Thorlabs recently acquired the Chromatis Dispersion Measurement System from KMLabs, and this manual is currently being reviewed. Please refer to the website for the most up-to-date information.

Instruction Manual

Chromatis

Version 1.2 , November 2015

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1. Device description, principles, and capabilities

Chromatis is a white light interferometer (WLI) designed to measure the dispersion characteristics of reflective and transmissive optics. The WLI itself can be implemented as a simple interferometer as shown in Figure 1.

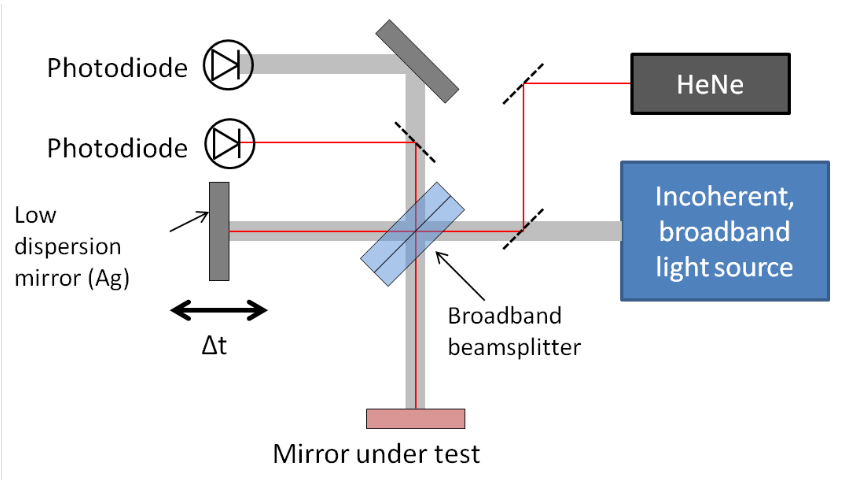


Figure 1 - White Light interferometer – A broadband, temporally incoherent light source (such as a halogen bulb) is collimated and sent through an interferometer consisting of a broadband, low dispersion beamsplitter, and two delay arms. One arm (reference arm) uses a low dispersion mirror, while the other arm (test arm) contains the test mirror. The time delay (Δt) between the two arms is scanned across $\Delta t = 0$. In the regions around $\Delta t = 0$, the white light signals from each arm interfere with each other, giving an interference pattern that is detected by a photodiode and recorded by a computer. A coherent source (HeNe laser) is co-propagated with the white light to serve as a distance reference for the time delay scan. The HeNe fringes are recorded on a separate photodiode.

The white light interference pattern contains information about the relative phases of the light from the test arm and the reference arm. A computer is used to process the interference pattern and extract the phase and dispersion properties of the mirror under test. This device also can measure the dispersion of a transmissive sample by replacing the test mirror with a low dispersion mirror and placing the transmissive sample in the beam path.

Chromatis directly measures the phase of the optic under test and converts the phase to dispersion through numerical derivatives:

$$Phase = \varphi$$

$$Group\ Delay = \frac{\partial\varphi}{\delta\omega}$$

$$Group\ Delay\ Dispersion = \frac{\delta^2\varphi}{\delta\omega^2}$$

…

More in-depth information can be found in: S. Diddams and J. Diels, "Dispersion measurements with white-light interferometry," J. Opt. Soc. Am. B 13, 1120-1129 (1996).

This method of dispersion measurement is very versatile because only a single element detector is needed for the white light measurement and automatic wavelength calibration is built-in because of the HeNe optical reference. This means that a dispersion measurement can be made at any wavelength that you can provide a broad bandwidth source and a detector. In addition, an increase in real resolution is obtained by scanning over a longer delay.

There are some practical limitations to this measurement. Chromatis uses a fiber-coupled white light source, which simplifies the optical setup but introduces some wavelength limitations. Typical fiber optic cables attenuate more in the visible and greatly in the UV. In addition, the white light source was chosen to provide the broadest measurement bandwidth possible and to provide a smooth spectral curve. The white light source in Chromatis allows easy characterization of mirrors designed for Ti:sapphire (around 800 nm), Yb:fiber (around 1030 nm), and Er:fiber (around 1550 nm). The output spectrum from the white light source tapers off greatly in the visible and has no light output below 360 nm. With the typical configuration of Chromatis, the Si detector package can measure from 600-1080 nm (500-1100 nm with reduced specs) while the InGaAs detector package can measure from 900-1650 nm.

In addition, real world measurement issues like light noise, amplifier noise, and digitization put a limit on the amount of time delay you can scan before the integrated noise becomes greater than the signal. Chromatis uses low noise components, but the time delay scan still is limited to less than ~5000 fs (resolution of about 0.5 nm at 800 nm center wavelength). At this level, absolute noise is very high; however, most optics do not require this extreme resolution. Optics that do require this resolution have very large dispersions and the relative noise is still very low (GDD noise/GDD value). At more moderate resolutions (5 nm is ideal for most optics), both the absolute and relative noise is low and standard deviations of less than 5 fs^2 are typical over most of the measurement range for only a few scans. The Chromatis interface has built-in averaging so that the effects of this noise can be reduced simply by increasing the number of scans.

2. Instrument Overview

The Chromatis instrument is designed to be easy to use. There are three separate user-swappable fixtures that enable four different measurement types, discussed in detail in the next section. Figure 2, Figure 3, and Figure 4 show an overview of the Chromatis instrument head.

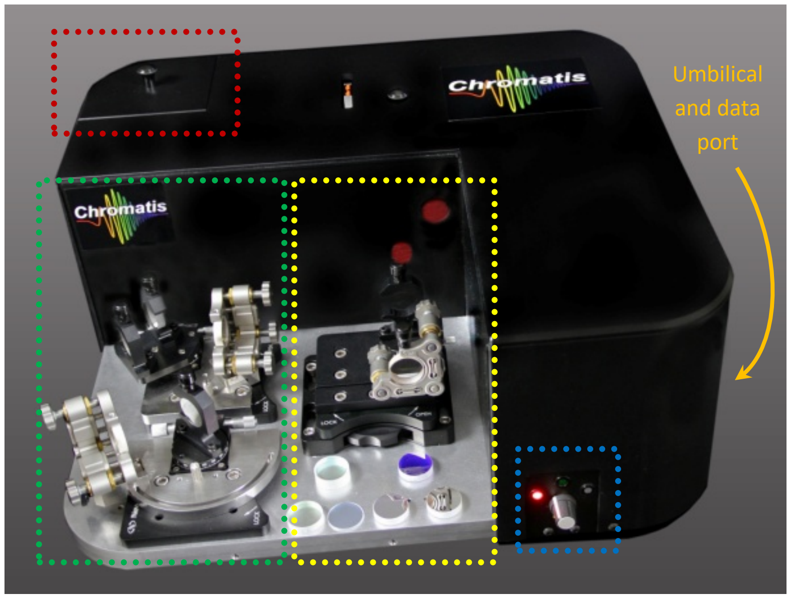


Figure 2 – Chromatis instrument head. The fixture being used for the current measurement is installed in the measurement area (outlined in yellow). The other fixtures are locked to the baseplate in the fixture storage area (outlined in green). The detectors are contained in a user-accessible section (outlined in red), and two detector options are available. The light selection switch also is shown on the front of the device (outlined in blue). The umbilical and data port is on the side indicated by the arrow.

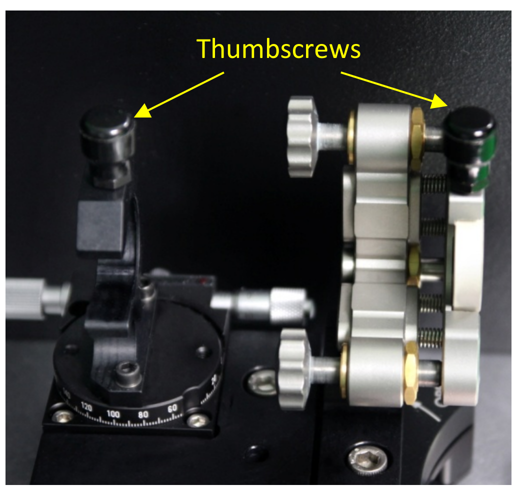


Figure 3 – All of the user mounted optic positions have thumbscrews for easy tool-less operation. The thumbscrews contain spring-loaded nylon tips to provide the right amount of mounting force on the optics. Optics mounted without thumbscrews should not be removed or replaced without checking with KMLabs.

Figure 4 – Umbilical and data port. This panel also contains the instrument on-off switch. The on position is denoted by "**I**" and the off position is denoted by "**O**". The silver cable is the fiber optic cable carrying the light from the various light sources to the instrument head. The black D-sub connector provides power and control for the various components of Chromatis. The USB Motor and Data connections are plugged directly into the included laptop computer.

The electronics for Chromatis are contained within a rack-mountable 2U enclosure, which also can operate free-standing. There only is one user-serviceable component within the electronics enclosure: the white light source bulb. See "

Appendix B – White light bulb replacement" for instructions on how to replace the white light bulb. There is a power switch in the back of the electronics enclosure (Figure 5) that should remain on unless the instrument is being moved or the bulb is being replaced. When Chromatis is not in use, turn the instrument off using the on-off switch on the instrument head (shown in Figure 4), but leave the power supply on-off switch in the On position. Leaving the power supply on ensures that the motor position does not have to be re-established each time the instrument is used.

Figure 5 – Chromatis power supply front (upper picture) and back (lower picture). The power supply on-off switch is next to the power cord plug. The umbilical cables plug into the Fiber Out and Power Out ports.

3. Measurement Procedure

Chromatis Alignment and Fixture Overview

Chromatis is designed to enable easy and fast measurements of mirrors and transmissive optics in four different modes of operation: **0 degree reflection**, **transmission**, **angled reflection**, and **mirror pair reflection**. These fixtures are mechanically registered and easily swappable. There are three separate fixtures that provide these different measurements, as described below.

