate Delay is the time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse for the first of the two frames to be acquired. The goal is to set both gate width and gate delay in such a way that the intensifier is gated ON during the entire event of interest.

Note: The minimum gate delay in the DIF mode for the 1st pulse is 85 µs.

Initial Gate Width (DIF Gating)

Initial Gate Width is the time during which light will be detected by an intensifier, intensified, and applied to the sensor for the first frame to be acquired. Basically, the intensifier controls what the sensor 'sees' during the exposure time. For signal to be detected, it must both fall in a valid gate width.

Second Gate Delay (DIF Gating)

Second Gate Delay is the time between the shift of the first frame under the mask to the beginning of the photocathode gate pulse for the second of the two frames to be acquired. The goal is to set both gate width and gate delay in such a way that the intensifier is gated ON during the entire event of interest. The shortest delay possible is 500 ns. Keep in mind that phosphor decay delay adds to the delay between the gates and you will need minimize that value in order to get the 500 ns delay.

Note: The drawback to entering a phosphor decay delay that is smaller than the time it actually takes for the phosphor fluorescence to decay is that there may will be signal persistence from the first image into the second.

Second Gate Width (DIF Gating)

Second Gate Width is the time during which light will be detected by an intensifier, intensified, and applied to the sensor for the second frame to be acquired. Basically, the intensifier controls what the sensor 'sees' during the exposure time. For signal to be detected, it must both fall in a valid gate width.

Modulation Duration (RF Modulation Gating)

Sets the duration of the RF modulated signal. The range of possible values is 1 ms to 21 s, in increments of 1 ms.

Modulation Frequency (RF Modulation Gating)

Sets to frequency of the modulated signal. The range of possible values is 1 to 200 MHz, in increments of 1 MHz.

Modulation Phase (RF Modulation Gating - Repetitive)

Sets the phase of the modulated signal. The range of possible values is 0º to 359º, in increments of 1º.

Modulation Starting Phase (RF Modulation Gating - Sequential)

Sets the phase of the first modulated signal in the sequence. The range of possible values is 0º to 3600º, in increments of 1º.

Modulation Ending Phase (RF Modulation Gating - Sequential)

Sets the phase of the last modulated signal in the sequence. The range of possible values is 0º to 3600º, in increments of 1º.

AUX Output

If you are using the AUX Output signal from the SuperSYNCHRO to trigger a piece of equipment, enter the **AUX Output Delay** and **AUX Output Width** values required to trigger that equipment at the desired time. The delay is based on T0 and in effect is a delay from SyncMASTER1which is

also based on at T0. The pulse will be output via the AUX OUT connector on the rear of the PI-MAX camera. This pulse train is ON only while the camera is acquiring data.

Ending Gate Delay (Sequential Gating)

Ending Gate Delay is the time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse for the last frame to be acquired. The goal is to set both gate width and gate delay in such a way that the intensifier is gated ON during the entire event of interest.

Ending Gate Width (Sequential Gate)

Ending Gate Width is the time during which light will be detected by an intensifier, intensified, and applied to the sensor for the last frame to be acquired. Basically, the intensifier controls what the sensor 'sees' during the exposure time. For signal to be detected, it must both fall in a valid gate width.

Note: If a picosecond gate width has been selected for the **Starting Gate Width**, the **Ending Gate Width** value must be the same.

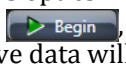
Kinetics and the SuperSYNCHRO Timing Diagram

The purpose of the SuperSYNCHRO timing diagram is to show you what you might see on an oscilloscope as the experiment is running. When **Kinetics** is the selected **Readout Mode** (**Readout** expander), the readout may or may not appear for a gate. If it does appear on the timing diagram, it may be annotated with "Readout is intermittent due to kinetics window height and number of frames" or "No readout before next frame". "Readout is intermittent..." will always be displayed for the readout if you are using Repetitive Gating. If you are using Sequential Gating, the messages that may appear for the **Starting Gate** and the **Ending Gate** readouts will vary based on the kinetics window height and number of frames and on the **Run Duration** setting (**Infinite** or **Single Sequence of Frames**).

Chapter 6: Alignment, Calibration, and Step & Glue

Rotational Alignment and Focusing

Spectrometer Alignment Helper

Align Spectrometer..., selected from the **Experiment** menu, opens the **Spectrometer Alignment** dialog. This dialog describes the changes that LightField will make to the current setup to assist you in performing rotational alignment and focusing of the sensor to the spectrograph's optics. When you click on the **Begin** button 

, the changes are made and continuous live data will be displayed as you rotate the camera to achieve the best vertical alignment.

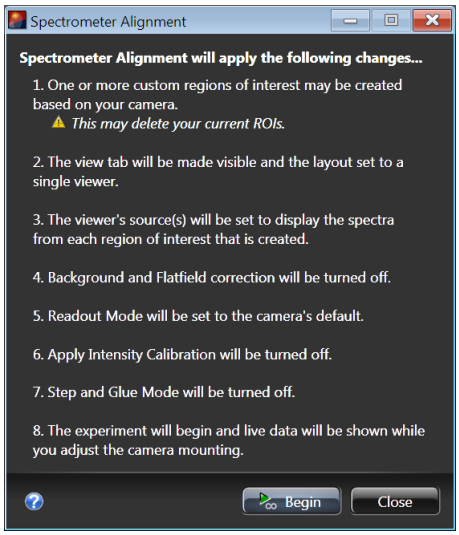


Figure 127. Spectrometer Alignment dialog

TIP: If you have created custom ROIs, set up online corrections, and changed other default experiment parameters, close the dialog and save the experiment. LightField deletes custom ROIs and changes other experiment settings when setting up the alignment function. By saving the experiment, you can restore those ROIs as well as all of your other experiment settings such as exposure time and any online corrections after you have finished the alignment.

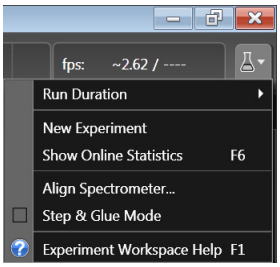


Figure 128. Experiment menu

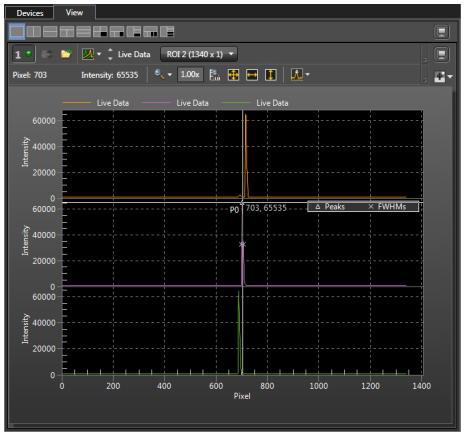


Figure 129. Spectra in Alignment Helper ROIs Before Alignment

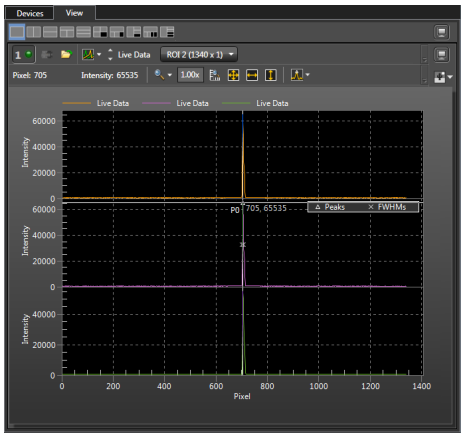


Figure 130. Spectra in Alignment Helper ROIs After Alignment

Rotational Alignment and Focusing for an Acton SP Series Spectrograph

The camera sensor MUST be rotationally aligned and focused to the spectrograph optics before a good calibration can be achieved. This means positioning the camera at the exit port for the best vertical alignment (spectral line is perfectly vertical) on the sensor and focus (narrowest possible symmetrical peak). First, the camera is rotated until the spectral line is vertical. Then by use of the spectrograph thumbwheel, the camera (mounted to the slide tube) is slowly slid in or out from the spectrograph while you are watching the Live Data Viewer, until the output of the spectrograph is focused on the sensor.

Notes:

1. The procedure below is for an Acton SP series spectrograph. This procedure is not appropriate for an Acton LS 785 spectrograph. For LS 785 instructions, see ***"Calibrating an LS 785" on page 94***.
2. This procedure assumes that LightField has been installed and that the spectrograph is not calibrated.

Setup Procedure:

1. Mount the camera to the appropriate spectrograph adapter and slide the tube's adapter into the spectrograph. Refer to the spectrograph and the camera system documentation. Do not tighten the set screws or split clamp.
2. Make all required cable connections between the spectrograph and the camera and host computer.
   - If the camera has an external power supply, verify that the power supply is turned off before making the power cable connections.
   - If the spectrograph has an external power source, verify that the source is turned off before making the power cable connections.
3. Turn on the camera and the spectrograph
4. Mount a light source to the spectrograph entrance port and connect it to power. In most cases, a standard mercury lamp can be used.
5. Start LightField.
6. Drag the camera and the spectrograph icons into the Experiment Devices area.
7. If LightField is using a previously created experiment, click on **New Experiment** to load the defaults for these devices.
8. On the **Common Acquisition Settings** expander, verify that the **Exposure Time** is about 100 ms.
9. On the **Spectrometer** expander:
   - Choose the appropriate grating.
   - Set the center wavelength to **435.8 nm** or **546.07 nm** if using a mercury lamp, or 0.0 nm for a broad band source, or another wavelength corresponding to a spectrum produced by another "line" source.
   - Set the entrance slit width to **10 µm**, if possible.
10. Save the experiment. This will save the device information and setup up to this point.
11. If the camera has a shutter or is controlling a shutter, open the **Shutter** expander and set the **Shutter Mode** to **Always Open**. Because the shutter will always be open during the alignment and focusing, you need to make sure that saturation does not occur (as evidenced by signal clipping at 65,536). To prevent saturation, you can reduce the exposure time and/or the amount of analog gain.
    - **Exposure Time** is set on the **Common Acquisition Settings** expander. Try **10 ms**.
    - **Analog Gain** is set on the **Analog to Digital Conversion** expander. Try **Low**.
12. Make sure the light source is turned **OFF**.

Rotational Alignment Procedure:

1. Verify that the set screws or split clamp securing the slide tube are loose.
2. Turn **ON** the light source.
3. Click on the **Experiment menu** (in the upper right corner of the Experiment workspace) and select **Align Spectrometer.**

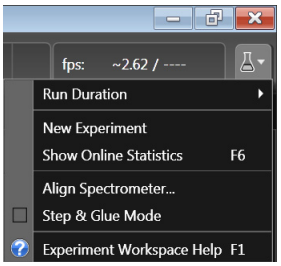


Figure 131. Experiment menu

4. When the **Spectrometer Alignment** dialog pops up, read the list of changes that will be made when you click on the **Begin** button.

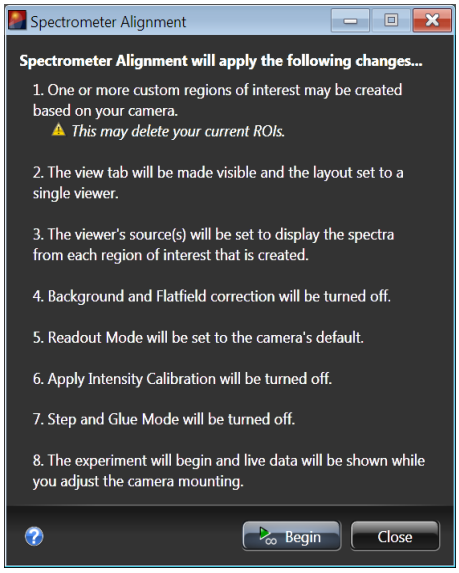


Figure 132. Spectrometer Alignment dialog

5. After you click on **Begin**, ROIs are created and continuous acquisition begins. Typically three are created: a single row ROI at the center of the sensor, one below, and one above the center ROI.

   Note: You can close the dialog at any time.

6. For rotational alignment, you can either continue with the stacked graphs (default) or you can change to overlay mode. If you right-mouse click to open the Viewer's context menu and uncheck **Stacked Graph**, the three spectra will be overlaid rather than stacked.
7. Choose a sharp peak and while looking at the three spectra, rotate the camera until the selected peak coincides in all three spectra. If you want to use the Data Cursor as a vertical reference for the alignment, right-mouse click and select it from the context menu.
8. Stop data acquisition.
9. If you have not focused the camera to the spectrograph optics, continue to the **Focus Procedure**.
10. If you have previously focused the camera and do not need to do so again:
    a. Secure the camera position:
       - **Set Screws:** Tighten the #10-32 set screw on the top of the front plate first, and then tighten the one on the side to secure the detector.
       - **Split Clamp:** Tighten the clamp.
    b. If you saved the Experiment as suggested in Step 11 of the **Setup Procedure**, you can just reload the Experiment. Otherwise, you may want to reset the **Exposure Time** and **Analog Gain** settings; and if there is a shutter, return its setting to its **Normal** mode.

Focus Procedure:

1. ***If rotational alignment has been performed, do not move the slide tube.*** Verify that the set screws or split clamp securing the slide tube are loose.
2. Click on the **View** tab if the Experiment Viewer is not already visible. Position the cursor in the view area, right-mouse click, and select the **Display Type|Graph**. You may also want to select **Always Autoscale**.
3. Turn on the light source if is not already on.
4. Click on the **Run (Infinite)** button 

to begin continuous Live Data display. If **Run (Single Sequence of Frames)** 

is active, open the **Experiment** menu and change the **Run Duration** to **Infinite**.

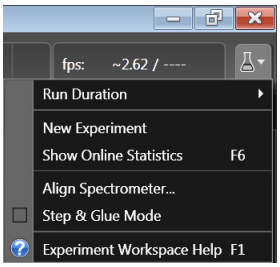


Figure 133. Experiment menu

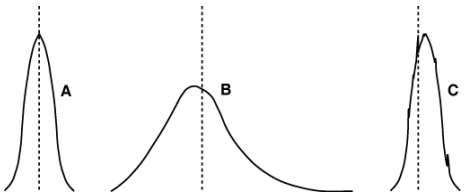


Figure 134. Peak Examples

5. While watching a strong symmetrical peak (similar to Peak A in image above), rotate the thumbwheel and observe the spectral peak (or peaks) go from broad to narrow and back to broad. Maximize the intensity level and minimize the FWHM of the selected peak or peaks. If the **Peak Finding** function is not active, turn it on so you can monitor the FWHM information to achieve the narrowest line width: the **TIP** that follows tells you how

to activate Peak Finding and FWHM information display.

> **TIP:** Available when the Display Mode is Graph, the Peak Finding function locates peaks and the peak widths at Full Width Half Maximum (FWHM). Click on the **Peak Finding** button and choose the icon that most resembles your data, the peaks will be identified. If **Verbose** is checked, wavelength (x) and intensity (y) are shown next to each peak label, and a width next to the Full Width Half Max **X**s if you are showing them. The **Show Full Width Half Max** (FWHM) check box determines whether or not the Full Width Half Max **X**s are shown.

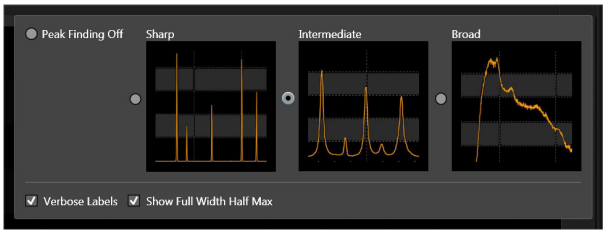


Figure 135. Peak Finding Choices

> **Note:** The Peak Finding function will remain on until you click on the **Peak Finding** button and click on the **Off** radio button, or until you change the Display Type from Graph to Image.

6. Secure the camera position:
   - **Set Screws:** Tighten the #10-32 set screw on the top of the front plate first, and then tighten the one on the side to secure the detector.
   - **Split Clamp:** Tighten the clamp.
7. Stop data acquisition.
8. Turn off and remove the standard lamp from the entrance slit.
9. If you saved the Experiment as suggested in Step 11 of the **Setup Procedure**, you can just reload the Experiment. Otherwise, you may want to reset the **Exposure Time** and **Analog Gain** settings; and if there is a shutter, return its setting to its **Normal** mode.

Alignment for an Acton LS 785 Spectrograph

Rotational Alignment

When purchased with a Princeton Instruments camera such as a PIXIS with flange, the LS 785 is normally focused and aligned at the factory and shipped as a complete system, ready to operate. If the PIXIS has been purchased separately from the LS 785 or you have removed the PIXIS from the LS 785, you will need to perform rotational alignment after you install or remount it to the spectrograph.

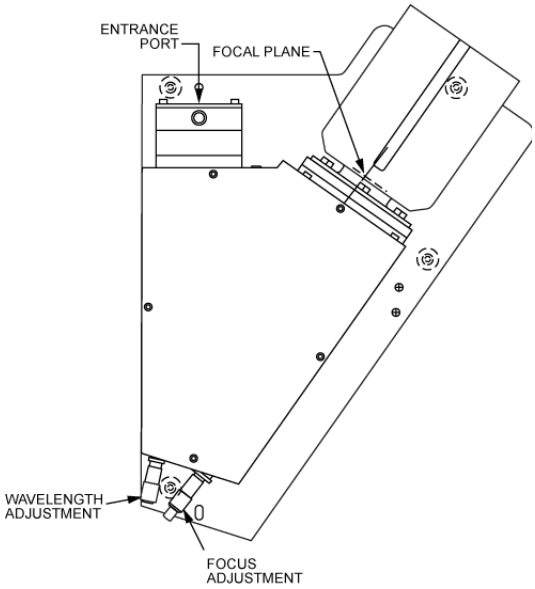


Figure 136. Drawing of LS 785 with Callouts

Rotational Alignment Procedure:

1. Mount the camera to the exit port.
2. Mount a neon light source to the entrance port and set the entrance slit width to 20 µm.
3. Using a 5/16" wrench, loosen the three 10-32 flat head bolts securing the flange so the camera can rotate within the range of the slots.
4. Power on the camera and neon light source.
5. Start LightField and after the camera is detected, move the LS 785 and the camera icons into the **Experiment Devices** area.
6. On the **Common Acquisition Settings** expander, set the Exposure Time to 100 ms.
7. Click on the **Experiment menu** (in the upper right corner of the Experiment workspace) and select **Align Spectrometer.**

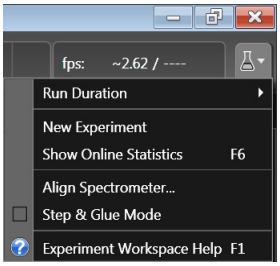


Figure 137. Experiment menu

8. When the **Spectrometer Alignment** dialog pops up, read the list of changes that will be made when you click on the **Begin** button.

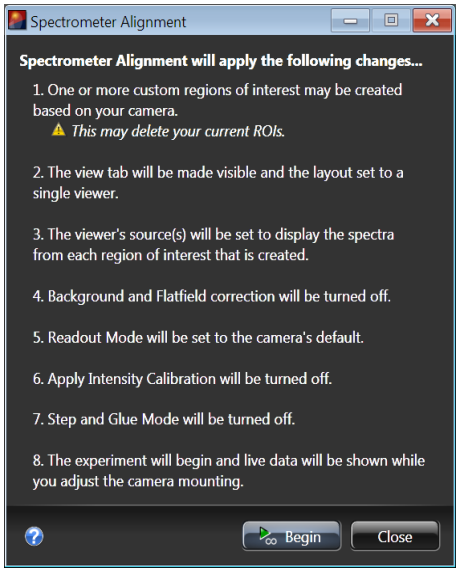


Figure 138. Spectrometer Alignment dialog

9. After you click on **Begin**, ROIs are created and continuous acquisition begins. Typically three are created: a single row ROI at the center of the sensor, one below, and one above the center ROI.

> **Note**: You can close the dialog at any time.

10. For rotational alignment, you can either continue with the stacked graphs (default) or you can change to overlay mode. If you right-mouse click to open the Viewer's context menu and uncheck **Stacked Graph**, the three spectra will be overlaid rather than stacked.
11. Choose a sharp peak and while looking at the three spectra, rotate the camera until the selected peak coincides in all three spectra. If you want to use the Data Cursor as a vertical reference for the alignment, right-mouse click and select it from the context menu.
12. Tighten down the flat head bolts.
13. Stop data acquisition.

Focus Adjustment

When purchased with a Princeton Instruments camera, the LS 785 is normally focused and aligned at the factory and shipped as an integrated system ready to operate. In this instance no further adjustments are required. Focus adjustments are recommend in the following instances:

1. The grating has been adjusted to a new wavelength position.
2. The camera is purchased separately from the LS 785 and is being installed at your facility.
3. The camera has been removed from the LS 785 and is being re-installed.
4. The user wishes to check or optimize focus.

Focusing Procedure:

1. If you have not already done so, mount a camera to the exit port.
2. Mount a neon light source to the entrance port and set the entrance slit width to 20 µm.
3. Locate the FOCUS ADJUSTMENT micrometer at the rear of the LS 785.
4. Rotate the Focus Adjustment locking nut counter-clockwise to unlock the micrometer spindle.
5. Power on the camera and neon light source.
6. Start LightField and after the camera is detected, move the LS 785 and the camera icons into the Experiment Devices area.
7. If the camera has a shutter or is controlling a shutter, open the **Shutter** expander and set the Shutter Mode to **Always Open**.
8. Click on the **View** tab on the Experiment workspace and then click on the **Preview** button to begin continuous live data acquisition.
9. Rotate the focusing micrometer until the best focus (image quality or spectral resolution) is obtained.

> **Caution:** Do not apply excessive force to the knob.

> **Note:** The data acquisition rate is determined by the Exposure Time (set on the Common Acquisition Settings expander). A shorter exposure time will update the viewer more frequently.

10. Lock the micrometer in place by rotating the locking nut clockwise.
11. Stop data acquisition.
12. Turn off the light source.

13. If a shutter was set to **Always Open**, return its setting to **Normal**.

Wavelength Adjustment

For wavelength adjustments, the LS 785 includes a "WAVELENGTH ADJUSTMENT" micrometer located on the rear of the housing. Please note that we refer to Wavelength Adjustment as moving (rotating) the grating to a new center wavelength position on the sensor.

Wavelength Adjustment Procedure:

1. With the camera and neon light source powered on, start LightField.
2. After the camera is detected, move the LS 785 and the camera icons into the **Experiment Devices** area.
3. If the camera has a shutter or is controlling a shutter, open the **Shutter** expander and set the **Shutter Mode** to **Always Open**.
4. Click on the **View** tab on the Experiment workspace and then click on the **Preview** button to begin continuous live data acquisition.
5. Open the **Spectrometer** expander and enter the **Center Wavelength**.
6. Under the **Micrometer Values** heading, note the Wavelength micrometer setting displayed.
7. Rotate the micrometer clockwise or counter-clockwise until the desired micrometer setting is reached. If desired, the micrometer can be locked into position by rotating the locking nut 1/8 turn clockwise.
8. Stop data acquisition.
9. Turn off the light source.
10. If a shutter was set to **Always Open**, return its setting to **Normal**.

Calibration

Introduction

Calibration for spectroscopy is the process of preparing LightField to assign appropriate calibration values over the scanned range of an acquired spectrum. LightField can be calibrated by performing either a **Standard Calibration** or a **Fixed** or a **Broad Calibration** via **IntelliCal**™ (a purchased add-on to the LightField software). Calibration units can be electron volts, Angstroms, nanometers, microns, absolute wavenumbers, or relative wavenumbers (requires Laser Line entry). The choice of units is made from the drop-down list on the **Application Options** dialog's **Units** tab. This tab can be opened after clicking on the **Application Menu** button (upper left of the workspace) and selecting **Application Options** or by clicking on the X axis label below the view.

A **Standard Calibration** is a broad calibration that precisely calibrates the movement of a spectrograph grating using the spectrograph stepper motor.

An IntelliCal **Fixed Calibration**, which relies upon the positions of known peaks of a known source such as a mercury or neon lamp, is valid for only one position of the grating. If the grating is moved, either manually or by controlling the stepper motor, a new **Fixed Calibration** must be performed for the new spectrograph position.

An IntelliCal **Broad Calibration** calibrates for all wavelengths on the selected grating: the software will tell you wavelength accuracy for every pixel in an array, or equivalently, at every point on a spectrum.

Notes:

1. If **Remove Sensor Blemishes** has been turned on via the **Online Corrections** expander, blemish correction will be applied during calibration.
2. The **Clear All Calibrations** function will clear ALL calibrations (wavelength and intensity) for the current camera and spectrograph combination.
3. Even after the spectrometer setting has been fixed, moving the sample, refocusing, or almost any adjustment of the input optics can affect a **Fixed Calibration**. For the most accurate calibration possible, Princeton Instruments recommends recalibration after any optical adjustment.

Standard Calibration

Introduction

Standard calibration is a broad calibration that is grating specific. LightField uses a three-step method in performing a standard broad calibration for the selected grating: determining offset, adjusting the difference between the calculated and the actual position of a reference peak, and calculating the dispersion based on the entered low and high reference wavelengths selected before starting the calibration.

Background Correction for Calibration

Introduction

The purpose of background correction is to minimize the effect of constant background in the signal and thereby make low intensity signals more visible. Background correction applies an automatic subtraction of any constant background in the signal. This includes both constant offsets caused by the amplifier system in the controller as well as the time-dependent (but constant for a fixed integration time) buildup of dark charge. It also includes the small offset applied by Princeton Instruments systems to insure that small signals are not missed. Background subtraction data files are sometimes acquired with the shutter open to include any ambient light background.

Acquiring a Background File:

1. Set the sensor temperature to precisely the same temperature to be used in data collection. Wait at least 30 minutes after the sensor has reaching operating temperature to ensure stability.
2. Set the same binning parameters and ROIs as will be used for data collection.
3. In most cases, you will want to prevent light from falling on the sensor. If there is no shutter, block light from falling on the sensor. If there is a shutter, LightField will close it during background acquisition.
4. On the **Online Corrections** expander, click on **Acquire New Background File...** button 

.
5. When the **Save Background File As...** dialog appears, you can change the file name from the default name “BackgroundSubtraction.spe” so it will not overwrite a previously acquired background. You can also specify a directory other than the default “Username”\Documents\LightField\Correction Files. When creating the file name, it is a good idea to include some indicator in the name that this is a background file and perhaps a short description of the experiment. This is especially a good idea if you decide to store file outside of the default Correction Files directory. Click on **Save** when you finished. If this file will overwrite an existing file, you will be given a second chance to change the name or destination.

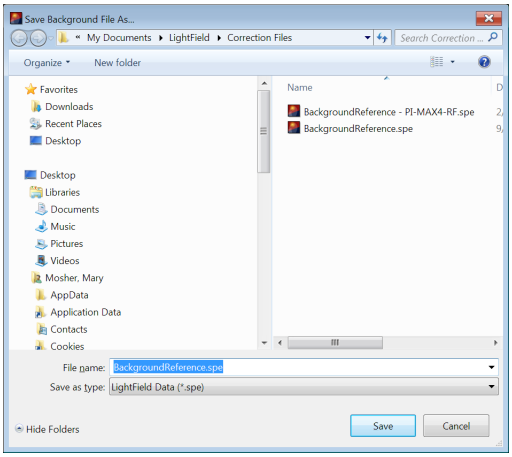


Figure 139. Save Background File As... dialog

6. Once the background name is saved, the background file is acquired using the current experimental parameters. If there is a shutter, LightField will close the shutter while data are acquired. The file will be stored and background subtraction will be turned on and applied to subsequently acquired data until it is turned off, a new background is acquired, a different background is selected, a new experiment is opened, or a previously saved experiment is loaded.

Performing a Standard Calibration

This procedure assumes that you have already aligned and focused the camera to the spectrograph optics.

Notes:

1. The **Finish Later** button allows you to quit the **Standard Calibration** dialog and resume the calibration for the currently selected grating by clicking on **Spectrometer Calibration** later in the current LightField session.
2. If **Remove Sensor Blemishes** has been turned on via the **Online Corrections** expander, blemish correction will be applied during calibration.

1. Set up the experiment parameters.
2. Open the **Region of Interest** expander, and select **Rows Binned** and enter the number of rows to binned.
3. Open the **Online Corrections** expander, acquire a background file, and activate Background Subtraction. This will minimize background noise and thus make small peaks more visible.

4. Open the **Spectrometer** expander.
5. Choose the grating and enter the center wavelength.
6. Specify the light source you are using for the calibration and make sure that source is mounted to the entrance port, selected, and turned on.
7. **Optional:** Click on **Show Reference Spectrum**. When you do this, LightField will display a reference spectrum for the selected light source in the viewer.
8. **Optional:** Click on **Find Center Wavelength**. LightField will acquire a spectrum and calculate the actual wavelength at the grating position.
9. Click on **Standard Calibration**.
10. On the **Standard Calibration** dialog, select two reference wavelengths to be used in calculating dispersion. The dropdown lists of available wavelengths are based on the selected light source.

> **Note:** The wavelengths recommended by Princeton Instruments are the ones above the line in the dropdown lists.

11. Click on **Start Calibration**.

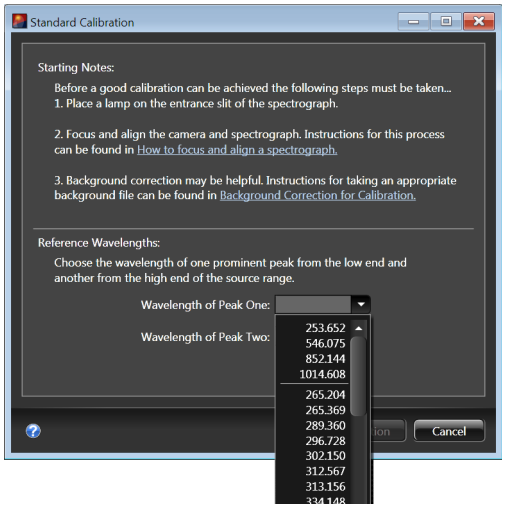


Figure 140. Standard Calibration dialog

12. Click on **Calculate** (under the Offset column) to begin the Offset calculation. Offset uses 0 nm wavelength as the center.

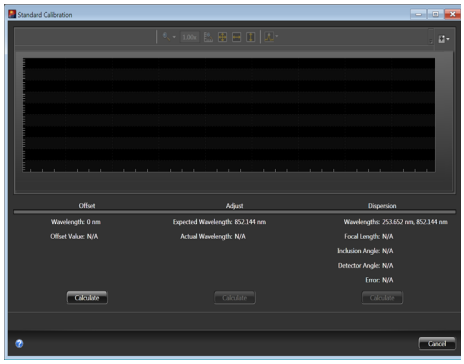


Figure 141. Standard Calibration: Offset Calculation

13. The grating will be repositioned, a spectrum will be acquired, and the offset value will be calculated and reported. Graphs for the calibration standard and for the data are displayed.
14. Click on **Calculate** (under the Adjust column) to begin the adjustment process.

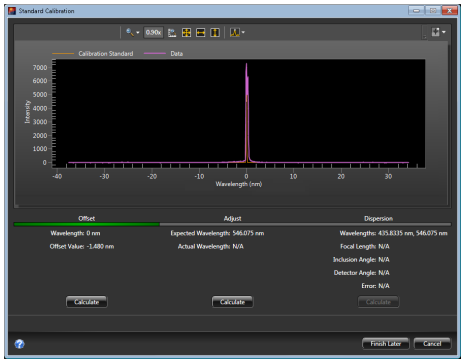


Figure 142. Standard Calibration: Adjust

15. The grating will be repositioned, a spectrum will be acquired, and the expected and actual wavelengths for the peak will be calculated and reported. Graphs for the calibration standard and for the data are displayed.
16. Click on **Calculate** (under the Dispersion column) to begin the dispersion process. The dispersion process repositions the grating so the low reference wavelength peak is on the left of the display, then on the right; repeats this operation with the high wavelength; and then begins an iterative process to find the best values. Dispersion calculation takes much longer than the Offset and Adjust calculations. Be patient.

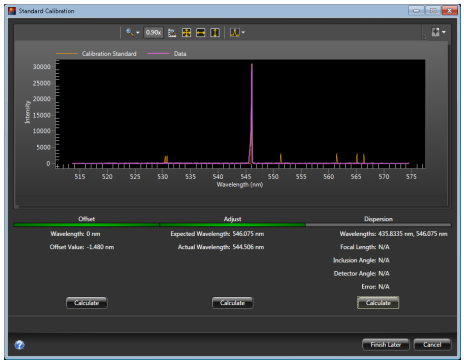


Figure 143. Standard Calibration: Dispersion

17. When the Dispersion calculation has finished, the **Focal Length**, **Inclusion Angle**, **Detector Angle**, and the **Error** (in nm RMS) are reported. If the LightField determines that the error value is too high (the icon is displayed, you will not be allowed to use the calibration. If the error is high (the icon is displayed), you will have the choice of using or discarding the calibration.

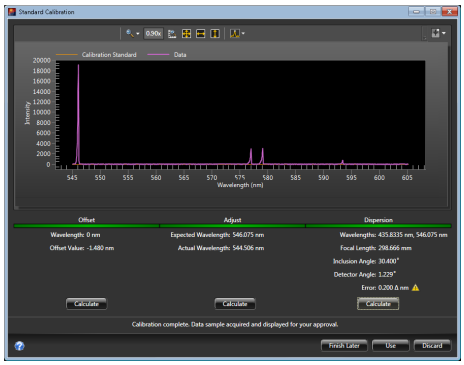


Figure 144. Standard Calibration: Completed

18. When you click on **Use** or **Discard** the dialog is closed. If you selected **Use**, the X axis in the viewer will be changed to Nanometers (if these are the default wavelength units). The next acquisition will have the calibration applied to it.

19. If you have another grating that you would like to calibrate, repeat Steps 5-18 for it.

> **Note:** As of LightField Version 4.2, calibrations (including Intensity Calibration) are now exit port dependent. Older calibrations will remain port independent until they are replaced with new calibrations.

Is Standard Calibration Disabled?

If the Standard Calibration function is not available, possible reasons for this are:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are horizontally binned (i.e., in the serial direction).
- Multiple ROIs must all be the same width
- The spectrograph is not an Acton SP series or IsoPlane SCT-320 spectrograph.
- **Apply Intensity Calibration** is checked but there is no valid Intensity Calibration reference file.
- The grating selection is **Mirror**.

IntelliCal™ Wavelength Calibration

Introduction

IntelliCal™ is Princeton Instruments' add-on calibration routine that refines spectrograph parameters to match observed and calculated emission spectra in intensity space. The result is an order of magnitude increase in wavelength accuracy and a substantial reduction in the need for user input. The routine reports wavelength error at each point and stores the calibration information in the file header. LightField reports the wavelength accuracy for every pixel in an array, or equivalently, at every point on a spectrum. Once a spectrograph has been calibrated, a one-click search-match algorithm identifies the current center wavelength position without the need for a new refinement cycle. The system incorporates NIST spectral tables.

A USB-powered dual light source using switchable Hg and Ne/Ar sources provides the emission lines that are used in the calibration. This source is sold with IntelliCal or can be purchased separately.

Warnings

LightField reviews camera, light source, and spectrograph characteristics and will notify you if there is an uneven line distribution or insufficient lines for a calibration.

- **Insufficient lines:** If you see this warning, more lines are needed to perform an accurate calibration. You will not be able to select the referenced calibration in the **IntelliCal** dialog. If there are not enough lines for Fixed Calibration and for Broad Calibration, the **IntelliCal** button will be grayed out.

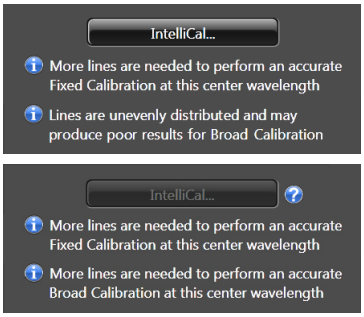


Figure 145. Insufficient Lines warnings

- **Uneven line distribution:** If you see this warning, the spectral lines are unevenly distributed. However, you are not prevented from performing the referenced calibration.

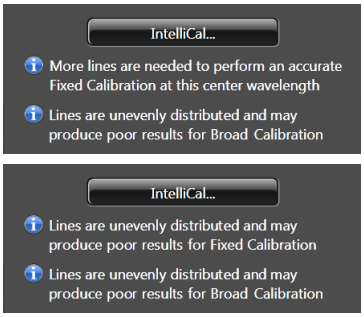


Figure 146. Uneven Line Distribution warnings

Performing an IntelliCal Fixed Calibration

Introduction

A **Fixed Calibration**, which relies upon the positions of known peaks of a known source such as a mercury or neon lamp, is valid for only one position of the grating. Even after the spectrograph setting has been fixed, moving the sample, refocusing, or almost any adjustment of the input optics can affect a **Fixed Calibration**. For the most accurate calibration possible, Princeton Instruments recommends recalibration after any optical adjustment.

> **Note:** If **Remove Sensor Blemishes** has been turned on via the **Online Corrections** expander, blemish correction will be applied during calibration.

Procedure:

This procedure assumes that you have already focused and aligned the camera to the spectrograph optics.

1. Set up the experiment devices, such as Exposure Time.
2. Open the **Region of Interest** expander, select **Rows Binned**, and enter the number of rows to be binned.
3. Open the **Spectrometer** expander.
4. Choose the grating and enter the center wavelength. A fixed calibration will only be good for the grating position at that wavelength.
5. Specify the light source you are using for the calibration (PI Mercury or PI Neon/Argon) and make sure that source is mounted to the entrance port, selected, and turned on.
6. **Optional:** Click on the **Show Reference Spectrum** button to display a reference spectrum for the selected light source as Source 1 in View 1.
7. **Optional:** Click on **Find Center Wavelength.** LightField will acquire a spectrum and calculate the actual wavelength at the grating position.
8. Open the **Online Corrections** expander, acquire a background file, and activate **Background Subtraction**. This will minimize background noise and thus make small peaks more visible.
9. On the **Spectrometer** expander**,** click on the **IntelliCal** button to open the **IntelliCal** dialog.
10. **Optional:** (Not available for PI-MAX3 and PI-MAX4 cameras) If you select **Auto-Expose**, LightField will expose the sensor until one of the following occurs:
    - It gets 4 or more peaks 2000 counts above the baseline.
    - It gets 1 peak to within a few counts of 35,000.
    - It increases the exposure to 20 seconds and still sees no peaks.
    - It decreases the exposure to 1 ms and there are still peaks or signals over 35,000 counts.

    > **Note:** There is no response to the user if the auto-exposure fails. The original exposure is restored and IntelliCal performs the calibration operation without the auto-exposure function.
11. Select **Fixed** calibration and then click on **Start Calibration**.

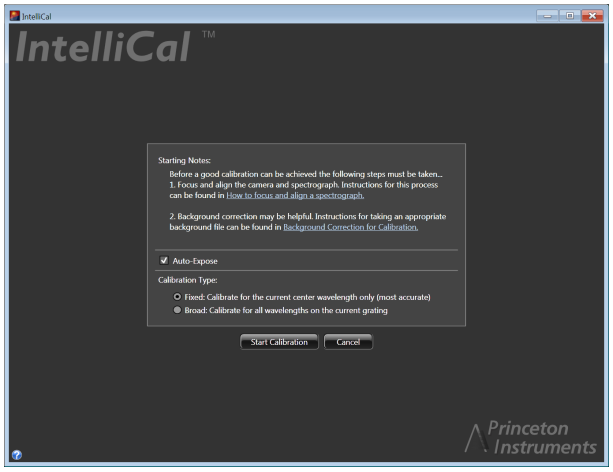


Figure 147. IntelliCal Calibration: Fixed Calibration Selected

12. The calibration process will start and continue to completion without any further actions required from you. Calibration can take several minutes. Be patient.
13. When the **Calibration** has finished, the **Center Wavelength**, **Error** (in nm RMS), **Focal Length**, **Inclusion Angle**, and **Detector Angle** are reported. The buttons displayed when calibration stops depend on the reason the calibration stopped and the error value.

Figure 148. IntelliCal Calibration Completed

- If IntelliCal determines that the error value is too high (the icon is displayed), you will not be allowed to use the calibration.
- If you stop the calibration before it has finished, you have the choice of resuming the calibration (the Resume Calibration button will be displayed) or discarding it.
- If calibration has finished and the error is high (the icon is displayed), you will have the choice of resuming calibration, using the current calibration, or discarding it.

14. If you click on **Resume Calibration**, the dialog will remain open and the calibration process will continue from the point at which it stopped: this gives IntelliCal additional time to refine the calibration. If you click on **Use** or **Discard**, the dialog is closed. If you selected **Use**, the X axis in the viewer will be changed to Nanometers (if these are the default wavelength units). The next acquisition will have the calibration applied to it.

Notes:

1. Even after the spectrometer setting has been fixed, moving the sample, refocusing, or almost any adjustment of the input optics can affect a Fixed Calibration. For the most accurate calibration possible, Princeton Instruments recommends recalibration after any optical adjustment.
2. As of LightField Version 4.2, calibrations (including Intensity Calibration) are now exit port dependent. Older calibrations will remain port independent until they are replaced with new calibrations.

Is IntelliCal Wavelength Calibration Disabled?
If the IntelliCal Wavelength Calibration function is not available, possible reasons for this are:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are horizontally binned (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- The spectrograph is not an Acton SP series or IsoPlane SCT-320 spectrograph.
- There are not enough lines for either Fixed or Broad calibration.
- The selected light source must be PI Mercury or PI Neon/Argon.
- **Apply Intensity Calibration** is checked, but there is no valid Intensity Calibration reference file.
- The grating selection is **Mirror**.
- The camera is a PyLoN-IR 2.2.

Performing an IntelliCal Broad Calibration

Introduction
A **Broad Calibration** calibrates for all wavelengths on the selected grating: the software will tell you wavelength accuracy for every pixel in an array, or equivalently, at every point on a spectrum.

> **Note:** If **Remove Sensor Blemishes** has been turned on via the **Online Corrections** expander, blemish correction will be applied during calibration.

Warnings
LightField reviews camera, light source, and spectrograph characteristics and will notify you if there is an uneven line distribution or insufficient lines for a calibration.

- **Insufficient lines:** If you see this warning, more lines are needed to perform an accurate calibration at the current center wavelength. You will not be able to select the referenced calibration in the IntelliCal dialog. If there are not enough lines for Fixed Calibration and for Broad Calibration, the IntelliCal button will be grayed out.

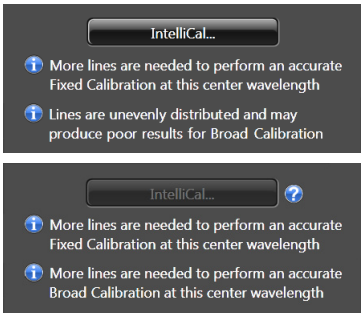


Figure 149. Insufficient Lines warnings

- **Uneven line distribution:** If you see this warning, the spectral lines are unevenly distributed. However, you are not prevented from performing the referenced calibration.

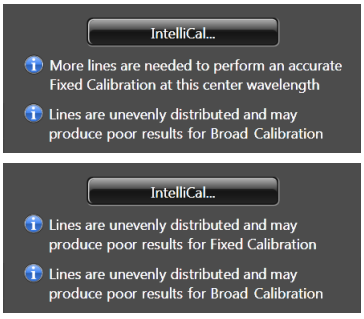


Figure 150. Uneven Line Distribution warnings

Performing a Broad Calibration:
This procedure assumes that you have already focused and aligned the camera to the spectrograph optics.

1. Set up the experiment parameters, such as Exposure Time.
2. Open the **Region of Interest** expander, select **Rows Binned**, and enter the number of rows to be binned.
3. Open the **Spectrometer** expander.
4. Choose the grating and enter the center wavelength.
5. Specify the light source you are using for the calibration (PI Mercury or PI Neon/Argon) and make sure that source is mounted to the entrance port, selected, and turned on.
6. **Optional:** Click on the **Show Reference Spectrum** button to display a reference spectrum for the selected light source as Source 1 in View 1.
7. **Optional:** Click on **Find Center Wavelength.** LightField will acquire a spectrum and calculate the actual wavelength at the grating position.
8. Open the **Online Corrections** expander, acquire a background file and activate **Background Subtraction**. This will minimize background noise and thus make small peaks more visible.
9. On the **Spectrometer** expander, click on the **IntelliCal** button to open the **IntelliCal dialog**.
10. **Optional:** (Not available for PI-MAX3 and PI-MAX4 cameras) If you select **Auto-Expose**, LightField will expose the sensor until one of the following occurs:
    - It gets 4 or more peaks 2000 counts above the baseline.
    - It gets 1 peak to within a few counts of 35,000.
    - It increases the exposure to 20 seconds and still sees no peaks.

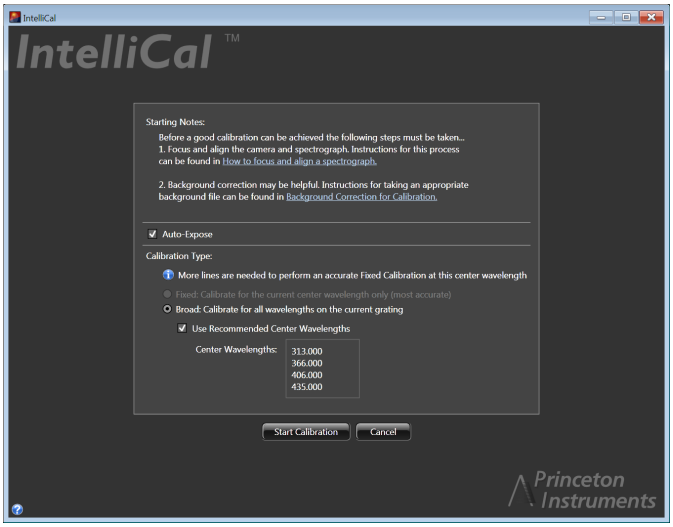


Figure 151. IntelliCal Calibration: Broad Calibration Selected

- It decreases the exposure to 1 ms and there are still peaks or signals over 35,000 counts.

> **Note:** There is no response to the user if the auto-exposure fails. The original exposure is restored and IntelliCal performs the calibration operation without the auto-exposure function.

11. Select **Broad** calibration. You can either use the recommended wavelengths (these are associated with the selected light source) or, if you deselect the check box, enter your own set of wavelengths.
12. Click on **Start Calibration**.
13. The calibration process will start and continue to completion without any further actions required from you. Calibration can take several minutes. Be patient.
14. When the **Calibration has finished**, the **Center Wavelength**, **Error** (in nm RMS), **Focal Length**, **Inclusion Angle**, and **Detector Angle** are reported. The buttons displayed when calibration stops depend on the reason the calibration stopped and the error value.
    - If IntelliCal determines that the error value is too high (the icon is displayed), you will not be allowed to use the calibration.
    - If you stop the calibration before it has finished, you have the choice of resuming the calibration (the **Resume Calibration** button will be displayed) or discarding it.
    - If calibration has finished and the error is high (the icon is displayed), you will have the choice of resuming calibration, using the current calibration, or discarding it.

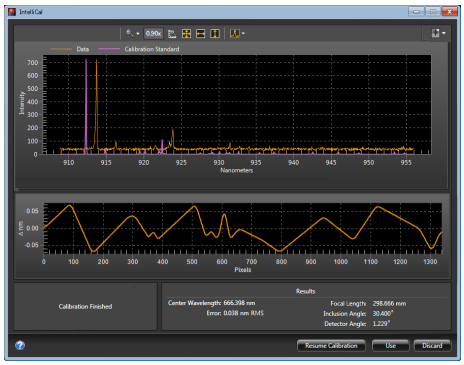


Figure 152. IntelliCal: Finished

15. If you click on **Resume Calibration**, the dialog will remain open and the calibration process will continue from the point at which it stopped: this gives IntelliCal additional time to refine the calibration. If you click on **Use** or **Discard**, the dialog is closed. If you selected **Use**, the X axis in the viewer will be changed to **Nanometers** (if these are the default wavelength units). The next acquisition will have the calibration applied to it.

> **Note:** While performing the calibration, LightField has probably changed the **Center Wavelength** value on the **Spectrometer** expander. Enter the center wavelength appropriate to your experiment.

16. If you have another grating that you would like to calibrate, repeat Steps 5-15 for it.

> **Note:** As of LightField Version 4.2, calibrations (including Intensity Calibration) are now exit port dependent. Older calibrations will remain port independent until they are replaced with new calibrations.

Is IntelliCal Wavelength Calibration Disabled?
If the IntelliCal Wavelength Calibration function is not available, possible reasons for this are:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are horizontally binned (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- The spectrograph is not an Acton SP series or IsoPlane SCT-320 spectrograph.
- There are not enough lines for either Fixed or Broad calibration.
- The selected light source must be PI Mercury or PI Neon/Argon.
- **Apply Intensity Calibration** is checked, but there is no valid Intensity Calibration reference file.
- The grating selection is **Mirror**.
- The camera is a PyLoN-IR 2.2.

Intensity Calibration

Introduction

Intensity Calibration is a feature that is available whenever IntelliCal is available. This process uses a Princeton Instruments, USB-powered Intensity Calibration light source to generate an intensity calibration file. This file can then be applied to data that are subsequently acquired using the same grating and center wavelength or over the same wavelength range if the **Step & Glue** function will be used to acquire data. For information about the **Step & Glue** function, ***"Setting Up and Performing a Step & Glue Acquisition" on page 95***.

Performing an intensity calibration over the spectral range used for Step & Glue will not only correct frame-to-frame discontinuities produced when spectra are mended together but will also correct for changes in grating diffracting efficiency, detector efficiency, and fixed pattern noise as well. When Step & Glue is not being used, an intensity calibration will correct single frame spectral acquisitions with respect to the aforementioned wavelength dependant changes in system throughput.

Each IntelliCal intensity calibration lamp comes preprogrammed with its own relative irradiance spectrum that is read from the lamp's on-board memory at the time of calibration. For best results, place the lamp in a position such that the emitted light will traverse all optics in the beam path of the spectrometer. Optics not sampled by the lamp will impart a change in system throughput that cannot be anticipated by IntelliCal.

Notes:
1. A certificate of calibration is provided with each lamp showing its relative irradiance and expected calibration accuracy.
2. As of LightField Version 4.2, calibrations (including Intensity Calibration) are now exit port dependent. Older calibrations will remain port independent until they are replaced with new calibrations

Creating an Intensity Calibration File

1. Set up the experiment, keeping mind that:
   - Software binning cannot be active.
   - Regions cannot be horizontally binned (serially binning) using either hardware or software binning.
   - A background is required and background subtraction must be active when the intensity calibration is performed.
2. On the **Spectrometer** expander, select the **Grating** and enter the **Center Wavelength**.
3. On the **Online Corrections** expander, select an appropriate background file or acquire a new background file. Make sure **Apply Background File** is checked.
4. If your system is already wavelength calibrated for the current grating and center wavelength, go to Step 9. Otherwise, continue to Step 5.
5. Turn on the light source you are using for wavelength calibration.
6. On the **Calibration** expander, specify that light source and perform a wavelength calibration.
7. After the calibration is completed, turn off the light source. If **Custom Sensor Active Rows** (**Sensor|Custom Sensor** pane) is set to a value LESS than the default, LightField will acquire multiple times to ensure that the last image is clean, and has usable data. The smaller the number of **Active Rows**, the more acquisitions will be performed.
8. Remove the light source used for the wavelength calibration.
9. Mount the Intensity Calibration light source to the entrance port and connect it to a USB port on your computer.
10. On the **Calibration** expander, click on the **Light bulb icon** to the left of the **Calibrate Intensity** button.
11. After the light bulb lights up, click on the **Calibrate Intensity** button.

12. When the Intensity calibration finishes, a calibration file will stored.
13. Click on the Light bulb icon to turn the **Intensity Calibration** light source **OFF**.
14. Disconnect the light source from the USB port and remove the light source from the entrance port.
15. You are now ready to use the Intensity Calibration file.

Applying an Intensity Calibration File

1. Before acquiring data with the **Apply Intensity Calibration** box checked, confirm that your experiment setup meets the following requirements:
   - There are no **Experiment Conflicts**.
   - There is a valid background file selected.
   - Regions are not horizontally binned (serially binning).
   - Software binning is not active.
   - A calibration (fixed or broad) is in place for the grating and center wavelength.
   - An intensity calibration is available for the current grating and center wavelength.
   - The grating selection is not **Mirror**.
   - If there was no Hardware binning in place at the time that the Intensity Calibration file was created, and there was only one ROI, then you can use that Intensity Calibration reference file for ANY sub-ROI of the Intensity Calibration ROI.
   - If there **WAS** Hardware binning active when the Intensity Calibration file was created, then the ROI selected must match the Intensity Calibration file **EXACTLY**.
   - If more than one ROI was used to create the Intensity Calibration file, then the acquisition ROIs must match the Intensity Calibration ROIs **EXACTLY**.
2. Check the **Apply Intensity Calibration** check box.
3. Click on the **Run** or **Acquire** button to begin acquiring intensity calibrated data.
4. The output intensity values will all be between 0 to 1.

Is Intensity Calibration Disabled?

Reasons why this button is not active include:

- There is an **Experiment Conflict.**
- An intensity calibration light source is not selected and ON.
- There is no background file selected or the selected background file is not valid.
- Regions are horizontally binned (i.e., in the serial direction) using either hardware or software binning.
- Software binning is in use.
- A calibration (fixed or broad) is not in place.
- An experiment is running.
- A spectrometer component is moving.
- The grating selection is **Mirror**.
- The camera has an InGaAs sensor.

Additional reasons why you may not be able to acquire or apply an intensity calibration are that

- You have made a change to **Custom Sensor** settings.
- You have set the **Readout Mode** to **Kinetics, Spectra Kinetics,** or **DIF**.

Calibrating an LS 785

Introduction

The Acton LS 785 is an 85 mm focal length high throughput lens spectrograph specifically designed and optimized for near infrared (NIR) applications. The system features fast f/2 lenses for maximum light gathering power and proprietary anti-reflection coatings for exceptional throughput from 750-1050 nm. The unique multi-element f/2 lenses provide a flat 2D focal plane optimized for a wide variety of Princeton Instruments sensors up to 8 mm x 27 mm. Gold-coated plane reflection gratings are used in the LS 785 providing resolution capability of $5cm^{-1}$. The standard LS 785 also features micrometer-controlled grating rotation which allows you to change wavelengths in order to explore different spectral regions of interest.

Calibration

Because an LS 785 is not computer-controlled, this calibration procedure differs from the procedures used for other Acton spectrographs. Each LS 785 is supplied with a file that contains information about the spectrograph. This information and the current Center Wavelength value is used by LightField and IntelliCal to perform a fixed calibration at the current Center Wavelength. Upon completion, IntelliCal determines the best fit to the calculated emission line spectrum (Reference Spectrum) as observed by the sensor. An acquired spectrum of the light source after calibration (set to NeAr) should now overlay the reference spectrum. Any deviation in spectral agreement is reported as Calibration Error (RMS wavelength error over entire focal plane) displayed in the "Current Calibration In Use" section of the **Calibration** expander.

1. Mount a PI camera to the exit port.
2. Mount the PI Acton USB-Hg-NeAr light source to the entrance port.
3. Switch the light source to NeAr.
4. With the camera and light source powered on, start LightField.
5. After the camera is detected, move the LS 785 and the camera icons into the **Experiment Devices** area.
6. Click on the **View** tab on the **Experiment** workspace.
7. Open the **Region of Interest** expander and set the **Rows Binned to Center 1**.
8. Open the **Common Acquisition Settings** expander and set the **Exposure Time**. You may want to acquire a spectrum just to confirm that the NeAr spectrum appears and that the intensity levels are not clipped or too low.
9. Open the **Spectrometer** expander and enter the **Center Wavelength**.

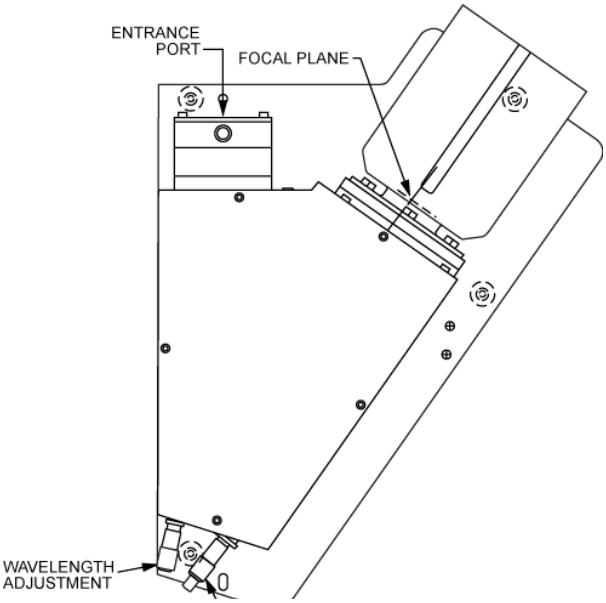


Figure 153. Drawing of LS 785 with Callouts

10. LightField will report the **Wavelength** and **Focus** values to use for setting the micrometers for that center wavelength. Make those adjustments.
11. Click on the **Show Reference Spectrum** button to display a Neon/Argon Standard spectrum in View 1. If the two spectra do not appear very similar, adjust the Wavelength and Focus micrometers until the observed spectrum most closely matches the Reference Spectrum. Pressing the **Find Center Wavelength** button will adjust the center wavelength to more accurately match the observed spectrum.
12. For greater accuracy, you may want to acquire a background file before proceeding with the calibration. See ***"Background Correction for Calibration" on page 85*** for more information.
13. If there is a camera shutter or a camera-controlled shutter, open the **Shutter** expander and set the **Shutter Mode** to **Always Open**.
14. Click on the **IntelliCal** button to open the **IntelliCal** dialog.
15. **Optional:** (Not available for PI-MAX3 and PI-MAX4 cameras) If you select **Auto-Expose**, LightField will expose the sensor until one of the following occurs:
    - It gets 4 or more peaks 2000 counts above the baseline.

- It gets 1 peak to within a few counts of 35,000.
- It increases the exposure to 20 seconds and still sees no peaks.
- It decreases the exposure to 1 ms and there are still peaks or signals over 35,000counts.

Note: There is no response to the user if the auto-exposure fails. The original exposure is restored and IntelliCal performs the calibration operation without the auto-exposure function.

