OSA201, OSA202, OSA203, OSA205
Optical Spectrum Analyzer

User Guide

Rev G, November 21, 2013

Table of Contents

Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
	Direct Current
	Alternating Current
	Both Direct and Alternating Current
	Earth Ground Terminal
	Protective Conductor Terminal
	Frame or Chassis Terminal
	Equipotentiality
	On (Supply)
	Off (Supply)
	In Position of a Bi-Stable Push Control
	Out Position of a Bi-Stable Push Control
	Caution: Risk of Electric Shock
	Caution: Hot Surface
	Caution: Risk of Danger
	Warning: Laser Radiation
	Caution: Spinning Blades May Cause Harm

Chapter 2 Safety

2.1. Safety

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly.

SHOCK WARNING

High voltage inside. To avoid electrical shock, prior to powering on the unit, make sure that the protective conductor of the 3-conductor power cord is correctly connected to the protective earth contact of the socket outlet. Improper grounding can cause electric shock, resulting in severe injury or even death.
Do not operate without the cover installed.

CAUTION

This unit must not be operated in explosive environments.

Only use the instrument standing on its feet.

WARNING

Avoid Exposure – Laser Radiation Emitted from apertures.

If purging gas other than dry air is used, make sure that the environment for the operator is well ventilated since the gas will leak out from the instrument.

Chapter 3 Warranty

Thorlabs warrants material and production of the OSA201, OSA202, OSA203, and OSA205 for a period of 24 months starting with the date of shipment. During this warranty period, Thorlabs will see to defaults by repair or exchange if the product is entitled to warranty. For warranty repairs or service the unit must be sent back to Thorlabs or to a place determined by Thorlabs. The customer will carry the shipping costs to Thorlabs; in case of warranty repairs Thorlabs will carry the shipping costs back to the customer. If no warranty repair is applicable, the customer also has to carry the costs for return shipment. In case of shipment from outside, EU duties, taxes, etc., that may arise have to be carried by the customer.

Thorlabs warrants the hardware and software determined by Thorlabs for this unit to operate fault-free provided that they are handled according to our requirements. However, Thorlabs does not warrant a fault free and uninterrupted operation of the unit, of the software or firmware for special applications, or this instruction manual to be error free. Thorlabs is not liable for consequential damages.

3.1.1. Restriction of Warranty

The aforementioned warranty does not cover errors and defects as a result of improper treatment, software or interface not supplied by Thorlabs, modification of product, unauthorized maintenance, or misuse or operation outside the defined ambient stated by Thorlabs.

Further claims will not be consented to and will not be acknowledged. Thorlabs does explicitly not warrant the usability or the economical use for certain cases of application.

Thorlabs reserves the right to change this instruction manual or the technical data of the described unit without notice.

Chapter 4 Description

The OSA is a general purpose spectrum analyzer for optical research and production applications. It has a user friendly Graphical User Interface and can be controlled from a standard PC via High Speed USB 2.0 port. The standard optical fiber input receptacle is FC/PC, but special designs with other input receptacles are available on request. The instrument is designed for measurements of CW light sources, but works in some applications where pulsed light is used. Please contact Technical Support at **techsupport@thorlabs.com** to discuss your application if you have a pulsed source.

4.1. Introduction

Thorlabs' Optical Spectrum Analyzers are general-purpose instruments that measure optical power as a function of wavelength. These OSA instruments are versatile enough to analyze broadband optical signals, Fabry-Perot modes of a gain chip, or long coherent length, single mode external cavity lasers.

Commonly available OSAs are typically grating-based monochromators. The Thorlabs OSA is a Fourier Transform Optical Spectrum Analyzer (FT-OSA), which utilizes a scanning Michelson Interferometer in a push/pull configuration, as shown in Figure 1 on Page 6. This approach allows for the design of a full-featured OSA with the additional benefit of a high precision wavelength meter.

The Thorlabs FT-OSA has an FC/PC-style optical fiber input (both single mode and multimode fibers up to Ø50 µm can be used). After collimating the input light, a beamsplitter divides the optical signal into two separate paths. The path length difference between the two paths is varied from 0 to ± 40 mm. The collimated light fields then optically interfere as they recombine at the beamsplitter. The detector unit shown in Figure 1 on Page 5 records the interference pattern; commonly referred to as an interferogram. This interferogram is the autocorrelation waveform of the input optical spectrum. By applying the Fourier transform to the waveform, the optical spectrum is recovered. The resulting spectrum offers both a high resolution and a very broad wavelength coverage with a spectral resolution that is related to the optical delay range. The wavelength range is limited by the bandwidth of the detectors and optical coatings. Furthermore, the accuracy of our system is ensured by including a frequency-stabilized HeNe reference laser, which acts to provide highly accurate measurements of beam path length changes, allowing the system to continuously self-calibrate. This process ensures accurate optical analysis well beyond what is possible with a grating-based OSA.

4.2. Interferometer Design

As mentioned, the instrument uses an arrangement of two retroreflectors as shown in Figure 1 on Page 6. These retroreflectors are mounted on a voice-coil-driven platform, which dynamically changes the optical path length of the two arms of the interferometer simultaneously and in opposite directions. The advantage of this layout is that it changes the optical path difference (OPD) of the interferometer by four times the mechanical movement of the platform. The longer the change in OPD, the finer the spectral detail the FT-OSA can resolve. Each OSA model has a spectral resolution of 7.5 GHz, or 0.25 cm^{-1}. The wavelength resolution is dependent on the wavelength of light being measured. For more details see Section 4.12, Resolution and Sensitivity. In this context, the spectral resolution is defined according to the Rayleigh criterion and is the minimum separation required between two spectral features in order to resolve them as two separate lines. These spectral resolution numbers should not be confused with the resolution when operating in the wavelength meter mode, which is considerably better.

The Thorlabs FT-OSA utilizes a built-in, actively stabilized HeNe reference laser to interferometrically record the variation of the optical path length. This reference laser is inserted into the interferometer and closely follows the same path traversed by the unknown input light field. The interferometer utilizes a dispersion compensation plate to nullify the wavelength-dependent optical path length differences of the two arms of the interferometer, which is mainly attributed to the beamsplitter. To reduce the effect of water absorption, the OSA203 and OSA205 have a purge inlet on the back panel, through which the interferometer can be filled with dry air (or nitrogen), see Chapter 6.

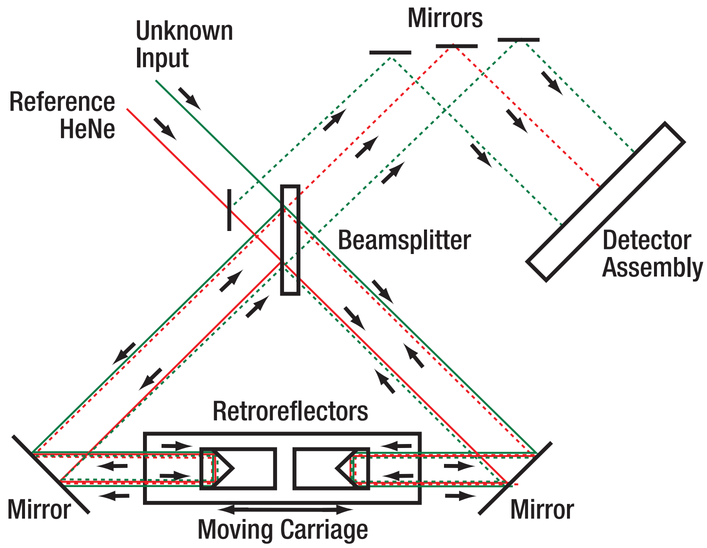


Figure 1 Optical Schematic of the Thorlabs FT-OSA Detailing the Dual Retroreflector Design

Note: Both retroreflectors are attached to a common carriage that is moved via a voice-coil-motor. This configuration provides an optical delay that is four times the displacement of the carriage.

4.3. Interferogram Data Acquisition

The interference pattern of the reference laser is used to clock a 16-bit Analog-to-Digital Converter (ADC) such that samples are taken at fixed, equidistant optical path length intervals. The HeNe reference fringe period is digitized and its frequency is multiplied by a phase locked loop (PLL) leading to an extremely fine sampling resolution. Multiple PLL filters enable frequency multiplication settings of 16, 32, 64, or 128. At the 128 multiplier setting, the data points are acquired approximately every 5 nm. The multiple PLL filters enable the user to choose system parameters optimized for measurements that range from high speed, reduced sensitivity, and reduced resolution to lower speed, higher sensitivity, and higher resolution.

A high-speed USB link transfers the interferogram for the device under test at 6 MB/s with a ping pong transfer scheme, enabling the streaming of very large data sets. Once the data is captured, the OSA software, which is highly optimized to take full advantage of modern multi-core processors, performs a number of calculations to analyze and condition the input waveform in order to obtain the highest possible resolution and signal-to-noise ratio (SNR) at the output of the Fast Fourier transform (FFT).

A very low noise and low distortion detector amplifier with automatic gain control provides a large dynamic range, allows optimal use of the ADC, and ensures excellent SNR for up to 10 mW of input power. For low-power signals, the system can typically detect less than 100 pW from narrowband sources. The balanced detection architecture enhances the SNR of the system by enabling the Thorlabs FT-OSA to use all of the light that enters the interferometer, while also rejecting common mode noise.

4.4. Interferogram Data Processing

The interferograms generated by the instrument vary from 0.5 million to 16 million data points depending on the resolution and sensitivity mode settings employed. The FT-OSA software analyzes the input data and intelligently selects the optimal FFT algorithm from our internal library.

Additional software performance is realized by utilizing an asynchronous, multi-threaded approach to collecting and handling interferogram data through the multitude of processing stages required to yield spectrum information. The software’s multi-threaded architecture manages several operational tasks in parallel by actively adapting the PC’s capabilities, thus ensuring maximum processor bandwidth utilization. Each of our FT-OSA instruments ships with a laptop computer that has been carefully selected to ensure optimum data processing and user interface operation.

4.5. Wavelength Meter Mode

When narrowband optical signals are analyzed, the FT-OSA automatically calculates the center wavelength of the input, which can be displayed in a window just below the main display, presenting the overall spectrum. The central wavelength, λ, is calculated by counting interference fringes (periods in the interferogram) from both the input and reference lasers according to the following formula:

$$\lambda = \frac{m_0}{m} \cdot \frac{n_\lambda}{n_0} \cdot \lambda_0$$

Here, m_o is the number of fringes for the HeNe reference laser, m is the number of fringes from the unknown input, n_o is the index of refraction of air at the reference laser wavelength, n_λ is the index of refraction of air at the wavelength λ, and λ_o is the vacuum wavelength of the HeNe reference laser.

The resolution of the FT-OSA operating as a wavelength meter is substantially higher than the system when it operates as a broadband spectrometer because the system can resolve a fraction of a fringe up to the limit set by the phase locked loop multiplier (see the section on Interferogram Data Acquisition). In practice, the resolution of the system is limited by the bandwidth and structure of the unknown input, noise in the detectors, drift in the reference laser, interferometer alignment, and other systematic errors. The system has been found to offer reliable results as low as ±0.1 pm in the visible spectrum and ±0.2 pm in the NIR/IR (See Specifications in Section 13.1 for details).

The software evaluates the spectrum of the unknown input in order to determine an appropriate display resolution. If the data is unreliable, as would be the case for a multiple peak spectrum, the software disables the wavelength meter mode so it does not provide misleading results.

4.6. Wavelength Calibration and Accuracy

These FT-OSA instruments incorporate a stabilized HeNe reference laser with a vacuum wavelength of 632.991 nm. The use of a stabilized HeNe ensures long-term wavelength accuracy as the dynamics of the stabilized HeNe are well-known and controlled. The instrument is factory aligned so that the reference and unknown input beams experience the same optical path length change as the interferometer is scanned. The effect of any residual alignment error on wavelength measurements is less than 0.5 ppm; the input beam pointing accuracy is ensured by a high-precision ceramic receptacle and a robust interferometer cavity design. No optical fibers are used within the scanning interferometer. The wavelength of the reference laser in air is actively calculated for each measurement using the Eldén formula with temperature and pressure data collected by sensors internal to the instrument.

For customers operating in the visible spectrum, the influence of relative humidity (RH) on the refractive index of air can affect the accuracy of the measurements. To compensate for this, the software allows the RH to be set manually. The effect of the humidity is negligible in the infrared.

4.7. Dynamic Range/Optical Rejection Ratio

The ability to measure low-level signals close to a peak is determined by the optical rejection ratio (ORR) of the instrument. It can be seen as the filter response of the OSA, and be defined as the ratio between the power at a given distance from the peak, to the power at the peak.

If the ORR is not higher than the optical signal-to-noise ratio of the source to be tested, the measurement will indicate the limit of the OSA rather than the tested source. Figure 2 and the table below provide some example values for the optical rejection ratio of the OSA203 at 1550 nm with the following settings: high resolution, low sensitivity, average 4, apodization Hann. All OSA20X models show similar behavior if the distance from the peak is measured in GHz.

From Peak	Optical Rejection Ratio
0.2 nm (25 GHz)	30 dB
0.4 nm (50 GHz)	30 dB
0.8 nm (100 GHz)	30 dB
4 nm (500 GHz)	39 dB
8 nm (1000 GHz)	43 dB

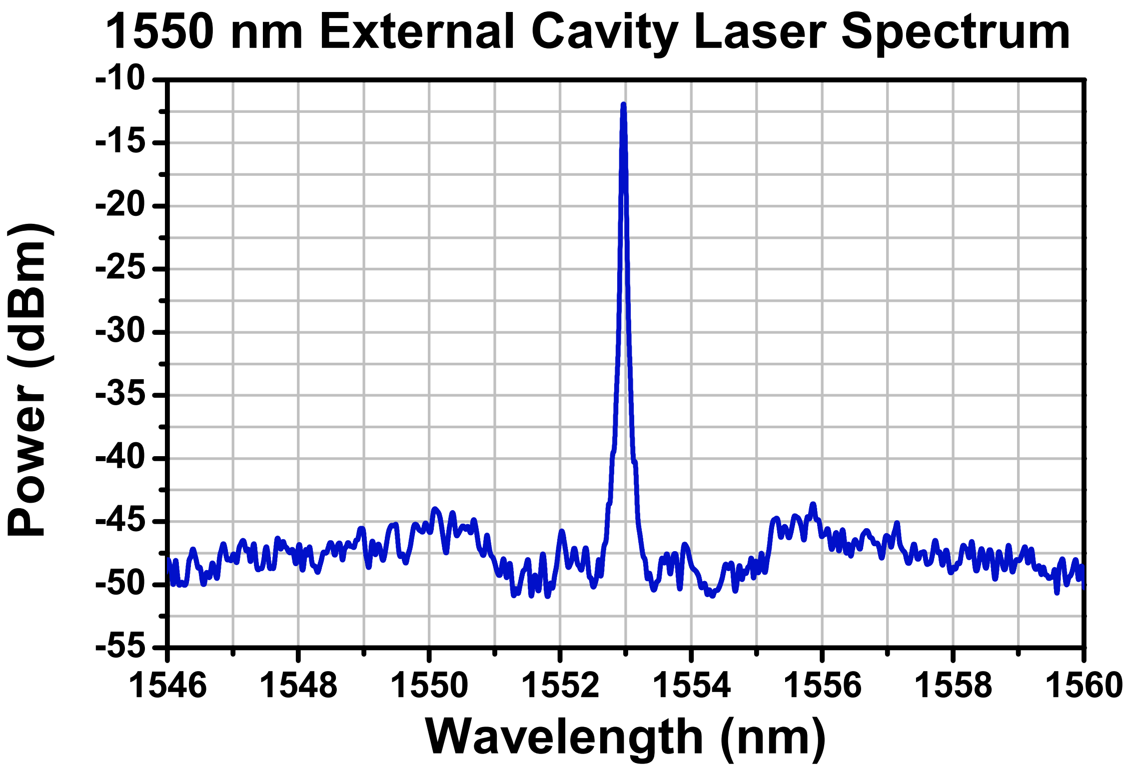


Figure 2 Spectrum of a 1550 nm External Cavity Laser

4.8. Absolute Power and Power Density

The vertical axis of the spectrum can be displayed as absolute power or power density, both of which can be represented in either linear or logarithmic scale. In absolute power mode, the total power displayed is based on the actual instrument resolution for that specific wavelength; this setting is recommended to be used only with narrow spectrum input light. For broadband devices, it is recommended that the power density mode is used. Here the vertical axis is displayed in units of power per unit wavelength where the unit wavelength is based upon a fixed wavelength band and is independent of the resolution setting of the instrument.

4.9. Apodization

According to Fourier theory, the spectrum of the unknown input light can be exactly determined from the Fourier transform of the measured interferogram, but only if the interferogram is acquired over an optical path difference extending from zero to infinity. Of course, the mirrors in the FT-OSA can only translate through a finite distance. We have therefore implemented several apodization functions in the OSA software to account for the effect of the finite path length on the measured interferogram.

The measured, finite interferogram can be thought of as an ideal, infinite interferogram that consists of measured values over a short interval (say, *-L* to *+L*) and is equal to zero everywhere else. This treatment is equivalent to multiplying the measured interferogram (which has measured values from *–L* to *+L*) by a boxcar function that is equal to 1 from *–L* to *+L* and is equal to zero everywhere else. Mathematically, the Fourier transform of the product of two functions (i.e., the interferogram and the boxcar function) is equal to the *convolution* of the Fourier transform of the first function (i.e., the interferogram) with the Fourier transform of the second function (i.e., the boxcar). That is, if *F(f)* is defined as the Fourier transform of *f*, then

$$F(f \cdot g) = F(f) * F(g)$$

The Fourier transform of the interferogram is the spectrum, and the Fourier transform of a boxcar function is the sinc function: $\mathrm{sinc}(x) \equiv \sin(x)/x$. A sinc function is a periodic function with diminishing amplitude away from zero. Therefore, the Fourier transform of a measured, finite interferogram yields the spectrum, but it is convolved with additional periodic structures that are not representative of the unknown input light.

The effect of the additional periodic structures is strongest when measuring a narrowband source, because the amplitude of the interferogram of a narrowband source is high over the entire measurement range. To remove them, the interferogram is multiplied by apodizing (dampening) functions that decrease the amplitude of the interferogram close to the edges of the measurement range. This reduces or removes the artificial ringing, but at the expense of reducing the resolution of the final spectrum.

For a detailed description of the apodization functions implemented in the OSA software, please see Section 16.2.

4.10. Zero Fill

Zero filling means that the interferogram is extended with zeros. This effectively interpolates the spectrum by adding more data points between the measured data. It is especially interesting for spectra that contain sharp features. More data points close to a sharp spectral feature can make it easier to determine a peak's center frequency or intensity.

In the OSA software, ZFF = 1 means that the interferogram is made twice as long (equally many zeroes as true data points) and ZFF = 2 means that the interferogram is made four times as long (three times more zeroes than data points).

It is important to notice that since no real data is added, the resolution of the final spectrum does not change. This means that, for example, two peaks located close to each other in frequency would not be more resolvable if ZFF = 2 were used, rather than ZFF = 0.

4.11. Software

The FT-OSA is shipped with the software package pre-installed on the laptop computer that is included with the purchase of this instrument. The software has a customizable graphical user interface for acquiring, inspecting, manipulating, and analyzing spectra and interferograms. The software makes it easy to locate and track spectral peaks or valleys, measure the optical input power over any wavelength range, calculate an absorption spectrum in real-time, or track a large number of parameters over time. A device interface library containing a multitude of routines for data acquisition, instrument control, and spectral processing and manipulation, is also provided with the instrument. The library can be used to develop customized software for your own application using LabVIEW, C, C++, C#, Java, or other programming languages. Each OSA ships with a set of LabVIEW routines to assist with writing user defined applications.

4.12. Resolution and Sensitivity

The resolution of this type of instrument depends on the optical path difference (OPD) between the two paths in the interferometer. In this case it is easier to work with wavenumbers (inverse centimeters) than wavelength (nanometers) or frequency (terahertz).

Assume we have two narrow-band sources, such as two lasers with a 1 cm^{-1} energy difference, 6500 cm^{-1} and 6501 cm^{-1}. To distinguish between these signals in the interferogram, we would need to move away 1 cm from the point of zero path difference (ZPD). The OSA can move ±4 cm in OPD, and so it can resolve spectral features 0.25cm^{-1} apart. The resolution of the instrument can be calculated as:

$$\Delta\lambda = \Delta k \times 100 \times \lambda^2$$

where $\Delta\lambda$ is the resolution in pm, Δk is the OPD in cm^{-1} (maximum 0.25 for this instrument) and λ is the wavelength in µm.

The resolution in the OSA can be set to high and low in this instrument. In high resolution mode, the retroreflectors move the maximum ±1 cm mechanically (±4 cm in OPD) while in low resolution mode, the retroreflectors move ±0.25 cm mechanically (±1 cm in OPD). In the Setup Section of the Thorlabs OSA software (Chapter 7), the length of the interferogram that is used in the calculation of the spectrum can be cut to reduce the resolution to the level the user wishes.

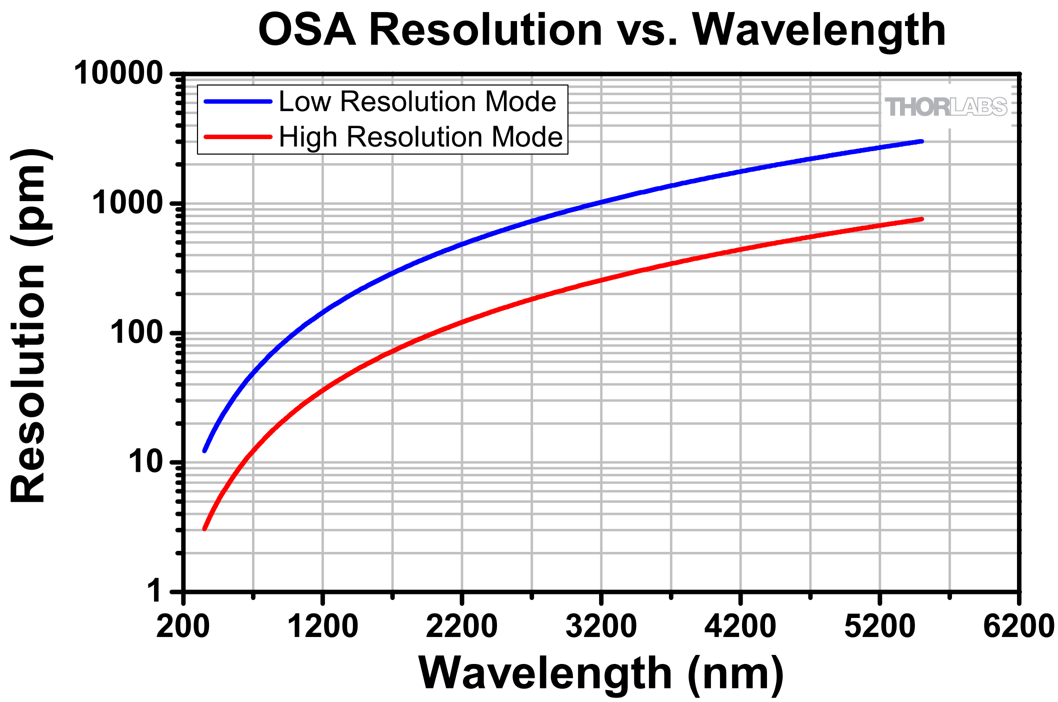


Figure 3 Resolution as a Function of Wavelength

The sensitivity of the instrument depends on the electronic gain used in the sensor electronics. Since the increased gain reduces the bandwidth of the detectors, the instrument will run slower when higher gain settings are used. The figures 4 and 5 on the following page show the dependency of the noise floor on the wavelength and OSA model.