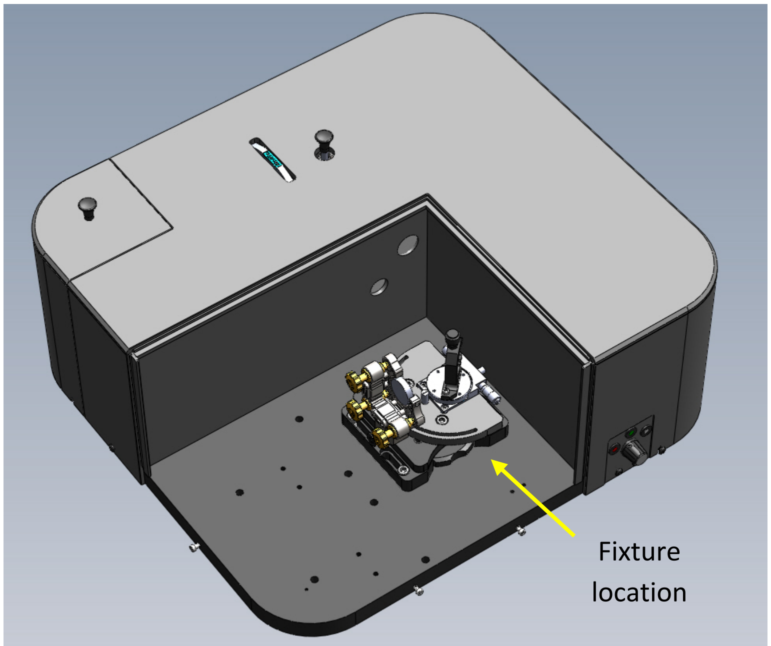


Figure 6 – Chromatis measurement head showing fixture measurement position. There are three fixtures that are interchangeable and allow different measurement modes.

Figure 7 – Fixture locking and unlocking occurs through rotation of the locking wheel in the fixture baseplate. Rotate the wheel to the left to lock a fixture into place, and rotate the wheel to the right to unlock a fixture for removal from the baseplate.

IMPORTANT – No tools are necessary to change fixtures. Do not remove the fixture baseplate or loosen any of the screws affixing the baseplate to the instrument breadboard.

0 degree and transmission fixture

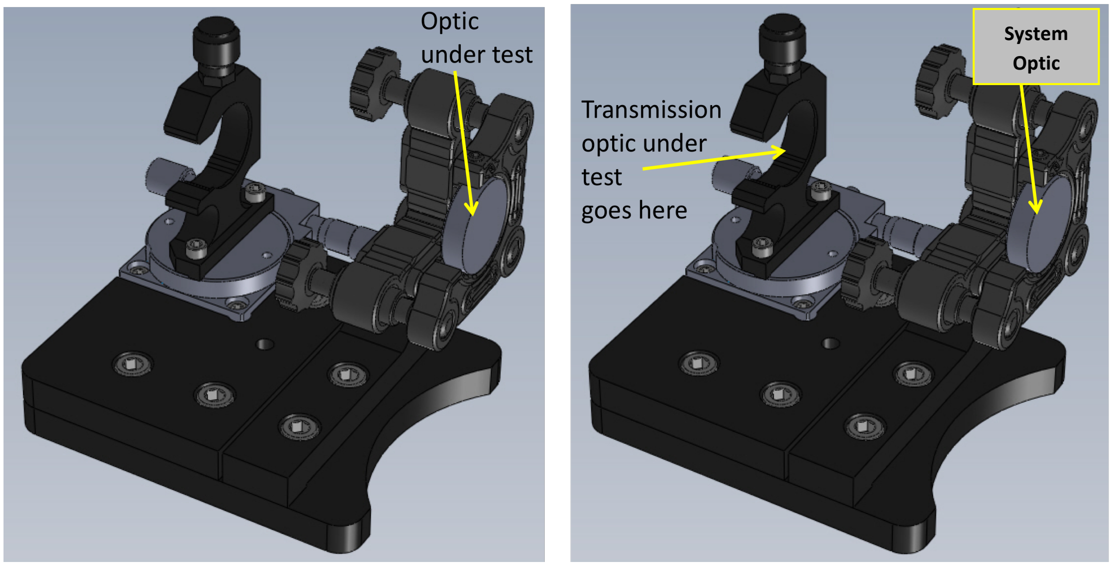


Figure 8 - Fixture designed for measurement of either a reflective optic at 0 degrees angle of incidence (left picture), or a transmissive optic at 0-70 degrees angle of incidence (right picture).

Angle of incidence reflection fixture

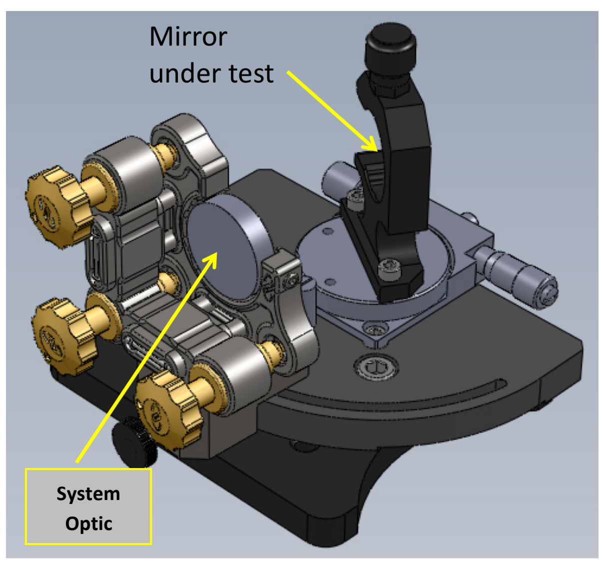


Figure 9 – Fixture for the measurement of a reflective optic at a user defined angle of incidence. The optic is placed in a front-surface-registered mount (black) and the angle of incidence is read off of the scale on the rotation stage. The system optic is then positioned to reflect the measurement light back into the device for analysis.

Mirror pair fixture

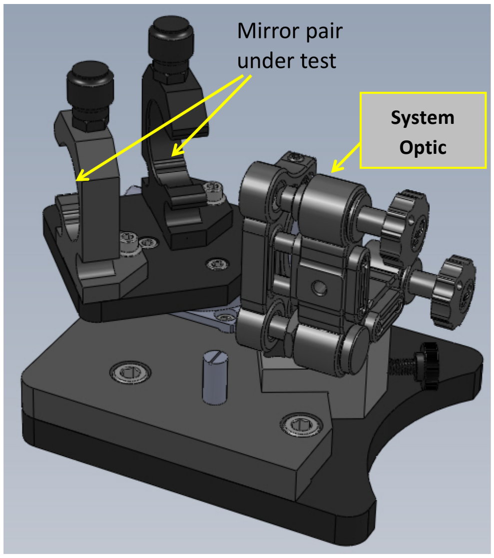
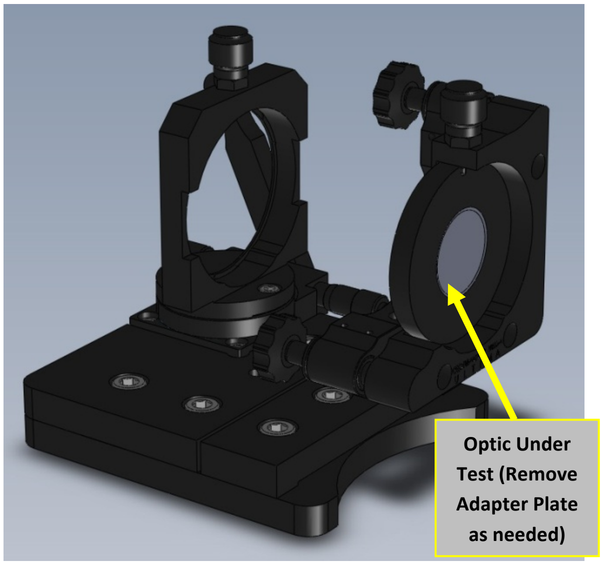


Figure 10 – Fixture for measurement of complimentary mirror pairs. Both mirrors are placed in the fixed mounts on the rotation stage and the angle of incidence is selected by the user. The system optic is then moved to reflect the measurement light back into the instrument for analysis.

2-inch 0 degree and transmission fixture



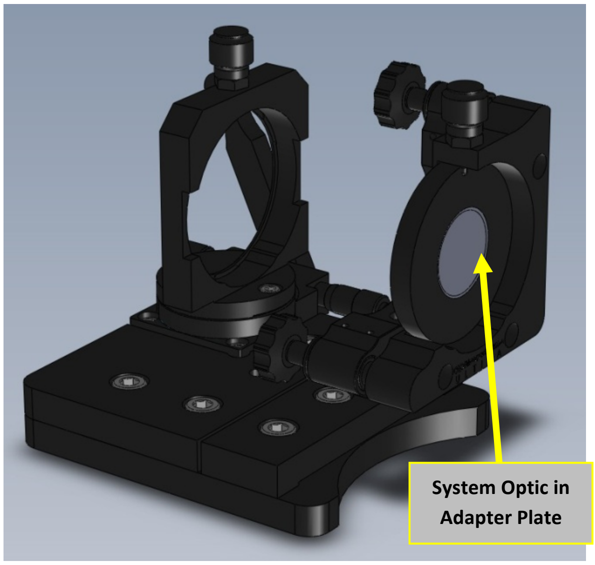


Figure 11 - Fixture designed for measurement of either a reflective optic at 0 degrees angle of incidence (left picture), or a transmissive optic at 0-70 degrees angle of incidence with the system optic in a 2-inch adapter plate (right picture).

2-inch Angle of incidence reflection fixture

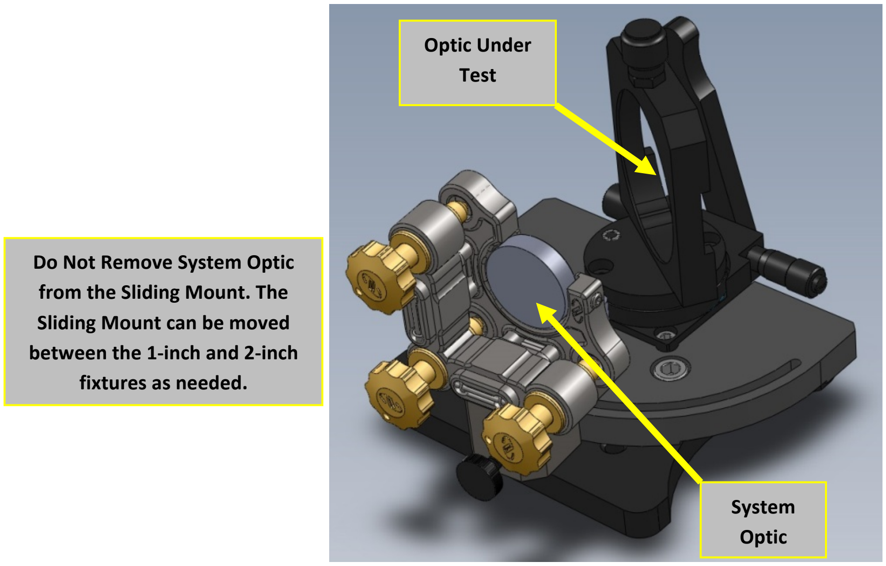


Figure 12 - Fixture for the measurement of a reflective optic at a user defined angle of incidence. The optic is placed in a front-surface-registered mount (black) and the angle of incidence is read off of the scale on the rotation stage. The system optic is then positioned to reflect the measurement light back into the device for analysis.