16. Click on **Start Calibration**.
17. The calibration process will start and continue to completion without any further actions required from you. Calibration can take several minutes. Be patient.
18. When the calibration has finished, the **Center Wavelength**, **Error** (in nm RMS), **Focal Length**, **Inclusion Angle**, and **Detector Angle** are reported. The buttons displayed when calibration stops depend on the reason the calibration stopped and the error value.
    - If IntelliCal determines that the error value is too high (the icon is displayed), you will not be allowed to use the calibration.
    - If you stop the calibration before it has finished, you have the choice of resuming the calibration (the Resume Calibration button will be displayed) or discarding it.
    - If calibration has finished and the error is high (the icon is displayed), you will have the choice of resuming calibration, using the current calibration, or discarding it.
19. If you click on **Resume Calibration**, the dialog will remain open and the calibration process will continue from the point at which it stopped: this gives IntelliCal additional time to refine the calibration. If you click on **Use** or **Discard**, the dialog is closed. If you selected **Use**, the X axis in the viewer will be changed to Nanometers (if these are the default wavelength units).
20. Reset the **Shutter Mode** to **Normal**.
21. You may want to take a single spectrum to confirm the calibration.
22. Turn off and remove the light source.

Step & Glue

Introduction

The function is available for computer-controlled Acton SP Series spectrographs. This function can be activated on the **Spectrometer** expander or from the **Experiment** menu.

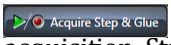
This function allows you to enter a wavelength range that defines the range across a series of spectra will be acquired and glued together to create a single spectrum. When you start the acquisition, the grating moves to the beginning wavelength, a spectrum is acquired, the grating moves, another spectrum is acquired and "glued" to the previous spectrum, and so on until the wavelength range is covered. When the spectra are glued together intensity variation due to grating position and other factors during acquisition may distort the comparative intensities of peaks within the range. To acquire a step and glue spectrum that more accurately reflects comparative peak intensities within the spectrum, perform an intensity calibration using the same wavelength range. For information about performing an intensity calibration (available when the IntelliCal component is installed), see ***"Intensity Calibration" on page 92***.

Setting Up and Performing a Step & Glue Acquisition

1. Set up the experiment, keeping mind that:
   - **Number of Frames** and **Time Stamping** (on the **Common Acquisition** expander) are unavailable when Step & Glue is active.
   - Background subtraction is not necessary unless you will be applying an intensity calibration.
   - You must have performed a broad wavelength calibration.
2. Skip this step if you will not be acquiring or applying an intensity calibration. Otherwise, open the **Online Corrections** expander, click in the **Apply Background Subtraction** box to activate background subtraction. Either select an appropriate background or click on **Acquire New Background** to acquire a new one. If you acquire a new background, make sure that **Apply Background Subtraction** is still selected.
3. On the **Spectrometer** expander, select the **Grating**, check the **Step & Glue** box, and enter the beginning and ending wavelengths in the **Wavelength Range** fields. Note that the **Acquire** button will be retitled **Acquire Step & Glue**.

4. Skip this step if you will not be applying intensity calibration. Mount the **Intensity Calibration** lamp to the entrance port. Connect the lamp to a USB port in your computer. Click on the **Light Bulb** icon to turn on the lamp and activate the **Calibrate Intensity** button  Click on the **Calibrate Intensity** button to acquire the intensity reference file. After the file is acquired, click on the **Light Bulb** icon to turn the lamp off, remove the lamp from the entrance port, and check the **Apply Intensity Calibration** box.

   Note: If **Custom Sensor Active Rows** (**Sensor**|**Custom Sensor** pane) is set to a value LESS than the default, LightField will acquire multiple times to ensure that the last image is clean, and has usable data. The smaller the number of **Active Rows**, the more acquisitions will be performed.

5. Click on the **Acquire Step & Glue** button 

to start the Step & Glue acquisition. Starting at the beginning wavelength, a series of spectra will be acquired as the grating is stepped through a series of positions until the ending wavelength is reached. At each position, a spectrum is acquired and, if this is not the first spectrum, it will be "glued" to the previous spectrum. Note that the progress bar (to the right of the **Stop** button) reports the number of steps and the step being acquired. If **Apply Intensity Calibration** was active for the acquisition, the intensity calibration file will be applied to calibrate the intensities of the spectral peaks.

Is Step & Glue Disabled or Not Present?

If the Step & Glue function is not available, possible reasons for this are:

- There is an **Experiment Conflict**.
- **Custom Sensor** changes have been made.
- **Kinetics** readout mode is active.
- **Spectra Kinetics** readout mode is active.
- Multiple ROIs are not the same width.
- The spectrograph is an LS 785.

Chapter 7: Data Acquisition and Display

Data Acquisition

Introduction

After selecting and setting parameters for your experiment, the next step is to take a look, preview, or acquire data. Note that the only time that data are stored is when you click on the **Acquire** button. The **Take a Look** and **Preview** (Run) functions only display data.

A data acquisition may include multiple frames, multiple exposures per frame, sequential gating, or some combination of these. For this reason, you may see a circular progress indicator or two concentric circular indicators in addition to the standard progress bar. These indicators give an idea of what is happening during the preview or acquisition process. Examples of the indicators are shown below.

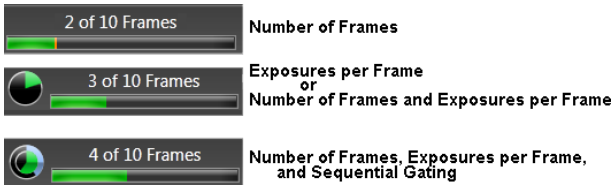


Figure 154. Acquisition Progress Indicators

Taking a Look

If you want to take a quick look to verify the experiment setup, click on the **Take One Look** button  A single frame of data will be displayed. The only time multiple frames will be displayed is if you have set **Exposures per Frame** to a number greater than one. For example, if **Exposures per Frame** is set to 7, 7 frames will be needed to give you one resultant frame.

Previewing Acquisition

After you have set up your equipment and the experiment settings, you can preview what will happen when you actually acquire data. The duration of the preview (auto, infinite, or single sequence) is selected via the **Experiment** menu. Preview mode data are available only while shown in the **Experiment viewer**.

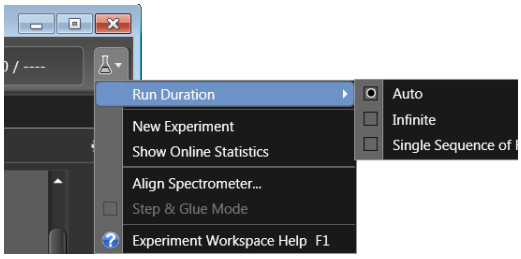


Figure 155. Experiment menu: Run Duration Choices

- In **Auto** mode, the preview will be in **Run Infinite mode** unless **Sequential Gating Mode** is active (PI-MAX3 and PI-MAX4 only). When Sequential Gating Mode is active, the preview will be run in Single Sequence of Frames mode.
- In **Run (Infinite)** mode, acquisition starts in preview mode when you click on the **Run (Infinite)** button  Data are displayed until preview mode is stopped or acquisition mode is activated; no data are stored in preview mode. When this mode is stopped, the last frame is displayed in the viewer. The **Review Acquired Data** button will not be displayed unless acquisition mode was active.

  Note: Due to the possibility of frequent user interaction during **Run (Infinite)**, all experiment settings are considered in flux and all data are assumed temporary and are continually overwritten. **Run (Infinite)** may sample only some of the data to ensure the display keeps pace with the experiment.

- In **Run (Single Sequence of Frames)** mode, acquisition starts in preview mode when you click on the **Run (Single Sequence of Frames)** button  . LightField will only ever give you from the camera the number of resultant experiment frames indicated by the **Number of Frames** setting on the **Common Acquisition Settings** expander. This means that if Number of Frames is 50 (Exposures per Frame = 1), and you start in acquisition mode, you acquire and store 10 frames, and then switch into Preview (Single Sequence of Frames) mode, LightField will stop showing frames after it has shown a total of 50 frames (10 were stored, and 40 were previewed). If you start the experiment in Preview (Single Sequence of Frames) mode and do not switch to acquisition mode, it will display 50 frames and stop, without storing anything. When this mode is stopped, the last frame is displayed in

the viewer. The **Review Acquired Data** button will not be displayed unless acquisition mode was activated.

Note: The actual number of frames collected during a run in order to display the Number of Frames is determined by the Number of Frames, Exposures per Frame, and On-CCD Accumulations (PI-MAX3 and PI-MAX4 only) values. For example, if the Number of Frames value was 10 and Exposures per Frame was 2, LightField would have to collect 20 frames to meet the Number of Frames requirement.

Acquiring Data

Acquire mode is the standard acquisition mode. When satisfied with all experiment settings and the incoming data as viewed in **Preview** mode, clicking on the **Acquire** button initiates acquisition, display, and storage of incoming data. Data are saved to a temporary file until saved with a file name based on the file name and naming options on the **Save Data File** expander. The experiment is continued and data are saved until the designated number of frames are collected, the **Stop** button is clicked on, or the **Acquire** button is clicked on again. At the end of the data acquisition, you can examine the final data frame in the Experiment Viewer or you can click on the **Review Acquired Data** button  . Clicking on this button opens the Data workspace and loads the data into the Data View. An advantage to the Data Viewer is that you can play back or page through the entire set of frames in an acquisition.

Clicking on the **Acquire** button also initiates the acquisition progress bar in the **Status** panel (to the right of the **Stop** button) and frame rate reporting.

Switching between Previewing and Acquiring Data

LightField allows you to be in a **Preview** mode and, without clicking on the **Stop** button, click on **Acquire** to initiate data acquisition. If the experiment design includes multiple frames, you may be able to switch back and forth between **Preview** and **Acquire** modes until the acquisition is stopped or all of the frames are acquired. This allows you to monitor your experiment in **Preview** mode and switch to **Acquire** mode when you see something starting to change, record the event, and then switch back to monitoring until another event of interest occurs.

- If you began by previewing and want to switch to acquiring data, click on the **Acquire** button. To switch back to previewing, click on the **Acquire** button again.
- If you skipped preview and began in Acquire mode, just click on the **Acquire** button to switch to **Preview** mode. Click on the **Acquire** button again to return to acquiring data.

Note: There is a delay between the arrival of raw data from the camera and the display of the data in the viewer. Depending on the experiment design, you may see orange and green in the acquisition progress bar displayed in the Status panel. Orange indicates the frame rate at which raw data are coming into the computer. Green indicates that the data have been processed and are being displayed. When you toggle between previewing and acquiring, the switch will be based on the green portion of the progress bar (i.e., it is based on what you are seeing in the viewer).

A LightField feature called **Frame Tracking** may be useful if you are switching between the two modes while acquiring data. When **Frame Tracking** is active, LightField keeps a running record of the number of frames. This feature can be especially useful when combined with time stamping information for time-resolved or time-lapse experiments.

You can activate **Frame Tracking** by selecting it on the **Common Acquisition Settings** expander. When frame tracking is turned on, each frame (acquired or discarded) will be tagged with the number that corresponds to its place in the record. This information will be displayed in the **Timing** panel below the data in the **Experiment View** area and below the data in the **Data View** and **Comparison View** areas. If frame tracking was active at the time of data acquisition, you can hide or show the frame tracking information after clicking in the Timing panel to pop up the **Time Stamp/Tracking** dialog.

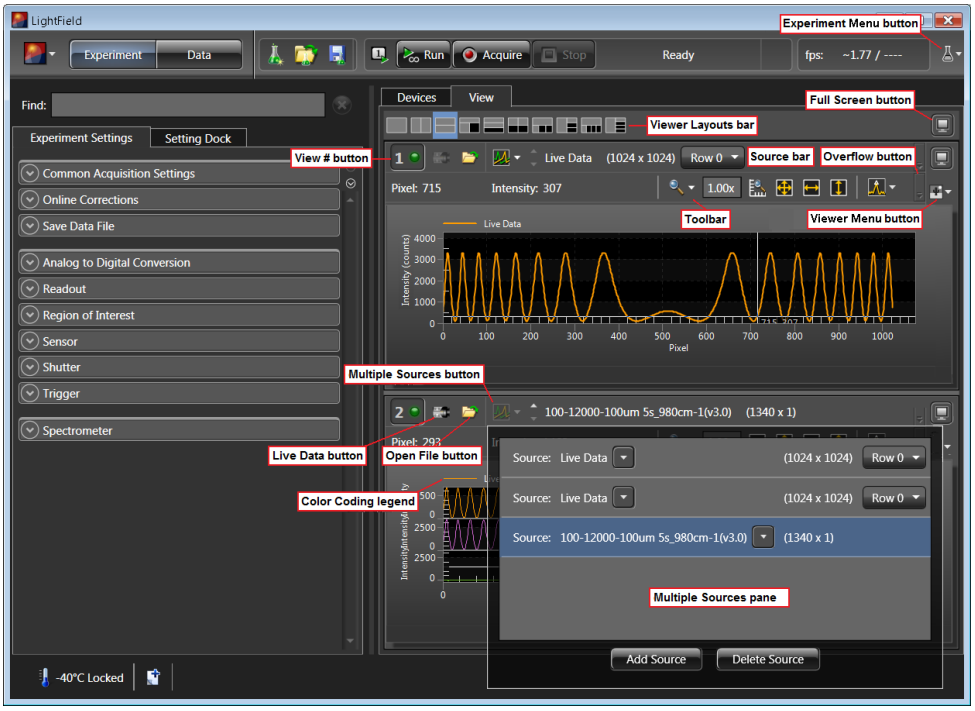


Figure 156. Experiment View with Callouts

Example of Switching between Previewing and Acquiring Data

Suppose you have set up an experiment with 40 frames and click on **Acquire** to start acquisition. After 10 frames you realize that nothing of interest is occurring, so you click on **Acquire** again to go into **Preview** mode. If frame tracking is currently on, the tracking numbers will continue to increment while **Preview** mode is occurring (acquiring, displaying, and discarding data) and will continue to increment when you click on **Acquire** to resume the uncompleted data acquisition. Frames 1-10 will have Tracking numbers 1-10. If you realized that change was occurring in the data you were seeing and you restarted the interrupted acquisition after 20 Preview frames, these frames will have been associated with Tracking numbers 11-30. The remainder of the frames in the data set will have Tracking numbers 31-60. The break in the Tracking number sequence in the data set lets you know that there was an interruption and can be used to approximate the timing of the event.

Experiment View

Introduction

When you start previewing or acquiring data, the live data are displayed in the **Experiment View**, which is accessed in the **Experiment** workspace by clicking on the **View** tab. By default, the Live Data are shown in any open view. The Experiment Viewer allows you to open up to five views and to have either one image or up to five spectra per view. If there are multiple spectra in a view, you have the additional capability of either stacking or overlaying the spectra.

Note: Comparing previously acquired data sets is usually done in the Data workspace Comparison View window. See ***"Using Comparison View" on page 131*** for more information.

Experiment Menu

The **Experiment Menu** button opens a menu of options for the Experiment workspace. The available choices change depending on the the experiment devices and settings. For example, **Align Spectrometer...** is available because there is a spectrograph in the Experiment Devices area. Because the spectrograph is an LS 785, the **Step & Glue Mode** choice is not available.

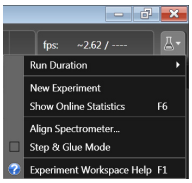


Figure 157. Experiment menu

Viewer Menus

Choices on the Viewer Menu (available when data viewers are active) determine whether data will be displayed as an image or a graph; with autoscaling; with pseudo color for images; or with stacked graphs, marked data points, grid lines, calibrated data with horizontal axis in pixels, and/

or line or point-only plotting for graphs. Each view in a selected view layout has its own **Viewer Menu** button for access to choices that control how data in a view will be displayed. There will be some variation on the choices available depending on the workspace and window.

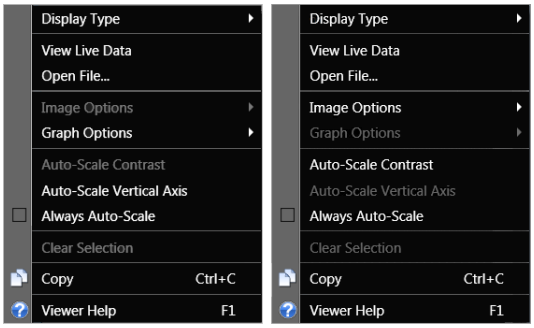


Figure 158. Experiment Workspace: Viewer menus

Context Menus

A context menu is specific to a view and is opened by right-clicking within a view. Note that some items in the context menus are also listed in the Viewer Menus and their submenus.

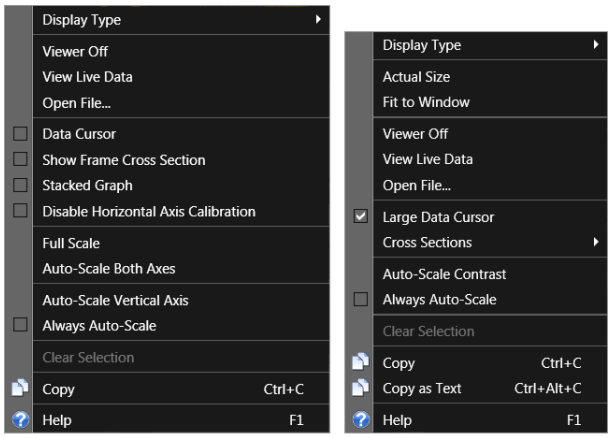


Figure 159. Context menus

Other Experiment Workspace Features

- The **Application Menu** button allows you to view application information and to change application options (default working and scratch directories, calibration units, exposure time units, and monitor power down during an experiment).
- The **Full Screen** button associated with each viewer or view will display the viewer or view across the entire monitor screen.
- The **Experiment Workspace** and **Data Workspace** buttons Experiment Data (5) open the Experiment or the Data workspace. If you are in the Experiment workspace, that button is highlighted.
- The **Experiment File buttons** Untitled Experiment allow you to start a New experiment (it clears the Experiment Settings stack, Setting Dock stack, and the Device tab), Save an experiment, or Load a previously defined experiment.
- The **Find entry field**, above the Experiment Settings and Setting Dock stacks, is used to search for a set of characters in either of these stacks. As you key characters into that field, LightField will examine the expanders for terms that contain those characters. If there are any matches, only the expanders and the settings containing those characters will be shown in the Experiment Settings stack or Setting Dock stack. The stack will have an orange outline to indicate that you have used the Find function. You can restore all of the expanders and/or settings to the stack by clicking on the **Clear** button to the right of the field.

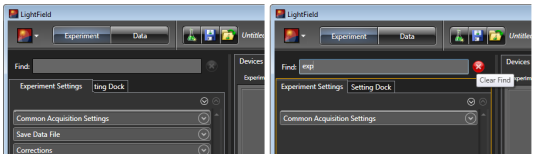


Figure 160. Find entry field

- LightField's online help can be opened at any time by pressing the F1 key on your keyboard. Each expander has its own help topic that can be accessed by clicking on the expander title bar and pressing the F1 key. Many of the menus contain links to help topics related to the feature you are using.

Using Experiment View

Step-by-Step Procedure

1. Open the **Experiment** workspace.
2. Click on the **View** tab.
3. Select the number of views from the **Viewer Layouts** bar.
4. Open one or more views by clicking on the **View #** button 1 for each you want to open. Unless you open a file in a view, the view or views will automatically display Live Data when you click on the **Run** or **Acquire** button.
5. If you have acquired data or previewed data acquisition the last frame of that data (Live Data) will be displayed by default.
6. If the Live Data contains multiple ROIs, the initial display is ROI1. The **ROI** button ROI 1 (224 x 100) is labeled with the current

ROI number and its dimensions. You can change the displayed ROI by clicking on this button, scrolling down the list, and clicking on a different ROI.

7. If you want to view data from a file, you can open a file in a view by one of the following methods:

   - Click on the **Viewer Menu** button, choose **Open File...**, and retrieve the file.
   - Right-mouse click in the view, choose **Open File...** from the context menu, and retrieve the file.

   Note: Use the above methods when an image or only one graph will be displayed in the view. Clicking on the **View #** button a second time will clear the contents of the view and turn it off. Open File... overwrites an existing graph or image in the view with the contents of the file. If there is a file open in a view, Live Data will not be displayed in that view when you click on the **Run** or **Acquire** button. Before you can see Live Data in the view, you will have to turn the view off and back on or select **View Live Data** from the view's context menu.

8. If you want to see multiple graphs (up to five) in a single view, after loading the first spectrum, click on the **Multiple Sources** button. In the **Multiple Sources** pane, click on the **Add Source** button, select a file, and repeat the add and selection until you have the other files. Click outside of the pane to close it when you have finished loading files into the current view.

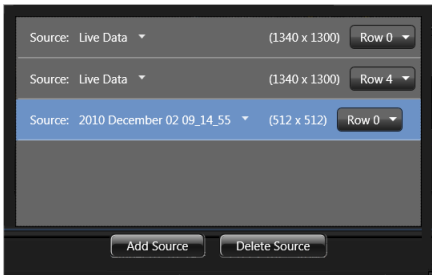


Figure 161. Multiple Sources pane

Note: If there are multiple ROIs and/or rows in a file, the Multiple Sources pane also allows you to choose the ROI and/or row to display. The first ROI and the first row are selected by default.

9. If there are multiple graphs in a view, you can either stack or overlay them. Turning **Stacked Graph** on and off is a function provided on the context menu and as one of the Graph Options on the Viewer Menu. Each graph in a view is drawn with a different color. If there are two or more spectra in a view, clicking on a graph name in the color coding legend makes that spectrum the active graph and, if spectra are overlaid, it will bring the selected spectrum to the front.

   Note: The active graph is the one that will be used to report statistics on the **Comparison Statistics** dialog (opened by selecting **Show Comparison Statistics** from the **Data Menu**).

10. Where there is room on the view, the Source bar displays the name of the data source and the ROI and/or Row number if there multiple ROIs and/or rows. The Toolbar below it displays pixel and intensity information (graph) or cursor location (image), brightness and contrast tools (image), zoom tools, pixel ratio (image), and Peak Finding (graph). When there is not enough room to display all of a bar's contents, the contents are hidden but can be accessed by clicking on the **Overflow** button at the right side of the bar.

Viewing Live Data

When live data is being collected, the term “Live Data” will be shown in the Source bar. However, since you can open a file in a view, the current contents of a view may be from previously acquired data. If this is the case, you must select **View Live Data** from the Viewer Menu or the view’s context menu before the view will display data as it is acquired.

Opening a Data File in a View

In the Experiment Viewer, you can open a data file after selecting **Open File...** from a view's context menu or after selecting **Open File...** from the **Viewer Menu** (each view has one of these menus).

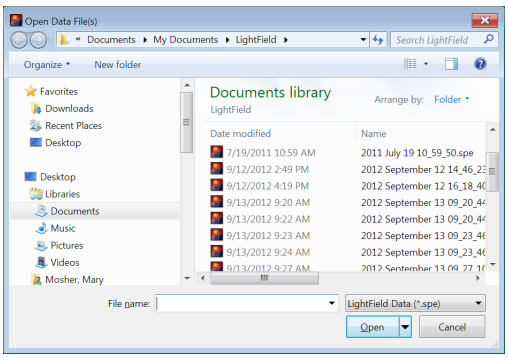


Figure 162. Open Data File(s) dialog

If the data are displayed as a graph, you can add data sources to a view after clicking on the **Multiple Sources** button and clicking on the **Add Source** button Add Source to add a data source to pop up the **Open Data File** dialog.

Adding a Source

If you are looking at the Experiment Viewer, the topmost or leftmost view (depending on the selected view layout) will initially contain Row 0 of the Live Data. Adding a source allows you to display multiple graphs in the same view. Initially, the graphs will be overlaid one on top of the other: the graphs share the X- and Y-axes. You can, however, choose to stack the graphs.

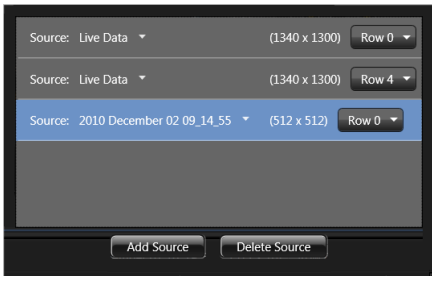


Figure 163. Multiple Sources pane

Open the **Multiple Sources** pane by clicking on the **Multiple Sources** button. To load a different row from the same Live Data, click on the **Add Source** button Add Source, and after the new source is added to the list, then click on the **Row** button and make your selection.To load data from a previously saved data set, click on the small arrow (Change Source) next to Live Data (in the **Multiple Sources** pane). This will drop down a list that allows you to **Select File....** If the highlighted source is a loaded file, you will be able to **Select Live Data** or **Select File...** from the list. By default the row to be displayed is Row 0, but you can change the row by selecting from the list dropped down by the **Row** button.

Each graph within a view is color-coded (the legend with color-code and data source name is shown above the view). To move the Data Cursor from one graph to another, click in the view and press the keyboard up or down arrow key. To move along a graph, click in the view and press the keyboard right or left arrow key.

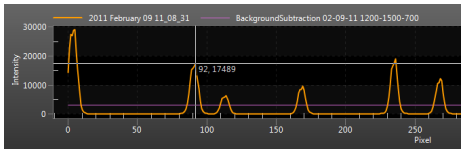


Figure 164. Overlaid Graphs

Stacking Graphs

By default multiple graphs in the same view are overlaid (Figure 164). However, you can choose to show the data stacked one above each other in same view via the context menu (**Stacked Graph**) or **Viewer Menu** (**Graph Options|Stacked Graph**).

When multiple graphs are stacked, the X-axis will be shared by the graphs but each graph will have its own Y axis.

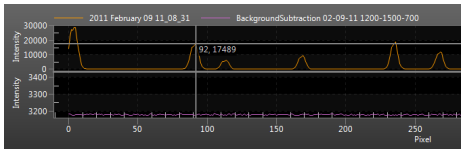


Figure 165. Stacked Graphs

Selecting the Active Graph

When there a multiple graphs in a view, the active graph is drawn with a heavier line than the others. The data cursor will move along the active graph. If you select a portion of the active graph, autoscaling will be applied to that portion. You make a graph active by:

- Pressing the keyboard up or down arrow key after you have clicked in the view. This moves the data cursor to the next graph and makes it the active graph.
- Clicking on the source name in the legend above the view.
- Clicking on the graph.

Changing the Frame Displayed

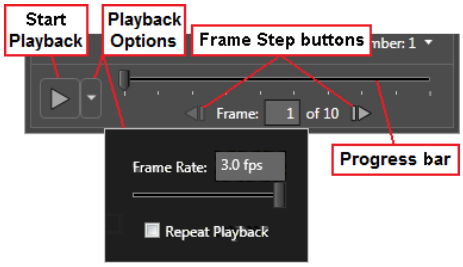


Figure 166. Playback and Step buttons

Live data does not allow you to step through frames that have just been acquired. However, if you have loaded previously acquired data that contains multiple frames, the **Playback** buttons, **Frame Step** buttons and **Progress** bar are displayed below the data. You can manually cycle through the frames by clicking on one of the **Frame Step** buttons, you can pull the slider along the **Progress** bar, or you can set up **Playback** options (frame rate of display and playback repetition), and click on the **Start Playback** button to automatically step through the frames.

Note: If you selected the **Always Auto-Scale** function, each frame will be autoscaled when it is displayed.

Comparing Live Data to Previously Acquired Data

When multiple images are being compared, each image must be in a separate view.

1. Open the View window in the Experiment workspace.
2. Click on a multi-pane layout in the Viewer Layouts bar.

Figure 167. Viewer Layout bar

3. Click on the **Open File** button to the right of the **View 1** button.
4. Find the file you want to use as the reference and open it.
5. Click on the **View Live Data** button to the right of the View 2 button.
6. Click on the **Run (Infinite)** button Run to begin continuous acquisition and display of data (data are not saved) or click on the **Acquire** button Acquire The live data will be displayed in View 2.

> **Note:** If **Run (Single Sequence of Frames)** is active, you can change to **Run (Infinite)** by opening the **Experiment** menu and selecting from the **Run Duration** choices.

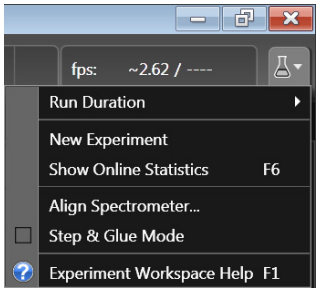


Figure 168. Experiment menu

Maximizing/Restoring a Viewer or View

You can maximize the entire Viewer Layout to a monitor or you can maximize individual views (within a Viewer Layout) to a monitor (the viewer and each view have **Full Screen** buttons). Click on the **Full Screen** button for the view or viewer to maximize. The full screen version of your viewer will have a button in the upper right corner to return it to normal size. If you have maximized a single view, it will also have a button to return it to normal size.

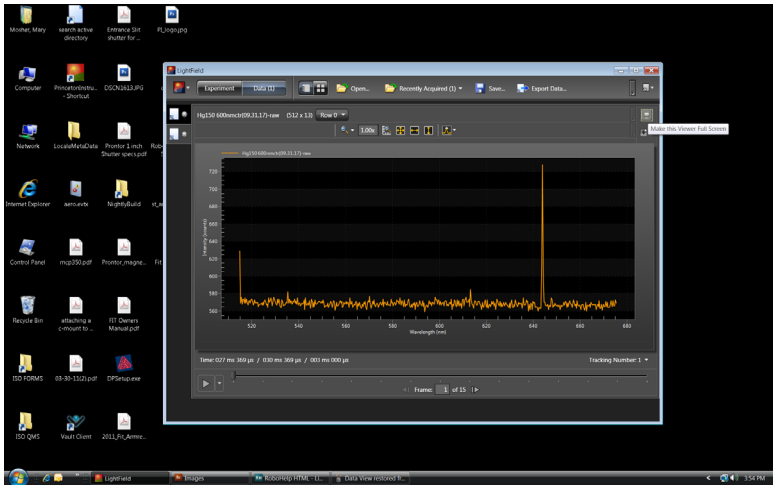


Figure 169. Data View: Normal Size

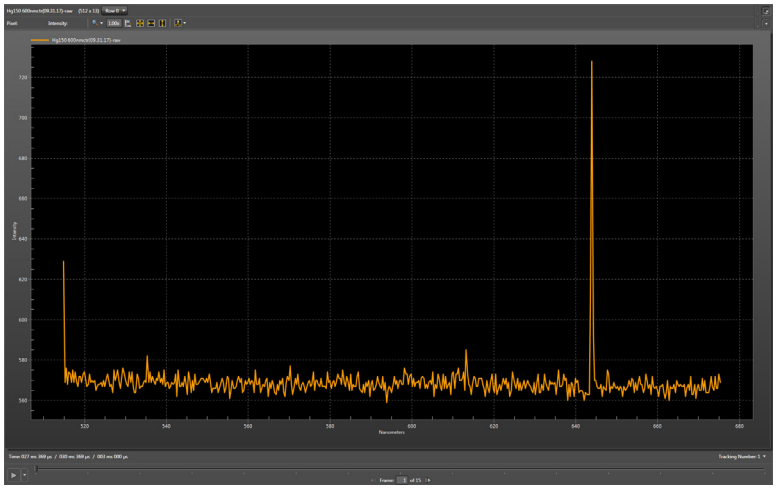


Figure 170. Data View: Maximized

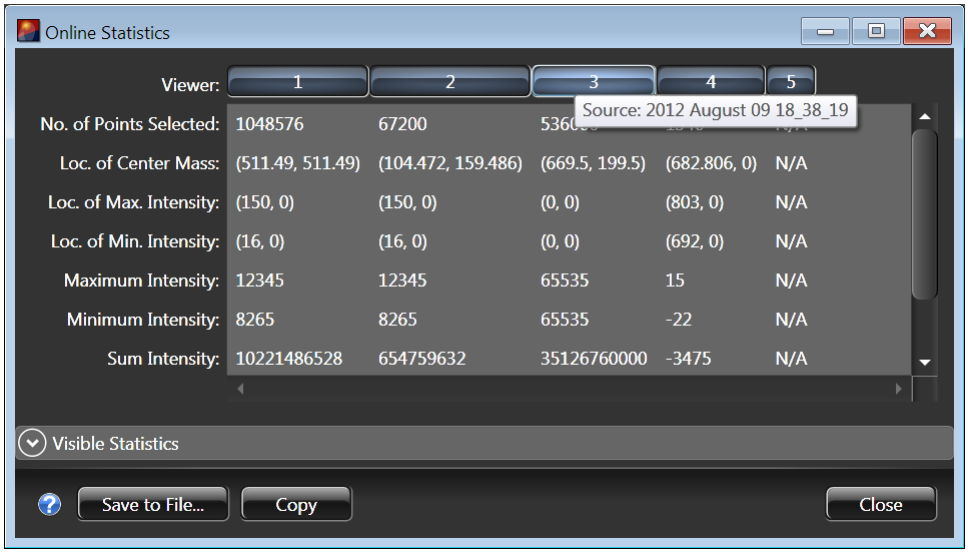


Figure 171. Online Statistics dialog

Sending a Viewer or View to Different Monitor

If your computer has been configured with two monitors, the main LightField window can be stretched to span across more than one monitor. You can click the drop-down button to the right of the **Maximize** button to send the view or viewer to a different monitor. When you send something to a different monitor, the statement "This element is located on another monitor." appears along with a **Restore** button. The view will be maximized on the second monitor.

Viewing Online Statistics

Introduction

If data are displayed in one or more views, you can view statistical information for that data by opening the **Experiment** menu and selecting **Show Online Statistics**. This will pop up the **Online Statistics** window which will display up to nine pieces of statistical information for the data. You can select/deselect a statistic and you can hide the statistics for a view by clicking on the **Viewer #** button above the appropriate column. Only those statistics that are displayed in the table will be available for saving to a file or copying to the clipboard.

Using Online Statistics
The **Online Statistics** dialog can be open while data are being acquired so you can watch the statistics change or you can open the dialog after data are acquired. You can compare Live Data to previously acquired data by opening additional viewers and loading data files into them. The statistics for data in all active viewers will be displayed in the dialog. If multiple graphs are displayed in a viewer, the statistics will be reported for the active graph.

1. In the Experiment workspace, open the **Experiment** menu and select **Show Online Statistics** from the menu.

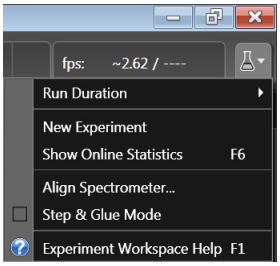


Figure 172. Experiment menu

2. If you have only one viewer, Live Data will be displayed in that viewer as it is being acquired.

> **Note:** If you had previously opened a file in that viewer, you need to delete that data or add Live Data as a source. Otherwise, the viewer may not be updated with Live Data even though it is being acquired.

3. If you would like to compare Live Data statistics with previously acquired data, select the appropriate number of viewers from the Viewer Layouts bar.
4. Open a file in each of the additional viewers. You can do this by right-mouse clicking in a viewer, selecting Open File... from the context menu, and opening a file from the **Open Data File(s)** dialog.

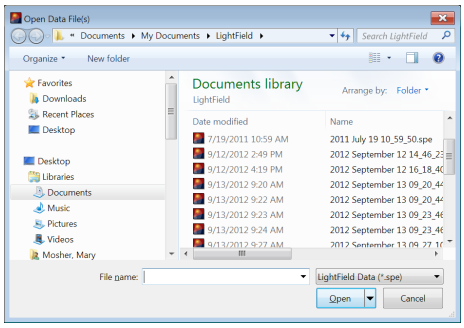


Figure 173. Open Data File(s) dialog

5. Acquire data.
6. When the **Online Statistics** dialog is open, a set of statistics will be listed for each viewer containing data. If there is no data in a viewer or the viewer has been turned off, N/A is displayed. If you position the cursor on a **Viewer** button, the data source information for that column of statistics will be displayed in a tool tip.

> **Note:** If there are data in more viewers than are currently being displayed in the Viewer panel (for example, a two-viewer layout was selected even though four viewers are active and contain data), the statistics will still be listed for the hidden viewers.

7. By default, the online statistics for Live Data are updated every second. You can slow the update frequency by entering an integer greater than one. You can also cause an update by clicking on the **Refresh** button  .
8. Functions on the dialog allow you to choose the statistics to be saved. Only the statistical information visible on the dialog will be saved to the .CSV file or copied to the clipboard. You can limit the statistical information by
   - **Viewer:** For example, if there are data in all five viewers but you only want data from Viewers 1-3, click on the Viewer 4 and Viewer 5 buttons to hide the statistics in those columns. Now when you save the statistics, the information from those viewers will not be included in the .CSV file or copied data.
   - **Statistic:** Up to nine pieces of statistical information can be saved for each viewer containing data. If these statistics and their check boxes are not visible, click on the expand button to the left of Visible Statistics (at the lower left of the dialog). Select or deselect the statistics you want. When you deselect a check box, the statistic associated with it will no longer be displayed in the dialog.
9. Now that you have chosen the statistics, you can click on
   - **Save to File...** to save the information to a .CSV file in the working directory or directory of your choice. The default name for a statistics file is "statistics". You may want to enter a more informative name before saving the file.
   - **Copy** to copy the information to the Windows clipboard. Once the information is in the clipboard, you can paste it into documents, spreadsheets, etc.

Close to quit without saving or copying or to quit after you have saved or copied the information.

Copying

The **Copy** function copies the contents of a view as data points or as an image to the clipboard.

- When the data are displayed as a graph, the data points are copied as as tab-delimited text (culture-sensitive) and CSV (culture-invariant). Large image sizes or selections may take several seconds to copy.
- When the data are displayed as an image, the data are copied and are pasted as an image into graphics programs, spreadsheets, and word-processing programs.

Copying as Text

Copy as Text option is available when data is being displayed as an image. While **Copy** typically copies the image in the viewer as a picture, **Copy as Text** copies the data from the entire image or the data within the red pixel selection rectangle into the clipboard as tab-delimited text (culture-sensitive) and CSV (culture-invariant). Large image sizes or selections may take several seconds to copy.

Converting WinX/32.SPE Files

If you are opening a data file and LightField detects that it is a WinX/32 version 2.x SPE file it will pop up a dialog stating that LightField cannot open the file will be displayed. This dialog offers you the choices of making the conversion to a version 3.0 SPE file and opening the converted file in the image viewer or opening the **SPE Conversion Tool** which will locate version 2.x SPE files and convert those you select. After conversion, the data are stored to a file (or files) using the same name as the original data file(s) but with (v3.0) added to the file name. For example, if the original version 2.x file is named "**laser scatter.spe**", the converted file will be named "**laser scatter(v3.0).spe**".

Note: LightField version 3.0 SPE files are more complex than WinX/32 version 2.x SPE files. The LightField converter allows you to view the data in LightField. File information, however, will be limited and multiple ROIs will be displayed using the WinX/32 side-effect ROIs (***see Figure 174.***). Converted data can be exported but it cannot be used in post-processes.

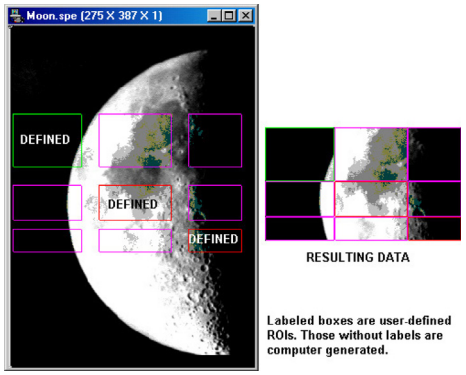


Figure 174. WinX/32 Side-Effect ROIs

Changing Data Display Attributes

Introduction

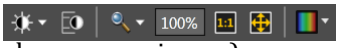
Newly acquired and previously acquired data can be displayed as images or as graphs. If you have just acquired data, the last frame of that data will be automatically displayed in the **Experiment Viewer** (accessed by clicking on the View tab on the Experiment workspace). Up to five separate views can be displayed: the view arrangement is selectable by clicking on one of the view layout icons at the top of the viewer. Because the information is being displayed as a graph, the initial display a single row "Row 0" (the row at the top if the data were being displayed as an image).

The **Row** button 

is labeled with the current Row number (you can change the displayed row by clicking on this button, scrolling down the list, and clicking on a different row).

Figure 175. Viewer Layout bar

The way in which the data are displayed can be modified by

- using the **Display Attribute buttons** 

(if the data are shown as an image) or 

(if shown as a graph),
- the **Viewer Menu**,
- the **context menu** (right-mouse click),
- and for graphs - clicking on the vertical axis **Intensity (Counts)** label.

Changing the Display Type

LightField automatically displays the data based on the experiment setup. However, you can change the display type to show data as images or graphs. To change the Display Type, right-mouse click on the view to open context menu. Select **Display Type** and select **Auto**, **Image**, or **Graph**. You can also change the display type via the view's **Viewer Menu**.

Adjusting Brightness and Contrast

You can change the overall brightness levels and/or change the grayscale contrast of an image by clicking on the **Brightness/Contrast** button , and on the **Brightness and Contrast** control, changing the low to high intensity range via buttons, drag bars, and/or keyboard entry. The brightness and contrast of the image will change as you change intensity levels.

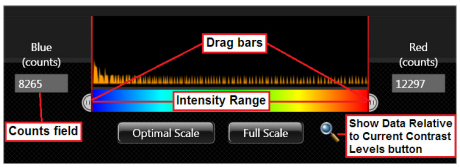


Figure 176. Brightness and Contrast control

New data is displayed using **Optimal Scale** or **Full Scale**, depending on the check box state on the **Application Options|General** tab. If **Optimal Scale** is the default, the drag bars are positioned to EXCLUDE the lowest and highest 1% of intensity values. If **Full Scale** is the default, all pixel intensities are used in the histogram and the drag bars positioned at outer edges. The **Show Data Relative to Current Contrast Levels** button can be used if your data is changing (due to light levels, for example) and you want to show your histogram with respect to new data.

Pressing the **Optimal Scale** or **Full Scale** button on the **Brightness and Contrast** control refreshes the histogram and moves the right and left drag bars out to those limits. You can either the use the drag bars to change histogram settings or you can also type the exact intensity value into a **Counts** field to position its related drag bar, rather than using the less precise way of clicking and dragging. When typing intensity values into one of these fields, you can enter a value that is less or GREATER than what is already there: this functionality is useful if you KNOW that during the course of your experiment your intensity values will end up within that range. When you type into these fields, LightField automatically adjusts to **Show Data Relative to Current Contrast Levels**. This is helpful when you enter an intensity value (in the left field) that is less than what is currently visible or a right field intensity value that is greater than what is currently visible. When you move a drag bar, the related **Counts** field updates with the new value. When you change the value in a **Counts** field, the related drag bar moves accordingly.

Note: The colors used in the slide bar gradient below the histogram are those selected via the **Pseudo Color** option. The field labels are also affected. For example, if the pseudo color range choice is **None**, the fields will be labeled **Black** and **White**. If the choice is **Blue/Red**, the fields will be labeled **Blue** and **Red**.

Autoscaling Contrast

Auto-Scale Contrast is used to adjust the intensities across the image to the contrast scaling as determined from the values in the entire image or in a selected area of the image. You can select an area of an image by using the mouse cursor to draw a selection box in the viewer. If you then click on the **Auto-Scale Contrast** button , the selected area will then be used to determine the amount of contrast to be applied across the entire image. If you have used the **Brightness/Contrast** function, clicking on the **Auto-Scale Contrast** button restores the contrast scaling of the image as determined from the values in the selected data set.

Zooming

Clicking on the **Magnifier** button opens the **Zoom** control which allows you to change the magnification used to display the graph or image. Typically, the baseline magnification for graphs 1.00x and 100% for images.

Graph Zoom or Image Zoom

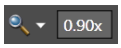
Figure 177. Zoom controls

Note: Depending on the sensor size, image magnification may be less than 100%. If, for example, the data set is from a 2048 x 2048 sensor, the image display area is small, and "Fit to Window" is selected, the resulting magnification may be less than 100% (for example, 35%) and that percentage will be the baseline from which you can zoom in.

Zooming a Graph

The zoom functions available for the displayed data depend on the current display type. This topic discusses the zoom controls for graphs. In addition to the zoom tools located in the viewer, you can zoom in and out using a mouse scroll wheel or you can use keyboard commands.

Zoom Tools



Zoom Controls: Displayed when you click on the **Magnifier** button, the slider zooms in or out. Drag the slider up to zoom in and down to zoom out. The currently selected button determines the direction(s) of the zoom. When zooming is in process or has been performed, a slide bar is activated below the viewer.

Figure 178. Zoom control

- Zooms horizontally and vertically.
- Zooms horizontally.
- Zooms vertically.

Zoom Level (0.90x-100.00x): Reports the zoom level. The entry field allows you to key in a value for more precise control of the zoom.

> **Note:** When used, the **Horizontal and Vertical Autoscaling**, and **Horizontal Autoscaling**, and Vertical Autoscaling functions set the **Zoom Level** to **0.90x**.

Mouse Scroll Wheel: If your mouse has a scroll wheel, you can use it to change the zoom level in the viewer. Position the cursor on the viewer. Roll the wheel up to zoom in and down to zoom out.

Keyboard Commands: If you prefer to use keyboard commands for the zoom function, click in the display area and use the following keys:

- **Plus** = Zoom in
- **Minus** =Zoom out

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad.

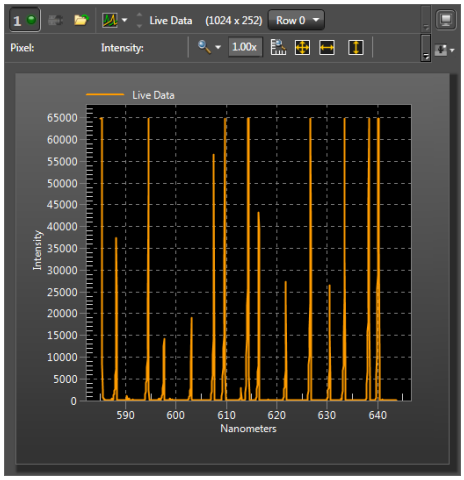


Figure 179. Graph at 1.00x

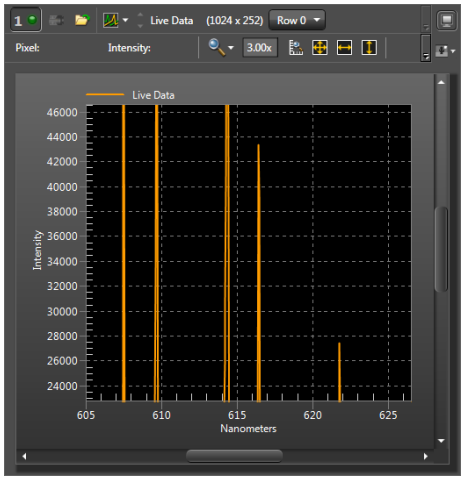
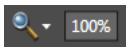


Figure 180. Same Graph Zoomed 3.00x

Zooming an Image

The zoom functions available for the displayed data depend on the current display type. This topic discusses the zoom functions for images. In addition to the zoom tools located in the viewer, you can zoom in and out using a mouse scroll wheel or you can use keyboard commands. If the entire image is too big to fit in the display window, you can use the scrollbars to see the entire image or you can zoom out.

Zoom Tools



Zoom Slider: Displayed when you click on the **Magnifier** button, the slider zooms in or out. Drag the slider up to zoom in and down to zoom out. When zooming is in process or has been performed, a slide bar is activated below the viewer.

Zoom Percentage (100%-6400%): Reports the zoom percentage. The entry field allows you to key in a value for more precise control of the zoom.

Mouse Scroll Wheel: If your mouse has a scroll wheel, you can use it to change the zoom level in the viewer. Position the cursor on the viewer. Roll the wheel up to zoom in and down to zoom out.

Keyboard Commands: If you prefer to use keyboard commands for the zoom function, click in the display area and use the following keys:

- **Plus** = Zoom in
- **Minus** =Zoom out

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad.

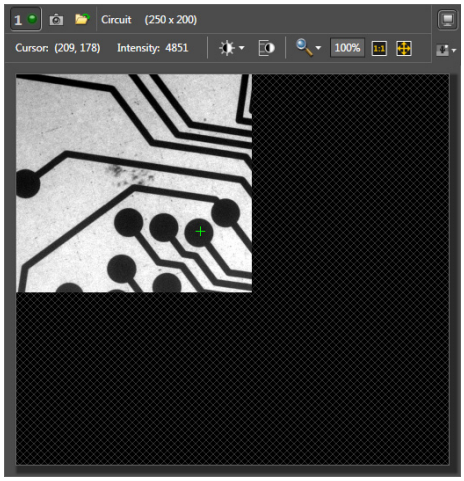


Figure 181. Image at 100%

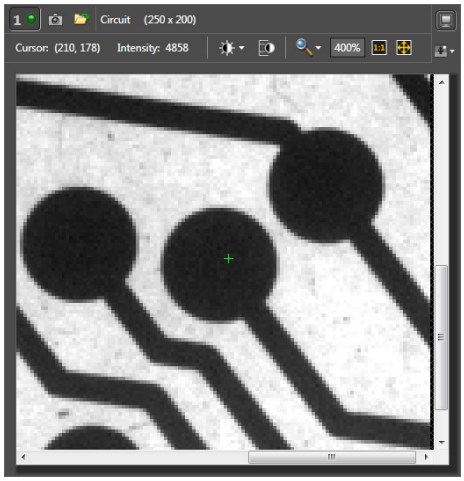


Figure 182. Same Image Zoomed to 400%

Autoscaling a Graph

The **Autoscale** tools are used to fit the graph to the viewable area. The spectral line(s) can be stretched horizontally, vertically, or in both directions. Autoscaling can be applied to the entire graph or to a selected area of the graph. Keyboard commands are also available for some of the autoscaling functions.

Autoscale Tools

- **Horizontal and Vertical Autoscaling**: Stretches the spectral line(s) in the horizontal and vertical directions to fit into 0.90x of the viewer height and width.
- **Full Scale**: Sets the vertical and horizontal axes to the 0.90x scale (whichever is the greater range, the one specified by the data or the one specified by the user via setting a greater Axis Visible Range).
- **Horizontal Autoscaling**: Fits the graph (or selected section of the graph) to 0.90x of the viewer width.
- **Vertical Autoscaling**: Fits the graph (or selected section of the graph) to 0.90x of the viewer height

Keyboard Commands

If you prefer to use keyboard commands instead of the **Horizontal and Vertical Autoscaling** and **Full Scale** tools, click in the display area and use the following keyboard combinations:

- **Ctrl+Minus** = This command is equivalent to the **Horizontal and Vertical Autoscaling** tool.
- **Ctrl+Plus**: This command is equivalent to the **Full Scale** tool that restores the vertical and horizontal axes o the 0.90x scale (whichever is the greater range, the one specified by the data

or the one specified by the user via setting a greater Axis Visible Range).

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad. For key combinations joined by a plus sign (Ctrl+S), press and hold the first key while you press the second key.

Scaling a Selected Area

1. Position the cursor on the viewer at a starting point for the selection box.
2. Depress the mouse button and drag the selection box to surround the area of interest.
3. When you release the mouse button, spectral line(s) within the blue selection box will be highlighted in blue and this section of the graph will be autoscaled when you use one of the **Autoscale** tools.
4. You can now use the **Autoscale** tool(s) to expand the selected area.

Example of a Selected Area and an Autoscaled Graph

The selected portion of the graph was autoscaled using the **Horizontal and Vertical Autoscaling** tool.

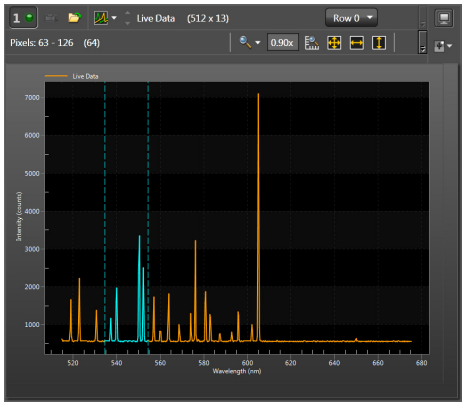


Figure 183. Graph with Selection Box

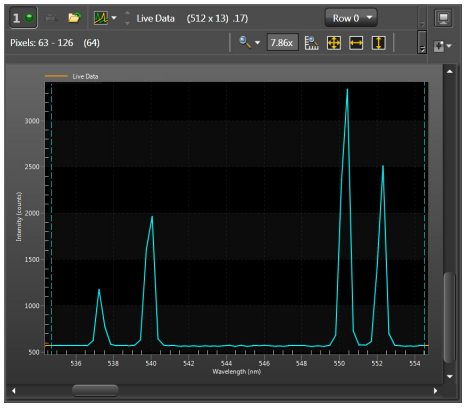


Figure 184. Autoscaling based on Selection

Fitting an Image to a Viewer

The **Fit to Window** tools are used to fit the graph or image to the viewer area. In the case of images, the aspect ratio of the image is always maintained. In the case graphs, the spectral line(s) can be stretched horizontally, vertically, or in both directions. Autoscaling can be applied to the entire image or graph or to a selected area of the image or graph. Keyboard commands are also available for some autoscaling functions.

Fit to Window Tools

Fit to Window : This tool fits the entire image (or selected area) as large as it can into the viewable area.

Actual Size : Sets the vertical and horizontal axes to full scale (whichever is the greater range, the one specified by the data or the one specified by the user via setting a greater Axis Visible Range).

Keyboard Commands

If you prefer to use keyboard commands instead of the tools, click in the display area and use the following keyboard combinations:

- **Ctrl+Minus** = This command is equivalent to the **Fit to Window** tool.
- **Ctrl+Plus**: This command is equivalent to the **Actual Size** tool.

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad. For key combinations joined by a plus sign (Ctrl+S), press and hold the first key while you press the second key.

Scaling a Selection

1. Position the cursor on the viewer at a starting point for the selection.
2. Depress the mouse button and drag the selection box to surround the area of interest.
3. When you release the mouse button, the area of interest within the red selection box will be autoscaled when you use one of the autoscale tools.
4. You can now use the Autoscale tool(s) to expand the selected area.

Example of a Selection Box and Fitting to a Window
The selection was fitted to the viewable area using the **Fit to Window** tool.

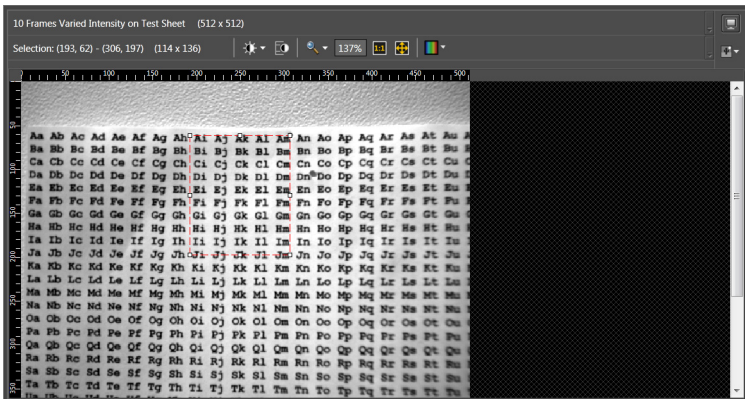


Figure 185. Image with Selection Box

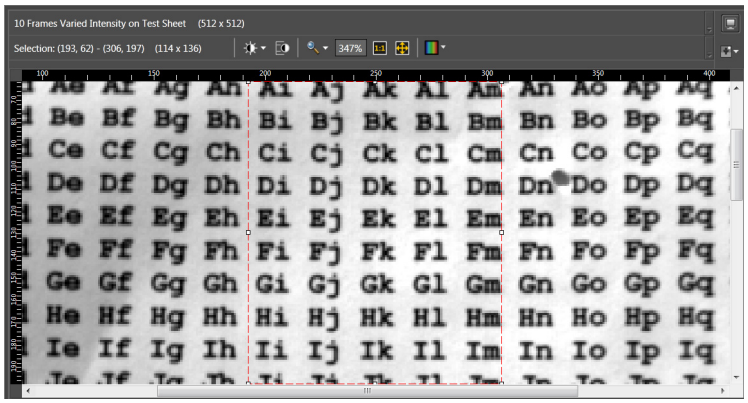


Figure 186. Fit to window based on Selection

Identifying Peaks

Available when the Display Mode is Graph, the Peak Finding function locates peaks and the peak widths at Full Width Half Maximum (FWHM).

Click on the **Peak Finding** button and choose the icon that most resembles your data, the peaks will be identified. If **Verbose** is checked, wavelength (x) and intensity (y) are shown next to each peak label, and a width next to the Full Width Half Max **X**s if you are showing them. The **Show Full Width Half Max** (FWHM) check box determines whether or not the Full Width Half Max **X**s are shown.

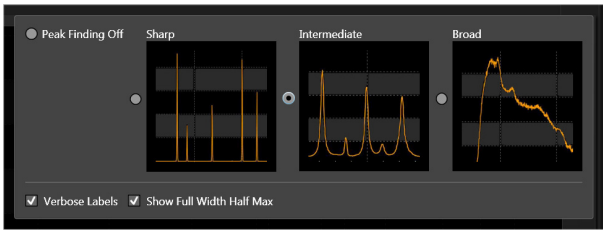


Figure 187. Peak Finding Choices

Displaying the Data Cursor

By default the cursor is either a small cursor (image) or it is not shown (graph). You can, however, change to a large cursor (image) or display a large cursor (graph) by making the selection via the context or viewer menu.

Showing a Frame Cross Section

Frame cross sections can only be displayed for previously acquired data containing multiple frames. When this function is active, a frame cross section of the multiple frame data will be displayed below the viewer. The frame cross section displays a cross section based on the cursor's location in each frame. The cross section of data containing five frames would have five data points (one for the same location in each frame).

Before you can view a frame cross section, you must load a multi-frame data file into one of the views. Then for graphically displayed data, you can select **Show Frame Cross Section** via the context or **Viewer Menu** (**Graph Options**). For data displayed as an image, you can select **Show Frame** from the context menu (**Cross Sections**) or **Viewer Menu** (**Image Options|Cross Sections**).

Disabling Horizontal Axis Calibration

When calibrated data are displayed, the horizontal axis is drawn in terms of the calibration. By selecting **Disable Horizontal Axis Calibration** from the **Viewer Menu**'s **Graph Options** submenu, you force the axis label to be changed to Pixels and the vertical grid lines and horizontal axis to be drawn accordingly. The data has not changed: it is the same information but drawn relative to the sensor pixels. The horizontal axis will be redrawn using calibration units when you deselect this option.