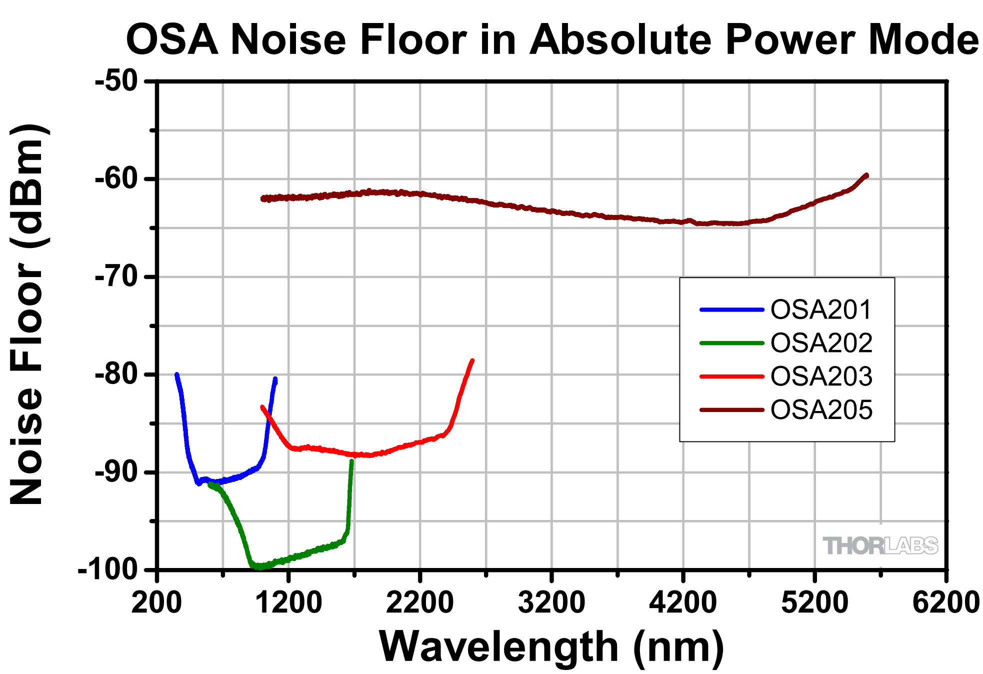


Figure 4 Noise Floor in Absolute Power Mode

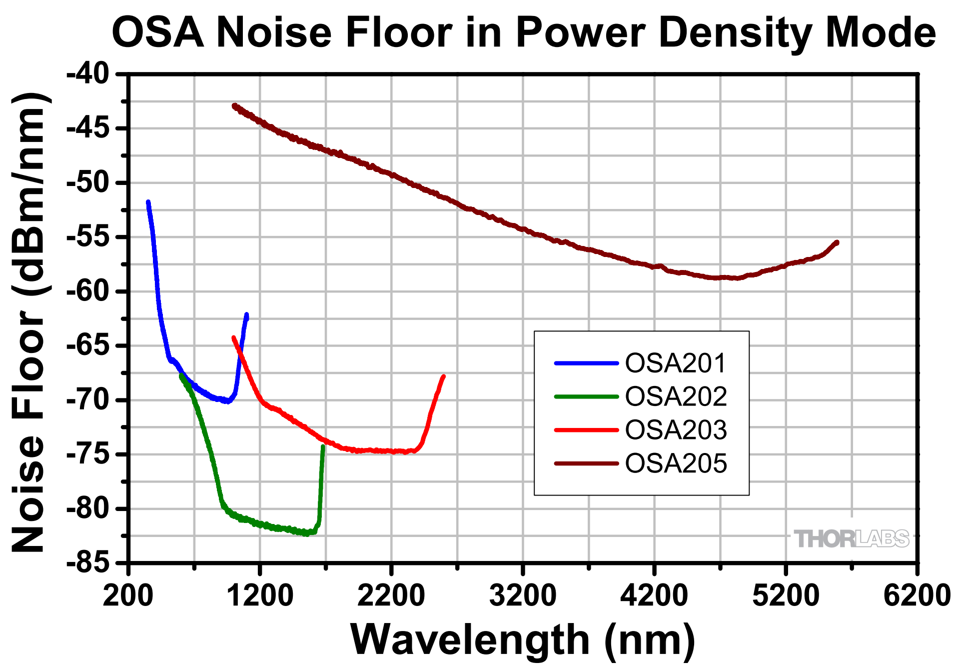


Figure 5 Noise Floor in Power Density Mode

The OSA is also designed so that it samples more points/OPD when it runs slower. The data sampling is triggered by the reference signal from the internal stabilized HeNe laser. A phase locked loop multiplies the HeNe period up to 128 times for the highest sensitivity mode. This mode can be very useful when the measured light is weak and broadband, hence only a very short interval in the interferogram at the ZPD contains all the spectral information. This is normally referred to as the zero burst.

Chapter 5 Using the Free Space Input (OSA205 only)

Figure 6 Front Panel of the OSA205

The OSA205 has two input options, FC/PC and free space. It is not possible to use both input options at the same time. All other OSAs have a FC/PC input only.

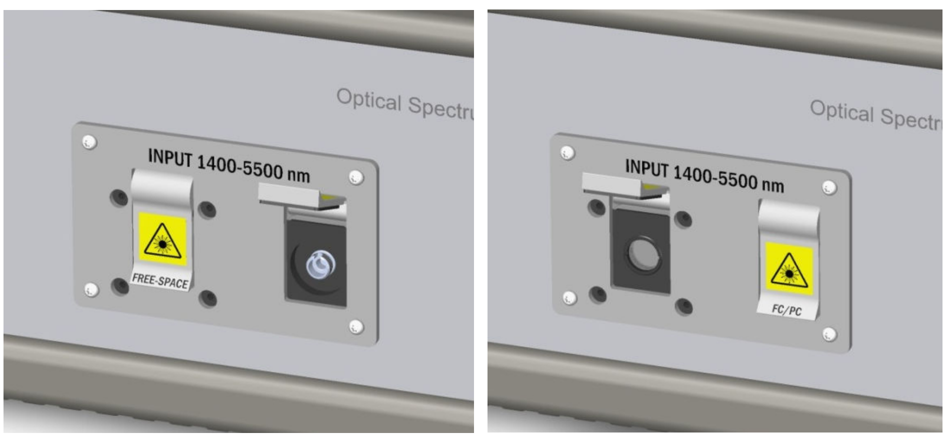


Figure 7 FC/PC Input (Left) and Free Space Input (Right)

5.1. Table Mounting when Using Free Space Option

When the free space lid is open, a red alignment beam is emitted from the OSA205. The input beam needs to be aligned along the same path as the alignment beam.

Figure 8 Attach the posts (included) and secure to the breadboard using CF175 clamping forks when using the free space input on the OSA205.

Since the interferometer assembly normally “floats” on gel bushings inside the case when using the fiber input, it is necessary to lock the interferometer to the table surface when using the free space input. This can be accomplished by using the posts supplied and mounting the OSA205 to the breadboard using two Thorlabs’ CF175 clamping forks as shown in Figure 8.

5.2. Free Space Beam Alignment

5.2.1. Visual Alignment

Use the mirror closest to the test source to optimize the position of the input IR source, using a viewing card (such as Thorlabs item # VRC6) and an alignment plate (such as Thorlabs item # CPA2) in the cage system. Then use the mirror closest to the OSA to point the aiming beam at the center of the source. Repeat this step several times so that the beams overlap over the whole beam path. If the source is sensitive to 633 nm light, put a dichroic mirror in front of it. Figure 9 shows an example of this setup.

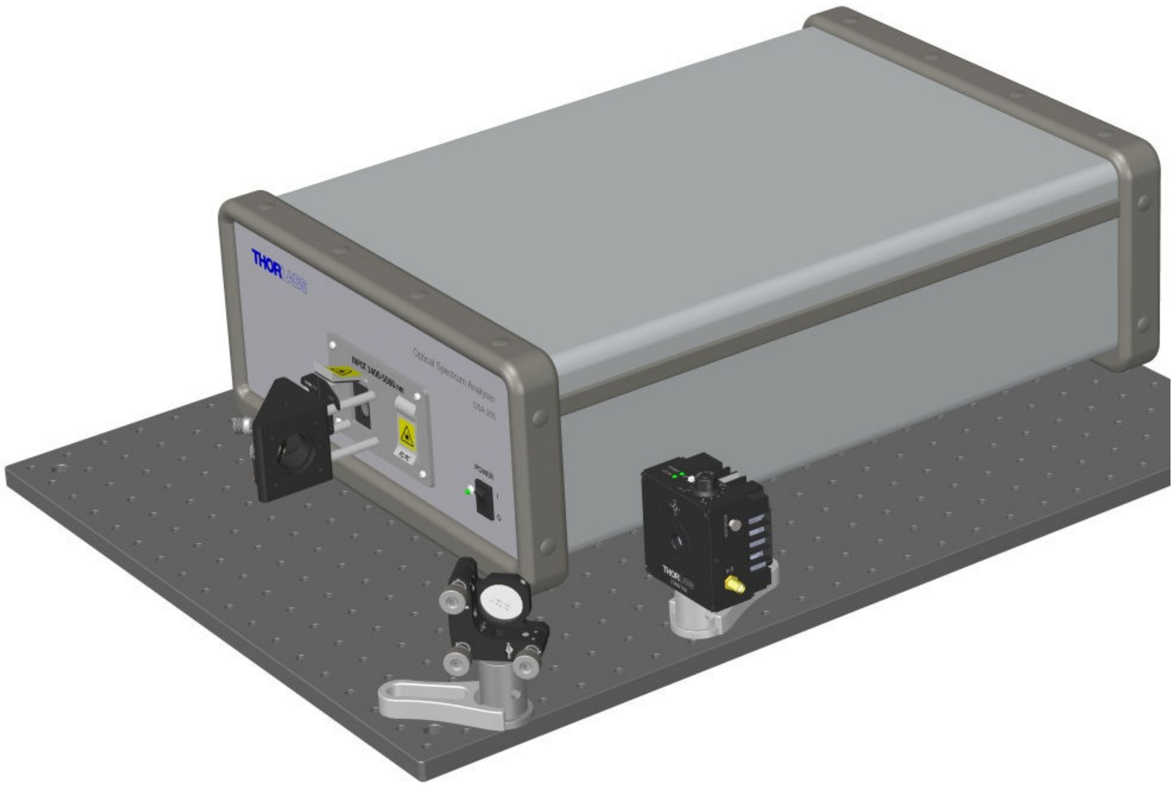


Figure 9 Example Setup for Aligning the Free Space Input

5.2.2. OSA Settings

You should now be able to get a signal in the interferogram window. Adjust the settings to Medium High Sensitivity and Low Resolution. Under the Analysis menu, select “Signal” and choose a fixed gain level that yeilds a good reading where the interferogram is not saturated. You can also start a time series measurement of the power to get a reading of how the input power changes.

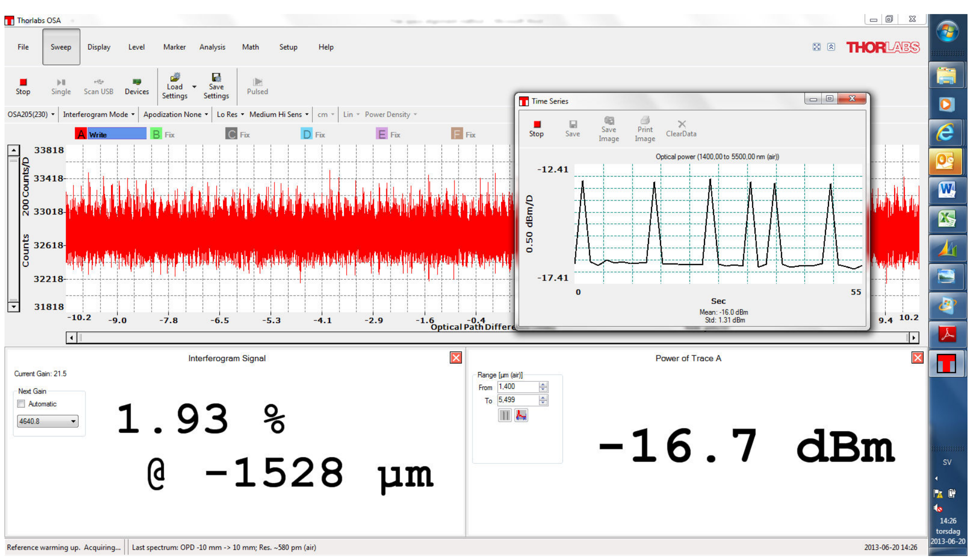


Figure 10 Software Settings for Free-Space Alignment

5.2.3. Final Alignment

Repeat the alignment process in section 5.2.1, but utilize the OSA readings to optimize the alignment instead of the viewing card.

5.2.4. Error Estimation

When the signal cannot be optimized further, the wavelength error caused by any remaining misalignment can be calculated. Measure the offset (d) between the source exit point and the aiming beam. The wavelength error is the path difference between the aiming beam and the source beam, and can be estimated as $1 - \cos\left(\tan^{-1}\frac{d}{D}\right)$, where D is the distance between the source and the detector (the distance between the OSA aperture and the source plus 450 mm for the path inside the OSA). It should be possible to have d better than 1 mm for D = 1000 mm, which yeilds an error of less than 5 x 10^{-7} (about 1 - 3 pm depending on the source wavelength range).

Chapter 6 Pure Air (OSA203, OSA205)

For the OSA203 and OSA205 it is possible to use an external air purifier, such as the Thorlabs PACU. Simply connect two hoses (one supply and one return) to the 1/4" outer diameter quick connections on the back of the OSA.

Figure 11 ¼"Outer Diameter Quick Connections for a Purified Air Supply (OSA203 and OSA205 only)

Chapter 7 Software Setup

7.1. Requirements

To run the OSA, you need to have a computer that meets the following requirements:

Minimum Hardware and Software Requirements

- Operating System: Windows Vista, Windows 7 or newer (32 or 64 bit)
- Free USB 2.0 high speed port (**Notice that a USB 1.1 port cannot be used**)
- Minimum monitor resolution: 800 x 600
- Processor: Intel Pentium 4 or AMD Athlon 64 3000+
- 2.0 GB RAM
- .NET framework 4.0 or higher

For optimal performance, Thorlabs suggests the following configuration:

Recommended Hardware and Software Requirement

- Operating System: Windows 7, 64 bit
- Free USB 2.0 high speed port (**Notice that a USB 1.1 port cannot be used**)
- Processor: Intel Core i5 or AMD Athlon II
- 6.0 GB RAM
- .NET framework 4.0 or higher

You will also need a USB cable qualified for high speed USB 2.0 standard (included with instrument).

Note: The OSA must not be connected to your PC before the software has been installed completely.

7.2. Software Installation

The Thorlabs OSA is shipped with a laptop with all required drivers and software pre-installed. If you wish to install the software on another computer or need to re-install the software please follow the instructions below.

The instrument comes with a USB flash drive with an installation package which will install all the necessary software. Follow the on screen instructions to do so. If you are running Windows Vista or Windows 7, a prompt may appear asking to change to “elevated mode;” please ask your system administrator if you do not have administrator privileges. The software will install four device drivers, two for the OSA20X series and two for the Thorlabs CCS device series.

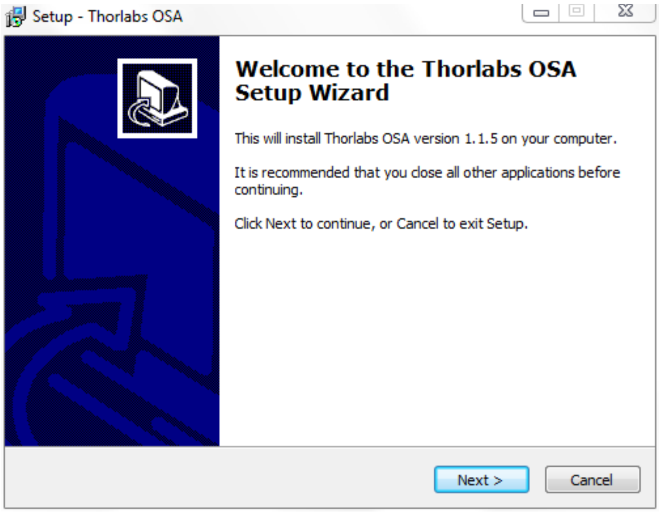


Figure 12 On Screen Software Setup Screen

7.3. Connecting to the PC

After the software installation has finished, you can connect the Thorlabs OSA to an available USB 2.0 port on the PC. Use only the cable that comes with the OSA or a cable qualified for high speed USB 2.0 standard.

After connecting the instrument to the PC, the operating system will load the appropriate USB drivers for the OSA. Please wait for this procedure to finish before doing anything else.

7.4. Starting the Application

After the PC software is installed and the OSA is connected to the PC, the application controlling the instrument may be started. The Thorlabs OSA software can be found by clicking the “Start” button and then “Programs” → “Thorlabs” →”OSASW,” and clicking on the application icon named “Thorlabs OSA”.

When the Thorlabs OSA application starts it will automatically detect all Thorlabs Optical Spectrum Analyzers connected to the PC. A list of all connected OSAs can be seen by clicking the button “Devices” found under “Sweep” on the main window menu.

Chapter 8 Operation

8.1. Interface Overview

When the Thorlabs' OSA Software is first started, the main window is composed of five areas:

- The Main Menu, containing the command buttons
- The Settings Bar, providing quick access to the settings of the software
- The Trace Controls, containing the options for the traces
- The Data Display area
- The Status Bar

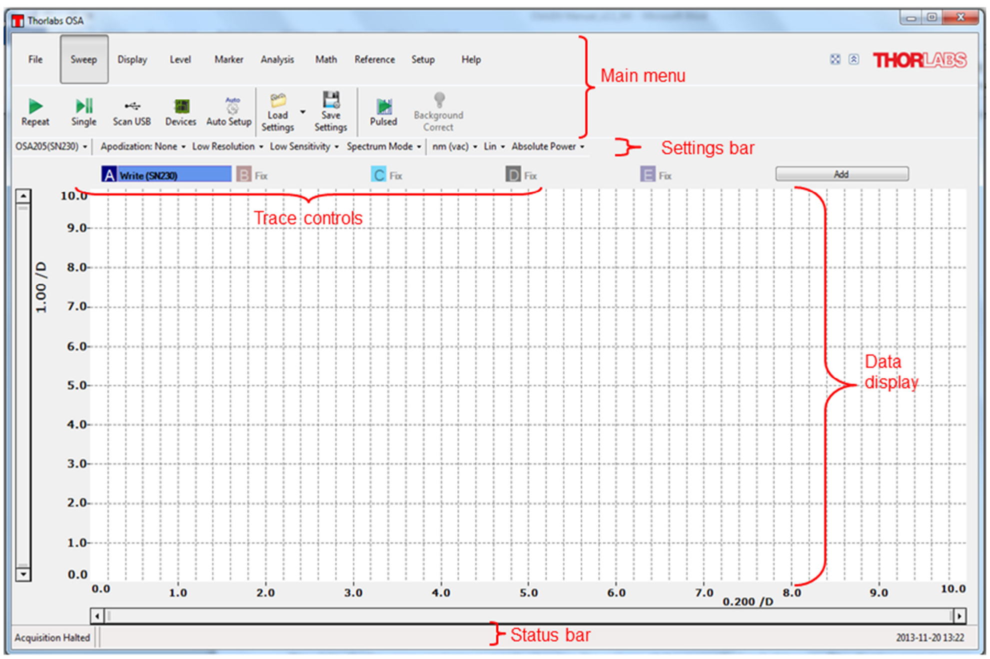


Figure 13 Layout of the Main Window of the Thorlabs OSA Software at Startup

The data display area contains a graph showing the values of the currently loaded traces. The display area is capable of showing two vertical axes, one primary with its unit and range shown on the left hand side of the graph and one secondary with its unit and range shown on the right hand side of the graph (only displayed when any trace is drawn on the secondary vertical axis). In the background is a grid with 10 by 50 divisions (customizable) displayed.

8.2. Spectrum Mode and Interferogram Mode

The Thorlabs OSA can be operated in one of two modes: Spectrum mode or Interferogram Mode.

8.2.1. Spectrum Mode

In Spectrum Mode,

- Only spectra are shown
- Only analysis tools and math tools applicable only to spectra are enabled
- Interferograms are still acquired in the background but will not be displayed until interferogram mode is selected.

8.2.2. Interferogram Mode

In Interferogram Mode,

- Only interferograms are shown
- Only analysis tools and math tools applicable to interferograms are enabled
- Spectra are still acquired in the background but will not be displayed until interferogram mode is selected

To switch between the modes use the quick-switch button found in the settings bar, or open the setup dialog (by pressing the button "Setup" in the main menu) and changing the selection under "Working With".

8.3. Customizing the Display

8.3.1. Zooming the Horizontal Axis

When first acquiring a spectrum or interferogram, the display is set to show the entire spectrum/interferogram.

The data display can be zoomed in or out by either:

- Scrolling the mouse wheel (hold down the Ctrl button for extra speed)
- Simultaneously pressing Ctrl and "+" or "-"
- Changing the width of the slide bar displayed below the horizontal axis

The data display can be scrolled by:

- Dragging the data display area with the left mouse button pressed
- Simultaneously pressing Ctrl and the left or right arrow button on the keyboard
- Sliding the slide bar displayed below the horizontal axis

The horizontal display range can be set more precisely by typing in a desired minimum and maximum value in the two text boxes found under the "Display" menu. The horizontal display range can also be set by clicking on the horizontal axis itself, which will bring up a dialog box (see screenshot below) in which the minimum and maximum value, division, center wavelength and span can be set.

Notice that the displayed horizontal range can be locked by checking the button "Lock Axis". A locked axis cannot be dragged or zoomed using the mouse or keyboard in order to prevent the user from accidentally changing the data displayed.

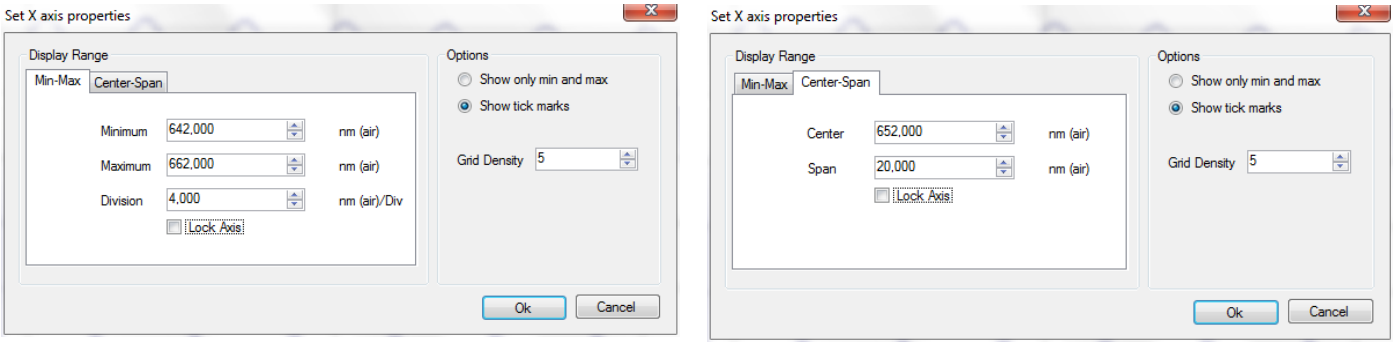


Figure 14 Axis Options Dialog Opened for the Horizontal Axis

If the two line markers are displayed then the horizontal display range can also be set to the range between the two line markers by clicking on “Display” and pressing the button “Get From Line Markers”.

To restore the display area to the full zoom out, press “Display” and the button “Zoom Out” or scroll the mouse wheel until the full horizontal axis is displayed.

8.3.2. Zooming the Vertical Axis

The vertical axis can be set manually by clicking on the (primary or secondary) vertical axis itself. This will bring up a dialog box, (shown in Figure 14) in which the minimum and maximum value, division, center wavelength and span can be set.

Right clicking anywhere in the graph will resize the vertical axis to fit the full vertical range of the currently displayed data (as determined by the settings for the horizontal axis).

The primary vertical axis can be zoomed and scrolled by using the slide bar displayed to the left of the vertical axis. In the same way, the secondary vertical axis can be zoomed and scrolled using the gray bar displayed to the right on the secondary vertical axis (only displayed when any trace is displayed on the secondary axis).

If both level markers are displayed, then the vertical range can also be set to the range between the level markers by pressing “Level” and the button “Get From Level Markers”.

Notice that the displayed vertical range of the primary or secondary can be locked by checking the button “Lock Axis” in the dialog box displayed above. On a locked axis it is not possible to resize the graph using the mouse or keyboard, in order to prevent accidental change of the data displayed.

8.3.3. Setting the Unit of the Horizontal Axis

In interferogram mode, the horizontal axis unit is set to optical path distance in cm, which cannot be changed.

In spectrum mode, it is possible to switch the horizontal axis unit between the following options:

- Wavenumber (cm^{-1})
- Wavelength (nm) in air
- Wavelength (nm) in vacuum
- Frequency (THz)
- Photon Energy (eV)

The unit of the horizontal axis is set by using the x-axis unit button in the settings bar.