Optical alignment with software guidance

The Chromatis software is designed to guide the user through each type of measurement in a step-by-step way. The main software home screen has options for the four types of measurements.

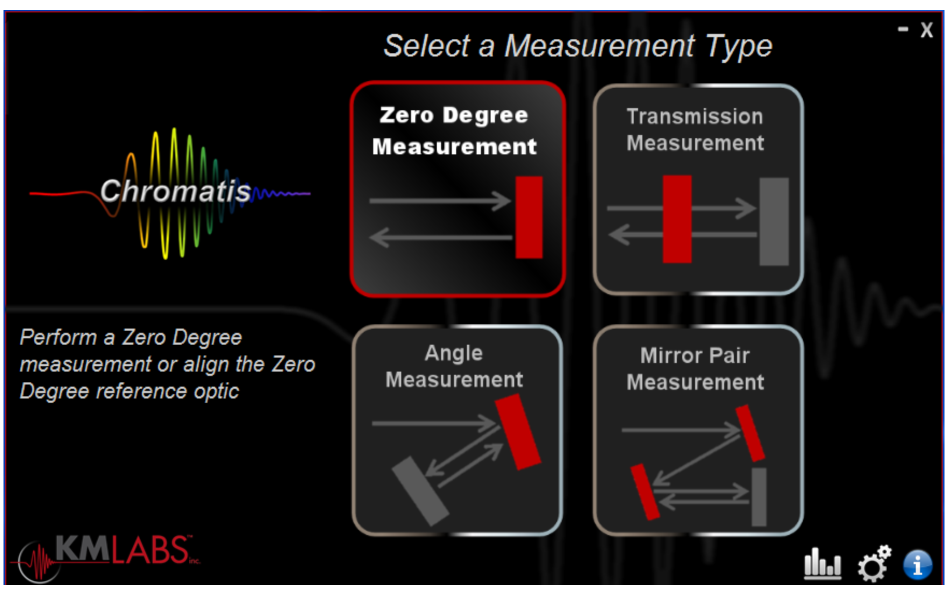


Figure 13 – Home Screen of Chromatis software. The four measurement types are available for selection.

Clicking on any of the four measurement types will open a screen where you can select between a reference optic measurement (used to verify the correct operation of Chromatis) and a test optic measurement (to measure the optic under test).

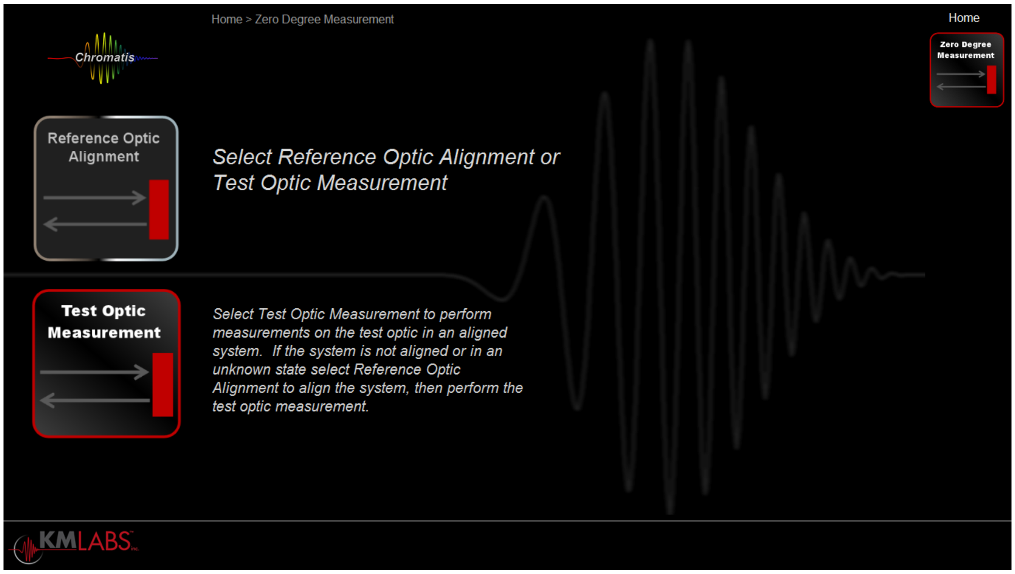


Figure 14 – Each measurement has two possible procedures: Reference Optic or Test Optic. Reference Optic Alignment is used to verify that the instrument is operating properly with a known "reference" optic. Test Optic Measurement is used to measure any other optics.

Within the test or reference instructions is a step-by-step procedure with on-screen instructions. The user can navigate through these instructions by clicking the "Next" and "Back" buttons. Completed steps will have a checkmark by them.

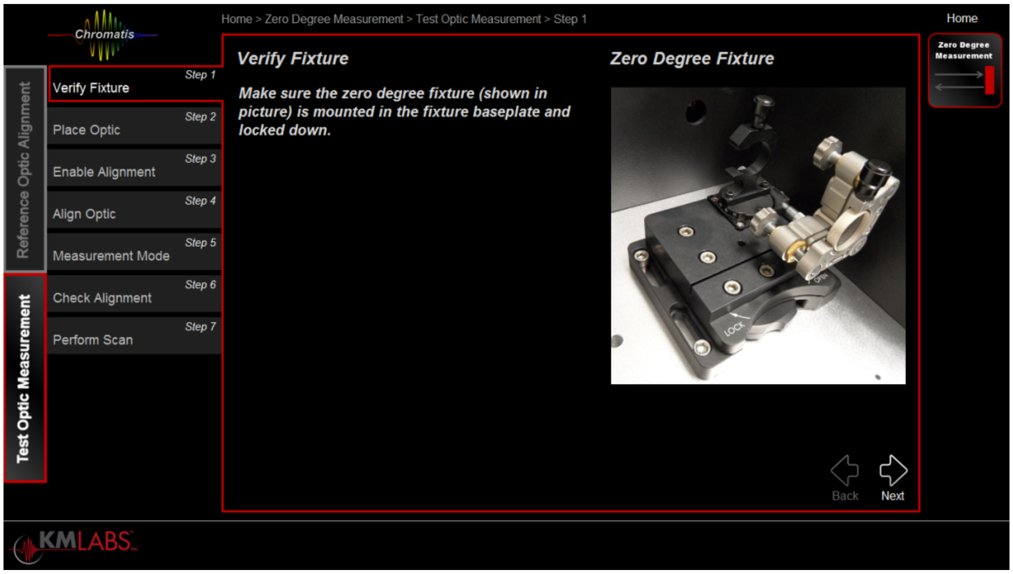


Figure 15 – Measurement instructions with "Next" and "Back" buttons in the bottom right. Follow the on-screen instructions to perform a measurement. At any time in the procedure, you can click "Home" in the top right and go back to the Home screen. At this time, skipping steps is not enabled.

The general steps for a typical optic measurement are:

1. Place correct fixture and optic in Chromatis
2. Align the optic under test
3. Software automatically finds the zero delay position around which measurements take place
4. Final alignment at the zero delay position
5. Take data and measure the dispersion of the optic under test

Of these steps, the second step is the most difficult to master, so we have devoted several instruction screens to help the user obtain the proper alignment.

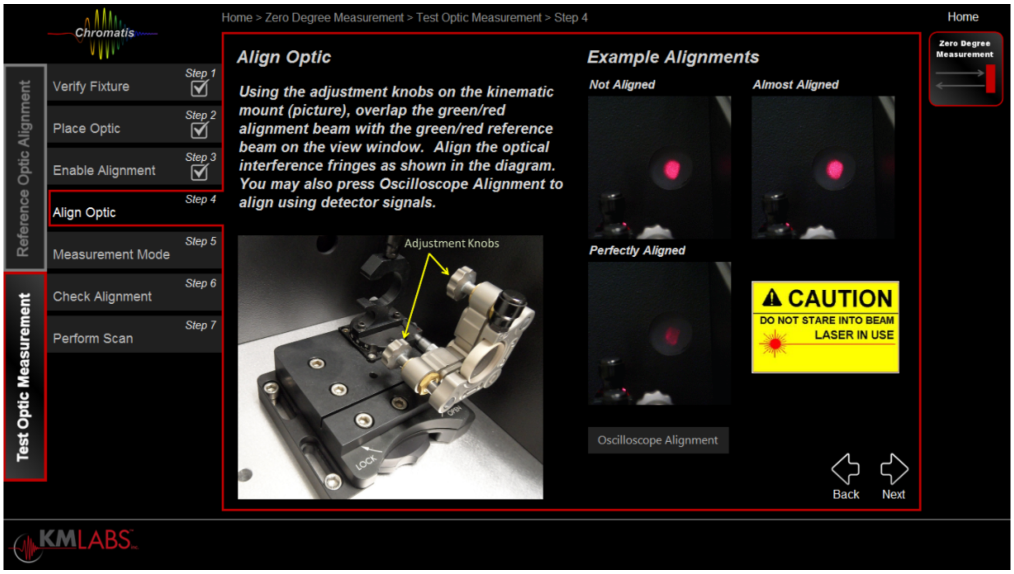


Figure 16 – Alignment instructions. An animation on the right hand side shows what the fringes should look like when close to optimum alignment while the picture on the left shows which alignment knobs to adjust. If visual alignment is too difficult for a user, "Oscilloscope Alignment" may be selected. This changes the screen to a view of the detector signals.

The first few alignment instruction screens assist users in performing the visual alignment step. Step 4 shows the alignment knobs that need to be adjusted and an animated example of what the optical fringes should look like on the view screen. There are three cases, overlapped but no fringes, some fringes, and the perfect fringe pattern (shown in Figure 16). Step 4 also contains a separate alignment method, accessible by clicking "Oscilloscope Alignment".

