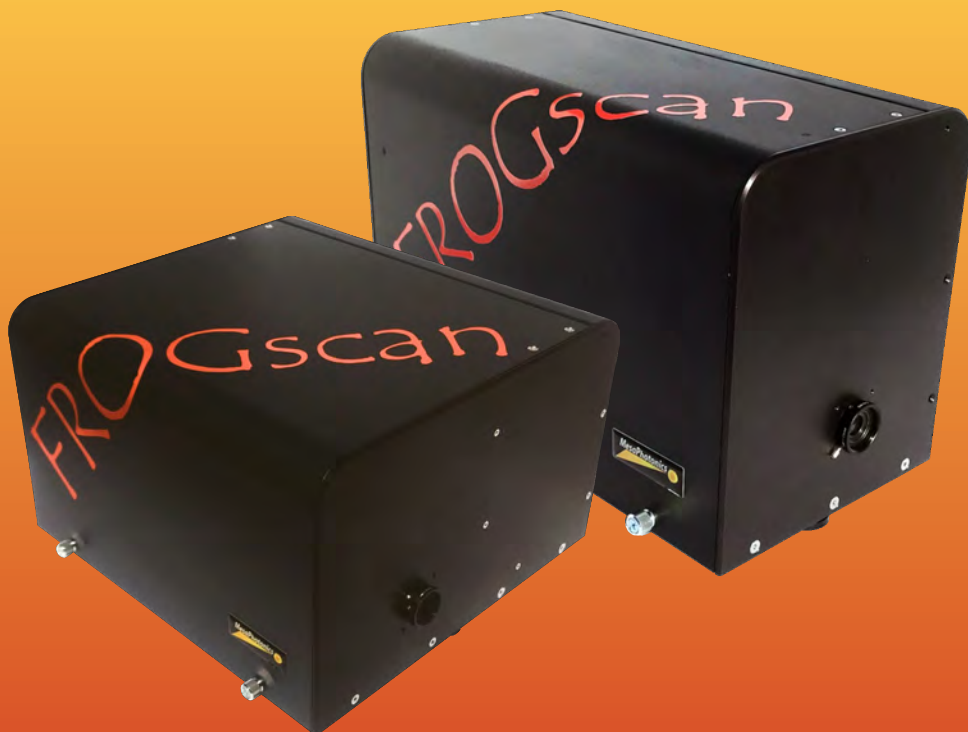
VideoFROGscan

Realtime Ultrafast Pulse Measurement



USER'S MANUAL

FROGscan products are protected by United States patents 8068230, 7130052, 6219142, 10274378, 9423307, and patents pending.

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Mesa Photonic's Support Policy

We hope this product is trouble free and easy to use. Unfortunately, with all the operating systems, computers, programs, and other systems beyond our control, it is impossible to guarantee the program will work perfectly, 100% of the time. If you have problems with the program within 30 days of installation, feel free to call us (and feel free to continue to call us until the problem is resolved). After that time, we would prefer you e-mail us. If for some reason we cannot resolve the issue over the phone or via e-mail, we will suggest you use a different computer. If that is not possible, we will be happy to fix the problem if you send us your computer. We expect you to pay for shipping to our facility, but we will cover return shipping (not necessarily air or insurance, however). If we are still unable to fix the problem, the only solution is to use a different computer. We will not cover hardware issues in this matter. If you cannot get the hardware to work on your computer, then your computer is incompatible with VideoFROGscan.

All users are entitled to free software upgrades within one year of delivery of the FROGscan. Software upgrades come out periodically. Typically within a version, software upgrades are more frequent. If you are not entitled to a free upgrade, the new upgrades are available at a reduced cost. We recommend keeping your software up to date for the best support of your product.

What to e-mail us if you are unable to resolve the problem: E-mail Mesa Photonics the following files along with a description of the problem: FROGscan.ini, MPFROGScanLogFile.txt. All of the files should be located in the Mesa Photonics documents directory and sub-directories. Please send the e-mail to support@mesaphotonics.com.

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Chapter 1. Overview

1.1 General Information

FROGscan is a high-performance ultrashort laser pulse measurement system that runs under VideoFROGscan (VFS) laser pulse measurement software. It uses a unique combination of a high performance servo delay line and a high performance, compact spectrometer. This combination provides real-time performance and high dynamic range. FROGscan has the following features:

- High speed, high accuracy servo delay line
- Easy to align optical platform
- USB interface
- Compact spectrometer that is field replaceable
- Small footprint
- High performance VideoFROGscan software that fully controls the hardware and provides real-time ultrafast laser pulse measurement.

Note: PC operating systems, software and hardware are constantly updating and changing. Every effort is made to enable VideoFROGscan software to run well on a variety of computers and operating systems, but even previously installed data acquisition devices may sometimes conflict with the frame grabbers used in this product. Unfortunately, Mesa Photonics, LLC cannot guarantee that any particular brand or model of Personal Computer will be compatible with any or all of the features or hardware contained in the VideoFROGscan application, either now or in the future.

Windows, **Windows 7, Windows 8,** and **Windows 10** are registered trademarks of Microsoft Corporation.
Core Duo, **i3**, **i5** and **i7** are registered trademarks of Intel Corporation.
LabView is a registered trademark of National Instruments Corporation.
MATLAB is a registered trademark of MathWorks, Inc.

1.2 Safety Considerations

Optical radiation hazards

FROGscan does not present the operator with many safety hazards; however, this instrument is intended for use with LASER systems. While the beam is well-contained when FROGscan is properly aligned, use of this instrument may require the operator to work in the optical path of the LASER itself where exposure to hazards may be sufficient to warrant the use of protective equipment. Exposure hazards include reflected radiation, for example, when the crystal is tuned for different wavelengths, as well as radiation from the direct beam that may cause damage to the eyes and skin. When working in an open beam path, it is advisable to operate the laser at eye-safe power levels and to wear protective eye shields and clothing.

Electrical hazards

FROGscan utilizes only low voltages, derived from the USB bus in the host PC and the servo power supply (+/- 15V); therefore, it poses little risk of electrical shock. FROGscan should always be operated with its covers in place and in accordance with the manufacturer’s recommendations. The computer connected to FROGscan should always be properly grounded. Additionally, ensure the power supply is plugged into a grounded AC outlet with the supplied AC power cord. Failure to properly ground the power supply may result in poor performance and is unsafe.

1.3 Specifications

Environmental

Operating temperature: +10° C to +40° C

Storage temperature: -30° C to +70° C

Humidity: 95% non-condensing

Operational

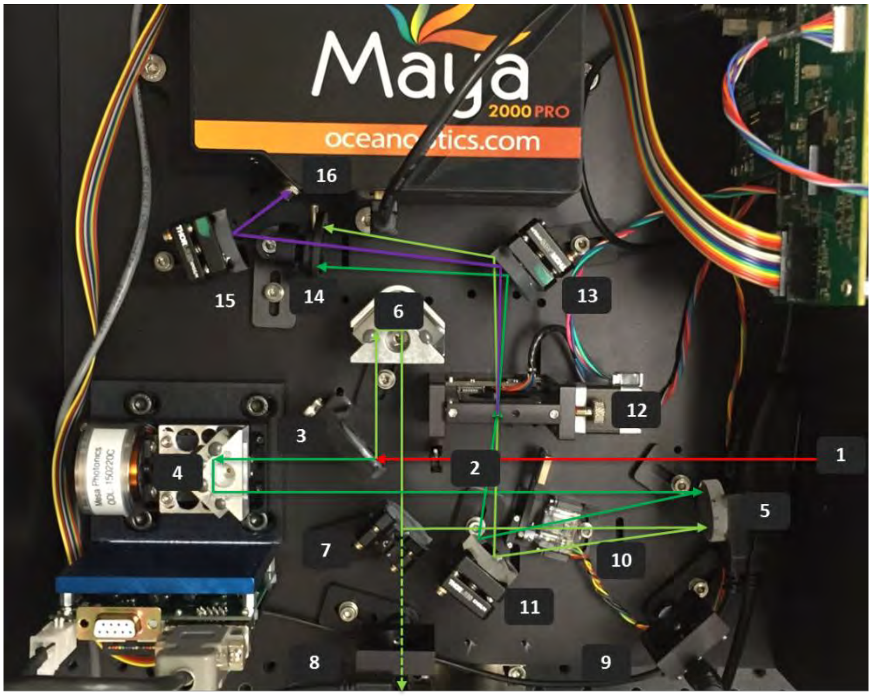
Computers vary widely in their characteristics and performance. The exact pulse retrieval rate depends on many factors including the speed of the processor, the speed of the bus, the speed of the memory, and the graphics card. Typically, FROGscan runs from about 1 to 4 Hz on modern Core Duo computers running a Windows 7 or later operating system.

Instrument Specifications

Parameter	**Specification**
Input Pulse Wavelength Range	450 nm - >2000 nm
Pulse Length Range	< 15 fs - 12 ps
Temporal Range	30 ps
Temporal Resolution	2 fs or better
Delay Increment	1 fs
Spectral Resolution	0.20 nm - 1 nm
Spectral Range	100 nm - 600 nm
Pulse Complexity	TBWP > 50
Intensity Accuracy	2%
Phase Accuracy	0.01 radians
Real-time Sensitivity (IpeakIave)	4 W^2
Averaged Sensitivity (IpeakIave)	< 0.1 W^2
Input Beam Size	2 - 8mm collimated
Nominal Polarization	Horizontal (vertical by rotating crystal)
Acquisition Speed	> 1 Hz 64 x 64 grid
Spectra required for measurement	Number in grid

FROGscan instruments are calibrated by the factory. Wavelength calibration is stored in the spectrometer, and the temporal calibration is determined by the servo delay line. Typically, the delay line is about 1 fs/step plus or minus a few percent. If you suspect that the temporal calibration is incorrect, please contact the factory.

1.4 FROGscan System Components and Beam Path



1= Entrance Iris
2= Center Iris
3= Beam Splitter
4= Servo Mirror
5= Focusing Mirror
6= Fixed Delay Mirror
7= Overlap Mirror
8= Fixed Delay Beam Camera
9= Focusing Mirror Camera
10= Diverter Mirror
11= 1st Turning Mirror
12= SHG Crystal
13= 2nd Turning Mirror
14= Lens + Iris
15= 3rd Turning Mirror
16= Spectrometer

Figure 1. Keyed image of the internal FROGscan Ultra component, including optional alignment cameras. FROGscan Standard is not equipped with the Lens/Iris and 3rd Turning Mirror.

The LASER beam (red) enters through the Entrance Iris and is split into 2 parts by the Beam Splitter. The Servo Beam (dark green) travels to the time delayed Servo Mirror and from there to the Focusing Mirror.

The Fixed Beam (light green) is reflected by the Fixed Delay Mirror. In an instrument with Alignment Cameras, a small part of the Fixed Beam travels through the Overlap Mirror onto the Fixed Delay Beam Camera.

The Fixed Beam and the Servo Beam meet on the 1st Turning Mirror from where they are directed through the SHG crystal to generate the Signal Beam (purple).

In FROGscan Ultra, the 2nd Turning Mirror directs the Signal Beam through the Lens/Iris, where the Servo Beam, the Fixed Beam and their respective harmonics are shuttered out by the iris. The Lens focuses the Signal Beam onto the 3rd Turning Mirror from where it enters into the Spectrometer. In FROGscan Standard, the Servo Beam and the Fixed Beam travel to the 2nd Turning Mirror from where they are directed to either side of the Spectrometer Aperture. Only the Signal Beam enters into the Spectrometer.

The Servo Beam (A) and the Fixed Beam (B) each generate a second harmonic (A*A and B*B) through interaction with the nonlinear SHG crystal. The Signal Beam (A*B) is produced only when the Servo Beam and the Fixed Beam overlap temporally and spatially in the crystal (see Figure 2 below).

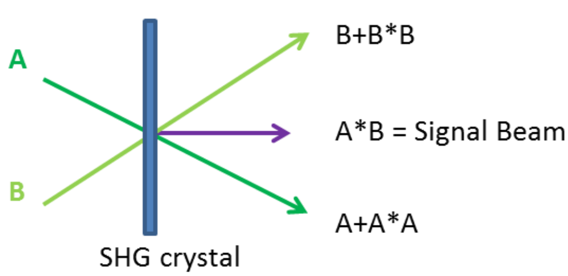


Figure 2. Second Harmonics generated through interaction with a nonlinear crystal. The fundamental beams, A and B, pass through the crystal and generate second harmonics (SHG) A*A and B*B. The signal, A*B, is formed by mixing the two fundamental beams. Depending on the wavelength of the LASER and the type of crystal and spectrometer used, both halves of the split LASER beam, each of their harmonics, and the Signal Beam can be seen on a fluorescing card.

Chapter 2. Setup

2.1 Inspecting the FROGscan Shipment Contents

Inspect the contents of the FROGscan box, which contains the following:

1. FROGscan Device.
2. Power Supply and Mini XLR Power Supply plug. The Mesa Photonics power supply requires a minimum 87 Watt USB-C PD (Power Delivery) AC adapter, such as the included Apple MacBook Pro Power Adapter.
3. 2 USB Cables (for the Spectrometer and Servo Motor).
4. Tools: 5/64 Hex-L-Key, 4 mm Hex-L-Key (FROGscan Ultra), 3 mm Hex-L-Key (FROGscan standard).
5. Computer (optional) with preloaded VideoFROGscan Software.

   OR
6. USB Flash drive with preloaded VideoFROGscan Software.
7. FROGscan Manual.
8. FROGscan Quick Setup Guide.
9. Calibration sheets and Warranty Information appended in the FROGscan Manual.

2.2 Setting up FROGscan

The servo motor and crystal have been secured for shipping and must be released before use.

PLEASE READ THESE INSTRUCTIONS CAREFULLY TO AVOID DAMAGE TO THE INSTRUMENT

Always wear powder-free gloves when manipulating components within FROGscan.

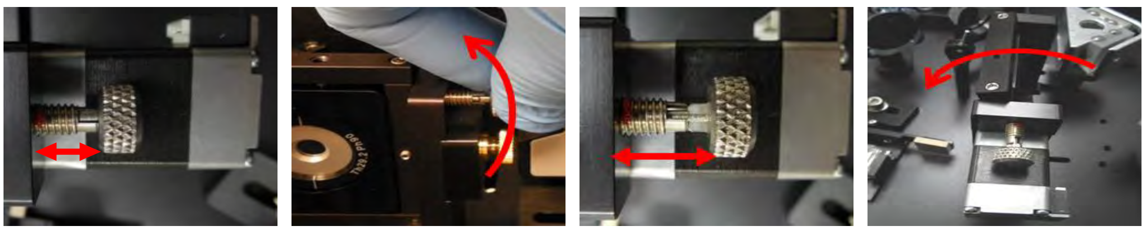
1. Remove the anti-static covering from FROGscan and place the unit in the approximate desired location on the optical table.
2. Open the FROGscan cover by twisting the two captive thumb screws on the base of the hinged cover. Carefully lift the cover up until it remains in the upright position.
3. Remove the foam cushion from the beam block.

<u>To free the servo:</u>

4. CAREFULLY release the Servo Motor (see **Figure 1** for the location of the Servo) by removing the tape and the white **REMOVE** label along with the yellow tipped servo clip. Carefully place one fingertip on top of the servo motor and verify that the Servo Stage moves freely.

To free the crystal:

1. Follow the steps shown in the Figure 3 below.
    (a) Release the crystal by pulling out the knurled head of the locking screw.
    (b) Rotate the locking screw 90˚.
    (c) The Crystal Tilt is now in the unlocked position.
    (d) Carefully place one fingertip on top of the crystal frame and verify that it is free to rotate a few degrees in either direction. Do not touch the optical surface of the crystal.
2. Remove the warning label from the power input connector on the exterior of FROGscan.
3. Lower the FROGscan cover.
4. Place the Power Supply in a location that is out of the way.
5. Connect the Mini-XLR power supply plug to the Mini-XLR jack on the back of FROGscan.



(a) (b) (c) (d)

Figure 3. The Crystal Tilt Assembly

2.3 Installing VideoFROGscan Software

If your order with Mesa Photonics did not include an optional computer with pre-loaded VideoFROGscan Software, follow the steps below to install VideoFROGscan on a Windows Computer.

System Requirements

Windows 7 or later

i3 or better (Celeron processors are not recommended)

180 MB hard drive

4GB RAM

IN INSTRUMENTS WITH ALIGNMENT CAMERAS, DO NOT REMOVE THE DONGLE FROM THE BACK OF FROGSCAN UNTIL SOFTWARE UPLOAD IS COMPLETE.

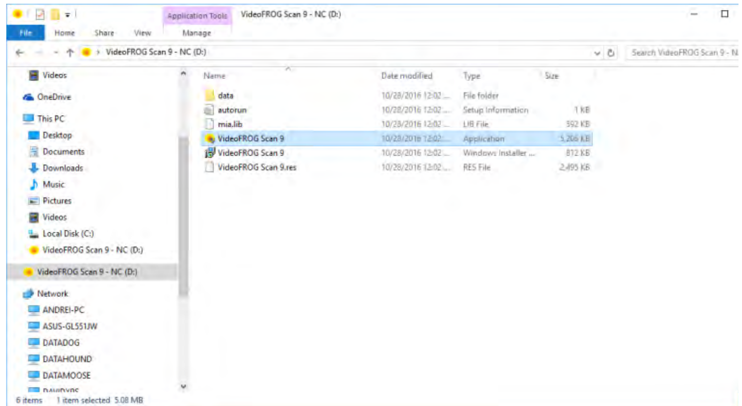
DO NOT CONNECT EITHER USB CABLE FROM FROGSCAN TO THE COMPUTER UNTIL VIDEOFROGSCAN SOFTWARE HAS BEEN INSTALLED. OTHERWISE, INCORRECT DRIVERS WILL LOAD, WHICH MAY MAKE FROGSCAN UNUNSABLE WITH THAT COMPUTER.

Follow these steps:

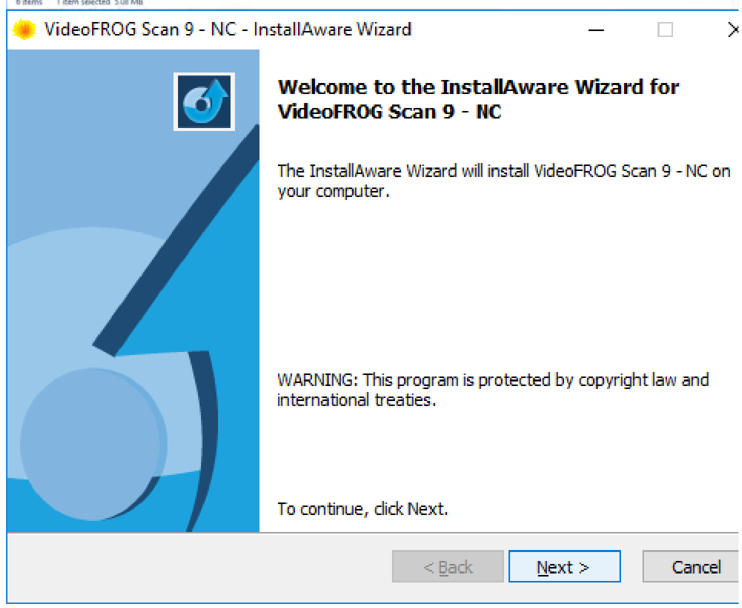
1. Insert the USB Flash drive into a USB port on your computer.

2. Open the VideoFROGscan 9 folder and right click on the VideoFROGscan 9 application. Select **Run as Administrator**.

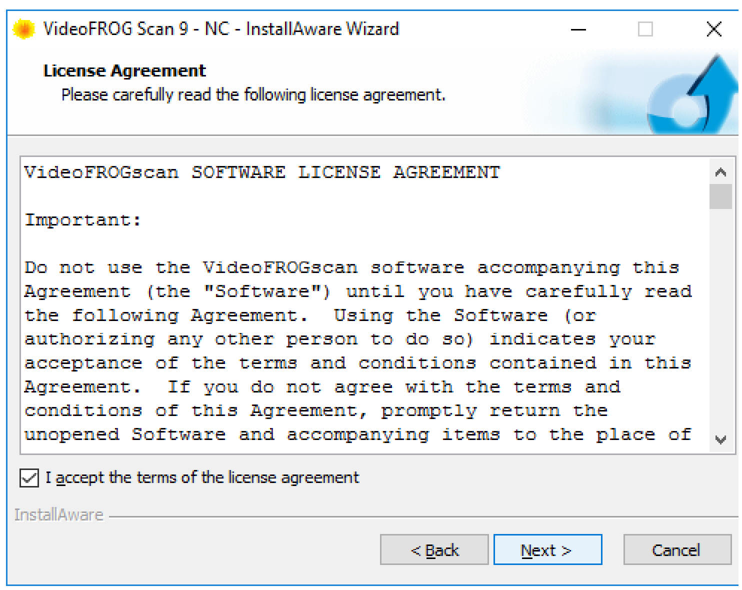
3. In the User Account Control Window, click on **Yes** to allow the app to make changes to the computer.



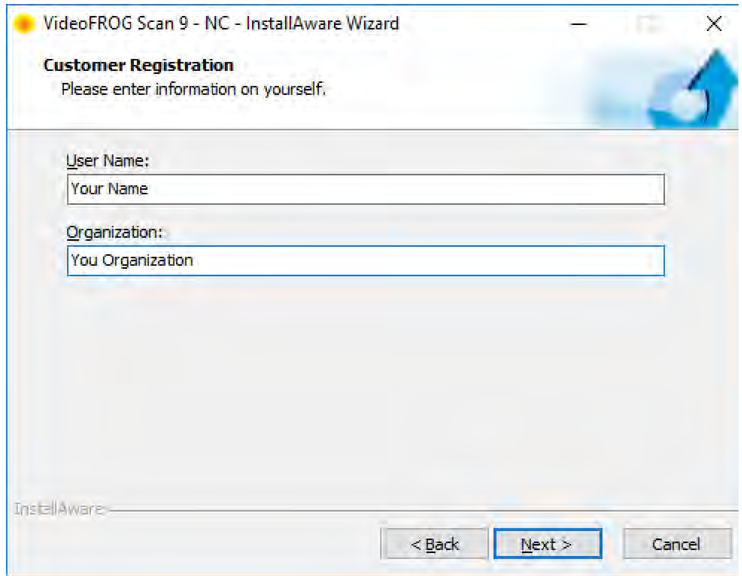
4. In the InstallAware Wizard Window for VideoFROGscan, click on **Next** to continue.



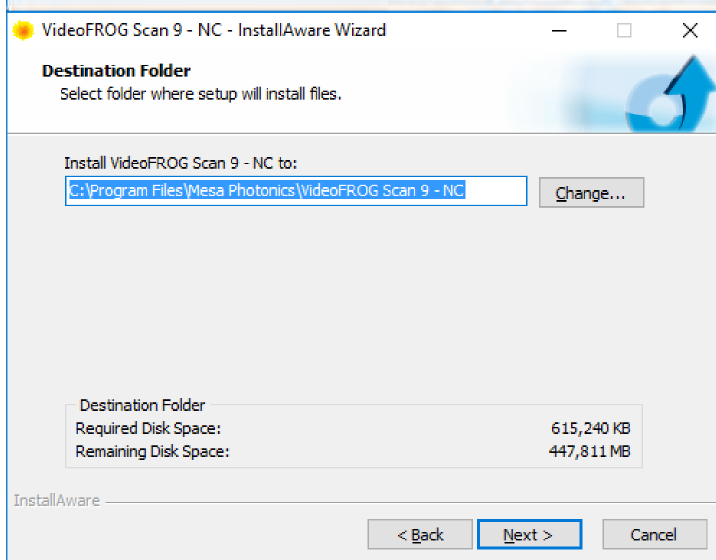
5. Read and Accept the Software License Agreement by clicking on the box next to **I accept the terms of the license agreement.** Click on **Next.**



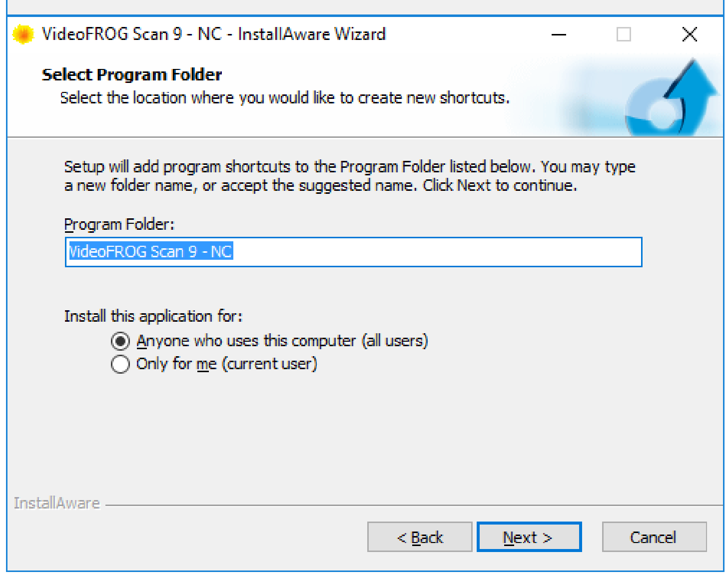
6. In the Customer Registration window input the User Name and Organization, then click **Next**.