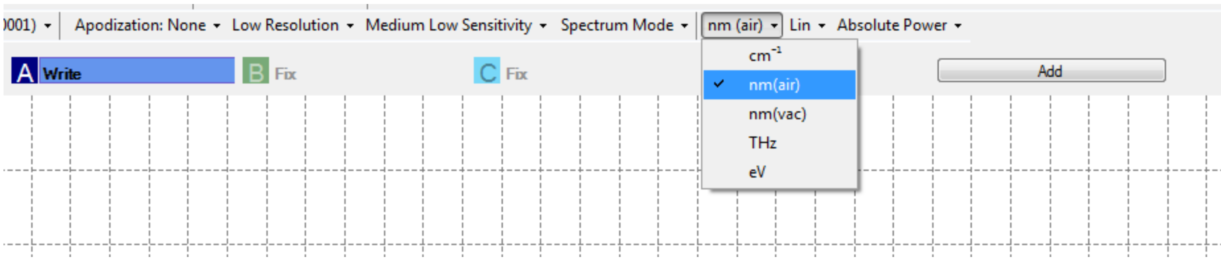


Figure 15 Setting the Horizontal Axis Units

8.3.4. Setting the Unit of the Vertical Axis

In interferogram mode, the vertical axis displays the interferogram as a percentage of the full measurable range (default) or in “counts” on the ADC. To switch between the two modes, open the Setup Dialog, select the Display page, and check or uncheck the box “Interferogram in Percent”. (See □)

In spectrum mode, the vertical axis is set by default to optical power in Watts, but can also be set to dBm by selecting “Log” from the button in the settings bar.

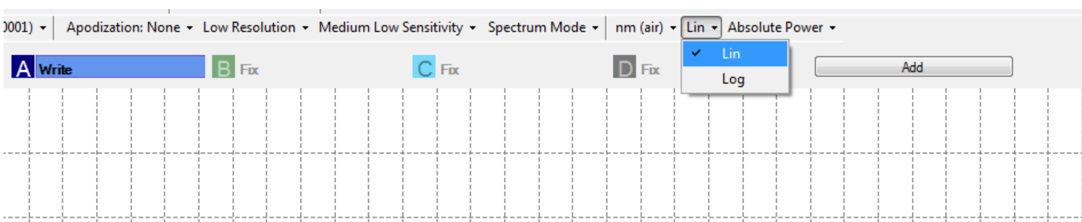
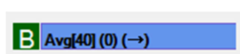


Figure 16 Setting the Vertical Axis Units

8.3.5. Displaying the Secondary Vertical Axis

In the Thorlabs OSA Software the traces can be shown on either the primary axis with its labels and units displayed on the left of the graph, or on the secondary axis, with its labels and units displayed to the right of the graph.

To change which vertical axis a trace is displayed on, click the icon of the trace you want to change. This will bring up a menu with options and operations for the trace that was clicked on. Click on the option “Move to Secondary Axis” to move the trace to the secondary axis. To move the trace back to the primary axis, click on the trace again, and the option will have changed to “Move to Primary Axis”. Every trace which is displayed on the secondary axis will have a small arrow displayed on its icon in the Trace Bar that looks like this:



When working with data on both the primary and secondary axis:

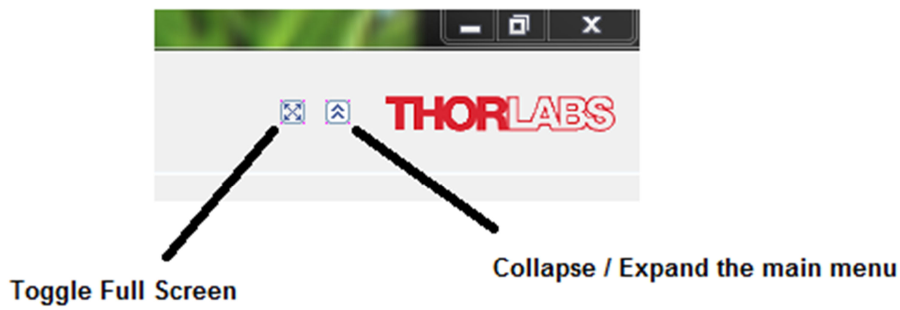
- The range of the primary and secondary axis can be set individually by clicking on (the gray part of the) axis which brings up the Axis Options Dialog (see Figure 14) for the selected axis notice that the grid density is always the same for the primary and the secondary axis. Changing the grid density on one axis will change the grid density on the other.
- Right clicking on the graph will rescale both the primary and the secondary axis.
- The primary and secondary axes can be locked individually to any desired range by checking the “Lock Axis” check box in the Axis Options Dialog (see Figure 14).

- Changing linear/log mode or Absolute Power/Power Density mode will change the units of both the primary and secondary axes.

8.3.6. Hiding the Menus and Full Screen Mode

There are two buttons located in the top right corner of the main menu, close to the Thorlabs logo.

- The leftmost of these buttons toggles between full-screen mode and regular window mode.
- The rightmost of these new buttons collapses or expands the main menu. The first time this button is clicked, the main menu will collapse so that the second row is hidden completely and only the labels of the top level menu are shown. The menu can be expanded again by pressing the same button or by clicking on any label of the top level menu.



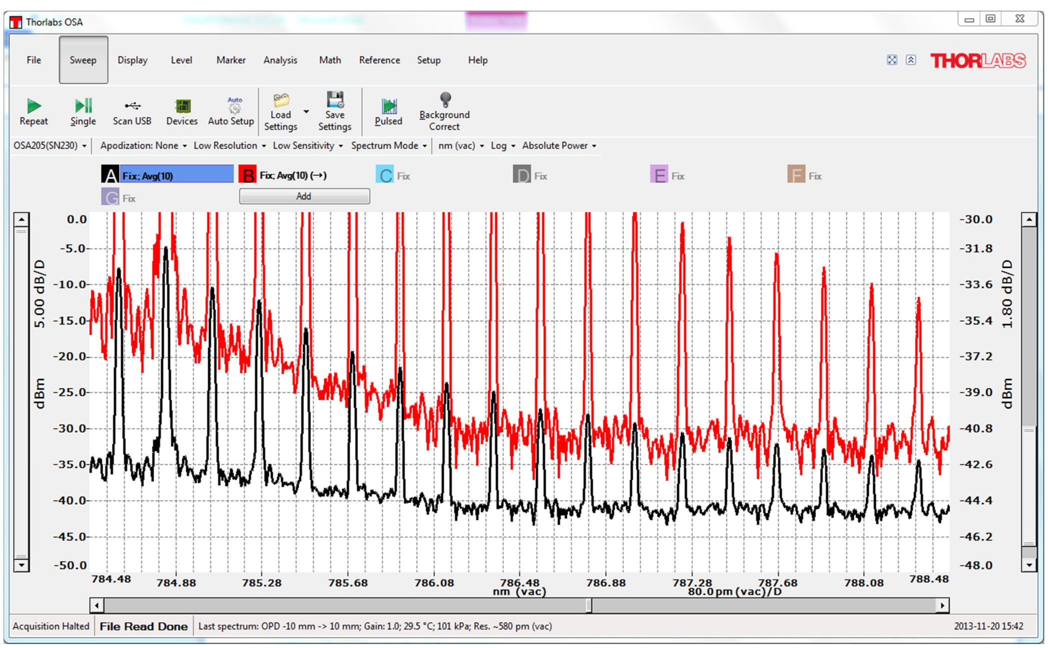


Figure 17 Displaying Data on Both the Primary and Secondary Axis

In Figure 17 above, Trace “A” (Black) is shown on the primary axis. Trace “B” (Red) is displayed on the secondary axis. Notice the small arrow on the icon for Trace “B” showing that Trace “B” is displayed on the secondary axis.

8.3.7. Switching Between Power Density and Absolute Power

The power per wavelength, or frequency, unit is called the power density (e.g. mW/nm or dBm/THz) and the power per resolution unit is called the absolute power. By default, the Thorlabs OSA is set to display the retrieved spectra in absolute power.

For light coming from a very narrowband source, such as a laser, the bandwidth of the source is smaller than the resolution of the instrument and all the optical power is accommodated within one resolution unit in the measured spectrum. Thus, the peak level of the measured spectrum is equal to the total power of the light source when the display is set to Absolute Power.

For light from a broadband source, such as LEDs, the bandwidth of the source is much larger than the resolution of the instrument and the level of the measured spectrum will vary with the resolution mode when the display is set to Absolute Power. By setting the display mode to Power Density, it is possible to compare spectra from broadband sources measured at different resolution modes.

- Absolute Power mode is the recommended mode for narrowband sources.
- Power Density mode is the recommended mode for broadband sources.

When the display is set to Absolute Power, the y-axis unit will display the power unit (e.g. “nW” or “dBm”). When the display is set to Power Density the y-axis unit will display the power unit per x-axis unit (e.g. “nW/nm” or “dBm/cm^{-1}”)

8.3.8. Displaying a Split View

Pressing “Display” and selecting the option “Split View” from the second selection box from the left shows a secondary display area above the standard display area. The two areas show the same data but the lower part can be zoomed in and out whereas the upper part is fixed at the full display range. The upper display will gray out the area not displayed by the lower display, thus highlighting the currently displayed part of the graph.

In Split View mode, the entire graph is displayed above the currently zoomed in region in the graph. The region that is currently displayed is highlighted in the upper graph.

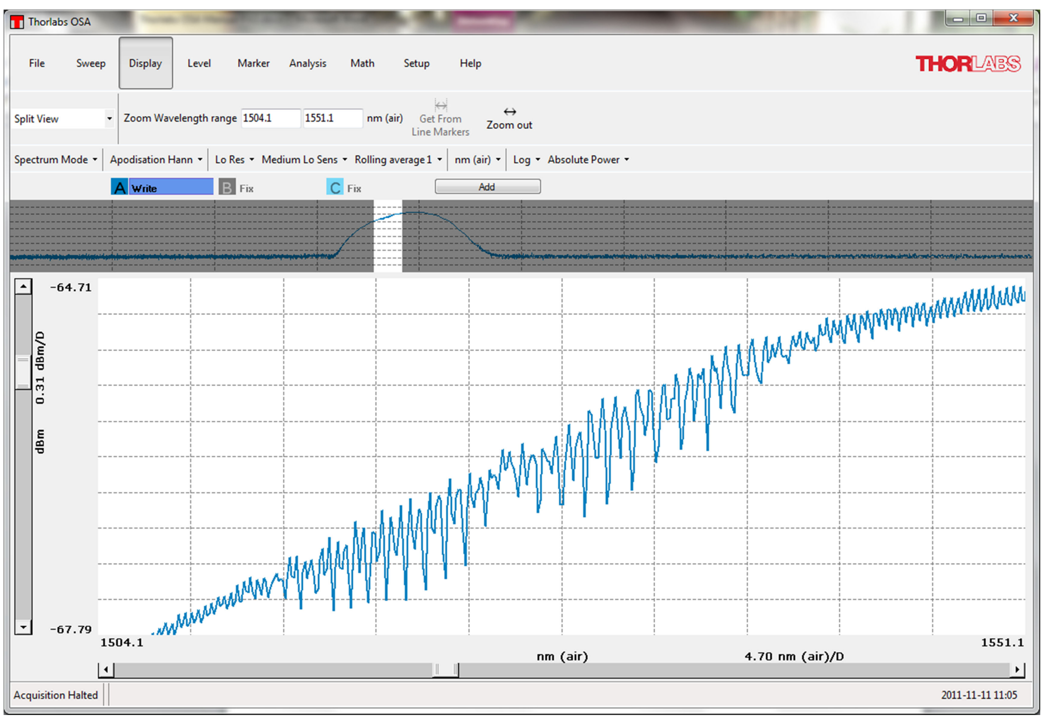


Figure 18 Split View Mode

8.3.9. Displaying the Interferogram while Working in Spectrum Mode

Pressing “Display” and selecting the option “Interferogram View” from the second selection box from the left while working in spectrum mode shows the secondary display area above the standard display area. The upper area will show the entire interferogram while the lower will still display the spectrum. This can be useful to see that there are no undesired structures in the interferogram causing problems in the spectrum.

This option is only available if an OSA is connected to the computer or at least one spectrum/interferogram from an OSA has been loaded into the software.

8.3.10. Displaying a Legend in the Data Display

A legend can be added to the main window data display to make it easier to remember what each collected trace contains. The text in the legend can be taken from the name of the traces, from the comment of the traces, the filename of the traces (only useful if the traces have been saved or loaded from a file) or from the resolution or sensitivity mode applied when the trace was collected.

The legend is enabled and the options for selecting the legend text is configured on the Display menu on the main window menu or from the Display page in the Setup Dialog (see section 9.1.3).

See the section “Viewing Properties of a Trace” to see how to set the name and comment of a trace.

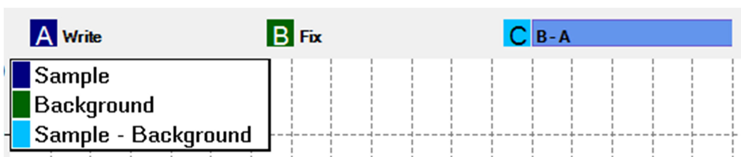


Figure 19 Display a legend in the data display

8.4. Acquiring Data

Spectra are acquired from the active spectrometer (selected in the Device dialog) and processed according to the currently set settings.

8.4.1. Finding the Spectrometer

When the software starts it will automatically detect and read the properties of all Thorlabs spectrometers connected to the computer through USB. If the program was started before the instrument was connected or before it was started, then the software will not be able to find the instrument. To tell the software to search for connected spectrometers, press the ‘Scan USB’ button found under the “Sweep” menu. This will cause the software to search all USB ports for connected Thorlabs spectrometers as well as read their properties and settings. Notice that the software interface may freeze for a short while during the time in which the scan is performed. If the device cannot be found please see the chapter on Troubleshooting.

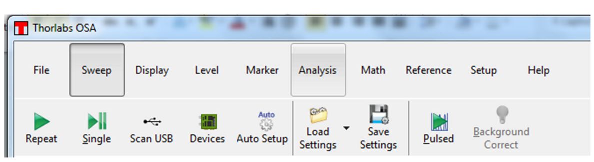


Figure 20 Thorlabs OSA Sweep Menu Interface

8.4.2. Selecting Which Instrument to Work With

If several instruments are connected to the PC, the OSA software will select one of them as an active instrument and collect all data from that one.

The selection of the active instrument can be changed by selecting a different device from the drop down list of devices found on the leftmost side of the screen, just above the Traces.

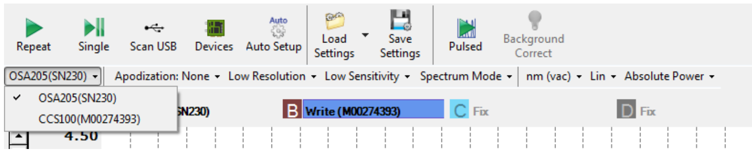


Figure 21 Selecting the active device from the settings bar.

The selection can also be changed by pressing the button “Devices” found under the “Sweep” menu. This displays a dialog window with all currently connected devices and their properties. Selecting one of the instruments and pressing the “Select” button will change which instrument the data is collected from.

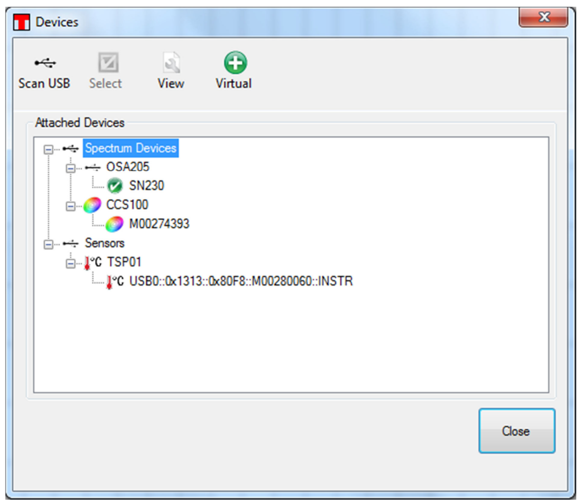


Figure 22 Device Dialog Listing All Currently Connected Devices

To acquire data from several connected devices simultaneously, start by setting up which Trace should receive data from which device. This is done in the trace menu (see Figure 25). Under the menu item “Write”, click on the entry with the serial number of the device. When the trace is setup in this way, the trace label displays “Write” followed by the serial number of the device in parenthesis. To start acquiring data from devices, select the desired device as the active device and press “Repeat” or “Single”. Devices set to running a continuous acquisition will continue to acquire data also when another device has been selected as active.

8.4.3. Acquiring a Single Spectrum / Interferogram

To acquire a single spectrum interferogram from the spectrometer, press the button “Single” found under the “Sweep” menu.

The new spectrum interferogram will be stored in the trace(s) currently in “Write” mode. Notice that these traces will be overwritten with the new information. Any trace set to automatic calculation will also be updated.

During the time the new spectrum/interferogram is collected the “Single” and “Repeat” buttons are disabled.

8.4.4. Repeated Measurements

To acquire multiple spectra/interferograms, press the button “Repeat” found under the “Sweep” menu. If the communication with the spectrometer is successfully established then the spectrometer status label in the lower left corner of the display is changed to “Acquisition running” and the “Repeat” button changes into a “Stop” button. This signals that the acquisition is running.

If any problem occurs during the communication with the spectrometer, a message box will appear giving information on what type of error has occurred. If the measurement cannot be started then the "Repeat" button will not alter and the spectrometer status label will display "Acquisition Stopped".

As soon as a new spectrum/interferogram is available, all traces currently in "Write" mode will be overwritten with the new information. Any trace set to automatic calculation will also be updated at each acquisition.

8.4.5. Automatic Setup

The automatic setup routine performs a series of measurements on the unknown light source currently being coupled into the OSA and adjusts the measurement settings to those most suitable for that source. The settings that will be adjusted are the Resolution (Section 4.12), Sensitivity (Section 4.12), Apodization (Section 4.9), Zero Fill Factor (Section 4.10), and Gain.

This routine is started by clicking on the "Auto-Setup" button in the Sweep menu. It can take up to a minute to complete, and no other measurements can be performed while it is running. Upon the completion of the routine, the OSA software will obtain one measurement using the automatically determined settings, allowing the user to inspect the result. At this point, measurements can again be taken.

8.4.6. Averaging Spectra

Averaging multiple spectra normally reduces noise levels of the measurement. It can therefore be beneficial to average at least some spectra if the intensity of the incoming light is low.

In the Thorlabs OSA software, spectra are averaged as a rolling average, meaning that the screen will be updated for each new spectrum that is collected and the average of all the measured spectra will be displayed on the screen. The rolling average is calculated as

$$S_j(i) = \frac{S_{j-1}(i) \times (n-1) + S(i)}{n}$$

Where $S_j(i)$ is the newly displayed average, $S_{j-1}(i)$ is the previously displayed average, $S(i)$ is the newly acquired spectrum and n is the smallest of the number of spectra to average and the number of spectra averaged so far. To restart the averaging procedure click on the option "Clear" for the trace containing the averaged spectrum; this will reset the number of spectra averaged so far (n) and the displayed average to zero.

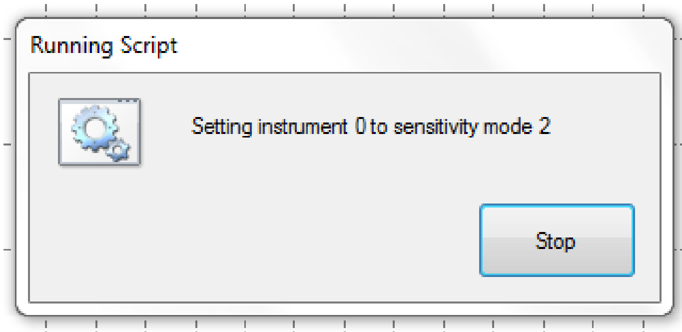
It is possible to automatically stop the averaging when the required number of spectra have been reached by checking the option "Average and Stop" found in the sub menu 'Average' on the trace menu (see the section "Working with Data in Traces").

Notice it is not possible to average interferograms.

8.4.7. Measurements of Pulsed Sources

The pulsed source measurement mode is a module specialized for measuring spectra from pulsed light sources. To start this measurement, press the button "Pulsed" found under the "Sweep" menu. If the communication with the spectrometer is successfully established then a dialog appears, as shown below, describing the progress of the current operation. When the pulsed measurement is started the software is switched to spectrum mode and the currently active trace is set to 'Min Hold'. Spectra are then acquired in each sensitivity mode and stored in the currently active trace.

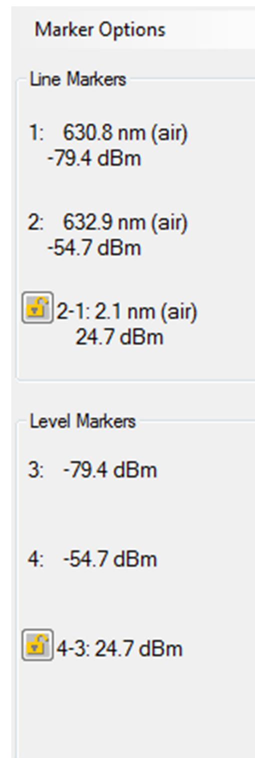
The pulsed measurement will run repeatedly in the background until the "Stop" button is pressed. Notice that there can be a delay after the "Stop" button is pressed until the measurement is actually stopped and the dialog is closed.



While the measurement is in progress, the buttons “Repeat”, “Single” and “Pulsed” are disabled.

8.5. Movable Markers

The Thorlabs OSA software has four movable markers (two line markers and two level markers), which can be enabled and disabled by pressing their respective button found under “Marker” in the main menu. The line markers are labeled “Marker 1” and “Marker 2”, and the level markers are labeled “Marker 3” and “Marker 4”. The markers can also be enabled and disabled by pressing Ctrl and their respective number on the keyboard.



The movable markers can be used to inspect the value of the data at different positions, change the displayed area of the graph (see zooming the vertical axis, and zooming the horizontal axis), or place fixed markers.

8.5.1. Moving

The movable markers can be moved by placing the mouse cursor over the marker, where the mouse cursor changes into a double arrow. Press and hold the left mouse button down to drag the movable marker to the desired position.

The position of the movable markers can also be changed by clicking on the number of the marker to move in the cursor panel. This brings up a dialog in which it is possible to type in the position of the cursor manually.

8.5.2. Value at Line Marker Position

As long as any movable marker is enabled, the cursor panel will show in the area to the right of the data display. The cursor panel shows the position of each enabled line marker and the value of the active trace at the position of the line marker. If both line markers are enabled then the distance between them and the difference in value of the active trace at the two positions is also shown.

8.5.3. Level Marker Value

The cursor panel also shows the level of each enabled level marker on the primary y-axis. If both level markers are enabled, then their difference or quotient is also displayed. By default, the difference between the level markers is displayed when the y-axis is in logarithmic scale and the quotient displayed when the y-axis is in linear scale. This can be changed by clicking the menu “Marker Options” displayed above the cursor values.

8.5.4. Locking the Markers

If both level markers or both line markers are displayed then a small pad lock is also displayed just left of the difference/quotient label. Clicking this pad lock will lock the difference between the markers, so that moving one of the markers will also move the other with the same amount. Whenever two markers are locked, a locked pad lock will be displayed; clicking this pad lock again will unlock the markers.

8.6. Fixed Markers

The Thorlabs OSA software can handle up to 2048 fixed markers. A fixed marker has a fixed position and is connected to a single trace (not necessarily the active trace) and will track the value of its trace at the given position. The fixed markers are identified by a number, starting with 0 for the first fixed marker added. The levels of the fixed markers can be tracked in a time series analysis.

Each fixed marker added is shown in the data plot as a triangle with its identifying number above it. The location of the triangle is determined by the position of the fixed marker and the value of the connected trace at the given position.

The values of the fixed markers and their positions can be stored to file or copied to the clip board for processing in other software. To store a set of fixed markers for later use in another experiment, make sure that the position of the fixed markers is shown in the data table, then store the data table to file by right-clicking in the data table and selecting "Save Table to File". This data file can later be read in the program by pressing the "Open" button to the left of the data table. Notice that only the position of the fixed markers will be read from the file; the levels will be calculated from the currently active trace.