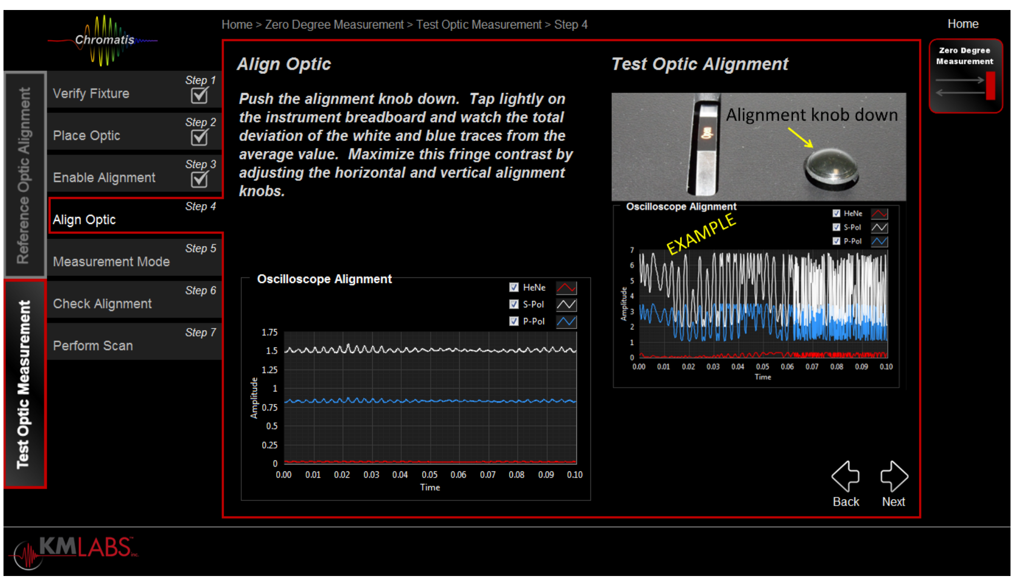


Figure 17 – Oscilloscope alignment screen. The user can use the oscilloscope signal to optimize the alignment of the optic under test if the visual alignment is difficult.

After the alignment is optimized, clicking next will cause the software to search for the zero delay position (the position around which data is taken). Once this process is complete, the software will display a pop up window that allows the user to test whether zero delay was found correctly. Basically, if zero delay was found correctly, tapping lightly on the instrument baseboard will cause oscillations in the white light signals that only happen at zero delay.

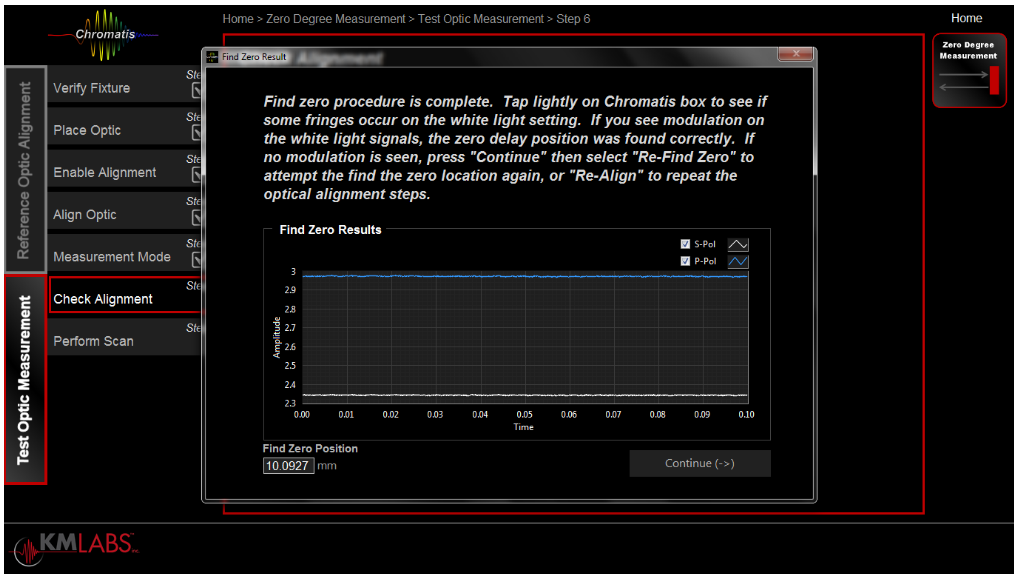


Figure 18 – Find zero results popup screen. This screen allows the user to determine if the zero delay position has been found correctly. At zero delay, the white light will interfere, causing detectable oscillations.

If zero was found correctly, advancing will take the user into the Scan step. The software takes a reference scan at the last saved scan parameters to allow the user to verify that interference signals are being detected. The results are shown upon entering the Scan screen.

Figure 19 – Results of the initial scan showing interference patterns are detected properly (bottom right). The user now can choose the scan settings that are appropriate for the optic under test.

If the initial scan looks good, the user should set the scan settings to values appropriate for the optic under test. The wavelength range should be set for the region of interest, and the time range should be set so that the whole interference pattern is captured. The resolution of the wavelength points is inversely proportional to the time range and also depends on the center wavelength as shown in Table 1. Low dispersion optics like protected silver or most simple quarter-wave-stack mirrors generally only require 150 to 500 fs to capture the whole interference pattern. In general, the smaller the time range, the smaller the noise. High dispersion optics generally require 500 to 2000 fs to capture the whole interference pattern. There is not one time range setting that is optimal for every optic. A good procedure is to start with a small time range, then increase the time range until the dispersion features do not change any more. A series of different interference patterns showing correct and incorrect Time Range settings are shown in Figure 20, Figure 21, and Figure 22.

Table 1. Wavelength resolution for various Time Range settings

Time Range	Δλ at 600 nm	Δλ at 800 nm	Δλ at 1064 nm	Δλ at 1550 nm
150 fs	8.01 nm	14.23 nm	25.18 nm	53.43 nm
250 fs	4.80 nm	8.54 nm	15.10 nm	32.06 nm
500 fs	2.40 nm	4.27 nm	7.55 nm	16.03 nm
1000 fs	1.20 nm	2.13 nm	3.78 nm	8.01 nm
2000 fs	0.60 nm	1.07 nm	1.89 nm	4.01 nm
4000 fs	0.30 nm	0.53 nm	0.94 nm	2.00 nm

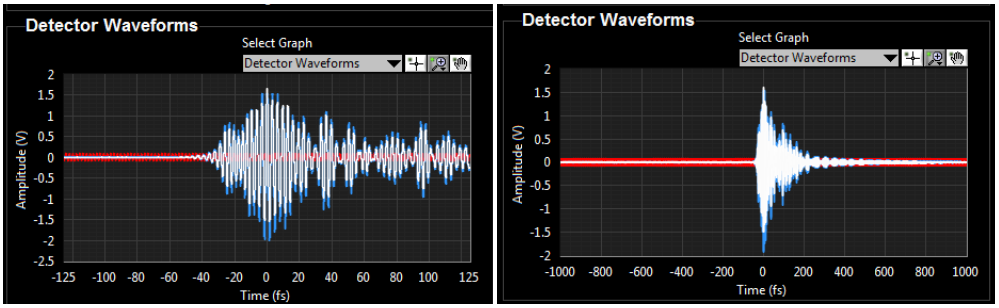


Figure 20 – High dispersion optic interference pattern. The left interference pattern uses a Time Range of 250 fs and does not capture the entire interference pattern. A time range of 1000-2000 fs is appropriate for this high dispersion optic (2000 fs shown in right graph).

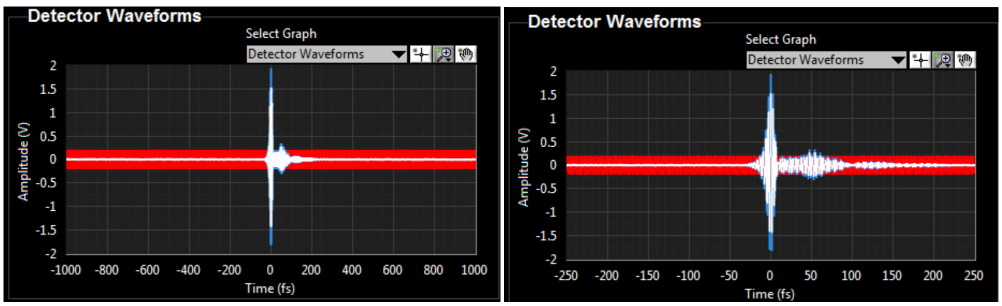


Figure 21 – Quarter-wave stack reflector at 800 nm center wavelength. Too long of a time scan (left graph) will cause excess noise in the measurement. A time range of 250-500 fs is appropriate for this optic (500 fs Time Range shown to the right).

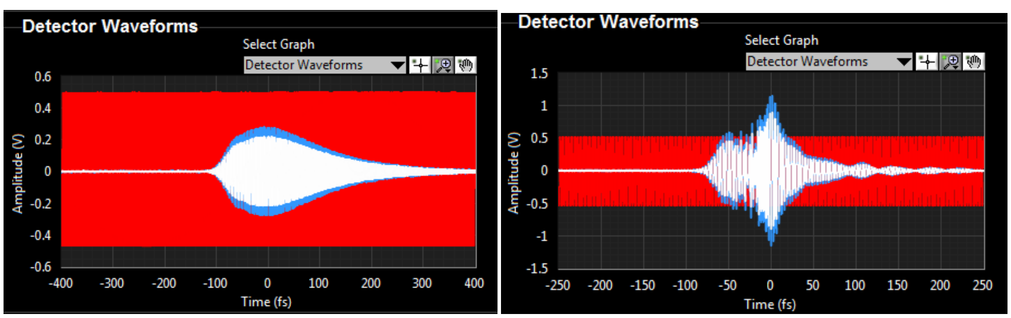


Figure 22 – Two more interference patterns with appropriate time delays. The left graph shows the interference pattern for a 3 mm thick piece of fused silica for a Time Range of 800 fs. The right graph shows a chirped mirror designed for the visible at a 500 fs Time Range.

Once the appropriate time range and wavelength range has been set, the user should start a scan (by clicking Start Scan) with the desired number of averages. 5-10 averages is a good place to start, and more averaging can be added as necessary. As the system takes data, the GDD graph is updated in real time with the average result (white line) and the standard deviation of the measurements (blue fill) as shown in Figure 23. After the scan is complete, the user can select which data to display by selecting from the drop down menus for each graph (Figure 24). All the graphs are editable, so you can change the scale to your liking.

Figure 23 – The results of a completed scan are shown. The data is shown in white, with the standard deviation of the data shown with blue fill (plus and minus one standard deviation).