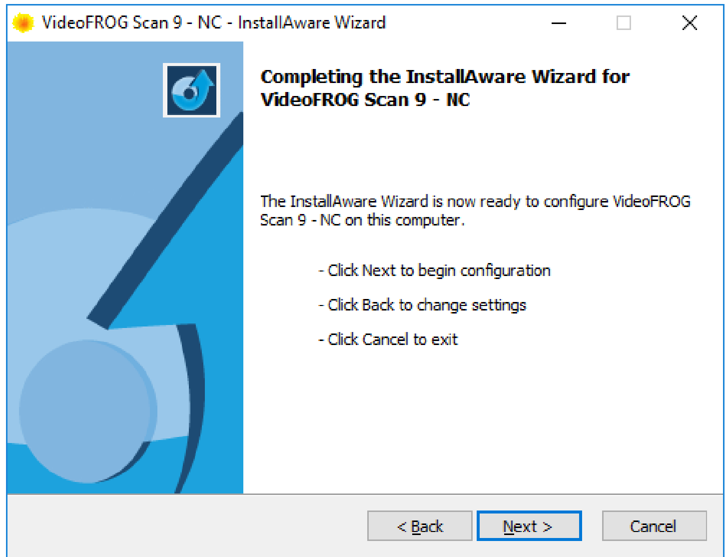
7. The default Destination Directory is C:\Program Files\Mesa Photonics\VideoFROG Scan 9 - NC. It is highly recommended not to change the Destination Directory. Click **Next** to accept the directory.



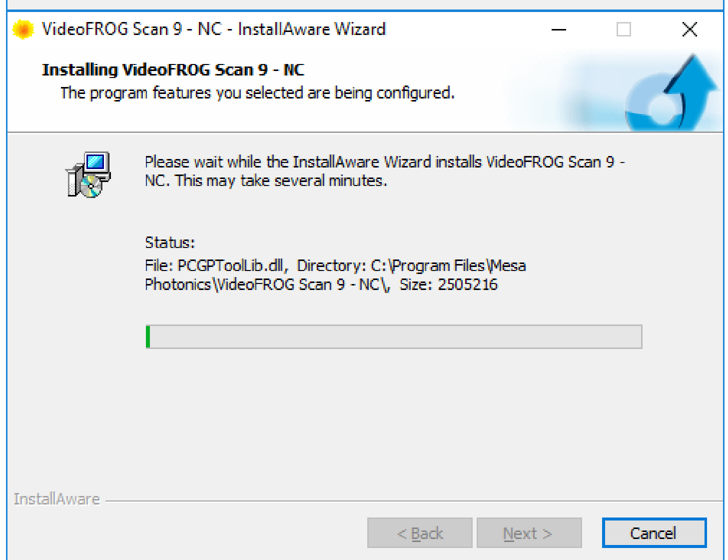
8. The default Program Folder for creating a new shortcut folder is VideoFROG Scan 9 – NC. It is highly recommended <u>not</u> to change the Program Folder. Click **Next** to accept the Program Folder.



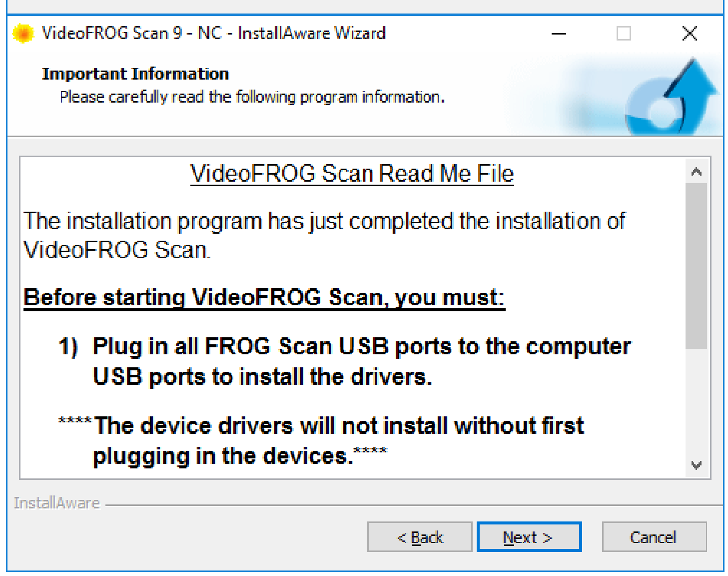
9. Click **Next** in the **Completing the InstallAware Wizard** Window to start the installation and configuration.



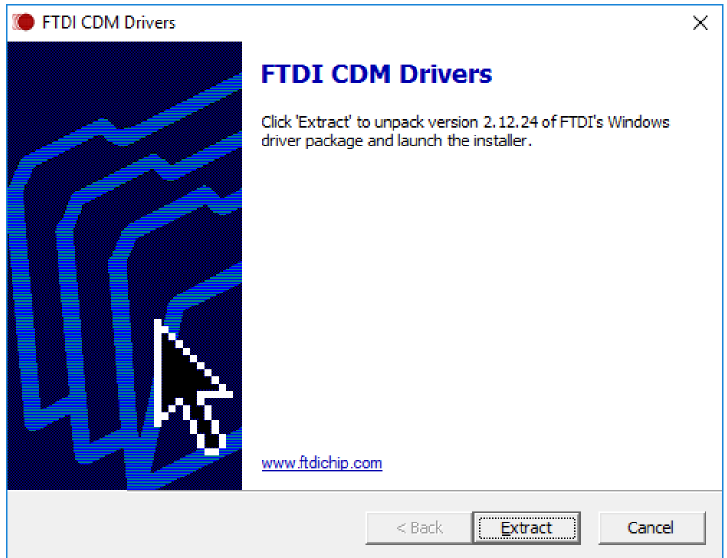
The installation will take several minutes.



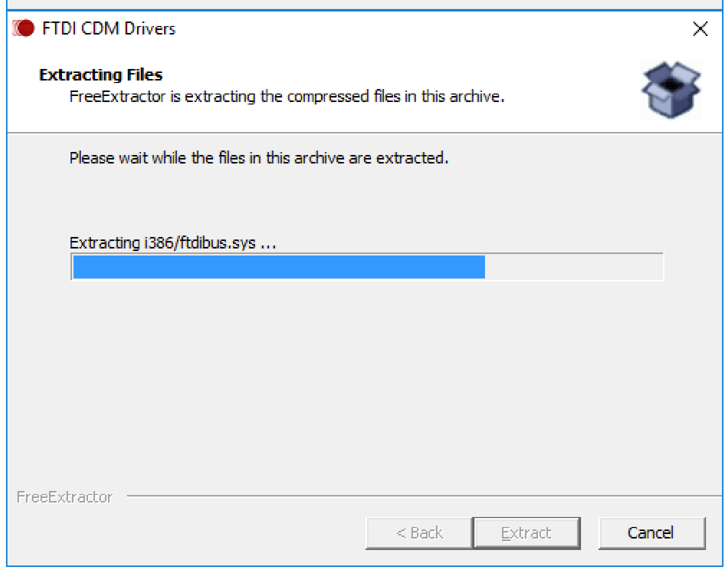
10. Read the information in the **Important Information** Window pertaining to the USB connections from the computer to the FROGscan. Then click **Next** to continue with the installation. Note the **Information Window** may not close.



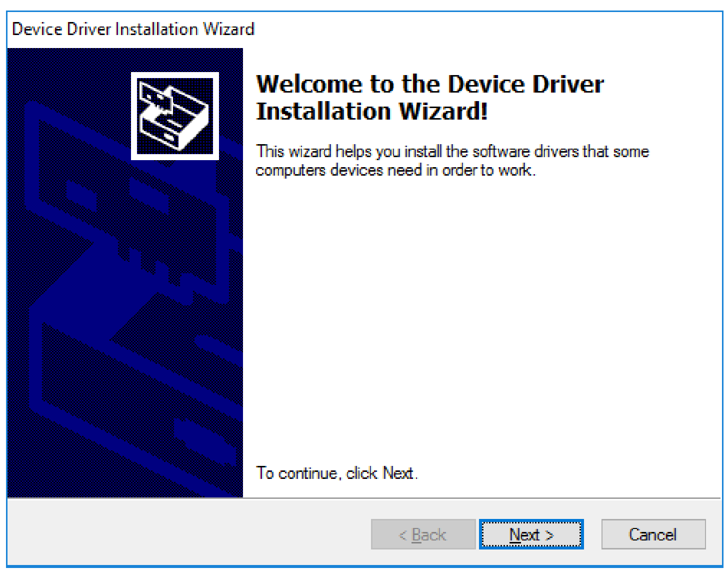
11. The installation program will install the Drivers for both the FTDI and the Ocean Optics Spectrometer. Click on **Extract** to start the process for the FTDI drivers.



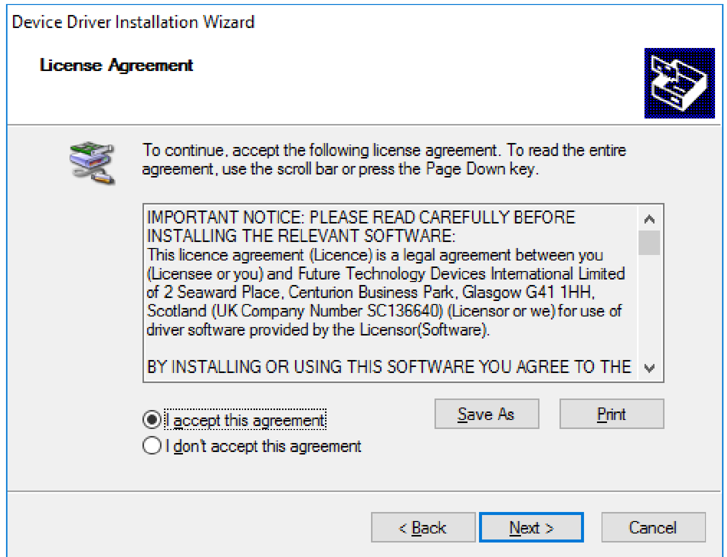
12. Wait until the drivers are extracted.



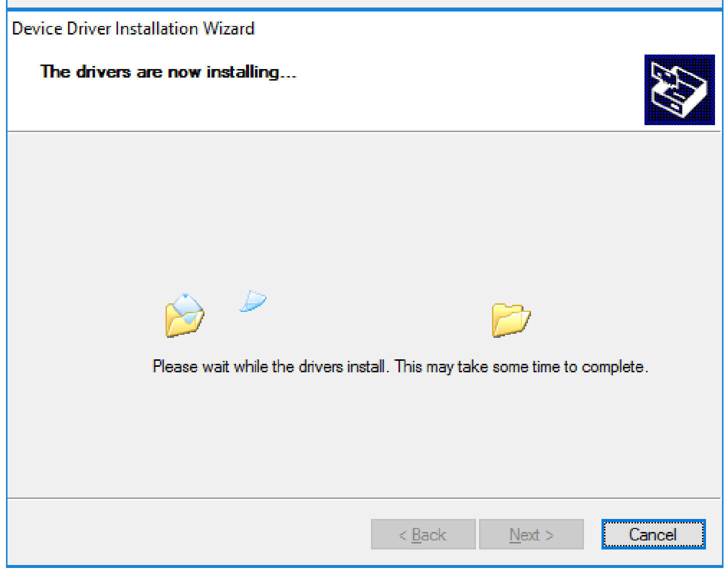
13. Click on **Next** in the **Device Driver Installation Wizard** to start the FTDI driver Installation.



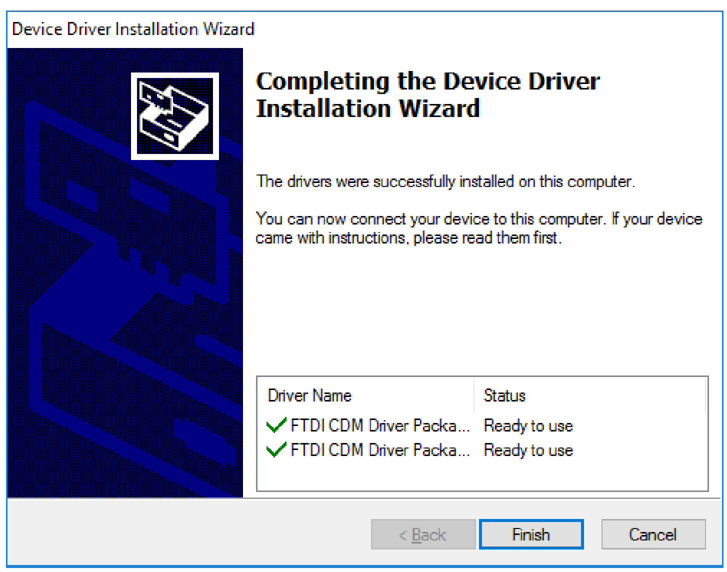
14. Click on **I accept this agreement** to accept the License Agreement in the Device Driver Installation Wizard.



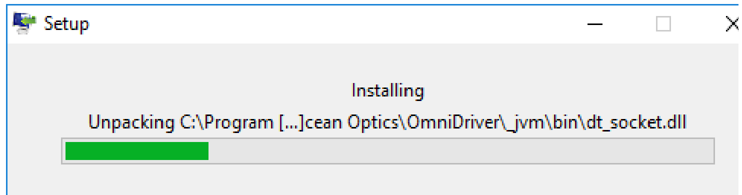
15. Wait while the FTDI Drivers install.



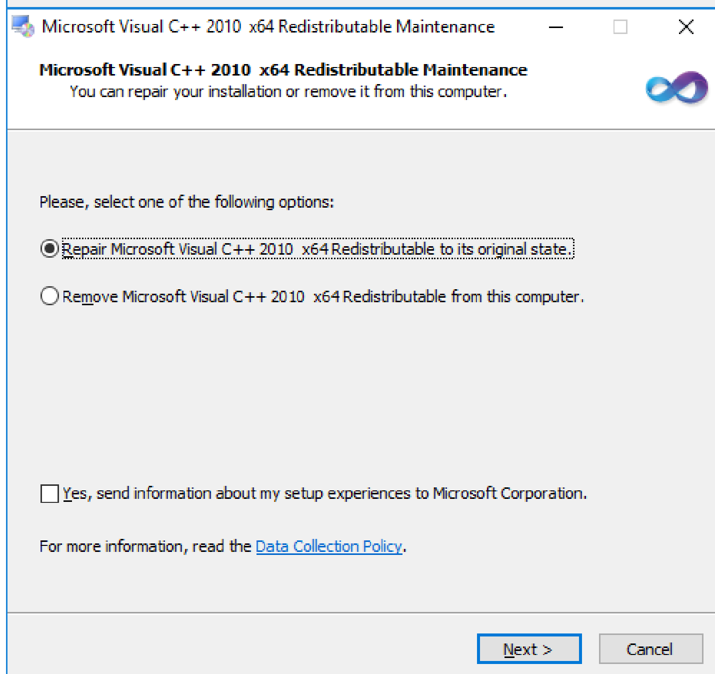
16. Installation is complete when the Completing Device Driver Installation Wizard Window appears. Click on **Finish** to close the window.



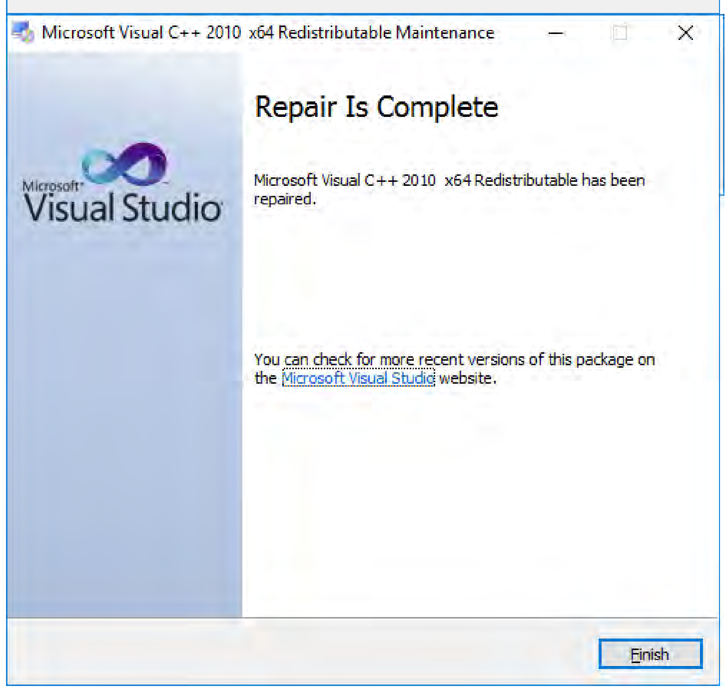
17. The Ocean Optics Drivers will now install. A **Setup** window with a progress bar will open to indicate the start and progress of the Omni Driver.



18. Part of the Ocean Optics driver installation includes Microsoft Visual C++. In some cases, the software requires the Visual C++ Redistributable Maintenance to be repaired.
Click on **Next** in the Microsoft Visual C++ 2010 x64 Redistributable Maintenance window.



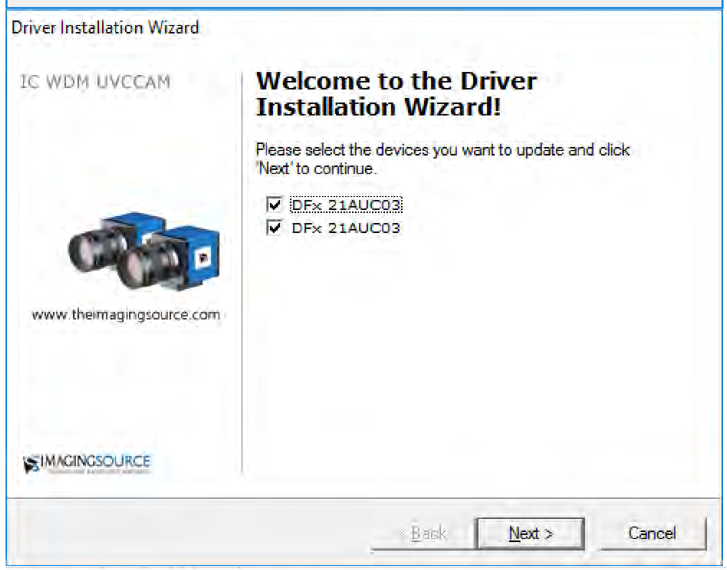
19. Click on Finish when the repair to the Microsoft Visual C++ is complete.



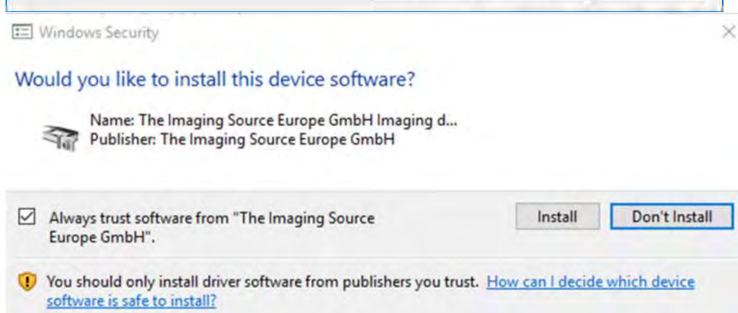
If your FROGscan instrument includes the optional Camera Alignment system, the software will load the Camera Drivers. Otherwise, continue with Step 25.

20. The VideoFROGscan 9 – WC InstallAware Wizard will open. Follow the instructions in the open Window by plugging both USB Cables from the FROGscan device to the computer and allowing the drivers to load. Click **OK**.

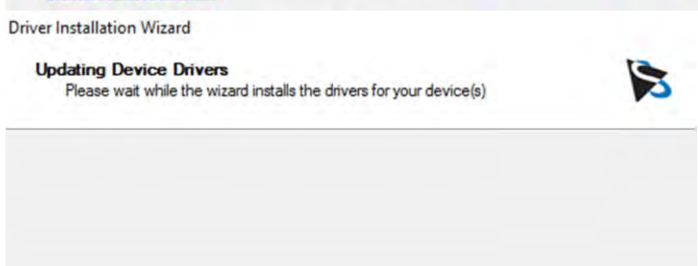
21. In the Driver Installation Wizard window, ensure both boxes are checked and then click **Next**.



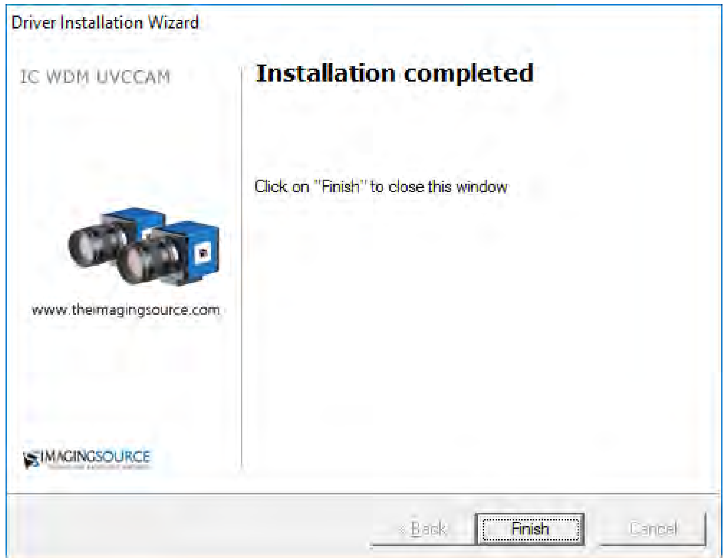
22. In the Windows Security window, ensure the box next to Always trust software from The Imaging Source Europe GmbH is checked. Then click on **Install** to install and update the Camera Device Drivers.



Wait while the drivers are installed.

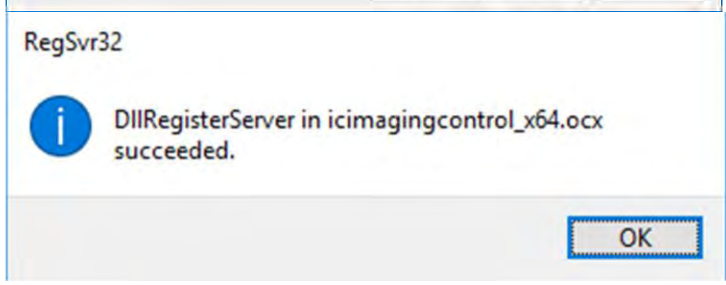


23. When the Installation is complete, click on **Finish** in the Driver Installation Window.



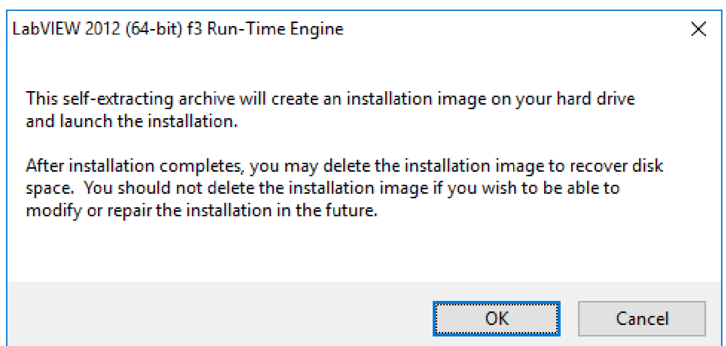
24. Ensure the RegSvr32 window opens and then click on **OK**.