8.6.1. Adding

A fixed marker can be added to the currently active trace by moving line Marker 1 to the desired position in the data plot and pressing the button "Add Fixed" found in the right most part of the "Marker" menu. (See Figure 23). The fixed marker can be removed again by moving line Marker 1 to the position of the fixed marker to remove and pressing the button "Remove Fixed".

8.6.2. Auto Add to Peaks

Pressing the button "Mark Peaks" will add one fixed marker to each automatically detected peak in the currently active trace (See section 8.7). The first marker will be added to the highest peak in the spectrum, the second marker to the second highest peak, etc. Notice that this will add fixed markers to the found peaks in the currently active spectrum; the positions of these markers will not change until you move them.

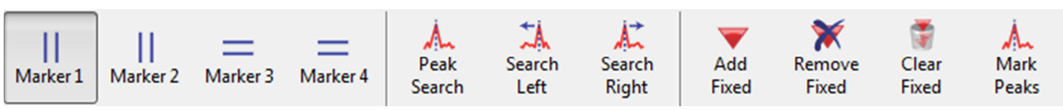


Figure 23 Marker Tool Bar

8.6.3. Value of

As long as at least one fixed marker is enabled then the data table will be shown in the area below the data plot (see Figure 24 below). The data table lists all currently shown fixed markers with its identifying number, position, the trace that the fixed marker is connected to and the value of the connected trace at the fixed markers position. Right clicking in the data table will bring up a context menu through which it is possible to re-arrange the data table, copy the selected part of the table to clipboard or save the data table to file.

A fixed marker can be moved by editing the value in the position column.

To the left of the data table are a small set of tools, through which it is possible to store the data to file, copy data to the clip board, determine which columns to display in the data table, and also to read a set of previously used fixed markers stored to file.

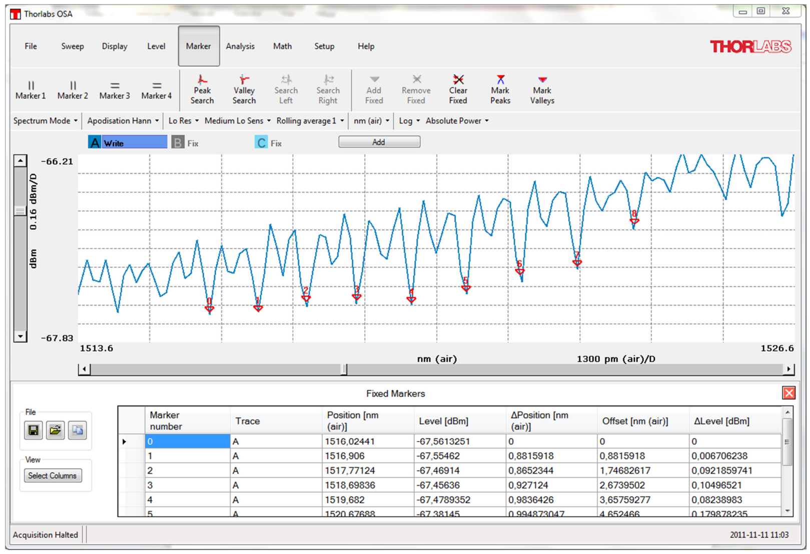


Figure 24 Data Table Shown Below Plot, Occurs When at Least one Fixed Maker is Enabled

8.7. Working with Data in Traces

The collected interferograms and spectra are stored in what is called "traces." The Thorlabs OSA software can handle up to 26 traces labeled from "A" to " Z". The controls for the traces are found in the area between the data display area and the main menu (See Figure 13). The color of each trace is seen from the square surrounding the trace's letter in the trace control area; traces which are not displayed in the data display area are shown in a more faded out nuance than the displayed traces. To the right of the trace letter ("A", "B", etc.) is the update option for the trace displayed. This option determines what will happen with the trace during the next data acquisition. The following standard options are available:

- **Write**: Traces with this option will be overwritten at the next acquisition. In interferogram mode the trace will be overwritten with the acquired interferogram, and in spectrum mode the trace will be overwritten with the calculated spectrum. If multiple devices are present then the option exists to specify the exact device to update the data from.
- **Fix**: Traces with this option will not be updated at the next acquisition.
- **Average**: Traces with this option will be updated at the next acquisition as a rolling average of the data already existing in the trace and the newly acquired spectrum. This option is only available in spectrum mode. It is possible to let the running average stop updating once the required number of spectra has been collected by selecting the option "Average and Stop"
- **Min**: Traces with this option will be updated as the minimum between the currently existing data in the trace and the newly acquired spectrum/interferogram.
- **Max**: Traces with this option will be updated as the maximum between the currently existing data in the trace and the newly acquired spectrum/interferogram.
- **Difference**: A trace can be updated as a difference between two other traces. The trace label will then read how the current trace will be calculated (e.g. "B-A" or "A-C"). This trace will be updated when the option is set and any of the traces that it is calculated from are updated.
- **Quotient**: A trace can be updated as a quotient between two other traces. The trace label will then read how the current trace will be calculated (e.g. "B/A" or "A/C"). This trace will be updated when the option is set and any of the traces that it is calculated from are updated..
- **Derivative**: A trace can be updated as the derivative of another trace. The trace label will then read in an abbreviated form how the current trace will be calculated, e.g. D1(A) where the one stands for the

first order derivative and ‘A’ is the trace to calculate the derivative of. This trace will be updated when the option is set and the input trace is updated.

- **Envelope**: Only available in Interferogram Mode. Updates the trace as the envelope of the last acquired interferogram. This trace will be updated on each acquisition of an interferogram. The envelope is offset corrected and thus has its lowest point set to zero. If the display is set to show the interferogram in percent then the envelope will lie on top of the displayed interferogram.

- **Transmission**: A trace with this option will be updated as a quotient between two other traces expressed in percent.

- **Absorbance**: A trace with this option will be updated as –Log10(X/Y) where X and Y represent two separate traces.

If the calculation of a trace cannot be performed, e.g. if the two input traces have different lengths, then the trace label will be shown in red and the trace info window will display the reason for the error.

One of the traces will be marked as the **active trace**. This is indicated by a blue square around the trace option, just to the right of the trace letter. The active trace is the trace onto which all math operations will be applied, the trace that is analyzed by the analysis features, as well as the trace that will be saved when the “Save Trace” button is pressed. To change the option for a trace or change the active trace, click on the trace to modify. This will bring up a menu with options and operations for the trace that was clicked on. The top line of the menu displays the name of the trace which will be modified. To move a displayed trace from the primary axis to the secondary axis, click on the option “Move to Secondary Axis”. To move the trace back to the primary axis, click on the trace again. The option will now have changed to “Move to Primary Axis”. The secondary axis in the data display area will only be shown if at least one trace is drawn on the secondary axis.

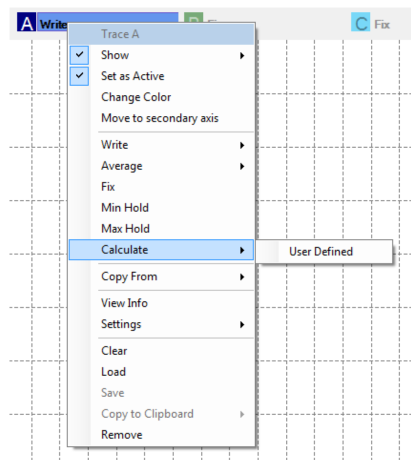


Figure 25 The Active Trace / Trace Utilization Screen

8.7.1. User-Defined Update Options

To specify any other update option than the pre-configured options, click on the menu items “Calculate”→”User Defined” in the menu which is displayed by clicking on the trace label (see Figure 25). This opens up a dialog with a text box where it is possible to enter an expression to be calculated upon each acquired spectrum/interferogram.

This expression uses the same rules as described in the “Spectrum Math” section in section 8.7.4 on Page 32. In addition to these can the following update options also be used:

- **Average(T,N)**: Updates the trace as a N-point rolling average of the Trace’s current value and the trace / trace expression given as first parameter.

- **Min_hold(T)**: Updates the trace as the minimum of the Trace’s current value and the value of the given trace or trace expression.

- **Max_hold(T)**: Updates the trace as the maximum of the Trace’s current value and the value of the given trace or trace expression.

- **Stitch(T1,T2)**: Updates the trace by combining the contents of the traces (or trace expressions) T1 and T2

- **Derivative(T, N)**: Updates the trace as the N:th derivative of the trace or trace expression given as the first parameter. Order must be a scalar ranging from 1 to 5.

Examples of possible update options are:

- A + B
- Exp(-A*B)
- -Log10(A/B)
- Min_hold(A-B)

8.7.2. Viewing Properties of a Trace

To see the properties of a trace, click on the icon of the trace that you want to inspect, and click on the menu option “View Info”. This will open a window displaying basic information on the trace, such as the serial number of the OSA, date and time of the acquisition and the settings that were applied to the acquisition.

The trace info window will hover above all other windows as long as it is open and automatically update whenever the trace is updated.

The trace info window contains two fields named ‘Name’ and ‘Comment’.

- The name field allows the user to give the trace a short name. The name can be up to 31 characters long and only contain basic ASCII characters. The name will be stored when storing the trace to file.
- The comment field allows the user to give a description of the trace. The comment can be up to 127 characters long and only contain basic ASCII characters. The comment will be stored when storing the trace to file.

The name and comment will be stored automatically while typing and retained when the trace is updated. Clearing the trace will also clear the name and comment. The name or comment can be shown in the legend of the data display area, see Section 8.3.10.

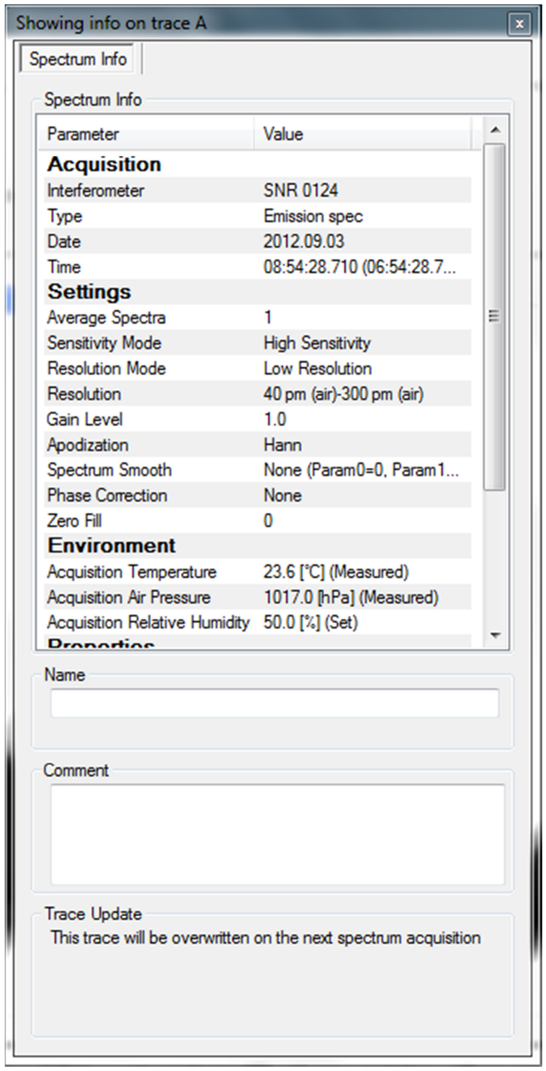


Figure 26 Viewing Properties of a Trace

8.7.3. Reordering Traces

The traces will always be drawn from the left to the right, i.e. Trace “A” will always be drawn first followed by Trace “B,” Trace “C,” etc. If one trace covers another you may wish to change the order of the traces. This can be done by dragging and dropping the trace labels into the desired order. Put the mouse cursor over the icon of the trace you want to change, press down the left mouse button, and move the mouse cursor to the right or the left. As you move the mouse cursor, the traces will be reordered in the Trace Controls menu and in the graph. Release the left mouse button when you are happy with the new ordering of the traces.

8.7.4. Math Operations

The buttons on the math menu all work on the currently active trace and are disabled while collecting spectra. The math operations can be undone by pressing the “Undo” button. The buttons functions are explained below.

Figure 27 Math Menu Operations Buttons Bar

Spectrum Math: This brings up a dialog making it possible to perform mathematical operations on one or several spectra/interferograms, e.g. multiplying a spectrum with a scalar, adding together two spectra or dividing one spectrum by another. The expression to be calculated is typed into the text box of the dialog that is opened with the following rules for formatting:

- Traces are identified by letters A through Z (case insensitive). Only the traces which can be seen in the trace controls area can be used.
- Scalars with decimal fractions are entered using a decimal point to separate the integers from the decimals.
- Allowed operators are: Subtraction (**-**), Addition (**+**), Division (**/**), Multiplication (*****) and Power of (**^**).
- Operations can be grouped using round parentheses.

The expression can also involve the following functions:

- **Ln(T)**: Calculates the natural logarithm of a trace or an expression involving a trace.
- **Log10(T)**: Calculates the base-10 logarithm of a trace or an expression involving a trace
- **Sqrt(T)**:Calculates the square root of a trace or an expression involving a trace.
- **Exp(T)**:Calculates the Exponential function of a trace or an expression involving a trace.

The calculation will be performed when the button 'Calculate' is pressed. Pressing the button 'Close' will close the window without doing anything more.

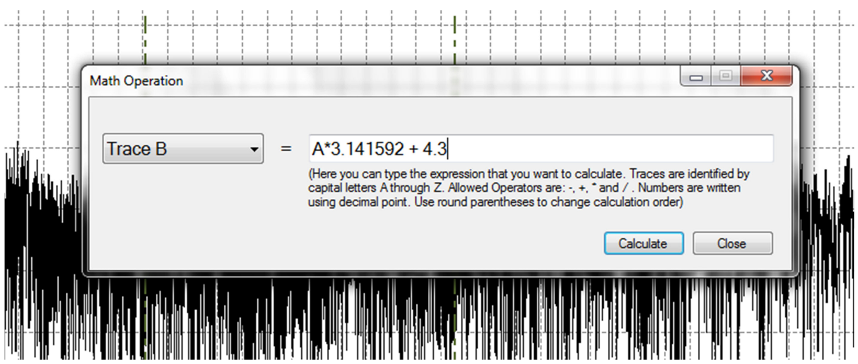


Figure 28   Mathematical Operations Dialog

Cut Spectrum: This will cut the currently active trace to the region between the two line markers, removing all data outside the selected range. This is only available if the two line markers are displayed.

Apodize: This performs an apodization of the current interferogram; this option is only available for interferograms.

Invert: Calculates the reciprocal of the currently active trace.

Zero Out: Sets all values between in a specified region of the spectrum/interferogram to zero. This brings up a dialog where the region can be specified.

Smooth: Performs a smoothing operation on the currently active trace and brings out a dialog in which it is possible to select a smoothing algorithm to use and to set the parameters for the smoothing. The trace to operate on is displayed in black in this dialog and the smoothed spectrum is displayed in red.

Curve Fit: Makes it possible to fit a mathematical curve to the currently active trace or a portion of it. Available math functions are: Gaussian, Lorentzian, and Polynomial. See Section 8.7.5.

Derivative: Calculates the derivative of the current trace. Derivatives are available up to the fifth order.

Add Noise: Makes it possible to add white noise to the current trace.

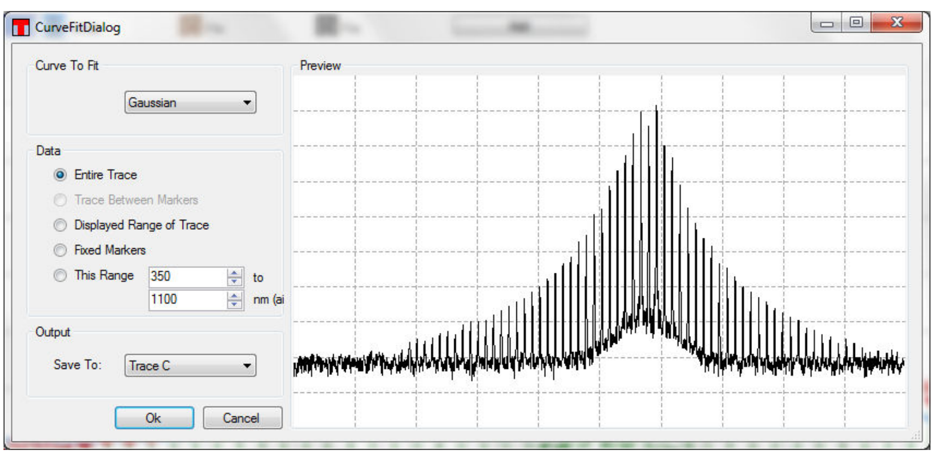
Resample Data: Makes it possible to change the sample points in the current trace. Brings up a dialog where it is possible to select the resampling factor. The resampling factor is the desired length of the trace divided by the current length of the trace. For example selecting a resampling factor of 0.5 reduces the length of the trace by a factor of two and a resampling factor of 4.0 increases the length of the trace by a factor of four. The resampling is performed using a quintic spline interpolation to make the resampled trace as similar to the original trace as possible.

Convert Unit: Brings up a small calculator where the different units used in the software can be converted to each other. Also allows for converting resolutions from one unit to another.

8.7.5. Functional Traces

By using the function “Curve Fit” found under the “Math” menu is it possible to fit a mathematical function to a trace. The calculated function will be stored in one of the traces as a mathematical function and drawn in the data display along with the other traces. The currently available types of functions are Gaussian, Lorentzian and polynomial. In the dialog which is opened when pressing the “Curve Fit” dialog is it possible to select the type of function to fit, the dataset to use for fitting and the trace which will hold the fitted curve. The available options for the data set are;

- **Entire Trace**: Every data point in the currently active trace will be used to fit the function.
- **Trace Between Markers**: (Only available if both Line Marker 1 and 2 are shown). Every data point between the two line markers will be used in the fit.
- **Displayed Range of Trace**: Every data point which is currently visible in the main window data display will be used in the fit (NOTE: this is not the region currently displayed in the curve fit dialog).
- **Fixed Markers**: (Only available if at least one fixed marker is shown). Only the data points at the currently set fixed markers will be used in the fit. Use this option to fit a curve to a set of peaks in the spectrum.
- **This Range**: Makes it possible to specify a given x-axis range that will be used in the fit.



Pressing the “Ok” button in the Curve Fit Dialog will fit a function of the desired type to the selected range of data points. The output will be stored in one of the traces and displayed in the main window data display. If the fit failed then the status bar will display the error message “Fit Failed”.

Notice that the fitted function will only be defined for the x-axis range that was used to create the function.

Opening up the trace properties window of a functional trace will display the type of function stored in the trace together with the parameter values used to define the function.

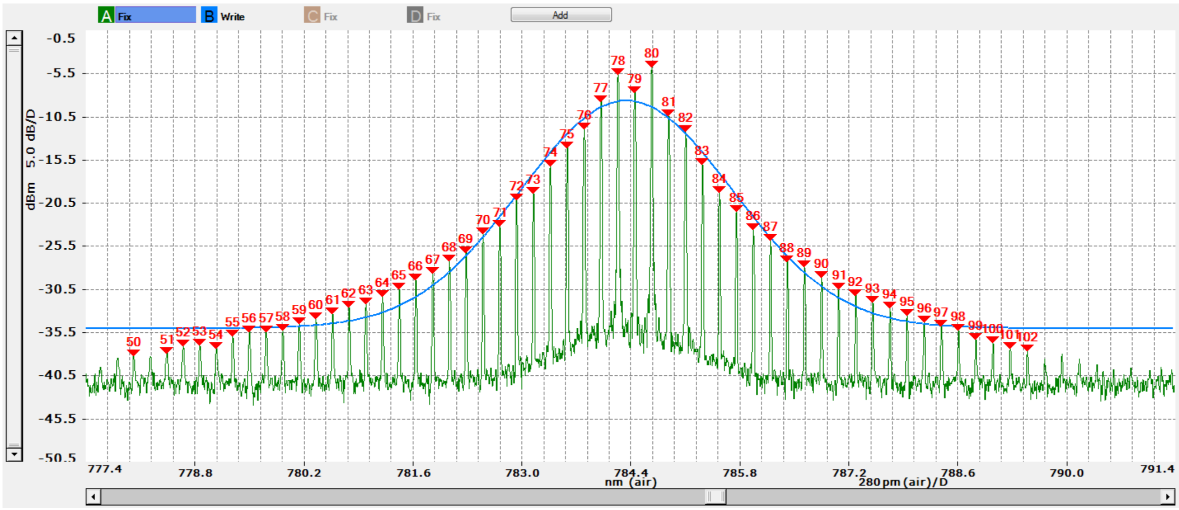


Figure 29 Example of a Gaussian fitted to a set of fixed markers.

Functional traces have some limitations compared to ordinary traces, not all mathematical operations can be performed on them.

8.8. Saving / Loading Data

Thorlabs OSA software can read and write in the following spectral file formats:

- **Thorlabs OSA Spectrum File format (.spf2):** Native file format for Thorlabs OSA Software.
- **Comma Separated Values (.csv) with Thorlabs OSA Header:** Raw ASCII file format but with a header which the Thorlabs OSA Software can read. Columns separated by comma, semicolon or tab (configurable)

Thorlabs OSA Software can also export spectral data in the following file formats:

- **Grams Galactic SPC (.spc):** For data exchange with other spectral software.
- **JCAMP-DX (.jdx):** For data exchange with other spectral software.
- **Matlab v5 binary file (.mat):** For easily loading data into Matlab™ and compatible software.
- **Text File (.txt):** Raw ASCII file format, columns separated by comma, semicolon or tab (configurable)
- **Zipped Text file (.txt.zip):** One txt file stored compressed in a zip folder, reduces disk usage.
- **Zipped Comma Separated Values (.txt.zip):** One CSV file stored compressed in a zip folder.

8.8.1. Saving Spectral Data

To save the data in the currently active trace (spectrum or interferogram), press the button “Save Trace” found under the “File” menu or click the option “Save” found in the trace drop down menu.

To export the data in the currently active trace, press the button “Export Trace” found under the “File” menu.

To save the data in all traces (in either spectrum mode or interferogram mode), press the button “Save All” found under the “File” menu. This only allows the data to be stored in Thorlabs OSA Spectrum File format (.spf2).

8.8.2. Loading Spectral Data

There are two ways of loading spectral data into a trace.

- Click a trace label and select the menu option “Load” in the drop down menu that appears. This loads the data into the selected trace, if the trace already contains data then the previous data will be erased (unless the mode needs to be switched, see below).

- Click on the menu item “Load” found under the “File” menu. This loads data into the first trace that does not contain any data already. If no trace is empty then a dialog will appear from where it is possible to select which trace to store the data in.

If the software is currently running in spectrum mode and the loaded trace is an interferogram then the mode will be switched to interferogram mode automatically. Likewise will a spectrum is loaded in interferogram mode switch the current to spectrum mode.

8.9. Analyzing Data

The Thorlabs OSA software contains a number of analysis modes, each analyzing one aspect of the data from the spectrometer. The result of each analysis is displayed in a display area below the data display area. As long as one analysis mode is active, the corresponding button in the Analysis menu will be highlighted. To stop the analysis, click the corresponding button again or click the close button in the corresponding analysis area.

Each analysis area has an options panel displayed to the left of the displayed values. In the options panel can the settings for the analysis be seen and modified.

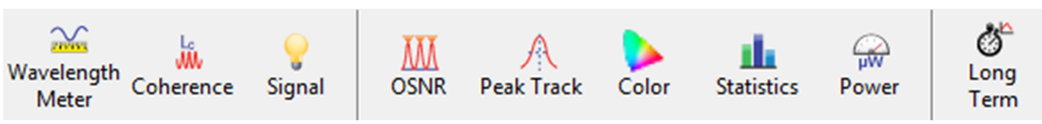


Figure 30 Data Analysis Toolbar: Notice Not All Analysis Modes are Available in all Modes for all Spectrometers

8.9.1. Wavelength Metering

The wavelength metering analysis allows for very accurate determination of the wavelength in the input light to the spectrometer. The wavelength metering analysis is only available for light from sources with a bandwidth of 10 GHz or less. This mode works by analyzing the periodicity of the collected interferograms before apodization is performed. The number of cycles in the interferogram are counted and compared to the number of cycles in the interferogram of the built-in reference laser (see the explanation in the Introduction of this manual).