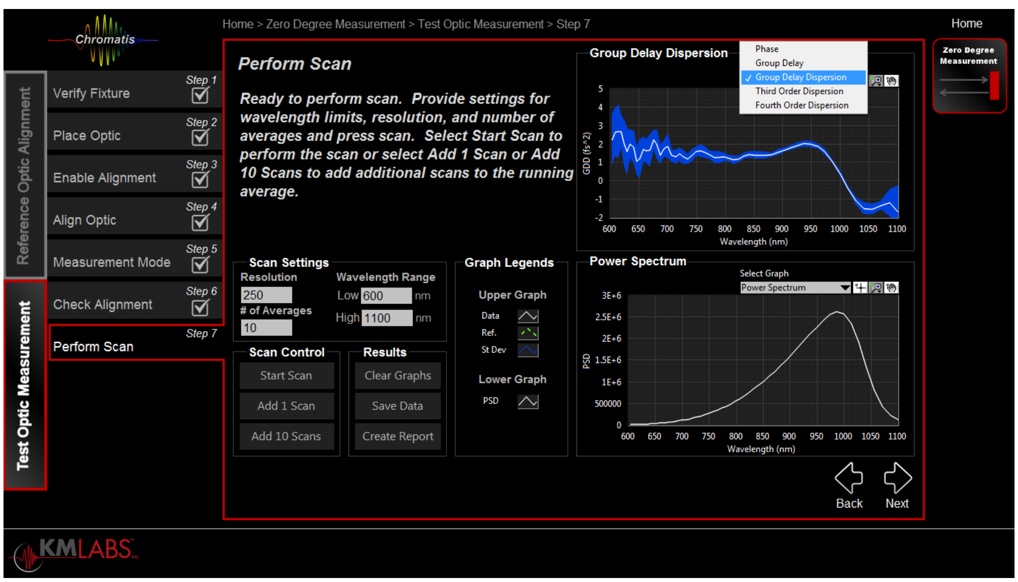


Figure 24 – Different graphs can be selected for display by choosing from the drop down menus above each graph.

Once the data is satisfactory, clicking "Save Data" will open a dialog box where the user can save all the data from the run in a .CSV file. The file contains column headers so it can be imported easily into many data analysis programs. Saved along with the .CSV file is a .TXT file containing any user-specified notes as well as the scan settings for that data set. Clicking "Create Report" opens a screen where the user can select six graphs for display at one time (Figure 25). This custom report can be saved as a JPEG or printed.

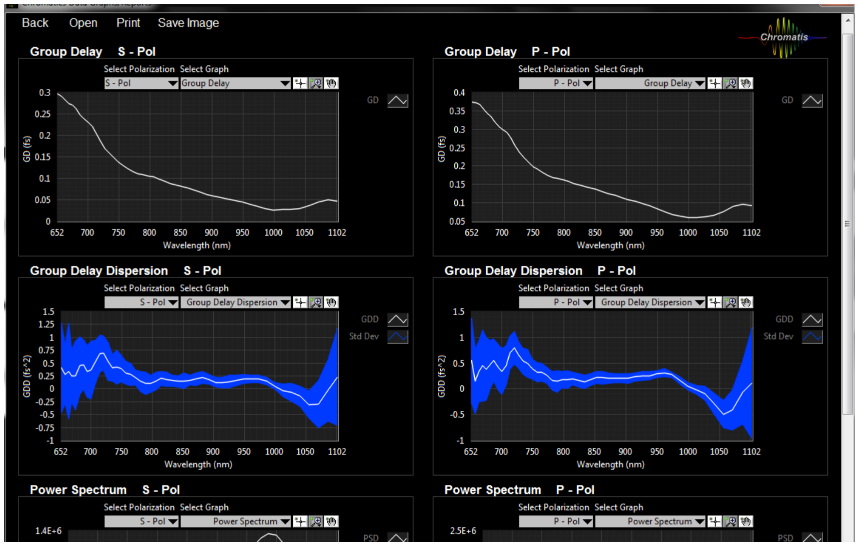


Figure 25 – Report generation feature where six graphs can be displayed at once. These graphs can be printed or saved as a .JPEG file.

These reports also can be generated from previously saved data by clicking the "Load Previously Saved Data" button on the Home screen (Figure 13). This concludes the instructed measurement walk-thru.

Optical alignment without software guidance (Advanced Panel)

The Chromatis software provides step-by-step instructions for how to align each measurement fixture for the current optic under test. However, you can choose to use the advanced panel to make measurements without step-by-step instructions (Figure 26).

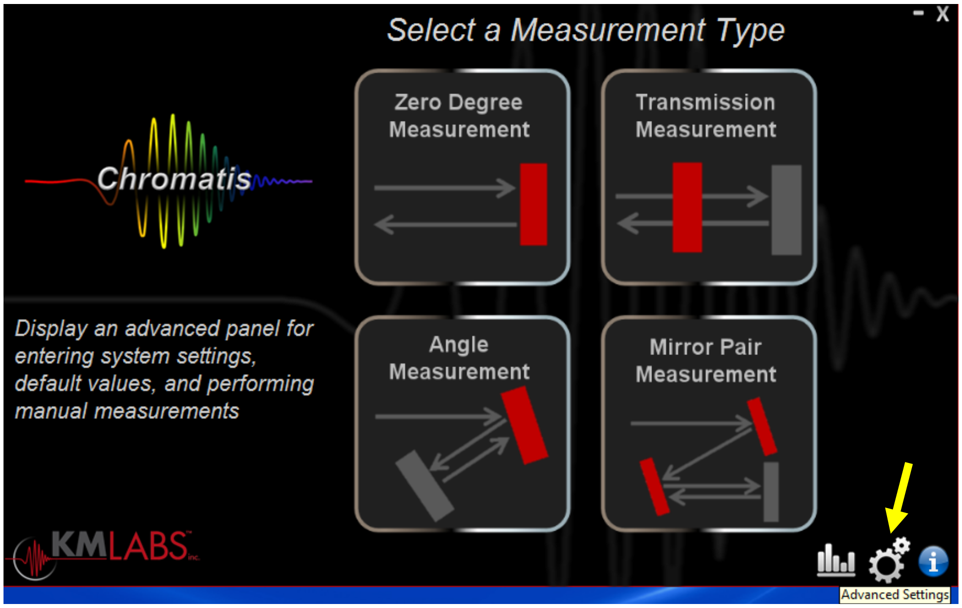


Figure 26 – Home Screen with yellow arrow pointing to location of Advanced Settings button. Clicking this button will take you to the Advanced Panel where settings can be modified and measurements can be made without going through step-by-step instructions.

The advanced panel has 4 different tabs that allow you to modify the settings of the instrument and view data without going through the step-by-step instructions.

Configuration Settings Tab

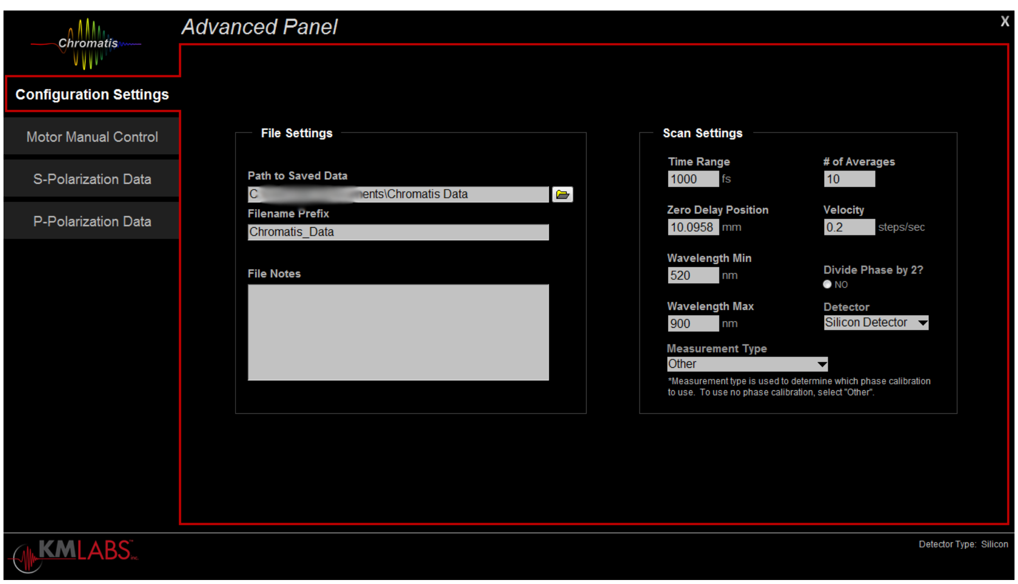


Figure 27 – Configuration settings screen. Advanced users can use this screen to manually set some of the Chromatis hardware and software parameters.

The file settings options change the default software configuration for saving data.

Path to Saved Data: This path is the default path that will open when the user clicks the "Save Data" button.

Filename Prefix: This value will be the default name that is used for saving data (along with a time/date stamp). This could be useful to set if the same type of optic is being measured multiple times.

Notes: Use this field to add text to the Notes text file that is saved along with each data file.

The scan settings options change the default software configuration for saving data.

Time Range, # of Averages, Wavelength Min, Wavelength Max: These settings can be set here or in the measurement screens in both the S-polarization/P-polarization tabs and in the Scan step of the measurement walk-thrus.

Zero Delay Position: This is the current value of the zero delay position. This value can also be edited in the Motor Manual Control tab, or can be found automatically with the Find Zero function in the Motor Manual Control tab or in the measurement walk-thrus.

Velocity: This changes the speed at which the motor travels during a measurement scan. Only very advanced users should change this from its default value (0.2 mm/s). Changing this value can help reduce noise in some cases.

Measurement Type: Allows the user to select which measurement type they are performing, so that the correct calibration file is used. The user also can choose to use no calibration file.

Divide Phase by 2?: Selects whether the phase/dispersion calculation should be divided by two. For angled reflection, mirror pair, and transmission measurements, the optic under test is reflected off of or transmitted through twice and this value should be enabled. For zero degree reflection measurements, the optic only is reflected once, and this value should be disabled.

Detector: Allows the user to select which detector is in use so that the program uses the correct calibration file.