    The software will now continue with the installation of LabView Run Time Engine.

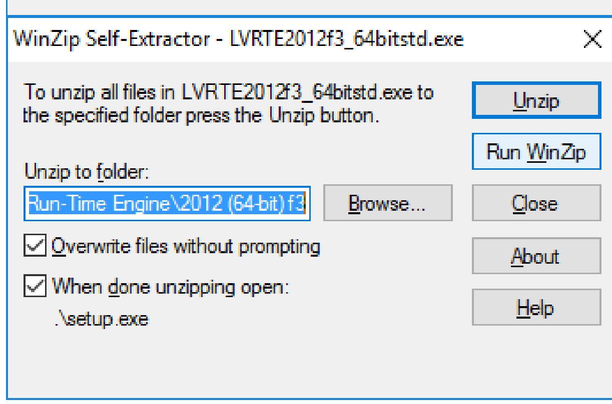


Continue with the following installation steps for FROGscan Instrument with or without cameras.

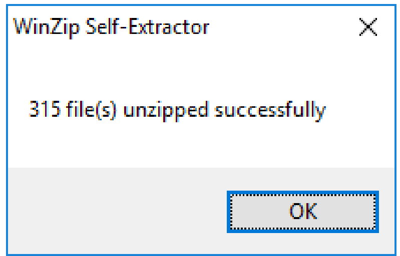
25. Steps 20-28 pertain to the LabVIEW 2012 Run-Time Engine. Click **OK** to start the process.



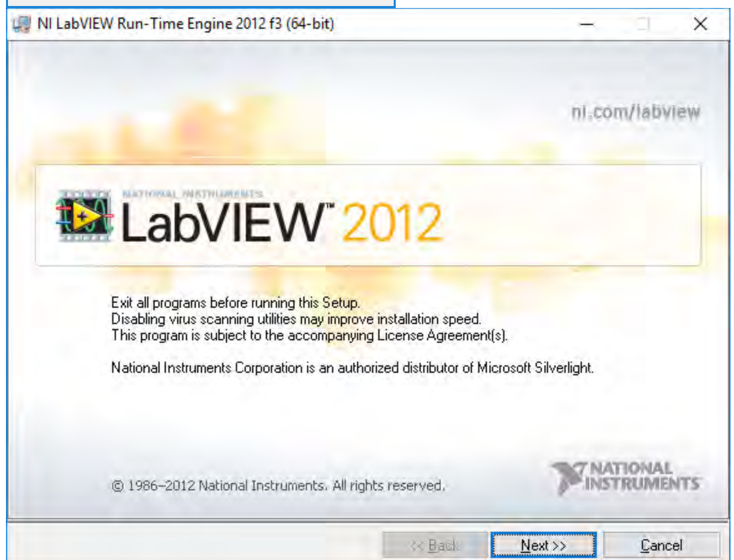
26. In the WinZip Self-Extractor Window click on Unzip to extract the LabView RunTime Engine files. Do <u>not change</u> the folder location.



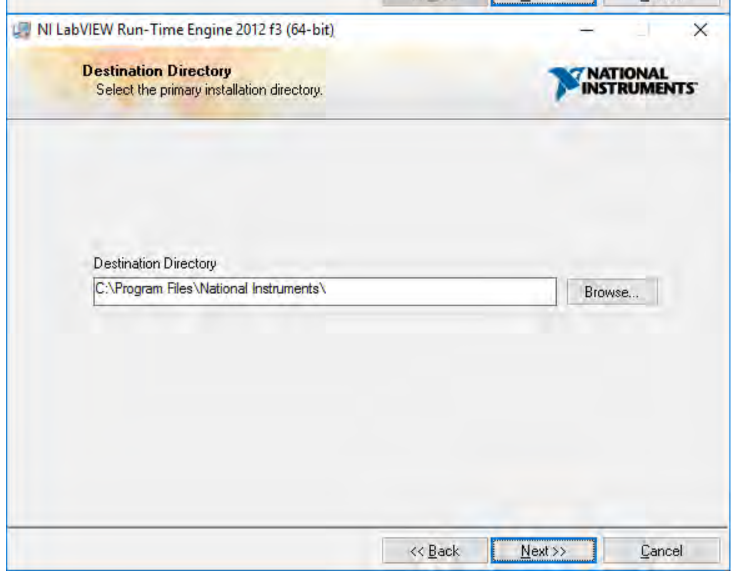
27. Click on **OK** to acknowledge that the extractor unzipped 315 files. The installation will now begin.



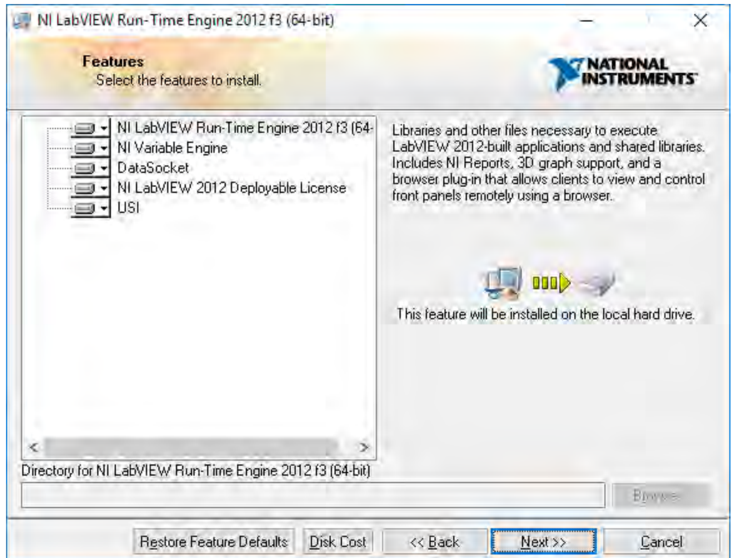
28. Click **Next** in the NI LabVIEW Run Time Engine Installation window.



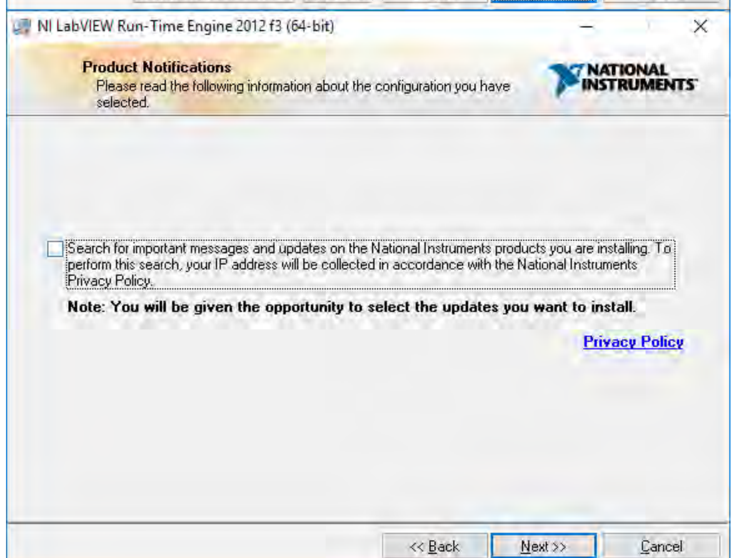
29. The default Destination Directory is C:\Program Files\National Instruments.
    It is highly recommended not to change the Destination Directory.
    To accept the directory click **Next**.



30. In the Features Window, click **Next** to accept all the default features.

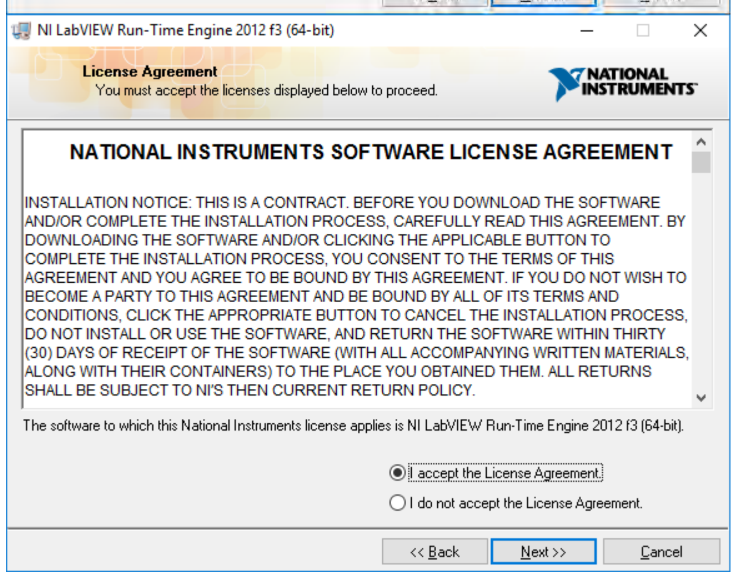


31. In the Products Notification Window, uncheck **Search for important messages…** then click **Next**.

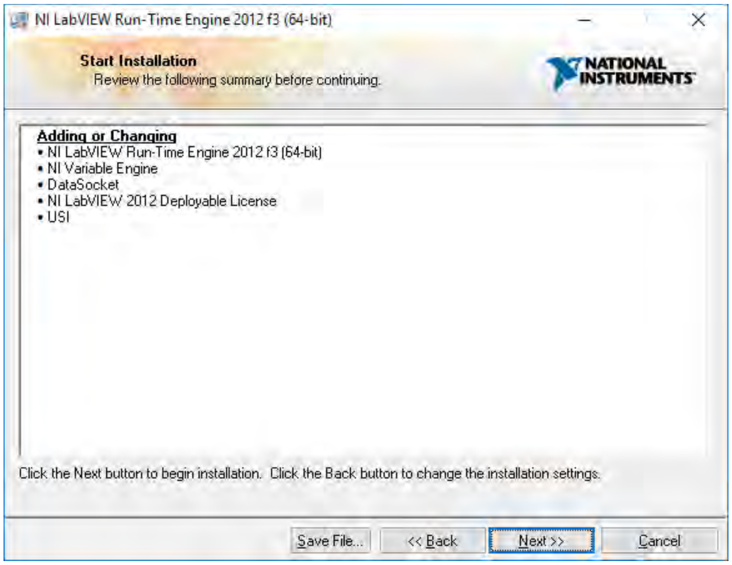


32. Accept the National Instruments License Agreement by selecting **I accept the License Agreement**

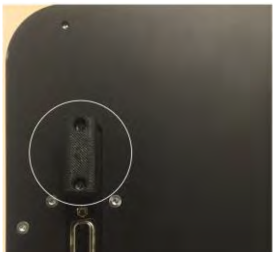
Then click **Next**.



33. Click **Next** in the Start Installation Window. The installation may take a few minutes to complete.



34. Click on **Finish** when the Installation Complete Window is displayed.
35. Close all open windows, then reboot the computer.
36. If the FROGscan came with the camera align option, remove the **dongle** in the DIO port from the FROGscan External Interface before starting VideoFROGscan.



37. If the spectrometer drivers DO NOT install, complete the following steps:
    a. Go to Device Manager and find the Ocean Optics spectrometer (it should be under the category Other Devices).
    b. Right click on the Ocean Optics spectrometer and select **Update Driver Software**. You can choose to find the driver automatically or **Browse My Computer**.
    c. Select **Browse** and then browse to the following directory: OmniDriver: C:\Program Files\Ocean Optics\OmniDriver\winusb_driver. Please be sure to select the winusb_driver directory, and not either of the subfolders.
    d. After you select the appropriate directory, click **OK** and then **Next** and you may get a message that Windows cannot verify the publisher.
    e. Click on **Install Anyway** and the device driver installation will begin.
    f. It should display **Your hardware was installed successfully** when finished.
38. Connect a USB cable from the computer to the Servo USB connector on the FROGscan Exterior Interface and wait until the connection has been established.

VideoFROGscan is now ready to use.

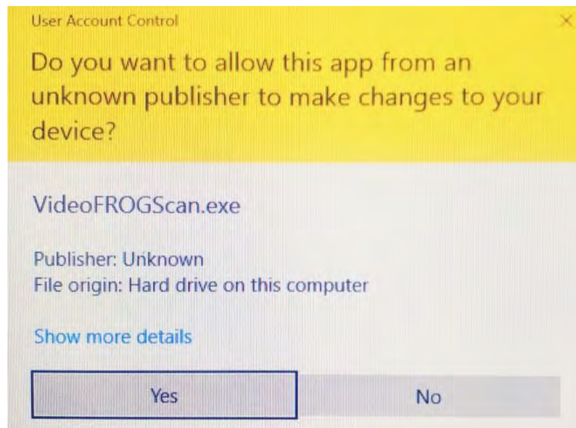
2.4 Opening the VideoFROGscan Software Program

Now that VideoFROGscan has installed, follow these steps to open the program on your computer:

1. Connect the power supply to FROGscan (Don't Plug Wall wart into the wall).
2. If the USB cables were connected as part of the VideoFROGscan installation, disconnect the USB cables before running VideoFROGscan for the first time.
3. Connect the USB spectrometer cable to the computer. If the **New Hardware Wizard** appears, click **NO**, since the drivers were already installed during VideoFROGscan installation. Then connect the Servo USB; it does not invoke the New Hardware Wizard.
4. Turn the power supply on by Plugging wall wart into the wall.
5. Click on the VideoFROGscan application on the computer.

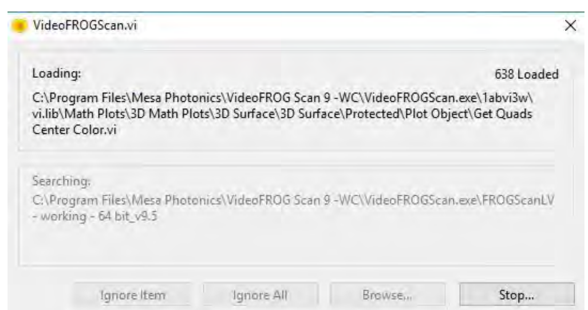
The following window will appear.

Click **Yes.**



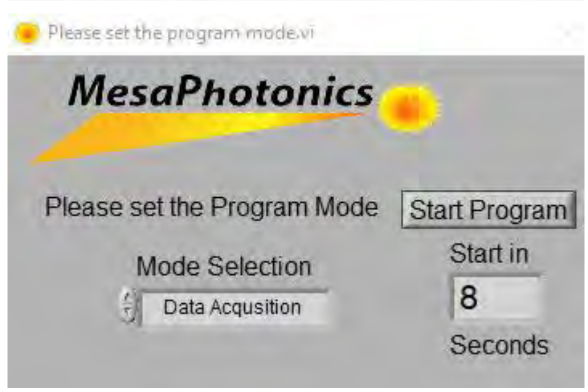
VideoFROGscan will then load.

Allow VideoFROGscan to complete initialization (slightly more than one minute).



Do not change the Program Mode.

Click on the Start Program button if you would like to start the program immediately.



6. You will see the live view of the FROG trace update when VideoFROGscan is collecting data even if no signal is present

Chapter 3. Program Menus

Now that VideoFROGscan has been uploaded, please familiarize yourself with the program menus. VideoFROGscan has been carefully designed to provide near turnkey operation while providing the user with very sophisticated options for FROG pulse retrieval. New as of Version 8 is an entirely new, more intuitive user interface that uses a tabbed interface to allow different operating windows to be displayed. Further, popup windows that contain more detailed information can be opened by clicking on the desired plot or heading.

3.1 Menu Panel

The Main Menu appears at the top of the VideoFROGscan Front Panel (Figure 4) and enables the following operations:

File (Figure 4)
Log Processed Data – Saves 10 files of FROG data in rapid succession.

Save Raw FROG Trace – Saves the raw FROG trace (Live FROG trace data) in a file that can be read by the VideoFROGscan software.

Page Setup – Sets up printer output for printing hard copies of the screen.

Print Window – Prints the window to a printer

See Appendix B for details on the file format

Operate (Figure 5)
Reinitialize Values to Default and Reset Algorithm are the only functions supported at this time.
Reinitialize Values to Default – Reinitializes all control values to the default values.

Reset Algorithm – Resets the FROG inversion algorithm when the algorithm becomes stagnated. Stagnation occurs when the measured FROG Trace does not match the retrieved FROG Trace or the FROG Trace error is high (several percent).

Save Screen – Saves a screen capture of the display as a jpeg file. A dialog box is opened to choose the name.

Popups to Front – Moves all the windows to the front allowing them to be moved and viewed. Clicking on the main front panel moves the front panel to the front.

Help (Figure 6)

Show Context Help – Allows the user to turn on and off a detailed description of each control that opens when the mouse hovers over the control.

Email Support – Currently unsupported.

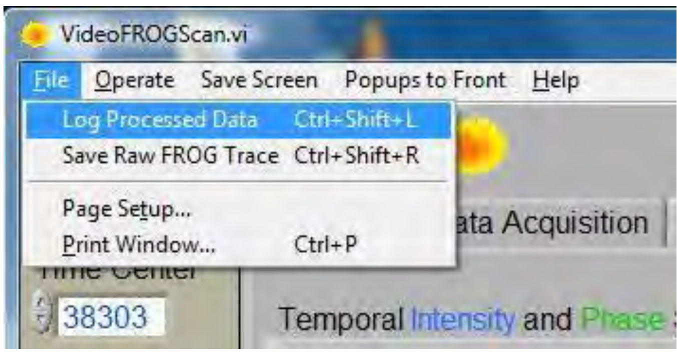


Figure 4: Main Menu with several data saving options and hardcopy output. The directory where the data is saved is set in the VideoFROGscan Configuration program.

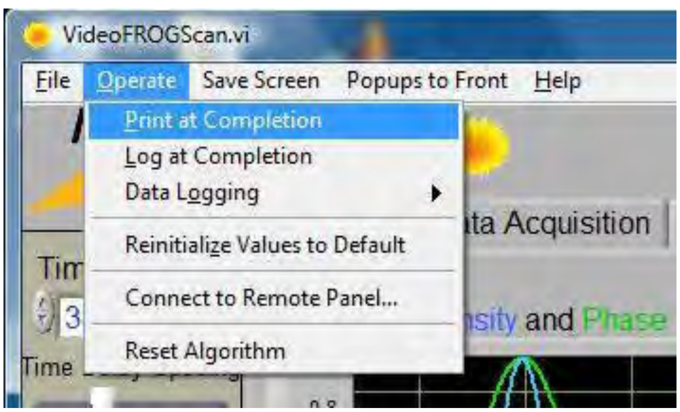


Figure 5: Operate menu with options for program operation.

Figure 6: Help menu with options for support.

3.2 Left Control Panel

Remember to activate popup windows containing more detailed information by clicking on the desired heading.

Video FROGscan data is displayed in eight different Panels. Each of these Panels displays a panel on the left in which the following parameters can be set:

Time Center – Controls the steps the servo motor must complete in order to achieve temporal overlap of the beams. This number was determined in the factory, but can be adjusted so that the raw FROG Trace is exactly centered in the Summary Panel (Section 3.3).

Recenter – Returns the Time Center to the previous number.

Offset – Displays the number of pixels the center of the FROG trace is from the correct location. This value should never be more than 2X the Time Delay Spacing.

Time Delay Spacing – Determines the duration of the temporal scan and the amount of frequency space used in the FROG Trace retrieval. The number can be changed by clicking the stepper control or by sliding the toggle. Each step is nominally 1 fs. As the time spacing increases, the amount of frequency data decreases; therefore, setting the time delay spacing requires deciding on the trade-off between time and frequency information.

Crystal Tilt – Not applicable for instrument without the Crystal Autotilt function. For instruments with the Autotilt function, see the Data Acquisition Panel, Section 3.4.

Center Wavelength – Center of the FROG Trace area used by the algorithm.
This number should be set to correspond to the center of the Live FROG Trace in the Summary Panel, Section 3.3.

Integration Time – The length of time that the spectrometer detector is allowed to collect photons before passing the accumulated charge to the A/D converter for processing. This is the only spectrometer setting that can be controlled using the FROGscan Interface. Short exposure times decrease the sensitivity whereas long exposure times increase dark levels and noise. Do not decrease the integration time below the minimum for a given spectrometer; this will cause a software hang-up (see Chapter 8). The minimum times are 1000 μs for an Ocean Optics Flame and HR series spectrometers, 7200 μs for the MayaPro, and 8000 μs for the QEPro spectrometers.

Images to Average – The number of raw FROG images averaged between retrievals. This setting allows extracting small signals from the noise background. However, increasing the number of images to average will increase the acquisition time.

Use Background Subtraction – Activating this features (can be activated only in the Summary Panel) activates different types of background subtraction options that can be entered in the Data Acquisition Panel (see Section 3.4). Because the background of spectrometers is high, activating this feature is recommended.

Save Data – Saves the measured FROGscan Trace and retrieved pulses in a set of time-stamped files to the directory selected in the Program Information Panel, Section 3.8.

Warnings – See Chapter 8 for different types of warnings.

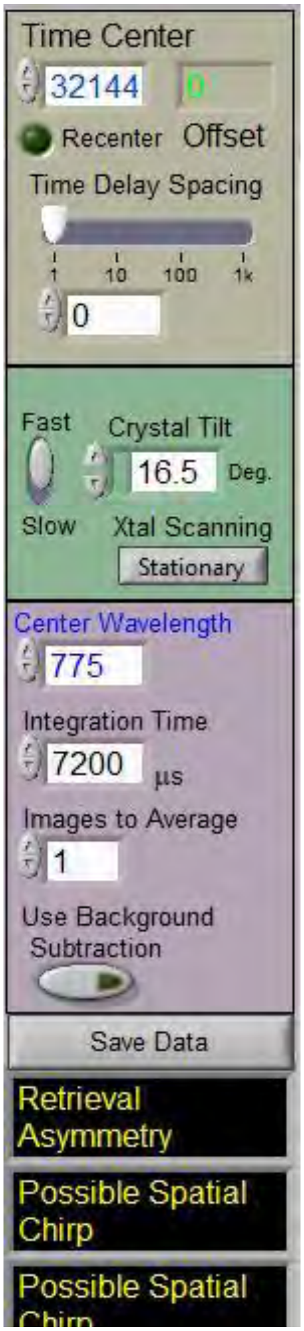


Figure 7. Important settings can be entered on the control panel on any of the eight Menu Panels.

3.2.1 Quitting VideoFROGscan software

VideoFROGscan can be exited from any panel by clicking the **QUIT (Exit)** button on the top right of the front panel. This allows the program to stop correctly and close all drivers.

Do not close down VideoFROGscan by clicking on the “X” in the upper top right corner of the screen.

After “QUIT” was clicked, a set of icons will appear below the Menu Panel (Figure 8):

Hollow Arrow Icon **–** Resumes VideoFROGscan.

Double Arrow Icon **–** (Not supported, do not use)

Stop Icon **–** Aborts the execution.

When VideoFROGscan is stopped, the menu Panel changes (Figure 9).

File menu now contains the Exit function that allows to properly exit out of VideoFROGscan.

Figure 8. Menu panel that appears when VideoFROGscan is properly exited by clicking on the QUIT (Esc) button.

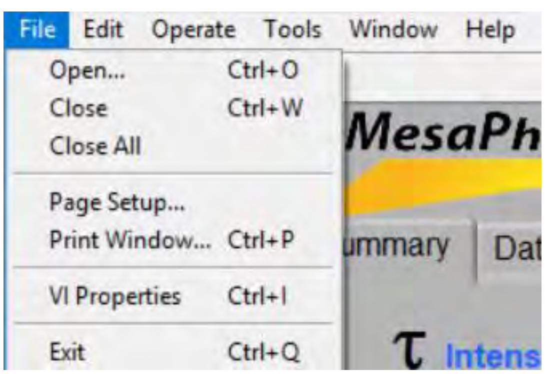


Figure 9. New File menu panel that appears when VideoFROGscan is exited.

3.3 Summary Panel

Clicking on the plots will bring up popup windows of the plots (except for the autocorrelation on the right) and a more detailed description of the function (see Figure 10). Double clicking on the FROG Results opens a floating FROG Results window.