When the wavelength metering mode is enabled, the wavelength metering area is displayed below the data display area. The calculated wavelength is displayed in the currently set spectrum (x-axis) unit. If the input light is not monochromatic enough for the analysis to work properly, the text “Invalid Value” will be displayed instead of a number. The calculated wavelength is displayed with an accuracy that corresponds to the estimated error in the measurement. If the source shows multimode behavior, the number of significant decimals displayed will be reduced to reflect the reduced precision of the measurement. The analysis estimates the error in the measured wavelength, displaying the significant digits in black and the not significant digits in gray. The control “Decimals Displayed” in the wavelength metering options panel makes it possible to manually set the number of decimals to display.

The measured values can be averaged to further increase the accuracy of the result- select the number of data points to average together by typing in a value in the text box “Average”, found in the options panel. The number of values that have been averaged together in the currently displayed value is shown with a smaller font below the calculated value. To clear the average, press the button with a red “X” near the “Average” option.

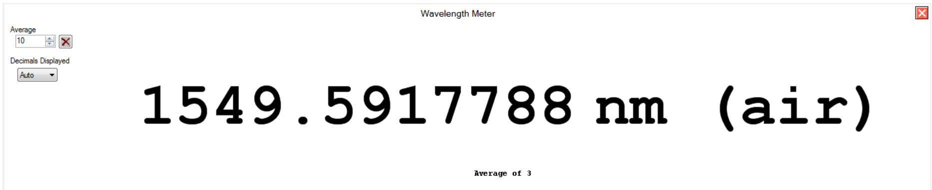


Figure 31 Wavelength Metering Display

Notice that the wavelength metering is performed on the interferogram during the collection process prior to apodization and it is not necessary to turn off the apodization for this analysis mode to function.

8.9.2. Coherence Length

Coherence length measurement analyzes the interferogram to estimate the coherence length of the input. The coherence length measurement mode looks at the envelope of the interferogram and determines the coherence length as the optical path length difference between the two points closest to the maximum amplitude of the envelope where the envelope has decreased to 1/e from its maximum amplitude.

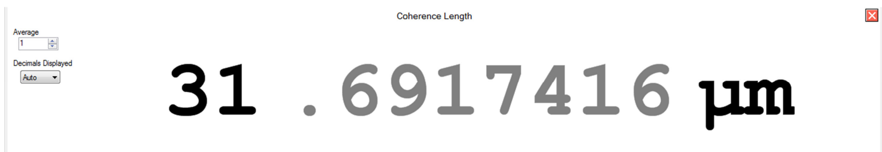


Figure 32 Coherence Length Display

If the coherence length of the input source is longer than the Optical Path Difference attained by the instrument in the currently used resolution mode, then the calculated value will merely be displayed as larger than the current Optical Path Difference (e.g. '> 81.67 mm' in high resolution mode and the error message 'Coherence Length Too Large To Be Measured' will be displayed).

Coherence length analysis is very sensitive to saturation in the interferogram. Whenever a saturated interferogram is analyzed, the analysis result be displayed in red and the error message 'Saturated interferogram' be displayed below the analyzed result.

Notice that the Coherence Length metering is performed on the interferogram during the collection process prior to apodization and it is not necessary to turn off the apodization for this analysis mode to function.

8.9.3. Signal

The signal inspection allows for inspection of the amount of light entering the spectrometer; this is useful for alignment purposes.

In signal mode the signal area is displayed below the data display area. This displays the maximum percentage of the full range that is used by the last acquired interferogram as well as the location of this maximum in the interferogram. The peak to peak intensity of the interferogram gives information if the interferogram is saturated or if the interferogram contains too little light for the measurement to be useful.

The options panel in the signal mode displays the currently set gain level and has a control where it is possible to manually change the gain level of the detectors.

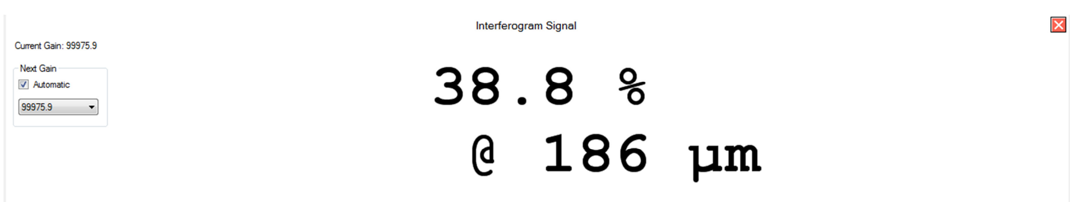


Figure 33 Interferogram Signal Display

8.9.4. Color

The color analysis is only available for instruments covering the visible wavelength range. For all other instruments, this mode will be disabled.

The color analysis performs a color analysis of the currently active trace. The analysis calculates the chromaticity coordinates (x, y, and z) and the main wavelength in the spectrum. The Thorlabs OSA software calculates the correlation between the collected spectrum and the three color matching functions x(λ), y(λ), and z(λ) defined from the CIE 1931 2° standard observer to obtain the tri-stimulus values X, Y, and Z. These are then normalized to obtain the chromaticity coordinates x, y, and z. The calculated chromaticity coordinates x and y are displayed in the CIE 1931 color space chromaticity diagram as a dark circle as well as displayed numerically next to the diagram.

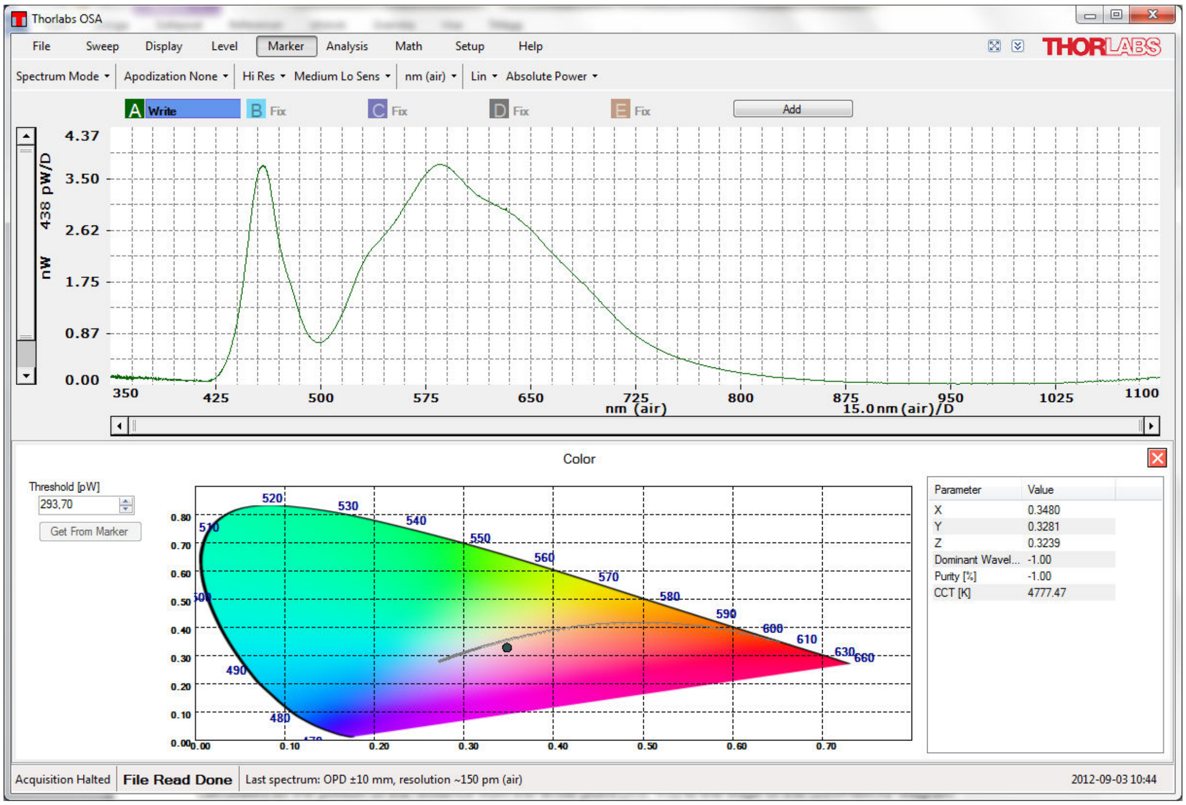


Figure 34 Thorlabs OSA with Color Mode Active – Calculated Chromaticity Coordinates as well as Main Wavelength Displayed in the Color Mode Analysis Area

The main wavelength is calculated as the interception between the straight line from the white point (1/3, 1/3) through the calculated chromaticity point (x, y) and the edge of the chromaticity diagram. The purity is calculated as the portion of the distance from the white point (1/3, 1/3) to the edge of the chromaticity diagram that the distance from the white point (1/3, 1/3) to the calculated chromaticity represents. A purity of 100% represents a point on the edge of the chromaticity diagram, i.e. a pure color, and a purity of 0% represents a mix of all colors, i.e. the white point itself.

The correlated color temperature (CCT) can be calculated for a light source that is close enough to the Planckian locus in the 1960 UCS. The CCT is calculated by converting the calculated chromaticity point (x, y) into a point in the CIE 1960 color space (u, v) and finding the closest Planckian locus. If the distance to the closest Planckian locus ($\Delta_{u,v}$) is larger than 0.05 then a temperature of -1 Kelvin is returned as an error code.

The threshold option makes it possible to ignore data points in the spectrum with low intensity; this can be useful if the spectrum is very noisy.

8.9.5. Power Analysis

Power analysis allows for tracking of the incident optical power into the spectrometer. (See the specs for the precision of the power analysis at different wavelengths). The optical power is calculated by integrating the currently active trace over a wavelength interval, by default the entire measurable wavelength interval.

As long as power mode is active, the power mode analysis area is displayed in the region below the data plot. This displays the calculated optical power in the current y-axis unit (mW or dBm) integrated over the required wavelength range. In the area below, the displayed power are two text boxes where it is possible to specify the wavelength/frequency range over which the power should be measured. Changes to the wavelength range will take effect immediately. An interval can be marked graphically using the movable markers 1 and 2, enabling these will activate the button “Get From Markers” located next to the two input boxes. Pressing this button will retrieve the positions of the two movable markers and recalculate the optical input power. The interval can also be retrieved from the currently displayed range of the data display by pressing the button “Use Plot Range” found below the input boxes. Notice that this takes the range at the instant when the button is pressed, zooming or scrolling the graph will not change the interval used until the “Use Plot Range” button is pressed again.

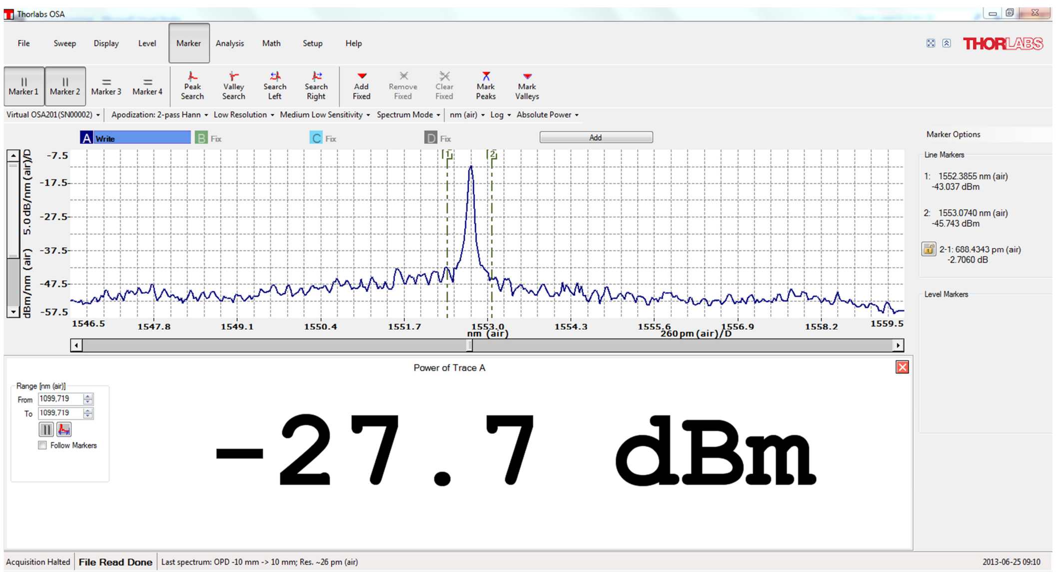


Figure 35 Thorlabs OSA with Power Mode Active – Calculated Power Displayed in Power Mode Analysis Area Below Data Display

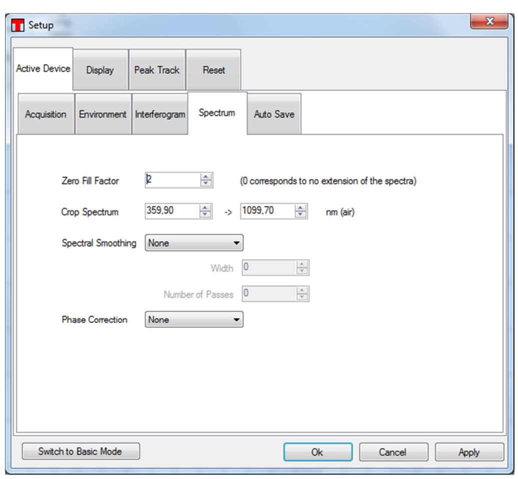


Figure 36 Advanced Mode Setup Menu, Demonstrating Changes to the Zero Fill Factor

To get an accurate reading of the power level on narrowband sources in Absolute Power mode, it is recommended that you use Zero Fill Factor 1 or 2 which can be set in the Setup menu (advanced mode).

This feature adds more data points to the spectrum, so that the peak location is clearer. However, it does not increase the resolution. Green traces have Zero Fill set to 0 and blue trace have Zero Fill 2 (four times as many points in the spectrum). The blue trace gives a more accurate power level of the laser peak. If the peak precisely between two data points as in this case with Zero Fill=0, the error in power level reading can be large, like 17% to low power as in the example shown on the next page.

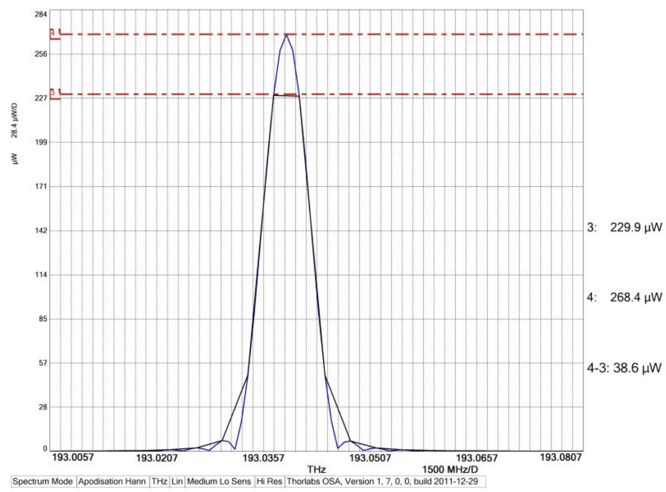


Figure 37 If the Spectrum Peak is Located Precisely Between Two Data Points as in this Case with Zero Fill = 0, the Error in Power Level Reading Can Be Large. In this Example, 17% too Low Power.

Since the wavelength range is wide and the dynamic range is limited (see Section 4.7), the Power Analysis tool will give an exceedingly high value if the range is not limited.

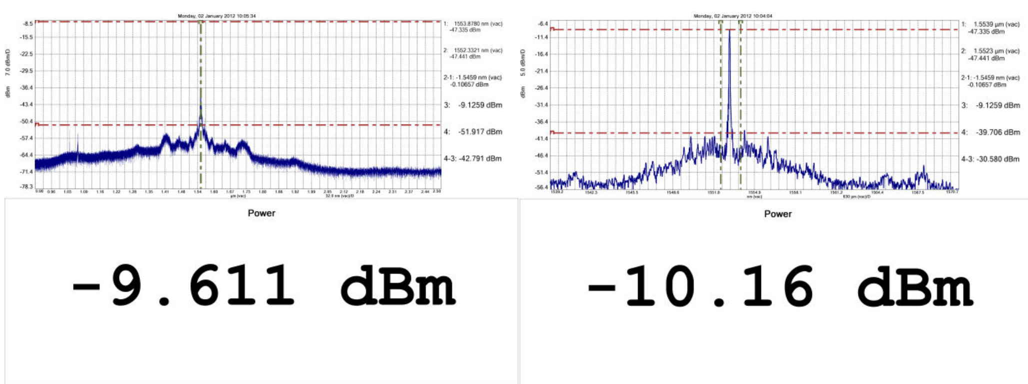


Figure 38 ~100 µW of 1550 nm Laser Used to Test Source. To the Left is the Full Range Used for the Power Analysis, to the Right is the Range Between the Line Markers Used

8.9.6. Peak Track

Through the peak track analysis mode it is possible to track the position, amplitude, and width of peaks in the spectrum over time.

As long as peak track mode is active, the peak track analysis area will be displayed below the data display (see Figure 39 below). Here, a data table shows information about the peaks and as well as a small toolbox with the settings that used to find the peaks. It is also possible to select which columns can be displayed in the data table by clicking on the button “Select Columns”.

The parameters used to find the peaks are:

- **Threshold**: Only data points with intensity above this level will be used when searching for peaks.

- **Min Peak Height**: Only peaks which have a peak to base ratio of at least this value will be found. Notice that this affects the reported width of the peaks, the reported width is the width of the peak at this level from the maximum value. For example, a value of 3 dB here will give the FWHM of the peak and a value of 6 dB here will give the width of the peak and a quarter of the maximum value.

- **Minimum and Maximum Wavelength**: (Wavenumber/Frequency) Limits the x-axis range in which the search for peaks is performed.

- In peak track mode the currently active spectrum is checked for peaks upon the collection of a new spectrum from the instrument. By default the peaks are sorted in order of decreasing intensity. Right clicking in the data table brings out a context menu from which it is possible to save the data in the data table to file or copy to the clip board for analysis in some other software.

- The peaks found in peak track mode can be tracked over time in a time series analysis (see Long Term Tests) if the peak track analysis mode is started before the time series analysis is started. Notice that since the peaks are ordered by decreasing intensity, they can be rearranged if the relative intensity of the peaks in the spectrum is changed.

- If no peaks are found in peak track mode, check the settings for the threshold and min-peak height to make sure that the expected peaks in the spectrum are higher than this. The settings can be changed either in the Setup Dialog or directly in the Options Control box found to the right of the data table in the peak track analysis area.

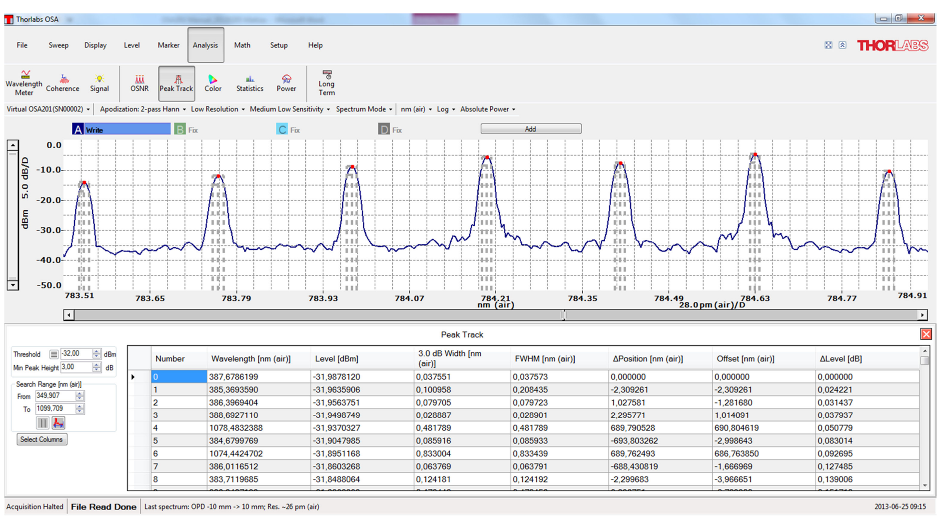


Figure 39 Thorlabs OSA with Peak track Mode Active

For each peak that is found in the currently active trace, there is one line displayed in the table shown in the Peak Track analysis area (found below the data display). The data reported for each peak is as follows;

- **FWHM:** The full width of the peak at half of the maximum value.
- **Level:** The value of the peak at the center wavelength.
- **Width:** The width of the peak at 'Min Peak Height' dB below the maximum value.
- **Wavelength (or Frequency/Wavenumber/depending on the currently used x-axis unit):** The center point of the peak. This is calculated as the weighted average of the data points which are less than 'Min Peak Height' dB below the maximum value of the peak.
- **Δ Position:** The difference in position between the current peak and the previous peak in the table.
- **Offset:** The difference in position between the current peak and the first peak in the table.
- **Δ Level:** The difference in level between the current peak and the first peak in the table.

8.9.7. OSNR Analysis

OSNR analysis allows for the analysis of the Optical Signal to Noise Ratio (OSNR) of the currently active spectrum. The OSNR analysis mode uses the parameters for the peak search to automatically find the peaks in the spectrum (See the section on setting up the peak search parameters).

The OSNR for each peak is calculated as:

$$10log_{10}\left(\frac{P}{N}\right) + 10log_{10}\left(\frac{B_m}{B_r}\right)$$

Where,

- **P** is the optical power of the peak
- **N** is the interpolated noise at the peak
- $\mathbf{B_m}$ is the optical resolution of the measurement
- $\mathbf{B_r}$ is the reference resolution (0.1 nm)

When multiple peaks are present in the spectrum, the noise at each peak is calculated by first calculating the average intensity around the mid points between the current peak and the peaks to the left the right (the so called left and right noise areas). The noise at the peak is then linearly interpolated between these two values. The first and the last peak is half the average distance between the peaks in the spectrum used to find the left and right noise areas.

When only one peak is present in the spectrum, the noise is calculated by first finding the points to the left (and the right) where the (smoothed) first order derivative is no longer positive (or negative). The noise at the peak is then the linear interpolation of these two values.

8.9.8. Long-Term Tests

The long-term analysis mode is intended for long-term monitoring of optical systems. These tests can track any output parameter from the analysis modes as well as the status parameters of the connected spectrometers.

Setting Up and Running

To start a long term test, press "Analysis" and then the button "Long Term". This will bring up a dialog box where the parameters to be monitored are selected as well as the desired duration of the test.

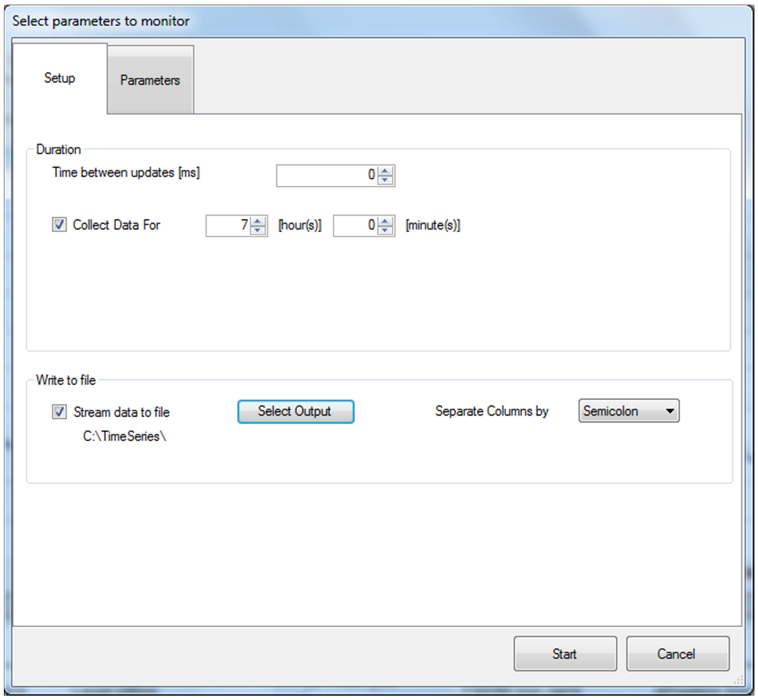


Figure 40 Setting up the Long Term Test – General Setup

The general options can be selected from the the "Setup" tab in this dialog box. The duration of the test can be specified in hours and minutes. If the duration is set to zero, then the measurement will run until the "Stop" button is pressed. The time interval between each two updates can be set by selecting a value in the box "Time between updates". Notice that this only defines the minimum time between the updates of the measurement; the actual rate will be determined by the update rate of the instrument.