Marking the Data Points

By default, data displayed as a graph are shown as a continuous line. You can change the line to include each data point drawn as a circle on the graph by selecting **Marked Data Points** on the **Viewer Menu**'s **Graph Options** submenu.

Displaying/Hiding Grid Lines

By default, grid lines are not shown in a view. However, you can choose to show all grid lines, vertical or horizontal grid lines, or no grid lines via the **Viewer Menu**'s **Graph Options|Grid Lines** submenu.

Plotting as Line or Points

By default, data displayed as a graph are shown as a continuous line. You can change the data plotting to a series of data points represented by small circles by selecting **Point Only** on the **Viewer Menu**'s **Graph Options|Plot** submenu.

Manually Modifying the Vertical Axis Range

If data are shown as a graph, you can mouse click on the vertical axis to open the **Vertical Axis Visible Range** popup. There you can enter new beginning and/or ending point(s) for the vertical axis range. To implement this new range, click on the **Set** button 

: the popup will close and the vertical scale will be redrawn. To revert to the full scale vertical range, click on the **Auto-Scale Vertical Axis** button .

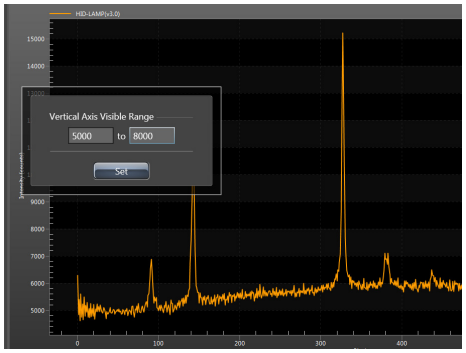
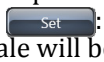


Figure 188. Vertical Axis Visible Range popup

Manually Modifying the Horizontal Axis Range

If data are shown as a graph, you can mouse click on the horizontal axis to open the **Horizontal Axis Visible Range** popup. There you can enter new beginning and/or ending point(s) for the vertical axis range. To implement this new range, click on the **Set** button 

: the popup will close and the vertical scale will be redrawn. To revert to the full scale vertical range, click on the **Auto-Scale Horizontal Axis** button  .

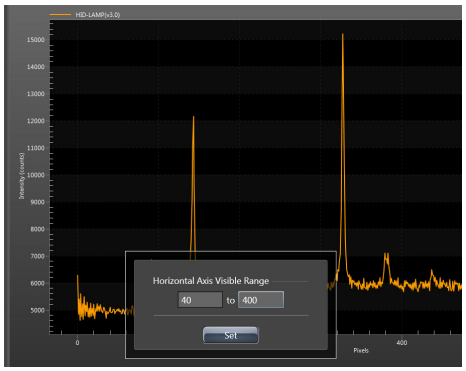


Figure 189. Horizontal Axis Visible Range popup

Selecting Cross Sections

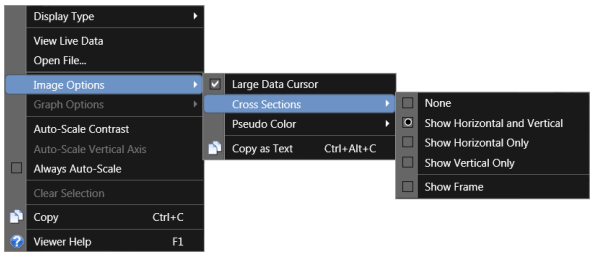


Figure 190. Cross Sections selection

The Horizontal and Vertical Cross Sections selection is available when the data are displayed as an image. When you select Cross Sections, you can choose whether horizontal and/or vertical cross sections

will be displayed with the image data. To activate cross sections from the **Viewer Menu**, select **Image Options**, select **Cross Sections**, and then make your choice. Alternatively you can activate them from the viewer context menu, by selecting **Cross Sections** and then making your choice. When you begin previewing or acquiring data, the cross section(s) will be displayed based on the cursor location.

In the Experiment Viewer, a frame cross section can only be turned on if you have loaded previously acquired data into a view and the data set has multiple frames.

Tip: You can turn a horizontal or vertical cross section on or off by right-clicking in that cross section and then de-selecting it. A frame cross section can only be turned off via this method.

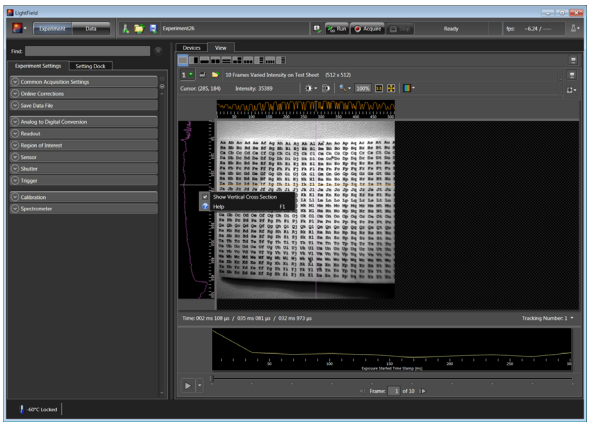


Figure 191. Horizontal, Vertical, and Frame Cross Sections in a Viewer

Selecting Pseudo Color/Grayscale

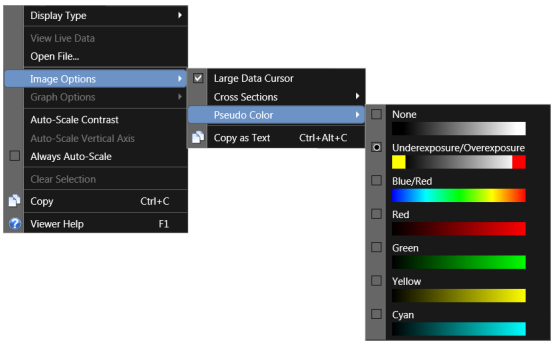


Figure 192. Pseudo Color selection

The **Pseudo Color** option determines whether the image will be displayed using grayscale or using a combination of grayscale; a combination of grayscale, yellow, and red; blue to red; black to red; black to red; black to yellow; or black to cyan. You can choose the image color scheme via the **Pseudo Color** menu item (shown in above) or via the **Pseudo Color** button in the Viewer toolbar.

- **None:** Only grayscale colors will be used.
- **Underexposure/Overexposure:** Underexposed areas in an image will be colored yellow (pixel values from 0-100). Overexposed areas will be colored red (pixel values from 65,000-65,535). This allows you to see potential image quality issues and make changes to your experiment design. Depending on experiment requirements, you may want to adjust the ambient light level, exposure time, binning, and/or gain settings.
- **Blue/Red:** Uses the full spectrum to display an image.
- **Other Choices:** Use a gradient composed of black and shades of the designated color to display an image.

Note: If you use the Brightness and Contrast control, the colors used in the slide bar gradient below the histogram are those selected via the **Pseudo Color** option.

Making a Selection on an Image or Graph

Selections can be used to define the portion of data to be used for autoscaling functions. When data are shown as a graph, click and drag the mouse cursor horizontally and then release to draw the selection box (the area between the blue dashed lines has been selected). When data are shown as an image, click and drag the mouse cursor in any direction and release to draw the selection box (the area within the resizable red dashed box is selected).

Clearing a Selection

Clearing a selection removes the selection box. Clearing a selection removes the selection box and subsequent scaling will be based on the entire image or graph.

Turning Timing Panel Information On/Off

When **Time Stamping**, **Frame Tracking**, **Modulation Tracking** and/or **Gate Tracking** is active on the **Common Acquisition Settings** expander, this information will be displayed in the **Timing** panel below the displayed data while the data are being acquired or previewed (i.e., data are being acquired, displayed, and discarded) in the **Experiment workspace** or being reviewed in the **Data workspace**. If time stamping, frame tracking, and/or gate tracking was active for an acquisition, you can also turn off/on the display of this information after clicking on the small triangular button at the righthand side of the Timing panel. When the **Time Stamp/Tracking** dialog pops up, you can change time stamp scaling and select/deselect the display of time stamping, calculated exposure time, gate width tracking, gate delay tracking, modulation phase tracking, and frame tracking numbers.

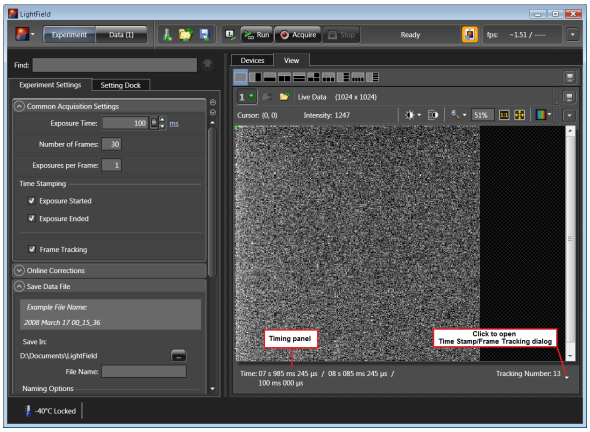


Figure 193. Timing panel

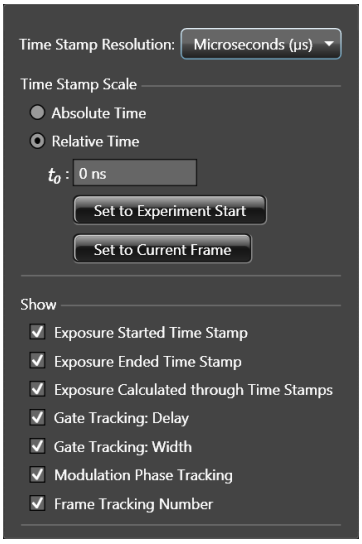


Figure 194. Time Stamp and Tracking dialog

Chapter 8: Data Workspace

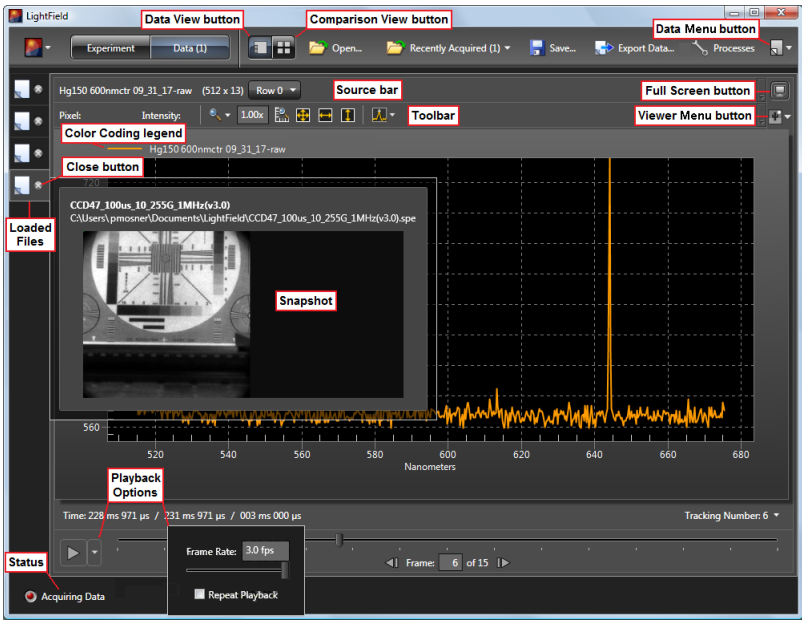
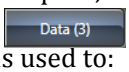


Figure 195. Data View with Callouts

Introduction to the Data Workspace

The Data workspace, accessed by clicking on the **Data** button 

in the Experiment workspace, is used to:

- Display recently acquired and/or stored data: no live data is displayed
- Perform post-processing operations on selected data
- Save modified data to .SPE files
- Export data to other file formats (.FTS, .SPC, .TIF, and .TXT)
- Examine and compare multiple data sets

The task you want to perform determines whether you will be using the Data View or the Comparison View window. Operations that modify data or export data to other file formats are performed in the Data View window. Viewing and comparing multiple data sets are performed in the Comparison View window.

This chapter briefly describes the Data View and Comparison View windows. Then it reviews the data display functions that both windows use: many of these functions were previously described for the Experiment Workspace in ***"Chapter 7: Data Acquisition and Display" on page 97***.

Specifying the Default Data Directory

The default working and scratch directories can be specified after selecting **Options** from the **Application Menu** and selecting the **General** tab on the **Applications Options** dialog. Unless you change the directory on the **Save Data File** expander, LightField will automatically store data to the working directory. The scratch directory is used for temporary files.

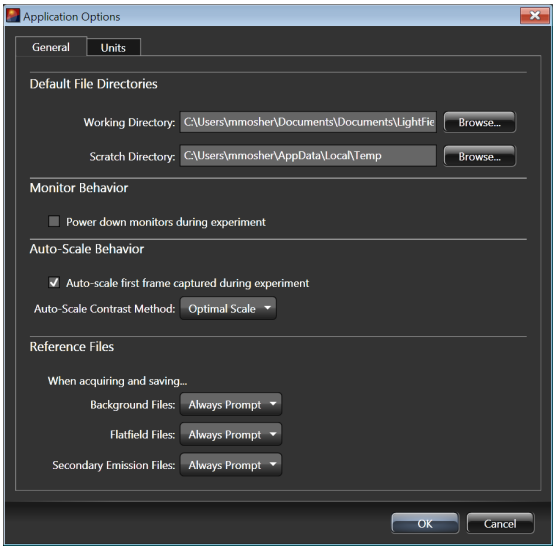


Figure 196. Application Options dialog: General tab

Data Menu

Data and Comparison window choices are listed on the related Data Menus (accessed by clicking on the **Data Menu** button). Active choices depend on the active Data workspace window.

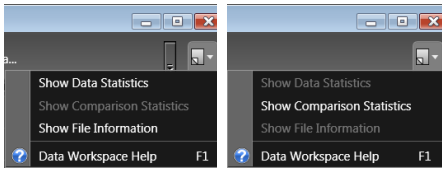


Figure 197. Data Menu: Data and Comparison Views

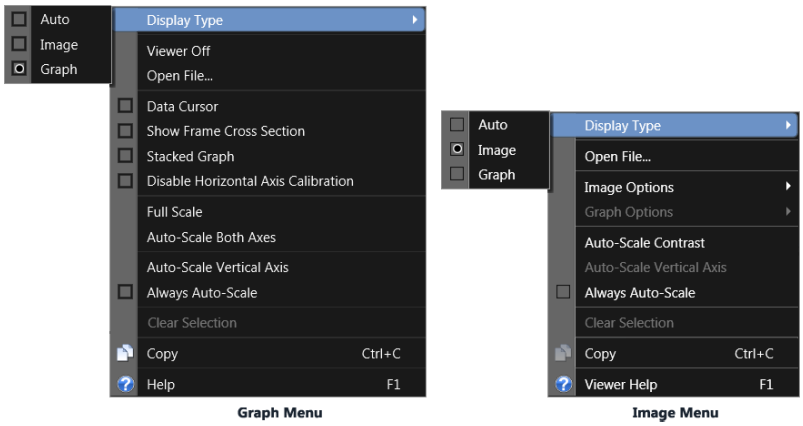


Figure 198. Data Workspace: Viewer menus

Viewer Menus

Choices on the Viewer menu (available when data viewers are active) determine whether data will be displayed as an image or a graph; with autoscaling; with pseudo color for images; or with stacked graphs, marked data points, grid lines, calibrated data with horizontal axis in pixels, and/or line or point-only plotting for graphs. Each view in a selected view layout has its own **Viewer Menu** button for access to choices that control how data in a view will be displayed. There will be some variation on the choices available depending on the workspace and window.

Context Menus

A context menu is specific to a view and is opened by right-clicking within a view. Note that some items in the context menus are also listed in the Viewer Menus and their submenus. The menus shown (Figure 199) are from the Comparison View: the **Viewer Off** and **Open File...** choices are not available on the context menus for the Data View.

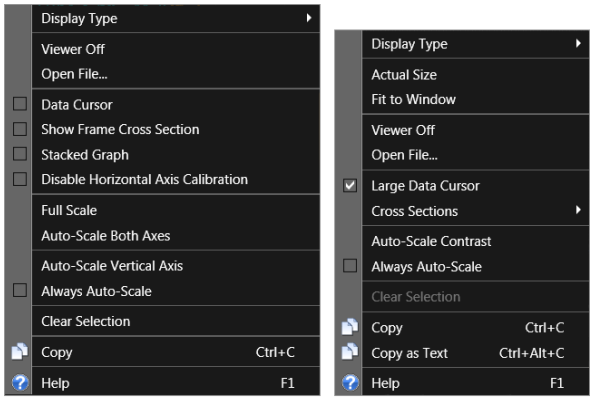


Figure 199. Context menus

Other Data Workspace Features

- The **Application Menu** button allows you to view application information and to change application options (default working and scratch directories, calibration units, exposure time units, and monitor power down during an experiment).
- The **Full screen** button associated with each viewer or view will display the viewer or view across the entire monitor screen.
- The **Experiment Workspace** and **Data Workspace** buttons Experiment Data (5) open the Experiment or the Data workspace. If you are in the Data workspace, that button is highlighted.
- The **Data View** and **Comparison View** buttons allow you to switch between the two Data Workspace views.
- LightField's online help can be opened at any time by pressing the F1 key. Expander help topics can be opened by clicking on the expander title bar and pressing the F1 key. Many of the menus contain links to help topics related to the feature you are using.

Changing Data Display Attributes

Introduction

Recently acquired and previously acquired data can be displayed as images or as graphs. If you have just acquired data, the last frame of that data will be automatically displayed in the **Experiment View** and can be viewed in the **Data View** by clicking on the **Review Acquired Data** button: this automatically loads the file into the Data View.

You can also load data into the Data View, by selecting data from the **Recently Acquired** folder or by using the **Open...** folder function. A data file that has been loaded to the Data View is indicated on the left side of the window by a Loaded File icon and can be viewed by clicking on that icon. Only one file can be displayed at a time. One advantage to Data View over Experiment View is that if there are multiple frames in the data set, you can playback any or all of the frames.

If you are in the Comparison View, up to five separate views can be displayed: the view arrangement is selectable by clicking on one of the view layout icons at the top of the viewer. Because the information is being displayed as a graph, the initial display a single row "Row 0" (the row at the top if the data were being displayed as an image).

The **Row** button Row 0 is labeled with the current Row number (you can change the displayed row by clicking on this button, scrolling down the list, and clicking on a different row).

Figure 200. Viewer Layout bar

The way in which the data are displayed can be modified by

- using the **Display Attribute buttons** 100% 1:1 (if the data are shown as an image) or 0.90x (if shown as a graph),
- the **Viewer Menu**,
- the **context menu** (right-mouse click),
- and for graphs - clicking on the vertical axis **Intensity (Counts)** label.

Changing the Display Type

You can change the display type to show data as images or graphs. To change the Display Type, right-mouse click on the view to open context menu. Select **Display Type** and select **Auto**, **Image**, or **Graph**. You can also change the display type via the view's **Viewer Menu**.

Adjusting Brightness and Contrast

You can change the overall brightness levels and/or change the grayscale contrast of an image by clicking on the **Brightness/Contrast** button, and on the **Brightness and Contrast** control, changing the low to high intensity range via buttons, drag bars, and/or keyboard entry. The brightness and contrast of the image will change as you change intensity levels.

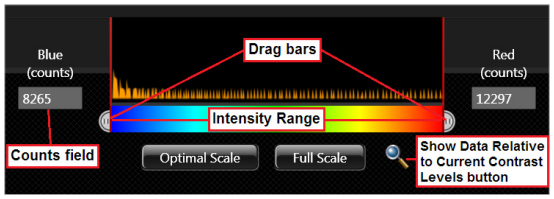


Figure 201. Brightness and Contrast control

New data is displayed using **Optimal Scale** or **Full Scale**, depending on the check box state on the **Application Options|General** tab. If **Optimal Scale** is the default, the drag bars are positioned to EXCLUDE the lowest and highest 1% of intensity values. If **Full Scale** is the default, all pixel intensities are used in the histogram and the drag bars positioned at outer edges. The **Show Data Relative to Current Contrast Levels** button can be used if your data is changing (due to light levels, for example) and you want to show your histogram with respect to new data.

Pressing the **Optimal Scale** or **Full Scale** button on the **Brightness and Contrast** control refreshes the histogram and moves the right and left drag bars out to those limits. You can either the use the drag bars to change histogram settings or you can also type the exact intensity value into a **Counts** field to position its related drag bar, rather than using the less precise way of clicking and dragging. When typing intensity values into one of these fields, you can enter a value that is less or GREATER than what is already there: this functionality is useful if you KNOW that during the course of your experiment your intensity values will end up within that range. When you type into these fields, LightField automatically adjusts to **Show Data Relative to Current Contrast Levels**. This is helpful when you enter an intensity value (in the left field) that is less than what is currently visible or a right field intensity value that is greater than what is currently visible. When you move a drag bar, the related **Counts** field updates with the new value. When you change the value in a **Counts** field, the related drag bar moves accordingly.

Note: The colors used in the slide bar gradient below the histogram are those selected via the **Pseudo Color** option. The field labels are also affected. For example, if the pseudo color range choice is **None**, the fields will be labeled **Black** and **White**. If the choice is **Blue/Red**, the fields will be labeled **Blue** and **Red**.

Autoscaling Contrast

Auto-Scale Contrast is used to adjust the intensities across the image to the contrast scaling as determined from the values in the entire image or in a selected area of the image. You can select an area of an image by using the mouse cursor to draw a selection box in the viewer. If you then click on the **Auto-Scale Contrast** button , the selected area will then be used to determine the amount of contrast to be applied across the entire image. If you have used the **Brightness/Contrast** function, clicking on the **Auto-Scale Contrast** button restores the contrast scaling of the image as determined from the values in the selected data set.

Zooming

Clicking on the **Magnifier** button opens the **Zoom** control which allows you to change the magnification used to display the graph or image. Typically, the baseline magnification for graphs is 1.00x and 100% for images.

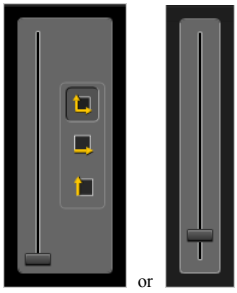


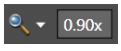
Figure 202. Zoom controls

Note: Depending on the sensor size, image magnification may be less than 100%. If, for example, the data set is from a 2048 x 2048 sensor, the image display area is small, and "Fit to Window" is selected, the resulting magnification may be less than 100% (for example, 35%) and that percentage will be the baseline from which you can zoom in.

Zooming a Graph

The zoom functions available for the displayed data depend on the current display type. This topic discusses the zoom controls for graphs. In addition to the zoom tools located in the viewer, you can zoom in and out using a mouse scroll wheel or you can use keyboard commands.

Zoom Tools



Zoom Controls: Displayed when you click on the **Magnifier** button , the slider zooms in or out. Drag the slider up to zoom in and down to zoom out. The currently selected button determines the

direction(s) of the zoom. When zooming is in process or has been performed, a slide bar is activated below the viewer.

Figure 203. Zoom control

- Zooms horizontally and vertically.
- Zooms horizontally.
- Zooms vertically.

Zoom Level (0.90x-100.00x): Reports the zoom level. The entry field allows you to key in a value for more precise control of the zoom.

Note: When used, the **Horizontal and Vertical Autoscaling**, and **Horizontal Autoscaling**, and Vertical Autoscaling functions set the **Zoom Level** to **0.90x**.

Mouse Scroll Wheel: If your mouse has a scroll wheel, you can use it to change the zoom level in the viewer. Position the cursor on the viewer. Roll the wheel up to zoom in and down to zoom out.

Keyboard Commands: If you prefer to use keyboard commands for the zoom function, click in the display area and use the following keys:

- **Plus** = Zoom in
- **Minus** = Zoom out

Note: "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad.

Zooming an Image

The zoom functions available for the displayed data depend on the current display type. This topic discusses the zoom functions for images. In addition to the zoom tools located in the viewer, you can zoom in and out using a mouse scroll wheel or you can use keyboard commands. If the entire image is too big to fit in the display window, you can use the scrollbars to see the entire image or you can zoom out.

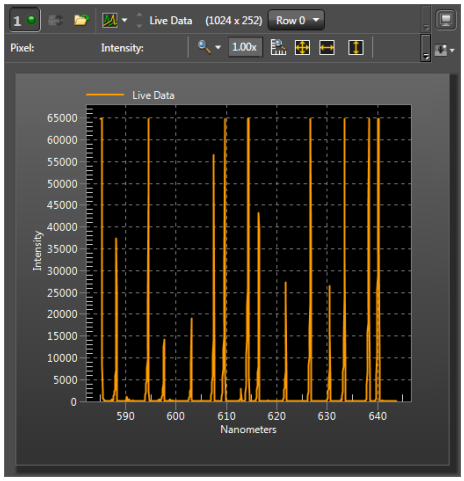


Figure 204. Graph at 1.00x

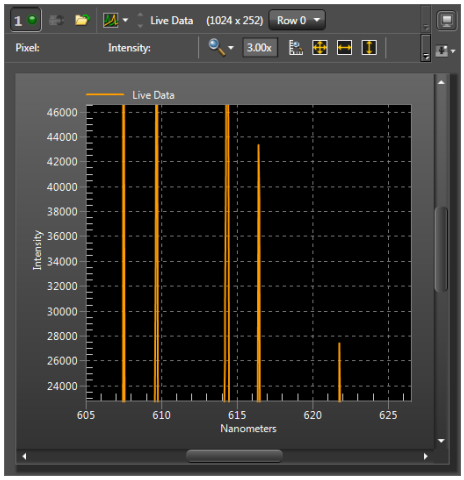
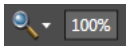


Figure 205. Same Graph Zoomed 3.00x

Zoom Tools



Zoom Slider: Displayed when you click on the **Magnifier** button, the slider zooms in or out. Drag the slider up to zoom in and down to zoom out. When zooming is in process or has been performed, a slide bar is activated below the viewer.

Zoom Percentage (100%-6400%): Reports the zoom percentage. The entry field allows you to key in a value for more precise control of the zoom.

Mouse Scroll Wheel: If your mouse has a scroll wheel, you can use it to change the zoom level in the viewer. Position the cursor on the viewer. Roll the wheel up to zoom in and down to zoom out.

Keyboard Commands: If you prefer to use keyboard commands for the zoom function, click in the display area and use the following keys:

- **Plus** = Zoom in
- **Minus** = Zoom out

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad.

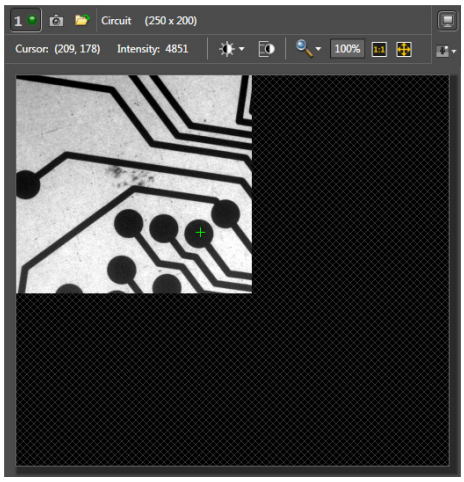


Figure 206. Image at 100%

Figure 207. Same Image Zoomed to 400%

Autoscaling a Graph

The **Autoscale** tools are used to fit the graph to the viewable area. The spectral line(s) can be stretched horizontally, vertically, or in both directions. Autoscaling can be applied to the entire graph or to a selected area of the graph. Keyboard commands are also available for some of the autoscaling functions.

Autoscale Tools

- **Horizontal and Vertical Autoscaling :** Stretches the spectral line(s) in the horizontal and vertical directions to fit into 0.90x of the viewer height and width.
- **Full Scale :** Sets the vertical and horizontal axes to the 0.90x scale (whichever is the greater range: the one specified by the data or the user-specified Horizontal and/or Vertical Axis Visible range(s)).
- **Horizontal Autoscaling** : Fits the graph (or selected section of the graph) tto 0.90x of the viewer width.
- **Vertical Autoscaling :** Fits the graph (or selected section of the graph) to 0.90x of the viewer height.

Keyboard Commands

If you prefer to use keyboard commands instead of the **Horizontal and Vertical Autoscaling** and **Full Scale** tools, click in the display area and use the following keyboard combinations:

- **Ctrl+Minus** = This command is equivalent to the **Horizontal and Vertical Autoscaling** tool.
- **Ctrl+Plus**: This command is equivalent to the **Full Scale** tool that restores the vertical and horizontal axes to full scale (whichever is the greater range: the one specified by the data or the user-specified Horizontal and/or Vertical Axis Visible range(s)).

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad. For key combinations joined by a plus sign (Ctrl+S), press and hold the first key while you press the second key.

Scaling a Selected Area:

1. Position the cursor on the viewer at a starting point for the selection box.
2. Depress the mouse button and drag the selection box to surround the area of interest.
3. When you release the mouse button, spectral line(s) within the blue selection box will be highlighted in blue and this section of the graph will be autoscaled when you use one of the **Autoscale** tools.
4. You can now use the **Autoscale** tool(s) to expand the selected area.

Example of a Selected Area and an Autoscaled Graph

The selected portion of the graph was autoscaled using the **Horizontal and Vertical Autoscaling** tool.

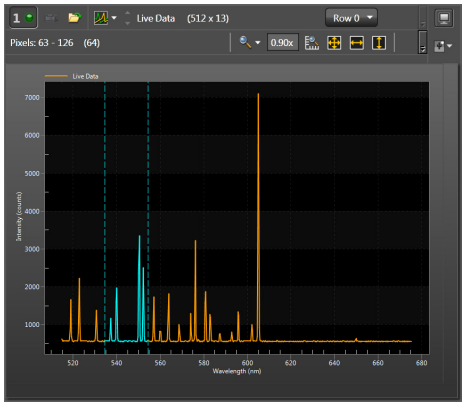


Figure 208. Graph with Selection Box

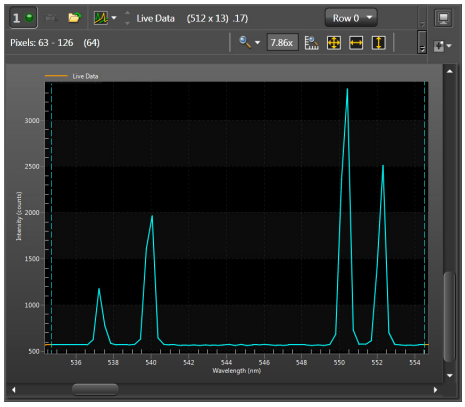


Figure 209. Autoscaling based on Selection

Fitting an Image to a Viewer

The **Fit to Window** tools are used to fit the graph or image to the viewer area. In the case of images, the aspect ratio of the image is always maintained. In the case graphs, the spectral line(s) can be stretched horizontally, vertically, or in both directions. Autoscaling can be applied to the entire image or graph or to a selected area of the image or graph. Keyboard commands are also available for some autoscaling functions.

Fit to Window Tools

Fit to Window : This tool fits the entire image (or selected area) as large as it can into the viewable area.

1:1: This tool shows as much of the entire image (or selected are) at its actual size. There is a one-to-one match of image pixels to display pixels.

Keyboard Commands

If you prefer to use keyboard commands instead of the tools, click in the display area and use the following keyboard combinations:

- **Ctrl+Minus** = This command is equivalent to the **Fit to Window** tool.
- **Ctrl+Plus**: This command is equivalent to the **1:1** tool.

> **Note:** "Plus" and "Minus" are the "+" and "-" keys on the keyboard number pad. For key combinations joined by a plus sign (Ctrl+S), press and hold the first key while you press the second key.

Scaling a Selection:

1. Position the cursor on the viewer at a starting point for the selection.
2. Depress the mouse button and drag the selection box to surround the area of interest.
3. When you release the mouse button, the area of interest within the red selection box will be autoscaled when you use one of the autoscale tools.
4. You can now use the Autoscale tool(s) to expand the selected area.

Example of a Selection Box and Fitting to a Window

The selection in Figure 210 was fitted to the viewable area using the **Fit to Window** tool. The result is shown in Figure 211.

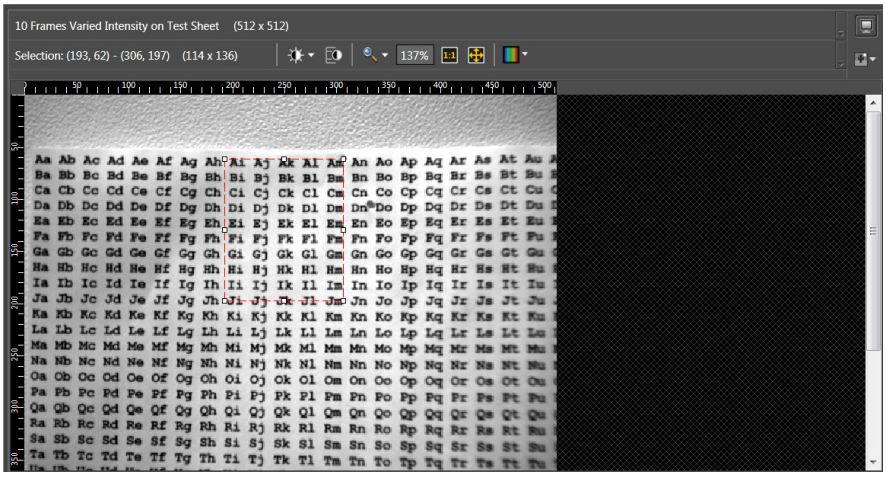


Figure 210. Image with Selection Box

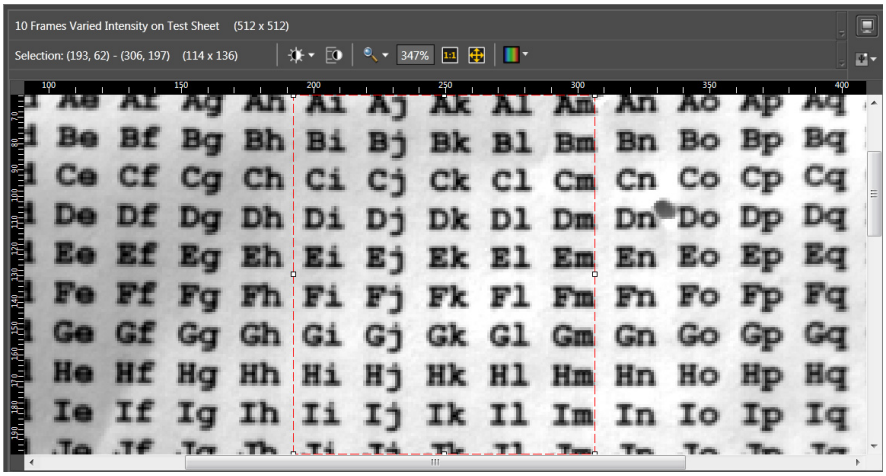


Figure 211. Fit to window based on Selection

Identifying Peaks

Available when the Display Mode is Graph, the Peak Finding function locates peaks and the peak widths at Full Width Half Maximum (FWHM). Click on the **Peak Finding** button and choose the icon that most resembles your data, the peaks will be identified. If **Verbose** is checked, wavelength (x) and intensity (y) are shown next to each peak label, and a width next to the Full Width Half Max **X**s if you are showing them. The **Show Full Width Half Max** (FWHM) check box determines whether or not the Full Width Half Max **X**s are shown.

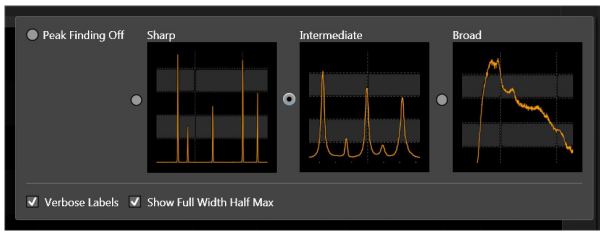


Figure 212. Peak Finding Choices

Displaying the Data Cursor

By default the cursor is either a small cursor (image) or it is not shown (graph). You can, however, change to a large cursor (image) or display a large cursor (graph) by making the selection via the context or viewer menu.

Showing a Frame Cross Section

Frame cross sections can only be displayed for previously acquired data containing multiple frames. When this function is active, a frame cross section of the multiple frame data will be displayed below the viewer. The frame cross section displays a cross section based on the cursor's location in each frame. The cross section of data containing five frames would have five data points (one for the same location in each frame).

Before you can view a frame cross section, you must load a multi-frame data file into one of the views. Then for graphically displayed data, you can select **Show Frame Cross Section** via the context or **Viewer Menu** (**Graph Options**). For data displayed as an image, you can select **Show Frame** from the context menu (**Cross Sections**) or **Viewer Menu** (**Image Options|Cross Sections**).

Disabling Horizontal Axis Calibration

When calibrated data are displayed, the horizontal axis is drawn in terms of the calibration. By selecting **Disable Horizontal Axis Calibration** from the **Viewer Menu**'s **Graph Options** submenu, you force the axis label to be changed to Pixels and the vertical grid lines and horizontal axis to be drawn accordingly. The data has not changed: it is the same information but drawn relative to the sensor pixels. The horizontal axis will be redrawn using calibration units when you deselect this option.

Marking the Data Points

By default, data displayed as a graph are shown as a continuous line. You can change the line to include each data point drawn as a circle on the graph by selecting **Marked Data Points** on the **Viewer Menu**'s **Graph Options** submenu.

Displaying/Hiding Grid Lines

By default, grid lines are not shown in a view. However, you can choose to show all grid lines, vertical or horizontal grid lines, or no grid lines via the **Viewer Menu**'s **Graph Options|Grid Lines** submenu.

Plotting as Line or Points

By default, data displayed as a graph are shown as a continuous line. You can change the data plotting to a series of data points represented by small circles by selecting **Point Only** on the **Viewer Menu**'s **Graph Options|Plot** submenu.

Manually Modifying the Vertical Axis Range

If data are shown as a graph, you can mouse click on the vertical axis to open the **Vertical Axis Visible Range** popup. There you can enter new beginning and/or ending point(s) for the vertical axis range. To implement this new range, click on the **Set** button Set: the popup will close and the vertical scale will be redrawn. To revert to the full scale vertical range, click on the **Auto-Scale Vertical Axis** button .

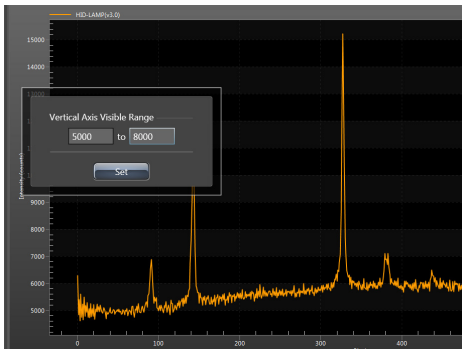


Figure 213. Vertical Axis Visible Range popup

Manually Modifying the Horizontal Axis Range

If data are shown as a graph, you can mouse click on the horizontal axis to open the **Horizontal Axis Visible Range** popup. There you can enter new beginning and/or ending point(s) for the vertical axis range. To implement this new range, click on the **Set** button Set: the popup will close and the vertical scale will be redrawn. To revert to the full scale vertical range, click on the **Auto-Scale Horizontal Axis** button .

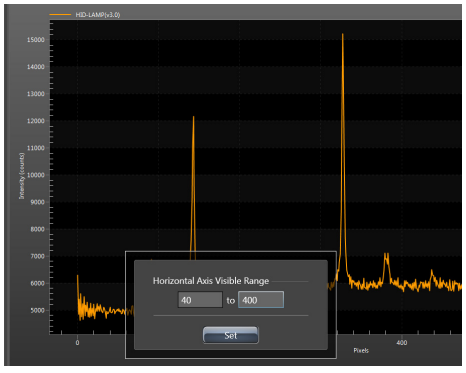


Figure 214. Horizontal Axis Visible Range popup

Selecting Cross Sections

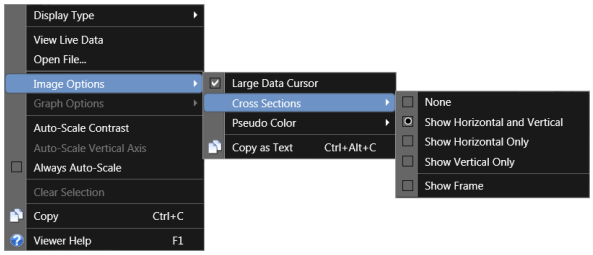


Figure 215. Cross Sections selection

The Horizontal and Vertical Cross Sections selection is available when the data are displayed as an image. When you select Cross Sections, you can choose whether horizontal and/or vertical cross sections will be displayed with the image data. To activate cross sections from the **Viewer Menu**, select **Image Options**, select **Cross Sections**, and then make your choice. Alternatively you can activate them from the viewer context menu, by selecting **Cross Sections** and then making your choice. When you begin previewing or acquiring data, the cross section(s) will be displayed based on the cursor location.

A frame cross section can only be turned on via the **Viewer Menu** or context menu if the loaded data set has multiple frames.

Tip: You can turn a horizontal or vertical cross section on or off by right-clicking in that cross section and then de-selecting it. A frame cross section can only be turned off via this method.

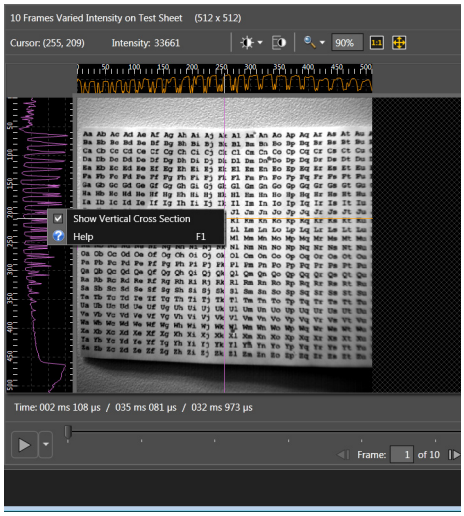


Figure 216. Horizontal and Vertical Cross Sections in a Viewer

Selecting Pseudo Color/Grayscale

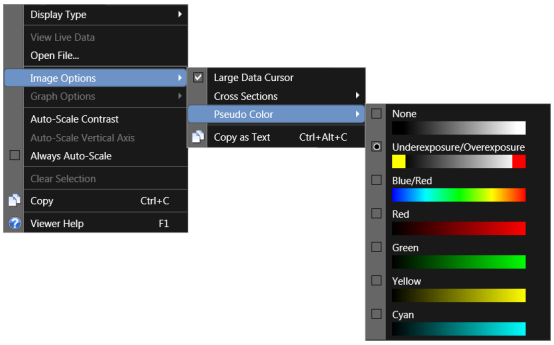


Figure 217. Pseudo Color selection

The **Pseudo Color** option determines whether the image will be displayed using grayscale; a combination of grayscale, yellow, and red; blue to red; black to red; black to red; black to yellow; or black to cyan. You can choose the image color scheme via the **Pseudo Color** menu item or the **Pseudo Color** button in the Viewer toolbar.

- **None:** Only grayscale colors will be used.
- **Underexposure/Overexposure:** Underexposed areas in an image will be colored yellow (pixel values from 0-100). Overexposed areas will be colored red (pixel values from 65,000-65,535). This allows you to see potential image quality issues and make changes to your experiment design. Depending on experiment requirements, you may want to adjust the ambient light level, exposure time, binning, and/or gain settings.
- **Blue/Red:** Uses the full spectrum to display an image.
- **Other Choices:** Use a gradient composed of black and shades of the designated color to display an image.

> **Note:** If you use the **Brightness and Contrast** control, the colors used in the slide bar gradient below the histogram are those selected via the **Pseudo Color** option.

Making a Selection on an Image or Graph

Selections can be used to define the portion of data to be used for autoscaling functions. When data are shown as a graph, click and drag the mouse cursor horizontally and then release to draw the selection box (the area between the blue dashed lines has been selected). When data are shown as an image, click and drag the mouse cursor in any direction and release to draw the selection box (the area within the resizable red dashed box is selected).

Clearing a Selection

Clearing a selection removes the selection box. Clearing a selection removes the selection box and subsequent scaling will be based on the entire image or graph.

Turning Timing Panel Information On/Off

When **Time Stamping**, **Frame Tracking**, **Modulation Tracking**, and/or **Gate Tracking** is active on the **Common Acquisition Settings** expander, this information will be displayed in the **Timing** panel below the displayed data while the data are being acquired or previewed (i.e., data are being acquired, displayed, and discarded) in the **Experiment workspace** or being reviewed in the **Data workspace**. If any of the time stamping and/or tracking features were active for an acquisition, you can also turn off/on the display of this information after clicking on the small triangular button at the righthand side of the Timing panel. When the **Time Stamp/Tracking** dialog pops up, you can change time stamp scaling and select/deselect the display of time stamping, calculated exposure time, gate width tracking, modulation phase tracking, gate delay tracking, modulation phase tracking, and frame tracking numbers.

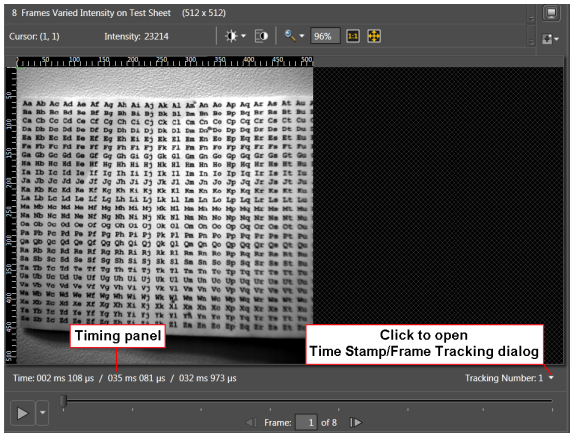


Figure 218. Timing panel

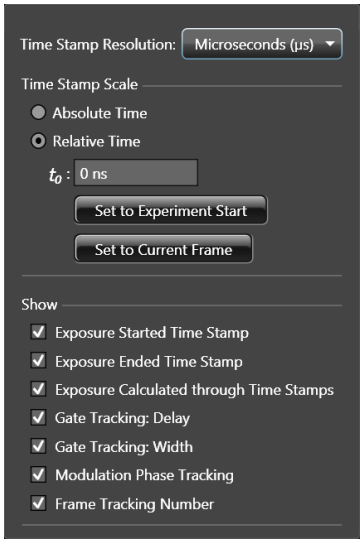


Figure 219. Time Stamp and Tracking dialog

Using Data View

Introduction

When a data set is opened in the **Data View**, an icon is placed in the lefthand panel. Positioning the mouse cursor above this icon opens a snapshot containing the file name and location of the data as well as a small image of the data set. Clicking on the icon will display the data in the view area.

- If the data contains multiple frames, you can manually cycle through the frames or set up playback (frames per second), with or without looping.
- If the data is shown as a graph or set of graphs, you can display the data one row at a time by selection from the Row drop-down list or by pressing the arrow keys on the keyboard.
- If there are multiple ROIs, you can select the ROI for display from the ROI drop-down list.

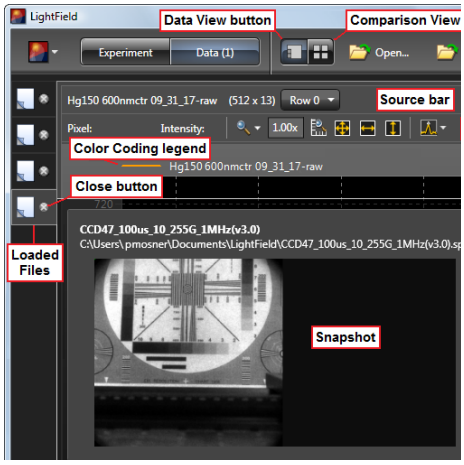


Figure 220. Loaded File icons and a Snapshot

The **Data Menu** allows you to access metadata and to view up to nine statistics for the currently displayed data file.

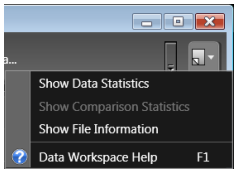


Figure 221. Data View: Data Menu

For detailed information about post-processing functions, ***see "Chapter 9: Data Export" on page 137***.

Note: If you are reviewing data in the Data View while LightField is running in Preview mode or Acquiring data, the message Running Experiment or Acquiring Data will be shown in the lower left corner of the viewer.

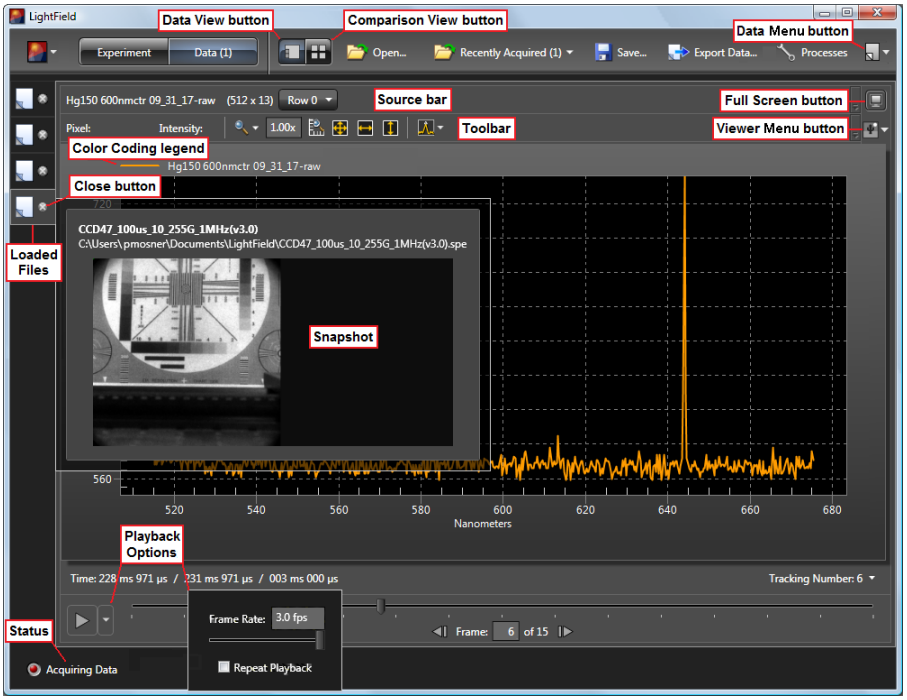


Figure 222. Data View with Callouts

Step-by-Step Procedure

1. Open the **Data** workspace.
2. Click on the **Data View** button if the Comparison View is currently open.
3. Retrieve the file or files you want to look at. You can open a file by:
   - Clicking on the **Open File...** button Open..., and retrieve the file.
   - Clicking on the **Recently Acquired** button Recently Acquired, select one or more of the files listed (use Shift+mouse click or Ctrl+mouse click), and click on the **Open** button.

   Note: A number such as (3) on the **Recently Acquired** button indicates how many recently acquired files have not yet been viewed in the Data View. A star next to a listed file indicates it has not been viewed. A listed file without a star has either been already viewed or is currently in the Data View.
4. After a file is opened, an **icon** representing it is shown in the lefthand panel. Mousing over the icon will open a panel that shows the file name, the file location, and a snapshot of the file contents. Clicking on the icon opens the file in the viewer.

   Note: If the icon is a light brown color, changes have been to the data in the file.
5. When a file is displayed in the viewer, you can change display attributes, export the data to a different file format, post-process the data, view statistics for the data, view file metadata, and save any changes you have made to the data file.
6. To change the contents of the viewer, click on a different file icon or open another file.
7. To close a file, click on the **Close** button to the right of the icon.
8. To open the Comparison View, click on the **Comparison View** button.

Opening Data Files

The **Open...** button pops up the **Open Data File(s)** dialog where you can select one or more files to open in the viewer. By default, the working directory is opened, but you can browse and open files from other file locations.

If you select version 2.x SPE file, a pop up dialog stating that LightField cannot open the file will be displayed. You can have LightField make the conversion to a version 3.0 SPE file and open the converted file in the viewer. Alternatively, you can open the SPE Conversion Tool which will locate version 2.x SPE files and convert those you select. After conversion, the data are stored to a file (or files) using the same name as the original data file(s) but with (v3.0) added to the file name. For example, if the original version 2.x file is named

"**laser scatter.spe**", the converted file will be named "**laser scatter(v3.0).spe**".

Note: LightField version 3.0 SPE files are more complex than WinX/32 version 2.x SPE files. The LightField converter allows you to view the data in LightField. File information, however, will be limited and multiple ROIs will be displayed using the WinX/32 side-effect ROIs (***see Figure 223.***) Converted data can be exported but it cannot be used in post-processes.

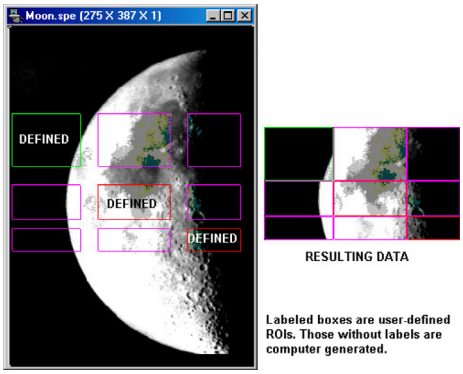
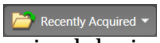


Figure 223. WinX/32 Side-Effect ROIs

Opening Recently Acquired Data

The **Recently Acquired** button 

drops down a list of data files acquired during the current LightField session. The most recently acquired data will always be at the top of the list. Data that has not been displayed before in the Data View has a star to the left of the file name. If the box to the left of the file name is empty, the data has already been opened. You can open multiple files by using Shift+mouse click or Ctrl+mouse click and then clicking on the **Open** button. An icon for each file will be placed in the lefthand panel.

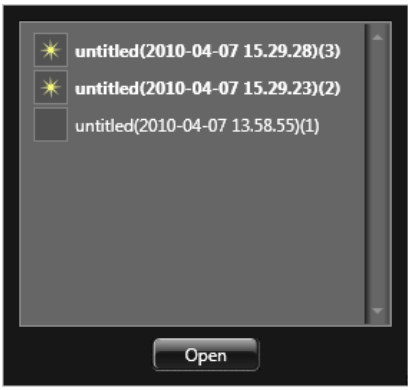


Figure 224. Recently Acquired Files list

Exporting Data

LightField always saves data to .SPE files (Princeton Instruments' proprietary file type). However, you can export data to other formats suitable for other data analysis or image processing applications. For detailed information, see ***"Introduction" on page 137.***

Post-Processing Data

The post-processing functions allow you to apply data corrections to data that has already been acquired and saved. These processes are the same corrections that can be applied as on-line corrections or frame combination while data are being acquired. For background subtraction, blemish correction, and flatfield correction, you will need to specify a valid correction file to be applied to the selected data.

The post-process functions are briefly described below. For detailed information, see ***"Chapter 10: Post-Acquisition Processes" on page 147***.

- **Background Subtraction:** The background subtraction file must have been acquired using the same experiment settings and equipment that was used to acquire the selected data.
- **Blemish Correction:** A user-generated .CSV file appropriate to the data will be used to remove column, row, and pixel blemishes.
- **Flatfield Correction:** The flatfield correction file must have been acquired using the same experiment settings and equipment that was used to acquire the selected data.
- **Frame Combination:** Sums or averages two or more frames into a single frame. If the number of frames to be combined do not evenly divide into the number of frames in the data set, the leftover frames at the end of the original data set will not be saved when you save the modified data.
- **Orientation Correction:** If after viewing the data, you realize that they are horizontally/vertically reversed or rotated, this correction rearranges the pixel information in the data set according to your choice.
- **Software Binning:** Allows you to bin data in the width and/or height directions.

Saving Data

After applying post-processing to a data set, you can save the modified data to disk.

Changing the Frame Displayed

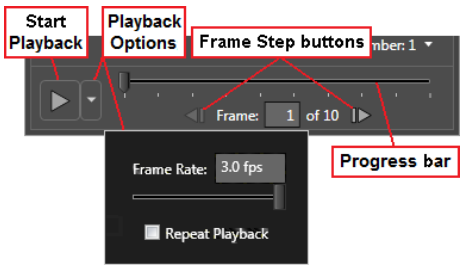


Figure 225. Playback and Step buttons

If you have loaded a previously acquired data set that contains multiple frames, the **Playback** buttons, **Frame Step** buttons and **Progress** bar are displayed below the data. You can manually cycle through the frames by clicking on one of the **Frame Step** buttons, you can pull the slider along the **Progress** bar, or you can set up **Playback** options (frame rate of display and playback repetition), and click on the **Start Playback** button to automatically step through the frames.

Note: If you selected the **Always Auto-Scale** function, each frame will be autoscaled when it is displayed.

Maximizing/Restoring a Viewer or View

You can maximize the entire Viewer Layout to a monitor or you can maximize individual views (within a Viewer Layout) to a monitor (the viewer and each view have **Full Screen** buttons). Click on the **Full Screen** button for the view or viewer to maximize. The full screen version of your viewer will have a button in the upper right corner to return it to normal size. If you have maximized a single view, it will also have a button to return it to normal size.

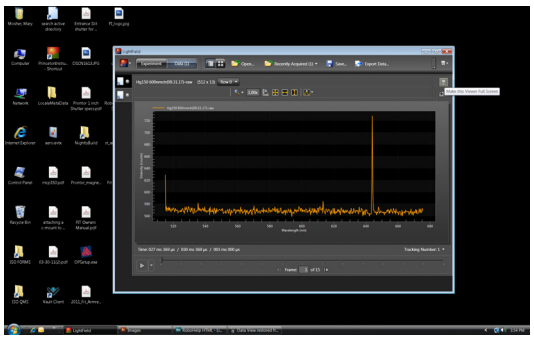


Figure 226. Data View: Normal Size

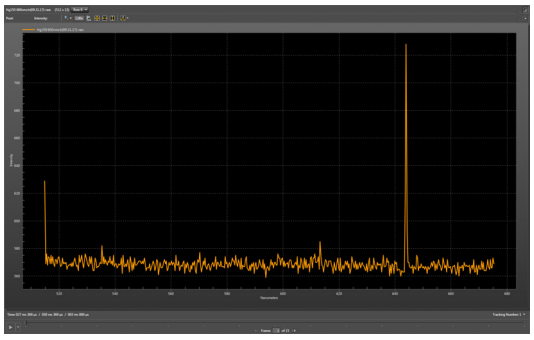


Figure 227. Data View: Maximized

Sending a View or Viewer to Different Monitor

If your computer has been configured with two monitors, the main LightField window can be stretched to span across more than one monitor. You can click the drop-down button to the right of the **Maximize** button to send the view or viewer to a different monitor. When you send something to a different monitor, the statement "This element is located on another monitor." appears along with a **Restore** button. The view will be maximized on the second monitor.