T Intensity and Phase – Display of the temporal profile and the temporal phase of the retrieved pulse.

λ Intensity and Phase – Display of the spectrum and the spectral phase of the retrieved pulse.

Live FROG Trace Summary – Display of the Trace directly constructed from the spectrometer. This image is used to set the center wavelength of the FROG Trace area.

Measured FT – Display of the FROG Trace sent to the retrieval algorithm that was constructed by resampling the FROG Trace. After resampling, any residual background remaining after background subtraction is removed. Other calculations are also performed on this Trace.

Retrieved FT – Display of the Trace constructed from the retrieved pulse. The measured and retrieved pulses should appear identical.

Pulse Autocorrelation and Time Marginals – The autocorrelations calculated from the retrieved pulse and the time marginal calculated from the retrieved FROG Trace. The three spectra should overlap. The cursors can be used to mark points on the autocorrelation to determine FWHM etc.

Retrieved Stats – Display of the statistics calculated on the retrieval. If the exact phase is not too important, these data can provide a "good enough" indication of the quality of the pulse re-compression. In general, it is possible to measure changes in the pulse width of about 1 - 0.5 fs. Pulses with time-bandwidth products of less than 0.5 are generally considered "transform-limited."

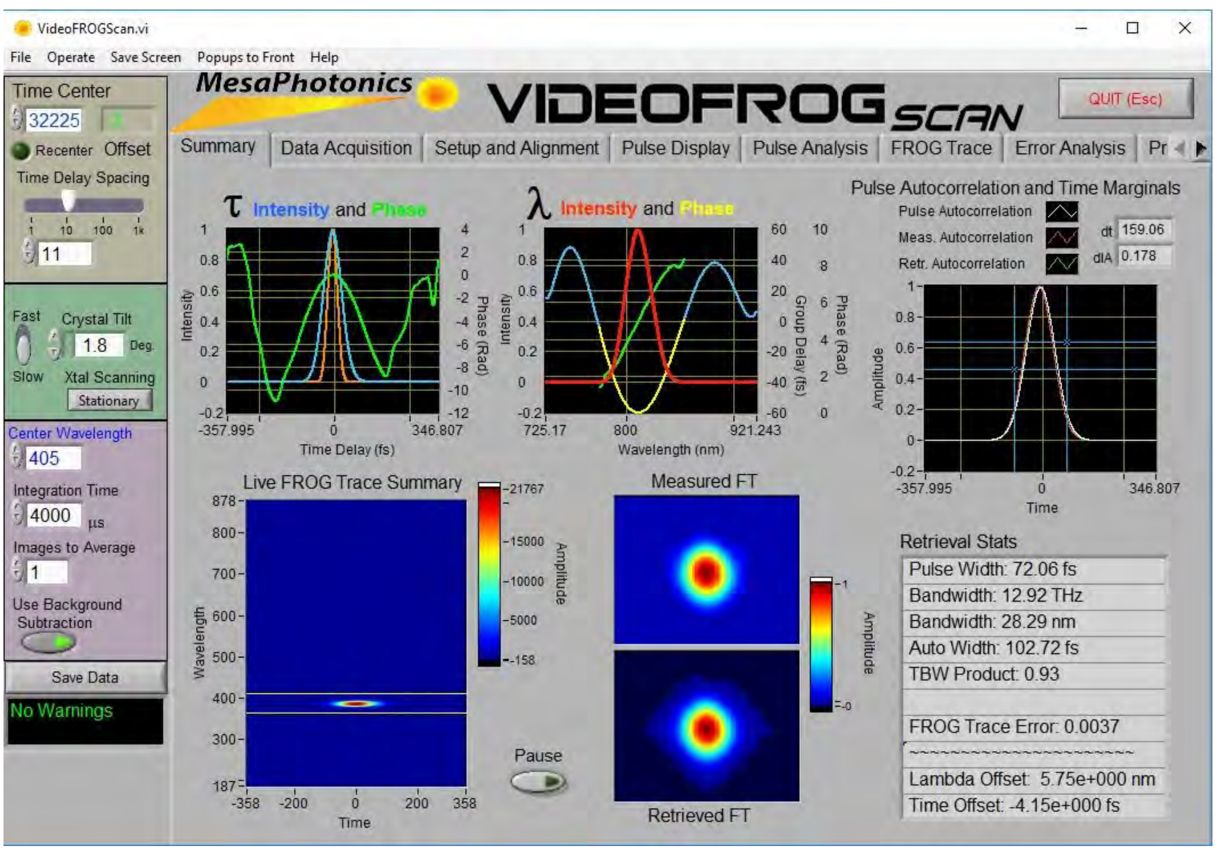


Figure 10. Summary panel of VideoFROGscan software. This is the panel that is used most often.

3.4 Data Acquisition Panel

Most of the program settings can be set in this Panel.

Time Calibration – The servo calibration constant in femtoseconds per step; each step is ~ 1 fs or 150 nm.

Grid Size – Determines the size of the FROG Trace sent to the retrieval algorithm. For example, when a 64 x 64 array is selected, the region inside the square on the raw video display is resampled to a 64 x 64 pixel array before the pulse characteristics are extracted from the FROG Trace. Larger grid sizes require more computational time, which causes the program to run more slowly. A good compromise between speed and resolution is the 64 x 64 array, although for the high-speed computers available today, real-time performance can be achieved on a 256 x 256 grid. If the program updates the pulse slowly on large grid sizes, reduce the frame rate.

Scan Mode – Determines the servo settling time. The FAST setting produces faster updates but causes more FROG Trace instability (oscillation time). High Fidelity reduces the FROG Trace instability to a minimum.

Sawtooth – This setting uses a sawtooth waveform on the delay servo rather than a triangle wave that is the default. Using a sawtooth prevents the FROG trace from shifting when the servo changes direction. The sawtooth wave may increase bearing wear a small amount. Using it does not void the warranty.

Program Mode – Displays the mode of the program: 1) Data acquisition, 2) Demo (synthetic data with noise added), and 3) Read File (reads a raw FROG Trace file saved by the program.

The other Program Mode display shows the file name as a file is being read.

Using Calibration File – Loads spectrometer response calibrations performed at the factory on request. The data is appended in Appendix E, where applicable. VIDEOFROGscan must be closed and then restarted to load calibration files.

Servo Fault – Indicates a servo error. Flashing indicates that VideoFROGscan has recovered, a steady illumination requires the program to be exited.

The **Control Menu** contains the following features:

Time Offset Correction – Centers the FROG Trace along the time axis to remove any effects of pulse front tilt.

FROG Trace Tilt Correction – Removes any tilt in the trace caused by spatial chirp. Either the wavelength offset (WO) correction or the spatial chirp (SC) correction (removes both wavelength tilt and wavelength offset) can be activated. Both cannot be activated simultaneously.

Wavelength Offset Correction – Centers the FROG Trace in wavelength.

Median Filter – Removes speckle in the measured, resized FROG Trace. A 3 x 3 window is moved across the resized FROG Trace one point at a time. At each point, the center point of the 3 x 3 window is replaced by the median value, rather than the average. The median is better at removing speckle noise than the average. Also, the median filter tends to preserve high frequencies better than a low-pass filter. The median filter should be used when there is sparse, but noticeable speckle.

Background Filter – An adaptive rank filter that removes the background from the FROG Trace.

Level and Threshold sliders determine how the rank filter is applied to the FROG Trace. By adjusting these sliders, all but the most severe backgrounds can be removed from FROG Traces. The Level adjustment sets the rank of the absolute value in the 3 x 3 window moved across the FROG trace. The Threshold sets the maximum signal value for filter application. Typically, the best position for the Level slider is on the "Low" side (smaller magnitudes) while the best position for the Threshold sliders is on the Mid to High side. The Background filter should be used when there is background that the background subtraction cannot remove and the retrieved pulse "wiggles."

Edge Background – Averages four spectra on the edge of the FROG Trace (two on each side) and subtracts their average from the rest of the spectra. This mode almost always works best.

3 Frame Background – Requires one dark frame for each beam being blocked. This can be complicated, and is only needed when one or both of the beams is creating scatter in the spectrometer.

Background Frames to Average – sets the number of background frames to be averaged for the 3 Frame Background subtraction.

Meas FT – A live update of the resampled and conditioned FROG Trace that is sent to the retrieval algorithm so that different background adjustments can be monitored.

Settings that control the crystal tilt are changed here. See Section 3.4.1.

Turn on XFROG Pulse Server – Activates a server that writes the output files to a file directory. The files can be selected and changed in the XFROG file location settings.

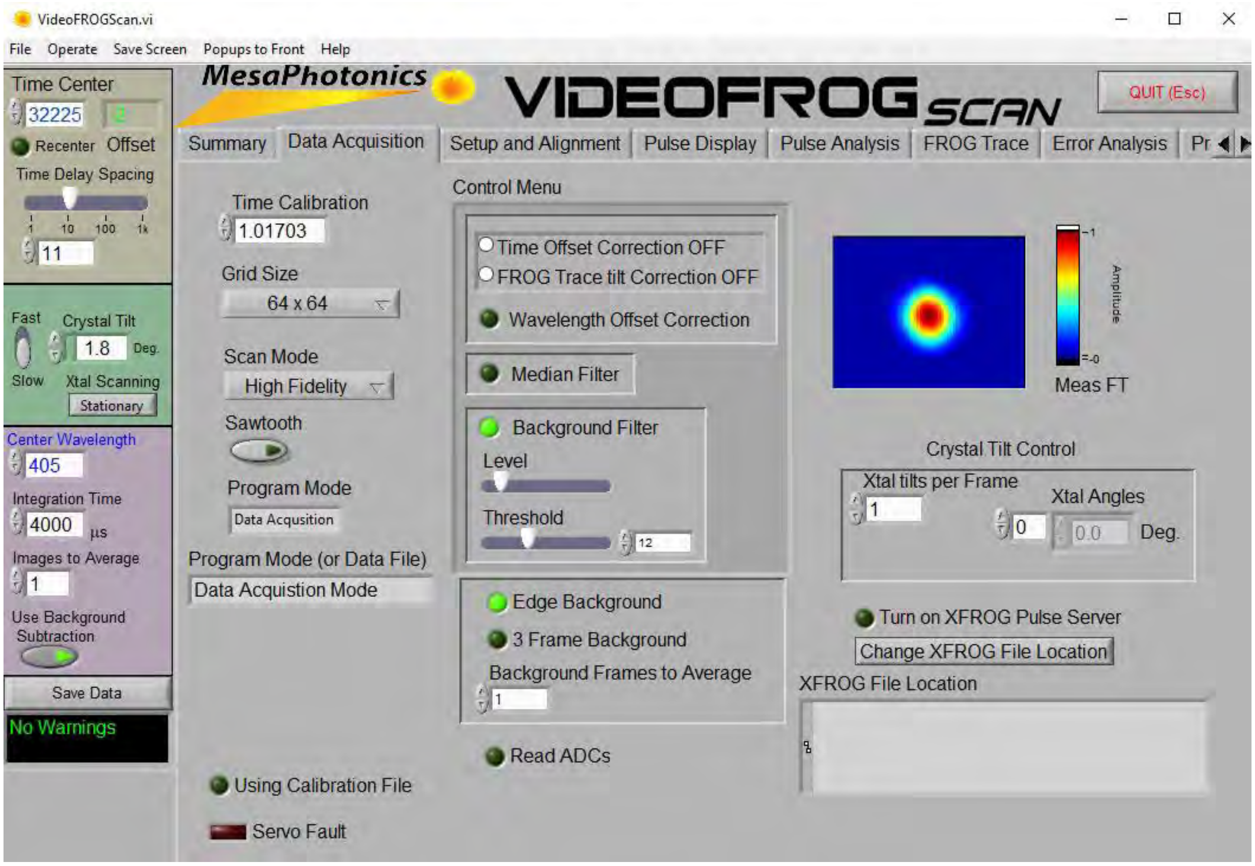


Figure 11. Screen capture of the Data Acquisition Panel.

3.4.1 Automated Crystal Tilt Function

In instruments with Autotilt function, the crystal tilt settings are entered in the Data Acquisition Panel. The crystal tilt is controlled using a direct drive, five pole stepper motor designed specifically for microstepping. Two pins and an opto-interrupter are used to home the crystal when the software is first started, or when the Change Crystal button is clicked.

The angle of the crystal tilt can be changed in the Left Control Panel (Figure 12) by either clicking on the spinner controls or by entering numbers into the display. The values are saved when the software is exited and the crystal is tilted using the saved settings when the program is restarted.

Crystal Tilt – Displays the external crystal tilt from vertical in degrees.

Fast – Tilts the crystal by 1 degree for each click on the spinner.

Slow – Tilts the crystal by 0.1 – 0.2 degrees.

Stationary – The crystal sits at only one position.

Xtal Scanning – When a crystal is too thick to phase match all of the wavelengths present in the pulse at a single angle, it acts like a wavelength filter that limits the bandwidth of the measured pulse. When a thinner crystal is not available or would reduce the signal to an undetectable level, the crystal can be tilted while the data is being acquired between scans. VideoFROGscan takes an image for each crystal tilt angle, and sums all of these images together to form the FROG trace used in the retrieval.

After the angular positions are recorded in the Left Control Panel, the crystal tilt scan is activated when the Xtal Scanning button in the left Panel is clicked. A popup window opens in the Data Acquisition Panel in which the Tilt Points are entered (Figure 13).

Crystal Tilt Control

Xtal tilts per Frame – Crystal tilts required to complete a scan so all of the different frequencies in the pulse are phase matched.

Xtal Angles – Records the angle of the crystal.

Once the number of tilts is set, the actual crystal tilts can be saved in the XFROG Pulse Server and File Location selected (see above).

Figure 12. Crystal Tilt functions in the Left Control Panel.

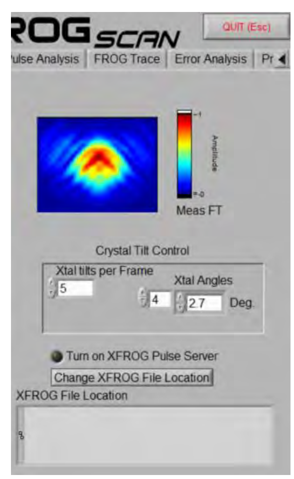


Figure 13. Popup window that appears after Xtal Scanning was clicked.

3.5 Setup and Alignment Panel

The intensity of the signal is displayed in this Panel, which is used when the intensity of the Signal Beam is maximized (Chapter 5).

Raw Spectrum (red) – Displays the spectrum recorded by the spectrometer.

Center Spectrum (green) – Displays the center spectrum of the FROG Trace, nominally the peak value.

Scaling – Activating this button opens a dropdown menu that enables Intensity Units to autoscale once or display the Intensity Units in a Fixed window.

Clicking on the x-axis opens a dropdown menu with settings that allow changes to be made to the x-axis display. For example, the autoscale can be turned off allowing small wavelength regions to be viewed more easily.

Change Crystal – If more than one crystal is used, clicking this button tilts the crystal holder to the vertical position for easier changing of the crystal cartridge. To change the cartridge, the top bar is removed by removing the two 2-56 screws. The crystal cartridge then will slide out (a small amount of force may be needed to overcome the friction of the SD card socket). Once the new cartridge is installed, the Change Crystal button is turned off, and the program will update the crystal information in the display above the button.

Release Crystal Tilt – In instruments with the crystal Autotilt function, clicking this button turns off the servo motor control of the crystal tilt, allowing manual tilt.

Alignment Mode – Clicking this button activates the optional cameras that aid in aligning the LASER beam into FROGscan instruments. See Section 4.2 for details on the Alignment Camera settings.

Diverter Mirror Position – Clicking this button turns the camera setting ON. A dropdown menu appears:

Delayed Beam Diverted – When this setting is selected, an image of only the delayed beam is displayed.

Both Beams Diverted – When this setting is selected an image of both beams as they appear on the center of the cameras is displayed. Position in Degrees and Change Position indicators should only be used with instruction from the factory.

Crystal Information Display:

VideoFROGscan will read the microSD card and present the encoded information about the Crystal on the just above the Change Crystal button

Function – Either "PH" for a pinhole or SHG for a second harmonic generating crystal.

Crystal type – BBO (Beta Barium Borate), LN (Lithium Niobate), etc.

Angle – The cut angle of the crystal.

Thickness – The crystal thickness.

If a pinhole was installed, the angle will be "N/A" and the thickness will be the pinhole diameter, typically 50 μm.

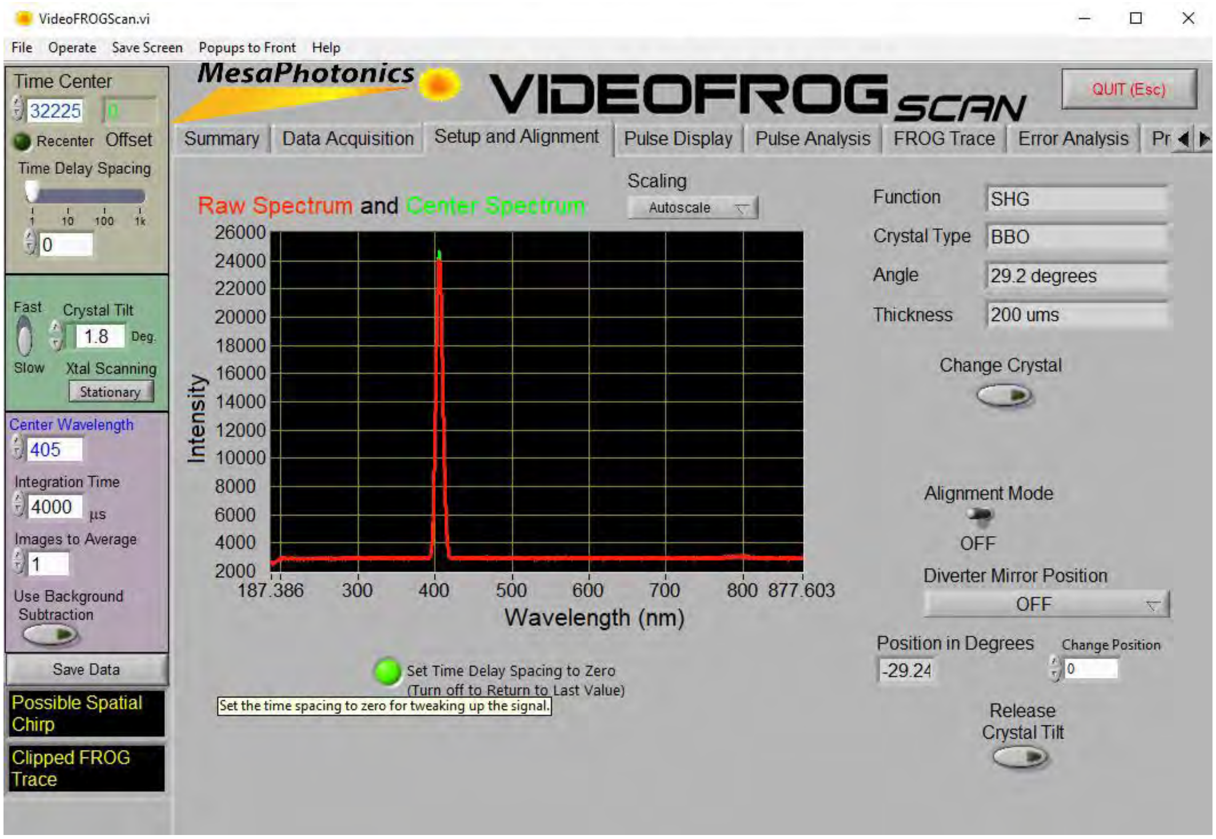


Figure 14. Setup and Alignment Panel. The wavelength range a given spectrometer is able to read is automatically displayed on the x-axis.

3.6 Pulse Display Panel

The retrieved pulses are displayed in two separate windows (see Figure 15). The Temporal Panel displays the temporal intensity and phase, and the Spectral Panel (not shown) displays spectral intensity and phase. Each window contains the plot area as well as the plot menu. Shown are the Pulse Width, the Time Bandwidth Product (TBWP), and the FROG Error.
The cursors in this Panel can be moved to select the pulse width to be measured, and the values of the position of the cursor lines with respect to 0 are displayed in the cursor box.
dT – Displays the difference in time between the two cursors.
dIT – Displays the intensity level difference between the two cursors.
+ Icon
Magnifying Glass icon – Allows to zoom in on the plots (Be sure to turn off the autoscale on both axes).
Grab Icon – Moves the zoomed region.

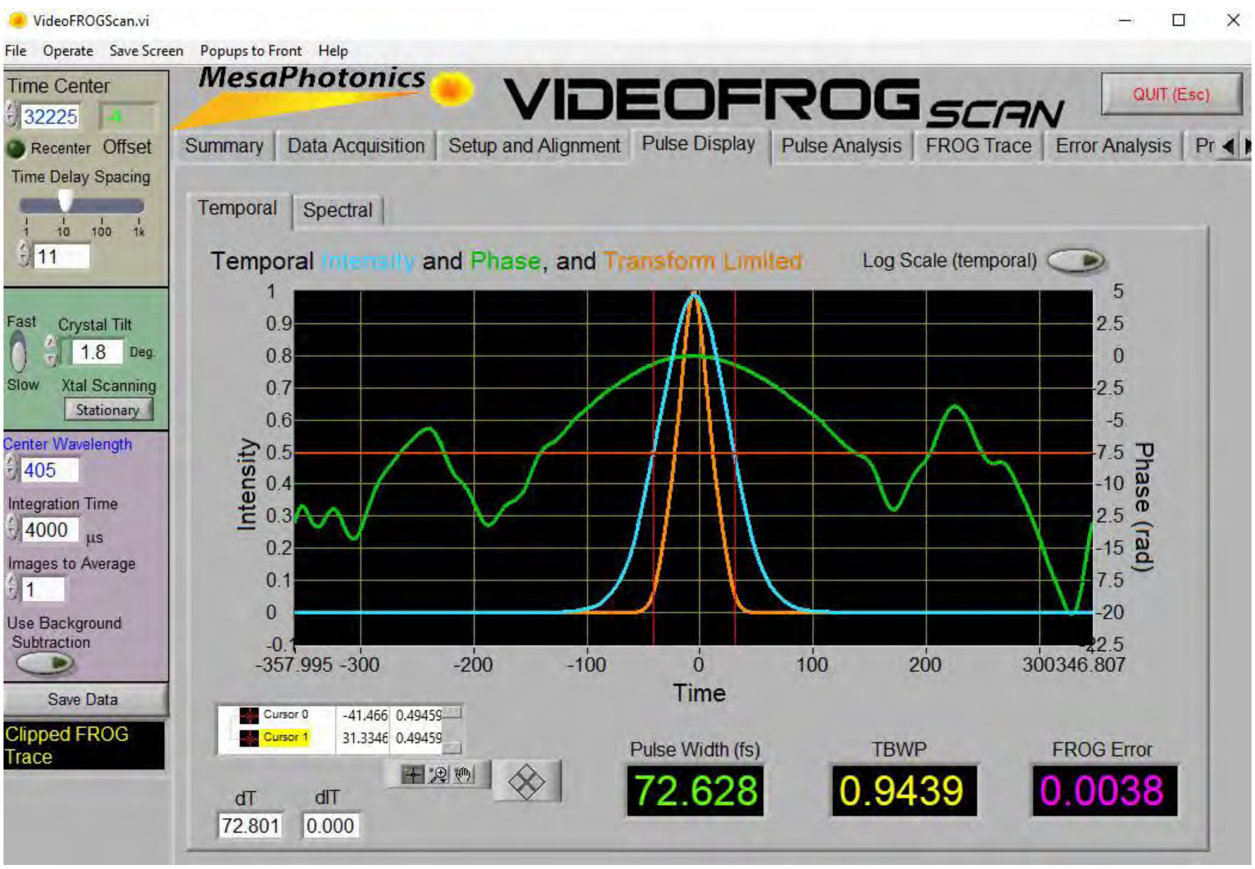


Figure 15. Screen capture of the Pulse Display Panel.

3.7 Pulse Analysis Panel

The Measured and Retrieved FROG Traces are displayed as in the Summary Panel (see Section 3.3).