Motor Control Tab

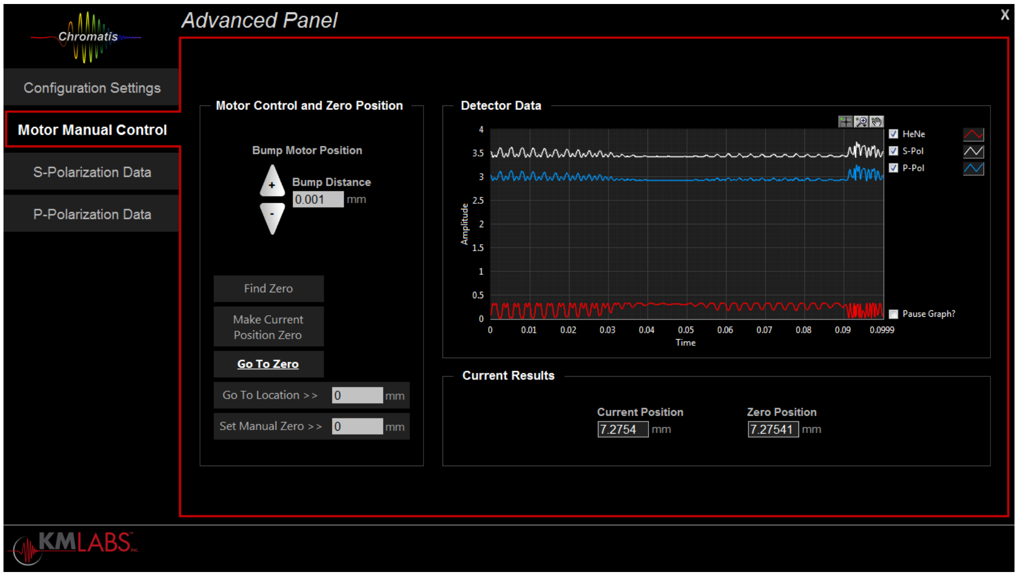


Figure 28 – Motor control tab. The user can manually move the motor and watch the photodetector signals live.

The motor control tab lets the user watch the photodiode signals while manually moving the motor. The user can run the Find Zero process, set the zero position manually, go to a location, and bump the motor arbitrary steps in either the forward or backward directions.

S-Polarization Tab

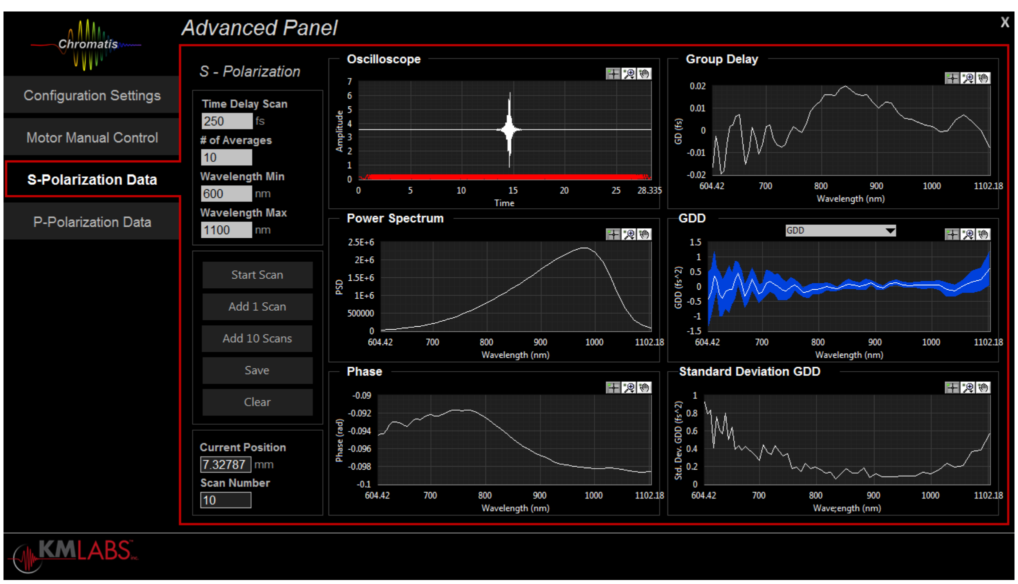


Figure 29 – S-polarization tab. The data from the S-polarization detector is displayed in this tab.

The S-polarization tab displays data from the S-polarization detector. There are six graphs displaying various information. The dispersion graph can be changed from GDD to TOD or FOD. The scan settings are just like in the measurement walk-thrus. Data can be saved by clicking the “Save” button.

P-Polarization Tab

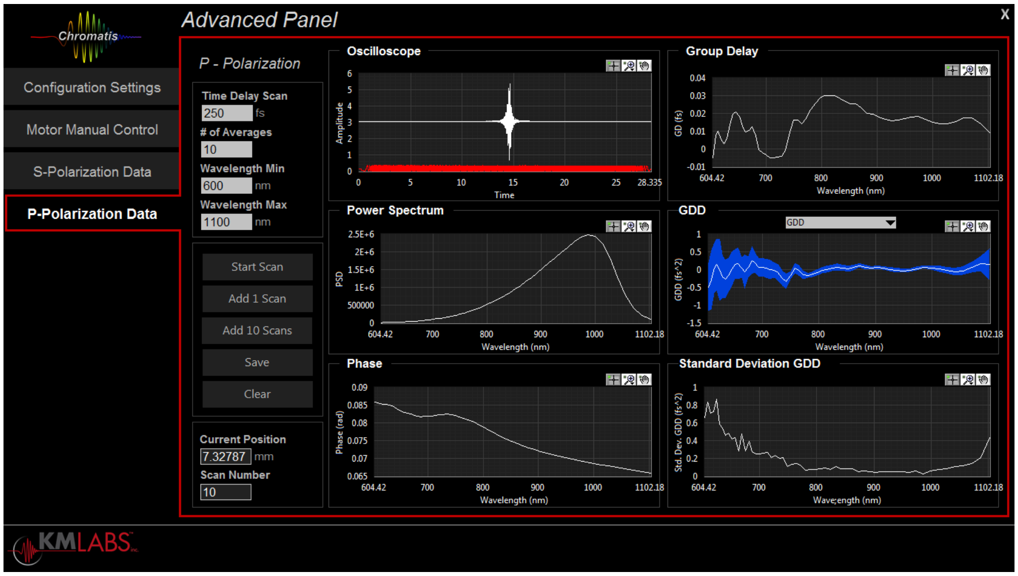


Figure 30 – P-polarization tab. The data from the P-polarization detector is displayed in this tab.

The P-polarization tab displays data from the P-polarization detector. There are six graphs displaying various information. The dispersion graph can be changed from GDD to TOD or FOD. The scan settings are just like in the measurement walk-thrus. Data can be saved by clicking the “Save” button.

4. Reference Optics and Calibration

Chromatis is provided with reference optics so that the user can verify the instrument is working as it was at the factory.

Table 2 – Reference optics provided for each measurement mode

Measurement Mode	Reference Optic(s)
Zero Degree Reflection	Bare gold mirror
Transmission	3 mm fused silica (measured at 0 degrees AOI)
Angled Reflection	Bare gold mirror (measured at 45 degrees AOI)
Mirror Pair Reflection	2x bare gold mirrors (measured at 20 degrees AOI)

The software provides measurement walk-thrus for the reference optics that provide step-by-step instructions for measuring each of the reference optics. The reference optics do not need to be measured very often.

Chromatis also is factory calibrated to remove any residual dispersion from system optics. Although we have chosen very low-dispersion elements, there is still some small amount of residual dispersion imbalance that is calibrated out. Basically, the dispersion is measured at the factory for each fixture under a null dispersion measurement condition (GDD being measured == 0). For example, for the transmission fixture, we simply put no optic in the transmission optic mount. The reflection fixtures are calibrated with a reflection off of an uncoated bulk dielectric interface.   Contact KMLabs if you have any questions about the calibration of your Chromatis.

5. Wavelength Selection Filters and Detector Gain Setting

For some optics, it is helpful to restrict the wavelength range under test with optical filters. This can reduce the total time range over which the interference pattern needs to be scanned, reducing total noise. Because some of the light is attenuated, the detector gain setting should be increased by one step when using these filters (Figure 31). Some examples of optics that would benefit from this filtering are transmissive optics in the visible and near IR and high dispersion optics with small wavelength ranges of interest. In certain cases, the filters can increase the signal-to-noise ratio in the lower end (below 600 nm) of the Silicon detector range, improving the standard deviation of the measurement.

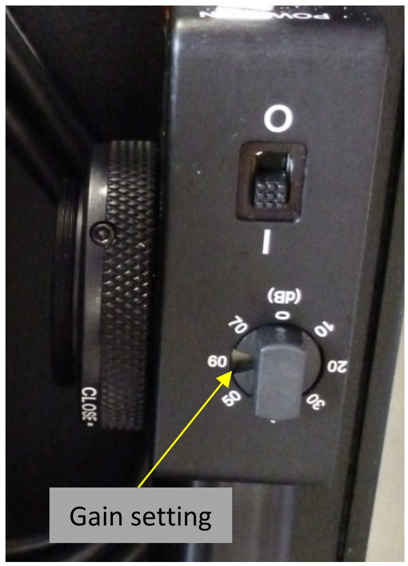


Figure 31 – View of the detector gain setting. The Silicon detectors generally operate at 60 dB when the filter select wheel is set to “Open” and 70 dB in other cases.

Chromatis comes standard with 3 filters for the Silicon detector. There are 6 total filter positions available, so two more filters positions are available for future use (one position needs to remain open to let all the light through). The filters are labeled with approximate wavelength ranges over which measurements should be performed, as shown in Figure 32.

Figure 32 – Pictures of the four wavelength selection filter positions. Each position rotates one filter into the white light beam path. The filter labels indicate the approximate wavelength ranges that can be measured with each filter and the Silicon detector. Open indicates no filter.

Appendix A – Changing Detectors

Chromatis is available with two different user-replaceable detector modules: Silicon and InGaAs. To switch between the two detector modules, follow this procedure:

1. Loosen, but do not remove completely, the screws holding the detector module cover in place (Figure 33).
2. Remove the detector module cover by pulling up on the knob shown in Figure 33.
3. Disconnect the power and signal cables from each detector as shown in Figure 34.
4. Remove the detector module mounting screw using a 5 mm Allen wrench (Figure 35).
5. Pull upwards on the detector module to remove from the baseplate. There are precision pins that register the module to the baseplate that might require some wiggling to disengage.
6. Place the other detector module into the same position, making sure the precision pins go in straight.
7. Replace the detector module mounting screw and tighten using a 5 mm Allen wrench.
8. Reconnect the electrical and signal cables to the two detector modules.
9. Replace the detector module cover. It is not necessary to retighten the screws.
10. Go to the Advanced Settings in the software (Figure 26) and change the detector to the module you have installed (Figure 36).