Viewing Data Statistics

Introduction

The **Data Statistics** dialog is selectable from the **Data Menu** after you have loaded data in the **Data View**. Up to nine pieces of statistical information for the data for the displayed data are reported on this dialog and can be saved to a .CSV file. This file can then be opened by an ASCII text editor or in a spreadsheet for analysis and graphing.

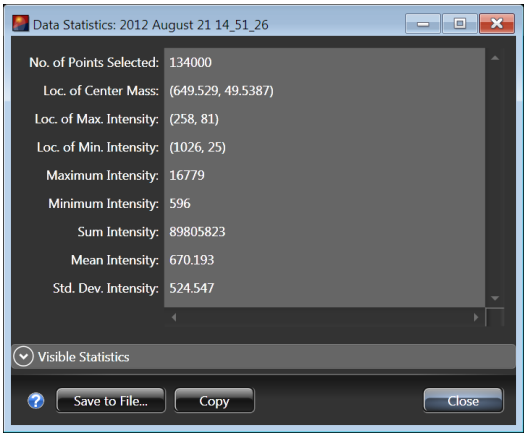


Figure 228. Data Statistics dialog

You can select/deselect a statistic and you can hide the statistics for a view by clicking on the **Viewer #** button above the appropriate column. Only those statistics that are displayed in the table will be available for saving to a file or copying to the clipboard.

Using Data Statistics

The statistics for the currently displayed data will be displayed in the dialog.

1. Open the **Data** workspace.
2. Click on the **Data View** button  to open Data View.
3. Open a recently acquired data set or load and open a data file. After that data are displayed, open the **Data Menu** and select **Show Data Statistics**.

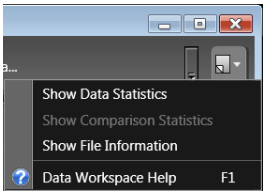


Figure 229. Data View: Data Menu

4. When the **Data Statistics** dialog opens, a set of statistics will be listed for the data.
5. Functions on the dialog allow you to choose the statistics (up to nine) to be saved. Only the statistical information visible on the dialog will be saved to the .CSV file or copied to the clipboard. To view the possible statistic choices, click on the expand button to the left of **Visible Statistics** (at the lower left of the dialog). Select or deselect the statistics you want. When you deselect a check box, the statistic associated with it will no longer be displayed in the dialog.
6. Now that you have chosen the statistics, you can click on
   - **Save to File...** to save the information to a .CSV file in the working directory or directory of your choice. The default name for a statistics file is "statistics". You may want to enter a more informative name before saving the file.
   - **Copy** to copy the information to the Windows clipboard. Once the information is in the clipboard, you can paste it into documents, spreadsheets, etc.
   - **Close** to quit without saving or copying or to quit after you have saved or copied the information.

Viewing File Information

Introduction

Each data file generated by LightField contains both the data and an extensive set of metadata. The metadata that includes information about the experiment setup, calibration, and other information that describes how the data was acquired and stored. If data are displayed in the viewer, you can view file information for that data by opening the **Data Menu** and selecting **Show File Information**. This pops up the **File Information** window which displays **General, Calibration**, **Frame Calibration**, and **Notes** information on separate tab panels, as appropriate. Information about the devices and settings used during the data acquisition and is shown on the **General** tab. If spectral data were acquired with a calibrated system, the Pixel/Wavelength values are available on the **Calibration** tab. The **Frame Calibration** tab will appear if the data being viewed are the result of generating and saving a post-process frame cross section: the information on the tab includes data for each point on the cross section and is calibrated in terms of any Time Stamping metadata features (such as Exposure Started, Frame Tracking, or Modulation Tracking, Phase) active when the original data were acquired.The **Notes** tab gives you a place to enter any additional notes about the experiment: just click in the tab panel and begin typing. These notes will be added to the file when you use the **Save Data** function.

Displaying File Information

1. Open the **Data** workspace.
2. Open **Data View**.
3. Open a recently acquired data set or open a data file. After that data are displayed, open the **Data Menu** and select **Show File Information**.
4. You can now review the metadata included in the data file.
5. After you have finished looking at the information, you can either
   - click on the **Save to File...** button to save the file information to an XML file that can be easily viewed in Internet Explorer, Visual Studio, Microsoft Word, or a text editor or
   - click on the **Close** button to close the window
6. If you have added notes or entered a laser line values to the file information, you will be asked if you want to save the file when you close the data file.

Notes:

1. Metadata may be limited if the data file has been converted from a WinX/32 version 2.0 SPE file to a LightField version 3.0 SPE file. Detailed information about the experiment setup may not be available.
2. If you have made changes to the file information for an SPE file, the file icon on the left will change from a light blue to a light tan and show a circle and dots. When you save the changed SPE file, the icon color will revert to the light blue. Unless you save the changed file, you will have to re-enter the added or changed information the next time you open the file.

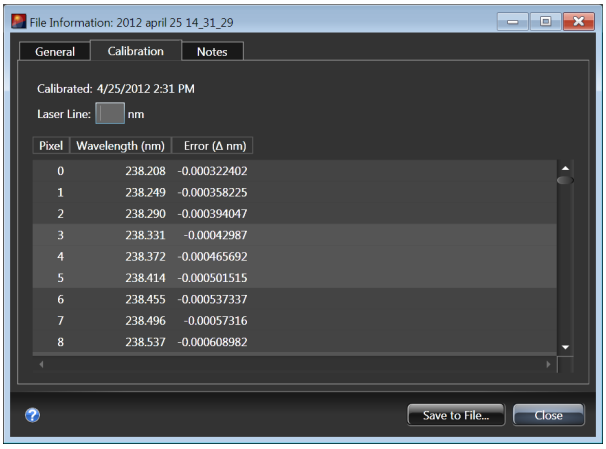


Figure 230. File Information: Calibration tab

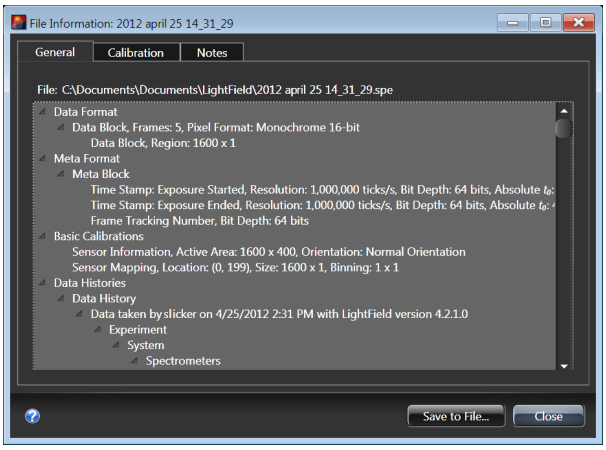


Figure 231. File Information: General tab

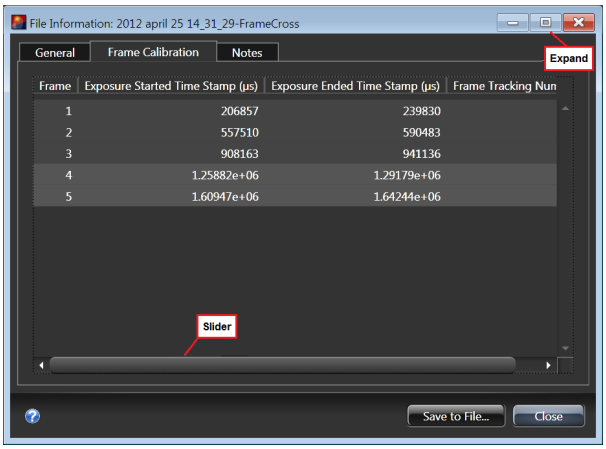


Figure 232. File Information: Frame Calibration tab

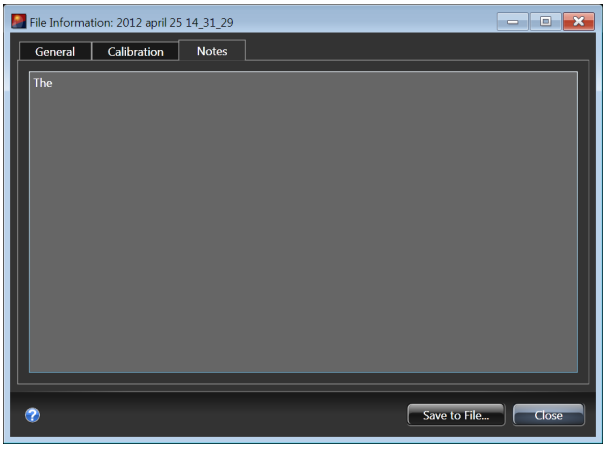


Figure 233. File Information: Notes tab

Copying

The **Copy** function copies the contents of a view as data points or as an image to the clipboard.

- When the data are displayed as a graph, the data points are copied as as tab-delimited text (culture-sensitive) and CSV (culture-invariant). Large image sizes or selections may take several seconds to copy.
- When the data are displayed as an image, the data are copied and are pasted as an image into graphics programs, spreadsheets, and word-processing programs.

Copying as Text

Copy as Text option is available when data is being displayed as an image. While **Copy** typically copies the image in the viewer as a picture, **Copy as Text** copies the data from the entire image or the data within the red pixel selection rectangle into the clipboard as tab-delimited text (culture-sensitive) and CSV (culture-invariant). Large image sizes or selections may take several seconds to copy.

Converting WinX/32.SPE Files

If you are opening a data file and LightField detects that it is a WinX/32 version 2.x SPE file it will pop up a dialog stating that LightField cannot open the file will be displayed. This dialog offers you the choices of making the conversion to a version 3.0 SPE file and opening the converted file in the image viewer or opening the **SPE Conversion Tool** which will locate version 2.x SPE files and convert those you select. After conversion, the data are stored to a file (or files) using the same name as the original data file(s) but with (v3.0) added to the file name. For example, if the original version 2.x file is named

"**laser scatter.spe**", the converted file will be named "**laser scatter(v3.0).spe**".

Note: LightField version 3.0 SPE files are more complex than WinX/32 version 2.x SPE files. The LightField converter allows you to view the data in LightField. File information, however, will be limited and multiple ROIs will be displayed using the WinX/32 side-effect ROIs (***see Figure 234.***). Converted data can be exported but it cannot be used in post-processes.

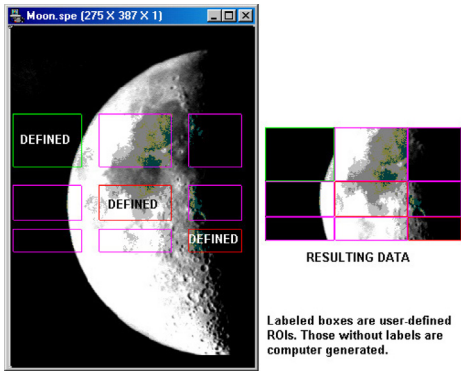


Figure 234. WinX/32 Side-Effect ROIs

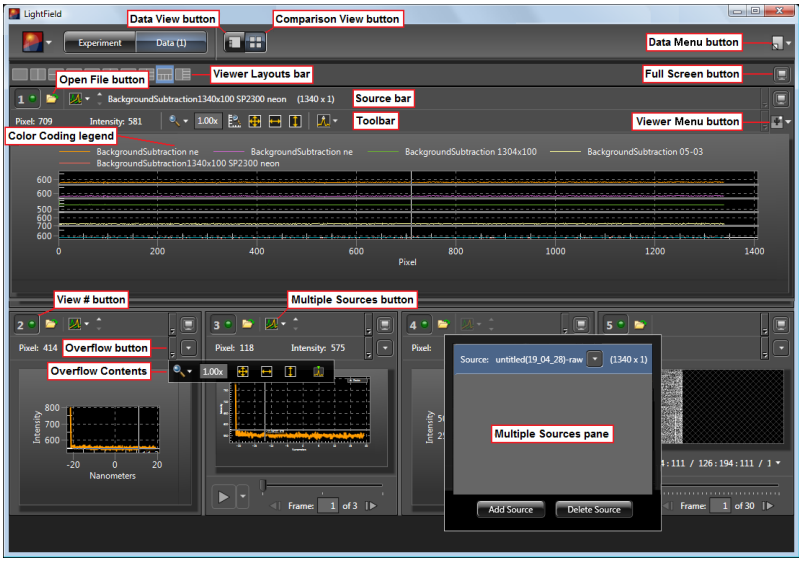


Figure 235. Comparison View with Callouts

Using Comparison View

Introduction

The **Comparison View** (used for comparing previously acquired data) is accessed on the **Data** workspace by clicking on the **Comparison View** button. Comparison View allows you to open up to five views and to have either one image or up to five spectra per view.

If there are multiple spectra in a view you have the additional capability of either stacking or overlaying the spectra. Another feature of this view is the **Comparison Statistics** dialog accessed via the **Data Menu**. Statistics for the contents of Viewers 1-5 (limited to the current source in the view if more than one graph is displayed). Clicking on the **Data View** button returns you to the Data View.

Step-by-Step Procedure

1. Open the **Data** workspace.
2. Click on the **Comparison View** button if the Data View is currently open.
3. Select the number of views from the Viewer Layouts bar.
4. Retrieve the file you want to see in the view. You can open a file in the view by one of the following methods:
   - Click on the **View #** button and retrieve the file.
   - Click on the **Viewer Menu** button, choose Open File..., and retrieve the file.
   - Right-mouse click in the view, choose **Open File...** from the context menu, and retrieve the file.

Note: Use the above methods when only one graph will be displayed in the view. Clicking on the **View #** button a second time will clear the contents of the view and turn it off. Open File... overwrites an existing graph or image in the view with the contents of the new file.

5. If you want to see multiple graphs (up to five) in a single view, after loading the first spectrum, click on the **Multiple Sources** button In the **Multiple Sources pane**, click on the **Add Source** button, select a file, and repeat the add and selection until you have the other files. Click outside of the pane to close it when you have finished loading files into the current view.l

Note: If there are multiple ROIs and/or rows in a file, the Multiple Sources pane also allows you to choose the ROI and/or row to display. The first ROI and the first row are selected by default.

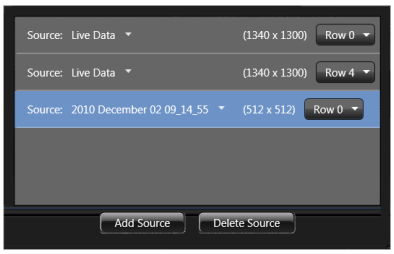


Figure 236. Multiple Sources panel

6. If there are multiple graphs in a view, you can either stack or overlay them. Turning **Stacked Graph** on and off is a function provided on the context menu and as one of the **Graph Options** on the **Viewer** menu. Each graph in a view is drawn with a different color. If there are two or more spectra in a view, clicking on a graph name in the color coding legend makes that spectrum the active graph and, if spectra are overlaid, it will bring the selected spectrum to the front.

Note: The active graph is the one that will be used to report statistics on the **Comparison Statistics** dialog (opened by selecting **Show Comparison Statistics** from the **Data Menu**).

7. Where there is room on the view, the Source bar displays the name of the data source and the ROI and/or Row number if there multiple ROIs and/or rows. The Toolbar below it displays pixel and intensity information (graph) or cursor location (image), brightness and contrast tools (image), zoom tools, pixel ratio (image), and Peak Finding (graph). When there is not enough room to display all of a bar's contents, the contents are hidden but can be accessed by clicking on the **Overflow** button at the right side of the bar.

8. To open the Data View, click on the **Data View** button

Opening Data Files

Introduction

In the Comparison View, you can open a data file after turning on a view (up to five depending on the layout selection), after selecting **Open File...** from a view's context menu, or after selecting **Open File...** from the **Viewer** menu (each view has one of these menus). If the data are displayed as a graph, you can add data sources to a view after clicking on the **Multiple Sources** button and clicking on the **Add Source** button Add Source to add a data source to pop up the **Open Data File** dialog.

Adding a Source

If you are looking at the Experiment Viewer, the topmost or leftmost view (depending on the selected view layout) will initially contain Row 0 of the Live Data. Adding a source allows you to display multiple graphs in the same view. Initially, the graphs will be overlaid one on top of the other: the graphs share the X- and Y-axes. You can, however, choose to stack the graphs.

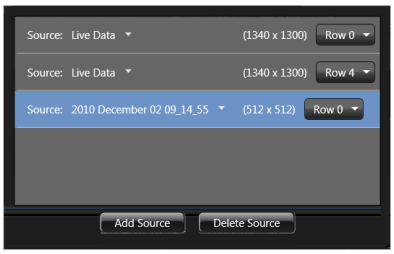


Figure 237. Multiple Sources pane

Open the **Multiple Sources** pane by clicking on the **Multiple Sources** button To load a different row from the same Live Data, click on the **Add Source** button Add Source, and after the new source is added to the list, then click on the **Row** button and make your selection.To load data from a previously saved data set, click on the small arrow (Change Source) next to Live Data (in the **Multiple Sources** pane). This will drop down a list that allows you to **Select File....** If the highlighted source is a loaded file, you will be able to **Select Live Data** or **Select File...** from the list. By default the row to be displayed is Row 0, but you can change the row by selecting from the list dropped down by the **Row** button.

Each graph within a view is color-coded (the legend with color-code and data source name is shown above the view). To move the Data Cursor from one graph to another, click in the view and press the keyboard up or down arrow key. To

move along a graph, click in the view and press the keyboard right or left arrow key.

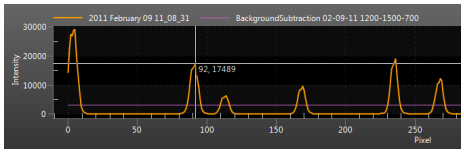


Figure 238. Overlaid Graphs

Stacking Graphs

By default multiple graphs in the same view are overlaid (Figure 238). However, you can choose to show the data stacked one above each other in same view via the context menu (**Stacked Graph**) or **Viewer Menu** (**Graph Options|Stacked Graph**).

When multiple graphs are stacked, the X-axis will be shared by the graphs but each graph will have its own Y axis.

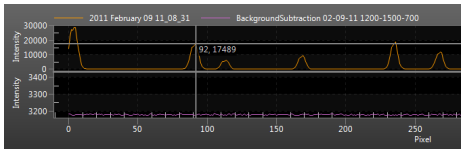


Figure 239. Stacked Graphs

Selecting the Active Graph

When there a multiple graphs in a view, the active graph is drawn with a heavier line than the others. The data cursor will move along the active graph. If you select a portion of the active graph, autoscaling will be applied to that portion. You make a graph active by:

- Pressing the keyboard up or down arrow key after you have clicked in the view. This moves the data cursor to the next graph and makes it the active graph.
- Clicking on the source name in the legend above the view.
- Clicking on the graph.

Changing the Frame Displayed

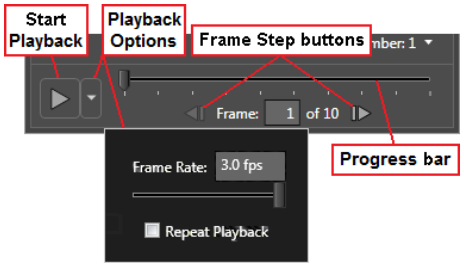


Figure 240. Playback and Step buttons

If you have loaded a previously acquired data set that contains multiple frames, the **Playback** buttons, **Frame Step** buttons and **Progress** bar are displayed below the data. You can manually cycle through the frames by clicking on one of the **Frame Step** buttons, you can pull the slider along the **Progress** bar, or you can set up **Playback** options (frame rate of display and playback repetition), and click on the **Start Playback** button to automatically step through the frames.

Note: If you selected the **Always Auto-Scale** function, each frame will be autoscaled when it is displayed.

Maximizing/Restoring a Viewer or View

You can maximize the entire Viewer Layout to a monitor or you can maximize individual views (within a Viewer Layout) to a monitor (the viewer and each view have **Full Screen** buttons). Click on the **Full Screen** button for the view or viewer to maximize. The full screen version of your viewer will have a button in the upper right corner to return it to normal size. If you have maximized a single view, it will also have a button to return it to normal size.

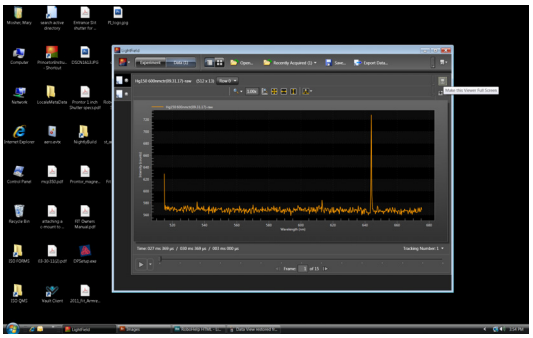


Figure 241. Data View: Normal Size

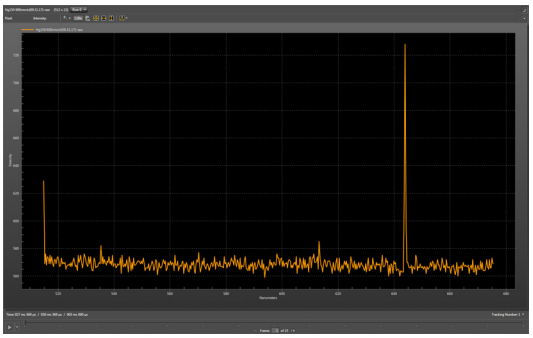


Figure 242. Data View: Maximized

Sending a View or Viewer to Different Monitor

If your computer has been configured with two monitors, the main LightField window can be stretched to span across more than one monitor. You can click the drop-down button to the right of the **Maximize** button to send the view or viewer to a different monitor. When you send something to a different monitor, the statement "This

element is located on another monitor." appears along with a **Restore** button. The view will be maximized on the second monitor.

Viewing Comparison Statistics

Introduction

When data are displayed in Comparison View (there may be up to five views containing data), you can view statistical information for that data by opening the **Data Menu** and selecting **Show Comparison Statistics**. The **Comparison Statistics** dialog shows up to nine statistics for the contents of Viewers 1-5 (limited to the current source in the viewer if more than one graph is displayed). By clicking on a **Viewer#** button above a column, you can show or hide the statistical data from that view. Only statistics that are selected and visible in the columns will be available for saving to a file or copying to the clipboard.The statistical information can be saved to a .CSV file and the resulting file can then be opened by an ASCII text editor or in a spreadsheet for analysis and graphing.

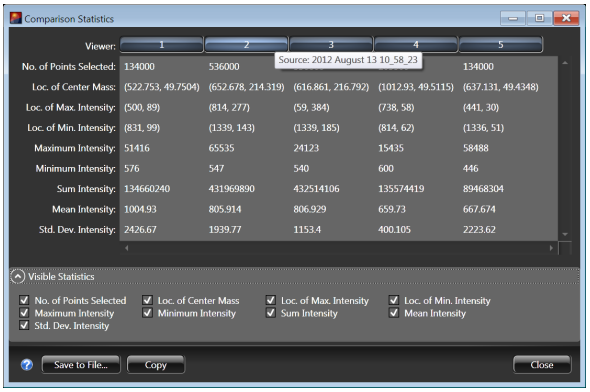


Figure 243. Comparison Statistics dialog

Using Comparison Statistics

The statistics for data in all active viewers will be displayed in the dialog. If multiple graphs are displayed in a viewer, the statistics will be reported for the active graph.

1. Open the **Data** workspace.
2. Click on the **Comparison View** button  to open Comparison View.
3. Select the number of views from the Viewer Layouts bar.
4. Load the data for each view. After that data are displayed, open the **Data Menu** and select **Show Comparison Statistics**.

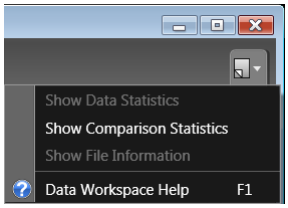


Figure 244. Comparison View Data Menu

5. When the **Comparison Statistics** dialog opens, a set of statistics will be listed for each viewer containing data. If there is no data in a view or the view has been turned off, N/A is displayed. If you position the cursor on a **Viewer** button, the data source information for that column of statistics will be displayed in a tool tip.

> **Note:** If there are data in more views than are currently being displayed in the **Comparison View** panel (for example, a two-view layout was selected even though four views are active and contain data), the statistics will still be listed for the hidden view.

6. Functions on the dialog allow you to choose the statistics to be saved. Only the statistical information visible on the dialog will be saved to the .CSV file or copied to the clipboard. You can limit the statistical information by
   - **Viewer:** For example, if there are data in all five views but you only want data from Viewers 1-3, click on the Viewer 4 and Viewer 5 buttons to hide the statistics in those columns. Now when you save the statistics, the information from those views will not be included in the .CSV file or copied data.
   - **Statistic:** Up to nine pieces of statistical information can be saved for each viewer containing data. Only the statistical information visible on the dialog will be saved to the .CSV file or copied to the clipboard. To view the possible statistic choices, click on the expand button to the left of **Visible Statistics** (at the lower left of the dialog). Select or deselect the statistics you want. When you deselect a check box, the statistic associated with it will no longer be displayed in the dialog.
7. Now that you have chosen the statistics, you can click on
   - **Save to File...** to save the information to a .CSV file in the working directory or directory of your choice. The default name for a statistics file is "statistics". You may want to enter a more informative name before saving the file.

- **Copy** to copy the information to the Windows clipboard. Once the information is in the clipboard, you can paste it into documents, spreadsheets, etc.
- **Close** to quit without saving or copying or to quit after you have saved or copied the information.

Copying

The Copy function copies the contents of a view as an image and as data points to the clipboard. When the copied information is pasted, it is pasted into the destination program as either an image or as four columns of data. It is copied as an image into graphics programs and spreadsheets. It is copied as data points into text editors and word-processing programs.

Converting WinX/32.SPE Files

If you are opening a data file and LightField detects that it is a WinX/32 version 2.x SPE file it will pop up a dialog stating that LightField cannot open the file will be displayed. This dialog offers you the choices of making the conversion to a version 3.0 SPE file and opening the converted file in the image viewer or opening the **SPE Conversion Tool** which will locate version 2.x SPE files and convert those you select. After conversion, the data are stored to a file (or files) using the same name as the original data file(s) but with (v3.0) added to the file name. For example, if the original version 2.x file is named "**laser scatter.spe**", the converted file will be named "**laser scatter(v3.0).spe**".

Note: LightField version 3.0 SPE files are more complex than WinX/32 version 2.x SPE files. The LightField converter allows you to view the data in LightField. File information, however, will be limited and multiple ROIs will be displayed using the WinX/32 side-effect ROIs (***see Figure 245.***). Converted data can be exported but it cannot be used in post-processes.

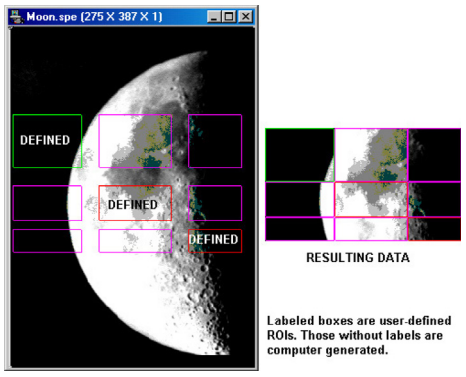


Figure 245. WinX/32 Side-Effect ROIs

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Chapter 9: Data Export

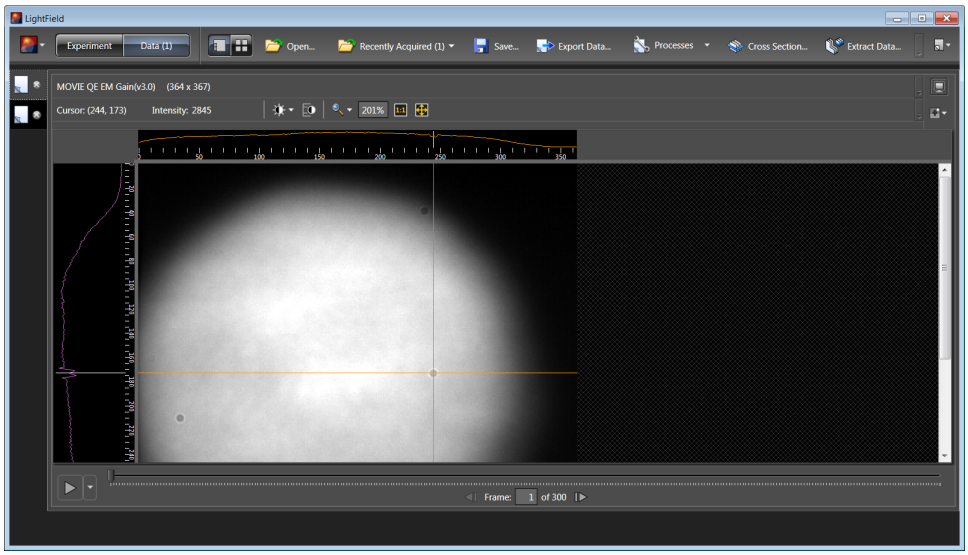


Figure 246. Data View

Introduction

If you have opened one or more LightField .SPE data files in the **Data** workspace Viewer, you can export single or multiple .SPE data file(s) in a form useful for other software. Before exporting a data file, you can make choices regarding Regions of Interest (ROI), Frames, and where the exported data are to be saved (the source file's location, the working directory, or another directory on your computer). The file name will include the name of the source file. The ROI(s) and Frame(s) selected for export will also be referenced in the file name.

Export File Formats

The supported export formats are:

- **Audio Video Interleave (AVI):** This format is used to export a file containing multiple frames to a video clip. AVI files can be played by various video players, but the player must support the codec used to encode the video data. Data compression provides the greatest compatibility. If the AVI is uncompressed and your player does not play the file, try a different player. If pseudo coloring is applied to an open file and the file is exported to AVI, the pseudo coloring will be applied to the AVI as well.

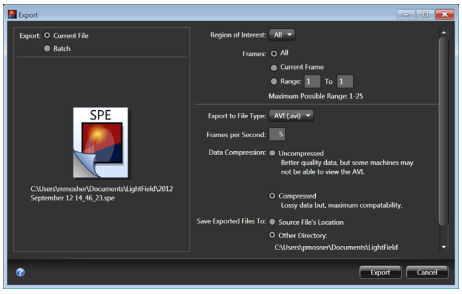


Figure 247. Export dialog: AVI

- **Flexible Image Transport System (FITS):** This format is typically used for astronomical imaging and supported by a variety of software packages used by astronomers. A subset of version 2.1b can be exported; i.e. uncompressed, multi-frame, luminance, image data with some metadata describing experiment information only.

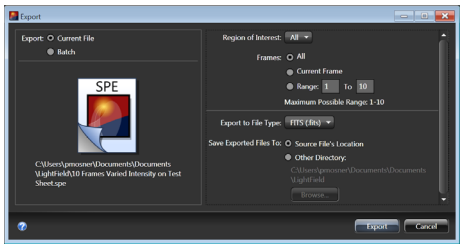


Figure 248. Export dialog: FITS

- **Thermo Scientific File Format (SPC):** This format is typically used for spectroscopy and supported by a variety of spectroscopic data analysis packages. A subset of version 0x4B can be exported; i.e. uncompressed, multi-frame, spectral data with some metadata describing experiment information only.

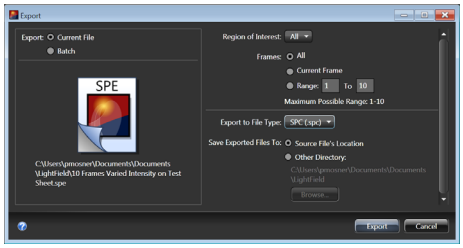


Figure 249. Export dialog: SPC

- **Tagged Image File Format (TIF):** This format is typically used for imaging and supported by a variety of software packages. A subset of version 6.0 can be exported; i.e. uncompressed, multi-frame, luminance, image data with some metadata describing experiment information only.

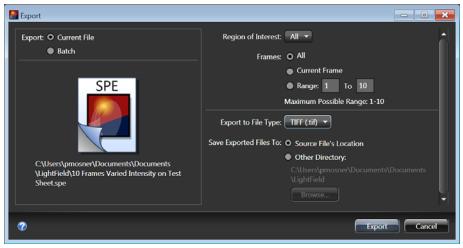


Figure 250. Export dialog: TIF

- **CSV File Format (CSV):** This format is typically used for general data analysis by a variety of spreadsheet packages. Data are exported to a TXT file with internal CSV formatting containing uncompressed, multi-frame, luminance, data with calibrated axes (if applicable). You can specify whether a specific ROI or all ROIs and the current frame, a range of frames, or all frames are to be exported. You can also specify whether that data should be saved to a single file, a file per ROI, a file per frame, or a file per ROI per frame. After the data have been exported, you can open the resulting CSV files in a text editor or a spreadsheet.

Notes:

1. **AVI:** This format supports only one ROI at a time (**One File per ROI**), so LightField will always write a separate file for each ROI, with all chosen frames inside that file. For example, if there are two ROIs, four frames of data in the source file, and all ROIs and frames are selected for export, two files will be created.
2. **FITS, SPC, and TIF:** Prior to LightField version 4.5, these formats supported only one ROI at a time. You now have a choice of **One File per ROI** or **One File per ROI per Frame**.
3. **CSV:** Data can be exported to **One File**, **One File per Frame**, **One File per ROI**, or **One File per ROI per Frame**.
4. **SPC:** When data are exported to an SPC file, a TXT file is written to the same directory as that SPC file: the TXT file has the same filename as the SPC file but with the TXT extension. The TXT file lists some of the fields and values in the SPC file and is used for testing and troubleshooting.

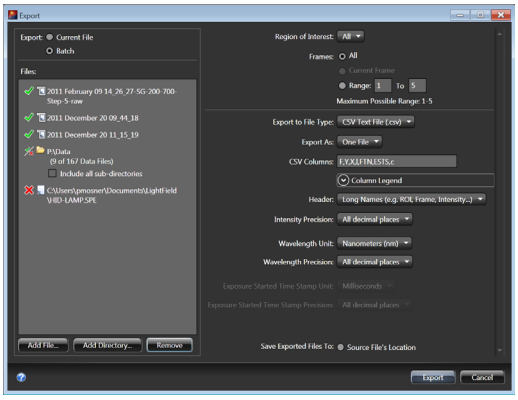


Figure 251. Export dialog: CSV

Single File (Current File) Export

AVI

Overview

AVI Export and the playback of AVI exports created in LightField were tested using Windows 7 (Service Pack 1) and several versions of Windows Media Player version 12. Compressed AVIs offer greater compatibility, but result in lossy data. Uncompressed AVIs offer better data quality, but may not offer a wide range of compatibility with different machines, media players or image sizes.

The codecs used to export and play back compressed AVIs depend upon the codecs

available to your particular machine. From the About window in Windows Media Player, you can click on the Technical Support Information link to see a list of the codecs available.

If you cannot export or play a compressed AVI on your machine, it is likely due to a missing codec or a codec conflict on your machine. More information about working with codecs and troubleshooting AVI issues can be found here:

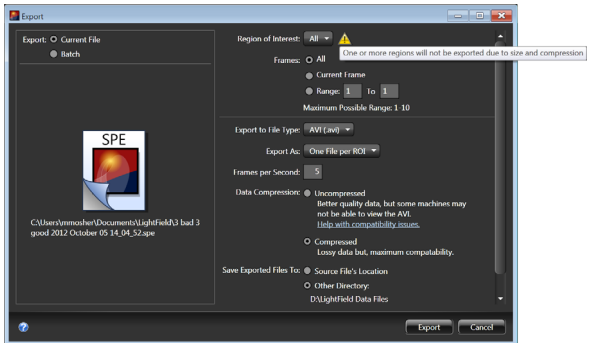
http://windows.microsoft.com/en-US/windows7/Codecs-frequently-asked-questions

If you have difficulty playing uncompressed AVIs, you can try opening the AVI in different media players, or try varying the size of the image that is exported.

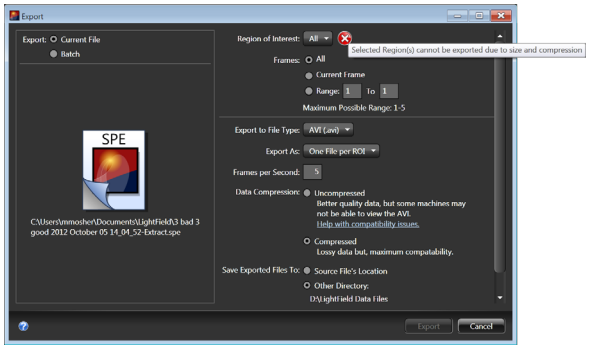
ROI Constraints

LightField will not allow you to export compressed AVIs if an ROI has fewer than 8 rows or columns (this is a limitation of the type of compression used). Because of these constraints, you may see one of the following warnings or errors.

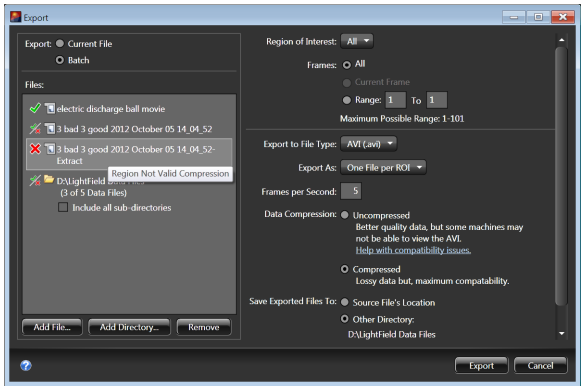
1. If you are in Current File mode, are exporting compressed AVIs, and have multiple ROIs, you could potentially get the following warning: "One or more regions will not be exported due to size and compression."



2. If you are in Current File mode, are exporting compressed AVIs, and have multiple ROIs, you could potentially get the following error: "Selected Region(s) cannot be exported due to size and compression." This means that none of your ROIs are valid for export to compressed AVIs.



3. If you are in Batch mode, files and directories can now be fully or partially red-Xed based upon the size of the ROI and export to compressed AVI.



Autoscaling

The state of the Always Autoscale check box determines whether or not each frame

will be autoscaled based upon the values from the first frame (Always Autoscale is unchecked), or each frame will be autoscaled based upon its own values (Always Autoscale is checked). If the file being exported is currently open, the current autoscale contrast method (Full Scale or Optimal Scale) is applied. If the file being exported is currently closed, the default autoscale contrast method (as selected on the Application Options|General tab) will be applied.

Any ROI being exported that has fewer than 100 pixels must always use the Full Scale contrast method of autoscaling.

Exporting Current File to AVI

1. Open one or more files in the Data workspace.
2. In the viewer, display the data to be exported.
3. Click on **Export Data...**
4. Select the **Current File** radio button at the upper left corner of the **Export** dialog.
5. Make your selections of **Region of Interest** and **Frames**.
6. Choose **AVI (.avi)** as the **Export to File Type**.

7. The only **Export As** selection available for exporting to AVI is **One File per ROI**.
8. In the **Frames per Second** field, enter the number of frames per second.
9. Check or uncheck the **Always Autoscale** check box depending on how you want autoscaling to be applied. See the preceding "**Autoscaling**" section for more information.
10. For **Data Compression**, select the appropriate radio button. See preceding "**Overview**" and "**ROI Constraints**" sections for more information.
11. Choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
12. Click on the **Export** button to complete the export.

CSV (Table or Matrix)

Overview

This format is typically used for general data analysis by a variety of spreadsheet packages. Data are exported to a TXT file with internal CSV formatting containing uncompressed, multi-frame, luminance, data with calibrated axes (if applicable). You can specify whether a specific ROI or all ROIs and the current frame, a range of frames, or all frames are to be exported. You can also specify whether that data should be saved to a single file, a file per ROI, a file per frame, or a file per ROI per frame. After the data have been exported, you can open the resulting CSV files in a text editor or a spreadsheet.

When exported in table format, the data will be stored in selectable CSV columns such as R,F,C,Y,X,I, and ESTS where R=ROI, F=Frame, C=Wavelength, Y=Row, X=Column, I=Intensity, and ESTS=Exposure Started Time Stamp (several other columns are also selectable). You can choose the number of decimal places for wavelength and intensity precision. You can specify whether a header should be included and if so whether it should use short or long names (for example: R,F,C or ROI, Frame, Wavelength).

Additionally, you can select units for intensity and select units/precision for calibration, exposure started/ended, gate delay/width.

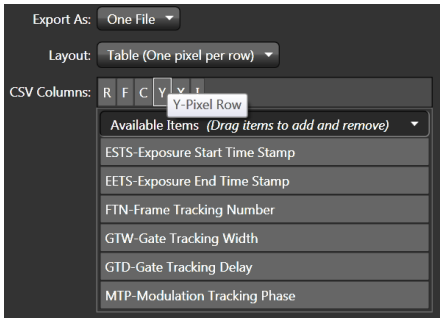
Because matrix layout is more complex, there are different formatting choices to make when data is to be exported in that format. For example, there are choices for X Header Rows, Y Header Column, Metadata Column, and Markers.

The following procedures step you through exporting data from a single .SPE file that contains multiple ROIs and Frames.

Exporting Current File as a Table

1. Open one or more files in the Data workspace.
2. In the viewer, display the data to be exported.
3. Click on **Export Data...**
4. Select the **Current File** radio button at the upper left corner of the **Export** dialog.
5. Make your selections of **Region of Interest** and **Frames**.
6. Choose **CSV** as the **Export to File Type**.
7. Choose the **Export As** type: **One File**, **One File per Frame**, **One File per ROI**, or **One File per ROI per Frame**. The number of files generated during the export will vary depending on your choice and the number of frames and/or ROIs in the source file. The file naming of the exported files will always include the name of the source file. It may also include Frame and ROI information.

   Example: If the source file **2013 March 05 16_48_39.spe** has 4 ROIs and 20 Frames, you select **One Frame per ROI** selection, and you export as CSV 10 of the frames and all of the ROIs, the four files created will be named **2013 March 05 16_48_39-Roi-1.csv**, **2013 March 05 16_48_39-Roi-2.csv** and so on. If you select **One File per ROI per Frame** for the export, the resulting forty files will be named **2013 March 05 16_48_39-Roi-1-Frame-01.csv** . . . **2013 March 05 16_48_39-Roi-4-Frame-10.csv**.
8. Choose **Table (One pixel per row)** as the **Layout** for the exported file(s).
9. In the **CSV Columns** field, decide which columns you want to include in the exported file. To see the full name of an item, position the mouse cursor over the item to see its tool tip description. To make changes to the currently displayed items, drag an item to or from the **Available Items** drop down list.



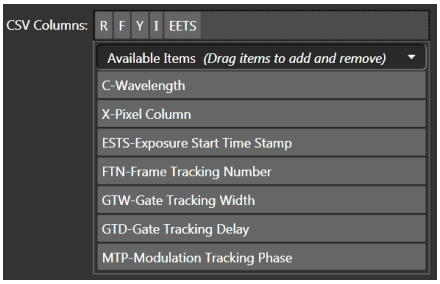


Figure 253. Available Items: C-Wavelength and X-Pixel Columns dragged into list, EETS dragged out

10. Click on **Header Labels** and choose whether you want a header to be included and if so whether it should show short or long names.
11. The availability of the next selections depends on what you have entered for the CSV Columns field and other information available in the data file.

> **Note:** Experiment start/ended, gate tracking width/delay, frame tracking number, and modulation tracking phase metadata can be exported as actual metadata via the **Export Data** function. Or, if there are one or more metadata calibrations associated with frame cross-section files and used for horizontal (X) axis calibration in these files, it can be saved via the **Frame Calibration** tab on the **File Information** dialog.

12. After you have finished entering the rest of the formatting information, choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
13. Click on the **Export** button. An exported file can then be opened in a text editor or a spreadsheet program. Note that because the source file did not contain an **Exposure End Time Stamp (EETS)**, the cells under that heading contain **N/A**.

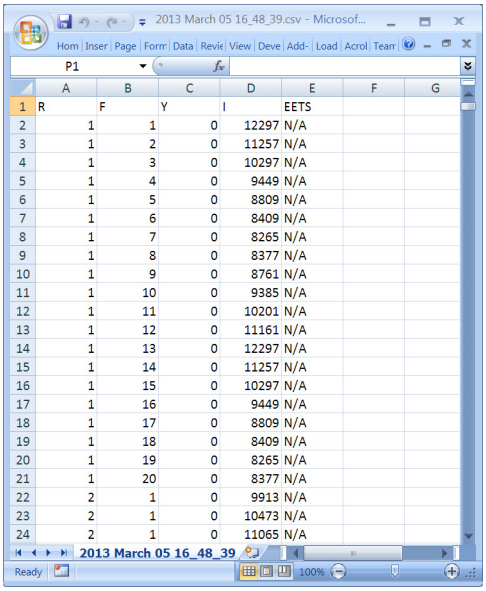


Figure 254. Exported File: No Header Labels

Exporting Current File as a Matrix

1. Open one or more files in the Data workspace.
2. In the viewer, display the data to be exported.
3. Click on **Export Data...**
4. Select the **Current File** radio button at the upper left corner of the **Export** dialog.
5. Make your selections of **Region of Interest** and **Frames**.
6. Choose **CSV** as the **Export to File Type**.
7. Choose the **Export As** type: **One File**, **One File per Frame**, **One File per ROI**, or **One File per ROI per Frame**. The number of files generated during the export will vary depending on your choice and the number of frames and/or ROIs in the source file. The file naming of the exported files will always include the name of the source file. It may also include Frame and ROI information.

   Example: If the source file **2013 March 07 10_15_10.spe** has 3 ROIs and 20 Frames, you select **One Frame per ROI** selection, and you export 10 frames and all ROIs as CSV, the three files created will be named **2013 March 07 10_15_10-Roi-1.csv**, **2013 March 07 10_15_10-Roi-2.csv** and so on. If you select **One File per ROI per Frame** for the export, the resulting thirty files will be named **2013 March 07 10_15_10-Roi-1-Frame-01.csv** . . . **2013 March 07 10_15_10-Roi-3-Frame-10.csv**.
8. Choose **Matrix (Pixels in a grid)** as the **Layout** for the exported file(s).
9. In the **X Header Rows** field, choose the appropriate header to be included in the

exported file. An X Header Row shows the calibration for each pixel in a row. To make changes to the currently displayed items, drag an item to or from the **Available Items** drop down list. Since the X-axis of the data in the source file was not calibrated, **X-Pixel Column** was selected. Any other X Header Row selected would show **N/A** in the exported file.

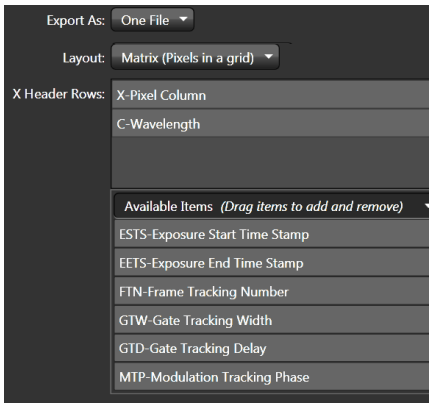


Figure 255. X Header Rows: X-Column and C-Wavelength

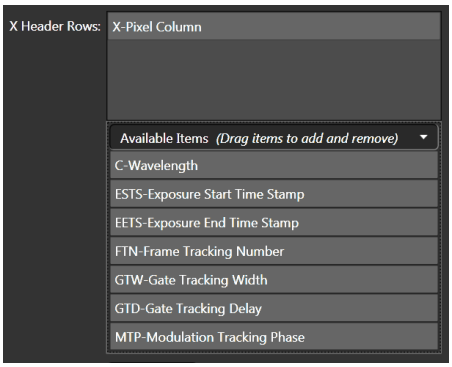


Figure 256. Available Items list: C-Wavelength dragged into list

10. Click on **Y Header Column** and choose either **Pixel Row** or **No Header**. If you select **Pixel Row**, the Y pixel location is (0, 1, 2, etc.) is provided in the lefthand column.

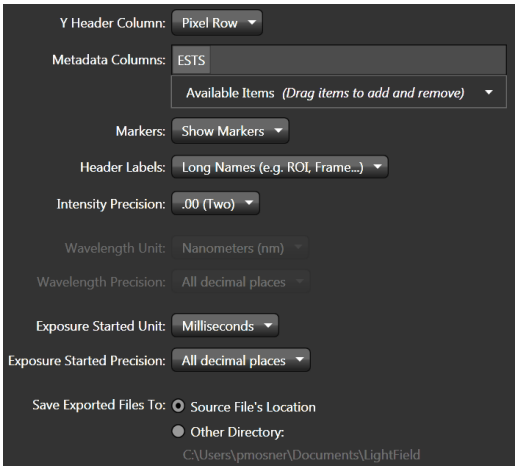


Figure 257. Y Header Column through Save Exported Files To

11. To include **Metadata Columns**, drag one or more items to or from the **Available Items** drop down list. Note that in this example, ESTS was chosen as a Metadata column to be included. This information will be placed at the end of the frame.
12. Click on **Markers** and choose either **Show Markers** or **None (blank row).** When Show Markers is selected, information such as Begin Frame 1, Begin Region 1, End Region 1, Begin Metadata, End Metadata, and End Frame 1will be included to indicate the beginning and end of a subset of the entire data.
13. Click on **Header Labels** and choose whether you want a header to be included and if so whether it should show short or long names. If you select either short or long names, these headers will be shown in the first column of the exported file. If you select **No Header**, only data will be shown in the first column.
14. The availability of the next selections depends on what you have entered for the **X Header Rows** field and other information available in the data file.

> **Note:** Experiment start/ended, gate tracking width/delay, frame tracking number, and modulation tracking phase metadata can be exported as actual metadata via the **Export Data** function. Or, if there are one or more metadata calibrations associated with frame cross-section files and used for horizontal (X) axis calibration in these files, it can be saved via the **Frame Calibration** tab on the **File Information** dialog.

15. After you have finished entering the rest of the formatting information, choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
16. Click on the **Export** button. An exported file can then be opened in a text editor or a spreadsheet program. Note that **Metadata Columns** for a frame appear after the data for the last ROI in the frame (at line 1149 in Figure 259. Metadata Columns).

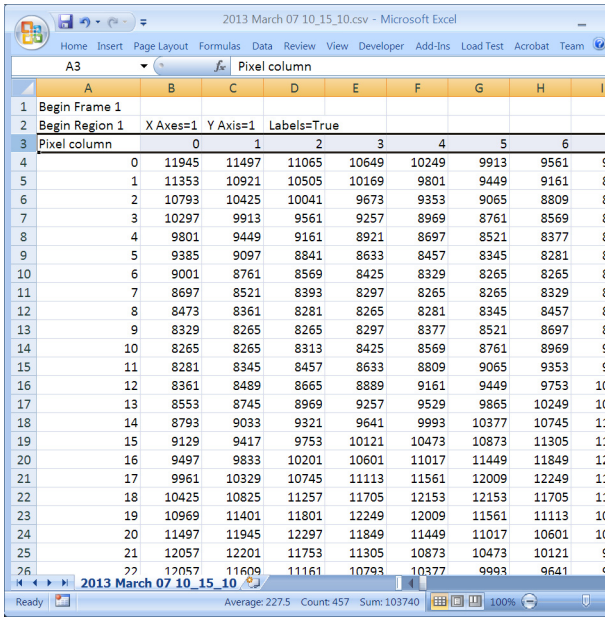


Figure 258. Header Labels and X Header Rows (Pixel column)

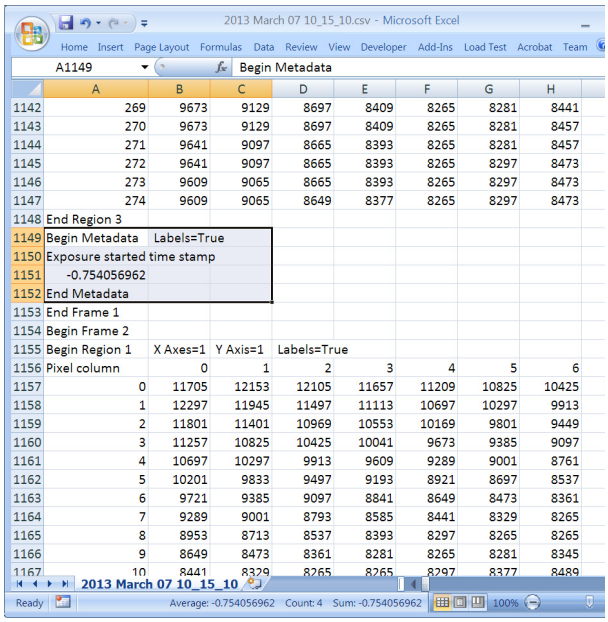


Figure 259. Metadata Columns

FITS, SPC, or TIF

1. Open one or more files in the Data workspace.
2. In the viewer, display the data to be exported.
3. Click on **Export Data...**.
4. Select the **Current File** radio button at the upper left corner of the **Export** dialog as shown in Figure 250.
5. Make your selections of **Region of Interest** and **Frames**.
6. Choose the **Export to File Type**.
7. Choose the **Export As** selection.
8. If the **Time Unit** field is active, you can choose the units. This field will be active when you are exporting Frame Cross Section data to SPC.
9. If you also want to include all of the experiment settings and information found in the SPE file, select the **Include All Experiment Information** check box. This information will be included at the end of the exported file.
10. Choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder
11. Click on the **Export** button to complete the export. An exported file can then be opened in a text editor or a spreadsheet.

Batch Export

AVI

1. Open one or more files in the Data workspace.
2. Click on **Export Data...**
3. Select the **Batch** radio button at the upper left corner of the **Export** dialog. A list of all of the files open in the Data workspace will be displayed in the **Files** panel.
   - To add a file the batch, click on the **Add...** button, locate the file, select it, and click on the **Open** button. Note that a red **X** indicates that an SPE file cannot be exported in its current format (i.e., it is an SPE file that needs to be converted to the LightField SPE file format).
   - To add a directory's worth of files, click on the **Add Directory...** button, locate the directory, select it, and click on **OK**. You can then also select all of its subdirectories. The number of files will be reported as the number of acceptable SPE files/total number of SPE files. A ✓/**X** next to the directory name indicates that one or more of the SPE files is unacceptable in its current format.
   - To remove a file from the batch, click on the file name and then click on the **Remove** button.
4. After you have made your final file selections, begin choosing the **Region of Interest** and **Frames**.
5. Choose **AVI (.avi)** as the **Export to File Type**.
6. The only **Export As** selection available for exporting to AVI is **One File per ROI**.
7. In the **Frames per Second** field, enter the number of frames per second.

8. Check or uncheck the **Always Autoscale** check box depending on how you want autoscaling to be applied. See the preceding "**Autoscaling**" section for more information.
9. For **Data Compression**, select the appropriate radio button. See preceding **"Overview"** and "**ROI Constraints**" sections above for more information.
10. Choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
11. Click on the **Export** button to complete the export.

CSV (Table or Matrix)

As Tables

1. Open one or more files in the Data workspace.
2. Click on **Export Data...**
3. Select the **Batch** radio button at the upper left corner of the Export dialog. A list of all of the files open in the Data workspace will be displayed in the **Files** panel.
4. Choose the files to be exported.
   - To add a file the batch, click on the **Add...** button, locate the file, select it, and click on the **Open** button. Note that a red X indicates that an SPE file cannot be exported in its current format (i.e., it is an SPE file that needs to be converted to the LightField SPE file format).
   - To add a directory's worth of files, click on the **Add Directory...** button, locate the directory, select it, and click on **OK**. You can then also select all of its subdirectories. The number of files will be reported as the number of acceptable SPE files/total number of SPE files. A ✓/**X** next to the directory name indicates that one or more of the SPE files is unacceptable in its current format.
   - To remove a file from the batch, click on the file name and then click on the **Remove** button.
5. Make your selections of **Region of Interest** and **Frames**.
6. Choose **CSV** as the **Export to File Type**.
7. Choose the **Export As** type: **One File**, **One File per Frame**, **One File per ROI**, or **One File per ROI per Frame**. The number of files generated during the export will vary depending on your choice and the number of frames and/or ROIs in the source file.
8. Choose **Table (One pixel per row)** as the **Layout** for the exported file(s).
9. In the **CSV Columns** field, decide which columns you want to include in the exported file. To see the full name of an item, position the mouse cursor over the item to see its tool tip description. To make changes to the currently displayed items, drag an item to or from the **Available Items** drop down list.
10. Click on **Header Labels** and choose whether you want a header to be included and if so whether it should show short or long names.
11. The availability of the next selections depends on what you have entered for the **CSV Columns** field and other information available in the data file.

    Note: Experiment start/ended, gate tracking width/delay, frame tracking number, and modulation tracking phase metadata can be exported as actual metadata via the **Export Data** function. Or, if there are one or more metadata calibrations associated with frame cross-section files and used for horizontal (X) axis calibration in these files, it can be saved via the **Frame Calibration** tab on the **File Information** dialog.

12. After you have finished entering the rest of the formatting information, choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
13. Click on the **Export** button. An exported file can then be opened in a text editor or a spreadsheet program.

As Matrices

1. Open one or more files in the Data workspace.
2. Click on **Export Data...**
3. Select the **Batch** radio button at the upper left corner of the **Export** dialog. A list of all of the files open in the Data workspace will be displayed in the **Files** panel.
4. Choose the files to be exported.
   - To add a file the batch, click on the **Add...** button, locate the file, select it, and click on the **Open** button. Note that a red **X** indicates that an SPE file cannot be exported in its current format (i.e., it is an SPE file that needs to be converted to the LightField SPE file format).
   - To add a directory's worth of files, click on the **Add Directory...** button, locate the directory, select it, and click on **OK**. You can then also select all of its subdirectories. The number of files will be reported as the number of acceptable SPE files/total number of SPE files. A ✓/**X** next to the directory

name indicates that one or more of the SPE files is unacceptable in its current format.

- To remove a file from the batch, click on the file name and then click on the **Remove** button.