This Panel contains various controls:

Bar Graph: Shows the spectral dispersion coefficients calculated from a linear least squares fit to the spectral phase. The units are fs^N, where N = the order of the phase coefficient.

Autoscale – Turns on autoscaling for the bar graph.

Order? – Sets the order used for the autoscale. For example, to obtain the best results, you may need to fit the phase to a higher order than you wish to monitor. The autoscale allows you to monitor the coefficient of interest to the highest precision.

Fit Controls:

Fit Order – Sets the order of the fit. Higher is not always better.

Residuals – Displays the residuals of the fit. Smaller is better. Zero is best.

Filter Controls:

Time Constant – An exponential filter is used to filter the coefficients. The “Time” is number of samples.

Reset Filter – Resets the exponential filter.

Temporal Cursor: Shows the time and intensity differences in the cursors displayed on the temporal intensity plot.

Spectral Cursor: Shows the frequency and intensity difference in the cursors display on the spectral intensity plot.

Spectral Dispersion Coefficients: The dispersion coefficients for the spectral phase found by doing a least squares fit of the spectral phase. The numerical indicator shows which order is displayed in the first box. The next two sequential dispersion coefficients are displayed as well. This allows the user to obtain exact values of the dispersion coefficient of interest.

Please realize that even though we use normalization in the fitting of the coefficients to improve the fit, there is significant cross-talk between coefficients in the fitting process. In order words, changes in the fourth order phase can influence the second order, etc., especially when the fit is not exact. However, even when the fit appears good, there can still be cross-talk. Therefore, these numbers are not truly quantitative.

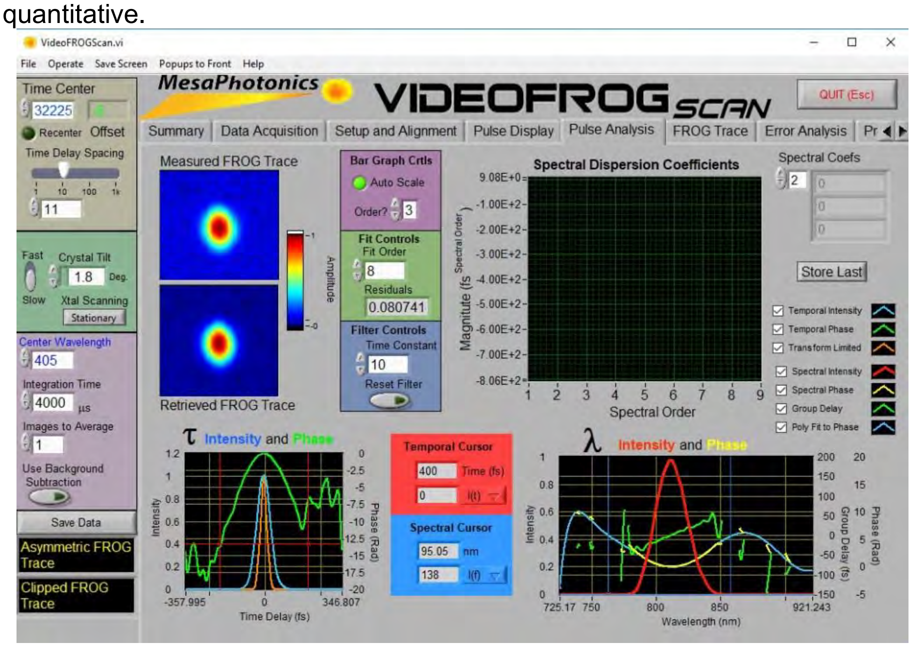


Figure 16. Screenshot of the Pulse Analysis Panel.

3.8 Program Information Panel

Various program settings and operations can be checked in the Program Information Panel (see Figure 17).

Retrieved Stats – Displays the retrieved pulse statistics.

VI Name and Application Name – Program information only required if the program is not operating correctly.

Directories – Directories required for program operation. The only directory that can be changed is the Data Directory, which is where saved data is stored. To change this directory, click anywhere on the directory name.

Loop Count Get Pulse – The number of algorithm iterations the last time the pulse has been retrieved.

Loop Count send Spectrogram – The number of algorithm iterations the last time a new spectrogram was sent.

Lock the Loop Count – Prevents the loop count from being updated.

Loop Count Loaded – Loads after the lock loop count is clicked.

Loop Count per Iteration – Number of algorithm iterations between each graphical user interface update. Typically, only about 10-20 iterations are needed between updates. On a 64 x 64 grid, it is not uncommon for this number to be in the 10's of thousands.

Minimum Number of Iterations – Determines the minimum number of iterations between updates. This can come in handy when the grid size is so large and the computer is so slow that fewer than 40 – 60 iterations occurs between updates, or the pulse is complex and the algorithm is having a hard time converging. -1 means that no checking occurs, and the algorithm iterates only for as long as it takes to acquire a frame.

Spectrometer Serial Number and Spectrometer Name – Serial number and type of spectrometer entered at the factory.

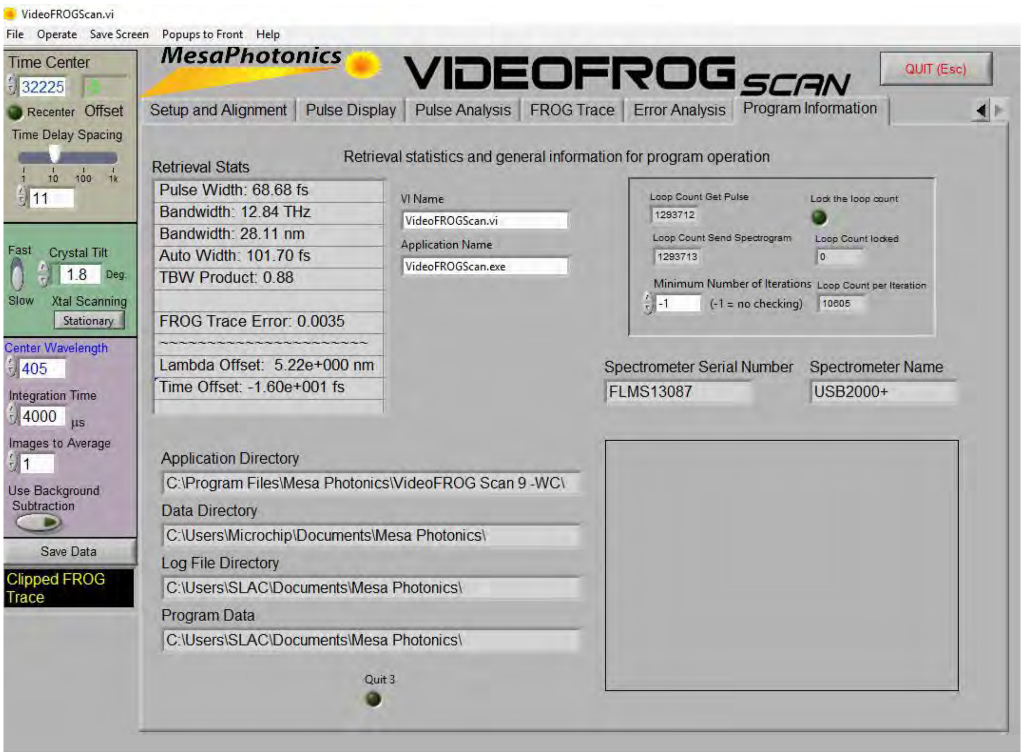


Figure 17. Screenshot of the Program Information Panel.

3.9 FROG Trace Panel

The steps required for measuring an ultrafast laser pulse using FROGscan first involve first obtaining all the spectra required to build up the raw FROG Trace. At each time delay, a single spectrum is taken, with N time delays taken, where N x N is the grid size for the resampled FROG Trace. The FROG Trace is then resampled and sent to a phase retrieval algorithm. After each frame, the retrieved pulse is extracted from the algorithm.

Three different types of FROG Trace images collected are displayed in the FROG Trace Panel.

Raw FROG Trace – The FROG Trace, also called the live FROG Trace, as it appears immediately after data acquisition (also located on the Summary Panel). Data acquisition can be set up here, which includes the servo centering, the center wavelength, and the FROG Trace averaging.

The FROG Area that is actually used in the retrieval is determined by the two parallel yellow lines. The spacing between the lines is independent of the grid size, and is directly proportional to the time delay spacing. In frequency space, the spacing between the yellow lines is given exactly by 1/dt where dt is the time delay spacing. As the time delay spacing is increased, the lines move closer to each other; as the time step delay spacing is decreased, the lines move further apart. Larger grid sizes also increase the line spacing. If the FROG Trace is outside of the region between the yellow lines, the center wavelength needs to be adjusted.

Measured FROG Trace – The FROG Trace as it appears after it has been resampled. This FROG Trace is input into the FROG inversion algorithm (also located on the Summary Panel and the Data Acquisition Panel).

Retrieved FROG Trace – The FROG Trace constructed from the retrieved pulse. It should be very close in appearance to the measured FROG Trace (also located on the Summary Panel).

Servo Time Center – can also be adjusted in this window.

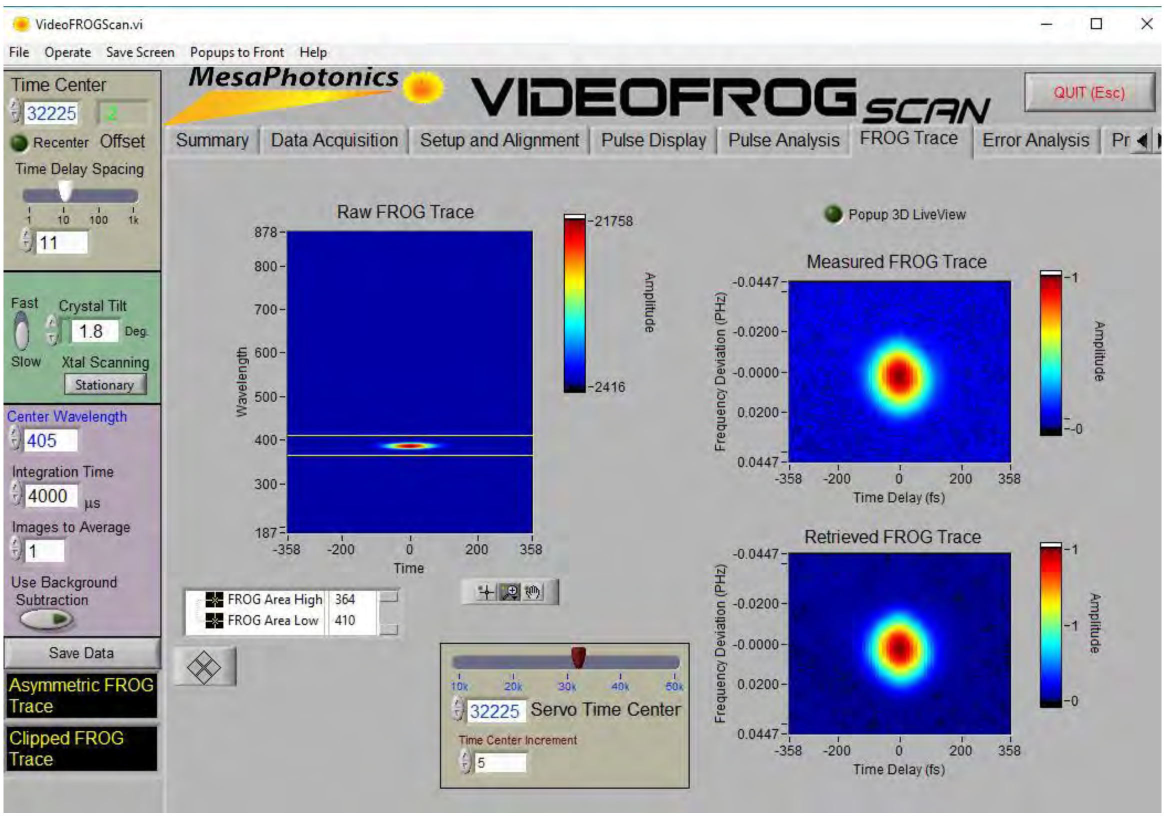


Figure 18. Screenshot of the FROG Trace Panel.

3.10 Error Analysis Panel

Under this Panel, the plots of the measured and retrieved frequency and time marginals are displayed. For good retrievals and measurements, the measured and retrieved marginals are the same.

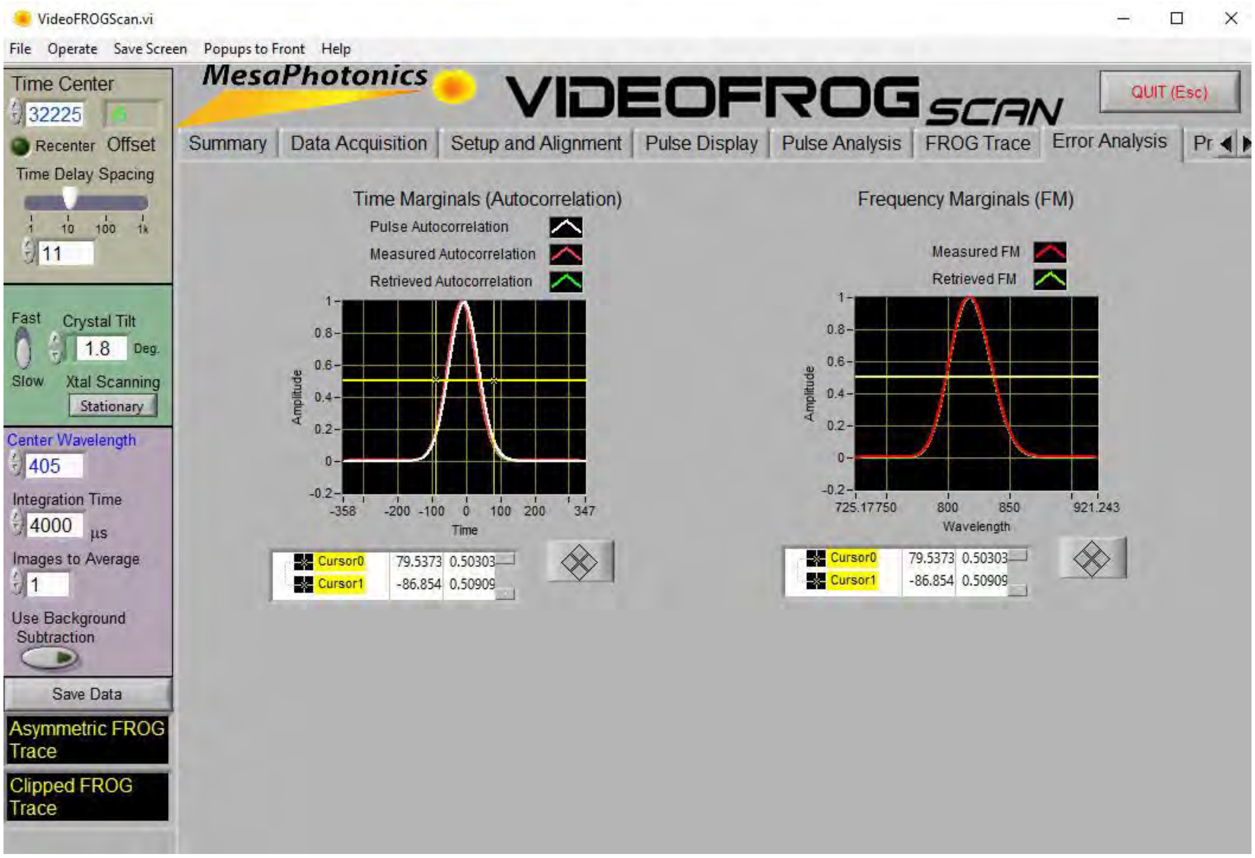


Figure 19. Screenshot of the Error Analysis Panel.

Chapter 4. Aligning a LASER Beam into FROGscan

FROG Scan is factory aligned and in most cases all that is required to obtain a FROG signal is

- Proper alignment of the LASER beam into FROGscan
- Adjustment of the Crystal Tilt
- Proper alignment of the Signal beam into the Spectrometer

4.1 Aligning a LASER Beam into FROGscan without Alignment Cameras

1. Position FROGscan in the desired location on the optical table and loosely secure using the three supplied clamps.
2. Raise the cover to the open position.

OBSERVE ALL WARNINGS AND SAFETY PRECAUTIONS STATED IN SECTION 1.3 SAFETY CONSIDERATIONS IN THIS USER'S GUIDE.

3. Ensure that the LASER beam is level to the table and perpendicular to the front of FROGscan as it enters through the Entrance Iris. Even small deviations in the entry angle can cause difficulty in alignment. The optimal height for the laser beam is 2.625" (66.67mm) from the surface of the optical table, which corresponds to the height of the FROGscan optical centerline.
4. Move FROGscan around on the optical table until the LASER beam is approximately aligned through the Entrance Iris and the Center Iris (Figure 20).
5. Secure FROGscan on the optical table.
6. Use two external mirrors to more precisely align the LASER through the center of the two irises.

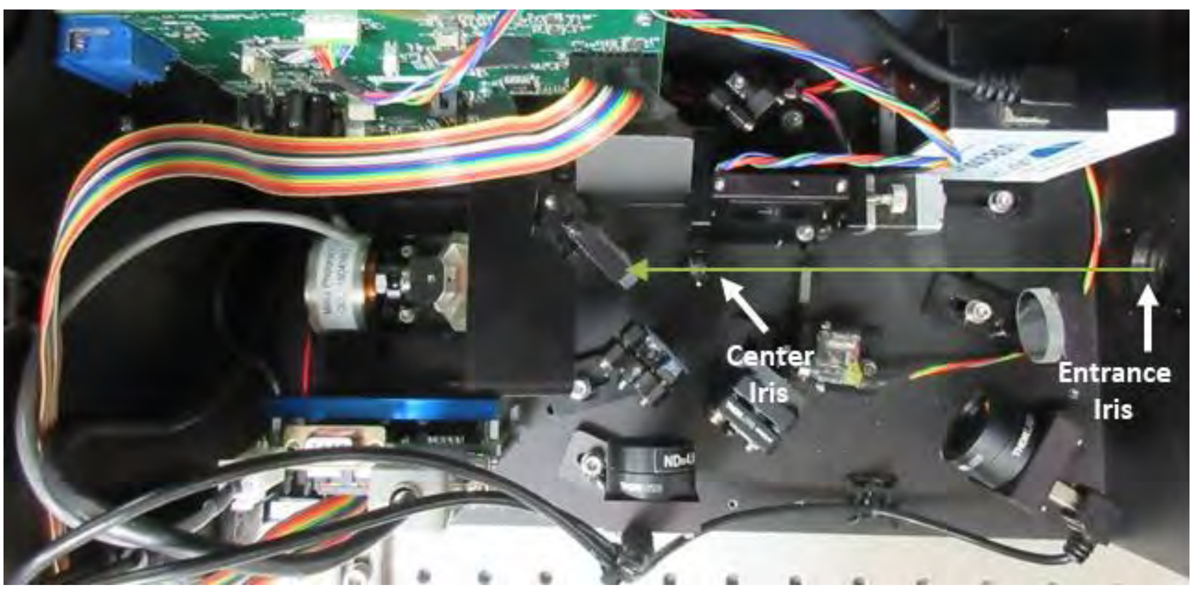


Figure 20: Aligning a LASER beam through the Entrance Iris and the Center Iris in a FROGscan Standard without cameras.

The **Center Iris** can be removed after initial alignment if it is blocking part of a beam that is wider than 8 mm. Ensure that the input laser is blocked and that laser light is not entering into FROGscan. Remove the Center Iris by twisting it counterclockwise. The Iris will unscrew from the Iris Rod. The Rod will remain in place on the base plate. Store the Iris in a safe place that is free from contaminants. The Iris may need to be reinstalled to assist with future realignment.

7. Next, align the beam vertically (parallel to the FROGscan base) using the external mirrors until the beam halves visible on the Focusing Mirror are approximately equal in size. In a device with Alignment Cameras, the Fixed beam is less bright than the Delayed beam because part of its beam is directed through the Overlap Mirror for alignment onto the camera.

Figure 21: Both halves of a TiSapphire LASER beam visible on the Focusing Mirror.

8. Check to see if the Signal Beam is visible on a card. If the Signal beam is not visible, see Section 5.4, Troubleshooting. **The system is aligned when:**

- The beams pass through the Entrance and Center irises when the irises are closed down.
- Both halves of the beam are approximately equal in size on the Focusing Mirror.

If these criteria are not met, further alignment adjustments are required using the two external mirrors.

4.2 Aligning a LASER Beam into FROGscan using Alignment Cameras

The camera alignment option was added to FROGscan systems to simplify LASER beam alignment into FROGscan.

The camera on the right (**Focusing Mirror Camera**, see Figure 1) is positioned such that the distance between the Focusing Mirror – Camera Diverter Mirror – Camera Lens corresponds to the distance between the Focusing Mirror – Overlap Mirror – Crystal. Therefore, this camera displays the overlap of the two beams as they would appear in the crystal. This overlap in the crystal is required to generate the Signal Beam.

The camera on the left (**Fixed Delay Camera**, see Figure 1) displays the appearance of the Fixed Delay beam shortly before it reaches the Focusing Mirror.

To begin the alignment, proceeds as follows:

7. Direct the LASER beam through the Entrance Iris and Center Iris using the external mirrors as described in 4.1.
8. Start the Alignment mode by clicking on the Alignment Mode switch in the Setup and Alignment mode Panel (Figure 22).

   Starting this mode causes the diverter mirror to rotate into the beam path between the Focusing Mirror and the crystal, causing both the Servo Beam and the Fixed Beam to be diverted to the camera.

   A popup screen appears that shows the images from the cameras (Figure 23).

   The Focusing Mirror Cameras (top) displays the overlap of both beams as they would appear in the crystal.

   The image recorded by the Fixed Delay Beam Camera (bottom) corresponds to the position of this beam at a location shortly before the Focusing Mirror and serves as a virtual alignment iris further downstream than the physical Center Iris.

   The bottom half of the beam goes to the Servo Mirror (variable delay) and the top half to the Fixed Delay Mirror (the camera image is upside-down). The Fixed Delay Beam appears as a semi-circle in this Figure due to the spatial, zero dispersion beam splitter used in FROGscan. The focused spot appears oval because it is approximately the Fourier transform of the semi-circular beam.

   The cursors aid in positioning the beams for optimal alignment and are stored whenever the alignment mode is ended. During initial setup, the cursors positions are from the factory. A screen capture showing the factory alignment is provided in the documents with your instrument.
9. Upon initial input of the laser into FROGscan, at least one beam should be visible in the cameras. If the beams are off-center after the LASER beam was aligned sub-optimally into FROGscan, adjust FROGscan by sliding it on the optical table until the beams are close to their ideal position.
10. Secure FROGscan on the optical table using the three clamps provided.
11. Align beams precisely using two external mirrors.
12. Check for overlap of the beams on the camera. Block one of the beams by setting the Diverter Mirror Position control to **Block Only One Beam**. A change in the intensity of the overlapping beams should be observable in the top panel as the diverter mirror is moved from blocking only one beam to blocking both beams.
13. Set the cursors so they intersect the beams displayed in the top panel.
14. Once the beams are positioned correctly, the alignment mode can be turned off by clicking on **END ALIGNMENT MODE** in the popup window. This closes the popup window, restores the diverter mirror to the “off” position (unblocking the beams), unloads the camera drivers, and reconnects the spectrometer to the computer. Do not exit by clicking on “X” at the top right of the screen.
    A few seconds is normally required to place the system back into the data acquisition mode.