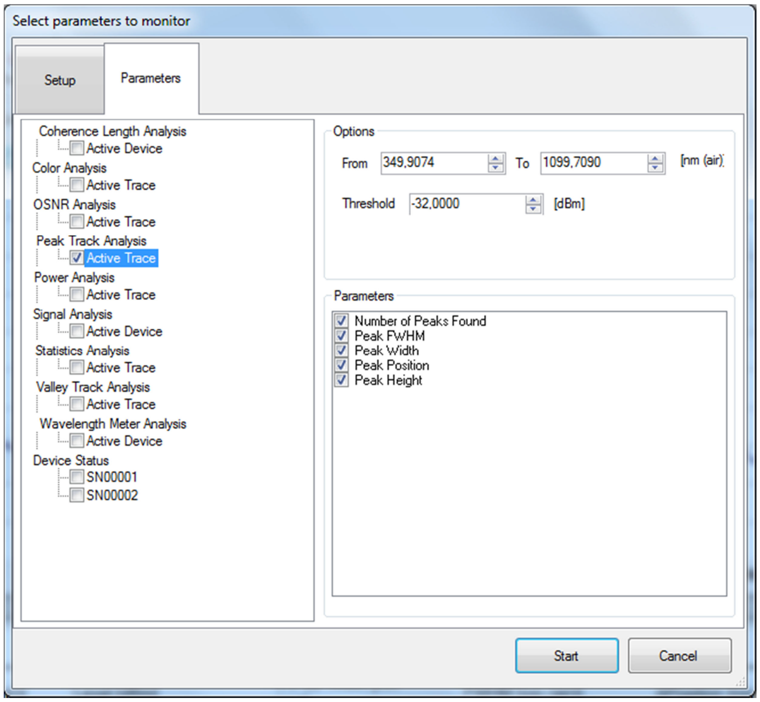


Figure 41 Setting up the Long Term Test – Selecting the parameters to track

The parameters to track can be selected in the "Parameters" tab of the Long Term Setup Dialog. The left portion of the dialog shows the types of parameters which can be collected. Selecting one group shows the available parameters and the options for the collection, e.g. selecting the "Power Analysis" bring up controls where the x-axis range over which the power should be calculated can be defined.

Note: To track a parameter, the parameters group (e.g. "Peak Track Analysis") **and** the parameter to track (e.g. "Peak Position") **must** be checked.

When the settings have been completed in the long-term setup dialog, press the "Start" button found in the lower right corner of the dialog box. This will open the time series window, showing one graph for each parameter being collected as well as a menu with options for managing the long term test.

Storing Results

The time series of collected data can either be streamed to disk, meaning that the data will be written to a file as soon as it is collected, or it can be stored to file after the collection has been done.

To stream the collected data to disk, check the button "Stream Data to File" found in the "Setup" tab of the Time Series Setup Dialog (see Figure 40) and select a directory in which to store the data. Streaming data to file will create one file per parameter group (e.g. peak track data or device status data) and will write one line in this file for every spectrum that is collected from the instrument.

When the long term test has been stopped (see below) it is possible to store the collected data to file. This is done by pressing the "Save" button in the Time Series window. This will store all the collected data into one file.

Stopping and Restarting

To stop a long term test that has been started, press the "Stop" button in the Time Series window which was opened when the test started (notice that this window may be hidden behind the main window of the Thorlabs OSA software).

Each of the graphs in the dialog can be minimized by clicking on the small icon to the left of the parameter name. This will automatically make the other graphs in the dialog larger.

The top most part of the dialog, right below the menu, displays the status of the measurement. If data is streamed to file then this will display the location of the file, and if a time limit is set on the test then the current duration of the test will also be displayed.

When the "Stop" button is pressed it will transform into a "Continue" button. Pressing this will continue the long term test where it was left off and will use the same parameters.

To clear the long term test of collected data, stop the measurement and press the "Clear" button. The measurement can then be restarted by clicking on "Continue".

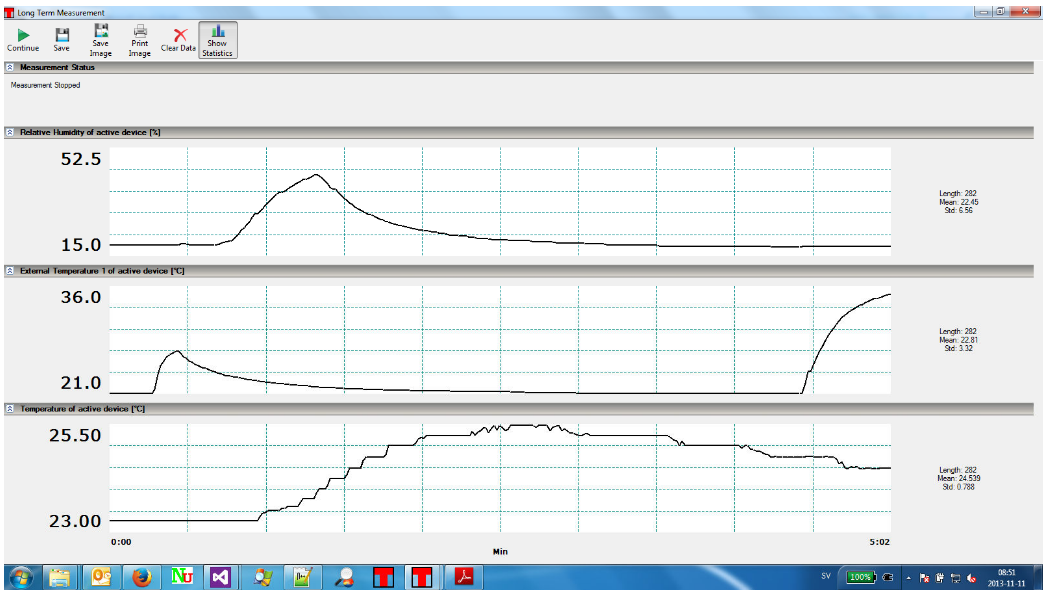


Figure 42 Time Series Window

The results of the measurement can be stored to file by pressing the "Save" button or a screenshot of the measurement can be stored as an image file or printed by pressing the "Save Image" or "Print Image" buttons.

8.10. References

8.10.1. Reference Databases (e.g., HITRAN)

The OSA software ships with built-in spectroscopic reference standards from the HITRAN database (**http://www.cfa.harvard.edu/hitran/**) for acetylene (C_2H_2), water vapor (H_2O), and carbon dioxide (CO_2). These standards can be used to identify these gases in acquired spectra. To identify other foreign constituents of an acquired spectrum, the OSA software can import additional HITRAN reference standards, as well as reference spectra saved in any of the other export formats that the OSA software supports (see Section 8.8). This allows the user to acquire, analyze, and save a baseline spectrum that is specific to a given lab environment.

Saved spectra are used directly by the OSA software without further modification. On the other hand, HITRAN standards (sometimes referred to as "line-by-line references") must be converted to a spectrum before they can be used in further analysis. This conversion is detailed below.

Importing References

The Reference Database window displays the user's currently available references. To add a new reference, open this window from XXX and click the "Import" button. HITRAN line-by-line references must have the .par file extension and be saved in HITRAN's 160-character format.

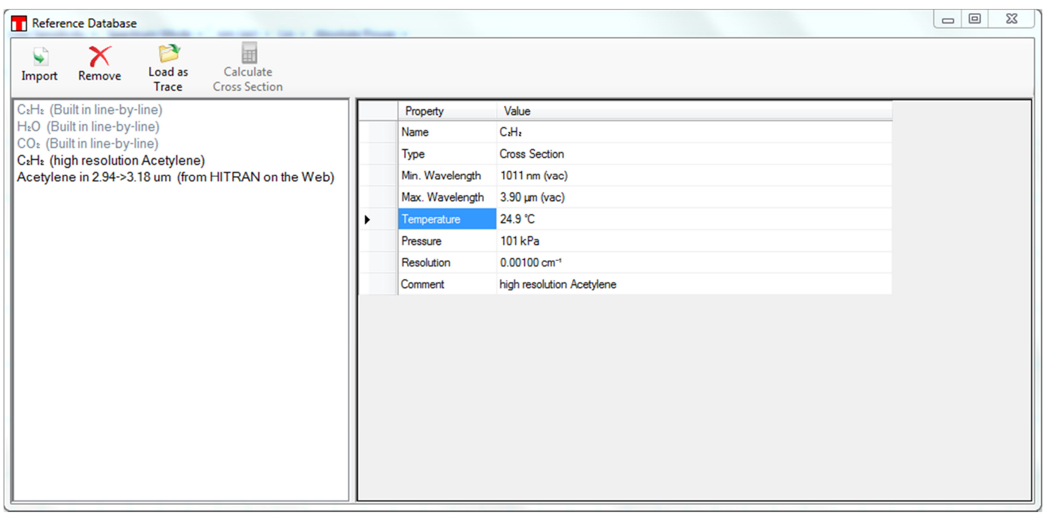


Figure 43 Reference Database Window

Converting HITRAN References into Absorption Cross Sections

A line-by-line reference must be converted into a regular spectrum before it can be used as a baseline. This spectrum will be used during the Reference Fitting step to help account for line shifts, modulations in line intensity, line broadening caused by air, and self-broadening. To obtain a regular spectrum, an *absorption cross section* must be calculated first.

An absorption cross section is a physical property of a molecule that describes how strongly the molecule absorbs light at a particular wavelength. It is denoted by $\sigma(\lambda)$ in the Beer-Lambert law:

$$I(\lambda) = I_0(\lambda)\, e^{\sigma(\lambda)\cdot cL}$$

Here, λ is the wavelength, $\sigma(\lambda)$ is the wavelength-dependent absorption cross section, c is the concentration of the gas of interest, and L is the total path length traversed by the light as it passes through the gas. The calculated absorption cross section has units of cm^2/*molecule*.

The absorption cross section is related to the *absorption coefficient*, denoted by *k*. The absorption coefficient can be calculated by multiplying the absorption coefficient by the so-called *mass path*

$$k(\lambda) = \frac{qP}{k_B T}\sigma(\lambda)$$

where k_B is Boltzmann's constant, *P* is the total pressure, *T* is the temperature, and *q* is the volume mixing ratio of the gas.

The OSA software takes into account the total pressure and temperature in order to calculate the absorption cross section and resulting spectrum. By clicking the "Calculate Cross Section" button, the following dialog box will appear, which displays all the needed input parameters. Please note that the usable X-axis data range will be limited by the data range from the HITRAN line-by-line reference.

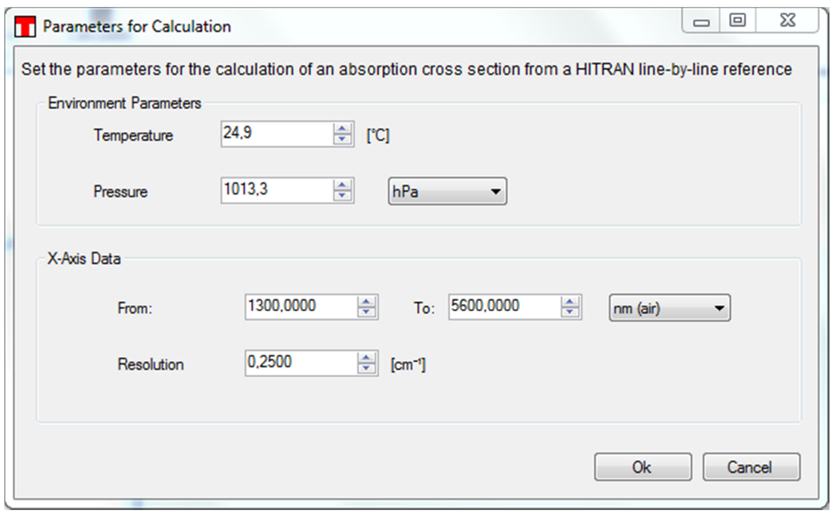


Figure 44 Cross Section Calculation Setup Window

Loading Traces

Except for line-by-line references which have not yet been converted by the procedure outlined above, reference spectra can be loaded into the main OSA software window and handled as any other trace. Simply click the reference you wish to load in the Reference Database dialog box, then click "Load as Trace." This will copy the reference to an empty trace in the main window.

8.10.2. Reference Fitting

The Reference Fit dialog box is used to assign peaks in an unknown spectrum to peaks from one or more reference spectra. To open this dialog box, click the "Fit" button underneath the "Reference" section of the main menu.

The Setup tab of the dialog box displays all the saved reference spectra (e.g., those created by converting the HITRAN line-by-line references).

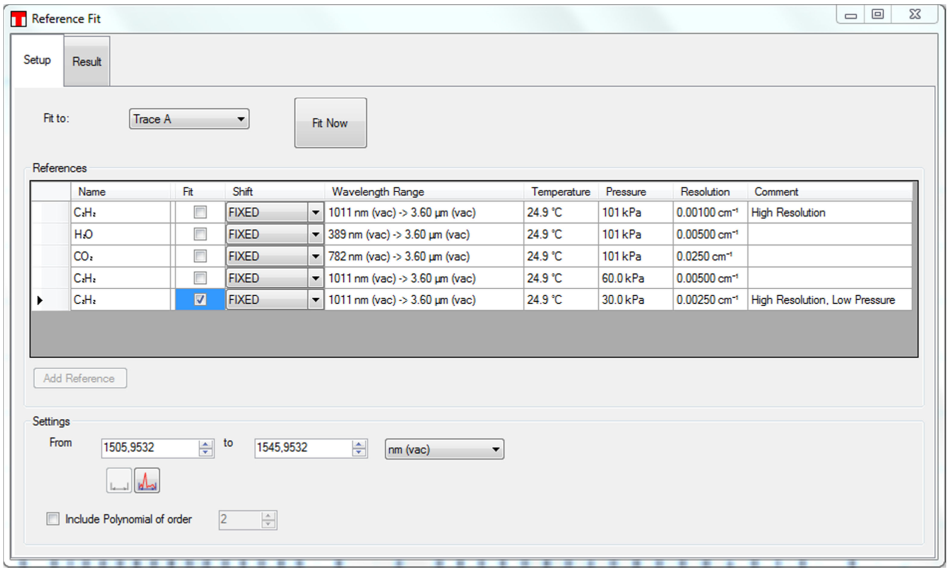


Figure 45 Setting Up a Fit in the Reference Fit Window

- Clicking the “Fit” checkbox includes the selected reference spectrum in the fit.
- The “Shift” drop-down menu has two options: “Fixed” and “Free.” “Fixed” means that the peaks in the reference spectrum will not be shifted in wavelength, while “Free” means that the peaks in the reference spectrum will be allowed to shift to improve the fit.
    - If no references are allowed to shift—that is, if all reference spectra are set to “Fixed”—then a linear least-squares fit is performed that scales the reference(s) to the measured spectrum.
    - If at least one reference is allowed to shift, then a search is performed for the optimal combination of scaling and wavelength shifting by using a Levenberg-Marquardt minimization algorithm.
- The “Wavelength Range” box lets the user denote the wavelength range over which the reference spectrum is used. A range can be configured by typing it in directly, by moving the two vertical markers in the main window, or by taking the entire spectral range that is currently displayed in the main window.
    - It is possible to place the Reference Fit dialog box behind the main window, so that the spectral range between the markers or the range of the displayed spectrum can be adjusted without having to exit the Reference Fit box.

The Result tab contains a graph that displays the measured spectrum, each scaled (and possibly also shifted) reference spectrum, and the sum of all the reference spectra. Below the graph is a table that displays the fit coefficient for each reference spectrum that was used.

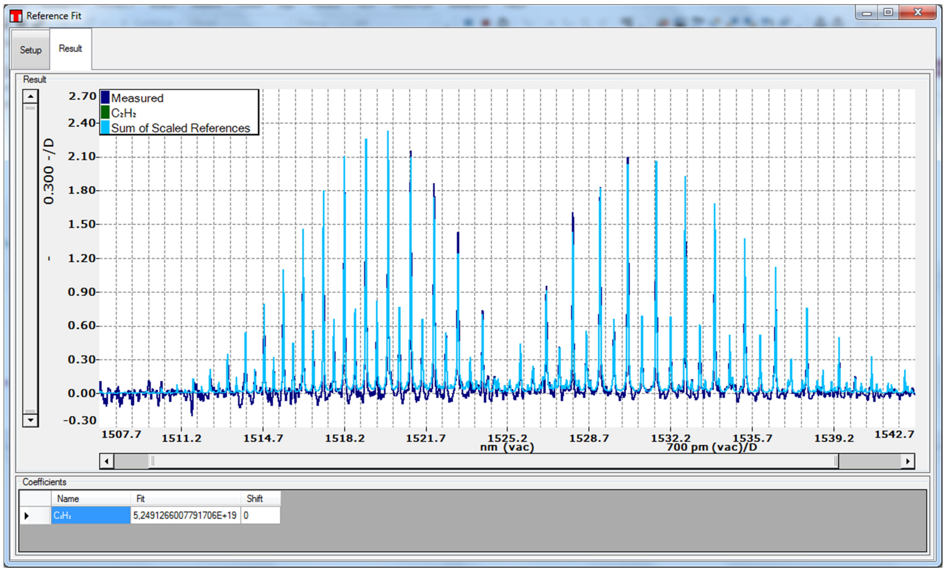


Figure 46 The Result of the Fit, Displayed in the Reference Fit Window

8.10.3. Baseline Correction

As shown in **Error! Reference source not found.**, the baseline correction function removes baseline absorption from an acquired spectrum.

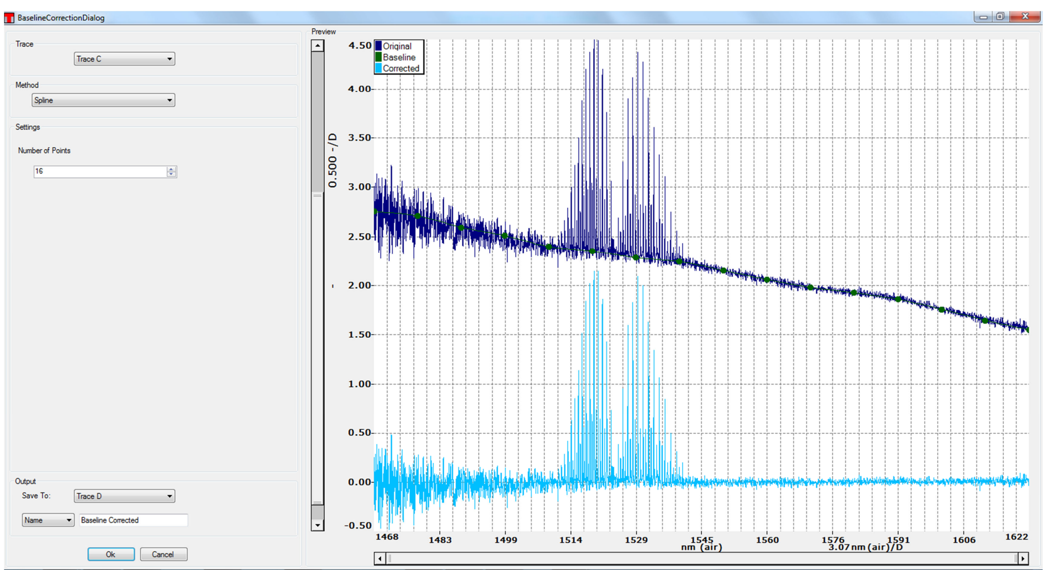


Figure 47 Baseline Correction Window

To perform a baseline correction, click the “Baseline” button underneath the “Reference” section of the main menu. The Baseline Correction dialog box, which allows you to adjust the baseline correction while viewing the results of your adjustments in real time, will appear.

Baseline correction can only be performed on one trace at a time. Select the trace you wish to correct from the Trace drop-down menu in the upper left corner, then select the correction method from the Method drop-down menu directly below. There are four available methods:

- **Spline**: *N* baseline points with linear spacings are placed along the trace, and the local median value is determined around each point. The baseline is then calculated as a cubic Hermite spline, fitted to the locations and local median values of the *N* baseline points. The baseline points are displayed in the graph in the dialog box, and can be dragged around freely to adjust the baseline. The number of points to base the calculation upon can be set by the Settings drop-down menu underneath the Method drop-down.
- **Polynomial**: The baseline is determined by fitting a polynomial to the entire trace. The Settings drop-down menu allows the order of the polynomial to be set.
- **Polynomial Below**: The baseline is determined by fitting a polynomial to a set of baseline points. These points are chosen iteratively. In the first iteration, the entire trace is fit to the polynomial. Next, the points in the trace that lie below the fitted polynomial are used to designate a new set of baseline points. These steps are repeated until either no more points can be excluded, or the number of baseline points is less than (*polynomial order + 1*).
- **Polynomial Above**: The baseline is determined in the same fashion as the **Polynomial Below** method, but points lying above the fitted polynomial are selected instead.

The input trace, the calculated baseline, and the final corrected trace will be displayed in the Baseline Correction dialog box. When you are satisfied, use the Output drop-down menu to select the trace you wish to export the corrected trace to, and click “Ok.” The corrected trace will appear in the main window.

8.11. Keyboard Shortcuts

- **Ctrl+O**: Load a spectrum from a file to an available trace
- **Ctrl+S**: Save a trace to a file
- **Ctrl+Shift+S**: Save all traces to a file
- **Ctrl+P**: Print a screenshot of the currently displayed window
- **Ctrl+Z**: Undo the last math operation performed (if any)
- **Ctrl+Y**: Redo the last math operation undone (if any)
- **Ctrl+I**: Show information about the currently active trace
- **Ctrl+N**: Collect a new single spectrum/interferogram
- **Ctrl+R**: Start/stop repeated measurements
- **Ctrl+L**: Toggle between linear and logarithmic scaling (spectrum mode only)
- **Ctrl+1**: Enable/disable movable line marker #1
- **Ctrl+2**: Enable/disable movable line marker #2
- **Ctrl+3**: Enable/disable movable line marker #3
- **Ctrl+4**: Enable/disable movable line marker #4
- **Ctrl+ "+"**: Zoom into the graph
- **Ctrl+ "-"**: Zoom out from the graph
- **Ctrl+Left Arrow**: Move the graph one step to the left
- **Ctrl+Right Arrow**: Move the graph one step to the right
- **Ctrl+PageDown**: Set the active trace to the trace after the one that is currently active
- **Ctrl+PageUp**: Set the active trace to the trace before the one that is currently active
- **Ctrl+W**: For the currently active trace, toggle between "Write" and "Fix"
- **Delete**: Clear the currently active trace

Chapter 9 Software Setup

9.1. Basic Settings

Pressing the "Setup" button on the main menu will open the setup dialog. By default, the setup dialog box will start in "Basic Mode". To see more advanced settings, press the "Switch to Advanced Mode" button in the lower left corner of the window.

9.1.1. Spectrum Page

The first page in the setup dialog allows the user to setup the general properties of the data acquisition. The resolution vs. update frequency slider allows the user to indicate whether to prioritize spectral resolution or high (temporal) update frequency.

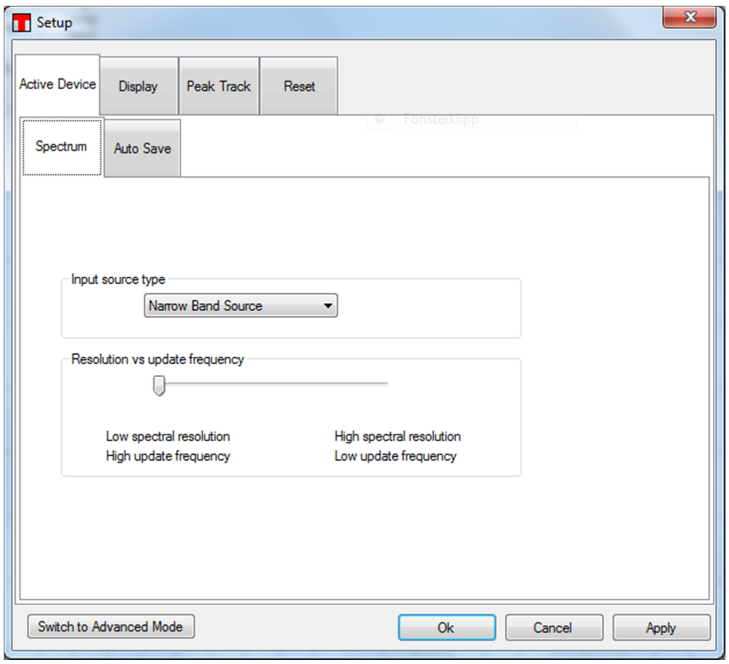


Figure 48 Spectrum Setup Page in Basic Mode

9.1.2. Auto Save Page

The Thorlabs OSA software comes with the ability to automatically store all collected interferograms and/or spectra to file as they are collected.