5. Make your selections of **Region of Interest** and **Frames**.
6. Choose **CSV** as the **Export to File Type**.
7. Choose the **Export As** type: **One File**, **One File per Frame**, **One File per ROI**, or **One File per ROI per Frame**. The number of files generated during the export will vary depending on your choice and the number of frames and/or ROIs in the source file.
8. Choose **Matrix (Pixels in a grid)** as the **Layout** for the exported file(s).
9. In the **X Header Rows** field, choose the appropriate header to be included in the exported file. An X Header Row shows the calibration for each pixel in a row. To make changes to the currently displayed items, drag an item to or from the **Available Items** drop down list.
10. Click on **Y Header Column** and choose either **Pixel Row** or **No Header.** If you select **Pixel Row**, the Y pixel location is (0, 1, 2, etc.) is provided in the lefthand column.
11. To include **Metadata Columns**, drag one or more items to or from the **Available Items** drop down list. Metadata Columns for a frame appear after the data for the last ROI in the frame.
12. Click on **Markers** and choose either **Show Markers** or **None (blank row).** When **Show Markers** is selected, information such as Begin Frame 1, Begin Region 1, End Region 1, Begin Metadata, End Metadata, and End Frame 1will be included to indicate the beginning and end of a subset of the entire data.
13. Click on **Header Labels** and choose whether you want a header to be included and if so whether it should show short or long names. If you select either short or long names, these headers will be shown in the first column of the exported file. If you select **No Header**, only data will be shown in the first column.
14. The availability of the next selections depends on what you have entered for the **X Header Rows** field and other information available in the data file.

> **Note:** Experiment start/ended, gate tracking width/delay, frame tracking number, and modulation tracking phase metadata can be exported as actual metadata via the **Export Data** function. Or, if there are one or more metadata calibrations associated with frame cross-section files and used for horizontal (X) axis calibration in these files, it can be saved via the **Frame Calibration** tab on the **File Information** dialog.

15. After you have finished entering the rest of the formatting information, choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
16. Click on the **Export** button. An exported file can then be opened in a text editor or a spreadsheet program.

FITS, SPC, or TIF

1. Open one or more files in the Data workspace.
2. Click on **Export Data...**.
3. Select the **Batch** radio button at the upper left corner of the **Export** dialog. A list of all of the files open in the Data workspace will be displayed in the **Files** panel as shown in Figure 251.

- To add a file the batch, click on the **Add...** button, locate the file, select it, and click on the **Open** button. Note that a red **x** indicates that an .SPE file cannot be exported in its current format (i.e., it is an SPE file that needs to be converted to the LightField .SPE file format).
- To add a directory's worth of files, click on the **Add Directory...** button, locate the directory, select it, and click on **OK**. You can then also select all of its subdirectories. The number of files will be reported as the number of acceptable .SPE files/total number of .SPE files. A ✓/**x** next to the directory name indicates that one or more of the .SPE files is unacceptable in its current format.
- To remove a file from the batch, click on the file name and then click on the **Remove** button.

4. After you have made your final file selections, begin choosing the **Region of Interest** and **Frames**.

5. Choose the **Export to File Type**.
6. Choose the **Export As** selection.
7. If the **Time Unit** field is active, you can choose the units. This field will be active when you are exporting **Frame Cross Section** data to SPC.
8. If you also want to include all of the experiment settings and information found in the SPE file, select the **Include All Experiment Information** check box. This information will be included at the end of the exported file.
9. Choose the destination for the exported data file: the file can be saved to the source file's location, the LightField working directory, or you can browse for a folder.
10. Click on the **Export** button to complete the export. An exported file can then be opened in a text editor or a spreadsheet program.

Chapter 10: Post-Acquisition Processes

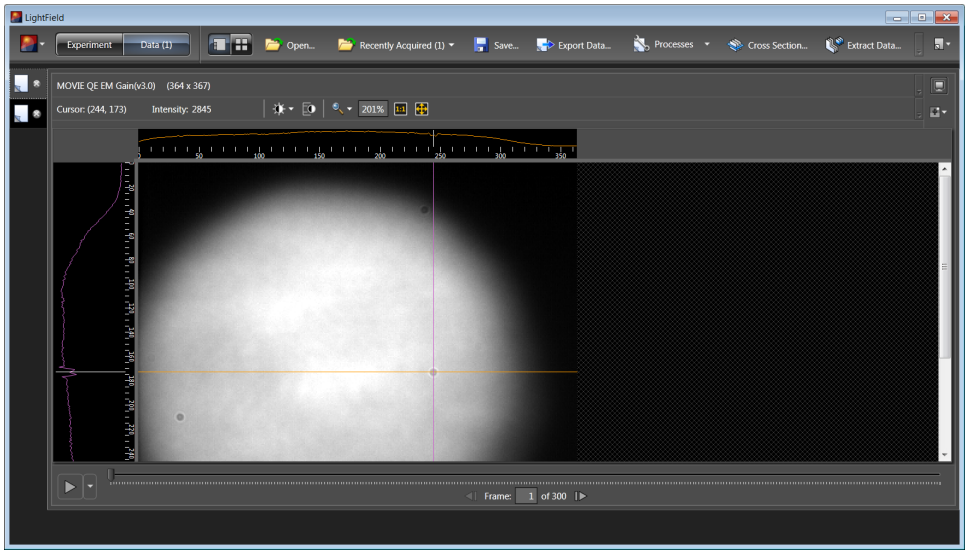


Figure 260. Data View

Introduction

Data can either be corrected (modified) while it is being acquired or it can be modified afterwards.

Online Processes (occur while data are being acquired) are selectable on the Experiment Workspace and include: Background Subtraction, Flatfield Correction, Exposures per Frame, Sensor Blemish Correction, Orientation, and Binning (software or hardware).

Post-Processes (applied after data has been acquired) are selectable on the Data Workspace and include: Background Subtraction, Blemish Correction, Flatfield Correction, Frame Combination, Orientation, and Software Binning.

When a data file is loaded into the Data workspace, its icon (in the panel on the left) is a light blue. After a post-process operation has been performed on the data in that file, the icon changes to a light tan with a circle and dots. This change indicates that the data have been modified but the file has not yet been saved. You can then click on the **Save** button 

and save the processed data to a location and a file name of your choice.

Figure 261. Original Data

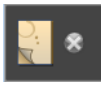


Figure 262. Modified Data

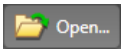
Background Subtraction

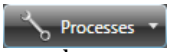
Introduction

Background subtraction applies an automatic subtraction of any constant background in the signal. This includes both constant offsets caused by the amplifier system in the controller as well as the time-dependent (but constant for a fixed integration time) buildup of dark charge. It also includes the small offset applied by Princeton Instruments systems to insure that small signals are not missed. Background subtraction data files are sometimes acquired with the shutter open to include any ambient light background.

A previously acquired background file can be used whenever the settings in the file match the settings in the selected data file. If the settings within a background file do not match, you will not be allowed to use the selected background file for data correction.

Applying Background Subtraction to Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button 

and retrieve the file you want to process.
3. Click on the **Processes** button 

and then select Background... from the menu. When the **Background** dialog appears, the data you retrieved will be displayed in the **Before** viewing area.

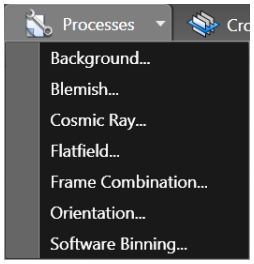


Figure 263. Processes menu

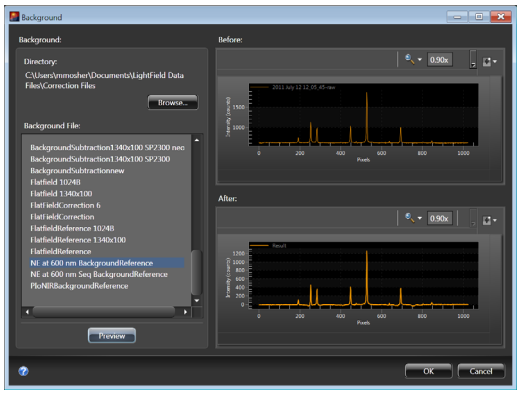
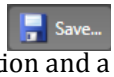


Figure 264. Background dialog

4. Select the appropriate background subtraction file. If the file is suitable, the **Preview** button 

will be activated.
5. When you click on the **Preview** button, the effect of the subtraction will be shown in the After viewing area.
6. After you have finished examining the resulting data, made any changes, click on **Cancel** to quit the dialog, or click on **OK** to apply the background subtraction.
7. If you click on **OK**, the background correction is applied and you are returned to the Data workspace. Note that the icon for the data is tinted yellow to indicate that the data have been corrected but not saved. At this time, you can now click on the **Save** button 

and save the processed data to a location and a file name of your choice.

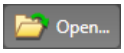
Blemish Correction

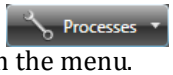
Introduction

Blemish correction requires a user-generated .CSV defect map file that can be created in a spreadsheet program such as Microsoft Excel or in an ASCII text editor such as Notepad. This file documents the type of blemish, its location, and the extent of the blemish. The defect map file must be based upon a Normal orientation (i.e., pixel locations in the file must reflect the image as seen by the naked eye). Once the file has been created and stored (usually in the Corrections subdirectory of the working directory), the file can be selected for blemish correction.

A blemish file is specific to a particular sensor. If you have blemish files for more than one camera sensor, make sure the selected blemish file is appropriate for the selected data. If you need to create a file that will correct for the defects you see in the displayed image, refer to ***"Creating a Defect Map" on page 46*** for instructions.

Applying Blemish Correction to Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button 

and retrieve the file you want to process.
3. Click on the **Processes** button 

and then select **Blemish...** from the menu. When the **Blemish** dialog appears, the data you retrieved will be displayed in the **Before** viewing area.

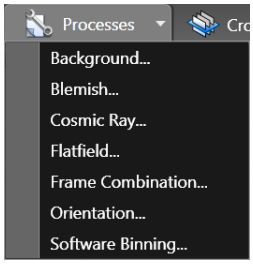


Figure 265. Processes menu

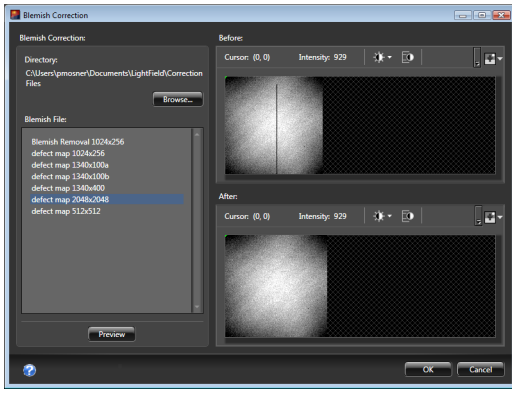
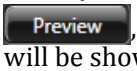
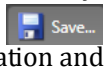


Figure 266. Blemish dialog

4. Select the appropriate blemish file. You may need to use the **Browse** button to change the file directory.
5. When you click on the **Preview** button 

, the effect of the blemish correction will be shown in the **After** viewing area.
6. After you have finished examining the resulting data, made any changes, click on

Cancel to quit the dialog, or click on **OK** to apply the blemish correction.

7. If you click on **OK**, the blemish correction is applied and you are returned to the **Data** workspace. Note that the icon for the data has changed color from a light blue to a light tan with a circle and dots. This change indicates that the data have been corrected but not saved. At this time, you can now click on the **Save** button 

and save the processed data to a location and a file name of your choice.

Cosmic Ray Removal

Introduction

This function removes highly localized spikes (such as those that could be caused by cosmic rays interacting with the silicon of the sensor) from previously acquired. There are two filters (Despeckle Filter and Median Filter) and a choice of Kernel Size (3x3, 5x5, or 7x7). When one of these filters is used to correct data, the selected kernel matrix is applied to every pixel in the image. The overall data is smoothed during the correction.

Note: If the region height is smaller than the kernel size, the kernel is resized to the region height. For example, if you have a single row selected, an image width of 512, and a 3x3 kernel, the kernel will be resized to 3x1. If there were two rows, the kernel would be resized to 3x2. In these examples, the filter puts the result into the middle or top middle pixel, respectively (indicated by gray shading).

5	3	6

Figure 267. 3x1 Kernel

5	3	6
2	16	9

Figure 268. 3x2 Kernel

- The **Median Filter** adds the values of the pixels within the selected matrix and then divides by the number of pixels in the matrix. The center pixel value is replaced by the result of the calculation.
- The **Despeckle Filter** compares the original center pixel value with a **calculated median** value. If the difference between the two is greater than the **sens** constant, the center value will be replaced with the **calculated median** value. If the difference is less than or equal to the **sens** constant, the center value will not be changed.

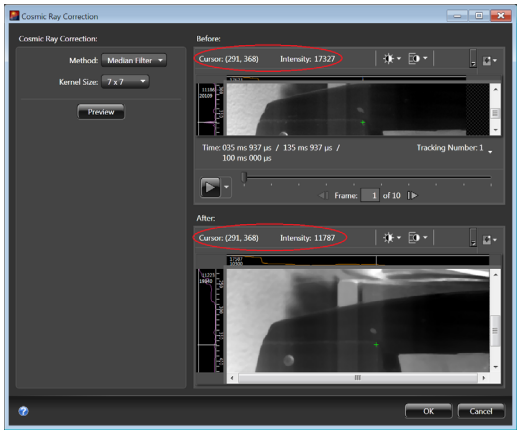


Figure 269. Cosmic Ray Correction dialog

Applying Cosmic Ray Removal to Previously Acquired Data

1. Open the **Data** workspace.
2. Click on the **Open** button and retrieve the file you want to process.
3. Click on the **Processes** button and then select **Cosmic Ray...** from the menu. When the **Cosmic Ray Correction** dialog appears, the data you retrieved will be displayed in the **Before** viewing area.
4. Select the filter method and the kernel size.
5. When you click on the **Preview** button, the effect of the filtering will be shown in the After viewing area.
6. After you have finished examining the resulting data, click on **Cancel** to quit the dialog or click on **OK** to apply the filtering.
7. If you click on **OK**, the filtering is applied and you are returned to the **Data** workspace. The file icon on the left will change from a light blue to a light tan and show a circle and dots to show that file data has changed but has not been saved. At this time, you can now click on the **Save** button and save the processed data to a location and a file name of your choice.

For more information, see ***"Cosmic Ray Removal Filters" on page 181***.

Cross Sections

Introduction

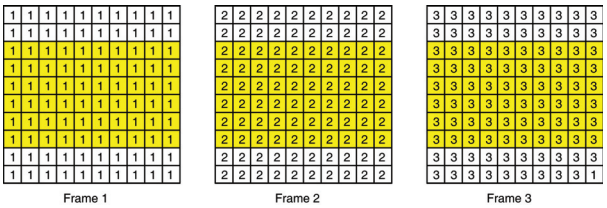
If you have an SPE with multiple ROIs, you can only perform a Cross Section operation on one ROI at a time. Horizontal Cross Section will leave you with a horizontal strip one pixel high (for however many frames you have chosen). Vertical Cross Section will leave you with a vertical strip a single pixel wide for however many frames you have chosen (for display purposes, this strip is displayed horizontally in the dialog and X axis

units will be Pixels). Frames Cross Section will leave you with a single pixel for however many frames you have chosen (for example, if you have selected 4 frames, 4 pixels are used to draw the cross section).

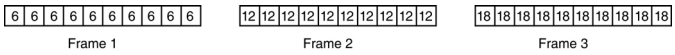
Examples of Cross Sections

Below are a few examples with 10×10 images and 3 frames. The number in each "pixel" is its intensity value.

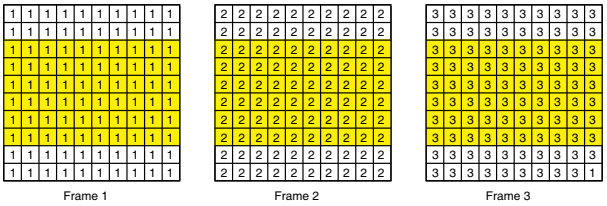
In Example 1, the ROI is defined by X = 0-9 and Y = 2-7, only the Y dimension is collapsed, and Sum is selected.



The resultant images would be:

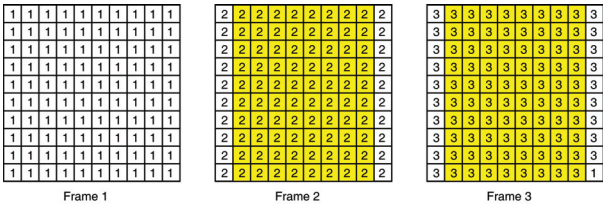


In Example 2, the ROI is again defined by X = 0-9 and Y = 2-7, only the Y dimension is collapsed, and Average is selected.

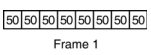


The resultant images would be:

In Example 3, the ROI is defined by X = 1-8 and Y = 0-9, the Y dimension and frames 2-3 are collapsed, and Sum is selected.



The resultant image would be:



Generating a Cross Section in the Data Workspace

1. In the Data Workspace, open a data file.
2. Click on the **Cross Section...** button 

to open the **Cross Sections** dialog (if the button is not visible, open the **Overflow** button  to access it). When the **Cross Sections** dialog opens, the data file will be displayed in the upper left.

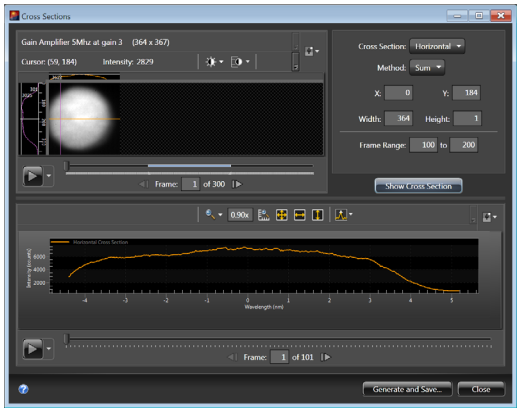
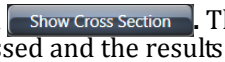


Figure 270. Cross Sections dialog

3. If the data were acquired with multiple ROIs, select the one you want to use.
4. Then click on the **Cross Section** button and select the type of cross section: Horizontal, Vertical, or Frames.
5. Chose the **Method**: Sum or Average.

> **Note:** When a sum or average is performed on the data, then the data type of the output file will be changed to floating point.

6. Enter the X, Y, Width, and Height values that determine the area that will be used to generate the cross section. You can key the values into the fields or you can use the data cursor to specify the X,Y position (the Width and Height values depend on the cross section type) or use the data cursor to select an area and its parameters will be entered into the fields.
7. If there are multiple frames, you specify that all of the frames (for example 1-5 of a five frame data set) or a subset (for example 1-2 of that same data set) be used in the generation.
8. After you have finished, the entries and selections, click on the **Show Cross Section** button 

. The data set will be processed and the results will be displayed in the bottom panel. A vertical cross section is shown horizontally.

9. You can change the horizontal axis calibration of a frame cross section. If the data were acquired while one or more Time Stamping functions were selected in the **Common Acquisition Settings** expander, you can change the horizontal calibration of the points used to create the cross section. Left mouse-click on the horizontal axis label to pop up the Horizontal Axis Calibration pane: this pane only lists the functions that were active when the data were acquired. You can then select a different calibration, change the units, or disable Horizontal Axis Calibration. Figure 272. shows a frame cross section calibrated in Frame Tracking Numbers in the horizontal axis. The data cursor shows that the sum of intensities for Frame 3 is 16325528 counts.

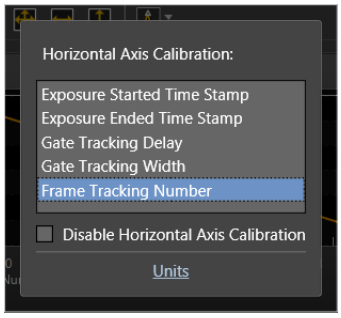
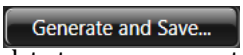
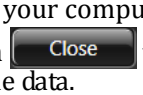


Figure 271. Horizontal Axis Calibration pane

10. At this point, you can click on the **Generate and Save** button 

to save the cross section data to your computer or click on the **Close** button 

to quit the dialog without saving the data.

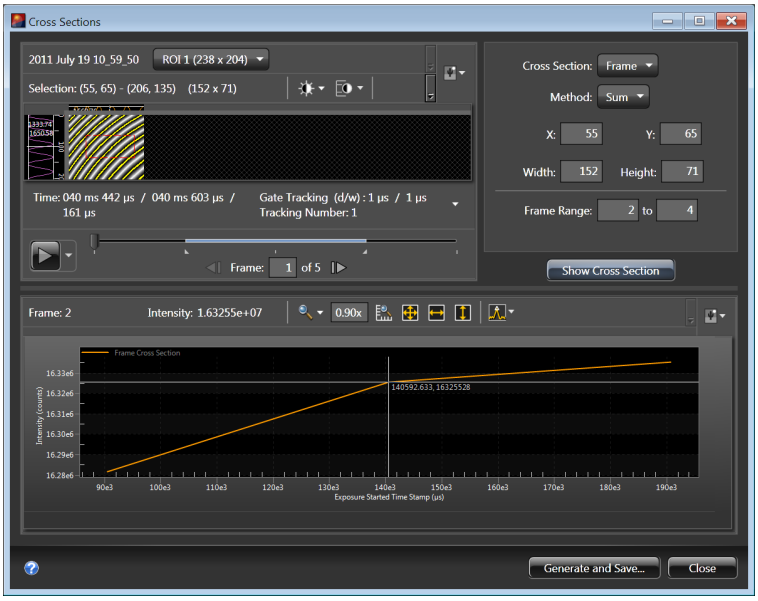


Figure 272. Frame Cross Section

Viewing a Generated Frames Cross Section

When a frames cross section is generated, tracking information (if active at the time of acquisition) is included in the file. This information includes exposure time stamps, frame tracking numbers, and gate width and delay. When you display the generated file in the Experiment or Data Workspace and there are two or more kinds of tracking associated with the data, the types of tracking will be available in the **Horizontal Axis Calibration** drop-down list so you can display the data in relationship to the selected tracking. The two images below use the same data and the cursor is on Frame 5 in each.

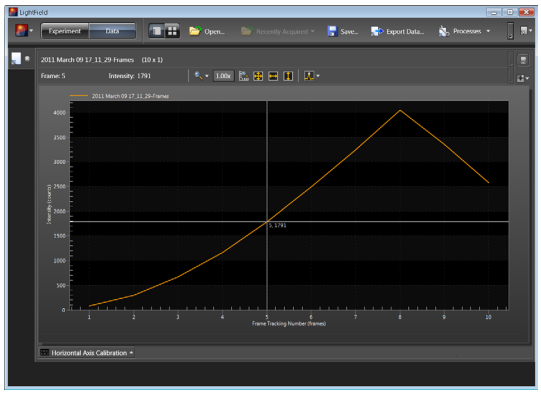


Figure 273. Cross Section: Intensity vs. Frame Tracking Number

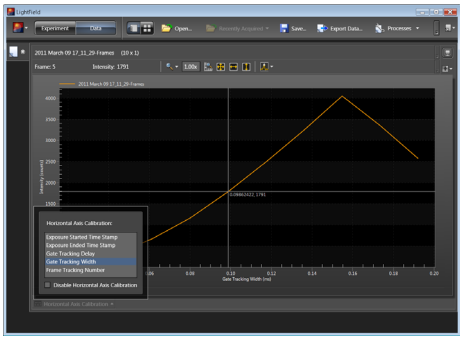


Figure 274. Cross Section: Intensity vs. Gate Tracking Width

Frame Calibration Information

Frame calibration information for a saved frames cross section can be reviewed after you load the file into the Data viewer. Once the file is loaded, select **Show File Information** from the Data menu. Click on the **Frame Calibration** tab to see the calibration information for all of the Time Stamping functions active when the original data were acquired. If there is a slider at the bottom of the tab, expand the tab to see all of the values. If you click on the **Save to File...** button, the **Save File Information** dialog will pop up and allow you to save the General, File Calibration, and Notes information to an XML file that can be easily viewed in Internet Explorer, Visual Studio, Microsoft Word, or a text editor.

Extraction

Introduction

Extraction allows you to extract and save data from the data set shown in the **Extract Data** dialog. If there are multiple ROIs in the data set, the data will be taken from the currently displayed ROI. You can either use the selection box (i.e., draw a box with the mouse cursor around the data of interest) or enter X, Y, Width, and Height values to specify the data for extraction. If there are multiple frames, you can enter a range of frames to be extracted.

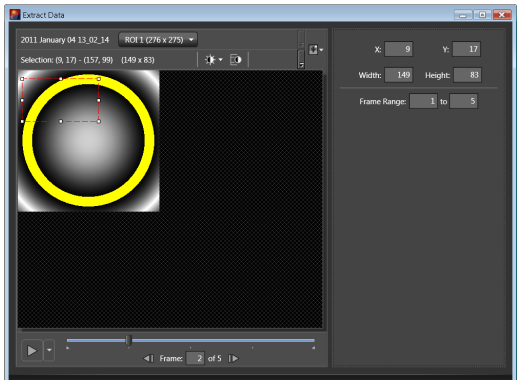
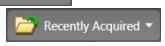
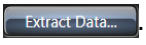


Figure 275. Extract Data dialog

Extracting Data from Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button  and or the **Recently Acquired** button  to retrieve the data you want to process.
3. Click on the **Extract Data** button  to open the **Extract Data** dialog (if the button is not visible, open the **Overflow** button  to access it). When the **Extract Data** dialog appears, the data you retrieved will be displayed in the viewing area.
4. If the data set contains multiple ROIs, select the ROI to be used in the extraction.
5. Select the portion of the data that you want to extract from the data in the viewer. You can select the data by:
   - Editing the values in the X, Y, Width, and Height fields.
   - Drawing a selection box around the area of interest by depressing the left mouse button, dragging the box around the area, and releasing the button when finished. You can move the box by positioning the cursor inside the box, depressing the left mouse button, and dragging the box. You can resize the box by dragging the handles on the box. The X, Y, Width, and Height fields will be populated based on the box location and size.
6. If the data set contains multiple frames, select the frame or range of frames to be extracted.
7. When you have finished, making the data selection, click on the **Extract Data...** button  .
8. When the **Save Data File** dialog appears, the default name of the file will be entered in the form of SourcefilenamExtract.spe. If the source file name was 2010 December 23 08_58_14.spe, the default name for the new file would be 2010 December 23 08_58_14Extract.spe. You can change the file name and the save location.

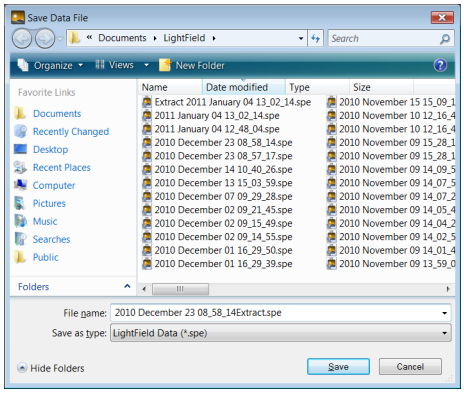


Figure 276. Save Data File(s) dialog

9. After you click on the **Save** button, the data will be saved, and the **Extract Data** dialog will close.

Flatfield Correction

Introduction

Uniform illumination of an ideal sensor would result in all pixels producing identical signals and a uniform (flat) image. However, uniform illumination of a real sensor results in a range of signal values. Variations in signal over an array arise from random noise associated with dark current variations and from gain variations (due to the signal processing electronics, variations in illumination, lens effects, and sensor characteristics). Flatfield normalization adjusts the signal of each pixel to account for these variations and yields a more uniform camera response.

A previously acquired flatfield file can be used whenever the settings in the file match the settings in the selected data file. If the settings within a flatfield file do not match, you will not be allowed to use the selected flatfield file for data correction.

Applying Flatfield Correction to Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button 

and retrieve the file you want to process.
3. Click on the **Processes** button 

and then select Flatfield... from the menu. When the **Flatfield** dialog appears, the data you retrieved will be displayed in the Before viewing area.

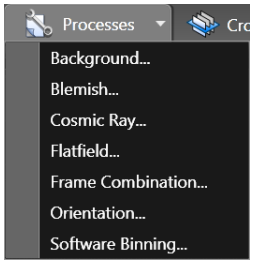


Figure 277. Processes menu

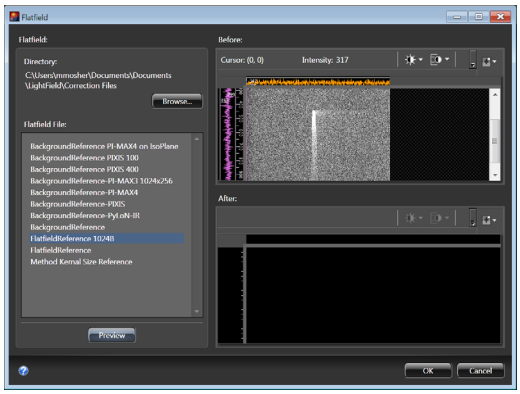


Figure 278. Flatfield dialog

4. Select the appropriate flatfield file. If the file is suitable, the **Preview** button 

will be activated.
5. When you click on the **Preview** button, the effect of the correction will be shown in the After viewing area.
6. After you have finished examining the resulting data, made any changes, click on Cancel to quit the dialog, or click on OK to apply the flatfield correction.
7. If you click on **OK**, the flatfield correction is applied and you are returned to the Data workspace. Note that the icon for the data is tinted yellow to indicate that the data have been corrected but not saved. At this time, you can now click on the **Save** button 

and save the processed data to a location and a file name of your choice.

Frame Combination

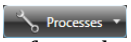
Introduction

Frame combination is the process of adding or averaging two or more frames worth of data and creating a single frame from the result.

Post-acquisition frame combination allows you to take any previously acquired LightField .SPE data file with multiple frames, select either average or sum, enter the number of frames to be combined, preview the effect of the combination, apply the combination, and then save the result to another data file or overwrite the original file. Post-

acquisition frame combination parameters are entered via the Frame Combination dialog accessed from the Processes drop-down list on the Data workspace.

Combining Frames in Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button  and retrieve the file you want to process.
3. Click on the **Processes** button  and then select Frame Combination... from the menu. When the **Frame Combination** dialog appears, the data you retrieved will be displayed in the Before viewing area.

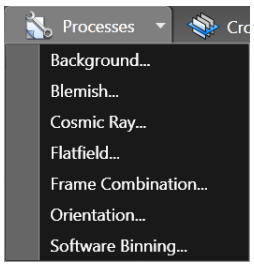


Figure 279. Processes menu

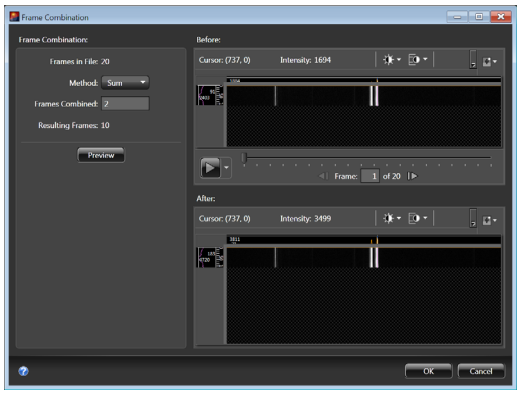


Figure 280. Frame Combination dialog

4. Select the combination method: **Average** or **Sum**.
5. Enter the number of frames to be combined. The resulting number of frames will be reported.

> **Note:** If the original file contains 20 frames and 2 frames are to be combined, the resulting number of frames will be 10. Using the same original 20 frames but combining 3 frames, the resulting number of frames will be 6 and the last two frames from the original file will be dropped.

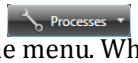
6. When you click on the **Preview** button  , the effect of the combination will be shown in the After viewing area.
7. After you have finished examining the resulting data, made any changes, click on Cancel to quit the dialog, or click on OK to apply the frame combination.
8. If you click on OK, the frame combination is applied and you are returned to the Data workspace. Note that the icon for the data is tinted yellow to indicate that the data have been corrected but not saved. At this time, you can now click on the **Save** button  and save the processed data to a location and a file name of your choice.

Orientation

Introduction

If for some reason, the data you had previously acquired is not oriented correctly you can use this post-process to make the necessary change(s).

Correcting the Orientation of Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button  and retrieve the file you want to process.
3. Click on the **Processes** button  and then select Orientation from the menu. When the **Orientation Correction** dialog appears, the data you retrieved will be displayed in the Before viewing area.

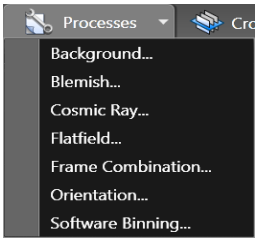


Figure 281. Processes menu

Figure 282. Orientation Correction dialog

4. Three operations are available: flip along the blue line, flip along the red line, and rotate 90°,

180°, or 270°. These may be performed in any combination and in any order.

- To flip the image along the blue line, click on the rotisserie button at the end of the blue line.
- To flip the image along the red line, click on the rotisserie button at the end of the red line.
- To rotate the image without flipping, click on one of the rectangular rotate buttons along the perimeter of the gray circle to rotate the image such that the button at the end of the blue line moves to the location of that rotate button.

5. While you make the orientation changes, the effect of the changes will be shown in the After viewing area.
6. After you have finished examining the resulting data, click on Cancel to quit the dialog, or click on OK to apply the binning.
7. If you click on **OK**, the binning is applied and you are returned to the Data workspace. Note that the icon for the data is tinted yellow to indicate that the data have been corrected but not saved. At this time, you can now click on the **Save** button 

and save the processed data to a location and a file name of your choice.

Software Binning

Introduction

Binning is the process of combining the charge from adjacent pixels in a CCD sensor. It can be done in real time in either a hardware or software mode, and also during post-processing. Hardware binning takes place before sensor readout, whereas software binning takes place after readout. Hardware binning is faster than software binning but subject to blooming and thus data invalidation. Hardware or software binning can be active during data acquisition.

Post-acquisition software binning allows you to take any previously acquired LightField .SPE data file, enter binning parameters, preview the effect of the binning, apply the binning, and then save the result to another data file or overwrite the original file. Post-acquisition software binning parameters are entered via the **Software Binning** dialog accessed from the **Processes** drop-down list on the **Data** workspace.

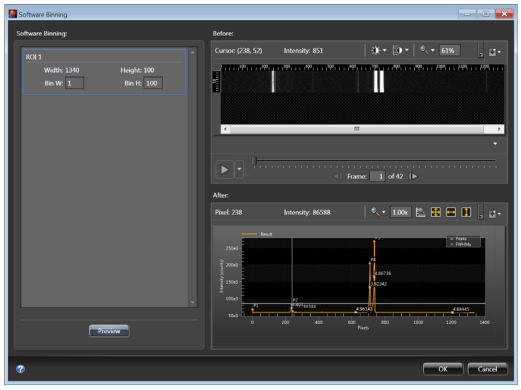
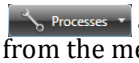


Figure 283. Software Binning dialog

Binning Previously Acquired Data

1. Open the Data workspace.
2. Click on the **Open** button 

and retrieve the file you want to process.
3. Click on the **Processes** button 

and then select Software Binning... from the menu. When the **Software Binning** dialog appears, the data you retrieved will be displayed in the Before viewing area.

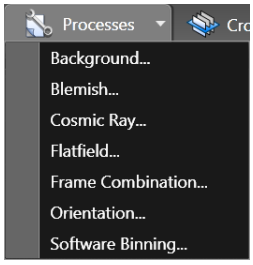


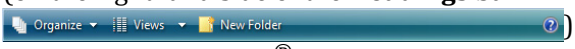
Figure 284. Processes menu

4. Enter the binning values. If these values do not evenly divide into the width and/or height, the binning will be applied and the remainder(s) will not be included in the data set.
5. When you click on the **Preview** button 

, the effect of the binning will be shown in the **After** viewing area.
6. After you have finished examining the resulting data, click on Cancel to quit the dialog or click on OK to apply the binning.
7. If you click on **OK**, the binning is applied and you are returned to the Data workspace. Note that the icon for the data is tinted yellow to indicate that the data have been corrected but not saved. At this time, you can now click on the **Save** button 

and save the processed data to a location and a file name of your choice.

Save

The **Save** dialog, opened by clicking on the **Save** button  on the Data Workspace, allows you to specify the name and location of the file you are about to save. Click on the **Folder Help** button  (on the righthand side of the **Headings bar** ) to access the Windows® Help files for this dialog.

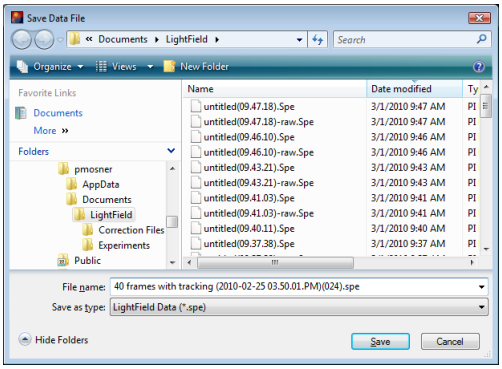


Figure 285. Save Data File dialog

Chapter 11: Troubleshooting Topics

Add-in Crashes

An Add-in may crash when LightField starts up or it may crash when you try to run the Add-in. LightField's response depends on when the crash occurred and whether the crash also crashed LightField.

- If an Add-in crashes when LightField is starting up, a message displays the name of the Add-in and when you click on **OK**, deactivates it for the current session but does not change the Add-in's checked status in the **Manage Add-ins** dialog. If you correct the cause of the crash, you can reactivate the Add-in by opening the **Manage Add-ins** dialog and clicking on **OK**.

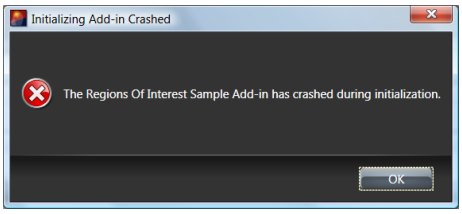


Figure 286. Initializing Add-in Crashed message

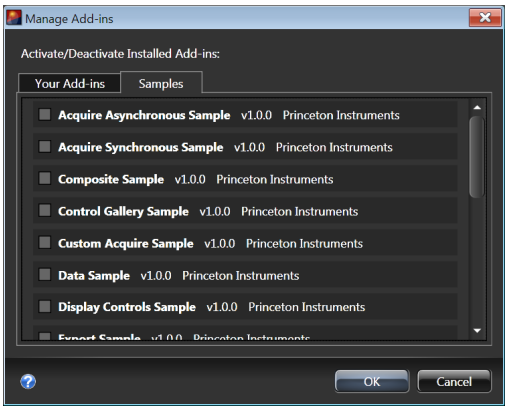


Figure 287. Manage Add-ins dialog

- If the Add-in crashes when you try to run it, a message displays the name of the Add-in and you are given the choice of reactivating or ignoring the Add-in. Clicking on **Reactivate** will reactivate the Add-in for this session. Clicking on **Ignore** will leave it disabled for this session. The Add-in's checked status in the **Manage Add-ins** dialog is not affected. If during the current session you correct the cause of the crash, you can reactivate the Add-in by opening the **Manage Add-ins** dialog and clicking on **OK**. If you do not reactivate the Add-in during the current session, the next time you launch LightField, the Add-in will be activated because it is still checked in the **Add-In Manager** dialog.

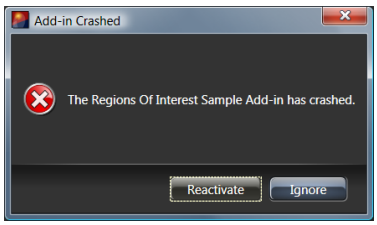


Figure 288. Add-in Crashed message

- If an Add-in crashes and also crashes LightField, the program will try to note this information. When you restart LightField, the program will try to put up a message indicating that the Add-in crashed LightField and ask if you want to start LightField with or without loading the Add-in. Depending upon your response, the Add-in would then be checked in **Add-In Manager** and loaded, or it will be unchecked in Add-In Manager and not loaded.

AVI File Does Not Play

Overview

AVI Export and the playback of AVI exports created in LightField were tested using Windows 7 (Service Pack 1) and several versions of Windows Media Player version 12. Compressed AVIs offer greater compatibility, but result in lossy data. Uncompressed AVIs offer better data quality, but may not offer a wide range of compatibility with different machines, media players or image sizes.

The codecs used to export and play back compressed AVIs depend upon the codecs available to your particular machine. From the About window in Windows Media Player, you can click on the Technical Support Information link to see a list of the codecs available.

If you cannot export or play a compressed AVI on your machine, it is likely due to a missing codec or a codec conflict on your machine. More information about working with codecs and troubleshooting AVI issues can be found here:

http://windows.microsoft.com/en-US/windows7/Codecs-frequently-asked-questions

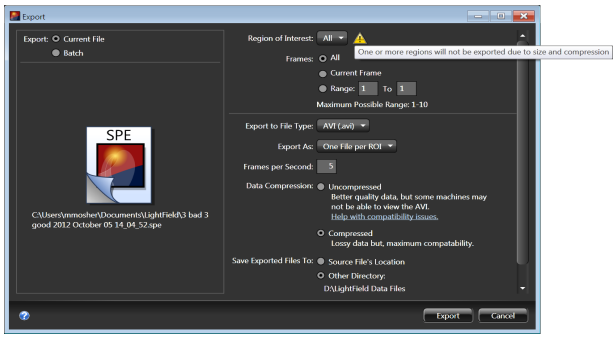
If you have difficulty playing uncompressed AVIs, you can try opening the AVI in different media

players, or try varying the size of the image that is exported.

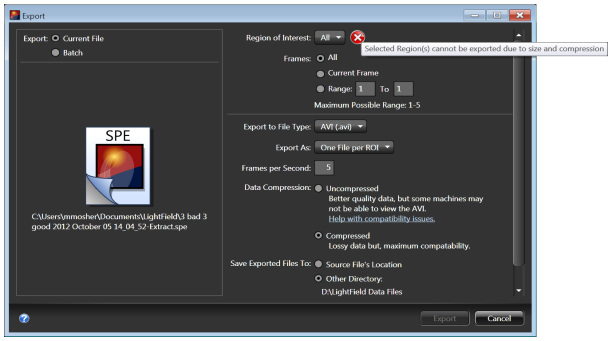
ROI Constraints

LightField will not allow you to export compressed AVIs if an ROI has fewer than 8 rows or columns (this is a limitation of the type of compression used). Because of these constraints, you may see one of the following warnings or errors.

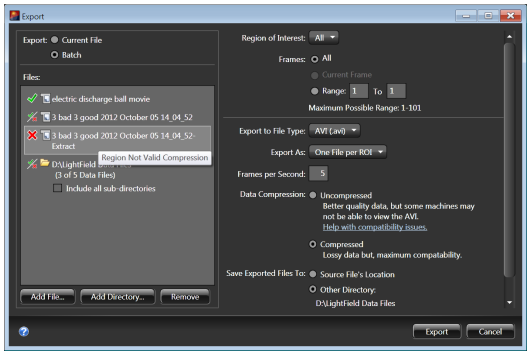
1. If you are in **Current Mode**, are exporting compressed AVIs, and have multiple ROIs, you could potentially get the following warning: *"One or more regions will not be exported due to size and compression."*



2. If you are in **Current Mode**, are exporting compressed AVIs, and have multiple ROIs, you could potentially get the following error (meaning none of your ROIs are valid for export to compressed AVIs.): *"Selected Region(s) cannot be exported due to size and compression."*



3. If you are in **Batch** mode, files and directories can now be fully or partially red-Xed based upon the size of the ROI and export to compressed AVI.



Blemish Correction File Is Not Valid

	A	B	C
1	Defect Map		
2	Version	1	1
3	Sensor Width	1024	
4	Sensor Height	256	
5			
6	Column Defects		
7	Column	Row	Length
8	3	0	256
9	Row Defects		
10	Column	Row	Length
11	0	10	1024
12	Pixel Defects		
13	Column	Row	
14	10	3	
15	1023	255	

Figure 289. Blemish File

LightField checks a selected blemish file to see if the sensor dimensions in the file match the dimensions of the sensor in the camera and if entries make sense based on the sensor dimensions. If the file does not pass the check, LightField will not prevent you from acquiring data with an invalid blemish file, but it lets you know there is a problem by posting an **Experiment Warning** next to the **Browse** button and in the **Status** bar. In the case of Post-Process Blemish Correction, a grayed out **Preview** button indicates there is a problem with the file. Please note that there are two versions of blemish files:

- **1.X (column, row, and pixel correction):** The 1.X files created for previous versions of LightField are compatible with LightField versions 4.4 and higher.
- **2.X (cluster, column, row, and pixel correction):** The 2.X files are compatible with LightField versions 4.4 and higher.

If a **Warning** or **Conflict** is displayed for Online Correction or the **Preview** button is grayed out for Post-Process Correction, examine the contents of the blemish file via a spreadsheet such as Excel or a text editor such as Notepad.

- Check the blemish file version. If the version is 2.X and you are currently running a LightField version less than 4.4, you cannot use a file that allows Cluster Defect correction. You will need to upgrade to version 4.4 or higher to use this feature.
- If you have LightField 4.4 (or higher) and you have specified a 2.X blemish file, verify that all pixels within a cluster are touching, even if only diagonally. Verify that none of the Cluster IDs is 0. Verify that Cluster Pixel Defect length is 1: if it isn't or the field is blank, the file is invalid.
- If you are not sure of the sensor dimensions, open the Sensor expander, click on Custom Sensor to open the flyout pane, review the dimensions, and click outside of the pane to close it. The width and height of the sensor's Active Area are reported here. Open the blemish file if you have not already done so. Make sure that the values in the Sensor Width and Sensor Height rows match the sensor dimensions of the Active Area.

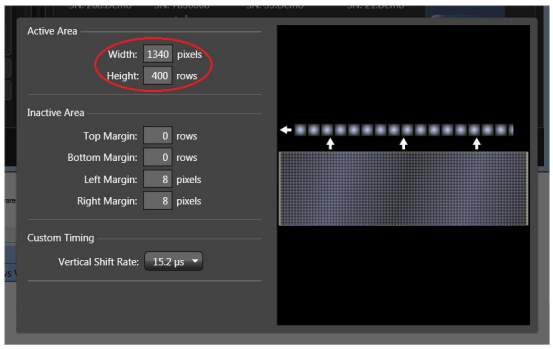


Figure 290. Custom Sensor flyout pane

- If the dimensions match, you need to see if the values in the Length columns are appropriate.
  - A Column Defect will have the column number entered under Column (keep in mind that the first column on the sensor is Column 0), there should be 0 in the Row column, and the Length of the Column Defect is the height of the sensor.
  - A Row Defect should have a 0 under Column because this defect is a defective row, the row number should be entered (keep in mind that the first row on the sensor is Row 0), and the Length of the Row Defect is the width of the sensor.
  - A Pixel Defect is denoted by its Column,Row position. The first pixel on the sensor is at position 0,0 (top left). If the defect is in the last column and last row (bottom right), its location would be Sensor Width - 1, Sensor Height - 1 (for example, if the sensor is 1024 wide by 256 high, a pixel defect in the last column,row would be located at 1023,255.

In some cases, it may not be apparent that a blemish file is inappropriate or incorrect. If the data you are acquiring or have previously acquired do not seem to show the blemish correction from your blemish file, you can do a dry run of the blemish correction. To do this:

1. In the Experiment workspace, create a Demo camera of the type and sensor size of your actual camera.
2. Move the Demo camera icon from the **Available Devices** area into the **Experiment Devices** area.
3. Next, without **Online Correction** active, acquire a single demo frame.
4. View that data in the **Data** workspace and then select **Processes|Blemish...**.
5. Select your blemish file and click on the **Preview** button.
6. Using the mouse and the keyboard arrow keys, position the cursor on the b image at a pixel that should be affected by the blemish file.
7. Then position the cursor in the **After** image at the same pixel location.
8. Compare the reported intensities.
   - If the two intensities are different, blemish correction has occurred.
   - If the two intensities are identical, blemish correction has not occurred (review the contents of the selected blemish file) or the values of the adjacent pixels used in the correction resulted in no change (choose a different defect location in the images).

Device Is Not Found

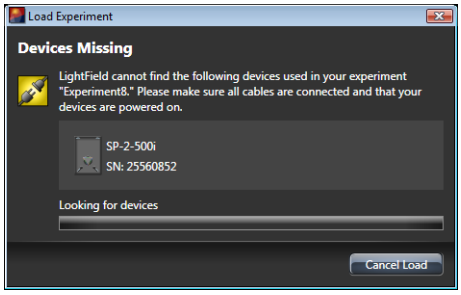


Figure 291. Devices Missing dialog

When LightField is started, it looks for devices that are powered on and connected via a communications interface to the host computer. If it cannot find a device that was used in the last experiment, it will continue to look for it.

- Make sure the device is connected and powered on. If LightField cannot find a spectrograph that is connected and powered on, turn the spectrograph off and back on. LightField should now find it.
- Make sure the device is connected and powered on. If LightField is not able to detect a camera that is powered on and connected via the GigE interface, UDP ports 20200-20202 may need to be opened. These ports must be open before LightField can detect a Princeton Instruments GigE camera, but they may have been closed as part of your computer security (such as an anti-virus program or a firewall). Contact your Information Technology specialist for assistance.
- Cancel the Load: Cancelling a load means that the last used experiment will not be loaded automatically when LightField opens. However, you can load the experiment after all the devices are available, you can start a new experiment design, or you can load a different experiment that matches the devices you are using.

Find Center Is Disabled

Reasons why this button is not active include:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are binned horizontally (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- The reference spectrum is not shown.
- **Step & Glue** mode is checked.
- The grating selection is **Mirror**.

Image Is Saturated

Saturation occurs when the value of the signal in pixels is near the upper intensity limit of 65,535. This can be because too much light is falling on an area (due to ambient light levels or exposure time), high intensity areas are binned, multiple frames are being summed, or too much gain is applied. Depending on the scene being captured, saturation may occur in an area of an image or across the entire image. When an area is saturated, that area in the image is white and contains little or no contrast. To make saturation more apparent, open the **Image Viewer Options** menu, select **Image Options**, select the **Pseudo Color** option, and then select **Underexposure/ Overexposure**. Overexposed areas will be colored red (pixel values from 65,000-65,535). This allows you to more easily see potential image quality issues and make changes to your experiment design.

To reduce or eliminate saturation you can:

- reduce the ambient light level,
- acquire and apply a background,
- reduce the exposure time,
- reduce the amount of binning,
- reduce the number of frames being summed, and/or
- reduce gain settings.

Image Is Underexposed

Underexposure occurs when the value of the signal in pixels is near the lower intensity limit of 0. This can be because too little light is falling on an area (due to ambient light levels or exposure time), too little gain is applied, not enough binning is being applied, or too few frames are being summed together. Depending on the scene being captured, underexposure may occur in an area of an image or across the entire image. When an area is underexposed, that area in the image is black and contains little or no contrast. To make underexposure more apparent, open the **Viewer Options** menu, select **Image Options**, select the **Pseudo Color** option, and then select **Underexposure/Overexposure**. Underexposed areas in an image will be colored yellow (pixel values from 0-100). This allows you to more easily see potential image quality issues and make changes to your experiment design.

To reduce or eliminate underexposure you can:

- increase the ambient light level,
- increase the exposure time,
- increase the amount of binning,
- increase the number of frames being summed, and/or
- increase gain settings.

IntelliCal Intensity Calibration Is Disabled

Reasons why this button is not active include:

- There is an **Experiment Conflict**.
- An intensity calibration light source is not selected and ON.
- There is no background file selected or the selected background file is not valid.
- Regions are binned horizontally (i.e., in the serial direction) using either hardware or software binning.
- Software binning is in use.
- A calibration (fixed or broad) is not in place.

- An experiment is running.
- A spectrometer component is moving.
- The grating selection is **Mirror**.
- The camera has an InGaAs sensor.

Additional reasons why you may not be able to acquire or apply an intensity calibration are that:

- You have made a change to **Custom Sensor** settings.
- You have set the **Readout Mode** to **Kinetics**, **Spectra Kinetics**, or **DIF**.

IntelliCal Wavelength Calibration is Disabled

Reasons why this button is not active include:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are binned horizontally (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- The spectrograph is not an Acton SP series or IsoPlane SCT-320 spectrograph.
- There are not enough lines for either Fixed or Broad calibration.
- The selected light source must be PI Mercury or PI Neon/Argon.
- **Apply Intensity Calibration** is checked, but there is no valid Intensity Calibration reference file.
- The grating selection is **Mirror**.
- The camera is a PyLoN-IR 2.2.

LightField Crash Report

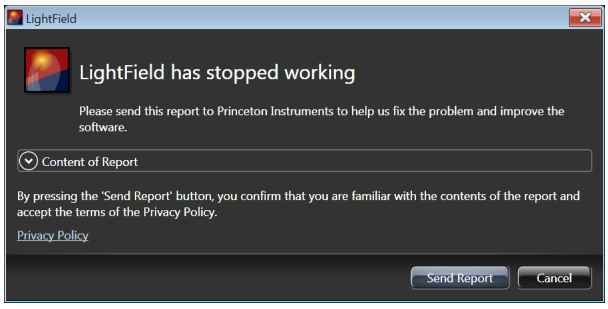


Figure 292. LightField has stopped working dialog

Before LightField restarts after a crash, the "LightField has stopped working" dialog will be displayed so you can send a crash report directly to Princeton Instruments if your computer is connected to the Internet.

To see what may be included in the crash report, click on the **Content of Report** expander to display the **Details** and **Attachments** tabs. The report provides Princeton with details about the environment: OS, Region, number of processors, LightField licenses, system hardware, and the LightField "Available Devices" for the session that crashed. Additionally, you can key in a comment about the circumstances of the crash and decide whether any of the three possible attachments should be included with the report. The attachments are: an LFE file containing the XML information about the experiment, a screen shot of the LightField window, and the Windows Event Log of the crash and can be viewed by clicking on the appropriate hyperlink. Attachments that have a check mark next to them will be sent. Note that a hyperlink to the Princeton Instruments Privacy Policy is located at the bottom left corner of the dialog. Please review this policy before you click on the **Send Report** button.

After you either click on the **Send Report** or the **Cancel** button, LightField will restart and check for unsaved data and an unsaved experiment. If any unsaved items are found, LightField will give you the option of saving or discarding them. ***See "LightField Crashes during Data Acquisition" on page 161*** for more information about unsaved data and experiment recovery.

LightField Crashes because Computer Goes into Sleep or Hibernate Mode

LightField may crash if the Sleep and Hibernate modes have not been turned off for your computer. To prevent this kind of crash, disable the computer's Sleep and Hibernate modes.

LightField Crashes during Data Acquisition

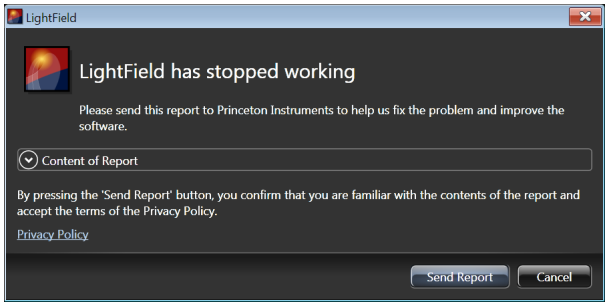


Figure 293. LightField has stopped working dialog

With the release of version 4.4, LightField can now automatically restart and recover from a crash. Before LightField restarts, the "LightField has stopped working" dialog will be displayed so you can send a crash report directly to Princeton Instruments if your computer is connected to the

Internet. After you have sent or canceled sending a report, LightField will restart. While restarting, it checks to see if there are unsaved data and/or unsaved experiment that it can recover. If the crash occurred while you were acquiring data, you will be offered the opportunity to recover or discard any partially written data. And, if LightField detects an unsaved experiment, you will be given the option of recovering or discarding that experiment unsaved experiment, you will be given the option of recovering or discarding that experiment.

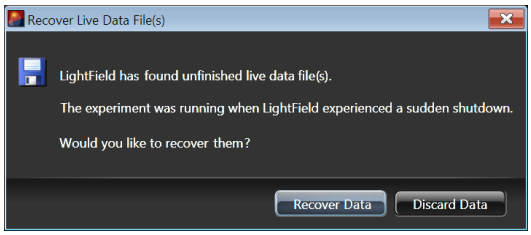


Figure 294. Recover Live Data File(s) dialog

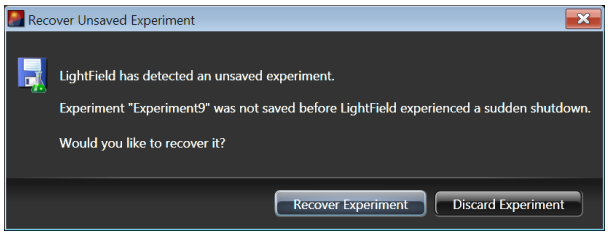


Figure 295. Recover Unsaved Experiment

Recovered data will be saved to the working directory and will have the file name it would have had if the acquisition had finished. Because there may be bad data at the end of the recovered data set, it is a good idea to open the data file in the Data workspace and review the entire data set. If there are bad data, you can use the **Extract Data** process to extract the good data from the recovered file to a different file. ***See "Extraction" on page 152*** for more information about data extraction.

LightField Crashes when Adding GigE Camera to System

If you have a dual port Intel Pro/1000 Ethernet card and LightField crashes when trying to add a GigE camera to the system, you will need to modify the default IP address for one of the ports.

Procedure:

1. Click on the Windows **Start** button and click on **Control Panel**.
2. On the **Control Panel**, click on **Device Manager**.
3. After the **Device Manager** opens, scroll down until **PRO/1000 Grabber Devices** (or similar label) appears.

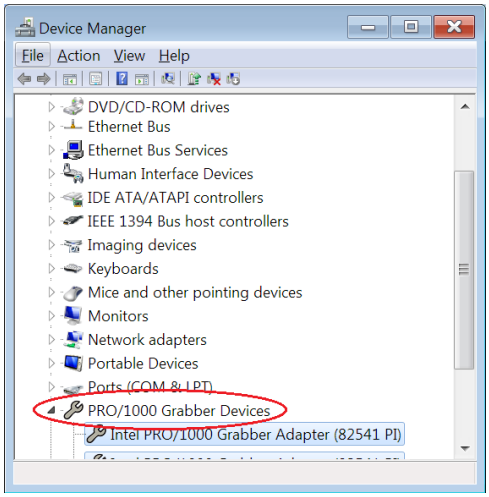


Figure 296. Device Manager dialog

4. Click on that label to expand it and then right-click on one of the ports. On the popup menu, click on **Properties**.