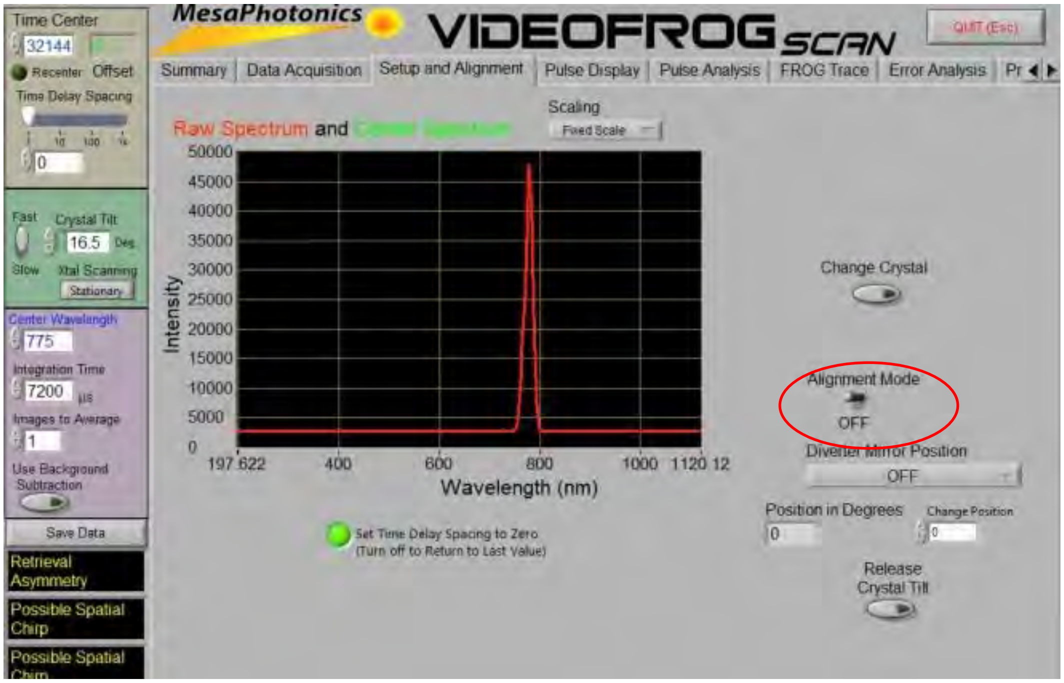


Figure 22. Clicking Alignment Mode to **ON** turns off data acquisition and pops up an image viewer for the beam cameras.

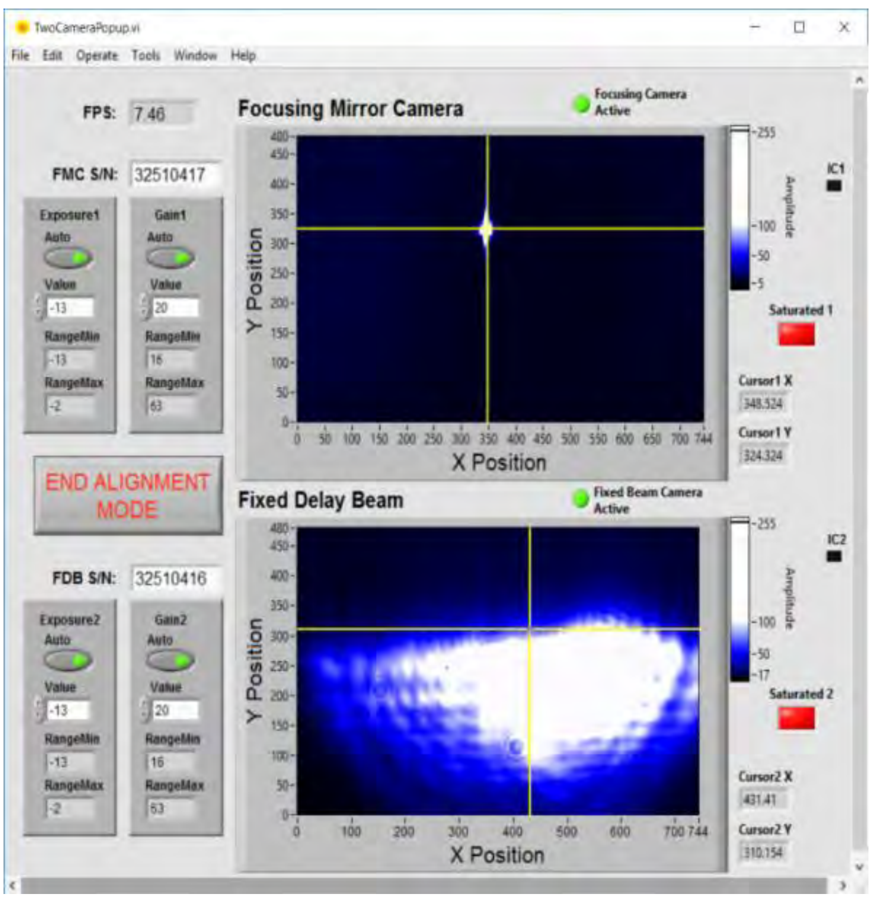


Figure 23. Screen capture of the alignment screen. In this image the Fixed Delay Beam appears in the lower half of the screen because the FROG instrument contains a hollow retroreflector that inverts the beam.

Chapter 5. Maximizing the Intensity of the Signal Beam

Once initial alignment is achieved, the SHG beams should be visible by eye on a fluorescing card or with the aid of a viewer if the instrument is set up correctly. The setup process then continues to:

5.1 Optimizing the crystal tilt.

5.2 Optimizing the entry of the Signal beam into the SMA Aperture of the Spectrometer.

5.3 Optimizing the time settings of the instrument.

To optimize the settings, proceed as described below.

1. Start VideoFROGscan to initiate data acquisition and the inversion process.
2. Allow FROGscan to warm up for a few minutes. NOTE: the zero time may drift as the servo warms up; the FROG Trace may not appear in the scan window immediately after power up.
3. To obtain a live view of the intensity of the signal beam changes as the Overlap Mirror and the Last Turning Mirror are adjusted, go to the Setup and Alignment Panel in VFS. Click the “LED” button at the bottom of the spectrogram to set the time delay spacing to “0.” If preferred, set the menu item Scaling in the Setup and Alignment Panel to Fixed Scale to fix the Y-axis (Figure 24).
4. In the vast majority of cases, only the Overlap Mirror and the Last Turning Mirror need to be adjusted. Use the provided 64 ball head driver to adjust the 5/64 hex sockets on the back of the Mirrors until the signal is maximized in the VideoFROGscan Setup and Alignment spectrogram.
5. Once the signal is maximized, unclick the “LED” to restart scanning.

INTENSITY WARNING

DO NOT EXCEED AN AVERAGE POWER EQUAL TO

$$\sqrt{\mathbf{50,000}\ \boldsymbol{x\ repition\ rate}\ (\boldsymbol{Hz})\boldsymbol{x\ pulse\ width}\ (\boldsymbol{seconds})}$$

OR CRYSTAL DAMAGE MAY OCCUR. IF A POWER GREATER THAN THE ABOVE VALUE MUST BE EXCEEDED FOR ALIGNMENT PURPOSES, PLACE A FILTER IN FRONT OF THE ENTRANCE IRIS.

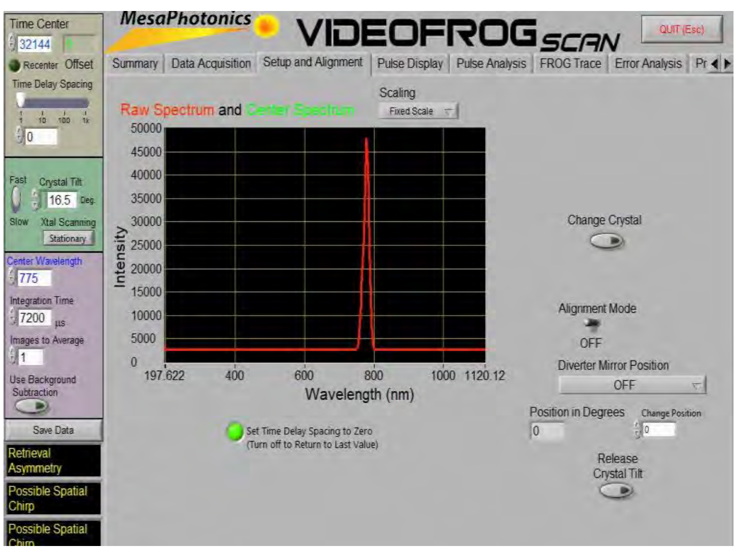


Figure 24. Raw intensity of the signal beam generated by a 1550 nm LASER displayed as a function of wavelength in the Setup and Alignment Panel.

5.1 Optimizing the Crystal Tilt

1. Ensure that your LASER has the same <u>horizontal</u> polarization as the crystal. If the crystal cut angle corresponds to the Theta angle for a particular wavelength, the crystal will be vertical. When the crystal cut angle corresponds to the phase matching angle for the input wavelength. For example, for 800 nm, BBO's phase matching angle is 29.2 degrees. If the crystal is cut at that angle, and the wavelength is 800 nm, the crystal will be vertical when properly phase matched. If the Theta angle differs from the crystal cut angle, the crystal tilt must be tilted by the difference of the two angles plus the internal refraction of the crystal.
2. Follow steps 1 to 3 above.
3. In instruments without the crystal autotilt control, change the crystal tilt by tilting the crystal cartridge manually until the SHG signal is maximized. Follow the instructions below to unlock the crystal cartridge.

   Remove the crystal bars as described in Section 2.2.

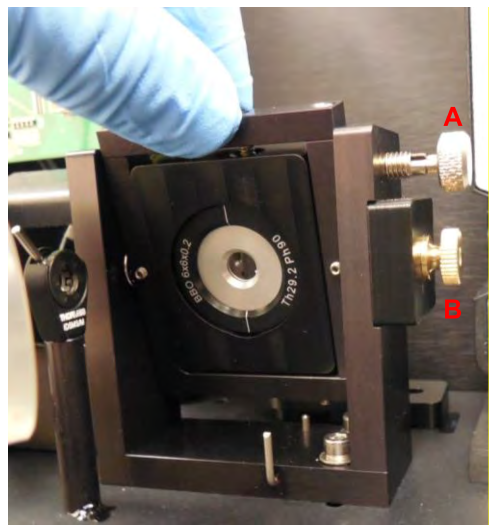
   Manually hold the Crystal Mount in place while the Adjustment nut is loosened or tightened.

   Loosen the Adjustment nut, then tilt the crystal by hand until it is approximately vertical.

   Secure in place with the Locking Screw by turning the knurled head 90 degrees.

   A: Locking screw to secure the crystal tilt in vertical position. Disengage to tilt crystal.

   B: Adjustment nut: loosen to adjust the tilt angle; tighten to secure in place.

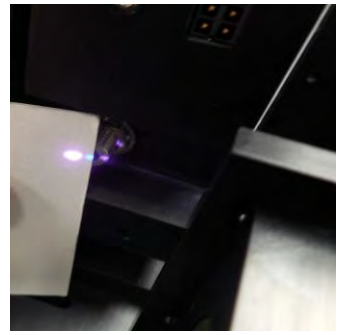


4. In FROG instruments with automated crystal tilt function, adjust the crystal using the Crystal Tilt functions in the Left Control Panel and as described in Section 3.4.1.
6. Once the optimal crystal tilt was determined, optimize the spatial overlap of the beams in the crystal by adjusting the Overlap Mirror. Use the provided 64 ball head driver to adjust the 5/64 hex sockets on the back of the Mirrors until the signal is maximized in the VideoFROGscan Setup and Alignment spectrogram.
5. Click on the "LED" again to restore the time spacing to the previous value.

PROTECT YOURSELF AND OTHERS AGAINST REFLECTIONS FROM THE SHG CRYSTAL WHEN TILTING THE CRYSTAL

5.2 Optimizing the Entry of the Signal Beam into the Spectrometer

FROGscan Ultra contains additional optics behind the crystal as compared to FROGscan Standard (see Figure 1 and 20, respectively). The spectrometer alignment procedure is therefore described for each instrument separately, although the principle is the same.



<u>FROGscan Standard:</u>

1. Using a fluorescing card, confirm that the Signal beam enters the Spectrometer SMA Connector.
2. Optimize the raw signal intensity as described above by adjusting the 2nd Turning Mirror.

<u>FROGscan Ultra:</u>

1. Using a fluorescing card, confirm that the two beams hit the Iris-Lens Mount equidistant from the center.
2. Open the Iris on the Iris-Lens mount to confirm that the two beams are approximately centered on the Spectrometer SMA connector.
3. Use the iris on the Iris-Lens Mount to shutter out the non-cross correlated second harmonics.
3. Optimize the entry of the Signal Beam into the spectrometer slits as described above by adjusting the 3rd Turning Mirror.

If a spectrometer was replaced (see Section 6.2), only loosely secure the baseplate/spectrometer assembly. Gently move the assembly around until the raw intensity units observed on the VideoFROGscan Setup and Alignment Panel are maximized. Then tighten the two socket cap head screws.

DO NOT ATTEMPT TO MOVE OR ADJUST ANY OPTICAL COMPONENTS OTHER THAN THE OVERLAP MIRROR AND THE LAST TURNING MIRROR

5.3 Optimizing the Time Center on the Instrument

1. Check the paperwork from the Factory to ensure that the Time Center number for temporal overlap is entered correctly in the Summary Panel.
2. Expand the time range of servo motor by changing the Time Delay Spacing. If the FROG trace is visible, it will narrow.
3. Center the FROG Trace by adjusting the Time Center so that the center of the Live FROG trace is at t=0 and the three autocorrelation spectra (top right) overlap.
4. Now adjust the Overlap Mirror to favor symmetrical FROG Traces—not maximum intensity. On some lasers, the beam may not be exactly collimated, and the spatial chirp may be large enough (especially OPAs) to cause the FROG Trace to be asymmetric. This occurs because the SHG crystal may not be exactly at the focus and, therefore, there may be some structure in the region where the two beams overlap.

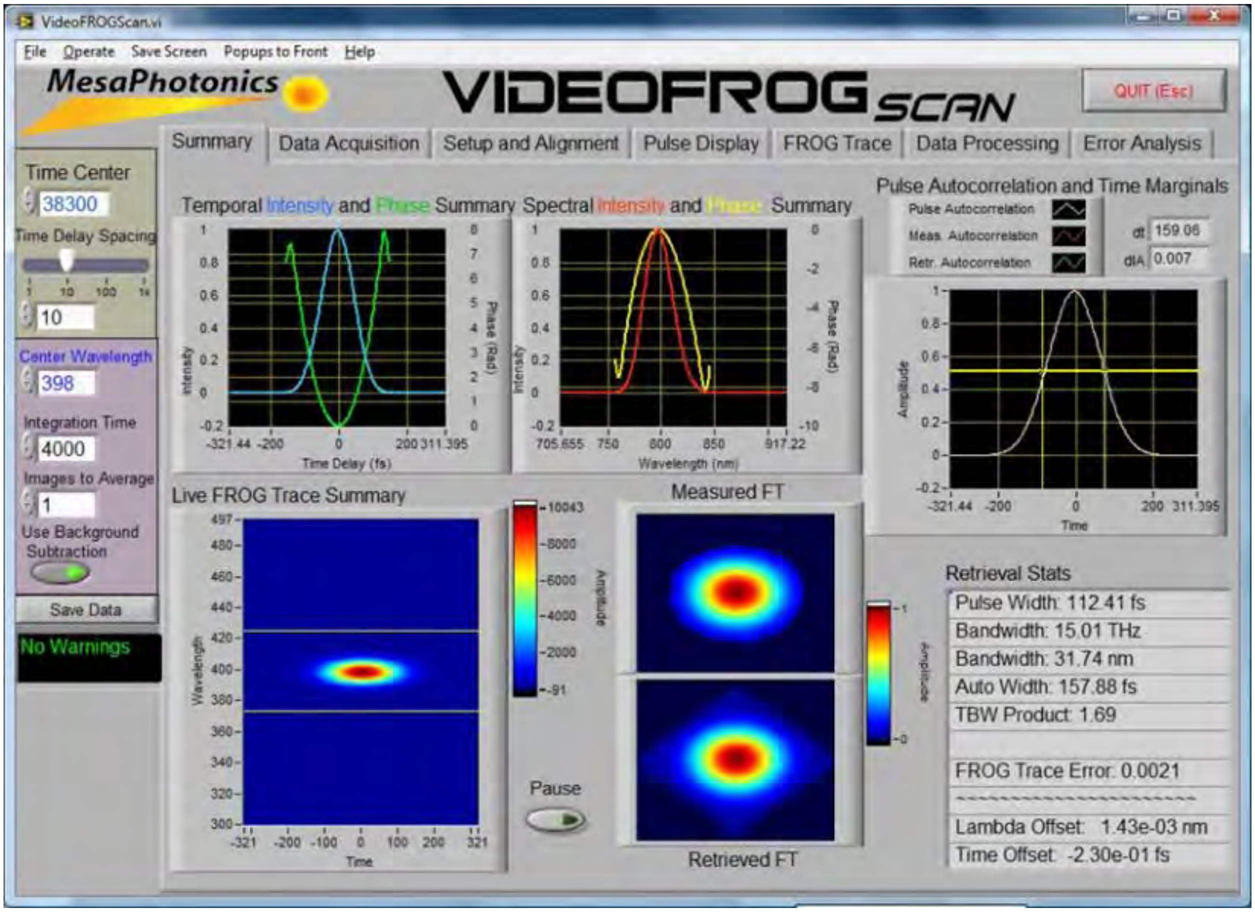


Figure 25. Summary panel of the VideoFROGscan software showing the pulse characteristics of a ~ 400 nm Signal beam generated by a 800 nm TiSapphire LASER.

5.4 Troubleshooting

The Signal beam is not visible.

The Signal beam will appear only when the beams overlap in the crystal. Therefore, the device must be aligned for simultaneous temporal overlap and spatial overlap, which can be very difficult. The following approaches have been used successfully:

1. Replace the crystal with the 50 μm Pinhole supplied and confirm that both beams are visible behind the pinhole. Ensure that the Pinhole is in the same vertical plane as the Crystal. Using a 5/64 ball head driver to adjust the 5/64 hex sockets on the back of the 1st Turning Mirror so that the Delay beam is visible through the Pinhole. Then adjust the Overlap Mirror so that the beam from the fixed delay is visible through the pinhole. Reinsert the crystal and check whether the Signal beam is now visible.
2. To make sure that the beams overlap spatially, walk the beams off the SHG crystal using a 5/64 ball head driver to adjust the 5/64 hex sockets on the back of the 1st Turning Mirror. At the edge of the crystal, the beams will diffract both because of the edge of the crystal and the glue attaching the crystal to the substrate. When using a visible laser, the diffraction will be visible on a business card. If the beams are in the same place, when moving the 1st Turning Mirror, the diffraction on both beams will appear at the same time, in exactly the same way. Do this for both X and Y (vertical and horizontal) directions. Repeating this procedure 2-3 times will almost always get the beams overlapped well enough to see the Signal SHG beam.
3. If the Signal beam is still not visible, loosen, BUT DO NOT REMOVE, the socket head cap screws that hold the Crystal holder to the base plate, using a 2.5mm ball end hex driver. Then move the entire crystal holder assembly forward, toward the center of the FROGscan. This places the crystal at a point where the input beams are large enough to be visually overlapped without the use of a pinhole. The Last Position Mirror may need to be adjusted in order to get the SHG signal into the center of the Spectrometer SMA Connector.

   Then adjust the overlap mirror so that the beams are overlapped. Now look for a FROG signal by running the software on a large grid size, e.g. 256x256. Once there is a FROG Trace, adjust the Time Center to center the FROG Trace. The device is now “timed.”

   Slowly and systematically walk the crystal back to the point where the beams are focused while adjusting the spatial overlap of the beams and the Last Turning Mirror. Tighten the socket head cap screws in the base of the crystal mount using the 2.5mm ball end hex driver.

   In the Data Acquisition Panel of VideoFROGscan, set the grid size to 256 x 256.

   Returning to the Summary Panel, set the Time Delay Spacing to about 2X smaller than your approximate pulse width. Increase the Time Span using the timespan control and look for the FROG Trace in the live view. You can also use the live view of the spectrometer to view the spectrometer output as the servo is scanned.

The spectrometer appears to have moved during shipment

The Spectrometer is optimally positioned in the factory. If during shipping the spectrometer has shifted position it may be necessary to reposition it. This is only for extreme cases.

1. Adjust the physical location of the Spectrometer until there is a signal in the plot of the Setup and Alignment Panel in VideoFROGscan.
2. Follow the steps described in Section 5.2 “Optimizing the Entry of the Signal Beam into the Spectrometer.”

Chapter 6. Installing and Changing Hardware

FROGscan systems enable data acquisition at different wavelengths without the need for purchasing a separate instrument. All that is needed to switch between different wavelength measurements is to change the crystal and the spectrometer. The relationship between a desired wavelength and the angle of the crystal required for that wavelength is illustrated in Figure 26.

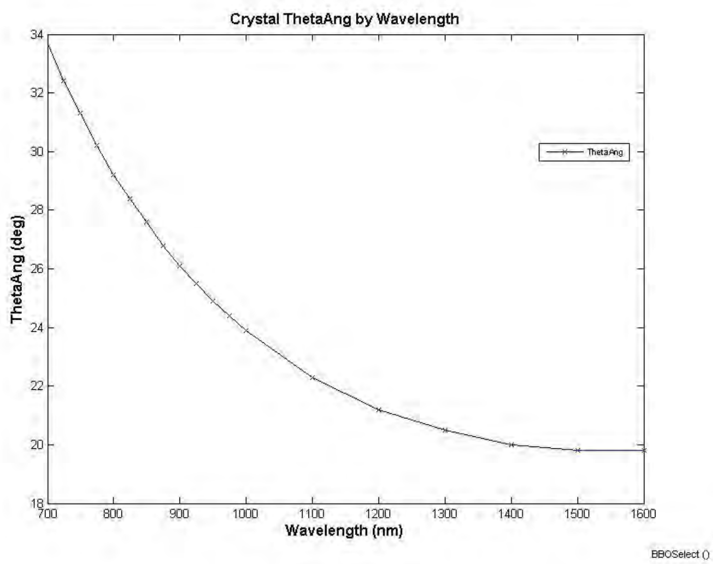


Figure 26. Relationship between the wavelength and the Theta angle of the crystal in nm.

6.1 Changing the Crystal

One crystal is installed into the cartridge at the factory, aligned for horizontally polarized light, and the crystal tilt is set for 800 nm or 1550 nm according to customers' specifications.

The custom crystal and a 5/64 Ball point Hex L-key tool needed for replacing the crystal are included with FROGscan or FROGscan Ultra.

Ensure that the input LASER is blocked and that LASER light is not entering the FROGscan.

Heed all warnings and safety precautions as expressed throughout the Manual.

Always wear powder free gloves when working with optics.

Follow the steps below:

1. In VideoFROGscan, open the **Setup and Alignment** Panel (Figure 14) and click on **Change Crystal**, turning on the green indicator.

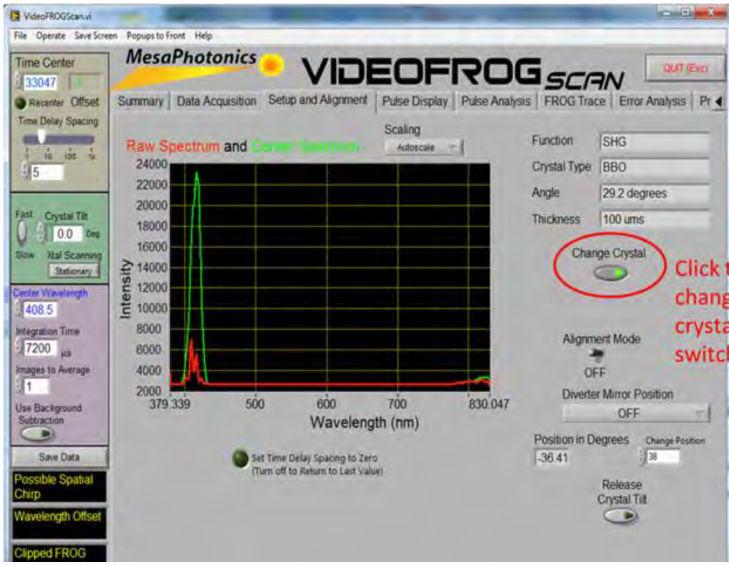
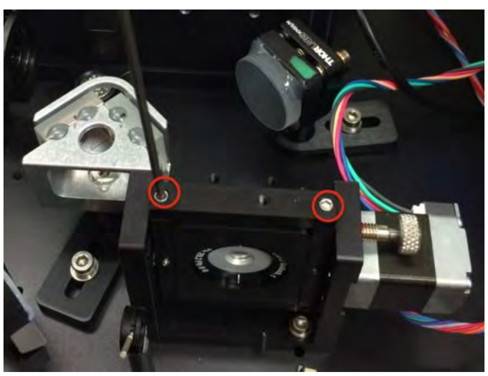
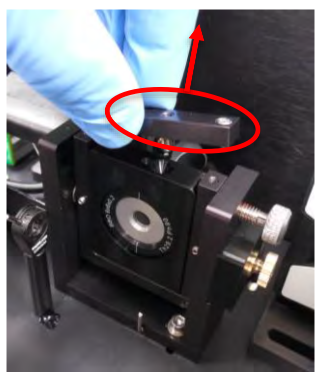


Figure 27. Change Crystal button in the Setup and Alignment Panel.