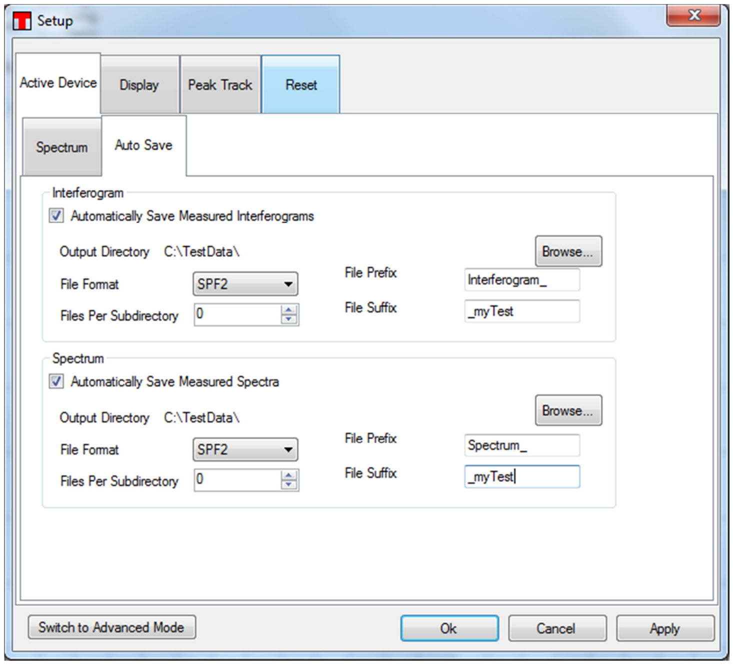


Figure 49 Setting Up Automatic Storing of Interferograms / Spectra

To enable automatic data storing of interferograms follow the steps below:

1. Check the button "Automatically Save Measured Interferograms".
2. Select a directory where to store the files by pressing the button "Browse" and select a directory.
3. Select the desired file format and the number of files per sub-directory. Setting the number of files per sub-directory to 0 will store all interferograms in the same directory. Setting the number of files per sub-directory to a larger value, such as 1000, will create a sub-directory in the given directory named "000000" and store the first 1000 interferograms there, then create a sub-directory named "000001", and store the next 1000 interferograms there and so on.

To enable automatic storing of the spectra, check the button "Automatically Save Measured Spectra" and proceed with the interferograms as described above.

It is also possible to specify a common prefix and suffix for the files to be saved; the names of the saved files will then be on the format:

PREFIXXXXXXXXXXSUFFUX.FILEENDING, where XXXXXXXXX corresponds to a nine-digit auto-incrementing number and FILEENDING is the default file-ending for the selected file format.

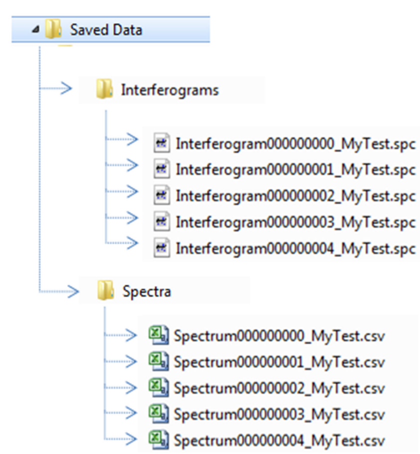


Figure 50 (Right) Resulting File Structure when Running a Series of Measurements with Automatic Save Selected

9.1.3. Display Page

On the display page it is possible to change the properties of the display, such as the background color of the display and the number of traces used. Notice that the color of each trace is not changed here; see "Working with Data in Traces".

The Line Width option changes the width of the lines used for drawing the traces in the main data display. Using thicker lines can be beneficial if the screen is located at a distance from the operator or the screen is hard to read.

The legend drop down box enables or disables the legend of the main window data display and makes it possible to select what text data to display in the legend, see section "Display a Legend in the Data Display".

The check box labeled 'Interferogram in Percent' toggles between showing the interferogram as percent of the full measurable range (default) or in "counts" on the ADC. See also the section "Setting the Unit of the Vertical Axis".

If the check box "Show Individual Data Points" is checked then the display will show crosses at the individual data points in the spectra when the graph is zoomed in so much that only one hundred data points are drawn.

If the check box "Activate Persistence" is checked, then the display will also display the last few spectra/interferograms acquired.

Note: enabling persistence will severely slow down the update rate of the screen.

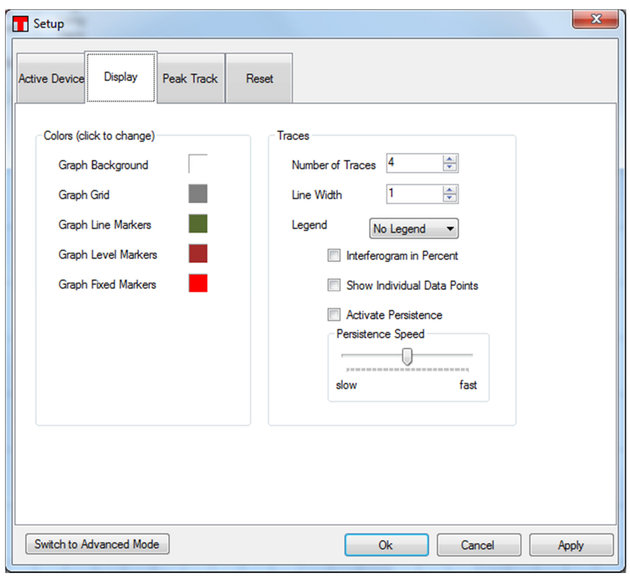


Figure 51 Display Setup Page

9.1.4. Peak Search Page

The automatic peak search routine uses a number of parameters for finding the peaks in the spectra. These options are the same as can be specified in the options panel for the peak-track analysis (see the Section 8.9.6)

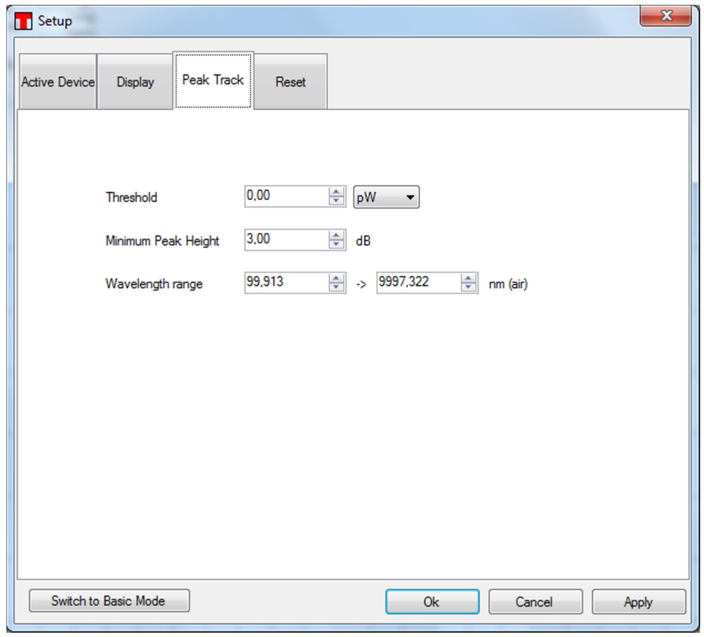


Figure 52 Peak Search Setup Page

- **Threshold**: Only peaks with a peak intensity higher than this given threshold level will be returned by the automatic peak search routine. Use this to reject noise peaks in the spectrum.
- **Min Peak Height**: The automatic peak search routine will only return peaks with a peak to baseline ratio higher than this value. Use this parameter to reject low peaks in the spectra. Notice that this value is in dB (i.e., a min peak height of 3.0 corresponds to the peak level being a factor two higher than the local baseline)
- **Wavelength Range**: The automatic peak search routine will only return peaks located between the two given wavelengths. NOTICE: The unit of this option and its label will change with the currently used x-axis unit. For instance, the label will read ‘Frequency Range’ and the unit be in THz if THz is selected as x-axis unit.

9.1.5. Reset

To completely reset all parameters to their original default values, press the button “Restore Factory Settings” found under the “Reset” tab page. Notice that this action cannot be undone other than by manually changing all parameters again.

9.2. Advanced Settings

9.2.1. Acquisition Settings

On the acquisition page, it is possible to specify the mode of operation of the instrument.

The resolution mode can be set to either “High” (higher resolution, slower update rate) or “Low” (lower resolution, faster update rate).

The Sensitivity mode can be set to “Low”, “Medium Low”, “Medium High” or “High”. Setting a higher sensitivity mode gives a higher SNR of the measurement but also a slower update rate.

Note: When changing the resolution or sensitivity mode, the speed and stroke length of the motor in the instrument will change. Please allow a few seconds for the motor to adjust to the new mode before performing measurements.

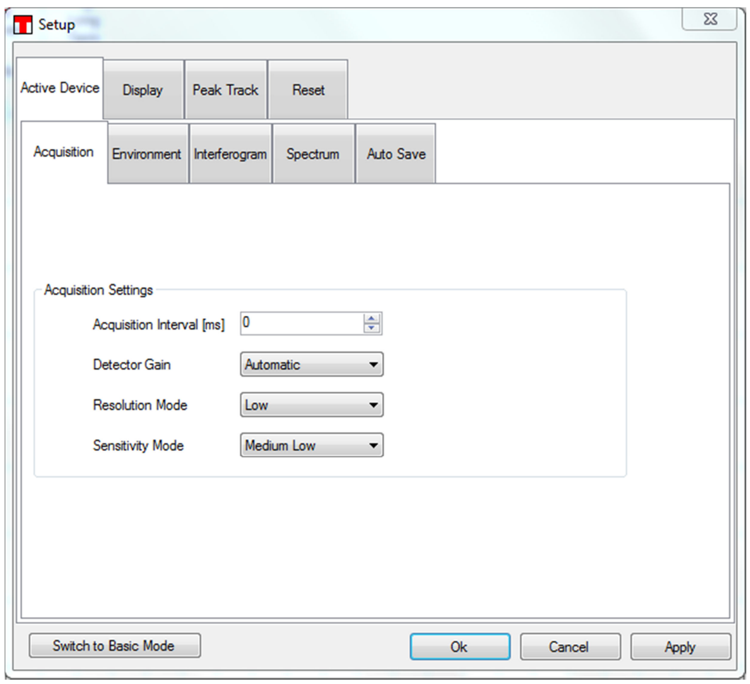


Figure 53 Acquisition Settings Interface

The Acquisition Interval is the minimum time between two subsequently collected interferograms. Setting this to zero will cause the software to perform the measurements as fast as possible. Setting this to a higher value will induce a pause between each collected interferogram which can be beneficial under some circumstances, such as when collecting a long time series of measurements.

The gain of the detectors can be specified using the drop down box on the Acquisition page. The “Automatic” option automatically adjusts the gain used after each acquired interferogram to optimize the SNR of the acquired spectra. To manually set the gain to use, select the desired gain from the drop down box. Note that the used gain will be changed just before acquiring the next interferogram which can take several seconds. The gain can also be se in the options panel of the signal analysis (see Section 8.9.3).

9.2.2. Environment

In the environment page it is possible to determine whether the temperature and atmospheric pressure saved in each interferogram and spectrum should be measured using the built in sensor in the instrument or be set to a fixed value.

9.2.3. Interferogram

In the interferogram page it is possible to set the processing that should be applied to each collected interferogram.

The type of apodization to apply to each interferogram is set by selecting a value in the combo box “Apodization”. This same setting is available in the settings bar in the main window (see screenshot in section 8.1 on Page 18).

The interferograms can be cut to a shorter length than what is normally possible by changing the resolution mode. If you wish to have a shorter interferogram than what is set by the current resolution mode, check the box “Cut interferogram” and specify the desired Optical Path Difference (notice that this is given in millimeters). The maximum value that is possible to specify is given by the current resolution mode of the instrument.

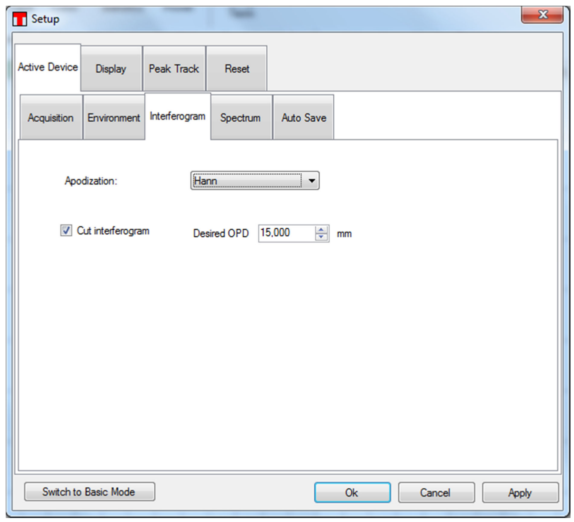


Figure 54 Setting Up the Processing of the Interferogram

9.2.4. Spectrum

In the spectrum page it is possible to specify a large number of settings for the processing of the spectra.

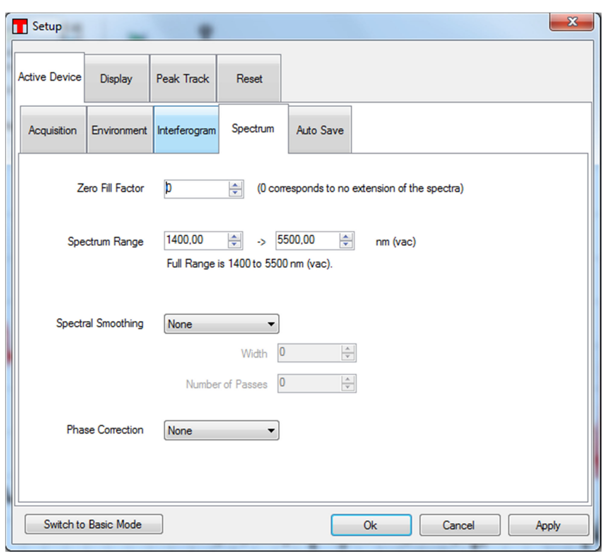


Figure 55 Setting Up the Processing of the Spectrum

- **Zero Fill Factor**: If not zero, the interferograms will be extended with zeros before the Fourier Transform is applied. A value of one means that the interferogram will be doubled in the length and a value of two means that the interferogram will be quadrupled. This increases the number of data points in the spectrum and increases the apparent resolution of the spectra.

- **Crop Spectrum**: If only a sub section of the available wavelength range is required for the measurement then it can be beneficial to crop the spectrum to the desired range to reduce the amount of data to work with. Notice that this cropping is not reversible.

- **Spectral Smoothing**: If the spectra are collected at a much higher resolution than necessary then smoothing can be applied to reduce the noise in the measurement.

- **Phase Correction**: When the interferogram is transformed into a spectrum the phase error of the interferogram can be corrected to reduce the error in the measurement.

9.3. Saving and Loading Settings

When the Thorlabs OSA software closes it will store the currently used setting to file and restore them on the next startup. However, when alternating between different sets of settings it can be beneficial to store settings to file and restore these at a later time.

To store the currently used settings, press the button “Save Settings”, which is found under the “Sweep” menu in the main window. This brings up the dialog shown below in which it is possible to inspect the parameter setup that will be saved and to specify a name for these settings. It is highly recommended that you give the parameter setup a descriptive and easy-to-remember name.

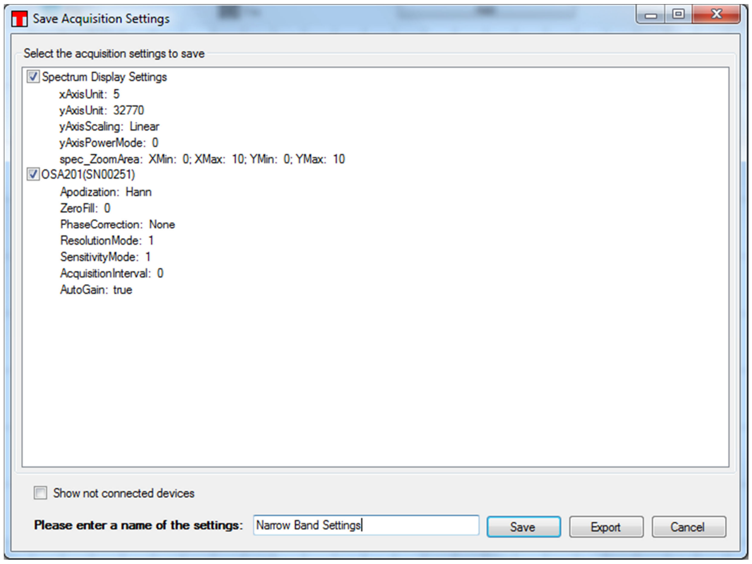


Figure 56 “Save Acquisition” Settings Dialog, Making it Possible to Store Parameter Settings to File for Later Use

Saved settings can be restored in either of two ways:

1. Clicking on the small arrow next to the button “Load Settings”, found under the “Sweep” menu on the main window, brings up a list of the names of previously saved setups. Clicking on one of these names will instantly load these settings and apply them. Please allow a few seconds for the settings of the motor to apply if the Sensitivity Mode or Resolution Mode has changed.
2. Clicking on the “Load Settings” button will bring up the “Load Acquisition Settings” dialog (see Figure 57). Here you have the possibility to carefully inspect the settings behind a saved name before loading the settings. It is also possible to rename or delete a stored parameter setting from the menu that is displayed when right clicking on any element on the list.

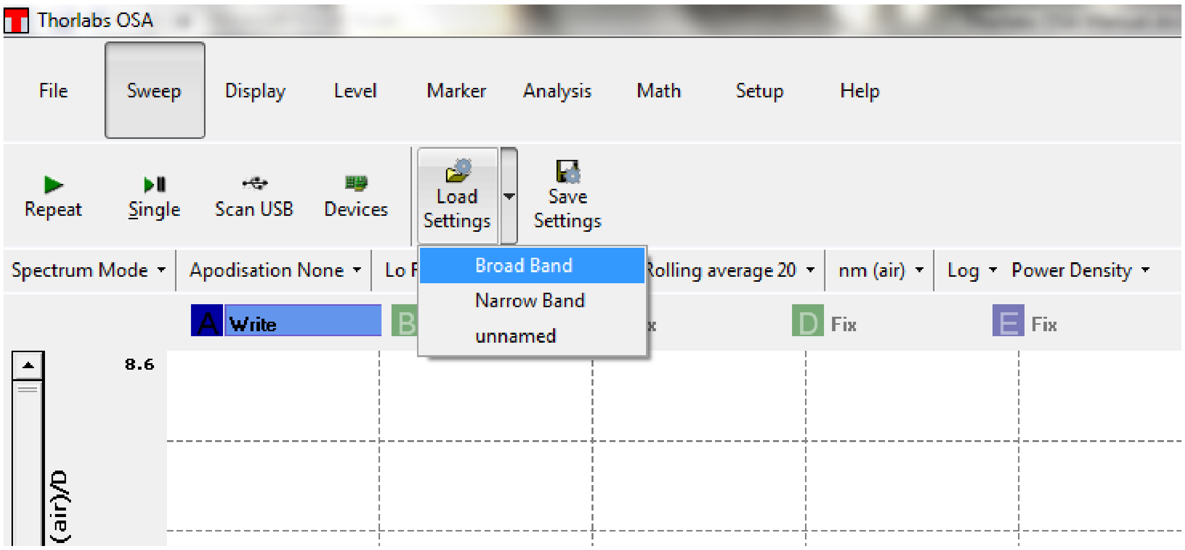


Figure 57 “Load Settings” Button, Allowing Saved Parameter Settings to be Quickly Loaded and Applied to Setups

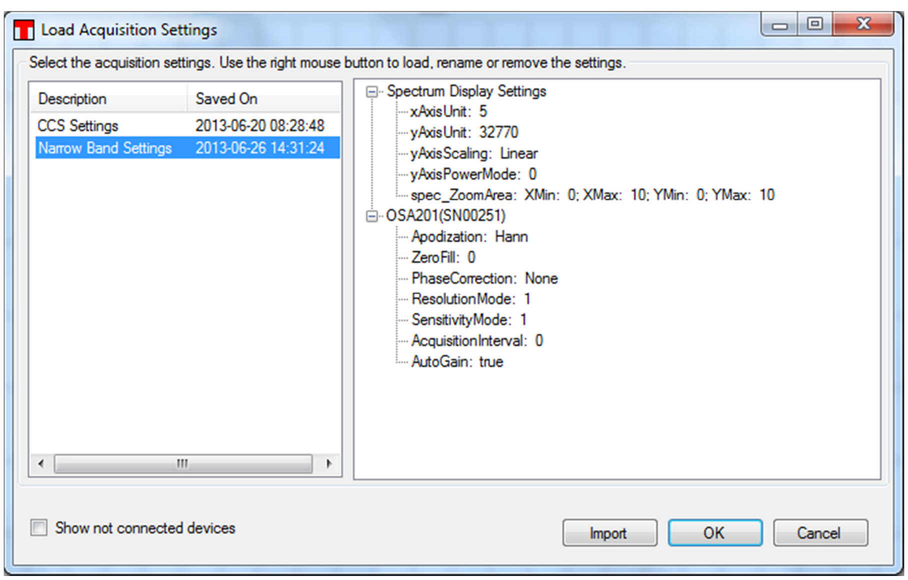
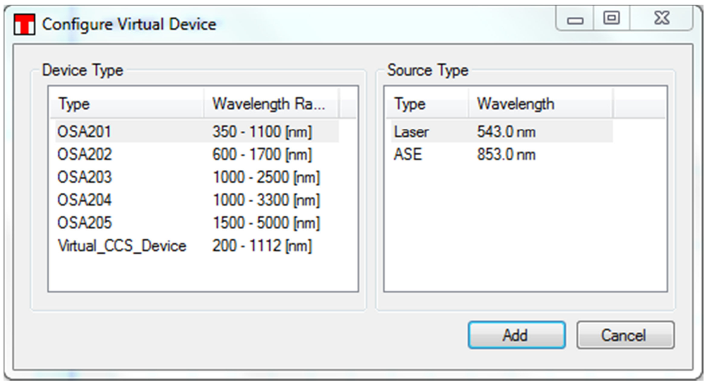


Figure 58 “Load Acquisition Settings” Dialog, Allows for Careful Inspection of Settings behind the Description of Parameter Settings Prior to Loading Them

Chapter 10 Virtual Instruments

Thorlabs OSA software can be used without a spectrometer connected to the PC through the use of virtual instruments. A virtual instrument is a simulation of a Thorlabs OSA and allows for getting a feeling for the instrument and the software without a real Thorlabs OSA.

To setup a virtual instrument, start the Thorlabs OSA software and open the Device dialog by pressing the button “Devices” found under the “Sweep” menu in the main menu. In the device dialog, press the button “Virtual”. This will bring up a dialog like the one shown below where the virtual instrument can be configured. Start by selecting the type of OSA that you wish to simulate by selecting one of the device types in the list to the left. Then select the type of source that you wish to simulate by selecting one of the source types in the list to the right. Clicking ‘Add’ will then create the virtual OSA and add it to the list of instruments displayed in the Device Dialog.



Once the virtual instrument is setup then it can be operated in the same way as a regular Thorlabs OSA, press the button “Repeat” or “Single” to acquire interferograms/spectra from the instrument.

To remove the virtual instrument, press the ‘Scan USB’ button or restart the software.

Chapter 11 LabVIEW™ Drivers

The LabVIEW™ driver llb contains functions for acquiring, processing, analyzing and plotting interferogram and spectra with different options. The drivers are based on functions found in the FTSLib.dll which is also used by the application GUI. See Thorlabs OSA/Lib/Manual FTSLib.pdf in the Start menu for details.