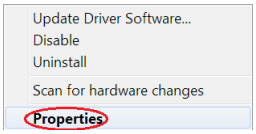


Figure 297. Popup menu

5. On the **Settings** tab, change the third number from the left in the IP Address. For example, replace the "2" in the IP Address 192.168.2.1 with "4" so the IP Address is now 192.168.4.1

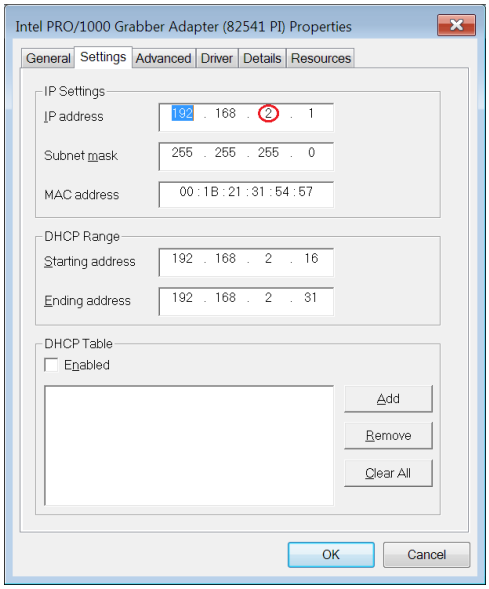


Figure 298. Properties|Settings tab

6. Click on **OK**.
7. When the **System Settings Change** dialog appears, click on **Yes** to restart your computer now or click on **No** to restart it later. The

change will not take place until you restart the computer.

Live Data is Not Appearing in the Experiment Viewer

If you are acquiring or have acquired data but the Experiment Viewer is empty or an image or a graph is displayed but does not change, verify that the **Review Acquired Data** button has shown up to the right of the **Status panel** Ready. This tells you that data were acquired. If you click on the **Review Acquired Data** button, you will see the recently acquired data in the **Data** workspace viewer. There are two possible reasons for not seeing Live data during acquisition:

- You turned off the viewer. Right-mouse click in the viewer. If **View Live Data** is selectable from the context menu, select it. You should now see the final frame from the data acquisition.
- You used the **Open File...** function on the Experiment Viewer's context menu to load a file into the viewer. To remove this file from the viewer, change the **Display Type** to "Graph" in the context menu if it is currently displaying an image. Then, open the **Source** drop-down pane by clicking on the **Source** button. Click on the **Change Source** button (to the right of the file name) and click on **Select Live Data**. The most recently acquired data will be displayed in the viewer. The viewer will now be updated with live data whenever you are previewing or acquiring data.

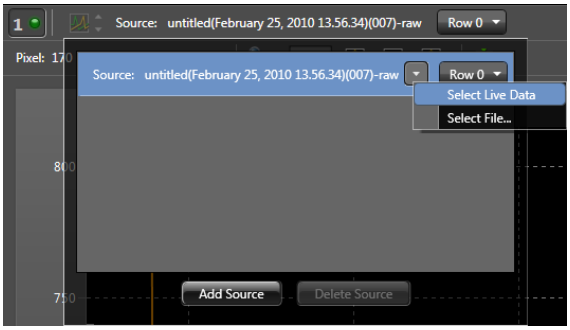


Figure 299. Multiple Sources pane

LS 785 Is Not Shown in the Available Devices Area

The LS 785 icon will only appear if LightField finds the NoComDevices.xml file in the **hidden directory** C:\ProgramData\Princeton Instruments\Spectral Devices directory. If you do not see this directory on your C drive, you probably need to unhide it: see instructions below. Search for the file and, if you find it, move it to that directory. If you cannot locate the file, contact Princeton Instruments Customer Service.

Unhiding a Hidden Directory

1. Open the Windows Control Panel.
2. Enter hidden in the search field at the top right of the panel.
3. Click on **Show hidden files and folders**.
4. Click on the **Show hidden files and folders** radio button.
5. Click on **Apply** and then click on **OK**.
6. You should now be able to see the ProgramData directory and its subdirectories on your C drive.

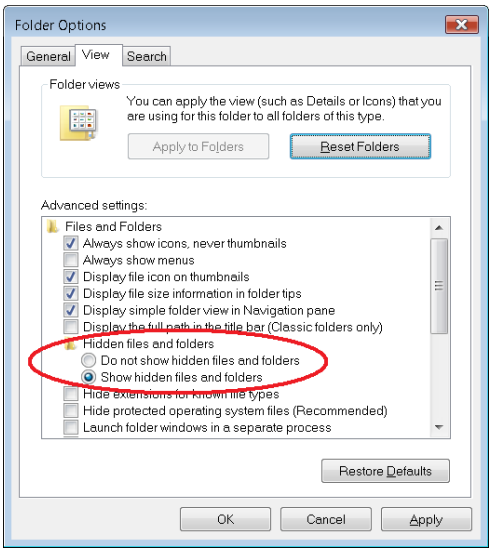


Figure 300. Folder Options dialog

Princeton Instruments Camera Using GigE Interface Is Not Found

When LightField is started, it looks for devices that are powered on and connected via a communications interface to the host computer. If LightField is not able to detect a camera that is powered on and connected via the GigE interface, UDP ports 20200-20202 may need to be opened. These ports must be open before LightField can detect a Princeton Instruments GigE camera, but they may have been closed as part of your

computer security (such as an anti-virus program or a firewall). Contact your Information Technology specialist for assistance.

Show Reference Spectrum Is Disabled

Reasons why this function is not available include:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are binned horizontally (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- **Step & Glue** mode is checked.
- The grating selection is **Mirror**.

Standard Calibration Is Disabled

Reasons why this button is not active include:

- There is an **Experiment Conflict**.
- An experiment is running.
- A spectrometer component is moving.
- Regions are not full width.
- Regions are binned horizontally (i.e., in the serial direction).
- Multiple ROIs must all be the same width.
- The spectrograph is not an Acton SP series or IsoPlane SCT-320 spectrograph.
- **Apply Intensity Calibration** is checked but there is no valid Intensity Calibration reference file.
- The grating selection is **Mirror**.

Step & Glue Is Disabled or Not Present

Reasons why this function is not available:

- There is an **Experiment Conflict**.
- **Custom Sensor** changes have been made.
- **Kinetics** readout mode is active.
- **Spectra Kinetics** readout mode is active.
- Multiple ROIs are not the same width.
- The spectrograph is an LS 785.

Customer Support

For immediate support in your area, please call the following locations directly:

North America	1 877 4 PIACTON (877 474 2286)
Benelux	+31 (347) 324989
France	+33 (1) 60 86 03 65
Germany	+49 (0) 89 660 7793
Japan	+81 (3) 5639 2741
UK & Ireland	+44 (0) 28 3831 0171
Singapore	+65 6293 3130
China	+86 10 6262 5862

Otherwise, please contact Customer Support by using the Support Request form (http://www.princetoninstruments.com/support/contact.aspx) or by sending an e-mail request at techsupport@princetoninstruments.com.

Appendix A: System and Camera Nomenclature

System and Camera Type Cross-Reference

Use the cross-reference table below if you need to determine the camera/CCD type used by your system. This table is based on the systems that are currently being sold by Princeton Instruments. Many of these systems incorporate non-volatile RAM (NVRAM) that has been factory programmed with the default hardware setup parameters for the camera and CCD array included in your system. If you know the controller type used by your system, you should be able to download these default parameters. However, if this functionality is not available for your system, you will need to manually enter the information.

The eXcelon® sensors provide photon detection capabilities across a wide spectrum; from 200 nm to 1100 nm. They are especially beneficial to applications requiring enhanced sensitivity in the blue to near-infrared (NIR) region. In addition, the eXcelon back-illuminated sensors significantly reduce problematic etaloning – or the appearance of fringes due to constructive and destructive interference in the back-thinned silicon when imaged in the NIR region (750-1100 nm).

Because Marconi changed its name to e2v, you may see CCD types with the prefix "MAR", "EEV", or "e2v". These CCDs are manufactured by e2v.

System	Camera/CCD Type
NIRvana:640 (formerly PIoNIR:640)	PI InGaAs 640
PI-MAX3:1024i	Kodak KAI-1003
PI-MAX3:1024x256	e2v 256x1024F CCD 30-11
PI-MAX4:1024i	Kodak KAI-1003
PI-MAX4:1024i-RF	Kodak KAI-1003
PI-MAX4:1024x256	e2v 256x1024F CCD 30-11
PI-MAX4:1024x256-RF	e2v 256x1024F CCD 30-11
PI-MAX4:512EM	e2v CCD97
PI-MAX4:512B/EM	e2v CCD97
PIoNIR:640 (renamed NIRvana:640)	PI InGaAs 640
PIXIS:100F, B, BR, R	EEV 100x1340F/B
PIXIS:100B eXcelon	EEV 100x1340F/B
PIXIS:256F, B, BR, E	e2v CCD30-11

System	Camera/CCD Type
PIXIS:400F, B	EEV 400x1340F/B
PIXIS:400 B eXcelon	EEV 400x1340B
PIXIS:512F, B, BUV	MAR 512x512 CCD 77
PIXIS:512B eXcelon	MAR 512x512 CCD 77
PIXIS:1024F, B, BR, BUV	EEV 1024x1024 CCD 47-10
PIXIS:1024B eXcelon	EEV 1024x1024 CCD 47-10
PIXIS:1300F, B, BR	PI exclusive 36-40
PIXIS:1300B eXcelon	PI exclusive 36-40
PIXIS:2048F, B	e2v CCD42-40
PIXIS:2048B eXcelon	e2v CCD42-40
PIXIS:2KB, BUV	e2v CCD42-10
PIXIS:2KB eXcelon	e2v CCD42-10
PIXIS-XB:256BR	e2v CCD30-11
PIXIS-XF:1024F, B	e2v CCD47-10
PIXIS-XF:2048F, B	e2v CCD42-40
PIXIS-XO:100B, BR	PI 1340x100B
PIXIS-XO:400B	PI 1340x400B
PIXIS-XO:512F, B	e2v 512x512B CCD 77-00
PIXIS-XO:1024F, B, BR	e2v 1024x1024 CCD 47-10
PIXIS-XO:2048B	e2v CCD42-40
PIXIS-XO:2KB	PI 2048x512B
ProEM:512B	e2v CCD97
ProEM:512B eXcelon	e2v CCD97
ProEM:512BK	PI exclusive
ProEM:512BK eXcelon	PI exclusive
ProEM:1024B	e2v CCD201
ProEM:1024B eXcelon	e2v CCD201
ProEM+:512B	e2v CCD97
ProEM+:512B eXcelon	e2v CCD97
ProEM+:512BK	PI exclusive
ProEM+:512BK eXcelon	PI exclusive
ProEM+:1024B	e2v CCD201
ProEM+:1024B eXcelon	e2v CCD201
PyLoN:100F, B, BR	PI 1340x100B
PyLoN:100B, BR eXcelon	PI 1340x100B
PyLoN:400F, B, BR	PI 1340x400B

System	Camera/CCD Type
PyLoN:400B, BR eXcelon	PI 1340x400B
PyLoN-IR:1024-1.7	SUI 1024x1 InGaAs (LE-1.7)
PyLoN-IR:1024-2.2	SUI 1024x1 InGaAs (LE-2.2)
Quad-RO:4096	FCD 4096x4096F MT
Quad-RO:4320	KAF 2084x2084 MT

System Descriptions

The following information briefly describes Princeton Instruments brand systems and the system components. For more information, contact your Princeton Instruments representative or Customer Support.

NIRvana: Formerly called PIoNIR. Compact, permanent vacuum camera platform with internal controller. Designed with FPA for NIR spectroscopy and imaging.

PI-MAX3: Intensified CCD (ICCD) with internal controller, high voltage power, and gating.

PI-MAX4: Intensified CCD (ICCD) with internal controller, high voltage power, and gating.

PI-MAX4-EM: Intensified CCD (ICCD) with internal controller, high voltage power, gating, and an EMCCD (electron-multiplying CCD).

PI-MAX4-RF: Intensified CCD (ICCD) with internal controller, high voltage power, gating, and RF modulation capability.

PIoNIR: Renamed NIRvana. Compact, permanent vacuum camera platform with internal controller. Designed for NIR spectroscopy and imaging.

PIXIS: Compact, permanent vacuum camera platform with internal controller. Designed for low-light-level spectroscopy and imaging.

PIXIS-XB: Compact, permanent vacuum camera platform with internal controller. Designed with front illuminated, deep-depletion CCD and Beryllium window.

PIXIS-XF: Compact, permanent vacuum camera platform with internal controller. Designed for lens-free, indirect imaging of X-rays using phosphor screens or other Lambertian sources.

PIXIS-XO: Compact, vacuum open-nose camera platform with internal controller and rotatable ConFlat flange. Designed for direct imaging of very low energy X-ray (<30 eV).

PROEM/PROEM+: EMCCD (electron-multiplying CCD). Optimized for both traditional CCD and "on-chip multiplication gain" operation. Internal controller. Air- and liquid-cooling. Vacuum guaranteed for the life of the camera.

PyLoN: Liquid nitrogen cooled detector with internal controller and 1.7 liter Dewar capacity.

PyLoN-IR: Liquid nitrogen cooled detector with internal controller, InGaAs array, and 1.7 liter Dewar capacity.

QUAD-RO: High performance X-ray system. Systems can effectively provide X-ray photon-counting capability with up to 16-bit dynamic range. 1:1 fiberoptic taper and multi-port output. Thermoelectric cooling

Sensor Designators

In the past, the designators in the following list were often used on camera serial labels to identify the sensor in the camera.

B: Back-illuminated CCD

E: CCD made by EEV

F: Front illuminated CCD, in many cases no letter is used

FPA: Focal Plane Array

FT: Frame Transfer detector

H: CCD made by Hamamatsu

K: CCD made by Kodak

M: MPP (multi-pin phasing) CCD

P: (Usually) CCD offered exclusively by Princeton Instruments

R: Deep depletion

S: Usually refers to SITe arrays, also see TK

T: CCD made by Thomson

TK: CCD made by SITe (formerly Tektronix), sometimes labeled S

UV: UV-to-VIS standard lumogen coating for UV-response to 195 nm

UVAR: Permanent UV-to-NIR A/R coating on some SITe CCDs (not lumogen/metachrome)

VISAR: Permanent VIS to NIR A/R coating on some SITe CCDs (not lumogen/metachrome)

Y: Interline CCD made by Sony

/1: grade 1 CCD

/2: grade 2 CCD

/3: grade 3 CCD

100: array format is 1340 x 100 pixels

256: array format is 1024 x 256 pixels

400: array format is 1340 x 400 pixels

512: array format is 512 x 512 pixels

1024: array format is 1024 x 256 or 1024 x 1024

1300: array format is 1300 x 1030 pixels or 1300 x 1340 pixels

2K: array format is 2048 x 512 pixels

2048: array format is 2048 x 2048 pixels

4096: array format is 4096 x 4096 pixels

4320: array format is 2084 x 2084 pixels

Appendix B: Glossary

A

Acquisition: A unit of data collection consisting of one or more exposures and a readout.

Active Area Height: The active rows that run parallel to the serial register.

Active Area Width: The active columns that run perpendicular to the serial register.

Active Spectrograph: The spectrograph whose motor will be controlled and whose position can be used to automatically calibrate the wavelength scaling of acquired data whenever the spectrograph method of calibration is used. If only one spectrograph has been installed, it is the active spectrograph. If two or more have been installed, the active one must be designated.

ADC: See ***Analog-to-Digital (A/D) Converter***.

ADC Bit Depth: Bit depth (width) as determined by the chosen ADC Speed. See Bit Depth.

ADC Quality: This is the type of A/D conversion to be used. If this setting is applicable with the experiment hardware, the valid values are Low Noise and High Capacity.

ADC Speed: The speed at which data are digitized.

Add-Ins: Custom commands and features created by the user or third-party developers to add controls and functionality to the LightField software. LightField checks for add-ins upon start up and, via the Manage Add-ins dialog, allows you to turn them off or on.

ADU: Analog-to-digital unit. A number representing a sensor's output. The relationship between the ADUs generated and the number of electrons acquired on the sensor is defined by the system gain. Intensities given in ADUs provide a convenient method for comparing images and data generated by different cameras.

Analog Gain: In digital cameras, system gain defines the relationship between the number of electrons acquired on a CCD and the analog-to-digital units generated. User-selectable values are Low, Medium, and High. When choosing the value of this setting, the ADC Quality should be taken into account. Actual gain at the Low, Medium, and High settings depends on the camera selected ADC mode system gain. Gain is typically expressed as e–/ADU.

Analog-to-Digital (A/D) Converter: In a CCD detector system, this is the electronic circuitry that converts the analog information acquired by the detector into the digital data used for image display.

ARC_DATA: This is the file name extension for files created by Acton's SpectraSense software.

Avalanche Gain: See ***EM Gain***.

AVI: Filename extension for the Audio Video Interleave format.

B

Backlash: Applied to the movement of gratings or slits, this is the amount of play between gears when changing the direction of travel.

Bias: See ***Offset***.

Binning: Binning is the process of combining the charge from adjacent pixels in a CCD to increase camera speed and sensitivity to weak signals. Hardware binning takes place before the signal is read out, whereas software binning takes place after the signal is read out. Hardware binning is faster than software binning but is subject to blooming.

Bit Depth: The number of bits (smallest unit of information in a notation using the binary system) that are digitized by a system's A/D converter.

Blooming: Occurs when the charge generated in a pixel exceeds the well capacity of the pixel. This can also refer to the spillage of charge out of a serial register pixel due to excessive binning.

Bottom Margin: Non-active parallel strips (of dark pixels) that follow the active strips in reaching the serial register.

Bracket Pulsing: See ***MCP Bracket Pulsing***.

Bulb Trigger Mode: (ProEM) The camera exposure is set by the External Sync input at the EXT SYNC connector. This allows an external timing generator to control the exposure time of the camera. In Full Frame, Frame transfer, or Kinetic modes, the transition from the inactive state to the active state of the External Sync at the EXT SYNC connector starts the exposure; and the transition from the active state to the inactive state ends the Expose. Kinetics mode-Single trigger is not a valid option for Bulb Trigger mode.

C

Center Wavelength: The wavelength that falls on the center of the sensor array of a calibrated spectrograph.

Charge Smearing: The residual charge left behind in pixels (potential wells) when an image is shifted on a sensor. This occurs because of light falling on the sensor during the shift.

Charge Transfer Efficiency: Refers to the percentage of charge that is transferred when electrons in one potential well are moved to an adjacent well. Scientific-grade CCDs typically have a charge transfer efficiency (CTE) of 99.9998%, where 100% is perfect.

Clean Before Exposure: Only provided for cameras that have a Frame Transfer sensor, and is only available for selection when in Full Frame readout mode and the

trigger mode is Start on Single Trigger. When these settings are active, cleaning will occur during acquisition: immediately after reading out, the whole sensor will be cleaned once before each exposure.

Clean Cycle Height: Number of parallel strips in each clean cycle.

Clean Serial Register: When Pre-Active Parallel Strips are available, they clean the serial register prior to readout of the active strips. If Pre-Active Parallel Strips are unavailable, selecting Clean Serial Register forces a clean of the serial register prior to readout of the active strips.

Clean Until Trigger: In triggered modes, selecting Clean Until Trigger forces the system to clean continuously while awaiting the beginning of the next exposure.

Cleaning: The clearing of accumulated charge on the sensor by shifting the charge to the serial register and discarding it.

Closing Delay: The length of time by which read out is delayed to compensate for the time it takes the shutter to fully close.

Computer Interface: Shows the type of connection between the hardware and the computer.

Count: See ***ADU***.

CTE: See ***Charge Transfer Efficiency***.

Cumulative Histogram: A graphical representation of a data set that groups pixels of a similar intensity together, using the X axis to show intensity. The Y axis indicates the total number of pixels with intensity less than or equal to the range. A cumulative Histogram is always an increasing function.

D

Dark Charge: Thermally-induced buildup of charge on the array in the absence of light.

Dark Current: (1) The charge that accumulates within a pixel (potential well) in the absence of light. (2) The background current that flows in a CCD camera system. Cooling the photodetector's primary imaging surface (i.e., the CCD's photoconductor) can reduce or eliminate dark current. Also called thermally generated charge.

Data Rate: The rate at which data from the camera arrives at LightField\. Also known as Frame Rate.

Data Type: Four data types are used: Unsigned 8 (0 to 255), Unsigned 16 (0 to 65,535), Signed 32 (–2,147,483,648 to 2,147,483,647), and Float 32 (–3.402823E–38 to 3.402823 E+38).

DIF: Dual Image Feature. Allows you to acquire a pair of gated images in rapid succession. Requires PI-MAX3 or PI-MAX4 with interline CCD.

Dynamic Range: Ratio of the largest signal the sensor can handle to the readout noise of the camera system. Essentially, dynamic range defines the brightest and darkest image data that the camera can reliably reproduce. A true 12-bit digital camera is capable of providing a dynamic range of 4096:1. A true 16-bit camera is capable of 65536:1. Readout speed affects the dynamic range of a pixel: the faster the speed, the higher the noise, and the smaller the dynamic range.

E

EM gain: Also called "on-chip multiplication gain". A technology that enables multiplication of charge (i.e., electrons) collected in each pixel of the CCD's active array. Secondary electrons are generated via an impact-ionization process that is initiated and sustained when higher-than-typical voltages are applied to an "extended" portion of the CCD's serial register. Multiplying the signal above the read noise of the output amplifier enables ultra-low-light detection at high operation speeds. (Some CCD cameras with on-chip multiplication gain utilize two output amplifiers, an "on-chip multiplication gain" amplifier that allows the camera to be used for low-light, high-speed applications and a "traditional" amplifier for wide-dynamic-range applications.)

Entrance Port: Where the light enters the spectrometer, usually on the front or side.

Exit Port: Where the light exits the spectrometer, usually on the front or side.

Experiment: In the context of LightField\, an experiment is the collection of all hardware devices and setting values needed to acquire data.

Exposure Time: The length of time the shutter is open to capture a single image and the sensor is accumulating charge. If no shutter is present, the exposure time is the time interval between readouts.

External Sync: Readout synchronization mode where the sensor array is synchronized to an external source (i.e., the array is scanned upon arrival of an external trigger pulse).

F

Filter Wheel: A device that holds a number of filters and allows the filter with the desired characteristics to be rotated into an optical aperture. Depending on the design, rotation may be manual or, if it has an RS232 interface, may be software-controlled. Some designs permit both means of control.

Final Section Count: The number of blocks of size Final Section Height that are defined before geometrically increasing block size with Final Section Height as the base for the geometrical growth.

Final Section Height: The number of strips (rows) that are binned into the smallest block during a single clean.

FireWire: IEEE-1394 High Performance Serial Bus. Commonly known as 1394 or FireWire®. This is a high-speed serial input/output (I/O) technology for connecting peripherals to a computer.

FITS: Filename extension for files created in the Flexible Image Transport System format.

Frame: The area of a sensor array that is read out after an exposure is completed. For a 512×512 array, a full frame would consist of the entire 512×512 pixel area.

Frame Rate (fps): The number of frames that can be read out per second. The effective frame rate can be increased by defining a Region of Interest (ROI) that is smaller than the full-frame size. This means that a selected portion of the image can be displayed and the remainder of the accumulated charge discarded. The frame rate generally increases with reduction in the size of the detected area. For example, a sensor with a 1000 x 1000 array and an output rate of ten frames/second can produce 100 frames/second if the readout region is reduced to 100 x 100 pixels.

Frame transfer CCD: A frame-transfer CCD divides the parallel register into two areas (arrays): an image array (for image collection) and a storage array (for image storage). After the image array is exposed to light, the electronic image is shifted to the storage array and read out. A frame-transfer CCD can operate without a shutter, running continuously at high rates.

Full-frame CCD: The simplest type of CCD. A full-frame CCD uses the entire array to expose photons and to integrate and transport charge. A shutter is used to control the exposure and block light during CCD readout, preventing charge smearing.

Full-well Capacity: The number of electrons that can be held in a single array pixel (potential well). It is assumed that all pixels on a CCD have the same well size and that each well can hold the same number of electrons. The term is also applied to the capacity of a single serial (shift) register pixel.

G

Gate Delay: The time between the beginning of the trigger pulse (either internal or external) and the beginning of the photocathode gate pulse.

Gate Width: Time during which light will be detected by an intensifier, intensified, and applied to the CCD. Basically, the intensifier controls what the sensor 'sees' during the exposure time. For signal to be detected, it must both fall in a valid gate width and in a valid exposure time.

Grating: A diffraction grating is an optical component with a number of parallel grooves that disperse light. The dispersion is dependent on groove spacing and the wavelength of the light.

Grating Density: The number of grooves per unit length on a diffraction grating, usually expressed in units of grooves per millimeter.

Grayscale: An image is mapped into 256 levels of gray. Luminance range extends from black to white.

H

Hardware Binning: Binning performed before the signal is read out by the preamplifier. Hardware binning of large sections (large values of the serial binning factor and/or the parallel binning factor) may result in saturation and blooming.

Histogram: A graphic representation of the number of pixels (Y axis) with given intensity values (X axis), showing the distribution of intensities in a data set.

Horizontal Register: See ***Serial Register***.

I

ICCD: Intensified CCD. The PI-MAX3 and PI-MAX4 are ICCD cameras.

Interline Transfer CCD: Also called interline CCD. A type of CCD in which the parallel register is subdivided so that, like a Venetian blind, opaque strips span and mask the columns of pixels. The masks act as storage areas. When the CCD is exposed to light, the image accumulates in the exposed areas (photosites) of the parallel register. In the serial register, the entire image is under the interline mask when it shifts for CCD readout. It is possible to shift the integrated charge quickly (200 ns) under the storage areas. Since these devices function as a fast shutter (or gate), they are also sometimes referred to as gated interline CCDs.

K

Kinetics Mode: A mode of operation in which most of the CCD is mechanically or optically masked, leaving a small section (i.e., window) open to light. A series of images is rapidly acquired during a single data acquisition period by repeatedly opening/closing a shutter. Kinetics mode results in multiple images/spectra (subframes) collected on a single frame.

L

Left Margin: The number of non-active serial strips (made up of dark pixels) that come before the active strips on a sensor as they exit the serial register.

lp/mm: Line pairs per millimeter. A measure of resolution based on the ability of the imaging system to differentiate between two parallel lines. The higher the value, the finer the resolution.

M

MCP Bracket Pulsing: Available for PI-MAX3 cameras with Gen II intensifiers. This technique enhances the intensifier's on/off ratio in UV measurements by automatically adjusting the on/off switching of the MCP to bracket the photocathode gate pulse. When setting up for MCP bracket pulsing, keep in mind that it takes about 500 ns to turn the MCP fully on and 200 ns to turn it fully off. UV photons can travel entirely through the photocathode and strike the front surface of the MCP. These UV photons are energetic enough to generate photoelectrons from the MCP surface and, once generated, the photoelectrons are drawn into the MCP channel and multiplied. The net effect is that the on/off ratio of the intensifier drops from 107 in the visible to 104 in the UV. Bracket pulsing turns off the MCP voltage except immediately before, during, and immediately after the main photocathode gate pulse and the high 107 on/off ratio of the intensifier in the UV

is maintained. Even though the bracket timing is controlled automatically by the software, in an experiment where it is necessary to delay the arrival of the laser pulse at the sample, this will mean inserting an additional delay of 500 ns (compensating for the MCP turn on time) to accomplish coincidence at the detector. MCP bracket pulsing should not be used in experiments where the delay between the trigger and the photocathode gate is less than 1 µs.

MCP Gating: Applies the primary gating pulse to the microchannel plate (MCP) portion of the intensifier tube and applies the bracket pulse to the photocathode.

Metadata: Information about the data, such as the experiment devices and settings, the time and date of creation, the user name, the storage location, and the calibration values.

Model: New software setting. This will display the Model Name of the hardware.

N

Number of Clean Cycles: Automatic clean cycles occur in the background between exposures. Number of Clean Cycles is the user-selected number of additional clean cycles run after a start exposure signal has been received and the current clean cycle has finished.

NVRAM: Non-Volatile Random Access Memory. NVRAM contains factory programmed information about the controller and, in many cases, the camera/detector.

O

Offset: The offset value adjusts the electronic zero offset of the analog-to-digital converter within the camera's electronics. Without adding any light, the offset allows charge to be read out on the CCD while raising the intensity level high enough to ensure that the camera does not deliver a negative number to the A/D converter.

On-CCD Accumulations: Allows you to specify the number of times the photocathode will be gated on during the exposure. Charge will accumulate on the CCD array as those gates occur during the exposure and the accumulated charge will be readout at the end of the exposure.

Online: In this documentation "Online" generally refers to the state of the hardware-software system when previewing or acquiring data. "Online" settings are those that can be modified while the system is previewing or acquiring data.

Output Node: The location on a CCD (often a single pixel) adjacent to the serial register where charge is collected as a discrete picture element for CCD readout. Data enters the output node from the serial register and exits to the A/D converter.

Output Signal Type: The choice of Output Signal determines which signal is output via the LOGIC OUT connector on the back of the camera. The available options are hardware dependent.

P

Parallel Binning: The accumulation of multiple rows of charge in a CCD's serial register. The amount of charge shifted is defined by the user-specified binning factor. Also called vertical binning. See CCD readout.

Parallel Binning Factor: In the parallel register of a CCD, the number of pixels (in the parallel direction) to be shifted to the serial register, read out, and processed into an image. The binning factor is specified by the user in the imaging software prior to exposure of the CCD.

Parallel Direction: In a serial, parallel (s, p) coordinate system, the direction that begins at the origin and runs perpendicular to the serial register. Also called vertical direction.

Parallel Gap Size: The distance (in µm) between two adjacent pixels parallel to the serial register.

Parallel Pixel Size: The length (in µm) of a pixel in the parallel direction.

Parallel Register: A column of array pixels perpendicular to the serial register. Also known as a vertical register.

Parallel Shift Rate: The speed (ns/strip) at which parallel strips are shifted towards the serial register.

Parallel Size: In CCD imaging technology, the size of the pixels extending in the parallel direction.

Peripheral: Any hardware device in the experiment or system that is neither a camera nor a spectrometer. This includes software detectable and non-software detectable hardware.

Phosphor: A chemical substance that fluoresces when excited by x-rays, an electron beam, or ultraviolet radiation. Phosphors are composed of rare earth oxides or halides (e.g., gadolinium, lanthanum, yttrium) and usually emit green light with decay times ranging from hundreds of nanoseconds to a few milliseconds. P43 offers high resolution (3 ms decay) while P46 offers fast decay for high-repetition rate spectroscopy (3 µs decay). The shutter compensation time inserted between the end of the exposure time and the beginning of the array readout, allows for the decay time.

Phosphor Decay Delay: This is a parameter used to compensate for the time it takes for phosphor emissions to decay before readout occurs. As set in LightField, this is a waiting period after the Gate width before the CCD is read out. If the end of an AUX Output width occurs after the Gate width, there will be an apparent delay after the end of the Gate width before the phosphor decay delay time (if a value has been entered) starts. At the end of the phosphor decay delay time, the sensor is read out.

Phosphor screen: One of the major components of an image intensifier. Electrons exiting the microchannel plate (MCP) are accelerated by a constant voltage and strike the screen, where they are converted back into light photons for detection by a CCD.

Photocathode: One of the major components of an image intensifier. Coatings on the photocathode convert a portion of the incident light photons into electrons. Good QE is critical, as photons that are not captured by the photocathode are lost from the final signal produced by the intensifier.

Photon Shot Noise: Unwanted or undesirable disturbance resulting from the quantum (particulate) nature of light. Photon noise is always present in an imaging system and is due to the random arrival of photons at a given pixel. Also known as Shot Noise.

PICam™: The standard 64-bit software interface for cooled CCD cameras from Princeton Instruments. PICam is an ANSI C library of camera control and data acquisition functions. Currently, the interface supports Windows Vista and Windows 7.

Pixel Gap Height: The distance (in µm) separating adjacent array pixels in the serial direction.

Pixel Gap Width: The distance (in µm) separating adjacent array pixels in the parallel direction.

Pixel Height: The size (in µm) of an array pixel in the serial direction.

Pixel Width: The size (in µm) of an array pixel in the parallel direction.

Port Width: With motorized ports, the widths of the Entrance and Exit Ports are software controllable.

Ports Used: The number of ports used for data transfer from the sensor to LightField. The available values are camera dependent.

Post-acquisition Binning: This type of binning is performed during post-processing the data.

Post-active Serial Strips: Non-active serial strips (of dark pixels) that follow the active strips in reaching the serial register.

Potential Well: In a CCD, a discrete region within the device's imaging array where an incident photon may free an electron that contributes to the image intensity for that

Pre-active Serial Strips: Non-active serial strips (of dark pixels) that precede the active strips in reaching the serial register.

Pre-masked Parallel Strips: Non-active parallel strips (of dark pixels) that follow the active parallel strips on a sensor and precede the masked parallel strips in reaching the serial register.

Preview: A mode that provides a trial run of an experiment without data storage.

Pulse ensemble: Consists of a Gate Start pulse, a Gate Stop pulse, and one or more Auxiliary pulses. At the end of the ensemble, the photocathode is gated off, Phosphor Decay Delay (if set) elapses, and then the CCD array is read out.

Q

QE: Quantum Efficiency. The number of photoelectrons generated per incident photon and a measure of the effectiveness of a sensor to produce charge from incident photons.

R

Raw data: Raw data are data that have not been modified before storage. Irreversible online data manipulations/ corrections that will be backed up with raw data include software binning, background subtraction, flatfield correction, sensor blemish correction, and accumulations (exposures per frame).

Read Noise: Unwanted signal or disturbance that is generated by the on-chip output amplifier. The noise can be reduced to a few electrons by modifying operating conditions. Also called preamplifier noise.

Readout: CCDs are analog devices. In order to obtain a digital signal that is appropriate for doing quantitative analysis, the analog signal must be converted to a digital format. When a CCD exposure is complete and the array ready to be read out, a series of serial shifts and parallel shifts occurs. First, the rows are shifted in the serial direction towards the serial register. Once in the serial register, the data are shifted in the parallel direction out of the serial register, into the output node, and then into the A/D converter where the analog data are converted into a digital signal.

Readout Mode: The selected method of data transfer from the sensor to the application software. The available readout modes are camera dependent.

Readout Register: See ***Serial Register***.

Readout Time Calculation: The time (in ms) required to read out the entire chip.

Region of Interest: A user-defined rectangular set of contiguous pixels on the CCD array that is usually smaller than the full frame. Using an ROI to acquire data results in a faster readout of the array since data from pixels outside of that ROI is discarded.

Right Margin: The number of non-active serial strips (made up of dark pixels) that come after the active strips as they exit the serial register.

ROI: See ***Region of Interest***.

S

Saturation: The state of a pixel being filled to capacity. Once a pixel is saturated, additional charge will spill over (bloom) into adjacent pixels.

Serial Binning: The accumulation of charge from two or more pixels of a CCD's serial register into the output node before the charge is shifted for CCD readout.

Serial Binning Factor: In the serial register of a CCD, the number of pixels (in the serial direction) to be shifted to the output node, read out, and processed into an image. The binning factor is specified by the user in the imaging software prior to exposure of the CCD.

Serial Direction: In a serial, parallel (s, p) coordinate system, the direction beginning from the origin and moving away from it in a direction parallel to the serial register.

Serial Gap Size: The distance (in µm) between adjacent serial pixels.

Serial Number: The serial number of the hardware. This is a read-only setting.

Serial Pixel Size: The length (in µm) of a pixel in the serial direction.

Serial Register: A row of high-well-capacity pixels perpendicular to the parallel registers and extending to the output node. Once a row of charge is shifted from the array into the serial register, it is shifted one pixel at a time into the output node. Also known as the serial shift register, shift register, horizontal register, horizontal shift register, or readout register.

Serial Size: In CCD imaging technology, the size of the pixels extending in the serial direction.

Serial, Parallel (s, p) Coordinate System: In CCD imaging technology, a nomenclature based on the point of orientation located on the parallel register in the corner closest to the output node. Coordinates increase as the locations move away from this origin. S represents the serial coordinate; p represents the parallel coordinate.

Shot Noise: See ***Photon Shot Noise***.

Shutter Timing Mode: A setting that determines shutter behavior during acquisition.

Slit Height: Defines the ROI height dimension for Spectroscopy Mode ROIs. A slit height of 4 means that 4 pixel rows will be binned to create a single spectral data strip.

Smearing: The residual charge left behind in the pixel wells after an image is shifted on a CCD.

Software Binning: Binning performed after the signal is read out by the preamplifier. Software binning (in place of hardware binning) will prevent saturation of the CCD serial register pixels but is not as fast as hardware binning.

SPC: Filename extension for the Thermo Scientific file format.

SPE: Filename extension for files created by WinX/32 (WinSpec/32, WinView/32 or WinXTest/32) and LightField.

Spectra-Kinetics Mode: A ProEM kinetics option for frame-transfer sensors in which the row or rows just below the frame-transfer mask are exposed and then shifted and binned into a single row in the frame-transfer mask.

Spectrometer Input Port: Light enters the spectrometer here, usually located on the front or side of the spectrometer.

Spectrometer Output Port: Light exits the spectrometer here, usually located on the front or side of the spectrometer.

Storage Shift Rate: Used in the Kinetics and Spectra-Kinetics modes, this is the time (in microseconds) required to shift a single row up one row toward the serial register.

Strip: "Strip" is a general term that can refer to any one-dimensional collection of contiguous pixels, such as that comprising a row or column on the sensor array. The term does not imply any particular geometric orientation of the collection with respect to the sensor array.

SuperSYNCHRO: Timing generator integrated right into the camera head in PI-MAX3 and PI-MAX4. It allows complete control over intensifier gating (e.g., gate width/delay) even in complex timing scenarios. It has a timing resolution of 10 psec and only 35 psec of jitter.

Supplemental Information: This information is not required to complete a valid system setup, but it enhances the overall user experience when provided.

SyncMASTER: PI-MAX3 and PI-MAX4 can output two continuous pulse trains to be used as master clock for the entire experiment. For example, the output pulses can be used to trigger a Q-switched laser at a desired constant repetition rate (even during the camera is idle) for energy stability and beam quality. It also eliminates the need for external delay generators. Since the intensifier gating is based on the same clock, the jitter for the entire experiment is as low as possible (often limited only by the laser jitter).

T

Temperature Set Point: The desired (target) temperature of the sensor.

Temperature Status: The status of the camera with respect to achieving the Temperature Set Point, displayed as either Locked (Unlocked) if the camera has (has not) locked into the Temperature Set Point.

TIF: Filename extension for the Tagged Image File Format.

Top Margin: Non-active parallel strips (of dark pixels) that precede the active strips in reaching the serial register.

Trigger: A signal (typically a TTL signal) that is transmitted in order to synchronize two or more instruments; something that acts like a mechanical initiator in setting up a process or reaction.

Trigger Polarity: Indicates whether the camera initiates an exposure on the negative or positive edge of a trigger.

Trigger Response: Determines if and how the system will respond to external TTL signals.

Turret: A rotating platform inside a spectrometer upon which gratings are mounted.

V

Vertical Register: See ***Parallel Register***.

Vertical Shift Rate: The time (in microseconds) required to shift a single row into the serial register.

W

Width: When working with a motorized Entrance Port or Exit Port, a user can control the Width of the port through the software.

WinX/32: Global term for the Princeton Instruments WinSpec/32, WinView/32, and WinXTest/32 applications.

Appendix C: LightField Keyboard Shortcuts

LightField Startup

Shift: Do not load experiment or devices at startup. Before starting LightField, press and hold the **Shift** key and then start LightField. Continue to hold the **Shift** key down for about 3 seconds (about the time it takes for the LightField splash screen to appear) and then release the **Shift** key. Doing this will ensure that no experiments are loaded and no devices are moved into the **Experiment Devices** area.

Note: To force LightField to NOT load any experiments or devices at startup you can add an " /empty" switch to the Target string of your LightField shortcut. Right-click on the shortcut and then select **Properties**. On the **Shortcut** tab, add /empty at the end of the target string. Be sure to insert a space between the LightField.exe" and the /empty. Then click on the **Apply** button to apply the change and then on **OK** to close the **Shortcut Properties** dialog. Now, every time you start LightField, no experiment and devices will be loaded. Because this forces LightField to not load an experiment and devices, you do not have to use the **Shift** key method described above.

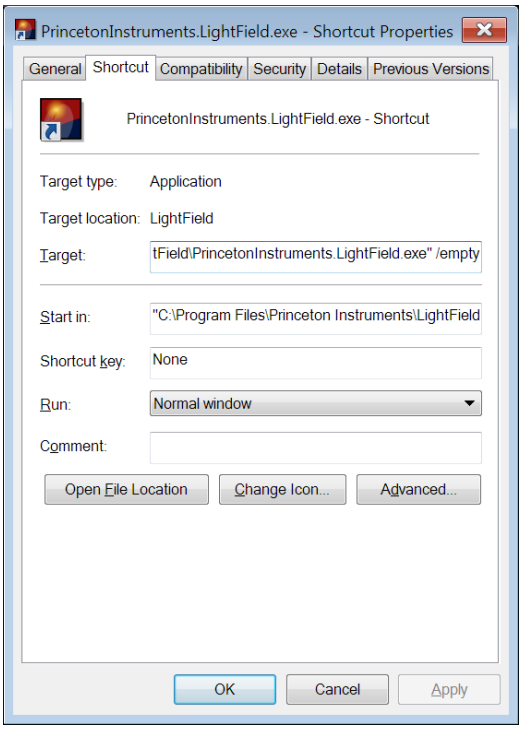


Figure 301. Shortcut Properties dialog

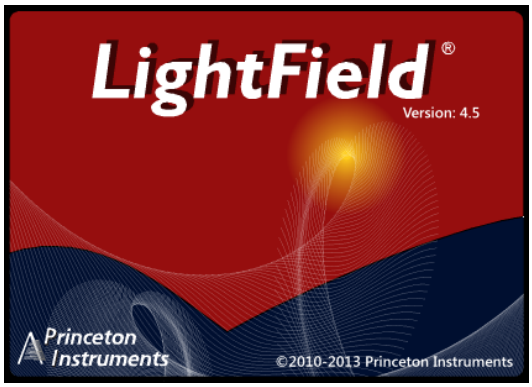


Figure 302. LightField splash screen

Global Keys

F1: Help.

Ctrl + Q: Quit LightField if you are in primary window (such as the Experiment workspace). If you are in a secondary window (such as the Edit Regions of Interest window), you must close this window first. Note that if you are in the process of acquiring data or editing an experiment, you will be asked if you want to stop the acquisition or save the experiment before LightField will close.

Experiment Workspace Keys

F3: Load experiment.

F4: Save experiment.

F6: Show Online Statistics.

F8: One Look.

F9: Run.

F10: Acquire.

F11: Stop.

Ctrl+B: Acquire background reference.

Ctrl+F: Find experiment setting.

Ctrl+O: Load experiment.

Ctrl+S: Save experiment.

Alt+E: Find exposure time setting.

Alt+F: Find number of frames setting.

Alt+R: Find regions of interest setting.

Alt+W: Find center wavelength setting.

Data Workspace Keys

F3: Open data file.

F4: Save data file.

F6: Show Data Statistics.

F7: Show File Information.

Ctrl+O: Open data file.

Ctrl+S: Save data file.

Comparison Workspace Keys

F6: Show Comparison Statistics.

Edit Regions of Interest Keys

Delete: Deletes selected ROI. You must click on the ROI in the list before pressing **Delete**.

Insert: Creates new ROI.

Ctrl+drag: Drags a selection box to group-select multiple ROIs in the viewer.

Shift+drag: Constrains area selection to a square.

Arrow keys: Move the selected ROI.

Viewer Keys

Click in Viewer and then use the keys. This may mean clicking on the image or on a spectrogram.

Shift+drag: Constrains image area selection to a square.

→: Moves the cursor to the right along the X axis for an image or to the right along the spectrogram. On an image, moves a selection box to the right.

←: Moves the cursor to the left along the X axis for an image or to the left along the spectrogram. On an image, moves a selection box to the left.

↑: Moves the cursor up along the Y axis for an image or up to the next spectrogram when multiple graphs are displayed in a view (graph). On an image, moves a selection box up.

↓: Moves the cursor down along the Y axis for an image or down to the next spectrogram when multiple graphs are displayed in a view (graph). On an image, moves a selection box down.

***** (on number pad)**:** Auto contrast.

Ctrl+C: Copy the data as an image (if displayed as an image) or as data points (if displayed as a graph).

Ctrl+Alt+C: Copy data displayed as an image to the clipboard as data points.

Ctrl+Plus (+ on number pad)**:** Actual size (images). Restore horizontal and vertical axes to full scale (graphs).

Ctrl+Minus (- on number pad)**:** Fit to window/ Best fit. Horizontal and Vertical Autoscaling (graphs).

Plus (+ on number pad)**:** Zoom in.

Minus (- on number pad)**:** Zoom out.

Page Up: When the cursor is on multi-frame data, pages to previous frame.

Page Down: When the cursor is on multi-frame data, pages to next frame.

Delete: Clears selection from an image.

MultiViewer Layout Keys

Ctrl+0: Open view.

Ctrl+1: Open view.

Ctrl+2: Open view.

Ctrl+3: Open view.

Ctrl+4: Open view.

Ctrl+5: Open view.

Ctrl+6: Open view.

Ctrl+7: Open view.

Ctrl+8: Open view.

Ctrl+9: Open view.

Appendix D: Reference Topics

Introduction

This appendix is a collection of topics containing detailed information about LightField features and experiment design. Some of this information may also be found in the camera manual or programming manual shipped with your system. Topics are in alphabetical order.

Add-ins

Introduction

Microsoft's Managed Add-in Framework (MAF) allows users and third-party developers to extend LightField's capabilities. Add-ins have the potential to dynamically and dramatically change the look of the LightField application as well as extend the abilities and function of the core program. For detailed information about building add-ins or automation modules for LightField, refer to the ***LightField Add-ins and Automation Programming Manual*** (on the LightField cd or downloadable from ftp://ftp.princetoninstruments.com/Public/Manuals/Princeton Instruments/). Note that the add-in samples provided with LightField were built using Microsoft's Visual C#® programming language.

Manage Add-ins

The Add-In Manager is accessed via the **Application menu - Manage Add-ins...** option and looks similar to Figure 303.

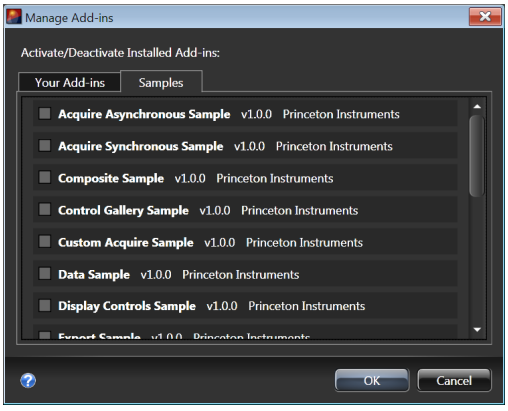


Figure 303. Manage Add-ins dialog

The **Manage Add-ins** dialog allows you to control which add-ins are currently active when the program starts up. When starting, LightField checks for available add-ins (sample add-ins provided by Princeton Instruments and any user created add-ins) and populates the lists alphabetically with those that it detects and loads their current status (checked or unchecked) on the appropriate tabs (**Samples** and **Your Add-ins**). This dialog can also be used to activate and deactivate add-ins from within a current session of LightField.

To change which add-ins are activated, select or de-select check boxes and click on the **OK** button.

Add-in Zones in LightField

LightField currently contains five zones where add-ins are allowed to provide simple buttons for custom User Interfaces (UIs). An individual add-in may only support one zone or could potentially support all five zones. The add-in author decides how the UI will be implemented.

Application Toolbar Add-in Zone

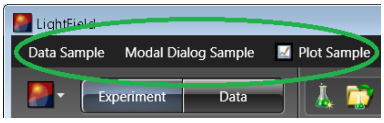


Figure 304. Add-ins in the Application Toolbar Zone

Application-wide controls are displayed in the Application toolbar add-in zone. The toolbar is always visible when an add-in with an application-wide control is active.

Add-ins can provide a single control (a button or a toggle type check box) in the **Application** toolbar add-in zone. The image below shows three add-ins supporting the Application toolbar zone. The first two add-ins are supporting a simple button and the third add-in is supporting a simple button with a custom bitmap element.

Data Toolbar Add-in Zone

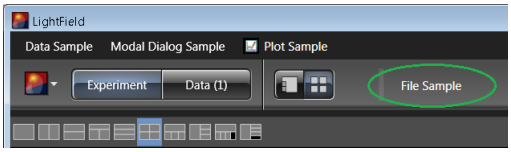


Figure 305. Add-ins in the Data Toolbar Zone

The Data toolbar supports the same as the Application toolbar and has the same restriction of one control per add-in. This toolbar can only be seen when the Data or Comparison View mode is selected.

The key differences between the Application and Data toolbars are toolbar location and typical usage. Add-ins providing support for the Data toolbar location are more likely to be post-processing or data manipulation functions. The image below shows two Data toolbar add-ins: the first of which is the toggle type and the second is a

simple button. Although not shown below, add-ins can provide their own bitmaps for these buttons.

Application Menu Add-in Zone

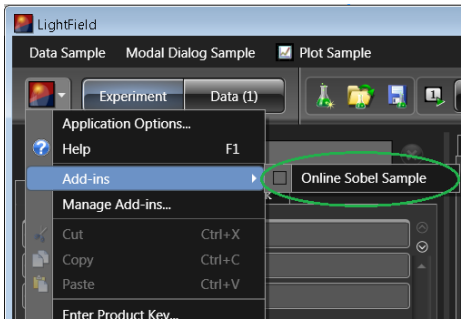


Figure 306. Add-in in the Application Menu Zone

Another location add-ins can contain support for is the Add-ins menu item on the Application menu. Add-ins can provide two types of menu elements: a single button or a toggle type of check box. Shown below is one of each type: a simple menu button and an item that has two states (on/off). Each add-in can include support for only one menu element in this zone.

Experiment Settings Add-in Zone

More sophisticated add-ins may require more user-configurable settings than a single button or menu item, and these add-ins can choose to support the Experiment Settings stack. This zone provides a larger space in which to place completely custom controls. LightField will create a tab for all Add-ins called appropriately "Add-ins" shown below it will also create the top level expander for each add-in.

The image below shows that currently four active add-ins support the Experiment Settings type of add-in interface. The contents of the expander are entirely at the discretion of the add-in provider and could be anything from a single button to an entirely custom UI.

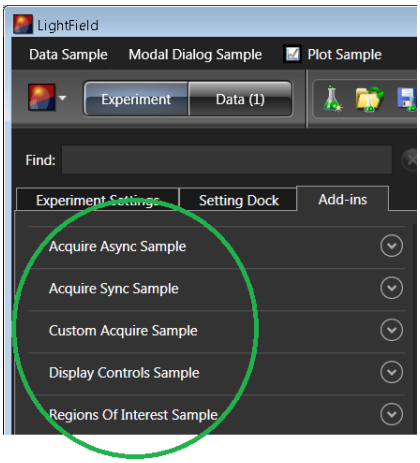


Figure 307. Add-ins in the Experiment Settings Zone

Figure 308 shows two of the expanders open to show the diversity possible when supporting this user interface in the add-in. The Acquire Sync Sample expander has a simple button but the Display Controls Sample expander contains a complete set of controls and settings. The only limitation here is that your controls be fairly narrow since a maximum width will be imposed by the application. By default, the controls will inherit the LightField style although it is entirely possible for the add-ins to show controls in whatever style you chose.

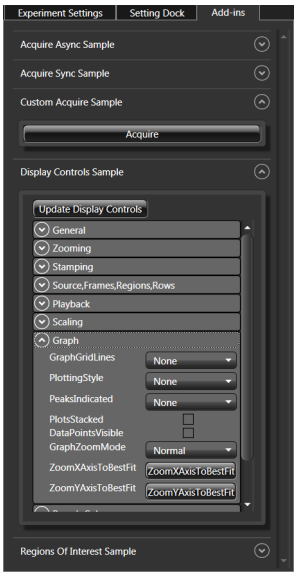


Figure 308. Add-ins Expanded in the Experiment Settings Zone

Experiment View Add-in Zone

LightField supports add-in UI creation in one more location and this is the Experiment view location. This location is intended for add-ins to present their view of data but it also provides the large area for add-in controls. The tabs created in this view can be used for either purpose since a tab's contents are determined entirely by the add-in.

The image below shows the Control Gallery Sample tab. Each add-in that supports an Experiment view will create a new tab like the one outlined by the green circle. The tab name is provided by the add-in. Add-in tabs will always appear in the same order (alphabetically, based on the add-in names shown in the Add-in Manager dialog).

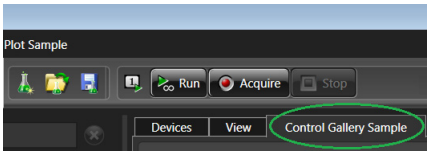


Figure 309. Add-in in the Experiment View Zone

The Experiment view zone has enough space for add-ins to supply pretty much whatever they need in the way of custom user interface controls. Shown below is the Princeton Instruments "Control Gallery Sample" which is used to check the default styles of various controls and how they will look by inheriting LightField's resources.

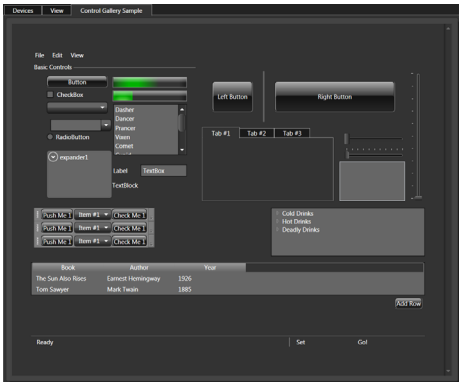


Figure 310. Control Gallery Add-in in the Experiment View Zone

Sample Add-ins

The descriptions below are provided for add-ins supplied with LightField. Additional add-ins may also be supplied although not described here. Open the **Manage Add-ins** dialog to see which add-ins have been included with your version of the software. All samples were built using the Visual C# programming language. Note that [Term] indicates where the controls for the add-in appear.

1. **Acquire Async Sample:** Shows events for acquire and how to acquire data via the events. [Experiment Settings]
2. **Acquire Sync Sample:** Shows how to acquire data and wait for its return with blocking. [Experiment Settings]
3. **Composite Sample:** Shows how to dynamically change Add-ins components that are shown in the five LightField add-in zones. [Experiment view]
4. **Control Gallery Sample:** Shows all of the Windows Presentation Foundation (WPF) components in a window to demonstrate how well the styles have been applied. [Experiment view]
5. **Custom Acquire Sample:** Demonstrates acquiring with a set exposure, file name and some other regularly used parameters. [Experiment Settings]
6. **Data Sample:** Generates data in memory and dumps it into data views for display. [Application toolbar]
7. **Display Controls Sample:** Demonstrates most of the controls for adjustments on a view of data (i.e., source, zoom, type, cursor, etc.) [Experiment Settings]
8. **Export Sample:** Demonstrates how to select an SPE file or folder of SPE files and an export format. Clicking on the Export button will then export the selected data file(s). Note that there is an Error reporting field. [Application Toolbar]
9. **File Sample:** Generates data in memory, stores the data in two .SPE files in the user-designated location. One file contains multiple frames with a single region, and the other file contains a single frame with multiple regions. [Data toolbar]
10. **Metadata Sample:** Demonstrates metadata tagging and how to access the timestamps on the data after acquisition on a frame by frame basis. [Experiment Settings]
11. **Modal Dialog Sample:** Displays a modal dialog with a variety of WPF components. [Application Toolbar]
12. **Modeless Dialog Sample:** Displays a modeless dialog with a variety of WPF components. [Application Toolbar]
13. **Online Sobel Sample:** Hooks into the data path and performs edge detection on the buffers before the application displays or saves them. A camera must be active and the add-in must be selected before acquisition begins. [Application menu]
14. **Plot Sample:** Generates data in memory and plots to Data view. Also shows putting more than one source on a view. [Application toolbar]
15. **Regions Of Interest Sample:** Demonstrates the modes of regions: full frame, binned, line sensor and custom. [Experiment Settings]
16. **Setting Snoop Sample:** Demonstrates an Add-in with no user interface that registers for setting changed events and logs them.
17. **Spectroscopy Sample:** Demonstrates how to read the existing calibration data out of an existing SPE file as well as how to create and display your own calibrated data files. [Application Toolbar]
18. **System Building Sample:** Demonstrates how to determine Available Devices as well as check the Devices in Use. [Application toolbar]
19. **Viewer Sample:** Demonstrates opening a file through LightField and then putting it into a custom WPF view. [Experiment View]

High Speed Camera Add-in

The **High Speed Camera** add-in (formerly named High Speed ProEM) will, with the click of a button, change the experiment settings to minimize readout time and maximize the number of frames that can be acquired per second. This add-in will only become available on the Experiment workspace **Add-Ins** panel if the High Speed Camera add-in has been activated in the **Manage Add-ins** dialog and the **Experiment Device** is a camera that supports this function. Keep in mind when using the add-in that there is tradeoff between increased spectral readout rate and data quality (increasing the frames per second tends to decrease data quality). For more information about using this add-in, ***see "High Speed Camera Add-in" on page 194***.

Shutter Configuration Add-In

Starting with Version 4.4, LightField has a **Shutter Configuration** add-in for PyLoN and PyLoN-IR cameras. This add-in allows you to configure the camera's Shutter connector for one of 5 supported external shutters. An external shutter may be one that is mounted to a spectrograph. This add-in will only become available on the Experiment workspace **Add-Ins** panel when an actual PyLoN or PyLoN-IR camera is detected by LightField, its camera icon is in the **Experiment Devices** panel, and the **Shutter Configuration** add-in has been activated on the **Manage Add-ins** dialog. For more information about using this add-in, ***see "Shutter Configuration Add-in" on page 205***.

Binning

Binning is the process of combining the charge from adjacent pixels in a sensor. Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations.

Binning can be done during data acquisition in either a hardware or software mode, and also during post-processing. When binning occurs during acquisition, hardware binning takes place before sensor readout, whereas software binning takes place after readout. Hardware binning is faster than software binning but subject to blooming and thus data invalidation. Software binning can also be applied as a post-acquisition process.

Online binning parameters are entered via the Advanced flyout pane on the **Region of Interest** expander; post-acquisition software binning parameters are entered via the **Software Binning** dialog accessed from the **Processes** drop-down list on the **Data** workspace. Rectangular groups of pixels of any size may be binned together, subject to some hardware and software limitations. For multiple ROIs, the binning factor in the serial direction must be the same for all ROIs having boundaries along the same serial row.