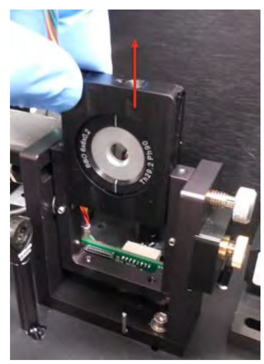
2. Open and carefully lift the FROGscan cover and follow the steps below.



1. With the 5/64 Ball point Hex L-key included with the shipment, remove the two 2-56 Socket Head Cap Screws.



2. Remove the loosened bar and set aside.



3. Carefully, with an upwards motion, slide the installed Crystal Cartridge out of the mount. There will be a small amount of resistance when the microSD Card disengages from the SD Card holder.

4. Place the removed Crystal Cartridge in the supplied Gel Pack, ensuring the SD Card is under the membrane.

Figure 28. Steps required to remove the crystal from the cartridge

Install the new Crystal

5. Carefully, slide the Crystal Cartridge into the Crystal Mount, taking note of the location of the microSD Card with respect to the SD Card slot.
6. Ensure that the microSD Card has fully engaged into the SD Card slot by gently pushing on the top of the Crystal Cartridge.
7. Reinstall the top bar to secure the Crystal Cartridge in place, taking note of the Cone Point Screw location and the mating surface on the Crystal Cartridge.
8. Tighten the 2-56 Socket Head Cap Screws to secure the top bar to the Crystal Mount.
9. In VideoFROGscan, click on the Change Crystal switch to turn off the green indicator light.
10. If the FROGscan was supplied with the Optional Software-controlled Crystal Tilting, the Crystal Mount will perform a homing procedure. At the end of the homing process, the crystal will be returned to the previous tilt angle.
11. If the FROGscan has a manual tilt mechanism, see Section 5.1 to unlock the crystal and set the tilt angle before proceeding.

6.2 Changing the Spectrometer

One of the specified spectrometers was installed into FROGscan at the factory and can easily be changed if more than one spectrometer was purchased in order to obtain data at different wavelengths. Each spectrometer is already mounted on its own baseplate so that only the baseplate/spectrometer assembly is replaced.

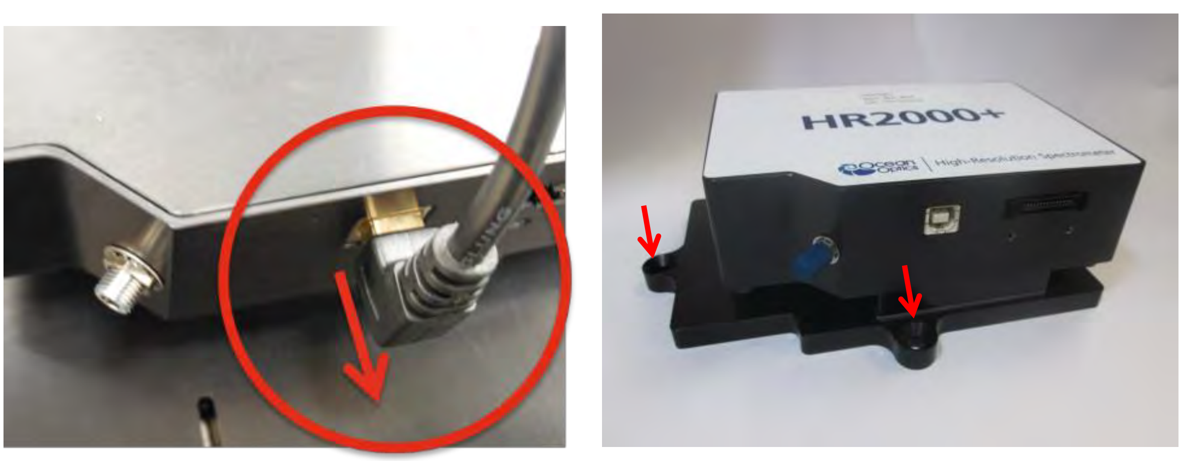
The optional spectrometer(s) and a 5/64 Ball point Hex L-key tool needed for replacing the crystal are included with the FROGscan or FROGscan Ultra shipment.

Ensure that the input LASER is blocked and that LASER light is not entering the FROGscan.

Heed all warnings and safety precautions as expressed throughout the Manual.

Always wear powder free gloves when working with optics.

1. Turn OFF the power supply and disconnect the USB connections between the computer and FROGscan.
2. Open and carefully lift the FROGscan cover.
3. Carefully unplug the USB connector in the installed spectrometer and secure the spectrometer cable so that it is out of the way of the surrounding optical components (Figure 29a).
4. Use a 2.5 mm Ball End Hex Driver to loosen the spectrometer/baseplate assembly and carefully lift out of the FROGscan instrument. Do not unscrew the spectrometer from the baseplate.
5. Remove the protective cap on SMA aperture of the replacement spectrometer (Figure 29b).
6. Insert the replacement assembly into the device and loosely tighten the Socket Head Cap Screws (SHCS) using the 2.5 mm Ball End Hex Driver.
7. Move the spectrometer around until maximum signal intensity is obtained as described in Section 5.2.
8. Tightly secure the spectrometer/baseplate assembly in the instrument.
9. Before running VideoFROGscan, connect the FROGscan device to the computer using two USB cables. Allow the device drivers for the new spectrometer to fully load before attempting to run VideoFROGscan.
10. If device drivers fail to load, please see Section 2.3, Step 37 that details how to proceed when the Ocean Optics device drivers fail to load.
11. Once drivers have installed, proceed to aligning the LASER into the new spectrometer as described in Section 5.2.



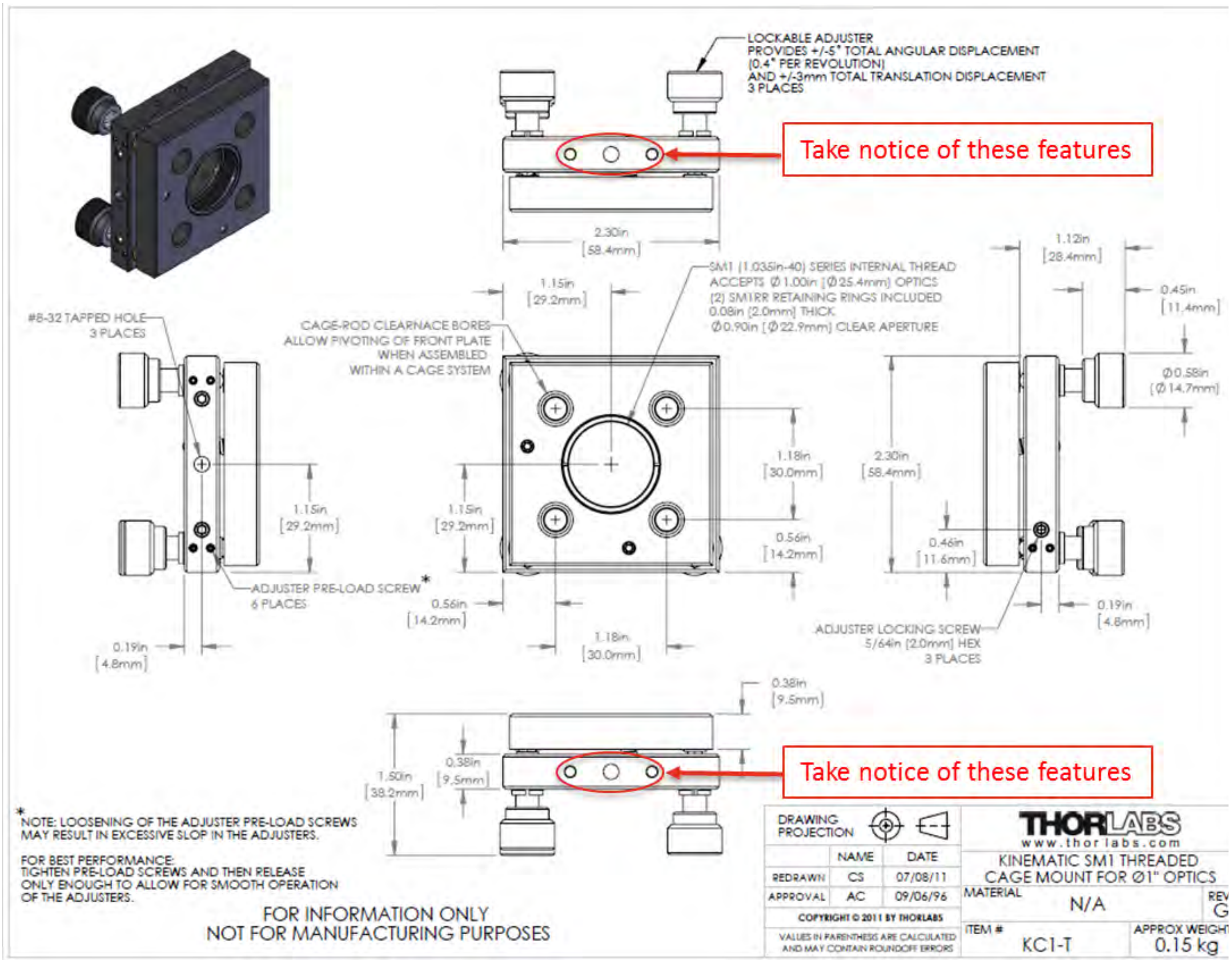
a **b**

Figure 29 a) and b). Unplugging the USB connector and b) spectrometer baseplate assembly

6.3 Installing a Reflective Fiber Collimator

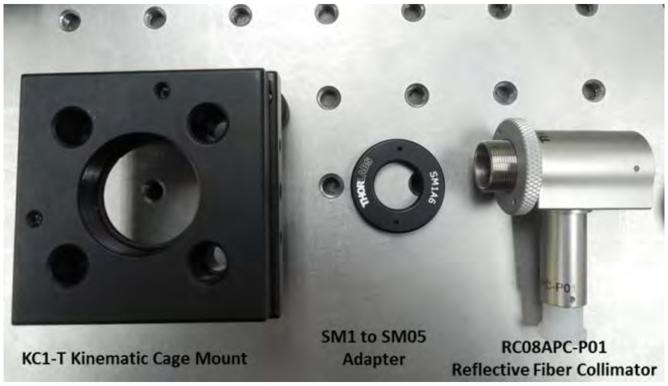
If your LASER is guided through a fiber collimator, Mesa Technologies will supply you with a kinematic mount that fits in the Thorlabs cage rod system, 4 short cage rods, an adaptor, and a fiber collimator (usually reflective).

Please view the Schematic of the Kinematic Cage Mount used to mount the Fiber Schematic Collimator to FROGscan.



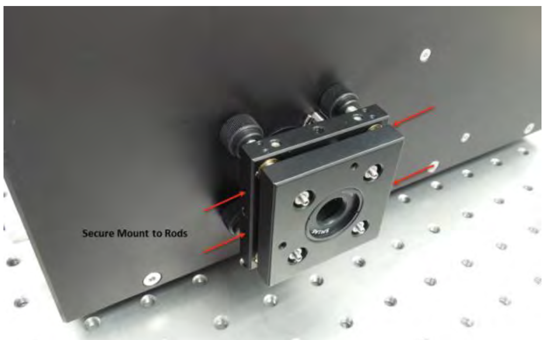
To mount the collimator, proceed as follows:

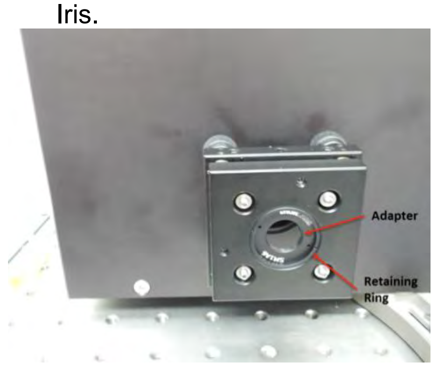
1. Ensure that the input LASER is blocked and that LASER light is not entering the FROGscan.
2. Heed all warnings and safety precautions as expressed throughout the Manual.
3. If possible, align the FROGscan in free space before adding the Fiber Coupler.



Kinematic mount that fits in the Thorlabs cage rod system, adapter, and a fiber collimator.

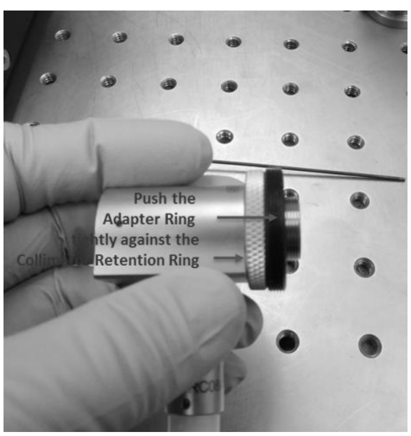
4. Install four (4) Cage Assembly Rods to the 4-40 tapped holes surrounding Entrance Iris.

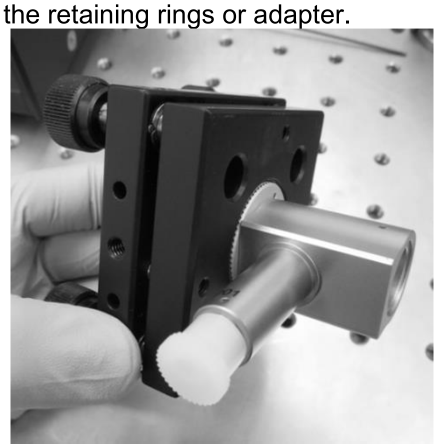




5. Secure the Kinematic Mount to the Rods by tightening the set-screws on both sides of the Kinematic Mount. Set the relative position of the adjusters so they are approximately 3mm from the Side Plate of the FROGscan.

The Adapter is installed in the mount at the factory. It is secured in place with two retaining rings and mounted such that one of the retaining rings is as close to the front of the mount as possible. Please do not change the positions of the retaining rings or adapter.

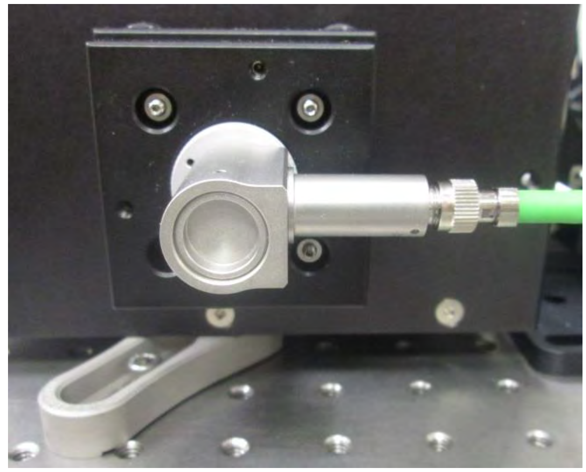




6. Tightly push the Adapter Ring against the Collimator Ring.

7. Fully install the Collimator in the Kinematic Mount. Be sure to set the correct orientation for the angled part of the Collimator such that the fiber can be easily installed when the Assembly is mounted on the FROGscan.

8. Use the Locking Ring on the Kinematic Mount to secure the Collimator in place.



9. The final assembly should look like this.

Chapter 7. Retrieving Pulses

Once the system is aligned and FROG Traces are appearing on the raw video display, pulses will be automatically retrieved by the VideoFROGscan software. Through the use of controls on the Panel, the measured FROGscan Trace can be adjusted and optimized. For best operation, the FROG Trace must be centered in the Live FROG image displayed in the Summary Panel.

7.1 Optimizing Pulse Symmetry

For the best retrievals, the FROG Trace should be centered and symmetric about the t=0 delay displayed in the live FROG Trace, Summary Panel.

If the trace is off-center along the wavelength axis, a linear phase will appear in the spectral phase. This can be quite bothersome when trying to null the phase of a pulse compressor, for example.

If the FROG Trace is not centered along the time axis, the pulse and gate will separate in time causing a loss of accuracy of the retrieved pulse. For the most accurate reconstruction, the pulse and gate should overlap perfectly.

In addition, non-symmetric live FROG Trace may cause spectral chirp in the pulse. Large amounts of spatial chirp are often observed in ultrafast optical parametric amplifiers.

If you are having problems with the FROG Trace symmetry, adjust the Overlap Mirror until the FROG Trace is symmetrical. This may result in reduced signal intensity, but smaller signals are better than inaccurate results.

7.2 Centering the FROG Trace in time

To center the FROG Trace in time, set the scan center by adjusting the servo center using Time Control on the main panel or use the automatic FROG Trace re-centering under the Data Acquisition Panel. The time center is set correctly when all of the traces overlap in the autocorrelation graph on the summary page.

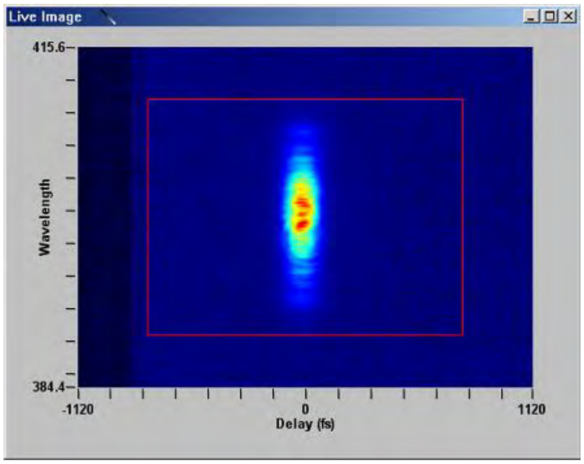
7.3 Adjusting the Grid Size

Increase the Grid Size in the Date Acquisition Panel if the pulse is so chirped that the Time Window must be increased in order to capture the entire temporal part, and the spectral portion of the FROG Trace is being clipped. Selecting the Grid Size menu item under in the Data Acquisition Panel gives access to the grid size radio buttons.

NOTE: increasing the grid size increases both the amount of time required for data acquisition and the amount of time required for convergence. While typical frame times for a 64 x 64 grid size is about 0.5 seconds for the USB2000+ spectrometer, increasing the grid size to 256 x 256 increases the frame to about 2 seconds (0.5Hz.).

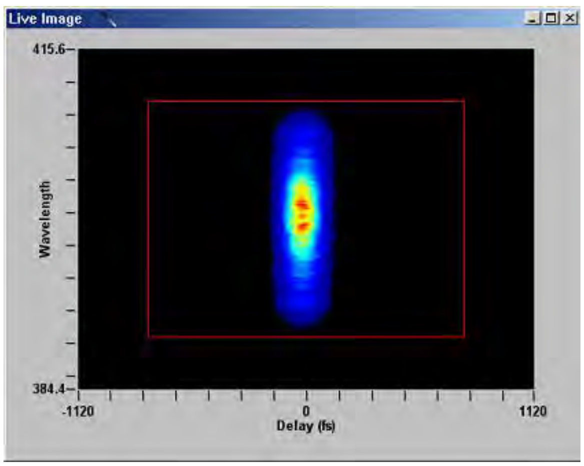
7.4 Setting the Background Level

The spectrometer has a large offset that can cause problems with retrievals unless it is removed. Indeed, background has a very deleterious effect on the retrieval of FROG Traces. If too much background is present, retrievals will appear noisy. However, if too much background is removed, the pulses will not be measured correctly and unphysical time-bandwidth products can appear. Examples of FROGscan Traces with **a**) too much background, **b**) too much clipping and **c**) good background are shown in the following Figure 30, using a diode LASER beam as an example.



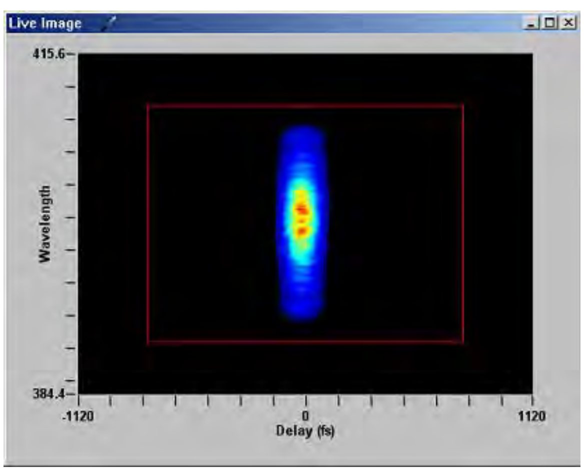
a) Too much background.

This Trace contains too much speckle (light blue) If you are unsure about the adjustment, or see what you think is too much blue speckle, error on the side of too much blue speckle.



b) Too much clipping

Because the Live View is on while the adjustment is being made, it is easy to see the change in the size of the FROG Trace while the background is being adjusted. In this case, too much background was removed, causing the FRIG Trace to become clipped.



c) Good background level

The FROG Trace is solid, not speckled and close to the main trace.

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Figure 30. FROG Traces from a diode LASER beam with different levels of background subtraction applied.

The best way to remove background is to set the background level in VideoFROGscan. This is a very important and relatively simple adjustment. Thus, it is worth a few minutes of your time to become familiar with this adjustment.

Beginning with version 6.0, VideoFROGscan includes automatic adjustment of the background, and it is suggested that you use it. However, under some circumstances, this automatic adjustment may not work properly. As a result, the background may need to be adjusted manually.

How does one know what is background and what is part of the FROG Trace? The FROG Trace will be solid, not speckled, and it will usually be close to the main trace.

Once the background adjustment is made, it will probably never have to be adjusted again unless the gain on the camera is changed or a different camera is used.

1. Go to the Summary panel and activate **Use Background Subtraction**.
2. Go to the Data Acquisition Panel. A check in the Background Filter box indicates that background subtraction it is on.
3. Click the **Background Filter** button to remove “speckle,” which causes problems with retrievals, placing noise out in the wings. This speckle is a complete artifact, and can be removed by setting the **Level** of the Background Filter to adjust the amount of speckle removed, with lower values increasing the amount of speckle removed. Lower the **Threshold** if too much of the wings of the FROGscan Trace are being removed.

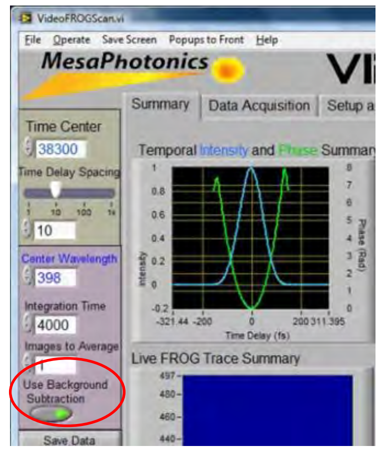


Figure 31. Screenshot of the Summary Panel with the Background Subtraction function circles in red.

4. Click **Edge Background.** This function uses an average of the right and left most portions of the FROG Trace to determine the background. It works surprisingly well. If no choice is selected, a prompt window opens to ask you to block the beam when you turn on the background subtraction.
5. The **3 Frame Background** should only be used if there is scatter from one of the beam arms into the spectrometer.
6. Remove spectral Tilt from the FROG Trace by activating the **FROG Trace tilt correction** button.