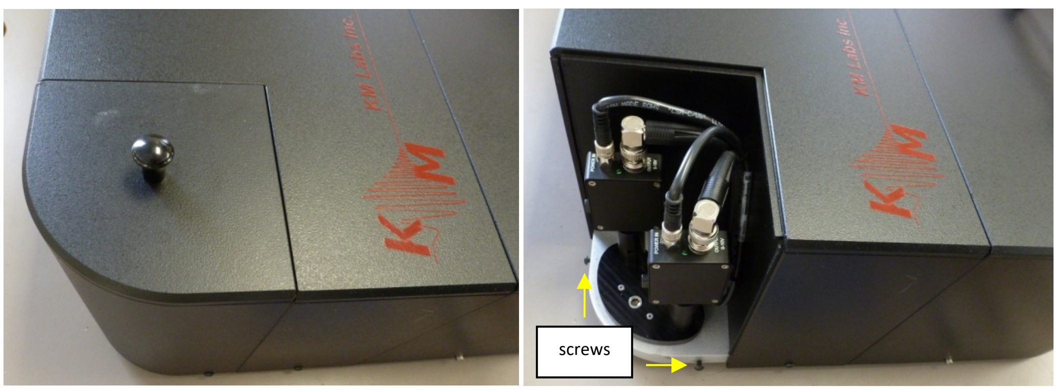


Figure 33 – Pictures showing the closed detector housing cover (left) and open detector housing cover (right). To remove the cover, loosen but do not fully remove the screws indicated in the picture to the right.

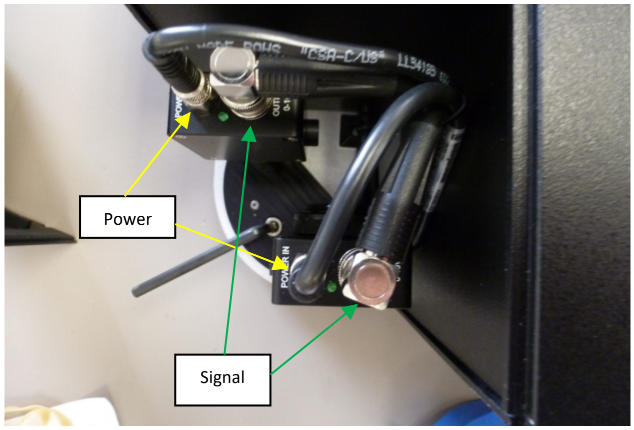


Figure 34 – Top view of detector electrical and signal connections. Unscrew the power connectors from each photodiode and disconnect the BNC signal cables before removing the detector module. Make sure the signal cables remain in the same relative positions when re-attaching them to the detectors.

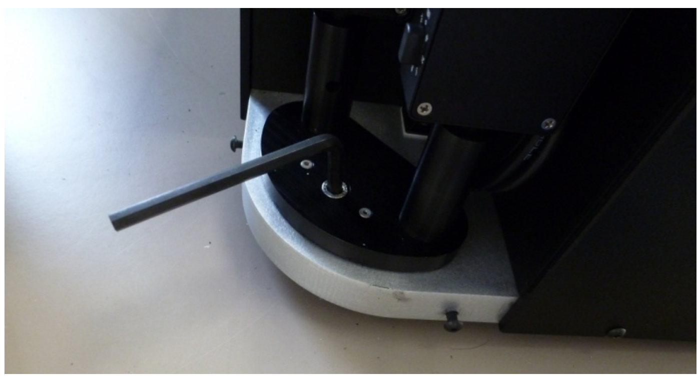


Figure 35 – Use a 5 mm Allen wrench to unmount the detector module from the baseplate. Fully remove the screw before removing the detector module.

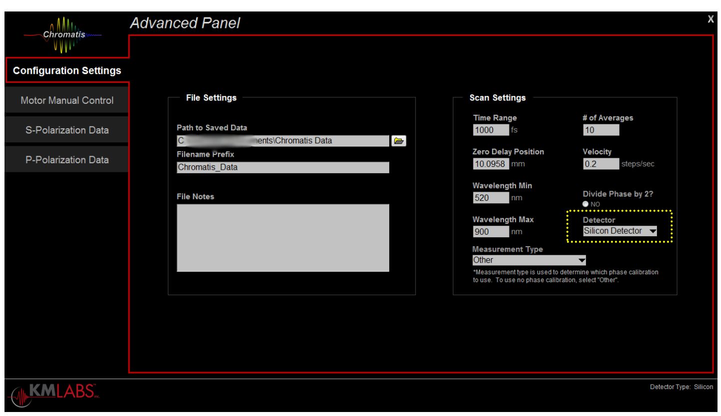


Figure 36 – To change the detector in the software, go to the advanced panel and change the value of Detector (highlighted in yellow) to either Silicon Detector or InGaAs detector (whichever you are using currently).

Appendix B – White light bulb replacement

The first step to replacing the white light bulb is to turn off the instrument and the Chromatis power supply unit. First turn the instrument ON/OFF switch to OFF (denoted by **O**, seen in Figure 4). Next, turn the power to the Chromatis power supply unit off and disconnect the power cable (Figure 5). If the white light has been operational within the last 20 minutes, allow the bulb to fully cool by waiting 20 minutes after disconnecting the power. Finally, open the lid to the Chromatis power supply unit by unscrewing the four screws shown in (Figure 37).

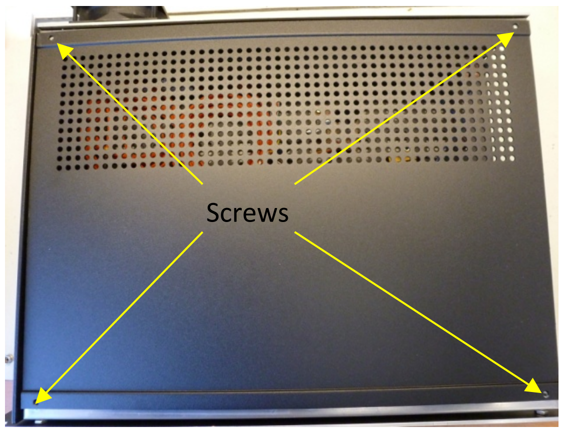
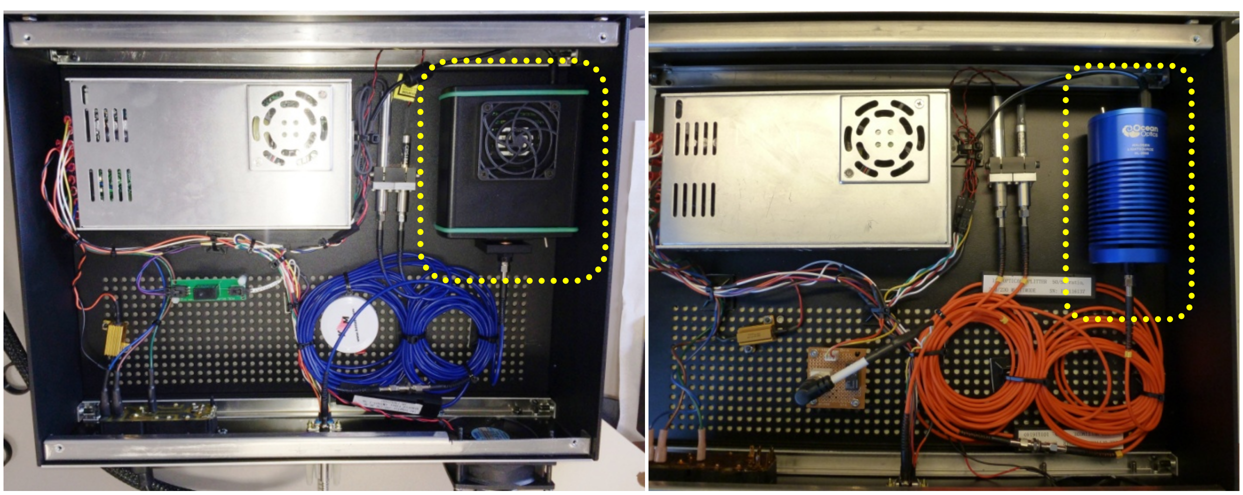


Figure 37 – Top view of the Chromatis Power Supply. Remove the top by removing the four screws holding the lid on.

The white light source is shown in Figure 38. Follow the procedure below to replace the white light bulb within this module.



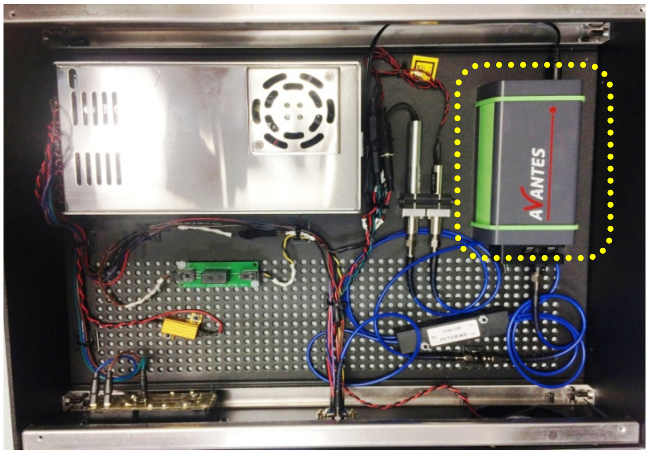


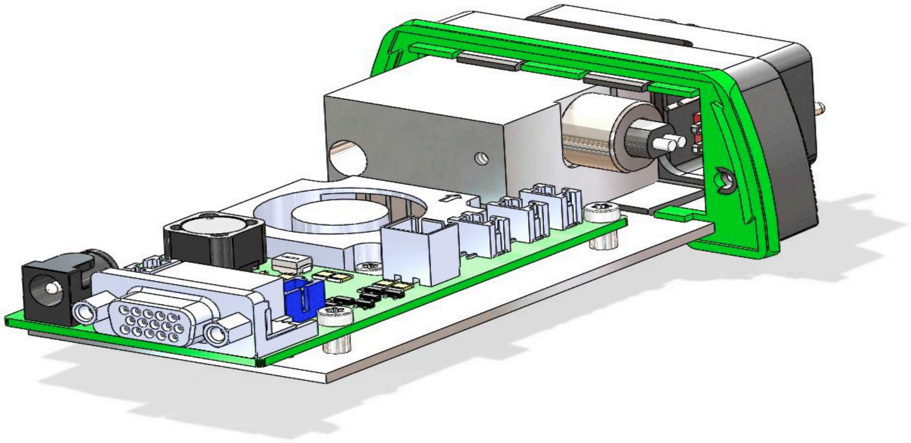
Figure 38 – Identify which light source you have, the one on the left is "Avantes" and the one on the right is "Ocean Optics" The location of the white light source within the power supply box is shown in the pictures (yellow dashed boxes).