Hardware Binning

Overview

Hardware binning is performed on the sensor while the signal is shifted into the serial register and before the signal is read out of the output amplifier. For signal levels that are readout noise limited this method improves S/N ratio linearly with the number of pixels grouped together. For signals large enough to render the camera photon shot noise limited, the S/N ratio improvement is roughly proportional to the square-root of the number of pixels binned.

Binning in hardware also reduces readout time and the burden on computer memory, but at the expense of resolution. Since serial register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and "blooming", or spilling of charge back into the image area.

When 2x2 binning has been set up, each pixel of the image displayed by the software represents 4 pixels on the sensor. Rectangular bins of any size are possible. Binning also reduces readout time and the burden on computer memory, but at the expense of resolution. Since shift register pixels typically hold only twice as much charge as image pixels, the binning of large sections may result in saturation and "blooming", or spilling of charge back into the image area.

Notes:

1. With the Quad-RO:4320 camera, the output amplifier pixel capacity is equal to that of a single array pixel.
2. Hardware binning is not available for NIRvana/ PIoNIR cameras.

The readout rate for n x n binning is approximated using a more general version of the full resolution equation. The modified equation is:

$$t_R = \left[N_x \cdot N_y \cdot \left(\frac{t_{sr}}{n} + \frac{t_v}{n^2} \right) \right] + (N_x \cdot t_i)$$

Binning is the process of adding the data from adjacent pixels together to form a single pixel (sometimes called a super-pixel). The combination of pixels can be along the X axis, the Y axis, or along both axes. When hardware binning is active, the combination occurs while the signal is shifted into the serial register and before the signal is read out by the preamplifier.

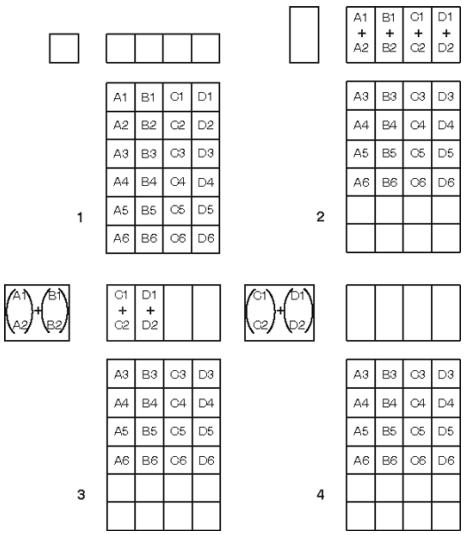


Figure 311. Example of 2 x 2 Binning

Note: Hardware binning is an irreversible process. Because this type of binning occurs before the data has been digitized, a raw data backup file containing the non-binned data will not be generated. If "Back Up Raw Data" is selected on the Save Data File expander because some other online correction is active, the raw data will not contain the non-binned data but will contain the other uncorrected information (for example, if Number of Frames=1 and Exposures per Frame=4, there will be four frames in the raw data).

Selecting Hardware Binning

1. Open the **Region of Interest** expander.
2. Click on the **Advanced** button to open the flyout pane.
3. Click in the **Hardware** radio button.
4. Click outside of the pane to close it.
5. **Optional.** Before acquiring data, open the **Online Corrections** expander, acquire a new background file, and activate Background Subtraction.

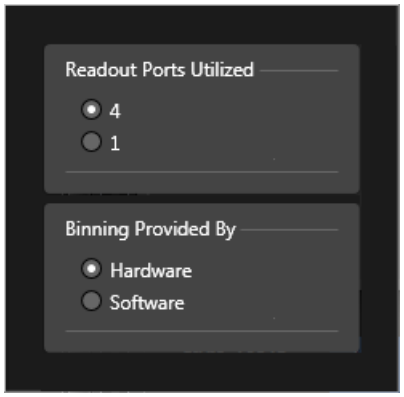


Figure 312. Region of Interest: Advanced flyout pane

Software Binning

Overview

One limitation of hardware binning is that the serial register pixels and the output node are typically only twice the size of imaging pixels. Consequently, if the total charge binned together exceeds the capacity of the serial register or output node, the data will be corrupted. This restriction strongly limits the number of pixels that may be binned in cases where there is a small signal superimposed on a large background, such as signals with a large fluorescence. Ideally, one would like to bin many pixels to increase the S/N ratio of the weak peaks but this cannot be done because the fluorescence would quickly saturate the sensor.

The solution is to perform the binning in software. Software averaging can improve the S/N ratio by as much as the square-root of the number of scans. Unfortunately, with a high number of scans, i.e., above 100, camera 1/f noise may reduce the actual S/N ratio to slightly below this theoretical value. Also, if the light source used is photon-flicker limited rather than photon shot-noise limited, this theoretical signal improvement cannot be fully realized. A background subtraction from the raw data is necessary.

Software binning is also useful in high light level experiments, where the camera is again photon shot-noise limited. Summing multiple pixels in software corresponds to collecting more photons, and results in a better S/N ratio in the measurement.

Note: Software binning is an irreversible process. However, if you activate "Back Up Raw Data" on the Save Data File expander before starting acquisition, a raw data backup file will be generated and saved to the same directory as the regular acquisition file when acquisition occurs. The raw data file will be given the same name as the regular acquisition file, but with "-raw" appended. For example, if your regular acquisition file was "untitled.spe", the raw data file would be "untitled-raw.spe".

Selecting Software Binning

1. **Optional.** Activate **"Back Up Raw Data"** on the **Save Data File** expander.
2. Open the **Region of Interest** expander.
3. Click on the **Advanced** button to open the flyout pane.
4. Click in the **Software** radio button.
5. **Optional.** Before acquiring data, open the **Online Corrections** expander, acquire a new background file, and activate Background Subtraction.

Post-Acquisition Software Binning

As mentioned in the introduction, software binning can be applied to previously acquired data. The advantage to this function is that LightField allows you take any previously acquired LightField .SPE data file, enter binning parameters, preview the effect of the binning, apply the binning, and then save the result to another data file or overwrite the original file. Post-acquisition software binning parameters are entered via the **Software Binning** dialog accessed from the **Processes** drop-down list on the **Data** workspace.

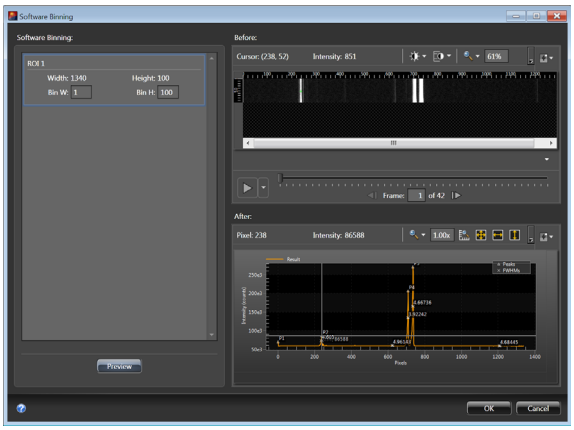


Figure 313. Software Binning dialog

Cleaning and Skipping Algorithm

The cleaning and skipping algorithm is applied during all cleaning cycles and during the readout of ROIs that are smaller than the full sensor. This is done to speed up the processing of rows that need only be cleared and have their charge discarded.

The algorithm decomposes a sensor segment to be cleared into sections of unequal size on the basis of two parameters: **Final Section Height** and **Final Section Count**. **Final Section Height** determines how many rows are binned into the smallest of the sections, and **Final Section Count** determines how many of these small sections are defined before geometrically increasing section size with **Final Section Height** as the base for the geometrical growth. The default values of these parameters will generally give good results.

The algorithm is illustrated in the Figure 314 for the readout of a 10-row full-width ROI on a hypothetical 30×30 sensor where **Final Section Height** was set to 2 and **Final Section Count** was set to 3. The object is to read out and discard rows 1–18 preceding the ROI as rapidly as possible without overflow of charge onto the ROI. First, Section A (8 rows) is read out and discarded. Given that the well capacity of a serial register pixel is usually 2–3 times that of an sensor pixel, depending on pixel amplitudes in this section, blooming may occur and place spurious charge in the next few rows (9–10). Section B (4 rows) is then read out and discarded, with blooming still possible but likely less severe. Then, Sections C, D, and E (2 rows each) are read out and discarded without blooming. The ROI has now reached the serial register after 5 readouts (rather than 18) and without data corruption by any prior blooming.

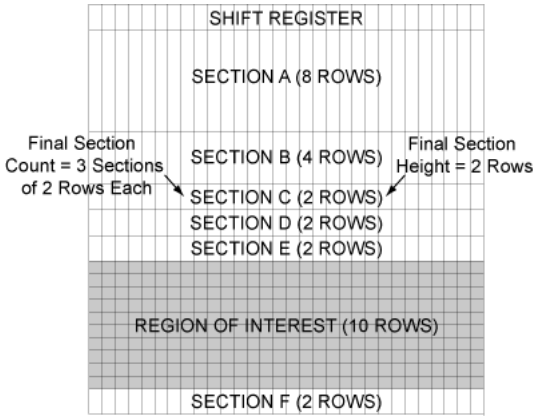


Figure 314. Illustration of Cleaning and Skipping Algorithm

The algorithm is also applied to any sizeable vertical segment below a ROI (though such a segment is not present in the above example). The largest section is again read out first and the last sections read out should be small enough (2 rows) to avoid blooming, thus leaving no charge on the sensor when the next exposure begins.

Setting the Final Section Height and Count Parameters

Caution: Princeton Instruments does not encourage users to change these parameter settings. For most applications, the default settings will give the best results. We advise contacting the factory for guidance before changing these parameters from their default values.

1. Open the **Sensor** expander.
2. Click on the **Sensor Cleaning** button to open the **Sensor Cleaning** flyout pane. The choices will depend on the sensor.

Figure 315. Sensor Cleaning flyout pane

3. Keeping in mind that the default settings for **Final Section Height** and **Final Section Count** will in most cases give the best results, make your entries for these parameters. These values will be used during all cleaning cycles and during the readout of ROIs smaller than full sensor.

Note: Clean Cycles, Clean Until Trigger, and **Clean Before Exposure** use the **Cleaning and Skipping** algorithm. For information about this algorithm, ***see "Cleaning and Skipping Algorithm" on page 180***.

Cosmic Ray Removal Filters

Introduction

The Cosmic Ray function removes highly localized spikes, such as would be caused by cosmic rays interacting with the silicon of the sensor, from the data after it is acquired but before it is stored. When activated, one of the two filters (**Despeckle Filter** or **Median Filter**) and its **Kernel** Size (3x3, 5x5, or 7x7) can be selected. When one of these filters is used to correct data, the selected kernel matrix is applied to every pixel in the image. The overall data is smoothed during the correction.

Because of this, both the raw data and the corrected version of the data are saved in separate files (the basic file names are identical but the raw data file name has "-raw" appended to it).

Note: If the region height is smaller than the kernel size, the kernel is resized to the region height. For example, if you have a single row selected, an image width of 512, and a 3x3 kernel, the kernel will be resized to 3x1. If there were two rows, the kernel would be resized to 3x2. In these examples, the filter puts the result into the middle or top middle pixel, respectively (indicated by gray shading).

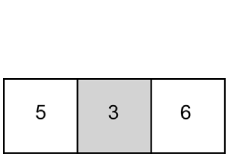


Figure 316. 3x1 Kernel

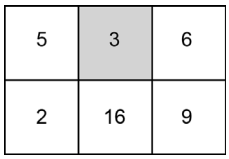
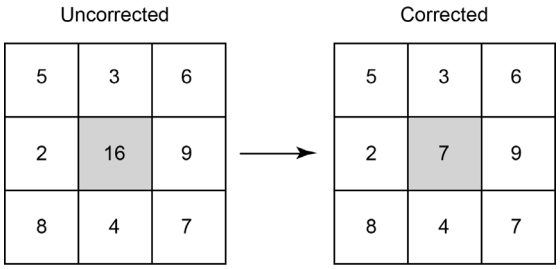


Figure 317. 3x2 Kernel

Median Filter

The **Median Filter** kernel corrects the data set by summing the pixel data In the kernel matrix, dividing by the total number of pixels in the matrix, and entering the result as the new value for the center pixel. If there is a fractional component to the result, the value will be rounded up if the fractional part is greater than or equal to 0.5. The filter is applied to every pixel in the region of interest. Note that this is a simplified explanation of the correction process. Additional processing occurs when pixels at the region of interest boundaries are corrected.



$$\frac{5+3+6+2+16+9+8+4+7}{9} = 6.666\ldots \text{ (rounded up to 7)}$$

Figure 318. Median Filter Example

Despeckle Filter

The Despeckle Filter compares the original center pixel value with a calculated median value. If the difference between the two is greater than the sens constant, the center value will be replaced with the calculated median value. If the difference is less than or equal to the sens constant, the center value will not be changed.

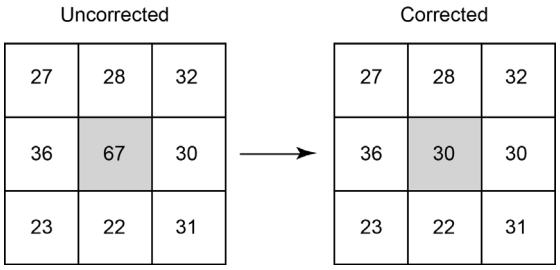


Figure 319. Despeckle Filter Example

Example of Despeckle Filter Operation

Princeton Instruments uses a set of constants while determining whether the center pixel value in a matrix needs to be changed. The purpose of the example is to give an idea of how the filter operates. The actual values of the constants may

differ from the values given below. The sequence of operations is basically:

1. The median pixel value is determined.
2. **min** is subtracted from that value and multiplied by 66536/(max – min) to generate **index$_m$**.
3. Using **index$_m$**, a calculated median (**median$_c$**) is determined and then compared with center pixel value.
   - If the difference between the two values > than **sens**, the center pixel value will be replaced by the calculated median value.
   - If it is ≤ than **sens**, the center pixel value will not be changed.

Constants:

sens = 19.531

max = 110

min = 10

In Table 6, note that **index$_m$** is a whole number: the decimal portion has been dropped.

Pixel Values (from Uncorrected matrix)	indexm = (value-min) *65536/(max-min)	indexm
22		
23		
27		
28		
30 (median)	(30-10)* 65536/(110-10) = 13107.2	13107
31		
32		
36		
67		

Table 6. Despeckle Example Values

Electron Multiplication

Currently, electron multiplication is a feature unique to the ProEM/ProEM+ and PI-MAX4-EM series of cameras. The principal difference between an electron-multiplying CCD (EMCCD) and a traditional CCD is the presence of an extended serial register in the array. Electrons are accelerated from pixel to pixel in the extended portion of the serial register (also referred to as a multiplication register) by applying higher-than-typical CCD clock voltages. This causes secondary electrons to be generated in the silicon by impact ionization. The degree of multiplication gain is controlled by increasing or decreasing the clock voltages for this register (gain is exponentially proportional to the voltage). Although the probability of generating secondary electrons is fairly low (typically 0.01 per stage), over the large number of stages of a typical multiplication register, the total gain can be quite high. This technology combines the ease of use and robustness of a traditional CCD with the gain capabilities of an intensified CCD in a single device. As the on-chip multiplication introduces additional noise, it is recommended that the multiplication be used only as required.

When the multiplication is sufficiently high, it is possible to see extremely low-light events. For ProEM and ProEM+ cameras, electron multiplication is selected on the **Analog to Digital Conversion** expander and the amount of gain is entered in the **EM Gain** field. A Gain setting of one (1) refers to a no-gain state where the camera behaves like a standard high speed CCD (with rather high read noise). Values 1 to ~1000 are mapped linearly to the internal serial clock voltages that vary the multiplication gain for a one-to-one relationship between entered gain value and actual gain. Even though the camera is capable of delivering large multiplication gain factors, EM gain should be used only as needed to preserve as much dynamic range as possible. For PI-MAX4-EM cameras, Intensifier gain and EM gain are controlled via the **emICCD Gain** field on the **Common Acquisition Settings** expander and the **emICCD Gain Mode** button on its **Advanced** panel. The default setting for the emICCD Gain Mode is **Optimal** (the other setting is **Manual**). **Optimal** means that based upon a single setting input in the **emICCD Gain** field, LightField will control the values that are used for Intensifier Gain and EM Gain (a maximum of 100 for EM Gain). If you switch to **Manual** gain control, the

Intensifier Gain and EM Gain settings become relevant again and you can change each one individually: Intensifier gain is changed on the **Common Acquisition Settings** expander and EM gain is changed on the **Analog to Digital Conversion** expander. Note that if you switch to Optimal mode after making Manual gain adjustments and subsequently change back to Manual mode, you will have the same values you had when you left Manual mode.

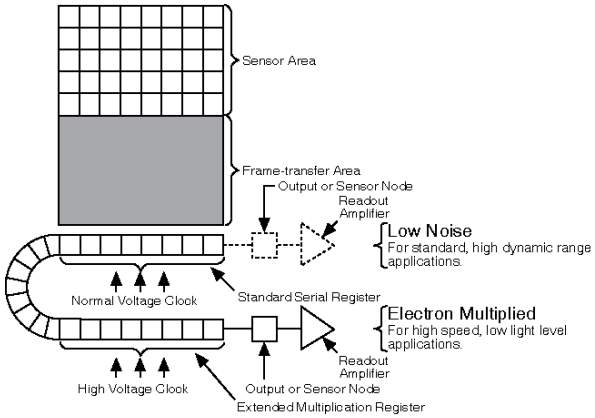


Figure 320. EMCCD Array Structure

Electron Multiplication Gain Calibration

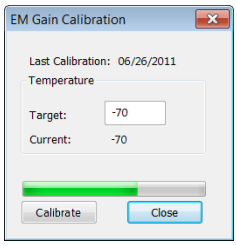


Figure 321. EM Gain Calibration dialog

EM gain is calibrated for the camera before it is shipped. However, over time you may find it necessary to recalibrate the EM gain with the **EMGainCalibration.exe** program in the Program Files\Princeton Instruments\LightField subdirectory.

Note: EM Gain Calibration is only used for ProEM and ProEM+ cameras.

To perform an EM gain calibration:

1. Make sure the camera is turned on and is the only ProEM or ProEM+ camera connected to the computer.
2. If LightField is running, exit the program.
3. If the camera has a manual shutter (for example, the camera is a ProEM:1600), close the shutter. If the camera has an internal shutter, the calibration program will automatically shut it before starting the calibration.
4. Launch **EMGainCalibration.exe**
5. When the **EM Gain Calibration** dialog appears, the default temperature will be automatically entered in the **Target** field.
6. When the **Current** temperature reaches the **Target** temperature, the **Calibrate** button will become active.
7. When you click on the **Calibrate** button, the internal shutter will close (if it is a manual shutter, you should have closed it before starting the EMGainCalibration program), the internal light will illuminate the sensor, a succession of data frames will be acquired, and the calibration map will then be calculated. A progress indicator is displayed during calibration.
8. Wait until the calibration has completed (it may take up to 10 minutes), and then close the dialog before starting LightField. If the camera is a **ProEM:1600** or **ProEM+:1600**, the process may take up to **30 minutes or longer**.

Gating Modes

Repetitive Gating Mode

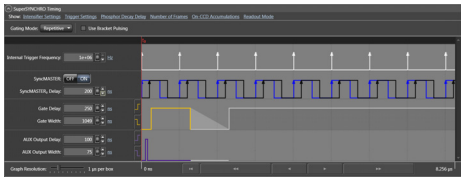


Figure 322. SuperSYNCHRO Repetitive Timing (Internal Trigger, No On-CCD Accumulations, Phosphor Decay Delay)

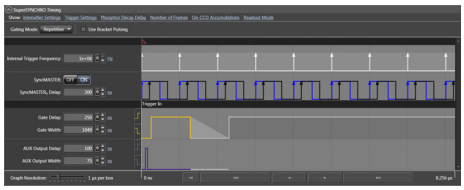


Figure 323. SuperSYNCHRO Repetitive Timing (External Trigger, No On-CCD Accumulations, Phosphor Decay Delay)

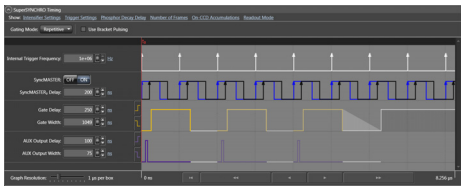


Figure 324. SuperSYNCHRO Repetitive Timing (Internal Trigger, 3 On-CCD Accumulations, Phosphor Decay Delay)

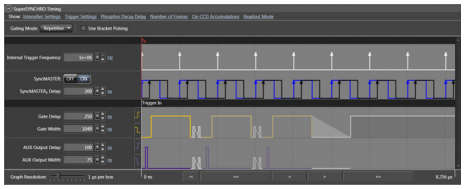


Figure 325. SuperSYNCHRO Repetitive Timing (External Trigger, 3 On-CCD Accumulations, Phosphor Decay Delay)

Introduction

With Repetitive Gating, the Gate Width and Gate Delay remain constant at the values specified during the acquisition. Values can be keyed into the fields, changed via the spin buttons, changed via the up and down arrows to the right of the fields, or by dragging on the graphs to the right of the parameter panel to achieve the desired settings.

The **Repetitive Timing** panel is opened by clicking on the **Gating Mode** button and selecting **Repetitive** from the drop-down menu. Not only can you enter timing values in the fields on the lefthand side of the panel, but you can also grab a pulse edge (or pulse center) in the timing graph to change Internal Trigger Frequency, Gate Width and/or Delay, AUX Output Width and/or Delay, or SyncMASTER$_2$ Delay.

Refer to ***"SuperSYNCHRO Timing" on page 75*** for information about the ways you can enter parameter values and use the other functions on this expander. Other functions include using hyperlinks to access important settings on other expanders and using the buttons related to the timing graph to view the diagrams at a different resolution level or move quickly to the left or right when the pulse ensembles extend beyond the current viewing area.

Setting Up a Repetitive Gating Experiment

Read the PI-MAX manual supplied with your camera to learn more about factors to be considered when setting up a sequential gating experiment.

Sequential Gating Mode

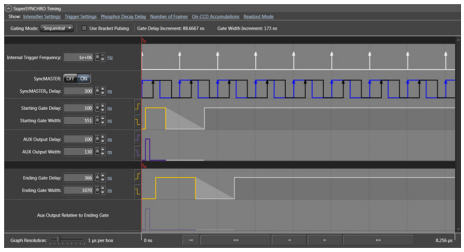


Figure 326. SuperSYNCHRO Sequential Timing (Internal Trigger, No On-CCD Accumulations, Phosphor Decay Delay)

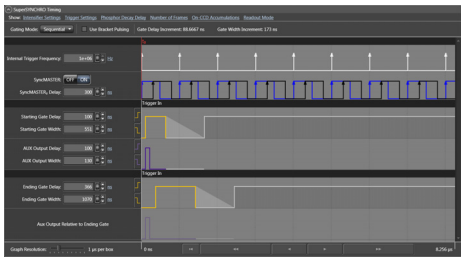


Figure 327. SuperSYNCHRO Sequential Timing (External Trigger, No On-CCD Accumulations, Phosphor Decay Delay)

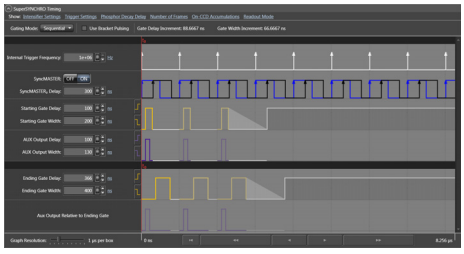


Figure 328. SuperSYNCHRO Sequential Timing (Internal Trigger, 3 On-CCD Accumulations, Phosphor Decay Delay)

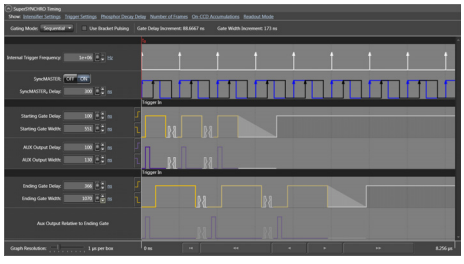


Figure 329. SuperSYNCHRO Sequential Timing (External Trigger, 3 On-CCD Accumulations, Phosphor Decay Delay)

Introduction

Unlike repetitive gating where the gate width and gate delay are constant for the specified number of exposures, sequential gating increments or decrements either or both gate width and gate delay as images or spectra are acquired. This sweep is accomplished linearly. Linear sequential operation is well suited to locating and recovering a transient effect that always occurs at the same time with respect to T_0. A sequential gating experiment requires a minimum of two frames (**Number of Frames** ≥ 2 on the **Common Acquisition Settings** expander).

The **Sequential Timing** panel is opened by clicking on the **Gating Mode** button and selecting **Sequential** from the drop-down menu. Not only can you enter timing values in the fields on the lefthand side of the panel, but you can also grab a pulse edge (or pulse center) in the timing graph to change Internal Trigger Frequency, Starting Gate Width and/or Delay, Ending Gate Width and/or Delay, AUX Output Width and/or Delay, or SyncMASTER2 Delay.

Refer to ***"SuperSYNCHRO Timing" on page 75*** for information about the ways you can enter parameter values and use the other functions on this expander for information about the ways you can enter parameter values and use the other functions on this expander. Other functions include using hyperlinks to access important settings on other expanders and using the buttons related to the timing graph to view the diagrams at a different resolution level or move quickly to the left or right when the pulse ensembles extend beyond the current viewing area.

Setting Up a Sequential Gating Experiment

Read the PI-MAX manual supplied with your camera to learn more about factors to be considered when setting up a sequential gating experiment.

MCP Gating

Introduction

MCP Gating can only be performed if your PI-MAX3 or PI-MAX4 camera contains an MCP Gating board. MCP gating (not to be confused with MCP bracket pulsing) provides you with a unique combination of nanosecond-scale gating speed and high ultraviolet QE. Normally, such high UV QE is only available in so-called slow gate intensifiers (i.e., those without a nickel underlay). The PI-MAX applies the primary gating pulse to the MCP portion of the intensifier tube and applies the bracket pulse to the photocathode. Consequently, it provides the full benefit of bracket pulsing along with enhanced QE.

The main limitations with this option are that there is a somewhat larger propagation delay and larger optical FWHM than a standard fast gate PI-MAX. Insertion delay between trigger and T0 is ~12 ns. Insertion delay to the photocathode gate is = 30 ns. Insertion delay to MCP gate is 75-225 ns (dependent on the individual intensifier): this delay allows the photocathode to be fully on before the MCP is gated. Pulse repetition rate is limited to 1 kHz.

Note: There is no indication on the **SuperSynchro Timing** expander that the MCP is being gated. You can, however, check the camera properties by right-clicking on the camera icon in the **Experiment Devices** area. Click on **Properties...** to open the **Device Properties** dialog. Then, click on the **Intensifier Attributes** tab.

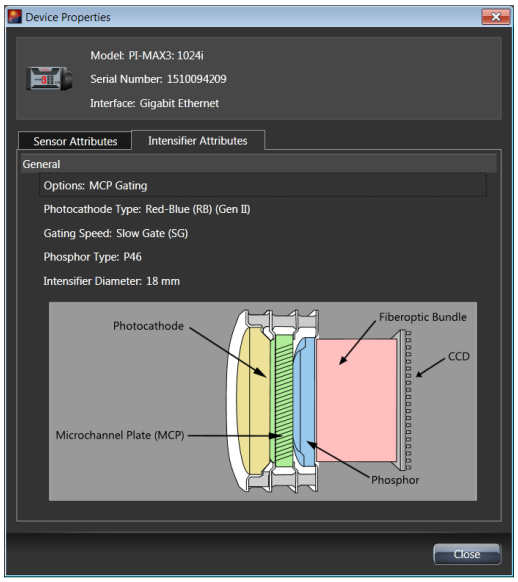


Figure 330. Device Properties dialog: PI-MAX Intensifier Attributes

Setup and Operation

The PI-MAX3 or PI-MAX4 must have an installed MCP Gating board.

1. Make all of the required cable connections for your experiment.
2. Switch on the equipment and start the application software.
3. Set up the gating parameters. You may want to start with a relatively long gate to acquire the phenomenon of interest.
4. Begin running the experiment.
5. Finally, narrow down the gate to the desired operation.

When possible in the experiment, it is a good idea to use bracket pulsing to limit the photocathode ON time.

Note: Pulse repetition rate is limited to 1 kHz.

Gain Variation

MCP gain approximately doubles for each 50 V increase in voltage. Therefore, small ripples in the MCP voltage as a result of the gating waveform will cause gain changes that vary with time after the rising edge of the gate pulse. A gain overshoot of 20 to 30% during the first 20 ns of a gate pulse is typical, with smaller variations later in time if a wider gate pulse is used. For a given gain setting and pulse width, these variations are reasonably repeatable, and may be calibrated.

Fluorescence Experiment

A typical laser-induced fluorescence experiment might incorporate a pulsed laser that excites a sample with the laser beam and that additionally provides a trigger to the PI-MAX. When the laser pulse hits the sample, some atoms are raised to a higher energy state and then spontaneously relax to the ground state, emitting photons as they do to generate the fluorescence signal. This signal can be applied to a spectrograph that spreads the fluorescence spectrum across the photocathode of the PI-MAX. The spectrum would then be intensified and applied to the PI-MAX's CCD array.

Cabling for MCP Gated Operation

The laser trigger output is applied to the PI-MAX's Trigger In connector to initiate the timing sequence. SuperSYNCHRO outputs gate the MCP on and off. To prevent artifacts from the laser from degrading the data, it is essential that SuperSYNCHRO be inhibited during each readout. Figure 332 shows a timing diagram for MCP gating.

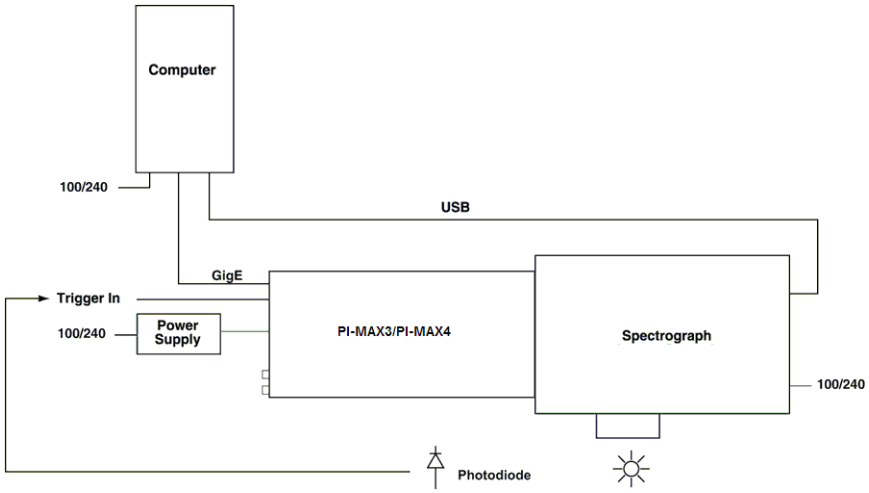


Figure 331. Cabling Diagram for an MCP Gated Experiment

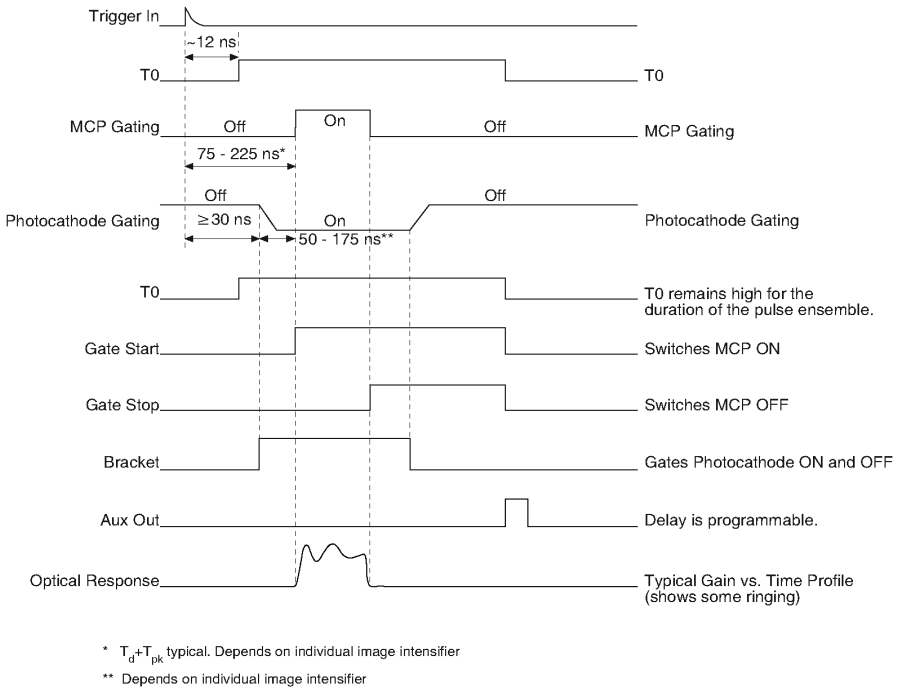


Figure 332. Timing Diagram: MCP Gating of Photocathode

DIF Gating Mode

Introduction

The purpose of PI-MAX DIF is to acquire a pair of gated images in rapid succession. The time between frames can be as short as 450 ns: the second image will have some remnants from the first image due to the longer persistence of the P46 phosphor. Exposure times can be as short as 2.5 ns. The DIF capability is ideally suited to capturing rapidly evolving events. These experiments will fall into one of two broadly applicable categories: single trigger and dual trigger experiments. Single trigger experiments involve a single impulse event that evolves over time such as a laser-induced plasma or luminescence decay. Dual trigger experiments involve two impulses separated in time such as double laser pulse velocimetry measurements.

Requirements

For DIF operation, the PI-MAX3 or PI-MAX4 must use an interline CCD and **DIF** must be the selected **Readout Mode** (**Readout** expander). The number of frames must be a multiple of 2 and is set via the **Common Acquisitions Settings** expander. In addition, it is recommended that the intensifier have a fast decay phosphor (P46). Since DIF operation involves acquiring images in rapid succession, phosphor persistence can become the limiting factor in the rate of image acquisition.

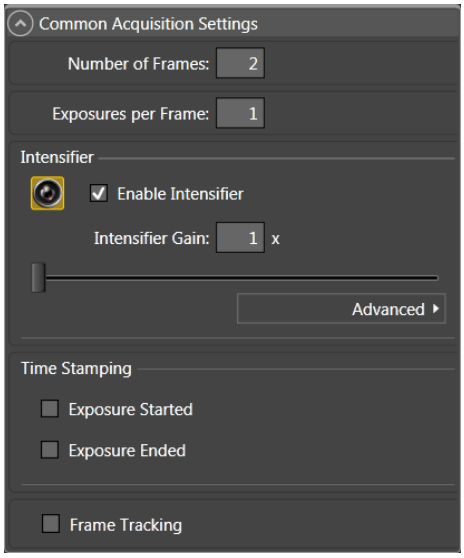


Figure 333. Common Acquisition Settings expander

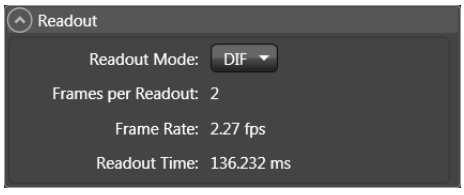


Figure 334. Readout expander

Note: The PI-MAX3:1024i, PI-MAX4:1024i, and PI-MAX4:1024i-RF are currently the only PI-MAX cameras that can operate in DIF mode.

Trigger Response

Triggering for DIF operation is set up on the **Trigger** expander. The selected **Trigger Response (Readout Per Trigger** or **Shift Per Trigger**) determines whether one or two triggers will be required for the acquisition. The trigger(s) can either be internally generated by the PI-MAX or can be generated by an external source connected to the **TRIGGER IN** connector on the rear of the camera. The trigger source is selectable via the **Trigger Source** drop-down list.

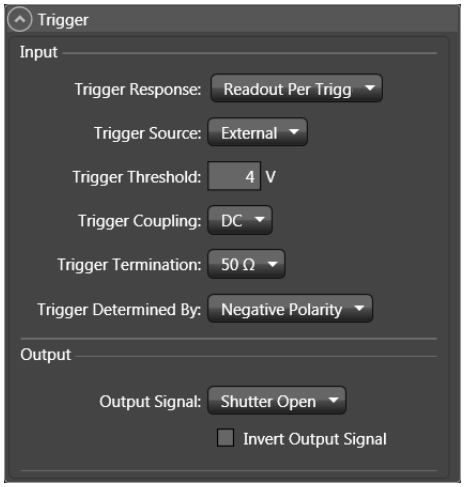


Figure 335. Trigger Response:

- **Readout Per Trigger:** Two shot, one trigger for both shots.
- **Shift Per Trigger:** Two shot, each shot requires a trigger.

Trigger Source

- **Internal:** Trigger pulses will be generated by the PI-MAX3 or PI-MAX4 based on the Internal Trigger Frequency setting (entered on the **SuperSYNCHRO Timing** expander). The range of settings is 2 Hz to 1MHz, in 1 Hz increments. Note that the Internal Trigger Frequency setting also determines the frequency of SynchMASTER1 and SyncMASTER2 outputs.

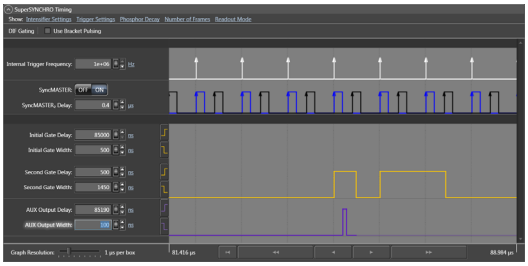


Figure 336. SuperSYNCHRO Timing expander: DIF

- **External:** In order for the PI-MAX3 or PI-MAX4 to recognize triggers from an external source, you will need to enter the characteristics of the triggers to be used in triggering DIF acquisition. These characteristics include trigger threshold, coupling, termination, and polarity and are entered on the **Trigger** expander.

Setting Up a DIF Mode Experiment

Hardware Setup

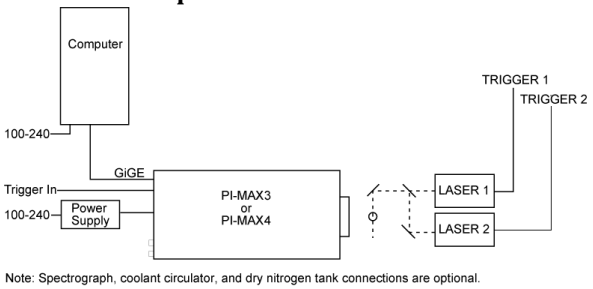


Figure 337. DIF Hardware Connection diagram

Software Setup and Operation

The operation of the PI-MAX3 or PI-MAX4 in DIF mode is similar to the standard operation of a PI-MAX with SuperSYNCHRO. There are only a few differences due to the special timing modes of DIF, and they will be outlined here. Because there are two timing modes in DIF operation, there are two procedures for setting up the experiment.

Single Trigger Mode

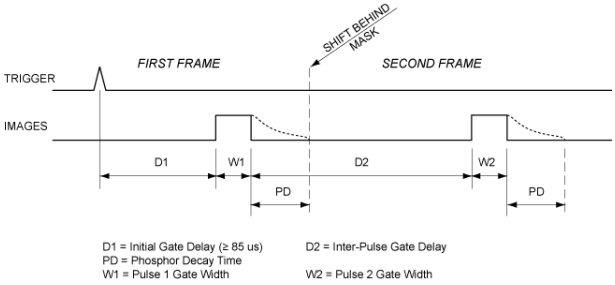


Figure 338. DIF Single Trigger Mode Timing diagram

1. The first requirement is that the PI-MAX camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX is operating in Full Frame readout mode (i.e., before switching to **DIF** mode on the **Readout** expander). Verify that the **Phosphor Decay Delay** is appropriate to the phosphor used by your camera: the phosphor decay delay time entered in LightField can be viewed or changed after clicking on the Advanced button on the **Common Acquisition Settings**

expander. The procedure for initial focus is outlined in Chapter 4 of the PI-MAX manual.

> **Note:** The **Phosphor Decay Delay** setting is used to tell LightField how long to wait after the gate pulse to shift the image. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image. If residual image is not an issue, then the Phosphor Decay Delay setting can be decreased to reduce the time between the two DIF images.

2. After the alignment and focus, the PI-MAX system needs to be put into DIF mode. On the **Readout** expander, select **DIF** as the **Readout Mode**.
3. On the **Trigger** expander, verify that **Readout Per Trigger** is the trigger response.
4. On the **Trigger** expander, select **Internal** or **External** triggering.
   - For External triggering, make sure the trigger characteristics on the Trigger expander match the active trigger edge, etc. of the trigger pulse that will be used.
   - For Internal triggering, set the Internal Trigger Frequency on the **SuperSYNCHRO Timing** expander
5. Open the **SuperSYNCHRO Timing** expander (at the bottom of the window) and begin entering the internal trigger frequency, gate width, gate delay, Aux output delay, Aux output width, and the SyncMASTER state (On or OFF).
   a. Use the hyperlinks at the top of the expanded panel to make any changes to the intensifier settings, trigger settings, phosphor decay delay time, number of frames (a multiple of 2), and readout mode (DIF or Full Frame).
   b. If you are using PI-MAX generated internal triggers for DIF acquisition, enter the internal trigger frequency.
   c. Enter the gate width and delay times for the first and second image.
      - The Initial Gate Delay time will be ≥ 85 µs.
      - The Second Gate Delay time will be ≥ 0.441 µs.
   d. If required, set up **AUX Output** trigger.
   e. If you want to have trigger output from the SyncMASTER1 and SyncMASTER2 connectors on the **AUX I/O** cable, click on the SyncMASTER **ON** button. When you enable SyncMASTER, the output of the SyncMASTER1 connector will be at the **Internal Trigger Frequency**. The SyncMASTER2 output will be at the same frequency but can be delayed (range for delay is from 0 to 999700 ns, in increments of 100 ns).
6. Verify that the I.I.T. Power switch on the rear of the PI-MAX is turned ON and that **Enable Intensifier** has been checked on the **Common Acquisition Settings** expander.
7. When the experiment is ready, click on the **Acquire** button.

Dual Trigger Mode

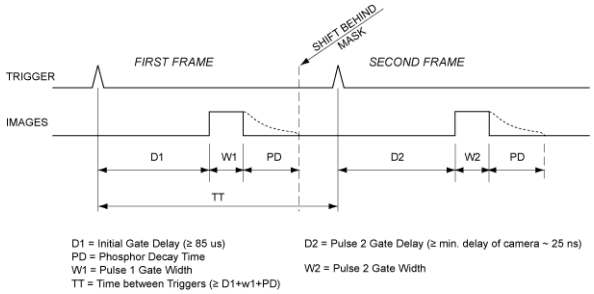


Figure 339. DIF Dual Trigger Mode Timing diagram

1. The first requirement is that the PI-MAX camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the PI-MAX is operating in Full Frame readout mode (i.e., before switching to DIF mode). Verify that the Phosphor Decay Delay is appropriate to the phosphor used by your camera: the phosphor decay delay time entered in LightField can be viewed or changed after clicking on the Advanced button on the Common Acquisition Settings expander. The procedure for initial focus is outlined in Chapter 4 of the PI-MAX manual.

> **Note:** The **Phosphor Decay Delay** setting is used to tell LightField how long to wait after the gate pulse to shift the image. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image. If residual image is not an issue, then the Phosphor Decay Delay setting can be decreased to reduce the time between the two DIF images.

2. After the alignment and focus, the PI-MAX system needs to be put into DIF mode. On the **Readout** expander, select **DIF** as the Readout Mode.
3. On the **Trigger** expander, verify that **Shift Per Trigger** is the trigger response.
4. On the **Trigger** expander, select **Internal** or **External** triggering.

- For External triggering, make sure the trigger characteristics on the **Trigger** expander match the active trigger edge, etc. of the trigger pulse that will be used.
- For Internal triggering, set the **Internal Trigger Frequency** on the **SuperSYNCHRO** expander.

5. Open the **SuperSYNCHRO Timing** expander (at the bottom of the window) and begin entering the internal trigger frequency, gate width, gate delay, Aux output delay, Aux output width, and the SyncMASTER state (On or OFF).

   Use the hyperlinks at the top of the expanded panel to make changes to the intensifier settings, trigger settings, phosphor decay delay time, number of frames (a multiple of 2), and readout mode (DIF or Full Frame).

6. If you are using PI-MAX generated internal triggers for DIF acquisition, enter the internal trigger frequency.
7. Enter the gate width and delay times for the first and second image.
   - The Initial Gate Delay time will be ≥ 85 µs.
   - The Second Gate Delay time will be ≥ 0.441 µs.
   - If required, set up **AUX Output** trigger.
   - If you want to have trigger output from the SyncMASTER1 and SyncMASTER2 connectors on the **AUX I/O** cable, click on the SyncMASTER **ON** button. When you enable SyncMASTER, the output of the SyncMASTER1 connector will be at the **Internal Trigger Frequency**. The SyncMASTER2 output will be at the same frequency but can be delayed (range for delay is from 0 to 999700 ns, in increments of 100 ns).
8. Verify that the I.I.T. Power switch on the rear of the PI-MAX is turned ON and that **Enable Intensifier** has been checked on the **Common Acquisition Settings** expander.
9. When the experiment is ready, click on the **Acquire** button.

Tips and Tricks

Experiments using the PI-MAX DIF feature can be complex, and timing of the events is usually rather exacting. Here are several points to consider that may make the experiment setup or troubleshooting much smoother and easier.

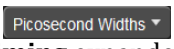
- The most important piece of equipment in a DIF experiment is an oscilloscope. The PI-MAX has a MONITOR BNC on the back of the camera which is very useful for seeing when the two image exposures occur during the course of the experiment. The use of the MONITOR BNC and an oscilloscope is discussed in more detail in the Tips and Tricks chapter.
- The short time between the two images in DIF requires an intensifier with a fast phosphor. P46 phosphor has a decay time of ~ 2 µs which means it takes 2 µs for the phosphor emission to drop to 10% of its peak value. The decay is not a simple single exponential; even after 100 µs there may be 1% or more of the first image on the phosphor screen. It is usually possible to subtract a percentage of the first image from the second image to remove the residual image. If this is not possible, there are intensifiers with P47 phosphor, which is an order of magnitude faster than P46.
- The software uses the **Phosphor Decay Delay** setting to determine how long to wait after the gate pulse to shift the image. This value can be adjusted in **Advanced** flyout pane on the **Common Acquisition Settings** expander. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image. If residual image is not an issue, then the Phosphor Decay Delay setting can be decreased to reduce the time between the two DIF images. This setting has no effect on the actual phosphor decay time; it is just used to adjust timing.

Picosecond Gating

Introduction

The picosecond gating option for the PI-MAX3 or PI-MAX4 allows optical gates down to less than 450 ps (or to the lowest gate width the intensifier will support, whichever is faster). It consists of a picosecond gating board installed in the PI-MAX and some other modifications to support the board. The picosecond option can operate up to 100 kHz repetition rate* (the main gate generator goes to 1 MHz) and has a few nanoseconds larger insertion delay than the main gate generator. The MONITOR BNC output operates differently in picosecond operation.

Activating Picosecond Operation

The **Picosecond Widths** button 

is added to the **SuperSYNCHRO Timing** expander when a PI-MAX3 or PI-MAX4 containing the picosecond gating board is detected and loaded as an experiment device. The **Picosecond Widths** button will appear below the Gate Width or Starting Gate Width field. You can either use non-nanosecond widths (enter the width as if the button were not present) or click on the button to access a list of valid gate widths for nanosecond timing. When you choose a width from the list,

that value will be entered in the Gate Width (or Starting Gate Width) field. If sequential gating is active, that value will also be entered into the Ending Gate Width field.

Gain and Gate Width

The apparent gain of the intensifier falls off as the gate width is reduced. Typically, at the lower limit, the gain is less than 10% of the value observed at 50 ns. The user selects one of the available gate widths from the **Picosecond Widths** dropdown list and that width will be automatically entered in the Gate Width field(s).

Note: When Sequential Gating is active, the starting and ending gate widths are the same: there are NO gate width sequences. However, differing starting and ending gate delays (swept delay) can be used with a constant gate width.

MONITOR Operation

The MONITOR output (at the BNC on the rear panel) is calibrated to provide a rising edge at the time the optical gate is opening (+/- 500 ps). The MONITOR width is NOT indicative of the optical gate width. It does NOT change width when the gate width is changed in the picosecond mode. This is because at these speeds, the electrical pulse width is not directly translated into optical gate width. In addition, many users do not have oscilloscopes available that will reliably capture picosecond pulse widths. Therefore, it was decided to use a pulse width of ~6 ns, regardless of the selected gate width. The true optical gate width is shown in the application software and this is calibrated at the factory using a fast pulsed laser.

Repetition Rate Issues

The picosecond gate generator operates at high peak power levels and therefore has a lower repetition rate capability than the main gate generator. The normal peak repetition rate for the picosecond gate generator is 100 kHz. However, it will allow 2 gates to be generated at up to 1 MHz to allow for DIF operation. In addition, the 100 kHz repetition rate cannot be sustained continuously. Practically, it must be interrupted periodically to read the CCD so this is not as great a problem as it may seem. The picosecond gate generator includes a digital average duty factor limiting circuit that will lock out gating (and light the red LED on the rear panel) to limit the average heat buildup in the gating circuit. This allows continuous operation at 10 kHz, and varying numbers of gates per frame at higher rates, depending on the read out time. Acquisitions of a few frames can usually be done with more gates per frame without hitting the limit and red light. If Trigger Source=Internal, LightField will show a Warning if your Internal Trigger is faster than 10 kHz; the Internal Trigger value cannot be set to faster than 100 kHz (faster than 100 kHz is an error condition).

Some typical numbers for sustained operation with a PI-MAX3:1024i are shown in Table 7.

Repetition Rate (kHz)	ADC Rate (MHz)	Binning & ROI	Readout Time (ms)	Gates/ Frame
90	16	Full frame	~40	450
75	16	Full frame	~40	461
50	16	Full frame	~40	500
50	16	1Hx100V ROI	~3.4	145
25	16	Full frame	~40	666
10	any	any		No limit

Table 7. Typical Picosecond Rates, Readout Times, and Gates/Frame for PI-MAX3:1024i

SyncMASTER and Trigger Source=External Selection

The SyncMASTER feature allows you to output 500 ns wide pulses generated internally by the PI-MAX3 or PI-MAX4. The pulses will appear at the SyncMASTER1 and SyncMASTER2 connectors on the AUX I/O cable and are at the frequency set by the value in the Internal Trigger Frequency field. These pulses can be used to synchronize the PI-MAX camera and other devices (such as a laser). These outputs are activated by clicking on the SyncMASTER ON button and the output of SyncMASTER2 can be offset from that of SyncMASTER1 by entering a delay.

If you are running a picosecond camera and have selected Trigger Source=External and SyncMASTER=ON, the Internal Trigger Frequency field appears on the SuperSYNCHRO Timing expander because that frequency drives the SyncMASTER pulse. Because this pulse is going OUT, LightField does not have to worry about the camera's ability to keep up. However, if you are putting that SyncMASTER pulse back IN at the camera's TRIGGER IN connector, LightField does not know if the SyncMASTER pulse is being used to run the camera. Because this is possible, LightField allows you to set a Trigger Frequency of up to 1 MHz but a WARNING will be displayed if the frequency is greater than 10 kHz.

Timing

When using optical gate widths from a few nanoseconds to a fraction of a nanosecond, timing is obviously critical. The PI-MAX3 or PI-MAX4 is calibrated with respect to the optical input plane (front mounting plane) and the rear panel. All other propagation paths must be accounted for by the user. These are significant, considering a 1 meter coaxial cable represents typically 4.5 ns delay or 9 times the gate width, assuming the gate width is set to 500 ps. To get the best representation of the MONITOR output, the user should use a high bandwidth oscilloscope set at 50Ω input impedance. The rise time of the

MONITOR pulse is typically less than 500 ps when terminated in 50Ω.

Methods for Finding a Short Optical Pulse

1. The "textbook" method is to calculate all the delays in the optical and trigger paths and set the PI-MAX delay accordingly. If one does all the arithmetic correctly and has accurate numbers for all of the delays involved, this method will work. In practice it seldom works because either some of the delays are not accurately known or something gets overlooked. The sum of the optical delays must be greater than the trigger delay (including the PI-MAX3 minimum delay). Doing the sums after the fact is still a valuable check on the system, even if the timing is achieved by the second method (see below).
2. A more direct and usually more convenient method is to start with a gate pulse much wider than the optical pulse and set the PI-MAX so the optical gate is wide enough to be sure it encompasses the optical pulse. This method works well if the pulse is conveniently repetitive, such as one derived from a repetitive laser. Once the pulse is found, it is an easy matter to reduce the pulse width and adjust the delay until the precise timing needed is achieved. The PI-MAX repetitive and sequential gating can be used to good advantage in this method.

Example:
This example is simplified in that it does not address all of the possible settings for Gate mode setup. It is intended to a sense of how to locate the signal of interest by successively decreasing gate pulse parameters.

1. Suppose we start with a 1 µs gate and delay set to the minimum value for the PI-MAX (approximately 25 ns), and we see the pulse. We then know the pulse is arriving between 25 ns and 1.025 µs.

   Gate Mode: Repetitive

   Number of Frames: 1

   Gate Delay: 25 ns

   Gate Width: 1 µs

2. We now set the sequential gating parameters for 20 ns gate width and 101 frames at 10 ns per frame: this spans the 1 µs. We set the starting gate delay of 25 ns, ending gate delay of 1025, and take the sequence. We can then quickly look through the images or spectra and see to the nearest 10 ns when the optical pulse arrived.

   Gate Mode: Sequential

   Number of Frames: 101

   Starting Gate Delay: 25 ns

   Starting Gate Width: 20 ns

   Ending Gate Delay: 1025 ns

   Ending Gate Width: 20 ns

   Reported Gate Delay Increment: 10 ns

3. Assuming we found the signal in the 12th frame, we now set a narrower gate (say 3 ns) and sweep about this value in 500 ps steps with a span of 60 ns to find the time within 500 ps. Adjust the experiment for best signal strength and/or signal to noise ratio, then jump down to the final gate width (if width < 500 ps is desired) and again do a sweep to find the exact timing that maximizes the result. This method has the advantage of assuring that the camera is seeing the pulse with the most favorable set-up before narrowing the gate width down.

   Gate Mode: Sequential

   Number of Frames: 121

   Starting Gate Delay: 116

   Starting Gate Width: 3 ns

   Ending Gate Delay: 176

   Ending Gate Width: 3 ns

   Reported Gate Delay Increment: .5 ns

RF Modulation

Introduction

The RF Modulation technique uses an RF source to vary the intensifier gain of an intensified CCD (such as that in a PI-MAX4:1024i-RF) at a radio frequency (RF) rate. Usually, the object under study is illuminated by a light source which also varies at an RF rate, equal (homodyne technique) or almost equal (heterodyne technique) to the rate at which the intensifier gain is varied. The signal delivered from the intensifier to the CCD is the product of the intensifier gain and input light intensity. Consequently, the signal contains (among other components) the product of the two RF sine waves (light source RF and intensifier RF). So the modulated intensified CCD behaves as an imaging lock-in amplifier, with the CCD acting as the output low pass filter.

Note: If you are using a PI-MAX4-RF with DIF capability, the Readout Mode will be set to Full Frame if you check **Use RF Modulation**.

Hardware Setup

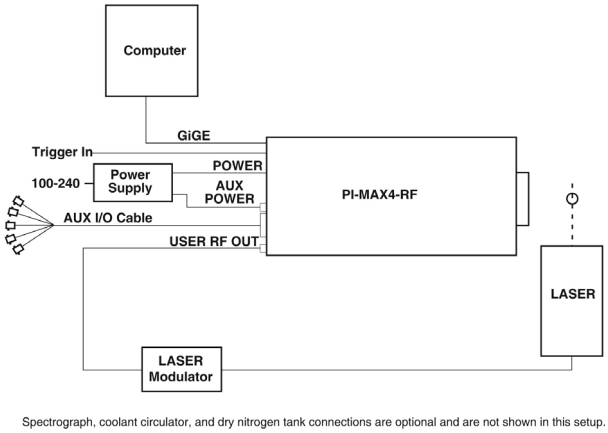


Figure 340. RF Modulation Hardware Connection diagram

Software Setup

Repetitive

1. The first requirement is that the PI-MAX4-RF camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the camera is operating in Full Frame readout mode. Verify that the **Phosphor Decay Delay** is appropriate to the phosphor used by your camera: the phosphor decay delay time entered in LightField can be viewed or changed after clicking on the Advanced button on the **Common Acquisition Settings** expander. The procedure for initial focus is outlined in Chapter 4 of the PI-MAX4 manual.

   Note: The **Phosphor Decay Delay** setting is used to tell LightField how long to wait after the gate pulse to shift the image. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image.

2. After the alignment and focus, the PI-MAX4-RF system needs to be put into RF modulation mode. On the **Common Acquisitions Settings** expander, select **Use RF Modulation**.

3. On the **Trigger** expander, select Internal or External triggering.

   - For External triggering, make sure the trigger characteristics on the **Trigger** expander match the active trigger edge, etc. of the trigger pulse that will be used.
   - For Internal triggering, set the **Internal Trigger Frequency** on the **SuperSYNCHRO Timing** expander.

4. Open the **SuperSYNCHRO Timing** expander (at the bottom of the window).

5. Select **Repetitive** as the Gating Mode and begin entering the setup information.

   a. Use the hyperlinks at the top of the expanded panel to make any changes to the intensifier settings, trigger settings, phosphor decay delay time, number of frames, and readout mode. Because **Use RF Modulation** is active, only Full Frame readout is available.

   b. If you are using camera-generated internal triggers for RF modulation acquisition, enter the internal trigger frequency.

   c. If you want to have trigger output from the **SyncMASTER1** and **SyncMASTER2** connectors on the AUX I/O cable, click on the SyncMASTER **ON** button. When you enable SyncMASTER, the output of the SyncMASTER1 connector will be at the Internal Trigger Frequency. The SyncMASTER2 output will be at the same frequency but can be delayed (range for delay is from 0 to 999700 ns, in increments of 100 ns).

   d. Enter the **Modulation Duration**, **Modulation Frequency**, and **Modulation Phase** values.

   e. If you want to drive an RF amplifier via the **User RF Out** connector on the back of the PI-MAX4-RF, click on the **User RF Output ON** button. Then select the appropriate frequency and amplitude level (Vp-p). Note that the **User RF Output** must be connected to a 50 Ohm load (standard for RF).

   f. If required, set up **AUX Output** trigger.