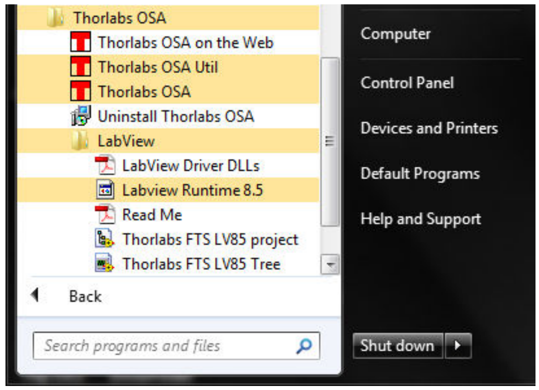


Figure 59 View of Labview™ Driver Interface

The drivers can be accessed from the Windows™ Start menu; Thorlabs/Thorlabs OSA/Labview, and are located under the installation directory at ".. \Labview". The driver library path can be altered, provided the hierarchy, folder named misc, and the util absolute path is maintained, (i.e. do not move the util folder; it is referenced in the path environment variable).

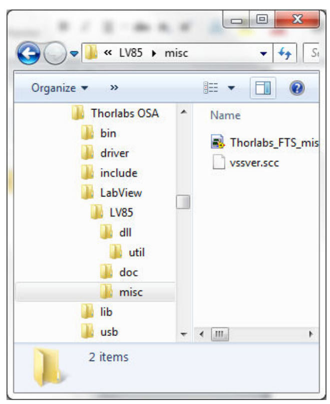


Figure 60 Accessibility of Drivers

The drivers comes in two versions; 32 and 64 bit platforms, (Labview 8.5 and 2011), check the readMe.pdf for more information on version compatibility.

Open the "Tree Vi" to get a categorized overview of the drivers and explore the examples for information on how they can be implemented. The small example shows the basic vis required for instrument communication and for acquiring of interferogram and spectra, and a larger how to implement data process and analyze functions. Plotting functions are also included to facilitate presentation of large data sets.

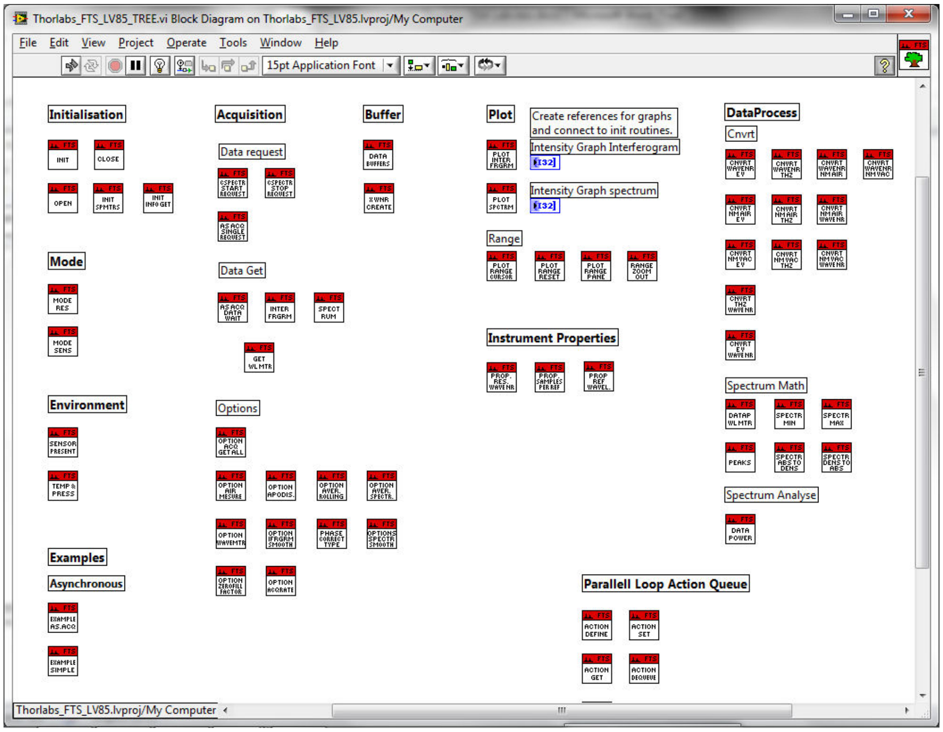


Figure 61 Vi Tree Diagram

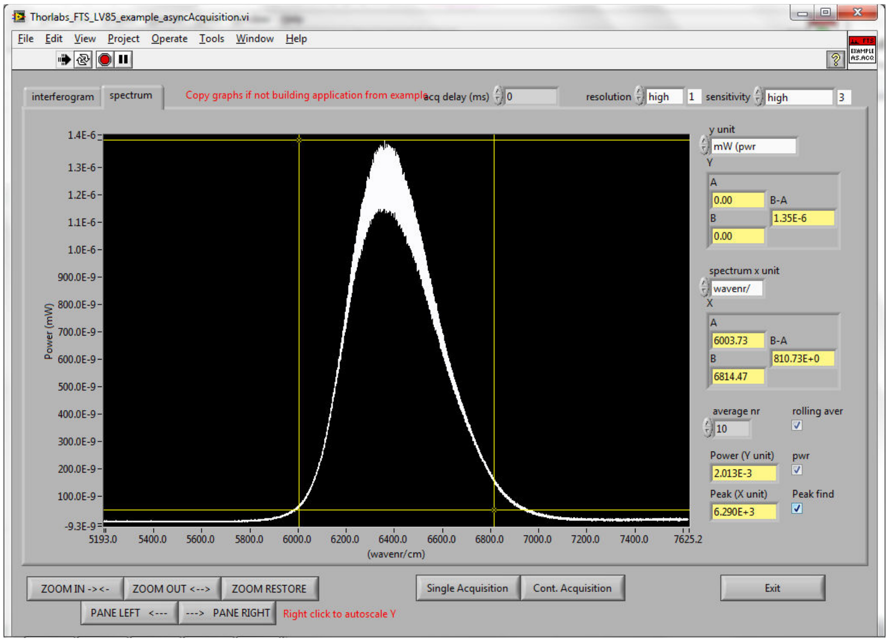
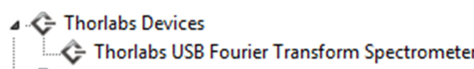


Figure 62 Example Vi

Chapter 12 Troubleshooting

Problem	Action
Software Installation Failed	Be sure to have administrative rights on your computer which enables you to install the software. Ask your system administrator to give you such rights or to simply do the installation.
Thorlabs OSA Software cannot find any instrument	If the instrument was connected after the Thorlabs OSA software was started then it will not automatically detect the instrument, press the button "Scan USB" found under "Sweep" in the main menu to search for connected instruments. Check that Windows has detected the instrument by opening the "Device Manager" found under the Windows Control Panel. The instrument will be presented under the item 'Thorlabs Devices', as shown below. If Windows has not detected the instrument, please make sure that the instrument is turned on and connected to the PC with a USB cable verified for high speed USB 2.0 communication. If no instrument is found, check the connection of the USB cable or reboot the instrument. 
I have started the measurement but the screen doesn't update	Start by checking your settings; • Certain combinations of settings have a very slow update rate, especially high resolution/high sensitivity. • Is sweep interval set to anything other than zero milliseconds? This setting is found in the Setup Dialog under the tab 'Acquisition' (you might need to switch to 'Advanced mode' in the Setup Dialog to see this). The sweep interval is the minimum time between two spectrum readouts.
I cannot change the vertical (/horizontal) axis of the data display	Check if the axis is locked. This is done by clicking on the axis itself. If the check-box 'Lock Axis' is checked then the displayed data range on that axis cannot be changed. This is to prevent accidental dragging or right-clicking in the graph to change the data range displayed. Simply uncheck the 'Lock Axis' check box and click 'Ok'. See the description found under **"Zooming the Horizontal Axis"**

Chapter 13 Technical Data

13.1. Specifications

Specification	Notes	Value			
Item #	**-**	**OSA201**	**OSA202**	**OSA203**	**OSA205**
Wavelength Range	**Detector-Limited**	350 – 1100 nm	600 – 1700 nm	1000 - 2500 nm	1000 - 5600 nm
Spectral Resolution	Broadband Mode, See Section 4.10	7.5 GHz			
Spectral Accuracy[a]		±2 ppm[b]			
Spectral Precision[c]		1 ppm			
Wavelength Meter Resolution	Wavelength Meter Mode, Linewidth <10 GHz, see Section 4.5	0.1 ppm			
Wavelength Meter Display Resolution[d]		9 Decimals			
Wavelength Meter Accuracy[a]		1 ppm			
Wavelength Meter Precision[e]		0.2 pm			
Input Power (Max)	CW Source	10 mW (10 dBm)			
Power Level Accuracy[f]	-	±1 dB			
Optical Rejection Ratio	See Section 4.12	30 dB			
Level Sensitivity[g]		-60 dBm/nm	-70 dBm/nm	-65 dBm/nm	-40 dBm/nm
Recommended Input Fiber Specifications	-	All Single Mode Fibers Step-Index Multimode Fibers with ≤Ø50 mm Core and NA ≤ 0.22 FC/PC Input Connector			All Single Mode Fibers
Dimensions	-	320 mm x 149 mm x 475 mm (12.6” x 5.9” x 18.7”)			

a. After a 30 minute warm-up. Single mode fiber with FC/PC connector. Operating temperature 20 - 30 ºC.
b. Specified in parts per million. For instance, if the wavelength being measured is 1 µm, the accuracy will be 2 pm. (2 pm of accuracy for every 1,000,000 pm, or 1 µm, of wavelength)
c. Spectral Precision is the repeatability with which a spectral feature can be measured using the peak search tool.
d. Can be set from 0-9 decimals and have an auto option that estimates the relevant number of decimals.
e. Using the same input single mode fiber for all measurements.
f. Level accuracy in Absolute Power Mode, Zero Fill = 2, Apodization = Hann. For the range 400 - 1000 nm for OSA201, 600 - 1600 nm for OSA202, 1000 - 2400 nm for OSA203, and 1300 - 5000 nm for OSA205. After a 30 minute warm-up. Single mode fiber with FC/PC connector. Operating temperature 20 - 30 ºC.
g. Minimum detectable energy per nanometer using highest resolution, highest sensitivity, and Zero Fill=0.
h. Limited by the damage threshold of the internal components.

13.2. Update Frequency

Time Between Updates		
Sensitivity	**Low Resolution**	**High Resolution**
Low Sensitivity	0.5 s	1.8 s
Medium Low Sensitivity	0.8 s	2.9 s
Medium High Sensitivity	1.5 s	5.2 s
High Sensitivity	2.7 s	9.5 s

Update Frequency		
Sensitivity	**Low Resolution**	**High Resolution**
Low Sensitivity	1.9 Hz	0.6 Hz
Medium Low Sensitivity	1.2 Hz	0.3 Hz
Medium High Sensitivity	0.7 Hz	0.2 Hz
High Sensitivity	0.4 Hz	0.1 Hz

13.3. Absolute Maximum Ratings

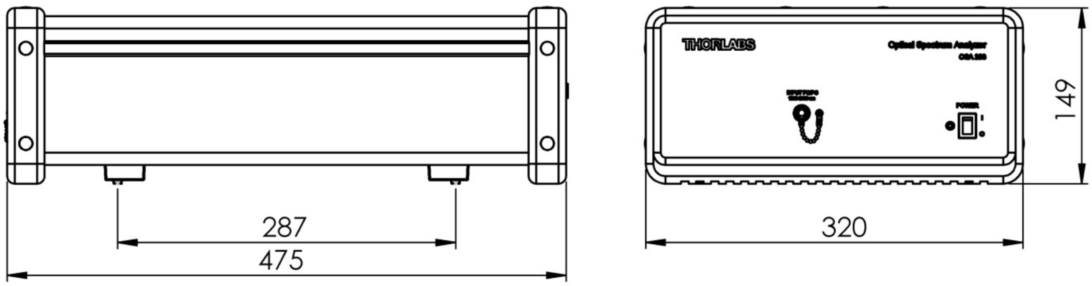
Specifications	Value
Input Voltage	100 - 240 VAC, 47 - 63 Hz, 250 W (Max)
Operating Temperature	10 °C to 40 °C
Relative Humidity	<80%, Non-Condensing
Storage Temperature	-10 °C to 60 °C
Optical CW Power (Max)[h]	20 mW / 13 dBm

h. Limited by the damage threshold of the internal components.

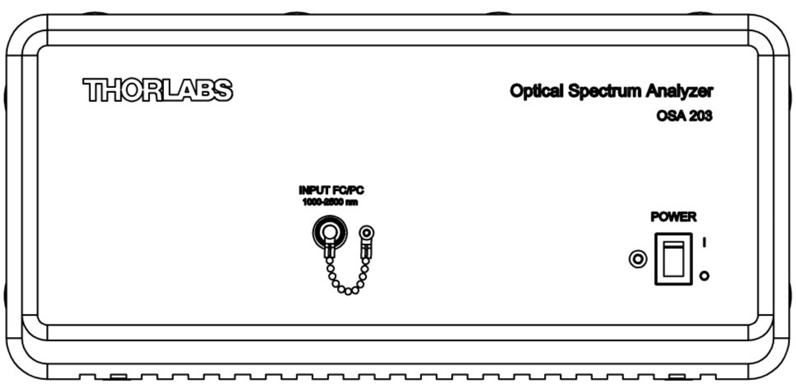
Chapter 14 Mechanical Drawing

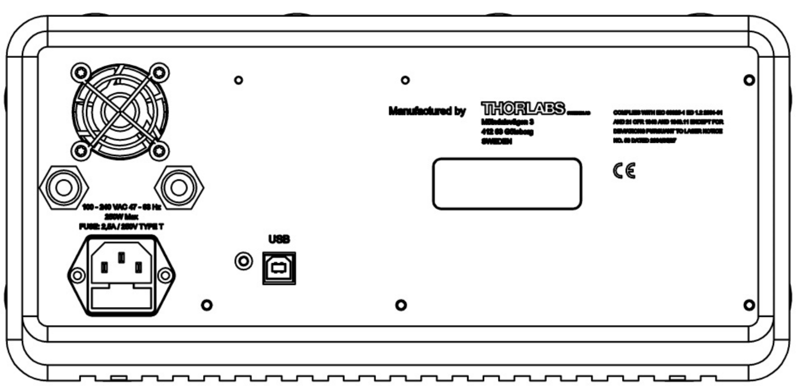
Note: All dimensions below are in mm.

14.1. Dimensions (OSA201, OSA202, OSA203)

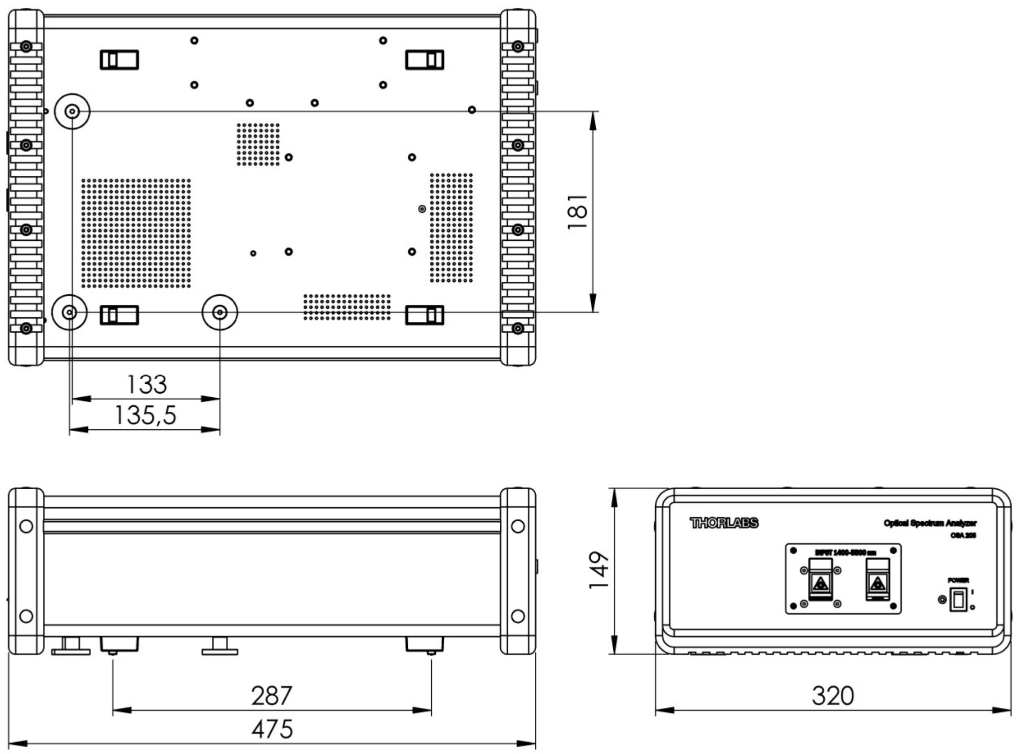


14.2. Front and Back Panel (OSA201, OSA202, OSA203)

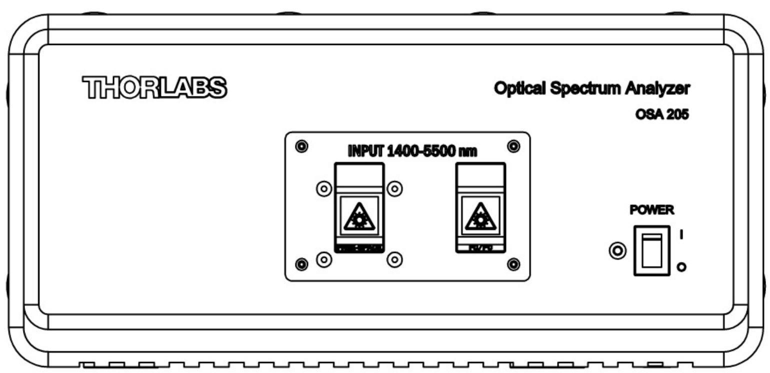


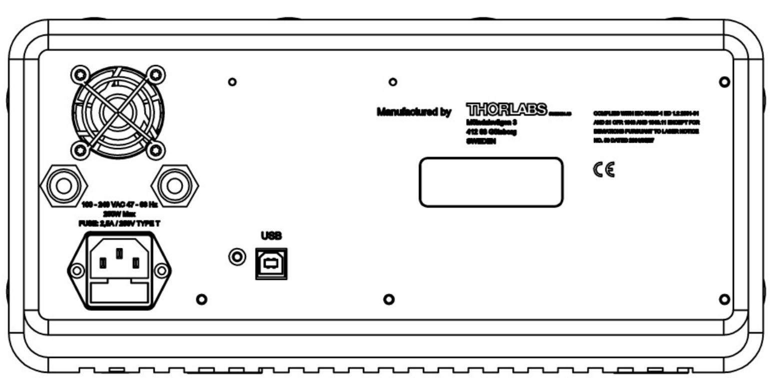


14.3. Dimensions (OSA205)



14.4. Front and Back Panel (OSA205)





Chapter 15 Certifications and Compliances

Category	Standards or Description
EN 61326-1:2006	Electrical equipment for measurement, control and laboratory use – EMC requirements
EN55011, Group 1, Class B	Emission
EN55011, Group 1, Class B	Conducted emission
EN 61000-3-2	AC Power Line Harmonic Emissions
EN 61000-3-3	Voltage Fluctuation and Flickers
EN 61000-4-2	Electrostatic Discharge Immunity (Criterion C)
EN 61000-4-3	Electromagnetic field immunity (Criterion A)
EN 61000-4-4	Electrical Fast Transient / Burst Immunity (Criterion B)
EN 61000-4-5	Power Line Surge Immunity (Criterion B)
EN 61000-4-6	Conducted RF Immunity (Criterion B)
EN 61000-4-8	Magnetic field immunity (Criterion A)
EN 61000-4-11	Voltage Dips, Short Interruptions and Voltage Variations Immunity (Criterion C)

Chapter 16 Appendix

16.1. Calculating Absorption Cross Sections

As described in Section 8.10, the OSA software calculates absorption cross sections from the HITRAN line-by-line references by separating each line into a *line strength* and a *line shape*:

$$\sigma(\nu) = S_{\eta\eta}(T) \times g(\nu - \nu_{\eta\eta}, -\delta)$$

Here, $\nu_{\eta\eta}$ is the center wavenumber of the line, $S_{\eta\eta}(T)$ is the temperature-dependent strength of the line, *g* is a function describing the shape of the line and δ is the shift in pressure.

The line strength, $S_{\eta\eta}(T)$, is dependent on temperature because the temperature determines how strongly the upper and lower energy levels are populated.

$$S_{\eta\eta}(T) = S_{\eta\eta} \times \exp\left(-\frac{hc}{k} E_{\eta} \left(\frac{1}{T} - \frac{1}{T_0}\right)\right) \times \left(\frac{T_0}{T}\right)^m \times \frac{1 - \exp\left(-\frac{hc\nu_{\eta\eta}}{T}\right)}{1 - \exp\left(-\frac{hc\nu_{\eta\eta}}{T_0}\right)}$$

Here, E_{η} is the energy of the lower energy level, *m* represents the temperature dependence of the partition function, *T* is the given temperature and T_0 is the reference temperature.

The line shape is affected by two effects: Doppler broadening, caused by random molecular motion; and pressure broadening, caused by collisions between molecules. Doppler broadening leads to a Gaussian line shape with half-width at half-max given by

$$\alpha_G = \frac{\nu_{\eta\eta}}{c}\sqrt{\frac{2kT}{m}}$$

where *m* is the molecular mass. In contrast, pressure broadening leads to a Lorentzian line shape with half-width at half-max given by

$$\alpha_L = \left(\frac{T_0}{T}\right)^n \times \left(\gamma_{air} \times (p - p_s) + \gamma_{self} \times p_s\right)$$

where γ_{air} is the broadening caused by collisions with other species, $\gamma_{self}$is the broadening caused by molecules of the same species, *p* is the pressure of the air, and p_s is the partial pressure of the gas. The exponent *n* is transition-dependent and given by the line-by-line reference.

The combination of Doppler broadening and pressure broadening can be calculated by a convolution between the Gaussian and Lorentzian line shapes, and produces a profile known as the Voigt line shape.

In many cases, pressure broadening has a significantly greater effect than Doppler broadening. If the half-width at half-max of the Gaussian line shape is less than 1% of the half-width at half-max of the Lorentzian line shape, then the software approximates the line shape by only using the Lorentzian. Otherwise, the full convolution is calculated.

16.2. Apodization Methods

The following apodization functions are implemented in the OSA software:

Norton-Beer (Weak)	$F(x) = 0.384093 - 0.087577\left(1 - \frac{x^2}{(L-1)^2}\right) + 0.703484\left(1 - \frac{x^2}{(L-1)^2}\right)^2$
Norton-Beer (Medium)	$F(x) = 0.152442 - 0.136176\left(1 - \frac{x^2}{(L-1)^2}\right) + 0.983734\left(1 - \frac{x^2}{(L-1)^2}\right)^2$
Norton-Beer (Strong)	$F(x) = 0.045335 - 0.554883\left(1 - \frac{x^2}{(L-1)^2}\right)^2 + 0.399782\left(1 - \frac{x^2}{(L-1)^2}\right)^3$
Triangular	$F(x) = 1 - \frac{\|x\|}{L-1}$
Cosine	$F(x) = 1 - \cos\left(\frac{\pi n}{L-1} - \frac{\pi}{2}\right)$
Hann	$F(x) = \frac{1}{2}\left(1 + \cos\left(\frac{2x\pi}{L-1}\right)\right)$
Hamming	$F(x) = 0.54 + 0.46\cos\left(\frac{2x\pi}{L-1}\right)$
3-Term Blackman-Harris	$F(x) = 0.4243801 + 0.4973406\cos\left(\frac{n\pi}{2(L-1)}\right) + 0.0782793\cos\left(\frac{n\pi}{(L-1)}\right)$
4-Term Blackman-Harris	$F(x) = 0.35875 + 0.48829\cos\left(\frac{n\pi}{2(L-1)}\right) + 0.14128\cos\left(\frac{n\pi}{(L-1)}\right) + 0.01168\cos\left(\frac{3n\pi}{2(L-1)}\right)$
Gaussian	$F(x) = exp\left(\frac{x^2}{2 * (0.4(L-1))^2}\right)$
2-Pass Hann	$F(x) = \frac{1}{4}\left(1 + \cos\left(\frac{2x\pi}{L-1}\right)\right)^2$

In these functions, *L* denotes the length of the interferogram, *n* is the index count (from *0* to *L-1*) and *x* is the index count from the center of the interferogram (from *–(L-1)/2* to *(L-1)/2*).

Chapter 17 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment) Directive of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

This offer is valid for Thorlabs electrical and electronic equipment:

- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

17.1. Waste Treatment is Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

17.2. Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE Directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 18 Thorlabs Worldwide Contacts

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

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