Avantes AvaLight-HAL-S-MINI:

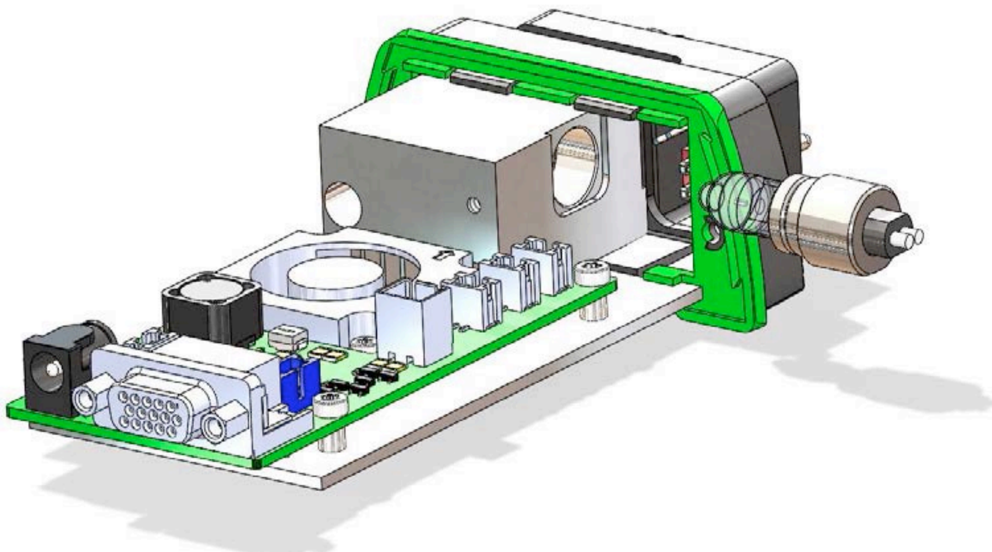
The procedure for replacing the white light bulb is taken from "**AvaLight-HAL-MINI/AvaLight-HAL-S-MINI light source Operating Manual",** that came with the White light Source from Avantes.

Changing the light source bulb

1. Disconnect the power connector from the socket.
2. Remove the screw protection caps on the front side.
3. Remove the screws with the torx screwdriver (Torx T10) (delivered with Avalight).
4. Take out the frontplate with mount plate (lamp house with PCB are attached to it).



6. Remove the lamp socket:



6. Disconnect the connector of the lamp socket.
7. Replace the lamp socket; WARNING: do not touch the glass with your fingers.
8. Put back the lamp socket into the lamp house.
9. Reconnect the connector of the lamp socket into the connector of the PCB.
10. Slide back the frontplate with mount plate (lamp house with PCB) into the housing of the light source. Be careful not to pinch the electrical wires.
11. Put back the 2 screws in the front and protection caps.

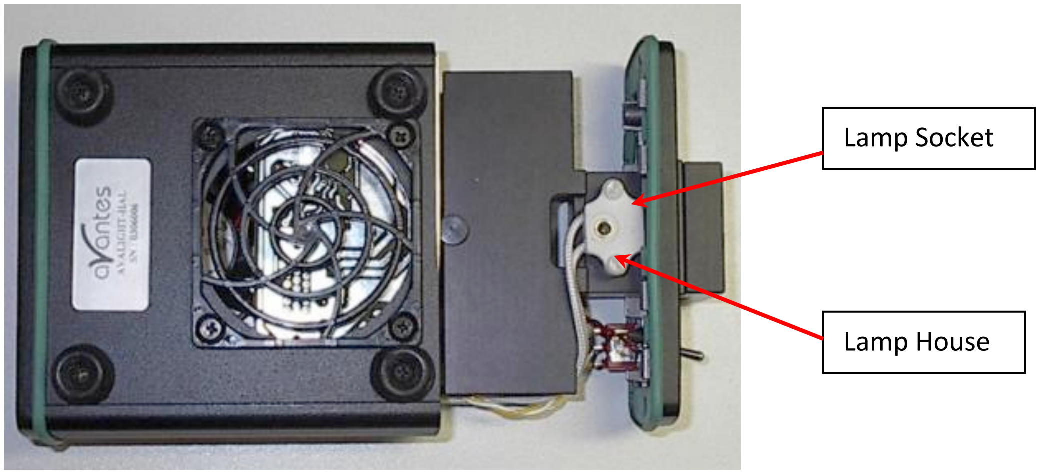
Avantes AvaLight-HAL Tungsten Halogen light source:

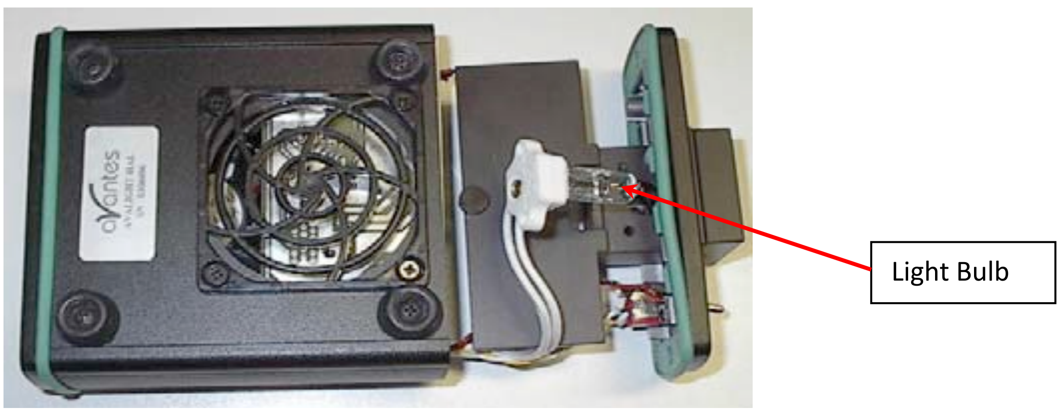
The procedure for replacing the white light bulb is taken from "**AvaLight-HAL Tungsten Halogen light source Operating Manual",** that came with the White light Source from Avantes.

Changing the light source bulb for Avantes White Light Source.

1. Plug out the power connector from the socket.
2. Remove screw protection caps on the frontside
3. Loosen 2 screws with philips screwdriver
4. Turn the lightsource upside down
5. Take out the frontplate and lamphouse
6. Remove 2 nylon screws from lamp socket
7. Take out the lamp socket
8. Take out the bulb (carefull, may be hot)
9. Replace by new bulb, do not touch glass with your fingers
10. Put back lamp socket and nylon screws
11. Slide back front plate and lamp house, be carefull not to pinch the electrical wires

12. Put back screws and protection caps





Ocean Optics

The procedure for replacing the white light bulb is taken from the **HL-2000 user manual** (http://www.oceanoptics.com/technical/hl2000.pdf). Replacement bulbs are available through Ocean Optics (www.oceanoptics.com).

Identifying the Bulb Type

► ***Procedure***

Perform the steps below to identify the bulb type:

1. Unplug the power connector from the power socket on the HL-2000.

2. Loosen the screws on the rear of the unit with a 2.5mm Allen wrench.

3. Remove the backside of the HL-2000 and remove the electronics board from the HL-2000, taking particular care not to disconnect the fan wires.

4. Remove the screws from the bottom plate of the unit with a 1.3mm Allen key.

5. Inspect the bulb for the bulb code/description. The bulb codes and descriptions are as follows:

Bulb Code	Description
HL-2000-B	Cable: Black and red Small housing AD = 13mm
HL-2000-BL	Cable: Black and yellow Small housing AD = 13mm
HL-2000-B-HP	Cable: Black and blue Small housing AD = 13mm

Replacing the Bulb

► ***Procedure***

Refer to Figure 39 and perform the steps below to replace the bulb in the HL-2000 Light Source:

1. Unplug the power connector from the power socket on the HL-2000.

2. Loosen the screws on the rear of the unit with the provided 2.5mm Allen wrench.

3. Remove the backside of the HL-2000 and remove the electronics board from the HL-2000, taking particular care not to disconnect the fan wires.

4. Remove the screws from the bottom plate of the unit with the provided 1.3mm Allen key.

5. Remove the bulb from the HL-2000.

6. Disconnect the wires from the connection block.

7. Replace the bulb and reconnect the wires to the connection block.

8. Slide the lamp into the housing and secure the housing with the bottom screw.

9. Slide the electronics board back into the HL-2000, taking particular care to ensure that the wires do not come into contact with the fan blades.

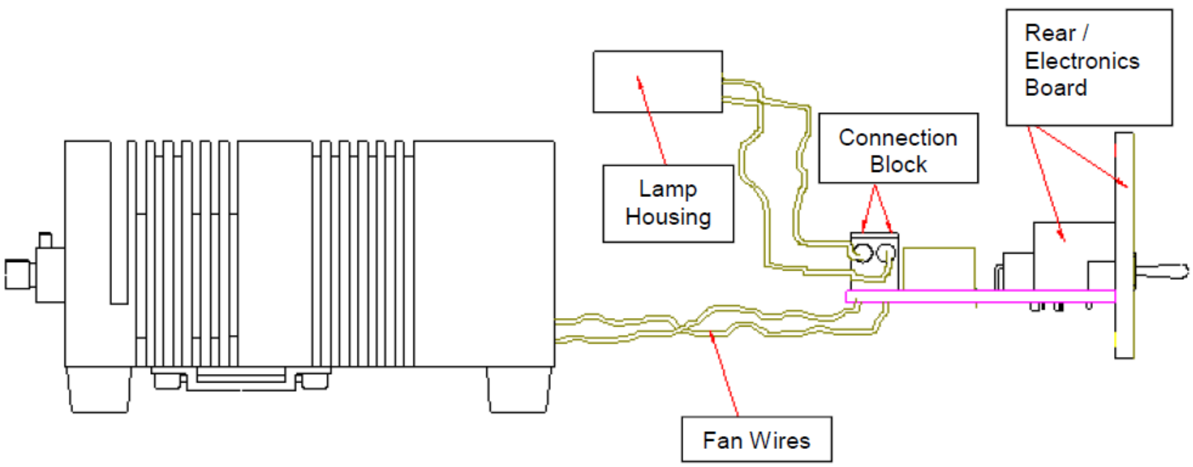


Figure 39 – Diagram of the HL-2000 light source with wiring connections.

After replacing the bulb, replace the top back onto the electronics module and reconnect the power supply cord. Turn the Chromatis power supply switch back to the ON position and resume using the instrument.