6. Verify that the **I.I.T. Power** switch on the rear of the PI-MAX-RF is turned **ON** and that **Enable Intensifier** has been checked on the **Common Acquisition Settings** expander.

7. When the experiment is ready, click on the **Acquire** button.

Sequential

1. The first requirement is that the PI-MAX4-RF camera be aligned and focused on the area of interest in the experiment. This is best accomplished while the camera is operating in Full Frame readout mode. Verify that the **Phosphor Decay Delay** is appropriate to the phosphor used by your camera: the phosphor decay delay time entered in LightField can be viewed or changed after clicking on the **Advanced** button on the **Common Acquisition Settings** expander. The

procedure for initial focus is outlined in Chapter 4 of the PI-MAX4 manual.

> **Note:** The **Phosphor Decay Delay** setting is used to tell LightField how long to wait after the gate pulse to shift the image. If there is some residual image from the first frame in the second frame, simply increase the Phosphor Decay Delay setting to allow more time for the phosphor emission to decay before shifting the image.

2. After the alignment and focus, the PI-MAX-RF system needs to be put into RF modulation mode. On the **Common Acquisitions Settings** expander, select **Use RF Modulation**.
3. Enter 2 or more in the **Number of Frames** field. The range is 2 to 1,023.
4. If you want to track the modulation phase, click in the **Modulation Tracking** check box.
5. On the **Trigger** expander, select Internal or External triggering.
   - For External triggering, make sure the trigger characteristics on the **Trigger** expander match the active trigger edge, etc. of the trigger pulse that will be used.
   - For Internal triggering, set the **Internal Trigger Frequency** on the **SuperSYNCHRO Timing** expander.
6. Open the **SuperSYNCHRO Timing** expander (at the bottom of the window).
7. Select **Sequential** as the Gating Mode and begin entering the setup information.
   a. Use the hyperlinks at the top of the expanded panel to make any changes to the intensifier settings, trigger settings, phosphor decay delay time, number of frames, and readout mode. Because **Use RF Modulation** is active, only Full Frame readout is available.
   b. If you are using camera-generated internal triggers for RF modulation acquisition, enter the internal trigger frequency.
   c. If you want to have trigger output from the **SyncMASTER1** and **SyncMASTER2** connectors on the AUX I/O cable, click on the SyncMASTER **ON** button. When you enable SyncMASTER, the output of the SyncMASTER1 connector will be at the Internal Trigger Frequency. The SyncMASTER2 output will be at the same frequency but can be delayed (range for delay is from 0 to 999700 ns, in increments of 100 ns).
   d. Enter the **Modulation Duration**, **Modulation Frequency**, and **Modulation Starting Phase** values.
   e. If you want to drive an RF amplifier via the **User RF Out** connector on the back of the PI-MAX4-RF, click on the User RF Output **ON** button. Then select the appropriate frequency and amplitude level (Vp-p). Note that the **User RF Output** must be connected to a 50 Ohm load (standard for RF).
   f. If required, set up **AUX Output** trigger.
   g. Enter the **Modulation Ending Phase**. You may need to scroll down.
8. Verify that the **I.I.T. Power** switch on the rear of the PI-MAX is turned **ON** and that **Enable Intensifier** has been checked on the **Common Acquisition Settings** expander.
9. When the experiment is ready, click on the **Acquire** button.

High Speed Camera Add-in

The **High Speed Camera** add-in (formerly named High Speed ProEM) will, with the click of a button, change the experiment settings to minimize readout time and maximize the number of frames that can be acquired per second. Keep in mind when using the add-in that there is tradeoff between increased spectral readout rate and data quality (increasing the frames per second tends to decrease data quality).

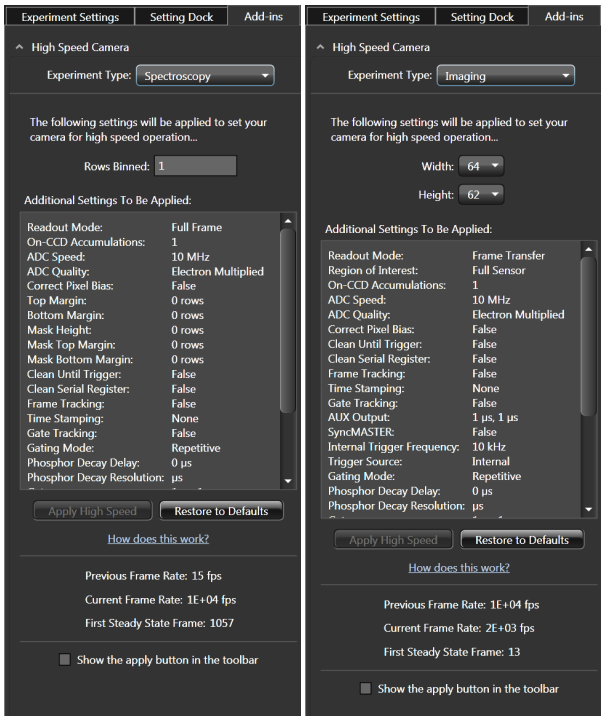


Figure 341. High Speed Camera expander

When the icon for a camera that supports the high speed function is in the **Experiment Devices** panel, the **High Speed Camera** add-in can be activated on the **Manage Add-ins** dialog. When the add-in is activated, an **Add-ins** panel and a **High Speed Camera** expander (see Figure 341.) are added to the set of panels at the left side of the

screen. The settings listed in the **Additional Settings To Be Applied** frame will vary depending on the camera and the selected experiment type.

1. Click on the **Add-ins** tab and open the **High Speed Camera** expander.
   - If the **Experiment Type** is **Spectroscopy**, you will be able to enter the number of rows to bin.
   - If the **Experiment Type** is **Imaging**, you can select width and height values. Note that some of the additional settings are updated when you change the width and/or height.
2. Click on the **Apply High Speed** button to replace the current experiment settings with the high speed settings. Note that the previous and the new frame rate information is reported. (If you click on **Restore to Defaults**, the experiment settings will be restored to the defaults for the camera.)
3. On the **Experiment Settings** panel, enter the **Number of Frames** (for example, 50).
4. Click on the **Acquire** button when you are ready to acquire the frame set.

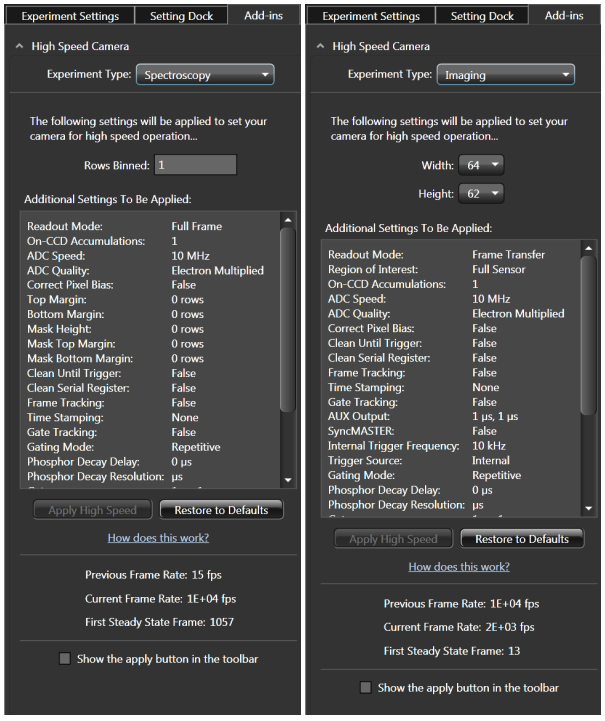


Figure 342. High Speed Camera expander

Interline CCD Operation

An interline CCD is composed of an array of hybrid pixels that incorporate a light-sensitive area and a masked area into each pixel element. Image data is collected in the light-sensitive area of a pixel and is then shifted into the masked area for readout. With this architecture, the CCD can acquire a second image while the first image is being read out, unlike a standard CCD, which must read out the first image before the second acquisition can begin. The ability of the interline CCD to quickly transfer an image into the masked areas and hold it there makes DIF possible. As soon as the first image is acquired, it is shifted into the masked area and held. The second exposure begins and is held in the light-sensitive area until the first image is read out.

Kinetics

Kinetics Mode

Note: Kinetics operation requires that the Kinetics option has been installed in the camera. If the Kinetics option has been installed in the camera, this readout mode will be made available when you move the camera to the Experiment Devices area.

Introduction

Kinetics mode is a special mode by which multiple frames are contained within a single readout, producing a burst frame rate. This mode requires support from the camera and is only applicable in certain experiments. Kinetics assumes that shifting data within the sensor is significantly faster than readout of the data. In Kinetics mode, you divide the active area of the sensor into an active area and a masked area (mechanically or optically masked). The masked area is a multiple of the active area in the parallel direction and is closest to the readout port(s) used. After each frame of data is acquired, the data are not read out. Instead, the data are shifted out of the active area into the masked area towards the readout port(s). The time it takes to shift each line (or row) on the sensor is as short as a few hundred nanoseconds to few microseconds, depending on the sensor. As new frames are shifted into the masked area, older frames are shifted within the masked area towards the readout port(s). This shifting accumulates frames on the sensor until the masked area is completely full. At this point, one final frame is acquired in the active area and all of the frames on the sensor are read out. Additionally, you can adjust the sensor's shift rate in the parallel direction in and effort to further increase the burst frame rate.

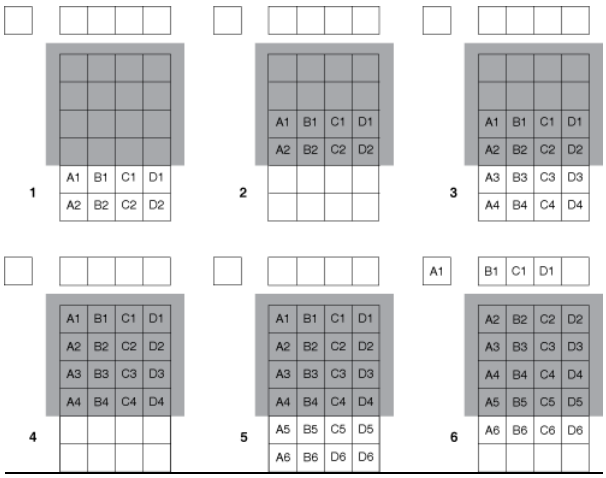


Figure 343. Illustration of Kinetics Mode

Figure 343 shows a simplified illustration of Kinetics mode. In the picture below (4 × 6 sensor example), 2/3 of the sensor is masked, either mechanically or optically. The shutter opens to expose a 4 × 2 region. While the shutter remains open, charge is quickly shifted just under the mask, and the exposure is repeated. After a third image is collected the shutter is closed and the sensor is read out. Since the sensor can be read out slowly, very high dynamic range is achieved.

Kinetics Selection

If the camera supports Kinetics mode, this readout mode can be selected on the **Readout** expander. After you have selected Kinetics, you can then indicate the window height (this should match the height of the unmasked rows on the sensor) and the storage shift rate (rate at which one row is shifted one row toward the serial register). The number of frames per readout, frame rate (the time spent acquiring the frames), and the sensor readout time are then reported.

Kinetics Trigger Response Modes

Kinetics mode operates with five trigger response modes: **No Response**, **Expose During Trigger Pulse** (Bulb Trigger Mode), **Readout Per Trigger**, **Shift Per Trigger**, and **Start on Single Trigger**. These modes are selectable on the **Trigger** expander.

- **No Response:** In the No Response Kinetics mode, the camera takes a series of images, each with the exposure time set through LightField. The time between image frames, which may be as short as a few microseconds, is limited by the time required to shift an image under the mask: this inter-image time equals the Storage Shift Rate (specified in µs/row) multiplied by the Kinetics Window Height (the number of rows allocated for an image frame). The exact number of frames is equal to the number of pixels perpendicular to the serial register divided by the Kinetics Window Height.

  Example: Referring to the readout shown in the figure above, there are 6 pixels perpendicular to the serial register and the window is 2 rows high. The number of frames is 3. If the Storage Shift Rate for the sensor is 1.6 µs/row, the Shift time is 3.2 µs per frame.

  The Integrate signal (Shutter Open) or the Readout signal (Not Reading Out) is provided at the LOGIC OUT connector for timing measurements.

- **Expose During Trigger Pulse:** Also known as Bulb Trigger Mode, Expose During Trigger Pulse uses the two edges of a trigger pulse input at the EXT SYNC connector to control the exposure time, allowing an external timing generator to control the exposure time of the camera. The transition from the inactive state to the active state of the External Sync at the EXT SYNC connector starts the exposure; and the transition from the active state to the inactive state ends the Expose.

- **Readout Per Trigger:** In the Readout Per Trigger Kinetics mode, the camera takes an entire series of images with each External Trigger Pulse (applied at the EXT SYNC connector on the rear of the camera). After the series is complete the shutter closes and the CCD is read out at normal speeds. Once the readout is complete the camera is ready for the next series of exposures.

- **Shift Per Trigger:** In the Shift Per Trigger Kinetics mode, the camera takes a single image in the series for each External Sync pulse received by the camera. Once the series is complete, the shutter closes and readout begins. Since the shutter is open during the entire series of images, if the External Sync pulses are irregularly spaced, the exposures will be of different lengths. Once a series has been read out, the camera is ready for the next series.

- **Start On Single Trigger:** In the Start On Single Trigger Kinetics mode, acquisition occurs in the same way that it does for No Response mode with the difference that when you click on **Run** or **Acquire** the camera will wait until it receives a trigger to start sending data to LightField. After that, it continues on performing the experiment without listening to (or waiting for) any further triggers.

Cleaning in Kinetics Mode

In Kinetics mode, **Clean Cycles** are done, and **Clean Until Trigger** is supported for some hardware. If selected, **Clean Until Trigger** cleans are applied only between the first **Not Reading Out** low-to-high transition and the External Sync

high-to-low transition. Because of the speed at which the sensor is then shifted, exposed, and shifted again, no further cleaning occurs until the last frame has been exposed and shifted. At that point, standard clean cycles resume.

Setting Up for Kinetics or Spectra-Kinetics Mode Procedure

1. Set up the mechanical or optical masking. For standard Kinetics, the exposed area of the sensor should be the rows furthest from the serial register. For Spectra-Kinetics, the exposed area of the sensor should be just below the frame-transfer mask. Remount the camera if necessary.
2. Make sure all devices for the experiment are connected to the computer and that they are powered on.
3. Start LightField, if it is not already running.
4. Make sure the experiment devices (camera, spectrograph, etc.) have been moved to the **Experiment Devices** area.
5. In the **Readout** expander, set **Readout Mode** to the appropriate mode **Kinetics** or **Spectra-Kinetics**. These kinetics modes are only available if supported by the camera.
6. Enter the **Window Height**. This height should match the height of the mask (optical or mechanical) that is being used. The **Frames per Readout** will be reported. For standard Kinetics, it is calculated by dividing the sensor height by the window height. If there are leftover rows (for example, sensor height=100, window height= 7, frames per readout=14 with 2 extra rows), they will be discarded. For Spectra-Kinetics, Frames per Readout is based on the number of rows under the frame-transfer mask.
   - For standard Kinetics, the acceptable Window Height range is 1 row to half the sensor height in rows.
   - For Spectra-Kinetics, the acceptable Window Height range is from 1 row to 410 rows for the ProEM:512BK, ProEM:512BK eXcelon, ProEM+:512BK, and ProEM+:512BK eXcelon cameras; from 1 to 512 for ProEM:512B, ProEM:512B eXcelon, ProEM+:512B, and ProEM+:512B eXcelon cameras; and from 1-1024 for the ProEM:1024B, ProEM:1024B eXcelon, ProEM+:1024B, and ProEM+:1024B eXcelon cameras.
7. Select a **Storage Shift Rate**. The default value gives good results in most measurements. Setting a lower value increases the shift speed. A higher value gives a slower shift. If the shift is too fast, not all of the charge will be transferred. If too slow, image smearing will be increased due to the exposure that takes place while the transfer is in progress. **Storage Shift Rate** is how fast a row is shifted up a row.
8. On the **Common Acquisition Settings** expander, set the **Number of Frames** to the **Frames per Readout** or a multiple of that number. Typically, if there are 10 frames per readout, you would enter 10 as the number of frames. However, you could enter 20 frames and LightField would read out the sensor twice.
9. In the **Trigger** expander, make sure the **Trigger Response** is appropriate to your experiment. If acquisition will be initiated by an external trigger, set up the trigger response and polarity.
10. In the **Shutter** expander, make sure the **Shutter Mode** is appropriate. If the event of interest is likely to occur while the shutter is opening, you may want to select **Open Before Trigger**.
11. If using external triggering, make the cable connection from the trigger source to the **EXT SYNC** connector and turn on the trigger source.
12. If you will be using background subtraction, select **Background Subtraction** on the **Online Corrections** expander. Acquire or load a data file that has the same settings that will be used for the actual experiment (exposure time, number of frames, etc.) but does not show the event of interest.
13. Start the experiment by clicking on the **Acquire** button; and initiate triggering (if active) and the event of interest.
14. The data will be acquired and each kinetics frame will be stored as an individual frame in the saved data. In **Data View**, (in the **Data** workspace) you can then view the frames in playback mode; manually advance from frame to frame through the data set; or in **Comparison View** (accessed in the **Data** workspace), load the data into two different views and compare one frame of the data in the first view with a different frame from the data set in the second view.

Configuring the Storage Shift Rate for Kinetics/Spectra-Kinetics

Introduction

Caution: Princeton Instruments does not encourage users to change the Storage Shift Rate parameter setting. For most applications, the default setting will give the best results. We *strongly advise* contacting the factory for guidance before customizing the sensor timing.

If you have selected **Kinetics** or **Spectra-Kinetics** as your readout mode, one of the settings available is **Storage Shift Rate**. The default value for this setting is loaded when a camera is selected for an experiment and placed in the **Experiment Devices** area. The Storage Shift Rate is the rate at which one row is shifted one row toward the serial register. Adjusting the shift rate can increase the frame rate by speeding up the shift or increase the quality of data by slowing down the shift. This level of hardware control is primarily utilized by Intermediate/Advanced users who are concerned about getting the full benefits of the hardware performance.

Selecting a Storage Shift Rate

1. Open the **Readout** expander on the Experiment Settings tab panel.
2. Select **Kinetics** or **Spectra-Kinetics** as the Readout Mode.
3. Enter the **Kinetics Window Height**.
4. Click on the **Storage Shift Rate** button and select the new shift rate from the drop-down list. The Frame Rate value will be updated accordingly.

Spectra-Kinetics Mode

Note: Spectra-Kinetics Mode is an option available for use with the ProEM/ProEM+ cameras having a frame transfer sensor. If the Spectra-Kinetics option has been installed in the camera, this readout mode will be made available when you move the camera to the Experiment Devices area.

Spectra-Kinetics (standard for the ProEM:512BK and ProEM+:512BK) is a purchasable software option for ProEM:512B ProEM:1024B, ProEM+:512B, and ProEM+:1024B cameras.

When this option is available you will be able to select Spectra-Kinetics as the readout mode. The Spectra-Kinetics option provides higher sensitivity (via binning) than our standard kinetics mode and is ideal for capturing longer duration events. Use of Spectra-Kinetics allows the ProEM/ProEM+ camera to acquire the full masked height's worth of spectra irrespective of the height of the "illuminated" rows — all while delivering the same temporal resolution as standard Kinetics.

In standard Kinetics mode, binning is performed in the serial register. This limits the total event time that can be captured, even for spectroscopy applications. By binning under the frame-transfer mask, however, Spectra-Kinetics is able to capture longer-duration events and provide higher sensitivity than standard Kinetics mode.

For the fastest possible acquisition, Spectra-Kinetics requires that an external mask blocks light from all but a window of rows just below the frame-transfer mask. During acquisition, the window is exposed and then the rows are shifted under the frame-transfer mask where they are binned into a single row. The next exposure occurs, followed by shifting and binning. And so on… until the **Number of Frames,** a multiple of the **Frames per Readout (**reported on the **Readout** expander), have been acquired. By binning into a single row, up to 528 kinetics frames can be acquired for a ProEM:512B/BK and up to 1037 kinetics frames for a ProEM:1024B.

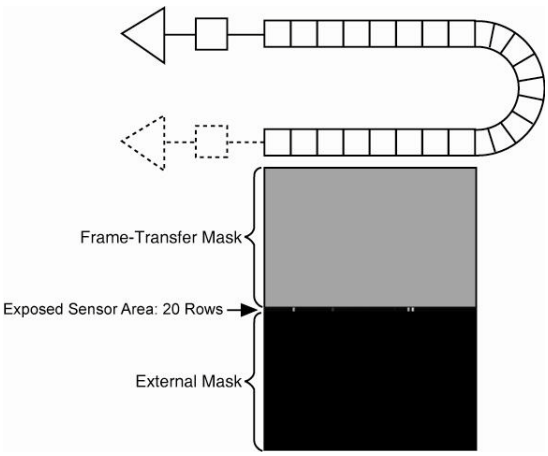


Figure 344. Drawing showing location of spectra-kinetics window

	Kinetics	Spectra-Kinetics
Rows illuminated	Farthest away from the serial register	Closest to the frame-transfer mask
Time resolution	N*V.shift speed	N*V.shift speed
Number of kinetic frames	Total height/N (N = illuminated number of rows)	Frame-transfer mask height (independent of N)
Included as standard option	Yes	Standard for ProEM:512BK and ProEM+:512BK Optional for ProEM:512B, ProEM:1024B, ProEM+:512B, and ProEM+:1024B

Table 8. Comparison of Kinetics and Spectra-Kinetics Modes

	ProEM:512B/BK		ProEM:1024B	
Rows illuminated	Total number of kinetic frames (Kinetics)	Total number of kinetic frames (Spectra-Kinetics)	Total number of kinetic frames (Kinetics)	Total number of kinetic frames (Spectra-Kinetics)
32	32	528	64	1037
64	16	528	32	1037
128	8	528	16	1037
256	4	528	8	1037

Table 9. Number of Frames Comparison for ProEM:512B/BK and ProEM:1024B

Readout Example - Full Frame

Figure 345 represents a sensor after exposure but before the beginning of readout. The capital letters represent different amounts of charge, including both signal and dark charge. This section explains readout at full resolution, where every pixel is digitized separately.

Note: Depending on the camera, you may have a choice of amplifier (low noise, high capacity, or electron multiplied). Depending on the selected amplifier, the shift register may be read out to the right or to the left. For simplicity this drawing shows the readout to the left.

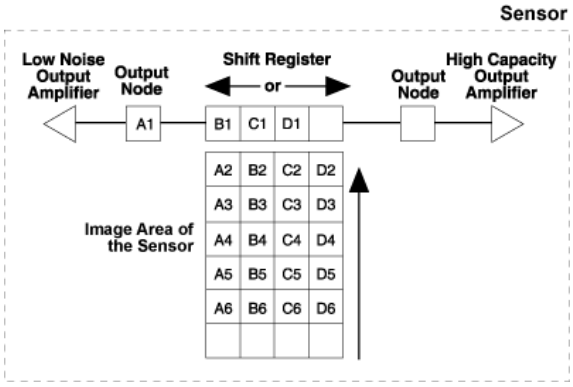


Figure 345. Drawing of Sensor

Readout of the sensor begins with the simultaneous shifting of all pixels one row toward the "serial register," in this case the row at the tope. The serial register is a single line of pixels along the edge of the sensor, not sensitive to light and used for readout only. Typically the serial register pixels hold twice as much charge as the pixels in the sensor's imaging area.

After the first row is moved into the serial register, the charge now in the serial register is shifted toward the output node, located at one end of the serial register. As each value is "emptied" into this node it is digitized. Only after all pixels in the first row are digitized is the second row moved into the serial register. The order of shifting in our example is therefore A1, B1, C1, D1, A2, B2, C2, D2, A3....

After charge is shifted out of each pixel, the remaining charge is zero, meaning that the sensor is immediately ready for the next exposure.

Below are the equations that determine the rate at which the sensor is read out. The time needed to take a full frame at full resolution is:

$$t_R + t_{exp} + t_c$$

where

t_R is the sensor readout time,

t_{exp} is the exposure time, and

t_c is the shutter compensation time.

The readout time is approximately given by:

$$t_R = [N_x \cdot N_y (t_{sr} + t_v)] + (N_x \cdot t_i)$$

where

N_x is the smaller dimension of the sensor

N_y is the larger dimension of the sensor

t_{sr} is the time needed to shift one pixel out of the serial register

t_v is the time needed to digitize a pixel

t_i is the time needed to shift one line into the serial register

A subsection of the sensor can be read out at full resolution, sometimes dramatically increasing the readout rate while retaining the highest resolution in the region of interest (ROI). To approximate the readout rate of an ROI, in Equation 2 substitute the x and y dimensions of the ROI in place of the dimensions of the full sensor. Some overhead time, however, is required to read out and discard the unwanted pixels.

Readout Port Selection

Introduction

After the exposure time has elapsed, the charge accumulated in the sensor pixels needs to be read out of the sensor, converted from electrons to digital format, and transmitted to the application software where it can be displayed and stored. Readout begins by moving charge from the image area to the serial register. The charge in the serial register pixels, which typically have 2-3 times the capacity of an image pixel, is then shifted into the output node and on to the output amplifier where the electrons are grouped as electrons/count. This result then goes to the preamplifier where gain is applied.

Note: The number and selection of readout port(s) are camera dependent. If there are multiple ports, the choice of readout port is made by opening the Analog to Digital Conversion (ADC) expander and choosing from the Quality drop-down list.

Readout Port

Typically, a sensor has a single readout port. However, some sensors have two ports with either (but not both) selectable for readout: the exception are the PI-MAX3:1024i and PI-MAX4:1024i which offer the option of simultaneous dual-port readout or single port readout. Other sensors have four ports and offer the option of simultaneous four-port readout or single port readout, where the port used is factory-selected for optimal performance. Because changing a port affects the image orientation, it would be a good idea to select "**Automatically Correct for Hardwar**e" on the **Online Corrections** expander: LightField will then automatically correct for any such orientation changes.

Dual Port

The PI-MAX3:1024i and PI-MAX4:1024i are designed for either dual or single port readout. Sensor readout occurs through both ports when dual-port readout is selected. Dual-port readout is about two times faster than single port readout and occurs whenever the full frame is being read out or when an ROI is symmetrical about the center of the CCD. The choice of **Readout Ports Utilized** is selectable via the **Advanced** pane on the **Region of Interest** expander.

If your camera (other than a PI-MAX3:1024i or PI-MAX4:1024i) has dual output amplifiers, either the **High Capacity** (or **Electron Multiplied** for ProEM/ProEM+ and PI-MAX4-EM cameras) or the **Low Noise** amplifier can be selected for the Quality setting on the **Analog to Digital Conversion** expander. The output amplifier amplifies the collected charge from the output node and outputs it as electrons/count.

- **High Capacity amplifier:** Provides a spectrometric well capacity that is approximately 3 times the well capacity for the Low Noise amplifier selection. High Capacity is suitable when intense light signals or signals with high dynamic range are present.
- **Low Noise amplifier:** Provides the highest sensitivity performance and is suitable for detection of weak signals.
- **Electron Multiplied:** ProEM/ProEM+ and PI-MAX4-EM camera-specific. Can be used to overcome the read noise of the fast amplifier and is most useful in applications requiring low-light sensitivity at high frame rates (e.g., single molecule fluorescence, ion imaging, etc.). EM gain in the 1-100 range is recommended for medium to high light level signals and is the least likely to cause damage to the EM sensor. Typically, only 100x or lower EM gain is required to achieve <1 e- RMS effective read noise. Because using higher EM gain can accelerate sensor ageing while lowering effective dynamic range, you may wish to activate the yellow to red gradient in the >100 region of the slidebar as a visual reminder that higher gains may have a negative impact on sensor life. This feature is activated by clicking on the **>100** button  . Note that for PI-MAX4-EM cameras, EM gain is automatically set if **I/E Gain Mode** is **Optimal** (selected on the **Common Acquisition Settings** expander's **Advanced** pane); if **Manual** is active, EM gain is selected on the **Analog to Digital Conversion** expander

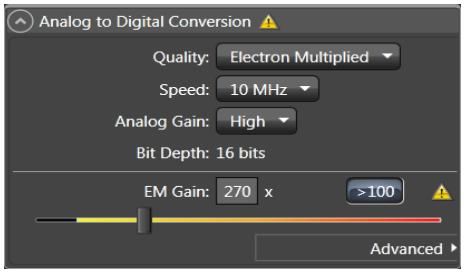


Figure 346. Analog to Digital Conversion expander

Note: The choice of output amplifier and gain setting should be considered together for the best signal capture. Examples of the interaction of output amplifier and gain selections are shown here.

Four Port

Quad-RO sensors have four quadrants, each having an associated readout port. Depending on the sensor size and the region of interest, readout is four-port or through the optimal single port. In LightField, four-port readout mode occurs if full image readout is selected or if the region of interest (ROI) is centered on the sensor and vertically and horizontally symmetrical.

Quad-RO:4096 cameras can use either four-port or single-port readout. The readout port selection is available on the **Advanced** flyout pane on the **Region of Interest** expander. Readout in single-port mode may be significantly slower than in four-port mode. Whenever a ROI does not meet the symmetrical and centered rules, LightField will automatically use the Quad-RO:4096 camera single-port for readout.

Note: Single port readout is not available for Quad-RO:4320.

Single Port

As mentioned before the Quad-RO:4096 camera can use single-port as well as four-ports for reading out acquired signal. The PI-MAX3:1024i can use single as well as dual-port readout. Readout via a single port is slower it allows you to create an ROI that does not conform to the symmetry rules for multi-port readout.

Regions of Interest - Editing

Introduction

The **Edit Regions of Interest** window (accessed by selecting **Custom Region(s) of Interest** on the **Region of Interest** expander and then clicking on the **Edit ROIs...** button) allows you to create, delete, and modify regions of interest. Once a ROI has been created, its attributes can be updated in this window by selecting the ROI (from the list or in the viewer) and editing its coordinates and bin values. The ROI list shows all ROIs for the current experiment. If any of the ROIs are invalid, an **Experiment Conflict** icon will be displayed next to the invalid ROI(s). You must correct the errors before you will be allowed to use ROIs defined on this window to acquire data. When you close the window, any invalid ROIs will be outlined in red. The ROIs will be available but will only be saved if you save the experiment. After the experiment is saved, they will be reloaded whenever that experiment is loaded, provided no subsequent changes have been made and saved.

Warning! If you plan to create a Custom Sensor and you have created ROIs for the current experiment, save the experiment before opening the **Custom Sensor** flyout pane. ANY time you change the **Active Area Width** or **Active Area Height** and there are ROIs, LightField will either delete or modify existing ROIs. If you use the **Align Spectrometer** function or the **Create ROI from Selection** function, your ROIs will be deleted. Because of this, be sure to save your experiment so you can reload the ROI information after you have finished the alignment or used the **Create ROI from Selection** function.

Special Cases

Quad-RO: These cameras do not support multiple ROIs. If a Quad-RO is using four-port readout, the ROI must be centered horizontally and vertically on the sensor and have an even number of pixels in the X and Y dimensions. A binned ROI for four-port readout must have an even number superpixels in the X and Y dimensions. Binning, centering, and dimensional constraints do not apply if a Quad-RO 4096 is using single-port readout.

PI-MAX3:1024i and PI-MAX4:1024i: If a PI-MAX:1024i is using dual-port readout, the ROI must be centered horizontally on the sensor and have an even number of pixels in the X dimension. A binned ROI for dual-port readout must have an even number superpixels in the X dimension. Binning, centering, and dimensional constraints do not apply if a PI-MAX:1024i is using single-port readout.

Capturing a Reference Image

Before creating or editing ROIs, you may want to acquire a reference image to help you in positioning ROIs. Click on the **Capture Reference Image** button to acquire an image: the current experiment settings (with the exception of regions of interest) will be used to acquire the image and it will be displayed in the **Edit Regions of Interest** viewer. You can then create and easily position ROIs over the areas of interest.

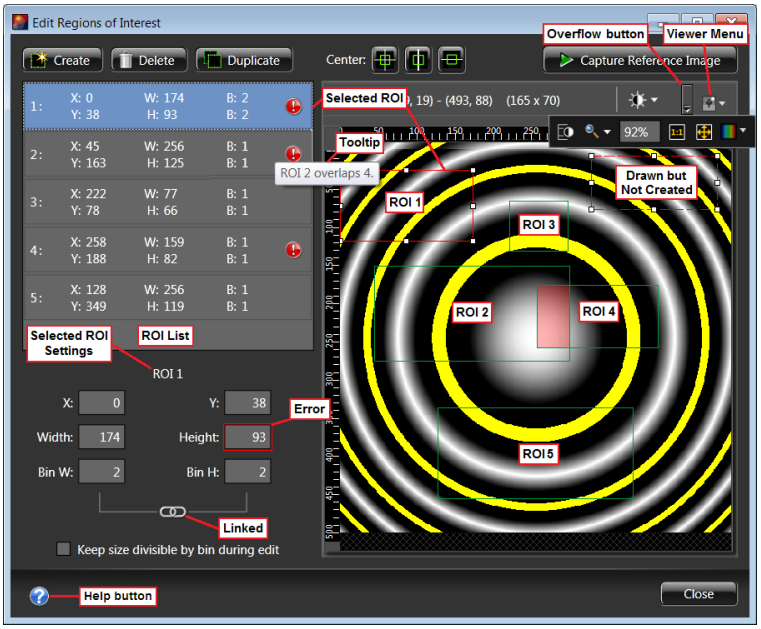


Figure 347. Edit Regions of Interest window with Callouts

Creating a New ROI

When you click on the **New Experiment** button, LightField will automatically create a full sensor ROI that will be available when you open the **Edit Regions of Interest** window. If ROIs already exist for an experiment, these ROIs will be listed and will be drawn in the viewer. Creating a new ROI can be done by clicking on the **Create** button to create and center a new ROI on the sensor, by drawing an ROI in the viewer and then clicking on the **Create** button, or by selecting an existing ROI (from the list or in the viewer) and clicking on the **Duplicate** button to create an exact duplicate. After you have created an ROI, you can resize, reposition, and set up binning by modifying the values in the ROI fields associated with that ROI.

Note: The coordinate starting point for an ROI is always the top left corner of the ROI as it appears in the current orientation. The X and Y coordinates for that starting point are zero-based: if the ROI starting point was the top left corner of the sensor, the coordinates would be 0,0.

To Create a New ROI:

Click on the **Create** button. The new ROI will be centered on the sensor.

To Draw and Create a New ROI:

1. Position the cursor in the viewer, depress the left mouse button, and drag the cursor to size the red dashed box representing the new ROI.
2. Release the mouse button when you have finished drawing the box.
3. You can resize the box horizontally and/or vertically by grabbing and dragging a handle (there are handles at each corner and at the midpoint of each horizontal and vertical side.
4. You can also reposition the box, by grabbing the box (the cursor becomes a hand) and dragging it to a different position.
5. You must click on the **Create** button to finalize the creation of the ROI.

To Duplicate an Existing ROI:

Duplicating an existing ROI allows you to quickly create identical ROIs. When you duplicate an ROI, a duplicate will be created at the same location as the original. This creates an **Experiment Conflict** that you can correct by either grabbing and moving the new ROI in the viewer or by changing its X and Y coordinates.

- Click on the ROI in the list and click on the **Duplicate** button or
- Click on the ROI in the viewer (the cursor will change to a hand) and click on the **Duplicate** button. Then move the duplicate to resolve the experiment conflict. Either drag the ROI in the viewer or after selecting the ROI in the list, edit its X and Y start positions.

Selecting an ROI

An existing ROI can be selected by clicking on it in the ROI list (to the left of the viewer). It can also be selected by clicking inside the ROI drawn in the viewer. The currently selected ROI will be highlighted in the list, will have its values written in the ROI fields below the list, and will have a brighter outline in the viewer.

Centering an ROI

Centering an ROI is particularly important if you are using a Quad-RO camera and four-port readout or a PI-MAX3:1024i or PI-MAX4:1024i using dual-port readout. Depending on how you want to center an ROI, you can use one of three centering buttons: **Center**, **Center Left-Right**, and **Center Top-Bottom**. These buttons allow you to create an ROI anywhere in the view and then precisely center it.

Center repositions the ROI around the vertical and horizontal center of the sensor.

Center Left-Right centers the ROI on the vertical axis of the sensor.

Center Top-Bottom centers the ROI on the horizontal axis of the sensor.

Modifying an ROI

An ROI can be resized, repositioned, and binned by selecting the ROI, keying new values into one or more of the ROI fields, and pressing the **Enter** key to finalize the changes. If there are no ROIs in the ROI list, you must first create an ROI before you are allowed to make entries. If a value results in an **Experiment Conflict**, LightField will suggest which field should be edited by outlining it in red. For example, if the ROI is 512 high and you enter a Bin H of 13, the Height entry field will be outlined. One solution would be to change the height to 520; another is to change the Bin H value to 8.

You can also resize and reposition an ROI by first clicking in the ROI in the viewer to select it and then

- dragging it (cursor is a hand) or
- grabbing and dragging a handle (cursor is a double-headed arrow) on the ROI outline.

ROI Values:

- **X:** Top left horizontal origin of the ROI
- **Y:** Top left vertical origin of the ROI
- **Width:** The number of pixels in the horizontal (i.e., the number of columns)
- **Height:** The number of pixels in the vertical (i.e., the number of rows)
- **Bin W:** The number of pixels in each horizontal grouping (i.e., the number of columns to binned horizontally)
- **Bin H:** The number of pixels in each vertical grouping (i.e., the number of rows to be binned vertically)

Setting up Binning

Binning set up in this window will either be performed in software or in hardware depending on the choice in the flyout pane opened by clicking on the **Advanced** button on the **Region of Interest** expander. X and Y bin values can be changed independently when they are unlinked) or, when linked, both values will change if you enter a new bin value in one of the fields. X and Y binning can be linked by clicking the linkage below the **Bin W** and **Bin H** entry fields. If you click in the **Keep size divisible by bin during edit** check box, LightField will automatically change the ROI's Width and/or Height values so the ROI stays valid when you change to a bin value that would not evenly divide into the selected height or width of the ROI.

Deleting an ROI

You can either:

- Click on the ROI in the list and click on the **Delete** button or
- Click on the ROI in the viewer (the cursor will change to a hand) and click on the **Delete** button.

ROI Errors

In the ROI list, ROI errors are indicated by the **Experiment Conflict** icon appearing to the right on an ROI and a red outline drawn around the offending ROI value. In the viewer, an ROI error is indicated by a red outline (for example if the ROI height is not evenly divisible by the Bin H value or if the ROI must be but is not centered) and by brown shading if ROIs overlap or two ROIs share rows but have different Bin H) values. The tool tip for the icon will summarize the problem(s).

- the X or Y value falls outside of the active sensor area
- the Height or Width value causes the ROI to extend outside the active sensor area
- one ROI overlaps another ROI.

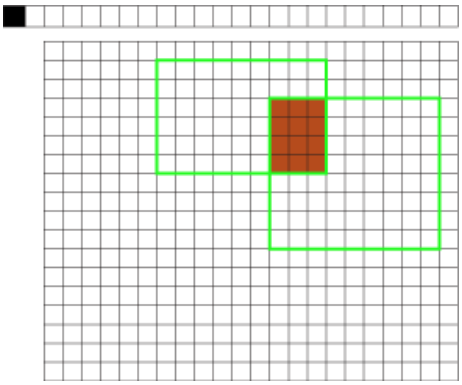


Figure 348. ROI Errors: Two ROIs Overlap

- two or more ROIs share rows but have different Bin H binning.

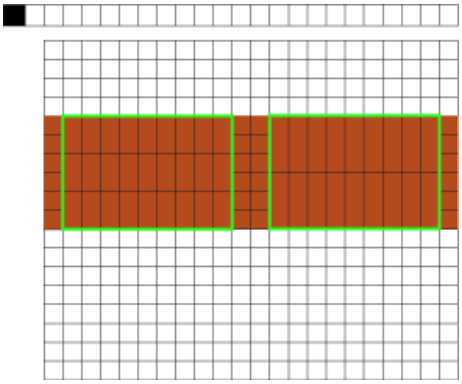


Figure 349. ROI Errors: ROIs share Rows but have Different H Binning Values

- two or more ROIs share rows, have the same Bin H values but the binned rows do not align between the two or more ROIs.
- a Bin value is greater than the associated ROI dimension (Height or Width)
- the Height or Width value is not a multiple of its associated Bin value.
- a combination of ROI Width and Bin W value causes an ROI not to be centered horizontally on the sensor (Quad-RO only).

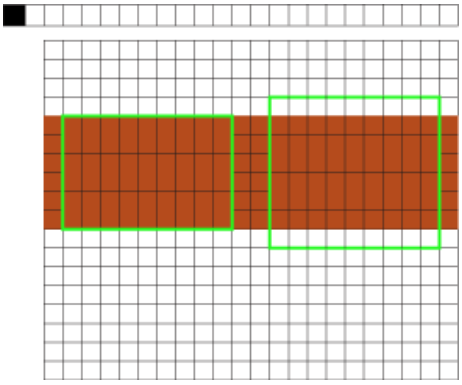


Figure 350. ROI Errors: ROIS share Rows, Have Same H Binning Values, but Binned Rows do not Align

  - An ROI for a Quad-RO:4320 must be centered horizontally and vertically on the active sensor area. Unless single-port readout is selected via the **Advanced** button on the **Region of Interest** expander, an ROI for a Quad-RO:4096 must be centered horizontally and vertically on the active sensor area. If single port is selected, the ROI can be positioned anywhere on the active sensor area.
  - An ROI for a PI-MAX3:1024i or PI-MAX4:1024i must be centered horizontally on the active sensor area. Unless single-port readout is selected via the **Advanced** button on the **Region of Interest** expander, an ROI for a PI-MAX:1024i must be centered horizontally on the active sensor area. If single port is selected, the ROI can be positioned anywhere on the active sensor area.
- a combination of ROI Height plus Bin H value causes an ROI not to be centered vertically on the sensor (Quad-RO, PI-MAX3:1024i, or PI-MAX4:1024i only).
  - An ROI for a Quad-RO:4320 must be centered horizontally and vertically on the active sensor area. Unless single-port readout is selected via the **Advanced** button on the **Region of Interest** expander, an ROI for a Quad-RO:4096 must be centered horizontally and vertically on the active sensor area. If single port is selected, the ROI can be positioned anywhere on the active sensor area.
  - An ROI for a PI-MAX3:1024i or PI-MAX4:1024i must be centered horizontally on the active sensor area. Unless single-port readout is selected via the **Advanced** button on the **Region of Interest** expander, an ROI for a PI-MAX3:1024i or PI-MAX4:1024i must be centered horizontally on the active sensor area. If single port is selected, the ROI can be positioned anywhere on the active sensor area.
- the Width value is not a multiple of 4 (NIRvana/PIoNIR).
- the X value is not 0 or a multiple of 4 (NIRvana/PIoNIR).

Selecting Multiple ROIs

When multiple ROIs are selected, the selected ROIs will be highlighted in blue on the list and shown with bright green boundaries in the ROI panel. Any attributes that the selected ROIs share will populate the ROI fields, all others will be blank.

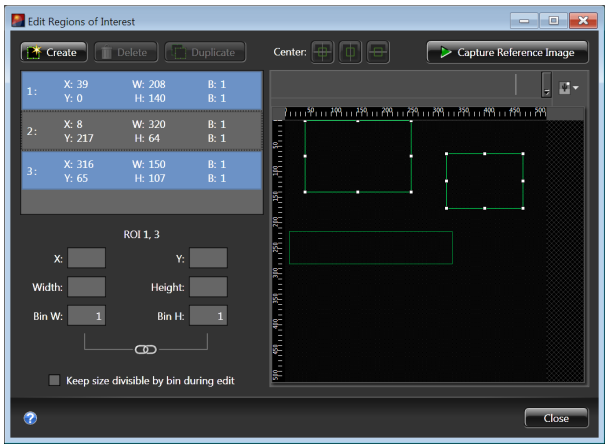


Figure 351. Example of Multiple ROI Selection

- If the **X** field is blank, you can enter a value and all of the ROIs will align vertically based on that value.
- If **Y** is blank, entering a value will align the ROIs horizontally.
- If **Width** is blank, entering a value will change the width of the selected ROIs to that width.
- If **Height** is blank, entering a value changes their height to that height.
- If either of the **Bin** values is blank, an entry will change the binning for the selected ROIs.

Note: Using this feature may result in experiment conflicts that you must correct before you can acquire data: a red boundary and the conflict icon indicate an **Experiment Conflict**. You make the corrections at this time or you can save the ROIs, turn off Custom Region(s) of Interest, acquire data, and edit the problem ROI(s) at a later time.

To Select and Edit Multiple ROIs

This procedure assumes that you are modifying existing ROIs.

1. Open the **Region of Interest** expander.
2. Click on the **Custom Region(s) of Interest** radio button.
3. Click on the **Edit ROIs...** button.
4. In the **Edit Regions of Interest** window, you have two ways to select multiple ROIs:
   - Depress the **Ctrl** key and click on the desired ROIs in the ROI listing. You can also select ROIs by using the Shift+mouse click combination.
   - Depress the **Ctrl** key and drag the cursor to select all or part of the ROIs you want.

Shutter Configuration Add-in

Starting with Version 4.4, LightField has a Shutter Configuration add-in for PyLoN and PyLoN-IR cameras. This add-in allows you to configure the camera's **Shutter** connector for one of 5 supported external shutters. An external shutter may be one that is mounted to a spectrograph.

When an actual PyLoN or PyLoN-IR camera is detected by LightField, its camera icon is in the **Experiment Devices** panel, and the **Shutter Configuration** add-in has been activated on the **Manage Add-ins dialog**, an **Add-ins** panel and a **Shutter Configuration** expander is added to the set of panels at the left side of the screen.

Caution: Save your existing experiment before changing the current shutter configuration. Clicking on the Update and Restore Experiment to Default button will change to the new shutter configuration and revert the Experiment Settings to their default values (i.e., as if you had selected New Experiment). If you saved your experiment beforehand, you can reload it after a shutter configuration change.

1. Click on the **Add-ins** tab and open the **Shutter Configuration** expander. The following shutters are currently supported: Vincent 25 mm, Vincent 35 mm, Vincent 45 mm, Prontor 25 mm, and Prontor 40 mm.

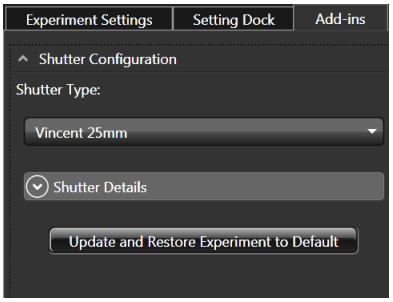


Figure 352. Shutter Configuration expander

Caution: If you do not know the shutter type, contact Customer Support before making any changes to the shutter configuration.

2. Open the **Shutter Type** expander and select the shutter to be controlled via the camera's Shutter connector.

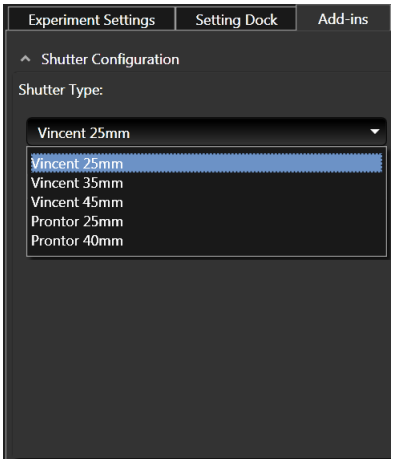


Figure 353. Shutter Type dropdown list

Note: Clicking on the **Shutter Details** expander will display shutter characteristics for the currently selected **Shutter Type**.

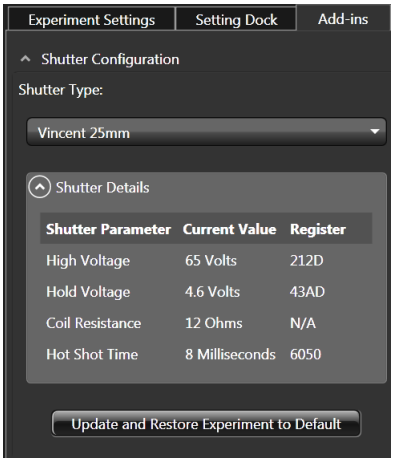


Figure 354. Shutter Details expander

3. At this point, you can either return to the **Experiment Settings** panel without changing the current configuration or you can click on the **Update and Restore Experiment to Default** button. Updating the configuration and restoring the experiment to its default settings will take a few seconds (the progress is reported in the **Status** bar).
4. If you have changed the shutter configuration, you can now load a previously saved experiment or set the values for a new experiment.

Triggering

Introduction

By using the 0 to +3.3 V logic level input trigger connector on the back of a Princeton Instruments camera, you can synchronize data acquisition with external events such as firing a laser. The name of the trigger input connector depends on the Princeton Instrument camera. For PI-MAX cameras, the trigger input is labeled **TRIGGER IN**, and it is labeled **EXT SYNC** for all other cameras.

Trigger Edge

External synchronization depends on a pulse that must be supplied to the EXT SYNC or TRIGGER IN connector on the back of the camera. A positive- or negative-going edge of that pulse must be identified in LightField as the trigger. This will ensure that the specified response to the trigger will be initiated by the correct polarity (selected on the **Trigger** expander after a **Trigger Response** is selected).

Shutter Requirements

Since a shutter requires a finite amount of time to fully open (shutter-dependent), the External Sync pulse provided by the experiment must precede the actual event of interest by at least that much time. If not, the shutter will not be open for the duration of the entire event, or the event may be missed completely.

Background Subtraction

Since the amount of time from initialization of the experiment to the first External Sync pulse is not fixed, an accurate background subtraction may not be possible for the first readout. In multiple trigger experiments, this is easily overcome by simply discarding the first frame.

Open Before Trigger

In the event that an External Sync pulse cannot be provided ~ 8 ms or ~ 20 ms (the length of time the 25 mm or 45 mm mechanical shutter takes to open) before the actual signal occurs, the Shutter mode **Open Before Trigger** will open the shutter when the experiment begins. Its main drawback is that the sensor is exposed to any ambient light while the shutter is open between frames. If this ambient light is constant and the triggers occur at regular intervals, this background can also be subtracted, providing that it does not saturate the sensor. As with the Normal Shutter mode, accurate background subtraction may not be possible for the first frame.

Dark Charge

In addition to signal from ambient light, dark charge accumulates during the "wait" time (t_w). Any variation in the external sync frequency also affects the amount of dark charge, even if light is not falling on the sensor during this time.

Possible Response to a Trigger

The **Trigger Response** choices are:

- **No Response:** The camera ignores any triggers.
- **Readout Per Trigger:** Data are read from the sensor after the appropriate camera shutter timing. A single trigger acquires a sequence of frames. Once the initial trigger is received, the camera ignores any further triggers until the entire exposure/readout sequence is completed. For DIF acquisition (PI-MAX with an interline CCD), the acquisition of each image for a dual image acquisition requires a trigger.
- **Shift Per Trigger:** Available only in Kinetics mode or DIF acquisition. For Kinetics mode, a trigger initiates either the shift of a new frame into the masked area or the readout of the entire array depending on the Kinetics setup. For DIF acquisition (PI-MAX with an interline CCD), a trigger initiates an acquisition and its subsequent shift behind the mask; a second trigger initiates the second acquisition and subsequent readout of the entire sensor.
- **Expose During Trigger Pulse:** Bulb Trigger mode. Available for ProEM/ProEM+, PyLoN, and PyLoN-IR cameras. The camera exposure is set by the input at the EXT SYNC connector. This allows an external timing generator to control the exposure time of the camera. In Full Frame, Frame transfer, or Kinetic modes, the transition from the inactive state to the active state of the External Sync at the EXT SYNC connector starts the exposure; and the transition from the active state to the inactive state ends the exposure. Kinetics mode-Single trigger is not a valid option for Bulb Trigger mode.
- **Start On Single Trigger:** (NIRvana/PIoNIR, ProEM, ProEM+, Pylon, and PyLoN-IR) After you start acquisition, the camera will wait until it receives the first trigger to start sending data to LightField. After that, it continues on performing the experiment without listening to (or waiting for) any further triggers.

When the Trigger Response is **Expose During Trigger Pulse**, **Readout Per Trigger**, **Shift Per Trigger**, or **Start On Single Trigger** and the camera is a NIRvana/PIoNIR, PIXIS, ProEM, ProEM+, PyLoN, PyLoN-IR or Quad-RO, the trigger edge or level is also selectable. If the camera is a PI-MAX3 or PI-MAX4, trigger characteristics (including polarity) must be entered when External is the trigger source.

Setting Up Triggering

Introduction

The following procedure assumes that you have already set up non-trigger related settings such as Exposure Time (not required for PI-MAX3 or PI-MAX4), Number of Frames, Exposures per Frame, On-CCD Accumulations (PI-MAX3 and PI-MAX4 only), Intensifier (PI-MAX3 and PI-MAX4 only), Time Stamping, Readout, Region of Interest, and other settings that will be required for the data acquisition.

Procedure:

1. On the **Trigger** expander, either **Trigger Response** or **Trigger Source** will be displayed depending on the camera included in your experiment setup.
   - **If Trigger Response is displayed:** select Expose During Trigger Pulse (Bulb Trigger Mode), Readout Per Trigger, Shift Per Trigger (Kinetics), or Start On Single Trigger, depending on your experiment. Chose the appropriate polarity (Negative or Positive) or edge (Rising or Falling). This determines which polarity or edge will be used to trigger the acquisition.
   - **If Trigger Source is displayed:** select Internal (for PI-MAX3 or PI-MAX4 generated triggers) or External (if triggers will be input at the PI-MAX's TRIGGER IN connector). If you select External, define the pulse that is to be recognized as a trigger by LightField. Enter the threshold, coupling, termination, and edge information.
2. If you plan to use the TTL signal at the LOGIC OUT connector to synchronize the camera with other equipment or as a way to monitor acquisition, select the Output Signal and make the cable connection between the camera and the other device.
3. On the **Shutter** expander (not present for PI-MAX3 or PI-MAX4), make sure the Shutter Mode is appropriate. If the event of interest is likely to occur while the shutter is opening, you may want to select **Open Before Trigger**.
4. Make the cable connection from the trigger source to the EXT SYNC connector (non-PI-MAX camera) or **TRIGGER IN** connector (if the PI-MAX will be triggered by an external source).
5. If you will be using background subtraction, select **Background Subtraction** on the **Online Corrections** expander. Acquire or load a data file that has the same settings that will be used

for the actual experiment (exposure time, number of frames, etc.) but does not show the event of interest.

6. If you are setting up an experiment for a PI-MAX3 or PI-MAX4, you will need to open the **SuperSYNCHRO Timing** expander and enter timing information for the gating. This includes the Gating Mode, Internal Trigger Frequency, Gate Delay/Width, AUX Output, and SyncMASTER2 Delay (if SyncMASTER is on).
7. Turn on the trigger source.
8. Start the experiment by clicking on the **Acquire** button and initiate triggering (if active) and the event of interest.

EXT SYNC Trigger Input

The selected **Shutter Timing Mode** determines how the camera will respond to an External Sync pulse input at the **EXT SYNC** connector on the rear of the camera.

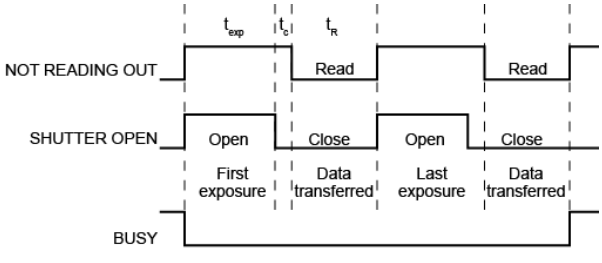
Characteristics associated with the **EXT SYNC** connector include:

- **Pulse Height:** 0 to +3.3V logic levels (TTL-compatible).
- **Pulse Width:** The time interval between trigger edges.
- **EXT SYNC Connector Impedance:** 50 Ω.
- **Trigger Edge:** The trigger polarity negative (falling edge) or positive (rising edge) must be indicated on the **Trigger** expander.

Synchronization with Other Equipment

Introduction

The TTL-compatible logic level output (0 to +3.3 V) from the **LOGIC OUT** connector on the camera's rear panel can be used to monitor camera status and control external devices. The timing of the level changes depends on the output type selected on the **Trigger** expander. The output signals available depend on the camera being used. All of the possible signal types are listed in the **OutPut Signals** topic that follows this introduction.



Note: t_c= Shutter close time, t_{exp}= Exposure time, t_R= Readout time.

Figure 355. Timing Diagram of Not Reading Out, Shutter Open, and Busy (2 exposures)

Output Signals

- **Acquiring:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the camera is acquiring or ready to receive the first trigger.
- **Always High:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is always high.
- **Always Low:** PIXIS. The signal is always low.
- **Busy:** PIXIS. The signal is high when the camera is busy.
- **Effectively Exposing:** ProEM, ProEM+. The signal is always high during the entire time the sensor is exposed.
- **Exposing:** NIRvana/PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the sensor is exposed for the entered Exposure Time.
- **Not Reading Out:** PIXIS, Quad-RO. The signal is low when the sensor is reading out.
- **Reading Out:** PI-MAX3, PI-MAX4, NIRvana/ PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the sensor is reading out.
- **Ready For Start:** ProEM, ProEM+. The signal is high when the camera is ready to receive the first trigger.
- **Shifting Under Mask:** PI-MAX3:1024i, PI-MAX4:1024i, ProEM, ProEM+, PyLoN. The signal is high when image is shifting under the sensor's mask.
- **Shutter Open:** Logic high when the shutter is open. The output precisely brackets the shutter-open time (exclusive of shutter compensation) and can be used to control an external shutter.
- **Waiting for Trigger:** PI-MAX3, PI-MAX4, NIRvana/PIoNIR, ProEM, ProEM+, PyLoN, PyLoN-IR. The signal is high when the camera is waiting for a trigger.

Index

C

D

E

S

T

U

V

W

X

Z

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Instruments
www.princetoninstruments.com
TOLL-FREE +1.877.474.2286 | PHONE +1 609.587.9797