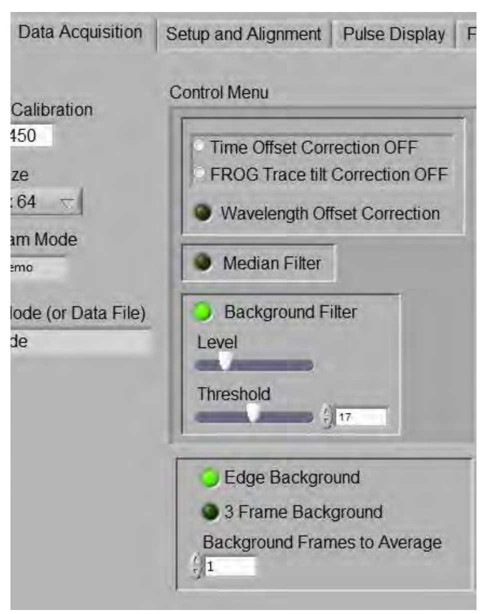


Figure 32. Screenshot of the Background Subtraction Control Menu in the Data Acquisition Panel.

To determine if the measurements are good, two different checks can be useful.

1. Check the **FROG Trace error,** although this can sometimes be misleading.

   Typically, the FROG Trace error should be below about 1-2% for small grids and less than 1% for larger grid sizes; however, if the trace is complex, the FROG Trace error might be larger than normal. Even FROG Trace errors as large as 4-5% on a 64 x 64 grid can be acceptable. However, in this case, another check should be performed to determine retrieval quality.

2. Another check for retrieval quality is to compare the measured FROG Trace (The FROG Trace fed into the algorithm) with the retrieved FROG Trace (The FROG Trace that is constructed from the retrieved pulse). The traces should be very close in general shape AND fine structure.

   If the two traces are generally close, the major features of the retrieved pulse are very likely correct. To have an excellent retrieval, the measured and retrieved FROG Traces must be very nearly exact.

Chapter 8. Warnings

The following warnings may appear in the bottom of the left panel.

8.1 Spatial Chirp

Spatial Chirp usually only occurs in amplified ultrafast laser pulses when the stretcher and the compressor of an amplifier are not well aligned. While FROGscan cannot quantitatively measure spatial chirp, it can provide an excellent qualitative indication of the spatial chirp. This is done by examining only portions of the beam and examining the retrieved spectrum. Changes in the spectrum reveal spatial chirp across the beam. Typically, these changes show up as spectral shifts, indicating that the spectral content changes across the beam, or that there is spatial chirp. Because FROGscan systems are multishot systems, they are relatively immune to the effects of spatial chirp.

8.2 Spectral Tilt

Spectral tilt occurs when the FROG trace is tilted as a function of wavelength.

Quick fix: Spectral Tilt can be removed from the FROG Trace by clicking the FROG Trace tilt correction box in the Data Acquisition Panel (Section 3.4) to on.

8.3 Pulse Front Tilt

If the FROGscan is properly aligned, and the Time Center well adjusted, the FROG Trace will be centered at t=0. If it is not centered, this warning will appear. Because FROGscan cannot actually measure pulse front tilt, this warning actually refers to a time offset that is large enough to cause problems with the pulse measurement. In a single shot FROG geometry, the time offset is caused by Pulse Front Tilt.

Quick Fix (one of the following):

Engage automatic re-centering in the top of the Left Control Panel.

Adjust the Time Center so that the FROG Trace is centered.

8.4 Wavelength Offset

When VideoFROGscan senses that the FROG Trace is off center in wavelength, the program will issue this warning. The quality of the retrieval does not suffer that much when the wavelength is off center; however, if the wavelength is too far off center, then part of the FROG Trace may be clipped, or FROGscan may not be providing the best possible FROG Traces, especially if it is operating near its bandwidth limit. If the FROG Trace is clipped, VideoFROGscan will issue another warning.

Quick Fix (one of the following):

Adjust the wavelength in VideoFROGscan.

Turn on the "Correct Central Wavelength" menu item in the Control Menu section of the Data Acquisition Panel (Checking this menu item allows the other parts of the section to be checked.) of the “Temporal Analysis” drop-down menu.

8.5 Time Offset

When VideoFROGscan senses that the FROG trace is not centered at t=0, it issues a time offset warning. This is a very important warning to correct because it affects the retrieval; in order for the algorithm to work properly, the FROG trace must be centered in time.

Quick Fix (one of the following)
Adjust the time center of the servo (best) by setting the Time Center control using the spinners at the left of the indicator (See Figure 31). Adjust this value so that all of the traces in the autocorrelation window sit on top of each other.

Turn on the time centering by clicking the Time Offset Correction on (under the Control Menu in the Data Acquisition Panel). Be sure the background subtraction is on.

8.6 FROG Trace Clipped

VideoFROGscan can sense when the FROG Trace is being vignetted or clipped. The clipping can occur either along the wavelength axis or the time axis. Clipping can, unfortunately, cause problems with both the stability and/or the accuracy of the retrieval. If the FROG Trace is being clipped temporally, then the temporal scan range can be increased. However, if this causes the FROG Trace to be clipped along the wavelength axis, then a larger grid size must be used.

<u>Quick Fix</u> (one or more of the following):

Change the shape of the FROG area to better accommodate the FROG Trace.

Use a larger grid size.

8.7 High Spatial Chirp

Spatial chirp occurs when the color varies across the spatial front of an ultrashort laser pulse, which can cause an asymmetric FROG Trace. However, FROGscan cannot detect this directly. Only single shot SHG FROG devices can detect this directly. FROGscan detects it indirectly. Because the spectral content varies across the spatial profile of the beam, if only a section of the beam is used to generate the FROG Trace, the retrieved pulse spectrum will show a spectral shift or different spectral characteristics. However, even in multishot geometries (such as FROGscan) spatial chirp can make the FROG Trace asymmetric. This occurs because the crystal may not be set at the exact focus, and the interaction at the crystal can still have spatial and hence spectral variations. Because a spatially chirped pulse is a pathological FROG Trace, the algorithm can sometimes fluctuate between two pulse lengths.

<u>Quick Fix</u> (one or more of the following):

Correct the asymmetry by adjusting the overlap between two beams at the crystal to make the FROG Trace symmetric.

Check for optics that can cause spatial chirp.

8.8 Other Warnings:

Retrieval Asymmetry, Time Calibration Warning, Frequency Calibration Warning

VideoFROGscan uses a fuzzy logic AI engine to try to diagnose abnormalities in the FROG trace and the retrieval. When abnormalities are detected, any one, or all of the above warnings (Including High Spatial Chirp) can appear. When these warning occur, the user should check to make sure:

1) The measured FROG trace is not much smaller that the retrieved FROG trace
2) The FROG trace error is not too high given the complexity of the pulse (small traces should be no more than about 1 % and large, complex traces can be several percent)
3) The retrieved FROG trace very nearly exactly matches the measured FROG trace
4) The measured FROG trace or the retrieved FROG trace are symmetric about t=0.
5) The FROG trace sets in a sea of blue (wings are near zero intensity)

If all of the above are true and you are still getting the warnings, you can ignore the warnings. The software is just doing the best it can.

8.8 Background

This warning appears either when the background was not subtracted or when settings were changed such that the background must be taken again. Sometimes, the adjustments are small enough so that that background looks OK. If this is the case, you can ignore the warning.

Quick Fix:

Re-take the background.

8.9 Software Warnings

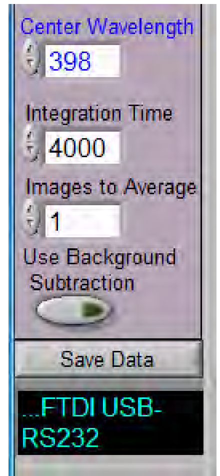
No matter how hard we try to make the software as trouble free as possible, sometimes problems still occur.

If the message **Servo Communication has failed** appears when you first start the program, and the servo power supply is not turned on, simply turn on the servo power supply, wait a moment, and click OK. The program should be able to recover communication with the servo. If the servo power supply is on, but the program has just started, click "OK" and let the program try to recover communication.

If this dialog appears during program operation, cycle the power on the servo supply, and click "OK."

Servo Communication error is a more serious error. If you press "OK" the program will loop and show the message box above again. You can try to cycle the power again, but you may have to give up and click "Exit," which exits the program. Follow the instructions in the message box, and restart the program again. Servo Communication should return.

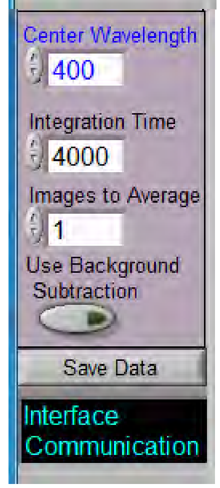
The program seems to hang while displaying the **…FTDI USB-RS232** message in the warning display. This usually happens when the program does not exit properly, and the communication systems have not closed out properly. Click the red “X” in the upper right hand corner of the VideoFROGscan program window, to completely exit the program. Restart the program. If you see this message again, click the red “X” again, but unplug (and plug back in) the servo’s USB plug before restarting the program.



The program seems to hang while displaying the **Interface Communication** message in the warning display.

This usually happens when the program does not exit properly, and the communication systems have not closed out properly. It may take a minute or two, but the software usually regains communication at this point, and the program will operate normally.

If not, click the red “X” in the upper right hand corner of the VideoFROGscan program window to completely exit the program. Unplug (and plug back in) the servo’s USB plug before restarting the program to cycle the power in the microcontroller and reset it. Communication should start normally.



Integration time too low

The minimum integration time for a given spectrometer depends on the spectrometer. For a USB2000+ or Flame spectrometer it is 1 ms; For HR2000+ and HR4000, it is 1 ms; for a QEPro, it is 8 ms; for a Maya2000 Pro it is 7.2 ms. If a value less than the minimum value is entered in the left panel, VideoFROGscan will hang up.

<u>Quick fix</u>

Click the QUIT/escape button on the top right of each Panel. If this does not resolve the issue, enter a higher integration time, then exit VideoFROGscan, and shut down the computer.

Chapter 9. Customization

9.1 Data Pipes

VideoFROGscan supplies access to "pipes" to access the retrieved pulse and resampled trace while the program is running in real-time. This allows running concurrent programs that have access to the data. These could be error analysis, database, or a variety of other programs such as those used to save data in any chosen format. These programs are easily written in LabView using the supplied VIs to monitor the specific data required. Included in the VideoFROGscan/LabView folder is an example LabView VI that monitors the retrieved pulse and the resampled FROG Trace.

9.1.1 Using the data pipe
Usually, the end goal of using real-time measurement of ultra-short laser pulses is not just to look at the pulses. We want to use the information gained from the pulse measurement to either learn something new about the system or to control our experiment in some way. To do so, we must have real-time access to the data in addition to the ability to conduct visual inspections of the retrieved pulses. It is unrealistic, however, to expect any software program to be exactly what we need for a given experiment, and software is almost impossible to customize.

To get around the need to customize the program, real-time access to the retrieved pulse and the original resampled FROG Trace is provided in the form of a DLL that can be called from any program that is running simultaneously. VideoFROGscan has been designed with the sharing of computer resources in mind. LabView runs very well with VideoFROGscan, as do other programs. All that is required is to minimize the VideoFROGscan program and run your application that uses the functions provided in the PCGPMonitor DLL. For your convenience, LabView VIs that call this DLL are provided with the VideoFROGscan software. If you have LabView, you can check the calling sequence for any of the functions in the DLL. For those of you who do not have LabView, full documentation of the DLL calls are provided in Appendix C.

11.1.1 LabView Vis

PCGPTestPipe.vi: This LabView VI tests to see if the memory-mapped file is available and if the PCGPMonitor DLL is working properly.

PCGPMonitorPulseWidth.vi: This LabView VI returns the pulse width from the memory-mapped file.

PCGPGetSize.vi: This LabView VI returns the size of the FROG Trace from the memory mapped files. Use this call to get the size of the FROG Trace for memory allocation.

PCGPMonitorPulseParams.vi: This LabView VI returns the pulse statistics displayed in the parameter display window to the right of the raw video display.

PCGPGetPulseandGate.vi: This LabView VI returns the retrieved pulse and gate from the memory-mapped file.

PCGPSpecMonitor.vi: This LabView VI returns the resampled FROG Trace from the memory-mapped file. The pulse and gate retrieved from PCPGPulseMonitor.vi are retrieved from this FROG Trace.

Chapter 10. Literature

Papers:

1. Measuring ultrashort laser pulses in the time-frequency domain using frequency-resolved optical gating
   Rick Trebino, Kenneth W. DeLong, David N. Fittinghoff, John N. Sweetser, Marco A. Krumbügel, Bruce A. Richman, Daniel J. Kane
   Review of Scientific Instruments 68, 3277 (1997); https://doi.org/10.1063/1.1148286

2. Simultaneous measurement of two ultrashort laser pulses from a single spectrogram in a single shot
   Daniel J. Kane, G. Rodriguez, A. J. Taylor, and Tracy Sharp Clement
   J. Opt. Soc. Am. B 14(4) 935-943 (1997)

3. Real-time inversion of polarization gate frequency-resolved optical gating spectrograms
   Daniel J. Kane, Jeremy Weston, and Kai-Chien J. Chu
   Appl. Opt. 42(6) 1140-1144 (2003)

4. Convergence test for inversion of frequency-resolved optical gating spectrograms
   Daniel J. Kane, Fiorenzo G. Omenetto, and Antoinette J. Taylor
   Opt. Lett. 25(16) 1216-1218 (2000)

5. Principal components generalized projections: a review [Invited]
   Daniel J. Kane
   JOSA B Vol. 25, Issue 6, pp. A120-A132 (2008) •https://doi.org/10.1364/JOSAB.25.00A120

6. Characterization of arbitrary femtosecond pulses using frequency-resolved optical gating
   D.J. Kane ; R. Trebino
   IEEE Journal of Quantum Electronics (Volume: 29, Issue: 2, Feb 1993)

7. Real-time measurement of ultrashort laser pulses using principal component generalized projections
   D.J. Kane
   IEEE Journal of Selected Topics in Quantum Electronics (Volume: 4, Issue: 2, Mar/Apr 1998)

8. Recent progress toward real-time measurement of ultrashort laser pulses
   D.J. Kane
   IEEE Journal of Quantum Electronics (Volume: 35, Issue: 4, Apr 1999)

Patents:

9,423,307	Method and apparatus for determining wave characteristics using interaction with a known wave
8,068,230	Real-time measurement of ultrashort laser pulses
7,130,052	Real-time measurement of ultrashort laser pulses
6,219,142	Method and apparatus for determining wave characteristics from wave phenomena
5,754,292	Method and apparatus for measuring the intensity and phase of an ultrashort light pulse

Chapter 11. Appendices

Appendix A: Pinout for Analog and Digital I/O

Pin Number	Pin Name	Notes
1	Analog Channel 1 +	16-bit A/D differential input (+) +/- 2V max
2	Analog Channel 1-	16-bit A/D differential input (-)
3	Analog Channel 2+	16-bit A/D differential input (+) +/- 2V max
4	Analog Channel 2-	16-bit A/D differential input (-)
5, 6	Analog Ground	Analog ground for position
7	Position In +	Differential input for analog position signal (+) +/- 4V
8	Position In -	Differential input for analog position signal (-)
9	Position Out	Actual position out. +/- 4V
10	Position Out CMD	Commanded position out, Internal DAC + analog position input.

Table A1: Analog I/O Pinout (10 pin IDC connector)

Pin Number	Pin Name	Notes
1	Frame Out	Pulses high when a data set is complete
2, 4	+5V	+5V from the Computer USB
3	Trigger Ready	High when a trigger can be accepted
6, 8, 10, 12, 14	DIG GND	GND to the Computer USB
5	Servo Ready	High when servo has settled (Optical Delay Line only)
7	Trigger In	Accepts a trigger (Not yet implemented on FROG)
9, 11, 13	Digital I/O	Digital channels that can be set or read via software.

Table A2: Digital I/O Pinout (14 pin IDC connector)

Appendix B: File Formats of Saved Data

Raw Video (Use drop down menu)
File Name Format: Specified name in the file dialog.raw
File Format: Calibration and wavelength axis is stored in a proprietary format. The FROG Trace is stored as single precision float (32 bit).

Standard Data files ("VideoFROGscan Menu" "Save Data" and "Log Data").
FROG Trace (resampled)
File Name Format: FROGTrace (date and time).txt
File Format: ASCII, space delimited
CR, LF after every row of the FROG Trace. Rows are time delay, columns are wavelength. No header, no time or frequency axis.

Pulse (retrieved) Data Files (3 different files, all have the same pulse, but in different formats and/or domains)
Pulse_Time_Domain (date and time).txt – Time domain retrieved pulse
File Format: ASCII, space delimited
Three columns of data:
Time axis (in femtoseconds)
Time domain intensity
Time domain phase

Pulse_Freq_Domain (date and time).txt – Frequency or Spectral domain retrieved pulse
File Format: ASCII, space delimited
Four columns of data:
1) Frequency axis (in Petahertz)
2) Wavelength axis (in nanometers)
3) Spectral intensity
Spectral phase
Pulse_Complex_Time_Domain (date and time).txt – Complex (real and imaginary) version of the time domain retrieved pulse
File Format: ASCII, space delimited
Three columns of data:
1) Time axis (in femtoseconds)
2) Real part of the time domain pulse
3) Imaginary part of the time domain pulse

Gate (retrieved)
File Name Format: GATE(date and time).txt
File Format: ASCII, space delimited
Three columns of data:
Time axis
Real part
Imaginary part
No spectral data for the gate is stored because the gate is equal to the pulse in SHG FROG and is equal to the intensity of the pulse in the case of PG FROG.

Appendix C: Function Reference for the PCGPMonitor DLL

General "C" code header file code for accessing the PCGPMonitor DLL calls

extern "C" double __stdcall __declspec(dllexport) GetPulseWidth(void);

extern "C" int __stdcall __declspec(dllexport) GetSize(void);

extern "C" void __stdcall __declspec(dllexport) ReturnPulseParams(double *);

extern "C" void __stdcall __declspec(dllexport) ReturnPulse(double *, double *, double *, double*, double*);

extern "C" void __stdcall __declspec(dllexport) ReturnPulsewAParams(double *, double *, double *, double*, double*, double *);

extern "C" void __stdcall __declspec(dllexport) ReturnPulseandGatewAParams(double *, double *, double *);

extern "C" void __stdcall __declspec(dllexport) ReturnSpec(double *);

extern "C" void __stdcall __declspec(dllexport) GetIntensityandPhase(double *, double *, double *, double*, double*, int);

Function Descriptions:

double __stdcall GetPulseWidth(void)

Calling sequence:

None.

This subroutine returns the pulse width.

int __stdcall GetSize(void)

Calling sequence:

None.

This subroutine returns the size of the FROG Trace.

void __stdcall ReturnPulseParams(double *PulseParams)

Calling sequence:

PulseParams is a pointer to a 4 element double float array to receive all of the pulse parameters.

This subroutine is void (returns nothing). All data is passed in the previously allocated double array.

void __stdcall ReturnPulse(double *pulse, double *tdI, double *tdP, double *fdI, double *fdP)

Calling sequence:

pulse is a pointer to double float array, double (64 bit float) of length 2 times the pulse size to receive the complex raw, retrieved pulse.

tdI is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the time domain pulse intensity.

tdP is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the time domain phase.

fdI is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the frequency domain intensity (pulse spectrum).

fdP is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the frequency domain phase.

This subroutine is void (returns nothing). All data is passed in the previously allocated double arrays.

void __stdcall ReturnPulseandGatewAParams(double *pulse, double *gate, double *axisparams)

This function returns the raw pulse and the raw gate together with the axis parameters. The axis parameters is an array of six (6) doubles that contains, in the following order, the time axis spacing, the start value of the time axis, the end value of the time axis, the frequency axis spacing, the start value of the frequency axis, and the end value of the frequency axis.

Calling sequence:

pulse is a pointer to double float array, double (64 bit float) of length 2 times the pulse size to receive the complex raw, retrieved pulse.

gate is a pointer to double float array, double (64 bit float) of length 2 times the pulse size to receive the complex raw, retrieved gate.

Axisparams is a pointer to an array of six doubles that contains the axis parameters as described above.

void __stdcall ReturnPulsewAParams(double *pulse, double *tdI, double *tdP, double *fdI, double *fdP, double *axisparams)

This function returns the raw pulse, the time domain intensity and phase, and the frequency domain intensity and phase as well as the axis parameters. See ReturnPulse and ReturnPulseandGatewAParams for the calling sequence.

void __stdcall ReturnSpec(double *Spec)

Calling sequence:

Spec is a pointer to double float array, double (64 bit float) of length isize*isize to receive the spectrogram used in the inversion.

This subroutine is void (returns nothing). All data is passed in the previously allocated double array.

void __stdcall GetIntensityandPhase(double *pulse, double *tdI, double *tdP, double *fdI, double *fdP, int N)

This function returns the intensity and phase in the time and frequency domain when provided a raw, complex vector pointed to by pulse. N is the number of complex values in the pulse. Because the pulse is a double, the complex values are stored as real and imaginary pairs where the even indices, starting with 0, are the real values and the odd indices are the imaginary values.

Calling sequence:

pulse is a pointer to double float array, double (64 bit float) of length 2 times the pulse size to send the complex raw, pulse for calculations

tdI is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the time domain pulse intensity.

tdP is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the time domain phase.

fdI is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the frequency domain intensity (pulse spectrum).

fdP is a pointer to a double array of length of the FROG Trace size (returned from GetSize) to receive the frequency domain phase.

N is the length of the complex pulse vector (N complex values = 2*N double values).

This subroutine is void (returns nothing). All data is passed in the previously allocated double arrays.

Appendix D: Warranty

Term and Coverage:

For a period of twelve (12) months from the date of shipment (the “Instrument Warranty Period”), we warrant that our instruments are free from defects in materials and workmanship (the “Warranty”). During the Instrument Warranty Period, except otherwise indicated by us in a quotation, we will provide the following services at no additional charge:

- For customer replaceable parts: parts
- For return-to-factory service: parts, labor, and cost of return shipping if requested by Mesa Photonics, LLC. The costs and expenses related to de-installation and re-installation shall be the responsibility of the customer.

Exclusions:

The following are not covered under our Warranty:

1. Crystals and optics are covered for a period of 90 days and are not warranted against laser damage, abuse, or damage caused by non-laboratory environments.
2. Mesa Photonics’ instruments may contain precision components. These components are not warranted against damage caused by non-laboratory environments or abuse.

Warranty on Service and Spare/Replacement Parts:

We warrant the services we perform and the spare and replacement parts we install, for a period of ninety (90) days from the date of performance of such services and the date of installation of the spare or replacement part, respectively. All repairs completed during the Instrument Warranty Period are covered for the remainder of the Instrument Warranty Period or 90 days from date of service, whichever is longer.

Warranty on Our Software:

We warrant that our licensed software, for a period of ninety (90) days from the date our software is received by the customer, shall perform substantially in accordance with the standards set forth in the user documentation related to such software. Our software Warranty, however does not extend and shall not apply to the extent that any breach of such Warranty is caused by the licensed software being: (a) not used in accordance with the user documentation supplied by us; (b) used in combination with any program material not licensed by us; (c) modified by the customer; or (d) used with equipment other than the designated equipment for such software.

Additional Exclusions and Limitations:

i) The Warranty excludes any equipment or accessories which are identified on applicable price lists, quotation, or special promotional materials for which our Warranty may be further limited. Included in the category are items which are sold at specially reduced prices with reduced Warranty protection (in some cases, extended Warranty protection may be available for purchase).

ii) The Warranty does not cover loss, damage, or defects resulting from: transportation to the customer’s facility, improper or inadequate maintenance by the customer, customer supplied software, interfacing, or parts, unauthorized modification or misuse, operation outside of the environmental specifications for the instrument, and/or improper site preparation of maintenance.

iii) The Warranty applies only to instruments within the country of original delivery.

iv) Except in the case of an authorized distributor, authorized in writing by us to extend the Warranty to distributor’s customers, the Warranty applies only to the customer as the original purchaser from us and may not be assigned, sold or otherwise transferred to any third party.

Appendix E: Calibration Sheets

Appended in the following are screenshots and calibration sheets for your instrument.

FROGscan Calibration Sheet

Servo Calibration Sheet

VideoFROGscan screen captures

Spectrometer Wavelength Calibration Sheet

Spectrometer Linearity Test Sheet

Hollow Retroflector Calibration Sheet (where applicable)